407987

Greenhouse #47 Vol 2

BEST COPY AVAILABLE

[redacted]

SHN-1497

SECRET

COMPLETION REPORT

U. S. ATOMIC ENERGY COMMISSION
CONTRACT NO. AT-(29-1)-507

ENIWETOK
PROVING GROUND FACILITIES

Reviewers | Class. | Date
OCT 6 1981

VOL. II

ENGINEERING

Special Re-review
Final [illegible]

HOLMES & NARVER, INC.
LOS ANGELES, CALIFORNIA

1 September 1951

SECRET

[redacted]

[redacted] DI

[redacted]

COMPLETION REPORT

ENIWETOK PROVING GROUND FACILITIES

CONTENTS

VOLUME I - GENERAL

Foreword
Abstract
Recommendations
Section 1 - Introduction
Section 2 - Preliminary Phase
Section 3 - Contract History
Section 4 - Organization
Exhibits

VOLUME II - ENGINEERING

Section 5 - Engineering
Exhibits

VOLUME III - CONSTRUCTION

Section 6 - Construction
Exhibits

VOLUME IV - COLLATERAL SERVICES

Section 7 - Security
Section 8 - Personnel
Section 9 - Labor Relations
Section 10 - Health and Safety
Section 11 - Fiscal
Section 12 - Estimates
Section 13 - Procurement
Section 14 - Logistics
Section 15 - Reports and Special Studies
Section 16 - Service Operations
Section 17 - Support of Scientific Operations
Section 18 - Roll-up, Maintenance and Salvage
Section 19 - Records

VOLUME V - RECONNAISSANCE REPORT (1)

Appendix A(1) - Reconnaissance Report

VOLUME VI - RECONNAISSANCE REPORT (2)

Appendix A(2) - Reconnaissance Report Supplement

VOLUME VII - SURVEYS AND LOCATIONS

Appendix B - Drawing Lists
Appendix C - Locations of Scientific Stations, Military Structures, and Buildings
Appendix D - Horizontal Control Survey

VOLUME VIII - FACILITIES AND STATIONS

Appendix E - Facilities and Stations

VOLUME IX - SPECIFICATIONS (1)

Appendix F(1) - Specifications

VOLUME X - SPECIFICATIONS (2)

Appendix F(2) - Specifications

VOLUME XI - OPERATING MANUALS

Appendix G - Operating Manuals

VOLUME II

ENGINEERING

CONTENTS

Page

SECTION 5. ENGINEERING

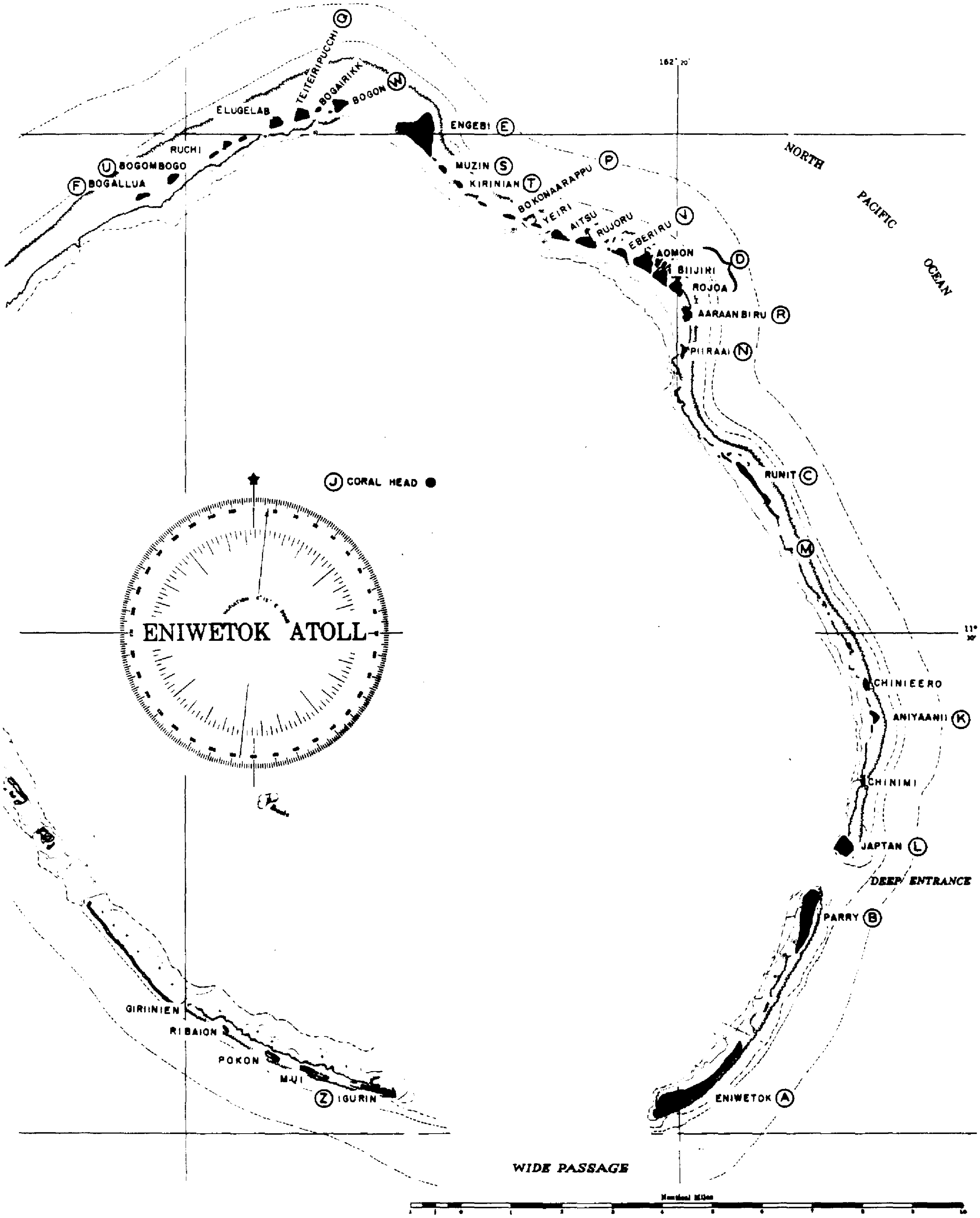
5.1 General....................5-1
5.2 Engineering Organization....................5-6
5.3 Home Office Engineering Procedures....................5-11
5.4 Field Engineering Procedures....................5-28
5.5 Engineering Contribution to Reconnaissance Survey....................5-36
5.6 Liaison to Obtain Design Criteria....................5-41
5.7 Master Planning and Site Planning....................5-43
5.8 Surveys....................5-56
5.9 Soil Investigations....................5-76
5.10 Personnel Buildings....................5-104
5.11 Towers....................5-128
5.12 Scientific Stations....................5-155
5.13 Waterworks Systems....................5-185
5.14 Sanitary Sewage Systems....................5-197
5.15 Power Generation....................5-202
5.16 Electrical Power Distribution....................5-231
5.17 Communications....................5-237
5.18 Control and Signal Cables....................5-246
5.19 Dehumidification, Air Conditioning, and Ventilation....................5-256
5.20 Refrigeration....................5-263
5.21 Fuel Handling and Storage....................5-270
5.22 Paving....................5-280
5.23 Airstrips....................5-294
5.24 Causeways and Piers....................5-296
5.25 Navigation Aids....................5-301
5.26 Engineering Services for Users....................5-303
5.27 Effects of Blasts on Structures, Paving, and Piers....................5-304

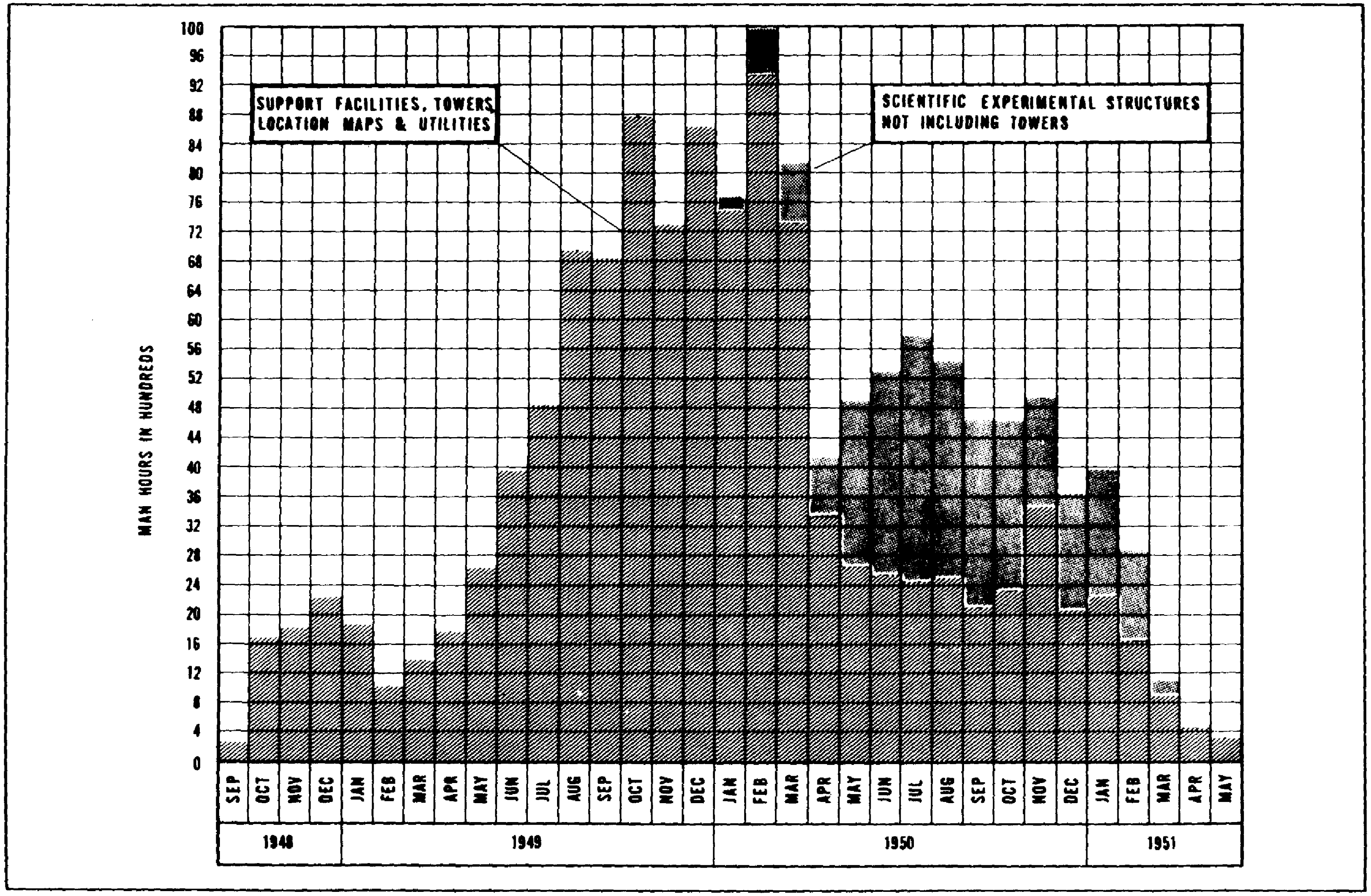
EXHIBITS

A Mechanical and Electrical Test Report, Runit Island Power Plant....................5-317
B Submarine Telephone Cable Test Record....................5-329
C Submarine Control and Signal Cable Test Record....................5-361
D Underground Control and Signal Cable Test Record....................5-379
E Maps....................5-387

Section 5

ENGINEERING


ENIWETOK ATOLL
NORTH PACIFIC OCEAN
DEEP ENTRANCE
WIDE PASSAGE
CORAL HEAD
162° 20'
11° 30'
Nautical Miles
BOGALLUA
BOGOMBOGO
RUCHI
ELUGELAB
TEITEIRIPUCCHI
BOGAIRIKK
BOGON
ENGEBI
MUZIN
KIRINIAN
BOKONAARAPPU
YEIRI
AITSU
RUJORU
EBERIRU
AOMON
BIIJIRI
ROJOA
AARAANBIRU
PIIRAAI
RUNIT
CHINIEERO
ANIYAANII
CHINIMI
JAPTAN
PARRY
ENIWETOK
GIRIINIEN
RIBAION
POKON
MUJI
IGURIN



Man Hours Spent in Engineering Design Work

[redacted]

CAUTION

CHAPTER 5.1

GENERAL

The engineering phase of the work performed by Holmes & Narver, Inc. under the Contract is identified as "Job No. 2- Engineering, Design and Inspection." In general, the scope of the work performed by the Engineering Division under "Job No. 2" consisted of three related tasks: design surveys, detail design, and construction supervision and inspection.

When Holmes & Narver received the Letter-of-Intent on September 16, 1948, very little information was available upon which engineering work could be based. The only item definitely firm was that the weapons were to be located on towers for detonation. Also, at this time, only the principals of the firm and the five members of the reconnaissance team had "Q" security clearances. This posed a major problem because, in the fall of 1948, the entire Project - even the fact that the AEC was contemplating the reuse of Eniwetok Atoll as a proving ground - was classified as "Secret."

Since it was possible for engineers to design a tower without knowledge of its projected location and use, this was one major feature on which design work could be started without waiting for security clearances. Accordingly, studies were begun and several basic tower designs were developed and submitted to the Los Alamos Scientific Laboratory even before the completion of the reconnaissance trip.

At the same time that the tower design studies were started, applications for security clearance were submitted for all personnel who were to be engaged in engineering work. Although clearance requirements were not a serious handicap, there were times in the early stages, when some delays were encountered due to the limited number of "Q" cleared personnel. This condition existed only for a short time; adequate personnel were soon cleared, including those who were working only part time on this Project. This clearance of part-time, as well as full time personnel, made for flexibility, for when required more people could be put to work on the Project to meet an emergency. Also, costs of having cleared personnel standing by but not occupied full time were avoided. This flexibility and economy was possible because the engineering design was carried out in the Home Office where personnel could be readily shifted from one project to another.

At the beginning of 1949, the scientific aspects of the tests had not yet been definitely worked out to the point where actual design of the necessary structures could be developed. Therefore, efforts were concentrated on the development of the camp islands, Parry and Eniwetok. The decision had been reached to follow the recommendation made in the Reconnaissance Report: to house military and civilian personnel separately. Because the only airstrip on the Atoll that could be utilized by C-47 and C-54 cargo aircraft was already located on Eniwetok Island

[redacted]

and because the military garrison was also quartered there, this island was made the "military island". A site plan was developed to provide housing, messing, office space, warehousing, shops, recreation facilities, and utilities for 600 men, the number of Army and Air Force personnel believed to be required to support the series of experiments contemplated when planning started on March 5, 1949. Similarly, it was planned at that time to provide for 600 civilians on Parry Island: 200 scientists and their assistants, and 400 men in the construction and operating force.

The type of building construction had not yet been fully developed, but it had been determined that an aluminum alloy would be used for all semi-permanent buildings; that personnel would be housed in groups, 8 or 16 men to a building for officers and scientists, and approximately 34 men to a dormitory for construction personnel and enlisted men; that water would be distilled and power generated on each island; that an open air movie and outside recreational facilities would be provided on each island; and that each group would be a complete unit with necessary administration buildings, mess hall, bakery, cold storage, PX and Post Office, maintenance shops, laundry, and infirmary. These fundamental ideas were incorporated in the original site plans.

The first site plans were developed from the few maps of the islands that had been previously prepared from aerial photographs, and from personal observations made by the members of the reconnaissance team. This was done because the work of planning and developing the engineering design was started as soon as the Reconnaissance Report was accepted.

At about the same time, February 1, 1949, the first group of H & N personnel (nine men) left Los Angeles for Eniwetok. The Chief of Surveys and one surveyor were included in this group. Because of the limited facilities available, the necessity for emphasis on workmen to initiate construction, and the inability of the garrison to support more than 30 men, it was May 17, 1949, before there was one complete survey party at the Atoll. In spite of such limitations, topographical survey work was started at once on Parry Island and then on Eniwetok. As data were accumulated, field sketches were prepared and sent to the Home Office, site plans were modified to fit the topography, and utility plans were developed.

Later, similar information was obtained for the three principal Experiment Islands -- Engebi, the Aomon group and Runit -- and tent camp sites were developed for those islands.

Because of the remoteness of the Project from the nearest practical source of supply of construction materials and because of the two or three month period required for supplies to reach Jobsite from vendor, the Engineering Division was required to make early estimates of probable equipment and material needs. Fortunately, the fact that Holmes & Narver was responsible for construction as well as for design and engineering made it possible to expedite procurement by stockpiling on the basis of early sketches

Purchase Specifications were prepared and the Purchasing Department obtained bids for special items, such as diesel engine-generator sets, water distillation units, aluminum buildings, electrical switchgear, transformers, and many others. The Engineering Division analyzed the bids and if the value of the purchase was less than $50,000.00 instructed the Purchasing Department as to which bid to accept. If the purchase value exceeded $50,000.00, the Engineering Division made recommendations, after analysis, to the Director of Engineering and Construction, Santa Fe Operations Office, Los Alamos, and his approval was obtained before the purchase was made.

The Engineering Division anticipated its designs and, based upon experience and judgment, made estimates of needed quantities of all construction materials, such as lumber, cement, reinforcement steel,wire, pipe and fittings, electric conduit, outlets, switches, poles and plumbing fixtures. Requisitions were then prepared for approximately 75 per cent of the estimated total quantities needed, and this material was purchased in the usual way and shipped to the Jobsite as a stockpile or warehouse stock to be drawn upon by the construction forces. This operation was carried out before the completion of working drawings and, in many cases, before any drawings had been started for the structures. If this had not been done, construction of any building could not have been started for from three to six months after the completion of drawings, for it would have taken that time to take off material lists, and procure, ship, and off-load the materials required to construct that particular building or facility.

By the end of 1949, the experimental program began to take form. The first of a long series of instrument charts was developed and issued on December 13, 1949. Structures to be used in connection with experiments were designated as "stations" as distinguished from "buildings", the latter being the support structures such as living quarters, laboratories, administration buildings, mess halls, shops, warehouses, etc. On the first chart, five groups of Users and thirty-eight stations were listed. Between December 13, 1949, and test time in the spring of 1951, the number of Users grew from five to twenty-seven (as broken down on the instrumentation chart),[1] and the number of stations had increased from 38 to 839. Also, the number of islands involved in the experiments continually increased. On December 13, 1949, all stations were planned for three islands (considering Aomon and Biijiri as one). Finally, there were scientific stations on 18 islands of the Atoll.

As soon as survey data were obtained for the first experiment island, the development of location maps was started. The geographical location of each scientific station, as well as the distance and direction of each one from its "zero" tower (the towers upon which the weapons were to be detonated) was plotted. Every time a new station was added or the location of a station changed, the particular location

[1] Cost Reporting requirements required a breakdown of Users into seventy-eight groups and subgroups.

map involved was revised and reissued. Thirty-seven location maps, 23 x 34 inches in size, were required to depict the exact location of the 839 stations. As the many experimental programs were developed and the use of additional islands became necessary, additional survey work was required. In many cases, stations were located on islands other than those containing zero towers, and a complete triangulation survey was required to determine the distance and direction of the stations from zero.

These were unique engineering and planning problems. Not only was the number of scientific stations being continually increased and their locations being frequently changed, but the types of structures and kinds of construction were many and varied. There were practically no structures which could be said to be of normal construction. The purpose of the particular experiment, the problem of shielding from radiation, the location of the structure with relation to the zero towers, the blast pressure, the heat given off by apparatus within the structures, and many other special requirements governed the material of which the structure was to be built and the engineering design necessary.

Not only did the development of the many scientific programs call for an almost continuous series of revisions, changes, and new designs for the experiment islands and scientific stations, but also the designs for camps on Parry and Eniwetok Islands were far from stable. As a natural result of the continually increasing scope of the scientific program, the number of people participating kept increasing. Each new group required laboratory and shop facilities. The addition of JTF-3 headquarters on Parry called for another administration building. The decision that drone planes would operate from Eniwetok greatly increased the Air Force requirements for housing, laboratories, shops, radar, and other facilities. The inclusion of animals in the experiments resulted in the development of Japtan Island as an animal colony and headquarters for the Medical-Biological group. These changes and additions caused many revisions to the plans for the non-experimental islands so that although the planning of these islands was started on March 5, 1949, and the design of the buildings was started on April 4, 1949, it was September 29, 1950, before the engineering design for these islands was finished, and the design of scientific stations was still in progress at the beginning of 1951.

Another feature which added to the complication of completing designs was the distance between the Zone of Interior and Eniwetok Atoll. Rapid communication by telephone, teletype, and air mail was possible between the H & N Home Office, representatives of the Laboratory, the AEC Engineering & Construction Division, and the many representatives of Users; however, communication between the H & N Home Office and the Jobsite was somewhat slower. Teletype facilities were helpful within their limitations, but mail service, including the delivery of drawings, was slow and uncertain. In the early phases of the work, in fact through 1949 and the first portion of 1950, air transportation was irregular. Air mail passing through the APO system was frequently a week to ten days in arriving. Even communications and drawings which were handcarried took varying lengths of time because of the uncertain schedules of air transportation, occasioned by delays at Fairfield-Suisan Field (later renamed Travis Air Force Base), at Hickam Field, and at Kwajalein. This was somewhat of a handicap, especially in keeping the personnel at the Jobsite informed of the latest revisions in drawings made necessary by changes in requirements.

The inconvenience and delays due to time required to get information from the Home Office to the Jobsite were more than offset by the close liaison that was possible between the Laboratory and the Engineering Division of H & N. The many contacts by phone and the many personal visits assisted materially in the development of the unusual designs required. It would have been almost impossible to have carried on the engineering designs at the Jobsite. Experience proved that the decision to carry on the design in Los Angeles was a wise one.

Throughout the Project, the far-sighted policy of test authorities in taking a long-range view of development of physical facilities of the proving ground served to advance the progress of the engineering work. It was recognized that the new and experimental nature of many of the concepts would require some trial and error and some adaptation to the site planning and to other, possibly conflicting, objectives. In a project of such complexity and magnitude all eventualities could not possibly be anticipated by any one person or group of specialists, and rapid scientific advancement during the planning period required constant modification of plans. Test authorities recognized that revisions and changes would be inevitable, and that if tests were not to be impeded engineering work would have to be spread out over a long period of time. The constantly changing requirements constituted a challenge to engineering ingenuity, but cooperation and teamwork carried the Project through to the successful tests of 1951.

CHAPTER 5.2

ENGINEERING ORGANIZATION

The planning, development, and operation of the proving grounds at Eniwetok involved various phases of engineering, both in the office and in the field, and required specialists in site planning; in architecture, civil, mechanical, electrical, structural, sanitary, electronic, refrigeration, and air-conditioning engineering; and in communications, power generation and distribution, water distillation, land and hydrographic surveying, and materials testing.

Although this Project was possibly more involved and diversified than some projects that have been successfully carried out over a period of years by the Engineering Division of Holmes & Narver, Inc., it did not impose a severe personnel burden on the Engineering Division. In fact, all of the engineering requirements were carried out by the Engineering Division as already organized. Additional personnel were placed under the direction of key men who had been directing engineering design for H & N for years.

There were three principal types of engineering work on the Project: field surveys, design, and field supervision and inspection.

Field surveys consisted of the following:

1. Horizontal and vertical control surveys
2. Topographical surveys
3. Hydrography
4. Mapping of experiment islands
5. Construction surveys (location on ground of structures, roads, and utilities)
6. Cross-sectioning of zero areas before and after tests
7. Remapping of all islands after tests to show surviving structures and new shore line

Surveys were under the direction of the Chief of Surveys who was a member of the initial party sent to the Jobsite on February 1, 1949. He or his replacement was at the Jobsite throughout the development and construction period. The Chief of Surveys reported directly to the Resident Manager at Jobsite until the Engineering Manager was appointed on March 1950. Design information obtained by surveys was forwarded to the Chief Engineer for use at the Home Office by the Engineering Division.

Design, under the direct supervision of the Chief Engineer, included all work carried on by the Engineering Division at the Home Office, consisting of the following:

1. Preparation of preliminary drawings and sketches based on information furnished by J-Division of LASL.

2. Preparation of working drawings for buildings and experimental structures.
3. Preparation of drawings of utilities, including fresh and salt water distribution, sewerage system, electric power distribution, communications, signal systems, and petroleum handling and storage systems.
4. Design of power plants and water distillation plants.
5. Preparation of location maps.
6. Preparation for material take-off and requisitioning of construction materials to provide a stockpile of such materials at Jobsite in advance of completion of definitive working drawings.
7. Checking of vendors' shop drawings.
8. Inspection of fabricated items.
9. Preparation of Progress Reports.

Field supervision and inspection, under the direction of the Engineering Manager at Jobsite, included the following:

1. Interpretation of working drawings for the Construction Department at the Jobsite.
2. Inspection of construction work.
3. Testing of materials such as concrete, paving, etc.
4. Preparation of change orders and estimates.
5. Testing of equipment such as pumps, engine-generators, water distillation equipment, dehumidifiers, refrigeration equipment, etc.
6. Compiling operating instructions.
7. Preparation of "as-built drawings".
8. Providing engineering advice and assistance to AEC, Users, and other H & N Divisions at the Jobsite.

The planned development of engineering requirements necessitated a gradual growth and change in the organization of the Engineering Division as the scope and nature of engineering functions extended. Figure 5.2-1 shows the Engineering Division Home Office organization during the fall of 1950. Figure 5.2-2 shows the Engineering Division Jobsite organization for the same period.

The Chief Engineer established general policies; consulted with and advised the Assistant Chief Engineer, his staff assistants, and eight department chiefs on major engineering problems; approved finished drawings; and acted as Holmes & Narver's liaison representative with J-Division in obtaining design criteria. Because of the nature of the Project, because design work was done at the Home Office, and because of the necessity for close liaison with J-Division at Los Alamos, the Chief Engineer was based at the Home Office. He made frequent trips to Los Alamos to coordinate with J-Division, (and frequent visits to H & N's Home Office were made by J-Division liaison personnel for the same purpose), and he made frequent visits to the Jobsite to coordinate the various portions of the work being carried on both in the Home Office and at the Jobsite.

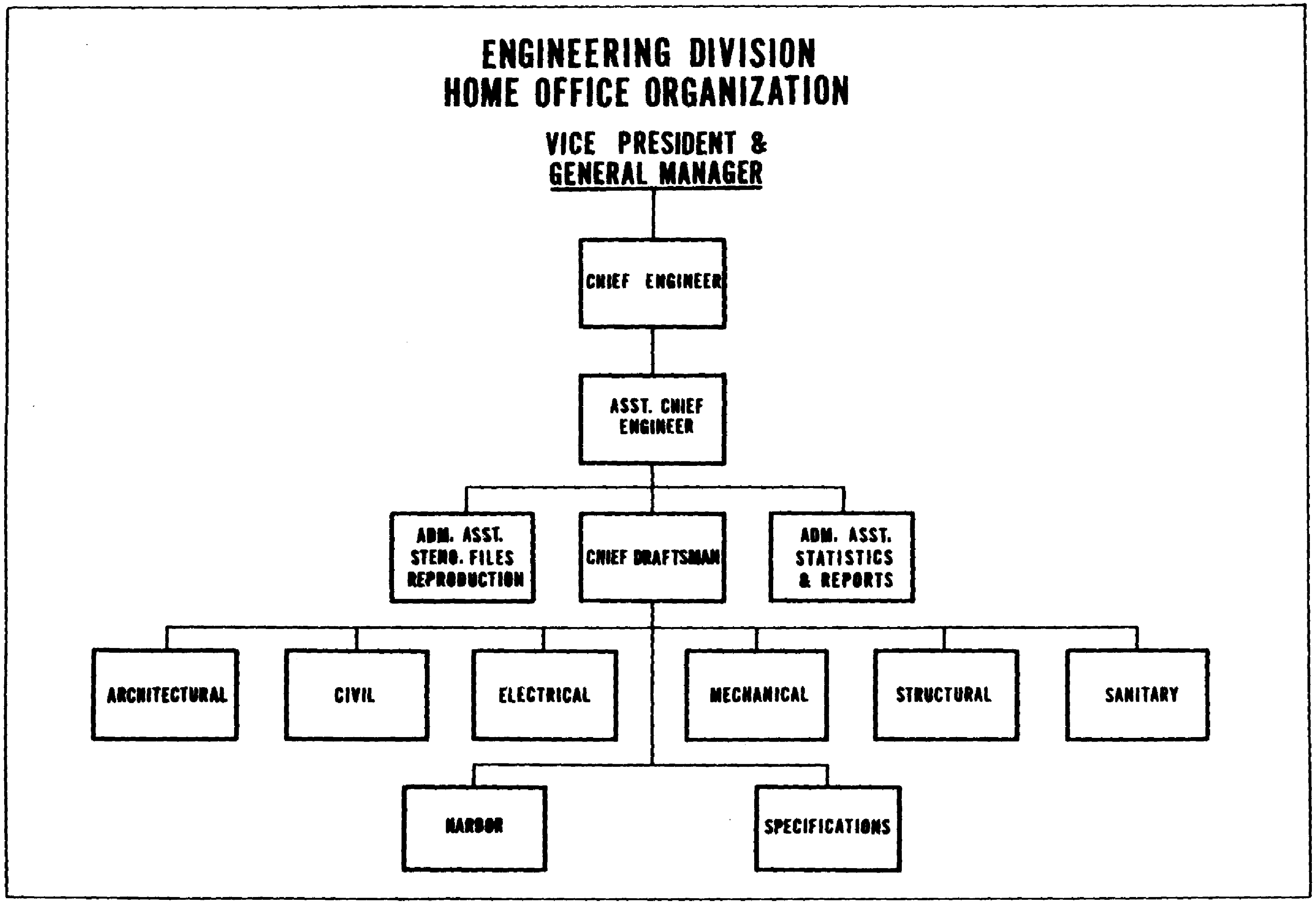


FIGURE 5.2-1 Engineering Division Home Office Organization

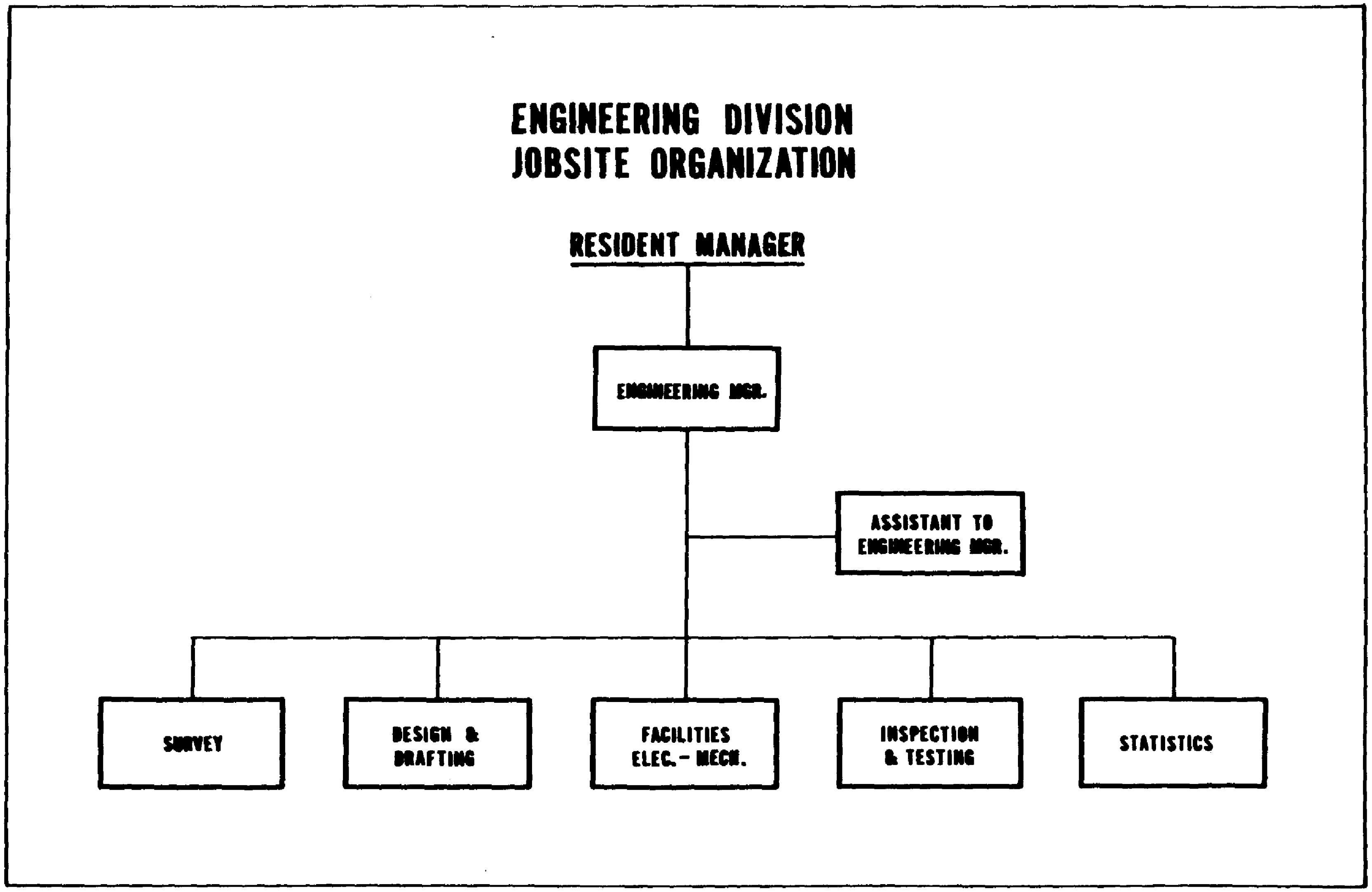


FIGURE 5.2-2 Engineering Division Jobsite Organization

The Assistant Chief Engineer assigned work through the Chief Draftsman to the department chiefs. The work of the departments was coordinated by the Chief Draftsman. During the initial phases of the project and until January, 1950, each department was responsible for the preparation of the required plans and bills of material as well as for the execution of the engineering design functions outlined above.

The Engineering Manager at the Jobsite established general policies and was responsible for the functioning of the five subordinate Jobsite departments. He and his staff assistant acted as liaison with the AEC Resident Engineer's Office. As the amount of liaison work grew and the Users' representatives began to arrive in large numbers early in 1951, the amount of this liaison work reached a maximum.

Coordination between the Jobsite Engineering Manager and the Home Office Chief Engineer was maintained through the Project Manager and by means of the Chief Engineer's frequent visits to the Jobsite.

CHAPTER 5.3

HOME OFFICE ENGINEERING PROCEDURES

Home Office engineering procedures included development of designs, production of design drawings, revision of drawings, and preparation of materials and equipment specifications and bills of material.

DESIGN CRITERIA

The early development of design of facilities provided for the scientific experiments was carried through by close liaison between the Chief Engineer of Holmes & Narver and the J-Division Leader, a scientist who had been assigned the direction of all technical and operational matters relating to the Contract. Later, this close liaison was maintained between the Chief Engineer and another scientist who took over these duties from the J-Division leader. Having highly competent men in charge of this phase of the Project was a distinct advantage.

Criteria were not provided by J-Division for the design of service facilities such as power and water distillation plants, petroleum products handling, utilities, mess halls, bakeries, cold storage and dry food stores, laundry, shops, warehouses, H & N headquarters, infirmary, post exchange, post office, piers, and causeways. Designs for these facilities were prepared by the Engineering Division under the supervision of the Chief Engineer, subject to the approval of the Director of Engineering and Construction, Santa Fe Operations Office.

The design criteria for certain other facilities, such as those provided for the Army and the Air Force on Eniwetok Island and JTF-3 headquarters on Parry Island, originated with Joint Task Force Three and were supplied to H & N by the Contract Administrator, representing the Director of Engineering and Construction, Los Alamos. The design of the military structures for Program 3 was not the responsibility of Holmes & Narver. The Army and the Air Force each appointed its own Architect-Engineers, and the Bureau of Yards and Docks designed the Navy structures. The instrumentation of Program 3 structures was delegated to Sandia Corporation. (See "Military Structures", Vol.III of this report.)

The design criteria for the rest, and by far the largest part, of the development of the proving ground were supplied by J-Division of the Laboratory at Los Alamos. These included the following facilities:

On Parry Island -- living quarters, recreational facilities, AEC headquarters, control and telemetering buildings, instrument laboratories, photo laboratory and buildings, and facilities for special purposes.

On Japtan Island -- laboratory, autopsy and X-Ray buildings, animal infirmary, small animal houses, and animal runs.

On thirteen other islands -- weapon towers, photo tower, instrumented structures, recorder building, and a great variety of instrumented facilities.

In all 839 separate scientific test facilities were ultimately designed and constructed.

DEVELOPMENT OF DESIGNS AND DRAWINGS

Information and criteria for the development of design were received in many ways: by letter, by conference, by telephone, by rough sketches, and in some cases by drawings quite completely indicating requirements. Throughout the entire period of two years starting early in 1949, the representative of J-Division, and the Holmes & Narver Chief Engineer, were in frequent and almost continuous contact by phone calls almost every day and by meetings at Los Alamos or at Los Angeles almost every week.

Upon receipt of information as to requirements, the Engineering Division prepared preliminary drawings showing physical dimensions and all information necessary to indicate the manner in which the Users' requirements would be fulfilled. Prints of the preliminary drawings were submitted to J-Division for approval. J-Division, at its discretion, submitted the preliminaries to the User; changes and suggestions made by J-Division and/or the User were then incorporated on the preliminary drawings and, if the changes were extensive, the drawings were resubmitted. The number of unscheduled preliminary drawings and the number of changes made on them was great.

After approval of preliminary drawings by J-Division, working drawings were started. In the development of working drawings all design departments had a part -- architectural, civil, sanitary, structural, mechanical, and electrical. Even while working drawings were being prepared, changes were frequently made at the request of J-Division. This was not at all unexpected, since new ideas were being put into definite form and many ideas never used before were being applied on these drawings. Although the many changes were sometimes discouraging to the men preparing designs and drawings, it was recognized by all that they were pioneering and taking part in the development of a new and significant undertaking and that change meant progress.

At the same time that drawings were being prepared for the many buildings and scientific stations, the location maps were also being developed. The exact location of each scientific station in relation to the weapon tower and in relation to the other stations was of great importance. Each station was plotted on one of 37 drawings which together made up the overall location map. The orientation of the station, its distance and direction from the zero tower, and its geographic location (determined by coordinates) were all shown for each station. The location maps were continually changing because stations were constantly being added and moved, and it was extremely difficult and at times impossible to keep the location maps current. Therefore, in addition to each station being shown on a location map, the pertinent data -- orientation, location, and distance and direction from the zero towers -- were also shown on the drawings of the stations.

APPROVAL OF DRAWINGS

When working drawings were completed, prints were sent to J-Division for final approval. Sometimes new ideas had been developed or changes had been decided upon so recently that the designers had not been made aware of them. In these cases, marked prints were returned, and the changes incorporated. Revised prints were then returned to J-Division. When all requirements had been met, the drawings were approved by J-Division and written authorization to proceed with construction was issued by the Contract Administrator.

This approval was functional approval only. Holmes & Narver was entirely responsible for proper and sound construction and the integration of all component parts.

CIRCULATION OF COMPLETED DRAWINGS

At the time prints of working drawings were sent to Los Alamos for approval, prints of the completed drawings were circulated to all design departments. This circulation was made for coordination between the departments. In most cases, prints covering complete design for a building or station were circulated as a group so that coordination of design criteria could be checked. After review, these prints were initialed by each department chief and returned to the reproduction unit with corrections or questions plainly marked with colored pencil. The returned prints were then reviewed by the Chief Draftsman or other delegated personnel and referred for corrections to the departments concerned. The marked prints were then filed for future reference. This print circulation procedure applied to revisions to drawings as well as to original issue.

DISTRIBUTION OF PRINTS

After all corrections indicated on the circulated prints or requested by J-Division were made, the drawings were signed as approved by the Chief Engineer or his assistant. Until a drawing was signed by the Chief Engineer it was considered a preliminary drawing. Upon signature by the Chief Engineer, a drawing became a working drawing. A complete record was kept of all prints made and distributed after approval.

The usual distribution of prints was as follows:

H & N Engineering Manager, Jobsite	8 prints, 1 transparency
AEC Resident Engineer, Jobsite	1 print

AEC Contract Administrator, Los Alamos	1 print
J-6, J-Division, Los Alamos	1 print (additional prints as requested)
H & N General Superintendent of Construction, Los Angeles	1 print
H & N Estimating Department, Los Angeles	1 print
H & N Engineering Division, Los Angeles	1 print

Prints issued to the Jobsite were ordinarily sent by air mail, but in many cases urgency required that the prints be hand-carried by authorized personnel going to the Jobsite. The transparency was issued for making additional necessary reproductions and for use as a basis for "as built" drawings. Each print or transparency was numbered and logged in a card index system in the engineering files, showing distribution, date issued, and number of revisions. All prints issued to Jobsite were accompanied by a letter of transmittal containing a receipted copy to be signed by the Engineering Manager at the Jobsite or by other delegated personnel and returned to the Engineering Division in the Home Office as evidence that they were received.

REVISIONS TO DRAWINGS

Changes in design or changes in location were often requested by Users after completed drawings had been approved by the Chief Engineer and issued to Jobsite. Drawings were revised to incorporate these changes and were then reissued in accordance with the procedure outlined above.

The total number of drawings required to complete the Project (839 scientific stations, 337 aluminum buildings with a total floor area of 482,765 square feet, 644 tents, and 115 rehabilitated buildings) was far in excess of the 876 final drawings prepared by the Engineering Division in the Home Office and approved by the Chief Engineer. In addition to the many preliminary drawings, there were 110 drawings completed and approved but later voided and replaced by new drawings because revisions were so numerous or extensive that the original drawings could no longer be used, and 575 drawings prepared by the engineering force at the Jobsite. There were 1289 recorded revisions to drawings prepared in the Home Office.

A system was set up for the identification and control of drawings. Preliminary drawings were identified by the letters "SK" followed by a number. The first digit indicated the originating department; the other digits, the serial number.

Numbers were allotted as follows:

Architectural	101-199
Civil	201-299
Electrical	301-399
Mechanical	401-499
Sanitary	501-599
Structural	601-699
Surveys	701-799
Miscellaneous	801-899

Working drawings were given numbers consisting of one-digit or two-digit number, a letter, a dash, and a three-digit number. The first element indicated the use feature of the work. Use features were assigned numbers as follows:

Site Plans	1
Buildings	2
Special Structures	3
Power Plants	4
Refrigeration	5
Electrical Distribution	6
Communications	7
Signal and Control	8
Water System	9
Sewer System	10
Fuel System	11
Airstrips	12
Roads	13
Grading and Paving	14
Subaqueous	15

Surveys	16
Instrumentation	17
Miscellaneous	18

The letter identified the location. The following are the locations and their letter symbols:

Eniwetok	A
Parry	B
Runit	C
The Aomon-Biijiri-Rojoa Group	D
Engebi	E
Bogallua	F
Experiment Islands	G
Eniwetok Atoll	H
Coral Head	J
Aniyaanii	K
Japtan	L
Tower-Site Southeast of Runit	M
Piiraai	N
Bokonaarappu	P
Teiteiripucchi	Q
Aaraanbiru	R
Muzin	S
Kirinian	T
Bogombogo	U
Eberiru	V
Bogon	W
Rigili	X
Igurin	Z

The first digit of the final element identified the department that prepared the drawing, and the last two digits gave the numerical order of preparation, by the same system as that used for preliminary drawings.

Thus, an example 12B-204 tells that the drawing has to do with the airstrip on Parry, was prepared by the Civil Department, and was the fourth drawing prepared by that department.

This system made for ease and clarity of reference to drawings and facilitated storage, classification, and use.

EQUIPMENT AND MATERIAL SPECIFICATIONS

Ordinarily, two methods of specification preparation could be followed. By the first method, a basic specification could be written covering the first work increment, and subsequent work increments added by amendment. By the second method, separate specifications could be written covering each successive work increment. By either method, the bulk of the specifications would be great and would be further augmented by addenda occasioned by changes in design or scope of the work. The resulting completed specifications in either case, it was estimated, would be unwieldy in size and confused by a maze of references and cross-references.

An even more important objection to the preparation of specifications by either of the foregoing methods was the consideration that if procurement of materials awaited completed construction specifications, the delay in the construction schedules would be excessive because of the distance of haul from source to Jobsite.

The procedure finally determined upon was based to a large extent upon the consideration that the services to be rendered by Holmes & Narver under the Contract were not those only of Architect-Engineer, but of Contractor-Manager as well. This type of contract permitted the preparation of the specifications to follow a plan calculated to achieve economies in time and money as well as to obtain clarity and reasonable brevity in the completed specification. This plan called for issuance of specifications at such times and in such increments as would best suit the construction schedules. At the same time, however, the specifications were to be in a form which would allow ready consolidation into one complete specification covering all phases of the work. The plan involved the preparation of two general types of specifications: Equipment and Materials Specifications and Construction Specifications.

Equipment and Material Specifications (commonly called Purchase Specifications) were prepared for the purchase of certain materials and equipment. These specifications covered types and qualities of materials, standards of workmanship, methods of fabrication and assembly, and, for equipment, designs, sizes, and capacities.

In the first place, use of these specifications made it possible for procurement procedures to be initiated at the earliest possible date, often long in advance of the completion of working drawings. This was of primary importance because of the distances separating Jobsite from points of supply and because many construction material items were not available from stock.

The second purpose was to achieve uniformity of equipment and materials at the various locations on Jobsite. Here, being able to procure materials and equipment well in advance of the completion of working drawings, or in advance of the requirements of construction schedules, aided in establishing the uniformity and interchangeability of equipment and machinery used on various locations at Jobsite. For example, by the use of a Purchase Specification, the procurement of an item of equipment for one site could be effected in time to meet the construction schedules, and at the same time procurement could be made of similar or identical items for other sites, well in advance of requirements.

The third objective was to issue specifications as required by construction schedules in such form as would allow their subsequent embodiment in a single, comprehensive unit. The Purchase Specifications were later incorporated into the final Construction Specifications (General Specifications).

Purchase Specifications for construction operations were supplemented by the inclusion on the working drawing of considerably more specification material than is ordinarily included on the drawings.

It is believed that the use of Purchase Specifications aided in the achievement of availability and uniformity of materials and in clarity and conciseness of specifications to an extent that the ordinary methods of specification preparation could not have approached.

In general, the criteria to which the Purchase Specifications were written were those followed in the preparation of the General Specifications. The basic requirements included the provisions that specifications be to government standards or to other applicable, recognized standards; that proprietary names to designate types or standards of quality be avoided where practical; and that the specifications be prepared so as to result in open competitive bidding among a minimum of three qualified vendors.

Because of climatic conditions at the Jobsite, it was of primary importance that materials used in the permanent construction be inherently resistant to or suitably processed against extremes of heat, humidity, and salt spray. In addition to this requirement, a short delivery period was often essential for the maintenance of construction schedules at Jobsite. The combination of these two conditions required that a greater than normal amount of time be spent in the preparation of Purchase Specifications. For many items, an exhaustive survey of available materials was necessary before the specification writing could be begun.

The Purchase Specifications originated with the various engineering design departments. The preparation procedure varied to suit the materials or equipment to be purchased. For the most part, Purchase Specifications for items of mechanical and electrical equipment were written by qualified personnel in the originating department and edited by the Specification Department of the Engineering Division. Other items were normally written and edited within the Specification Department, with necessary assistance furnished by the interested departments. Upon receipt of bids in the Purchasing Department, the bid papers and bid tabulations were made available to the interested engineering departments for their comments or recommendations. The Engineering Division cooperated with the Operations Division during the period between initiation of fabrication and delivery at Jobsite by passing upon the fabricator's material lists and shop drawings, and by rendering technical assistance to the Inspection and Shipping Departments of the Operations Division.

A uniform system of numbering was established for Purchase Specifications and Invitations for Bids. Corresponding Specifications and Invitations had identical numbers and dates. The number consisted of three parts, separated by dates. For example, on the Specification and Invitation prepared for packaged steam generators, the number is HN-2B-401. The letters in the first element identified the documents as issued by Holmes & Narver; the number in the second element represented the use feature of the equipment or supplies, and the letter the H & N code for the site on which the equipment or supplies were to be used, the number in the third element represented by its first digit the engineering department which originated the specification and by its last two digits, the assigned serial number. This system, it may be seen, corresponded with that used for design drawings.

Purchase Specifications prepared for the Project were later consolidated in Volume 3 of the General Specifications covering construction work. These specifications are presented as Appendix "F" of this report.

Three hundred and six pages of Purchase Specifications were prepared. Eight pages inadvertently omitted from the collected specifications, but used, are also reproduced in Appendix "F". Sixty-five pages prepared but not used because of changes in work required are not reproduced.

BILLS OF MATERIALS

In order that the Construction Department might be assisted in determining material requirements, the Engineering Division prepared Bills of Materials for design drawings. These were prepared on tracing paper so that reproducible vellums could be furnished to both the Home Office Construction Department and Jobsite. By use of these, it was possible for the Home Office Construction Department to check material stockpiles established by pre-design material estimates which the Engineering Division had made to expedite construction. In addition the Bills of Material served to simplify Jobsite expediting and coordinating of materials. Figure 5.3-1 is a sample Bill of Materials.

CONSTRUCTION SPECIFICATIONS

Although the original plans had called for the consolidation and reproduction of all Equipment and Material Specifications (Purchase Specifications) into construction specifications affording complete and comprehensive specifications for all facilities to be constructed, these plans were revised because of decisions made at a meeting of representatives of AEC, LASL, JTF-3, the 7th Engineer Brigade, the 79th Construction Battalion, and Holmes & Narver at Washington, D. C. on January 30, 1950.

In consideration of these decisions, which involved the Army's taking over construction work on Eniwetok Island, it was decided to divide construction specifications for the Project into two parts, the first of which would cover facilities on Eniwetok and the second, other islands. In this manner, the specifications for work to be done by the Army could be segregated and could be made available at Jobsite at the same time as the working drawings.

Because the construction work for Eniwetok Island was to be performed by the Army, except for pilot installations, and because construction materials were already in process of procurement, the specifications were designed to cover, for the most part, methods and procedures.

Actual writing of the specifications followed H & N standard procedures. Mechanical and electrical specifications were written by the Mechanical and Electrical Departments and edited by the Specification Department; all other specifications were written by the Specification Department. All specifications were reviewed by the engineering department heads concerned.

AEC basic specifications were used as guides in establishing the divisions of the work and for technical provisions where applicable; however, the unusual climatic and terrain conditions at the Jobsite and the extended haul for materials required extensive revision of the technical clauses.

Inasmuch as the great majority of the buildings were to be of the prefabricated aluminum type, particular emphasis was placed upon the section of the specifications covering these structures. Prints of the manufacturer's drawings were furnished the construction forces in the field. These were unusually informative, including over 100 drawings showing suggested methods of assembly and erection as well as details of parts and assemblies. In addition, Holmes & Narver drawings showing dimensions, arrangements, and other details were furnished. And finally, there were included in the specifications recommendations made by the building manufacturer's test erection supervisor as to procedures and necessary tools.

HOLMES & NARVER
Incorporated
ENGINEERS

RECORD OF MATERIALS REQUIRED

SHEET 1 OF 1 SHEETS

LOCATION & JOB NUMBER	TYPE OF WORK	DRAWING & REVISION NUMBER
A-640	50 MAN LATRINE BLDG. 126, 128, 129	2A-5106

ITEM NUMBER	QUANTITY REQUIRED	UNIT	ACCURATE DESCRIPTION & NOMENCLATURE	QUANTITIES REQUISITIONED				REMARKS
				REQ. NO 229	REQ. NO 343	REQ. NO 434	REQ. NO.	
1.	6	EACH	2" x 6" x 12'-0" (MUD SILL)	18				
2.	34	"	2" x 4" x 12'-0" (PLATE, BLOCKING)	102				
3.	34	"	2" x 4" x 8'-0" (STUD, HEADER)	102				
4.	12	"	2" x 4" x 16'-0" (RAFTER)	36				
5.	8	"	1" x 4" x 12'-0" (FASCIA, 1"x2" SCR. BAT'N. DOOR STOP)	24				
6.	4	"	3" x 3¼" ALUMINUM HINGE	12				
7	58	FEET	PLASTIC INSECT SCREEN (48" WIDE)	174				
8.	5	lb.	4d (1½") ALUM. NAILS	15				
9.	30	lb.	8d (2½") ALUM. NAILS	90				
10	30	lb	16d (3½") ALUM NAILS	90				
11.	1	EACH	2'-6" x 6'-8" x 1⅜" SCREEN DOOR		3			
12.	7	SHTS	¼" PLYWOOD (4'-0" x 8'-0")	21				
13.	13	EACH	ALUM CLOTHES HOOKS	39				
14.	3	"	ALUM TOILET PAPER HOLDER	9				
15.	2	"	1" x 6" x 12'-0" (HOOK STRIPS)	6				
16.	30	"	¾" - #8 R.H. ALUM. WOOD SCREWS	90				
17	6	"	¾" - #11 R.H. ALUM. WOOD SCREWS	18				
18.	100	"	¼" x 3 ALUM. BOLT W/NUT & WASHER			300		

Figure 5.3-1 Sample Bill of Materials

Similar details and procedures for erection of chain link fencing and gates were included in the specifications. Also methods and procedures for other construction problems were treated in detail in the specifications because reference works for such jobs could not easily be obtained at the Jobsite.

Through the courtesy of the Corps of Engineers, Los Angeles District Office, in permitting Holmes & Narver the use of their library facilities, considerable data were obtained from the Department of the Army Technical Manuals and Technical Bulletins. To supplement the construction specifications, it was decided to furnish copies of certain of these publications to Jobsite personnel. Copies of thirty bulletins and manuals were requisitioned, including the four publications listed below:

TM5-9611	Building, Erection, Procedures, Portable, Prefabricated
TM5-680D	Underground Distribution Systems (electric)
TM5-670	Refrigeration, Air Conditioning, Evaporative (Desert) Cooling, and Ventilation
TB5-283-1	Plumbing and Pipework

The construction specifications for facilities on Eniwetok Island were completed by March 15, 1950, and consisted of a total of one hundred and seventy pages. Addendum No. 1, consisting of five pages, was issued on April 20, 1950, to correct errata and to make minor changes in the technical provisions.

It had become apparent during the course of preparation of these specifications that the drawing list would not be complete at the time of completion of the specifications, because some drawings would not have been finally approved by the AEC. Rather than delay the issuance of the specifications, it was decided to incorporate the drawing list at a later date in the form of an appendix to the specifications.

Before the appendix could be issued, the Holmes & Narver participation in the actual construction operations at Eniwetok Island was augmented. The revised program of May 19, 1950, increased the Holmes & Narver construction activities to include facilities not included in the original scope of the work. These included sewage outfalls and an electrical distribution system. By letter dated October 13, 1950, the Holmes & Narver construction program was further increased by the addition of the Steam Cleaning Shelter (Building No. 117 F). Also, because the 7th Engineer Brigade was to be assigned new duties, Holmes & Narver was required to complete the construction of the Loran Station (Building No. 116). Therefore, in keeping with the original planning which restricted the Eniwetok Island construction specifications to the coverage of facilities constructed by the Engineer Brigade and the 79th Construction Battalion, Addendum No. 2 to the specifications, consisting of one page, was issued under date of March 23, 1951. This addendum revised the scope of work in conformity with the reassignment of construction operations and, in addition, incorporated Appendix "A" into the specifications. Appendix "A", consisting of eight pages, comprised the list of working drawing numbers and titles for approximately two hundred and fifty drawings.

The specifications covering construction work for facilities on Eniwetok Island, including the addenda and Appendix "A" consisted of one hundred and eighty-four pages. This material, except Appendix "A", is reproduced in Appendix "F" to this report.

Preparation of the construction specifications for all the other sites was the largest part of the work of the Specifications Department. Because the Purchase Specifications were planned for incorporation into the General Specifications ("Specifications, Atomic Energy Commission, Proving Ground Facilities, Eniwetok, M.I."), the date of the first Purchase Specification, May 18, 1949, may be considered the starting date for these General Specifications. But, it is to be noted that because the preparation of Purchase Specifications involved collecting and compiling data, the actual specification work began almost as soon as the engineering design work.

The requirements imposed by conditions at the Jobsite were limiting not only upon design but upon materials specifications as well. Materials either had to be intrinsically resistant to extremes of heat and humidity, mildew, and salt spray or had to be processed to resist these. Very few native materials could be used, and weight and bulk were important factors in transportation to the isolated Jobsite. Economy and use-expectancy added limitations as well. The result was that many common construction materials were virtually prohibited for their normal use and had to be the subject of special investigation to determine the practicability of their use. Such materials included structural steel, miscellaneous iron and steel items, ferrous sheet metal, ferrous rough and finish hardware, glass, ceramic tile, brick, concrete block, and similar products.

Although the problems involved in using available substitute materials were primarily those of design, the Specification Department was frequently called upon by various engineering design departments to make recommendations based on its familiarity with the various types of products and sources of supply. The investigation required for a considered recommenation was often extensive. For example, for finish hardware it was first necessary to consult reference files and then to contact six hardware suppliers. On the basis of information thus obtained, the Chief Architect and Chief Specification Engineer determined that aluminum hardware would best satisfy the governing criteria. It was then necessary for the Chief Specification Engineer to confer with suppliers and obtain quotations and samples.

Some items of finish hardware were not being manufactured either in aluminum or other corrosion-resistant metals. Therefore, a survey was made of fine metal working plants to find a manufacturer who could make the items, and conferences were held between the Chief Specifications Engineer and a representative of an aluminum producer to obtain recommendations as to the aluminum alloys to be used in fabricating the hardware items. Sufficient information was then made available to the metal working plants so that quotations could be obtained upon items to be fabricated.

In final conversations between the Chief Architect and Chief Specifications Engineer, decisions were made which were later approved by the Chief Engineer. The result of this time-consuming investigation was the specifications for finish hardware.

The procedure involved in preparing specifications for hardware items was typical of similar investigations involving such unrelated materials as explosive-driven stud bolts, paints, aluminum cabinets, plastic glass and surfacings, synthetic rubber gaskets and stripping, and vapor-seal coating. It was often impossible to obtain materials that satisfied all requirements completely, but every effort was made to insure that the material selected was the optimum obtainable.

Many investigations yielded only negative results and therefore were not reflected in the specifications. Other investigations resulted in specifications for materials which although ordinary in themselves represented the end product of considerable research.

One great deterrent to the collection of specification material was the security restrictions placed upon the dissemination of classified information. The restrictions, insofar as they influenced the collecting operations, were to the effect that personnel must not seek information not directly required for their work and must not give out information unless assured that the recipients had need of such information for their work. The result of the restrictions was to stifle the free exchange of information, even among cleared personnel. The combination of the security restrictions and the magnitude of the Project resulted, in some instances, in the Specifications Department personnel not being fully aware of certain developments as they occurred. Conversely, the personnel who were fully aware of such developments did not always know what specific information would be required by the Specification Department. The result was that when the time came for the completion of the General Specifications, it was necessary to search out certain items of information that normally would have been at hand.

By August 18, 1950, the preparation of working drawings had progressed to a point that permitted work to be begun on the final phase of specification preparation. The basic criteria were similar to those used in the preparation of Purchase Specifications and the specifications for Eniwetok Island. They were to be in accordance with AEC or government standards, in AEC standard format as much as possible, in form for use of competitive bidding (no proprietary names), and in accordance with security restrictions (no classification higher than

"Official Use Only "). They were to include the Purchase Specifications but exclude specifications for work by the Army on Eniwetok Island.

The actual writing and editing of the specifications began with the preparation of Part I, "General Conditions" and Part II, "Special Conditions", in order that all personnel having a part in specification preparation would be acquainted with the conditions involved and the terminology to be followed. The current AEC "General Conditions" and "Special Conditions" furnished by the Santa Fe Operations Office in Los Alamos, were used as guides. It was immediately apparent that the provisions contained in these guides, while applicable to construction work at established bases such as Los Alamos and Albuquerque, required extensive revision in order to apply to conditions at Eniwetok Island. Provisions covering the monthly rates to be paid for electricity, gas and water, connections to existing utilities, closing of streets, housing facilities, and the like were clearly inapplicable. These and similar provisions were deleted or modified as required to conform to conditions at Jobsite or as required by the terms of the Contract. Other provisions were amplified and new paragraphs added so that the scope of the work would be clearly defined. The general arrangement, titling, and numbering of the paragraphs, however, followed the basic AEC specifications as closely as possible. The completed drafts of the "General Conditions" and "Special Conditions" were then reviewed by the Budget Controller for conformance to contractural obligations and submitted to the Chief Engineer for his approval. To facilitate the work and to assure uniformity of terminology and paragraphing, copies of the revised drafts were furnished to the heads of each engineering department involved in specification preparation in order.

The writing and editing of Part III, "Technical Provisions" was then begun. The "Technical Provisions" consisted of thirty sections, each covering, for the most part, the work of one building trade, although the work specified in two or more sections could be performed by the same trade. Of these sections two originated in the Sanitary Department, three in the Civil Department, four in the Electrical Department, six in the Mechanical Department and the remaining fifteen in the Specification Department.

Throughout the preparation of the specifications a high level of coordination was maintained with the various engineering departments. The completed drafts of all sections were routed to each department whose work was in any way related to that section and were there reviewed by the department head or by other qualified personnel. After revisions occasioned by such reviews had been made, the drafts were reviewed by the Specification Department with particular respect to format and compliance with the established criteria and finally were subject to further review by the Chief Engineer or the Assistant Chief Engineer.

AEC guide specifications were used wherever applicable during the preparastion of the technical sections. As in the case of the

"General Conditions" and "Special Conditions", numerous provisions were found to be inapplicable only after modification.

As the preparation of the construction specifications entered the final phase, it became apparent that certain modifications to the original criteria would be advisable. The master plan for the preparation of the specifications had contemplated that the construction operations would be segregated into sections conforming to the work performed by the various building trades. But the construction work for scientific structures differed so radically from that required for ordinary structures that it was felt that greater clarity would be obtained if scientific structures were treated as a unit. Therefore specifications for them were incorporated into a separate section with materials and methods peculiar to these structures treated by individual buildings. The ordinary work involved in the construction of scientific structures was covered by references to the appropriate specifications for the types of work.

This change in organization of specifications brought up security considerations. It had been originally planned to keep the security classification of the specifications as low as possible by including no information in them as to number, extent, or location of specific facilities. This information was clearly indicated on the drawings and any changes in scope of work could have been expressed on them without addenda to specifications. It had therefore been anticipated that the specifications could be classified "Official Use Only." But the new arrangement and inclusion of building identifications and locations made this impossible. Accordingly, the specifications for scientific structures were put in a separate volume (Volume 4), along with the drawing list, and classified "Secret" by the Chief Security Officer of Holmes & Narver. The other volumes (1, 2 and 3) were classified "Official Use Only".

As a final check upon the accuracy of the specifications, duplicate copies of the final drafts were forwarded to Jobsite for review by the personnel engaged in the construction operations. Transmittal was made in two increments, accompanied by memoranda from the Chief Draftsman to the Engineering Manager, the first dated January 5, 1951, and the second February 23, 1951. Both sections were returned from the field by March 24, 1951, and revisions suggested by the field personnel were taken under advisement. After revisions had been made the specifications were reproduced.

On April 25, 1951, Holmes & Narver forwarded twenty sets of completed specifications to the Manager, AEC. Los Alamos. Volume 1 (159 pages) included Part I, "General Conditions"; Part II, "Special Conditions"; and Part III, "Technical Provisions", Sections 1 through 18. Volume 2 (142 pages) included Section 19 through 30 of Part III, "Technical Provisions", except for Section 28, "Scientific Structures". Volume 3 (233 pages) included Equipment and Material Specifications (Purchase Specifications). Volume 4 (95 pages) included Section 28 of Part III, Technical Provision, and the drawing list. All four volumes are presented as Appendix "F" of this report. In addition, the specifications for construction of facilities on Eniwetok Island (184 pages) are presented in Appendix "F" of this report.

CHAPTER 5.4

FIELD ENGINEERING PROCEDURES

The first Jobsite engineering service required by the Contract was to make all necessary topographical and other surveys and maps. Accordingly, the Chief of Surveys departed for the Jobsite with the first contingent of personnel, on February 1, 1949. The procedures by which the Survey Department accomplished the required work and the problems encountered and surmounted are described below in Chapter 5.8. The work included the establishment of a primary horizontal control network of twenty-three stations, with secondary control at each Project island, vertical control, topographic surveys and maps of sixteen islands, hydrography and location of submarine cable, location of special structures and instrumentation, construction staking, as-built surveys, and keeping of survey records and maps.

Until March 1950, the Chief of Surveys served as the head of all Jobsite engineering activities. By that time, design and other engineering activities had become more significant parts of the work, and the Engineering Manager assumed control. The procedures formulated and followed by the field engineering organization were developed as the scope of the work at Jobsite increased.

PRINTS RECEIVED AND DISTRIBUTED

The Design and Drafting Department at Jobsite was responsible for the distribution of prints and for maintaining a file of current prints of drawings, organized for ready reference.

Immediately upon receipt of the customary eight prints and one transparency of a drawing from the Home Office, the pertinent information concerning it was recorded in a card file or on a special index form. This task was simple, for the Home Office's letter of transmittal indicated the drawing title, number, and number of revisions. The same information was also used for check-out forms which served as the basic record for control of prints issued to various Jobsite departments. All prints issued were accompanied by a transmittal form showing drawing number, title, serial number, etc.

When prints were revised, proper precautions were taken to insure the return of obsolete prints from the field and to remove them from the field construction files.

INTERPRETATION OF DRAWINGS

It was inevitable that questions would arise concerning the proper interpretation of drawings because sometimes field conditions differed from those expected by the Home Office departments, and sometimes changing priorities required in construction schedules allowed only a minimum of time for checking at the Home Office. The

Engineering Sections at Jobsite (Inspection, Design and Drafting, Survey, and Facilities) and the Engineering Manager and his assistants were responsible for the interpretation of all H & N produced plans and specifications. If major revisions were required, a dispatch was sent to the Home Office Engineering Division requesting revised drawings or authority to redesign. If minor revisions were required, or if authority for major revisions were received from the Home Office, field sketches were prepared.

FIELD SKETCHES AND CHANGE ORDERS

Field sketches were prepared to augment Home Office drawings and to interpret changes and additional work authorized by the AEC Resident Engineer. A total of 575 of these were prepared at Jobsite.

Additional work requiring expenditures exceeding $100.00 required the preparation of change orders. These were prepared by the Field Engineering Division and submitted through channels to the AEC. The change order indicated the scope, magnitude, and description of the work to be done, its estimated cost, and the justification. Upon approval by AEC, the orders were distributed to the construction departments.

All departments of the Engineering Division contributed to the field designs necessary for preparation of change orders. However, the work of processing more than two hundred and fifty of these required the full-time services of an Assistant to the Engineering Manager for a period of several months during the fall of 1950.

A detailed record of both field sketches and change orders was kept at Jobsite and was available for use at the Jobsite Engineering Office.

INSPECTION AND MATERIALS TESTING

The Inspection and Testing Section of the Engineering Department at the Jobsite was established on the basis of the philosophy which dictated that the organization should act as a continuous check on all construction activities to assure compliance with plans and specifications. It was essential that the inspection be carried on in an unbiased manner and that the fact that the H & N organization was responsible for construction, as well as engineering, should not act as a limitation on inspection functions. In order to maximize the efficiency of inspection, Resident Inspectors were assigned to the various island locations at which construction work was being performed, and traveling inspectors specifically concerned with electrical activities, mechanical activities, paving, and concrete mixing circulated through the Atoll for the purpose of inspecting and noting progress in these specific fields of work. As warranted by work loads, Assistant Inspectors were assigned. Close collaboration was maintained between Inspection and Materials Testing personnel and, at the peak of operations, twenty four individuals were employed in these functions, including five Resident Inspectors, five Assistant Resident Inspectors, two Batch Plant Inspectors, one Electrical, and one Mechanical Inspector.

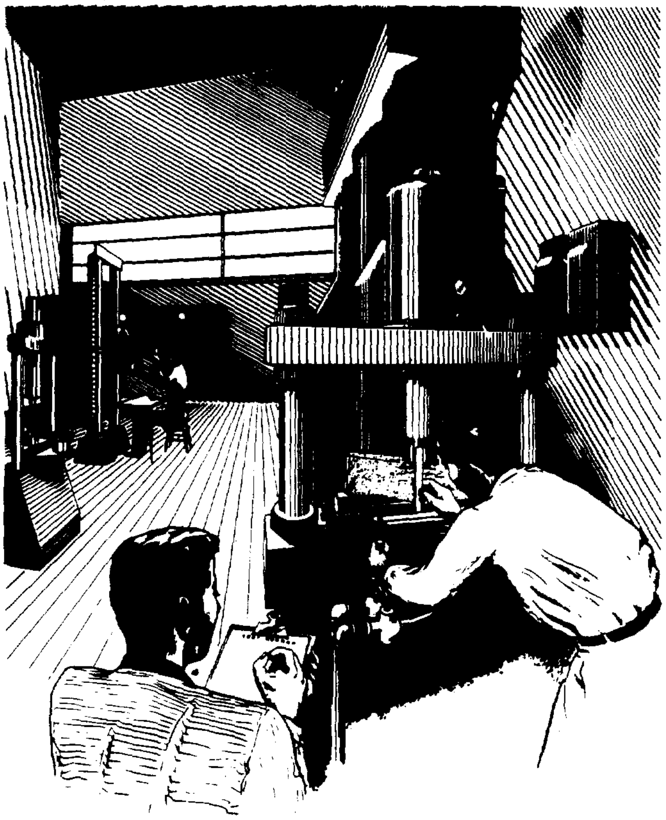
The assignment of Resident Inspectors to the principal construction sites were not permanent inasmuch as maximum utilization of the skills and experience of the inspectors employed made it desirable to have them assigned at locations where work in their fields of specialty was at a maximum.

The duties of the engineering personnel at the site, and of the inspection personnel in particular, included the interpretation of plans and specifications. It was, further, the duty of the inspector to determine that work being performed by construction forces was in accordance with plans and specifications and that all inserts, conduits, equipment, and the like were properly installed. Checks of scaffolding, ladders, excavation shoring, and other construction activities were made to assure that unsafe working conditions were not tolerated. One of the major items of inspection involved supervision of concrete work.

Each Resident Inspector was supplied with cylinder molds, a slump cone, and all necessary equipment for taking samples of concrete and making field tests in accordance with ASTM specifications. When forms were ready for the placement of concrete, an "Authorization for Concrete Pour" slip was issued by the Resident Inspector at the locality involved. The Foreman or Superintendent in charge of each phase of the construction involved was required to certify to the completion of the phase of work assigned to his group, eg., the completion of forms, placement of reinforcing steel, inserts, etc. Upon certification, inspection of the work was conducted by the Resident Inspector and if the work was found in accordance with plans and specifications, the "Authorization to Pour" was countersigned by the Resident Inspector.

The type and strength of concrete to be used in the pour was entered on the slip by the Resident Inspector and this served as an order to the Batch Plant Inspector to supply the Batch Plant Operator with mix criteria to meet the strength specified. Upon completion of the routine described, one copy of each slip was distributed to the AEC Resident Engineer, the H & N Construction Manager, the Statistical Section of the Engineering Department, and the Test Inspection files.

In December 1949, as part of the Jobsite inspection function, a materials testing laboratory was temporarily established in a rehabilitated quonset building on Parry. Initial equipment consisted of scales, a soil analysis screen kit, and two manually operated compression machines. In April 1950, the equipment was moved to Engebi to a quonset dugout where concrete and material testing was carried out under the direction of a Chief Technician. This move was deemed advisable because Engebi was the center of the major critical specification construction activity. In June 1950, a power-driven compression machine was installed and tested in the Parry laboratory, making possible the running of accurate compression and tensile tests.



All testing laboratories at the Atoll were under the supervision of the Principal Engineer, Test-Inspection Section, who made the work assignments. The Senior Testing Engineer was in physical charge of the laboratories, designating what tests were to be conducted and what methods were to be employed. It was the duty of the Senior Testing Engineer to evaluate the results obtained by his assistants and to report his finding to the Principal Engineer in charge of the Section. A daily log was kept of all work performed, copies of which were supplied to the Principal Engineer for file and distribution to the AEC Resident Engineer and Holmes & Narver Engineering Manager. The laboratory staff included, in addition to the Senior Testing Engineer, two Assistant Engineers, two Test Inspection Engineers, and two Laboratory Technicians.

The laboratory on Parry performed compressive tests only, and ample tank space was provided there for storing cylinders and beams in a moist condition. The full-time services of a Test-Inspection Engineer were required to make the compressive tests which were necessary to supply needed information to Users and to the laboratory on Engebi. A few requests were made by representatives of Users for tests of characteristics of timber and of reinforcing and structural steel. These tests were made, and results were transmitted to the Users through proper channels.

The laboratory on Engebi performed many different kinds of tests on construction materials, but the testing of cement, asphalts, and aggregates comprised the bulk of the testing work.

A very close check was maintained by the laboratory on the condition of cement. When a new shipment arrived, representative samples were immediately taken. The samples were taken from the palletized bags and given fineness, soundness, loss on ignition, time of set, and mortar strength tests in accordance with ASTM C-150-49.

Fineness was determined by the 200-mesh sieve; as specified by ASTM C-184-44, 15 per cent or more being retained was cause for rejection. A steam chest soundness test, ASTM C-189-49 was conducted. The loss on ignition test was conducted in accordance with ASTM C-114-47, with balances of 0.01; and time of set test, ASTM C-191-49, by a Vicat apparatus. Mortar strength tests were made according to ASTM C-109-49 with 2 inch cubes made with Ottawa sand aged from two to seven days in a moist condition before being tested to destruction.

The laboratory personnel and the Batch Plant Inspector working together kept a very close check on the aggregates used in concrete. No less than five daily gradations were run, and indicated changes in proportioning were made at once. Determinations of moisture content of the aggregates were made at least three times daily, with additional moisture tests at the discretion of the Batch Plant Inspector. Changes in the mix were predicated upon the results of the several tests performed by the Batch Plant Inspector. As part of the Batch Plant Inspector's daily routine, he took slump tests at such intervals as he deemed necessary. He cast at least three 6 inch by 12 inch cylinders from each structure where concrete was placed and no less than six cylinders from each 100 cubic yards of concrete placed in any one building at any one time.

In addition to the more routine duties outlined above, the Testing Laboratory was called upon from time to time for assistance in the accumulation of data required by the many agencies interested in the Proving Ground. Thus, for example, in connection with the Military Structures Program data on soil bearing values were obtained at the direction of the AEC Resident Engineer for analysis and evaluation by others. In addition, the Laboratory assisted in recording of results on a series of test holes drilled in the vicinity of certain designated Navy Structures under the supervision of the Navy representative.

Because of its importance in connection with construction requiring massive, high strength concrete, the Laboratory conducted a series of experiments directed toward the design of high strength concrete mixes. Results thus far obtained indicate that a 4000-pounds per square inch specification can readily be met using local materials and that even higher strengths may be possible.

Extensive experiments were performed to determine the effects of sea water and brackish well water on concrete. These experiments indicated very little if any impairment of the compressive strength of the concrete. With sea water, the action was very much like that in high early strength cement, the concrete gaining 80 per cent of its twenty-eight day strength in seven days. With brackish well water, the seven day strength was not quite so high, but the twenty-eight day compressive strengths were equal. The 6 inch by 12 inch cylinders used in the above experiments were cast from identical mixes, the only difference being the source of water. However, before any absolute conclusion can be drawn, further experimentation using water from both sources should be conducted.

The Paving Inspector submitted two daily samples of the finished paving to the laboratory for testing. This testing was conducted in accordance with ASTM Specification D-244-49. Some of the equipment used in the laboratory had to be improvised, and although this added somewhat to the difficulty of testing, very accurate results were obtained.

At the close of each day's work the Resident Inspector at each site submitted a report to the Principal Engineer in charge of the Inspection Test Section, setting forth in detail the construction accomplished. This report explained what problems were encountered and how they were solved or referred the problems to the Principal Engineer for action. It included figures for the number of yards and specified strength of concrete placed, lineal feet and size of reinforcement steel, square feet of forms built, cubic yards of aggregate crushed, square yards of pavement laid, and all other data pertinent to the day's activity. A copy of this report was then passed to the

Engineering Manager and through the Holmes & Narver, Inc. staff to the AEC Resident Manager. A weekly summary of work accomplished was submitted by each Resident Inspector to the Principal Engineer who in turn supplied figures to the Statistical Department for use in reports.

Stoppages of construction as a result of inspection activities occurred from time to time. Thus, for example, when it was determined that the coarse aggregates being used at the Engebi Batch Plant did not meet specifications on concrete, work was halted until a new source of aggregate could be opened. Likewise, paving operations were stopped on a few occasions because of poorly graded aggregates or because equipment was not functioning properly. Other work stoppages involving for the most part form work and alignment, were of a minor nature. It might be noted that none of the work stoppages involved serious delays in construction activities, although this was not used as a criterian in the determination of whether or not work should be stopped because of inspection objections. Upon completion of a particular feature of construction work, the inspector was required to submit a set of drawings on which notation had been made during the progress of the work of all changes which occurred. These notations were used in connection with the preparation of as-built drawings, discussed below.

STATISTICS AND REPORTS

In September 1949, the Statistical Engineer arrived at the Jobsite to initiate regular progress reports on construction. He was made responsible for setting up and maintaining physical completion reports, data, charts, and other accounts of construction for all Jobsite facilities. Until November 1949, daily narrative reports of construction were maintained and mailed to the Home Office each week. On November 12, 1949, a new report designed in the Home Office was substituted. It was the Construction Progress & Percent Completion Report, submitted semimonthly, and it usually consisted of some 60 pages. In addition, statistics for a report conforming to the SFO 25 report were teletyped from Jobsite to the Home Office on the 25th of each month. Copies of progress reports were supplied to the AEC Resident Engineer. The principal difficulties encountered in the preparation of these reports resulted from the constant changes in work requirements, lack of information concerning the complete scope of the work, and insufficiency of qualified personnel. It was virtually impossible to make accurate and meaningful percentage estimates of progress without knowledge of the scope of the work, which was continually changing.

During the period from September 1949 through June 8, 1950, files were set up; an Engineering Change Order form devised; Daily Inspection Reports devised and put into use; and a system of control of classified engineering documents instituted. Forms and reports were designed for general engineering use, such as an As-Built Data Report, Building Completion Check List, Concrete Pour Approval, and Concrete Cylinder Test Report.

Early in 1950, it had become apparent that the semimonthly progress reports were unsatisfactory because of the laborious work in compilation and the inadequacy of the information derived from them. In July 1950, a new form was devised at the Home Office, and it was used from July 16, 1950 until the end of construction. This new form reduced the average length of the reports from 60 pages to 45 pages.

Figures for completion percentages of construction work were obtained from physical checks in the field, from Daily Inspection Reports, and from other sources. Weights and percentage values of specific jobs were estimated from knowledge available as to the scope of the Contract. As more information was received concerning scope, changes were made. Major revisions to these basic figures were made in January 1950, July 1950, and March 1951.

The Statistical Section furnished other regular and special reports and charts for Jobsite Management. Several special tasks were performed, such as conducting of manpower requirement survey in August 1950.

In September 1950, the responsibility for Building and Facility Completion Reports was assigned the Statistical Section. Descriptions of property units were written, and quantities were ascertained and recorded for all buildings, facilities, and installed equipment. The reports were then forwarded to the Home Office for determination and recording of cost data.

AS-BUILT DRAWINGS

Inspectors were given copies of drawings of construction under their supervision. These drawings were to be marked to show all changes, and records were to be kept about changes which affected design or construction. No written procedure was promulgated for this work, but general instructions were that all necessary information should be included to make the inspector's copies as-built drawings.

An As-Built Data Form was devised and put into use, but the procedure was burdensome to field personnel and compliance was imperfect. In May 1950, draftsmen were sent to the Jobsite to assist in making as-built drawings, but because design requirements were heavy these men could not start as-built work until late in 1950. In January 1951, several draftsmen were sent on temporary duty from the Home Office to assist in the work.

The transparencies sent from the Home Office were used and information secured from field inspectors and engineers added to them. As buildings were declared completed and accepted, drawings for them were checked and revised. Completed and accepted drawings were signed by the Engineering Manager, and a copy attached to the Building and Facility Completion Report for transmittal to the Home Office. Completed transparencies were sent to the Home Office Engineering Office and two copies placed in the Jobsite engineering files.

CERTIFICATES OF COMPLETION

As construction of buildings and facilities was completed, it was necessary, as a matter of standard practice, to have Certificates of Completion so that a proper record could be maintained of completed facilities and their official acceptance for use. Forms for these certificates were designed and put into use late in 1950 but did not receive complete acceptance and general official use until early in 1951.

After representatives of the Engineering Division, the Construction Divison, and the AEC had made a preliminary check for omissions and variances, the Certificate of Completion, Form No. O/S 198, was filled out for each facility or building, except those on Eniwetok Island, for which Form No. O/S 199 was used. These certificates listed the building or facility identification, drawings, date of completion, and the page number of the Continuing Property Report upon which the building or facility was shown. Incomplete items, equipment not yet installed, and other omissions or variances were noted on the reverse side. For as-built drawings, for specifications, and for buildings or facilities for which specifications were furnished by the Military, Form No. O/S 274 was used. Three copies of each Certificate of Completion and as-built drawing were delivered to the AEC.

CHAPTER 5.5

ENGINEERING CONTRIBUTION TO RECONNAISSANCE SURVEY

The fundamentals of the philosophy underlying the development of the Eniwetok Proving Ground as a semi-permanent AEC facility were established by the Reconnaissance Report, dated January 7, 1949. This document, which was the combined result of briefings by the staff of J-Division (LASL), an on-the-ground survey by a team of engineers under the direction of the H & N Chief of Operations, and consultations with J-Division personnel on basic policy matters, set the basic pattern for Holmes & Narver activities during the ensuing two and one-half years. The Reconnaissance Report and the supplement issued in July 1949 not only established the master plan for the Proving Ground, but established as well the fundamental operational philosophies which assured the flexibility required by greatly expanded test and scientific activities.

During the meetings at Los Alamos, in late September 1948, a reconnaissance survey of Eniwetok Atoll was determined to be the wisest initial step in the development of semi-permanent proving ground. However, two limitations interposed. The existence of plans to carry out construction activities at Eniwetok was highly classified, and it was doubtful that the garrison forces at the Atoll could support more than a handful of visitors for even a short period of time.

Because of these limitations, detailed knowledge of the Project was limited to a small number of cleared personnel in the H & N Engineering and Operations Divisions, and the team chosen for firsthand studies at the site was limited to an even smaller number. Therefore the five H & N representatives who made the trip to the Atoll (accompanied by a representative of J-Division and two radiological safety monitors) were chosen because of considerable experience in and knowledge of construction activities and the relevant engineering fields, including master planning, site planning, power generation and distribution, water and sanitary systems, surveys, air conditioning and dehumidification, soils and aggregates, etc.

Immediately upon the completion of the September meeting, plans were pushed as rapidly as possible for the departure of the reconnaissance team. In the meantime, assignments of Home Office personnel were made for studies of generating equipment (both fixed and portable), water distillation plants, prefabricated building types and availability, and similar subjects, knowledge of which appeared to be necessary.

The overseas activities of the team occurred during the period October 1, 1948 through October 23, 1948. In addition to the actual reconnaissance at Eniwetok, the itinerary of the group included conferences at CINCPAC Headquarters, Pearl Harbor, T. H.; Public Works Office, Fourteenth Naval District, Oahu, T. H.; and Naval Operating Base, Kwajalein. All of these conferences proved very informative and helpful in the formulation of the engineering aspects of the over-all plan presented in the report.

At the site, all factors were examined which could even remotely bear upon engineering design, upon construction, or upon operation of facilities during test activities. An inventory was made of existing buildings, piers, airstrips, equipment, etc. Each island that could possibly be used during a test period was studied, both from the air and on the ground. Residual radioactivity levels resulting from Operation Sandstone detonations were recorded. Samples of beach sand and coral which might prove useful as sources of aggregates were obtained from various locations throughout the Atoll. Other samples were taken from several locations to provide material for preliminary soil studies. In all, some 30 different samples were shipped to the Engineering Division at the Home Office for analysis and test for the purposes of determining design mixes and cement requirements for the Project and establishing preliminary soil data. Even the scrap dumps at the Atoll were examined with a view toward determining the effects of climate and environment on all types of materials. (It might be noted here that this study yielded the significant data which ultimately led to the selection of particular types of aluminum for extensive semi-permanent buildings on Eniwetok, Parry, and Japtan Islands.)

Meetings were held with the commanding officer of the garrison to learn of logistic, communications, environmental, and morale problems and meetings were held with other staff personnel to cover details of housing and messing availability, inter-island transportation by small boat and aircraft, maintenance requirements in standby period, and the like.

The discussions held at the site and at the other installations mentioned in this section were directed towards the collection of all possible information which would have a bearing on design, construction, and operational activities at the Proving Ground. From the engineering standpoint, for example, the problem of logistics was a necessary consideration in the choice of materials, the choice of packaging, the choice of design, and other determinations. For example, one of the cogent reasons for the choice of the design of the prefabricated aluminum buildings was that it was realized that shipping space would always be at a premium throughout the course of the Project and that a building design which lent itself to the most efficient use of shipping space would afford an important advantage.

In view of the proximity of Kwajalein to Eniwetok, the experience of service and Trust Territories personnel there on many aspects of island life was deemed to be important in the proper study of the Proving Ground. Water and power usage factors, availability of construction materials, shipping and airlift schedules, mail delivery and communications, corrosion, refrigerated storage capacities, POL problems, and many other items which affected the engineering and design aspects of the survey were discussed.

Likewise, at CINCPAC Headquarters at Pearl Harbor, discussions were all extremely useful in establishing basic planning principles on all phases of the proposed development. These meetings involved discussions with staff and key personnel of CINCPAC and COMSERVPAC on such problems as POL storage and handling, equipment availability which could affect site planning and design, details of materials to be considered and related corrosion problems, communications equipment and system design, hydrographic and oceanographic information related to the Atoll, wage scales, and water distillation. These discussions provided much information which could be used by the Engineering Division in establishing planning criteria.

The meetings at the Public Works Office of the Fourteenth Naval District were also extremely fruitful inasmuch as this office was directly concerned with design and engineering as well as construction throughout most of the Pacific Ocean. Design criteria for military installations in the Pacific were reviewed. Maintenance requirements, specifications, material, supplies, soil stabilization, logistic considerations, and other relevant problems were considered. It is noteworthy that during these discussions the comparison was drawn between stateside construction costs and overseas construction costs for various Pacific installations. It was reported to the members of the reconnaissance team that the ratio of overseas cost to stateside cost varied, depending upon the particular location in the Pacific Ocean area, between 1.75 and 3.0 and that the latter figure was perhaps more realistic for work at locations such as Eniwetok, which was somewhat off the beaten track and had no native population available for employment.

Upon return of the reconnaissance team to Los Angeles, its members began the task of integrating the wealth of material accumulated during the trip with the information on equipment, prefabricated buildings, usage factors, and similar items of information worked up by engineering personnel at the Home Office. The screening process was tedious and, because of security limitations, the wealth of experience available througout the Engineering Division and clearly applicable to the job at hand could not be fully utilized. However, by the first week in November 1948, considerable progress had been made in resolving the data collected into the form of recommended criteria.

At this time it became apparent that the master planning of the Project could be expedited materially if "P" approved personnel were given access to isolated phases of the problem for study. Permission was granted to do this, and thus it was possible to utilize the added experience which could be brought to bear on the subject and new impetus was given to this phase of the work.

It was also apparent at this time that one of the major considerations affecting the production of a master plan for the Proving Ground was the determination of the intended period of utilization of the facilities. The type of structures and equipment to be recommended, the nature of installations, and the over-all philosophy of operation would obviously be quite different if only a single operation were planned in 1951 than if it was intended to establish structures, facilities, equipment, and installations which could be used for a series of operations to be performed over a number of years. Such policy determinations and those which concerned the extent of participation of military personnel would influence the ultimate location of camp sites, the nature of base facilities, and many other items of design and engineering significance.

Meetings to resolve these policy matters were held at Los Alamos between November 15 and November 19, 1948, and, by the end of November, decisions had been made by the AEC in Washington, D. C., that planning for the Project would be on the basis of tests in 1951 and one additional set of tests. It was intended that the planning basis should be for base facilities which would last for approximately 5 years. Request was made, however, that analysis of the master planning problem be so arranged that the difference in cost between one-experiment use and two-experiment use would be determinable.

With basic requirements and philosophies firm, the design and engineering phases of the Reconnaissance Report began to take shape. A letter from J-Division[1] clearly set forth the AEC position on criteria questions raised at the November meetings and resulted in immediate steps by the Engineering Division to collate the design data, previously worked up, along the lines indicated. Such sections as those which concerned camp layouts and base facilities, personnel buildings, power generation and distribution, water distillation, sewage and waste disposal, and surveys were rapidly moved toward final form in the light of agreed-upon principles.

One of the most significant engineering contributions to the Reconnaissance Report was the development, in close coordination with the Operations Division, of a master plan with the flexibility which H & N experience with other scientific and research projects had shown to be essential. Because the type, number, and size of scientific stations could only be surmised, because work on the proposed experimental programs had barely begun, and because the population requirements and facilities requirements provided H & N were based on experience during Operation Sandstone (essentially ship-based) rather than upon the defined scope of this operation, it was necessary to make careful analyses with a view to future expansion of a major nature. For example it was necessary to plan locations of offices, laboratories, and personnel facilities to provide convenience and accessibility as well as room for possible expansion.

That flexibility was designed into the master plan is evident from the fact that, of 28 recommendations of an engineering nature contained in the Reconnaissance Report, essentially 26 were followed throughout the Project in spite of radical changes in the experimental programs, in the numbers of personnel accommodated, in the greatly increased magnitude and complexity of the support required for scientific operations, and in the numbers of Users engaged in the scientific program. The master plans proposed in the report and in the various site layouts for base facilities and camps were followed, and the necessary expansion was provided within these basic concepts as the changing requirements were encountered.

[1]AEC letter LAB-J-509, November 29, 1948

In view of the multiplicity of the details involved in a project of the type then contemplated, complicated by the further fact of the off-shore and isolated location of the Project site, the significance of the flexibility afforded is apparent at the Proving Ground in the lack of congestion and in the orderly appearance of the various island developments.

CHAPTER 5.6

LIAISON TO OBTAIN DESIGN CRITERIA

The need for close liaison between the scientific and operational groups whose requirements would determine the Proving Ground facilities which the A-E-C-M Contract was to design, construct, and operate was recognized as essential to the long-range planning and development of Operation Greenhouse.

The procedures established to maintain this liaison between J-Division and the H & N Engineering Division are discussed in Chapter 5.3 of this report. More than thirty trips were made by the Chief Engineer or members of his staff to Los Alamos, Chicago, Washington, D. C., and the Jobsite for this purpose. These trips, as well as the many by personnel of J-Division, were supplemented by frequent telephone calls, dispatches, and letters.

The details of the development of master planning, site planning, and many other engineering features are given in subsequent portions of this volume. Because of the fact that the success or failure of the facilities provided at the Proving Ground to serve the needs of the Users hinged upon the success or failure of getting these requirements from the minds of scientists to the drafting boards of engineers, it is felt that a brief resume of the salient points of this liaison might be valuable at this point.

The liaison to obtain design criteria might be said to have started with a series of meetings at the Los Alamos Scientific Laboratory on November 15 to 19, 1948. This was attended by a large group from J-Division, the principals of Holmes & Narver, and the reconnaissance team. Shortly after this meeting, the direction and liaison of all technical and operational matters was delegated to J-Division.

Following the November meeting, at which some basic criteria were established, the Engineering Division started the preparation of master site plans and began a detailed study of types of building construction. The latter resulted in the selection of the 24-foot wide aluminum building that could be used in any length in multiples of four feet.

It was not until December 13, 1949, that the development of scientific test structures could be started, and thus initial design work was concentrated on the development of Eniwetok and Parry Islands and the living camps for the experiment islands: Engebi, Rojoa, and Runit. The Chief Engineer made a trip to the Laboratory at Los Alamos, submitted site plans, and thoroughly discussed them with representatives of J-Division. Changes were suggested and notations made which were later incorporated in the site plans.

By March 3, 1949, detailed plans and specifications had been completed and approved for the first 300-foot tower. The site plans for Parry Island were finally approved on April 8, 1949, but it was August 30, 1949 before definite information was received from JTF-3 about the requirements for Eniwetok Island and a new site plan was prepared. This was approved October 27, 1949. The camp site for Engebi was approved on September 23, 1949; for Runit on October 19, 1949; and for Rojoa on October 21, 1949. The detailed arrangement of buildings for administration and laboratories for Parry Island was developed by conferences at both Los Alamos and Los Angeles between March 31 and May 17, 1949. The animal colony on Japtan was added and basic criteria for it received during conferences at Los Alamos June 30, 1949. The site plan for Japtan Island to take care of the animal colony was approved August 22,1949.

With the beginning of the year 1950, the scientific program began to take shape, and throughout the entire year either the Chief Engineer visited Los Alamos or the J-Division representative visited Los Angeles almost weekly. Between visits were many phone conversations, as new Users were included in the tests and as all Users developed their requirements. There were many and frequent changes, and the design departments were kept current by means of these meetings and conversations. Information transmitted orally was later confirmed in writing.

The first of a series of instrumentation charts was received from J-Division on December 13, 1949. These charts gave the identifying number, location, a brief description, the User, requirements for power, telephones, and time signals for each station. Revised copies of these charts were issued frequently during 1950 to reflect the current status of these requirements. The H & N Los Angeles office carefully checked each new issue against criteria previously received, and any discrepancies or errors were immediately discussed and resolved with the J-Division representative. In addition to this direct liaison with the J-Division representative, H & N engineering representatives also met with Users and JTF-3 representatives. Some of these meetings were held at the H & N Los Angeles office; others were at Los Alamos, Chicago, Boston, Silver Springs, Md., and Washington, D. C. Such meetings were always with the approval and often at the request of J-Division. As information was obtained, drawings were prepared or revised, material take-offs made, and prints sent to Jobsite. Jobsite personnel were kept advised of changes by teletype as information became available. The information thus transmitted was supplemented by frequent visits to the Jobsite by the Chief Engineer and members of his division.

Without the interchange of ideas and the discussion of problems which this direct type of liaison to obtain design criteria permitted, it would have been impossible for the design and construction of facilities to keep pace with the growth and development of requirements which occurred and which had been anticipated in the initial planning for this operation.

CHAPTER 5.7

MASTER PLANNING AND SITE PLANNING

As a result of a series of conferences between representatives of Holmes & Narver and J-Division, held during the week of November 15, 1948, basic functional criteria were formulated which, together with the findings and recommendations of the Reconnaissance Report of January 7, 1949, provided the master planning for the Project.

Because the test dates had been rather firmly established for the early part of 1951, the indefinite nature of the early criteria imposed major planning problems upon the Engineering, Procurement, and Construction units of the Holmes & Narver Organization, and required that considerable judgement and foresight be exercised to anticipate changes in basic criteria and increases in the scope of the work and still schedule the work for completion within the time limit.

Because the Atoll had been used for similar tests before, there were some installations available for use. In the interests of economy it was decided to rehabilitate these wherever possible. Similarly, it was decided to use the several islands for the same purposes as in the previous tests. Thus Parry and Eniwetok were selected to serve as support islands, while Runit, the Aomon-Biijiri-Rojoa Group, and Engebi were to be used as experiment sites. In addition, based on the findings of the Reconnaissance Report, Bogallua Island was selected as an experiment site.

The over-all planning problem modified coordination and distribution of many types of installations for a limited area and for a Project whose ultimate scope was not known until the late stages of construction. Although the increases in population for the various sites do not constitute the most definitive index of growth in scope, it is significant that the planned population of the support islands, Parry and Eniwetok, increased from 1,200 to more than 4,400. Furthermore, developments showed that not even the Users could foresee the ultimate size of the Project. Yet, the attempt by the planners to provide for changes and increases in scope was proved successful by the fact that a very high percentage of the changes and increases were made without serious disruption of original plans.

Details of the planning for each major island are given in the following subsections. Maps showing site plans and layouts for each island are presented in Appendix C of this Completion Report.

PARRY ISLAND

Parry Island was chosen as the site for AEC headquarters, including the test control center and the base for laboratory personnel and functions. It was also to serve as the construction and maintenance headquarters for H & N and as dispatching center for inter-island communications and air and water transportation. It later developed that Parry was also to accommodate JTF-3 headquarters.

The facilities required for the operations of these groups included office and laboratory buildings, work shops, warehouses, and transport installation. Quarters, messing, laundry, and recreational facilities were to be shared by AEC, JTF-3 and H & N, as well as power, water, and communications services.

According to the original criteria furnished by AEC, the maximum number of personnel to be accommodated on Parry at any one time was to be approximately 600 persons. The initial planning was undertaken on this basis and a suggested layout was incorporated in the Reconnaissance Report. This planning provided for housing all personnel in semi-permanent aluminum buildings, 200 scientists in small buildings with partitions to provide for one or two men per room, and 400 construction workers in dormitories, 34 men per building. Administration buildings, mess hall, cold storage, power and water plant, shops, and maintenance warehouse were also planned as aluminum buildings. (See Chapter 5.10, Personnel Buildings.)

Subsequent expansion of the scope of the scientific program required corresponding expansion of laboratory and associated facilities, as well as a corresponding expansion in personnel accommodations. By July 1949, when Supplement No. 1 to the Reconnaissance Report was issued, the anticipated population for Parry had grown far beyond the original estimate of 600. The increased needs for housing, messing, and other personnel facilities and the increased needs for laboratory buildings, warehouses, freight receiving, transportation, and full handling facilities made necessary a major revision of the layout originally planned.

The extent of revision may be seen from a comparison of the two plans, the original from the Reconnaissance Report, Figure 5.7-1, and the revised from Supplement No. 1 to the Reconnaissance Report, Figure 5.7-2.

The revised site plan, as approved by AEC, remained firm as to general layout, but many revisions were made in details to accommodate additional personnel. In July of 1949 the Task Force Commander elected to set up his headquarters on Parry. This decision involved approximately 100 additional people, and the planning and construction of a headquarters building for the use of this group as well as the replanning of the tent camp area. As late as October 1950, instructions were received from the AEC to provide an addition to the tent camp area to quarter 400 more people. Along with this increase in living quarters, authorization was granted to increase the seating capacity of the mess hall. Because early planning had foreseen some increase in population at this site, the mess hall galley had been built and equipped to handle considerable additional load. It did so satisfactorily until the population increased far beyond that originally contemplated.

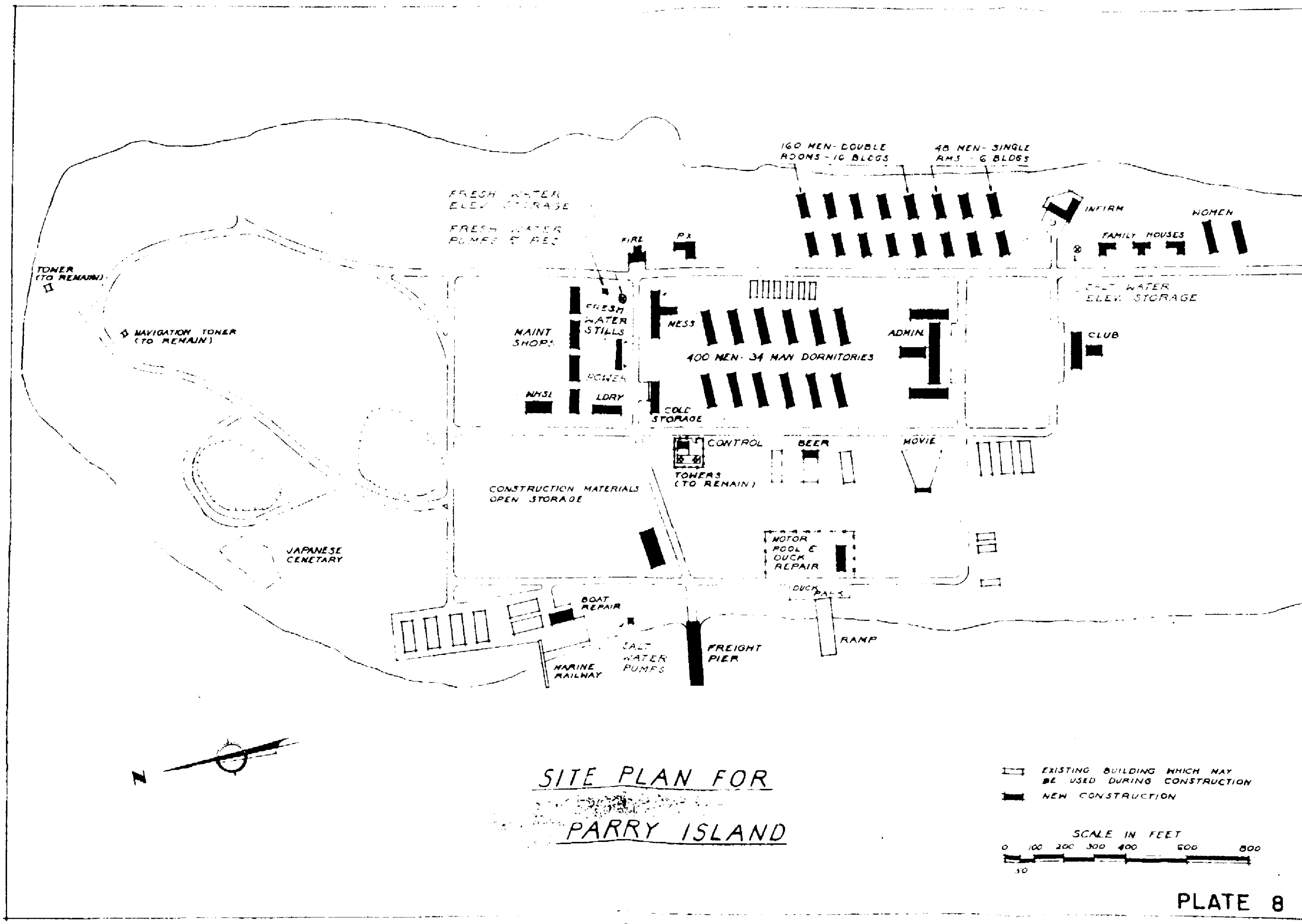
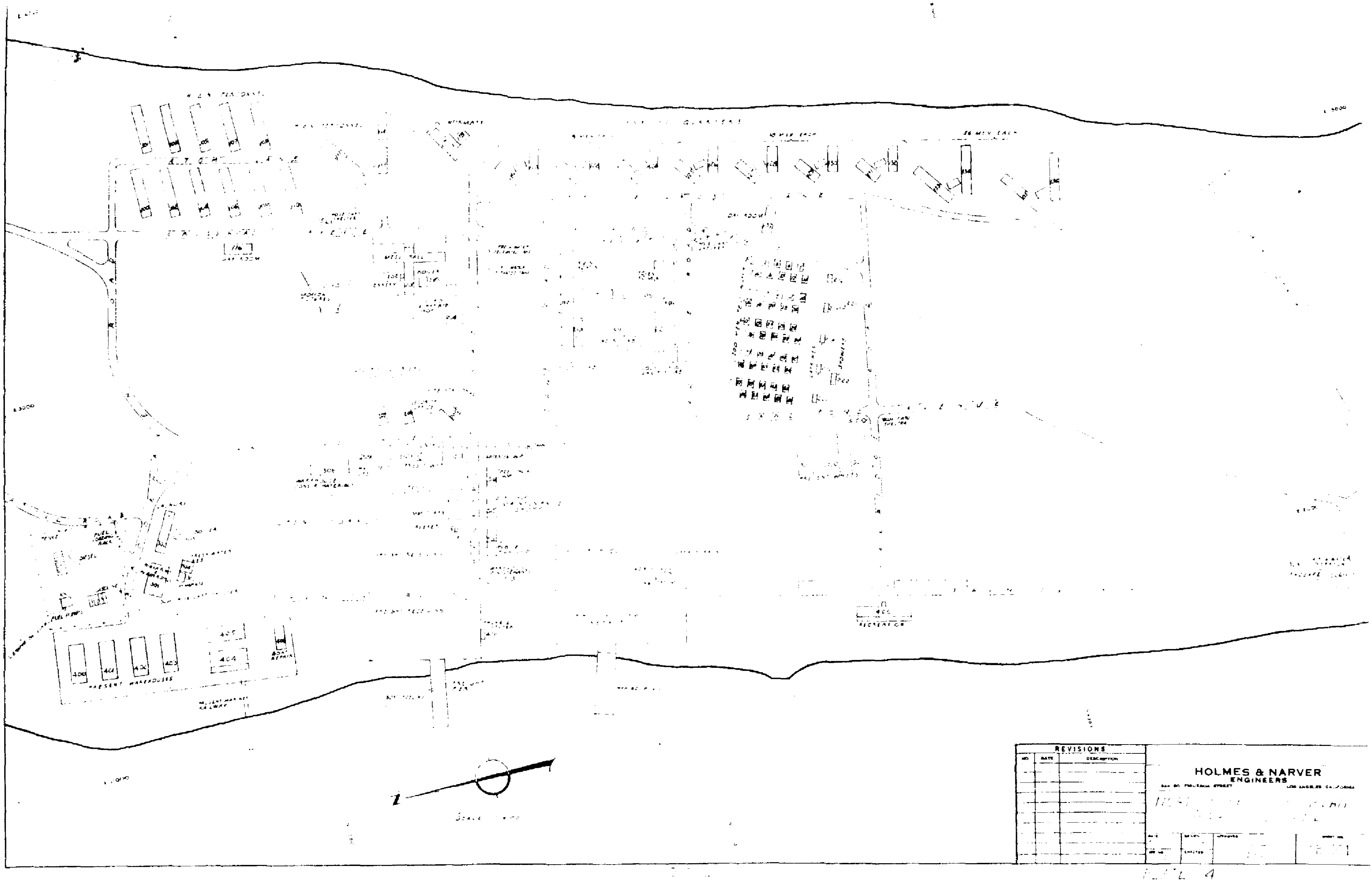

160 MEN - DOUBLE ROOMS - 10 BLDGS
48 MEN - SINGLE RMS - 6 BLDGS
FRESH WATER ELEV STORAGE
FRESH WATER PUMPS & RES
FIRE
PX
INFIRM
WOMEN
FAMILY HOUSES
TOWER (TO REMAIN)
NAVIGATION TOWER (TO REMAIN)
FRESH WATER STILLS
MESS
MAINT SHOPS
POWER
400 MEN - 34 MAN DORMITORIES
ADMIN
SALT WATER ELEV STORAGE
CLUB
WHSE
LDRY
COLD STORAGE
CONTROL
BEER
MOVIE
TOWERS (TO REMAIN)
CONSTRUCTION MATERIALS OPEN STORAGE
JAPANESE CEMETARY
MOTOR POOL & DUCK REPAIR
DUCK PARK
BOAT REPAIR
SALT WATER PUMPS
MARINE RAILWAY
FREIGHT PIER
RAMP
N
SITE PLAN FOR
PARRY ISLAND
EXISTING BUILDING WHICH MAY BE USED DURING CONSTRUCTION
NEW CONSTRUCTION
SCALE IN FEET
0 100 200 300 400 600 800
PLATE 8

FIGURE 5.7-1


PRESENT WAREHOUSES
BOAT REPAIR
REVISIONS
NO.
DATE
DESCRIPTION
HOLMES & NARVER
ENGINEERS
LOS ANGELES CALIFORNIA

In addition to these major changes and additions to the scope of facilities on Parry, there were numerous other changes which affected site planning. These other changes, directed by AEC, involved the addition, deletion, or relocation of structures. As had been anticipated during the early stages of planning, the over-all effect was a multifold expansion of both installations and personnel requirements. Indication of this can be gained from noting that population, estimated in the Reconnaissance Report at 600, reached a peak of 1530, with two or three-day peaks of over 2200.

Master planning had envisioned that on all sites, where possible and practical, advantage would be taken of existing roads, structures, airstrips, and other facilities. As indicated in the Reconnaissance Report, however, except for several usable warehouse buildings, practically none of the Parry facilities were usable. Even the airstrip was in poor condition and badly oriented.

Parry Island is the third largest in area of the many islands of the Atoll. It extends in a north-south direction. The narrow southern half of the island was not as well adapted to development as the wider northern half. On the extreme northern tip of the island were some permanent navigational aids and several borrow pits which were to be preserved. The north central section of the island, however, was wide enough for development and contained five or six usable quonset warehouses. In addition, the location of the airstrip and certain roads which could be repaired made this part of the island the logical choice for installations.

The location of these existing features, the size and shape of the site, and the interrelation of the different parts of the camp determined the final arrangement of the site. Because of the corrosive salt spray, all construction on the ocean side of the island, was kept at least 100 feet from the shore. The direction of the prevailing breeze determined the orientation of the individual buildings.

The combined administration building for both the scientists and H & N and the administration building for JTF-3, along with several laboratories, were enclosed in a security compound. This compound, the mess hall, a post exchange, two recreation buildings, and an open air movie theatre formed the heart of the camp and were readily accessible from any part of the site. East of this central group was the semi-permanent personnel area, extending along the open shore. This area was divided into two parts, one for the scientists and one for the construction workers. The infirmary was between them. At the request of AEC, the scientists' quarters were placed in pairs, each pair forming a "V", so as to funnel the wind between the buildings. South of the headquarters area and adjacent to the JTF-3 administration building were located the quarters for Task Force personnel, a tent camp of 50 4-man tents, later extended by the addition of 5 8-man tents.

Service facilities were placed along the west or lagoon side of the island. This arrangement allowed the POL facilities to be isolated near the shore and made for convenient unloading of tankers by submarine lines. The power plant and water distillation plant were placed near the POL storage area because they were prime consumers of fuel and fuel lines could thus be kept short. A further advantage was that the heat and noise of these facilities were thereby kept isolated and downwind of the quarters and administration areas. Similarly the laundry, a major user of water, was placed close to the stills.

In order that freight handling might be minimized, the maintenance and construction warehouses were located farther south, adjacent to the cargo pier and the open freight storage area. The fire station and security office were strategically placed at the intersection of two main roads from which all developed parts of the island were quickly reached.

The general location of the air strip south of the camp was satisfactory because it was far enough away to allow for future camp expansion without interfering with the operation of the strip. However, the strip was given a more favorable orientation into the wind, and a personnel pier was added on the lagoon side just west of the strip. The two formed a terminal for inter-island transportation. Such installations as the Loran station, compound, underground storage, and buildings No. 329, 330, and 331, were isolated on the south part of the island for safety and security reasons. This section was the most distant part of the island from the camp site and was not used by maintenance personnel.

ENIWETOK ISLAND

The island of Eniwetok was planned essentially as recommended in the Reconnaissance Report. Early master planning led to the conclusion that, for the maximum flexibility of operation and for the minimum of congestion between the scientific operations and the supporting military services, independent headquarters sites should be established for the scientific and military groups. Therefore, Eniwetok was planned for the military and Parry for the scientific groups. (This plan was modified somewhat when, in July 1949, the Task Force Commander elected to establish his headquarters on Parry.) Major reasons for this plan were that Eniwetok provided the most area for expansion of military facilities, that Eniwetok provided a main airstrip to accommodate drones and other facilities, and that existing communication facilities on Eniwetok could be used temporarily. In general, Eniwetok was planned to provide housing for the military garrison and to serve as the site for such other facilities as would be required by the military, aviation, and communication services.

At the time of the Reconnaissance Report, it was expected that a peak population of about 600 persons would be housed on Eniwetok Island. It was planned that some additional military personnel would be housed aboard ship. By the time of Supplement No. 1 to the Reconnaissance Report, however, the anticipated population had been increased to about 800, with corresponding increase in the facilities required for aircraft

Aerial View, Parry Island, Showing Quonsets, Administrative Area Security Compound, and Personnel Barracks

Aerial View, Eniwetok Island, Showing Headquarters, Hospital, PX, and Post Office Area support and drone plane operations. Original plans for aluminum building quarters for all personnel were changed to plans for semi-permanent aluminum buildings for 660 and a tent camp for approximately 200 short-stay personnel. Periodic increases in military personnel followed until ultimately the tent camp had been expanded to accommodate 2220 persons. With the semi-permanent buildings, housing was provided for approximately 2880 people.

At the outset of the planning of this site it was anticipated that the planning, designing and construction of all buildings, utilities, and facilities on Eniwetok would be performed by Holmes & Narver personnel; however, at a meeting held at JTF-3 Headquarters at Washington, D. C., on January 30, 1950, it was decided that the construction labor would be performed by a military Construction Battalion with the assistance of designated Holmes & Narver supervisory personnel.

Eniwetok Island, the longest and the second largest island of the Atoll, lies in a northeast-southwest direction. The northeast half of the island is narrow, but the southwest half widens out considerably. This widening allowed for extensive development of the existing runway so that it could function well as the Atoll's air terminal and as base for drone plane operations. For the same reason, the freight receiving area was located on this part of the island.

The existing communications facilities, operated by the Signal Corps and located near the center of the northeast half of the island, were retained. They remained in operation until the new facilities were built and ready for use.

The Loran station, added to the program at a later date and designed according to Coast Guard criteria, was located on the northeast tip of the island. To insure efficiency of operation of these facilities, no other installations were planned in the vicinity of the independent transmitter or Loran stations, and the area extending from the transmitter antenna farm to the Loran stations was to remain undeveloped. However, because of the desire of the atoll commander that one of the two existing recreation buildings in the area be retained for its original use, the Loran monitor antenna was located on Parry Island.

The airstrip, which was already the longest and widest on the Atoll, was realigned to permit its extension to 7000 feet. A drone control ramp was centered off the west end, and arresting cables were installed at its east end. The north side of the runway was devoted to drone plane facilities and the south side to general airport activities.

A drone parking area, 2600 feet long, was provided at the west end of the strip and connected to it by three taxiways. The northwest corner of the drone parking area was designated as the drone plane decontamination area, with personnel decontamination facilities provided close by. The new B-50 hangar and drone operations building were located adjacent to the center of the parking area. Three existing buildings also at that point were designated as air operations and base engineering shops. An isolated compound for NRDL and the Chemical Warfare Service was provided at the eastward end of the strip.

The general airport facilities on the south side of the runway consisted of a 2,300-foot-long plane park and a group of buildings near the center of the south edge of the strip. These housed the control tower, base operations, Air Task Group Headquarters, liaison plane operations and maintenance, a crash truck, weather data facilities, and radar. The existing perimeter road around the west end of the island was straightened to facilitate the lengthening of the runway and the creation of the plane park. A turn-off was added to serve the facilities along the drone park, and another was added south of the runway to accommodate the facilities in that area.

North of the airstrip, on the lagoon shore, a cargo pier and fuel dump had previously been built. Nearby were 12 warehouses, and farther along the perimeter road were 19 more warehouses. Because these installations were in fair condition, because they were sufficiently distant from the airstrip so as not to interfere with operations, and because ample space for open storage was also available there, the area was planned as a freight receiving area. These facilities were expanded and improved by the addition of a POL area and the lengthening of the cargo pier. Adjacent to the existing electronics warehouse west of the POL area was placed the permanent receiver station and its power plant.

With the airfield, freight receiving, and POL facilities occupying the west half of the island and the communications installation occupying its far east end, there remained for the cantonment area only the narrow east central strip of the island, 3000 feet long and an average 350 feet wide. Careful planning was required to accommodate over 2,800 men on this limited site and maximize the utilization of those existing structures which could economically be rehabilitated. The existing eastwest road, favorably located on the lee side, was straightened to leave maximum area free for the camp. The 8-man tent quarters were placed in staggered rows facing into the breeze, and their accessory shower and latrine buildings were placed at the downwind ends of alternate rows. This arrangement kept the shower and latrine buildings in a line along the road and facilitated the economical installation of water and sewer lines.

Two housing groups were planned, one for the Army and the other for the Air Force. The Army housing was placed east of the Army Task Group Headquarters; the Air Force housing was placed at the west end of the camp, nearest the airfield. Between the two and easily accessible were the mess hall, bakery, commissary, and reefer buildings. East of the mess hall and facing the east-west road were placed the fire station, laundry, and post exchange. Between the laundry and post exchange, but off the road, was located an open air movie theatre which could accommodate USO shows. Also in this area, but fronting the ocean and isolated from the other buildings and their accompanying noises, was the infirmary with its two ward buildings. The easternmost building of this central group was the Army Task Group Headquarters; the Army housing was adjacent to it. The semi-permanent aluminum buildings for Army Quarters (four 18-man buildings for officers, one 36-man building and three 72-man buildings for enlisted men) were placed nearest the headquarters building. The tents (one hundred and twenty-one 8-man type) were farther east.

West of the mess hall was located another open air movie theater with the Air Force housing beginning immediately south of it. Five semi-permanent 18-man quarters for officers were placed nearest the mess hall and five semi-permanent 72-man quarters for enlisted men were put farther to the west with forty-one 8-man tents for officers between the two. West of the semi-permanent enlisted men's quarters were one hundred and sixteen 8-men tents for enlisted personnel.

EXPERIMENT ISLANDS

The minimum facilities required for each of the experiment islands consisted of a weapon tower, an airstrip, and temporary housing.

The weapon Towers could not be located on exactly the same sites as those used for earlier experiments because of the old tower footings, but they were located on the same zero lines, seventy-five feet behind the original zero points (away from the existing and planned instrumentation structures).

Previous experience indicated the desirability of providing temporary camps at each of the experiment islands to house the scientists and workmen engaged in preparation for the experiments. Basic design criteria led to the estimate that each location would need facilities for approximately 50 scientists and 150 workmen. Camp layouts were developed therefore, to serve these estimated populations.

Inasmuch as accurate location data for scientific stations and other experimental structures were not available at the early stage of planning, particular care was exercised to locate camps as far from the towers and zero lines as practicable, leaving a maximum clear area along and adjacent to the zero lines available for scientific stations or structures.

All experiment island camps were designed to permit disassembly of structures prior to detonations. Therefore all structures were designed as temporary or semi-permanent. Quarters were in 4-man tents, and the recreation facilities were housed in tents. The other facilities were in semi-permanent buildings. These included mess halls, fire and first aid buildings, offices, 100-man shower and latrine buildings, and repair shops. The only exception was the power plant structures which were blast-proof concrete because power was required after the shots. Where practical, tents and equipment were to be dismantled just before shot times and stored on Parry.

The experiment islands were the sites of various scientific and military structures. Scientific structures were located from information furnished H & N by J-Division. Military structures were located and oriented under the direction of the Assistant Director of Program 3. Although H & N was not concerned directly in the master planning or site planning for scientific or military structures, their locations and relocations sometime brought about revisions in site plans prepared by H & N.

Runit Island. The weapon tower on Runit was located at the northern tip of the long narrow island and the camp area at the southern tip, in order to allow a maximum distance between them. There was an existing airstrip on the center part of the island, but because it was too short and too narrow it was rebuilt. In rebuilding the airstrip, its orientation was changed to allow a more favorable wind bearing.

The south tip of the island is shaped like an isosceles right triangle and is connected to the rest of the island by a narrow strip of land. The tent quarters were placed in two staggered rows along the equal sides of the triangle, with an open air movie theater located at the apex. The central area of the triangle was occupied by the mess hall, office, and fire and first aid building. The base of the triangle contained the power plant and repair shop; a maintenance building, grease rack, and basketball court were located on existing concrete pads within the area.

Aomon-Biijiri-Rojoa Group. The Aomon-Biijiri-Rojoa group of islands lie in a northwest-southeast line. An existing causeway connected Aomon and Biijiri. Originally it was planned that Aomon was to be the zero point for this test area. It was also planned that, in order to add to the land mass available for experiment purposes, the living camp for this group would be constructed on Rojoa and a trestle causeway would connect that island to Aomon-Biijiri. Later in the program, due to changes in the experiments to be performed, the decision was made to move the zero point tower for this test area from Aomon to Eberiru, the next island to the northwest of Aomon. A canal fill causeway connecting Eberiru with Aomon was then decided upon as the best plan in order to provide a conduit for coaxial cable lines as well as a traffic artery.

Because the existing airstrip on Biijiri was poorly surfaced and too short, a new strip was constructed adjacent to it and parallel with it on a site where grading had been started by an Army maintenance project.

The camp site on Rojoa was placed on the side of the island favored by the prevailing breeze. The tent quarters were placed in four staggered rows parallel to the shore, and other camp facilities were grouped behind and downwind from the tents.

Engebi. The original tower site for the "E" program was at the western apex of Engebi, an island whose shape is roughly that of an equilateral triangle. The site for the "E+" program added to the overall program in the Fall of 1950 was the northern apex. The existing airstrip, perpendicular to the east shore of the island and 1,500 feet south of the northern apex, was resurfaced and lengthened. The camp was located some distance south of the airstrip and on the east shore so as to catch the prevailing breeze.

The tent quarters were placed in staggered rows parallel to the shore with the other camp facilities grouped farther inland. After the decision was made to use this site for the Military Structures program, the capacity of the camp was approximately doubled. This enlargement was required to accommodate the increase in personnel necessitated by the acceleration of the construction program. The additional tent quarters were placed in staggered rows inland from and parallel to the earlier tent installation. The enlarged population necessitated increasing the other camp facilities. An additional mess hall building was placed adjacent and parallel to the original, with a covered passage connecting the two. The recreation building was enlarged to include a post office and post exchange. The first aid station was moved out of the combined fire and first aid building and an infirmary replaced it. The quarters vacated became the timekeeper's office. The open air movie theater was enlarged beyond the original design. The other buildings (recreation tent, day room, and power plant) remained unchanged.

Bogallua. The selection of a fourth experiment site had been one of the tasks assigned the Reconnaissance party. After investigation, the group recommended Bogallua, one of the islands west of Engebi, as the most suitable site, provided use could be made of the sand spit at the west end of the island. The main problem involved in the use of the sand spit was that of determining its stability. The age and extent of the vegetation on the spit indicated that it was stable, and studies of aerial photographs taken six months and eighteen months before corroborated the opinion that the spit was stable. After conferences among representatives of Holmes & Narver, J-Division, and the AEC Engineering and Construction Division at Los Alamos, Bogallua was selected as the fourth experiment island.

The planning of installations on Bogallua was based upon the fact that the time and nature of the experiment to be conducted there would require a less elaborate camp than those on other experiment islands. The camp was designed to house fewer than 50 men in tents, and provided for only a pit latrine and an open shower and lavatory slab. Storage and repair facilities were to be housed in tents. The weapons tower power plant were to be similar to those on other experiment islands. No movie theatre or airstrip was to be provided.

On December 2, 1949, after the site layout had been approved and after some construction work had been done, a break was observed in the sand spit. On December 10, 1949, a second break was observed; and shortly thereafter the sand spit disintegrated almost entirely. An attempt was made to stabilize at least a portion of the spit, but this proved unsuccessful. Consideration was then given to the use of Bogallua as the location for the weapon tower with instrumentation to be located on Bogombogo, but the distance between the two islands imposed costly obstacles. Therefore, on January 18, 1950, all work on Bogallua was stopped.

Because there was no other suitable site in the island group west of Engebi, the experiment was temporarily abandoned. Later, however, a fourth experiment was found to be vitally needed, and on October 20, 1950, it was decided that the fourth experiment would be from a tower on the northeast end of Engebi. This experiment was designated as "E+".

JAPTAN ISLAND

Japtan Island was selected as the site for the establishment of the animal colony called for in Supplement No. 1 to the Reconnaissance Report. It was selected because of its size, because of the favorable camp sites it provided, and because of its proximity to Parry Island, the scientific headquarters site.

Upon receipt of basic criteria pertaining to the animal facilities, laboratories, and personnel buildings required, a site layout was completed. Certain changes were made to this layout in conformance with requests by Users through J-Division. Notable among these changes were the addition of another animal house and an animal infirmary. The revised plan was approved and construction conformed to it.

The original criteria indicated that semi-permanent facilities for approximately 150 people would be required. The stabilization of the Medical-Biological test program resulted in a decrease in this figure, however, and semi-permanent facilities were finally provided for approximately 72 persons.

In order that the animals might become accustomed to the climate prior to the time of the experiments, all facilities at Japtan were given a high construction priority and scheduled for completion before September of 1950. Part of these installations were required to be made available as early as December 1949.

The island was covered with palm trees spaced about 20 feet apart. All buildings were located in such a way as to necessitate the removal of the fewest number of trees possible. The location chosen was the western side of the island, which afforded the best orientation into the breeze and had already been cleared. The living and laboratory facilities were toward the north and animal facilities toward the south. Three semi-permanent quarters and a mess hall for personnel were located along the shore of the island and faced into the breeze. Immediately south of the quarters, were placed the laboratory and autopsy building, with the X-ray building isolated east of these. Farther south and downwind, were placed the mouse houses, 32 animal runs, and the animal infirmary. Next came the food storage building, which was placed across the road from the pier on the lagoon side. Finally, the incinerator was located farther south and downwind from the rest of the camp.

PHOTO TOWER SITES

Findings of the Reconnaissance party indicated that the existing 75-foot photo towers at Aniyaanii and Coral Head were in fair condition and could be repaired to serve again for the forthcoming experiments. According to Supplement No. 1 to the Reconnaissance Report, it was intended to use ten photo towers, including these two. One tower was to be erected on Runit, one on Aomon, two towers for stereoscopic photography on Teiteiripucchi, one on Bokonaarappu, two on Piiraai, and one on the coral reef south of Runit Island. Two spare towers, which had been procured for Operation Sandstone were in storage at the Atoll. These were checked carefully and found to be in good condition, and it was planned to use these on Runit and Aomon. The six new-75 foot towers were to be of a new design because they were to be placed much closer to the zero towers. (See Chapter 5.11 for a discussion of tower design.)

Later, in July 1949, instructions were received to recondition the towers on Aniyaanii and Coral Head but that they would not be used for tests. Also, the spare towers which had been intended for use on Runit and Aomon were not used. Ultimately, six newly designed photo towers were used, two on Teiteiripucchi, two on Piiraai, one on Bokonaarappu, and one on the site southeast of Runit. In the course of planning of the photo towers, it was proposed to locate this last tower on Runit rather than build an artificial island. Site plans were revised accordingly, but when it was ascertained that this change would place the tower too close to the zero point, the tower was relocated to its originally planned position.

CHAPTER 5.8

SURVEYS

Survey requirements of the Project were based upon the Reconnaissance of the Jobsite made in October 1948. The Reconnaissance Report treatment of survey requirements and schedules was based upon limited knowledge of the scope of work involved. It outlined horizontal and vertical control surveys covering the Project islands as known at the time, topographic and hydrographic surveys for design purposes, and the construction and as-built surveys that would be required as work progressed. The later course of the Project and the increase in scope of work resulted in such expansion of the Project requirements that these early surveys became inadequate.

Schedules for these surveys were set up in the Reconnaissance Report. Because of a decrease in allowable manpower at the Jobsite during the early stages, inadequate transportation, and increased design and construction requirements, these schedules were met in the over-all but were not met in detail in all cases. However, design information was submitted to the Home Office as fast as it was obtained, and control requirements were completed without delaying any features of the work.

Available data for survey planning consisted of the Reconnaissance Report; the Report of the Engineer, Joint Task Force Seven; and certain Coast and Geodetic Survey charts of the Atoll. From this information, a proposed control network was laid out, and a priority of requirements for design information was schedules.

HORIZONTAL CONTROL SURVEY

To meet the requirements of the Project, a scheme of second order triangulation composed of check figures was executed from a second order base line on Runit Island. The scheme extended northward to Bogallua Island and southward to Eniwetok Island, and the purpose of the survey was to coordinate local surveys on Project islands and to establish distances and azimuth between certain installations.

Standard procedure and specifications of the U. S. Coast and Geodetic Survey for second order triangulation were the criteria for the survey. The geometry of the scheme was checked by the Los Angeles Office of the Coast and Geodetic Survey before field work started, and the results of observing the scheme were checked by the same group as to procedure in January 1950.

The scheme was so executed that it could be expanded to include the complete Atoll, and wherever possible the permanency of station locations was considered. All station markers on Project islands were referenced, but referencing of the two stations in the lagoon and on the sand spits south of Runit was not practical.

Two previous surveys had been made of the eastern portions of the Atoll. As stated in the Reconnaissance Report of January 7, 1949, these surveys were not readily adaptable to the requirements of this Project and were necessarily reoccupied to expand the present scheme.

The U. S. S. BOWDITCH Survey, made in 1944, was of third order accuracy and covered only the eastern portion of the Atoll from Igurin to Bogombogo. (See Figure 5.8-1 for the U.S.S. BOWDITCH Survey triangulation net.) The apparent purpose was to make hydrographic charts of the Atoll. It included a base line on Runit Island, control points on eleven other islands, and a station in the lagoon in the vicinity of the existing station Coral. The geographical position of station North Base on Runit Island and the azimuth of the base line between stations North Base and South Base were determined by astronomical observations. Because most of the stations of this survey were not on Project islands and because the reoccupation of the stations would have been necessary for system expansion, the values found in the U. S. S. BOWDITCH Survey were not incorporated into the present survey, except in that the determination of the latitude and longitude of station Runit by the Joint Task Force Seven Survey was based on the original geographical position of station North Base as established by the U. S. S. BOWDITCH Survey. Also, the azimuth of the line North Base Sand was accepted from the U. S. S. BOWDITCH Survey.

The Joint Task Force Seven Survey, made in 1947-48, and covering the eastern portion of the lagoon from Aniyaanii to Engebi, consisted of a limited scheme with stations on Engebi, Aomon, Runit, and Aniyaanii Islands, and station Coral in the lagoon. (See Figure 5.8-2 for the Joint Task Force Seven triangulation net) The scheme was stated to be of first order accuracy, and first order procedure had been used. However, the base expansion figure was not consistent with specifications of the U. S. Coast and Geodetic Survey, and it was only because of the limited extent of the scheme that the work could be considered of a high order of accuracy.

Of the seven stations included in the JTF-7 survey, station Graflex on Aomon Island had been destroyed, and the station on Aniyaanii was of little value in expanding the scheme. To establish a new station on Aoman required reoccupying three of the five remaining stations. It thus was apparent that the expanded requirements of the present survey involved re-establishment of a complete triangulation network. (See Figure 5.8-3 for the H&N primary triangulation net.)

Station South Base of the U. S. S. BOWDITCH Survey was not recovered, and a new station "Runit" was established at the south end of the island. The line North Base-Runit became the base line of the H & N survey.

The geographical position of station North Base and the azimuth of the line North Base-Sand as established by the U. S. S. BOWDITCH Survey were accepted and became the orgin of position and azimuth. Although

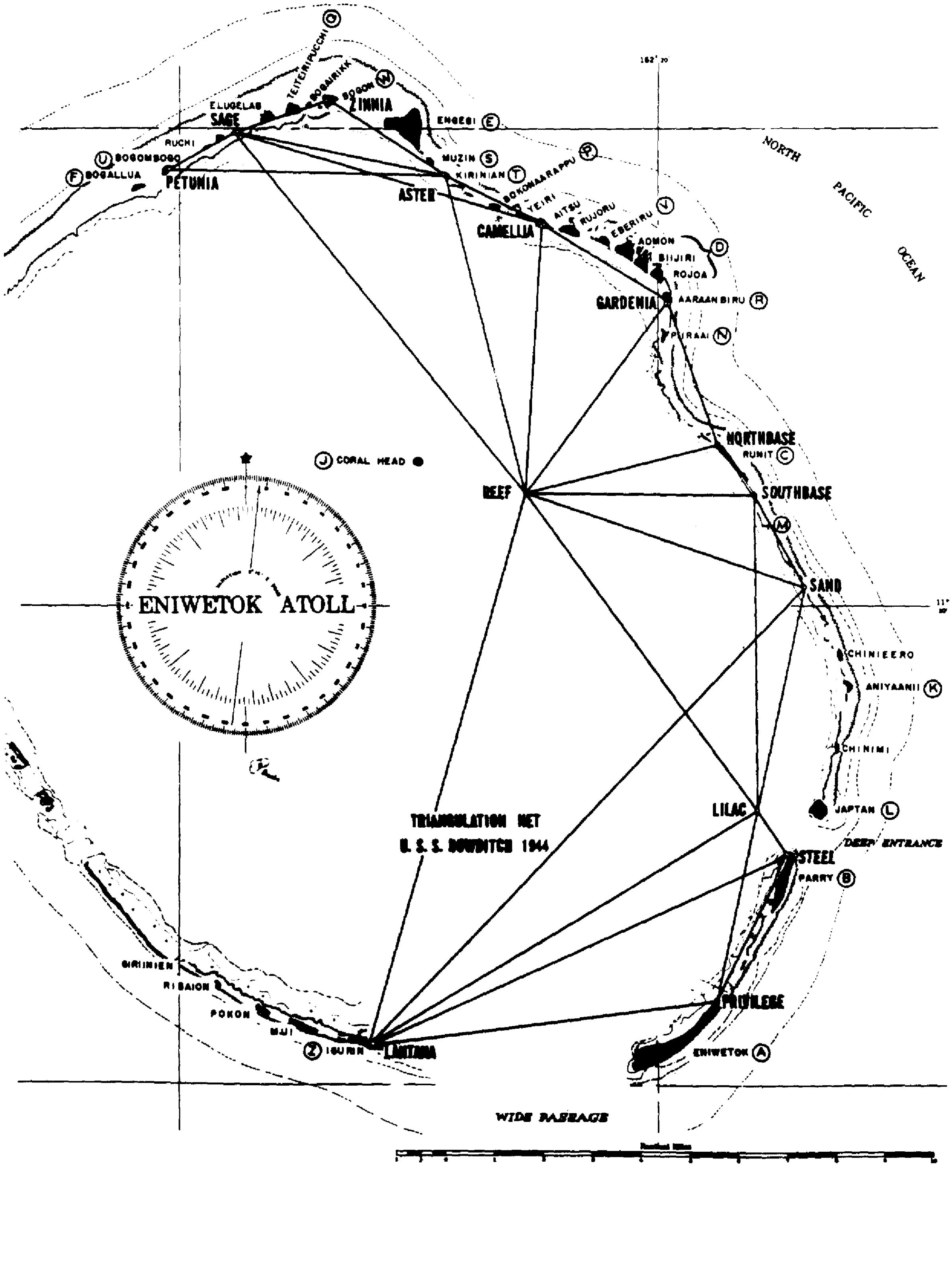


FIGURE 5.8-1 U.S.S. Bowditch Survey

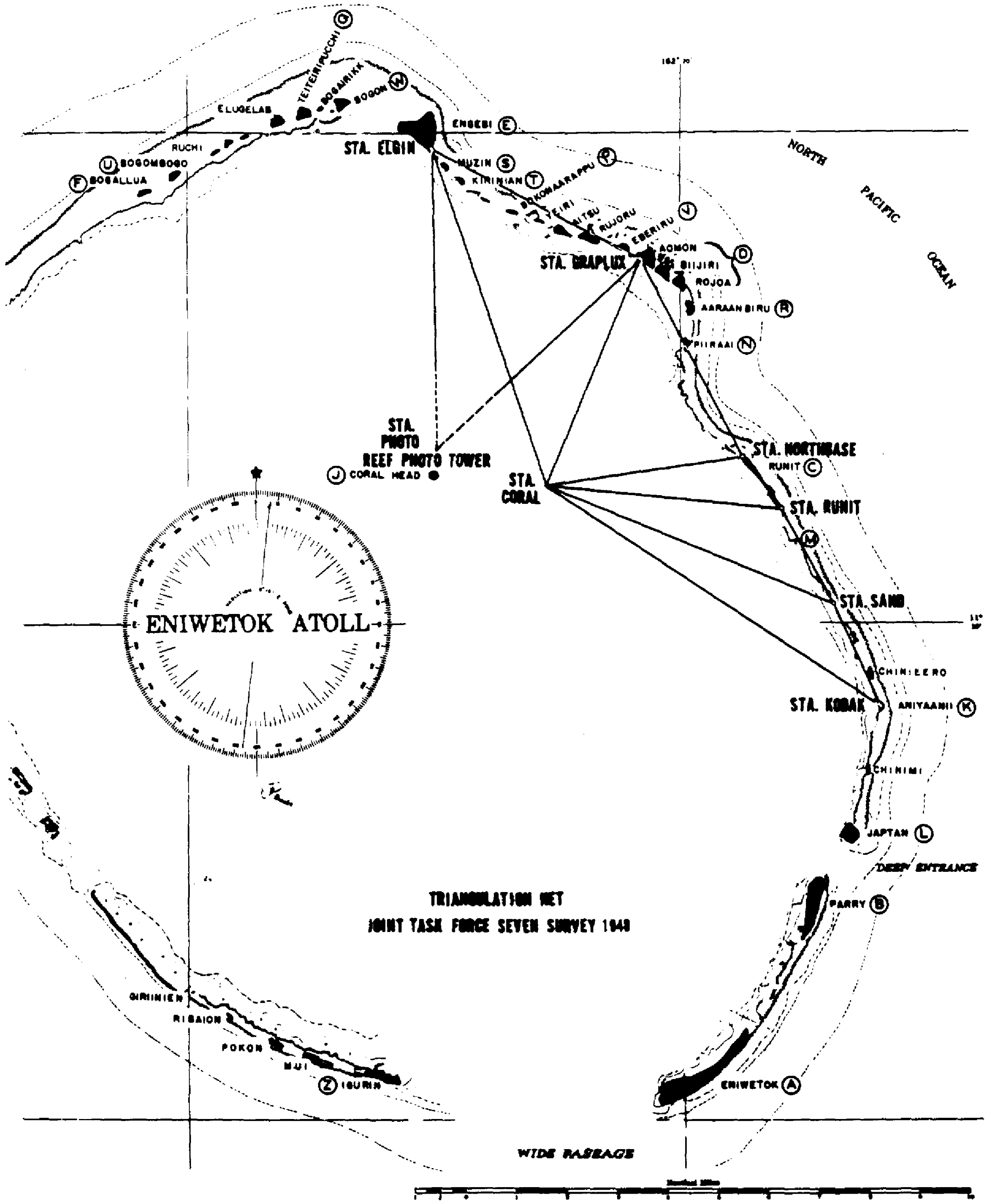


FIGURE 5.8-2 Joint Task Force Seven Survey

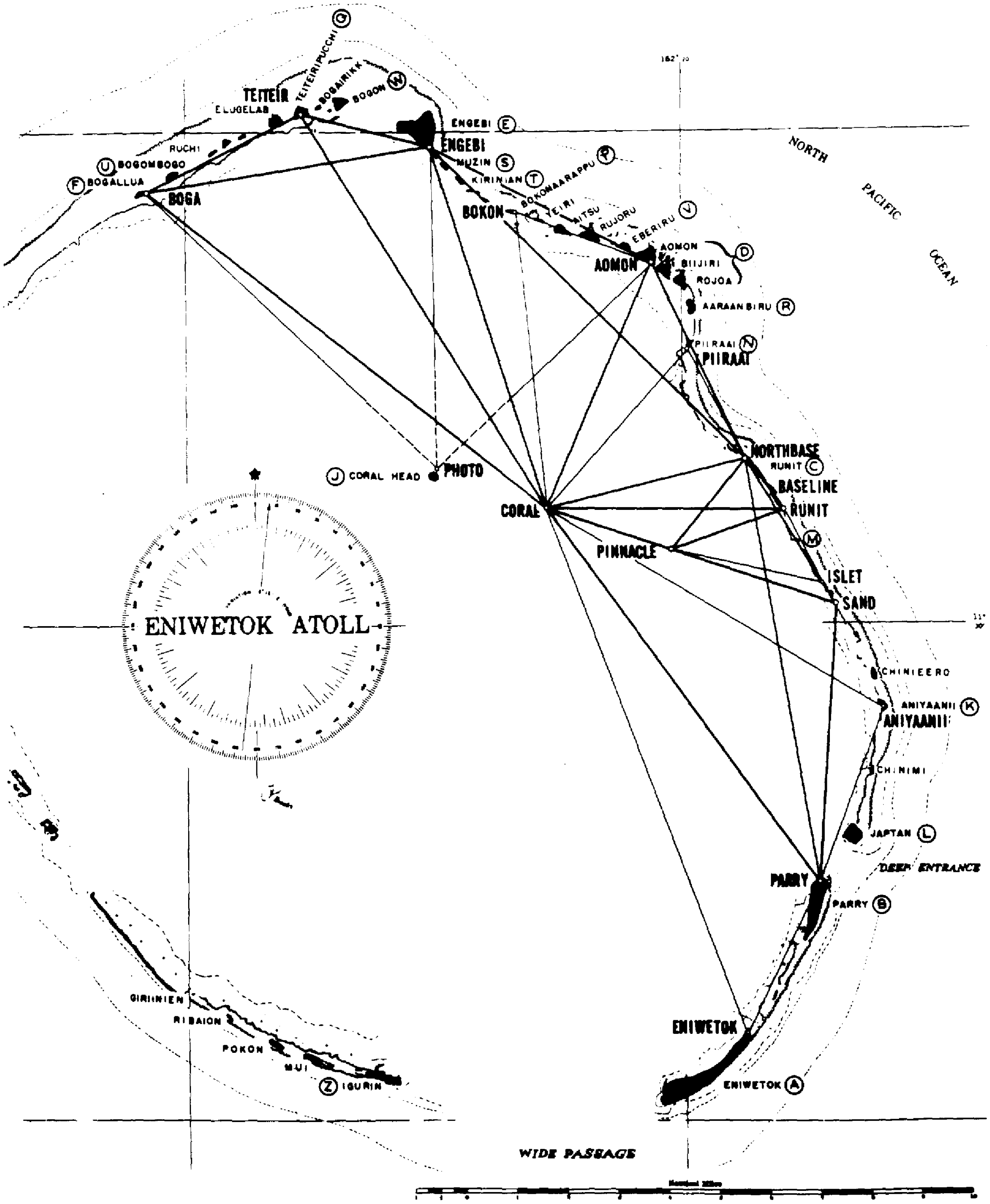


FIGURE 5.8-3   Primary Triangulation Net

the original azimuth observations were made from station North Base to station South Base, an examination of the corrections obtained for the angle in the U. S. S. BOWDITCH triangulations showed that little accuracy would be lost by accepting the azimuth of the line from station North Base to station Sand as the basis of azimuths for the survey. Therefore it was considered that the cost of re-observation for azimuth was not justified.

The line North Base-Runit was measured to first order accuracy, and the azimuth of the line was computed from its relation to the line North Base-Sand. The computations involved in establishing the azimuth of this new base line have been checked and are included in the horizontal control report for reference purposes.

A copy of the Report of the Engineer, Joint Task Force Seven, Part 2, was made available and was of great assistance in planning and executing this survey.

After completion of this primary network, additional Project requirements resulted in expanding the system to include stations on six additional islands, Muzin, Kirinian, Eberiru, Aaraanbiru, Bogon, Rigili, and location "M" on the reef south of Runit. Although except for Eberiru, Aaraanbiru, and Rigili these local systems do not meet all standards for second order work, particularly in strength of figure (because of limited area and values arrived at in adjustment), it is felt that the errors in the linear distances from those computed positions to any other point in the triangulation system will not exceed that allowed for second order work. (See Figure 5.8-4 for the supplemental triangulation net.)

The determination of positions on Eberiru and Aaraanbiru was necessarily made by poorly shaped triangles, but one side of every triangle used was precisely measured to first order accuracy, and computed lengths of common sides were in very close agreement. It is therefore felt that these determinations will exceed those normally obtained by second order work.

Rigili was located to third order accuracy because request for determination of a station on the island came quite late in the Project; because the island was to be used for only one camera station, results of which would be affected by the difference between a second or third order fix of position; and because, owing to the curvature of the earth, the only possible means of observation was by eccentric lights mounted in the cabs of the zero towers at Engebi and Runit and a light on top of 100' tower (now dismantled) over triangulation station Parry. Results obtained in occupying these towers with instruments were not very satisfactory and were used as a check in adjusting the position arrived at by using the two angles at Rigili, measured between the three lights mentioned above.

The completed network consisted of twenty-three stations, including five stations of the Joint Task Force Seven Survey, two of which were

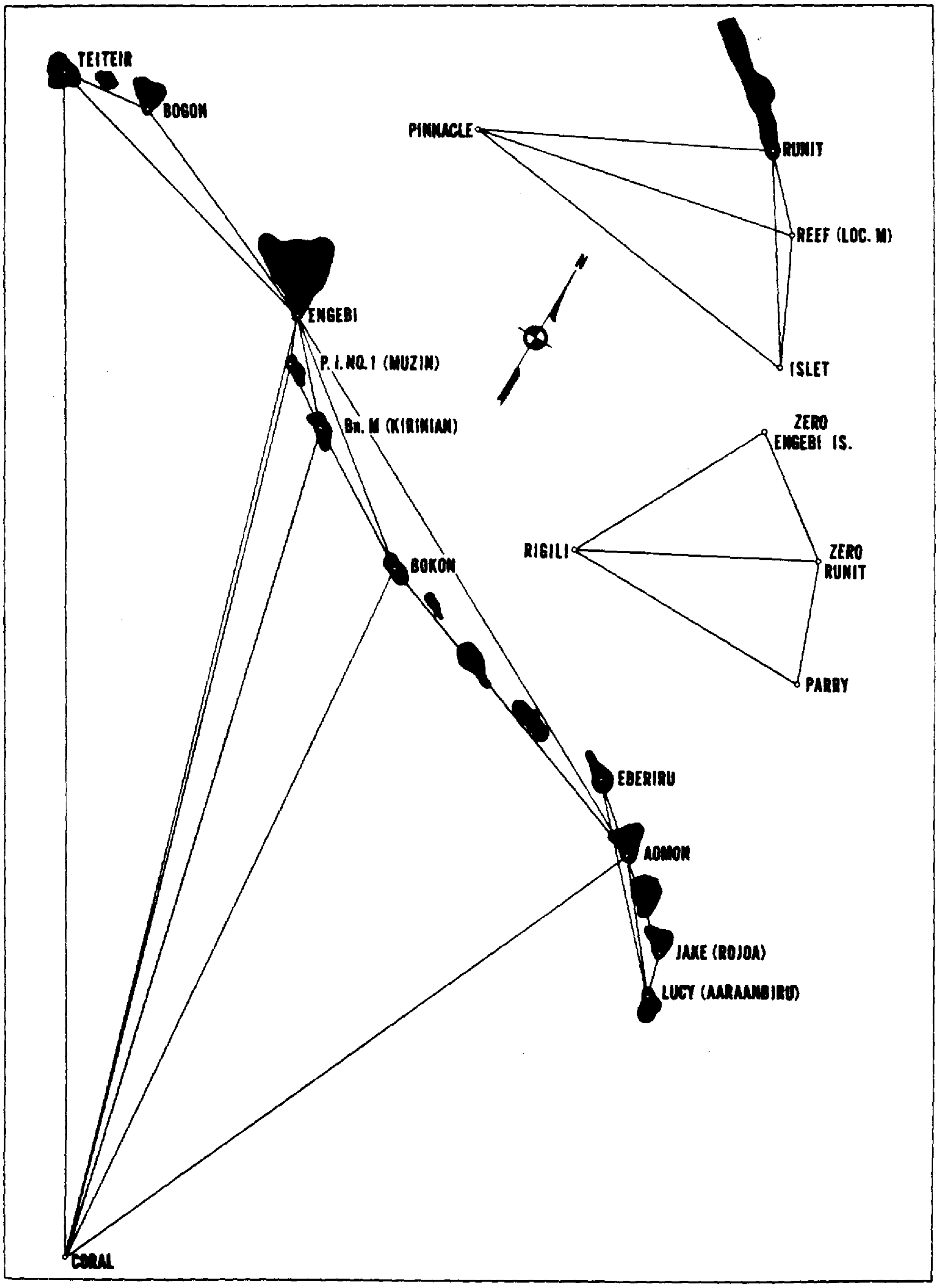


FIGURE 5.8-4 Supplemental Triangulation

original stations of the U. S. S. BOWDITCH Survey of 1944, and one station taken directly from the U. S. S. BOWDITCH Survey of Eniwetok. Stations were located so that all Project islands were tied in directly to the scheme or could be tied in by local triangulation. A new station in the lagoon off the south end of Runit Island was established to strengthen the base expansion quadrangle. Japtan was not included in the control requirements, but could be tied in by local triangulation.

To simplify reference to stations, where practical they have been given the name of the island on which they are located. Some of the U. S. S. BOWDITCH and Joint Task Force Seven stations have been renamed and reference to the renaming is made in the station recovery notes. The stations of the survey and location are as follows:

Boga----------------	Bogallua Island
Teiteir------------	Teiteiripucchi Island
Engebi-------------	Engebi Island
Bokon--------------	Bokonaarappu Island
Aomon--------------	Aomon Island
Piiraai------------	Piiraai Island
North Base---------	Runit Island
Runit--------------	Runit Island
Coral--------------	In lagoon
Pinnacle-----------	In lagoon
Photo--------------	Photo tower in lagoon
Islet--------------	First sand island south of Runit
Sand---------------	Third sand island south of Runit
Aniyaanii----------	Aniyaanii Island
Parry--------------	Parry Island
Eniwetok-----------	Eniwetok Island
Muzin--------------	Muzinbaarikku Island
Kirinian-----------	Kirinian Island
Eberiru------------	Eberiru Island
Lucy---------------	Aaraanbiru Island
Bogon--------------	Bogon Island
11-50--------------	Rigili Island
"M"----------------	On reef south of Runit

The complete record of the horizontal control survey is presented as Appendix "D" of this report.

GEOGRAPHIC POSITION AND AZIMUTH

In the interests of economy and because little accuracy would be lost thereby, it was originally planned to accept the geographic position of station North Base and the azimuth of the new base line as the origin of position and azimuth, as well as the length of the base line. But, after the new station Pinnacle had been built in the lagoon and the base expansion quadrangle could be observed, results indicated that the location of the North Base marker was eccentric to the position established by the Task Force Seven Survey and could not be accepted as the point of orgin of the H&N survey. A computed difference of approximately fourtenths of a foot in a northeasterly direction was found. This difference may have been caused by physical displacement of the monument.

The Los Angeles Office of the U. S. Coast and Geodetic Survey concurred in the conclusion that station North Base could not be accepted as being in its true position and in the decision to measure the lines from the present position of station North Base to station Runit to establish a base line for the present survey. The geographical position of Station Runit and the azimuth of the line from station Runit to station Coral could be accepted for position and azimuth because the limited extent of the adjustments involved would not appreciably affect the accuracy requirements of this Project.

FIELD PROCEDURE FOR PRIMARY CONTROLS

A reconnaissance was made of all locations involved, and markers were set for the triangulation stations. Actual observing on this survey was begun in October 1949.

The observing party consisted of an observer, a recorder, and a varying number of light tenders. The party was quartered on a LCT, which moved to convenient points in the lagoon as required. An LCM and DUKW were used for transportation to the stations and, when practical, planes were used between the islands having landing strips.

Four Bilby steel towers were available for the survey and were moved from station to station as the survey progressed. Where low towers could be used, they were constructed of wood. Towers were adequately braced, and little vibration was experienced.

All observing was done at night with a Wild T-2 theodolite, which proved very satisfactory, although some difficulty was experienced with interior lighting, probably because of moisture. Station lights were Navy battle lamps with rheostats installed so that light could be dimmed to proper intensity. They made very satisfactory targets.

Because of the remote location of the stations, continous interstation communications were maintained by Army Type 619 portable radios. Instant adjustments in light intensity were thus made possible, and considerable time was saved in communicating instructions and changes in plans often made necessary by changing weather conditions.

To take advantage of favorable weather, the survey had been scheduled for early summer; but delays in receiving specialized equipment and in constructing the new station in the lagoon postponed observing so that considerable rain and high wind interfered with access to the stations and visibility.

Water transportation was adequate but necessarily slow, and the men were usually away from the base of operations for fourteen to sixteen hours a day. Because during the early phases of the Project travel after dark in the lagoon was considered dangerous, the men were landed before dark in the evening and picked up after sunrise in the morning.

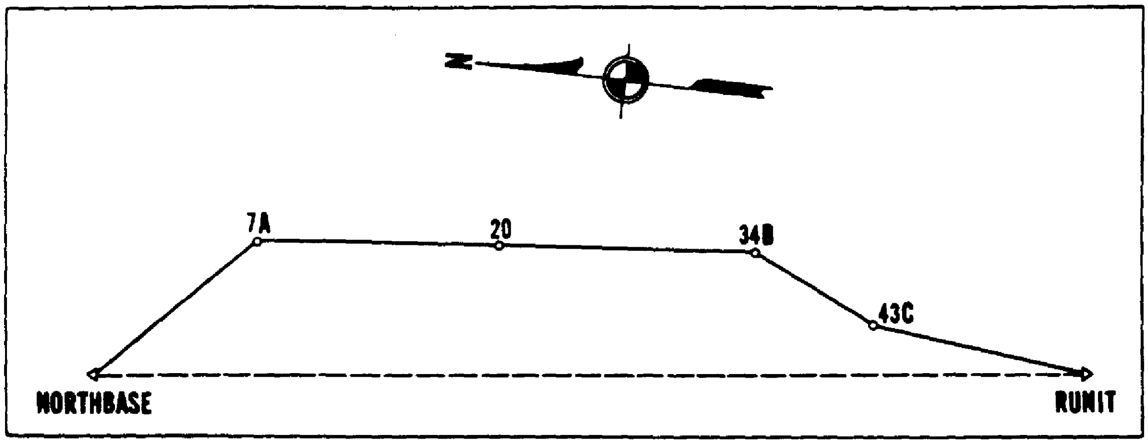


FIGURE 5.8-5   Runit Base Line

Observing procedure consisted of adjusting the intensity of the station lights to the minimum which could be observed and thereby obtaining a small target, considering the distance involved. This was done as early in the evening as sufficient darkness was obtained, and from one to three sets of six positions each were observed. Because of weather, it was sometimes possible to complete only one satisfactory set in an evening. Usually, from two to five hours each evening were spent in observing. When results obtained were within the specifications of the U. S. Coast and Geodetic Survey, no attempt was made to obtain further refinement.

The strength of figures obtained for the original portion of the net was an RI of 74.4 with a maximum of 130 allowed.

A maximum triangle closure of 2.5 seconds and an average closure of 1.3 seconds were obtained. This compares with a maximum of 8 seconds for one triangle and 3 seconds for the average closure allowed by specifications.

Because of the configuration of the island, the Runit Base Line was a broken base consisting of four sections connecting the stations North Base and Runit. Traverse Station Runit, used as an angle point in the Task Force Seven Survey, was again used as an angle point in the traverse for the H & N Survey. (See Figure 5.8-5.)

Standard procedure of the U. S. Coast and Geodetic Survey for second order base line measurement was used. Angles were measured with the Wild T-2 theodolite, and the measurement was made with three Lovar tapes. Thermometers and stretcher apparatus of an approved type were used. The calibration certificates of these tapes are included in the record of the survey.

Stakes were set at fifty meter intervals for chaining points, and the tapes were alternated so that in completing the forward and backward measurement all three tapes were used in each direction.

Because of velocity of the wind at this period of the year, it was necessary to use a windbreak in order to obtain accurate results. This consisted of a thirty-six inch wide strip of canvas approximately sixty yards long, held parallel to the line as each measurement was made. Eighteen men were required to hold the windbreak in place. The manpower at the time required to measure this base line would have been greatly reduced had it been possible to make the survey during the more favorable weather of the summer months.

The computed probable error of the total measurement is 1 part in 648,000. The allowable maximum probable error is one part in 500,000.

VERTICAL CONTROL

Because no records were available of vertical control established by previous surveys, a temporary datum was established on each of the Project islands as surveys were made. For each island, a datum approximating mean low water springs was arrived at by applying corrections from the U. S. Coast and Geodetic publication "Tide Tables of the Pacific Ocean" to a series of tidal observations. This gave a temporary datum, significant to less than a foot.

The procedure was to erect a tide staff at a suitable location at each island to take periodic observations as surveys were made at these islands. After corrections had been applied, a mean of these corrected observations was accepted as the temporary datum. This datum was transferred to a permanent monument in the vicinity and became the origin of all vertical control on the particular island.

Although the vertical datum of one island bore no exact relationship to that of another, there was no requirement that made knowledge of such relationship essential. Such inaccuracy as existed was of no consequence, inasmuch as most any one island is not related to any other.

Caution was taken that no tidal observations for establishing vertical datum were taken at times of storm, unusual high winds, or surge. It was observed that at such times high tides would be between six and seven feet in elevation, whereas the predicted tide might be four and one-half feet. No continous study of tides was made.

As stated, the datums established were sufficiently accurate for Project requirements. However, it is recommended that as future work is carried on, these datums be refined and the inter-relation of the datums established. An automatic tide gauge could be installed at one location, and tide staff observations could be recorded over an extended period at the other locations as work progressed, at a very low cost in manhours. The interrelation could be established by taking the mean of a series of simultaneous observations at all locations.

DESIGN SURVEY

No local control was available on the Project islands for use in completing early design surveys. Because these surveys could not wait on establishment of permanent controls to specified accuracy, it was necessary to establish local control suitable for topographic and hydrographic surveys. Later surveys were made to provide accurate monumented control points.

This preliminary horizontal control consisted of stadia or chained traverses of approximately third order, as required on the individual islands. Vertical control had been established by temporary datum.

The design surveys included topographical mapping of the Project islands, including locating of structures which would influence design, and hydrography for piers, causeways, and channel locations.

Topographic surveys were made on sixteen Project islands. Early surveys were made with limited personnel, and in order to expedite the furnishing of information for the Home Office to start design, the field work was held to a minimum. Existing structures that would influence design were located, and sufficient spot elevations were furnished to control grades. This information was plotted at the Jobsite and field sketches transmitted to the Home Office.

When additional personnel had arrived, complete topographic maps were prepared, including contours at varying scales to meet design requirements. Profiles and cross-sections were taken of existing and proposed airstrip locations. Detailed information was furnished on structures such as the Coral Head Photo Tower. Existing facilities at the north end of Eniwetok Island were located for purposes of planning the interim camp.

Hydrography in connection with channel, pier, and causeway locations, and the establishment of secondary stations suitable as navigational aids and as control for fixed positions during the laying of submarine cable assumed a magnitude not originally planned.

Pier location or improvement surveys were made at eight locations. In addition to location of existing facilities, soundings were required of the general area, and in some cases of a channel to deep water. At Bogallua the inner reef was surveyed to provide hydrography from which a study could be made to determine methods of erosion control and a channel through the reef to the island.

Hydrography for causeway locations was completed at five locations. Secondary control stations for the location of submarine cable were established from Eniwetok to Bogallua around the easterly perimeter of the lagoon. These were established by intersection angles from a craft in the lagoon between known stations and the stations to be located.

Existing navigational aids were located. Some stations that had been destroyed were reestablished, and the locations of new navigational aids set as a requirement of this Project were located.

By use of these controls all submarine cable was located from the cable laying barge as the work progressed.

CONSTRUCTION STAKING

Standard methods of construction staking were followed. Building and special structure corners were established by offset stakes at the corner, and bench marks were provided. Utilities were staked on offset lines, with required cuts and fills provided at necessary intervals. Grades were provided as required for area improvement and roads. Line and grade were provided for pier and causeway construction.

The volume of construction staking was considerably greater than anticipated and, in the final stages, accounted for most of the man-hours worked by survey personnel. A major problem was that in many cases plans were not received sufficiently in advance of actual construction to allow time to make up staking sketches to simplify the field work. Also, revisions which arrived after initial staking required additional field work.

Relations between the survey and construction forces were generally good and resulted in good planning in the use of construction equipment and the scheduling and accomplishment of the work of both departments.

AS-BUILT SURVEYS

Where construction deviated from approved plans, surveys recording changes were made by the Survey Department. Considerable difficulty was experienced in making these surveys because field changes were often made without the knowledge of the Survey Department. This resulted in field construction problems as well as in increased survey costs.

It is recommended that in future projects no construction be undertaken without clearance or location by the Survey Department, for the survey personnel are in a position to know whether proposed field construction will conflict with work in place or to be constructed. This is particularly important for underground construction.

LOCATION OF SUBMARINE CABLE

The inter-island submarine cable was located as laid, and cable location charts were plotted from this information.

With the primary stations of the horizontal control survey as a basis, additional shore stations on the various islands were located and targets erected. Two observers and a recorder were aboard the cable barge, and as cable was laid, the course of the barge was located by taking a series of simultaneous sextant angles to three visible shore stations. The shore stations were plotted to scale on a chart, and by setting off the angles obtained in a three-arm protractor and adjusting its positions on the chart until each arm bisected a shore station, it was possible to plot the locations of the barge at the instant the observations were taken.

This portion of the Project required many man-hours, but the results obtained were consistent with requirements.

LOCATION OF SPECIAL STRUCTURES AND INSTRUMENTATION

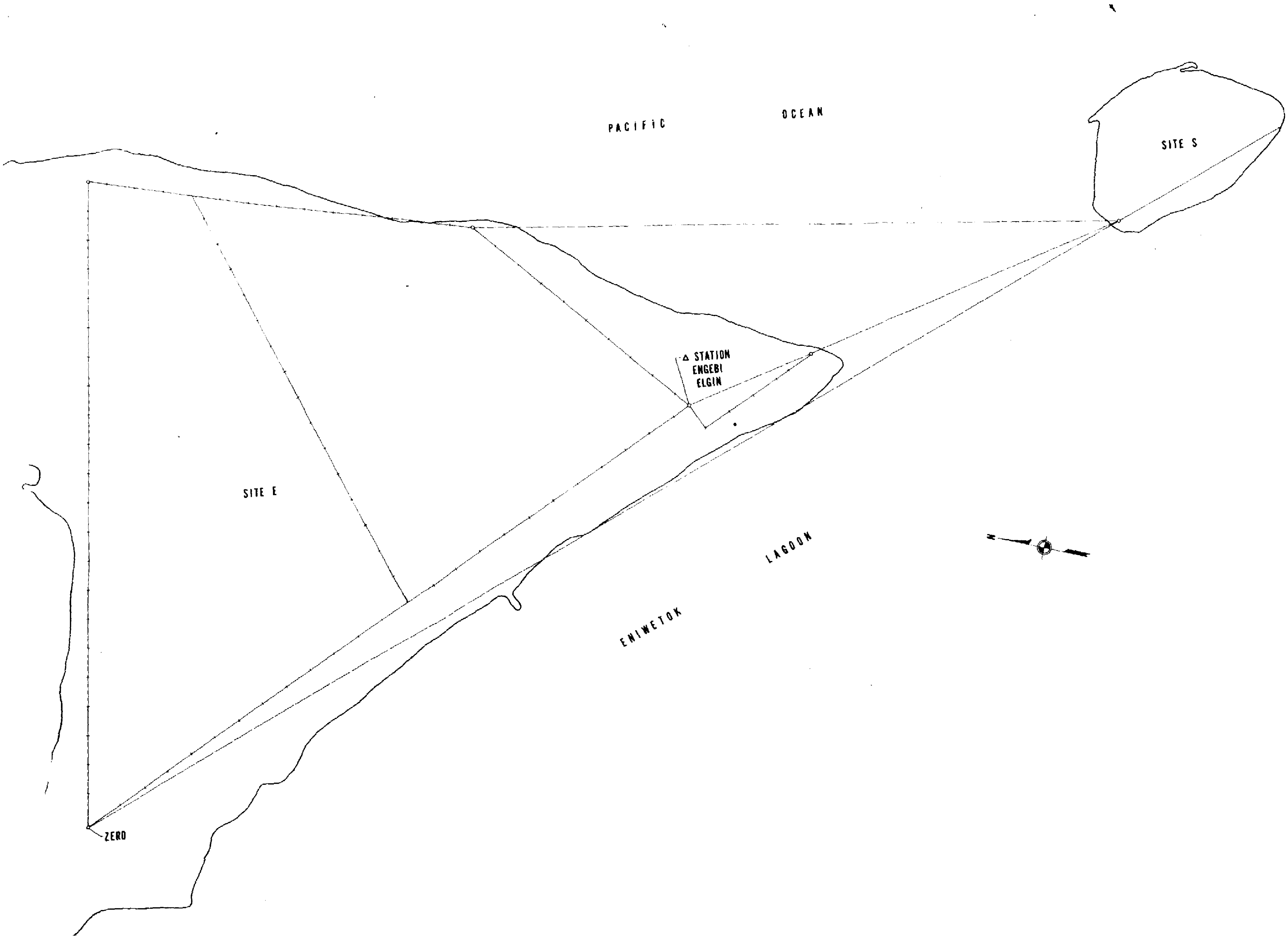
First order traverses were measured on the three experiment islands with 50-meter Lovar tapes, the angles with a 1-second Wild theodolite. (See Figures 5.8-6, 5.8-7, and 5.8-8.) Each chaining buck was a substantial post set in concrete, and after traverse adjustment, positions were computed for the marks on each of these posts. These traverse systems served as a framework from which the working points of all scientific and test structures were staked. To guard against errors in maps, calculations, or field work which would result in probable displacement of a station from its planned position and resultant distortion of scientific results, the following method of construction staking was used.

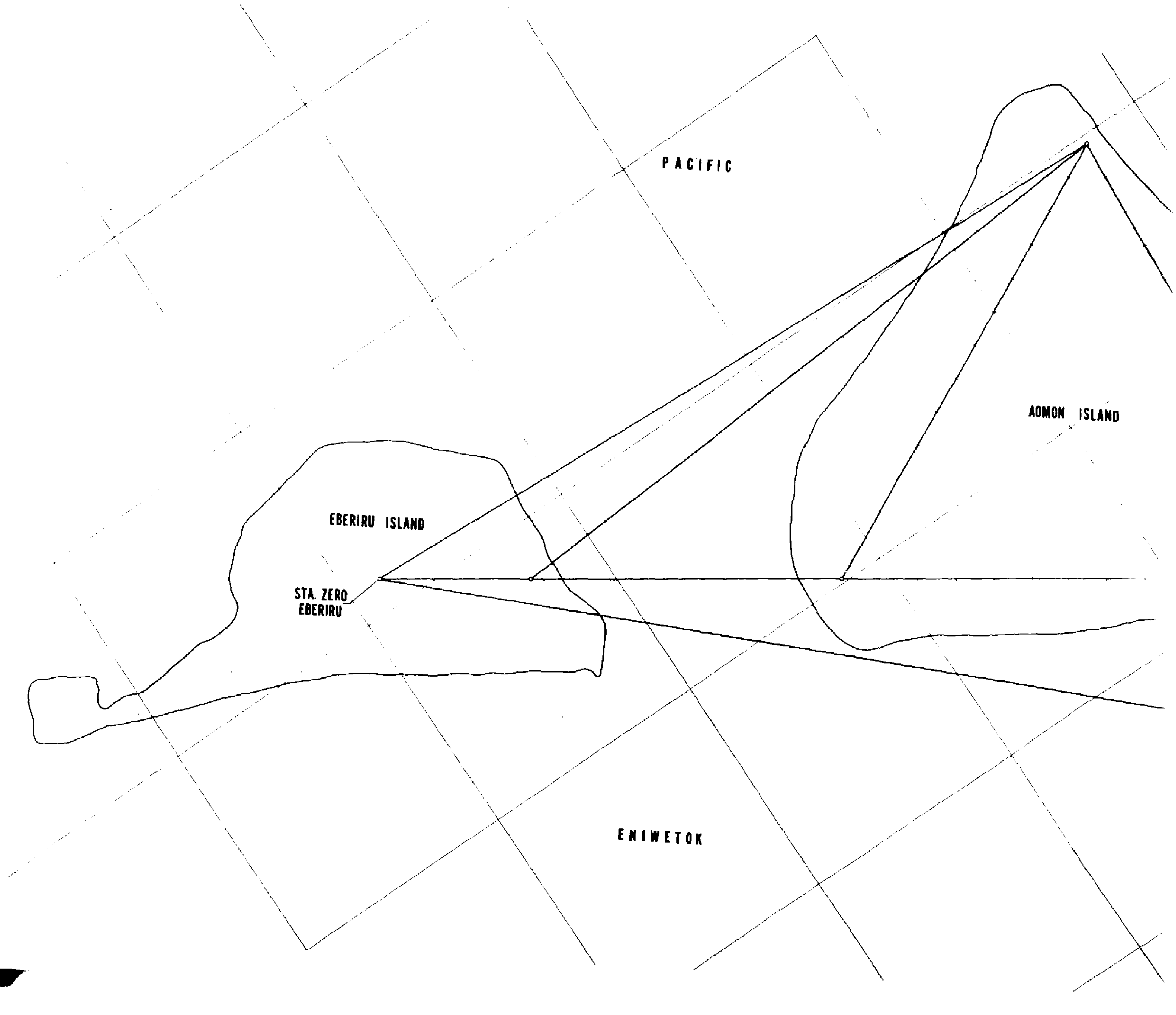
When maps arrived at the Jobsite fixing station locations, all coordinates were checked to see if the azimuths and distances from zero would in fact develop them. A staking diagram was then prepared for the use of the field party, with a bearing and distance computed from the traverse stake nearest the station; and bearings were computed from the working point of the station to two or three other traverse stakes.

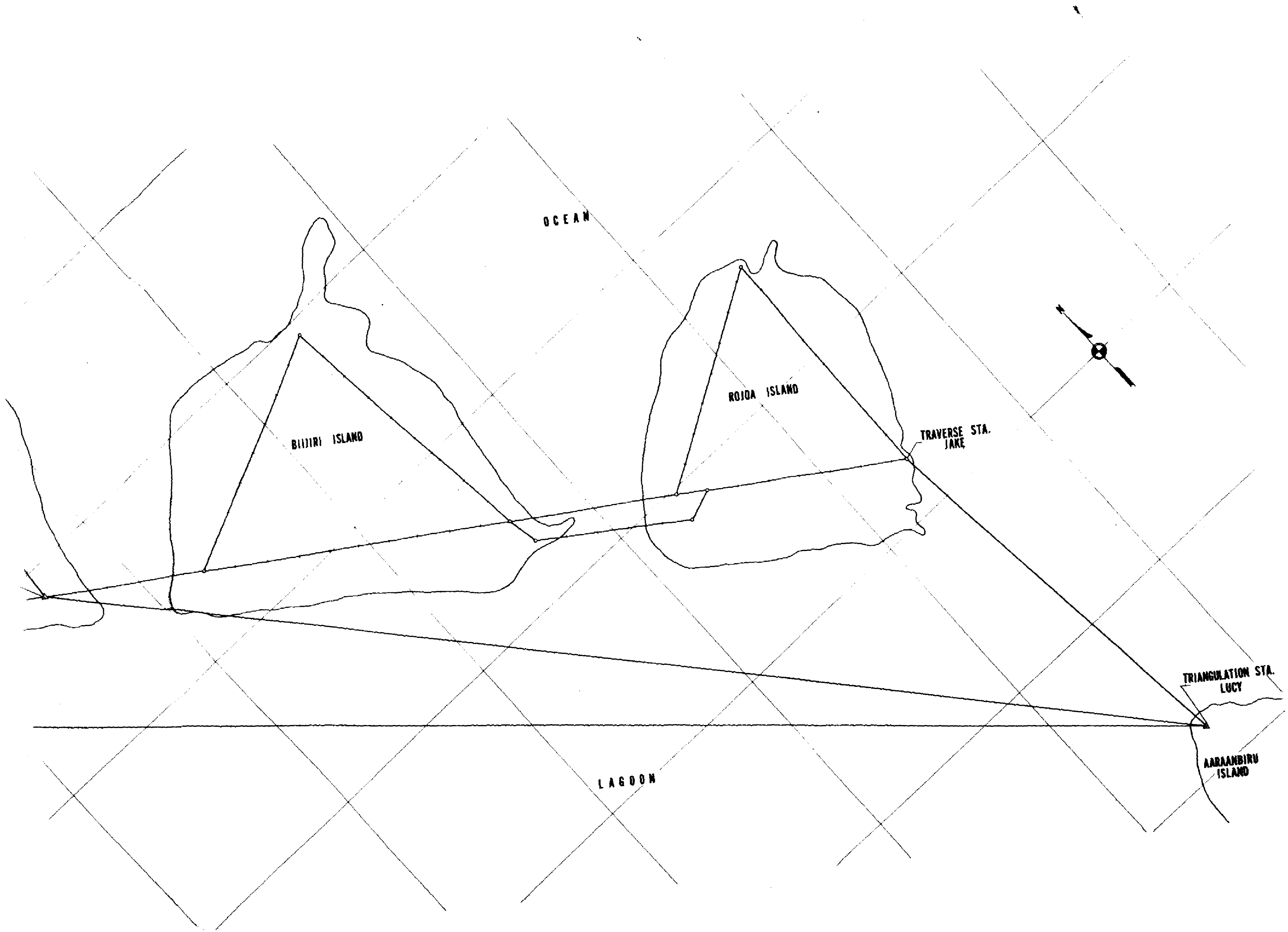
After staking the working point, the field party was required to set up on it and measure the three or four angles around that point (with the line to zero required) to make sure that they checked the computed angles. These being in order, they proceeded to stake out the structure itself.

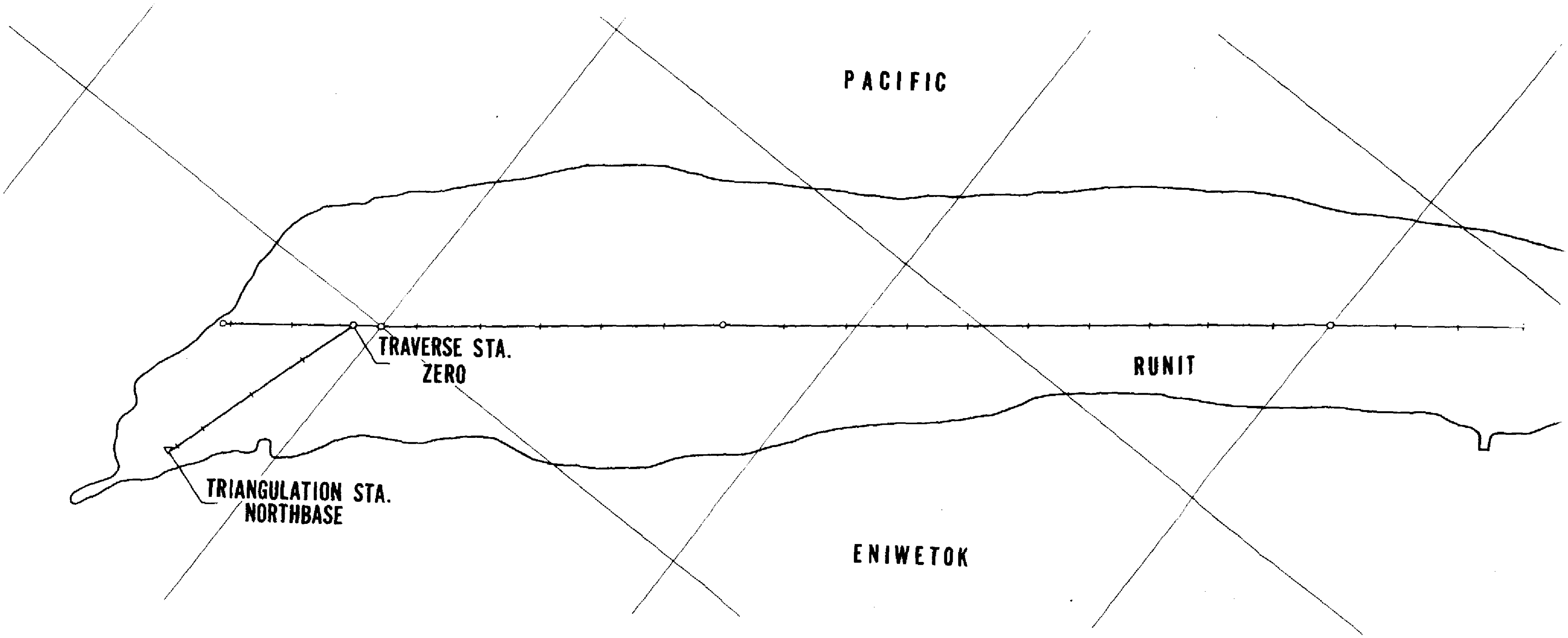
This was followed by the instrumentation phase, which included locating certain points before the tests and rechecking after the tests were completed.

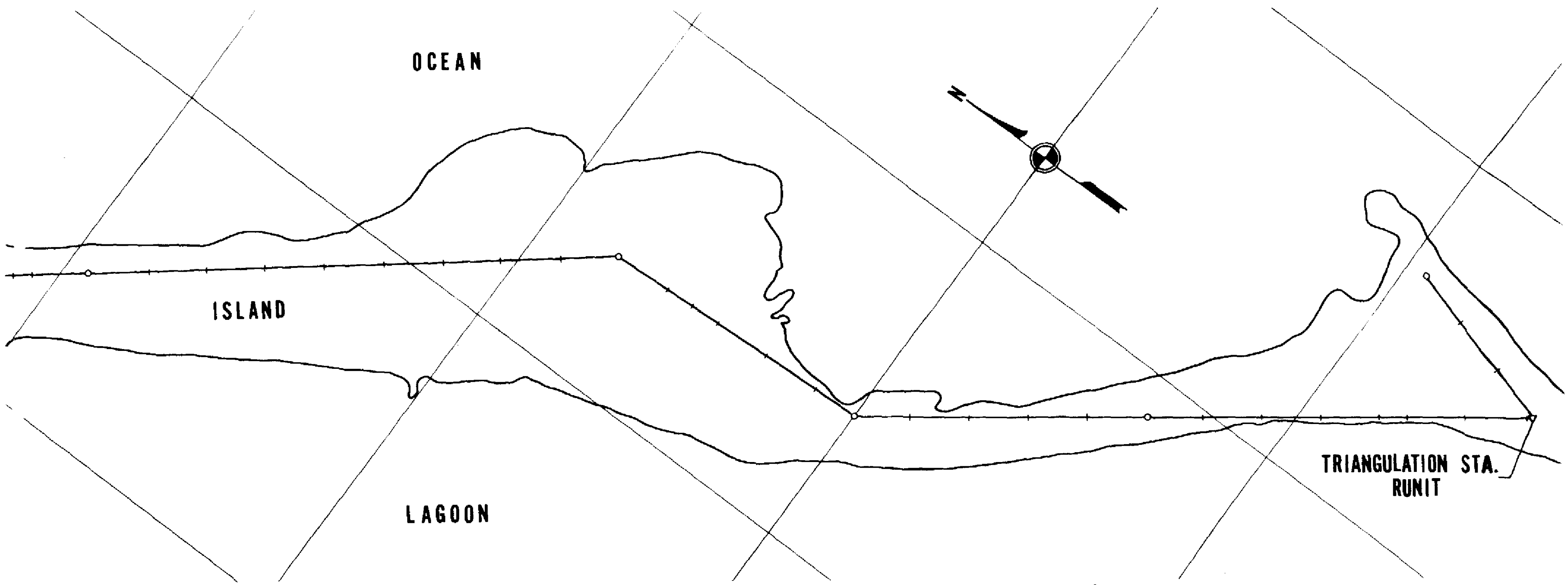
Work started on Special Measurement Survey Points, Military Structures for Engebi and Muzin on December 13, 1950, with a survey crew of five men - two frim Holmes & Narver and three from the Army personnel assigned to the Sandia group. The work was divided into three parts: Station 3.1.1; Stations similar to 3.3.3; and isolated groups such as the 3.2 series. The initial planning and detailed layout of the work was appreciably retarded because of lack of plans and because of insufficient information concerning the scope of the work. As finally determined, there were some 1,900 survey points established, requiring in excess of 11,000 individual measurements.


PACIFIC
OCEAN
SITE S
△ STATION
ENGEBI
ELGIN
SITE E
LAGOON
ENIWETOK
N
ZERO


PACIFIC
AOMON ISLAND
EBERIRU ISLAND
STA. ZERO
EBERIRU
ENIWETOK


OCEAN
BIIJIRI ISLAND
ROJOA ISLAND
TRAVERSE STA.
JAKE
TRIANGULATION STA.
LUCY
AARAANBIRU
ISLAND
LAGOON


PACIFIC
RUNIT
TRAVERSE STA.
ZERO
TRIANGULATION STA.
NORTHBASE
ENIWETOK


OCEAN
N
ISLAND
LAGOON
TRIANGULATION STA.
RUNIT

Control was established by placing brass-capped concrete monuments about six inches below the ground surface on axes radial and normal to ground zero. These monuments were then tied in to the local plane coordinate system. Locations for the points were laid out roughly; drive-it pins or drill holes were placed in the structures and then located in three planes by the use of a transit and tape and an engineer's level. During the pre-blast survey, considerable difficulty was experienced because of construction equipment, wind , and dust. As the work progressed, however, the men became more proficient in working with equipment and under conditions not usually associated with surveying. All work was completed prior to "E" day, including extra points requested by the Users.

The second phase of the work was started as soon as radiologically possible after "E" day. All monuments and bench marks were checked by re-establishing their position with respect to one another. All available men were used on this re-survey, and the work was completed on the last working day prior to "G" day. Because of lack of time, it was not feasible to re-establish the precise chaining bucks for a further check of the control monuments; however, within their own system there was no observed movement of the monuments either vertical or horizontal.

The results of the two surveys were assembled in tabular form and the differences in location of each point were obtained. It should be noted that while the notes indicate differences to 0.001 feet, it is believed that the accuracy of the survey does not exceed plus or minus 0.01 feet.

The azimuths and distances of each station built on the experiment islands are shown in Appendix C of this report.

SURVEY RECORDS

In setting up survey procedure, one objective was to provide permanent horizontal and vertical control which could be recovered for future surveys and make possible the avoidance of duplication of effort. All primary control points were set up as concrete monuments with an established elevation. When practical, reference monuments were set at these locations. Local control on the experiment islands consisted of concrete monuments whose interrelation was determined. Most of these monuments can be considered permanent or replaceable from other remaining monuments.

Field notes were kept in duplicating field books and are available covering all field surveys. Maps were made from these notes, showing the horizontal and vertical control layout for each location. Records of the primary horizontal control survey were made up on transparancies in order that duplicate copies could be prepared as required.

PERSONNEL

The survey personnel in the original group arriving at the Jobsite in February 1949 consisted of a department head and one instrumentman, and it was not until the middle of May 1949 that a complete four-man party and a computer-draftsman was available. In the interim, the department head alternated as chief of party and computer-draftsman. By late fall of 1949, two full parties were available and a third was on requisition. Later, additional personnel were requisitioned, until the department at maximum consisted of a department head, two senior engineers in charge of forces at Engebi and Biijiri, two computers, one draftsman, and twenty-four field men operating as six or seven parties as required.

The following Table gives a resume by months of the number of survey personnel at the Jobsite.

TABLE 5.8-1. MONTHLY TOTAL OF SURVEY PERSONNEL

1949		1950		1951	
		Jan.	11	Jan.	30
Feb.	2	Feb.	11	Feb.	30
Mar.	3	Mar.	8	Mar.	22
Apr.	4	Apr.	11	Apr.	20
May	6	May	14	May	13
June	6	June	17	June	8
July	6	July	19		
Aug.	7	Aug.	25		
Sept.	7	Sept.	30		
Oct.	10	Oct.	29		
Nov.	10	Nov.	30		
Dec.	11	Dec.	30		

EQUIPMENT AND SUPPLIES

Early in the Project, some difficulties were experienced with equipment because at times it was necessary to substitute makes other than those ordered, and because often, as with plumb bob points and red targets, these pieces of equipment were not interchangeable. Later these difficulties were avoided by the inclusion of instructions on requisitions, prohibiting substitutions.

Standardization of equipment was found desirable for several other reasons as well. Survey personnel work more surely when not required to change makes of tools; mainentance is made easier by familiarity; and unrepairable equipment can be cannibalized for use in repair of other equipment.

The humidity and the deteriorating effect of salt water made constant care of equipment vital. All survey tools were kept in ventilated lockers, heated constantly with electric lights. Conditions were particularly severe on steel tapes. It was found that nightly immersion of tapes and reels in engine oil kept them in fair condition. "Wyteface" tapes proved more resistant to corrosion than ordinary steel tapes.

Some surveys were delayed awaiting arrival of special equipment. Because of limited funds available for purchasing at the start of the project, limited transportation allowances, and late delivery dates of vendors, it was not possible to procure all required items in time to meet schedules. An instance of this is the measuring equipment for the Runit Base Line. The full equipment required did not arrive at the Jobsite until September 1949, and therefore this survey had to be made at a time when the personnel were needed for other work and under adverse weather conditions which added to expense and detracted from efficiency.

TRANSPORTATION

Throughout the job, transportation was of prime importance to survey operations. Early in the Project an LCT wartime landing craft, capable of carrying 250-ton load, was used as a mobile living base from which the triangulation party worked. This arrangement proved far more economical than transporting men from Eniwetok to the outer islands each day. The LCM, with loading ramp, capable of carrying a truck or DUKW, was used extensively. The DUKW proved invaluable for use in soundings and shoal water, particularly where reefs made impossible operations with conventional craft. The powered whale boat was of only limited usefulness, because of its unsuitability in shoal water. It could not be beached; its water circulating system sucked up sand in shoal water; and it was not as sturdy as other craft.

Some use was made of an L-5 two-place plane, and of an L-13 four-place plane, but their utility was limited to islands where landing strips were available. Late in the Project, a four-place helicopter was used several times. Automotive transportation used included pickups, personnel carriers, jeeps, and trailers. The ideal vehicle was found to be the Army weapons carrier with four-wheel drive and canvas top.

CHAPTER 5.9

SOIL INVESTIGATIONS

One of the important objectives of the reconnaissance of Eniwetok Atoll in October 1948 was to obtain visual information and soil samples in order to permit the determination of bearing values for use by Holmes & Narver in the design of foundations and structures, airplane landing strips, and road construction. In addition, on-site studies were to be made and samples obtained to locate sources of aggregate for concrete and pavement. In the accomplishment of these early investigations, the Reconnaissance Party excavated at widely separated points throughout the atoll, and took samples of the cross sections exposed. These samples were brought back to the United States and experts in the field of Soils Mechanics were retained to make a laboratory analysis for mechanical characteristics.

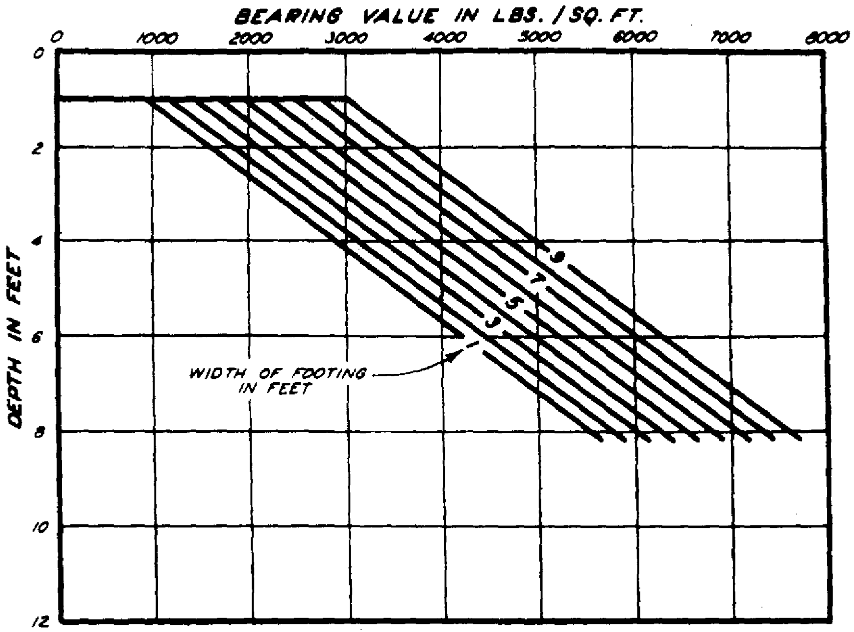
The terrain was seen to be formed of ancient and indurated coral masses capped with an overburden of disintegrated coral of sedimentary or wave-deposited origin. The overburden varied in gradation from sand to coarse gravel, was mixed with varying proportions of organic silt, and contained some intrusions of rocky coral extending above the coral shelf and into the sand. Foundation experts, on the basis of laboratory tests, were asked to evaluate as closely as possible the properties of the undisturbed natural deposits and to estimate the support which the undisturbed deposits would offer for foundations of structures, paving of roadways and areas, and cable anchors.

Samples were prepared by the Laboratory retained to preform the work to reproduce field conditions as closely as possible, Bearing values for all structures for which H&N had design responsibility were determined to be adequate. From the laboratory samples which simulated field conditions, bearing values for varying widths of spread foundations were established at different depths in the clean, coral sand deposits. Results of these analyses are presented in graphical form in Figure 5.9-1.

Based upon the results of consolidation tests performed, analyses were made to evaluate the settlement of spread foundations and results of such analyses are presented in graphical form in Figure 5.9-2.

In connection with the design of paving for airstrips, roads, and areas, standard curves for the design of flexible paving to support various wheel loads for a wide range of subgrade capacities, such as are shown in Figure 5.9-3, were employed.

Sheer test data obtained from the reconnaissance samples permitted analysis to be made directed toward the evaluation of the passive resistance which the coral sands would offer to cable anchors. Results thus developed are shown in Figure 5.9-4 which indicates the limits of desirable design. Anchors designed in accordance with the indicated recommendations had a factor of safety of approximately 1.5 against lateral movement.

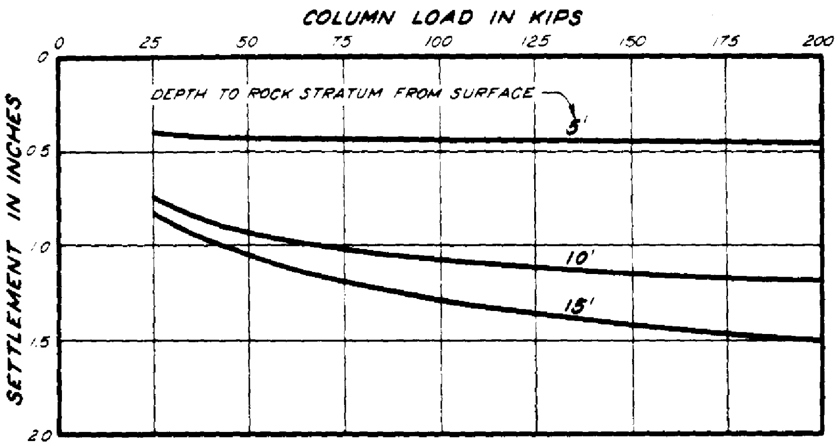


NOTE: THE GIVEN VALUES ARE INTENDED TO APPLY TO THE TOTAL OF ALL LOADS, DEAD, LIVE, AND SEISMIC.

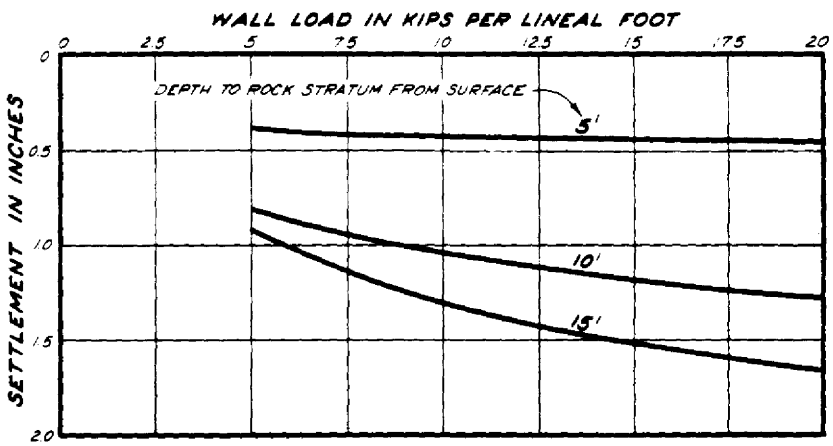
AVAILABLE BEARING VALUES

FIGURE 5.9-1 **Available Bearing Values**

SETTLEMENT OF COLUMN FOOTINGS



SETTLEMENT OF WALL FOOTINGS



NOTE:

THE SETTLEMENT VALUES SHOWN ARE FOR FOOTINGS FOUNDED AT A DEPTH OF APPROXIMATELY 3 FEET WITH A BEARING VALUE OF 3000 LBS./SQ. FT.

THE SETTLEMENTS WERE COMPUTED FOR A RATIO OF DEAD LOAD TO TOTAL LOAD OF ONE; FOR OTHER RATIOS OF DEAD LOAD TO TOTAL LOAD, THE SETTLEMENTS WILL BE REDUCED PROPORTIONATELY.

FIGURE 5.9-2

SETTLEMENT ANALYSES

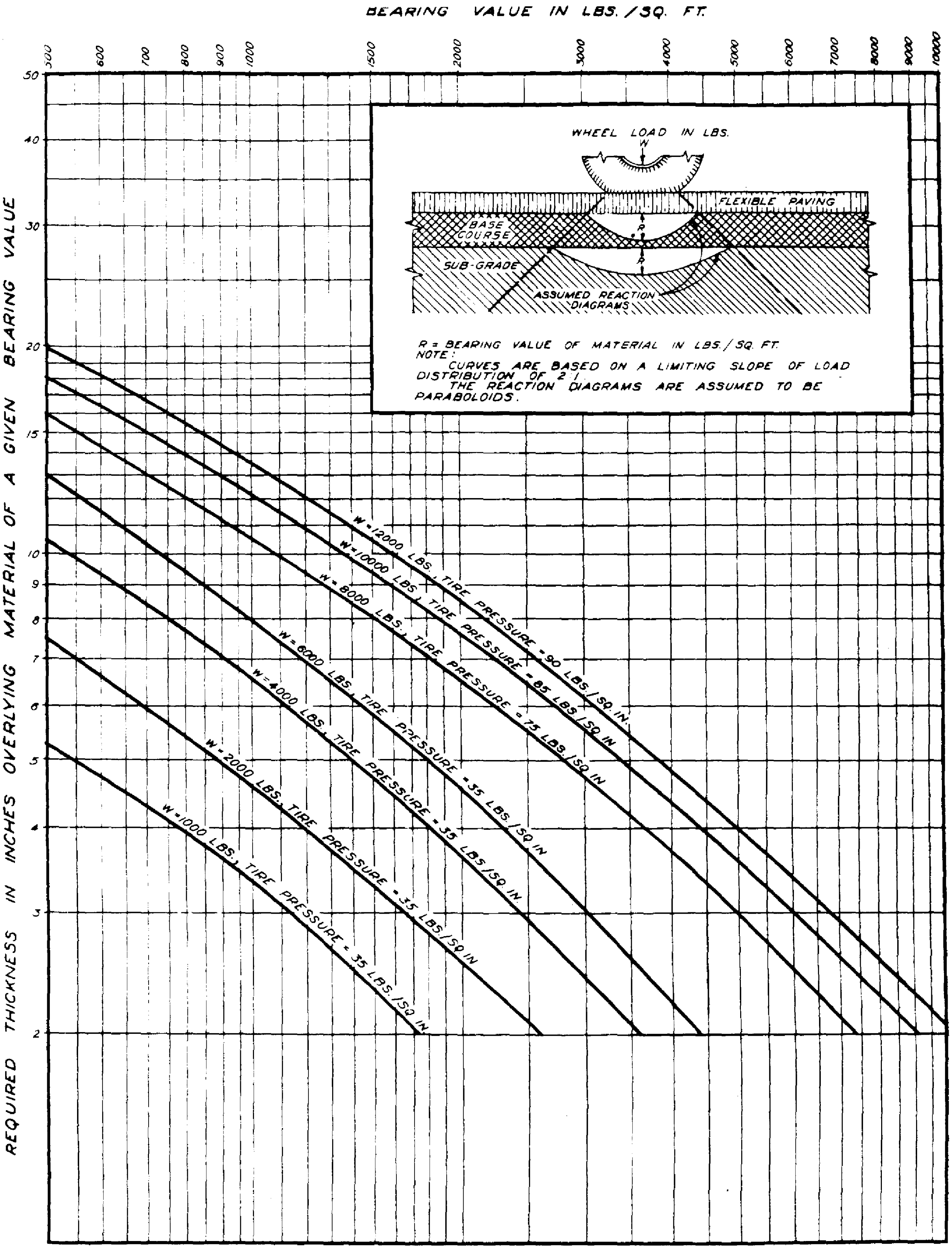
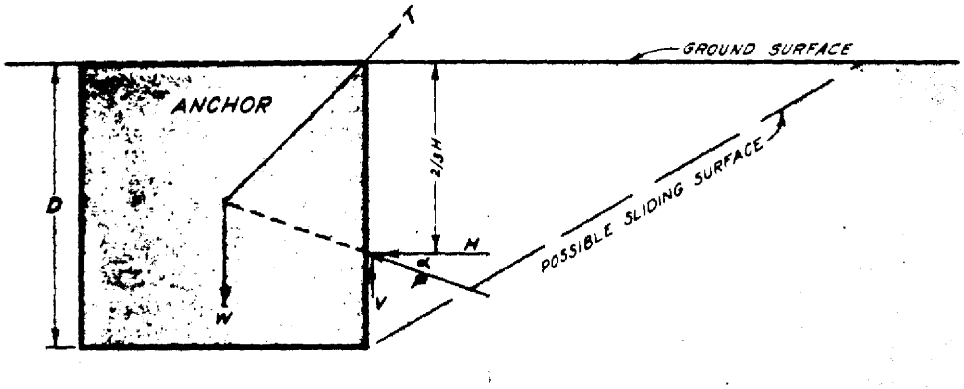


FIGURE 5.9-3

FLEXIBLE PAVING DESIGN

TYPICAL ANCHOR



NOMENCLATURE:

- W = WEIGHT OF ANCHOR
- T = TENSION IN ANCHOR CABLE
- P = PASSIVE THRUST ON FACE OF ANCHOR
- H = HORIZONTAL COMPONENT OF P
- V = VERTICAL COMPONENT OF P
- α = ANGLE OF FRICTION, SOIL ON CONCRETE

ASSUMPTIONS:

(1) SURFACE OF RUPTURE IS A PLANE.

(2) FRICTIONAL RESISTANCE ON ALL SIDES OF THE ANCHOR EXCEPT THE FACE IS NEGLIGIBLE.

(3) THE ANCHOR IS OF GREAT LENGTH PERPENDICULAR TO THE DIRECTION OF CABLE PULL.

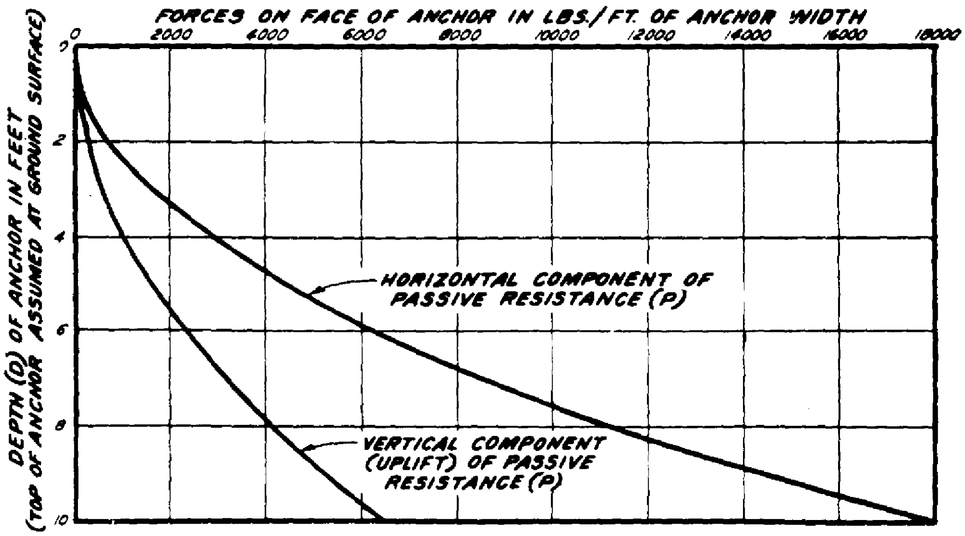
BASIC DATA:

ANGLE OF INTERNAL FRICTION, $\phi = 30°$

ANGLE OF CONCRETE FRICTION, $\alpha = 20°$

SUBMERGED DENSITY OF SOIL = 54 LBS./CU. FT.

PASSIVE RESISTANCE



DESIGN NOTES:

THE LINE OF ACTION OF "T" SHOULD NOT LIE ABOVE THE INTERSECTION OF "P" AND "W".

FOR CONSERVATIVE DESIGN, "W" MUST EQUAL THE VERTICAL COMPONENT OF "T" PLUS THE VERTICAL COMPONENT OF "P".

FIGURE 5.9-4

ANALYSIS OF CABLE ANCHOR

On the basis of recommendations contained in the report of the laboratory findings and result of the tests performed on the various samples brought back by the Reconnaissance Party, foundations were designed for a maximum soil bearing value of 3000 pounds per square foot where founded on sand, and 5000 pounds per square foot where founded on coral rock. In view of the fact that the accomplishment of design within these limits presented no unusual problem, it was determined to be, in the best interests of economy, unnecessary to carry out an exhaustive drilling and soil investigations program covering all of the islands proposed for inclusion in the Proving Ground Complex.

Late in 1949, in connection with the problem of rotating and extending the airstrip on Eniwetok Island, the H&N Engineering Division requested test borings on the southern extension of the existing strip. These borings revealed coral rock at depths of seven to eight feet below the surface of the airstrip, covered by a mixture of muck, organic silt, and fiberous material which had been used to fill in the area at some time in the past. At approximately the same time, the AEC requested that exploratory probing be accomplished on Engebi Island to prove, or disprove, the rumored existence of a large subsurface cavern near the center of the island. The area to be explored, and the spacing of the test holes, was specified and a further drilling program was anticipated which led to the requisitioning of wagon drills at this time. Pending the arrival of such equipment, probings were carried out by improvised methods which, although disclosing strata of varying resistance attributable either to degrees of water saturation or to granular compaction, indicated a hard, coral conglomerate at six to nine feet below grade. No gross voids were disclosed and these probings were, therefore, considered to have served the desired purpose. Samples of coral aggregate and sand were obtained during the course of these investigations and shipped to the Atomic Energy Commission for further analyses by interested agencies.

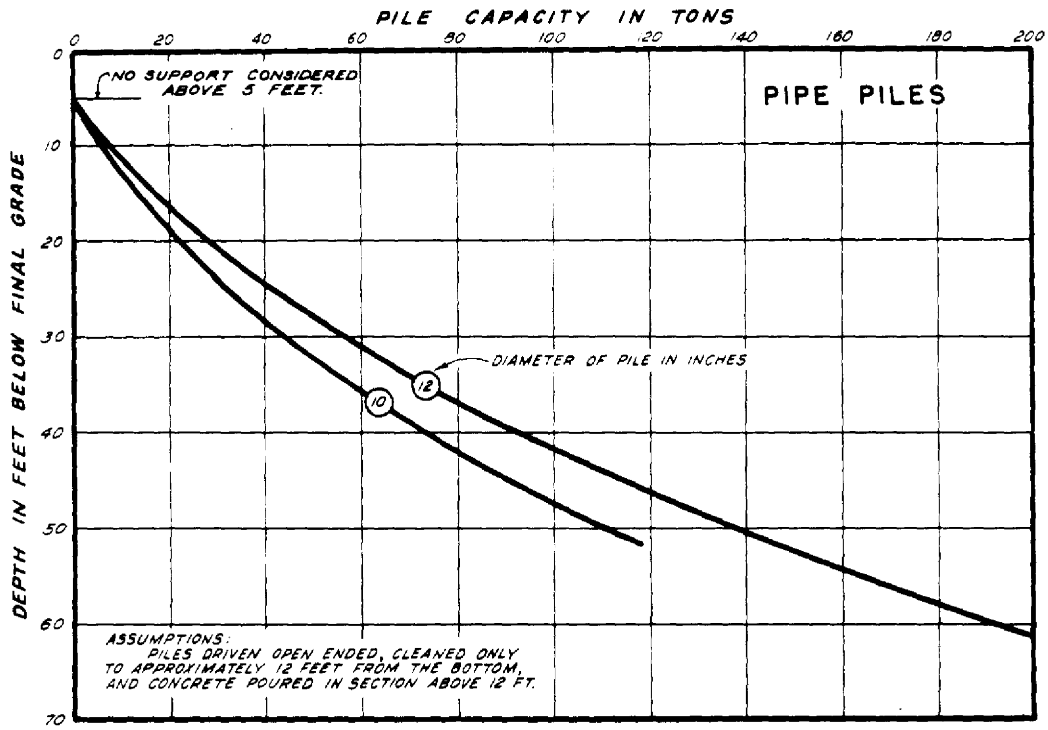
The adequacy of the original soils investigations for all structures for which Holmes & Narver had design responsibility continued until the late spring of 1950 when it was decided that for one or more experiments a rather complex tower would be required. The criteria for design included that the tower be 200 feet high and capable of supporting 200 tons in the cab at the top. Furthermore, in conjunction with the load just mentioned, a lead, or lead and limonite concrete column more than three feet in diameter and 200 feet high would be required, together with a limonite concrete blockhouse at the base of the tower characterized by walls four feet thick and a floor and roof each five feet thick. The total estimated weight upon the foundation was in the neighborhood of 2100 tons and the design criteria specified a maximum deflection at the top of the tower of not more than one inch. To permit designs which would satisfy these criteria, the original samples and investigation of bearing values were not considered to by adequate and, on July 1, 1950, AEC approval was requested for the employment of consultants to carry out further investigations now required. At about this same time, discussions concerning the foundations for Army Structure 3.1.1 were going on, in view of the concern expressed in some quarters on this subject. Permission was therefore requested and granted for the Holmes & Narver consultant to enter into the discussions of the 3.1.1 Structure problem at Eniwetok. The details of the foundation problems on Military Structures are covered in the Construction Section of this report (Vol. III) as H&N's activities in this regard were limited to construction.

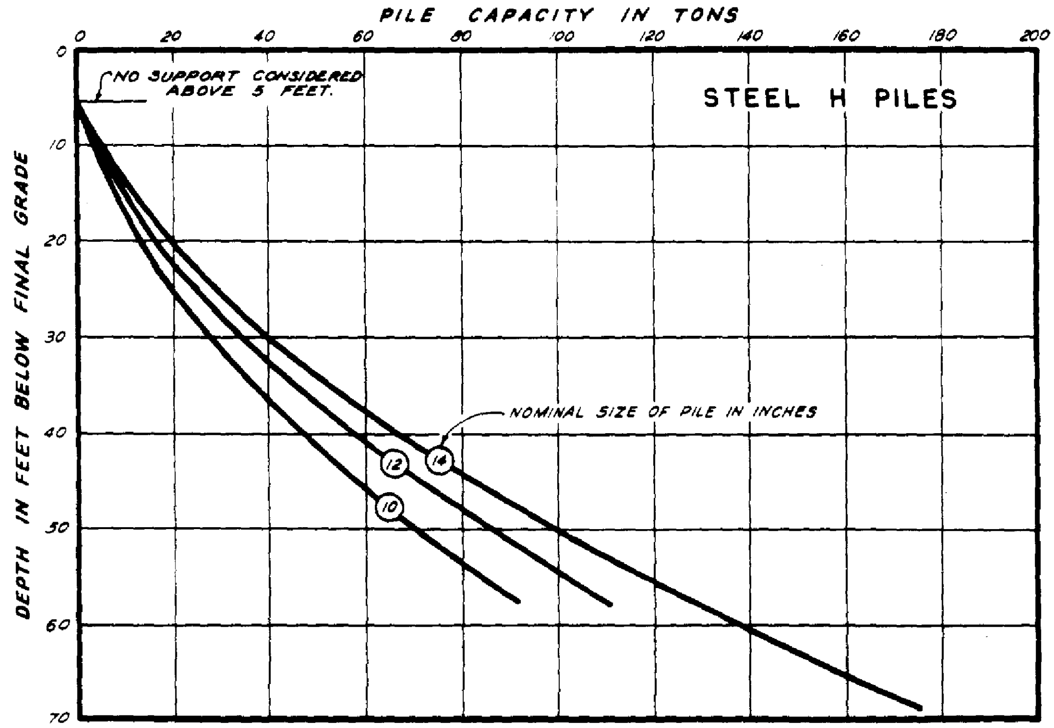
Samples were obtained by the H&N foundation experts sent to the Jobsite. Exploration was carried out at the various sites proposed for the heavy tower discussed above. However, in order to expedite design to the maximum degree possible, because of the shortages of critical materials which were then becoming evident, it was necessary in order to secure materials to require the H&N consultants to make recommendations based upon engineering experience upon their knowledge of the soils at the time of visual inspections of site conditions, before laboratory test aralyses were completed. This was done and the foundation designs recommended were later confirmed by the analysis of laboratory test data before the erection of the tower. A formal report was submitted later.

In order to insure restriction of tower deflections to the allowable limit, the decision was made to use piling for support of the foundations. Pile capacity curves were computed and are reproduced in Figure 5.9-5. Pile driving specifications were written and are presented as Figure 5.9-6. H&N elected to employ on the foundation designs 12-inch steel H piles, fifty feet long, loaded to 87 tons per pile; however, upon driving the first piles, a driving resistance lower than anticipated was developed to the required fifty foot depth. A ten-foot section was spliced to the top of the driven piles and further driving, to a total depth of 60 feet below ground, was accomplished; at which point the higher driving resistances required were developed. Discussions were had at this time which resulted in the decision that, while 50-foot pile lengths were most certainly adequate for the design loads, in view of the low resistance encountered in driving the first piles, it would be advisable to use 60-foot piles where necessary to obtain specified resistances and to obtain an expert review of the driving records on the balance of the piles.

The exploration carried on in connection with this foundation problem included the drilling of a total of fourteen borings to a depth reaching from seven to 53½ feet below the ground surface and the collection of undisturbed core samples and representative loose samples. The types of soils encountered were classified by visual and textural examinations in the field which were later supplemented by tests and laboratory inspection. The locations of the borings are shown in Figures 5.9-7, 5.9-8, and 5.9-9 in terms of the coordinate system established on each island. Logs of the soils encountered are reproduced in Figures 5.9-10 through 5.9-16. The depths at which both types of samples, (i.e. cores and loose samples) were obtained are indicated on the logs. The undisturbed core samples were subjected to a series of tests to determine the strengths and compressibilities of the soil. Direct sheer, friction, and consolidation tests were performed. In conjunction with these tests the moisture content and densities of the samples were determined. The results of the sheer tests and of the associated moisture and density determinations are shown on the graph appearing at the left of the log of each boring in the manner described by the key to test data in Figure 5.9-17. The summary of the results of the sheer tests appears in Figure 5.9-18. The values selected for the analysis of pile foundations are defined by the line passing through the test data.

Laboratory friction tests of the soils in contact with the piling materials, steel, concrete, and wood, were performed on selected samples and the resistances have also been summarized on the graphs appearing in Figure 5.9-18. To provide data for estimating the probable settlements of the proposed structures, consolidation tests were performed on four selected samples and the load-versus-consolidation curves obtained from these tests are presented on the graphs in Figure 5.9.-19. Figures 5.9-20, 5.9-21, and 5.9-22 show results of the tests made to provide data for classification of soils.





NOTE
THE INDICATED CAPACITIES APPLY TO THE TOTAL OF ALL EXTERNALLY APPLIED REAL LOADS; THE TOTAL OF ALL DESIGN LOADS, DEAD, LIVE, AND OVERTURNING, MAY EXCEED THESE VALUES BY ONE-THIRD.

FIGURE 5.9-5 Pile Capacities

200 FOOT TOWER FOUNDATION

LOCATION "V".

SPECIFICATION FOR DRIVING STEEL

"H" PILING.

SCOPE OF WORK:

01. This section covers the driving of all piling to form the foundation of the 200-foot tower as indicated on Drawings 3G-5651, 3G-5653, 3G-5654, and 3G-5656.

PILING:

02. The piling furnished for this project are steel bearing piles, 12" H @ 53#, 50 feet long.

DRIVING EQUIPMENT:

03. The driving hammer furnished for this project is a single-acting Vulcan No. 1 hammer, having a rated striking energy of 15,000 foot pounds at the normal stroke of 3 feet. This hammer requires 565 cubic feet per minute of free air at 80 pounds per square inch for its operation. Any other equipment capable of driving the piling may be used.

04. The driving leads furnished are 65 feet in length and must be firmly supported in such a manner as to guide the hammer in a straight line from the highest point to the lowest point which it must travel.

FIGURE 5.9-6. Pile Driving Specifications (Dames & Moore).

PILE DRIVING:

05. All piles shall be driven within 3 inches of the locations defined on the drawings. The piles must be driven not more than 1/8 inch per foot from vertical, and the tops shall be driven to within 2 inches of the indicated elevations.

06. All piles are to be driven their full 50-foot length below cut-off grade.

07. In event that either

(a) refusal is met before the piling is driven to grade, or

(b) the average driving resistance during the last 5 feet of driving is less than 25 blows per foot.

this fact and all pertinent observations of driving behavior, including the complete driving record, should be immediately communicated to the design office.

08. Jetting may be employed if necessary to secure the desired tip elevations. However, the jet must be withdrawn and the piles driven with the hammer alone for the final 5 feet of penetration.

RECORDS:

09. The tip elevation for each pile driven shall be recorded.

10. The blows per foot of penetration shall be recorded for all piling during the last 5 feet of penetration; for 20

FIGURE 5.9-6. (Continued.)

per cent of the piling these data shall be recorded during the entire period of driving.

INSERT PG1:

11. The embedment of this piling has been chosen, based on an analysis of the properties of the soil, so as to provide the desired design capacity. It is not intended that a dynamic formula be used in the field to select or modify the desired depths of penetration of the piling.

FIGURE 5.9-6. (Continued.)

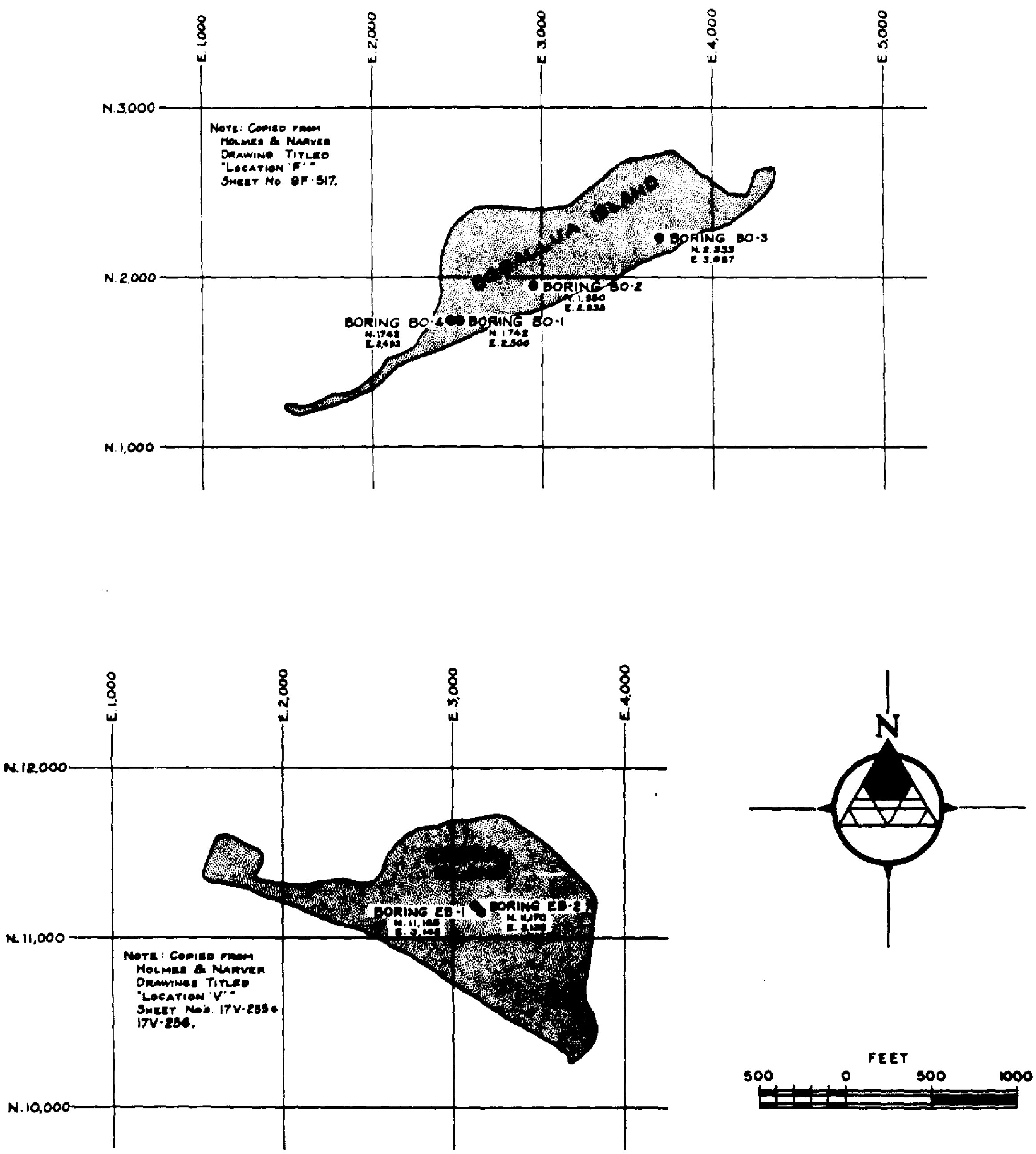


FIGURE 5.9-7 Boring Locations, Bogallua and Eberiru Islands

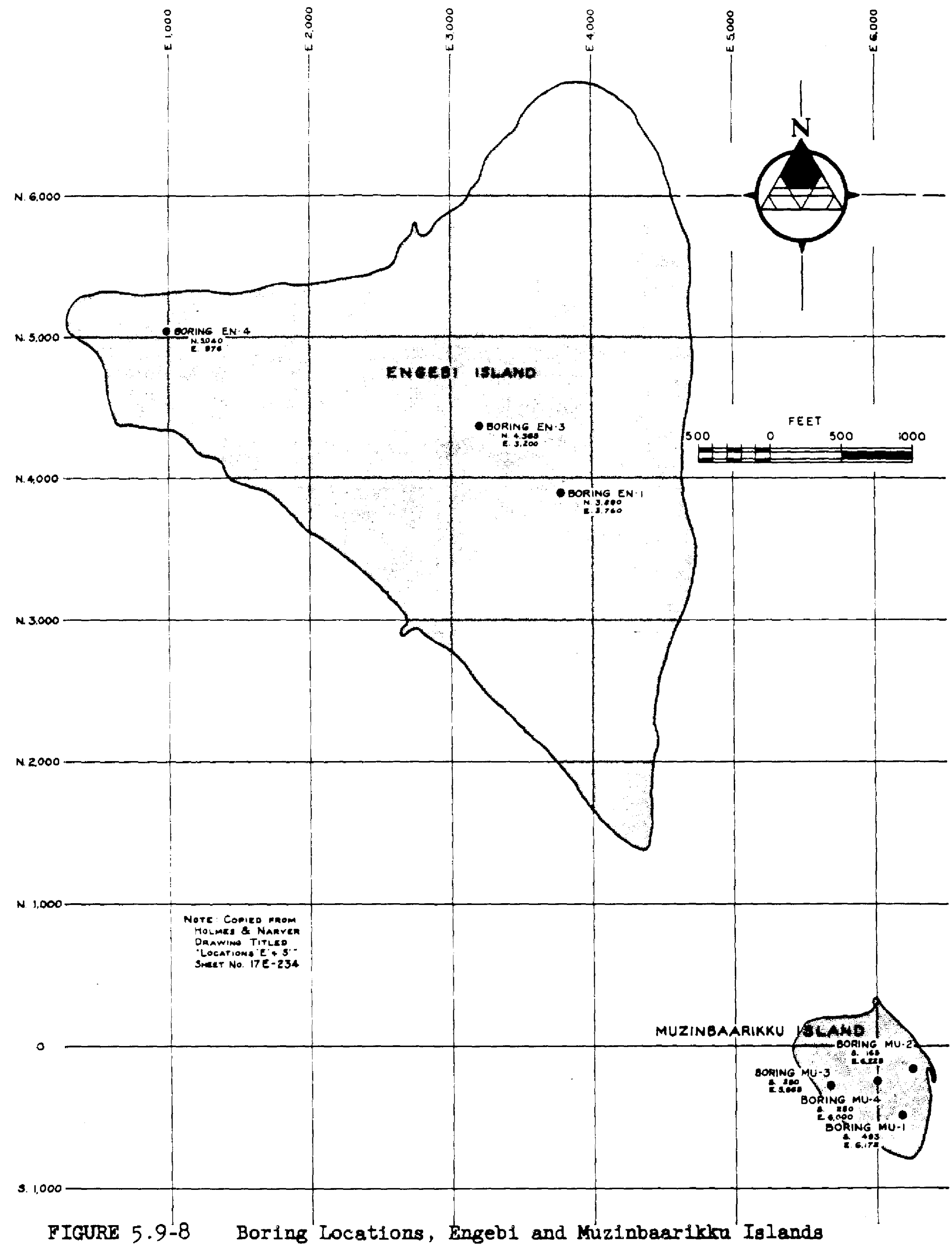


FIGURE 5.9-8 Boring Locations, Engebi and Muzinbaarikku Islands

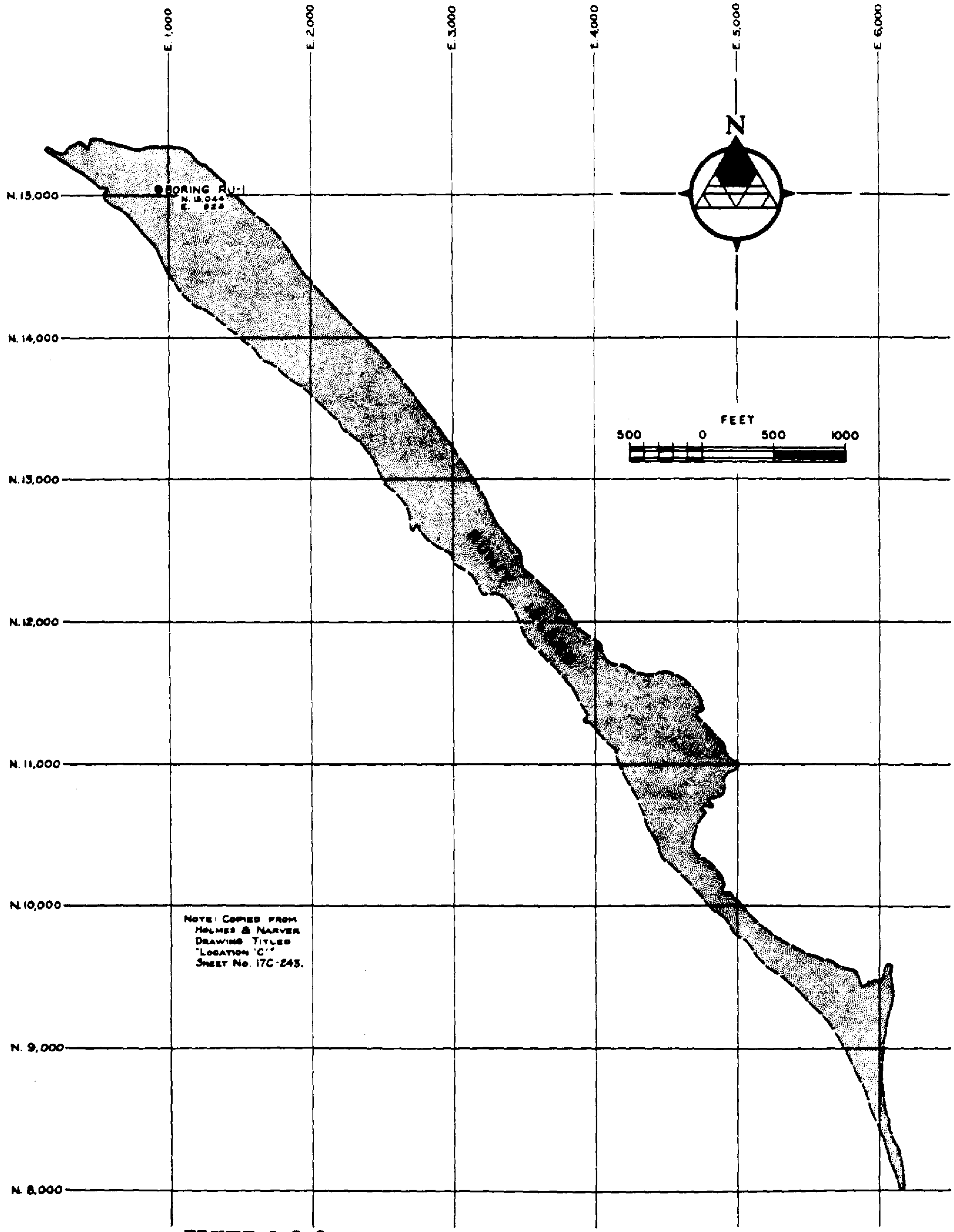


FIGURE 5.9-9 Boring Location, Runit Island

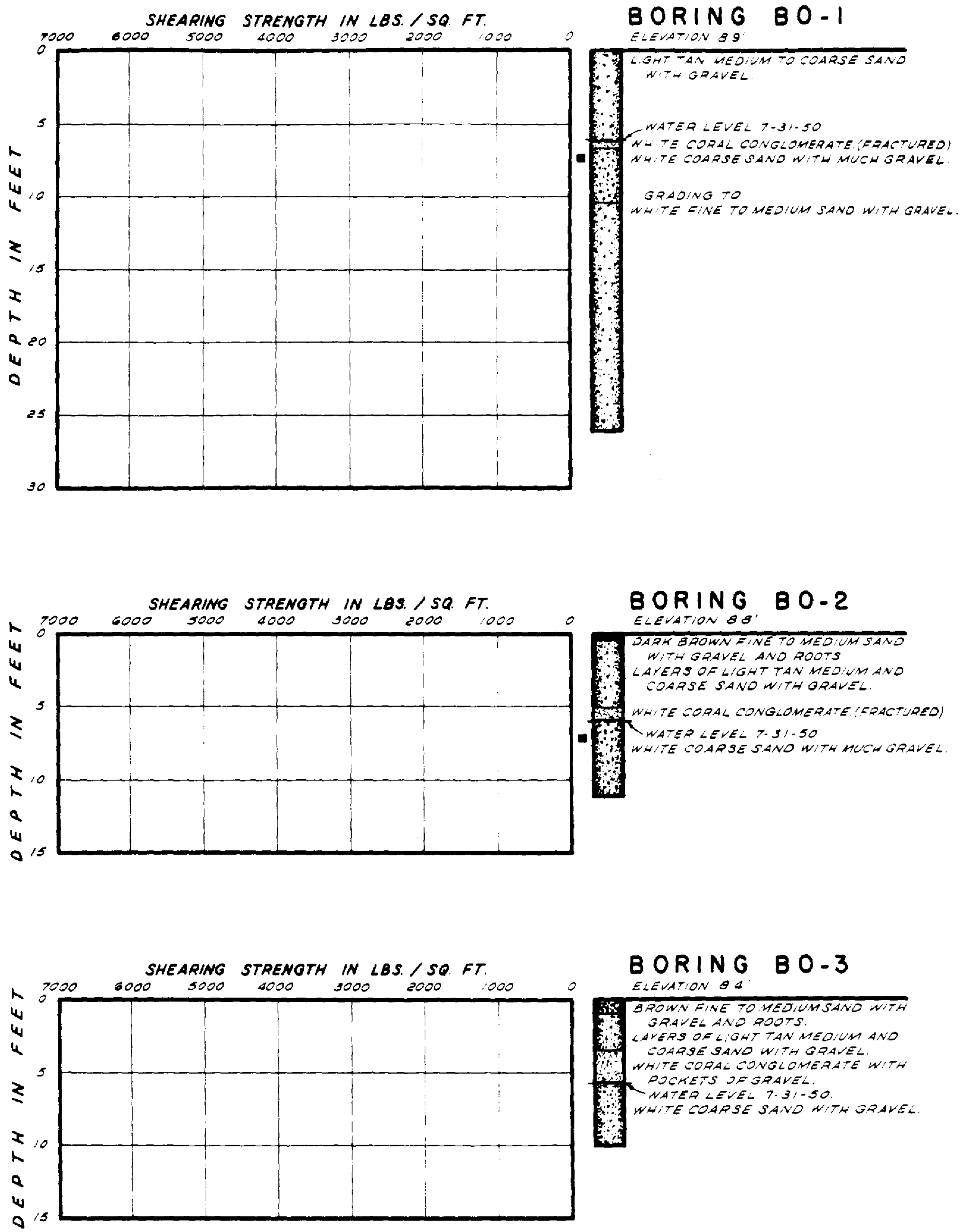
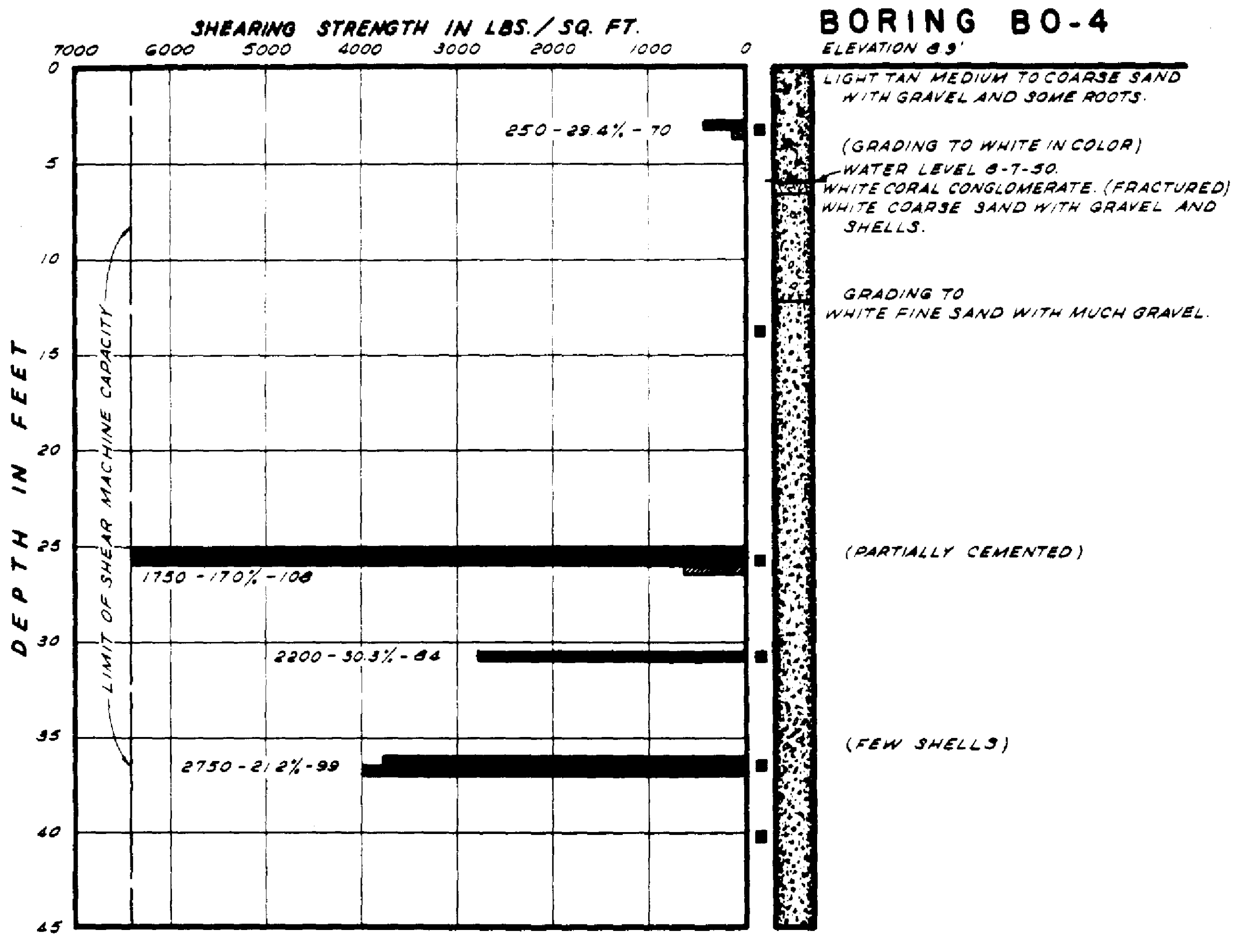


Figure 5.9-10 Log of Borings



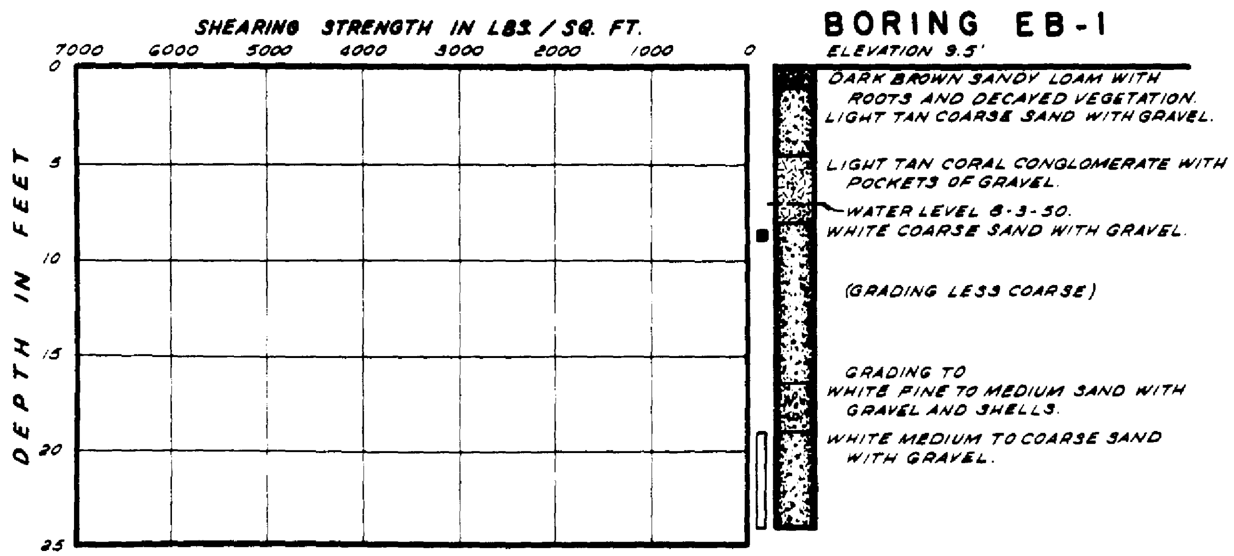


Figure 5.9-11 Log of Borings

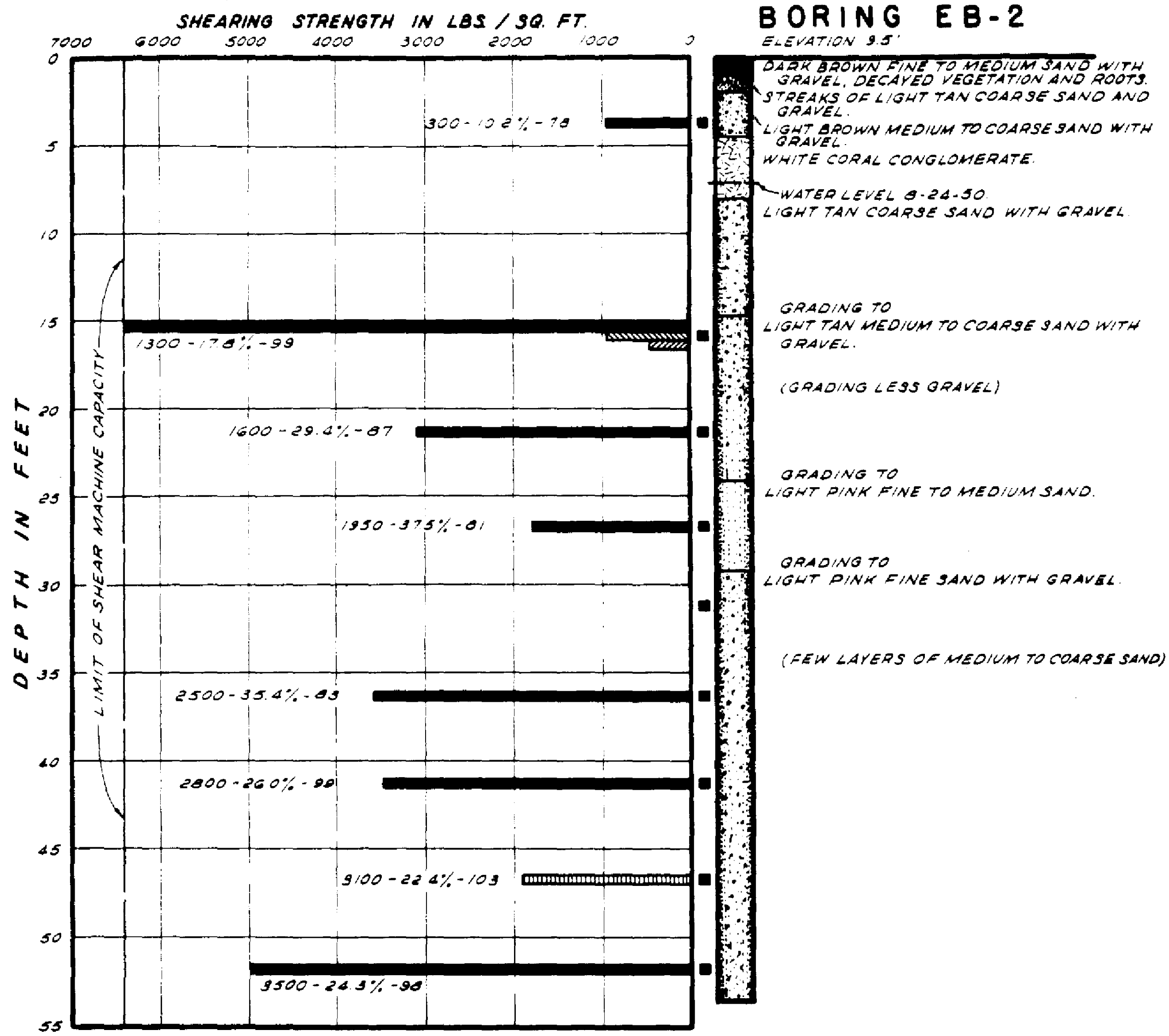


FIGURE 5.9-12 Log of Borings

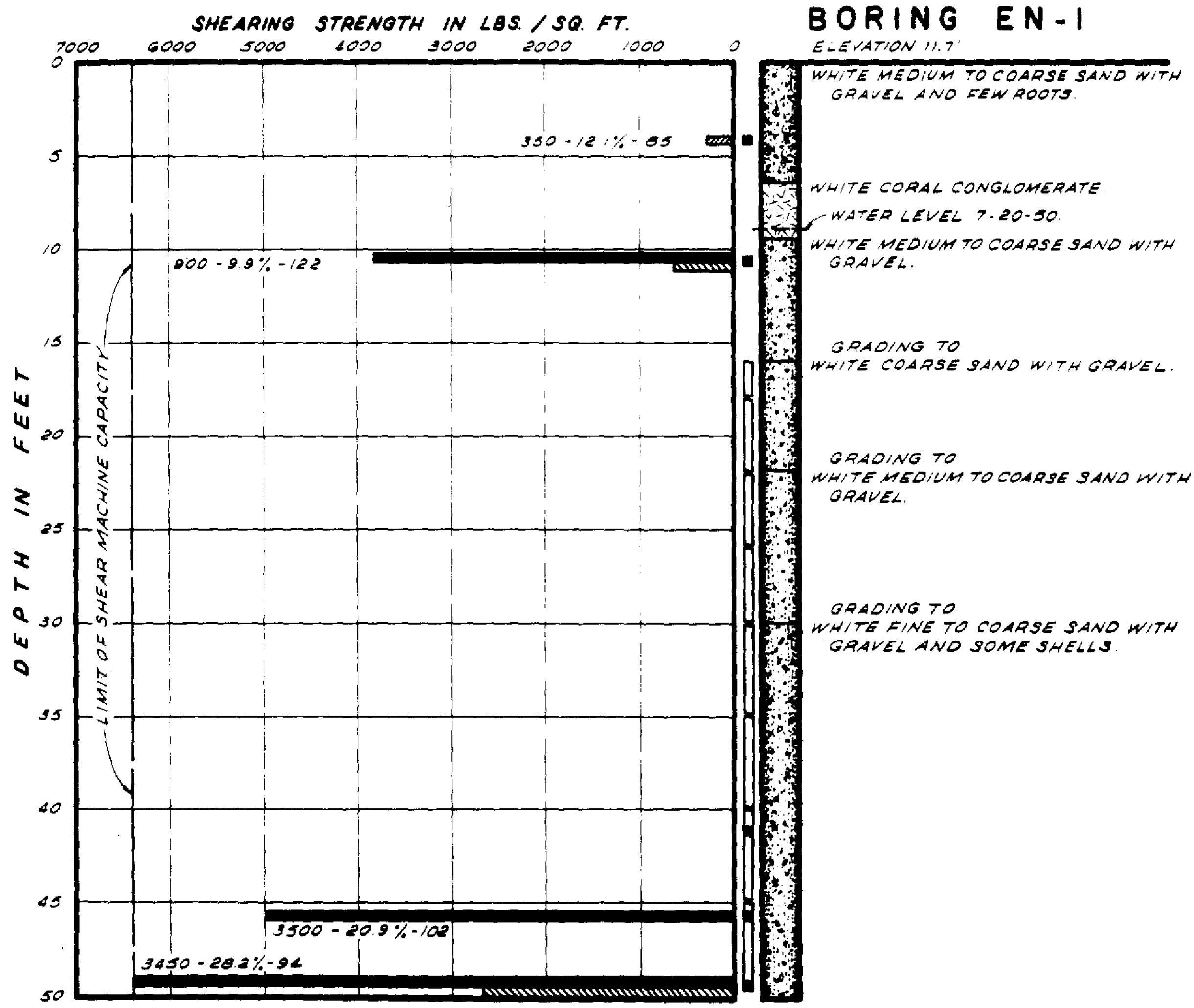


FIGURE 5.9-13 Log of Borings

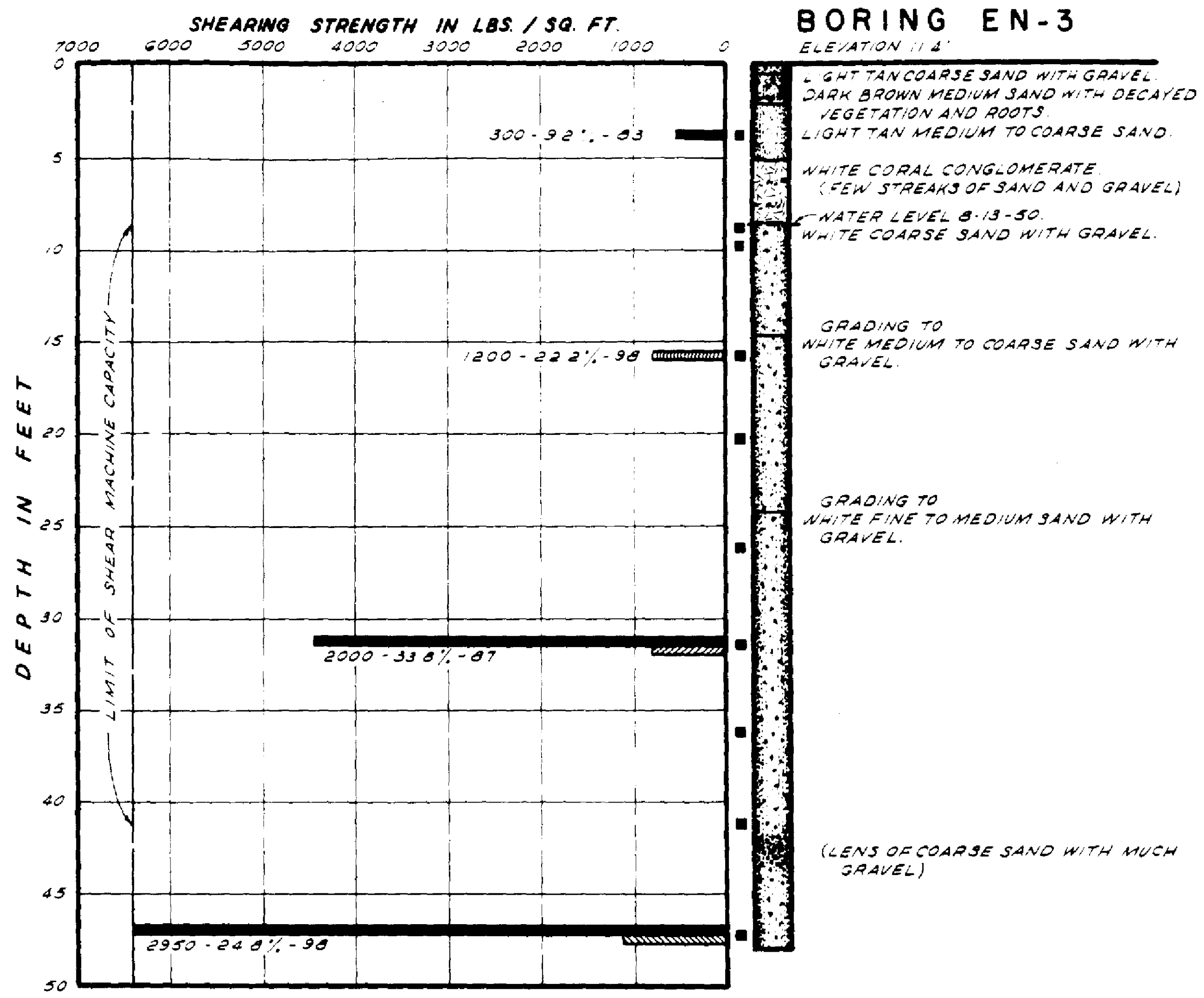


FIGURE 5.9-14 Log of Borings

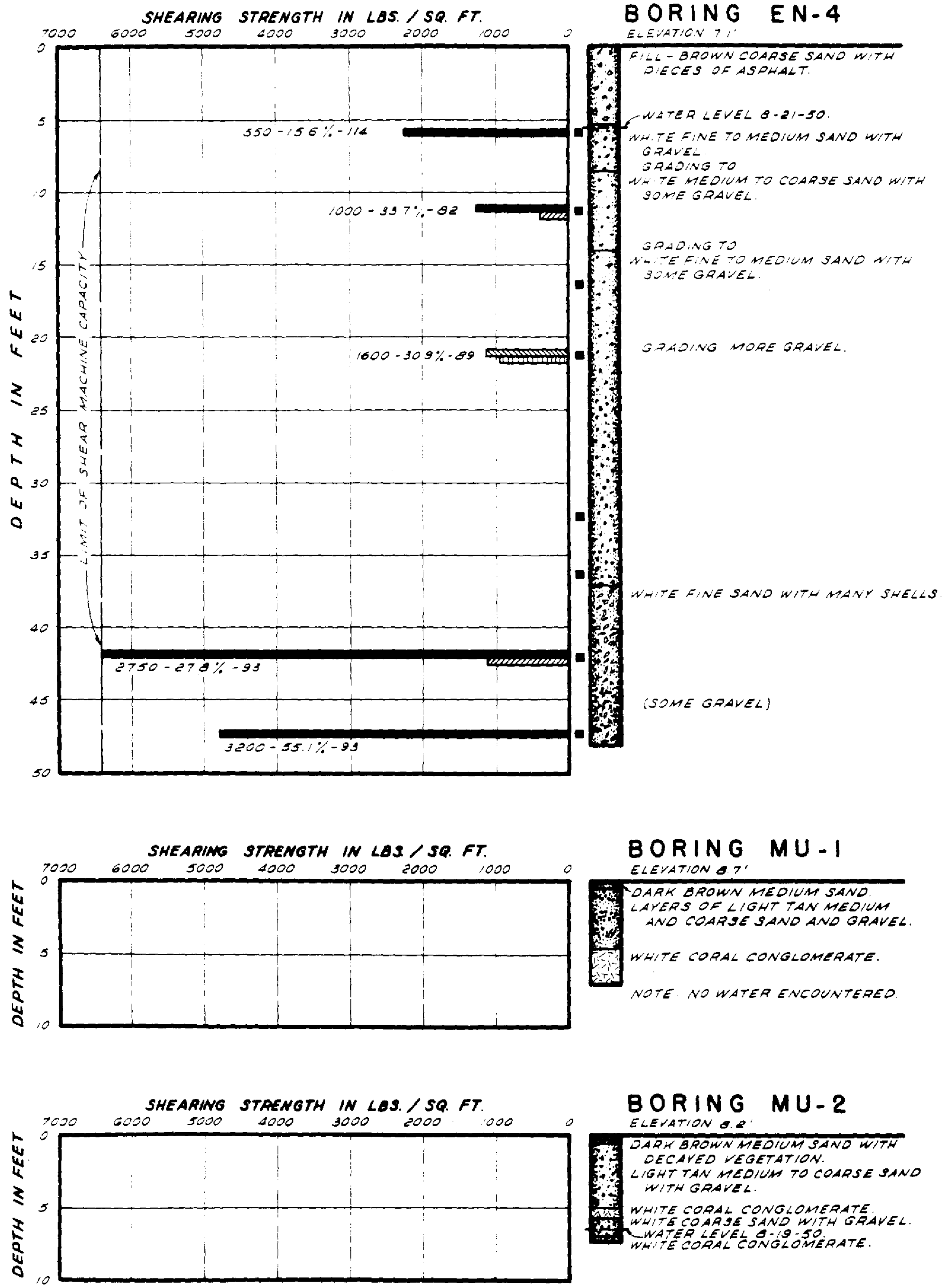


FIGURE 5.9-15 Log of Borings

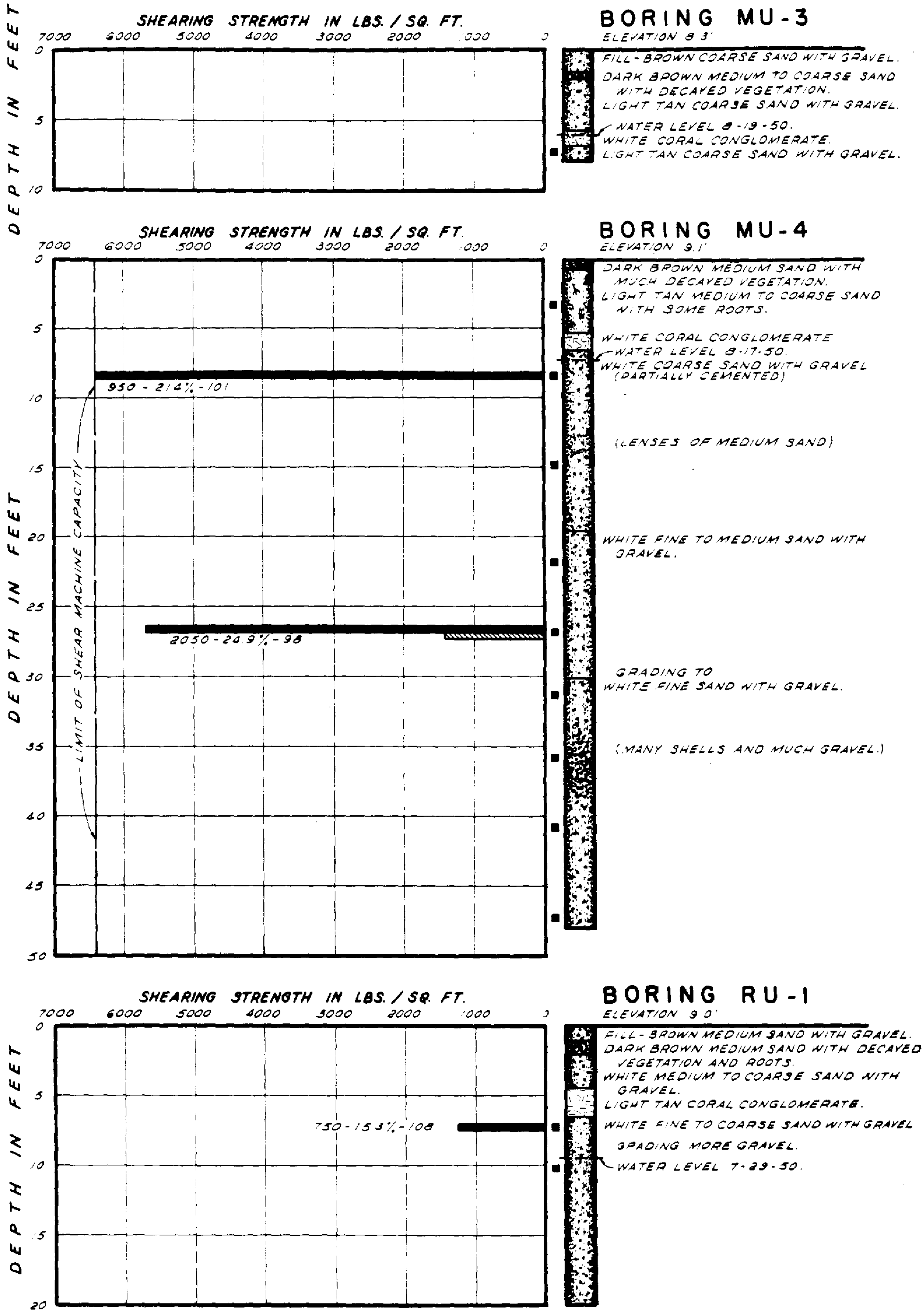
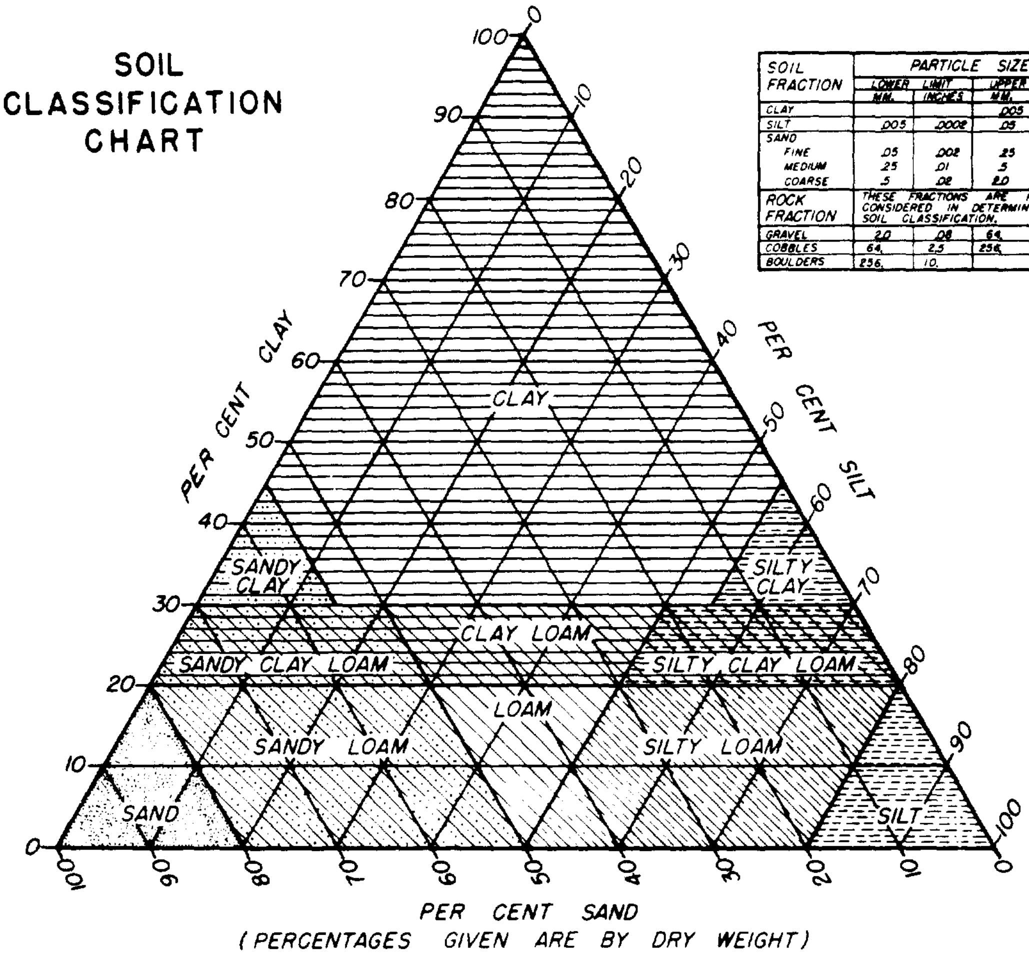


FIGURE 5.9-16 Log of Borings

SOIL CLASSIFICATION CHART



SOIL FRACTION	PARTICLE SIZE			
	LOWER LIMIT		UPPER LIMIT	
	MM.	INCHES	MM.	INCHES
CLAY			.005	.0002
SILT	.005	.0002	.05	.002
SAND				
FINE	.05	.002	.25	.01
MEDIUM	.25	.01	.5	.02
COARSE	.5	.02	2.0	.08
ROCK FRACTION	THESE FRACTIONS ARE NOT CONSIDERED IN DETERMINING SOIL CLASSIFICATION.			
GRAVEL	2.0	.08	64.	2.5
COBBLES	64.	2.5	256.	10.
BOULDERS	256.	10.		

KEY TO TEST DATA

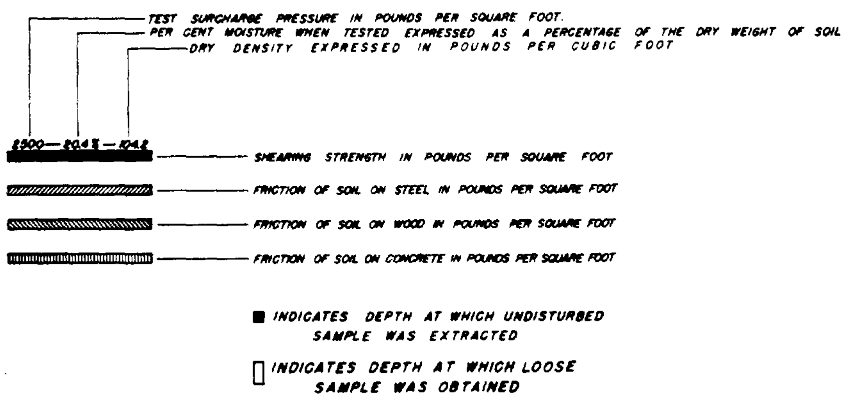


FIGURE 5.9-17 Soil Classification Chart and Key to Test Data

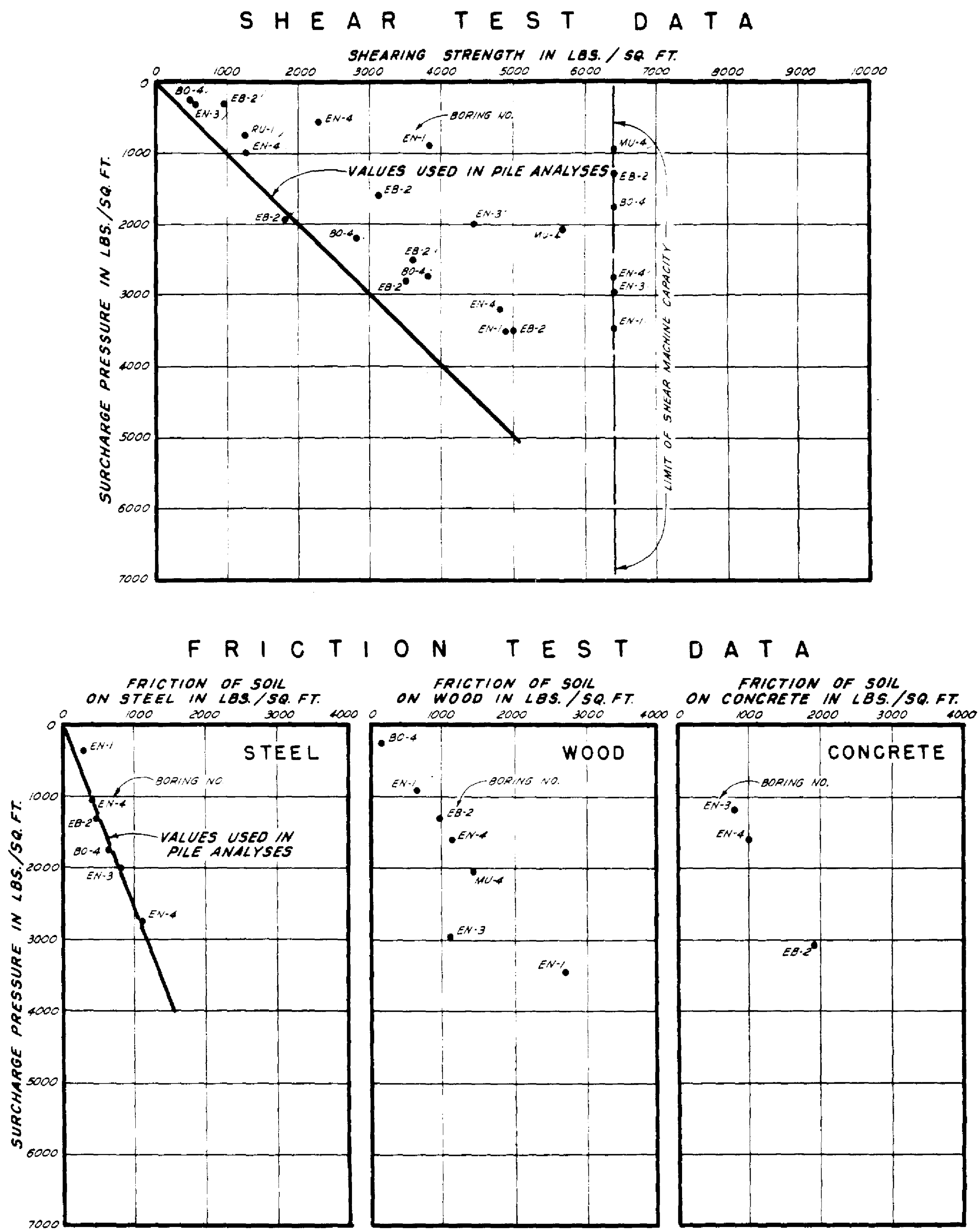
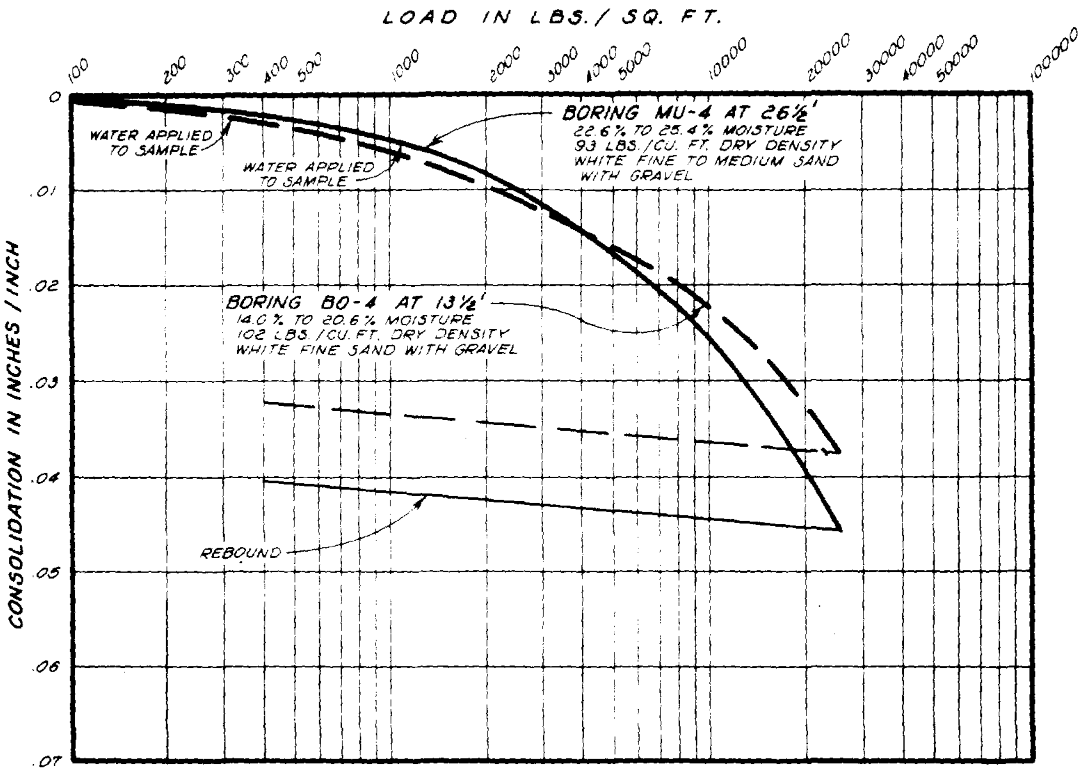


FIGURE 5.9-18 Shear and Friction Test Data



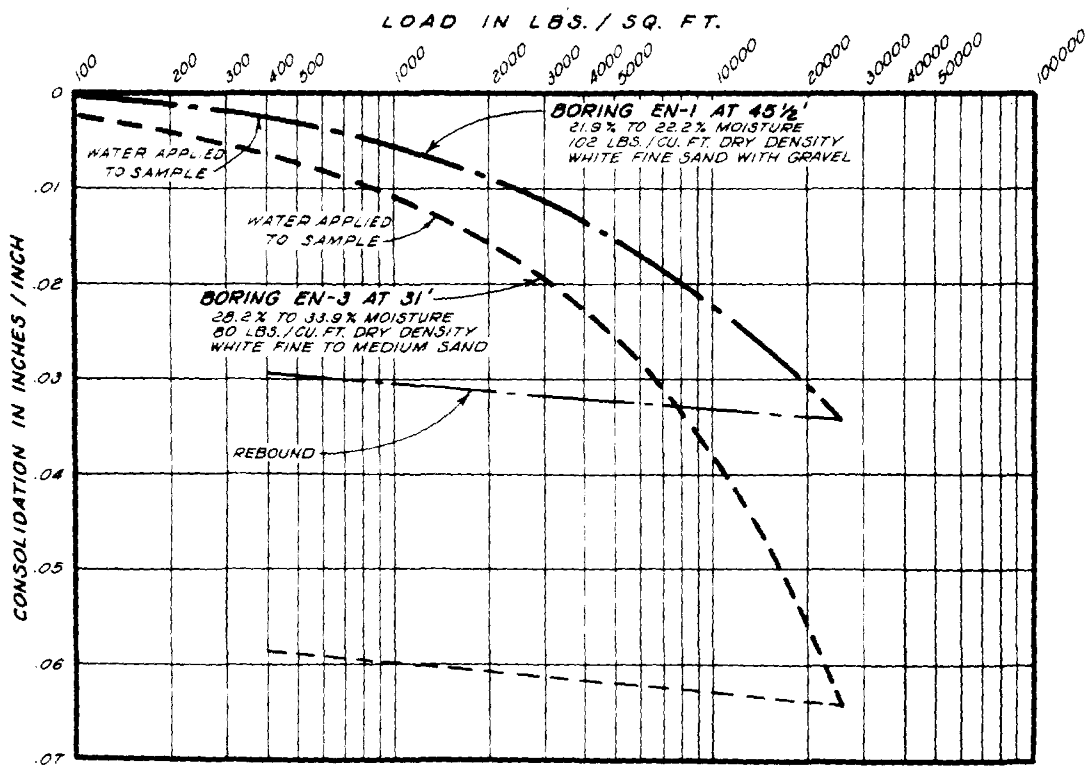
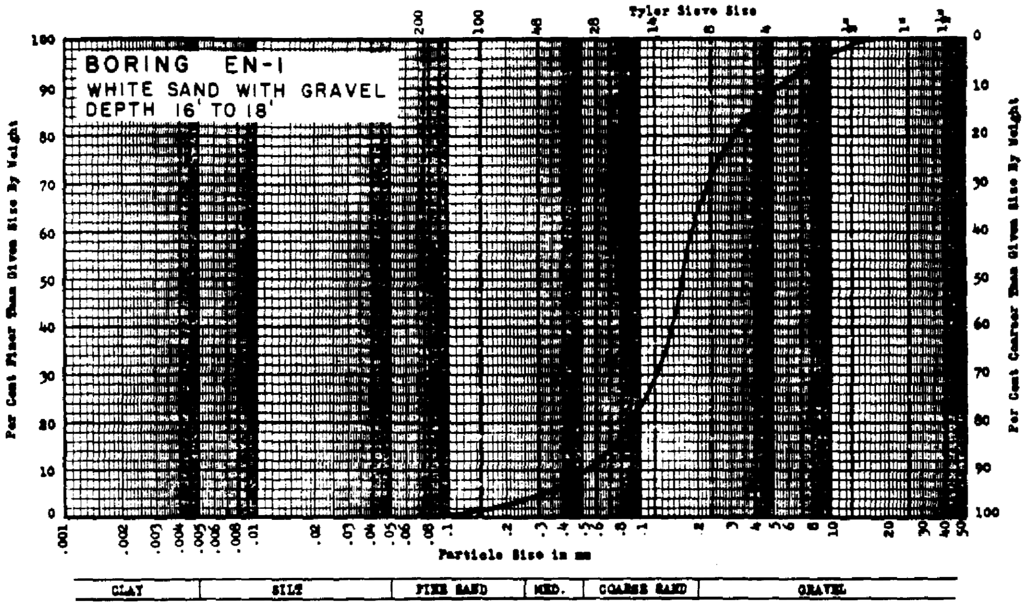


FIGURE 5.9-19 Consolidation Test Data



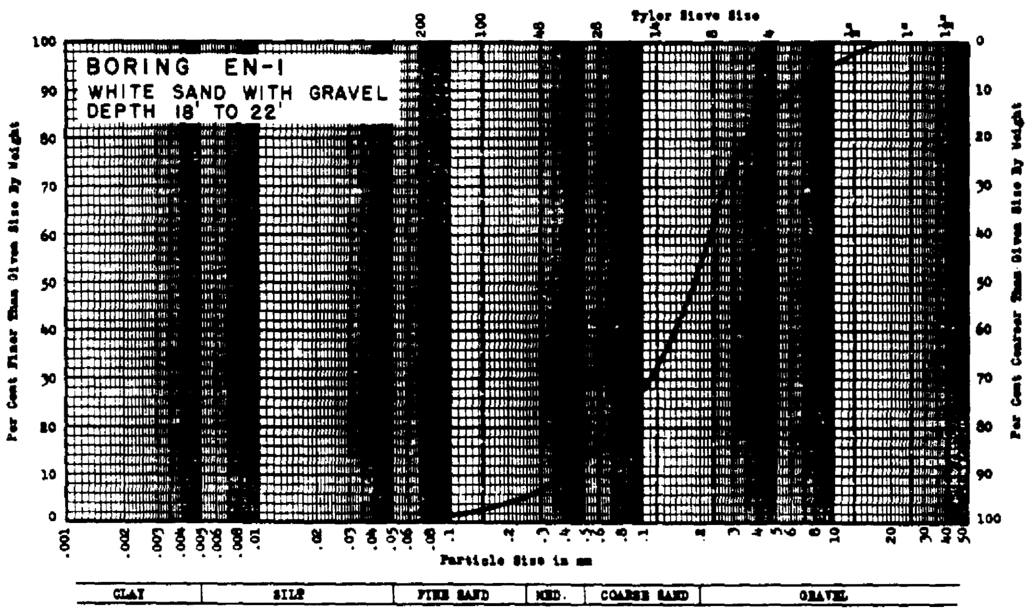
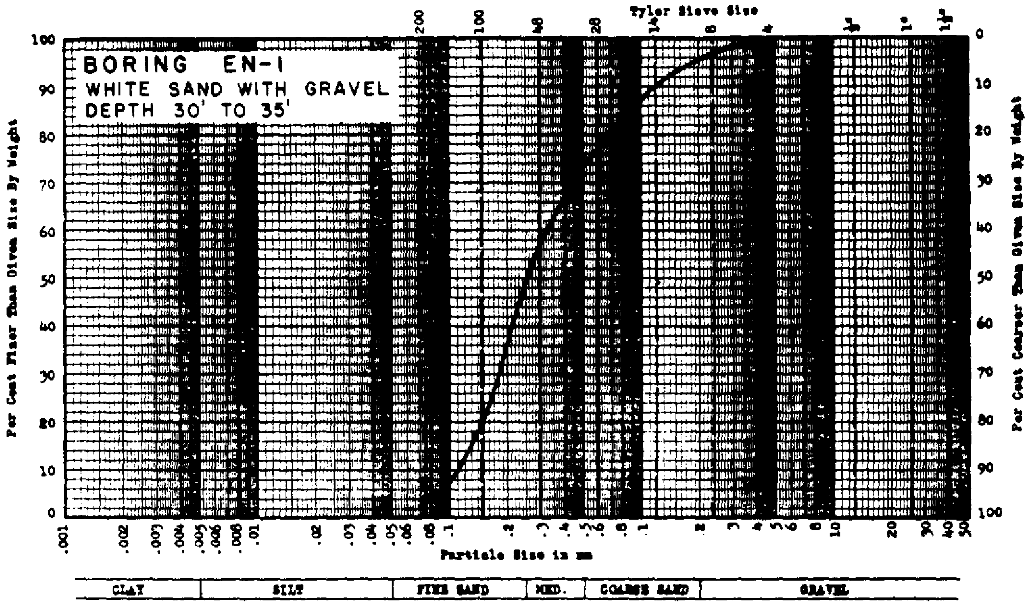


FIGURE 5.9-20 Particle Size Analyses



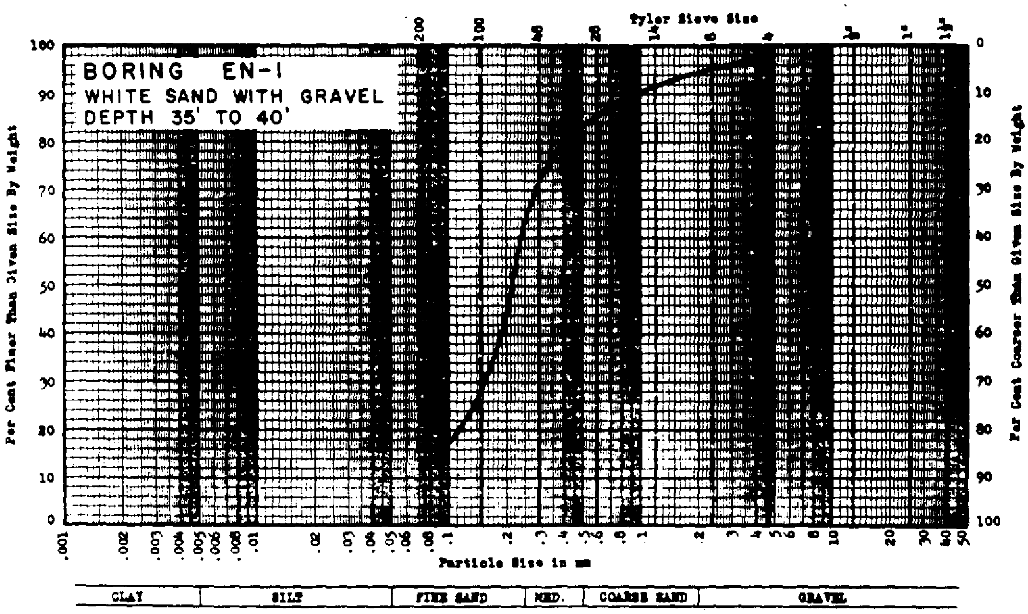
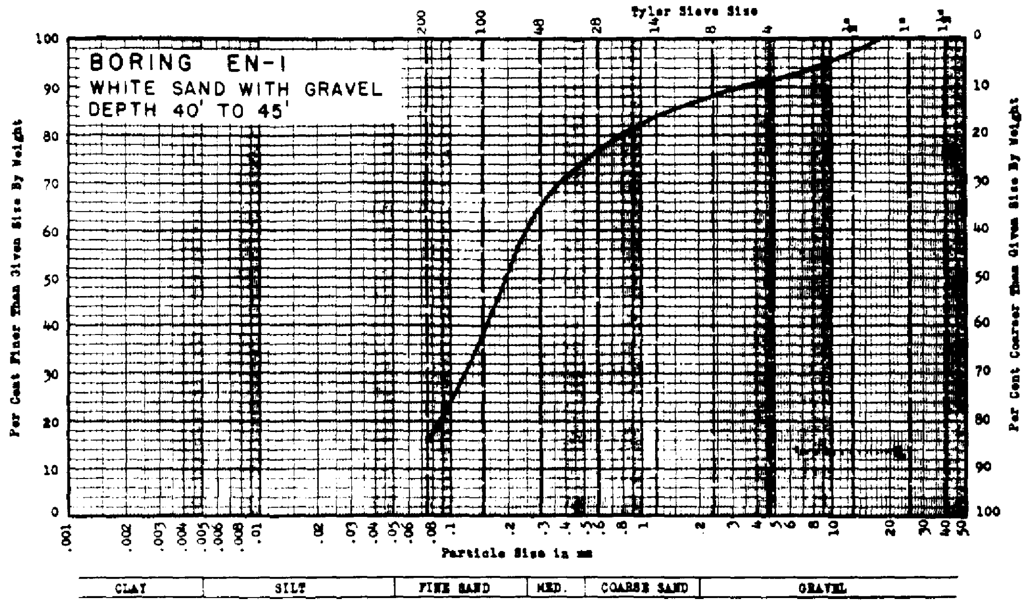


Figure 5.19-21 Particle-Size Analyses



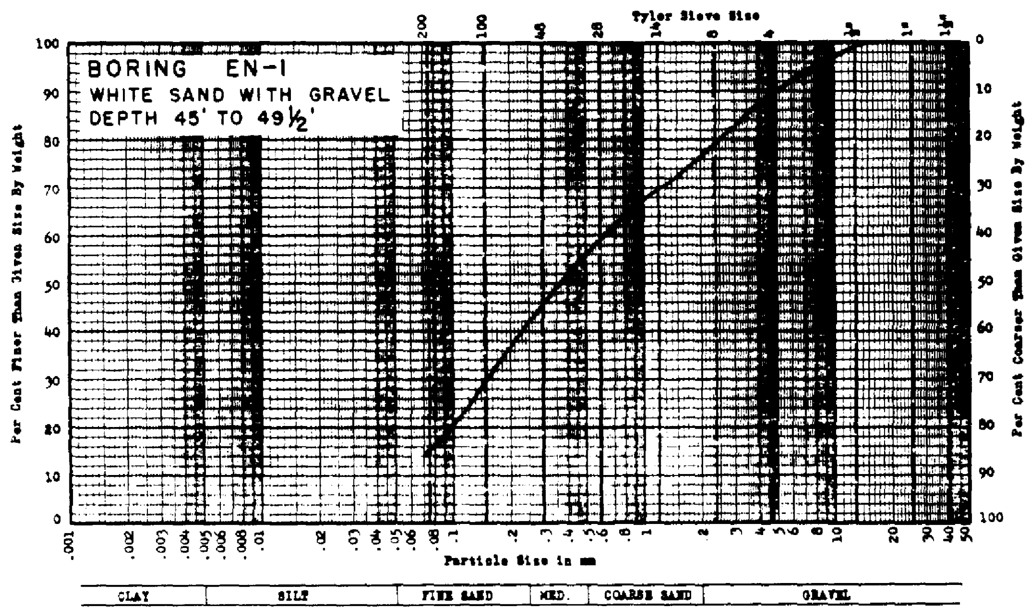


Figure 5.9-22 Particle-Size Analyses

CHAPTER 5.10

PERSONNEL BUILDINGS

One of the major expenditures in developing camp facilities was to be for housing. Therefore, extensive investigations were made of various kinds of buildings, both those which could be domestically prefabricated to a maximum extent and those which could be built at the Jobsite. These included concrete, concrete block, brick, frame with stucco, plywood, steel, aluminum, and various combinations of these materials.

Careful cost analyses were made of all types, and it was found that prefabricated metal buildings were most advantageous both as to adaptability and final cost. It then became necessary to find some metal or combination of metals which could be prefabricated in modules of 3 or 4 feet and which would offer sufficient resistance to the elements of high humidity, high temperature, and constant salt spray. Steel, the most conventional building metal, could not be used because, even with very frequent painting, it could not last the five years required by design criteria.

It had been observed that scrap sections of airplane wings and fuselages that had been lying in the surf on the reef for more than five years (since wartime operations on the Atoll) were still bright, shiny, and basically sound. The only corrosion was on aluminum castings, the alloy used for castings being particularly susceptible. Investigation disclosed that the aluminum sheets were a clad aluminum alloy, and it was reasoned that this would be an ideal material for the skin of buildings that would be subjected to the continuous spindrift carried across the islands from the breakers by the constant trade winds. An additional advantage was the good heat insulation quality of the alloy.

It was learned from aluminum manufacturers that they had a sheet aluminum that would develop the structural characteristics required as well as a corrosion resistance equal to that of the airplane wings.

Preliminary designs were then made by the Engineering Division of H & N, and determination was reached that a structure 24 feet wide, clear span, with vertical walls, would be most adaptable and useful for the structures to be built. Structural analysis showed that if an aluminum alloy could be obtained with a tensile strength corresponding to the 52S structural designation, yet clad with pure aluminum, a practical rigid frame structure could be fabricated to meet the design requirements.

Based upon these design criteria prepared by H & N, bids were requested from manufacturers of prefabricated structures for a 24-foot clear span structure with a double roof, two-thirds of side walls vented, and an 8-foot eave line, all parts to be of a clad aluminum equal in strength and corrosion resistance to 52S.

Pacific Iron and Steel Company, which had developed a formed sheet metal construction for buildings, was given the contract for construction of these buildings in conformance with drawings and specifications prepared by H & N. The design presented a rigid frame structure using columns, roof frame, knees, and sheets pressed into shapes required to withstand wind pressures of 25 pounds per square foot. Multiple punching jigs were to be used to insure interchangeability of connecting parts and to permit erection to be started from any column location.

Upon placing orders, it was discovered that the basic manufacturers were not making a standard clad sheet with strength of 52S. Accelerated salt spray tests of uncoated 52S specimens showed pitting and oxidation so severe that strength and appearance were seriously impaired. Tests of other clad alloys showed no pitting or loss of section in basic material. The cladding oxidized and sealed cut edges to form a protective coating.

Search was made for an alloy with a tensile strength of over 30,000 pounds per square inch and clad to protect the basic material. Reynolds Aluminum Company offered a special sheet which was called 4S clad. Extruded parts such as channels, angles, and clips were made of 61S material. Samples of this 4S clad material were sent to a recognized testing laboratory for testing of strength and resistance to salt spray. Tests for salt spray resistance were made at 100°F for periods up to 250 hours. Results were very satisfactory, and subsequent inspection of structures at Jobsite has verified the durability of the material.

The buildings were quite flexibly designed in that they were framed structures with arched ribs four feet on centers, each four-foot module self-supporting against all design loads. This design left a clear space within the building, with 8-foot vertical side walls and no interior supports. Thus buildings 24 feet wide and almost any length could be constructed. Later developments brought combinations of T, L, and parallel-shaped buildings, all capable of being erected on four-foot modules to any length.

In addition, when nested and crated, most of the parts for aluminum buildings measured approximately forty cubic feet to the weight ton, the optimum relationship for water shipment.

Because these buildings were a new product, test erection for structure and weather tightness was required of the manufacturer. Results of tests showed strength of remarkable closeness to design factors. Tests were attended and approved by representatives of H & N, AEC, and J-Division.

After the selection of the prefabricated aluminum buildings as a basic building unit and upon receipt of AEC work authorization, the Architectural Department began the task of planning and designing the individual buildings and structures required at each site. Production of necessary drawings for camp facilities, criteria for which were

H & N responsibility, proceeded rapidly. Production of drawings for other structures, technical and laboratory facilities for which Users were to supply design criteria, was consistently retarded. This slowness can best be accounted for by the progressive increase in scope of the Project, the corresponding increase in personnel, and the addition of more complex structures. The numerous changes and revisions required the utmost in engineering effort and coordination in order to keep abreast of the construction schedule.

In addition to the semi-permanent housing for that portion of the population scheduled to be at the Jobsite for a considerable length of time, it was necessary to provide housing for personnel who would be at the Atoll only during the experiments or for other short times. When information was received that surplus tents were stored in Army supply depots and were available for transfer to AEC, it was decided to use these for short-time personnel. Use of these tents would make possible considerable economy, with no essential sacrifice of health, safety, or comfort.

A sample 4-man tent was sent to the Holmes & Narver Los Angeles warehouse, and a frame was designed which could be easily erected and also easily taken down and stored. Bids on this frame and on another less easily reused frame were both too high, and ultimately the frames were "job-built" at a considerable saving.

Later, the 4-man tent was frozen and the new 16 x 32-foot standard 8-man "squad tents" were used. Frames were designed from physical measurements and specifications of the tents, and although variations in tent size were common, frames were adjusted to fit the tents. Construction proceeded on this basis, and comfortable and economical housing was obtained. For tent-housed personnel, 100-man aluminum shower and latrine buildings were provided.

A total of 344 4-man tents and 289 8-man tents were used. These tents could normally house 3688 men; but during the peak population period, use of double tier bunks increased tent-housed personnel by 20 per cent.

PARRY ISLAND

Preliminary planning indicated that approximately 73 prefabricated buildings, with an aggregate floor area of about 152,832 square feet, would constitute the building construction on Parry Island. Actually, the Architectural Department prepared at the Home Office 105 sheets of working drawings covering the architectural design of 69 aluminum buildings and having a total of 163,772 square feet of floor space.

Wherever the function of the building would permit, a standard basic building was used without modification. Sometimes, however, the function of the building was somewhat restricted by the limited width and general construction afforded by the building type selected. In these cases, special consideration of detail was required to accomplish the desired results. Standard building parts were used for every aluminum structure.

Because of the high relative humidity, it was necessary to dehumidify buildings that were to house instruments, telephone equipment, and other delicate equipment. Dehumidifications posed a serious problem, because the prefabricated aluminum buildings, although excellent in most other respects, were not inherently airtight. After considerable study, a sprayed-on vapor seal was selected for use in making buildings airtight.[1] This method was used with good results. The Instrument Laboratory, the Counting and Sampling Building, and other buildings requiring dehumidification were treated in this manner, with the vapor seal sprayed directly on interior aluminum surfaces.

Wherever possible, single buildings of rectangular plan were designed and sized to conform with the established standard width of 24 feet inside dimension, and the lengths of the buildings were developed in increments of four feet. In the design of the mess hall and galley at Parry, a cross-shaped plan was deemed the most functionally efficient layout. The inside width of 24 feet was restrictive and made extremely careful planning necessary to include equipment and at the same time provide adequate work space and passage. In the course of the preparation of the plans for this building, it was decided that only the north dining wing would be constructed, but provisions were made for the addition of the south wing when and if it was required. The north dining wing was constructed in the first increment of work, and the south wing was added under the second increment. Later plans called for 32-foot extensions for both wings, but changes were made which ultimately resulted in an additional dining room adjacent and parallel to the north wing.

The introduction of plans requiring the intersecting and paralleling of standard building units produced the problem of designing satisfactory weatherproofing at intersections and between paralleled units. The general building construction did not lend itself to usual methods of intersecting roof surfaces, but this difficulty was overcome at buildings intersecting at right angles by placing the individual building wings in the desired positions, slightly separated from one another. The intervening space was then closed with a special gutter installed at eave height and pitched to downspouts at one or both ends, as conditions warranted. The remaining open vertical spaces in the walls above the gutter were closed by means of special filler panels and, in conjunction with the roof gutter, formed a neat and weathertight installation. Where standard buildings were placed in parallel, they were separated by approximately two feet and an aluminum gutter was suspended between the building eaves. For uniformity of construction and

---

[1]Vapor seal is described in Chapter 5.21, Dehumidification, Air-Conditioning, and Ventilation.

production of special parts, a standard spacing was established for intersecting and parallel buildings.

The bakery building, located adjacent to the galley wing of the mess hall, was connected to it by means of an all-aluminum covered passage to the galley. This covered passage was designed from standard building parts and provided a sheltered link between bakery and galley. One corner of the bakery was partitioned off from the baking area to serve as a lunch pantry. Lunches for men working at other sites were prepared here and picked up at deal windows by the workmen as they left the mess hall after the morning meal.

Interior partitioning was in general accomplished by the use of aluminum partitions starting approximately 1 foot, 3 inches from the floor and extending to a height of 6 feet, 9 inches. The "standard" partition used consisted of square extruded aluminum posts and rectangular extruded aluminum rails arranged to form a supporting framework to receive corrugated aluminum filler panels. The open spaces above and below were to provide for air ciruclation throughout the building; but where greater privacy or complete separation of rooms was required, special filler sections were designed to close from the floor to the bottom rail of the partition and from the top rail to the underside of the roof. These filler sections were usually aluminum panels, but in some of the more complex buildings these were not the most suitable or the most practical method of closure. In these buildings, the closure was made with plywood panels on wood framing. This method was particularly adaptable where walls were lined with plywood or where ceilings had been installed and the transition from wood construction to aluminum presented difficulties.

It was planned to install plumbing fixtures in most aluminum buildings on Parry Island and on other sites. Investigation of the standard aluminum partitions generally used indicated, however, that these partitions did not in themselves possess sufficient strength to support plumbing fixtures, and it became necessary to devise a suitable method of installing these fixtures. A support or rack was designed, its size dependent upon the number of fixtures. This support consisted of a system of separate posts and a flat aluminum plate, reinforced with aluminum angles, spanning between the posts. To provide lateral stability for these racks, the floor ends of the posts were bolted to the floor in the same manner as standard partitions posts. The upper ends were secured by aluminum clip angles or plates to wall girts or top rails of partitions. By this system support was achieved for the fixtures, and exposed plumbing was minimized.

Small aluminum hoods were provided as standard for all exterior doors, but in particular instances where it was desirable or necessary to provide more protection from the sun or weather, canopies or covered walks were designed. In the design of these canopies, as at the infirmary, administration buildings and bakery, standard building parts were utilized.

In an effort to obtain adequate segregation of personnel with respect to level and function, two basic types of semi-permanent living quarters were developed. The larger of the two, designated the 36-man quarters, was designed to provide for a normal capacity of 36 persons, four men to each room. In some instances, these buildings, by the use of double tier bunks, would have to accommodate as many as 72 people. The toilet facilities, although possibly generous for a normal capacity of 36 people, were proportioned to provide the practical minimum for 72 persons.

The smaller of the two basic semi-permanent living quarters was designed and intended for the use of scientists and other key personnel. The plan layout of these buildings was essentially the same as that of the larger quarters, but the buildings were planned for a normal capacity of 18 men per building, two men to each room. In some instances, it was assumed the rooms would be utilized as single rooms.

These buildings presented no particular design problems, as the prefabricated building was well suited to this use. However, after the erection and occupancy of some of these and other buildings, it developed that the original conception of providing vented panels equal to two thirds of the total wall area was excessive and admitted driving rain into the buildings. To remedy this situation, later buildings were constructed with the lower panels stationary or the vented panels left normally closed. In addition, where required because of driving rain or spindrift, triangular filler panels were provided at the ends of each bank of vented shutters, and the spaces between individual shutters were closed with filler panels to form a continuous canopy with closed ends.

The infirmary and male nurses' quarters were provided in two separate aluminum buildings arranged to form an L and connected by an aluminum canopy which ran the full length of the south wall of the infirmary wing. This building, which formed the stem of the L, was designed to provide facilities for X-ray, diathermy, and surgery, along with a doctor's office, treatment room, labs, kitchen, and small ward. The nurses' quarters provided living space for the doctors and nurses as well as a dentist's office. Both buildings were equipped with plastic insect screens.

The laboratory, kitchen, and surgery supply rooms of the infirmary were all aluminum equipped, except for counter tops and cabinets, which had baked enamel finish. After a lengthy investigation of the relative merits of wood, steel, and aluminum cabinets, baked enamel cabinets were chosen on the basis of economy, availability, and ease of cleaning.

Post office and post exchange facilities were housed in a single standard aluminum building approximately 104 feet long. Its area was divided to include the post office, post exchange, barber shop, and a snack bar. Since the building was used without particular modification, planning of space and the design of the necessary case work were the main issues. Case work required extensive detailing, but because it was determined that prefabrication would involve higher costs and shipping delays, designs were made by H & N personnel for job-building. Except those in the infirmary and in the CMR buildings, all cases were H & N designed and job-built.

The power plant structure was among the largest structures designed for this site, and use of the standard prefabricated building presented particular problems. The equipment planned for this plant could not possibly be housed in a 24-foot-wide building, nor did the standard building possess sufficient vertical clearance for the installation of engine mufflers, piping, etc. The equipment layout would, however, permit the use of a row of columns on the center line of the long axis. By the use of interior columns, two standard 24-foot-wide buildings were placed in parallel and spaced four feet apart. A special four-foot-wide aluminum gutter was designed to close the space between the two building units and to drain the roof properly. This presented a total inside building width of 52 feet, which was sufficient for the equipment layout. The standard building required wall studs at four feet on centers, but because the studs forming the interior row of columns would receive no paneling, every other stud was omitted. This practice provided columns at eight-foot centers, with aluminum lintels supporting the roof load between these columns. To obtain the required head room in this building, the entire aluminum structure was erected on a reinforced concrete wall six feet high and nine inches thick. This wall was pierced as required to provide doorways and vent openings near the floor.

After this building had been constructed in accord with original approved design, the addition of the CMR facilities to the program imposed additional electrical power load requirements. To fulfill these, an extension of 24 feet was made at the east end of the building to house the sixth generator unit. This extension was of the same construction as the existing portion.

Separate structures were designed for the H & N administration building and scientist's administration building. Each of these buildings was planned for construction from the standard aluminum building units, and a study of site restrictions, building areas, and functions led to the development of L-shaped floor plans.

The H & N building was subdivided into areas by standard aluminum partitions to provide management offices, drafting room, conference rooms, and telephone equipment and switchboard room. In this structure a fireproof vault for record storage was required, and this was best provided by a reinforced concrete vault placed outside but as close to the aluminum structure as construction would permit. The design of a weatherproof connection between the vault and aluminum building presented new problems which were solved by the use of special aluminum filler panels and eave gutter. Special attention to detail was required at the telephone room, as this room required dehumidification to protect the apparatus. A plywood ceiling was installed, and the walls were lined with plywood panels on wood furring. This provided a tightly sealed room. The dehumidifying equipment was installed outside the building and adjacent to the room.

The scientist's administration building was of the same general type as the H & N building. Aluminum partitions divided the building area into office space, conference rooms, toilet rooms, etc. Originally toilet facilities were provided for women employees, but following instruction to the effect that no women were to be provided for at this Project, the plans layout was revised and this space was used for additional offices.

In each of these buildings, the L-shaped plan caused a problem in connecting the two wings. This was solved by the means of a special gutter similar to that used on the mess hall. Arrangement of these buildings in spaced relationship on the site formed a U-shaped layout. The two buildings were then connected at the bottom of the U by a roofed passage of all aluminum construction. The columns supporting this roof were cut from standard interior partition post and the roof fabricated from aluminum rafters. Roof panels were standard with those of the buildings. Subsequently, along with the increase in the scope of the experiments, came the demand for more office space for scientific and AEC personnel. To provide the space, plans were prepared and construction undertaken to remove the covered passage between the buildings and install in its place approximately 1380 feet of standard prefabricated building, thus making two L-shaped buildings into one U-shaped structure.

As a facility for the repair and maintenance of instruments used by the various groups participating in the experiments, a large T-shaped building was designed. This structure, composed of intersecting standard aluminum buildings,was partitioned to form laboratories and a common machine shop for the separate groups involved. Certain of these laboratories required dehumidification; these were centrally located within the building in order to obtain an economical arrangement of duct work and equipment. For adequate sealing of rooms for dehumidification, all openings in the exterior roof and wall construction were filled with sponge rubber plugs, and the interior roof and wall surfaces sprayed with a "cocoon" type vapor seal.

About this building were grouped the photo laboratory, counting and sampling laboratory facilities, and two separate laboratory buildings pertinent to the experiments. These structures, along with the instrument laboratory building and the H & N and scientists administration buildings, were enclosed in a common security compound.

Following the decision, in July 1949, to establish the Task Force Headquarters on Parry, the planning of a building to provide the necessary office space and facilities was initiated. In addition to office space for the Commanding General and his staff, space was provided for conference rooms, message center, code room, etc. Because of the restrictions imposed by the use of a standard building type, an E-shaped plan seemed best suited both in terms of function and construction . Essentially, the message center, code room, teletype and communications offices, conference room and Commanding General's office were housed in the vertical stem of the "E", with the three outstanding legs housing the various other offices. Intersections of the wings with the stem of the building required the use of special gutters and filler panels as in other buildings.

The code room in this building was constructed entirely of reinforced concrete and provided with a fireproof vault door equipped with a combination locking device. To provide maximum security, special consideration was given to all openings from the message center and teletype rooms, and vertical steel bars were provided at exterior openings. Ultimately, instructions were received to soundproof as nearly as possible the Commanding General's office and the adjacent conference room. To accomplish this soundproofing, ceilings with wood joists were installed and inorganic acoustical tile was applied over plywood sheathing. In the general's office, acoustic tile and plywood sheathing were applied to wood furring strips affixed to the aluminum building framing. In the conference room, the enclosing interior partitions were framed with wood studs and sound deadening batts to obtain greater sound reduction through these walls. One end of the conference room was equipped with a sliding map board and a draw curtain, both suspended from overhead tracks. A low storage case was constructed along the exterior wall.

The design of the photo laboratory presented special problems in that it was necessary to provide both airtight and lighttight linings for the aluminum building. This was accomplished by affixing plywood panels to the interior surfaces of the aluminum structure. Because the central two-thirds of the building were to be air conditioned as well, a ceiling was installed in order to reduce the volume of space. Walls and ceilings were insulated and a vapor seal was applied. In effect, a complete wooden structure was built within the standard aluminum building.

After construction of the building was well under way, two major changes were requested by AEC. In March 1950, plans were revised to include two additional dark rooms. This change required an addition of eight feet to the building length, and this addition involved considerable engineering and construction change. Later, in January 1951, instructions were received to provide a refrigerated film storage space. Because it was not feasible to provide this space within the building, a refrigerator was placed outside, adjacent to the building, and an enclosed passage provided access to it from the laboratory rooms. At the same time a "chilled water" system was incorporated for service to the labs and dark rooms. Cooling units were located outside the structure, near the film storage refrigerator.

Laundry facilities were housed in a standard aluminum building with a separate aluminum boiler house constructed adjacent to and near the central portion of the laundry proper. Although the 24-foot width was not ideal for the equipment layout, an efficient plan was developed by careful study. The original layout and the equipment selected were based upon early population estimates, but because of the subsequent large increases in personnel it became necessary to expand the laundry facilities. In December 1950, plans were prepared for an addition of 20 feet to this building to provide space for more bundle racks and for two additional pressing machines. Otherwise, the construction of this building utilized the standard prefabricated aluminum structure with no modification other than the installation of deal windows for deposit and pickup of laundry and the necessary modification of toilet room partitions.

In the course of the previous experiments, a control tower had been erected near the central part of the island, and consideration was given to the possibility of erecting the new control building on the existing concrete slab supporting this tower. Further study indicated that this was not feasible and the control building was designed as an entirely new structure and located adjacent to the existing slab and tower. The shell of this building consisted of a 24-foot-long standard aluminum building. By means of wood studs and plywood sheathing, the interior was divided into three areas to provide a control room, observation room, and a dehumidification equipment room. In order to reduce the volume of the air to be dehumidified and thereby the equipment required to dehumidify the control room, a plywood ceiling was installed on wood joists in this room only. In the partition dividing the control room and observation room, a plate glass viewing window was installed. An area of 162 square feet was originally allotted to the control room. After the preparation and approval of plans, however, instructions were received on November 9, 1950, to increase the size of the control room. This was done, without changing the building size, by relocating the control room partition to provide 278 square feet for the control room. This building, along with the existing concrete slab and tower, was enclosed in a small compound formed by an 8-foot chain link fence with access gates.

On April 18, 1950, schematic drawings and preliminary criteria were given H & N, with instructions to proceed with the design of the CMR laboratories. These facilities required the use of two separate structures, one of which, by the nature of its function, could be a standard prefabricated aluminum building. The other, because of the equipment to be contained, required a larger building, and a steel-framed prefabricated building with aluminum roof and wall sheathing was selected. These structures were placed side by side, about ten feet apart. The intervening space was paved with a concrete slab floor for trucking and access from one building to the other. Over this slab and cantilevered from the steel framed building was a canopy to protect this space from the weather. A similar concrete slab and full length canopy was installed on the opposite side of the larger building to provide a covered storage area. It was required that both buildings be dehumidified and that a rapid air change ventilation system be provided. To accomplish this economically, a small wood framed structure was designed and erected to house the necessary mechanical equipment. This building was located to serve both lab buildings with the minimum of exterior duct work.

Dehumidifying of these buildings, as of others, dictated that they be made as nearly airtight as possible, and in this instance, sprayed-on "cocoon" type vapor seal was applied to walls and underside of the roof. Special rubber seals were designed for all exterior doors, except the large sliding doors provided for installation of equipment. These doors were very rarely used and therefore were simply sprayed with the vapor seal. No windows were provided in the larger building, and the natural light was through the glazed doors. In the smaller standard building, some natural light was obtained by installing standard wood frame screen units of the same type designed for the mess hall and infirmary and by replacing the plastic screen cloth with translucent sheets of plastic. Interior partitioning was accomplished with wood studs and plywood panels, and a four-foot-high plywood wainscot was installed in the large building. All laboratory benches and furniture was selected by the Users.

In addition to these buildings described in brief, many other prefabricated aluminum buildings were erected on Parry for use as boiler houses, fire station, recreation building, commissary reefer building, warehouse, etc. In general, where the structures were too small or too complex for economical use of the prefabricated type building, wood framed structures with aluminum siding were used. Buildings of this kind included the guard post, telephone shelter, theatre projection room, etc.

Because the prefabricated aluminum building could not economically be used as a theatre and because of the favorable climatic conditions, it was decided to design and construct an open-air auditorium with wooden benches arranged on a sloping fill facing the screen. The seating arrangement was based upon current practice, the maximum and minimum distance to the screen depending upon the "throw" of the projection apparatus and the critical viewing angles, both vertical and horizontal, established within the limits as determined by accepted standards of the motion picture industry. The benches were arranged so that the lines of sight of the viewers to the screen were uninterrupted.

The screen size was determined by the limitations of the projection lamp intensity and the magnification of the required image. Design of the screen required a flat matte surface with a reasonable reflectivity factor, without distortion or imperfections. For briefing and lecture purposes a small, raised, wooden platform with railing was placed adjacent to and made a part of the lower right portion of the screen framework. Access to this platform was by means of a wooden frame stairway.

To provide a measure of wind control during operation, the several rear rows of seats were sheltered by means of a roofed frame canopy anchored to suitable foundations. The back of this framework was provided with rolled-up canvas curtains between the rear supports. These curtains could be adjusted.

The projection room was located upon the roof construction at its axis and facing the screen. Access to the projection booth was by means of a vertical wooden ladder at the rear of the shelter, directly behind the booth. The height of the projector lens axis was almost in a horizontal line with the center line of the screen; thus distortion of the projected image was avoided.

ENIWETOK ISLAND

At the inception of the construction program, there were more than 120 buildings in all stages of deterioration on Eniwetok Island. Some were occupied by the garrison; others were immediately brought into use by construction personnel for temporary quarters, materials warehouses, construction shops, etc. Approximately 50 of these buildings, mostly warehouses, along with several recreation buildings, were repaired and became a part of the semi-permanent facilities of the island. The remainder, consisting mostly of those in the worst state of deterioration, were dismantled after their temporary usefulness to the construction crew was over, or after they had been replaced by new and improved installations, as in the case of the communications, base operations buildings, and the control tower at the airstrip.

For the great number of military personnel whose tour of duty on the island was to be of short duration, billetings were accomplished by the use of cantonments containing 8-man tents and 100-man aluminum shower and latrine buildings. For the garrison and for officers and enlisted men to be stationed for a longer period than the duration of the experiments, quarters were provided in 18, 36, and 72-man aluminum barracks. These barracks were the same type of aluminum building as used on Parry Island.

Mess hall facilities were planned for an anticipated population of 2200, but actually the facilities ultimately accommodated more than twice that number for a short length of time. Preliminary studies revealed that the 24-foot width of the standard building was insufficient to allow porper, or even workable, arrangement of equipment necessary to prepare 6,600 meals daily. Nor could adequate seating be provided in this width without making the dining rooms unrealistically long. The two alternatives were the construction of a less permanent building of other materials than aluminum or the adaptation of the standard building to meet the special requirements. The latter alternative was considered the more economical.

Standard buildings were used, set in parallel and in the form of a cross, resulting in a building of 50½ feet in inside width, with a double row of columns down the center. Two arms of the cross made up the enlisted mens' dining rooms; a third was the officers' dining room, and the fourth and shortest arm contained the kitchen, which extended into the intersection of the cross.

The serving area was placed around the perimeter of the intersection, facing into the three dining rooms. The rear of the kitchen contained receiving and storage areas, locker and toilet rooms, the scullery, and initial preparation facilities. Succeeding operations were arranged in sequence, with the final cooking being performed at the opposite end of the kitchen, nearest the dining rooms. Appendages were affixed to the dining rooms for dishwashing, so that the table china, glassware, and flatware could be kept in the dining area and did not pass through the kitchen or interfere with the operation of the food preparation area.

Bakery facilities were placed in a separate building adjacent to and linked with the mess hall kitchen by a covered walk. This arrangement kept the handling and rehandling of finished bakery products to a minimum. For the bakery, the use of a double width building was again advantageous in conveniently and economically arranging the required pieces of rather large equipment, especially the proofing cabinets and ovens. Storage, locker, and toilet rooms were relegated to one end of the bakery. The remainder of the building was divided into two preparation areas running parallel to each other, one for pastries, doughnuts, and specialties, and the other for bread. Baking was done at the ends of these areas nearest the passage to the mess hall.

The reefer and commissary buildings completed the messing installations. The floor of each of these buildings was raised to 4 feet or truck bed height and was extended 6 feet out from the building along one side as a loading platform. Otherwise, the commissary was a standard aluminum structure, but the reefer building, which contained ice making machines and prefabricated refrigerators with removable compressor units, had typical sliding door tracks added to the plate of its rear wall to give adequate bracing to the building when certain columns and wall panels were removed to allow enough clearance for pulling out the compressor units for occasional repair or replacement.

In the central part of the housing area, near the messing facilities, were the laundry and its boiler house, the fire station, post office, post exchange, dispensary and two ward buildings, and the Group Headquarters Building. These were all aluminum buildings with no structural peculiarities except that the Group Headquarters Building had appended a vault and a crypto room, both of reinforced concrete.

The power and water distillation plant, located between but somewhat isolated from the living area and the airport installations, was built of aluminum buildings connected in parallel and set on 6-foot concrete walls, giving a 14-foot plate line, an adequate height to clear the equipment, which was arranged in two rows running lengthwise with the structure. One row contained engines and electrical cubicals; the other, evaporators and distillation units. The standard buildings were spaced 4 feet apart, instead of 2½ feet apart as in most other buildings, to give ample piping space and a corridor down the center of the building.

The large B-50 hangar on the north side of the runway was a steel building procured by the Air Force and erected by Task Group 3.2.

On the south side of the runway was the steel-framed L-13 maintenance building with aluminum siding and roofing, very similar to a standard "Butler" building of 50-foot clear width.

The nearby Air Task Group Headquarters Building and the base operations building were standard aluminum structures. To one side of the latter building was built the three-story control tower. The first two stories were designed for wood frame construction with aluminum siding. The control room was designed to project out from its two-story base and to be enclosed with continuous aluminum sash set at an angle to reduce glare. To receive the sash and to support the roof, aluminum I-columns were used. A catwalk was designed to surround the control room, and access was planned by means of an exterior wood stairs.

The majority of the remaining structures on Eniwetok Island were designed as standard aluminum buildings except those so small that the standard building could not be economically used. These were wood frame with aluminum siding. Buildings of this type included the inflation shelter, weather station, sentry post, and others.

Two open-air theatres were designed; one with a seating capacity of 712; the other, with a capacity of 818. Seating arrangements in both were wooden benches on fill sloping down toward the screen. The seating arrangement, viewing and projection angles, and the projection room design were based on the same criteria as for theatre on Parry and resulted in similar layouts. However, no shelter was provided over the rear seats as at Parry. Instead, the projection rooms were designed as the second floors of small two-story buildings of wood frame construction with wood sheathing and aluminum siding and roofing. The lower floor of the building was designed for use as a recording room and as a radio station at the Air Force theatre, and as a recording room at the Army theatre. The Air Force theatre had a stage to accommodate local talent or USO shows; the Army theatre had a speaker's platform at the right of the screen. Beer halls and beach clubs were provided to be constructed by the Army task group personnel of available materials.

RUNIT ISLAND AND THE AOMON-BIIJIRI-ROJOA GROUP

All structures on the experiment islands were to be used for a shorter period of time than those on either Eniwetok or Parry. They were not expendable and dismantling before shots was specified. Therefore, to minimize dismantling effort all personnel were quartered in tents. A recreation or refreshment tent was provided at each site. However, because tents were thought to be inadequate to house most of the other camp facilites, aluminum structures were used. The only exception, in each case, was the reinforced concrete, blast-proof power plant which was required to supply power for a short time after the experiment. Showers, latrines, and timber grease racks were designed as for Parry and Eniwetok.

The 100-man mess halls used on these islands were aluminum buildings 100 feet long, with regular seating capacities of 104 men each. Personnel were served in shifts. The kitchen was separated from the dining area by a pickup counter backed by a steam table, cold pan, and ice cream cabinet; thus cafeteria or family style serving could be used. An island containing the coffee urns, the water station, and an ice bin was placed near the pickup counter, with an exterior door between them. This allowed personnel to line up outside the building, enter, be served, procure water and coffee, and proceed to the dining area with a minimum of cross traffic.

The kitchen contained a cooking island including the range, griddle, steamer, and fryers. These were covered by an exhaust hood and flanked by preparation tables, refrigerators, and a scullery and clean-up area containing a mechanical dishwasher. The sequence of operations in food preparation was studied and an efficient arrangement of facilities was provided. A storage room opened off the kitchen as did a covered passage to the reefers which were outside the building proper. A small post exchange occupied a corner of the dining room at the opposite end from the kitchen. All windows were screened. The boiler and hot water tank were housed in a separate shed.

The shop building and administration building on Runit and the Aomon Group were standard aluminum structures. The shop was 41 feet long and contained work benches and parts bins. The administration building was 45 feet long and divided into a scientists' office and a Holmes & Narver office by a typical metal partition with an intercommunicating door.

The 24-foot-square first aid and fire building used on these islands contained an engine room with a work bench and shelves along one side and a first aid room. The first aid facilities provided were minimum, since they were supplemented by the infirmary and dispensary on Parry and Eniwetok. Along with the first aid equipment, a toilet and space for a cot were provided, because an attendant was on duty at all times.

The open air motion picture theatre could accommodate 202 people on wooden benches. The screen was of transite painted white; a platform at one side could be used for briefing, and an 8 foot by 12 foot wood frame projection booth was provided.

The refreshment tent for each island was a standard 4-man tent furnished with a counter so that it could be used for beverage dispensing. Reefers were placed back of the tents, and a 20 foot by 45 foot canvas awning supported on 4 by 6 posts was placed along the tent fronts. No flooring was provided under the awning.

The concrete power and water distillation plants were banked with earth on three sides and covered on top by 2 feet of earth. The side away from zero was not banked and gave access to the building.

In addition to these buildings, a 20 foot by 50 foot temporary garage, constructed of 6 x 6 posts in 10 foot bays and sheathed in corrugated aluminum with one side left open, was built on an existing slab at Runit. A temporary recreation office was also added to this camp.

The only building added to the Aomon group was a temporary water distillation plant which was used until the permanent power and water plant was built.

ENGEBI ISLAND

Because the capacity of Engebi was doubled after its plan was approved and because it was built before the semi-permanent aluminum buildings were available, the camp contained several more wood frame, aluminum-sheathed buildings than did the other experiment island sites. Among these were a wood frame building for the postal service, post exchange, and recreation center and a temporary water distillation plant.

The originally planned fire and first aid building was considered inadequate; therefore a wood frame infirmary containing a three-bed ward, two treatment rooms, a laboratory, an office, and doctor's quarters was built. The fire station was combined with the timekeeper's office in a separate frame building.

The originally planned 170-man mess hall was built; it was quite similar to the mess halls on Runit and Rojoa, except for increased seating capacity and kitchen facilities. To provide messing facilities for the increased population, a wood frame building was placed parallel to it with covered passage connecting the two buildings.

The power and water distillation plant was of reinforced concrete, and was banked with earth designed to withstand the blast.

The theatre was similar to those on Runit and Aomon with benches added at the side and to the rear of the original block of seats.

A tent-covered saw mill was installed on an existing slab in the camp area, with a temporary saw mill office on another existing slab nearby.

Although not a part of the camp site, several temporary buildings were placed on the island to expedite construction of the more permanent installations. They were built near the boat pier on the south side of the island and included two warehouses, a tool storehouse, carpenter, electrical and AEC rigging shops, and a construction office.

BOGALLUA

As originally planned, Bogallua was to have the smallest and most temporary camp of the experiment islands. Buildings for the camp were designed, but because of changes in policy they were never built. They included the 4-man tents for quarters, a 4-man refreshment tent as on Runit and Aomon, and a pit latrine to be housed in a standard 4-man tent.

The storage and shop tent was designed of three 4-man tents placed together with splice plates connecting their ridge members. Thus by the omission of the individual tent ends, one 14 foot by 43 foot tent could be obtained. Two work benches were to be provided at one end for the shop, and the remainder of the tent was to be for storage.

A 9 foot by 33 foot slab with an aluminum shed roof supported on two by fours was to house the open-air showers and lavatories. A 6-foot high canvas screen was to circle the gang shower at one end of the slab. Two banks of 4 lavatories placed back-to-back at the other end of the slab would have completed the facility.

The power and water distillation plants were designed similar to those on Runit, Aomon, and Engebi, but considerably smaller.

JAPTAN

Several of the structures, such as the 18 and 36-man quarters and the timber grease rack, were the same as those at Parry, and the 100-man mess hall was the same as that used at Runit and Aomon. The salt water pump station, the booster pump station, and the feed storage building were unpartitioned standard aluminum buildings. A few wooden Navy buildings were on the island, some of which were utilized to provide a day room, office, first aid station, drafting room, biological lab, thermal lab, shop, and boat house.

The unique feature of the power plant and stills was that a 17-foot section of this standard aluminum building was raised on 6-foot concrete wall to give clearance for the diesel engine exhaust. The remainder of the building was on a slab at grade and connected to the raised section by specially designed gable plates.

The animal quarters consisted of two aluminum buildings placed about 9 feet apart and connected at one end by a concrete slab on which was placed a wash house for a sink and sterilizer. The side of the wash house facing the quarters was left open. Later, another quarters building was found necessary and was added beside the wash house.

The animal runs were concrete slabs divided into 3 runs each by 6-foot high fences. The slab sloped to a sump at one end to facilitate flushing out the runs and was sheltered at the opposite end by an aluminum building with the side facing the runs left open.

The X-ray building was a frame structure, with wood sheathing and corrugated aluminum siding and roofing, divided into two rooms by an 8-foot high reinforced concrete wall 10 inches thick, which was pierced by a lead glass window. Access to the rooms was from the exterior, since no inter-communicating door was desired.

The laboratory building differed from the other buildings of the Project in that it was built of two standard structures placed parallel to each other with a 7 foot corridor between them. This arrangement resulted in a building 55 feet wide, consisting of a central corridor and laboratories 24 feet deep off either side. The building contained eight laboratories separated by metal partitions or wood cabinets, a storage and refrigerator room, an office, a dehumidified dark room, and a toilet. All windows were screened, and double screen doors at each end of the corridor afforded ventilation. The corridor extended on past the building as a covered walk to the autopsy building which was an open frame building covered with plastic screening above a corrugated aluminum wainscot.

Adjacent to the laboratory building was a greenhouse with a lath roof, screen sides, and duck boards over a concrete slab which extended to the lab building. The greenhouse door was opposite a laboratory entrance, affording access to the greenhouse directly from the laboratory or from the outside.

Rather late in the program an infirmary for animals was required. This was provided in a simple wood frame building with no sheathing and with corrugated aluminum siding and roofing.

PLUMBING FOR PERSONNEL BUILDINGS

Plumbing for the personnel buildings was designed and installed in compliance with the requirements set down in Section IV of the Reconnaissance Report. The pertinent extract from that document is as follows:

"Plumbing Materials

Separate systems for the distribution of salt water and distilled water are contemplated. This will require separate connections between the main outside lines and certain inside fixtures. Water closet and urinal flush tanks will be connected to salt water service and wash bowls and shower heads to distilled water service. Sewer drain lines will be common to both systems. No duplication of fixtures is involved in this arrangement.

All plumbing fixtures located in buildings on Parry and Eniwetok should be of corrosive resisting materials. It is contemplated to utilize vitreous china for lavatories, toilets and urinals. Closet bowls and urinals will consequently be equipped with vitreous china tanks.

Due to the use of salt water supply, fittings in flush tanks should all be rubber. Pipe, fittings and fixtures utilizing either distilled water or salt water supply should be of special Copper Alloy, or other materials capable of resisting the corrosive effect of the spindrift which permeates the atmosphere. Detailed construction specifications applicable to these materials will be the result of additional research and investigation.

> Since latrine facilities on the Shot Islands are to be expended by experiment operations, the use of plumbing pipe and fixtures ordinarily adopted to minimum cost installations is contemplated. The expected useful life of this type of construction under the corrosive conditions present would not greatly exceed that required by experiment operations and ultimate economy of expendable costs is thus accomplished."

In compliance with these requirements, salt water and distilled water mains were installed to supply the various buildings. Water closet tanks, urinal flush valves, and hose bibs were connected to the salt water system. Lavatories, sinks, service sinks, showers, and all other fixtures and equipment requiring water were supplied from the distilled water system. Waste from all fixtures and equipment was discharged to common sewer drain lines.

Because of the corrosive effect of salt water, distilled water, and salt spray in the air, considerable thought and study was given to the selection of materials used for plumbing fixtures, pipe and fittings. When vitreous china fixtures were obtainable, they were selected for all plumbing fixtures. These included water closets, closet flush tanks, urinals, service sinks, sinks, lavatories, and special fixtures in the infirmary and dispensary. Enameled cast iron combination sink and laundry trays and enameled cast iron bath tubs were used in the dispensary at Eniwetok because these fixtures were not obtainable in vitreous china. Stainless steel sinks were provided and installed in all mess hall kitchens. In the following buildings, sheet metal sinks were installed as directed by J-Division:

Laboratory Building	Building #57	Eniwetok Island,	Stainless	Steel
Laboratory Building	Building #232	Parry Island,	"	"
Photo Laboratory	Building #210	Parry Island,	"	"
Rad Safe Building	Building #323	Parry Island,	"	"
Animal Quarters	Building #13	Japtan Island,	Galvanized	Steel
Autopsy Building	Building #49	Japtan Island,	"	"

Vitreous china closet and urinal tanks with rubber fittings were prescribed in the Reconnaissance Report. and hard rubber flush valves and ball cocks were specified for closet tanks as well as hard rubber or plastic connections between tanks and closets. However, because these items were not obtainable at the time orders were placed for the fixtures, regular trim was accepted.

After investigation, self-closing urinal valves were specified instead of tanks. These valves were found to be cheaper and anticipated to be more durable than tanks with ordinary fittings.

Cast iron was used for all floor drains, floor sinks, and traps, except integral fixture traps. All soil and waste piping was standard weight, cast iron, bell and spigot, soil pipe and fittings, made up with lead caulked joints.

Services from water mains to within five feet of buildings were shown on the Water Distribution Plans and were specified to be copper tubing, with flared fittings. When the first plumbing plans were drawn, aluminum pipe was shown for underground piping. These plans were revised in view of the short supply of aluminum pipe at the time and piping was changed to copper tubing. All subsequent plumbing drawings indicated copper tubing for underground water piping.

Copper tubing with solder fittings was used for oil piping from oil tanks to equipment.

63S-T6 anodized, iron pipe size, aluminum pipe, and anodized cast aluminum fittings were specified for all above-ground water and vent piping. Alumilite No. 204 treatment for aluminum pipe and fittings was authorized January 25, 1950, in lieu of anodizing because alumilite treatment was found to provide better protection and could be applied to full lengths of pipe whereas lengths of pipe longer than twelve feet could not be anodized.

To prevent electrolysis caused by joining dissimilar metals, plastic nipples on fittings were installed between all aluminum pipe or fittings and steel, brass, or copper pipe or fittings.

When construction work was started, aluminum pipe and fittings had not arrived at the site because of delays encountered in manufacturers' deliveries. In order to complete some of the buildings for occupancy, galvanized steel pipe was used for water piping in the toilet rooms. When aluminum pipe and fittings were available at the site, this piping was changed to comply with the specifications as it became necessary.

Pot sinks and dishwashers in all mess hall kitchens and in the kitchen of Dispensary Building No. 24, Eniwetok Island, were connected to grease traps located outside of the buildings and adjacent to the outside walls.

Hangars or supports for overhead pipes in the buildings were constructed of aluminum angles or aluminum straps bolted to building purlins or wall plates. Outside pipe supports were constructed of standard steel pipe with cross arms welded to uprights. Supports were set in concrete.

Since the temperature of the fresh water in the system was estimated to be from 75°F to 80°F, it was decided that hot fresh water would be furnished only to special buildings, such as mess halls, bakeries, laundries, post exchanges, barber shops, post offices, dispensaries and infirmaries, and the Task Force Commander's Quarters. Cold fresh water was furnished to all buildings requiring water.

Steam heated storage water heaters were used to supply hot water to fixtures and equipment in mess halls, bakeries, and laundries on all locations. All of these buildings were located near boiler houses where steam was available for the water heaters.

In the infirmary and nurses quarters on Parry and in the post exchange, barber shop, and post offices, on Eniwetok and Parry, electric storage water heaters were used to supply hot water to fixtures. In these buildings, the hot water demand was not excessive and sufficient electric power was available.

Oil-fired water heaters were used in the infirmary on Engebi and in the dispensary on Eniwetok. The demand for hot water in the infirmary was not great, but electric power at this location was limited. Heaters for the dispensary supplied fixtures in the kitchen in addition to regular plumbing fixtures. Steam was not available and the demand for hot water was too great for economical use of electric heaters.

Underground oil piping from elevated oil tanks located outside the buildings supplied oil-fired water heaters and oil-fired equipment in kitchens and laundries.

No particular code or manual was used in laying out the plumbing waste and vent systems. Soil and waste piping were sized according to usual practice. All vent pipes for plumbing in the aluminum buildings were run outside the buildings walls and terminated under the eaves of the buildings. Vent piping was run in this manner because of the difficulty and expense involved in making water tight flashings around pipes passing through the two corrugated roofs. This method of venting proved to be satisfactory.

INTERIOR WIRING FOR PERSONNEL BUILDINGS

The Reconnaissance Report recommended the use of corrosion-resistant wiring materials for buildings intended for use in more than one operation and of open wiring for expendable buildings and for tests. In accordance with these recommendations, considerable time was spent in investigating various types of conduit, outlet and junction boxes, cover plates, and similar fittings, in order to determine which types of materials would most successfully resist corrosion, fungus, and other deleterious effects. Initially, however, the best preventive measure was keeping to a minimum the number of outlets required.

The following list shows the considerations which were applied to the selection of materials:

1. Cost per outlet (material and labor).
2. Corrosion and fungus resisting qualities.
3. Per cent of expected breakage in shipment to Jobsite.

4. Shipping weights as they affected the cost of delivery.

5. Probable maximum service-life requirements.

6. Type and function of buildings in which these materials were to be installed.

7. Availability as it affected delivery and progress of the installation.

8. Possibility of substitution in the event the selected items were not available.

9. Suitability of the selected items to fit conditions where field changes were to me made.

As a result of these investigations the following criteria were set-up and, except in some specific instances, represented the type of installation:

1. Fixtures

   a. Aluminum reflectors with bare incandescent lamps were selected for general use because they were more economical than the vapor-proof type. Aluminum reflectors for all bed lights were originally specified but procurement efforts indicated that costs of manufacture would be inordinately high at the time. As a consequence, of the available steel or porcelain substitutes, steel was chosen because of considerations of weight, unbreakable character and very low cost. The last mentioned factor indicated economies in the use of steel even if frequent replacement was necessary.

   b. Glassteel diffusers were used in the dining portions of the mess halls to provide a high quality of light.

   c. Vapor-proof fixtures were used for outside bracket lights, in latrines and shower rooms, and elsewhere where excessive moisture conditions prevailed.

   d. Fluorescent fixtures were used only in areas specified by J-Division, as the initial cost of installation was considered to be too high to warrant general use.

   e. Class 1, Group D, explosion-proof fixtures were installed in hazardous areas along with rigid galvanized conduit, explosion-proof fittings, sealing fittings, etc.

   f. Security flood lighting was installed around the CMR and similar restricted areas on Parry and on each of the experiment locations.

2. Wiring Method

a. Non-metallic-sheathed cable was specified for most lighting branch circuits, and, for economy, standard service-drop cable for overhead services.

b. Where protection against moisture or injury was required, aluminum conduit and fittings were specified for overhead installation.

c. All wiring concealed in concrete walls or floors or underground, where direct-burial cable was not used, was specified as "TW" wire in hot-dipped galvanized conduit.

d. Conduit, where required, was hot-dipped galvanized for concealed work and aluminum (when available) for exposed work.

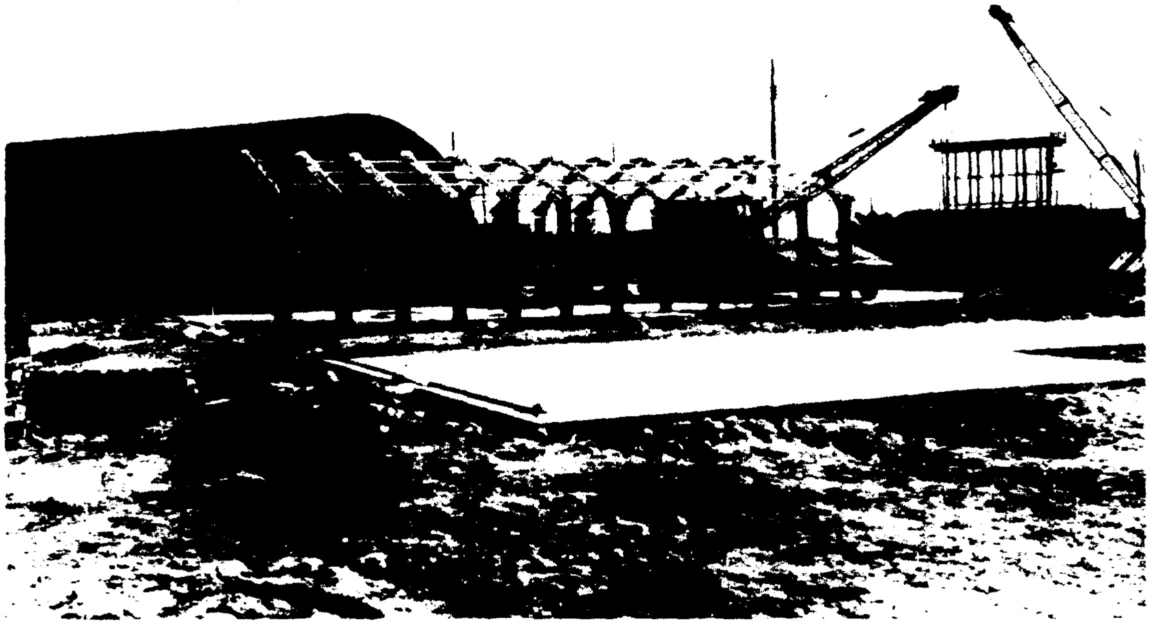
e. Flexible conduit connections were only used for short connections from outlets to meters and consisted of flexible steel conduit covered with a neoprene jacket to reduce corrosion.

f. Power wiring was installed in rigid, hot-dipped, galvanized conduit and metal boxes (aluminum when available). Steel boxes, where installed on aluminum surfaces, were insulated by mounting on plywood fastened to the aluminum structure. This was done to eliminate electrolytic action that would otherwise cause accelerated corrosion. Where conduit was installed exposed, it was aluminum (when available) and was fastened to the structure with aluminum straps, bolts, etc.

3. Overload Preventive Devices

a. Circuit breakers were specified for circuit protection in the majority of installations. Breakers were the thermal-magnetic type.

b. Lighting panels, which proved very satisfactory, were the MB or MO type. Most power panels were type MH, ML or ABQ, except in certain specific instances such as the laboratory building on Japtan. At this location, fused power panels were installed to permit easy increase or reduction of circuit capacity (changing fuse sizes) to suit changing requirements of laboratory equipment within the limits of wiring provided. Because of changes in construction schedules and slow delivery of panels on order, field changes were required. These changes involved the use of panels for buildings other than those for which they were ordered. In order to accommodate these panels and to avoid delay in construction, plans were revised as required.



Eniwetok Island: Framework of Officers Quarters, Bldg. 38

Eniwetok Island: Boiler House, Bldg. 34

Runit Tower Skip Hoist Cab

4. Outlets

   a. Outlet boxes and device covers generally were specified to be phenolic composition in order to effect economies and obtain corrosion-resistant qualities.

   b. Outlet box mounting brackets and plates were designed and made up of extruded aluminum. Design was such that they were suitable for a number of different type boxes.

In certain areas, such as the CMR, special equipment was installed. Design of the wiring for this equipment was made by Users.

As the work progressed, material scarcity and long delivery dates caused difficulties and it became necessary to make substitutions in order to keep within the construction schedules. Substituted materials were all Underwriters approved and performed satisfactorily. These substitutions consisted mainly of safety switches, some of which had to have fuse reducers installed; certain lighting fixtures; panels, as indicated above; conduit fittings, etc. Costs were, in some cases, greater than the original design specified, but the gain in completion more than offset the slight increase in costs.

Some difficulty was experienced with plastic-case circuit breaker handles sticking. Excessive absorption of moisture and small clearances between the handle and enclosing case were found to be the causes. This trouble was corrected by applying heat to drive out the moisture and, in some cases, by installing incandescent lamps in the panel to provide heat.

From the experience gained in the electrical work on this Project, several recommendations may be made for future jobs of like nature.

1. The use of fused switches instead of circuit breakers for circuits other than lighting should be considered. Fuses are more easily changed in ratings to accommodate last minute changes in loads, and their action on overload or short-circuit would not be materially affected by adverse moisture conditions. Exceptions to this might be installations where space would be at a premium. There circuit breakers would be used.

2. Light fixtures exposed to strong winds should be specified to have a screw-type reflector to prevent loosening such as might occur with other types.

3. Porcelain lamp-holders, with their heavier and stronger sections, should be used instead of composition lamp-holders which, because of their thin sections and low compression strength, were often broken at the socket or near the mounting holes.

4. Tumbler wall-type switches should be substituted for canopy-pull-chain switches, which often became defective.

CHAPTER 5.11

TOWERS

Engineering work to provide the facilities for the scientific program and experiments at the Eniwetok Proving Grounds was very extensive and required the solution of many unusual engineering problems. Furthermore, the criteria were supplied piecemeal, starting in September 1948 and continuing until December 1950. J-Division coordinated the requirements of the various scientific agencies involved, and Holmes & Narver supplied the engineering designs to meet these requirements.

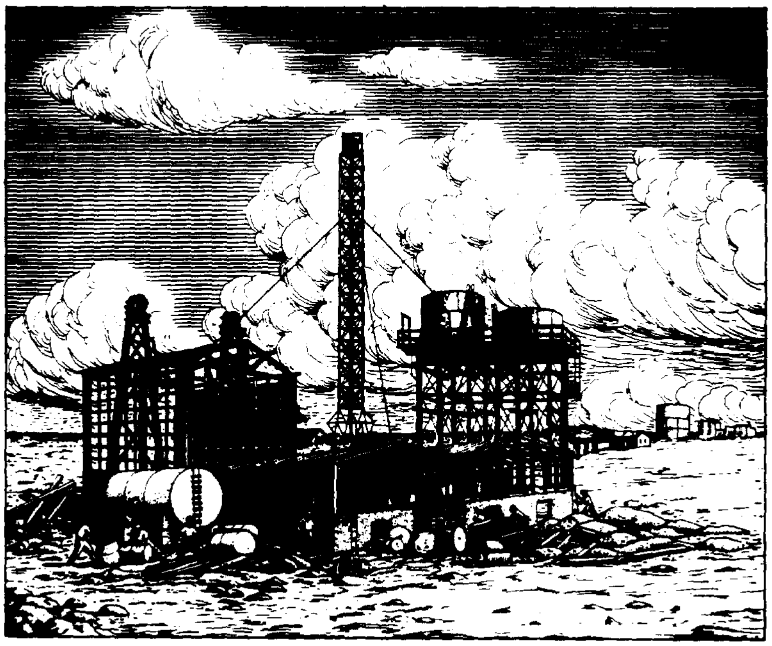
300 FOOT TOWERS

In a series of meetings at Los Alamos, September 12 to 18, 1948, group discussions were held as to the philosophy of coming tests. One such meeting concerned the criteria for design of scientific structures and another such meeting concerned the requirements, both scientific and structural, for the design of towers. The design of towers was of particular concern to J-Division personnel because the uncertainties of design, manufacture, and erection for the sort of towers then contemplated would leave no time to lose if the proposed 1951 test schedule was to be realized. It was also important to the scientific development going on to know whether practical engineering limitations existed to the scope of experiments desired by various groups. Studies were therefore started concurrently with the departure of the reconnaissance party to examine the Project site.

At the Los Alamos meeting on towers, it was stated by a group leader that it was desirable for the new experiments that the towers be at least 250 feet in height. The towers used for Sandstone had been 200 feet high and free standing. It was stated that the 250 foot height was a minimum and greater height would be highly desirable. It was developed that the hesitation on the part of the scientists for going higher was that they thought that the higher towers would require such a great amount of steel that it would affect the results of their experiment by introducing so much ferrous material into the clouds. H & N suggested that this might be overcome by the use of a guyed tower which would require a very much smaller quantity of material and that almost any height that would be satisfactory to them could be obtained. It was determined that the guys would not be detrimental to the experiment if they were kept down a proper distance from the top of the tower. The result of this meeting was an agreement to make some comparative preliminary designs to determine the amount of material in guyed towers versus free standing towers. The H & N representatives proposed that if the space planning could be arranged to suit the test requirements, a triangular tower would probably be of advantage over a square tower in that there would be less material required.

Comparative studies for towers started immediately, and these studies were presented to J-Division. In the meantime, it had been developed that a triangular tower could be built that would be entirely satisfactory.

The tower design was developed entirely within the Holmes & Narver Engineering Division. Considerations of feasibility, mass, and adequacy



for the experiment related to various tower heights required that several tower types be investigated. The Structural Department, after considerable study, presented the J-Division tower representative with a choice of 250 or 300 foot square cross section, free-standing towers or 300 foot guyed towers triangular in cross section. Because of the saving in weight which meant less iron would be drawn into the radioactive cloud, the 300 foot guyed tower was selected. The triangular cross section cut down the cost of materials and erection. The guying was by means of three cables attached to the tower at the 275 foot level, and guy wires were anchored to a concrete block 275 feet out from the tower base. Viewed from above, the guys were separated by 120°. The triangular cross section was 20 feet between legs from the 25 foot to the 300 foot level, this being the smallest cross section that would allow the clearances required for the main hoist and the personnel lift. Below the 25 foot level, the legs were battered out 7 feet to give additional space inside the shaft. The house at the top of the tower was rectangular, 16 feet, 4 inches by 18 feet by 12 feet high; the center of the building was only 1 foot, 5-1/2 inches from being over the center of gravity of the triangular section. This necessitated cantilevering about 4 feet of the house beyond the tower shaft. Above the house was an A-frame to hold the main hoist gear, which was also centered over the main hoist, which was 1 foot, 5-1/2 inches from center of gravity of the tower shaft. By placing the main hoist so near the tower's center of gravity, it was possible to distribute the forces from the primary moving loads almost equally to each of the three legs. The A-frame was placed 4 feet above the roof in order to permit all of the hoisting gear to clear the roof and thus be completely out of the house. In order to allow the main hoisting gear to pass through the house floor, three removable aluminum floor panels were used. The resulting opening was 7 feet square. The rail guides for the hoist stopped at the underside of the housing floor.

The personnel skip was designed so that all cables were kept below the 300 foot level, the sheaves on the lift being beneath the lift floor. The lift entered the house via a trap door that raised by the roof of the lift cab.

The hoisting drums and motors were located at ground level near the base of the tower. The two hoists utilized two part lines to give a mechanical advantage of 2. The skip hoist could be controlled from the ground, house, or lift. The speeds were automatically set and varied depending upon nearness to the ground or house. Safety devices were provided to stop the lift at the two ends of runs or in case a cable should break or a drum run free. A ladder extended the full height of the tower.

The completed preliminary drawings were checked by a J-Division representative on November 9, 1948, and were handcarried to Los Alamos for the Test Director's approval on November 15, 1948.

Weights of the materials in the tower increments of 25 feet were furnished Los Alamos on November 24, 1948.

Because of the importance of the towers to the tests, an outstanding consultant was asked to check the design; he completed this study and gave his approval on December 4, 1948.

The specifications for the tower and appurtenances were sent to Los Alamos for approval and were returned with a few comments on January 26, 1949. On March 3, 1949, approval was given by J-Division and AEC to submit the design to prospective fabricators for bids.

Bids on four towers were received by Holmes & Narver on April 25, 1949. Because of high bids, all bids were rejected so as to give bidders some more time to study the towers. The specifications were revised and new bids were received on June 3, 1949. The results of these bids were forwarded to AEC on June 17, 1949, after Holmes & Narver had carefully investigated all alternatives proposed and subcontractors listed by the prime bidders. On June 28, 1949, J-Division proposed the bids be changed from 4 steel towers to 3 steel, and 1 aluminum. This suggestion was over-ruled by the Test Director on June 30, 1949.

On July 7, 1949, approval was given by the AEC Director of Engineering to award a contract for four steel towers to Pacific Iron and Steel Company, which was low bidder at $206,061.00 for all structural, mechanical, and electrical equipment, with the provision that negotiations be made with Pacific Iron and Steel to construct one aluminum tower in lieu of the fourth steel tower. The aluminum tower required new design.

On July 14, 1949, Holmes & Narver issued a purchase order to Pacific Iron and Steel Company; however, the contract could not be signed until after the negotiation on the aluminum tower. The plans for the aluminum tower were completed and sent to Pacific Iron and Steel Company on September 2, 1949. Their proposal for the aluminum tower was received on September 23, 1949; the additional amount was $40,296.63. On September 28, 1949, a representative of Los Alamos requested that the matter be delayed another two weeks so that J-Division of Los Alamos Scientific Laboratory could consider the matter further. Authority for Pacific Iron and Steel to purchase materials was given October 5, 1949.

On October 18, 1949, authorization was received from AEC to procure five 300 foot towers: four steel and one aluminum. The aluminum tower was withdrawn from negotiations with Pacific Iron and Steel Company and was put up for separate bids.

The first tower, complete with all the collateral gear, was sent to Oakland for transhipment on February 13, 1950 after a successful test erection of two sections. The Engineering Division sent a structural designer to the Jobsite for a month to check the complete erection of the first tower.

The structural members of the next three towers were shipped to Oakland on April 12, 1950. Shortly thereafter the collateral gear was shipped, thus ending the Engineering Department's work with the exception of small changes made in the field to suit a User's last minute requirement.

The mechanical design criteria were furnished by a representative of Sandia Corporation who was also in charge of weapon assembly and therefore vitally interested in the tower design in all details. The mechanical problems consisted of designing the following.

Design work on the mechanical portion of the 300 foot towers was started by the middle of October 1948. This consisted of preparation of drawings M-1 through M-5. At the beginning, this work was guided by "Preliminary Specification 250'-300' Steel Tower," Consolidated Steel Corporation shop drawings for 200 foot steel towers previously used by AEC for Operation Sandstone, and verbal instructions and information - all of which were furnished by a representative of Sandia Corporation. This information provided the Mechanical Department with valuable criteria gained from experience. Because mechanical design was closely coordinated with structural design as each progressed, the necessity for changes was minimized. The mechanical design problems consisted of:

1. A main hoist capable of handling 10,000 pounds on a 2-part line with a maximum hoisting speed of 30 fpm, from ground level to the tower cab.

2. A skip hoist (elevator) for personnel and freight, capable of handling a net load of 2,000 pounds on a 2-part line with a maximum hoisting speed of 125 fpm from ground level to the tower cab. Hoisting speed was established by Sandia Corporation on October 27, 1948.

3. A hand winch and accessories located in the tower cab for pulling coaxial cables up on messenger cables. This was requested by Sandia Corporation on November 3, 1948.

The main hoist consisted of a 900 pound load block on a nonrotating steel cable. The cable was reeved over a series of steel sheaves which were mounted on the structural A-frame at the top of the tower, above the tower cab. From these sheaves the cable ran down outside the tower to the main hoisting machine which was located on the ground outside of the tower.

One of the criteria for the tower was that a personnel skip or elevator that could be operated from the ground, from the tower cab, or from the skip itself should be installed. This skip was to be fully equipped with safety devices for protection in case of accident to the hoist cable or to the hoisting equipment itself. Although such safety devices were in common use in modern commercial buildings, these devices did not fit the requirements of the tower. Ordinarily, elevators are lifted from above, but the tower skip was to be lifted from below the skip platform. Comercial safety devices were much too complicated for use on the skip, so an entirely new system of safety mechanism was developed by Holmes & Narver and tested to the satisfaction of all concerned.

The skip hoist consisted of an open type platform (elevator cab), traveling on elevator-type steel guide rails which were attached to the tower. The platform was raised and lowered by a steel cable which was reeved over a series of steel sheaves mounted below the house floor at the top of the tower and under the skip floor. From these sheaves, the cable ran down outside of the tower (parallel to the main hoist cable) to the skip hoisting machine mounted on the ground near the main hoisting machine.

The hand winch and accessories, located in the tower cab, consisted of a lightweight spur-gear, hand-cranked portable winch, equipped with a brake, and with a capacity of 650 feet of 3/16 inch wire rope. The accessories consisted of mounting brackets for the winch and guides and sheaves for the wire rope.

Considerable study and investigation was given to safety devices for the skip hoist. Various passenger and freight elevator manufacturers were consulted, with the final conclusion that standard type instantaneous safety rail grips and standard type overspeed governors as manufactured and used by the Kimball Elevator Company would be most adaptable and satisfactory for application to the skip hoist. The overspeed governor required some minor modifications to operate the instantaneous safety grips, as applied to the skip hoist platform. Because no standard device was available, a broken rope device for operating the safety grips was designed by H & N. This device consisted of a spring loaded idler sheave held in normal position by tension on the hoisting cable. In the event of a break in the cable, the spring lifts the idler sheave and actuates the instantaneous safety rail grips. All of these safety devices proved very satisfactory in drop tests which were made before shipment overseas. Standard elevator-type bronze guide shoes were used to guide the skip platform on the guide rails. Figure 5.11-1 shows detail of a safety rail grip, and Figure 5.11-2 shows the overspeed governor used in 200 foot and 300 foot towers.

The skip hoist platform (elevator cab) had to be designed to accommodate the safety devices, guide shoes, and limit switch strikes. The floor and railing of the skip were substantially the same as that used for Sandstone, but the overhead frame was designed to open the trap door in the tower house floor when the skip came up through the floor and to provide support for a controller in the skip. The hoist rigging for the skip hoist was mounted entirely below the house floor so that the entire floor area would be clear when the trap door was closed. Figure 5.11-3 shows the skip hoist cab assembly for a 300 foot tower.

Because many safety features were of a new design, a requirement was set up in the specifications that a section of guide rails 30 feet high be erected and the skip platform mounted thereon to test the safety devices. Drop tests were made and the safety grips, overspeed governor, and broken rope device were individually tested to the complete satisfaction of the Sandia representative, the AEC Contract Administrator, and H & N designing engineers.

The hoist rigging for the main hoist was mounted on the structural A-frame above the tower house so that the load block could be raised entirely above the roof. Figure 5.11-4 shows the main hoist sheave assembly and cable arrangement for a 300 foot tower.

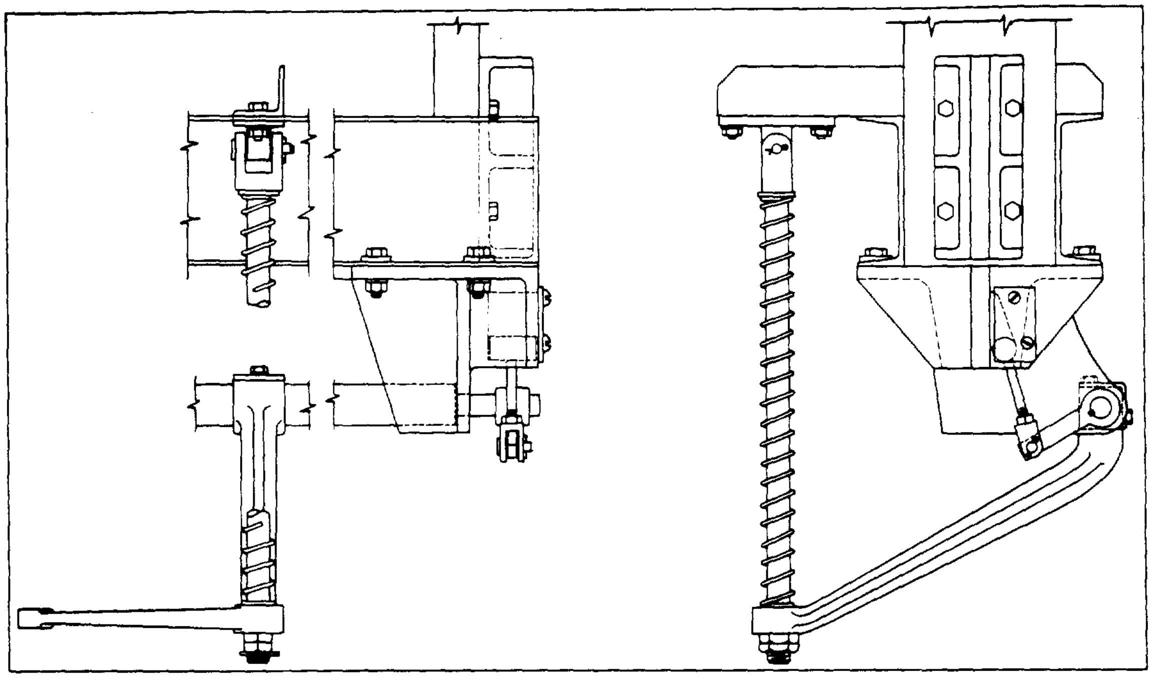


Figure 5.11-1 Detail of Safety Rail Grip and Guid Shoe,

200-Foot and 300-Foot Towers

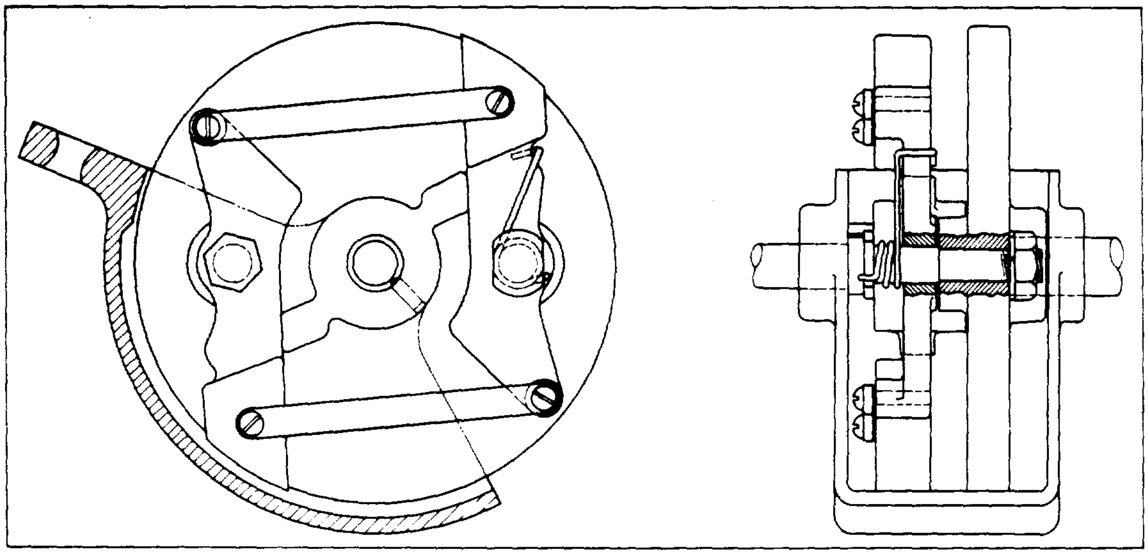


Figure 5.11-2 Overspeed Governor for Skip Hoist,

200-Foot and 300-Foot Towers

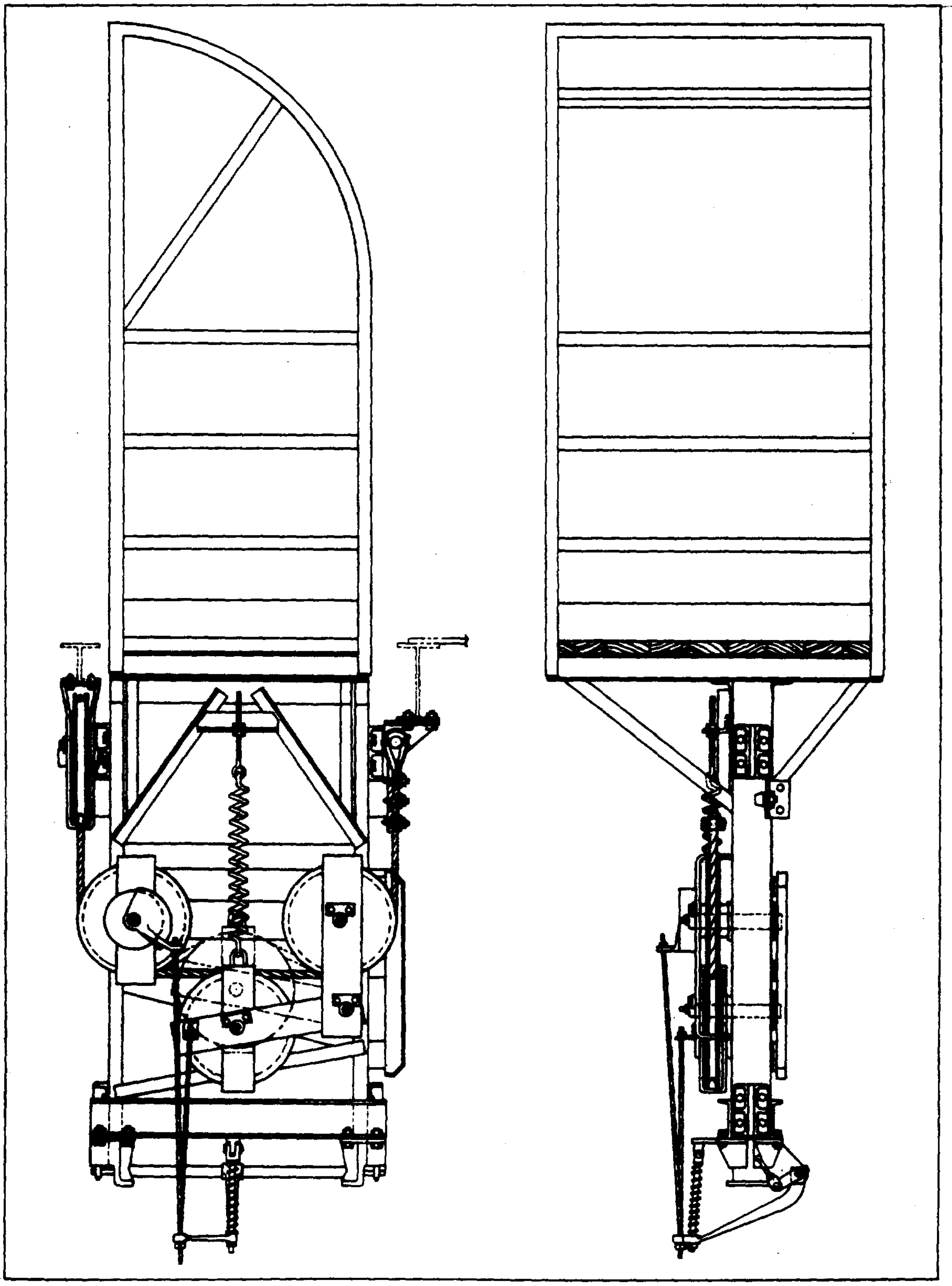


FIGURE 5.11-3 300 Foot Tower-Assembly of Skip Hoist Cab

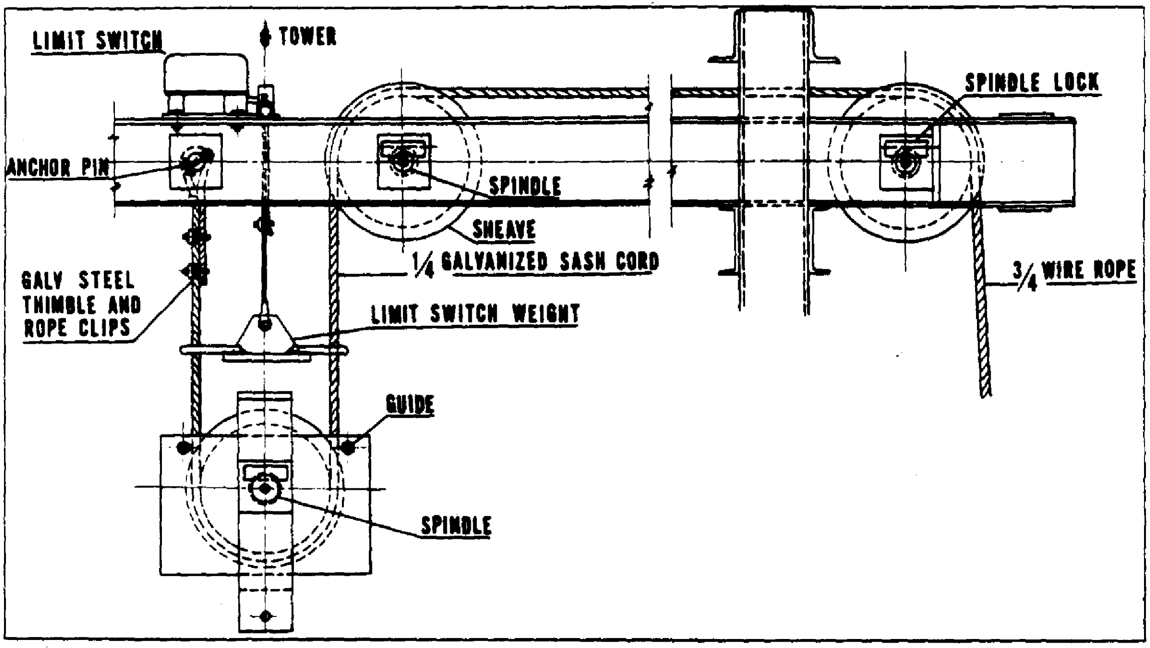


FIGURE 5.11-4 **Main Hoist** 300 **Foot Tower Sheave Assembly and Cable Arrangement Elevator Control Cable Guide**

Letters from the Sandia Corporation on October 7 and 21, 1948 advised that nonspinning cable was absolutely necessary for the main hoist, to eliminate twisting or rotating of the load block during its unloaded travel up or down.

The use of nonrotating wire rope for the main hoist made a single wrap winding drum necessary on the hoisting machine. Several wire rope manufacturers were consulted, and none of them would recommend multiple wrapping of nonrotating wire rope on the drum. Because of the amount of rope to be handled, a rather large winding drum was required. A very extensive survey was made in an attempt to locate a standard make of hoist machine which would meet the rope capacity, line pull, and hoisting speed requirements, but no such machine could be located. It was then decided that a custom-built machine would have to be used.

Inasmuch as a single wrap drum was necessary for the main hoist machine, it was decided to use an identical drum on the skip hoist machine in order to keep the skip hoist and main hoist machines as similar as possible and reduce types of replacement parts to a minimum.

The main hoist load block was substantially the same as that used on the Sandstone towers. Check weights were attached to the block to make its total weight 900 pounds. This was done to insure proper wrapping of the cable on the hoist drum under no-load operation.

A main hoist top limit switch was mounted on top of the structural A-frame to stop the up travel of the load block when its clevis pin hole was 13 feet, 3 inches above the floor level of the tower house. This distance was established in the preliminery specifications furnished by the Sandia Corporation representative.

All of the mechanical equipment for the 300 foot towers was installed at the Jobsite as shown on the drawings and covered in the specifications and operated satisfactorily at test time.

The electrical design criteria, as stated by the Sandia representative, stressed smooth and positive operations of both the main hoist and the personnel skip hoist. For this service, the Ward Leonard system of control was selected. In this system of control, a direct-current motor is used to drive the cable drum, and the speed of the motor is varied by varying the voltage applied to the armature of the drive motor. The variable voltage source is obtained from a motor-generator set with the output of the generator exciter connected directly to the drive motor field and through a rheostat to the generator field. The voltage of the generator is then varied by adjusting the generator field rheostat. In addition to providing smooth operation, this system provides a means of obtaining regenerative braking, which is necessary to provide smooth deceleration.

The actual control of speed of either equipment was by means of push buttons, up and down, faster and slower, which operated a reversible control motor driving the rheostat.

The basic electrical equipment specified consisted of a motor-generator set, a drive motor, and a control panel for the hoist and for the elevator. It was later found, that it would not be necessary to operate the hoist and the elevator at the same time. On this basis, one motor-generator set was omitted, at a saving of approximately $7,500.00 per tower. The capacity of the motor-generator set was made large enough to supply the largest drive motor, and a selector switch located in the building housing the motor-generator set was provided to transfer the controls from the hoist to the elevator or vice versa. This switch was not duplicated in the tower cab, since telephone communication was provided between the tower cab and the building which housed the control cabinet and motor-generator set.

In the development of the control scheme for the hoist and elevator, duplicate sets of controls were specified. A control pedestal was required at the hoist and at the elevator cable drums for the control of each unit. In addition, a duplicate set of controls was provided in the house at the top of the tower for both the skip and the main hoist. For the skip hoist, there was a third control in the elevator cab. Limit switches were provided at the top and the bottom of the tower for the elevator and the hoist. These switches were provided to stop either unit automatically, thus providing for emergency stops as well. Other required electrical safety devices included cable limit switches and an overspeed switch, both located on the cable drum, and a door interlock switch located on the cab door. The cable limit switches were provided to stop the elevator or hoist automatically to prevent overtravel of either unit in the event that the limit switches on the tower failed to operate. The elevator cab door limit switch was provided to prevent travel of the cab when the door was open.

After the equipment was fabricated, a test of the first unit was conducted to demonstrate that it would operate satisfactorily. This test was witnessed by a representative of the Sandia Corporation as well as by representatives of the AEC. The entire test was conducted on the ground, using a prony brake to load the drive motor. All conditions of operation were checked, and errors in the control scheme were corrected so that the equipment performed to the complete satisfaction of the AEC representatives who witnessed the test. The remaining units were not tested prior to shipment, but all modifications in the first unit were incorporated in the remainder of the units prior to shipment.

The elevator control cable being over 100 feet long, gave considerable trouble because of the high velocity winds blowing it against the structure. This caused chafing and eventual breakdown of the cable. This condition was partially remedied by the installation of a cable guide and counterweight consisting of a guide sheave mounted on a 6 inch aluminum channel. Figure 5.11-5 shows the elevator control cable guide used for 200 foot and 300 foot Towers.

Use of this guide, while preventing excessive swaying of the cable, did result in added tension on the cable. This added tension tended to

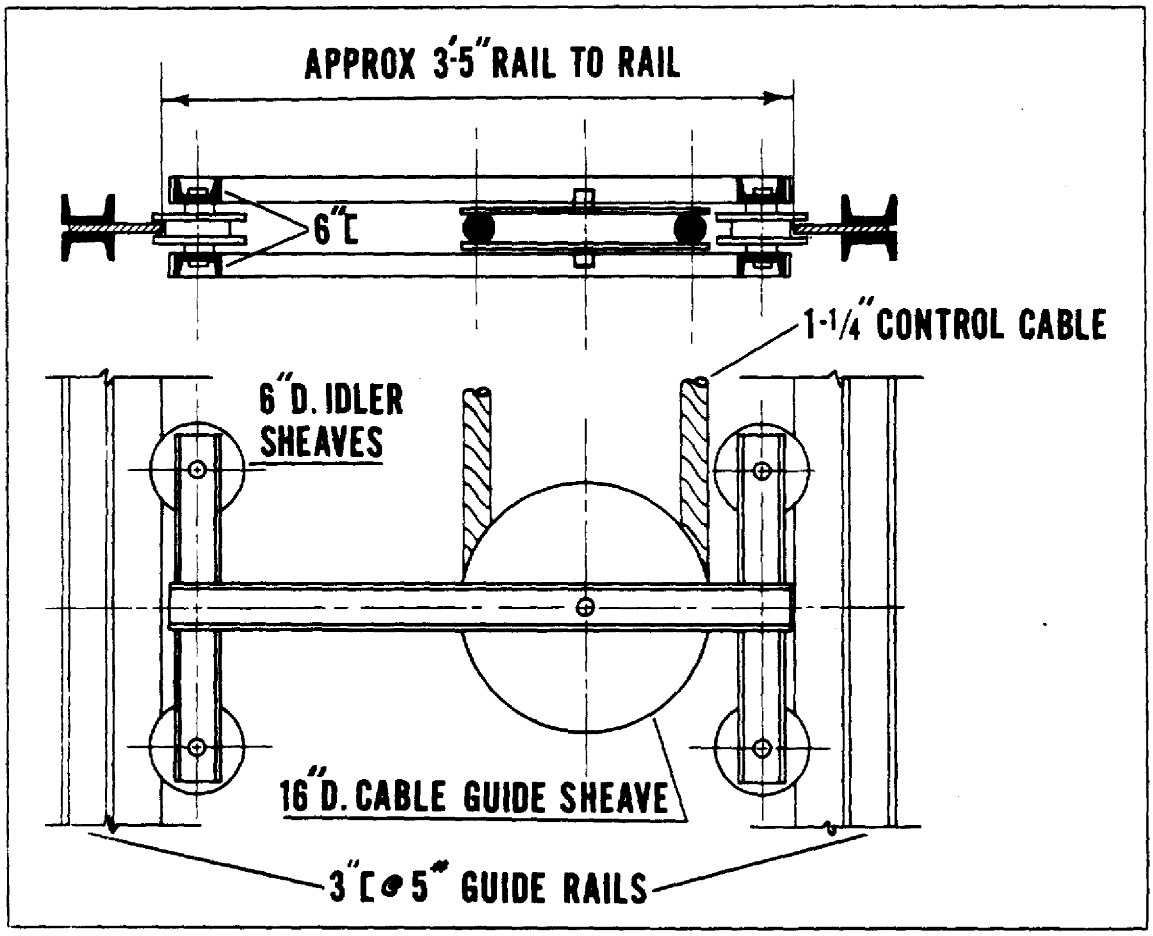


FIGURE 5.11-5 Elevator Control Cable Guide 200 Foot and 300 Foot Tower

straighten the cable spiral lay of conductors and eventually caused a cable break. Two cables on Runit and Engebi and one on the Eberiru tower had to be replaced. One method for solving this problem which has the recommendation of a leading elevator manufacturing company involves installation of a continuous aluminum gutter from the base of the tower to the top-cab, with its slot facing the elevator cab. The control cable would then be supported from the cab by a bracket extending into the gutter. Cross sectional dimensions would be approximately 6 inches wide by depth sufficient to permit normal loop in cable.

Difficulty because of moisture was experienced in the operation and maintenance of the electrical apparatus and controls for the towers. The equipment was specified to be moisture and fungus resistant, and on inspection appeared to be well protected. However, it developed that some parts were not adequately protected and shorts developed when the equipment was installed in the highly humid conditions at the Proving Grounds. This was overcome by installing large electric lights in the building housing the motor-generator set and control panel and maintaining a temperature of 110° F.

It is recommended that for future installations the moisture-proofing of equipment be thoroughly tested under conditions of 90° F temperature and 90 per cent relative humidity before shipment and that electric strip heaters be provided for the control and switch panels.

The suggestion of an aluminum tower was first presented to Holmes & Narver in a letter from a J-Division representative dated June 28, 1949. The letter was primarily in response to bids received on the 300 foot steel towers but it proposed a contract be made for supplying three all-steel towers and one tower constructed of aluminum to as great extent as possible. Chemistry considerations had made it appear desirable to have one tower with as little steel in it as possible. The condition stated was that steel should not represent more than 10 per cent of the total weight of the tower.

The Structural Department made some quick calculations and presented them at a meeting at Los Alamos on July 5, 1949. The use of approximately 21,000 pounds of steel was then approved, except for elevator and hoist guide rails. The steel was all in the lower 25 feet and would not affect the scientific requirement. Approval was given to go ahead with the design and the plans were completed on September 2, 1949. The lower 25 feet remained identical to the steel 300 foot tower so that the tower could be placed on any of the tower foundations that were being constructed, without modification of the foundations. Aluminum was used for all structural elements above the 25 foot level, even to the use of aluminum structural rib bolts.

Until October 18, 1949, the aluminum tower was being negotiated as a part of the order for the steel towers; however, on that date the AEC Engineering Director authorized H & N to put the tower up for separate bids. These bids were received December 7, 1949, and approval on January 3, 1950, allowed a purchase order to be given to International Derrick and Equipment Co. on January 23, 1951, for their low bid of $47,927.00.

Because of a subsequent decision not to use this tower at the Proving Ground, the purchase order was cancelled on August 24, 1950. On October 12, 1950, the work was reinstated. On December 7, 1950, AEC requested that the tower be rushed to completion and forwarded to an AEC storage yard for holding until required by the AEC.

200 FOOT TOWERS

Characteristic of the rapid scientific advances that produced engineering challenges throughout the Project was LASL's request, nineteen months after tower design had started, that H & N design a 200 foot tower capable of supporting 200 tons. This was an entirely different type of tower, requiring a completely new analysis and design. Speed, both in design work and procurement, was essential in order to have towers of this new type erected at the Proving Grounds in time for tests early in 1951. This change in test objectives, although made late in the period of design and construction, did not relieve the date established for completion of all facilities. Careful coordination of design, procurement, fabrication, transportation and construction made possible this unprecedented accomplishment.

Chronologically, this assignment was handled as follows:

On April 27, 1950, official authority was given to the design group, and on April 28, a preliminary drawing based on J-Division's telephone call was submitted to J-Division. The preliminary design was approved on May 3, 1950. Because of the loads involved and the desire to keep the tower weight as low as possible, the use of silicon steel for the legs was approved. The design of the tower was complicated by the large amount of scientific gear that occupied a large portion of the space within the tower shaft, i.e., the NRLK coaxial cables and their special shielding and the UCRL vacuum pipes that had to be held to close tolerances. The inclusion of the User's equipment made it necessary to place the main hoist and the skip hoist outside of the tower shaft. Because of the eccentric loading, this complicated the design. In addition, the house on top was equipped with a standard industrial traveling bridge crane, which could develop some large lateral forces as well as impact forces.

When authorization was given to design a tower according to the new criteria, it had not yet been decided how many towers of this design would be required or what to do with the 300 foot aluminum tower which was being fabricated. However, due to the short time available the decision was quickly made to procure three towers of the new design plus a 25 foot top section and house to be shipped to Los Alamos as a mock-up. Consequently bids were taken on a price per pound of steel basis, using the preliminary sketch as a bidding drawing. The contract was awarded to Union Iron and Steel Co. on May 12, 1950, the bid being $ 0.097 per pound.

To save the time usually required to get the large beams needed in the floors, the use of 36-inch deep beams salvaged from an old bridge in the Los Angeles area was sanctioned. As the design progressed the steel fabricator was able to stockpile more of the material he needed.

From May 19, 1950, until the time of the test, these towers were constantly undergoing changes. Each change of tower loading or requirement came in separately and required many reanalyses and new drawings. An illustration of the magnitude of these revisions is shown by the fact that although only 9 drawings were required to show the structural portion of the shaft and house at the time fabrication began, by the time the towers were erected, 16 more full size drawings had been added to depict the changes. A few of the major revisions are as follows. Limonite inside the house was changed to lead on May 19. On June 23, the original size of the house was changed from 20 feet by 20 feet by 12 feet to 20 feet by 29 feet by 16½ feet. One tower was to be provided with a special 9 foot by 7 foot overhanging platform capable of supporting 4 tons. UCRL's vacuum pipes and NRLK's limonite column, which are described more fully later, were never really firmed up. The vacuum pipes had to be lead-shielded at different levels; therefore special supports were needed. The lead-limonite column that was first proposed to shield the NRLK coax cable from the ground into the house at the top, a vertical distance of 200 feet, was originally 4 feet in diameter. Later the lead-limonite concrete was discarded in favor of a lead column 3 feet in diameter. This necessitated changing some of the interior bracing. Prior to this change, it had been necessary to build sufficient inherent strength into the tower shaft to carry the construction loads that would be imposed during the building of the column. This required close coordination with the Holmes & Narver construction forces.

In order to satisfy the initial requirements, a four leg, guyed tower 200 feet high to the underside of the floor of the house at the top was selected. The shaft of the tower was 20 feet square at all elevations. Eight guys were provided at the 175 foot level.

A summation of all loads involved at the base of the tower indicated a load of approximately 2100 tons. To keep the soil pressure within 3000 pounds per square foot would have required a foundation mat approximately 40 feet square. However, because of the sequence of construction of the heavy units comprising this total load, the foundation mat would be subjected to nonconcentric loading which would have involved unequal soil loading, resulting in possible tilting of the mat out of a true horizontal plane. This, in turn, would have induced unknown loads into the tower shaft, which would be securely guyed in a vertical position. This necessitated sending a foundation consultant to the Proving Ground to investigate the foundation conditions at the tower sites. The firm of Dames and Moore, a nationally recognized firm of soils consultants, had been used by H & N to analyze the soil samples obtained by the reconnaissance group. In connection with this work several of the key personnel had been "Q" cleared, so it was possible to send a recognized soils expert to the Jobsite immediately.

On August 10, 1950, the decision was made to use steel H-piling to support the foundation. The piling used was 12 inch BP 53# in 60 foot lengths. The bearing pressure value per pile was approximately 85 tons.

At the time this piling was being installed at Eberiru, it had not been determined what the total loading would be on the 200 foot tower for the E⁄ experiment. In view of this, the AEC requested that a foundation similar to that at Eberiru be installed.

The subcontractor finished fabrication of the tower on September 15, 1950, and the towers were shipped on that date to Oakland for overseas shipment.

Although no requirements were placed as to torsional stability, tests on the finished towers indicated that a normal day's rotation due to wind and temperature was only 40 seconds of arc. A request was made to keep the tower's horizontal movement to plus or minus 1 inch at the 200 foot level during normal wind conditions, and the field tests indicated movement of only plus or minus $\frac{1}{4}$ inch. This movement was due primarily to temperature changes of the structural members as the relative position of the sun changed during the day.

In addition to the vertical loading previously mentioned, the tower was designed to withstand a wind pressure of 30 pounds per square foot on twice the projected area of one face.

Since most of the load produced in the tower legs was contributed by actual vertical loads rather than wind loads, the allowable stresses selected for design were more conservative than those used for the 300 foot tower design. The possible overload factor for this tower (approximately 100 per cent) was necessary because it was never fully known what the Users would require of the tower.

User's sketches received in the fall of 1950 called for a lead-limonite concrete circular column 200 feet high extending from the base of the tower to the underside of the house at the top. Because the lead would flow under the heavy pressures involved, it was decided that flanged sections of welded steel casing would be employed to act as forms for the limonite concrete encasing the lead and also to restrain the lead from flowing.

The original plan for installing the coax cable called for supporting a piece of 12 inch pipe, out of which one-third of the circumference had been cut, the full height of the tower. The cables would then be fitted into this shell. After all of the cables had been installed, the other third of the pipe would be replaced and held secure by banding. The 2 foot diameter lead blocks were then to be placed to a height of approximately $12\frac{1}{2}$ feet, after which the 4 foot diameter steel casing was to be placed and the space between the lead and the casing was to be filled with limonite concrete. The lead was then to be placed for $12\frac{1}{2}$ feet more and the process repeated until the full height of 200 feet was reached.

Design and drawings were practically complete on this basis when the User requested that the column be shielded with lead only and that the pipe used for encasing the coaxial cable be changed from 12 inch diameter to 8 inch diameter.

The new plan of installation, and the one that was actually used, involved hanging the top 180 feet of the 8 inch pipe from the lower structure and pulling the coax cables up through the pipe as the cables were welded together. The bottom 20 feet of the pipe was 10 inches in diameter, and it was slipped over the 8 inch pipe before the placing of the cables began. The coax cable was of the rigid type and was shipped in 20 foot lengths. A length of cable was pulled up into the 8 inch pipe and a second length soldered on. This was pulled up and this operation was repeated until all coaxial cables were in place. After all of the cables had been placed, secured, and tested, the 10 inch pipe was lowered into place, and the placing of the lead blocks began. The lead, in the form of split doughnuts, was placed to a height of a little more than 12½ feet; then the first section of the flanged steel casing was placed in two parts and these parts welded together. This series of operations was repeated until the column was completed. The grouting of the one inch space was done section by section.

To retain the lead, it was decided that the flanged welded steel casing sections would be employed as contemplated in the original requirements. A clearance space of one inch would be allowed between the lead and the steel retaining shells which would be pressure grouted as the construction of the column progressed. Holes and nipples for the grouting hose connection were provided in the walls of the shell.

Designs and drawings were completed on this basis and material placed on order, but after the User reviewed the plans, he requested that the steel grillage supporting the column at the base over the coaxial cable trench in the foundation be designed so that it could be installed after the coaxial cable was in place, including the bends into the trench in the foundation. Design therefore had to provide a hole in the grillage for passing the coaxial cable.

On checking the status of the material on order it was found that the grillage as originally designed had been shipped. Because field changes on these to meet the later requirements would have been difficult, a new grillage was immediately designed which could be installed in halves around the coax. This was ordered and shipped to the Jobsite.

The coaxial cable and the lead were furnished by NRLK and installed by H & N under the User's direction. H & N designed, furnished, and installed the remainder of the column.

A portion of the test gear for the UCRL experiment involved the use of a vacuum tube system which extended from the top of Station 131, located at the base of the 200 foot tower, to the floor of the house at the top of the tower. The tubes started from the roof of Station 131 as four pipes, converging into two pipes at the 137½ foot level, and finally into a single pipe at the 150 foot level. The tubes were shielded with lead at different tower levels. The sketches showing the weights involved were furnished H & N by the User at a meeting held at Los Alamos on June 23, 1950.

To speed procurement, UCRL furnished the tubes, the lead shielding, and platforms to support the lead; however, H & N had to adapt the tower to these loads and also install this equipment under the direction of UCRL.

After the tower was fabricated and shipped, the User requested that the weight of the lead at the first level above the base be increased considerably above that first stipulated. Since the tower framing was not capable of taking this increased loading, H & N prepared designs and supplied material for a platform for the lead, supported from the roof of Station 131 by steel pipe columns.

Since the 200 foot tower or towers were to be used in lieu of 300 foot towers, no additional hoisting equipment was required. Main hoist equipment, skip hoist equipment, and the portable hand winches, however, had to be modified to conform to the new requirements. The changes involved were due to:

1. The load required for the 200 foot tower main hoist was 15,000 pounds instead of 10,000 pounds as used on the 300 foot tower (Drawing 3G-5422).

2. The skip hoist was operated outside at the 200 foot tower instead of inside as on the 300 foot tower and did not have to open a trap door as it approached the top level (Drawing 3G-5423).

3. The hand winch used in the tower cab for pulling coaxial cables, mountings, and cable guides had to be redesigned due to difference in structural conditions in the tower cab (Drawing 5430.1).

In order that the 300 foot tower main hoist machine might be used for the 200 foot tower and its 15,000 pound load, it was decided to raise the load at 20 fpm maximum on a three-part cable. This required the relocation of one sheave and the addition of one sheave, mounted on the structural A-frame, but did not change the power requirements. It also required dead-ending the hoisting cable at the load block, instead of at the A-frame as was done on the 300 foot tower. This required a minor change in the load block yoke for attaching the cable. A slight change in the location of the limit switch on top of the A-frame was also required as well as a slight change in mounting the limit switch weight. Drawings were prepared showing these changes. Figure 5.11-6 shows the hoist machine used for both 200 foot and 300 foot towers.

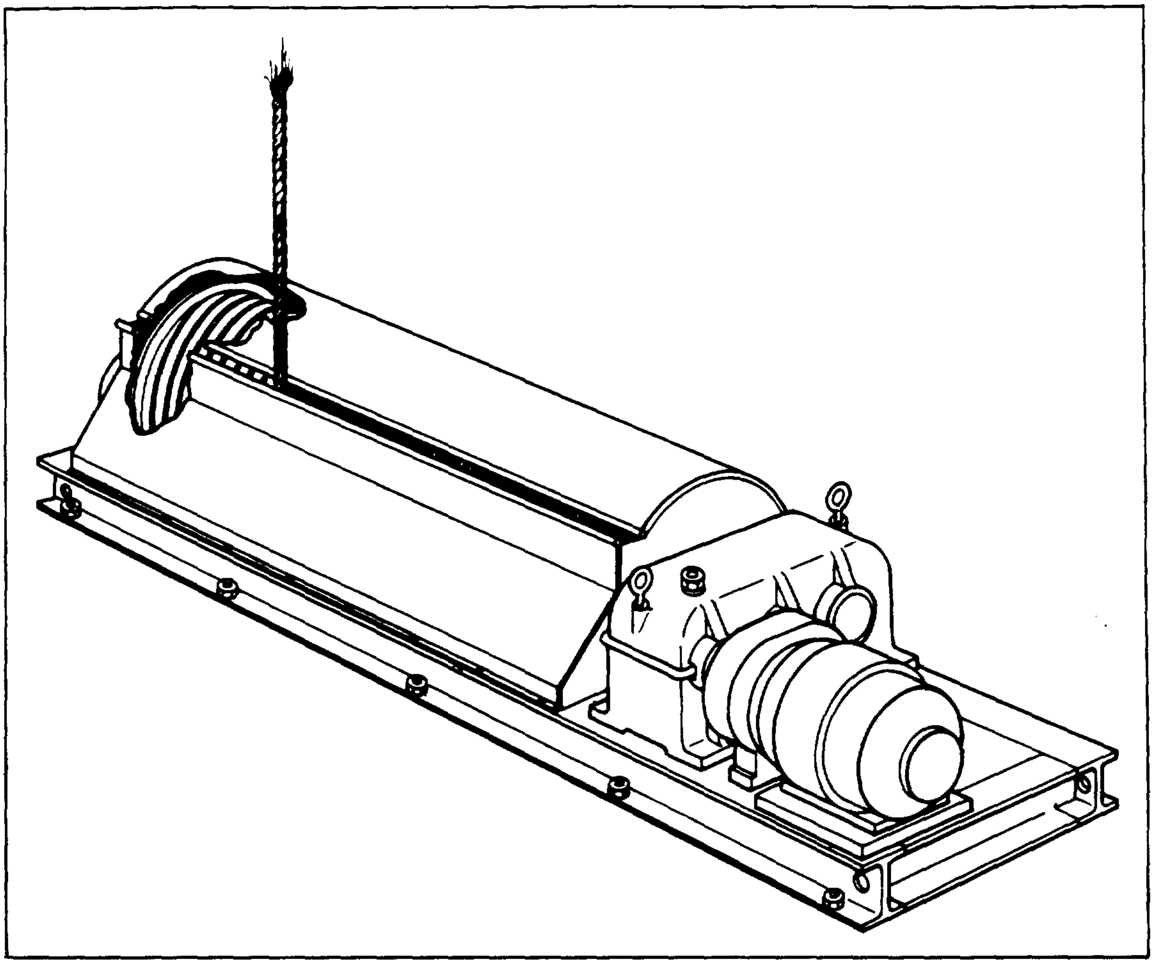


FIGURE 5.11-6 Hoist Machine for 200' and 300' Towers

Since the skip hoist operated outside of the 200 foot tower and passed up through an opening in a platform at the top level, minor changes were required on the skip cab (platform). As it did not have to open a trap door at the top level, the framing above the railing level was removed. Because the skip was loaded at one end at ground level and at one side at the top level, it was necessary to make the railing on one side removable (the removable end portion used for 300 foot towers was not changed). These changes on the skip cab were necessarily made in the field at the time of installing on the 200 foot tower, because the cab had been shipped with the 300 foot towers before the 200 foot towers were conceived.

The portable hand-operated winches and cable from the 300 foot tower cab, were used on the 200 foot tower, but because of structural design of the tower house, the supports for the winches, cable, and sheaves had to be of a different design. The winch supports were mounted on the tower house structural members instead of on the A-frame as on the 300 foot tower. Figure 5.11-7 shows the main hoist sheave assembly and cable arrangement for a 200 foot Tower.

A 7½ ton single I-beam type traveling crane was provided for each 200 foot tower. The crane was equipped with a 2-speed electric hoist with gear type trolley. Hoisting speeds were 2½ fpm and 10 fpm on the total lift of 17 feet for the full height towers and total lift of 36 feet for the 25 foot mock-up section of the tower which was installed at Los Alamos. Proposals were received from three crane manufacturers and analyzed. The acceptance of the low bid was recommended on May 24, 1950.

In a phone conversation on May 31, 1950, J-Division requested H & N to design a detachable main hoist platform (or pallet) for lifting freight from the ground to the tower house, using the main hoist. At this point the pallet would be transferred to the 7½ ton traveling crane, to be moved to any desired location in the tower house. H & N prepared a sketch showing a platform composed of a structural channel rectangular frame and covered with ¼ inch plate with a 6 inch high toe plate on all four sides. The platform was lifted by a wire rope sling attached to each corner and was provided with double sets of roller guides on opposite sides of the platform framing. The roller guides were to operate along the main hoist T-guide rails and were spaced approximately 1 foot apart vertically. Because eccentric loading of the platform was possible, the double-roller guides were changed to single-roller guides. Also, the platform was provided with pull-out legs on each corner, so that the platform could rest on the floor of the tower house while it was being transferred from the main hoist to the bridge crane. To comply with this request, a new drawing (3G-5445) was made, using 6 inch pipe and 7 inch channels for the platform framing, single-roller guide assemblies, and lifting cables at each corner of the platform. The pull-out legs were of 5 inch pipe and made to telescope into the 6 inch pipe. The platforms were fabricated according to this drawing. Figure 5.11-8 shows a main hoist pallet platform for a 200 foot Tower, and Figure 5.11-9 shows a complete perspective of a 200 foot Tower.

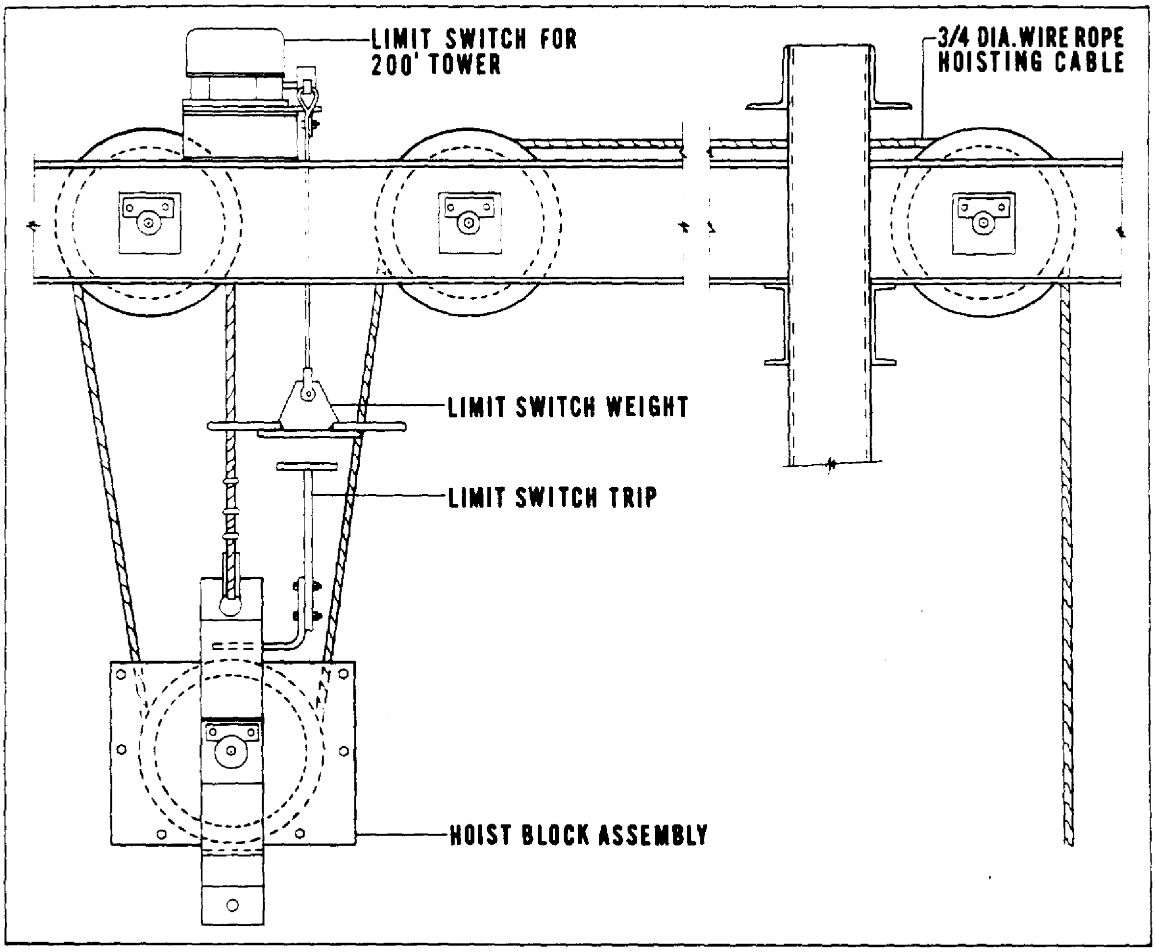


FIGURE 5.11-7 **Main Hoist - 200 Foot Tower Sheave Assembly and Cable Arrangement**

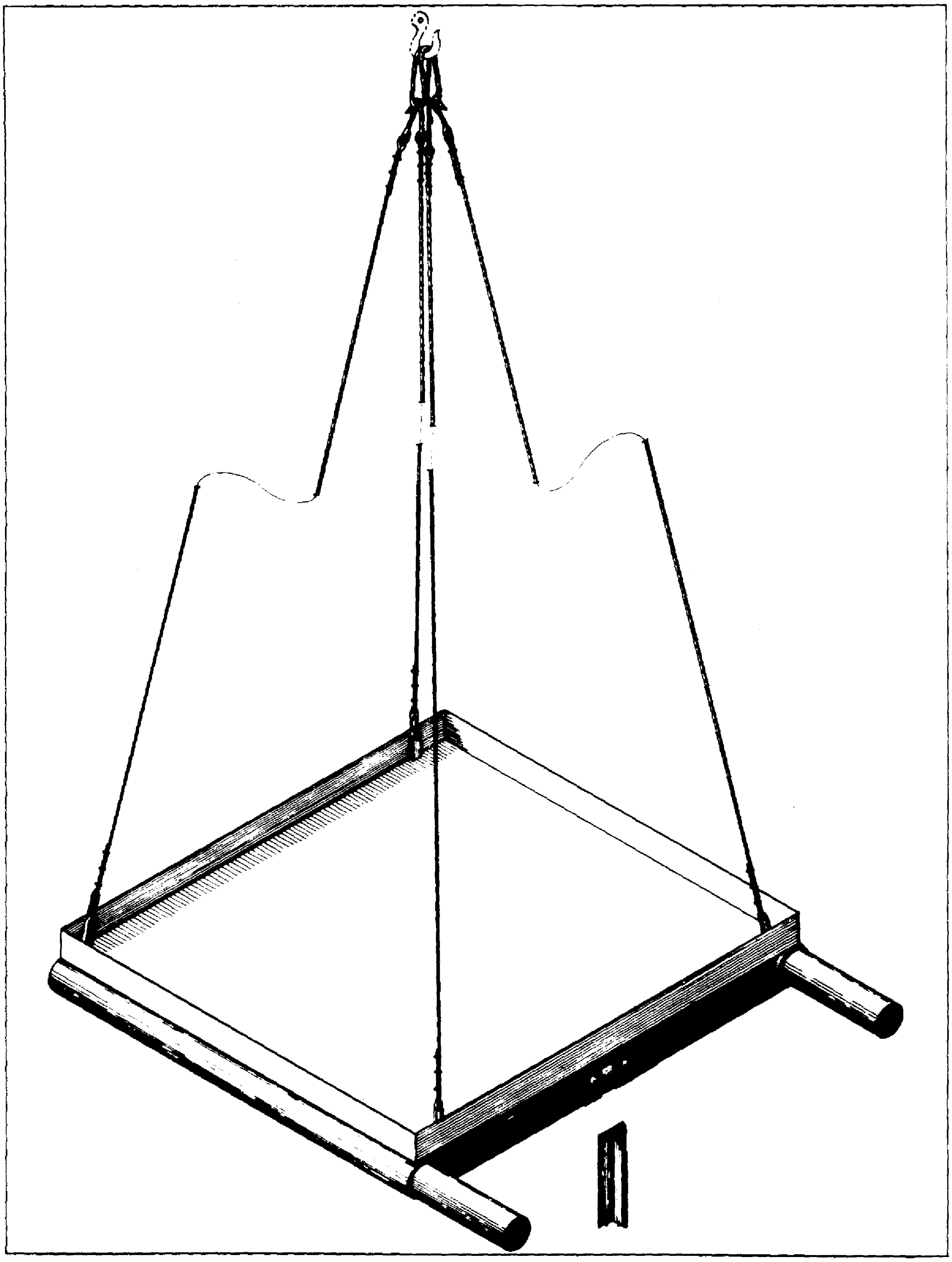


FIGURE 5.11-8 Main Hoist Pallet Platform 200 Foot Tower

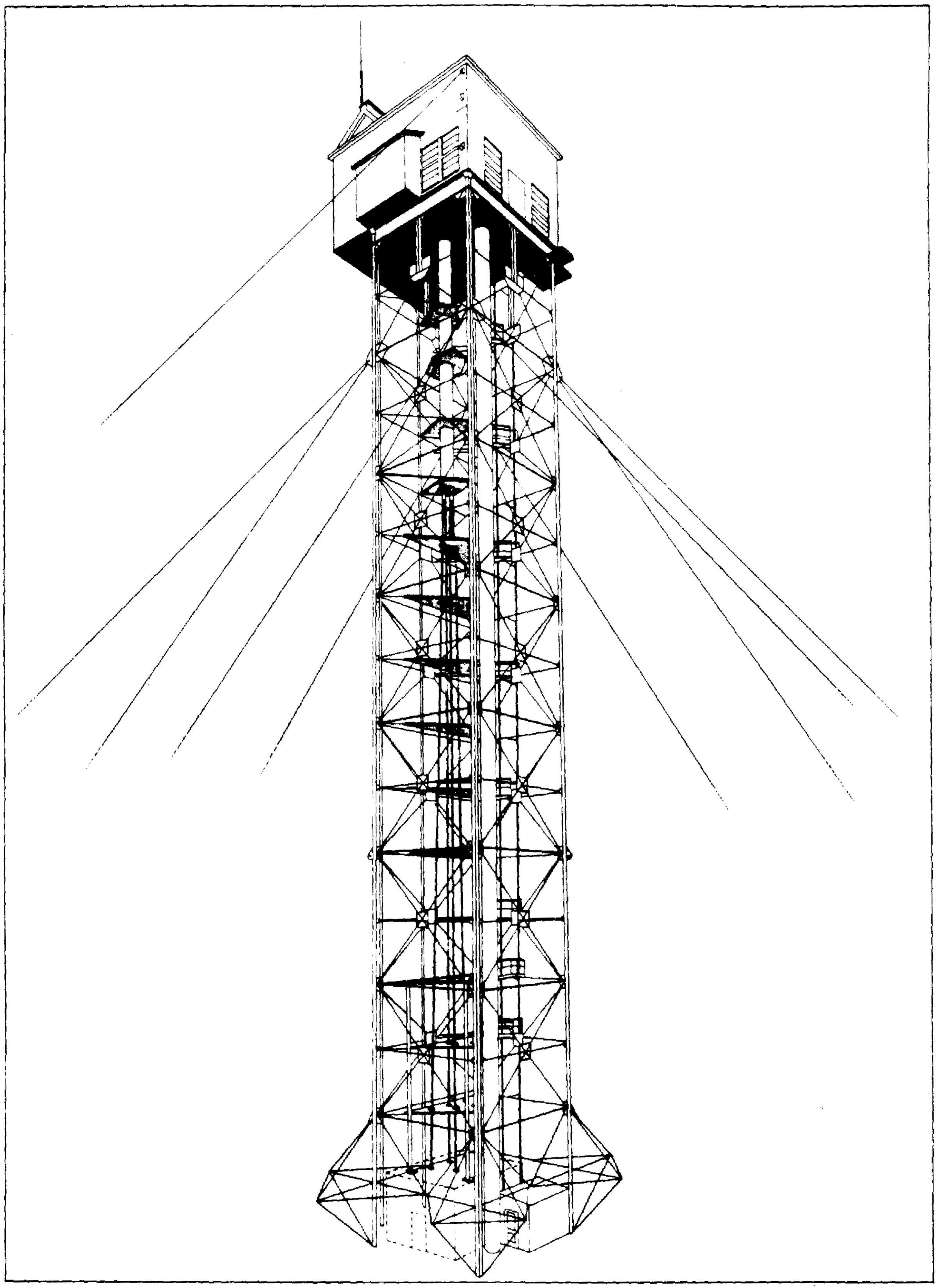


Figure 5.11-9 200-Foot Tower

75 FOOT TOWERS

The 75 foot towers were used as phototowers. The prime User was Edgerton, Germeshausen, and Grier. Standard radar towers using standard design were considered, but in addition to not being designed with the special requirements of photography as a basis, they would be subjected to excessive horizontal forces. These facts were presented to Los Alamos by letter on April 22, 1949. On July 28, 1949, a letter from LASL set up the preliminary design specifications for six towers and requested H & N to proceed with preliminary drawings. The preliminary tower design was submitted to AEC on September 13, 1949, and design comments by Los Alamos and Edgerton, Germeshausen, and Grier were returned to H & N on October 5, 1949.

Authorization for purchase of six towers was received by H & N on December 6, 1949, with the provision that the low bid not exceed the estimated cost of $88,800.00. Bids were requested and on January 16, 1950, six firms submitted bids, the low bid being $76,470.00 by International Derrick and Equipment Co. The purchase order for the six towers was released to the low bidder on March 31, 1950.

On May 15, 1950, the tower shafts were completed and ready for shipment. The tower cabs were entirely aluminum and by the time the aluminum had been procured, the subcontractor was hampered by a labor strike. The work was moved to the Union Steel Company's yard and completed by Union Steel Company on October 6, 1950.

As one of the towers was located at a site on the coral reef at the Proving Ground, it was necessary to change the one tower so as to include a battery room at the 25 foot level. This design was made in Los Angeles and the materials required sent to the field, where all the necessary changes were made.

A small change in the original scope occurred on September 22, 1950, when E G & G requested that H & N purchase the rolling metal doors that comprised the siding for two sides of each tower. Until that time E G & G was to furnish them. H & N let bids and had the doors in the field in sufficient time so that the User was not delayed in his installation work.

The mechanical design required for the 75 foot towers consisted of an open type dumb waiter capable of handling a net working load of 1500 pounds at a hoisting speed of approximately 40 fpm, powered by an electric hoist mounted on the ground, outside of the tower base. The dumb waiter platform was guided by bronze guide shoes, riding on standard 15 pound elevator guide rails, mounted on the outside of the tower. The guide shoes were mounted on the substructure of the platform. The platform was provided with instantaneous safety rail grips to prevent the platform from dropping in the event of hoisting cable failure or a slack cable condition. This safety device was designed after considerable study and investigation of devices used in standard dumb waiter service. The design arrived at was not standard; it was completely developed by H & N and called for specially designed safety grips similar in general design to those used for the skip hoist on the 300 foot tower. The mechanism for operating the safety grips was entirely different from that of the 300 foot towers. It worked only in the event of a broken rope or slack hoisting rope conditions, as no personnel were to be carried on the dumb waiter.

The hoisting rigging for the dumb waiter was mounted entirely below the level of the tower house floor to eliminate any obstruction at the unloading space at the top. The cable was attached low on the dumb waiter platform subframing to permit the platform to go 2 feet above the floor level, for easier handling of freight in loading or unloading.

Extra-flexible hoisting cable was used for hoisting the platform; this allowed the use of comparatively small diameter sheaves. All sheaves were cast steel with grooved bronze bushings and were provided with Alemite lubrication fittings. The hoisting rope operated inside of the tower line. A pipe guide was provided for the hoisting rope at a point where the rope operated between the stairs and the tower framing. This was done to eliminate the possibility of the rope rubbing against the tower or stairs. Figure 5.11-10 shows assembly of a dumb waiter for a 75 foot tower.

On September 19, 1950, H & N received a request from Edgerton, Germeshausen & Grier, Inc. asking that motor operated roll-up type doors be provided on two sides of the 75 foot tower house. These doors and operating motors were to be mounted on the outside of the building, to close openings 14 feet, 3 inches wide by approximately 7 feet high. This request was approved by J-Division on September 20, 1950, and the H & N Mechanical Engineering Department contacted the Los Angeles representative of the Kinnear Manufacturing Co., at the request of E G & G. to obtain information on the type of motor operated rolling doors required. On the basis of the information obtained about price and delivery, the doors were purchased from the vendor by H & N. The vendor furnished shop drawings of the doors, which were approved by the Mechanical Engineering Department. Since the doors would have to be installed in the field, it was necessary for H & N to prepare installation drawings for the doors. This work was shown on two drawings which supplemented the vendor's drawings and showed how the door guides were to be attached to the tower cab. Because the door and motor were mounted outside the building and above the roof, it was also necessary to design a support for them. As this was a special condition, such supports were not supplied by the door vendor. These drawings were completed October 5, 1950, and prints of each were submitted to the vendor for his check. They were found to satisfy the conditions required for mounting the doors, and the doors were installed according to the drawings.

The electrical facilities for each of the six 75 foot towers consisted of lighting panel, lighting fixtures and wiring, time-switch-

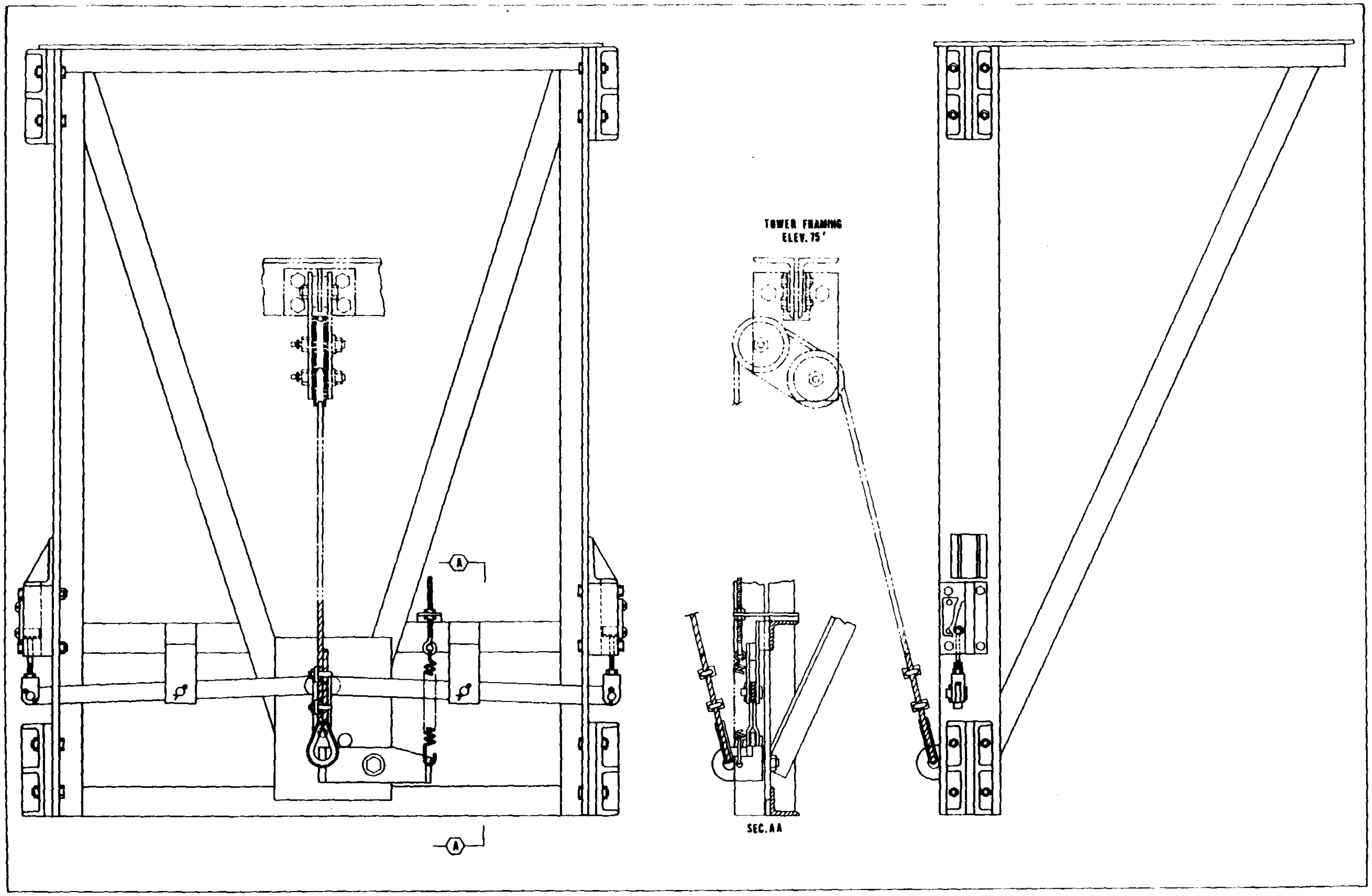


FIGURE 5.11-10 75 **Foot Tower-Assembly of Dumb Waiter**

controlled obstruction lights, rolling door controls, signal lights, battery huts, and motor-operated hoist. Interior lighting was provided by standard reflectors at approximately 25 foot-candles and exterior lighting by vaporproof units. Stairway lighting was controlled by switches at base and top of towers. This electrical material was purchased with the towers as a packaged unit and was installed in the field.

The original electrical demand for each of these towers was set at 15 kw plus 2 kw for battery charging. These loads had to be supplied by a dependable source with good voltage regulation characteristics. Accordingly two 50 kw diesel-generator units were installed in Station 64 on Piiraai, Bokonaarappu, and Teiteiripucchi. Site M. southeast of Runit was supplied from the main power plant on Runit. Control, signal, and telephone cables for tower operation entered the site terminal cabinets in Station 64 and thence to each tower. One telephone was provided in each battery hut and tower cab.

Rolling doors were added to the towers on September 19, 1950. E G & G furnished the timers for operating these doors and requested that the electrical equipment panel be moved to the rear wall opposite the personnel door. E G & G advised that they would furnish the generator for operating doors on site M tower. Figure 5.11-11 shows a complete perspective of a 75 foot tower.

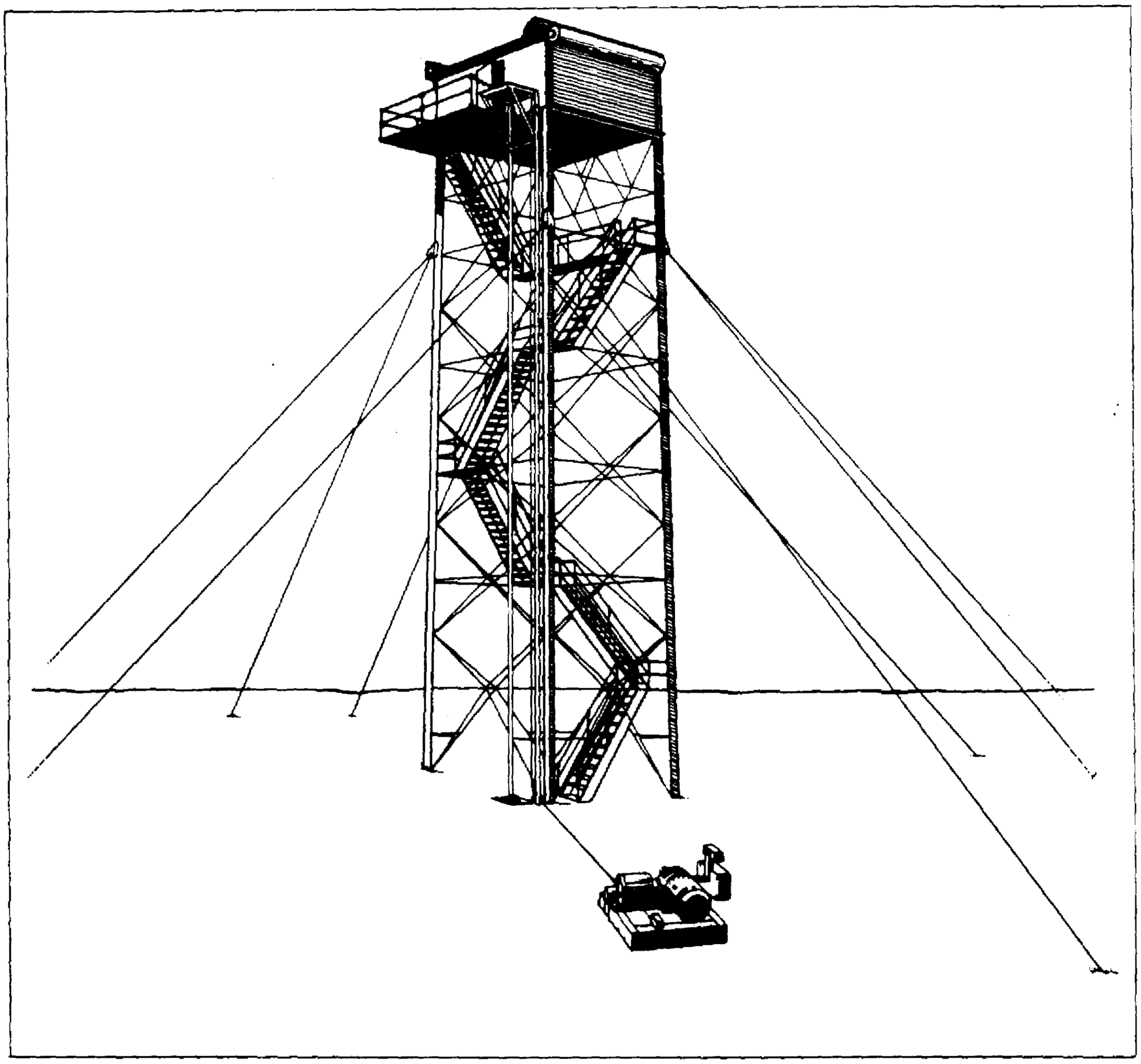


FIGURE 5.11-11 75 Foot Tower

CHAPTER 5.12

SCIENTIFIC STATIONS

The Engineering Division of Holmes & Narver prepared designs and drawings for many Scientific Stations from sketches or outline specifications furnished by the various scientific groups participating in the experiments for Operation Greenhouse. This phase of the work of the A-E-C-M Contractor grew steadily as additional scientific groups were included in the experimental program and as the requirements of others were increased in scope. Many changes were requested late in the program, and the Engineering Division of Holmes & Narver was under pressure to prepare plans and requisition materials to meet requirements on time.

To provide for anticipated changes or additions desired by the Users, certain materials were stockpiled at the Jobsite. Accurate records of these stockpiles were kept in the Engineering Division office in order that designs might be made to utilize these materials and thus save considerable time. Other materials were requisitioned from drawings as soon as they were prepared and before the Users had reviewed them or from sketches supplied by Users. In this manner, loss of time in waiting for special materials was minimized.

Drawings were revised to include changes required by Users and then forwarded to the field. If the structure was already under construction, changes were teletyped to the Jobsite and drawings were revised and sent later. Most of the scientific structures were designed to resist blast pressures, the magnitude of blast-resistance being established by J-Division of the Los Alamos Scientific Laboratory. These blast-resistance requirements underwent a considerable number of changes as the program developed, and these changes involved a great deal of back checking of designs to evaluate the effects of modifications to structures. The pressures for which various structures were designed are recorded in code designations on the drawings, and the apparent structural performances of the structures during the experiments are recorded in Chapter 5.27 of this volume.

CIVIL ENGINEERING FOR SCIENTIFIC STATIONS

In accordance with recommendations in the Reconnaissance report of January 7, 1949, the new zero tower position on each of the three experiment islands was located on the old zero line extended 75 feet northwesterly from the old Sandstone zero point. The new zero location on each experiment island is the focal point from which all scientific structures are oriented by azimuth and distance. The azimuth of the zero line as shown on the maps of Joint Task Force Seven is used as the base of bearings on each experiment island. On the plans for scientific and special structures prepared by Holmes & Narver, the azimuth shown reads from the scientific structures looking toward zero, measured in degrees of angle clockwise from due north.

A separate rectangular grid system was adopted locally on each of the three experiment islands, and computations of coordinates of working points for scientific structures are based thereon. Coordinates of working points for scientific structures are based thereon. Coordinates were arbitrarily assigned to the Sandstone zero points as follows: Runit, N 15000, E 1000; Aomon, N 10000, E 5000; Engebi, N 2000, E 4000. Therefore the grid coordinate system for any one experiment island is independent of that for any other experiment island, although each rectangular local grid extends to and includes all adjacent islands, points, photo towers, etc., referred to a given experiment.

The adoption of a separate local grid system for each experiment island was necessary in order to avoid delays while primary triangulation of the Atoll was being completed.

Eventual computations were based on the final overall triangulation survey of the entire Atoll, to which the zero line on each experiment island was tied by position and angle, thus placing all related stations in each experiment in their true geometrical positions on each local rectangular grid, free from distortion due to any meridianal convergences.

The final locations of all scientific structures for the 27 different users involved the preparation of 58 separate drawings and 204 revisions after the drawings were completed and signed. Some of these separate changes and revisions covered scores of stations, as shown in detail on the table of revisions listed on each drawing. These changes and revisions were made pursuant to relocations ordered in many verbal and written directives from J-Division, and to conform to shifting locations indicated in the several re-issues of the Instrumentation Charts received from time to time. Each time a structure was shifted, a new computation of coordinates was required, so that on the whole the number of precise computations was increased over the basic requirement by many thousands. In some cases, changes requested by one User interferred with locations of structures selected by other Users, thus setting in motion a chain of revisions requiring approval of two or more Users before final positions could be firmed up. Other revisions necessarily occurred where new structures were located on remote islands before field surveys were received showing their topographic position relative to their parent experiment island.

Because of the great number of revisions requested by Users for the relocation of scientific stations (often while construction was in progress in the field) it was in many cases impossible to supply construction forces with revised location plans immediately. To avoid delay and waste, coordinates for the working points for the stations were calculated and entered on the Architectural and Structural Department drawings sent to the field in advance of revised location plans. This enabled construction forces to continue their building work without waiting for the next revised set of Civil Department drawings.

STATION DESIGNS

The following is a complete list of scientific stations by number, location, User, descriptive identification, and brief design history. (A list of Users may be found in Chapter 1.2. Volume 1 of this report.)

Station 1 - Engebi, Eberiru, Runit, and E+. These stations were zero towers, discussed in Chapter 5.11 of this Volume.

Station 2 - Engebi, The Aomon Group, Runit, and E+ - NRL. The requirements of this building necessitated only a 9 foot by 3 foot by 7 foot wooden building strong enough to withstand normal loadings plus 2 feet of earth cover; it did not have to withstand blast conditions. The floor was placed 3 feet, 6 inches below natural grade, so that only half the hut extended above grade. J-Division for the AEC furnished H&N the floor plan, building description, and location on March 31, 1950. Further information was given on May 12, 1950. The locations of the buildings at the various sites were revised on May 24, 1950, and again on November 10, 1950, by J-Division.

Stations 3, 4, and 5 - Engebi, Runit, The Aomon Group, and E+ - NRL. Stations 3, 4 and 5 were power outlets on posts. The original sketch was furnished April 24, 1950. All Stations 3 and 4 were relocated on November 10, 1950 by J-Division. At the same time Station 5 was added to the program. Station 5 at Engebi was deleted by AEC on December 19, 1950. Station 3 on Engebi was relocated and Station 5 on Runit added by AEC on February 6, 1951.

Station 6a - Engebi, The Aomon Group, and Runit - NRL. These concrete buildings were built for the Sandstone Operation, and the revamping consisted of plugging the conduits in the front wall and drilling 34 new holes in the side and rear walls. These holes varied in size from 2 inch to 8 inch diameter. Because of the desire for uniformity of dehumidification equipment, the existing units were removed and new ones installed.

Station 6b - Engebi, The Aomon Group, Runit, and E+ - NRL. Because of the increased scope of NRL's projects, an additional timing station was required of the same interior size as Station 6a - 23 feet by 13 feet, by 7½ feet. The preliminary sketches furnished in October 1949 contained sufficient information so that only minor revisions, such as changing an electrical panel at the Jobsite on February 12, 1951, were necessary. The walls and roof of the building were 14 inches thick. The structure was streamlined by placing earth fill up to the top of the roof slab. The earth was kept away from the access doors in the rear by concrete wing walls.

Station 6c - Engebi, The Aomon Group, and Runit - NRL. This station was a 16 foot by 32 foot tent placed adjacent to the Station 6a and 6b structures for use as a work shop. The description and locations were furnished by the AEC on October 10, 1950.

Station 7 - Site M, Southeast of Runit, Piiraai, Bokonaarappu - NRL. This was a wooden building 9 feet by 9 feet by 8 feet placed in the general vicinity of the photo towers (Station 60). Preliminary sketches were furnished on January 31, 1950. Because site M was placed on the coral reef, the site M Station was deleted as of March 14, 1950, and not reinstated until June 14, 1950. When it was reinstated, a design was sent to the field showing the building supported on four concrete piers, the floor of the house over 4 feet above high tide level. An exterior skin of 0.032 inch aluminum sheeting was provided to seal the building against the elements.

Stations 8 and 9 - Engebi, The Aomon Group, and E+- NRL. The Tenex collimators were furnished by the User; however, these blocks (81 inches by 60 inches by 55 inches) had to be supported in fixed orientation with respect to zero. The support brackets for the collimators were made of built up H - beams, webs and flanges being 1 inch by 10 inch plate. The fabrication of these was completed on June 6, 1950. On June 2, 1950, locations of U-bolts that held the collimators and the adjustment screws that centered the unit were changed by the User. Final criteria for the bases was received on October 8, 1950, at which time J-Division informed H&N that it was permissible for Station 8 to roll, whereas Station 9 had to remain in place. In order to prevent Station 9 from moving, 13 cubic yards of concrete were required at Engebi and 34 cubic yards at The Aomon Group and E+. The whole assembly was surrounded and covered by prefabricated limonite blocks. The stations were relocated on November 16, 1950, by the AEC Resident Engineer.

Stations 10, 11, 12, 14, and 15 - Engebi, The Aomon Group, Runit, and E+ - LASL. These structures were also collimating blocks. They were supported in the same manner as those at Stations 8 and 9. Allowable tolerances for bases were 15 seconds of arc from a line through zero and ± 6 inches of distance from zero. The volume of these foundations varied from 13 cubic yards to 48 cubic yards, depending upon distance from zero.

Stations 16 and 17 - Engebi, The Aomon Group, Runit, and E+ - LASL. Station 16 was only the cable and samplers attached to the cable that was extended from a winch, Station 17. No design was necessary, but the location of the cable line had to be fixed in order to avoid interference with and shielding of samplers.

Station 18 - Engebi, The Aomon Group, Runit, and E+- LASL. In order to wash the cable and samplers of Station 16, it was necessary to provide a salt water pump station with an adjacent well. To protect the pump, which was rated at 200 gpm, at 50 psi, it was necessary to build a blast-proof concrete building 4 feet by 6 feet by 6½ feet. The protection was necessary because the pump was needed for a few hours after test times and it would not have been feasible to haul a pump to the site and set it up. The hose provided a coverage of 200 feet ahead of Station 17.

Station 19 - The Aomon Group, Runit, and E+- LASL. Same as Stations 10, 11, 12, 14, and 15.

Stations 20a through 20f - Engebi and Runit - NOBL. For making various blast measurements, NOBL had a blast line established on Engebi and Runit. The Station 20 series were small concrete walls 5 feet high, 1 foot wide, and 29 feet long, the middle 8 feet of which were fabricated steel sections to hold the various pressure gauges. These walls were mounted on concrete footings 4 feet by 2 feet, 9 inches, by 33 feet, the long axis being on a radial line from zero. To give a smooth wall surface, the specifications stipulated a trowel finish. On October 17, 1949, the chief of NOBL Blast Program proposed that H&N and his engineers have a meeting to firm up the designs. This meeting took place on January 30, 1950, in Washington, D.C., with representatives from NOL, BRL, and H&N present. The H&N representatives proposed that a revision in tolerances would make an appreciable difference in the costs of the units. This change was made on final drawings. Tolerances for location of walls were given on June 21, 1950. H&N was instructed to locate the walls within 36 inches of proposed locations; measure final location to within 1 inch; and align wall to $\pm$ 12 minutes of arc on a radial line from zero. A final conference was held on July 7, 1950, at which time minor problems were discussed. Approval of steel plate material was given by NOBL on July 10, 1950; fabrication began shortly afterwards.

Stations 21a, b, and c - Engebi - NOBL. Same as Station 20. These stations placed along a second blast line on Engebi.

Stations 22a and b - Engebi, Runit, and The Aomon Group - NOBL. These stations consisted only of standard tents without special floor slabs and were erected at the Users' request in the field.

Station 23a - Engebi, The Aomon Group, and Runit - NOBL. These structures, called "blast huts," were 15 feet by 10 feet by 7 feet with 18 inch concrete sides and roof. They served as recording shelters for NOBL. A print of the proposed layout was given to H&N on January 30, 1950, at a meeting in Washington, D.C. The stations were existing buildings built for the Sandstone test. These were altered by the addition of four 6-inch conduits through the 18 inch walls, a 14 inch by 10 inch ventilation duct, and 135 feet of "Unistrut" channeling to fasten equipment in place.

Station 23b - Engebi - NOBL. In order to increase the working area in Station 23a on Engebi, an additional building 15 feet by 8 feet by 7 feet was built immediately adjacent to Station 23a, one side of the new building tying into the existing footing. The layout for this station was provided by NOBL on January 30, 1950. The entrance to Station 23b was through Station 23a, via a 2 foot, two inch by 6 foot, 6 inch opening that had to be cut out of the existing 18 inch wall. This new addition was amply provided with slots to insert fastenings that anchored equipment in place.

Stations 24a and b - Engebi - NOBL. Same as Station 22.

Station 25 - Engebi - NOBL. This structure was another blast hut for the same purpose as Stations 23a and b. The building was new. The original interior size, as per drawings received by H&N on January 30, 1950, was 20 feet by 15 feet by 7 feet high. On April 24, 1950, a letter from J-Division changed the size to 15 feet by 14 feet by 7 feet. The walls and ceiling were 16 inch reinforced concrete, with an earth fill placed against the front and two sides up to the elevation of the roof. Originally the structure was to have had a partition to divide the space into two rooms, with a separate exit door from each room, but this idea was discarded in favor of one room and one exit. So as to standardize the blast doors, a clear opening of 2 feet, 2 inches by 5 feet, 6 inches was set. The doors were then made strong enough to resist the maximum anticipated side-on pressure. They were also so constructed to be airtight and watertight. In nearly every case, the doors were installed in pairs, one on each side of the opening provided in the concrete wall.

Stations 26a and b - Engebi - NOBL. These stations were the anchors for the barrage balloons. The anchors were concrete footings 5 feet by 5 feet by 2 feet deep. The drawings were completed February 8, 1950. On March 15, 1950, the bolt arrangement was changed, and on May 27, 1950, the final location of the stations was given by Los Alamos.

Station 26c - Runit - NOBL. Same as Stations 26a and b, Engebi.

Stations 27a through d - Engebi and Runit - NOBL. The stations were ball-crusher gauge mounts utilizing a concrete foundation. The original sketches were given H&N on January 30, 1950, at a meeting in Washington, D.C. The concrete footing was approximately 2 feet, 6 inches square by 6 feet deep. A special problem that arose was that of a designing a hook and latch to hold the cover plate on during test time when the pressure and temperatures were extremely high and still permit the removal of the cover plate rapidly a short time after the test. NOBL furnished the copper balls used in the gauges, H&N furnished all other parts. The top plate dimensions were revised by NOBL on September 27, 1950. Stations 27a and b on Engebi were relocated on October 27, 1950, in order to give clear access to the 300 foot tower base.

Stations 28a through j - Engebi and Runit - NOBL. These stations were velocity instrument posts for measuring the velocity of the shock wave and consisted primarily of an NOBL instrument mounted on a 10 foot high, 3 inch diameter pipe. These were used as part of the blast line measurements. The pipe was embedded in a concrete foundation, the pipe being curved 90° inside the foundations. An access pit was left at the point where the pipe emerged from the footing. The first design information was an oral description by the Blast Program Chief at the January 30, 1950, meeting in Washington, D.C. On June 21, 1950, the location tolerances were established. Final corrections by NOBL were made on June 28, 1950. On October 26, 1950, it was necessary to move Station 28j at Runit in order to move it out of the camp area.

Stations 28a through g - The Aomon Group - NOBL. Same as Station 28a, Engebi and Runit.

Stations 29a through k - Engebi - NOBL. Same as Station 28a

Stations 30a, b, and c - Engebi, The Aomon Group, and Runit - NOBL. These were small, 6 foot by 5½ foot interior dimensions, wood buildings used to store the component parts of the rockets. (See Station 32). The description was furnished to H&N orally by AEC. The building was protected from the blast by providing earth cover on the front, sides, and roof. On October 20, 1950, Stations 30a, b, and c on The Aomon Group were relocated.

Stations 32a through e - Runit and Engebi - NOBL. Although the rocket launchers required no engineering by H&N, the Civil Department was kept busy locating and relocating them on the site plans. The original locations were established by the first Los Alamos Instrument Chart. On January 16, 1950, it was necessary to move Station 32c on The Aomon Group because of relocation of Station 125. On February 10, 1950, Station 32a on Runit was relocated due to changing shore line of the island. On February 15, 1950, Station 32d on Runit was authorized, and on October 21, 1950, Station 32b on Runit was deleted. Another change in shore line necessitated moving Station 32c on Runit on December 23, 1950.

Stations 33a through i - Engebi and Runit - NOBL. Stations were essentially the same as Station 27 except that the gauges were each mounted on a 2 inch diameter steel stake instead of several being mounted in a concrete foundation. The stakes were 6 feet long with a threaded section at the top for fastening either a driving head for pounding the stakes into the ground or for fastening the ball-crusher mount. In order to give proper access to the base of the 300 foot tower on Engebi, it was necessary to move Stations 33a and b on October 27, 1950.

Stations 34a through d - Engebi and Runit - NOBL. Same as Station 33; the only difference was that these stations were located along a different line radiating from zero. On February 23, 1951, it was necessary to move Stations 34a, b, c, and d on Runit.

Station 35 - Engebi, The Aomon Group, and Runit - NOBL. This was a 15 foot long boom hung from the zero towers to support the pretest dynamite explosion for calibrating the velocity gauges. The charge was placed by a rope and pulley rig. The design information and location were given by J-Division on June 14, 1950. No trouble was encountered in the design or construction.

Stations 36a through f - Engebi, and Stations 36a through e - Runit and The Aomon Group - NOBL. These ground shock stations were holes in the ground to a depth where a steel mounting plate could be secured to the rock formation. The shoring of the hole was accomplished by use of 36 inch diameter, 12 gauge corrugated steel pipe. The mounting plate was secured to the coral rock by digging a hole roughly 2 feet cube in the rock, filling the hole with concrete and setting the anchor legs of the mounting plate in the concrete. The plate was required to be within $2\frac{1}{2}^{\circ}$ of level in both horizontal directions. Sketches for this station were furnished H&N on April 17, 1950. Station 36a, or The Aomon Group, was deleted on November 15, 1950, by the AEC Resident Engineer and was reinstated and relocated by the AEC on February 15, 1951. Station 36c at the same site was relocated on November 17, 1950, and Station 36e, Engebi, was found to be too near the tide line and therefore was relocated on January 22, 1951.

Stations 37a, b, and c - Engebi - NOBL. Another type of side-on pressure mounts were the pylons. These were steel assemblies that were 6 inches in width, 15 feet long and 15 feet above ground level. The skin of this mount was of 1/4 inch hot rolled steel that had been pickled and oiled. The interior supports were a series of four columns. The plate was fastened to the columns by machine bolts whose heads were countersunk and ground flush with the plating. The footing to support this metal assembly was of reinforced concrete, 2 feet, 9 inches deep, 17 feet long and 5 feet wide. The original sketches were furnished on June 22, 1950; and on November 1, 1950, it was found necessary during fabrication to add a series of 6 inch I-beam spacers to keep the skin from sagging and to maintain the stipulation that the plate be straight and true in all directions without waves or curves exceeding 1/8 inch. A sample wall-closure plate and sketch were forwarded to H&N on August 15, 1950, by NOBL.

Stations 37d, e, and f - Engebi - NOBL. Adjacent to the pylons were auxiliary units set with the top of cover plate flush with the ground level. These were simply 1 inch cover plates mounted on a vertical piece of 14 inch seamless open hearth pipe 18 inches long, which was in turn cast in a concrete foundation 2 foot cube. The cover plate was drilled to fit the gauges furnished by the User.

The original sketches from NOBL were furnished June 28, 1950.

Station 38 - Engebi and Runit - NOBL. These stations were 14 foot by 14 foot work tents set directly on the ground and provided with 1 Kw of power. The locations were firmed by J-Division on May 27, 1950.

Stations 39a and b - Engebi, and Station 39c - Runit - NOBL. In order to have facilities to care for the balloons while grounded, it was necessary to make a balloon bed approximately 100 feet away from each balloon anchorage (Station 26). The beds were slightly crowned areas 24 feet by 34 feet with two rows 20 feet apart of 2 inch by 1/4 inch steel rings on 6 foot centers to fasten the balloons to the ground. Each ring was required to hold 200 pounds of force from either a horizontal or vertical direction. The sketches for these were furnished H&N on May 27, 1950.

Stations 40 - Engebi, 41 - Muzin, 42 - Runit - J-7, LASL. The sketches for these stations were given to H&N on May 6, 1950. Stations consisted of a reinforced concrete well 5 feet, 2 inches, by 3 feet, by 3 feet, 6 inches deep capped with a 1/2 inch plate cover. Over the well was a rack 7 feet high and 7 feet wide made of 2 inch standard pipe. The electrical lines entered the well via a 2 inch conduit 10 feet long that was buried a foot beneath a 3 inch macadam surfacing. The surfacing covered an area 25 feet by 30 feet. The front of the well had a lead shield 12 inches thick which was also extended one foot along the side walls. Originally Station 42 was located on The Aomon Group, but it was moved to Runit on October 4, 1950. It was relocated on Runit on October 26, 1950, in order to clear the camp area.

Stations 50a, b, c, d, and e - Runit, The Aomon Group, and Engebi - NBS. As these stations measured radiation, the use of lead and limonite concrete was necessary. These stations had a limonite pad 8 feet, 6 inches by 8 feet by 1 foot, 4 inches thick, the top of which was flush with the ground level. Through the center of this pad was a 6 inch diameter hole with a 4 inch thick lead shield around the hole. Under the pad was a well with inside dimensions of 2 feet, 6 inches by 2 feet, by 1 foot, 8 inches deep. The well had plain concrete walls 12 inches thick. A center section of the pad 2 feet, 10 inches by 3 feet, 4 inches could be lifted out to give access to the well. Immediately adjacent was a redwood battery box 5 feet by 2 feet by 3 feet deep. Station 50a had two wells under the pad; therefore the pad was 8 feet by 11 feet in area. The original sketches were furnished on February 8, 1950. The necessary tolerances were given March 3, 1950. The battery boxes were added July 1, 1950, and NBS approved the drawings on July 18, 1950. Stations 50b, c, and d, Engebi and 50d, The Aomon Group, were relocated on August 4, 1950. Stations 50b, c, and d, Runit, and 50d, The Aomon Group, were relocated on September 6, 1950.

Stations 51a, b, c, and d - Runit, The Aomon Group, and Engebi - NBS. Essentially the same as Station 50, except that no lead collar is needed. The sketches for these were furnished June 1, 1950. On June 14, 1950, J-Division requested work stop until new sketches were forwarded by NBS. These were received on June 28, 1950. The battery boxes were added on July 1, 1950, and NBS approved the drawings on July 18, 1951.

Stations 52 and 53 - Runit and Engebi - NBS. On March 3, 1950 request was made for designs to be prepared for NBS Stations 52 and 53 based upon outline sketches of the requirements as prepared by the User. The essential requirement of the structures was to provide a unit which would support a considerable number of collimator tubes all alligned at different angles with the horizontal plane and protected with a minimum amount of limonite concrete shielding, all as established by the User. It was also required that information could be salvaged from these units after the test.

The final collimator tubes (40 in Station 52, and 20 in Station 53) were made of stainless steel tubing in accordance with sketches prepared by the User.

The problem presented a number of requirements that had to be met:

1. The finished structure had to be strong enough to preserve the information which was to be removed from it after the experiment.

2. Some adjustment had to be provided to align the structure as a whole after completion to correct for any unequal settlement in the foundations or any other misalignment during construction.

3. The many collimator tubes had to be maintained true to alignment within 15 minutes of arc and 1/8 inch in position.

It was decided that it would be impractical to cast the limonite concrete in place in wood forms at the site because it would be difficult if not impossible to set the collimator tubes to the close tolerances required and to maintain this alignment during the pouring of the limonite concrete and it would be very difficult to provide sufficient reinforcement steel in the space alloted and still leave enough clearance to pour the concrete.

It was decided that a complete unit including the basic collimator tubes should be shop fabricated to the close tolerances required and then shipped to the field ready for the installation of the limonite concrete and the final collimator tubes. The shell assembly containing the basic collimator tubes was designed to hold the tubes to true alignment during shipment and during the placement of the limonite concrete and also to take the designated blast loads. Structural steel back-stay grillages were provided to prevent the blocks from rolling backward under blast.

Vertical angular adjustment for the face of the block after installation of the concrete was provided by a set of opposing hand-operated jacks set between the block and the back-stay grillages. Hand-operated jacks were also installed at the base of the blocks to provide for fore and aft and sideway adjustment. It was also necessary to design special lifting slings and connections to handle the heavy steel units between the fabricator's shop and the final positioning at the Jobsite. The units weighed as much as 32 tons each. The footing for Station 52 contained 219 cubic yards of concrete alone, and Station 53 had 78 cubic yards.

Because the data furnished on March 3 was somewhat sketchy in places, it was necessary for a representative of NBS to come to the H&N office in Los Angeles on May 16. On May 16 the design data for Engebi was furnished, and on May 19 the data for Runit was provided.

Station 54 - Runit and Engebi - NBS. The first sketches were furnished on February 8, 1950. On May 16, 1950, a representative of NBS was in Los Angeles and furnished H&N with the necessary design data to complete engineering for Station 54, Engebi. Three days later the data was furnished for Runit. The buildings were constructed of limonite concrete above the foundation level. The foundations were made with coral concrete. The thickness of walls and roof was specified by the User as being the minimum required for shielding purposes; the front wall being 6 feet and the roof 5 feet thick.

Some structural failure was considered likely to occur in Stations 54, since it was considered impractical to design this station for the full pressure.

Because the basic collimator tubes extending through the face wall had to be set to relatively close tolerances established by the User, it was considered advisable to bolt them to the wood concrete forms and then tie them together and support them from the foundation with a steel rack fabricated in the field to suit the conditions encountered. Also, because the stations were to be mounded over with earth, it was necessary to construct a timber framed tunnel to the entrance doors. This timber tunnel was considered to be expendable.

The final collimator tubes were made from stainless steel tubing in accordance with sketches prepared by the User. These were "dry packed" in place in the basic tubes with limonite concrete after proper alignment.

A wooden tunnel over 26 feet long to act as battery storage was constructed under the fill in back of the stations. The studs in the tunnel were spaced to fit the batteries to be used, and the spacing was given on June 9, 1950.

The plans were approved by NBS on July 18, 1950, after minor changes, i.e. increased power requirements, and paving of the ramp. The ramp had to withstand 500 pound wheel loads and have a maximum slope of less than 15 per cent.

Station 55 - Engebi and Runit - NBS. Sketches for this building were furnished H&N by J-Division on February 8, 1950. The building's inside dimensions were 28 feet, 5 inches by 11 feet by 6 feet, 6 inches high. The 15 inch walls and roof were of coral concrete. In order to be able to fasten equipment any place in the building, a system of continuous slotted inserts on 1½ foot centers was provided on all four walls and ceiling. This made it possible to alter the User's gear up to the time of installation. The final building changes were received on March 23, 1950. The drawings were completed March 31, 1950. In May 1950, the station assigned to Aomon was moved to Runit. In July 1950, a change of location on Runit was made.

Station 56 - The Aomon Group - NBS. The sketches for this station were furnished March 18, 1950. Originally two of these stations were required, but the one on Bogallua was deleted at the time the test on Bogallua was removed from the program. The station was essentially the same as the Station 55 except that the inside dimensions were set at 13 feet, 6 inches by 15 feet by 6 feet, 6 inches high. The structural drawings were completed on June 6, 1950, with the electrical and mechanical drawings following a month later.

Station 57 - Runit and Engebi - NBS. These stations had the same design history as Station 54. The basic requirements were the same, and the data was furnished and checked at the same time as that for Station 54. The only difference was that because of the difference in distance from zero, the steel reinforcement in Station 57 was designed to develop the full value of the concrete wall and roof thicknesses specified by the User. It was felt that these stations would not be seriously damaged whereas the Station 54 structures were expected to suffer damage.

Stations 60 and 62 - Teiteiripucchi, Bokonaarappu tower southeast of Runit, and Piiraai - EG&G. These were the 75 foot photo towers described in Chapter 5.11 of this Volume. Tolerances established by the User for the final locations were 0.1 per cent of the distance from zero and ± 6 inches between photo towers on the same island.

Stations 61 and 63 - Teiteiripucchi, Bokonaarappu, Piiraai, and Site M, southeast of Runit - EG&G. The sketches for these structures (battery units) were provided H&N on January 24, 1950. One building was required for each photo tower. (See Station 60.) The choice of building material was left to H&N discretion. The final buildings were of wood framing with an aluminum skin over the wood sheathing. The aluminum was used because of its resistance to salt spray. On Teiteiripucchi, Bokonaarappu, and Piiraai, it was possible to erect the building on soil. However, Site M was on the coral reef, which was covered with water twice a day. This necessitated a few changes in the photo tower shaft at that site. The station was located at the 25 foot elevation inside the tower shaft, the flooring being wood instead of concrete as used on the ground locations. The inside clear dimensions were 6 feet by 7 feet by 7 feet, 11 inches high. Because of the anticipated loading, the studs were 2 inch by 8 inch on 12 inch centers and the roof joists were 2 inch by 10 inch on 12 inch centers.

Station 64 - Teiteiripucchi and Piiraai - EG&G. In order to have a power source other than batteries on the photo islands, these small power stations were built. These buildings housed a pair of 50 kw diesel generators and the necessary control panels. A small annex housed the timing controls for the island. The framing for roof and walls was 2 inch by 8 inch wood members on 16 inch centers. The exterior wood sheathing was covered with an aluminum sheeting. The building had two rooms; one, the power room, was 14 feet by 15 feet by 8 feet high, and the other, the timing room, was 6 feet by 4 feet by 8 feet high. The 4 foot dimension in the small room was changed to 8 feet on October 4, 1950.

Station 65 - Piiraai, Bokonaarappu, and Teiteiripucchi - EG&G. This was a 14 foot by 14 foot storage tent without a floor slab. No drawings were required.

Station 66 - Piiraai, Bokonaarappu, and Teiteiripucchi - EG&G. On those islands that were too small to justify a runway for airplanes, an asphalt mat 150 feet square was laid to provide a landing area for helicopters.

Station 69 - Runit, The Aomon Group, and Engebi - EG&G. Based upon discussions with J-Division, H & N submitted sketches of these stations on October 19, 1949. Los Alamos then made preliminary sketches for the timing and communications stations, which were received by H & N on November 18, 1949. The building had 3 interior sections with but one doorway into the building. The three sections were all 8 feet high inside, and the other side dimensions were 5 feet, 6 inches by 15 feet; 8 feet, 10 inches by 7 feet, 6 inches; and 8 feet, 10 inches by 7 feet. Originally all walls and roofs were 12 inch reinforced concrete sections. Because of revised pressure data for Runit, the walls and roof were changed to 15 inch sections. The drawings were completed February 8, 1950 and approved for construction on March 24, 1950.

Stations 70a through w - Engebi, and Stations 70a through z - The Aomon Group - Bio-Med. These stations were the animal cylinders, which were furnished by the Bio-Med group. The 8 foot by 10 foot by 1 foot concrete bases were designed and constructed by H & N. The size and location of these bases were obtained from a conference with the J-Division representative in the H & N offices on June 27, 1950.

Stations 71a through d - Engebi, and Stations 71a through g - The Aomon Group - Bio-Med. Same as Station 70. Station 71d on Engebi had to be relocated on October 23, 1950 and Station 71g on October 31, 1950 because of a lack of area.

Stations 72a through i - Engebi - Bio-Med. Except for Station 72i, these stations were the same as Station 70. The bases, however, supported longer cylinders. Base dimensions were 10 feet by 12 feet by 1 foot. Each station consisted of 9 slabs. Stations 72a, h, and g were relocated on October 24, 1950; Station 72h was deleted from the program on October 26, 1950. On January 5, 1951, a letter from Los Alamos authorized H & N to add Station 72i. Station 72i was to have been three 21 feet by 10 feet rafts to hold three long cylinders. On January 17, 1951, drawings were issued to the field. The floats were to be standard Navy design, but because it was found that additional buoyancy would be needed H & N had to alter the Navy design. In February 1951, a jetty was constructed to provide a quiet water area for small boats. This jetty was on an extension to the Bio-Med program line; therefore approval was given to utilize the outboard end of the jetty to locate Station 72i on firm ground. Because of this, Station 72i was changed to 8 large cylinders and 1 small cylinder on February 28, 1951.

Stations 73a through h - Engebi, The Aomon Group, and Runit, and Stations 74a through h - Engebi, The Aomon Group, and Runit - Bio-Med. The User furnished the assemblies; H & N's portion of the work was to dig holes 4 feet in diameter and 4 feet deep and backfill around the assemblies. Originally no H & N drawings of these stations were anticipated except for location, but it later developed that one was required to show a pipe support. Station 74h was relocated twice, once by the AEC Resident Engineer on October 23, 1950, and then again on February 9, 1951, by the AEC.

Station 75 - Engebi and Aaraanbiru; Station 76 - Muzin and Piiraai; Stations 77a and b - Kirinian; Station 78 - Runit and Kirinian; and Station 79 - Runit and Bokonaarappu - Bio-Med. The first sketches for these stations were received on February 16, 1950, from J-Division. The "final" revisions were submitted on March 28, 1950, by AEC. On April 12, 1950, J-Division submitted some additional corrections in the building as well as new locations. Revised sketches were submitted once again on May 22, 1950. Approval was again given on June 27, 1950. The User, on September 25, 1950, requested that the buildings be insulated. On December 28, 1950, Station 77 on Kirinian was split into two stations, Stations 77a and b, both of which were to be mounted on rafts. Station 78 on Runit was also transferred from a ground base to a raft base at the same time. On January 4, 1951, an investigation by H & N showed that the standard Navy type raft that had been proposed by the User was not buoyant enough to keep the stations above water level. On January 17, 1951, approval was given to add drums or pontoons to the rafts in order to increase the buoyancy.

The original work order left the type of material to be used to H & N's discretion. Station 75 on Engebi and Aaraanbiru had the highest pressure loading; it was therefore necessary to use 12 inch thick reinforced concrete walls and roofs. The inside dimensions were 4 feet by 20 feet by 5 1/2 feet high. Station 76 on Muzin and Piiraai, being farther back, had 8 inch concrete walls and roof. The other stations had wood framing with a skin of aluminum sheathing on the exterior to protect the occupants against the elements and flash fire due to the test. Where physically possible, buildings were to be oriented to within ± 15 minutes of the specified azimuth.

Stations 80a, b, c, and d - Engebi and The Aomon Group, and 80e - Muzin and The Aomon Group - Bio-Med. The assemblies were furnished by the User, but the concrete slabs were drawn and constructed by H & N. The details were furnished H & N on June 27, 1950, by J-Division. The concrete slabs were 4 feet by 12 feet by 1 foot deep. On October 21, 1950, the AEC Resident Engineer deleted Stations 80e on Engebi and Muzin. On October 23, 1950, he relocated Station 80d, Engebi.

Station 81 - Engebi, and Station 82 - Muzin - Bio-Med. Each of these stations was a combination of one station 72 and one station 80, the resulting concrete base being 25 feet long and 10 feet wide for 13 feet of the length and 4 feet wide for the remainder.

Stations 83a, and b - Engebi - Bio-Med. Each station consisted of a 4 inch aluminum pipe embedded horizontally in the middle of the long axis of a concrete base 5 feet by 1 1/2 feet by 1 foot deep, the top of the concrete being flush with the finish grade.

Stations 85a through f - Engebi - Bio-Med. On January 8, 1951, H & N received a letter authorizing these 6 additional stations which were the same as station 73, being a 4 foot diameter hole 4 feet deep into which an assembly furnished by the User was inserted and the hole then backfilled.

Stations 90a through j - Engebi; 91a through f - Muzin; 92a through d-Bokonaarappu; and 93a through d - Teiteiripucchi - AMC. The location of these stations was given on April 15, 1950, but the construction requirements were not furnished until November 7, 1950. Steel boxes, 2 foot 6 inches cube, were designed and specified to be buried so that the cover was flush with finish grade. All of the stations had at least 2 inches of lead on one side, and some of the closer stations (90a, b, e, f, g, h) had 4 inches of lead across the front face and 2 inches along the two sides. On December 26, 1950, H & N was informed that stations 91c, d, e, f, and 92a, b, c, d, were to be moved to Runit. These became the 95 series. An area 12 feet square around the boxes was stabilized with asphalt as per instruction from J-Division on July 17, 1950.

Stations 95a through h - Runit - AMC. As stated under station 91 and 92, these stations were made up of units moved from Muzin and Bokonaarappu. The requirements and locations were furnished by the AEC on December 26, 1950. Station 95h was relocated by AEC on February 23, 1951. Asphalting of the adjacent area was not required for this group.

Station 100 - Engebi, The Aomon Group, and Runit - All Users. These were the power houses and are covered in Chapter 5.15 of this volume.

Station 101 - Engebi, Muzin, Kirinian, Bogallua, and The Aomon Group - All Users. Timing signal and telephone cable termination stations were wood frame buildings with corrugated aluminum siding and roofing. The original size was 8 feet by 8 feet, but a field change by the AEC Resident Engineer on November 1, 1950, changed it to 8 feet by 12 feet.

Stations 120a through e, and 121a through e - Engebi and The Aomon Group - Rad Chem. On July 10, 1950, J-Division furnished an outline specification and general dimensional sketch covering its requirements for Stations 120 and 121. Pressures for which these stations were designed were established by the AEC. It was required that the design be such that information could be recovered from the structure after the test. The User requested that the station be constructed of limonite concrete if possible.

A preliminary study indicated that it would not be possible to construct it of limonite concrete with any assurance that the information could be recovered after the test. On September 26, 1950, authorization was received to fabricate these stations on the continent as steel castings and ship them to the jobsite ready for installation. Compartments and passage ways were required in the foundation for the castings. It was decided that these should be shop fabricated of steel plate and shipped to the Jobsite ready for installation in the concrete foundations.

On October 18, 1950, after approval was received on the design and while the castings were being fabricated, the User requested that attachments and other protective devices be installed on the castings to enable the application of a protective plaster coating in the field. These were installed on the castings before loading on the boat for shipment to the Jobsite.

On November 17, 1950 the AEC representative made some minor changes in the steel assembly and specified that the stucco was to be in 3 layers on all of the stations except 120e, Engebi and the Aomon Group, which were to receive no stucco. The specifications for the stucco were provided by AEC on January 9, 1951.

The 121 steel castings were 6 feet high and were approximately 18 inches wide and 10 feet long. The concrete foundations were 22 feet by 9 feet by 8 feet 2 inches deep.

Station 123 - Engebi and The Aomon Group - Rad Chem. These small battery huts were 4 foot by 4 foot by 6 foot wood frame buildings with waterproof plywood sheathing. The locations were given by the AEC on October 16, 1950.

Station 124 - Engebi, and Station 125 - The Aomon Group - Rad Chem. The original sketches for these rocket launcher bases were furnished by the AEC on December 12, 1950. The platforms were 4 feet by 200 feet by 4 feet thick, and the top surface was to be $\pm 1^{\circ}$ of being level. Anchor bolts were provided to attach the User's assembly. On January 15, 1951, the User deleted 124 from the program, relocated 125, and established the length of Station 125 as 220 feet to support 22 launchers.

Station 131a - Engebi, and 131 - The Aomon Group - UCRL. These detector stations were limonite concrete structures on coral concrete bases, the inside dimensions being 4 feet by 4 feet 6 inches by 6 feet 4 inches high with walls 3 feet 8 inches thick and roof 4 feet 7 inches. Design information was first obtained from J-Division on May 13, 1950. The User amplified this with layouts on June 28, 1950. Because of the small space available for equipment on July 19, 1950, J-Division agreed to placing the dehumidification equipment outside the structure. On August 18, 1950, the User requested the door be moved 1 foot to the side, and at a later date it was decided to leave the whole side open and fill the opening with limonite blocks instead of using a door. On September 1, 1950, additional drawings and details were forwarded by the User. These were confirmed and the changes approved by J-Division on September 9, 1950. Until November 22, 1950, Station 131a on Engebi had three vacuum pipes in the floor and ceiling, but on that date the center one was eliminated by the User. The requirements for four vacuum pipes in the floor and ceiling of Station 131 on the Aomon Group remained unchanged. The electrical requirements were revised on December 15, 1950.

The foundations were 12 feet 6 inches by 15 feet 8 inches by 5 feet deep. The 70 cubic yards of limonite alone weighed 285 tons. Station 130 was to be located inside the tower legs and its weight contributed to the total of 2100 tons load on the foundation for the 200 foot tower on Eberiru.

A sump pump was provided on Engebi to drain station 131a, discharging five feet outside station.

Station 132a - Engebi, The Aomon Group, and E+ - UCRL, and Station 132b - Engebi, The Aomon Group, and E+ - NRLK. These were partially buried recording stations made of reinforced coral aggregate concrete. On Engebi the buildings were two separate buildings, while at the Aomon Group the two stations were in one building provided with a dividing wall. E-132a was 12 feet by 16 feet by 18 feet high inside. E-132b was 12 feet by 28 feet by 8 feet high. Both structures had a minimum of 5 feet of earth cover. On the Aomon Group both rooms were 12 feet by 32 feet by 8 feet high. The anticipated loading was so great for the combined building on the Aomon Group that the reinforcing steel was supplemented with 20 inch I-beams at 12 inch centers. All of these stations were dehumidified.

Design details were first furnished by J-Division on May 13, 1950. The preliminary H & N sketches were then reviewed by the Users at a meeting at Los Alamos, June 23, 1950. On June 27, 1950, a layout of the whole 132 series was furnished. Lead doors were requested on July 5, 1950. On July 7, 1950 there were submitted sketches and locations pertaining to 132b. Until August 16, 1950, the 132 stations were still incorporated in the site plans for Engebi, but on that date they were deleted. Stations 132a and b on Bogallua were deleted on August 14, 1950 when site was removed from the Program. On September 1, 1950, more drawings were furnished by the User showing locations of equipment and conduit. These requirements were incorporated in the drawings after J-Division had confirmed the changes on September 9, 1950. By November 7, 1950, construction was well under way, but it was still possible to revise nearly all of the pipe sleeve locations as requested by the User through J-Division.

Station 132c - Engebi, The Aomon Group, and E+ - NRLK. So as not to occupy valuable space inside of 132b, the power supply station and some of the mechanical equipment were placed in a shelter formed by placing a wooden roof over the area between the wingwalls on Station 132b. This gave an area approximately 35 feet by 10 feet by 10 feet high. When the wingwalls were constructed, fasteners were embedded in the walls to facilitate securing the gear. The original sketches were furnished on May 13, 1950, by J-Division.

Station 132d - Engebi, The Aomon Group, and E+ - NRLK. Here again, the User consented to using a wooden lean-to roof over a concrete slab. The roof was fastened to the side of 132b and removed at the time the earth covering was placed over 132b. The saving in time and cost of these wooden lean-tos was considerable in both engineering and construction over the building of separate structures.

Stations 132e and f - Engebi, The Aomon Group, and E+ - NRLK. To provide temporary work shops and covered storage areas, 14 foot by 28 foot tents were sufficient. The location was directly behind Station 132b, the building being serviced. The User furnished sketches and locations of these stations on July 7, 1950.

Station 132g - Engebi, The Aomon Group, and E+ - NRLK and UCRL. This station was a photo trailer supplied by the Users.

Station 132h - Engebi, The Aomon Group - NRLK. To house the coaxial cable trucks, a garage was built in the immediate vicinity of 132b. The building was wooden frame with canvas covering, the size being 28 feet by 20 feet by 9 feet high. The locations for the 132h's was given December 22, 1950 by the AEC.

Station 133 - Engebi and The Aomon Group - UCRL. On September 9,1950, J-Division furnished this station. This work shop for UCRL was a 14 foot by 28 foot tent with a concrete slab floor placed adjacent to 132a. The requirement for this station on Engebi was canceled and this station was deleted on August 16, 1950.

Station 134 - Engebi and The Aomon Group - UCRL. This also was a 14 foot by 28 foot tent used as a work shop, but for 131a. The basic requirements were provided by J-Division on September 9, 1950. The electrical requirements were revised by the User on December 15, 1950.

Station 135 - Engebi and The Aomon Group - UCRL. Adjacent to, and having one wall in common with station 131, was a building used to store tools and equipment for station 131. It was a small wood frame building approximately 7 feet by 8 feet by 7 feet high. The exterior sheathing was of corrugated aluminum, and the interior paneling was plywood. The interior was given a coating of "cocoon" spray to seal the room to aid in the dehumidifying. The location of this hut was first shown on a location plan furnished by the User on September 1, 1950; however, it was not until December 19, 1950 that the AEC gave approval for the Aomon Group building and December 26, 1950 that it approved the Engebi station. The number 135 was not officially assigned until December 29, 1950. The drawings were all completed and on their way to the Jobsite by the first week in January,1951.

Station 140 - Engebi, The Aomon Group, and E+- NRLK. This station involved special design work within the 200 foot tower cab on Eberiru.

One feature involved provision of an equipment housing of lead blocks within the tower cab. This lead blockhouse was then further shielded with steel plate tanks which were to be filled with water. NRL designed and furnished all material for this installation. H & N assisted NRL in the design of the tanks for the water shielding and also furnished help for the construction work. The other feature of the work involved was providing apertures through the cabs, walls and roof for NRL's Ganex experiment. This required revision of the framing of cab walls and roof to provide for these openings. Two columns supporting the bridge crane rails and the cab roof had to be removed to clear the openings required. A considerable part of this work had to be done by the Engineering Department at the Jobsite because information on the holes and clearances was not received until after the tower was shipped.

Stations 141a and b - Engebi, The Aomon Group, and E+- NRLK. Adjacent to the zero tower was a wooden frame building 14 feet by 35 feet. This was divided into two rooms - 141a being a vacuum pump room and 141b the relay rack station. The exterior sheathing was of corrugated aluminum. The preliminary design data and sketches were furnished by the User on July 7, 1950. On July 11, 1950, the User relocated the building. Further changes were forthcoming when the User submitted new design data on November 9, 1950. On October 27, 1950, the AEC submitted the power and dehumidification data for 141b and on December 1, 1950, added another door to 141a.

Stations 142a and b - The Aomon Group - NRLK. This building containing the two stations--142a for magnet power supply and 142b for a work shop--was the same as 141a and b for design and dates for data. The size was slightly larger, being 14 feet by 40 feet.

Station 142c - Engebi, The Aomon Group, and E+- NRLK. This station was a trailer furnished by the User.

Station 143 - Engebi, The Aomon Group, and E+- NRLK. At the base of the zero towers it was necessary to have a pit to provide working space for terminating and joining the coax cables that went either up the tower or out away from the tower. This pit was assigned the station number 143. The enclosed space was approximately 16 feet by 10 feet. The bottom was 5 feet 3 inches below grade, and the top of the coral concrete walls were at grade. A 4 foot wide ramp sloped from station 141a into 143. A sump pump was provided at the Aomon Group to drain the pit. The first design data were furnished on July 7, 1950. Four days later the station was relocated. On August 9, 1950 the User submitted some more sketches of the station. On October 24, 1950 the User changed the opening for the cables from 10 inches by 3 feet to 12 inches by 4 feet. The last revision came on November 9, 1950 when the User forwarded his latest location drawings and design data.

Station 144a - Engebi, The Aomon Group, and E+- NRLK. This station was a limonite blockhouse 4 feet by 6 feet by 7 feet high inside dimensions to hold the Ganex tubes. This was another structure with limonite concrete walls (3 foot thick side walls) and roof (4 feet 6 inches thick) and a coral concrete foundation (14 feet by 14 feet 6 inches by 2 feet 6 inches deep). The front face of the structure contained 16 alignment tubes. A rack to hold the tubes was fabricated in the United States in order to assure the close tolerances required by the User. The rack was then held in place by forms and the limonite poured around it. The back wall was left open until a few days before the test, then it was filled with 8 inch cube limonite blocks so as to form a backwall 4 feet thick. The limonite concrete required amounted to 58 cubic yards per station. This structure was dehumidified by equipment located in the building that housed 144b.

On July 5, 1950, prior to the receipt of any design data, a lead door was requested by the User. This was discarded when the limonite block type of opening was proposed. On October 27, 1950 the AEC approved the User's letter which gave the design data.

On November 27, 1950 the User furnished the layout of the station for E+. On November 29, 1950 it was found necessary to move some of the minor structural members of the zero tower in order to give the Ganex tubes a clear sight at the zero point.

Station 144b - Engebi, The Aomon Group, and E+ - NRLK. AEC approval of the design data was given on October 27, 1950 for this wooden hut used in conjunction with 144a. The building consisted of two rooms - one 10 feet by 10 feet by 8 feet 6 inches high that was Station 144b proper, and one 6 feet 6 inches by 10 feet by 8 feet 6 inches high that was an equipment room for the dehumidification equipment. The entire building was sheathed with corrugated aluminum. Station 144b proper was given a vapor seal to help the dehumidification.

Station 145, 146 - Engebi, The Aomon Group, and E+ - NRLK. On December 4, 1950, a sketch was received showing the User's requirements for collimating towers for Ganex. Two towers were required on each site to support lead shields between station 144a and the zero tower. Three days later, on December 7, 1950, designs and plans were completed for the towers and the material was placed on order. The User furnished the shields and adjusting devices for the shields. All material was erected by H & N under supervision of the User.

Stations 160 through 166 inclusive - Engebi; Stations 167 through 174 inclusive - The Aomon Group; and Stations 175 through 180 inclusive - Runit-EG&G. These stations were 30 foot telephone poles which carried reflectors furnished by the User. No design was required, and the locations were obtained from the J-Division Instrumentation Chart.

Stations 190 and 191 - Eniwetok; Station 192 - Rigili - EG&G. Small photo huts were needed by the User. The least expensive structure that would meet the needs was chosen. This was a wood frame building 8 feet by 9 feet with a roof sloping from 9 feet above the concrete slab at the front to 8 feet in the back. The sheathing was corrugated aluminum.

Stations 301a, b, c, e, i, j, and k - Engebi; and Stations 301d, f, g, and h - Muzin - Military Structures Program. The recorder shelters for the Military Structures Program were originally conceived as small, underground vaults approximately two feet, six inches square, extending approximately two feet, seven inches deep. As time progressed and the program equipment became firm it was evident that a building of substantial size would be required which, in order to avoid distortion of shock and pressure patterns in the vicinity of the structures, would have to be underground. Definitive criteria on sizes of shelters, locations, power requirements, and disposition of equipment were provided on April 5, 1950. Each shelter was divided into two rooms, one for batteries and the other for electrical equipment. Access to the rooms was through the roof via separate square man holes provided with standard man hole covers. The lengths of the rooms varied in accordance with the number of recorders and timing racks located in each station. Thus, the recorder rooms of Stations 301a, d, e, g, and k were 7 feet long; 301b, c, f, and h were 11 feet long; 301i was 18 feet long; and 301j was 23 feet long. Battery rooms in all stations, other than 301i and j, were 4 feet long. The excepted cases were 6 feet long.

Wall thicknesses for the 301 series stations varied from 1 foot, 3 inches down to 8 inches in accordance with the distance of the station from zero. Shelves were provided in the battery room, and in the equipment room of each station a 12 inch wide shelf was hung 6 inches below the ceiling along the center line of the long axis of the room to act as a cableway and support for instrumentation cables and power cables. Ventilation of these stations is covered in Chapter 5.19 of this volume.

Stations 302a, b, c, and d - Engebi - Military Structures Program. These stations were blast proof, camera mounts provided with wing walls. The walls of these stations were two feet thick, the wall facing the structure under camera observation being provided with a flared, rectangular port. The port was furnished with a special glass window which protected the cameras installed in the stations from shock and radiation. The glass was fitted into a special lead lined assembly designed from rough sketches provided by the User. Access to the inside of the stations was provided through the top of each station and this accessway was closed during tests by means of a laminated steel lid. Provision was made for the positioning of a swivel rig for handling the steel lid. Small underground concrete vaults with steel tops were positioned adjacent to the camera stations to serve as containers for batteries which provided power to the cameras. Stations were streamlined by placing an earth fill against the side facing zero, the earth fill being stabilized with a thin layer of gravel.

Stations 302e through h, and j through r - Muzin - Military Structures Program. These stations were camera stations, but in view of the increased distance from zero, it was possible to use a pedestal-type mount two feet square by four feet high on top of which was placed a steel wall cubicle box two feet on each side, the side facing the structure under observation being left open.

Station 303a - Engebi - Military Structures Program. This station was a wood frame, aluminum sheath building, approximately 20 feet square, used as a "dry locker" in which delicate scientific equipment could be unpacked without danger of damage by the tropical conditions at the site.

Station 351 - Kirinian - Civilian Defense. This station served in the tests of various types of glass and sash. A representative came to Los Angeles in January 1951 and checked with the H & N structural department as to the design of the frame building he had drawn to hold the window sash. He stayed in the Los Angeles area until fabrication of the unit was completed and shipped. Approval for erection of the unit at the Proving Ground was authorized by the AEC on January 29, 1951.

Stations 421 and 423 through 429 inclusive - Engebi; Stations 4210 through 4212a - Muzin; Station 4213 - Kirinian; Station 4214 - Bokonaarappu; Stations 4215 and 4216 - Teiteiripucchi; Stations 4217 through 4221 - Eberiru; Station 4222 - Aaraanbiru; Station 4223 - Piiraai; Stations 4224, 4225, and 4226 - Runit - AFCRL. These stations were all 2 1/2 foot cube steel boxes made of 1/4 inch or 1/2 inch plate depending upon the overpressure at the various locations. The sketches of these boxes were sent to H & N by J-Division around the middle of May, 1950. The drawings were made, and bids were let for the box fabrication by June 14, 1950. On June 23, 1950 J-Division telephoned the information that the User was going to handle the purchasing, so drawings were sent to him and H & N orders were canceled. On July 28, 1950 J-Division deleted E-422, added E-4212a, D-4221a, and C-4226. On February 19, 1951 the AEC moved 4224a, b, c on Runit because of conflict with the coaxial cable ditch.

Stations 511 through 513 - Engebi - Program 5 Users; Stations 5141 through 5163 - Engebi - Program 5 Users; Stations 5171 through 5182 - Muzin - Program 5 Users; Stations 519 and 5192 - Bogon - Program 5 Users. These stations were the same as the station 74 series. The locations and description were obtained from the LASL Instrumentation Chart. Station 5182 was added on September 9, 1950 by J-Division. Stations E-5163, S-5173, S-5174 were added to the program on October 14, 1950 by the AEC.

Stations 591a and b - Runit and The Aomon Group - NBS. To provide a small, but dust-protected work area near stations 54 and 57 respectively, a 6 foot by 10 foot by 6 1/2 foot high wood frame building sheathed both inside and outside with plywood was designed. The two work benches across the ends of the building were provided with electrical outlets. These stations were added to the program by J-Division on June 14, 1950. Minor changes involving lights and openings were made by the User on August 10, 1950.

Stations 592a, b, c, and d - Engebi and Runit - NBS. These were standard 14 foot by 28 foot tents over wood frames. They served as workshops and covered storage areas. 592b was provided with a concrete slab; the rest had earth floors. J-Division approved the addition of these stations on June 14, 1950. 592a and 592e were relocated by the User on August 10, 1950.

Stations 593a, b, and c - Engebi and Runit - NBS. To cover the batteries that were required by stations 52 and 53, a wooden console was used. The console was a wood frame 14 feet 9 inches by 6 feet 3 inches by 2 feet 6 inches high sheathed on the exterior with plywood. This was mounted on a concrete slab. One end was hinged for access. These stations were added to the program on June 14, 1950 and relocated by the User on August 10,1950.

Stations 6101 through 6104 - Engebi; and Station 6105 - Muzin - CWS. This was a 3 foot by 3 foot by 3 foot hole in the ground with a 4 inch thick concrete slab at the bottom. At the time the User placed his equipment, the hole was backfilled with concrete. This requirement was given to H & N on May 23, 1950 by J-Division. The concrete base was added on January 5, 1951.

Station 622 - Engebi - NML; Station 624 - Muzin - NRDL; Stations 625a and 626 - Kirinian - NRDL. These stations were racks for exposing various samples during detonation. The racks were designed and furnished by the User. Information on the location of these stations was furnished by AEC October 14, 1950. 622 was deleted on February 17, 1951 by the AEC contract administrator.

Station 623 - Muzin - NML and NRDL; Stations 625 and 626a - Kirinian - NRDL. These instrument shelters were buried reinforced concrete buildings having inside dimensions of 5 feet by 8 feet by 7 feet 6 inches high. The building floors were set 2 foot 6 inches below final grade; the rest of the structure being covered with soil to a level with the roof on the two sides and back. The front side had four openings; two were 2 foot 5 inches by 6 inches, and two were 1 foot 3 inches by 8 inches. Two 6 inch diameter pipe vents were set in the roof. Four steel shelves 12 inches wide were fastened to the walls by brackets. The drawings were completed on November 1, 1950 and approved on November 28, 1950. Approval to relocate 623 was given on February 27, 1950.

Stations 621, 623a, and 624a - Muzin - NRDL. Fastened to a wing wall of military structures 3.3.4 and 3.3.3. were a series of incendiary test panels. The User did all of the design work required. 621 was originally on Military Structure 3.1.1; however a letter from AEC moved it to 3.3.3 on October 14, 1950. On December 19, 1950 it was deleted from the program entirely by the AEC.

Stations 623b and 624b - Muzin; Stations 625b and c - Kirinian; Stations 626b and c - NRDL. These stations were camera mounts and were the same as Station 302e; therefore no new drawings were required. The station description and locations were furnished by AEC on October 14, 1950. Additional information on location was given by J-Division on October 27, 1950.

Stations 6311 through 6351 - Engebi - BRL/APG. The User furnished all of the parts of these stations except for the power outlets that were needed. 6321 was relocated on December 8, 1950; 6341, 6342, and 6321 were relocated December 13; and 6321, 6322 on January 5, 1951 by the AEC Resident Engineer.

Station 771 - Engebi; Station 772 - The Aomon Group; Station 773 - Runit; and Station 774 - Bogombogo - USC & GS AFOAT. On April 17, 1950 J-Division furnished H & N with sketches and design data for this group of buildings to house seismographs. The structure consisted of two compartments, one being the seismograph room and the other an entrance well. The entrance well was 5 feet 6 inches square and 7 feet three inches deep with a cover made up of two hinged doors. The seismograph room was 6 feet square and 6 feet 6 inches deep, the entrance into the room being through a standard 2 foot 2 inch by 5 foot 6 inch blast door located in the common wall between this room and the well. The seismograph room had a coral sand floor. The instrument was mounted on a block of concrete 5 feet square and as deep as was necessary to bond it securely to the underlying coral bedrock. The whole structure was streamlined using a coral fill covering so as to minimize the building vibration due to the air shock. All of the walls and roof of this structure were 12 inch reinforced concrete, except for Station 774, which was 1 foot 4 inches. The drawings were approved, except for minor pipe changes, on June 28, 1950, by the User. On October 9, 1950, the AEC deleted 774.

Station 775 - Eniwetok - USC & GS AFOAT. This building served the same purpose as 771. However, due to its extreme distance from the experiment islands, the construction was wood frame and wood sheathed inside and outside. The sketches and design data were furnished by J-Division on April 24, 1950. The interior dimensions were 6 feet 3 inches square by 6 feet 10 inches high. The building was placed above ground, and no earth fill streamlining was used. The seismograph block was the same as for Station 771--5 inches square and deep enough to bond the block to the coral bed rock. These drawings were also approved by the User on June 28, 1950.

Station 811 - Engebi; Station 812 - The Aomon Group; Station 813 - Runit; and Station 814 - Eniwetok - AACS. These stations were radio beacons. Originally it was thought that no H & N design or construction would be needed because the User was to furnish all requirements. However, on November 3, 1950 the AEC Resident Engineer requested a concrete slab 6 feet 6 inches by 7 feet 4 inches be set at each site. He also relocated the stations on that date.

Station 821 - Engebi; Station 822 - Muzin; Station 823 - Teiteiripucchi; and Station 824 - Bokonaarappu - AMC. These stations were a series of concrete foundations for aircraft sections undergoing test. Most of the sections were fastened to 8 inch beams, which were in turn bolted to the foundation. Each station had a group of six major foundations varying in size from 10 feet by 16 feet by 3 feet deep to 6 feet by 9 feet by 1 foot deep. Two smaller pads, 3 foot 8 inches square were also included. These 8 units were spread over an area of 181 feet by 14 feet. The tops of all the foundations were level with the ground. A dust palliative was specified for the area approximately 315 feet by 200 feet around the foundations. The original design data and sketches were furnished by J-Division on April 27, 1950. The User's representative submitted revised sketches on May 5, 1950. On July 3, 1950 the User deleted three of the 8 inch beams and several of the J-bolts which were embedded in the concrete.

Station 825 - Engebi; Station 826 - Muzin; Station 827 - Teiteiripucchi; Station 828 - Bokonaarappu - AMC. These were the recording stations for the 821 through 824 stations. Originally they were designated 821a through 824a, respectively, but on June 7, 1950, J-Division assigned the new number designations. The interior size of these four stations was 8 feet by 10 feet by 6 feet 6 inches; however, the materials and structural elements varied considerably depending upon the distance from zero. The closest station, 825, was reinforced concrete with all four sides, roof and floor slab 1 foot 4 inches thick. Access was through a 2 foot 2 inch by 5 foot 6 inch blast door. Station 826 was the same as 825 except the concrete thickness was only 12 inches. The floors of both these stations were approximately 3 feet 6 inches below grade, and the rest of the building was covered to the level of the top of the roof with earth. Stations 827 and 828 were far enough away from the blast center so that a wood frame building with 2 inch by 8 inch boards for exterior sheathing and roofing and 1/2 inch plywood interior paneling would suffice. All of the exterior was covered with a skin of aluminum sheeting. Because these wooden buildings were set 3 feet 6 inches below grade, it was necessary to use redwood framing and sheathing. The floor slab for Stations 827 and 826 was a concrete pad 10 feet 2 1/2 inches by 12 feet 2 1/2 inches by 12 inches deep. All four of the stations were equipped with a 9 foot 8 inch by 2 foot 6 inch wooden work bench and a 3 shelf rack 4 feet high and 3 feet wide. These recorder stations were connected to the 821 through 824 station by a 6 inch conduit so that the instrument cables could be buried. The 6 inch conduit stopped in a junction box 4 feet short of the center pad of the 821 series, and 3 inch conduit went from there to the aircraft sections. The sketches and design data for the stations were furnished on June 7, 1950 by J-Division. Until that date, the verbal instructions had been to use the same design as for the 301 stations.

SPECIAL EQUIPMENT FOR SCIENTIFIC STATIONS

In addition to designing and preparing drawings for the installation of dehumidification and ventilating equipment for certain of the Scientific Stations (For a description and history of this, see Chapter 5.19 of of this volume.), the H & N Mechanical Engineering Department also participated in the design and preparation of drawings for special equipment for NOBL (Naval Ordnance Laboratory and Ballistics Research Laboratory). This equipment consisted of the following:

For Stations 20 and 21: Steel field panels for the blast walls.

For Station 27: Concrete gauge mounts.

For Stations 28 and 29: Instrument posts.

For Stations 33 and 34: Steel stake gauge mounts.

For Station 36: Gauge mounting plate.

For Station 37: Steel pylon assembly and pylon auxiliary.

In October 1949, instructions were received from J-Division to prepare drawings for a special piece of equipment called a "field panel" for NOBL. H & N was furnished with drawings prepared by the Naval Ordnance Laboratory to use as a guide in the preparation of its drawings. The field panel consisted of two 8-foot by 5-foot steel panels set parallel and held one foot apart by steel rod spacers welded to each plate. The steel panels were cut out to receive three cylindrical steel chambers and one rectangular steel chamber. Chambers were inserted into the assembly through the cut-outs and were welded at each end to the steel panels. The ends of the steel chambers were machined to receive steel closure plates, of special design, which were held in place by means of machine screws.

Early in November, 1949 NOL proposed that a meeting be held between the NOBL engineers and H & N to firm up the design. However, in a telephone conversation between H & N and J-Division on November 16, it was decided to postpone the meeting until later. Meanwhile, drawings were completed and quotations were obtained from two or three local manufacturers in order to get an idea of the cost of a field panel.

On January 30, 1950, a meeting was held at the Naval Ordnance Laboratory, Silver Spring, Md. Attending were engineers from NOL, BRL, and a representative of H & N. The design and manufacture of the field panels were discussed, and some slight changes in design were made. A marked set of prints of the NOL drawings was given to the H & N representative and brought back to Los Angeles to be used in revising H & N tracings. NOBL stated that 21 field panels would be required; 18 for the Field, 2 spares, and one to be delivered as a sample to NOL.

Also at this meeting various other items of special equipment required by NOBL were discussed, and prints of NOL drawings were given to H & N to use in preparing drawings for these items. These included velocity instrument posts and two different types of ball crusher gauge mountings. NOBL stated that a total of 44 instrument posts, 150 steel stake gauge mounts, and 15 concrete gauge mounts (12 for Field, 2 spares and 1 for NOL) would be required.

The velocity instrument post was an assembly consisting of a piece of curved 3-inch pipe cast in a concrete block set flush with grade, with a 3-inch pipe extending approximately 10 feet in the air above grade.

One type of ball crusher gauge mounting (concrete gauge mount) consisted of a 30-inch square steel plate, 3 inches thick, machine-grooved to a depth of 1 1/2 inches to receive a 4-inch wide by 33 1/2-inch long steel plate, which was held in assembly with the larger plate by means of a positive latching device at each end. Four 1 1/2-inch diameter holes were bored in the smaller plate, and four 2 1/4-inch diameter by 18-inch steel cans fastened to the larger plate, to receive the ball crusher gauges furnished by the User (NOBL). In the Field, this assembly was to be set flush with grade and anchored to a 6-foot deep concrete block by means of twenty-four 3/8-inch diameter anchor rods fastened to the underside of the 3-inch thick steel plate.

The steel stake gauge mount consisted of a 6-foot long, 2-inch diameter steel stake, tapered at one end and threaded at the other end to receive a threaded steel cap. In the Field, this assembly was to be installed by driving it into the ground as far as the threaded cap, which was then to be removed and replaced with a ball crusher gauge furnished by the User (NOBL).

On February 10, 1950, H & N was instructed verbally by J-Division to prepare final engineering drawings for the entire group of previously mentioned NOBL special assemblies. These drawings were prepared, and prints of them were sent to J-Division on February 16, 1950 for approval. H & N was also instructed to proceed with the manufacture of one field panel, one steel stake gauge mount, and one concrete gauge mount and have them sent to NOL at Silver Spring, Md. However, on February 20, 1950 instructions were received by telephone to hold up fabrication of the field panel (blast wall tank) until further notice, as the design would probably be changed. This was confirmed in a letter of February 24, 1950. By letter of March 6, 1950 H & N was instructed to fabricate one field panel and deliver it to NOL, Silver Spring, Md.

By letter of April 17, 1950 H & N received sketches of an additional assembly required by NOBL. This was a gauge mounting plate, consisting of a rectangular steel plate (18 inches by 12 inches by 1 inch thick). This plate was blank, except for eight 3/8-inch drilled and tapped holes and eight anchor rods to anchor the plate to a concrete base in the Field.

Eleven of these assemblies were required. The J-Division letter of April 17 also stated that before procuring any of these assemblies prints of H & N drawings were to be forwarded to them for approval. This drawing was prepared, and prints were forwarded to J-Division on May 11, 1950.

On June 25, 1950, at a meeting in Los Angeles, representatives of J-Division, NOL, and H & N discussed in detail the NOBL program. The NOL representative had brought with him from Washington marked-up prints of H & N drawings which had been forwarded to NOBL by J-Division. H & N was instructed to correct its tracings and send prints directly to NOBL for approval. H & N was further instructed as follows:

Stations 20 and 21 (Field Panels). Take bids on 16 assemblies, but wait for approval of H & N drawings by NOBL before awarding a contract.

Station 27 (Concrete Gauge Mounts). Take bids on 8 units, and procure same.

Stations 28 and 29 (Instrument Posts). Take bids on 50 units and procure same.

Stations 33 and 34 (Steel Stake Gauge Mounts). Take bids on 90 units and procure same.

Station 36 (Gauge Mounting Plates). Take bids on 11 units and procure same.

Also on June 28, 1950 H & N was furnished with NOBL sketches of Station 37a, b, c, (Pylon) and Station 37d, e, f (Ground Pylon Auxiliary) by NOL, and instructed by J-Division to prepare drawings and send prints to NOBL and J-Division for approval. These drawings were prepared and prints were sent out on July 13, 1950.

The Pylon consisted of steel plates bolted on structural I-sections to form a steel tank 15 feet long by 15 feet high by 6 1/2 inches wide and constructed in five sections to facilitate transporting and handling in the Field. The center section contained four cylindrical steel chambers open on one end to receive steel closure plates similar to those used in the Field Panel assembly. In the field, the Pylon was set upright on a concrete pad and securely anchored thereto.

The Ground Pylon Auxiliary consisted of a 14-inch diameter by 18-inch long steel chamber set vertically in a concrete block. The lower end was closed, and the upper end was open to receive a steel closure plate similar to those used on the Field Panel.

Also on July 13, 1950 prints of the revised drawings for Stations 20, 21, 27, 28, 29, 33, 34, and 36 were sent to J-Division and NOBL for approval and to the H & N Construction Department for use in obtaining bids and procuring those items for which approval had been received.

On July 19, 1950, in a telephone conversation with H & N, the J-Division representative stated that H & N drawings of the Field Panel

(Stations 20 and 21) had been approved, subject to minor corrections by NOBL. The drawings were revised and prints issued to the H & N Construction Department for initiating procurement.

By letters of July 15 and July 20, 1950, NOL transmitted sketches to H & N showing the special drillings required in the closure plates for the Field Panels. The drawing affected was redrawn, and prints were reissued to the Construction Department immediately in order not to delay fabrication of these assemblies. By letter of August 15, 1950 from NOL, H & N received sketches of the Pylon closure plates. This necessitated the preparation of a drawing to be issued to the Construction Department for use in the fabrication of the necessary plates. By letter of August 28, 1950 from NOL a sketch was received of a Ground Pylon cover plate. Again the H & N drawing affected was revised and reissued to the Construction Department.

On October 2, 1950 a representative of NOL visited Los Angeles for the purpose of inspecting the Field Panel and Pylon assemblies being fabricated. A number of questions that had arisen in regard to the manufacture of these assemblies were satisfactorily answered at that time and H & N drawings were corrected to show the necessary changes.

On October 23, 1950 a representative of NOL again visited Los Angeles to inspect the first Pylon and Field Panel assemblies. He stated he was pleased with the outcome of the inspection of these panels. At this same time he informed H & N that the circular cover plates for these assemblies should be boxed separately and sent to a location to be designated later.

On October 25 instructions were received from NOL to ship certain of the plates to BRL at Aberdeen Proving Ground, Md., and others to NOL at Silver Spring, Md. The remainder were to be shipped to the Field and held in a warehouse for NOBL.

On November 10, 1950 the plates for NOL were shipped by R.R. express, and on November 20 those for BRL were shipped air express.

This completed the work of the H & N Engineering Division in the Home Office in connection with these assemblies.

INTERIOR WIRING FOR SCIENTIFIC STATIONS

The Reconnaissance Report of January 1949 discussed the condition of the existing scientific stations as to electrical wiring and made recommendations for repairs for those structures being considered for reuse. Scientific requirements were not determined at this time, and consequently no designs could be prepared for the facilities. The Supplemental Report dated July 8, 1949 did not add any information with regard to these facilities.

The first design criteria was received in May 1950, and the first drawings were released in June 1950. Because of the fact that the majority of these structures were to be of concrete construction designed for use in more than one experiment, it was decided that type TW wire in concealed and/or surface mounted galvanized rigid steel conduit would be used for wiring.

A large number of Users were concerned with the operation of these experiment stations and their design criteria was cleared through J-Division. Since some of these Users were unable to forward their complete design criteria in time to meet the construction schedule, it was necessary to estimate their requirements and provide wiring and equipment in advance. J-Division concurred with this and, on the basis of their preliminary instrumentation criteria furnished the early part of August, 1950, all basic panels and special circuit breakers, switches, etc., were ordered.

Cancellation of stations 132a, 132b, 132c, 141, 142, 143, and 144, on Runit resulted in the first reassignment of panels on August 17, 1950. Final criteria was received from J-Division on October 12, 1950, as a result of which additional panels were ordered for stations 140 and 144 on the Aomon Group and Engebi. A final reassignment of power panels allocating each panel to the structure it would best serve was issued on December 14, 1950. All materials purchased for this phase of the job were tagged "SCISTAT" for identification purposes of shipping and storage and were used only for the Scientific Stations.

In order to assure a low voltage drop together with good voltage regulation for the instrumentation loads, it was decided to serve these loads from a separate transformer bank. The utility loads such as lighting, dehumidifiers, etc., were grouped together on a second transformer bank. This arrangement reduced the possibility of utility load fluctuations affecting the instrument circuits.

The utility system was supplied at 120/208 volts, 3-phase, 4-wire through type MO circuit breaker panels for lighting and through fusible switch panel containing circuit breaker main for power. The fusible switch type of panel was used for power distribution in order to provide flexibility in circuit arrangements and ease of changing ratings.

Lighting fixtures installed were vapor-proof type without guards except in a few cases where globe was omitted because of low ceilings.

The instrumentation circuits were supplied through a converti-fuse type panel containing main switch. Switch sizes used were 30, 60 and 100 ampere rating and ample link-type fuses and fuse-reducers were furnished to permit easy changing of fuse ratings. In other words, a 100 ampere switch could be fused at 10 amperes by using the proper size fuse reducer. This flexibility proved to be of great value during the actual operations.

Receptacle strips were installed in Stations 6a, 69, and 132a, b, c. These "plug-in" strips were cut to desired length and assembled with 2 and 3 wire receptacles. The assembled "strips" were mounted on the surface of the station walls. The purpose of these strips was to provide power for the Users' operational equipment.

120/208 volt direct burial service cables entered the stations through conduit sleeves which extended from the panel pull-box to just beyond the outside paved area. These cables were 600 volt, multiconductor, type RJ, installed between transformer and panel.

At stations 141 and 142 and the 132 Series on the Aomon Group and Engebi the User (NRLK) requested special circuit breakers. These were type AK-1 manually or electrically operated, with time delay, overload protection, instantaneous short-circuit trip and undervoltage trip.

CHAPTER 5.13

WATERWORKS SYSTEMS

The Reconnaissance Report outlined in considerable detail the water supply requirements and tentative design criteria applicable to the various island installations of the Proving Ground. By the time final design and working drawings for these installations were undertaken, the following basic factors and governing conditions were recognized:

1. Waterworks plant and systems installed would be no more extensive than could be justified on a two-use basis; i.e., the service required by the conduction of two complete series of atomic weapons test programs.

2. Each island installation would require its own individual waterworks.

3. Brackish water would be supplied to outlets not requiring potable water. This service would include wash down outlet, toilet flushing, fire protection service, and similar connections.

4. Fresh water for each island installation would of necessity be obtained from the distillation of brackish water obtained from the sea or from shallow dug wells.

5. The use and therefore the production of distilled water would be minimized by supplying such water only to outlets requiring potable water; i.e., lavatories, drinking fountains, showers, mess halls, photo laboratories, CMR and NRLK buildings, laundries, animal runs, and similar service connections. Thus a dual or split water distribution system would be required in some instances.

6. Further conservation of the use of distilled water would be accomplished by maintaining minimum permissible operating pressures upon the distribution systems.

7. In the interest of flexibility of construction, operation, and maintenance of the waterworks systems, items of equipment would be standardized where feasible. This would permit maximum interchangeability of units of equipment and produce optimum operating results.

8. Rain water collection as a supply of fresh water was not considered to be feasible because of the radioactive contamination hazard existing in the atoll and because the quantity of water which would be made available would be insufficient.

ESTIMATED PER CAPITA WATER CONSUMPTION

On the basis of experience and engineering judgment, estimates were made of the amounts of water needed each day for each man. It was assumed that personnel quartered in aluminum barracks would use 50 gallons of brackish water and 50 gallons of distilled water per man per day and that those quartered in tents would use 50 gallons of brackish water and 35 gallons of distilled water per day. These assumptions could not be checked because no comparable installations had been erected.

ESTIMATED TOTAL RAW WATER SUPPLY ALLOWANCES

It requires two gallons of brackish water to produce one gallon of distilled water, one half of the water supplied to the still being lost in the distillation process. Therefore an additional amount of raw water equal to the amount of distilled water had to be taken into the system to provide for the intake requirements of the stills. In addition, the generation of electric power required a relatively large amount of water (measured by percentage of total water requirements) for cooling purposes. (The details of power generation and cooling for power generation equipment are discussed in Chapter 5.15 of this volume.) Water requirements for cooling varied with the fluctuations of generation of power. A flat allowance of 70 gpm for each generator installed, less one, was made for this requirement. Consequently, raw water intakes and pumping stations were required to handle the total of raw water domestic use, plus two times the distilled water use, plus the electric power generation cooling water.

WATERWORKS SYSTEM DESIGN

In general, the hydraulic characteristics of the design of all island waterworks systems were similar. The detailed design and arrangement of the component parts varied in conformity with the particular requirements for each island, with little if any modification of the functions of these component parts. Each system consisted of the following integrated features:

1. The raw water intake took raw brackish or salt water into the system for distribution as salt water and for conversion to fresh water.

2. The salt water pumping station placed the salt water supply system under pressure by discharging salt water through a pipe or pipe network to elevated storage.

3. The salt water distribution system received the discharge from the salt water pumping station and transferred this water to the elevated storage tank, simultaneously distributing salt water through outlets or service connections to facilities requiring this service. Fire hydrants for operation in conjunction with mobile fire pumper apparatus were

provided on Eniwetok and Parry Islands for limited fire protection service. The temporary character and small size of other installations did not justify installing elaborate high pressure fire protection facilities.

4. The salt water elevated storage consisted of storage in a bolted steel tank (procured from Navy surplus supplies at Pearl Harbor) mounted on a wood tower of sufficient height to maintain desired operating pressure upon the salt water distribution system. Fifty foot towers were used on Eniwetok and Parry Islands and 30 foot towers at all other locations. Wood towers resisted the climate and could be erected by semi-skilled workmen. The elevated tank rode or "floated" upon the system and thus equalized static pressure throughout the distribution system. This tank simultaneously acted as a governor which permitted the system to operate at all times under the wide range of conditions caused by the summation of drafts upon the system as total output, and the constant rate or rates established by the raw water pumping units acting singly or in combination as total input. Tank sizes throughout the Proving Ground were standardized, where feasible, to take advantage of surplus Navy stocks at Pearl Harbor.

5. The distillation equipment consisted of a battery of compression type stills on each inhabited island for conversion of salt water to fresh or potable water. Each battery of distillation units was supplied from the salt water distribution system. This connection constituted the largest single draft upon that system. The manufactured product of these units (distilled water) was then transferred to surface storage tanks. For flexibility of design and installation, new distillation units were standardized in capacities. Two sizes, 85 gph and 600 gph, were specified throughout the Proving Ground installations. The sizes specified were chosen because the 85 gph units were readily available for procurement and the 600 gph units were the largest practical size for installation at Eniwetok. Larger units were much more complex in operation, and would introduce unnecessary problems in transportation, operation, and maintenance. In order to make available a sufficient supply of fresh water for construction forces, rapid procurement of the 85 gph units was essential in order to supplement the salvaged stills located on the Atoll and rehabilitated by H&N personnel. It might be noted at this point that the salvaged stills mentioned were later used as auxiliary units during peak population periods.

6. Chlorination of distilled water was provided to further safeguard potable water from contamination. Small hypochlorinators which permit the use of solutions mixed on the job for supplying the chlorine for disinfection were used to inject the chlorine solution into the fresh water system at a point in the

line of flow between the distillation units and the fresh water storage tanks. The additional security and protection was considered justified in view of the minor additional cost of this equipment and of the materials required for operation. Hypochlorinators have a wide capacity range and hence were standardized. Individual installations varied in accordance with the size of the meter used. The meter constituted the actuating device for control of rate of application of the sterilizing solution.

7. The fresh or distilled water surface storage tanks received the product of the battery of distillation units and furnished the source of supply for the fresh water pumps. This fresh water was accumulated and stored in tanks at ground elevation. Equalization between varying rates of distillation caused by the varying number of units in simultaneous operation and the varying rate of demand upon the fresh water pumping station was accomplished by the elevated storage tank.

8. The fresh water pumping station functioned in a manner similar to the salt water pumping station and differed only in capacity and the kind of water pumped.

9. The fresh water distribution system functioned in the same manner as the salt water distribution system and in general paralleled that system in extent and location. There were no cross connections between these systems; therefore there was no possibility of contamination.

10. The fresh water elevated storage functioned in a manner similar to the salt water storage, both storage tanks being placed upon a common elevated platform surmounting the common supporting tower.

ENIWETOK WATERWORKS SYSTEM

Raw water intake consisted of a vertical well-like structure 4 feet, 6 inches in diameter, constructed of prefabricated concrete pipe. The intake well was located just off shore on the lagoon side of the island near the northerly end of the island. From the bottom of this structure a short section of 15 inch pipe extended into the lagoon. This pipe conducted the sea water into the intake well, which was also the terminal point of the suction lines of the raw water pump station.

The raw water pump station was located ashore just south of the intake and housed the salt water pumps. This equipment consisted of three electric-motor driven, horizontal centrifugal pumps, each having a capacity of 300 gpm and one standby gasoline-driven horizontal centrifugal pump with a capacity of 300 gpm. The electric motor-driven pumps were equipped for automatic control of operation, the starting and stopping sequence of each pump being regulated by preestablished water levels in the salt water elevated storage tank. Two pumps operating in parallel would thus furnish the volume required by a fire pumper unit connected to a fire hydrant.

The salt water distribution system consisted primarily of a network of 6 inch and 4 inch transite pipes buried underground. Where feasible, the system was designed as a "looped" system to provide maximum flows with a minimum loss of pressure head. Isolated areas and buildings scattered along the shore line or located at the extremities of the island were served with a single pipe supply line with requisite branches serving the individual facilities. Later changes in location of structures and additional facilities did not seriously affect the main distribution system but simply required extensions to it or relocation of service connections.

Atomic weapons test operations required that there be made available at the drone plane parking area at the airfield on Eniwetok a supply of both salt and fresh water at a rate of 125 gpm under 50 psi pressure for washdown of drone planes. A small booster pump station, housing one 125 gpm salt water and one 125 gpm fresh water pump, was designed to provide this service. It was located at the southerly end of the island, near the cargo pier, and was arranged to take suction from the distribution line of the main system for supply and to discharge into the same line under added pressure. The station was manually operated. Check valves installed in both salt and fresh water lines between suction take-offs and points of discharge permitted the lines to function under the added pressures exerted by the pumps.

The salt water elevated storage tank was procured from Navy surplus stocks at Pearl Harbor and designed capacity was predicated upon sizes available. The tank for Eniwetok consisted of a two ring tank and had a rated capacity of 1000 barrels (42,000 gallons). The tower structure was located in the heart of the housing area near the north end of the island. It was 50 feet high. Because the ground contour of the island was essentially level, the height of the tower plus the additional head established by the minimum operating level of the water in the tank surmounting the tower provided approximately 25 psi static pressure upon the system. This pressure was considered the minimum for proper operation of the system. Maintaining the system at minimum pressure tended to eliminate waste, leakage, and excessive usage.

Distillation equipment finally designed and procured for the Eniwetok fresh water system comprised eight 600 gph units. The total daily rated capacity of these units was 115,200 gallons per day. The design population criteria was 756 persons housed in quarters and 1080 housed in tents for a total of 1836 persons. Estimated requirements for this population of 1836 men was 75,600 gallons per day. The difference between full rated capacity of 115,200 gallons per day and estimated consumption of 75,600 gallons per day was conceived as a tolerance or flexibility factor providing for one or more units for standby service, reduced number of hours of the operation schedule, and for shut-down periods of units requiring necessary periodic or emergency maintenance.

Because the final design and construction of the facilities on Eniwetok Island was undertaken relatively late in the program of development of the Proving Ground, due to changes in military requirements, insufficient time was available for the normal procurement of additional distillation equipment needed to cope with continuing increase in population. The military construction batallion brought to Eniwetok approximately 27 portable type, 150 gph distillation units for support of its initial field operations. Eight of these units were later installed as an additional battery to supplement the permanent distillation units during the peak period of test operations.

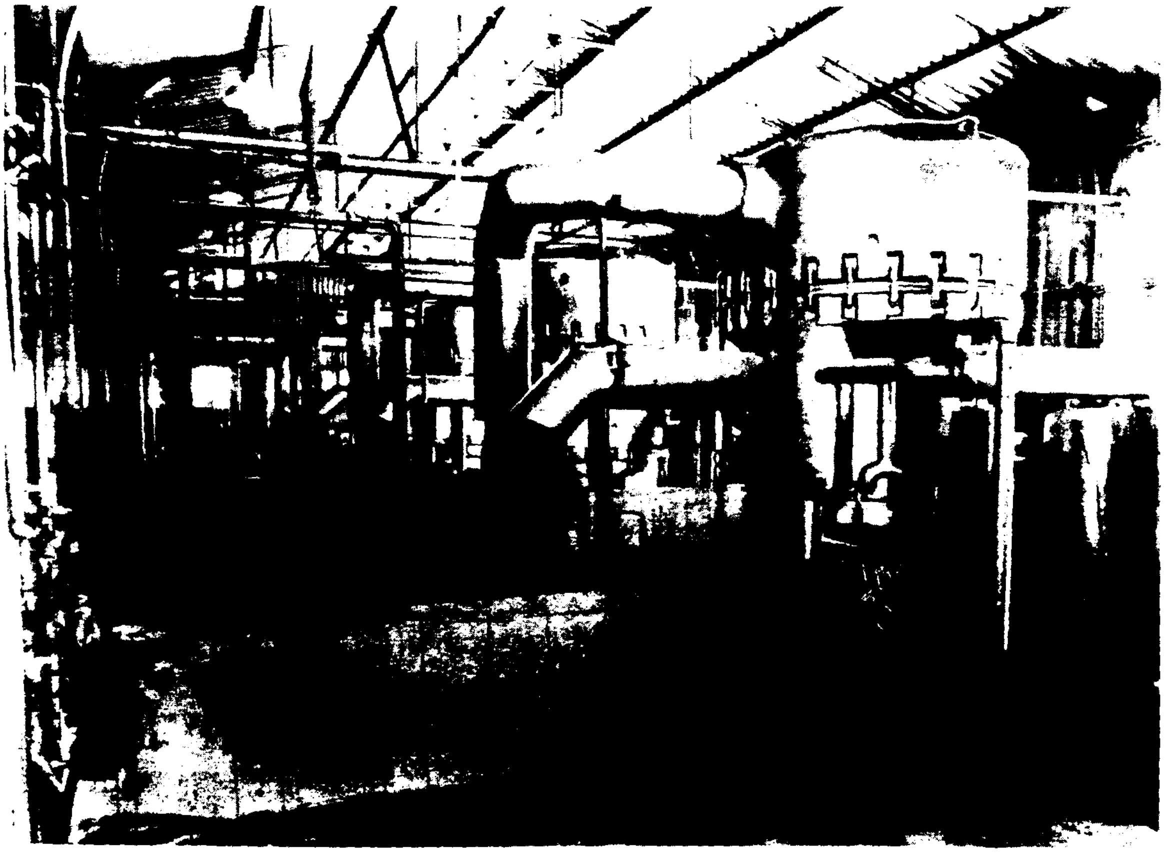
Design for a water barge-to-shore pipe line was prepared which would permit ships moored in the lagoon to supply water to the shore installation as an emergency source of fresh water in the event that it might be required. However, portable type stills and permanent units sufficed for all requirements.

Distilled water was chlorinated at a point in the line of flow between the discharge of the distillation units and the fresh water ground storage tanks. For this purpose, a small hypochlorinator was housed in the distillation building. The solution containing chlorine was mixed and stored in a drum and the hypochlorinator automatically injected the solution into the line of flow in proportion to the rate of flow. The proportioning and control of the rate of application of the chlorine solution was accomplished by means of a 3 inch meter installed in the 3 inch distillation discharge line.

Fresh water surface tanks were procurred from surplus naval stores at Pearl Harbor, and design of storage facilities was likewise predicated upon sizes and capacities available. Two 1000 barrel (42,000 gallons each) bolted steel tanks were provided at ground level adjacent to the distillation plant. Fresh water pumps for supplying the fresh water distribution system were housed within the distillation building and took their suctions from the fresh water surface storage tanks located adjacent thereto. Fresh water pumps consisted of two 100 gpm, electric motor driven horizontal centrifugal pumps and one standby 100 gpm gasoline engine driven horizontal centrifugal pump. The operation of these pumps was controlled by the liquid level of the elevated fresh water storage tank.

The fresh water distribution system consisted primarily of 6 inch, 4 inch, and 3 inch transite pipe mains arranged in a network similar to that of the salt water distribution system and in general paralleled that system. As with salt water distribution system, changes in locations of buildings or addition of additional buildings required only the relocation of service lines or extensions to the main network system. The fresh water elevated storage tank was placed on the platform of the 50 foot tower which supported the salt water elevated tank. This elevated fresh water tank was similar to the bolted steel salt water tank and had a capacity of 500 barrels (21,000 gallons).

Parry Island: Interior of Salt Water Pump House



Parry Island: Distillation Units in Power House

PARRY WATERWORKS SYSTEM

Raw water was taken into the system from a dug well located within the salt water pump station at the northwesterly corner of the site, adjacent to the power and distillation plant. The water from this well was brackish and was considered as salt water for distribution and use. The well was lined with precast concrete pipe four feet, six inches in diameter. Salt water pump suctions extended to a point below the drawdown level of the liquid surface of the water.

The salt water pump station was essentially a duplication of the Eniwetok installation, being equipped with three 300 gpm electric motor driven horizontal centrifugal pumps and one standby 300 gpm gasoline engine driven pump. Operation was automatically controlled by liquid levels of the salt water elevated storage.

The salt water distribution system consisted of a looped network of 6 inch and 4 inch pipe line covering the area upon which improvements were located.

Salt water elevated storage consisted of one 1,000 barrel bolted steel tank mounted on a 50 foot wooden tower, a duplication of the installation on Eniwetok Island.

Original design of the distillation plant on Parry Island provided three 600 gph distillation units with space for a future unit. Increased population later required the utilization of this space by the installation of a fourth unit and the provision of additional space to accommodate eighteen portable units temporarily connected to the system. The distilled water was chlorinated before storage in surface tanks.

Two 500 barrel bolted steel tanks were originally designed for surface storage of distilled water. Partly as the result of requirements imposed relatively late in the program in connection with the photographic laboratory and the CMR Building on Parry Island, a 187,000 gallon concrete storage reservoir was later constructed to permit accumulation of surplus distillation capacity for subsequent use during peak periods coincident with test operations.

The fresh water pumping station was housed in the power generation and distillation building. Pumping equipment consisted of two 100 gpm electric motor driven horizontal centrifugal pumps and one standby gas engine driven pump of similar size and capacity. Pumps were controlled by liquid levels of the elevated storage tanks.

The fresh water distribution system consisted essentially of 6 inch, 4 inch, and 3 inch transite pipe, and in general paralleled the salt water distribution system. Elevated fresh water storage was provided in a 500 barrel bolted steel tank mounted on the common platform of the 50 foot wooden tower, which also supported the salt water elevated storage tank.

OTHER ISLAND WATERWORKS SYSTEMS

The design of the waterworks systems for Runit, the Aomon Group, Engebi, and Japtan followed the same general pattern of the design of the systems on Eniwetok and Parry although on a much smaller scale. Fresh water and salt water pumps were installed within the blast proof power houses to prevent damage during tests. Table 5.13-1 shows equipment and facilities designed for these sites and delineates the comparative size and scope of the various systems.

TABLE 5.13-1 WATERWORKS FACILITIES ON EXPERIMENT ISLANDS

Equipment	Runit	Aomon Group	Engebi	Japtan
Salt water pumps, 300 gpm, electric	1	1	1	1
300 gpm, gasoline	1	1	1	1
Salt water storage, 100 bbl. 30 foot tower	1	1	1	1
Distillation units, 85 gph	2	2	2	4
600 gph	-	-	1	-
Hypochlorinator, 2 inch meter	1	1	1	1
Fresh water, surface storage, 100 bbl.	1	1	1	1
Fresh water pumps, 100 gpm, electric	1	1	1	1
100 gpm, gasoline	1	1	1	1
Fresh water elevated, storage, 100 bbl. 30 foot tower	1	1	1	1

Rojoa (Aomon Group) and Runit waterworks systems were designed for populations of two hundred persons each.

In addition to normal domestic requirements, a gasoline engine driven centrifugal pumping unit with a capacity of 250 gpm at 50 psi discharge head was provided for wash-down of the winch cable after weapons test operation. This pumping equipment was housed in a small blastproof structure. The pump took its suction from a shallow dug well cased with 3 foot concrete pipe.

The Engebi waterworks system was originally designed to serve a population of 340 persons. In general design, it was similar to the works for Runit and Rojoa, but larger distillation plant capacities were provided because of the larger population design figures. To supply the population, which doubled the anticipated number, four portable stills located adjacent to the mess hall were used. These were removed shortly before test detonations. This island also was provided with cable wash-down pump installation.

The Japtan waterworks systems compared generally in scope with those designed for the experiment island camps. Facilities, however, were of a more permanent nature and the buildings covered more area than did those on the experiment islands, even though the population design figures were less. The larger area was due primarily to the detached location of the animal colony development. Since there were to be no blast effect, a separate salt water pump station after the pattern of the designs for Eniwetok and Parry was provided. Original design contemplated provision for 150 persons; this figure was later reduced to 80. Actual peak occupancy of the island was 131 persons.

A small pumping station, housing one 100 gpm electric driven centrifugal pump and a 100 gpm gasoline engine driven standby unit was provided for animal run wash-down operations. This station took its suction from the salt water distribution system at a point adjacent to the animal run area and boosted the pressure for wash down service to this area.

WATERWORKS OPERATION

Actual records of distilled water production for each of the island installations are available for the 39 week period from September 3, 1950, through May 27, 1951. Figure 5.13-1 shows this record of production of distilled water plotted graphically. Due to the constant augmentation of the using population, no simultaneous population and production figures for individual islands are available for comparison, with the possible exception of maximum peak periods. Known populations for these short periods may be compared with known maximum peak production figures for the same periods and thus "spot" per capita consumption figures may be calculated. Calculations have been made by dividing the weekly total of distilled water produced by the days of a week for daily production figures and these daily figures have been divided by the maximum number of persons

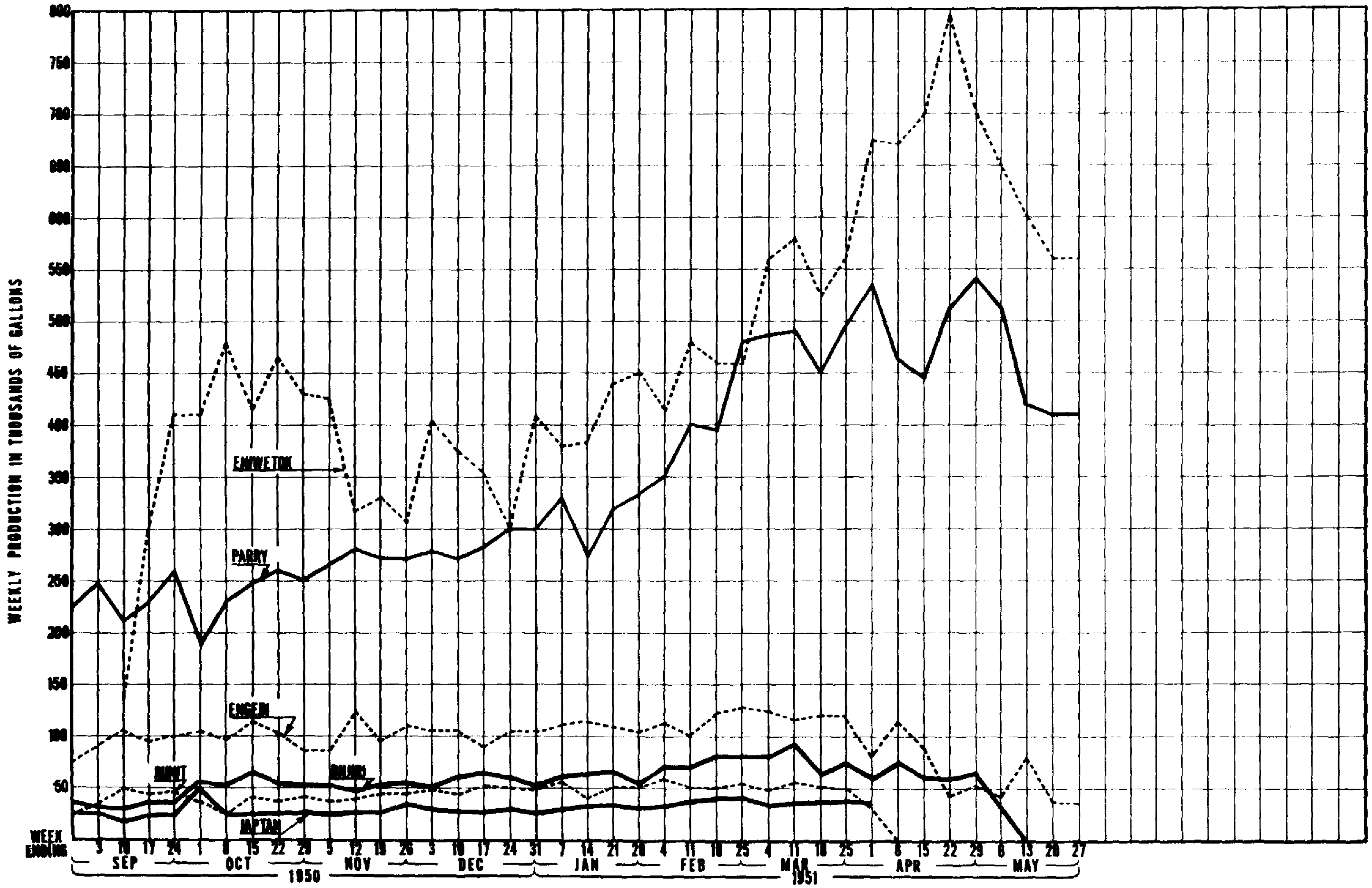


FIGURE 5.13-1 Weekly Water Production

identified with the particular island installation. These "spot" figures indicate that initial assumptions on per capita water consumption were adequate.

TABLE 5.13-2. DAILY PER CAPITA USAGE OF DISTILLED WATER

Site	Max. Weekly Water Production (Gallons)	Daily Avg. Water Production Max. week (Gallons)	Rated 24-hour Plant Capacity (Gallons)	Avg. Peak Period Population	Calculated Daily Per Capita Usage (Gallons)
Eniwetok	800,000	114,300	115,200	2560	45
Parry	585,000	83,600	57,600	1726	43
Runit	60,000	8,600	16,400	216	40
Aomon Group	92,000	13,100	16,400	280	47
Engebi	127,000	18,100	18,500	613	30
Japtan	40,000	5,700	8,200	131	44

Distillation of water on a relatively large scale was generally the result of development for the armed forces during World War II, and although present day equipment is greatly improved over wartime equipment, the vagaries of certain of its imperfections result in interruptions of service which rendered difficult the maintenance of the actual production rate of distilled water at or near the theoretical rated capacity of the installed plant.

In the final stages of the Project, when the influx of population exceeded all anticipations, it was necessary to reservice and reuse all of the advance base type distillation units that were available at the site and which had previously been used by the military and by early contingents of the civilian construction force. Eight were installed at Eniwetok, eighteen at Parry, two at Runit, three at the Aomon Group, and four at Engebi. These old units were subject to frequent mechanical failure and required considerable attention and maintenance; consequently total production from these units was far below total rated capacity. But the net production of these units enabled service to be maintained during these periods of extreme overload.

Additional water storage was also necessary to maintain adequate service through the peak period at experiment time. On Parry Island, this additional storage was provided by the construction of a compartmented concrete surface storage reservoir having capacity of approximately 187,000 gallons. This reservoir permitted accumulation of surplus production prior to the peak and provided the balance of supply required for handling the surcharge upon the system created by the excessive population load. At Eniwetok, a battery of four 1000 barrel steel tanks procured from surplus military supply at Pearl Harbor was installed. Thus, a temporary situation was met by an expediency requiring a minimum expenditure of funds, the basic systems remaining sufficient and adequate for all normal operation, and total costs kept consistent with these overall requirements.

CHAPTER 5.14

SANITARY SEWAGE SYSTEMS

The development of the design of the sanitary sewage system serving the constructed facilities for each island installation was naturally predicated upon the correlation of the building arrangement with the topography of the area in which these buildings or facilities were located. In general, the topography of all improved sites requiring sanitary sewers was similar in that the ground contour of all islands consisted of a comparatively level plane, the elevation of which was but a few feet above extreme high tide. If pumping of sewage was to be eliminated, upper ends of sewer lines would have to be shallow, the lower ends would be as deep as these factors would permit, and the length of any one line would be limited by the allowable gradient consuming the difference in elevation between the surface of the lagoon and the end of the line. Gradients, therefore, were generally established as being the minimum which would produce sufficient velocities of flow for proper functioning of the pipe sewer. As a result of these conditions, lengths of runs were also minimized where possible; thus excessive depths of trenching for the pipe lines were avoided.

The Reconnaissance Report conceived the alternate possibility of utilizing cast iron or transit pipe as a substitute for vitrified clay pipe which is the standard material for this type of service and installing substandard sizes as a compensating economic balance in the total cost. This alternative was predicated upon the probability of excessive breakage in the transshipment and rehandling required by the location of the Project.

During the early design stages, a trial shipment of 3400 lineal feet of 8 inch vitrified clay pipe for initial construction was made to the Jobsite, and although considerable breakage and damage was experienced (approximately 15 percent), an economic analysis indicated that the use of vitrified clay pipe for sewer construction would be the least expensive, and subsequent design specified the use of this kind of pipe. The next shipment involved 40 percent breakage, due primarily to the method of packaging. Vendors were advised and subsequent shipments experienced considerably less breakage, overall job figures reflecting less than 10 percent loss.

The design of all sewer systems followed the pattern established by standard practice, incorporating access manholes at about 400 foot intervals along the line, at breaks in gradient, and at junctions of two or more lines. Wye branches providing for connection with service lines to buildings were inserted in the line at strategic locations. Service connections to individual buildings were constructed of either 4 inch or 6 inch vitrified clay pipe, in accordance with requirements of individual buildings.

Conservation of shipping space and tonnage, as well as of on-site labor, was accomplished by providing manhole shells of prefabricated corrugated galvanized iron as a substitution for brick manholes constructed in place. Manhole shells varied in diameters and heights sufficiently to permit nesting of several shells for shipping and handling as one package.

The factors contributing to the selection of the method of disposal of sanitary sewage and to the design of subaqueous out-fall lines were outlined in the Reconnaissance Report, and are partially reproduced in this section because of appropriateness:

"Ocean Currents. From available information and from observations made on the site, it has been determined that, in general, the ocean currents in the vicinity of the atoll are predominately from east to west, and tend to sweep across the atoll in this direction. These currents are of lesser magnitude in areas wherein the coral reef is unbroken. Between the islands of Japtan and Parry is a section of broken reef which is known as the Deep Passage, the water having sufficient depth to safely accommodate the largest of ships. Across the lagoon almost directly west of the deep passage is a shallow opening through the reef, and which is designated the Southwest Passage, while between these two gaps on the south end of the atoll is a third opening called the Wide Passage. The Wide Passage has considerable depth and provides a convenient outlet for flows entering the lagoon through the Deep Passage. The direction of this flow is advantageous for the disposal of sewage into the lagoon, especially as applied to the Islands of Parry and Eniwetok, the points of greatest concentration. Otherwise the currents tend to sweep the atoll circumferentially in a westerly direction. Sewage from shot island installations will consist of slight volumes, and the general remoteness of these islands from other islands of habitation eliminates much of the hazard of disposing of sewage into the lagoon.

Subaqueous Outfall Sewers. It is contemplated that each island installation will require one or more subaqueous outfall lines to extend the point of discharge of sewage a sufficient distance from shore to preclude any possibility of the periphery of the sleek field from reaching the shore and consequently subjecting the beaches to bacterial contamination. Competent authorities on sewage treatment and disposal have determined that the area of a sleek field is related to the contributing population. From the accepted formula, the area of the field for a population of 600 is approximately seven acres. Assuming the shape of the sleek field to be circular and discounting any distortion of shape due to influence of ocean currents, the radius of this sleek field would be 310 feet. The length of outfall should then exceed 310 feet as measured lagoonward from the water's edge at periods of low tide. The ocean or tidal currents, unquestionably will tend to move the entire field off-shore, but nevertheless, it is considered advisable to allow a factor of safety of 50% of the radius of the field and to establish the lengths of outfall sewers at Parry and Eniwetok at approximately 450 feet. Similarly, the area of the sleek field for a shot island with a population of 200 would be 3.3 acres, the radius of the field 250 feet and the length of the outfall sewer should be established at 325 feet".

The lengths of the outfall sewers for individual installations tentatively established by the Reconnaissance Report were later adjusted for conformity with the designed systems and are covered in the detailed description of the design of each island system.

ENIWETOK ISLAND

The Island of Eniwetok is roughly gourd shaped. The protuberance or bulge at the southerly end of the island was entirely occupied by the airfield and its facilities, leaving only the long necklike portion to the north for development of living quarters and attendant facilities. This area was approximately one mile long and averaged between 500 and 600 feet wide. The elevation of this area varied from 9 to 14 feet above mean low tides, which established the elevation of the datum plane at zero. Maximum high tide occuring biannually was 5.6 feet above this datum, average high tides being about 3.5 feet in elevation. Because of the limiting conditions of elevation, tides, and proportion of length to width of the area, three central points of collection, at approximately equal distances apart and each comprising the head-point of a subaqueous outfall sewer, were required to serve the area. Minimum gradients of .30 percent, equal to .30 feet of slope per 100 lineal feet of pipe, were generally required for the lines that parrelleled the shore line, increased slopes being available in certain instances for lines branching therefrom and serving facilities located on slightly higher ground.

At the southerly end of the island, a small system was provided for the detached group of facilities located on the northwesterly side of the airfield. Individual sewer lines discharging directly into the lagoon through 100 feet or less of subaqueous outfall line were provided for each of the three separated and isolated latrines located along the northwesterly side of the airfield as well as for two detached buildings located on the southeasterly side of the airfield.

Since the two northerly subaqueous outfall sewers served the concentrated area and were to receive the major population load, each was required to be 750 feet in length for adequate protection against contamination of the tidal lands and inshore waters. The only sand bathing beach on Eniwetok Island was located at the extreme northerly tip, adjacent to the lagoon; this was taken into consideration in the design of the sewer system, and the outfall located nearest thereto was strategically placed (considering distance, wind direction, ocean currents, and tides) to minimize possibilities of pollution of the inshore waters and beach.

The third outfall served a much smaller percentage of the contributing total population load and was extended only 300 feet into the lagoon.

All subaqueous outfall sewers were constructed of 8 inch corrugated galvanized iron, asbestos impregnated, double dipped asphalt coated pipe. Individual sections were joined with a band type joint which permitted the outfall sewer pipe to be floated into position before submergence. Excessive costs of submarine construction operations were thus avoided and the installations were made with a minimum expenditure of funds.

PARRY ISLAND

One single unified sanitary system was designed to serve the installations on Parry Island. The site plan had been developed placing outfalls in a location contiguous to the excellent beach facing the lagoon. Protection of this beach from contamination was the prime factor in the design of the system. The flow of sewage had to be directed southwesterly from the site in order that this could be accomplished. Hence the main sewer was slightly longer than would otherwise have been required. Since the available slope was limited, this necessitated comparatively deep trenching for the lower portion of the main collecting sewer. Available slope also would not permit service to a group of ten barracks buildings located adjacent to the reef side of the island. The ground surface of the area in which these barracks were located was raised a maximum of two feet by grading operations, thereby permitting gravity flow service from this area and resulting in generally improved appearance of this and contiguous areas.

The basic design for the sewer system was little affected by the subsequent additions and changes in scope of the work at this site. Primarily, resulting changes in the design of the sewer system involved only the relocation of originally designed service lines or the extension of lateral sewers to serve added areas.

The subaqueous outfall sewer carrying the flow of this system was designed to be 1000 feet long, in accordance with requirements of the population load contributing to this flow and the resulting area of the sleek field within the lagoon.

RUNIT

The construction camp on Runit was located near the southerly end of the island. The extent of the land area available for the development of the campsite was extremely limited and the facilities required irregular arrangement. However, design of the sewer system provided for economical lengths of collecting lines. Location of the site at the southerly end of the island was somewhat advantageous for location of subaqueous outfall sewer, although adequate protection of the beach required an outfall sewer extending 500 feet from shore.

ROJOA

The construction camp on Rojoa was symmetrically and compactly arranged and as a result a single sewer line served all facilities. Location of the site permitted this line to be extended tangentially for location of outfall and disposal of sewage into the lagoon. Since there were no beaches contiguous to the point of disposal, and since the campsite proper was removed therefrom, only 300 feet of subaqueous outfall were required by this installation.

ENGEBI

The construction camp on Engebi was larger than those on other experiment islands and development of the site followed the pattern of an arc described using the location of zero as the center. The facilities and sewer system covered an elongated area. Available elevation for slope of sewers was limited and sewers were required to slope to a central point rather than in one general direction concentric with the axis of the developed area. From this central point the main sewer and subaqueous outfall line extended nearly due south for most advantageous location of the point of disposal. No beach was affected by this installation and only normal protection of adjacent tidal lands from nuisance was required. A subaqueous outfall sewer 500 feet long was provided for disposal of sewage.

JAPTAN

The site of the facilities and installations on Japtan Island essentially consisted of two separate areas, the campsite being located in the northwesterly portion and the animal colony being located in the southwesterly portion.

Ground elevation of Japtan Island is slightly higher than other islands of the Atoll; hence more slope for sewer installation was available. This enabled the design to provide for a single unified system, despite the separated locations and the relatively greater distances involved.

Advantageous location of outfall sewer was at the southerly end of the island near the "Deep Entrance" to the lagoon. From this point the main sewer line followed the shore line to the camp area, serving isolated installations between. The animal colony was located immediately adjacent to the land end of the outfall sewer and service to these facilities was extremely economical. Three hundred feet of subaqueous outfall sewer were provided.

GARBAGE AND TRASH DISPOSAL

Garbage and trash disposal presented no design problems because, in accordance with recommendations of the Reconnaissance Report, no special facilities were provided. Garbage was dumped at sea, and trash was burned in isolated pits provided on the lee side of each camp island.

CHAPTER 5.15

POWER GENERATION

The Reconnaissance Report outlined the power requirements of various islands of the Atoll for construction of facilities to serve utility and experimental loads. It also described the load cycle anticipated for two-experiment use of these facilities. Maximum power demand estimates were made for various sites in order to analyze the over-all power system.

Hydro-electric, steam electric, and diesel electric generating plants were considered. The hydro-electric plant was eliminated because of insufficient elevation for the required head pressure. Steam plants were judged to be too costly, involving expensive building construction and the employment of specially trained operating personnel.

One main plant location to serve all areas was considered and rejected because its use would involve long transmission lines, step-up and step-down transformers, and inefficient operation at all times except the relatively few times when the plant would be operating at full load.

Diesel engine generator plants were finally chosen as the type most suitable for use, with one or more units to be installed at each site. This choice offered a diversified plant which could be operated by experienced diesel engine operators. Because the units were small, they could be salvaged or relocated readily, and the diversification of plants meant that loss of one unit or plant would not result in loss of power throughout the entire site. In addition to the construction of power plants on the three major test sites and the three primary headquarters sites, it was determined that the power requirements at the photo tower locations would be met by portable generating equipment installed adjacent to the photo towers on three sites. Power for the fourth site was supplied by a submarine power cable from the power plant on Runit because the tower was on a reef which was submerged except at low tides. The decision to use separate power plants for the photo towers was made because power lines from island to island might not be dependable at experiment time and because power would be required for the photo towers for a considerable length of time after each experiment. The main power plants on the experiment islands were planned to operate for only a few seconds after the blast. In connection with the power plants for the photo towers, battery chargers and battery equipment were provided so that power would be available as long as needed.

SELECTION OF EQUIPMENT

The selection of the main generating units required very careful analysis of available equipment in order to meet the over-all requirements most economically. A general specification setting forth the major requirements was prepared and submitted to vendors of this type of equipment. Proposals were received from General Motors, Fairbanks-Morse, Caterpillar, and Worthington, and a careful analysis was made, giving consideration to the following factors:

- Total cost
- Cost per kilowatt of firm station capacity
- Cost per pound
- Fuel economy
- Engine speed
- Piston speed
- Standardization
- Maintenance
- Delivery

This analysis led to the elimination of General Motors because of light weight and high speed, and of Caterpillar because of high cost and maximum size limitation of 90 kw. The evaluation of Fairbanks-Morse and Worthington bids was accomplished on the basis of relative importance of the individual criteria listed above. These two proposals were based upon the standard units of each manufacturer. Fairbanks-Morse's bid was upon eight 142 kw and six 118 kw units, while the Worthington proposal was based upon six 237 kw units and six 125 kw units. Either of these proposals would fit the design requirements, and the contract was awarded to Fairbanks-Morse upon the basis of low bid.

The Fairbanks-Morse diesel engine-generators selected were available in three sizes, 5, 6, and 8-cylinder engines, all identical except for the number of cylinders, and providing the maximum interchangeability of parts as well as flexibility in selection of units to fit the load requirements of each plant. The generating capacities of the three sizes were 118 kw, 142 kw and 195 kw respectively, at 80 per cent power factor. All generators were wound for 2400 volts, 60 cycle, 3 phase alternating current when operating at 720 rpm.

The diesel engine accessories consisted primarily of a lubrication oil cooler, lubrication oil filter and strainer, hand pump, gauge board, jacket water heat exchanger, fuel oil hand pump, fuel oil drain tank and heat recovery exhaust silencer. In addition, a make-up water expansion tank was also provided for each engine. Each engine was provided with a 200-gallon fuel oil day tank located outside of the building and connected to each engine by copper tubing under the floor of the plant. The heat recovery exhaust silencer was used to provide steam for the water distillation units. (For description of the distillation units see Chapter 5.13 of this volume.) One starting air system was used to provide air for all engines in any one plant and consisted of one electrically driven and one gasoline engine driven air compressor, together with receivers.

Fresh water was used for cooling the jackets of each engine, in a closed circuit consisting of the engine jackets, closed heat exchanger, pump and piping. Salt water was used to remove the heat from the fresh water, and then wasted. Installation and piping of all units was conventional, and the recommendations of Fairbanks-Morse and of Cleaver Brooks, who furnished the water distillation units, were followed in detail.

Holmes & Narver and AEC representatives agreed that automatic voltage regulation of the primary distribution system would not be satisfactory because of the different requirements of the various Users. Some Users could operate on plus or minus 10 volts variation, while for other Users the value of the secondary voltage was very critical. Accordingly, it was decided that Users whose voltage requirements were critical would incorporate regulators in their equipment design. In this way it was believed that the over-all cost would be lower and the results much more dependable. The use of small individual regulators proved to be very satisfactory.

Fluctuation in voltage such as that caused by simultaneous starting of seven motors in the control tower (Building 310) on Parry Island were corrected by the installation of additional transformers and by balancing the circuits to the power house. In general, the application and removal of large loads which might affect the voltage and the frequency were correlated so that the minimum system disturbance occurred.

Prior to February and March of 1951, no specific requirements as to frequency had been received. During February and March 1951, frequency requirements were developed, the most exacting being that of E G & G who asked for an error of less than 1.0 second in the fifteen minute interval prior to H-hour. This corresponded to 0.111 per cent average error.

PLANT DESIGN

The Reconnaissance Report indicated the number, location, and capacity of power plants then proposed for the Project (see Plate 22, Appendix A, of the present report). Table 5.15-1 shows the number, location, capacity and use of power plants as installed and Figure 5.15-1 shows pictorially the number, location, and capacities of plants. A brief chronology of engineering activities leading to the final selection of generator units, types of buildings and mechanical arrangements follows.

Eniwetok Island. The Reconnaissance Report based upon criteria then available predicted a maximum population for Eniwetok Island of 600 personnel and a maximum electrical demand of 425 kw Supplement No. 1 to the Reconnaissance Report estimated population at between 600 and 2,200, as at that time it was believed that more people would be housed on Eniwetok than the original estimate of 600, although the number was not known. The increase in population, whatever the number, was to be housed in tents. On this basis the increase in power demands would not

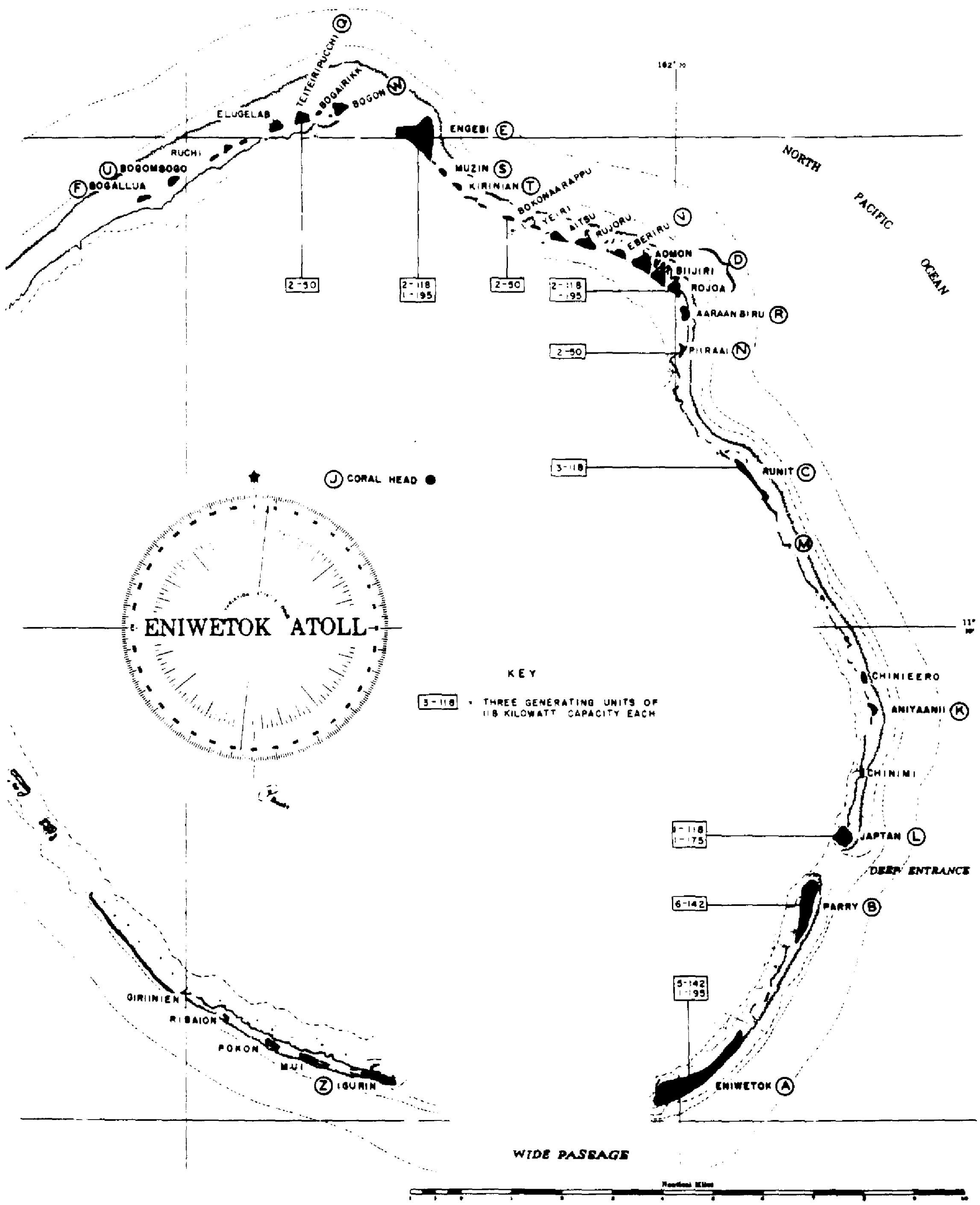


FIGURE 5.15-1 **Map of Power Plants Showing Number, Location, and Capacity Constructed**

TABLE 5.15-1. POWER GENERATION PLANTS

Site	No. Units	Manufacturer	No. Cyl.	Hp	kw	Volts	Plant Max. Capacity	Plant Firm Capacity	Use
Eniwetok	5	Fairbanks-Morse	6	210	142	2400	906	710	Campsite
	1	Fairbanks-Morse	8	280	195	2400			
Parry	6	Fairbanks-Morse	6	210	142	2400	852	710	Campsite
Runit	3	Fairbanks-Morse	5	175	118	2400	354	236	Camp & Sci. Stations
Aomon	2	Fairbanks-Morse	5	175	118	2400			
	1	Fairbanks-Morse	8	280	195	2400	431	313	Camp & Sci. Stations
Engebi	2	Fairbanks-Morse	5	175	118	2400			
	1	Fairbanks-Morse	8	280	195	2400	431	236	Camp & Sci. Stations
Japtan	1	Fairbanks-Morse	5	175	118	2400			
	1	Caterpillar	6	112	75	208	193	75	Campsite
Piiraai	2	Palmer	6	118	50	208	100	50	Photo Towers & Sci. Stations
Bokonaarappu	2	Palmer	6	118	50	208	100	50	Photo Towers & Sci. Stations
Teiteiripucchi	2	Palmer	6	118	50	208	100	50	Photo Towers & Sci. Stations
Portable	10	Caterpillar	6	118	75	208)			
	12	Wisconsin			1	120)			Scientific Stations
	4	Wisconsin			3	120)			Contractors

be proportional. The corresponding maximum electrical demand was estimated to be between 475 and 650 kw. The increase from 425 to 475 kw for 600 population was due to increased communication requirements.

By August 6, 1949, at which time generators were being procured, the estimated population was 1,830 and the corresponding demand for power was 545 kw, which included 45 kw for radio communication. Five 142 kw generators for a total capacity of 710 kw (providing a firm capacity of 568 kw with one unit out of service) were ordered.

In July 1950, the increased power demand of the Task Force Groups living and operating on Eniwetok Island made it necessary to provide a sixth unit for the power plant. This unit was one of the 195 kw units requisitioned on July 3, 1950. The addition of this 195 kw unit on Eniwetok increased the total generating capacity of this plant to 905 kw, with a firm capacity of 710 kw with the largest unit out of service.

Loads continued to increase on Eniwetok Island until, in September 1950, the maximum demand had reached 845 kw. This increase consisted of 652 kw originally estimated, plus 37 kw for five recreational buildings built by TG-3.2, library, hobby shop, athletic club, and a carpenter shop, plus 156 kw for the following buildings: transmitter, 90 kw; reefers, 2.5 kw; warehouses, 20 kw; and Air Task Group, 43.5 kw.

Since the firm generating capacity, with the largest unit out of service, was 710 kw, it was necessary to provide additional capacity. Certain facilities were already provided with standby power generating units, each with complete duplicate back-up units. These were of the following capacities: transmitter, 140 kw; receiver, 5 kw; Loran Station, 35 kw; Air Task Group, 60 kw. In addition, there were also available a number of 75 kw, 208 volt, selfcontained portable diesel engine-generator sets. These portable units were reconditioned, and five of them were placed in service on Eniwetok Island at points of heavy load concentration to reduce the maximum demand on the main power plant to a quantity within its firm capacity. In this manner the total maximum load was supplied.

Inasmuch as the power plant was considered a part of the permanent test base operations at Eniwetok Island, this plant was designed, using the standardized 24-foot prefabricated aluminum buildings which had been selected for all permanent camp buildings. Two standard buildings were erected side by side and 4 feet apart, making a total width of 52 feet. The entire aluminum building was built upon a 6 foot high concrete wall, so that sufficient head room was obtained for the exhaust silencers which were mounted above the diesel engines. The electrical generating equipment was located in one 24-foot wide section and the water distillation equipment in the other, with the 4-foot space between used as a pipe gallery.

The advantages of using generating units similar in design even though the ratings varied and of using distillation units identical in design in all plants became apparent at the time of designing the mechanical arrangements of the equipment. It became possible to standarize many items of piping to make equipment arrangements which were typical for the Eniwetok and Parry plants. Later the arrangement of the equipment in the experiment island power plants was standardized.

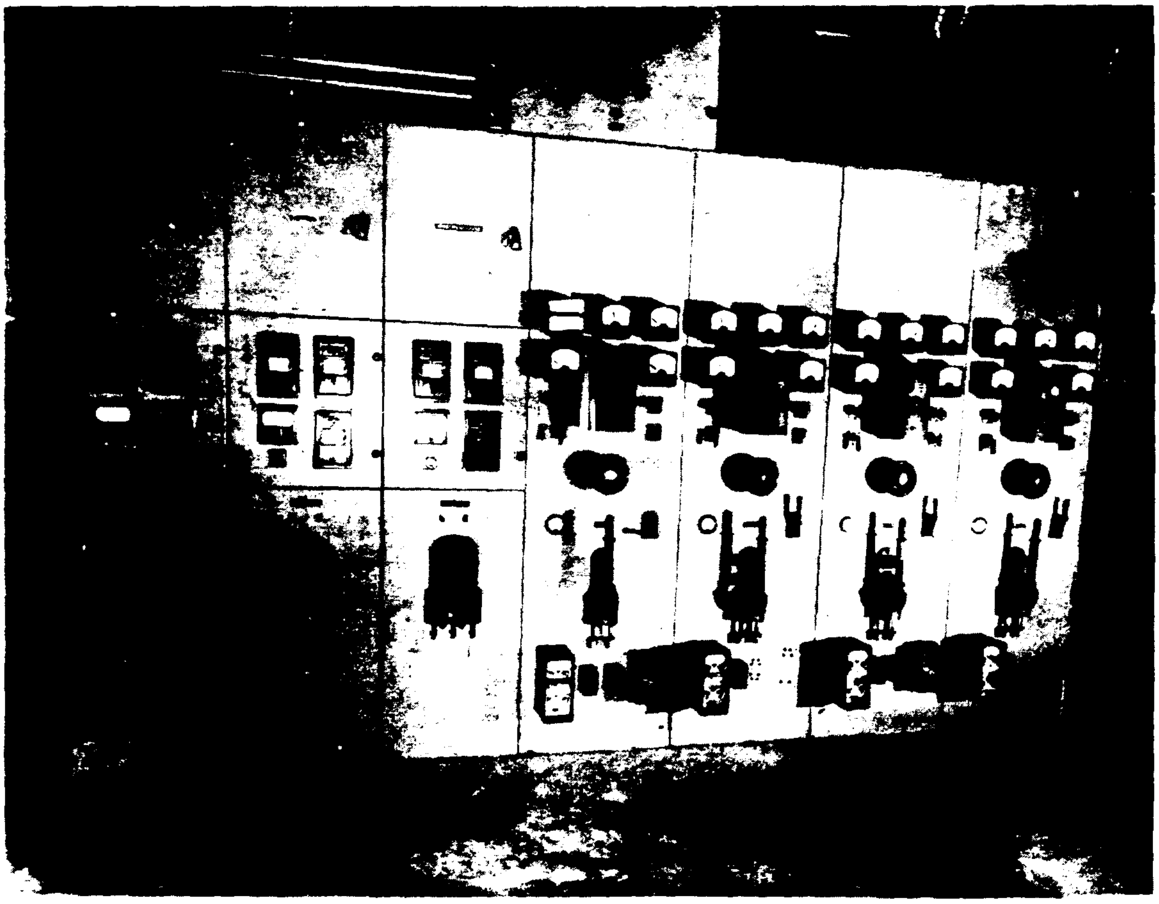
Parry Island. The Reconnaissance Report set up the estimated population for Parry at 600 and the estimated power demand at 300 kw. On this basis, four 142 kw diesel generator units were ordered for this plant, two on July 5, 1949, and two on July 19, 1949. This order was split in two parts because it was not until July 19, 1949, that funds for fiscal year 1950 were made available to Holmes & Narver. The power plant was similar in design and construction to the power plant on Eniwetok which has previously been described. This plant was designed for four 142 kw diesel generator units and a space for one future unit. Information contained in Supplement No. 1 to the Reconnaissance Report indicated an increase in maximum demand from 300 kw to 405 kw due to increase in the requirements for laboratories. Addition of the CMR (Stations 329 and 330) and contemplated enlarged water distillation requirements based upon an increase in population to 1060 people, resulted in the purchase of two additional 142 kw units in February of 1950. Consideration was given to the location of these two additional generator units in the area adjacent to the CMR facilities. However, careful analysis led to the decision to place these two additional units in the main power plant. Space had been provided for one spare unit, and to accommodate the second additional unit, the power plant was lengthened 20 feet. This additional length provided space on the water distillation side of the plant for the installation of the additional distillation units. Power plant drawings were revised, and the extension to the power plant was started in November 1950.

The final station installation of six 142 kw units provided a firm capacity of 710 kw (with one unit out of service) to handle the estimated maximum demand of 690 kw. The type of building for the power house on Parry and the mechanical equipment accessories and piping arrangements were generally the same as for Eniwetok Island. Figure 5.15-2 shows the power and water distillation plant and equipment and piping plan for Parry Island.

Japtan Island. The power plant at Japtan was a typical single bay prefabricated aluminum structure which housed the water distillation equipment as well as the power generating equipment. The portion of the building housing the generator unit was placed on a 6 foot concrete wall to provide the required headroom. Site electrical requirements were estimated to be 75 kw and therefore one 118 kw unit was designed and installed. Space was provided in the power plant for setting up a portable 75 kw unit which had been used on this site during the construction phase. This unit was rated at 208 volts and was installed to serve as a standby when the 118 kw unit was out of service for overhaul.

Addition of electrical loads in the laboratory and shops revised the maximum demand to the extent that the 75 kw unit was not of suffi-

Eniwetok Island: Power House, Bldg. 56



Parry Island: Interior of Power House Showing Switchboard for Generators. Note Feeder Cubicles at Left, Control Cubicles at Right, and Ground Indicator Above.

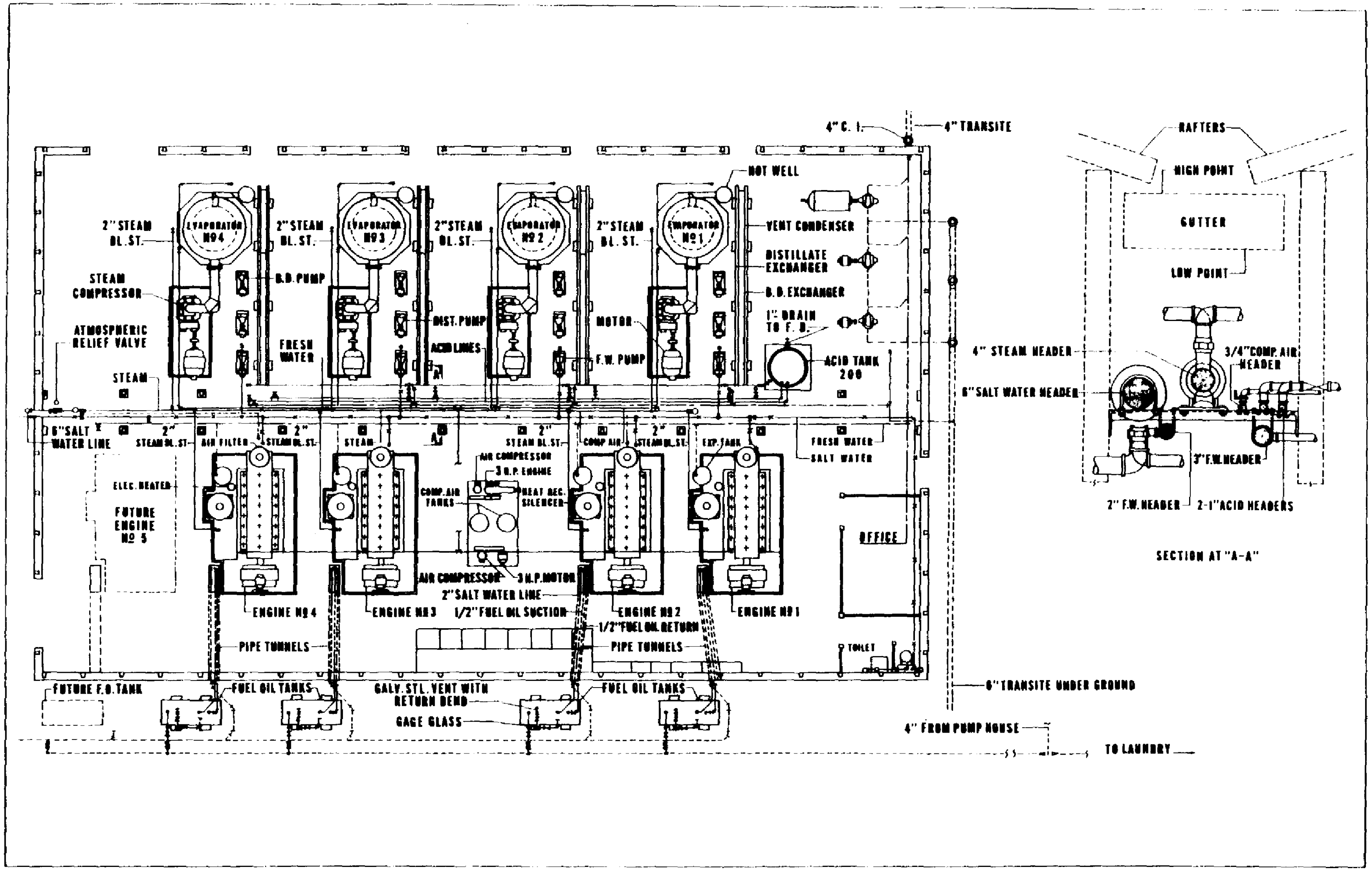


FIGURE 5.15-2 Power and Water Distillation Plant-Equipment and Piping Plan Prior to Additions-Parry Island cient capacity to serve as a standby, although the 118 kw unit could still carry the load. As a result it was necessary to arrange the water distillation schedule in such a manner that it could be shut down while the 118 kw unit was being overhauled. Figures 5.15-3 and 5.15-4 show the power and water distillation plant, equipment and piping plan for Japtan Island.

Runit Island, The Aomon Group, and Engebi Island. At the time of the Reconnaissance Report, the total maximum demand including camp load, utility, and instrumentation demands for scientific structures was estimated at 200 kw each for Runit, Aomon, and Engebi. On this basis each power plant was designed to accommodate three 118 kw units of which two were to be installed, with space for the third unit. During the middle of 1950, the loads required for the experimental islands were considerably increased due to additional experiments to be incorporated in the tests. The indicated increase in power demands made the installation of a third unit on each of the experimental islands necessary, and three units of 195 kw capacity each were requisitioned July 3, 1950. As the electrical demands of the new experiments became firm, it developed that the increase on Runit would not be as great as on Aomon and Engebi and that for Runit the addition of a 118 kw unit would be adequate. One unit of this size was available because it had been procured for an experiment on Bogallua and by this time the Bogallua experiment had been abandoned. Therefore a 118 kw unit was added to the power plant on Runit; a 195 kw unit on Aomon; and a 195 kw unit on Engebi. The third 195 kw unit was used in the power plant on Eniwetok as previously described. Figure 5.15-5 shows the power and water distillation plants and equipment plans for Runit, Aomon, and Engebi; Figure 5.15-6 shows diesel engine pipe for these power plants.

The power houses on Runit, Aomon, and Engebi were designed to withstand the pressures resulting from the experiments in order to insure the proper operation of the equipment installed. All were built of reinforced concrete. The buildings were 42 feet wide by 51 feet deep with a ceiling height of 15 feet. A small mezzanine platform 14 feet by 17 feet was provided in one corner for auxiliary equipment. The walls and roof slabs on Runit and Aomon were 17 inches thick, and at Engebi 18 inches thick. The roof slabs were designed as beamless flat slabs supported on four reinforced concrete columns having flared capital heads and on the exterior walls. The walls were designed to span from the floor slab to the roof slab and special framing was provided around the door openings.

The structures were set partially below grade level and mounded over with earth on three sides to a depth of two feet over the roof slabs. Wing walls were provided at the rear to retain the earth mounding on the side away from zero so that access could be gained to the doors in the rear wall before and after the experiments.

Steel blast doors were provided for two openings, one six feet wide by seven feet high for passing equipment and one two feet, two

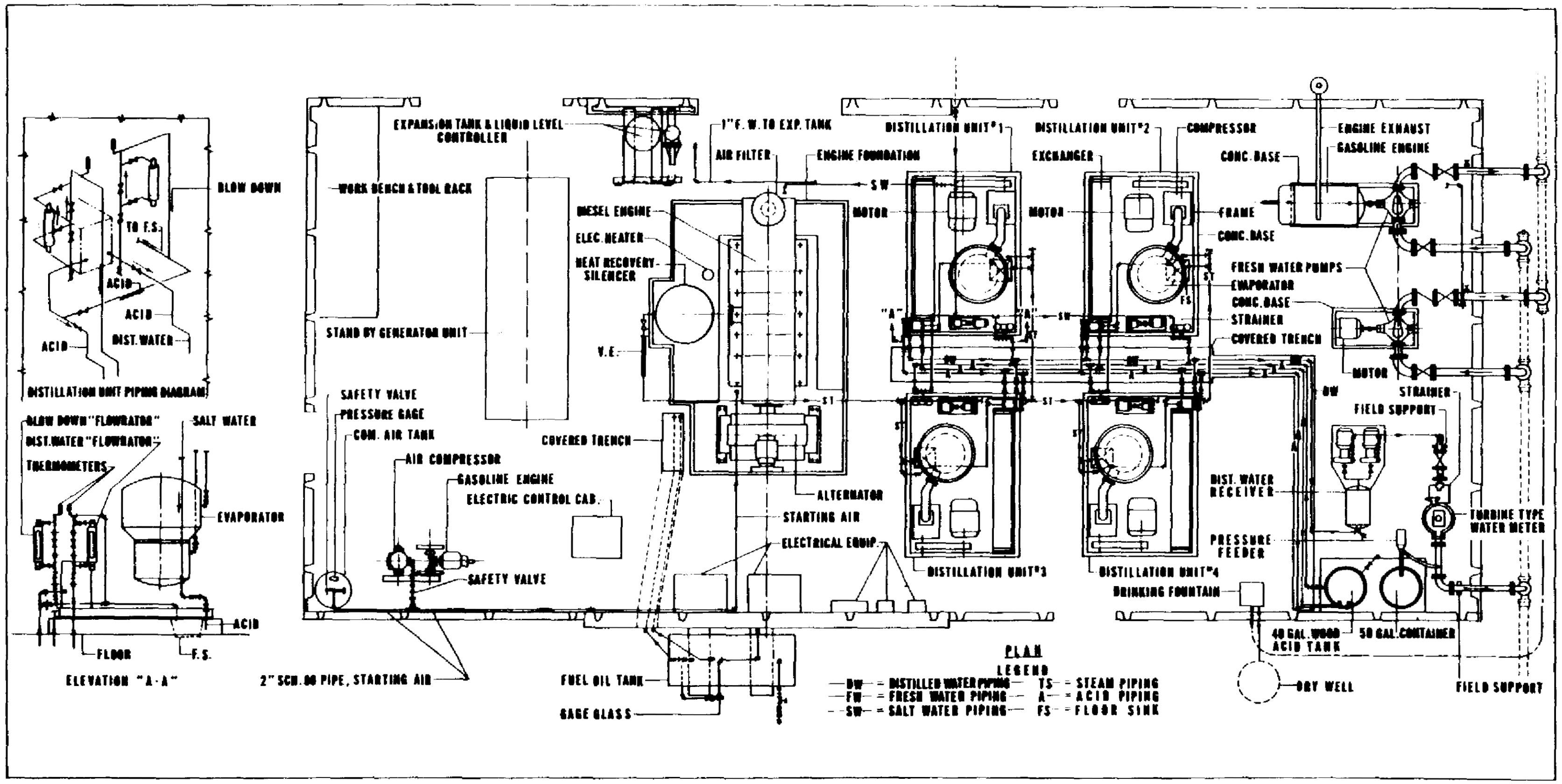


FIGURE 5.15-3 Power and Water Distillation Plant-Equipment and Piping Plan, Japtan Island

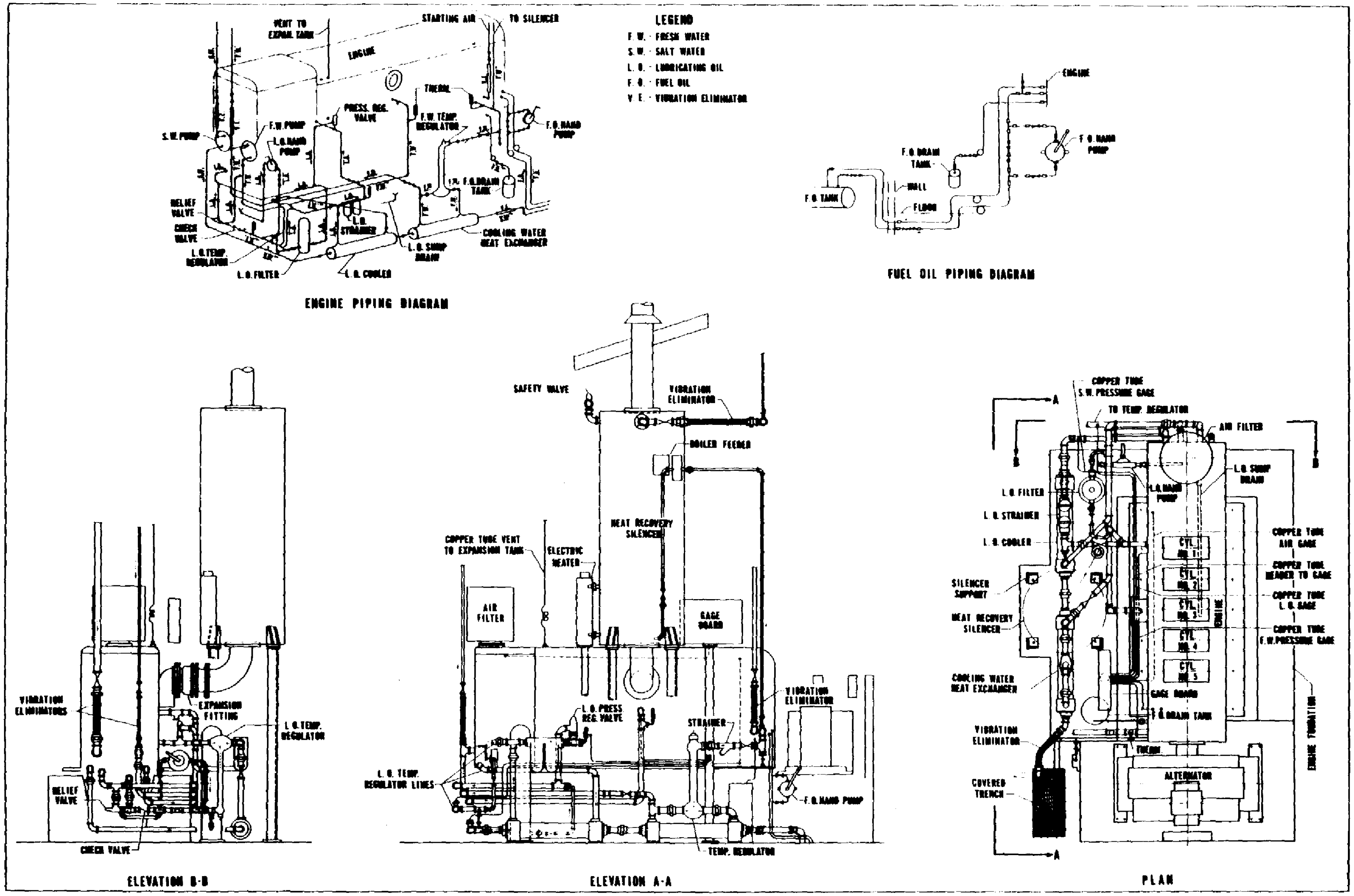


FIGURE 5.15-4 Power and Water Distillation Plant - Diesel Engine Piping, Japtan Island

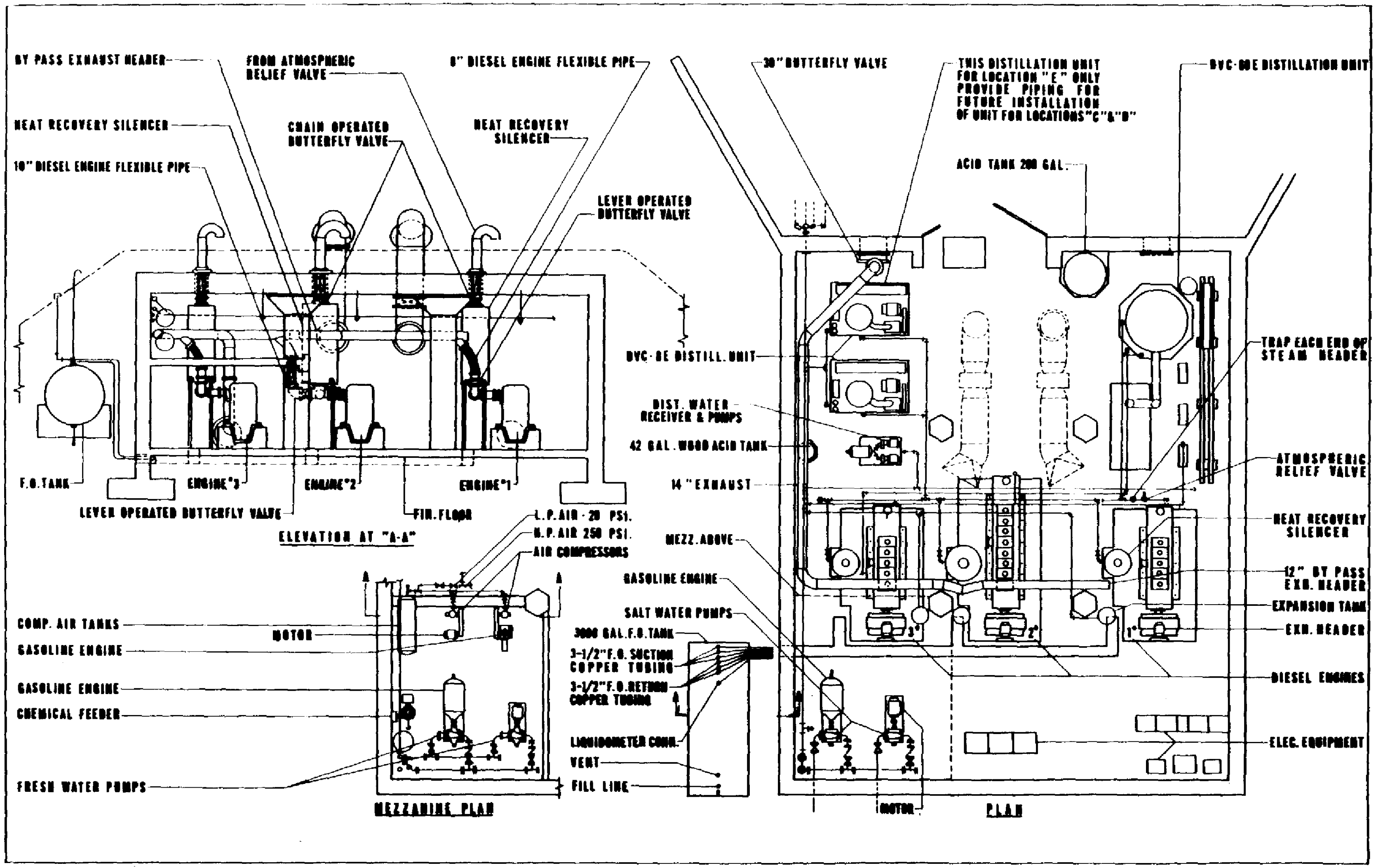
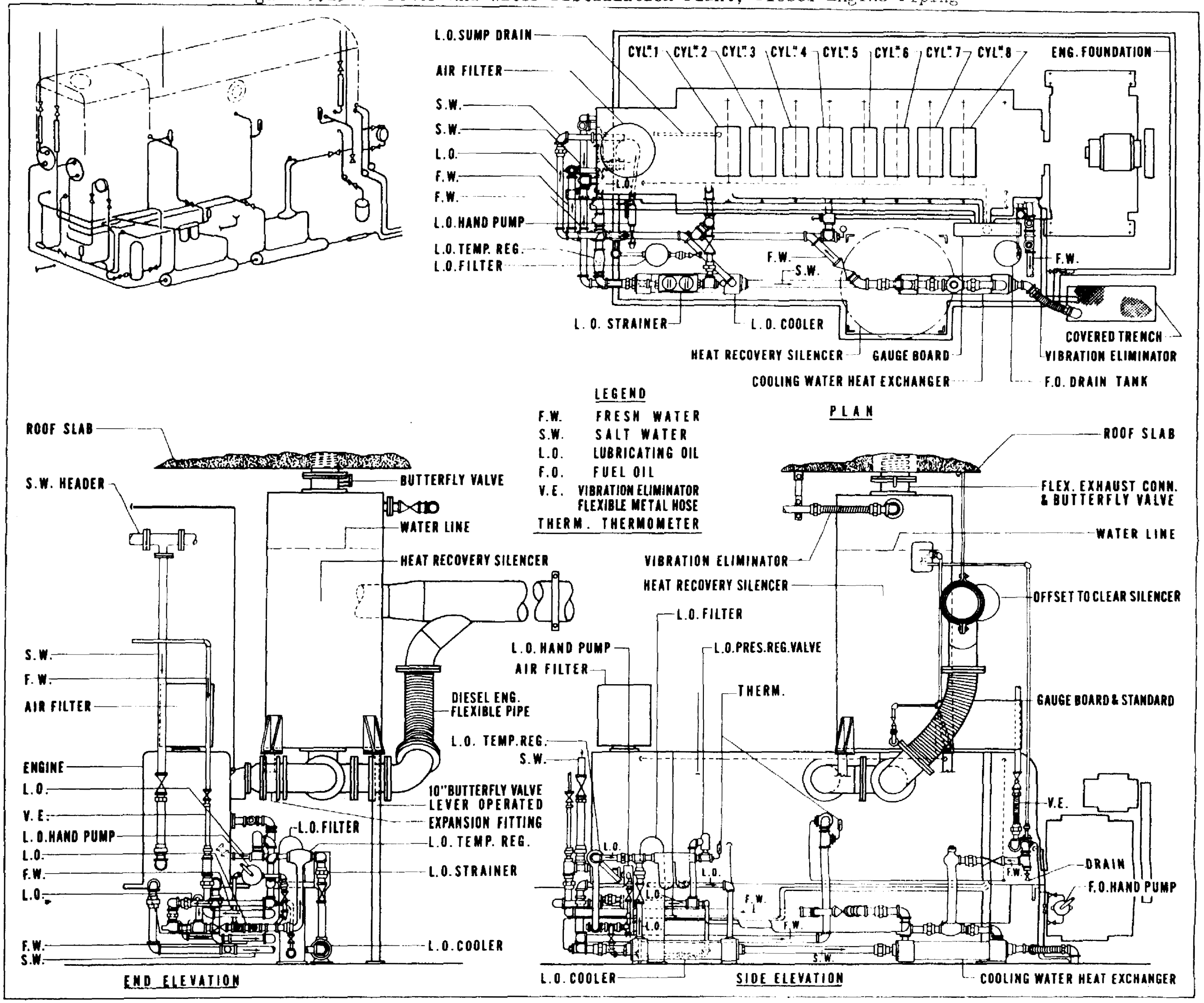


FIGURE 5.15-5 Power and Water Distillation Plant Equipment Layout - Runit, the Aomon Group and Engebi

Figure 5.15-6 Power and Water Distillation Plant, Diesel Engine Piping



inches wide by five feet six inches high for passage of personnel.

The second experiment on Engebi, which was added to the program later, subjected the power house to considerably more pressure than that for which it was designed, and the structure was not oriented properly for this experiment. A check on design calculations indicated that if it was mounted over with earth on all sides the equipment would probably be saved but some structural damage might occur. (See Chapter 5.27 of this volume for an account of blast damage.)

Two ventilated fans were provided near the ceiling in each power plant. The air was taken from outside through intake ducts from above the roof and was directed toward the front of the building and exhausted through openings in the rear wall near the floor. It was a requirement that the power plants on the experiment islands operate unattended for several hours before zero hour and that they then be shut down automatically a few seconds after zero. One air inlet and one air exhaust were each provided with blind flanges which were bolted over the openings before the operators left the plant, while the other air inlet and outlet were each provided with electrically operated butterfly valves. When the operators left the plant after shutting down one ventilating fan and bolting the blind flanges on to one intake and one exhaust opening, the blast doors were tightly closed and the engines were supplied with air by the fan still running. The piping from the engine exhausts was so arranged that they normally exhausted through the building roof, but during an unattended operation the exhaust pipes through the roof were closed and the engines exhausted directly in front of the air exhaust port remaining open. At H-hour minus 30 seconds, a time signal was received in the power plant from the sequence timer which was operated from the control building on Parry Island. This time signal energized a timing system in the power plant which was designed by Holmes & Narver. At H-hour minus 15 seconds, the timing system shut down the ventilating fan and started to close the electrically operated butterfly valves on both the air intake and the air exhaust. The closing of these valves required 10 seconds. From H-hour minus 5 seconds to H-hour plus 5 seconds, the engines operated on the air inside the sealed building and then shut down by another signal that electrically closed the fuel valves.

<u>Bogallua Island</u>. When it was planned in 1949 to use Bogallua for an experiment, a blastproof power plant was designed for this island. The plant was to be in an area of high pressure, and to keep the cost as low as possible, the blastproof building was designed to house only the 118 kw diesel generating unit. An 85-gallon distillation unit, a steam boiler, and the necessary auxiliary units for water distillation were to be located outside the blastproof building, and it was planned to remove these from the island after storing a supply of fresh water, prior to the experiment. The 85-gallon per hour distillation unit was a selfcontained, skid mounted piece of equipment. The building housing the diesel unit with its auxiliaries was to be located partially underground for protection from the blast. The engine piping was typical, except for exhaust piping which, for protection, was to be carried in an

underground exhaust line. Early in January 1950, the Bogallua experiment was cancelled and work on the plans for the power plant was stopped, although the development of these drawings was quite well along. A change in plans by the J-Division again activated Bogallua as a test site early in the summer of 1950, and Holmes & Narver was authorized to investigate a new design for power plant at this location. The design requirement was that the entire power plant equipment was to be housed in a wood frame building above ground, the major equipment to consist of two 195 kw diesel generating units, three 85-gallon per hour distillation units, two 100-gallon per minute fresh water pumps, two 300-gallon per minute salt water pumps, and a hydrochlorinator. All of this equipment was to be expended because the tower location selected at this time, near the center of the island, made the cost of a blastproof structure prohibitive. Drawings were started for this plant during the latter part of July, but Bogallua was again abandoned as an experimental site in early August 1950, and all work on the power plant was cancelled.

Bokon Island, Piiraai Island, and Teiteiripucchi Island (Photo Tower Locations). Based upon AEC furnished criteria, the estimated load for Bokon, Piiraai, and Teiteiripucchi was between 40 and 50 kw maximum power demand each. Two 50 kw units was installed at each location. One was ample for capacity load; the other was to act as a standby unit. No changes were made in power requirements for these sites. Palmer 6-cylinder 50 kw units were selected, based upon Engineering Division review of available equipment. This decision was concurred in by Los Alamos. At each photo tower site, these units were housed in a wood frame shelter. Fuel was supplied in 50 gallon drums and the units were serviced periodically by Holmes & Narver maintenance personnel. The units were capable of operating unattended and they functioned satisfactorily during test operations.

TESTS AND OPERATION OF UNITS

After the initial 200 hours of operation the crankshaft in generator unit No. 1 at Parry broke. This unit was a Fairbanks-Morse, 6-cyclinder, 142 kw set. The broken shaft was replaced and, after an additional 15 hours of operation, it broke. Both broken crankshafts were sent to the Fairbanks-Morse factory for inspection to determine the cause of the failure. It was determined that excessive vibration, occurring at a value of engine speed within the normal range of operation, was the cause. Torsional wheels to act as vibration dampeners were installed on this unit and on all other similar 6-cylinder units and no further trouble was experienced.

Telemetering equipment was installed to indicate and record remotely at control building No. 311, Parry Island, the bus voltage at the electric generating power plants (Station No. 100) on Runit, Aomon, and Engebi, the line voltage at the control stations (No. 69) on these same sites, and the generated voltage at the isolated generator plants on the photo tower locations. Esterline Angus standard model AW instruments were used, calibrated to measure voltage from 85 to 135 volts with full scale deflection. The accuracy of the units was proved to be, from extensive tests, within the guaranteed 0.2 volts. It was also ascertained from the test that there was no perceptible time lag between sending and recording voltage fluctuations and that satisfactory recordings could be obtained over loaded 19 gauge telephone pairs approximately 20 miles in length. Comparison of the telemetered record charts obtained by E G & G during the test periods with the record charts obtained from the power plant and control station recording instruments showed that the telemetering units functioned perfectly. This meant that it was possible to monitor voltages at the remote plants from the control station on Parry up to zero hour so that if the generating units shut down or the power system on the experiment islands failed from any cause an indication would have been shown on the control board and the firing delayed.

A standard procedure was developed for preparing the power plants at the test sites for actual test operating conditions. Prior to the tests, complete mechanical and electrical test runs were made at each power plant. A report of the tests made on Runit is presented as an exhibit at the end of this volume.

For the first experiment at Runit, the plant was readied for test according to the established procedure, except that only two of the three 118 kw units were operated. A check of the load was made and it was found to be between 70 and 75 kw. As this load was less than the capacity of one generator, it appeared that complete assurance of continuous power supply would be available if two units were running. This load condition was called to the attention of the Chief of the Firing Party, and after discussion by him with the Commander TG 3.1, it was decided to run two units instead of three.

The standard procedure was to seal the building approximately four hours prior to test time, as designated above, with air for combustion being supplied through the one air intake remaining in operation.

At 0815 on D-Day, Holmes & Narver was advised that the engines on Runit were still running, which indicated failure some place in the engine shutdown system. As soon as air transportation could be arranged, an engineer was sent to Runit. The doors of the plant were opened but because of heavy fumes it was impossible to enter. Since the engines were still running, the fuel oil drain valve was opened to permit the oil to drain from the tank. This stopped engine No. 1, but engine No. 3 continued to run for an additional 30 minutes. Inspections of the plant were later made and the conclusions drawn from the inspections were as follows:

1. The ground shock which followed the test caused the generator oil circuit breakers to open and deenergize the timing circuit used to shut down the engines.

2. The engines continued to run at reduced speed and at no load because of insufficient oxygen. At the time the doors were opened, the increased supply of air allowed the engine speed

to increase to a point where their overspeed devices opened. This stopped engine No. 1.

3. With the fuel supply shut off, engine No. 3 continued to run, probably because of heated lubrication oil's being forced into the cylinders and fired upon compression. When the crank case was cooled by the outside air the engine stopped.

The ground shock which caused the oil circuit breakers to open was quite severe and apparently no one was prepared for a shock of this magnitude. Holmes & Narver had not beer advised that a heavy ground shock would follow the blast and this accounts for no preparation being made to energize the fuel shut off valves on the engines when the main source of power was gone. As a result of the experience gained from the Runit experiment, the wiring of the solenoid operated fuel oil shut off valves was modified to provide battery energization for these valves in the power plants at Engebi and Aomon in the event circuit breakers in these plants also opened.

From minus 0210 hour on Easy Day on Engebi, the power output increased from 130 to 170 kw, the voltage increased from 120 to 124 volts, and the current increased from 43 to 53 amps at 2,400 volts. Frequency remained the same. This increase in voltage during the five hours prior to zero was evidently due to the heating in the power plant effecting the temperature element on the voltage regulator. The second of two short circuits at zero plus 14.72 seconds shut down the power plant before the timing circuit functioned.

For the George Experiment on the Aomon Group, battery energization of the fuel oil valve was again provided. Following is a summary of the power plant operational data on George Day:

Time	KW	Voltage	Current (amps at 2400 volts)	Frequency in cycles
Minus 60 minutes	138	120	40.5	60
Minus 30 minutes	170	120	50.0	60
Minus 15 minutes	200	118	64.0	60
Zero plus .83 seconds	220	120	64.0	60

Fluctuations in load at minus 15 and minus 30 minutes resulted in transient variations in voltage and frequency. Two engines shut down on short circuit at plus .83 seconds. The third continued to run until shut down manually the following morning at approximately eight-thirty.

The Item experiment at Engebi required operation of two engines in the power plant, and the plant was prepared for zero hour in accordance with established procedure. Examination of the charts after this test indicated that the voltage was continuous and uninterrupted from the time of securing until zero hour, with a variation of one volt. Frequency for the same time was constant except for normal instantaneous variation of plus and minus 0.1 cycles. The load was 105 kw until it increased to 115 kw at minus 32 minutes and to 125 kw at minus 17 minutes. The station operated normally until zero hour. Evidently a short circuit occurred in the power house transformer bank at plus 0.7 seconds, preventing the stop signal at plus 15 seconds from reaching the generators. The No. 3 engine stopped at plus 16 minutes, and the No. 2 engine continued to run until plus 2 hours and 14 minutes.

Figures 5.15-7 through 5.15-12 indicate the kilowatt hours generated by each plant. Figures 5.15-13 through 5.15-16 show the kilowatt demand values for Parry Island for the high day, the low day, average Sunday, and average work day in March 1951.

TABLE 5.15-2. POWER PLANT CAPACITY, BY SITES

Site	Plant Maximum Capacity (KW)	Plant Firm Capacity (KW)
Eniwetok Island	906	710
Parry	852	710
Japtan	193	75
Runit	354	236
Aomon	431	313
Engebi	431	236
Piiraai	100	50
Bokonaarappu	100	50
Teiteiripucchi	100	50

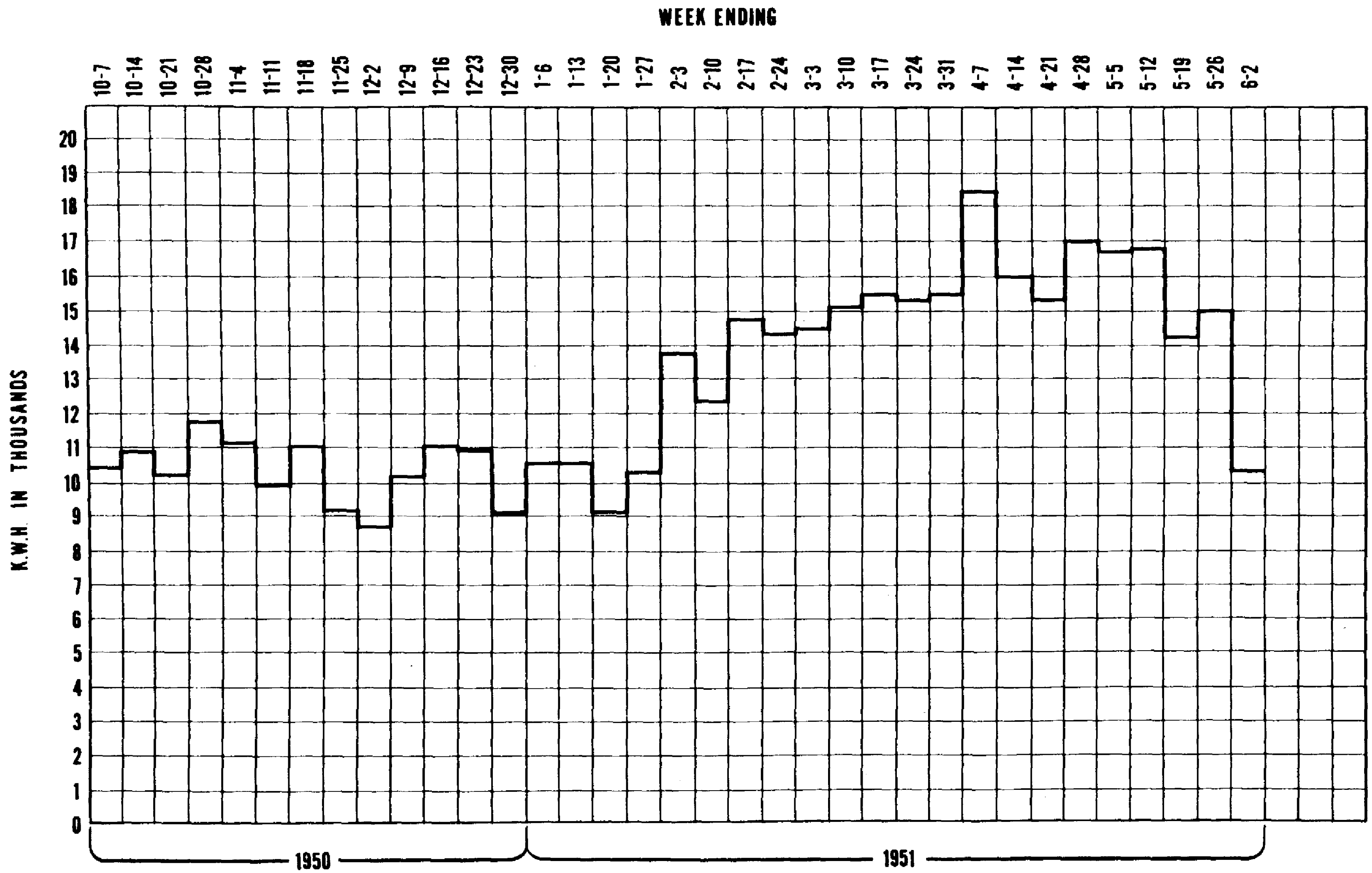


FIGURE 5.15-7 Power Generated, Eniwetok Island

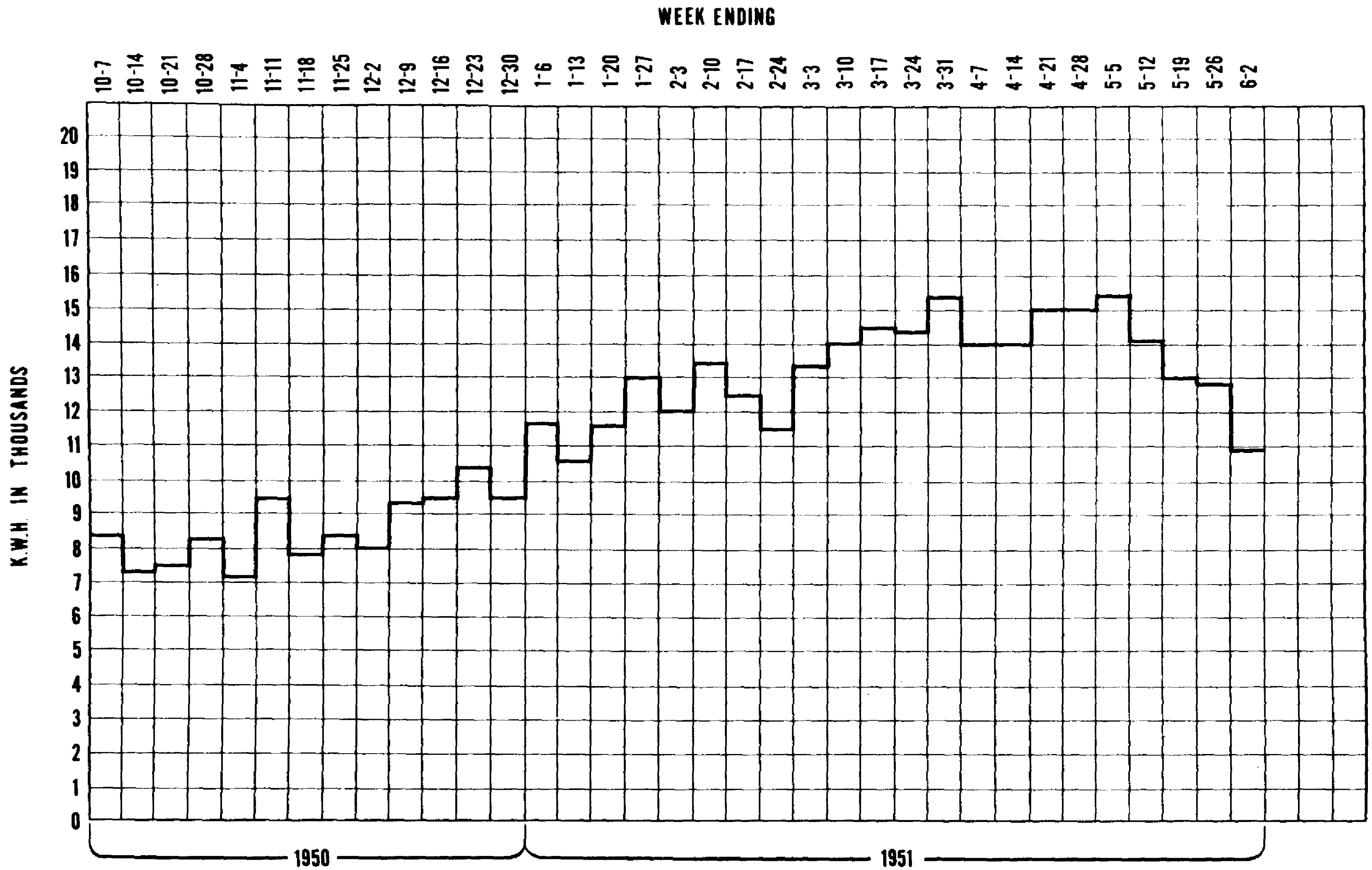


FIGURE 5.15-8 Power Generated, Parry Island

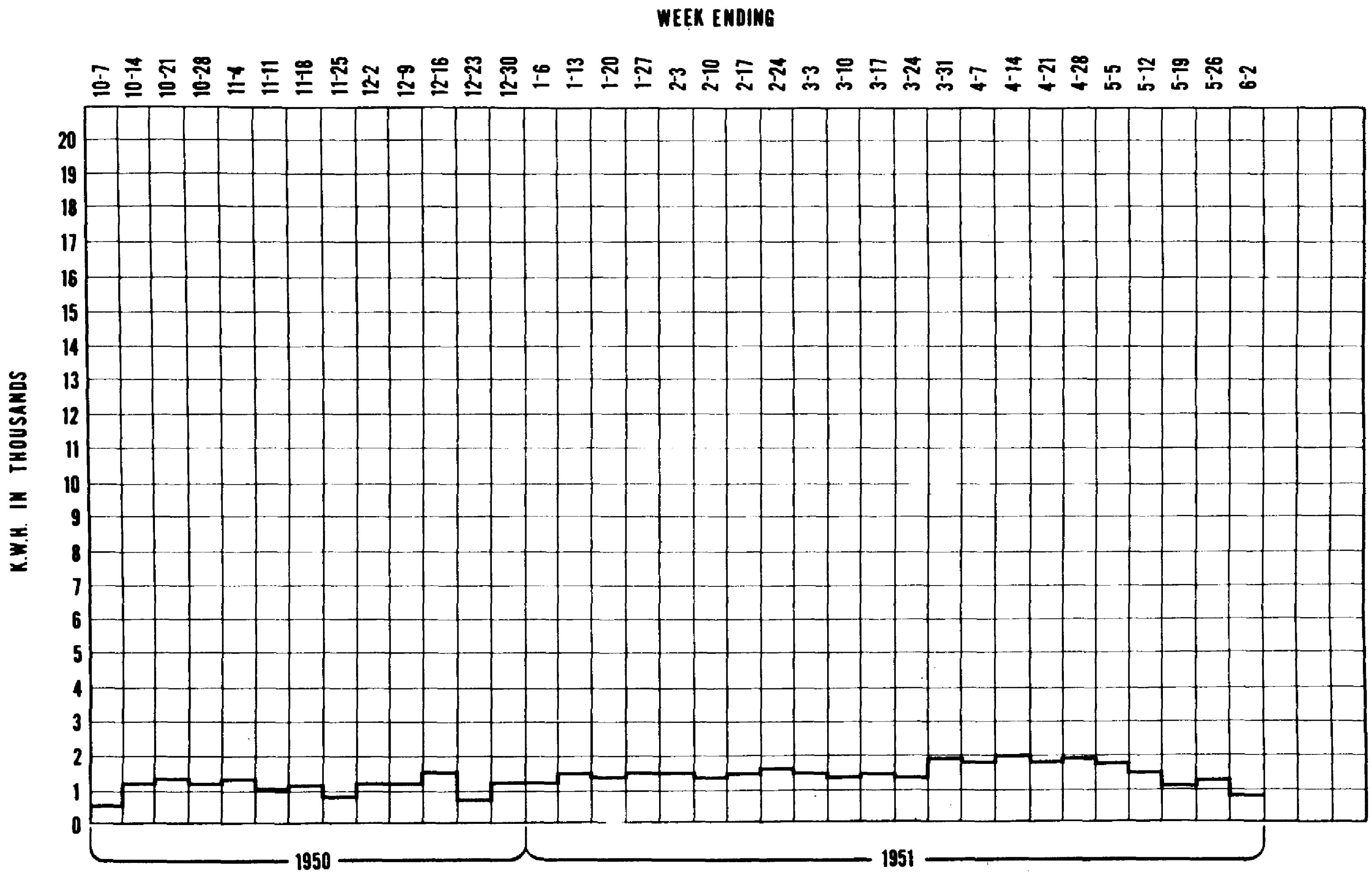


FIGURE 5.15-9 Power Generated, Japtan Island

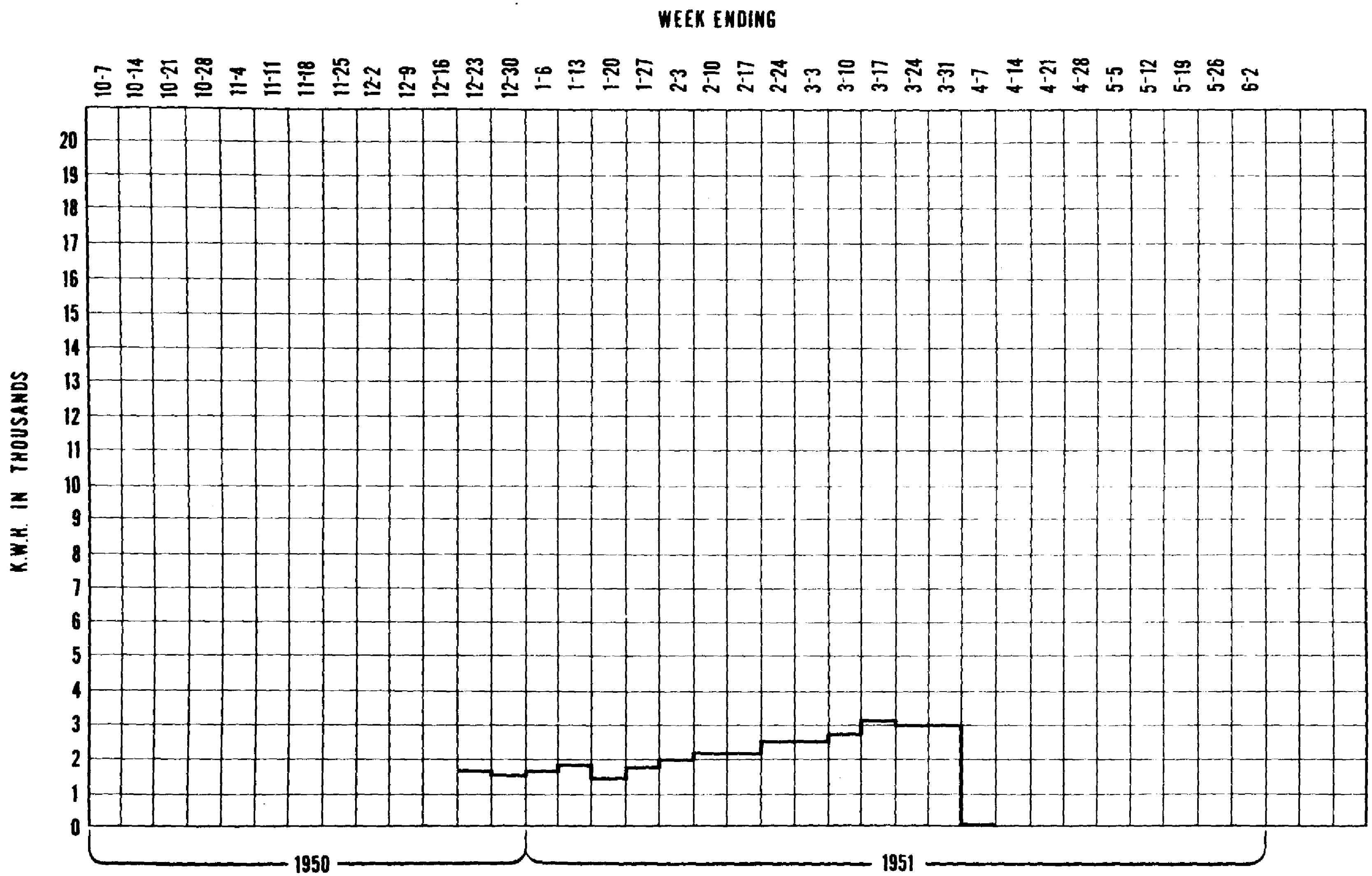


FIGURE 5.15-10 Power Generated, Runit Island

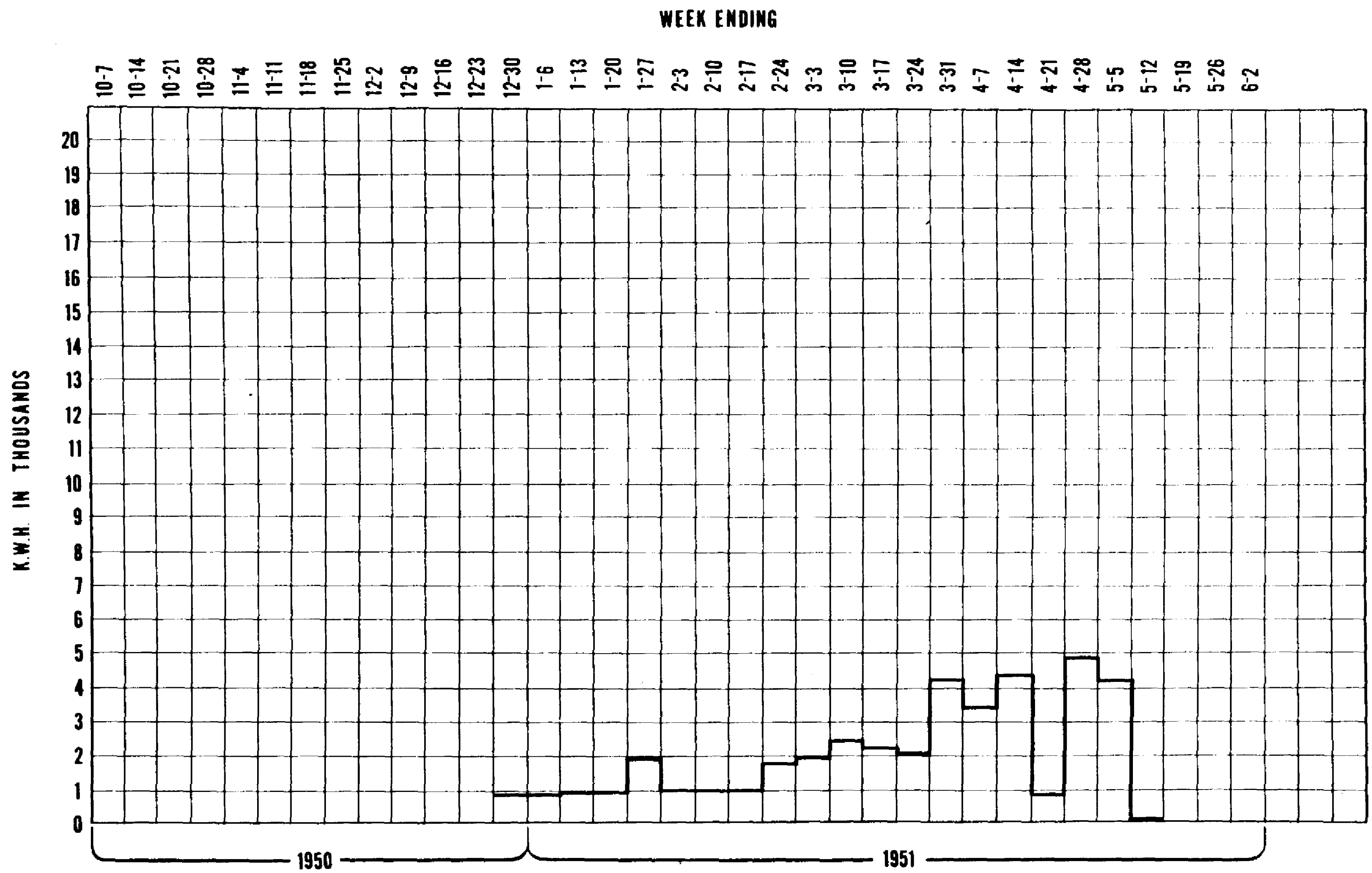


FIGURE 5.15-11 Power Generated, The Aomon Group

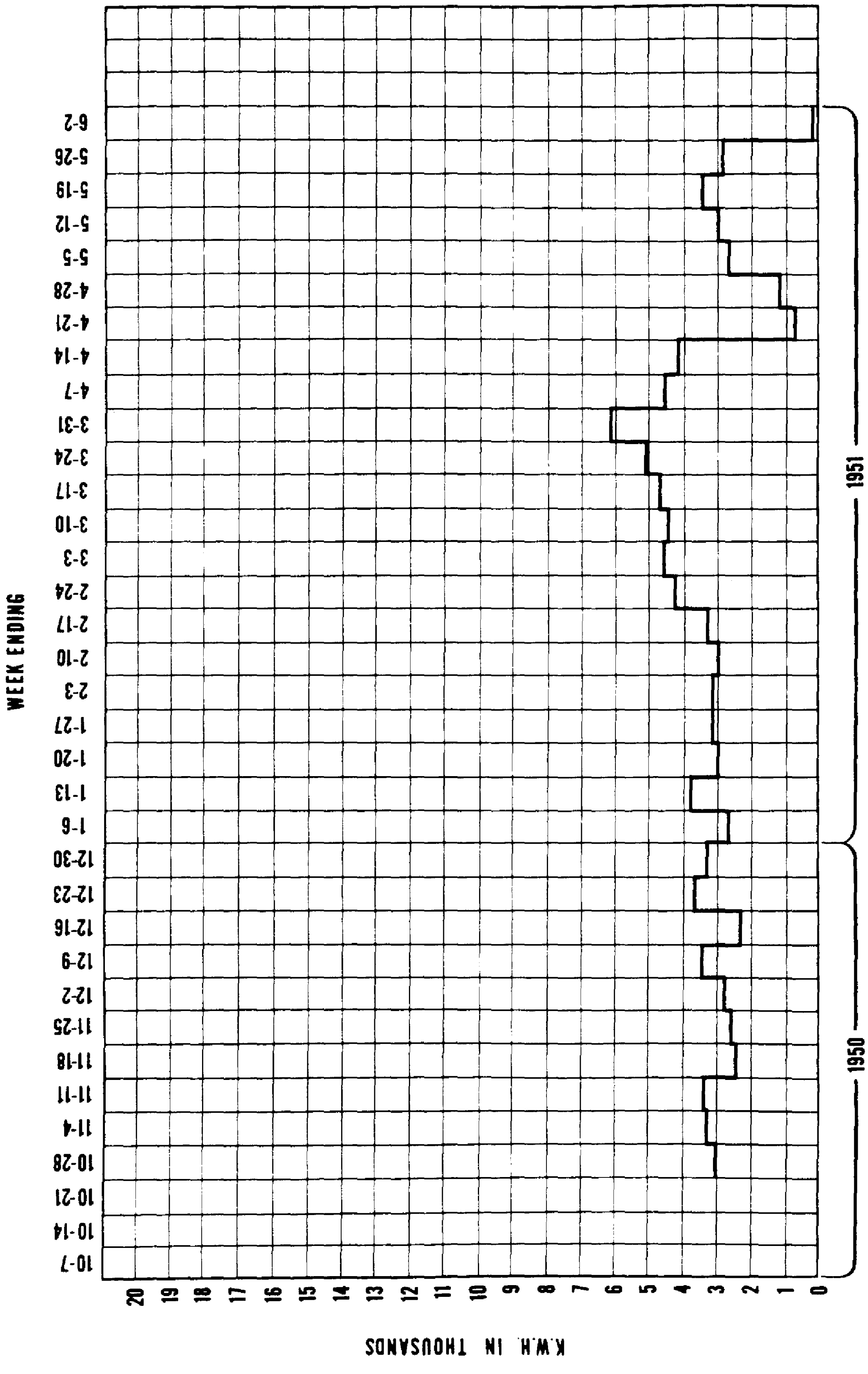


FIGURE 5.15-12 Power Generated, Engebi Island

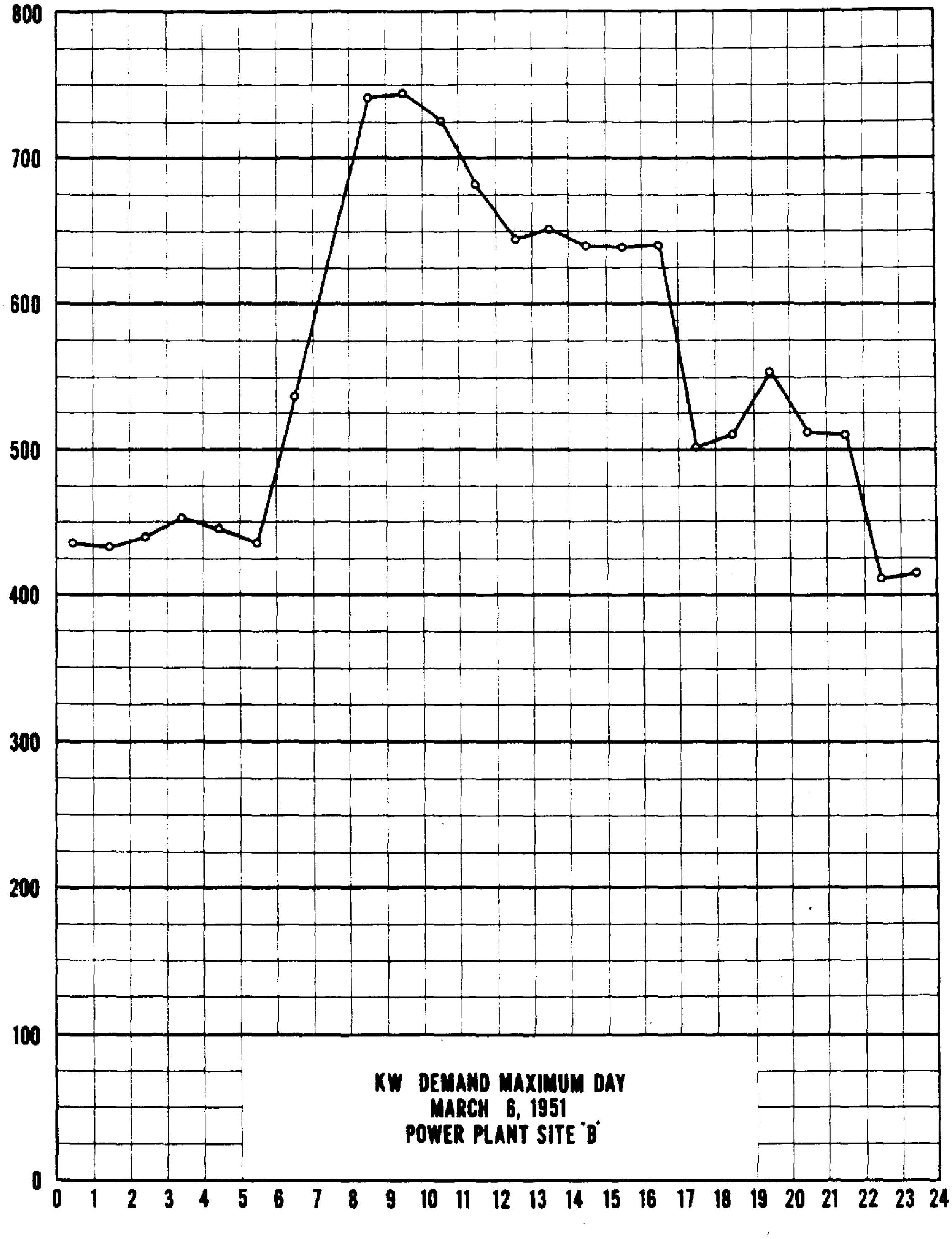


FIGURE 5.15-13 KW Demand - Maxim Day-Parry Island

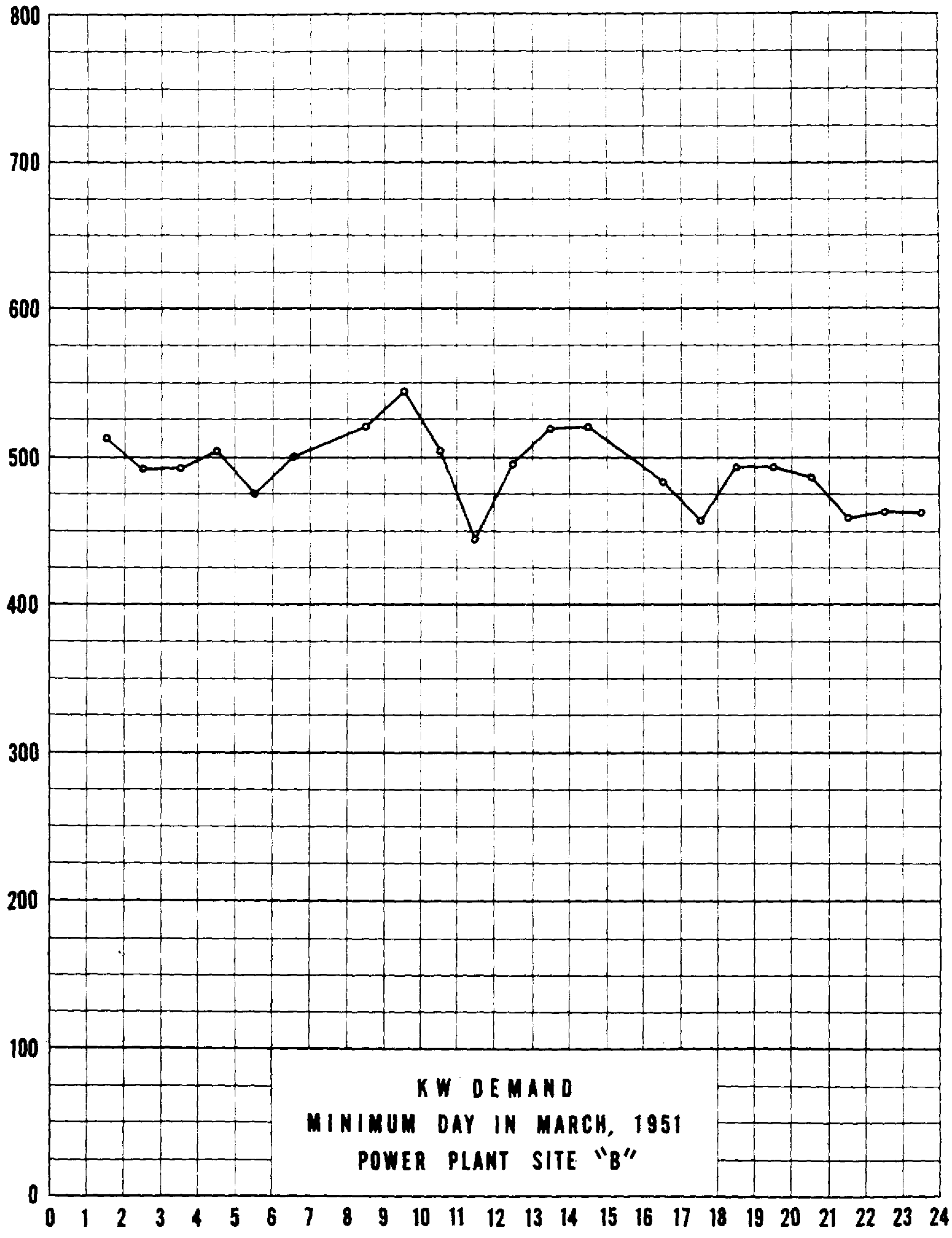


FIGURE 5.15-14 KW Demand - Minimum Day-Parry Island

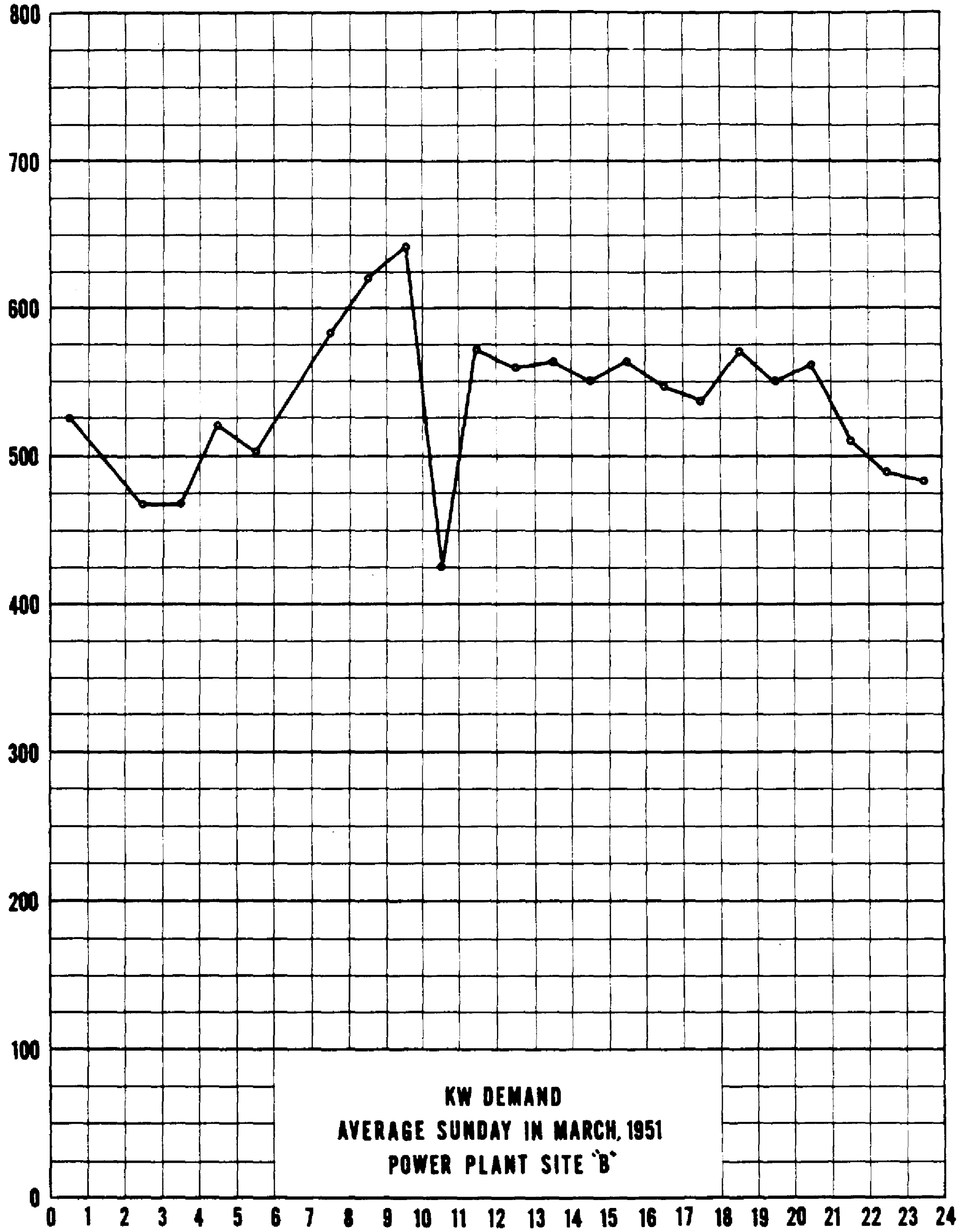


FIGURE 5.15-15 KW Demand - Average Sunday in March 1951 -

Parry Island

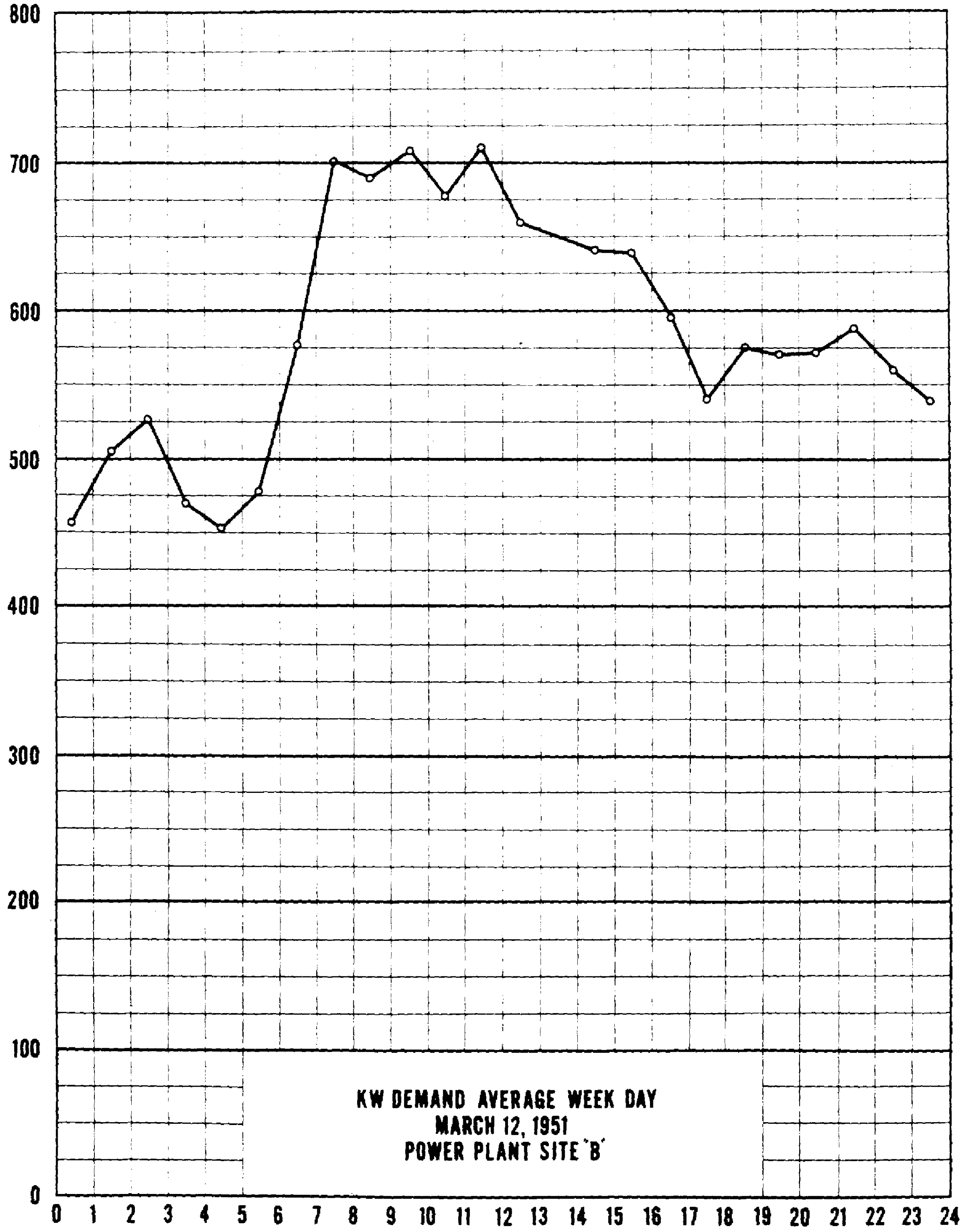


FIGURE 5.15-16 KW Demand - Average Week Day in March 1951 - Parry Island

CHAPTER 5.16

ELECTRICAL POWER DISTRIBUTION

The decision was made by J-Division to provide power plants for each of the headquarters islands and each of the main experiment islands, based on recommendations made by H & N. Consequently, the length of primary electrical power distribution lines was limited to not over two miles in any case. This led to the selection of 2400 volts as the generation and distribution voltage.

Overhead, underground and submarine distribution were all used either individually or in combination as conditions dictated. Overhead distribution, being cheapest, was used for Eniwetok, Parry and Japtan Islands and for the camp areas on Engebi, the Aomon Group, and Runit. Underground direct burial cables were used for primary distribution and secondary feeders serving instrumentation and utility loads on the experiment islands outside the camp areas and in the vicinity of airstrips, radio transmitter and receiver antenna farms and the Loran facilities provided for the Coast Guard. Submarine power cables were used for two water crossings. The experimental structures on Muzin were supplied from the power plant on Engebi and the photo tower on the reef south of Runit was supplied with power from the power plant on Runit.

DESIGN

The distribution systems were based on the criteria of locations, load, and other information known in the early part of 1949. As requirements increased changes were made, especially in the systems servicing experimental facilities. These changes sometimes resulted in less efficient power distribution system, but the flexibility of the overall system was maintained; and during the experiments, systems functioned well.

Overhead lines were designed and installed for "medium-loading" in accordance with the requirements of the "Rules for Overhead Line Construction - General Order No. 95" of the State of California. The California rules were followed because they are nationally considered to be one of the best. This was fortunate in that it permitted a 50 per cent increase in the original system load with not more than a 5 per cent primary voltage drop and made the system flexible enough to permit many changes and additions to meet new requirements made by the more than twenty Users served.

The overhead distribution system was designed to overcome many anticipated problems. It was sectionalized so that it would be possible to de-energize sections for the extraordinary maintenance that weather and salt spray would make necessary. Deterioration of transformer oil was foreseen, and oil testing and cleaning equipment was specified for this installation so remote from mainland electrical maintenance shops. This specification was made a part of the published engineering maintenance procedure, and the equipment was provided.

Submarine power cables between Runit and the tower site south of Runit and between Engebi and Muzin were designed for laying in a direct line along the reef between the sites. Power winches were used to pull the cable to Runit from the site south of Runit and to Engebi from Muzin. In this manner, considerable economy both in materials and labor was achieved over the alternative method of laying cable from a barge out in the lagoon away from the reef, and adequate clearance from signal cables was maintained.

Transformers used were conventional oil filled single phase 2400/120/240 volt transformers with four 2-1/2 per cent taps. For the overhead systems, single transformers sized up to and including 37-1/2 kva were mounted directly on single poles. Three-transformer banks (up to 25 each) were hung on cross-arms, and larger transformer banks were installed on two pole racks or concrete pads on grade.

Transformers for both the utility (power and light) and the instrumentation services on experiment islands were standard oil-insulated, self cooled, outdoor distribution type. These were placed upon concrete pads at grade and enclosed by wooden fences. Instrumentation services included services required by the Users to energize scientific instruments of all kinds.

Separate transformer banks were used for utility and instrumentation loads at most locations in order to assure good voltage regulation for the instrumentation. This arrangement was considered necessary to meet the Users requirements of plus or minus 1 to 2 per cent voltage regulation.

At stations where the load was not large enough to warrant transformers, wooden power posts were installed which supported a raintight enclosure containing two or three-pole receptacles and a fused switch. These posts were supplied by 600 volt direct burial cables. Groups of power posts were supplied with secondary service from a centrally located transformer bank. Approximately 75 such posts were installed and, since in most cases they were considered expendable, they were held to a minimum design for low cost.

Lightning arrestors were installed only on transformer poles and seem to have been adequate, for in two and one-half years no lightning damage has been noted.

Services to buildings were installed as overhead drops wherever possible. Where distances were too great, where the function of the building or area prohibited overhead service, or where the load was too great, underground services were installed. Overhead services which would pass over other buildings were avoided wherever possible.

All building structures were grounded to a 3/4 inch by 8 foot ground rod driven into the coral adjacent to the building. Building electrical equipment and service neutral conductor were grounded to a similar but separate rod. Power houses were similarly grounded. Individual rods were used for each piece or group of equipment. Transformer cases were grounded to ground rod at the base of the pole. Lightning arrestors for transformers were grounded to a similar but separate rod. Grounding was made difficult by the strata of ledge coral which often appeared near the surface and sometimes made blasting necessary.

Installation of voltage regulators was not considered advisable because of the uncertainty as to what the final disposition of loads would be. Because of this and the large number of Users, each with specific voltage requirements, it was decided that they should supply their own regulators.

OVERHEAD DISTRIBUTION

For corner and transformer poles on overhead distribution, Class 2 Douglas fir poles treated full length with 8 pound creosote were used; similar Class 4 poles were used for distribution at more lightly loaded locations. Poles were 30 to 40 feet long and set approximately five feet into earth. Cross arms were untreated Douglas fir, 3-1/2 inches by 4-1/2 inches for power distribution and 3-1/4 inches by 4-1/4 inches for signal and telephone installations. All pole-hardware was double-dipped galvanized. Guy wires were 7/16 inch size, 7-strand, galvanized, 10,000 pound breaking strength.

Insulators for the 2400 volt primary system were wet-process porcelain rated for 15 kv service, with a wet flashover rating of 60 kv. Both pin and suspension type were used. The high rated insulator was chosen to offset the effects of the high humidity and salt spray and to assure a great degree of mechanical strength.

Bare copper wire supported on 60 kv wet flashover insulators was used for primary overhead distribution of 2400 volts delta; and weatherproof wire was used for secondary services supported on secondary racks for 120/240 volt single-phase, 208 volt wye, and 240 volt delta distribution. The type of second service depended on the kind of load served.

The following list of major materials used in the overhead distribution indicates the magnitude of the work designed and installed.

5 kv Wire	77,800 feet
600 v Wire	172,050 feet
Transformers	287
Poles (All classes and lengths)	418
Street lights	131

UNDERGROUND POWER DISTRIBUTION

The underground primary distribution consisted of three-conductor, 5000 volt, rubber insulated, non-metallic sheathed, type RJ cable suitable for direct burial. This cable was laid on a bed of fine sand, covered by a layer of sand, and topped with 2 inch by 6 inch creosote-treated planks. Trenches were backfilled and trench depths varied from three to four feet. Taps to primary cables were made in the trench and extended to buildings or to transformers on concrete pads adjacent to buildings.

The underground secondary distribution consisted of two, three, or four conductor, 600 volt, rubber insulated, nonmetallic sheathed cable suitable for direct burial. These cables were not laid in sand, and plank covers were not installed. See Figures 5.16-1, 5.16-2, and 5.16-3 for schematic power-distribution drawings for Runit, The Aomon Group, and Engebi.

The following is a list of major items included in the underground distribution system:

5 kv direct burial cable	56,270 feet
600 v direct burial cable	45,850 feet
5 kw submarine power cable	27,500 feet

MAINTENANCE

It was known that steel, although galvanized, deteriorates rapidly in the climatic conditions prevalent at Eniwetok and a careful investigation was made of possible materials for guy wires other than galvanized steel. As a result, the conclusion was reached that there was no other material economically feasible, and galvanized steel guy wires were specified, knowing that there would be continual maintenance and replacement of guy wires required. Some oxidation occurred on the overhead bare copper lines. This oxidation is a surface phenomena and experience has shown that this does not result in an unreasonable maintenance problem.

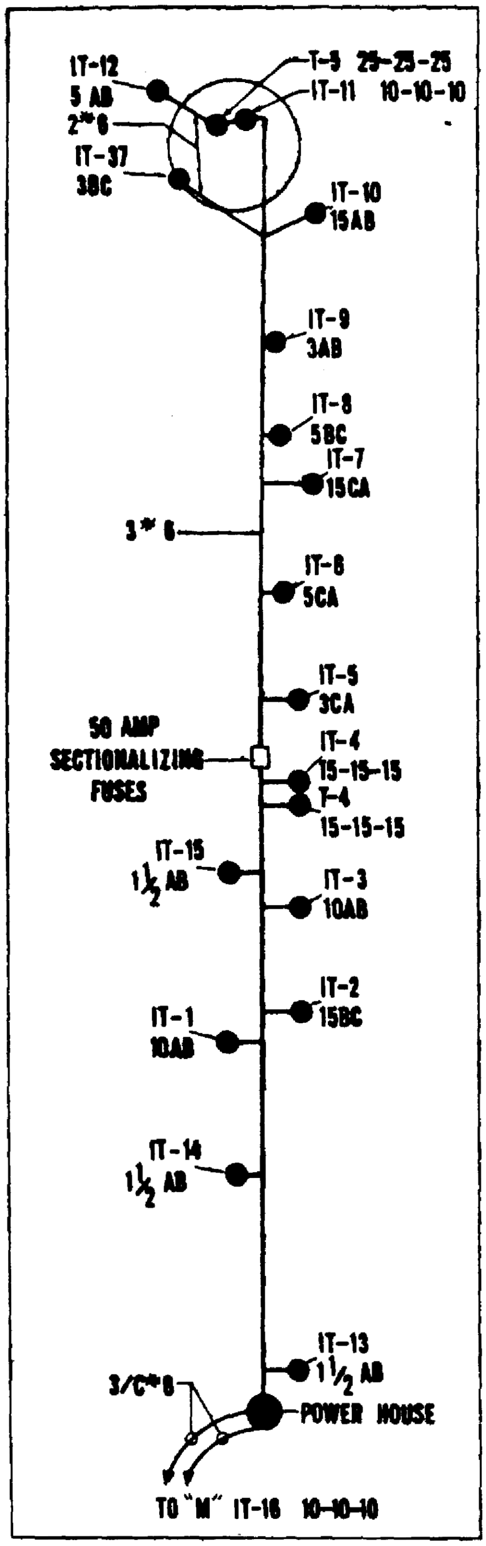


FIGURE 5.16-1 Power Schematic Diagram, Runit Island

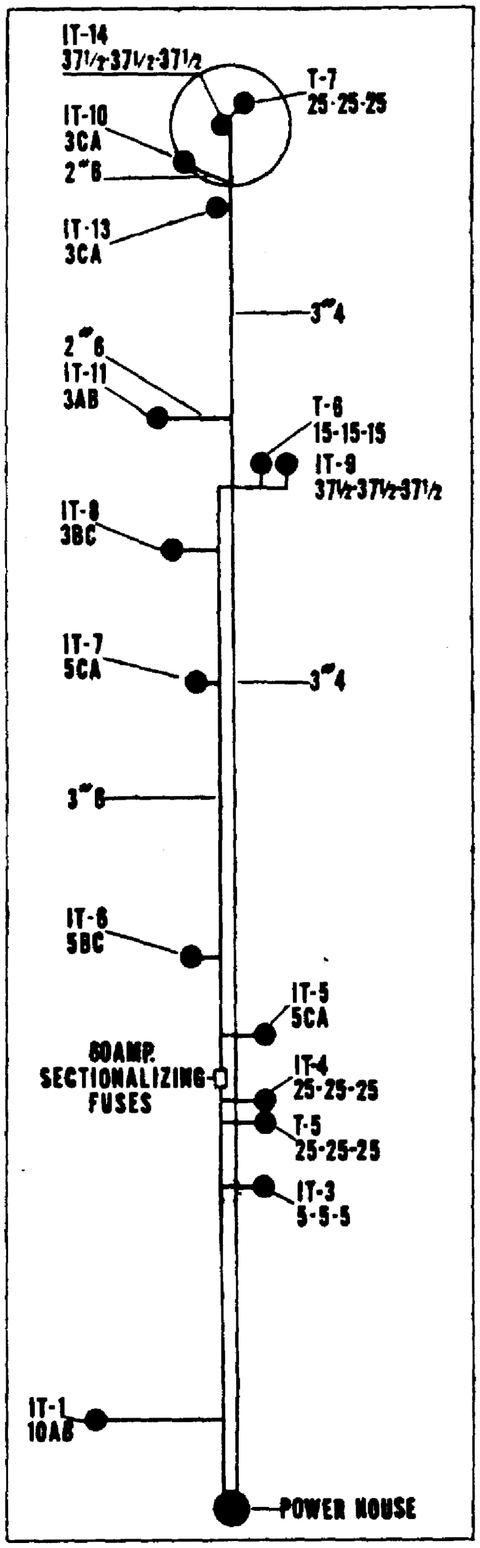


FIGURE 5.16-2 Power Schematic Diagram, The Aomon Group

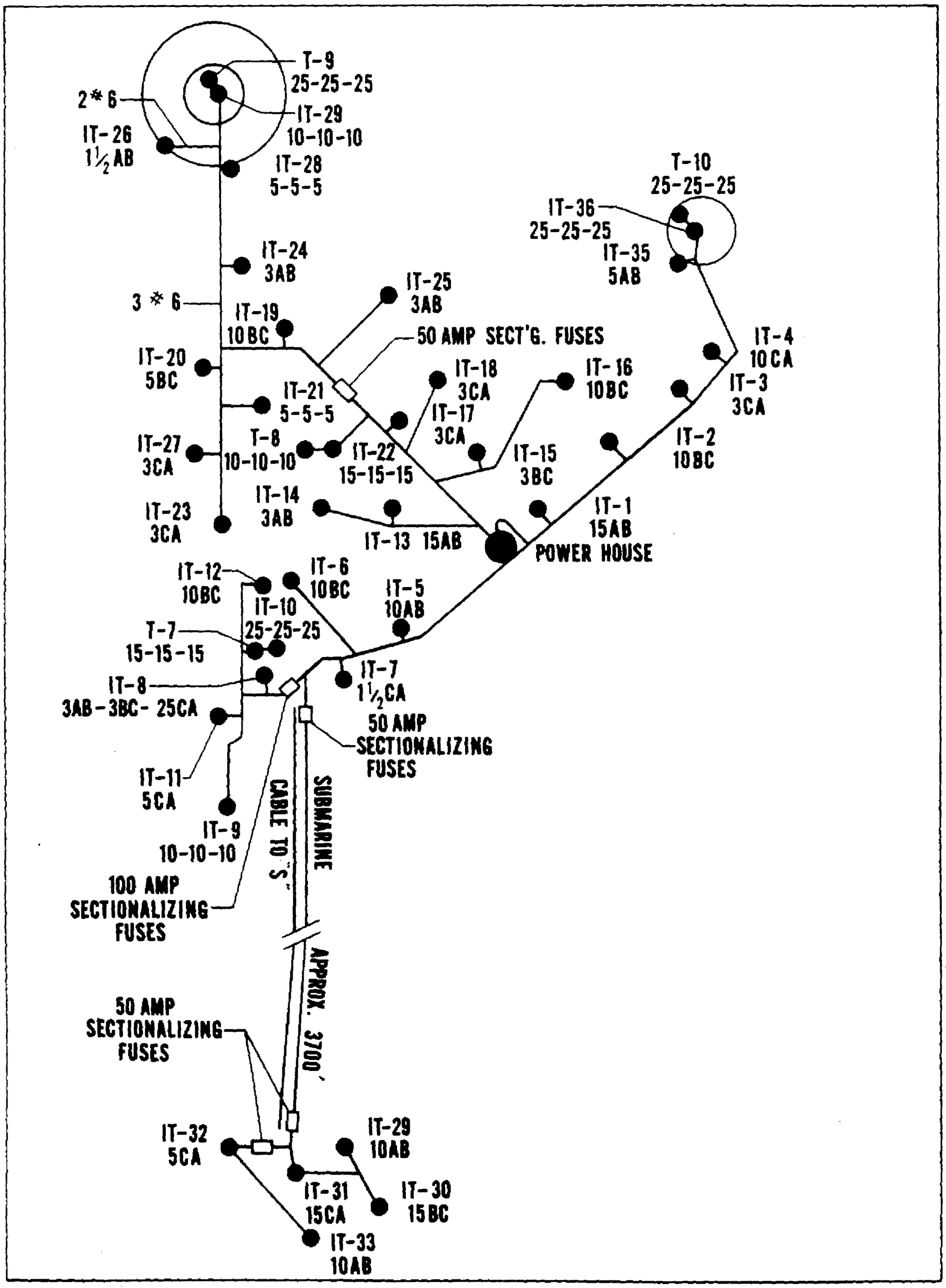
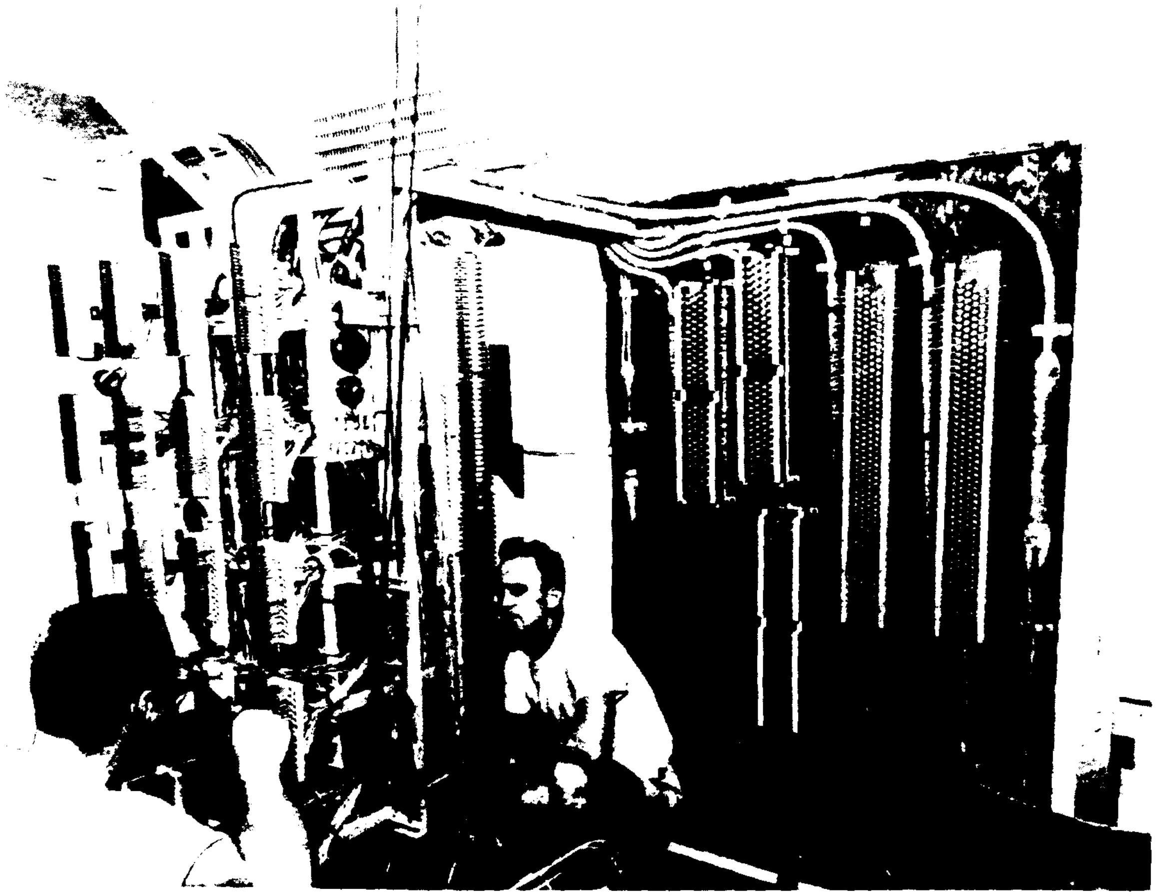


FIGURE 5.16-3 Power Schematic Diagram, Engebi and Muzin Islands

Parry Island: Pole Line



Parry Island: Telephone Office - Main Distribution Frame.
Running Jumpers for New Phone Installations.

CHAPTER 5.17

COMMUNICATIONS

The original criteria provided by J-Division established the need for reliable communications between stations located on Parry, Eniwetok, Japtan, the experiment islands, the photo towers, and ships anchored in the lagoon with the center of the Atoll communications system located at Parry. This requirement was particularly vital during the period immediately prior to each experiment. In addition, the armed forces would require the use of communication facilities on Eniwetok and the experiment islands for pre-operational security activities and during operational periods, and construction personnel would utilize communications between the various islands during the construction period.

In the Reconnaissance Report, various possible types of voice communications systems were considered, and, as a basis for comparison, a telephone system employing submarine telephone cable trunking was determined to be adequate and reasonable. The proposed location and number of switchboards, instruments, and trunking cables were shown on Plate 49 of the Reconnaissance Report. Various types of telephone instruments and switchboards were discussed. The relative merits of submarine telephone cable trunking, radio trunking, and wire and radio with carrier trunking were considered.

It was concluded in the Reconnaissance Report that local telephone systems would be required and should be provided for communication on individual islands and that public address systems should be provided on experiment islands to minimize the number of stations and to permit broadcast announcements. Cable trunking between islands was considered the most satisfactory means of communicating between sites because of its simplicity, reliability, resistance to atmospheric conditions, and contribution to security. It was recommended that a radio back-up system be provided. It was further proposed that limited inter-island telephone communication during the construction period could be provided by utilizing submarine control and signal cables for trunking, prior to installation of the communication cables.

A decision was reached by the time of Supplement No. 1 to the Reconnaissance Report (July 8, 1949) that a manual telephone system with submarine cable trunking would be employed, other basic concepts remaining unchanged. This system was designed to utilize common battery rather than magneto service because of the following advantages:

1. Less time and effort by User are required.

2. Automatic signalling is fast and reliable.

3. Work of switchboard operators is reduced.

4. Battery maintenance at telephones is reduced.

Manual rather than automatic service was selected because of its lower cost, smaller size of system, and simplicity of maintenance, particularly in a remote area where skilled personnel were expected to be few.

TELEPHONE SYSTEM

In March 1949, consultations were held with the Chief Transmission Engineer of the Pacific Telephone and Telegraph Company, who volunteered the advice and assistance of company engineers in the design of the system especially with regard to submarine cable.

It was decided that the design objective should be approximately 25 db effective transmission equivalent, in order to provide a service equivalent to that normal in commercial practice. Preliminary schematics of the telephone system disclosed that the overall maximum length of the trunking system would be approximately 40 miles. As a result of conferences with various cable manufacturers and with Pacific Telephone and Telegraph Company engineers, it was decided that the most conventional and economical type of cable for this application would be a dry core, paper-insulated, wire-armored, lead-covered telephone and telegraph cable containing 19-gauge pairs. In order to provide the design objective, an H88 loading system, obtained by placing 88-millihenry coils on approximately 6000-foot spacing in telephone trunking pairs, was specified.

The effect of the introduction of these coils was to decrease the effective transmission loss from 1.51 to 0.43 db per mile and increase the dc loop resistance from 85 to 92.9 ohms per mile. With losses in customers loops limited to 2-5 db, and allowing a loss of approximately 1 db at each switchboard, the system design thus fell within the established objective.

Specifications for the required 713,000 feet of submarine telephone cable were prepared, bids were obtained and analyzed, and on August 30, 1949, it was recommended that the low bid by Graybar Electric Company be accepted. See Appendix F at the end of this report.

Specifications for the required telephone switchboards and instruments were prepared. See Appendix F of this report. One Kellogg Masterbuilt Junior two-position switchboard was obtained for Eniwetok, and one for Parry. Each was wired and equipped for 220 common battery and 30 magneto lines and both were complete with power equipment, main distributing frame, and testing equipment. One Kellogg Masterbuilt Junior single-position switchboard was obtained for Runit, Engebi, and Aomon. Each of the boards was wired and equipped for 45 common battery and 5 magneto lines and all were complete with power equipment, main distributing frame, and test set. Wall type instruments were Kellogg No. 1100BA Masterphones, moisture and fungus proofed. Desk type instruments were Kellogg No. 1000, similarly treated. Field type instruments were Signal Corps Type EE-8A. Quantities of instruments required increased materially because of increased population and increased User requests, and it was necessary to obtain additional instruments to meet these needs. For instance, as late as December 1950, it was necessary to requisition and obtain as soon as possible 88 desk and 11 wall telephone instruments to meet newly established requirements. The comparison of original estimates and actual instrument installations is shown in Table 5.17-1.

Individual installations of communications systems for the several sites were designed to meet the differing physical conditions and special use requirements of each site.

It was originally understood that the underground telephone cable installed on Eniwetok Island for Operation Sandstone would be required for other facilities and could not be used for telephone loops. Preliminary estimates of material requirements were made and materials requisitioned. On March 9, 1950, advice was received that the installed cable on Eniwetok Island was in good condition and would not be required for any other purpose. It was also decided at this time that the Signal Corps would install the local telephone system for this Island. H & N plans and specifications were accordingly revised to use the existing underground cable for a major portion of the system of subscribers' loops.

Original plans for Parry called for joint use of power poles for overhead telephone cable. Because of the increase in facilities required, it became necessary early in 1951 to provide additional underground telephone cable for intercommunicating sets and additional control and signal cable facilities. Since telephone facilities requirements had also materially increased, plans were made to install additional cable while the ditches were open.

Overhead telephone cable was No. 22 AWG with double dry paper tape insulation and lead antimony sheath. It was spun to messenger with 0.091 inch OD lashing wire.

Subscribers' loops on experiment island sites were designed to be installed at an underground depth of approximately two feet. The relative advantages of duplex pairs and paper-insulated lead covered cables were considered, and No. 17 AWG duplex similar and equal to Whitnew Blake No. 17 TBPR was selected on the basis of greater economy and flexibility. It required no skilled cable splicers for an installation intended for short-time use. Wherever possible these cables were installed in the same ditches as experiment control and signal cable. Locations of underground telephone cables and pairs were marked by posts.

Because of the vital importance of the communications system to the Project and because of the highly specialized communication work involved, the advice and assistance of people with similar experience was obtained for planning and executing this operation so as to insure its success and so as to avoid the difficulties experienced with submarine control cable for Operation Sandstone. The principal difficulty reported had been in keeping cable laying ships on the desired course under prevailing winds and at the same time laying cables without paying out cable at an excessive speed.

TABLE 5.17-1 TELEPHONE EQUIPMENT

Site	Switch-boards	Telephones	Overhead Cable Ft.	Messenger Ft.	Sound-Powered Telephones
Eniwetok					
Estimated	1	120	12,000	-	-
Installed	1	300	4,130	-	-
Parry					
Estimated	1	185	2,500	9,000	0
Installed	1	300	17,750	12,750	12
Runit					
Estimated	1	35	4,800	1,400	-
Installed	1	46	2,800	700	-
Aomon Group					
Estimated	1	35	5,000	1,000	-
Installed	1	42	2,460	900	-
Engebi					
Estimated	1	35	5,000	-	-
Installed	1	86	3,700	-	-
Japtan					
Estimated	-	25	3,000	-	-
Installed	-	8	3,775	-	-
Experiment Islands					
Estimated	-	5	-	-	-
Installed	-	13	-	-	-
Totals					
Estimated	5	440	32,300	16,400	0
Installed	5	795	34,615	16,150	12

As a result of considerable investigation and study of the methods, equipment, and manpower which might most effectively be used for cable laying, it was decided that complete lengths of cable required for each run would be preassembled and tested on shore. Assembly involved the insertion of splice cases containing 88 mh loading coils at 6000 foot intervals in the cable length. The splice cases were rectangular, approximately 6 inches by 28 inches and weighed about 95 pounds. Based upon the experience reported in connection with cable laying operations for the Sandstone Project, it was planned to lay the cable from a towed barge upon which the cable was arranged in a figure-8 pattern, each successive coil of the figure-8 progressing by at least one diameter of the cable towards the stern of the barge. This type of arrangement avoided the cable torque encountered during the Sandstone activities. In addition, the tendency of the cable to stack up at the crossover of the figure-8 was considered beneficial because each successive coil could slide off freely in the direction of the fair lead to be provided on the cable laying barge.

The employment of a towed barge eliminated the propeller hazard previously encountered in the use of a landing craft and, thus, also made it possible to avoid the unnecessary flexing of the cable by laying it over the side of the ship. The cable laying barge was equipped, in addition to a set of fair leads for guiding the cable toward the stern, with a manually operated cable brake and a stern guide plate to lead the cable off the barge at an angle between 30° and 60° from the horizontal. Auxiliary equipment included winches, anchors, block and tackle, splicing gear, and the like. The cable brake was designed to be removable from the line of movement of the cable in order to permit the passage of the splice cases. In order to avoid any possibility of loss of efficiency, it was specified that communication cables were not to cross other submarine cables laid in the lagoon. It was, therefore, specified in addition that all existing cables should be accurately located and that the paths of newly laid cables should be fixed by successive sextant angle shots taken from the barge, during operations, to fixed points on shore. Cable landings designed called for a trench line depreciation in which the cables were closely grouped and covered with a compacted mixture of Bitumul, sand, cement, and water. Upon the completion of the laying of each cable, a series of tests was conducted to supplement the information obtained from the prelaying tests. These tests involved the continuity loop resistance of each pair in the cable and the unbalanced resistance between wires of each pair; the insulation resistance of each wire to every other wire in the cable; transmission loss at 1000 cycles and 2500 cycles for loaded pairs and 1000 cycles and 5000 cycles for nonloaded pairs; and the measurement of near end and far end crosstalk. The results of these tests are presented as exhibits at the end of this volume together with other test records of main telephone trunking cables and representative branch cables.

The successful operation of the manual telephone system with submarine cable trunking justified the original recommendations. It was possible, in addition, to allocate certain pairs of the submarine telephone trunking cable for control and signal use by at least one scientific group to serve their increased requirements. Trunking facilities functioned satisfactorily throughout the operation.

Experience on Operation Sandstone dictated that to make certain that communications would be available for emergency use at critical periods during test operations, a radio back-up be provided. However, it was not necessary to use this radio back-up. The telephone system is illustrated in block diagram form in Figure 5.17-1.

The equipment functioned satisfactorily and only normal maintenance was required. The quality of voice communication was good. The growth of system requirements was so large, however, that all, or most of the reserve capacity originally provided was utilized and it was necessary to provide party lines in some instances. (See Table 5.17-1 above). Furthermore this heavy increase in requirements came at a time when considerable effort was required to provide and install additional instruments, lines and drops. The resulting heavy traffic during busiest hours made a wait of several minutes necessary during the peak of operations, and preferred service had to be extended to certain individuals. Had the magnitude of requirements been known during the design stage of this work, 3-position or 4-position boards would have been provided rather than 2-position boards for Eniwetok and Parry and the capacity of the 1-position boards at Runit, the Aomon-Biijiri-Rojoa Group, and Engebi would have been increased.

Maintenance of underground lines on experiment islands offered some difficulty. To avoid delay in construction, materials were ordered for these lines before job requirements were fully settled. Therefore, underground telephone pairs were used instead of paper-insulated lead covered cables, because individual pairs permitted greater flexibility for future design requirements. Furthermore, the pairs were less expensive than cable, and there was a shortage of skilled cable splicers for the required work at the Jobsite.

RADIO SYSTEM

At the time the first Holmes & Narver forces arrived at the Jobsite, there was a need for radio communication to supplement the limited inter-island telephone facilities established by the beachhead party by utilizing existing submarine signal cables. The need for radio to facilitate construction and operational activities on islands not served by the telephone system continued from the time the first group of surveyors reached the Atoll through the entire program.

The first sets, portable Military Type SCR-300 and SCR-619, were used by the survey teams for inter-island communication.

In January of 1950 there were 12 SCR-619 units and several SCR-300 radio transmitter-receivers in use. The SCR-619 has a power output of 2 watts, voice (FM), with two preset frequencies in the range of 270 to 38.9 megacycles. The SCR-300 has a power output of approximately 1 watt, voice (FM), within a range of 40 to 48 megacycles.

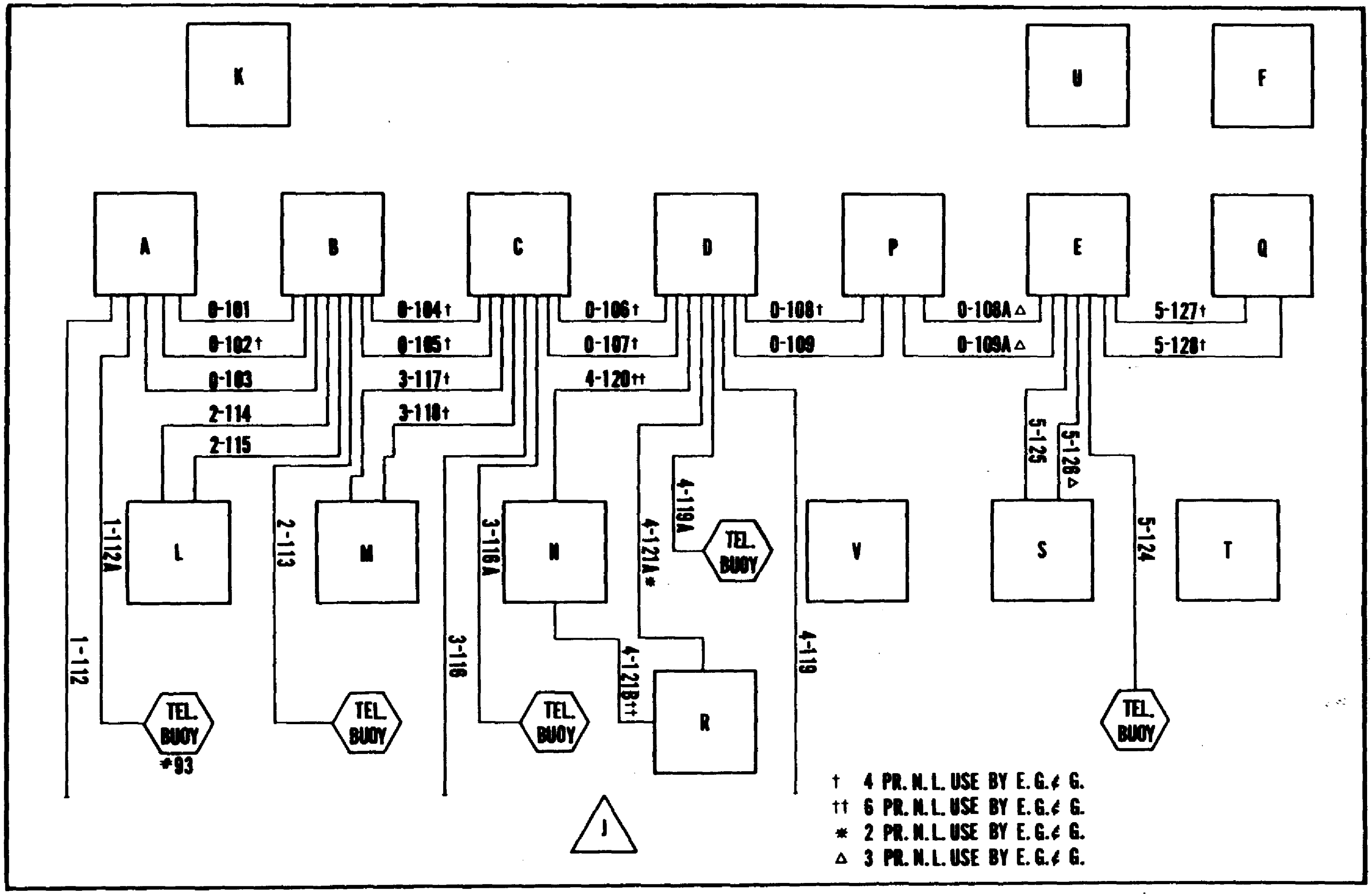


FIGURE 5.17-1 Telephone System Block Diagram

These radio transmitter-receivers were not sufficient to provide adequate communication facilities for the boat pool operations at the time noted. In addition, at the same time, consideration was being given to the type of radio equipment to be used as the back-up for wire telephone communications. After thorough investigation of the availability of military-type equipment and spare parts for maintenance purposes, it was decided that standard commercial equipment might provide the solution to both of these radio communication problems. However, further consultation with the Communications Officer of JTF-3 revealed that the Task Force was in a position to supply and maintain standard tactical-type military radio transmitters and receivers as required for H & N operational purposes such as boat pool working parties and, in addition, could provide a mobile unit incorporating AN/TRC equipment as a wire telephone back-up. The mobile unit mentioned could, in the event of complete cable failure by the trunking stations, be moved to the switchboard location beyond the failure and plugged directly into the telephone switchboard and would be tied into the AN/TRC equipment which JTF-3 planned to install in headquarters building No. 15 on Eniwetok and Headquarters Building No. 221 on Parry. Technicians and maintenance supplies for all of the equipment thus offered would be provided by JTF-3. In view of the "out of pocket" savings to be realized in following such a plan, the offer was accepted and no further design work on the part of H & N on the radio systems was involved. SCR-608 units were installed in the marine office, the radio shop, and aboard tugs, water taxis, and other craft operated by H & N within the lagoon. The AM-TRC mobile unit was present at the Atoll during the operational phase.

PUBLIC ADDRESS SYSTEMS

In accordance with initial recommendations, an outside paging system was provided for each of the experiment islands. The public address network had its origin at Station 69, the reinforced concrete, blastproof communications and timing station, and provided paging services to the camp area and the areas in which scientific stations were located, including the zero point and others. The equipment used was manufactured by RCA and was designed to withstand tropical conditions. The control console at Station 69 was adjacent to the telephone switchboard so that the telephone operator on duty could page personnel at any of the four remote locations of the system. Each location was complete with relay, power supply, preamplifier, and dynamic microphone. Power amplifiers and loud speakers were installed on poles.

INTERCOMMUNICATION SYSTEMS

On November 27, 1950, H & N was directed to procure and install 9 All-Master System intercommunication units, each with loudspeaker and earphone, equivalent to RCA MI-12596-2A and 7 sound-powered telephones for operational use by JTF-3 and T.G.3.1. Desired locations on Parry Island were indicated for 7 intercom units and 5 sound-powered phones including Buildings 311, 209, 221 (Headquarters JTF-3), 324, 208 and the boat dispatcher's shack.

Because existing overhead telephone cable facilities on this site were already overloaded by increased telephone requirements, and because a subsequent letter requested that separate cables be provided for intercommunication facilities, study was given to the materials available at the Jobsite to provide the required additional cable facilities. It was determined that surplus submarine telephone cable would be used and that ditching opened for this cable would also be used for the installation of additional submarine telephone cable for additional subscribers' loops. Plans were prepared, and this cable was installed in March 1951. The intercommunicating equipment was purchased in December 1950, shipped to the Jobsite, received, installed, tested, and put in operation by March of 1951.

CHAPTER 5.18

CONTROL AND SIGNAL CABLES

The Reconnaissance Report anticipated that existing submarine control and signal cables which had been installed on the floor of the lagoon in January, February, and March of 1948 for use in Operation Sandstone would be usable for future operations. (See Plate 50 of the Reconnaissance Report in Appendix "A" of this report.) A cable testing procedure was established, and it was recommended that the tests of installed submarine cable made during the reconnaissance trip be supplemented by future cable tests to be performed at approximately six-month intervals during the ensuing two years and that approximately 219,000 feet of existing control and signal cable, not installed, be tested to determine whether or not it could be used for future operations. It was also recommended that cable landings be protected by placing cables in trenches at the points where they were brought ashore and by identifying cable landings with signs.

It was assumed at this time that requirements for operations would be for 188,000 lineal feet of type 115-P submarine cable from Parry to Bogallua, plus terminal boxes, strips, and locks; and 34,400 feet of underground cable for local branch circuits from timing buildings to towers on experiment islands. It might be noted that the type 115-P cable is 10 conductor, plastic insulated, cutched jute served and steel wire armored; outer diameter is 1.4 inches and weight is 1.9 pounds per foot.

SUBMARINE TRUNKING CABLE

Additional requirements had not been firmed up by July 8, 1949, when Supplement No. 1 to the Reconnaissance Report was released. An analysis of cable testing completed by that date indicated that most of the submarine control and signal cable installed at Jobsite would be usable. Tests made during the early months of 1949 indicated that approximately 137,000 feet of the 219,000 feet of stored cable would be satisfactory for use. Data for cable tests are presented as an exhibit at the end of this volume.

On June 6, 1950, the total estimated requirements of type 115-P submarine cable were as follows:

Trunking to provide signals at sites remote from Runit, the Aomon Group, Engebi, and Bogombogo	33,000 feet
Extensions from Station 6 to Station 69 on Runit, the Aomon Group, and Engebi	46,000 feet
Trunking from Engebi to Bogallua and Engebi to Bogombogo	111,000 feet
Total to be installed	190,000 feet

Quantity recommended as a reserve for emergencies	61,000 feet
Total required	251,000 feet

On July 19, 1950, two preliminary copies of a schematic diagram of control and signal submarine cable were submitted to the AEC for approval prior to release to the field. On July 26, 1950, these drawings were forwarded to the Jobsite.

In addition to the above requirements it was estimated that 27,300 feet of type 115-P cable were required for trunking from Bogallua to Bogombogo, Engebi to Muzin, and Muzin to Kirinian; and 38,850 feet for extensions from Stations 6a to Stations 69 on Runit, the Aomon Group, and Engebi. Deducting the 20,000 feet still available at the Jobsite, 46,150 additional feet were required. Procurement was authorized for 50,000 feet on August 3, 1950.

This additional cable was installed, along with the stored cable; and, in addition, it was necessary to use a few pairs of telephone submarine trunk cables for control and signal circuits. Table 5.18-1 shows the location, type, quantity, and origin of all cable used. Figure 5.18-1 shows the complete schematic for the inter-island control and signal system installation, and Figure 5.18-2 shows the plan for the inter-island control and signal system.

The problems involved in installing the additional submarine control and signal cable for trunking purposes were similar to those for submarine telephone cable except that it was not necessary to use splice cases. For a discussion of the planning of this work, see Chapter 5.17 of this volume. Cable landings were protected in the same manner as the telephone cable landings and new cable terminal strips and terminal boxes were installed in Building 311, Parry; in Station 69 on Runit, the Aomon Group, and Engebi; and in Station 101 on Bogallua, Muzin, and Kirinian.

LOCAL BRANCH CIRCUIT CABLE

At the time of the Reconnaissance Report and Supplement No. 1, the assumed scope of local branch circuit cable work consisted of the installation of 34,400 feet of existing cable for distributing signals to the experiment island towers. On February 7, 1950, because specific requirements had not been established, the Engineering Division asked for information concerning these requirements.

On March 10, H & N was requested to make an investigation and submit recommendations as to the most economical wire to be used in large quantities for direct burial in trenches for control and signal use. It was indicated that because of the short-term usage, rubber or thermoplastic building wire (which had proved to be satisfactory for similar use on the previous operation) or nonmetallic sheathed cable would be suitable. These recommendations were submitted on March 31, 1950. Because of the

TABLE 5.18-1. SUMMARY OF NEW AND EXISTING SUBMARINE CONTROL AND SIGNAL CABLE

CABLE NO.	FROM	TO	CABLE TYPE	NO. CONDUCTORS	APPROX. LENGTH (FEET)	REMARKS
0-200	Sta. 69-Aomon Group	Sta. 69-Engebi	115-P	10	47,000	New
0-201	Aomon Group	Engebi	115-P	10	47,500	Existing
	Sta. 6A-Engebi	Sta. 69-Engebi	115-P	10	1,100	New
	Sta. 6A-Biijiri	Sta. 69-Rojoa	115-P	10	2,830	New
0-202	Aomon Group	Engebi	115-P	10	46,800	Existing
	Sta. 6A-Engebi	Sta. 69-Engebi	115-P	10	1,100	New
	Sta. 6A-Biijiri	Sta. 69-Rojoa	115-P	10	2,830	New
0-203	Aomon Group	Engebi	115-P	10	48,400	Existing
	Sta. 6A-Engebi	Sta. 69-Engebi	115-P	10	1,100	New
	Sta. 6A-Biijiri	Sta. 69-Rojoa	115-P	10	2,830	New
0-204	Runit	Biijiri	115-P	10	42,000	Existing
	Sta. 6A-Biijiri	Sta. 69-Rojoa	115-P	10	2,830	New
	Sta. 6A-Runit	Sta. 69-Runit	115-P	10	1,750	New
0-205	Runit	Biijiri	115-P	10	38,000	Existing
	Sta. 6A-Biijiri	Sta. 69-Rojoa	115-P	10	2,830	New
	Sta. 6A-Runit	Sta. 69-Runit	115-P	10	1,750	New
0-206	Runit	Biijiri	115-P	10	38,500	Existing
	Sta. 6A-Biijiri	Sta. 69-Rojoa	115-P	10	2,830	New
	Sta. 6A-Runit	Sta. 69-Runit	115-P	10	1,750	New
0-207	Runit	Biijiri	115-P	10	38,000	Existing
	Sta. 6A-Biijiri	Sta. 69-Rojoa	115-P	10	2,830	New
	Sta. 6A-Runit	Sta. 69-Runit	115-P	10	11,750	New
0-208	Sta. 69-Runit	Coral Head	115-P	10	44,000	Existing (not used)

0-209	Parry	Runit	113	3	6,400	Existing (unusable)
	Parry	Runit	104	3	56,400	Existing (unusable)
0-210	Parry	Runit	113	3	5,100	Existing (unusable)
	Parry	Runit	104	3	55,700	Existing (unusable)
0-211	Parry	Runit	115-P	10	61,000	Existing
	Sta. 6A-Runit	Sta. 69-Runit	115-P	10	1,750	New
	Bldg. 310-Parry	Bldg. 311-Parry	115-P	10	--	Rerouted
0-212	Sta. 6A-Runit	Bldg. 310-Parry	115-P	10	58,000	Existing
	Sta. 6A-Runit	Sta. 69-Runit	115-P	10	1,750	New
	Bldg. 310-Parry	Bldg. 311-Parry	115-P	10	--	Rerouted
0-213	Sta. 6A-Runit	Bldg. 310-Parry	115-P	10	57,750	Existing
	Sta. 6A-Runit	Sta. 69-Runit	115-P	10	1,750	New
	Bldg. 310-Parry	Bldg. 311-Parry	115-P	10	--	Rerouted
0-214	Sta. 6A-Runit	Bldg. 310-Parry	115-P	10	57,000	Existing
	Sta. 6A-Runit	Sta. 69-Runit	115-P	10	1,750	New
	Bldg. 310-Parry	Bldg. 311-Parry	115-P	10	--	Rerouted
0-215	Bldg. 310-Parry	Term. 10-Aniyaanii	113	3	30,800	Existing
0-216	Bldg. 310-Parry	Term. 10-Aniyaanii	104	3	41,900	Existing (unusable)
0-217	Bldg. 310-Parry	Term. 10-Aniyaanii	104	3	44,900	Existing (Unusable)
0-218	Sta. 69-Engebi	Sta. 101-Bogallua	115-P	10	39,000	New
0-219	Sta. 69-Engebi	Term.-Bogombogo	115-P	10	36,000	New
0-220	Sta. 69-Engebi	Term.-Bogombogo	115-P	10	36,000	New
0-223	Sta. 69-Engebi	Sta. 101-Muzin	104	10	5,300	New
0-224	Sta. 101-Muzin	Sta. 101-Kirinian	104	10	5,500	New

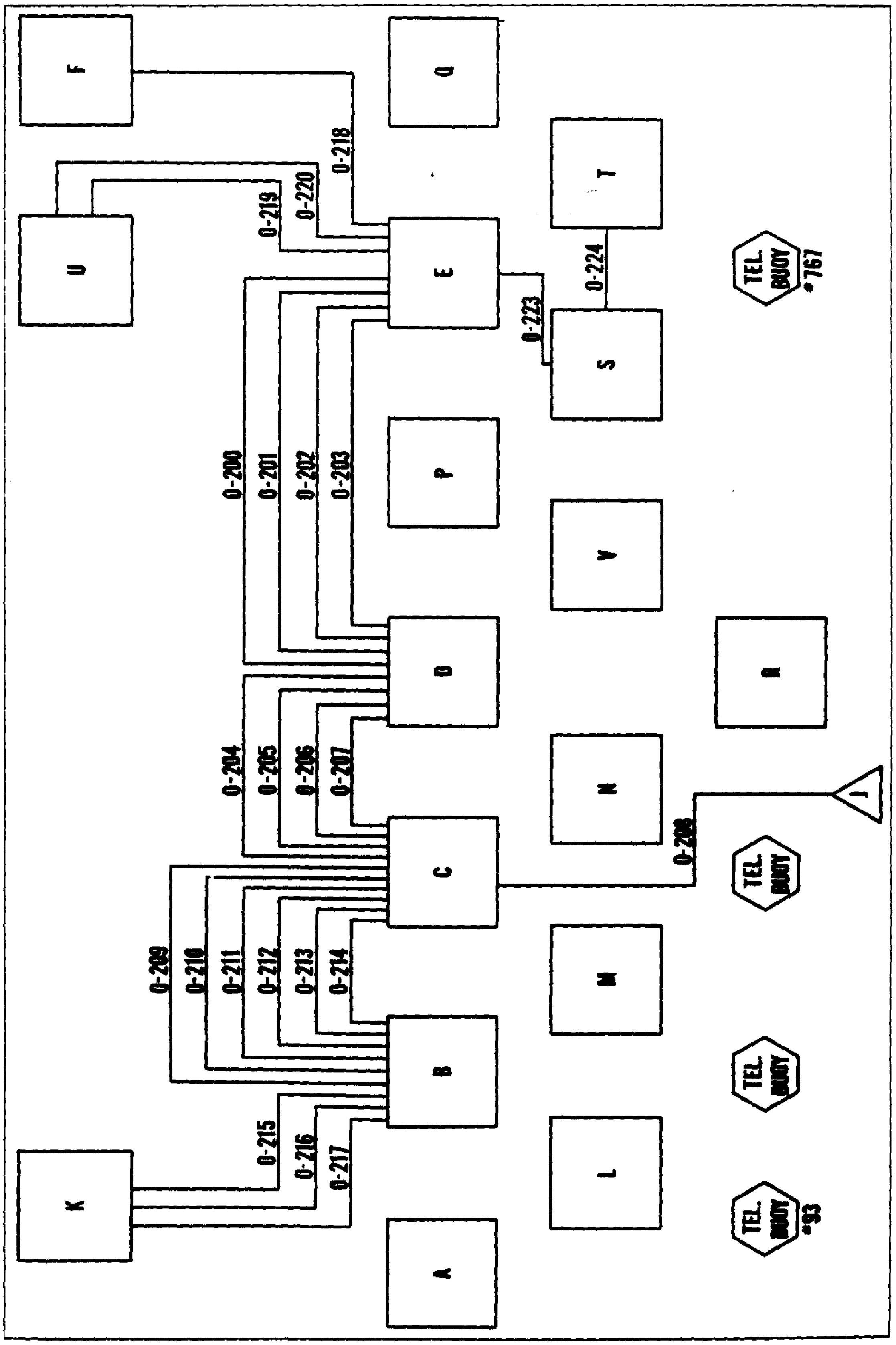


FIGURE 5.18-1 Control and Signal Block Diagram

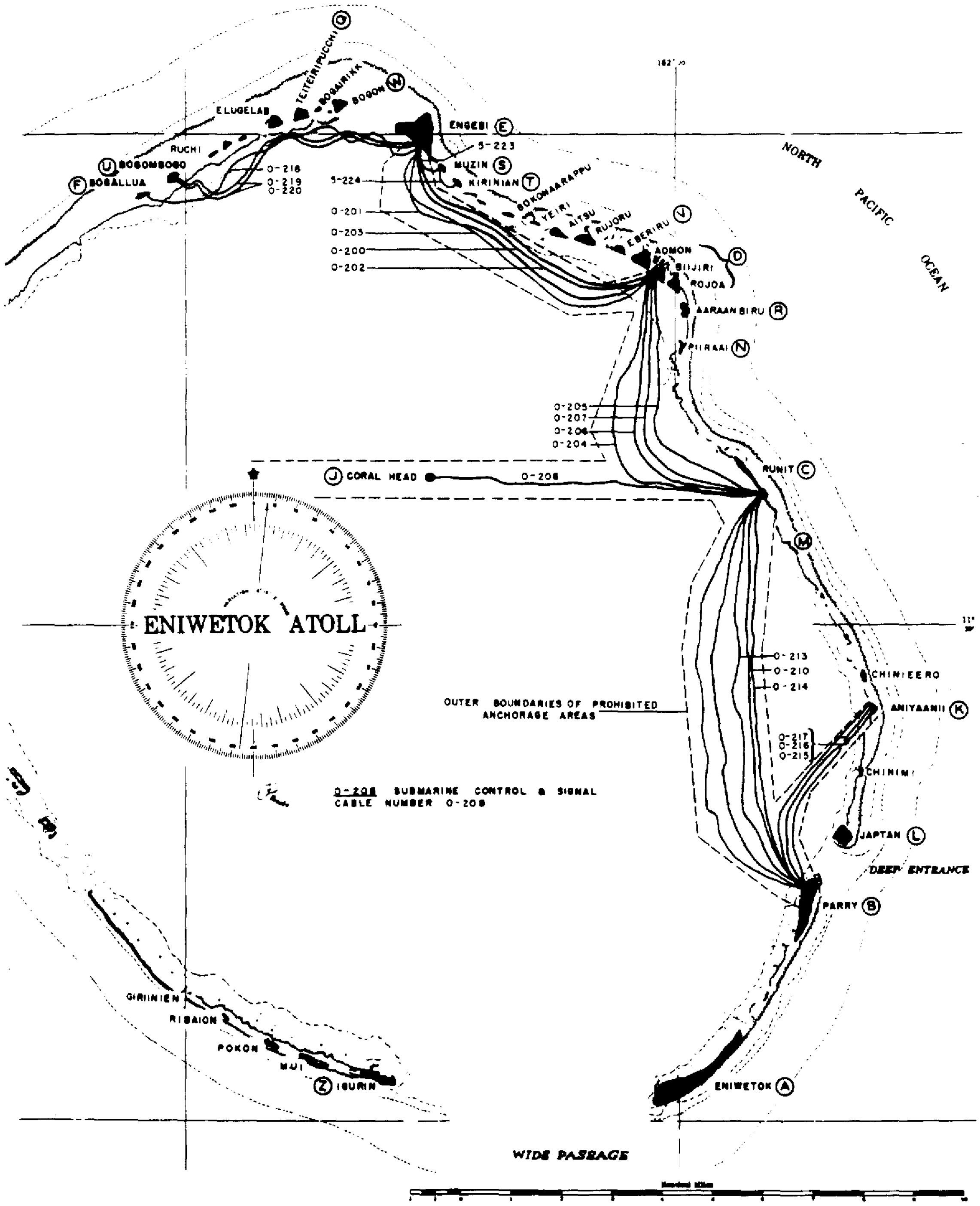


FIGURE 5.18-2 Inter-Island Control and Signal System

added operational convenience of having conductors in pairs, it was suggested that two-conductor nonmetallic sheathed cable be used instead of single conductor wires. The use of multiconductor cable was considered economically unjustifiable. It was suggested that cable be obtained on large reels rather than in 250 foot coils, in order to minimize the number of splices required.

In a series of conferences ending May 17, 1950, the requirements for control and signal cable on Engebi, Muzin, and Kirinian were firmed up, and total requirements for all sites were estimated to be between 800,000 and 1,200,000 lineal feet of two solid conductor 14-gauge cable. This cable was required for runs emanating from Station 69 on each experiment island, to be laid in trenches from these stations to various stations on these and other sites.

On June 15, procurement was requested of 1,200,000 feet of two conductor, 14-gauge parallel conductor solid copper, 600 volt nonmetallic sheathed cable with an insulation of thermoplastic compound moisture resisting type TW or equal, in 5,000 foot reels (500,000 feet) and 10,000 foot reels (700,000 feet) and of 30,000 lineal feet of conductor, 14-gauge solid copper, 600-volt cable with an insulation consisting of polyethelene on conductors and polyvinyl-chloride on the outer jacket on 5,000 foot reels.

Bids on the nonmetallic sheathed cable were received on June 21 and acceptance of the low bids recommended on June 26, 1950. Prior to the receipt of bids, J-Division advised that additional cables would be required between Station 69 and zero points on each island and specified 20-conductor No. 14-gauge copper wire cable for this purpose.

The quantity of 20-conductor cable required was increased to 35,000 lineal feet on July 11, 1950, and the acceptance of the low bid was recommended on July 12. On August 7, 1950, it was necessary because of the scarcity of polyethelene to permit the substitution of polyvinyl-chloride insulation to expedite delivery of this cable.

There were continued changes in the underground control and signal cable requirements until approximately December of 1950. These changes included:

1. The installation of an 8-pair cable for intercommunication between Buildings 311, 209, 221, 324, and the boat dispatcher's quonset, all on Parry Island.

2. The installation of a 2-pair cable between Buildings 311, 209 and 221 on Parry Island, for sound powered telephones.

3. The installation of an 8-pair cable between terminations of unloaded pairs of cables 0-104 and 0-105 at the main frame in Buildings 208 and 311 on Parry Island.

Table 5.18-2 compares originally estimated direct burial signal and control cable requirements and cable of this category actually installed:

TABLE 5.18-2. CABLE REQUIREMENTS

Site	Original Cable Estimated	14/2 Cable Installed	14/20 Cable Estimated on June 14, 1950*	14/20 Cable Installed
Runit	8,900	230,000	6,000	7,000
The Aomon Group	10,500	450,000	8,000	9,000
Engebi	15,000	632,000	6,000	7,000
Muzin	-	18,000	-	-
Piiraai Bokonaarappu Teiteiripucchi Kirinian	-	4,000	-	-
Bogallua Bogombogo	-	-	3,700*	-

*This estimate included 3,700 feet for Bogallua to Bogombogo which was later cancelled. The cable was received and used on the E+ operation, although this site had not been considered in the original estimate.

Direct Burial Control and Signal Cable Tests. Control and signal cables were tested for continuity before laying and after installation for wire-to-wire resistance of each pair, each pair to ground and loop. Cables were two-conductor No. 14 copper wire with thermoplastic insulation and were buried directly in the ground. Although this type of cable is not normally installed in this manner, it was decided that, because of the short duration of service requirements, it would be satisfactory. The operations verified this decision.

The wire-to-wire readings ranged from a low of 100,000 ohms to a high of infinity. The average value lay between 50 and 100 megohms. The pair-to-ground readings ranged from a low of 500,000 ohms to a high of 1,000 megohms. The average value was about 40 megohms. The loop test readings ranged from a low of 0.76 ohms to a high of 43 ohms. A large number of these readings were in the 10 to 20 ohm range. Data showing the range of these tests are presented as an exhibit at the end of this volume, and it can be said that, except for the few open or grounded lines indicated, all lines were classed as in good operating condition.

Installation Procedure. The 14/2 control and signal cables were, in general, installed from Station 69 to various stations on each site.

These cables were laid in trenches at a depth of two feet and entered Station 69 through pipe sleeves in the concrete wall. Cables within the station were terminated in a control and signal cabinet. Extensions from this terminal cabinet to the timing equipment within the Station 69 were made by the Users.

After trenches were excavated, a layer of sand was specified at the bottom. Cables were to be laid in place on this sand bed, using a large low-boy trailer which could handle six to eight 5,000 foot reels simultaneously.

When all cables were in place in the trench, a layer of sand was to be handplaced and the remaining portion of the trench mechanically backfilled to grade. Posts supporting signs indicating direct burial cable were then installed at appropriate intervals.

Cables serving stations which did not have enclosing structures were specified to be terminated six feet above the ground and supported on a driven stake to which was affixed the station number and wire identification. Extensions to equipment were made by the Users.

Cables and wires were identified by metal wrap-around tags with the site number, timing station number, controlled station or intermediate terminus, and the pair number stamped thereon. Plastic tags had been ordered for this purpose, but because of poor delivery they were not used.

TERMINAL CABINETS

Terminal cabinets for control and signal work were planned and specified prior to the firming of the ultimate requirements, in order to avoid delay in construction. These estimated requirements were increased 20 per cent to allow for spares. Burk's Series 1000 terminal strips were specified in galvanized terminal boxes which were complete with hinged doors and padlock hasps. Ample gutters for wiring space were provided. The spare capacity was sufficient for a great many of the increases, but at a few locations it was necessary to install additional terminal strips. The entire installation of terminal cabinets, with these additions, functioned satisfactorily.

COAXIAL CABLE

At the inception of the Project, it was known that a quantity of commercially available flexible coaxial cable would be required for the transmission of signals from detecting instruments to recording stations. However, this was a problem associated with particular experiments and no difficulties were anticipated by H & N in providing trenching plans to accommodate these signal systems.

As time passed and new experiments were added to the program, the quantity of coaxial cable to be installed at the various experiment islands reached large proportions and included, in addition to the flexible cable mentioned above, semi rigid 1 5/8 inch and rigid 3 1/8 inch cable of special design and manufacture. Accordingly, the network of trenches requested was complex, (requiring approximately 19 drawings to depict), and the shielding requirements imposed necessitated a considerable amount of engineering consideration.

The first shielding problem, that of affording adequate protection to the coaxial cables running between Eberiru and Aomon, called for an evaluation of various suggested schemes including the laying of steel or rubber conduit in a trench in the floor of the channel between these islands. After investigation at the site by representatives of the H & N Engineering Division, it was recommended that the most direct solution to the problem was the provision of an earth fill causeway in which a wood frame conduit could be provided for the coaxial cable. Such a causeway would have the additional advantage of serving as a direct above-water roadway between the islands, to facilitate both scientific and construction operations. This recommendation was approved, designs for the causeway were executed, and construction accomplished.

Additional shielding requirements involved the placement of coral berms over the buried rigid and semi-flexible coaxial lines. The heights of these berms varied from more than thirteen feet to five feet, decreasing with distance from zero.

As indicative of the magnitude of the problems involved in connection with coaxial cable, it will be seen from Table 5.18-3 that a total of more than 360,000 feet of rigid and semi-flexible coaxial cable and more than 2,000,000 feet of flexible coaxial cable was installed. Some trenches contained as many as fifty of these cables.

TABLE 5.18-3 COAXIAL CABLE

	Quantity in Lineal Feet				
	Runit	Aomon	Engebi	Engebi (E+)	Total
Rigid*					
Estimated	13,300	106,200	58,000	18,000	195,500
Installed	13,530	115,870	60,600	41,903	231,930
Semi-Flexible**					
Estimated	15,000	22,000	64,000	28,000	129,000
Installed	19,000	35,560	59,700	16,450	130,710
Flexible***					
Estimated	1,104,500	180,300	751,200	7,800	2,043,800
Installed	1,136,500	166,300	757,600	4,391	2,064,791
Other****					
Estimated	9,000	37,400	9,100	16,100	71,600
Installed	8,755	24,400	9,500	2,977	45,632
Site Total					
Estimated	1,141,800	345,900	882,100	69,900	2,439,700
Installed	1,177,785	342,130	887,400	65,721	2,476,036

* Rigid cable, 1-5/8 inch and 3-1/8 inch diameter
** Semi-Flexible, 7/8 inch diameter
*** Flexible, RG18U, RG 8U, and RG 36U
**** Other, 2/c #12, 2/c #4, Teleseal, and 7-Quad

CHAPTER 5.19

DEHUMIDIFICATION, AIR CONDITIONING & VENTILATION

The original Reconnaissance Report contained information regarding new air-conditioning units for timing buildings and the possibility of salvaging any existing portions of air-conditioning units in these buildings for use in less important locations. Supplement No. 1 to the report contained additional information regarding air conditioning of all laboratory buildings to the extent of reducing relative humidity only, except the photo laboratory where a temperature of 70° F with 50 per cent relative humidity was required. The report also specified ventilated range hoods for use in mess halls.

Preliminary estimates for air-conditioning loads and design outdoor conditions were started in May 1949. Design outdoor weather conditions of 82° dry bulb and 80°F wet bulb weather conditions were based on data obtained from a U. S. Department of Commerce publication titled "Weather Conditions in the Marshall Islands with Special Emphasis on Eniwetok Areas", dated February 1948. Tentative calculations were made for the counting and sample laboratory, instrument laboratory, rad-safe building, and the photo laboratory on Parry Island. The result of the study (which included load calculations, vapor seal, design conditions, and maintenance problems) was the realization that the major obstacle was vapor sealing of buildings for air conditioning. H & N promptly set out on an investigation which covered materials of some fifteen manufacturers. The only acceptable material proved to be a vinyl resin plastic known as "cocoon". This material, which is transparent or white depending on the number of spray coats applied, successfully eliminated the vapor transmission. Extreme care was necessary in its application, however, because of the acitate content of the material.

Problems confronting those concerned with dehumidification and allied matters at the Jobsite were relived only through the Engineering Division's intensified research and jobbers' full compliance with unusual demands.

The following terms used generally throughout this chapter are defined for purposes of clarity:

1. Dehumidification. This term denotes the supplying of a room or a building with air which has had some of its water content removed, thus lowering the humidity. The equipment used also controls the motion and distribution of air, in order to maintain relative humidity at a predetermined level.

2. Airconditioning. This term is used to define the control of air, including the dehumidification as well as the control of the final air temperature. This process also includes the distribution and motion of air to maintain predetermined air temperature and relative humidity.

3. Ventilation. The term ventilation as used in this report includes the continuous supply of outside air at ambient temperature and relative humidity and the control of its movement either by forced or induced fans. In some cases, ventilation included the removal of dust by means of filters.

DEHUMIDIFICATION

In accordance with design requirements as stated in the Reconnaissance Report the only building to be air conditioned was the photo laboratory. All other buildings were to be dehumidified only. In September 1949, H & N received information from J-Division that certain buildings for use of NRL on various experimental sites would be dehumidified.

The question of dehumidifying the telephone equipment room located in the H & N Administration Building on Parry was discussed with the manufacturers of telephone equipment and H & N decided to dehumidify this area to safeguard the expensive equipment against moisture and fungus attack.

The working drawings of the buildings to be dehumidified on Parry were being drawn when, in November 1949, H & N received design criteria from J-Division requesting a change in the design conditions from 50 percent to 40 per cent relative humidity for all dehumidification requirements throughout the Project, except for the photo laboratory. The details of the photo laboratory had not been firmed at that time, and H & N was advised that the extent of air conditioning that would be required for this building would be specified later. Because of this change in requirement, all work was stopped on drawings and all the calculations were revised. The new loads were compared with the capacity of equipment selected and the only change required was to increase the fan motors from 1hp to 1½hp. After this, it was determined that for easier maintenance and replacement, all equipment should be kept as nearly alike as possible.

The dehumidifier units each consisted of three major elements: the air drying unit, the dry coil condenser, and the compressor. The units were designed to be completely selfcontained and adaptable for installation either inside or outside of the conditioned space. They had a return plenum chamber through which air from the room was recirculated and mixed with a small portion of fresh, outside air. The air was filtered, cooled, and dehumidified by a direct expansion freon cooling coil and then reheated by the reheat coil to maintain the proper temperature within the building. Inasmuch as steam or hot water was not available for this heating, hot refrigerant gas from the compressor was used. The refrigerating compressor was of the hermetically sealed type, with the compressor shaft directly connected to the electric motor and the entire equipment hermetically sealed so that corrosive effect of the atmosphere would not reach the vital parts. The dry condenser consisted of a condensing coil, condenser fan, and air filters. The controls were designed so that once the unit was started it would dehumidify continually and would automatically hold the temperature constant within the specified range. All controls were located in a control box built into the unit.

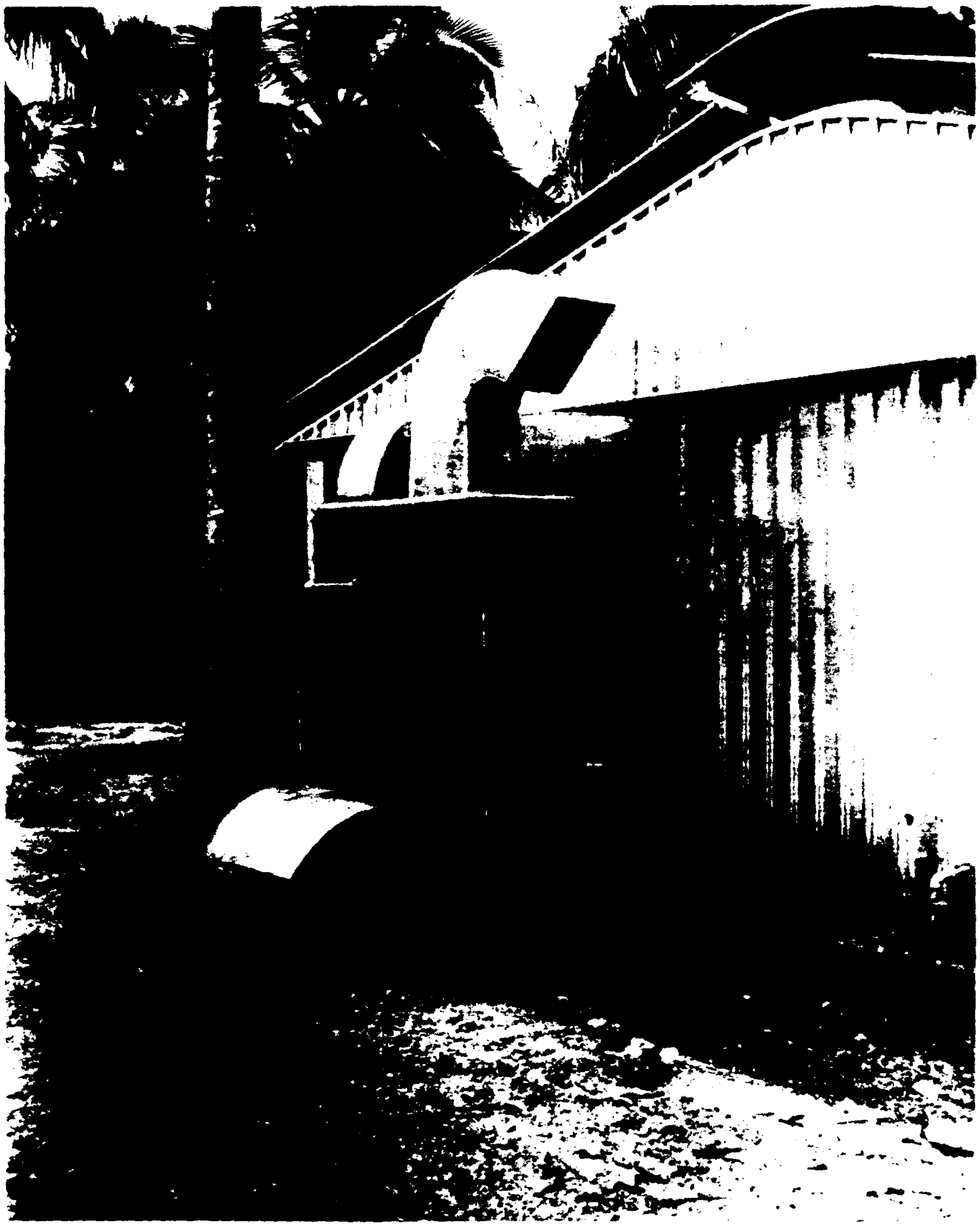
Insofar as was practicable, the equipment was constructed of non-corrosive materials, and all electrical equipment, where possible, was moistureproof and fungusproof. The units were constructed of aluminum external structural members with interior enclosed panels of 4S Alclad aluminum. The filters were of the cleanable type with aluminum media and frames.

All duct work was constructed of aluminum as were duct hangers, grills, registers, and ceiling outlets. Asbestos cloth was used for the flexible duct connections, and fibre glass was used for the duct installation, with two coats of oil base paint applied after installation.

As a result of an invesitgation of many materials, H & N decided that under existing climatic conditions built-up insulation, consisting of tar paper, jute string, hair felt, and friction tape was best suited for refrigerant suction lines. Specifications and invitation for bids on dehumidification equipment were sent to bidders on January 3, 1950, and proposals were opened on January 10, 1950. Because of the importance of the units in regard to the functioning of scientific instruments which were the heart of the tests, a thorough investigation was made of the two lowest bidders, and as a result the work was awarded to the second lowest bidder. This order covered 12 dehumidification units for six buildings on Parry, one building on Eniwetok, and one spare unit.

Holmes & Narver continued to recieve design criteria from J-Division and additional units were ordered until twenty-eight dehumidification units were ordered from the initial specifications. These included 18 units used for the buildings on all sites; 8 units for Stations 131a, 135, 141b, 144a and b, on Engebi and the Aomon Group; and 2 units assigned to Parry for use as spares. Additional design criteria received in February 1950, gave authorization to proceed with the rehabilitation of the existing Stations 6a and the design of a similar Station 6B adjacent to existing stations for Runit, Aomon, and Engebi. All stations were to be dehumidified and a survey made at the Jobsite indicated that the existing dehumidification units at these sites were beyond economical repair. Design loads were calculated and dehumidification equipment designed similar to the design of the previous units and in accordance with J-Division's request to mount the dehumidifier inside the station and the dry condenser outside. Dehumidification equipment specifications were altered to describe the new equipment and sent to bidders on April 26, 1950. After an engineering review of these bids, it was necessary to reject the proposal of the lowest bidder and place an order with the second lowest bidder, the same vendor who had built the first increment of dehumidification units. The reasons for selection of this bidder were primarily his ability to deliver on the required schedule and his ability to provide units which had many components interchangeable with the previous units supplied.

Parry Island: Dehumidification Unit for Telephone Switch-
board Office



Japtan Island: Dehumidification Unit Installed for Bldg. 12

Twenty-three dehumidification units were ordered in accordance with the new specifications for use in the following stations:

On Engebi:	2 units in Station 6a, 2 units in Station 6b, 1 unit in Station 132a, and 3 units in Station 132b.
On Aomon Group:	2 units in Station 6a, 2 units in Station 6b, 2 units in Station 132a, and 3 units in Station 132b.
On Runit:	2 units in Station 6a and 2 units in Station 6b.
On Parry:	2 units as spares.

Drawings were prepared for dehumidification units for Stations 6a, 132a and 132b on Bogallua and an order was placed on August 4, 1950. On August 14, 1950, AEC advised that Bogallua would not be used as an experiment island and the order was cancelled.

In accordance with instructions from Los Alamos on October 16, 1950, planning was started in preparation for a second experiment on Engebi with the tower located on the northeast corner of the island. Stations 6a, 6b, and 132b were to be used a second time in connection with the second experiment. The dry condensing and compressor units were located outside these stations and would be expended. Seven additional dry condensing and compressor units were ordered by H & N on October 26, 1950 as replacements for the expended equipment.

AIR CONDITIONING

As stated previously, the only building to be air conditioned was the photo laboratory on Parry. It was determined that in this building it would be necessary to maintain a temperature of 70°F with 50 per cent relative humidity. This was accomplished by using the same equipment which had been designed and used for dehumidification. The only difference in the use of this equipment was that when it was used as an air-conditioning unit, it was necessary to control air temperature as well as relative humidity. Extensive duct work was required because the building was broken up into many small darkrooms which were completely lighttight and airtight.

VENTILATION

Ventilation work for buildings was started early in October of 1949, the first unit being the mess hall exhaust hoods. As this work progressed, it became necessary for H & N to design special equipment to handle the job because of unusual conditions to which the equipment would be exposed and because of the importance of its operation at all times.

The power roof exhausters were of aluminum construction, complete with weatherproof cap. The fan was driven by a fungusproof and moistureproof electric motor mounted outside the airstream and protected by a weather hood easily removable for servicing and inspection. The fan shaft was stainless steel, and the fan blades were designed of heavy duty cast aluminum, balanced to insure vibrationless operation. The fan housing was made of heavy gauge aluminum adequately reinforced for maximum rigidity. Weight of these fan assemblies could not exceed 300 pounds because of building structural limitations. Exhaust hoods over ranges and friers designed for the installations of grease filters were constructed of stainless steel sheets reinforced with stainless steel angles. For ease of handling these hoods were sent to the Jobsite knocked down in sections. The grease filter assemblies for the range hoods were designed to withstand the salt air and excessive humidity. The filter media were corrosion resistant copper, and the filter frame was constructed of heavy silicon bronze. All filters used were standard sizes and of the cleanable type. Filters were placed in a V-type stainless steel adapter unit with removable drip pan. Exhaust hoods located over steam kettles, cookers, coffee urns, and dishwashers did not require grease filters. These hoods were designed similar to those located over ranges and friers, except that they were made of aluminum. The fume hoods used in the laboratory buildings were of standard construction similar to those used in commercial laboratories.

The three power house buildings on the test sites (Runit, the Aomon Group, and Engebi) were of solid reinforced concrete design, with the only openings those provided in the rear wall of the building. For this reason, it was necessary to ventilate these buildings whenever equipment was operating inside. The ventilation system for each building was designed so that the temperature inside the building would not rise above 110°F when outside air was 80°F.

Air was supplied into each building through two identical ventilating systems with axial flow fans mounted inside the building. One system was designed so that blind flanges could be installed for sealing the inlet and outlet of the system a few hours before zero. The other ventilating system was designed with electric motor operated butterfly valves installed over the exhaust and supply openings. This system was to continue operation until shutoff at zero hour. The butterfly valve was an electric motor operated two-position valve designed to close from wide open position in ten seconds, with an allowable variation of plus or minus 1 second. The valve was constructed of cast iron suitable for high humidity salt air at atmospheric temperature. The supply fan and other materials used for the construction of these ventilating systems were the best quality available for normal ventilation usage.

A power house building was designed for Bogallua and its ventilation system was similar to the one described above with the exception that it was a single ventilation system with electric motor operated butterfly valves mounted inside the building over the supply and exhaust openings. The decision not to use this island for a test site made it unnecessary to construct this power plant.

The ventilation for the scientific stations at various sites was in accordance with design criteria received from J-Division. The first criteria were received in November 1949, requesting the ventilation of the communications buildings (Station No. 69 on Runit, Aomon, and Engebi). The equipment and materials used in design of the ventilating systems for these stations were high quality, standard design products, with the exception of special wall fittings designed to fit particular buildings.

The ventilation of Station 69 was accomplished by mounting a centrifugal fan complete with weatherproofed hood and fungusproof and moistureproof motor outside the station, and blowing air into the metal ducts. All supply and exhaust ducts that penetrated the concrete walls were flanges; cast iron wall fittings were supplied with blind flanges so that the stations could be sealed before test. The exhaust ducts consisted of lightweight steel pipe terminated above the earth fill over the station in a welded 180° long radius ell.

Ventilation systems for Stations 54, 55, and 57 on Runit and Engebi and station 56 on Aomon were designed similar to those stations described above except that the duct work did not penetrate the concrete walls of the stations. The duct work located inside the station was connected to the supply fan mounted outside, with a removable, flexible, metal air tube that could be connected only when the door of the station was open.

Preliminary design for the ventilating system of Stations 301a through k was started in March 1950 to determine the amount of ventilation required to maintain a maximum temperature of 120°F in the stations for a period of 20 seconds after the ventilating system was out of operation. As a result of a conference with representatives of Sandia Corporation in April 1950, it was decided that the ventilation would be maintained as long as possible from the available power supply. After this conference, the following ventilation system was designed:

An industrial type centrifugal blower with fungusproof moistureproof, motor and weatherproof cover was mounted on the roof of each station. Filtered air was supplied through welded, light wall steel pipe into the station. The exhaust duct was constructed of similar material. Flanged cast iron wall fittings were used where the supply and exhaust ducts penetrated the concrete walls. Each station had two solenoid-operated butterfly valves, one on the air supply and one on the exhaust. The solenoids were actuated to close the valves at H-hour minus 5 seconds. The valves were constructed of cast iron suitable for high humidity salt air at atmospheric temperature. The maximum leakage specified was not to exceed one-half of one percent.

The exhaust systems for removal of sulphuric acid fumes from Stations 23a, on Engebi, Aomon, and Runit; Station 23b on Engebi, and Station 25 on Engebi were designed for standard equipment, except the fan, which was provided with an explosionproof motor and nonsparking wheel. Inside the station, a removable section of duct work was provided adjacent to the wall fitting to allow installation of the blind flange before experiment time.

Station 825 on Engebi, and Station 826 on Muzin, had ventilating systems designed to maintain a maximum temperature of 120°F for a period of 30 seconds after the system closed. Solenoid-operated butterfly valves were required on the supply and exhaust openings on these stations. Station 827 on Teiteiripucchi, and Station 828 on Bokonaarappu, had ventilating systems similar to those described above, except that butterfly valves were not used because the stations were constructed of wood and were at considerable distance from zero. The exhaust fans for these four stations were rubber coated because of the more concentrated sulphuric acid vapors passing through them.

For Station 75 on Engebi, Station 76 on Bogallua, Stations 77 and 78 on Kirinian, and Station 79 on Bokonaarappu, two identical supply systems were designed so that in the event of one fan failure the other fan would still supply the station with ventilation. The fans were to continue to run several hours after the experiment and were to operate from storage batteries. Design requirements were such that the systems had to be provided with a very high velocity air stream. The duct work was designed to be constructed of prefabricated welded light wall steel pipe assemblies. The working drawing was completed March 24, 1950; however in April, J-Division advised that the User would supply and install all interior ventilation and that this feature was to be omitted on the H & N drawing.

The CMR area on Parry was provided with a conventional ventilating system consisting of a large supply of fans and aluminum sheet metal duct work outside of each of the two large buildings. These were to supply air to the various locations within the building. Motor driven roof exhaust fans were provided over hoods that served the major pieces of equipment. In addition, one section of the laboratory space was provided with dehumidification equipment to provide protection for instrumentation and laboratory equipment.

CHAPTER 5.20

REFRIGERATION

The Reconnaissance Party found that the refrigeration equipment on the Atoll was in poor condition. The refrigeration units on Parry that still existed were corroded to such an extent that they should be considered as expended and, on Eniwetok the refrigeration equipment had deteriorated beyond the point where it would be feasible to recondition or reuse it in future operations. These refrigerators referred to were typical Army portable, walk-in reefers, lined with galvanized sheet metal which showed considerable deterioration. There were also several small Navy portable type reefers, 5 feet by 6 feet by 5-1/2 feet inside dimensions, in poor condition, and also considered to be unusable.

In April 1949, during preliminary planning for the Project and at the time preliminary sketch plans for various buildings were being prepared, considerable thought was given to the best method of providing for the necessary refrigeration facilities. Careful consideration was given to two basic methods of supplying equipment: permanent walk-in cold storage buildings constructed at Jobsite of materials shipped over in bulk; and prefabricated, portable, walk-in refrigerators manufactured domestically and assembled in the field.

If job-constructed cold storage buildings were to be used, construction from materials (insulation, concrete or concrete blocks, and lumber) shipped to the job would require the employment of construction labor skilled in this trade. Further, it was felt that concrete or wood structures of this type would not be well suited to expansion in case of increased requirements, nor would they be well suited to reduced requirements during standby or roll-up periods. In addition, the installation and maintenance of large refrigeration facilities would require the employment of construction laborers and maintenance workers highly skilled in this trade.

In recognition of these problems to be excepted in regard to construction personnel and the operation and maintenance of mechanical equipment, it was felt that the best solution lay in using a series of identical small walk-in refrigerators, all powered by identical air-cooled condensing units and so arranged that any refrigerator box could be operated at either 35° F or 0° F. In this way, as personnel increased, extra boxes could be added as required, and as few as two boxes (one at each temperature) could be used for a small standby crew.

Air-cooled condensing units were selected because of the extremely high relative humidity prevalent at Eniwetok Atoll. Approximately the same results could be obtained by either air-cooled or water-cooled equipment but because cooling water pumps, spray nozzles, and piping are not required for air-cooled equipment, maintenance of them is simplified.

These boxes, or groups of boxes, would be constructed, in the United States, of sections of such size as to be easily handled, and identified so they could be assembled quickly and correctly in the field by unskilled labor. The refrigeration equipment for each box would be factory-assembled and tested and would be mounted on a plug-in section, which could easily be inserted into or removed from the box in the field. Since the refrigerator equipment plug-ins would all be identical and interchangeable, the provision of a few spare units would facilitate greatly the maintenance of the equipment for individual boxes. In case of break-down of an individual refrigerating unit, the installed plug-in could be removed from the box and the spare inserted, quickly, and with a minimum of effort. The defective equipment could then be removed to the refrigeration maintenance shop to be repaired and made ready to insert in the place of another unit in case of breakdown. In this way, continuity of service could be maintained to a high degree, and loss of service due to mechanical or electrical difficulties could be reduced to a minumum.

Accordingly, in April 1949, when the preliminary sketch plan was prepared for the reefer and commissary building on Parry Island, a four-compartment refrigerator of the type described above was incorporated in the building layout. The building was a standard 24 foot wide aluminum structure 100 feet long, with a partition located so as to divide the building into two rooms, each approximately 50 feet long. One room contained the refrigeration units; the other was for dry storage, i. e., canned goods, paper goods, etc.

In July 1949, while the working drawings for this facility were in preparation, a specification was written for procurement of the main food storage refrigerator for Parry Island. This was for a four-compartment refrigerator of a type similar to that contemplated at the time the preliminary sketch plan had been prepared. As specified and furnished, the refrigerator was 42 feet, 6 inches long, 12 feet wide, and 8 feet, 6 inches high. overall outside dimensions, and was divided by partitions into four equal sized compartments, each having approximately 825 cubic feet gross internal volume. The refrigerator was of portable, sectional design to facilitate transporting, handling, and erecting in the field. It was designed to be completely self-sustaining, requiring only a level surface on which to lay the floor. See photo showing the front of four compartment refrigerator as described.

The sections or panels which formed the walls, floor, ceiling, and partitions consisted of frames of wolmanized Douglas fir, insulated with glass fibre, and completely sealed between sheets of 18-gauge aluminum in such a manner as to insure that each section was absolutely airtight and watertight. For ease in handling, no section exceeded 48 inches in width. The joints between sections were of tongue and groove design, and the sections were drawn together with lag bolts on resilient gaskets.

The rear wall of each compartment was provided with an opening for the insertion of a demountable, plug-in type insulated panel furnished as a part of the refrigeration equipment assembly. See photo showing a view of the interior of a typical compartment, looking through the opening provided for the refrigeration equipment plug-in.

Each refrigeration equipment assembly was capable of maintaining any compartment on the refrigerator at either 0° F or 35° F. Each assembly consisted of a unit cooler, a condensing unit, refrigerant piping, valves, automatic controls, and other standard accessories, all completely prefabricated and factory assembled on an insulated plug-in panel. The unit coolers, which were blower type fin-coil evaporators, were equipped with heaters for electric defrost with controls so arranged that, when set to maintain in the refrigerator at 35° F, the evaporator was defrosted automatically each time the condensing unit turned off during its normal operating cycle. When set for 0° F, the automatic defrost operated once each day to keep the evaporator free of ice. The condensing units were electric motor-driven, air-cooled reciprocating type, equipped with automatic controls to maintain each refrigerator compartment at the predetermined temperature. All motors were moistureproofed and fungusproofed for operation in the tropical location. See photographs which show two views of a typical plug-in refrigeration equipment assembly.

When this refrigerator was designed in June 1949, it was intended to have food storage capacity sufficient to serve 600 men for 30 days, based on an assumption that the food consumed per man per day includes 3½ pounds of perishable products and that the weight thereof is 40 pounds per cubic foot. On this basis, 600 men would require 63,000 pounds total for 30 days, and the necessary storage volume would be 1,580 cubic feet, net. Using an allowance of 33-1/3 per cent of the gross volume for aisles, waster space,etc., the necessity gross volume would be 2,100 cubic feet. Since each compartment of the refrigerator contained 825 cubic feet gross, any three of the four compartments, having a gross storage capacity of 2,475 cubic feet, would theoretically suffice, leaving one spare compartment to allow for temporary outage in case of mechanical difficulty.

In addition to this main storage refrigerator, in August 1949 a specification was written for the procurement of a three-compartment food refrigerator for the mess hall on Parry Island. This was a prefabricated, knockdown, walk-in type of similar construction to that described above. It differed only in size (19 feet, 0 inches long by 10 feet, 0 inches wide by 7 feet, 6 inches high, overall outside dimensions) and in the amount of refrigeration required. This was a single temperature refrigerator (35° F design), and it was therefore unnecessary to provide a separate refrigeration machine for each compartment. However, the single condensing unit selected and specified was identical with those furnished for the main storage refrigerator, in order to facilitate maintenance and repair and to reduce to a minimum the number of difference repair parts needed in stock.

In September 1949, a specification was written to procure a beverage storage refrigerator for the recreation building on Parry Island. This was a two-compartment refrigerator of identical construction to that previously described. Each compartment was designed to accomodate twelve dozen cases of bottled beverages and to cool this amount from 100° F to 55° F in ten hours. The refrigerating equipment of each compartment of this refrigerator was also specified to be identical to that furnished for the main refrigerator. The installation of the beverage storage refrigerator different from that of the two refrigerators previously described in that instead of being housed in an aluminum building it was located on a concrete pad outdoors closely adjoining the building. A section of the wall of the building was omitted to permit the refrigerator doors to swing into the building; this allowed the attendants to enter the refrigerator directly. The refrigerator was constructed of aluminum sheets of the same alloy as the aluminum buildings.

Ice is a necessity in the hot, humid climate of the tropics. The cooled drinking water required by each group of men working in the field was supplied in thermo containers filled with ice and water. According to the same basic reasoning that resulted in the selection of package type, sectional walk-in refrigerators, one-ton packaged flake ice machines were chosen for this purpose.

Accordingly, in November 1949, a material requisition was written for the purchase of four one-ton packaged flake ice machines, each complete with an individual air-cooled refrigeration condensing unit and a one ton storage bin constructed of redwood and equipped with stainless steel liners. It was decided to install these machines in the reefer and commissary building on Parry Island, and the drawings for this building were revised and reissued with this change to the field.

Late in December 1949 and in January 1950, the design of the reefer building for Eniwetok Island was firmed up. By this time, the expected maximum population of this island had increased from the 600 men contemplated in the Reconnaissance Report to over 1800 men. Accordingly, the main refrigeration facilities provided in the plans of this island consisted of six flake ice machines and four 5-compartment refrigerators, all identical in design to those for use on Parry Island. This equipment was all contained in one standard 24 foot wide aluminum building approximately 236 feet long. The four refrigerators were installed end-to-end in one continous line over 200 feet long.

In addition to the main storage refrigerators for Eniwetok Island, the mess hall was provided with a three-compartment refrigerator of similar design to that installed in the mess hall on Parry Island. Two compartments of this refrigerator were designed for storage of vegetables and dairy products at 38° F, and the third compartment was designed for storage of frozen foods at 0° F.

Also in January 1950, a specification was written for the procurement of food storage refrigerators and beverage storage refrigerators for the experiment island camps. These were specified to be aluminum-clad, knock-down, walk-in refrigerators similar in design to those previously described but of much smaller capacity. It was contemplated that prior to the experiments these refrigerators, along with other items of a portable nature, would be dismantled and removed to Parry Island for storage.

This specification was delivered to the Holmes & Narver Purchasing Department for action in procuring the specified refrigerators, but before such action had been initiated it was learned that refrigerators of somewhat similar design and approximate capacities were available from surplus stock at Navy Headquarters, Port Hueneme, California. These surplus refrigerators were of the portable, knockdown type but were constructed with galvanized steel sheets instead of aluminum sheets. However, taking into consideration the comparatively temporary occupancy of the experiment islands, it was felt that the steel refrigerators would be suitable, and of eight 675 cubic foot, six 150 cubic foot refrigerators were purchased from the Navy for this use.

By the end of 1949, the expected maximum population of Parry Island had risen from the 600 man originally contemplated to a total of over 1,000 men. It also was apparent that, because of unanticipated delays in water shipments, additional refrigerated storage capacity would be required to provide for 45 day storage periods instead of the 30 day periods originally expected.

Therefore, an additional 4-compartment main storage refrigerator was procured for Parry Island. This was identical to that originally purchased for this location, and in effect doubled the capacity of the permanent storage facilities. It was decided to locate the additional refrigerator in the reefer and commissary building and adjacent to the original main storage refrigerator; the drawings for this building were revised and issued to the field. Since the new refrigerator occupied the space in the building which had been originally allocated to dry storage, a new commissary building was erected adjacent to the mess hall. This new commissary building was a standard 24 foot by 68 foot aluminum building.

In August 1950, in discussions between representatives of J-Division and Holmes & Narver in regard to conditions at the Jobsite, it appeared that refrigeration capacity would be required for a maximum total of 1,668 men on Parry Island. In addition, it also appeared that the holding period between water shipments should be increased again, probably to 60 days. In view of this, it was decided to purchase additional refrigerators from Navy surplus stock to be sent to the field for use as additional temporary storage capacity. Accordingly, six 675 cubic foot and ten 150 cubic foot portable, knockdown refrigerators were obtained. These refrigerators were installed adjacent to the main refrigerator building on Parry Island.

Experience obtained during the construction period indicated that root vegetables could be stored for the extended period between arrivals of refrigerated cargo vessels only by chilling. The continued increase in the number of people to be fed resulted in increased demands for refrigerated storage space. Root vegetables required only moderate chilling and the type of refrigeration previously provided was not justified for this use.

Because of their low rate of heat transfer light weight concrete blocks, which had been shipped to the Jobsite for one of the Air Force test structures and had not been used, were ideally suited as a material with which to construct a chilled vegetable storage building. In September 1950, a building, 24 feet by 50 feet by 10 feet high to the eaves, was designed and constructed of this material and located near the Parry Island mess hall. It was refrigerated by equipment salvaged from refrigerators that were on the island prior to the Project.

On November 24, 1950, a letter was received from the AEC Contract Administrator requesting that a refrigerator or cooling room be provided for the photo laboratory on Parry Island. This cooling room was to have a capacity of approximately 1,000 cubic feet and was to be used for film storage at a temperature of 50° F. Request was made for determination of relative economy of a standard walk-in refrigerator or a cooling room with a separate cooling unit. Accordingly, a cost analysis was prepared by the Holmes & Narver Estimating Department that indicated that economically there would be very little choice between a building constructed in the field and a prefabricated, knockdown, walk-in refrigerator. Therefore, an aluminum-clad prefabricated refrigerator was procured for this service. The drawings for the photo laboratory building were revised to show the refrigerator located outdoors adjoining the building and connected thereto by means of a lean-to passageway.

Facilities for freezing and hardening ice cream were provided on Parry and Eniwetok Islands. A 20-quart capacity freezer was installed in the bakery building on Parry Island and two 10-quart capacity freezers in the mess hall on Eniwetok Island. These freezers were the direct expansion, flooded type, using freon as the refrigerant. Each of the 10-quart freezers was mounted on a 60-gallon combination hardening and holding cabinet, which also contained the refrigeration condensing unit. The 20-quart freezer was mounted on a cabinet housing a condensing unit, and a separate 40-gallon hardening cabinet was provided adjacent to the freezer in the Parry Island bakery. In addition a 40-gallon ice cream holding and dispensing cabinet was provided in the Parry Island mess hall. The mess halls on Runit, Biijiri, and Japtan Islands were each provided with a 30-gallon ice cream dispensing cabinet, and the mess hall on Engebi Island with a 40-gallon dispensing cabinet. These islands were supplied with ice cream from the freezer on Parry.

The criteria used for determination of ice cream freezing and storage capacity were obtained from the Reconnaissance Report. It had been observed by the reconnaissance team that one gallon was used to serve eight people at one meal. This generous allowance made it possible to continue to serve ice cream after popluation loads had increased very greatly.

Chilled drinking water was provided in each mess hall by means of refrigerated water coolers. These were self-contained units, equipped with air-cooled refrigeration condensing units, housed in an aluminum cabinet. Cabinet tops and water cooling coils and storage tanks were 18-8 stainless steel. Each cooler was provided with a chrome plated carafe filler and a bubbler and each cooler had a cooling capacity of 25 gallons per hour and a storage capacity of 25 gallons. Fresh water was piped directly to the coolers in all cases.

Because of the warm climate, the A-E-C-M Contractor was directed to provide self-contained, electric, bubbler-type water coolers in all living quarters buildings and in all major buildings on all sites. These were cabinet type units with individual air-cooled refrigeration condensing units. Cabinets were heavy gauge steel with baked enamel finish. Cabinet tops and water cooling coils and storage tanks were 18-8 stainless steel. Water cooling capacity of each cooler was 10 gallons per hour and fresh water was piped directly to each cooler. A total of 166 of these self-contained units were installed on the Project.

CHAPTER 5.21

FUEL HANDLING AND STORAGE

The Reconnaissance Report recommended that new fuel storage tanks be installed to replace existing tanks on Parry and Eniwetok Islands. To provide protection for the new tanks against the very corrosive action of salt spray, and to reduce maintenance requirements, it was decided to install the tanks in shallow excavations and to cover them completely with coral. In order that this might be done easily, it was suggested that 1,000 barrel (42,000 gallon) horizontal cylindrical steel tanks be used. The quantities of various fuels recommended for storage were based on estimates of requirements arrived at in conferences between representatives of J-Division and Holmes & Narver. Following are the tankages recommended in the original Reconnaissance Report:

Site	Fuel	Tanks	Gallons
Parry	L. C. gasoline	2	84,000
Parry	diesel oil	4	168,000
Eniwetok	aviation gasoline	4	168,000
Eniwetok	motor oil	4	168,000
Eniwetok	diesel oil	3	126,000

Because fuel supplies were to be delivered by the Navy, it was necessary to consider in detail the Navy requirements and delivery schedules and to coordinate with Eniwetok garrison requirements.

On June 7, 1949, at conferences held at Pearl Harbor and attended by representatives of Holmes & Narver, J-Division, (and CINCPAC) the fuel storage requirements for Eniwetok and Parry were again discussed, and revised quantities were approved. Specific instructions were given the Engineering Division on June 27, 1949, about the number and capacities of storage tanks for the two sites. These requirements firmed up at Pearl Harbor formed the basis for the statements about fuel storage capacity contained in the Fuel Handling and Storage Section of Supplement No. 1 to the Reconnaissance Report, issued in July 1949. Following are the tankages approved at the Pearl Harbor conferences and subsequently listed in Supplement No. 1:

<u>On Parry Island</u>:

1. Motor gasoline - 82,000 gallons in four 10,000 gallon tanks and one 1,000 barrel (42,000 gallon) tank.

2. Diesel oil - 134,000 gallons in five 10,000 gallon tanks and two 1,000 barrel (42,000 gallon) tanks.

On Eniwetok Island:

1. 73 and 80 octane aviation gasoline - 30,000 gallons in drums.

2. 115 and 145 octane aviation gasoline - 30,000 gallons in three 10,000 gallon tanks.

3. Motor gasoline - 62,000 gallons in four 5,000 gallon tanks and one 1,000 barrel (42,000 gallon) tank.

4. Diesel oil - 84,000 gallons in two 1,000 barrel (42,000 gallon) tanks.

The 5,000 and 10,000 gallon tanks referred to in the above tabulation were to be horizontal steel tanks and the 1,000 barrel tanks were to be vertical bolted steel tanks.

After the Reconnaissance Report was submitted, it was decided that maintenance of these tanks would be greatly simplified and their useful life increased if they could be periodically inspected and repainted as required. Therefore, it was decided to install the L. C. tanks above ground. The horizontal tanks were to be set on steel cradles on concrete foundations. The vertical Tanks were to be set on concrete pads with the bottoms of the tanks protected from contact with the concrete by means of a heavy coating of hot-mopped asphalt. These recommendations were included in Supplement No. 1 to the Reconnaissance Report.

Early in July 1949, design and working drawings were begun for the tank farm and ship unloading facilities on Parry Island. Design proceeded on the basis of the recommendations contained in Supplement No. 1. As indicated on Plate 4 of the Supplement, the fuel storage tank farm and pumping facilities were to be located at the northwest corner of Brookhaven Road and Atoll Road (later re-named Sandstone Avenue). This location had originally been selected to place the storage tanks reasonably close to the diesel power plant building, the point of maximum use, in order to reduce pumping distance to a minimum. This location also facilitated the loading of fuel trucks by allowing the truck loading racks to be installed adjacent to a cutoff between Brookhaven and Atoll Roads and keeping the trucks off the main streets while loading.

Motor gasoline and diesel oil were to be received from tankers through two 4-inch submarine lines, one for each fuel. These lines were to be standard weight seamless steel pipes with welded joints run side-by-side approximately 1,000 feet from the tank farm to a buoy anchored offshore in the lagoon. Of the 1,000 feet, about 400 feet of pipe was to run offshore under water and the remaining length onshore. The steel pipe was to terminate on the bottom of the lagoon near the buoy and be connected to the buoy by means of 4-inch submarine oil hose. In operation, a fuel tanker anchors adjacent to the buoy, makes connections

---

[1] See Appendix "A" to this report.

to it by means of flexible hose, and pumps fuel through the submarine lines into the onshore storage tanks.

The incoming fuel is dewatered, deaerated, and metered before introduction into storage. Electric motor-driven centrifugal petroleum-product pumps are installed to permit transferring fuel from storage tanks to tank trucks or from tank to tank, as required. These pumps act as booster pumps to assist in transferring fuel from tanker to storage tanks in case difficulty is experienced with the tanker's pumps. Dehydrators, air eliminators, meter equipment, flow control valves, and transfer pumps are installed in a standard 24 foot by 32 foot aluminum building for protection against salt spray and the humid atmosphere.

Tank truck loading stands, each consisting of a standpipe with counter weighted swing-joint loading arm and self-closing loading valve, are provided for both motor gasoline and diesel oil. In addition, diesel oil is pumped through underground lines to the diesel power plant and the laundry boiler plant and transferred by truck to the mess hall boiler plant and to the boat fuel storage tank located onshore adjacent to the freight pier. Fuel is transferred to small boats by pumping from the storage tank to two boat fuelers located on the freight pier. Motor gasoline is transferred by truck to a service station storage tank located adjacent to the tank farm and dispensed to vehicles by means of two metering, service station type gasoline pumps.

Early in August 1949, working drawings incorporating the above described design were completed and issued to the field for construction. At the same time bills of material were prepared by the Engineering Division and the Construction Department initiated procurement. The 1,000 barrel vertical bolted steel tanks used for fuel storage were obtained from CINCPAC at Pearl Harbor.

On August 29, 1949, a representative of Holmes & Narver returned from the Jobsite and advised the Chief Engineer that between the location selected for the fuel storage facilities and the fueling buoy there was a large amount of scrap which would have to be moved. Therefore, it was recommended by the Holmes & Narver field engineers that the new storage tanks be located where the war-time Seabee tanks were. Since these original Seabee tanks were in questionable condition and it appeared unwise to use them for the storage of hazardous liquids, the Engineering Division agreed to the removal of the original tanks and the installation of the new tanks in their place.

At the same time, Holmes & Narver's field engineers requested that consideration be given to lowering the horizontal storage tanks, which had been shown on the drawings to be installed on concrete supports at a height sufficient to permit loading tank trucks by gravity. This suggestion was accepted by the designers in the Home Office and the tanks were lowered. They were still supported on piers so that the bottoms could be inspected and maintained. This change eliminated the possibility of having gravity feed to the tank trucks, but this loss was not considered serious because transfer pumps were required in any event and could be used for the dual purposes of loading trucks and transferring to other points of use.

Accordingly, on August 30, 1949, the drawings were revised to show the above mentioned changes, and on September 1, 1949, new prints were issued to the field. Inasmuch as the relocation of the storage tanks and pump house reduced the length of the fuel receiving lines from the fueling buoy and at the same time increased the length of the diesel oil transfer line between the pump house and the power house, it was necessary to revise the materials records sheets. This was done and the revised records were re-issued to the Construction Department.

In August 1949, before design of the fuel facilities for Eniwetok Island had begun, a teletype message from AEC in Washington gave revised figures for storage requirements for Eniwetok Island. These new figures were:

1.	100 octane aviation gasoline	250,000 gallons
2.	JP-1 fuel	40,000 gallons
3.	91 octane aviation gasoline	6,000 gallons
4.	80 octane aviation gasoline	20,000 gallons

Prior to procuring the necessary tanks to store these quantities of fuel, Holmes & Narver's Chief Engineer wrote to the AEC Manager at Los Alamos requesting verification of the quantities. By letter dated December 30, 1949, the Director, Office of Engineering and Construction, AEC informed us the storage requirements had been changed and the following quantities would be stored:

1.	100 octane avgas	150,000 gallons
2.	JP-1 fuel	30,000 gallons
3.	91 octane avgas	18,000 gallons
4.	80 octane avgas	20,000 gallons
5.	Motor gasoline	60,000 gallons
6.	Diesel fuel	80,000 gallons

By the same letter, instructions were given to procure the necessary tankage for the above quantities. Accordingly, procurement of the following tanks was initiated early in January 1950:

1. 100 octane avgas, four 1,000 barrel vertical tanks, 168,000 gallons total storage.
2. JP-1 fuel, one 1,000 barrel vertical tank, 42,000 gallons total storage.
3. 91 octane avgas, two 10,000 gallon horizontal tanks, 20,000 gallons total storage.
4. 80 octane avgas, space for 480 drums.
5. Motor gasoline, one 1,000 barrel vertical tank plus two 10,000 gallon horizontal tanks, 62,000 gallons total storage.
6. Diesel fuel, one 1,000 barrel vertical tank plus four 10,000 gallon horizontal tanks, 82,000 gallons total storage.

The seven 1,000 barrel vertical tanks were procured from the Navy, as had been those for Parry Island.

During the first week of January 1950, design and working drawings were started for the fuel facilities on Eniwetok Island. In general, these facilities were similar to those described for Parry Island. Incoming fuel was received through submarine lines from tankers which discharged through hose connections at a fueling buoy anchored in the lagoon. Three 4-inch submarine lines were required to receive the incoming fuel. Diesel oil was received through one line and JP-1 fuel through another. Gasoline was received through the third line; motor gasoline, 91-octane, and 100-octane aviation gasoline were received through the same line by the degrading of a metered portion of aviation gasoline to the motor gasoline storage tanks in order to avoid contamination of the aviation gasoline. The use of JP-1 fuel, not contemplated in the Reconnaissance Report or the Supplement, required a separate incoming submarine line from the fueling buoy and separate onshore storage and handling facilities.

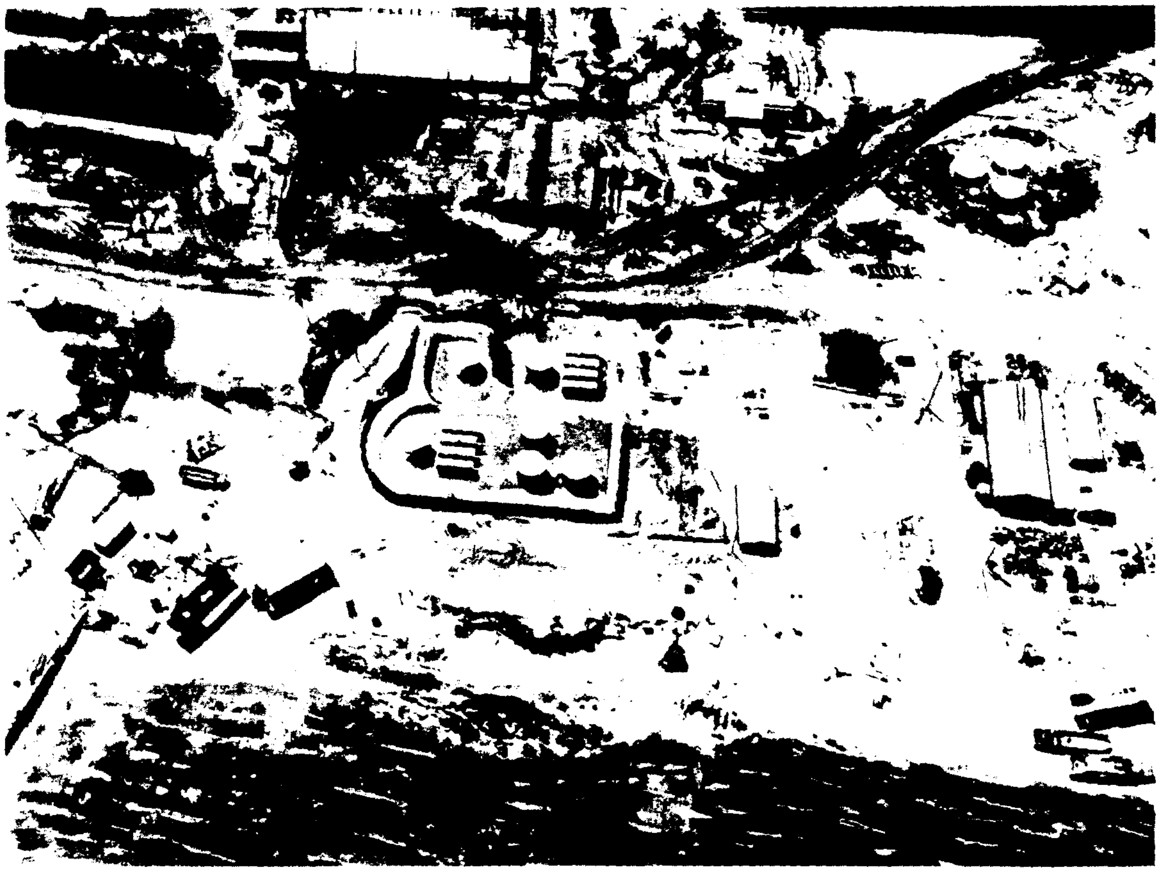
No facilities were provided for pumping fuel directly to the power plant, and no boat fuelers were provided. A truck loading stand was provided for each of the five fuels stored in bulk.

The drawings for Eniwetok Island facilities were completed during the last week in January 1950, and prints were sent through the H&N Jobsite Organization to the Construction Battalion (TG3.2) early in February 1950.

In recognition of the possibility of delays occurring in obtaining prompt deliveries of materials from manufacturers and of the necessary length of time required to transport materials to the Jobsite, it had been decided that materials would be stockpiled for use on Eniwetok Island. Accordingly, during the first week of October 1949, materials had been requisitioned in quantities sufficient to construct the fuel facilities as they were then contemplated. The revised fuel storage requirements received subsequent to that time increased the quantities of materials and equipment beyond the stockpiled amounts. Therefore when the final drawings were completed, the required additional materials and equipment were requisitioned. (Figures 5.21-1, 5.21-2, and 5.21-3 show piping, pumping, storage, and equipment plans and diagrams for Eniwetok Island.)

In December 1949, it was decided that water standpipes should be provided in the storage area in addition to the five protection measures already provided by design including a chain link fence to enclose the entire tank farm and pump house; dikes, or berms, surrounding the storage tanks having a retention capacity equal to the total tank capacity, and the location of 2-1/2 gallon foam extinguishers in the area. Accordingly, a drawing was prepared for the additional fire protection facilities for the fuel storage area on Parry Island. Prints of this drawing were immediately released to the field. Mean-

Eniwetok Island: POL Pump House, Bldg. 94, During Construction July 11, 1950



Aerial View: POL Area on Eniwetok Island

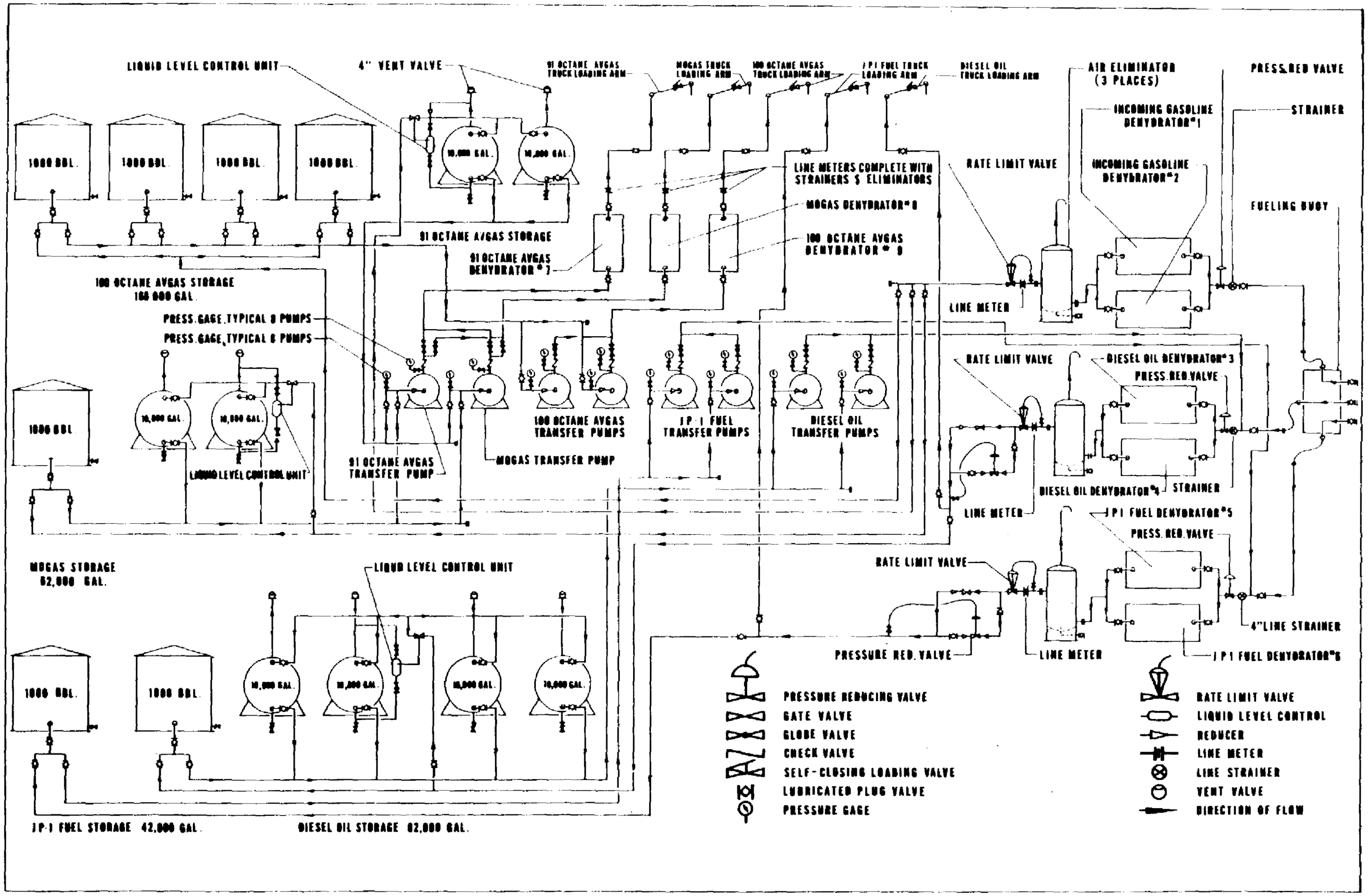


Figure 5.21-1 Typical Piping and Instrument Diagram POL Facilities

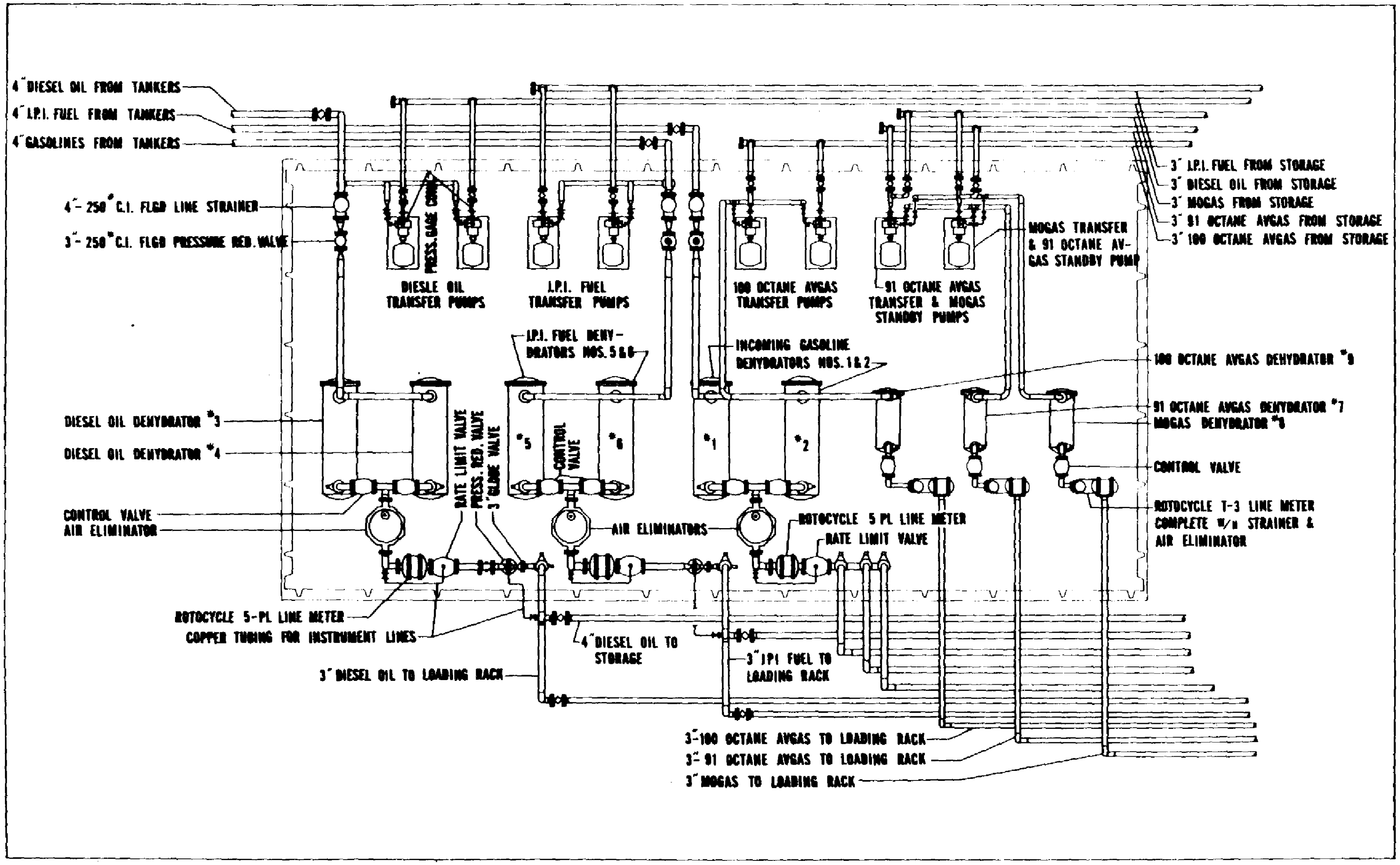


Figure 5.21-2 POL Pump House Equipment and Piping Plan - Eniwetok Island

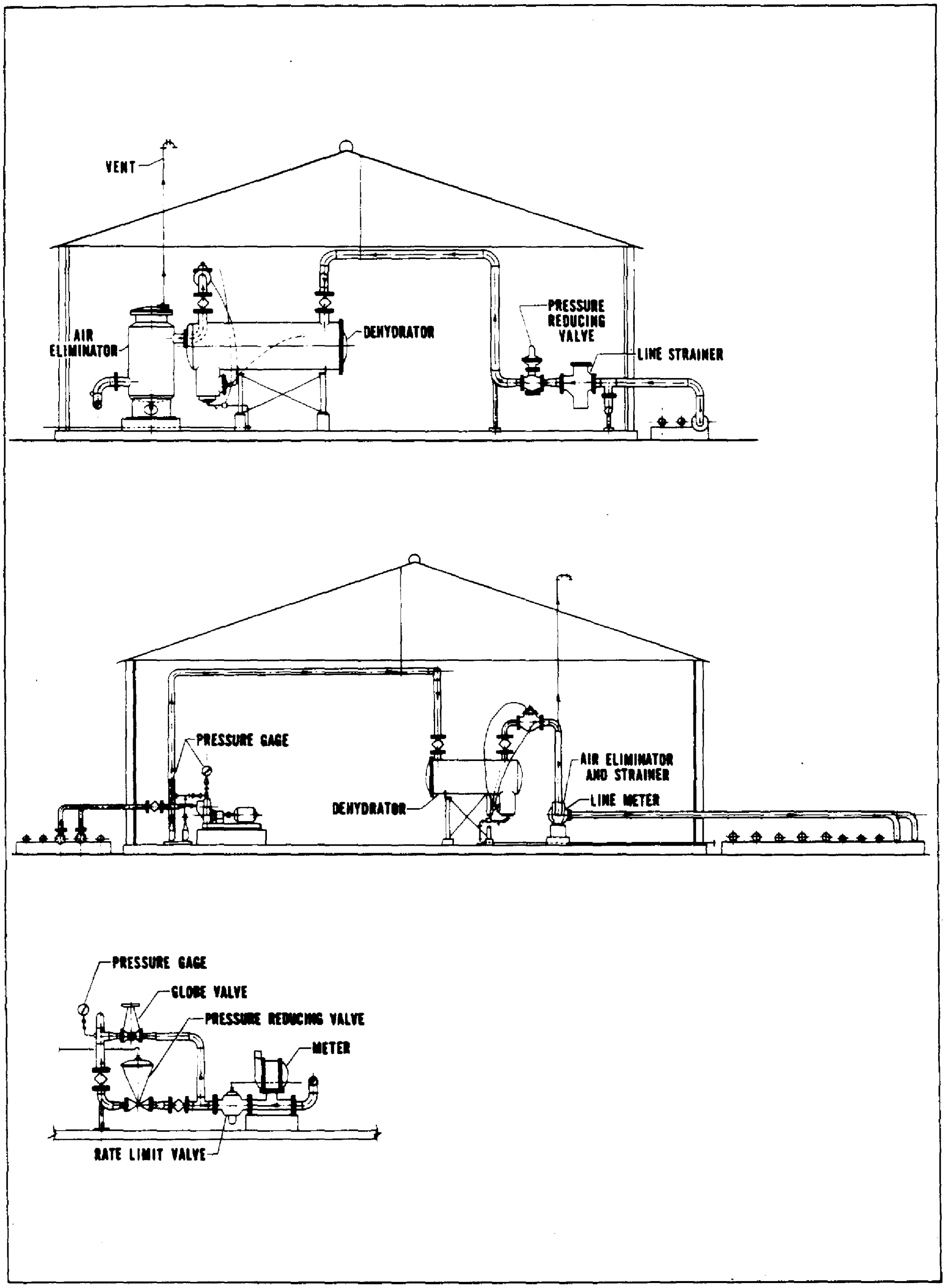


FIGURE 5.21-3 J.P.-1 Fuel Storage Piping and Equipment, Eniwetok Island

while, prior to completion of the drawing, materials and equipment required by these facilities were requititioned for stockpiling purposes.

As designed, the fire protection system consisted of four 2-inch standpipes, each provided with a 1-1/2 wharf hydrant, 100 feet of fire hose, a 1-1/2-inch fog nozzle, and a 20-foot Duralumin clay pipe equipped with a 1-inch fog-head. A booster water pump was provided which had sufficient capacity for operation of two fog nozzles simultaneously at recommended pressure (75 to 100 psig) and for operation of all four nozzles at minimum pressure. This pump took its suction from the island salt water mains and was a self-priming, manually-controlled, centrifugal pump. The 20-foot clay pipes were to permit extinguishing a fire anywhere in the diked area without exposing personnel to undue risk.

Simultaneously with the development of the drawing covering the water fog fire protection system for Parry Island, a drawing was prepared for a similar system for the fuel storage area on Eniwetok Island. Prints of this drawing were released to the construction battalion immediately upon completion in March 1950. It has been recommended by H&N that, because of the limited use of fuels on the experiment islands and the short period of occupancy, both motor gasoline and diesel oil be transported to these locations in drums or tanks by boat from Parry Island. Nothing developed during the course of design to warrant a change in this reasoning, and the diesel fuel storage facilities as designed for each island consisted of a 3,000 gallon storage tank for the diesel power plant and a 1,200 gallon tank for the mess hall equipment. These tanks were estimated to have sufficient storage capacity for one week's operation.

Consideration was given to three proposed methods of transporting the required quantities of diesel fuel from Parry Island to the experiment islands. Each of the three methods required the use of an "M" boat for the water travel portion of the trip.

One of the proposed schemes would have required transporting approximately sixty 55-gallon drums of diesel oil to each experiment island every week. Because the attendant manpower required in filling, emptying, trucking, loading and unloading this number of drums would have been excessive, this scheme was abandoned.

Another proposed scheme contemplated mounting a 5,000 gallon horizontal tank on the deck of an "M" boat. This tank would have been filled by tank truck at the cargo pier on Parry Island and emptied by means of a gasoline powered pump set at the various locations requiring diesel fuel. The "M" boat would have been docked at the cargo pier at each location, and the fuel transferred directly into the power plant and mess hall storage tanks by pumping from the tank on the boat through underground lines brought to the dock. This scheme had the disadvantage that it would have required an "M" boat to be devoted solely to transporting fuel.

The third scheme considered was to load a tank truck on an "M" boat at Parry Island and transport it to the various experiment islands. At each island the truck was to run ashore and be driven to the location of each fuel tank. This scheme had the advantages of permitting the truck to be filled directly from the fuel loading rack on Parry Island, thus reducing manpower requirements to a minimum, and of releasing the "M" boat for other assignments when not required for fuel transport. This was the scheme ultimately employed.

Late in August 1950, it became evident that it would be desirable to reduce the frequency of fuel deliveries to the experiment islands and, on the recommendation of the Holmes & Narver Service Operations Manager, banks of Navy cubes were installed on these islands to provide the following storage capacities at each location: Engebi, gasoline 3,000 gallons, diesel 25,000 gallons; Runit and the Aomon group, gasoline 2,000 gallons each site, diesel 10,000 gallons each site; Japtan, gasoline 1,000 gallons, diesel 2,000 gallons. These cubes were sufficiently elevated and interconnected to allow for one filling inlet and one outlet, with gravity flow between the tiers of tanks.

CHAPTER 5.22

PAVING

An important part of the work required for the development of the Proving Ground was the work of paving large areas surrounding the tower sites, of surfacing roads, of surfacing airstrips, and of providing a dust palliative treatment for control of dust in parking areas and near certain scientific structures. This large cost item was of particular interest to J-Division and required careful study, particularly in view of the reported difficulties with paving on Operation Sandstone.

PAVING MATERIALS

Considering the type and condition of materials, weather conditions at the site of operations, and the great transportation and handling problems involved, it was evident early in the design stage that the most economical and practical solution from an operations viewpoint would be the selection of one material suitable for all of the operations mentioned above and relatively easy to handle and transport in oceangoing vessels.

Available weather data indicated that temperatures to be expected ranged between 106°F and 68°F and annual rainfall was approximately 80 inches per year, equivalent to the wettest locations in the United States.

Like many atolls in the Pacific, the islands comprising Eniwetok Atoll are formed entirely of coral, either in the form of ledge rock or coarse sand, which is found mostly on the beaches. Because of the limited area and low surface elevation of the island, it was assumed that much of the aggregate for paving purposes would come from reefs or areas frequently inundated by high tides. It was expected that this aggregate would contain a high percentage of moisture, even after processing by crushing and screening.

Prior to September 1949, it was a moot question as to what binder material should be used in combination with the coral aggregate to produce the most economical and suitable pavement, but it was the consensus of opinion that one of the many widely used asphaltic materials produced commercially in the United States would meet the requirements more satisfactorily than any other cementing material.

It was generally understood that the scientific groups had a preference for a hot-mix, hot-laid asphaltic concrete paving, particularly for the surfacing of the test areas surrounding the towers, referred to also as zero areas.

A conference was held on September 21, 1949, in the Los Angeles offices of Holmes & Narver to outline the procedure to be followed in evaluating asphaltic products so that the most economical and desirable binder material might be selected. Ten representatives, including the

Project Manager, Chief Engineer, and members of the engineering staff of the firm attended and set in motion the first phases of the evaluation program. After many factors had been considered and the relative merits of various binders discussed in great detail, the decision was reached that tests be conducted on Parry Island using several types of asphaltic materials, namely: hot-mix with liquid asphaltic MC-3, cold-mix with MC-3, Bitumuls HX, and Bitumuls HRM, the latter two being emulsified asphalts.

Sufficient quantities of the materials were shipped to the Jobsite and the tests were conducted during December of 1949 and January of 1950. These were augmented by an additional test with Amalga-Pave, a patented process using powdered asphalt and a flux oil.

Presented below is a brief outline of the materials and procedures followed in performing the Jobsite tests.

<u>Test Section No. 1</u>

One 50 foot by 50 foot section of macadam (HX Bitumuls) was laid. Two-inch crushed rock was spread over the area and rolled with two passes of a 10 ton 3-wheel roller. One gallon per square yard of 150-200 asphalt emulsion HX was sprayed over the rock, and 1-inch small crushed rock spread over the test section and sprayed with one gallon per square yard of the emulsified asphalt. The test section was then broom sanded and rolled with one pass of the same roller.

<u>Test Section No. 2</u>

One 50 foot by 50 foot section (HRM Bitumuls) was laid. The material was mixed in a small pug mill, and aggregate and binder were weighed on scales. Three strips were laid with proportions and mixing as follows:

<u>Strip A</u>

60 per cent small crushed rock

40 per cent beach sand

6 per cent Bitumuls

These were mixed in pug mill, sand and Bitumuls added to rock, and batch mixed 3 to 5 minutes. The batch was then dumped on a platform and stockpiled for two days, after which it was laid by the Barber-Greene paver in the conventional manner. The test section was rolled with 2 passes of a 10 ton 3-wheeled roller at the time of laying.

Strip B

60 per cent small crushed rock

40 per cent beach sand

8 per cent Bitumuls

8 per cent water mixed with Bitumuls

Rock was placed in the pug mill and half the Bitumuls added and mixed with the rock; then sand and the rest of the Bitumuls were added, the material batched, and the strip laid as Strip A had been laid.

Strip C

60 per cent crushed rock

40 per cent beach sand

10 per cent Bitumuls

4 per cent water added to Bitumuls

The batch was mixed and laid in the same manner as Strips A and B.

Test Section No. 3

One 50 foot by 50 foot test section of Amalga-Pave was laid. The materials were proportioned by weight and mixed in a pug mill. Two strips were laid, one using 4 per cent asphalt and 4 per cent oil, the other using 5 per cent asphalt and 3 per cent oil. The material was mixed and batched as had been the Bitumuls, and one day was allowed between mixing and laying. The strips were laid with the Barber-Greene paver, and the test section was rolled with 2 passes of the 10 ton 3-wheeled roller at the time of laying and one pass with an unloaded lowboy 6-wheeled trailer on the following day.

Test Section No. 4

A trial batch of one-half yard of 15 per cent HRM Bitumuls and beach sand was laid on a hard surface and rolled with an unloaded truck.

Additional limited sections of paving were laid using hot and cold mixes with MC-3 but these proved unsatisfactory due to difficulties inherent in the use of coral aggregates with this type of binder. The following observations and results were noted for the tests performed:

Test Section No. 1

The two-course macadam (HX Bitumuls) proved to be well integrated, with sufficient asphalt to make a good road surface if rolling and working by traffic comparable to that given macadam in the U. S. could be provided. The rolling and compacting possible at the Jobsite, however, was insufficient for the dispersal of asphalt into the rock and could not provide a surface comparable to a batched mix surface.

Test Section No. 2

The batched HRM Bitumuls mix laid made a good pad, sufficient for traffic, and it would improve with use. The 6 per cent Bitumuls mix appeared slightly lean, but the 8 per cent and 10 per cent mixes were well bonded, elastic, and well set up.

Test Section No. 3

The Amalga-Pave was observed to be pliable and well integrated, but too soft. It showed no indication of setting up.

Test Section No. 4

The trial batch of 15 per cent Bitumuls and sand set up well, was plastic, and seemed to make a fairly good paving.

In view of these test results, it appeared that of the mixtures tested the mixture for Strip B of Test Section No. 2 would produce the best and most economical paving for the purposes intended.

The above described field tests were supplemented by a series of tests conducted in laboratories in the Los Angeles area using coral aggregate imported from Eniwetok. Hot mixed pavement was included in these tests but an analysis of costs, which was carefully prepared by and engineer having many years experience in the paving field, indicated that hot mixed pavement was not economical, and the laboratory tests, as well as the field tests, led to the conclusion that cold mixed pavement should be used. The following is an excerpt from the report of laboratory tests on coral aggregates:

Ledge Coral

The ledge coral compares favorably in hardness with limestone. Its absorption after being dried to constant weight and submerged for 48 hours is only 3.7 per cent which is not high, and also compares favorably with most normal aggregates.

The gradation of the ledge coral is as follows:

Per	cent	Passing	1"	100
"	"	"	3/4"	88
"	"	"	1/2"	50
"	"	"	1/4"	9
"	"	"	#10	5
"	"	"	#40	4
"	"	"	#80	2
"	"	"	#200	1

Coral Beach Sand

The coral beach sand is unusually good, being sharp, graded and of high stability. Absorption after being dried to constant weight and submerged for 48 hours is 3.5 per cent. The Modified Florida Bearing Value is unusually high, showing 1,000 pounds per square inch. The gradation of the coral sand is as follows:

Per	Cent	Passing	1/2"	100
"	"	"	1/4"	99
"	"	"	#10	98
"	"	"	#40	27
"	"	"	#80	1
"	"	"	#200	trace

Aggregate Blend

It is recommended in order to secure the most favorable gradation of the two aggregates mentioned above that they be blended in equal parts which will produce a combined grading as follows:

Per	Cent	Passing	1"	100
"	"	"	3/4"	94
"	"	"	1/2"	75

Per Cent	Passing		1/4"	54
"	"	"	#10	51
"	"	"	#40	16
"	"	"	#80	2
"	"	"	#200	1

The correct amount of Bitumuls HRM for the above blend is 8 per cent which, for estimating purposes, equals .8 gallon per square yard per compacted inch of thickness, and for batching purposes in the mix-pot equals .8 gallon per cubic foot loose of the aggregate blend. For sand mixes only using the coral beach sand the correct amount of Bitumuls HRM to use is 10 per cent which, for estimating purposes, equals 1 gallon per square yard per compacted inch of thickness, and for batching purposes 1 gallon per cubic foot loose of the coral sand.

Conclusions

If an ideal blend of aggregates is desired, this could be achieved by blending 40 per cent of the ledge coral of the above gradation with 40 per cent of the coral beach sand, and with 20 per cent of the crusher dust produced at the rock plant as a by-product of the crushing operations of the ledge coral.

The above laboratory study clearly discloses that the ledge coral is perfectly satisfactory for making Bitumuls mixes in combination with the coral beach sand, or if necessary it could be used as a straight crusher run without the addition of sand. The coral beach sand is unusually good and if desired, could be used exclusively for a Bitumuls sand mix for any type of paving and would give very satisfactory results.

On the basis of the above tests and analyses, the decision was reached by H & N engineers that the use of Bitumuls for paving purposes at Eniwetok Atoll had many advantages and warranted thorough study to determine the best design mix to be used in the evaluation of the various materials proposed. As a result of this decision an engineering expert with many years experience in the asphalt field and a broad knowledge of the characteristics of coral aggregate when used with asphaltic binders for pavement was selected to inspect the test strips on Parry Island and report his findings. His conclusions and general remarks were as follows:

CONCLUSIONS

These tests have proved that a very satisfactory asphaltic concrete can be made using Bitumuls HRM and ledge coral and coral beach sand.

Where ledge coral is scarce a satisfactory pavement can be made using Bitumuls HRM and coral beach sand. A very small patch was made of this mix and looks very good.

Where ledge coral is available and coral beach sand is scarce, a good open graded mix can be made using the ledge coral crushed and graded from 1 inch down to dust (crusher run) and mixed with Bitumuls HRM. As a general rule Bitumuls mixes will be more satisfactory than Bitumuls macadams.

A Barber-Greene mixing plant is available and is an ideal unit for making Bitumuls mixes either as a central mixplant or as a travel mixer if it is provided with an elevator.

A very substantial amount of money can be saved by shipping Bitumuls to the job bulk in tank steamers instead of shipping in drums.

Adequate floating storage is available. Floating storage is ideal for direct transfer in deep water from tank steamer and can be moved close to shore at any desired location where the Bitumuls can easily be pumped to shore through a fire hose using a centrifugal pump. Since Bitumuls is asphalt emulsified in water, it is always handled cold, it is easy to pump and presents no fire hazard.

SURFACE TESTS

The method of testing the surface of the test pavement sections was as follows: a 5 foot diameter circle was marked out on top of the Bitumuls macadam section and also the Bitumuls mix section, containing 6 per cent and 10 per cent of Bitumuls HRM. A transit was first used to establish the elevation at each circle. The actual test consisted of placing a wooden tripod directly over the circle, and suspended under this tripod and exactly 24 inches above the pavement surface was a charge of 18 pounds of 60 per cent hi-pressure gelatin which was then exploded, ~~after which~~ an observation was made of the damage done to the pavement area underneath.

Test #3 located on the section of Bitumuls HRM mix containing 10 per cent of Bitumuls gave the best results of all tests, because only a very small area within the painted circle was disturbed, and this only to a depth of about 1/2 inch.

Test #4 located on the Bitumuls HRM mix containing 6 per cent of Bitumuls disturbed the surface to an area slightly larger than the painted circle and to a depth of about 1 inch to 1-1/2 inch.

Test #5 on the Bitumuls Macadam was entirely unsatisfactory, as this area was entirely loosened and unbonded to the entire depth of 3 inch and to an area almost twice as large as the painted circle, and shock waves were visible for a distance of 10 feet from the center of the circle.

These tests clearly prove that a Bitumuls Macadam is not a satisfactory type of pavement for the purpose intended by these tests.

Test #3 of the Bitumuls 10 per cent mix is definitely the type best suited for the purpose intended.

GENERAL REMARKS

Bitumuls grade HRM in storage at the job location not only will make satisfactory pavements for all types of uses, but can also be used for dust control. It is suggested for this purpose that the Bitumuls HRM be diluted with water at the rate of from 10 to 20 parts of water to one part of Bitumuls and applied by gravity through an ordinary water sprinkling truck. A small amount of experimentation will be necessary to arrive at the correct amount of dilution of the Bitumuls and the number of applications of same to secure the desired degree of dust control. This is the same type of dust control which has proved satisfactory at Inyokern.

Another use for the Bitumuls which may prove handy would be the construction of sidewalks wherein one inch of Bitumuls mix could be laid between one inch header boards on a properly water bound sub-base and screeded and floated in the same method as cement concrete to a smooth finish.

Recreational areas for basket ball, volley ball, etc. can also be constructed, using your usual method of sub-base operation using water bound crusher run coral with a Bitumuls mix wearing surface of 1-1/2 inches to two inches in thickness.

Due to the magnitude of the paving operation and the many factors to be considered, a board composed of five members of the Engineering Division of H & N, each of whom was widely experienced in paving, was appointed to review all data relative to the subject and make a recommendation as to type and quantity of material to be purchased for paving.

The most extensive and important item of paving was that of the test areas surrounding the zero points and since much valuable time had been consumed in research, and construction activities at the Jobsite were rapidly nearing the time scheduled for surfacing operations, it was imperative that a final decision be reached as to the asphaltic binder to be specified.

After a thorough study of the reports covering the tests, both at Eniwetok and Los Angeles, the Board submitted its report on February 15, 1950 recommending that:

> The type of paving material for use on Job 640 should be emulsified asphalt, Type HRM, American Bitumuls Company, (which is equal to Type #M48-42 American Association of State Highway Officials and to Federal Specifications, Type VI Emulsified Asphalt), to be shipped in bulk by tanker and unloaded into suitable floating storage at the Jobsite, and then to be pumped ashore through suitable hose or pipes to shore tanks during paving operation on each location.

On the basis of this report, the culminating action of the long and careful investigation of paving materials, specifications were issued calling for HRM Bitumuls to be used for paving. Crushed coral aggregate was recommended, with coral sand second choice. One gallon of Bitumuls per square yard of pavement per inch of thickness was specified.

Communications received from Los Alamos stated that asphaltic paving 3 inches in thickness would meet requirements for the inner circle, which included all area within 400 feet of the zero point; and paving 1-1/2 inches thick would be required for the outer circle, which included all area between the 1000 feet outer circle and the 400 foot inner circle. The 3 inch pavement was considered adequate for vehicular traffic, whereas the 1-1/2 inch paving was strictly a nontraffic area. For the purpose of access to the inner circle, a 3 inch asphaltic roadway 20 feet in width was planned across the outer circle.

In compliance with the recommendations of the board and the AEC requirements for area paving, a requisition was submitted for 802,000 gallons of HRM Bitumuls to be used on the following sites: Aomon, 277,800 gallons; Engebi, 308,200 gallons; and Runit, 216,000 gallons. These quantities were estimated to fulfill the area paving needs as known at the time.

A major problem still confronted the Paving Board, that of transporting and unloading Bitumuls at the Jobsite. As a first step, a comparative cost estimate was compiled for handling of the material by bulk in tankers or in drums. This study revealed that based on 3-1/3, 55 gallon drums occupying 40 cubic feet of space, the bulk shipment would result in a considerable saving. Included in the cost of bulk shipment was the cost of purchase, transportation, and erection of three 10,000 barrel storage tanks, one to be provided for each of the test sites; and even with this item included, the bulk transportation and handling showed an estimated saving of approximately five cents per gallon over transportation in drums. In view of the savings to be effected, bulk shipment was adopted, contingent upon the development of a feasible method of handling Bitumuls at the Jobsite.

After conferences with a representative of the Bitumul supplier and after cost analysis of six different methods of unloading Bitumuls from off-shore tankers, it was decided to unload from ocean going tanker into a steel barge which was available at the Jobsite, by using the tanker's pumps and then moving the barge closer in shore, anchoring it and using a 6 inch pipe with Victraulic couplings(Army "invasion type"). A gear pump was located on the barge, designed for high viscosity liquids, which pumped the Bitumuls into shore tanks. It might be noted here that an attempt was made to utilize as Bitumul storage at the Atoll, a floating dry-dock section which had previously been used as a storage tank. During the filling of this auxiliary storage facility a leak developed which could not be plugged and the section sank with a loss of approximately fifty thousand gallons of Bitumuls.

On June 1, 1950, the final estimate of Bitumuls to meet all Project requirements then known was prepared which indicated that 1,705,900 gallons would be needed. The distribution was as follows:

Roadway paving	263,800 gallons
Roadway dust palliative	26,800
Test area paving	1,061,250
Airstrips	153,100
Dust palliative for scientific stations	45,850
	1,550,800
10 per cent for contingencies	155,100
Total	1,705,900 gallons

PAVING OF ROADS, AREAS, AND AIRSTRIPS

In accordance with criteria as to areas to be paved, and the findings of the Paving Board, estimates were made of the required paving for the Project. (Table 5.22-1 shows these estimates.)

TABLE 5.12-1 ESTIMATE OF PAVING AND DUST PALLIATIVES AREAS, IN SQUARE YARDS

Site	Roads 3"Paving	Roads Palliatives	Zero Circles 3"Paving	Zero Circles 1½"Paving	Airstrips 3"Paving	Airstrips Palliatives	Taxiways & Parking Palliatives	Instrumentation Strip Palliatives	Miscellaneous Areas Palliatives
Eniwetok	51,000	8,800	---	---	---	170,000	200,000	---	30,000
Parry	23,000	25,200	---	---	---	6,700	---	---	55,000
Runit	17,000	5,500	42,700	57,500	3,900	---	---	62,500	10,000
Aomon Group	11,000	9,000	85,690	161,780	6,100	---	---	62,500	10,000
Engebi	8,500	28,000	105,050	223,290	---	11,000	---	114,600	10,000
Bogallua	---	7,700	---	---	6,700	---	---	---	2,000
Japtan	---	10,000	---	---	---	---	---	---	---
Muzin	---	5,000	---	---	---	---	---	---	10,000
Totals	110,500	99,200	233,440	442,570	16,700	187,700	200,000	239,600	127,000

Summary:

3" Paving	360,640	Square Yards
1½" Paving	442,570	Square Yards
Palliatives: Traffic Areas	486,900	Square Yards
Palliatives: Non-Traffic Areas	366,600	Square Yards
Total	1,656,710	Square Yards

Radioactivity from former test operations was still a hazard during the early stages of construction and in order to minimize its effect on the construction crews, and to reduce the radiation to tolerance limits, it was decided that areas to be worked would be kept constantly wet down by an overhead sprinkler system and that material from the outer areas, more distant from the old tower location, would be hauled in and deposited and rolled on the areas of high radicactivity. This operation is more completely described in Chapter 6.2 of the Construction volume. Grading, therefore, was primarily for the purpose of reducing radioactivity at the surface, removing sudden changes in ground surface, and eliminating water pockets. Plans were drawn establishing finish grade of the Zero areas in accordance with this construction.

SCOPE OF PAVING OPERATIONS

The amount of paving actually accomplished on the various islands differed materially from that originally planned. In general, it was found that by grading, watering, and rolling, very satisfactory roadways were made. With the approval of AEC Contract Administrator, the paving of roadways on all islands except Eniwetok Island was eliminated, except the section through the 1-1/2 inch area paving around the Zero towers which would not support traffic. These roadways were made of 3 inch thick paving.

On Eniwetok Island, at the request of military groups stationed on the island, and approved by the AEC, plans were drawn for the paving of the perimeter road around the island and a portion of the main airstrip. This work involved the placement of approximately 11,500 yards of road paving and the paving of an area of approximately 50,000 square yards on the runway.

In addition to these requirements, which were not contained in original paving estimates, a requirement was established for helicopter mats at three photo tower sites and paving and dust palliative treatment adjacent to a large number of scientific stations and military structures.

It might be noted at this point that the paving on the Eniwetok Airstrip showed signs of failure at the feathered transition between paved and unpaved portions. Upon examination and consideration of the possible causes of failure it was determined that a reduction in the amount of paving authorized had resulted in the location of the pavement transition in the zone in which the effects from the take-off of jet aircraft were most destructive. Various proposals to remedy the condition and strengthen the pavement in the take-off zone were considered. However, it was found that by scarifying the pavement laid in this zone and adding Bitumuls to insure an ultimate mix of approximately one gallon per cubic foot of aggregate prior to respreading and rolling, the effects of jet aircraft take-off on the pavement were substantially eliminated.

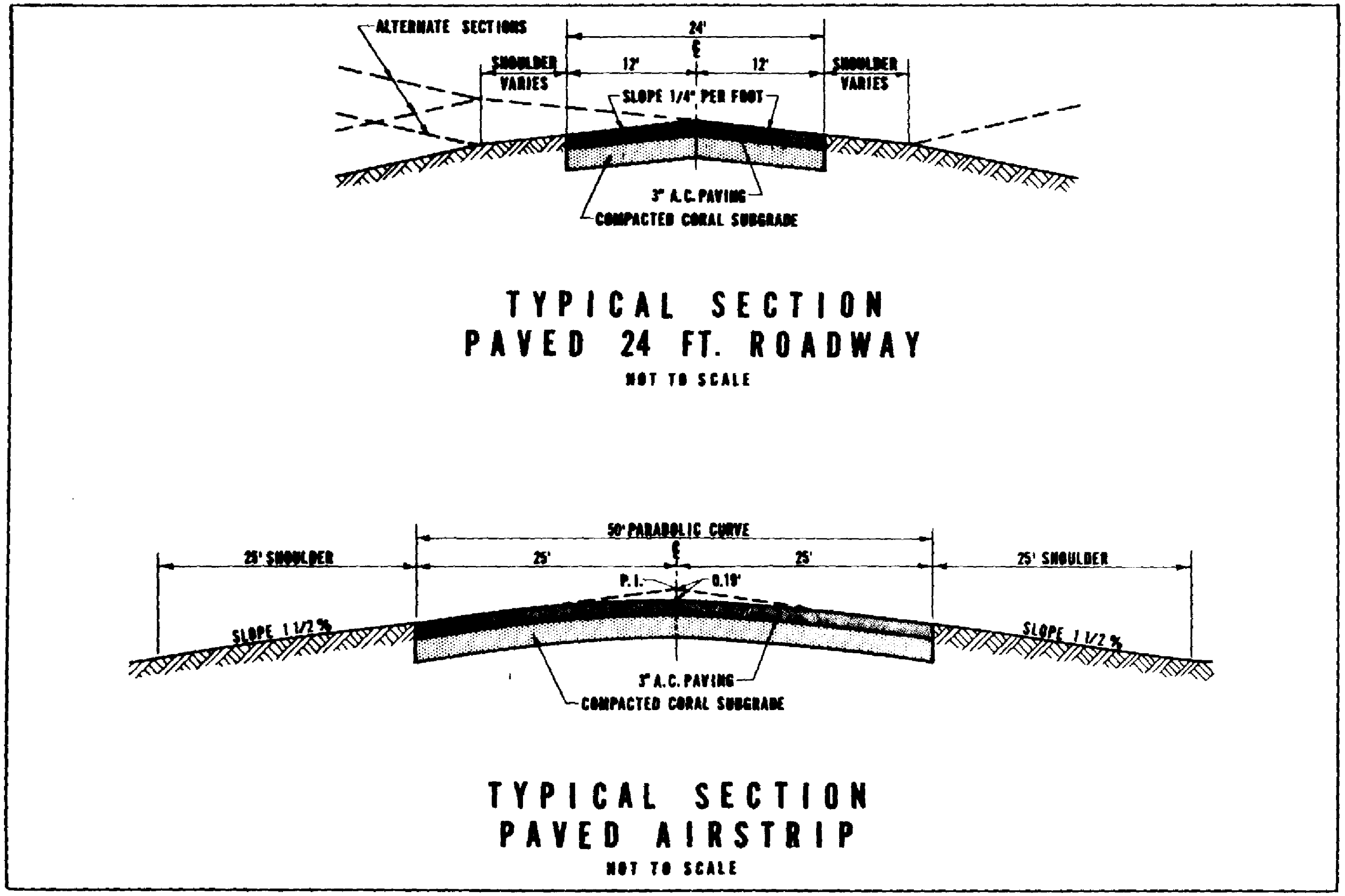


FIGURE 5.22-1 Typical Section through 24' Roadway
Typical Section Paved Airstrip

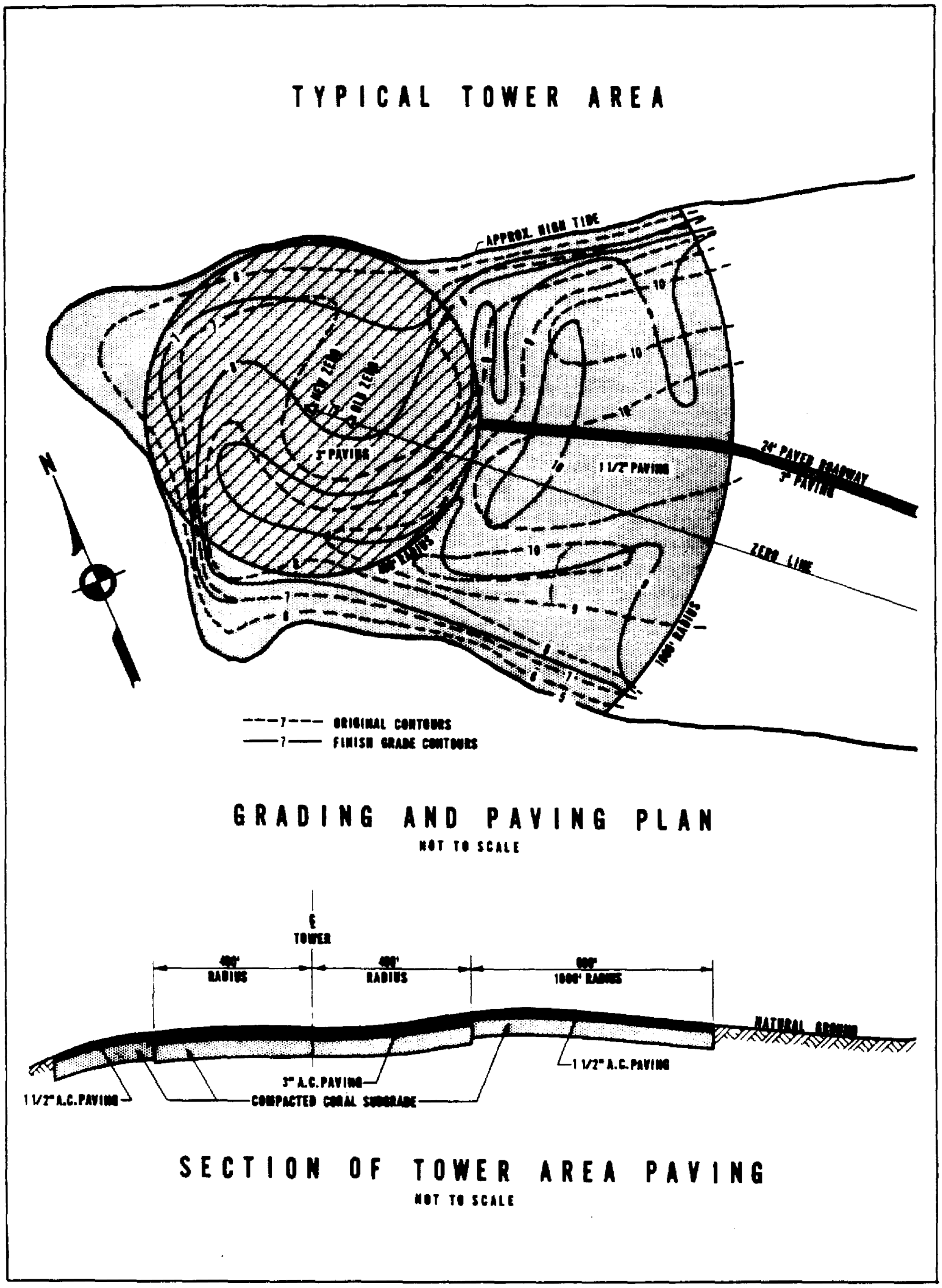


FIGURE 5.22-2 Grading and Paving, Typical Tower Area

CHAPTER 5.23

AIRSTRIPS

For Operation Greenhouse it was necessary to rehabilitate, rebuild, or relocate existing airstrips and to build new strips on several islands. The main airstrip on Eniwetok Island served for the large passenger and transport planes as well as for drone planes to be used in the experiment. Other strips, particularly on the experiment islands, served more limited purposes, i.e., for liaison planes for intra-island transportation.

ENIWETOK AIRSTRIP

The original length of the airstrip on Eniwetok Island was 6,400 feet, but operational needs demanded that it be extended. The possibility of an increase to 8,000 feet was considered, but to accomplish this would have required construction to the edge of the reef on the ocean side and introduced severe stabilization problems. As a consequence, it was decided at a meeting of representatives of AEC, JTF-3, TG3.2 and TG.4 that the cost of extending the strip out on the reef would be excessive. The strip was rotated two degrees counter clockwise and extended as far as possible without building on the reef and the result was a 7,000 foot strip. The new positions of the rotated strip were stabilized and sprinkled with water-diluted Bitumuls.

Because the length was less than that desired for drone plane operations, the plans also called for the construction of a substantial protective earthwork berm along the north 2,000 feet and around the north end of the runway and for the installation of twelve 1/2-inch steel arresting cables stretched at 50 foot intervals across the northerly 600 feet of the runway and anchored to 24 massive reinforced concrete deadmen set along the strip margin.

Plans did not contemplate any paving of this runway nor any paving on the warmup apron. However, at the request of the Air Force, H & N was authorized to plan and construct 50,000 square yards of paving for the Eniwetok runway and 12,500 square yards for the warmup apron. Details of paving design are given in Chapter 5.22 of this volume.

The runway axis, as rotated 2 degrees, had a bearing of N 62° E, which was as close to the direction of prevailing winds (N 70° E) as was possible on this island.

PARRY AIRSTRIP

The existing airstrip on Parry had been determined to be poorly oriented and a new strip was designed. This runway is 1,200 feet long, and its axis is oriented N 70° E, in the direction of the prevailing winds. The runway was not paved, but it was treated with available sub-standard cement and compacted.

RUNIT AIRSTRIP

The airstrip existing on Runit before this Project was begun was 700 feet long. It was radically off-wind and too short for safe operations in unfavorable weather. Therefore, a new strip was designed, oriented into the wind. This was extended to 1000 feet by providing for fill on the reef at the ocean side of the island, with borrow from the adjacent coral reef. The axis of this airfield has a bearing of N 70° E, in the direction of the prevailing winds on the atoll. Approximately 7,500 square yards of paving were used on this airstrip. Design specified paving with a well graded aggregate, and approximately 400 sacks of rejected Portland cement were experimentally added to the Bitumuls asphalt.

BIIJIRI AIRSTRIP

On Biijiri, an existing airstrip was paralleled with a new and longer strip having a length of 1100 feet and a bearing of N 78°27'28" E. Standard base and paved surface design was provided. The subbase of this new airstrip, although well prepared and properly stabilized, contained a high moisture content because of an excessive amount of rainfall during construction. Although the aggregate was of sand alone, it was of good gradation, and approximately 8 per cent of Bitumuls was used. Because of the free moisture already in the subgrade, together with the moisture in the mix, an abnormally long time was required for the curing process. More than the usual amount of rolling was done in an attempt to hasten the drying process. In a week or ten days after the rainfall returned to normal, the pavement dried out and resulted in a serviceable airstrip.

ENGEBI AIRSTRIP

The original airstrip on Engebi could be reconditioned in its existing location on its bearing of N 76°44'05" E. As a consequence, plans called only for clearing and blading. No paving was specified.

BOGALLUA AIRSTRIP

A plan showing the proposed complete development of Bogallua Island, including an airstrip, was prepared in October 1949. This strip was 900 feet by 50 feet. Its bearing was N 70° E, the direction of prevailing winds. Stabilized soil was to be covered with Marsden matting. The strip was constructed as planned between January 14 and January 21, 1950.

HELICOPTER MATS

Helicopter mats, essentially cleared, stabilized areas 150 feet by 150 feet were provided on Piraai, Bokow, and Teiteiripucchi to facilitate access to these sites during operational periods.

CHAPTER 5.24

CAUSEWAYS AND PIERS

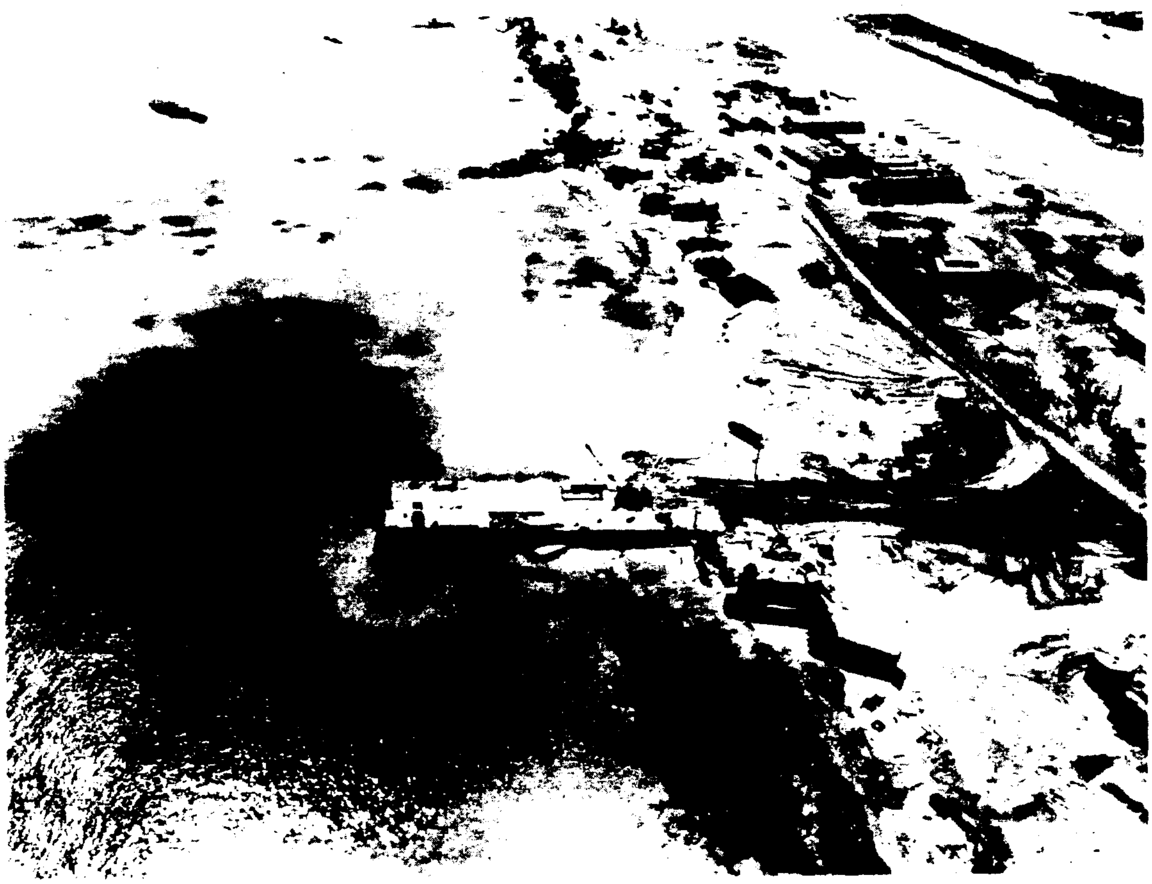
For Operation Sandstone a causeway consisting of two rows of steel sheet piling with a soild fill between them had been built between Aomon and Biijiri. This Project required a similar connection between Biijiri and Rojoa to provide vehicular access to the camp on Rojoa. Reports indicated that considerable difficulty had been experienced in closing the final gap in the causeway for Operation Sandstone, and it was anticipated that even greater difficulty would be encountered in the new construction because of the deeper channel and a probable increase in scouring action due to the existence of the Aomon-Biijiri causeway.

Careful study was made at five different points in order to obtain the best alignment and to effect the greatest economy in construction of the Biijiri-Rojoa causeway. Two of these locations had coral heads awash at low tide and were so spaced as to provide convenient pier foundations for 100 foot to 130 foot steel bridge spans. Approximately 600 feet of channel could thus be spanned, with all uncertainties as to pile driving, etc., eliminated. The cost of a steel bridge also compared favorably with the cost of a causeway of the trestle type. (Strictly speaking, a trestle is not a causeway at all, but that nomenclature persisted as the designated name of the structure as built.) Earlier plans for a steel super-structure were abandoned in favor of the relatively low and protected trestle type, comparatively unexposed to damaging action by the proposed experiments. Furthermore, because the location finally adopted was a straight alignment and radial to the zero tower it offered a minimum exposure to possible damage.

Prolonged study and field investigation were necessary to determine the penetrating ability and bearing power of wood piles. Here was the prevalent atoll formation consisting of a hard coral cap overlaying softer coral. The thickness of this cap varies and little was known of its ability to grip a driven pile after the cap was once shattered. This called for rigging a pile driver in the field for emplacement of a few test piles to determine whether wood piles could be driven in the desired locations and, if so, what lengths would be needed for sustaining the required loads. Preliminary tests were successful and designs for piers and causeways based upon driven piles were executed. Thereafter, through the use of standard pile driving equipment, driven piles for causeways, piers, and the like, were employed extensively on the project. In some cases, directional explosive charges had to be used to pierce the cap coral to permit proper starting. However, for most piles this technique was not required.

With the high degree of teredo and limnoria content in sea water and consequent rapid destruction of untreated wood, especially in the tidal range, it was specified that all wood except the deck lumber be pressure creosoted. Creosote in decking is injurious to many types of cargo and is beneficial only in its prevention of decay. Port Orford cedar was

Aerial View: Completed Causeway Biijiri to Rojoa



Aerial View: Cargo Pier on Eniwetok Island selected for all decking because it is decay resistant, stands up well under heavy usage, and cuts and handles well during construction. The thickness of the deck was made four inches for better distribution of heavy wheel loads and allowance for wear. The load assumption for design was a seven ton single wheel concentration, distributed over three 4-inch by 16-inch stringers, 16-inch O.C.

When it was decided to locate the zero tower for the Aomon Group experiment site on Eberiru, a continuous roadway between Aomon and Eberiru was desirable to expedite construction at the latter location. This was initially accomplished by bulldozing an underwater roadway course on the reef between the islands. Meanwhile, a design requirement had been established for a conduit for coaxial cable. Investigation by Engineering Division personnel at the site revealed that an earth-fill causeway would provide the most economical direct route for the cable. In addition, such a causeway could be used as an allweather roadway. The resulting recommendation was followed and necessary drawings were provided.

No design was necessary for the earth fill causeway itself, but the Structural and Electrical Departments of the Home Office Engineering Division designed the coax ducts to meet the safety cover requirements of the proposed experiments.

It was necessary that each island having any appreciable amount of passenger or freight handling should have a landing pier for the handling of heavier freight and economy of unloading directly from larger floating craft. Standards established called for eight to ten feet depth of water at low tide at the pierhead, but three to three and one-half feet depth was considered sufficient to accommodate smaller craft at the less important landings.

Pier locations were chosen coincident with Sandstone approaches only when an economy was apparent. Considerations in new locations were existing depth of water, ease of channel clearing, and probability of surviving the detonations. Convenience of location to shore installations or length of sea distance, was a major consideration only on Eniwetok and Parry Islands where these factors were important.

Studies centered about the various degree of usage to which each pier would be subjected. Points considered included the method of handling cargo, the heaviest single load likely to be handled, and the maximum load of temporary storage of material on the pier. A live load of 300 pounds per square foot was finally agreed upon for the heavier piers. (Concentrated loads occasioned by a 20-ton traveling crane, or five-ton capacity at 30 foot boom radius.) No concentrated loads were anticipated for the lighter piers, but the 300 pound loading factor was maintained for any occasional or emergency use.

Consideration was given the probability that sudden changes in the field might require piers to be built on such brief notice that to await on-continent design for individual structures would cause serious delay. Therefore, typical designs were drawn for freight, passenger, and combination piers and these plans were placed on file in the field, available for immediate use. Such plans were utilized, not only for some new piers which it was found necessary to construct, but for enlargement of existing piers.

The design for all piers was predicated upon at least two usages for experimentation purposes. As in the case of the Biijiri-Rojoa causeway, exceptionally rapid deterioration of all untreated wood in contact with sea water below highest tide, due to the attack of teredo and limnoria led to the requirement that all piles be specified for 16 pounds per cubic foot creosote treatment, and all diagonal bracing, pile caps, and stringers be creosote treatment to 8 pounds per cubic foot or 3/4 inch penetration by alternate vacum and pressure method. All bored holes in piles and diagonal bracing were thoroughly swabbed with creosote before insertion of bolts or pins.

Over all piles, 12 inch by 12 inch caps were used; 4 inch by 12 inch stringers were used on the lighter piers and 4 inch by 16 inch stringers for the major piers which were subject to heavier loading. Port Orford cedar decking was used for all piers for economy, workability, and wear. Bollards and cleats were firmly bolted to the decks for lashing boats alongside and these were supplemented by the driving of adjacent dolphins for the more important piers.

The decision to use timber and pile construction was reached after study of the effect of storm water and currents on Sandstone moles, and after an economic study of different methods. Test piles were driven before materials were ordered and the program accepted.

For the Sandstone experiments, solid jetties composed of Navy cubicles or other material at hand had been extended out into the lagoon, and shallow draft boats were lashed alongside for loading or unloading. In some cases these moles were repaired and utilized as the shore end of the new piers, the extension to deeper water being of the regulation pile and deck type.

Figure 5.24-1 shows a typical cargo pier, and Figure 5.24-2 shows a combination personnel and cargo pier.

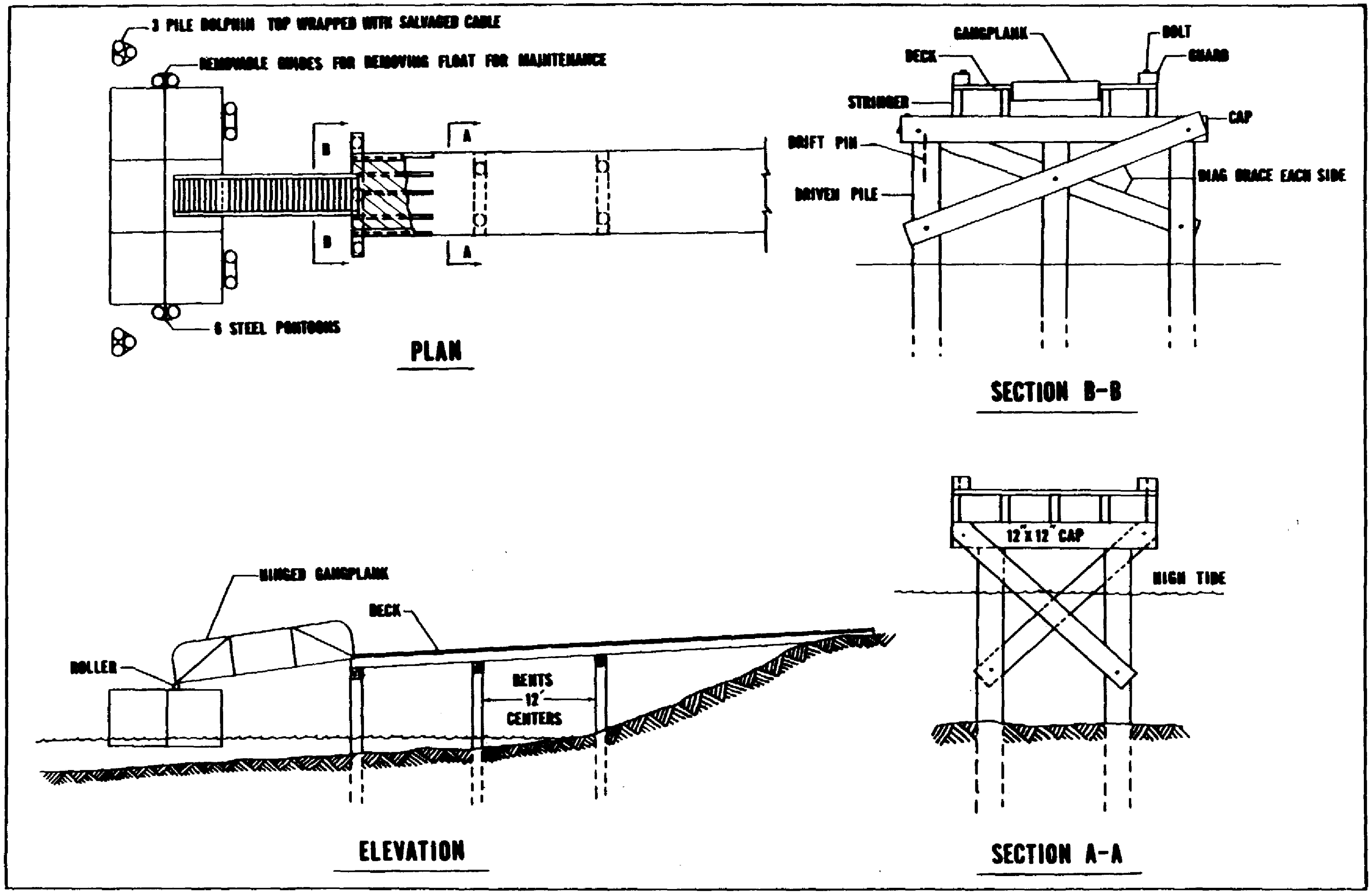


FIGURE 5.24-1 Typical Personnel Pier

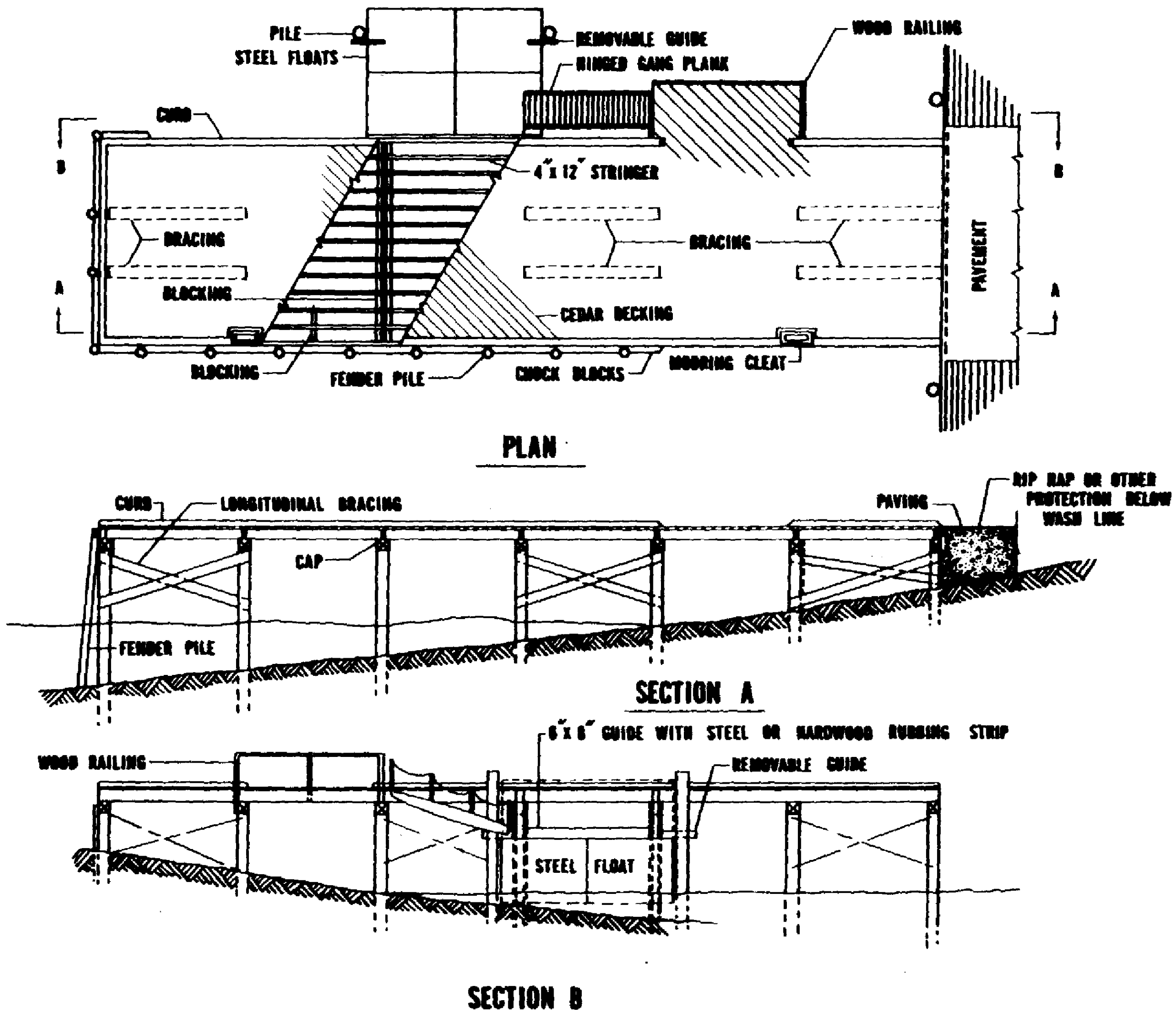


Figure 5.24-2 Combination Personnel and Cargo Pier

CHAPTER 5.25

NAVIGATION AIDS

The work involved in the clearing and marking of navigation channels was collateral to that of the pier construction program. At the time construction operations were initiated, there were two existing navigation channels within the lagoon, one channel beginning at the "Wide Passage" and continuing northerly, the second beginning at the "Deep Entrance" break in the Atoll reef and proceeding in a northwesterly direction to a junction with the first channel. The united channels then continued northerly toward Engebi and other of the northern islands. These channels had at one time been adequately marked with buoys, and additional buoys had been provided in scattered locations off the channels to mark navigation hazards within the lagoon. At the beginning of this Project, however, some of these buoys were found to have been lost or destroyed, and as construction work progressed and water traffic increased, it was found necessary to replace the lost buoys and to provide buoys in new locations as required, both for mooring and navigation.

As the pier construction program developed, the work of providing additional channels to provide boat approaches from the lagoon to the various piers was begun. Soundings were taken as part of the survey operation for the approach channels, and as a result of these surveys the location and characteristics of each of the approach channels were determined, including the requirements for marker buoys. This information is tabulated below:

TABLE 5.25-1. APPROACH CHANNELS

Channel Name	Length (Yards)	Course	Mean Depth at Entrance Marker Buoys (Fathoms)	No. Buoys Red	No. Buoys Black
Present or Old Runit	1400	Straight	12	3	3
New Rojoa	1500	Dog leg	8	6	6
Old Aomon	800	Straight	10	3	3
Bokonaarappu	600	Straight	5	3	3
Muzinbaaikku	550	Straight	5	3	3
New Engebi (South)	1000	Slight dog leg	5	4	4
Old Engebi (Main)	1000	Straight	9	3	3
Teiteiripucchi	650	Straight	5	3	3

In general, the water shallowed abruptly from the channel entrances to the extent that approximately one half the channel lengths were to a depth of ten feet or less of water. The depth of water at the heads of cargo or combination cargo personnel piers was required to be eight to ten feet minimum at low tide; for the smaller personnel piers, three feet was the minimum. Coral head obstructions were blasted and leveled off.

CHAPTER 5.26

ENGINEERING SERVICES FOR USERS

Because installation schedules for Users came at the end of the construction phase of the Project, representatives of Users arrived at the Jobsite relatively late in the course of the development of the Proving Ground. These representatives called for a considerable number of services which had not been anticipated and for a number of changes in construction either completed or in progress. The majority of these additional services or changes were provided by the labor pool provided for the Job 5 support program, but many made necessary the provision of engineering services.

For example, the firing party required help from the Mechanical and Electrical Departments in planning and supervising the removal of tower equipment and the closing down of power plants just prior to experiments; scientific agencies required Design and Drafting Department help for drawings, charts, and prints; and several Users required field and calculation work by the Survey Department.

An outstanding example of late changes and redesign was in the case of coaxial cables. As late as the latter part of February 1951, the Electrical Engineering and Survey Departments had to issue supplements to practically all coaxial cable layout maps, changing ditch sizes, widths, and layouts, and specifying additional trenching for selector stations, etc. Just prior to the tests additional fill cover was called for.

Considerable field engineering was required as well to analyze new additional power requirements of Users. For instance, major equipment additions in the photo laboratory required electrical and mechanical engineering to provide adequate continuity of power and satisfactory humidity for photographic work. These additional requirements occurred during the spring of 1950.

Revisions to the communications, control, and signal requirements which occurred after the installation was started in the fall of 1950 required engineering liaison and coordination, and engineering estimates for User services required consideration of availability and cost of materials, labor, and equipment, and many man-months of field engineering were expended in fulfilling this requirement.

Throughout the Job 5 phase, the Engineering Division provided advice and assistance to the AEC and the scientific Users, as well as to the Construction and Operations Division of H & N in the solution of many electrical, mechanical, structural, and civil problems resulting from Job 5 work orders.

CHAPTER 5.27

EFFECTS OF BLASTS ON STRUCTURES, PAVING, AND PIERS

Information as to the observed design adequacy of structures may be valuable in future planning. For this reason, a tabulation follows of scientific structures used in the experiments, with observations on the apparent effects of blast. Descriptions of the structures are given in Chapters 5.11 and 5.12 of this volume.

For the design of those structures intended to survive the experiments, probable blast pressures to which each would be exposed were furnished by J-Division, and in most cases these pressures controlled the design. However, in some cases, wall thicknesses were determined by the radiation shielding required. Design analysis showed in some cases that the anticipated blast pressures on structures at desired data points were so high that structures designed to survive would have been extremely costly.

Inspection of all structures was made from June 16 to July 2, 1951. In general, the inspection indicated adequate design and a good quality construction.

Comments which follow as to the adequacy of design relate only to the effect on structures themselves and not to their scientific purpose.

DAMAGE TO SCIENTIFIC STRUCTURES

Station 1 - 200 Foot and 300 Foot Steel Towers. These stations were expendable and were completely destroyed. Small quantities of tower steel were in evidence at the sites as were parts of the footings and anchors.

Station 2 - Wood Frame Structures. These structures were completely expendable and were destroyed at all sites. Design was adequate for the purpose intended.

Stations 3, 4, and 5 - Plywood Boxes Mounted on Four by Four Posts. These stations suffered various degrees of damage, but it is believed that they adequately served the purpose intended.

Stations 6a and 6b - Reinforced Concrete Structure. The 6a structures were Sandstone structures rehabilitated for Operation Greenhouse. These structures showed considerable cracking, but there was no evidence of structural failure.

Station 6b structures showed slight vertical cracking (0.02 inches or less in width) in the side walls. There was no evidence of failure, and the design is considered adequate. Cracks apparently did not extend continuously through the walls; and therefore probably did not provide paths for radiation or dust.

Stations 6c, 22, 24, 38, 65, 132e, f, and h, 133, 134, and 592 - Canvas Tent Shelters on Wood Frames. None of these stations was in evidence at the time of inspection except station 65 at Teiteiripucchi. This station was still intact except that the ridge member was broken about two inches back from the face edge. All canvas had been removed before the tests. These stations were used for work and storage space during the period of test preparation. Design was adequate for the purpose intended.

Station 7 - Wood Frame Structure. The station at the tower southeast of Runit was removed prior to this inspection. It is understood that the structure suffered no damage. The structures inspected were not damaged. The Piiraai structure showed a "belly-in" of about one-half inch of the face-on wall, but there were no cracks in studs, sill, or plate. The design for these structures was adequate.

Stations 8 and 9 - Reinforced Concrete Bases with Steel Frame. There was no damage to these structures on Engebi (Sites E and E+). Design is considered adequate.

As was expected, Station 8 at Aomon was severely damaged. The collimator block was blown apart, the base was badly broken up, and the steel framing was badly bent. There was no damage to Station 9 in the Aomon Group. Design is considered adequate.

Station 10 - Reinforced Concrete Base with Steel Frame. Station 10 on the Aomon Group was partially damaged. The collimator block and base were not damaged. The tie down rods were strained and bent; the steel frame was buckled about one inch; and the limonite blocks hung on the collimator for additional protection were shattered. However, it is understood that all data was obtained.

Station 10 was undamaged at all other sites.

Station 11 - Reinforced Concrete Base with Steel Frame. Some form of failure was anticipated for all Stations 11.

The collimator block at Station 11 on Runit was blown off the base because of failure by shear and elongation of the tie down rods (U-bolts). The design is considered adequate.

At Station 11 on Engebi, the 10 inch by 1 inch steel plates welded together to form an H-beam buckled about one and one-quarter inches at midspan; two tie down anchors on the lagoon side were broken in tension. The block remained in position on base.

At Engebi (E+), Station 11, the block was blown off its base; tie down anchors were not in evidence, and the steel frame was buckled.

The collimator block and steel frame at Station 11 on Aomon were completely gone. There was one section of a collimator block lying about 500 feet southeast of the structure, and it was assumed that this was part of the installation. There was no evidence of the rest of the structure. The base remained in place but was badly cracked; the tie down rods (U-bolts) sheared off at the upper plate on the lagoon side, and the anchor bolts sheared off at the base on the ocean side. As was anticipated, this structure was a complete failure.

Stations 12, 14, 15, and 19 - Reinforced Concrete Base with Steel Frame. These stations were not damaged, and design is considered adequate.

Station 18 - Reinforced Concrete Structure. These structures were not damaged. The Aomon Group structure showed a horizontal crack about one-hundredth of an inch wide approximately eight inches below the roof along one side wall and two small diagonal cracks above the door. The wells adjacent to these structures show no damage. The design for these structures is adequate.

Stations 20 a, b, c, d, e, and f - Reinforced Concrete Wall on Base. At Engebi, Stations 20 a and b tipped over towards the lagoon; Station 20 c tipped about 20° from vertical towards the ocean. At all stations, the base remained in place; the failure occurred at the connection between the wall and base and consisted of elongation and bending of reinforcing steel and spalling of concrete on the compression side of wall. All other structures at this site were not damaged.

On Runit, Stations 20 a, b, and c tipped over. Failures occurred in the foundation or in the connection of the wall to the footing. The failures did not cause loss of data.

Stations 21 a, b, and c - Reinforced Concrete on Base. These structures all were tipped over towards the lagoon by the Engebi blast. All bases remained in place; failure occurred at the connection between wall and base. It consisted of elongation and bending of reinforcing steel and spalling of concrete on the compression side of wall. Design of these structures is considered inadequate.

Stations 23 a and b - Reinforced Concrete Structures. The 23a structures are Sandstone structures rehabilitated for Operation Greenhouse. The Runit structure is in good condition. The Aomon Group structure showed considerable cracking but was believed to be sound. The Engebi structure showed a great deal of cracking as well as some inside spalling and was not considered to be structurally sound.

The Station 23b structure showed no blast damage, and the design is considered adequate.

Station 25 - Reinforced Concrete Structure. This structure had not been opened so that an interior inspection could be made. The exposed portions of the exterior showed no serious damage. Diagonal cracks of about two-hundreths of an inch existed above the door opening, and there was a horizontal crack of the same width along the north wall about two and one-half feet down from the roof. The earth protection for this structure was blown away to a point about three feet down from the roof.

Heavier construction to avoid failure does not appear to be justified in view of the fact that data was obtained.

Stations 26a, b, and c - Reinforced Concrete Base. There was no damage to these structures. The design was adequate.

Stations 27 a, b, c, and d - Reinforced Concrete Base. There was no damage to these structures. The design was adequate.

Stations 28 and 29 - Instrument Posts on Concrete Blocks. The concrete blocks for these structures were adequate. The pipes outside of an approximately 3500 foot radius withstood the blast, but inside of this area they were blown over. The point of failure was just below the union, and in a few cases the union itself was broken. It was noted that unions were 250 pound.

Stations 30a, b, and c - Wood Frame Structure. The three stations on the Aomon Group failed partially in that the doors were blown completely into the structure. This blowin occurred because the 3 inch by 8 inch door frames came loose from the sill and plate. The design was weak in method of fastening door frames to sill and plate.

Station 30a on Runit showed no blast damage. Stations 30b and c were completely demolished. The lumber in these two structures was completely broken and crushed.

The three stations on Engebi were substantially destroyed. The face wall in each was intact, but the roof, side, and back walls were nearly a 100 per cent loss. Not only were timber members of the structures cracked and broken, but they were also crushed by the blast.

After the E shot, it was reported that these structures were undamaged. These stations were not used in the E+ experiment.

Stations 33 and 34 - Steel Stakes. Very few of these were found; however, because of location it would have required a survey party to relocate them. No damage was noted to those found. It was believed the design was adequate.

Station 36 - Corrugated Metal Pipe Set Vertical from Ground Surface to Solid Rock and Gauge Plate. There was no damage to these structures. The design is considered adequate.

Stations 37a, b, and c - Double Steel Wall Filled with Concrete on Reinforced Concrete Base. The structure at 37a was blown completely over, the base remaining attached to the wall. The structure at 37b was blown about 45° out of plumb, the failure occurring at the connection between the base and wall. The structure at 37c was blown about 10° out of plumb, the failure occurring as at 37b. These structures were designed by the User and were extremely narrow in relation to the height.

Stations 37d, e, and f - Pipe Encased in Concrete, Underground. There was no damage to these structures.

Station 39 - Reinforced Concrete Bases. These structures could not be found on Engebi.

There was no serious damage to concrete on the structures at Runit; all anchor bolts were bent 90° over.

Stations 40, 41 and 42 - Reinforced Concrete Slab, Flush with Ground. These slabs were not damaged. Design is considered adequate.

Stations 50a, b, c, and d and 51a, b, c, and d - Reinforced Concrete Slab and Wood Frame Box Flush with Ground. Structures outside of an approximately 1200 foot radius from zero received no damage other than some cracking and splitting of the plywood cover on the battery boxes. Structures within an approximately 1200 foot radius of zero received considerable damage to the wood boxes, and in most instances the concrete slabs were broken. It is believed that the design was adequate as there was no requirement that these stations withstand the effects of blast.

Station 52 - Limonite Concrete Block on Reinforced Concrete Base with Back Stay Grillage. These structures were not designed to withstand the blast; only shielding was required, and data was obtained even though the structures moved. On Engebi, this structure was severely damaged by the blast. The upper grillage was buckled about eight inches and the lower about eleven inches above the base. Very little of the base was exposed, but there was no evidence of damage. On Runit, this structure was partially damaged by the blast. The block was cracked both vertically and horizontally with cracks as wide as one-quarter of an inch.

Station 53 - Limonite Concrete Block on Reinforced Concrete Base with Backstay. There was no damage to these structures. The design is believed to be adequate.

Station 54 - Reinforced Limonite Structure on Reinforced Concrete Base. On Engebi, there was no apparent damage to this structure. Exposed outside corners were spalled off by flying debris. The tunnel entrance to the structure had caved in and earth had not been cleared away; therefore no inside inspection was made.

On Runit, the structure was demolished by a clean-up crew prior to inspection. It was understood that the structure was not damaged except that equipment supports (unistruts) were pulled out of the walls, the tunnel entrance caved in, and the walls somewhat cracked.

The design of these structures is considered adequate except for the connection of the unistrut supports to the walls.

Station 55 - Reinforced Concrete Structure. These structures were not damaged, and design is considered adequate.

Station 56 - Reinforced Concrete Structure. This structure on The Aomon Group shows some blast damage. The upper face toward zero corners have diagonal cracks beginning about two and one-half feet below the roof and extending upward of 45° from vertical; these cracks extend into the roof and stop about three feet from the edge. Cracks are three hundredths of an inch wide at bottom. Minor spalling occurred around conduit embedded in the ceiling. Although this structure did not fail structurally, it suffered considerable damage. It is believed that an earth fill on the side toward zero and over the roof would have provided sufficient protection for the building as designed. It is understood that the damage described did not result in any loss of data.

Station 57 - Reinforced Limonite Structure on Reinforced Concrete Base. There was no damage to these structures. The design is considered adequate.

Stations 60 and 62 - 75-foot Tower. Five towers were inspected; the tower at Site M southeast of Runit was dismantled prior to the inspection. None of the towers inspected showed signs of blast damage or effect except that the rolling doors on the cabs of the towers at Teiteiripucchi were bellied in and out with about four inch differential from normal. It is believed that this tower design is adequate.

Stations 61 and 63 - Wood Frame Structure. None of these structures showed any blast damage or effect.

Station 64 - Wood Frame Structure. Although these structures were damaged, it is felt that the design was adequate since they served and are still serving the purpose of protecting the generating equipment from the elements. Repair of the structures would be a relatively easy matter.

These structures all showed evidence of partial failure. The main damage consisted of a "belly in" of the side of the structure toward zero with splitting and breaking of the two inch by six inch studs in the wall, blowing out of the main doors, and damage to louvers on the side toward zero. There was no evidence of movement of sills, plates, or roof joists, and no damage to the corner columns was noted.

The Riiraai structure received the most severe damage. All vertical two inch by six inch studs in the face-on-wall were cracked or broken. Some cracking of the diagonal sheathing occurred, but the wall remained in one piece and is still standing. The opposite wall had three cracked studs near the mid point; these were caused by a "belly in" of this wall. The face-on louvers were badly broken; one half of main door was demolished; and the panels were blown out of the back door.

Damage on Bokanaarappi consisted of six cracked studs on the face-on wall, slight damage to face-on louvers and one-half of the main door off at hinges.

Damage on Teiteiripucchi consisted of six cracked studs on the face-on wall, some damage to face-on louvers, and main doors off at hinges.

Station 69 - Reinforced Concrete Structure. The structure on Runit was not damaged. The structures at The Aomon Group and Engebi show two vertical cracks about 0.015 inch wide on the face-on wall and some very fine irregular cracks in the roof. There is no indication that the buildings failed structurally. The design of these structures is considered adequate.

Stations 70, 71 and 72 - Reinforced Concrete Slabs. There was no damage to these slabs; the design is considered adequate.

Stations 73 and 74 - Installations only, No Design.

Station 75 - Reinforced Concrete Structure. There was no damage to these structures. The design was adequate for Engebi and excessive for Aaraanbiru. However, since the same design was used for both locations, no material saving of cost would have resulted from a lighter design for Aaraanbiru.

Station 76 - Reinforced Concrete Structure. There was no damage to these structures. Design was adequate, possibly excessive for Piiraai.

Stations 77, 78 and 79 - Wood Frame Structures. There was no damage to stations 77, 78 and 79 on Kirinian and Bokonaarappu and to Station 79 on Runit. Design is adequate for these structures, possibly excessive for station 79 on Bokonaarappu.

Station 80 - Reinforced Concrete Slab. There was no damage to these slabs. The design was adequate.

Stations 81, 82, 83 and 84 - Reinforced Concrete Slab. There was no damage to these slabs. The design was adequate.

Stations 90, 91, 92, 93, 95, 421 and 422 - Steel Box with Top Set Flush with Concrete. There was no damage to these boxes. The design was adequate.

Station 100 - Reinforced Concrete Structure. These structures showed no evidence of failure due to blast effect. A certain amount of cracking was in evidence at Engebi and a very small amount at Runit and The Aomon Group; however, none of this cracking indicates a structural failure. It is believed that the design is adequate, but not excessive.

The quality of construction was evident throughout the structures. Concrete was well consolidated; there was no exposed reinforcement; forms were true; and there was no evidence of patching after forms were stripped. All concrete rang true when struck with a hammer. There was no evidence of settlement or cracking of building foundations, columns, pilasters, or equipment blocks. Strain gauge tests on engine crank shafts at all sites after the blasts indicate that there is no misalignment. Due to the water seal and earth fill, it was impossible to inspect the outside roof, face-on and side-on walls of these structures.

Engebi showed the largest amount of interior cracking. This consisted of three nearly vertical cracks at the center and quarter points respectively of each wall. These cracks varied in width from .01 inch to .03 inch; the center crack on the north wall was .04 inch to .05 inch wide. No cracks were noted at the corners. Roof cracks consisted of two east-west cracks less than .02 inch in width extending across the floor in an east-west direction and connecting the quarter point wall cracks; all other vertical wall cracks did not extend into the floor. There was a small area of irregular cracking between the main panel and the eight-cylinder engine probably caused during the installation of the engine. All of these cracks appeared to be recent ones and are not believed to be contraction cracks which occurred during curing of the concrete.

Runit has no evident wall or roof cracks. Two small irregular cracks occurred in the floor. It is believed that they were of no consequence.

The Aomon Group has three vertical cracks .02 inch or less in width and on the face-on and side-on walls, extending from the floor to a height of eight feet. The top of these cracks terminate at what is believed to be a construction joint. One vertical crack .01 inch in width exists above the door to the ceiling. A very small number of very fine hair cracks exist in the floor. It was difficult to determine if these cracks were definitely the results of blast. It is probable that they were.

Station 101 - Wood Frame Structure. Structures at Bogallua and Bogombogo were not damaged. The structure at Muzin was completely wrecked and the structure at Kirinian was partially wrecked. The roof was intact, but the side framing was broken and pulled apart. These structures were designed for weather protection only and are adequate for this purpose.

Stations 120a, b, c, d, and e - Reinforced Concrete Blocks Set in Ground, Encasing Steel Bottle. Station 120a at Engebi was blown partially out of the ground; Station 120d was moved about two inches. Movement in both cases was away from zero. None of the blocks was structurally damaged by the blast, but the special stucco was torn loose along the edges of the tops of the blocks, and the exposed mesh reinforcement was burned. There was no damage to the top plates and interior pipes.

The structures at Eberiru are all within the blast crater and were under water when inspection was attempted; therefore no data is available at this time.

Stations 121a, b, c, d, and e - Reinforced Concrete Block Set in Ground with Steel Casting. Structures at Engebi were not seriously damaged by the blast. Station 121e was blown slightly up and backwards; the special stucco finish on Stations 121a, b, c, and d was torn loose around leading edges, and the mesh reinforcement was burned. There is no evidence of structural failure of the castings or the concrete blocks. The design is considered structurally adequate.

Structures on Eberiru were all within the blast crater, and because the crater was under water no inspection could be made.

Station 123 - Wood Frame Structure. These structures on Engebi and Eberiru were not required to survive and were completely destroyed.

Station 125 - Reinforced Concrete Slab with 1 foot, 6 inch Steel Plates. There was no damage to the slab, but thirteen of the 1 foot, 6 inch steel plates were torn from the slab. The separation was due to the concrete's breaking out around the bolt head. Design of connection between plates and slab was not adequate.

Station 131a - Reinforced Limonite Concrete Structure. This structure on Engebi, designed for shielding only, showed considerable failure but was not blown apart. Two horizontal cracks occurred in the structure, one about three feet from the top and the other about seven and one-half feet from the top. These cracks are about 0.5 inch wide on the lagoon side and 0.1 inch on the ocean side of structure. There was no indication that the bond between reinforcing steel and concrete was broken, but it did appear that some elongation of reinforcing steel occurred. The limonite plug blew out about two inches. The structure apparently did not break loose from its base, but the six inch concrete slab and cable were demolished.

Station 131 - Reinforced Limonite Concrete Structure. The condition of this structure on Eberiru is unknown. The blast created a crater which filled with water, and structures in the vicinity of zero were not accessible.

Stations 132a and b - Reinforced Concrete Structure. These structures showed no serious effects of blast damage. At Engebi the lagoon side wing wall of Station 132b settled slightly, and a small amount of horizontal movement of both wings was evident. The design of these structures was adequate.

Stations 132c and d - Reinforced Concrete Slabs. There was no damage by blast to these slabs. The design is considered adequate.

Station 135 - Wood Frame Structure. This structure was completely demolished. Design was adequate for the purpose intended.

Stations 141 and 142 - Wood Frame Structure. These structures were destroyed by the blast. Design was adequate for the purpose intended.

Station 143 - Reinforced Concrete Pit. This structure was destroyed by the blast. Design was adequate for the purpose intended.

Station 144a - Reinforced Limonite Concrete Blockhouse on Reinforced Concrete Base. These structures were designed for shielding only. The structure on Engebi was partially destroyed. The top slab of the block was blown off and lies between the block and zero. The tubes were torn loose, and there was considerable fracture in the rest of the block but the base did not appear to be damaged.

At Engebi (E+) and the Aomon Group the blocks were completely blown apart and the bases partially fractured.

Station 144b - Wood Frame Structure. These structures were completely destroyed. The design was adequate for the purpose intended.

Stations 145 and 146 - Steel Towers and Lead Shields. Towers were completely destroyed as expected.

Station 301 - Reinforced Concrete Structure. Stations 301a, b, c, i, j, and k at Engebi were not damaged, and design is considered adequate. Station 301e could not be inspected because debris had not been cleared away. It appeared that there was no serious structural damage.

Stations 301 on Muzin were not damaged, and the design is considered adequate. At Station 301f, the collapse of a military structure built over 301f caused the bottom chord (three and one-half inch by five inch by three-eighths angles) of a truss in the military structure to buckle when it hit the top of the face on side of the station. The only damage to Station 301 was a spalled off piece of concrete, about 7 inches in diameter.

Stations 302a, b, c, and d - Reinforced Concrete Structures. There was no damage to these structures; design is believed to be excessive.

Stations 302e through r - Reinforced Concrete Structure with Steel Box. There was no damage to these structures; the design is believed to be adequate.

Stations 3.1.1, 3.1.3, 3.2.1a, 3.2.1b, 3.2.2a, 3.2.2b, 3.2.3a, 3.2.3b, 3.2.4a, 3.2.4b, 3.2.5, 3.2.6, 3.2.7a, 3.2.7b, 3.3.3, 3.3.4, 3.3.5a, 3.3.5b, and 3.3.8a through h. These are military structures (Program 3) and were not designed by Holmes & Narver.

Stations 421, 423, 429, and 4210 through 4226 - Reinforced Concrete Base and Anchors. There was no damage to these items; the design is believed to be adequate.

Stations 623b, 624b, 625b and c, and 626b and c - Reinforced Concrete Structure with Steel Box. There was no damage to these structures; the design is believed to be adequate.

Stations 623, 625 and 626a - Reinforced Concrete Structure. There was no damage to these structures; fine horizontal cracks occurred between the openings on the face-on side but are not considered of any consequence. The design is believed to be adequate.

Stations 771, 772 and 773 - Reinforced Concrete Structure. There was no damage to these structures; the design is believed to be adequate.

Station 775 - Wood Frame Structures. There was no damage; design is adequate.

Stations 821 through 824 - Reinforced Concrete Slabs. There was no damage to these slabs; the design is believed to be adequate.

Station 825. There was no damage to this structure; the design is considered adequate.

Station 826 - Reinforced Concrete Structure. There was no damage to this structure except fine diagonal cracks above the door frame, which were probably caused by contraction. Design of this structure is considered adequate.

Stations 827 and 828 - Wood Frame Structure. There was no damage to these structures. The design is considered adequate.

DAMAGE TO PAVED AREAS

Tower Sites, 3 inch Asphaltic Pavement within 400 foot Radius from Zero. The blast effect on the pavement in this area varied from total destruction in the crater area to a highly oxidized and badly cracked pavement at the outer limit. The heat from the blast vaporized the volative oils and burned the residual bitumen and aggregate to a cinderlike mass. At Engebi this mass is rather brittle and at Runit and The Aomon Group it is more friable. Most of this area is covered with a very fine dust.

The shock waves created by the detonations completely shattered the pavement at Engebi in a very irregular pattern and buckled the pavement into ridges about eight inches in height throughout the area. Due to the friable condition of the material at Runit and The Aomon Group, the ridging and cracking were not pronounced.

Tower Sites, 1-1/2 inch Asphaltic Pavement within 1,000 foot to 400 foot Radius from Zero. The blast effect on the pavement in this area varied from the condition at the 400 foot radius described above to an oxidized and friable mixture at the 1000 foot radius. The shock wave ridging at Engebi disappears about 850 feet from zero. The oxidized pavement at all sites seemed to become more friable near the 1000 foot radius line. In view of the fact that a substantial portion of the paved area withstood the effects of heat and blast, it is reasonable to assume that the paving was effective as a stabilizing agent.

Stabilization and Paving at Scientific Structures. These areas that existed outside of approximately a 1200 foot radius did not suffer any severe blast damage. The design is considered adequate.

Airstrips. The only airstrip that suffered blast damage was at Engebi. This damage consisted of high oxidation of the surface and considerable cracking. The blasts (especially E+) covered the strip with broken concrete, coral, etc. Blading and stabilization were required after the blasts to put the strip in an operable condition.

Roads. The only damage to unpaved roads at the various sites consisted of pieces of coral and broken concrete being scattered over the roadway. The asphaltic pavement on the road at Engebi, paralleling the lagoon and from about 1,000 to 2,300 feet out from zero received considerable damage. Approximately 35 per cent of the pavement in this area was torn loose from the base course and either blown completely away or scattered over the area between the road and lagoon. The top portion of the pavement was oxidized, but the bottom three-fourths was a resilient asphaltic mixture. Paving appears to have been stripped.

DAMAGE TO PIERS

Approximately 110 feet at the inshore end of the cargo and personnel pier at Runit suffered considerable damage from the blast. The damage consisted of the decking, stringers, and pile caps being lifted from the piles as a unit, inverted, and carried to the south side of the pier. The rest of the pier and the piling were unaffected, although some of the bent cross bracing was split where it was bolted to the pile caps that were carried away.

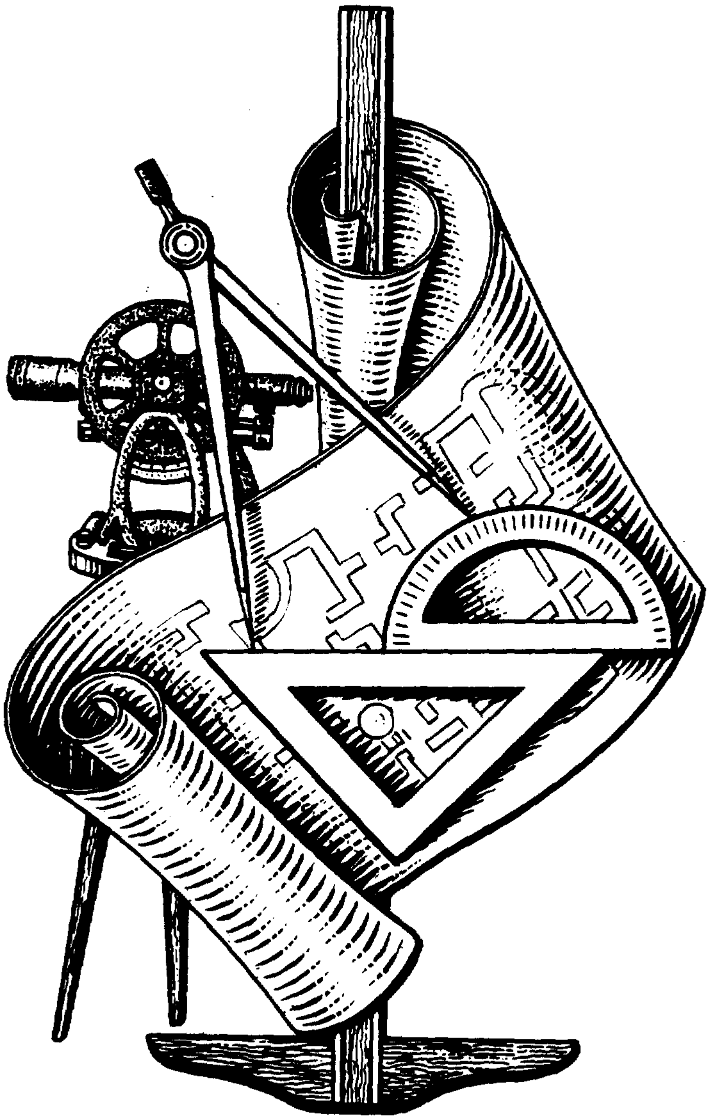


EXHIBIT A

Mechanical and Electrical Test Report
Runit Island Power Plant

DIESEL TEST RUNIT
FS. 423 FS 411 and 411A Apply

PREPARATION:

On March 5, 6, and 7th, mechanical and electrical test runs were made at the power house in order to obtain data on output, and also test the shut down time for the plant.

Prior to the test runs, the electrical panel board was wired and instruments installed, and all automatic shut down timing equipment was checked and put in operation and all electrical equipment was dried out.

A water rheostat was installed in the electrical system in order to simulate a balanced full load on the system. Also manometer, and thermocouple connections were installed as per Drawing F.S. 423 and instruments connected.

The Power Plant at Runit consists of three Fairbanks-Morse, 5 cylinder, 175 BHP at 720 RPM, diesel engines, direct connected to Fairbanks-Morse alternating current generators of 60 cycle 118 KVA capacity, with a V belt driven direct current exciter.

For the mechanical test Diesel Generator Unit No. 1 was used.

TEST NO. 1. MARCH 5 1951

This test consisted of a heat run on the equipment, and back pressure check was made on the regular exhaust system and auxiliary exhaust system with the following results:

TIME: 10:50

BACK PRESSURE TEST

1. Engine #1 Stack Exhaust open, Manometer #1 readings of 3.8+4.1 = 7.9" of water, or .285 lbs/sq. in. Stack Exhaust closed, Auxiliary Exhaust open. Manometer #1 readings of 1.4+1.6 = 3.0" of water, or .1083 lbs/sq. in. manometer #2 readings on Aux. Exhaust outlet = 0+0

2. Engine #2

   Stack Exhaust Closed, Auxiliary Exhaust open, manometer #1 readings 1.6+1.5 = 3.1" of water, or .111 lbs/sq. in. Manometer #2 reading on Aux. Exhaust outlet 0.0+0.5" of water, or .0018 lbs/sq. in.

3. Engine #3

   Stack Exhaust closed, Auxiliary Exhaust open, manometer #1 readings 2.3+2.6 = 4.9" of water, or .1768 lbs/sq. in. manometer #2 reading on Aux. Exhaust outlet = 0.0-.15 = .15" of water, or .0054 lbs/sq. in. vaccuum.

After the three units had run for a period of ten minutes, exhausting out the auxiliary exhaust system, the following results taken in reverse of the first, were obtained:

Time 1100

1. Engine #3

   Manometer #1 reading 2.4+2.7 = 5.1" of water, or .184 lbs/sq. in. manometer #2 reading at Aux. Exh. outlet = -.15-.15 = -.30" of water, or .01083 lbs/sq. in. vaccuum.

2. Engine #2

   Engine #3 Exhausting to stack. Engine #1 & 2 on Aux. Exh., manometer #1 reading 1.7+2.0 = 3.7" of water, or .1335 lbs/sq.

in. manometer #2 reading at Aux. Exh. outlet -0.1-0.1 = 0.2" of water, or .0072 lbs/sq. in. vaccuum.

3. Engine #1

Aux. Exhaust on Engine #2 & 3 closed. Aux. Exh. Engine #1 open, manometer #1 readings, 1.4+1.6 = 3.0" of water, or .1083 lbs/sq. in., manometer #2 reading at Aux. Exh. Outlet, .05+0.0 = +.05" of water, or .0018 lbs/sq. in.

4. All Engines on Stack Exhaust, manometer #1 reading, 3.8+4.1 = 7.9" of water, or .285 lbs/sq. in. readings on manometer #3 on stack outlet was -0.1 = -.2" of water, or .0072 lbs/sq. in. vaccuum.

5. RESULTS

It will be noted that in each exhaust system the readings at the exhaust outlets was a minus reading thereby creating a suction, also that the Auxiliary exhaust system offers less resistance to the flow of exhaust gases than the regular stack exhaust, due to the absence of silencers.

The data on the heat run that started at 1120 and ran until 1400 are contained on test chart Dwg. #FS 411-A.

TEST NO. 2 MARCH 6 1951

The results of this test are all tabulated on test chart, Dwg. No. FS 411; test was run for a four hour interval with readings every thirty (30) minutes; diesel generator unit No. 1 alone was used for this test carrying full load.

For the fuel consumption test, a 55 gallon oil drum was used, and the amount of fuel oil was calculated for each 1/8" of depth. This was filled to a depth of 31" at start of test and depth readings were taken every hour. The following results were obtained:

READINGS OF FUEL OIL IN BARREL

TIME	INCHES OF FUEL REMAINING	INCHES OF FUEL USED	GALLONS
1105	31"	--	52.70
1210	24½"	6½"	11.06
1300	17"	6½"	11.06
1405	10"	7"	11.90
1500	4½"	6½"	11.06
3 hrs 55 min		26½"	

A total of 26½ inches of fuel oil was used over a period of 3 hours and 55 minutes or 3.9166 hours. 26½ inches of fuel oil = 45 gallons; 45 ÷ 3.9166 = 11.48 gallons per hour.

11.48 x 5.8 = 66.584 lbs. per hour 66.184 ÷ 118 = .56 lbs. per K.W.H.

COMMENTS

From the results of the fuel consumption test, it is readily seen that the diesels are using more fuel per K.W.H. than they should. This is due in all probability to the use of a lower grade fuel oil than the recommended grade for these diesels and the full amount of power is not being realized from the present grade of fuel oil.

With a better grade of fuel oil being used it will be possible to operate these diesels within their recommended limits of .42 lbs. of fuel oil per kwhr.

TEST NO. 3 MARCH 7, 1951

This test was made to determine the results of the power plant running for fifteen (15) minutes with stack exhausts closed and diesels exhausting out of auxiliary exhaust, all doors closed, only auxiliary electric exhaust valve open to atmosphere.

1. Installed manometer connection in steel plate covering opening on west side of entrance, connected manometer to determine pressure inside of plant.

   1030

2. Closed stack exhaust, and opened auxiliary exhaust on all three units, closed large entrance door and personnel door, auxiliary exhaust valve open.

3. Manometer reading with power house closed as above .20/.25 = .45 inches of water, or .0162 lbs. per sq. in. pressure.

4. 1045 Pushed button to close auxiliary exhaust valve.

5. 1045:30 Auxiliary exhaust valve closed.

6. 1045:46 Power house units stopped in 16 seconds.

7. Manometer reading taken at 1045:46 as power house units shut off = 1.0/1.0 = 2.0 inches of water, or .0722 lbs. per sq. in. which is equal to 10.39 lbs. per sq. ft. pressure in power house.

Subject: Electric Generating Plants (Diesel) Testing Procedure for Diesel Engines

The procedure outlined below should be followed in obtaining information desired as outlined on Field Sketch No. 411. Use Field sketches No. 423, 430 & 435 as Reference Guide.

1. Engine to be running full speed (720 RPM) and carrying full load, governor controlled.

   (a) Check governor speed with actual speed of engine before test.

   (b) Set overspeed trip at 792 RPM and check. Check governor on Full load & No load to get overspeed for droop characteristic.

2. Check following temperatures:

   (a) Jacket water in and out - allowing less than 10 deg. F. differential - Normal 180 deg. F.

   (b) Lube Oil in and out - Normal 190 deg. F.

   (c) Salt Water cooling in and out.

   (d) Steam out of silencer

   (e) Fresh water thru silencer

   (f) Silencer exhaust gases in and out

   (g) Stack gases to Atmos.

3. Check following pressures:

   (a) Steam out of silencer.

   (b) Salt water cooling system

   (c) Lube oil pump and header

   (d) Fuel oil pump and header

   (e) Exhaust in and out of silencer

   (f) Aux. Exhaust out of engine

   (g) Aux. Exhaust out of engine

   (h) Aux. Exhaust to Atmos

   (i) Air intake to engine

4. Check Time on following:

(a) Time to close aux. Exhaust valve.

(b) To open Exhaust valve to stack

(c) To close electric Exh. valve

(d) Elapsed time of operation of engine

5. Check following (Misc.)

(a) Gallons per hour of water thru silencer

(b) Engine RPM

(c) Overspeed Trip (Should operate at 792 RPM)

(d) Vibration of engine-amplitude and frequency

(e) Quantity of fuel oil used - 4 hr. run

EQUIPMENT REQUIRED TO RUN TEST

1. Manometers
2. Revolution Counter
3. Stop watch
4. Potentiometer
5. Barometer
6. Vibrometer

EXHIBIT B

Submarine Telephone Cable Test Record

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

<u>CABLE NO. 0-101</u>
Parry to Eniwetok
4.5 Miles (23,640 Ft.)

16 Pairs - 19 Gauge
Pairs 1-12 88 MH
Pairs 13-16 Non-Loaded

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	5000 cps	N & XT Vol (db)	Remarks
1	393	0.5	200+	200+	4.4	13.2		
2	394	0.5	200+	200+	4.6	13.2		
3	394	0	200+	200+	4.6	13.3		
4	394	1.0	200+	200+	4.6	13.3		
5	394	0	200+	200+	4.6	13.1		
6	393	0	200+	200+	4.6	13.2		
7	395	0	200+	200+	4.6	13.0		
8	393	0.5	200+	200+	4.6	13.2		
9	393	2.0	200+	200+	4.6	13.5		
10	395	0	0.2	0.2	4.6	13.3		
11	393	0	200+	200+	4.6	13.3		Hi. Res. Sht.
12	393	0.5	200+	200+	4.5	12.9		
13	395	0	200+	200+	4.5	13.0		
14	394	1.0	200+	200+	4.6	13.1		
15	393	1.5	200+	200+	4.5	13.2		
16	394	0	200+	200+	4.4	13.0		

NEAR-END CROSSTALK COUPLING MEASURED AT PARRY (LEVEL 100)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	102+	102+	92	102+	102+	96	99	94	102+	98	99	92	100	95	90
2		102+	96	94	101	98	97	99	102	83	90	102+	96	100	102
3			101	93	96	95	102+	99	90	102	101	96	102	91	100
4				94	100	90	83	94	94	95	96	87	94	101	96
5					102+	91	102+	100	91	88	96	87	93	92	91
6						94	89	99	93	94	96	83	100	102+	98
7							87	91	99	102	87	97	88	92	94
8								90	93	95	102+	94	101	88	100
9									102	97	102+	102	102+	91	97
10										101	98	97	93	86	95
11											95	98	97	100	102+
12												99	98	93	96
13													96	95	102
14														95	89
15															99

NEAR-END CROSSTALK COUPLING MEASURED AT ENIWETOK

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	97+	97+	97+	85.5	96	91	93	95	97	97+	97+	92.5	96	93.5	97
2		97	97+	95	95.5	94	94.5	95	94	92.5	92	97+	97+	97	97+
3			97+	97+	97+	97+	97+	95	97+	97+	97	97	97+	94	97+
4				93	96	97+	97	96	92.5	97+	94.5	90.5	96	97+	97
5					97	92	97	96	97+	97+	97+	87.5	95.5	96	97
6						97+	97	97+	97+	97+	97+	91.5	97+	97	97
7							95	97+	97+	97+	97	97+	97+	97+	97+
8								95	97+	97+	97+	97	97+	97+	97+
9									97+	97+	97+	97+	97+	97+	97+
10										97+	97+	97+	97+	94	97+
11											97+	97+	97+	97+	97+
12												97+	97+	97+	97+
13													97+	97+	97+
14														97+	96
15															97

FAR-END CROSSTALK COUPLING MEASURED AT PARRY

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	102+	97	88	102+	102+	92	93	92.5	102+	92	102	90	96	102+	88.5
2		100	90	86	102	102	102	95	100	79	87.5	98	93	100	101
3			102+	95	92	93.5	100	95	87	93	102+	95	93	98	101
4				89	97	89	81.5	94	90	93	93	84	92	102+	100
5					102	88	100	95	97	86	92	82	90	92	90
6						92	84.5	95	91	93	95	79.5	100	102+	97
7							85	93	98	100	84	93	85	88	91
8								87	98	90	102+	90	93	87	102
9									97	102+	102+	102+	102+	89	100
10										102	99	93	89	82	102+
11											97	95	96	98	98
12												100	93	92	93
13													90	94	100
14														97	86.5
15															102

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

CABLE NO. 0-102
Parry - Eniwetok
4.7 Miles (24,960 Ft.)

16 Pairs - 19 Gauge
Pairs 1-12 88 MH
Pairs 13-16 Non-Loaded

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	cps	N & XT Vol. (db)	Remarks
1	447	1.0	200+	200+	3.0	3.2		
2	448	0	200+	200+	3.0	3.2		
3	446	1.0	200+	200+	2.7	3.0		
4	447	1.0	200+	200+	2.9	3.1		
5	447	0	200+	200+	3.0	3.2		
6	446	0	200+	200+	3.0	3.2		
7	447	0	200+	200+	2.9	3.1		
8	447	0	200+	200+	2.9	3.0		
9	448	1.0	200+	200+	2.8	3.0		
10	447	0.5	200+	200+	2.9	3.1		
11	447	1.5	200+	200+	2.8	3.0		
12	446	0.5	200+	200+	3.0	3.2		
13	416	1.0	200+	200+	5.3	14.5		
14	416	0.5	200+	200+	4.7	14.2		
15	416	0	200+	200+	5.3	14.6		
16	415	0	200+	200+	5.1	14.1		

NEAR-END CROSSTALK COUPLING MEASURED AT ENIWETOK (LEVEL 100)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	81.5	92	92	92	92	95	97	89	91	97	97	97+	97	95	97+
2		92	89	95	94	93	97+	97+	97+	94	97+	97+	97+	97+	97
3			94	97+	89.5	96	97+	84.5	97+	80.5	93	97+	95	97+	95.5
4				97+	89.5	95	95.5	96	97+	96	93	97+	96	97+	97+
5					94.5	93	95	94.5	93.5	97+	94	97	91.5	96	95
6						89.5	97+	90	97+	83	93.5	97+	97	97+	93.5
7							91.5	89.5	95	95.5	97+	97+	97+	97	92.5
8								97	94.5	89.5	96	97+	95	94.5	96.5
9									93	97+	95	94	96	97+	97+
10										94	94.5	97+	95.5	95.5	94
11											89	97+	97+	97+	97+
12												92.5	94.5	97	97+
13													94	97+	97
14														97+	97+
15															97

NEAR-END CROSSTALK COUPLING MEASURED AT PARRY

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	84	92	95	98	92	92	90	86	90	100	91	97	93	95	107
2		93	91	93	97	92	95	92	107	107	88	97	106	104	100
3			92	103	90	92	100	85	103	79	95	100	95	100	95
4				100	90	101	89	97	97	94	90	101	92	98	97
5					93	93	95	96	90	105	90	99	89	92	92
6						87	96	89	91	82	93	101	101	100	90
7							90	92	98	95	98	93	100	99	96
8								99	93	92	93	98	94	97	93
9									97	100	96	91	94	102	97
10										91	93	101	95	94	93
11											93	102+	99	102+	102+
12												93	93	94	102+
13													90	101	94
14														97	99
15															95

FAR-END CROSSTALK COUPLING MEASURED AT PARRY

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	78	99	95	94	95	98	90	94	88	102+	94	100	91	92	102
2		92	91	89	92	99	94	85	99	96	101	95	92	100	95
3			88	102+	97	92	102+	84	96	77	94	101	96	98	93
4				102+	88	94	100	90	102+	87	85	102+	90	99	96
5					95	98	90	96	101	102+	93	94	85	93	91
6						92	99	90	100	80	91	97	97	101	89
7							86	87	89	85	91	93	102	95	91
8								101	98	99	92	97	94	94	92
9									94	94	88	90	91	97	101
10										91	91	96	94	92	91
11											98	102+	96	94	102+
12												92	88	95	95
13													89	98	94
14														95	100
15															93

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

CABLE NO. 0-103
Parry - Eniwetok
3.2 Miles (22,980 Ft.)

16 Pairs - 19 Gauge
Pairs 1-2 88 MH
Pairs 13-06 Non-Loaded

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	5000 cps	N & XT Vol. (db)	Remarks
1	416	1.0	200+	200+	3.3	4.2		
2	414	0	200+	200+	3.2	4.3		
3	415	1.0	200+	200+	3.2	4.0		
4	415	0	200+	200+	3.3	4.3		
5	415	0.5	200+	200+	3.4	4.4		
6	414	1.0	200+	200+	3.3	4.4		
7	414	0	200+	200+	3.4	4.1		
8	414	0	200+	200+	3.3	4.1		
9	416	0.5	200+	200+	3.4	3.9		
10	415	0	200+	200+	3.3	4.3		
11	416	1.5	200+	200+	3.3	3.9		
12	415	0	200+	200+	3.3	4.1		
13	383	1.5	200+	200+	5.0	13.6		
14	383	2.0	200+	200+	4.7	13.8		
15	383	0	200+	200+	5.0	13.6		
16	382	1.0	200+	200+	5.0	13.6		

NEAR-END CROSSTALK COUPLING MEASURED AT ENIWETOK (LEVEL 100)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	97	97+	93	88.5	95	97+	92	90	97+	97+	92	92	96	96	97+
2		95	94	97+	94	91	97	96	97	94	91	97	92	90.5	97
3			94	92	97	90	97	93	97	97+	92	95	92.5	97+	97
4				97	95	95	92	97	96	96	94	93	94	97+	97
5					95	97+	97+	88.5	97	94	97+	93	97	97+	97+
6						92	95	97	97+	95	90.5	94	97+	97	94
7							97+	91.5	97+	97	92.5	91	97+	87.5	95
8								97	97	97+	90.5	95	97+	97	97+
9									94	96	89	95	97	97	97+
10										84.5	94	96	97+	97+	85.5
11											94	97	97+	94	95
12												97+	97	92.5	97
13													94	97	92
14														89.5	89.5
15															95

NEAR-END CROSSTALK COUPLING MEASURED AT PARRY

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	93	99	92	89	75	99	91	100	99	100	89	92	94	96	94
2		96	93	102	96	90	98	90	94	96	92	94	94	91	101+
3			91	88	97	95	102+	97	99	94	98	96	94	100	99
4				89	86	90	82	88	91	93	96	92	90	93	95
5					89	102+	102	88	98	94	100	92	100	94	102+
6						93	100	101	99	95	87	91	95	101	97
7							98	90	101	102	96	92	99	87	94
8								94	95	102+	91	93	99	94	102+
9									94	91	89	95	102+	92	102+
10										86	99	94	98	100	90
11											89	94	102+	90	97
12												102+	95	102	96
13													87	92	95
14														86	90
15															93

FAR-END CROSSTALK COUPLING MEASURED AT PARRY

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	97	86	90	83	88	101	95	82	102+	99	102+	90	92	91	95
2		98	102+	94	88	91	102+	90	92	87	94	92	89	86	102
3			96	87	90	85	102+	96	102+	90	83	90	91	98	102+
4				96	86	102+	84	95	91	92	89	95	94	93	100
5					102+	94	100	95	94	91	93	89	93	96	101
6						102+	96	101	94	95	96	92	95	99	94
7							97	92	101	94	96	89	96	85	90
8								92	95	95	95	89	99	100	94
9									95	96	95	91	98	94	95
10										85	92	95	102	92	83
11											89	94	102	91	96
12												102+	91	95	93
13													88	93	92
14														85	86
15															90

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

CABLE NO. 0-104
Parry - Runit
11.4 Miles

16 Pairs - 19 Gauge
Pairs 1-12 88 MH
Pairs 13-16 Non-Loaded

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	5000 cps	N & XT Vol. (db)	Remarks
1	991	0.5	200+	200+	6.0	6.4		
2	992	1.0	200+	200+	6.3	6.6		
3	992	0	200+	200+	6.3	7.0		
4	993	0	200+	200+	6.3	7.1		
5	989	1.0	200+	200+	6.3	7.2		
6	991	2.0	200+	200+	6.3	7.0		
7	991	0	200+	200+	6.5	6.6		
8	991	2.0	200+	200+	6.2	6.9		
9	991	2.0	200+	200+	6.4	6.5		
10	991				11.2	12.7		RING XED TIP 11
11	992				11.3	13.6		SEE PR 10
12					8.1	10.8		RING OPEN
13	921	4.0	200+	200+	12.8	28.3		
14	920	3.0	200+	200+	12.6	28.6		
15	920	2.0	200+	200+	13.0	28.5		
16	920	3.0	200+	200+	13.0	28.8		

NEAR-END CROSSTALK COUPLING MEASURED AT PARRY (LEVEL 105)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	89	89	93	90	90	95	87	95				97	95	91	94
2		93	89	97	90	91	92	90				95	95	95	94
3			94	93	92	94	87	92				94	94	92	96
4				84	84	88	91	87				92	92	91	89
5					93	90	92	82				93	94	96	85
6						87	84	94				93	98	90	96
7							90	88				94	92	95	96
8								89				90	98	93	95
9												93	94	94	94
10															
11															
12															
13													96	96	97
14														94	94
15															97

NEAR-END CROSSTALK COUPLING MEASURED AT RUNIT

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	93	90	97+	88	91	96	89.5	91				97	88.5	97+	97+
2		94	83	97	90.5	93	97	90				97	97+	94	91
3			96	93	95	96	93	97				91	97+	97+	97+
4				77	77	92	87	90				90	93	97	97+
5					93	93	97	77.5				97+	97+	97+	97+
6						93	91	97+				97+	97+	93+	97+
7							95	92				97+	96	97+	97+
8								89				94	94	90	97+
9												97+	87.5	97	97+
10															
11															
12															
13													97+	97+	97+
14														97+	97+
15															97+

FAR-END CROSSTALK COUPLING MEASURED AT PARRY

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	90	84	99	82	95	102+	88	89				97	86	88	93
2		97	82	96	93	99	94	90				99	102+	98	89
3			94	101	94	93	93	92				88	102+	92	95
4				81	76	98	78	86				86	90	90	91
5					88	100	94	73				90	94	101	103+
6						93	88	92				102	102	90	99
7							90	83				94	96	94	97
8								83				93	92	91	94
9												93	88	94	96
10															
11															
12															
13													97	100	102+
14														101	102
15															102+

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

<u>CABLE NO. 0-105</u>
Parry - Runit
11.1 Miles (58,440 Ft.)

16 Pairs - 19 Gauge
88 MH
Non-Loaded

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	cps	N & XT Vol. (db)	Remarks
1	1055	2.0	200	200	7.5	8.8		
2	1052	1.0	200	200	7.5	9.0		
3	1056	0	200	200	7.1	8.8		
4	1053	1.5	200	200	7.0	8.5		
5	1055	0	200	200	7.1	8.9		
6	974	0	0.6	200	14.9	30.2	NL	Hi. RES. TXR15
7	1054	2.0	200	200	7.0	8.9		
8	974	0	200	200	14.4	31.5	NL	
9	973	2.0	200	200	14.6	31.0	NL	
10	1053	0	200	200	7.0	9.4		
11	1054	0	200	200	7.1	8.6		
12	1054	1.0	200	200	7.0	9.2		
13	972	2.5	200	200	14.4	31.0	NL	
14	1052	1.0	200	200	7.0	8.2		
15	1054	0	200	0.6	7.0	9.0		See 6
16	1055	1.0	200	200	7.0	8.5		

NEAR-END CROSSTALK COUPLING MEASURED AT RUNIT (LEVEL 105)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	94	88	95	92	97+	94	97+	97+	93	94	92	97+	95	91	97
2		97	97	94	97	89	97	97+	92	92	97+	97+	91	97	89
3			97	93	97+	93	97+	97+	89	93	91	97+	97	97	92
4				92	97+	93	97+	97+	97+	87	91	97+	97	97	91
5					97+	97	97+	97+	91	94	95	97+	95	92	97
6						97+	97+	97+	97	97+	97	97+	97	97	97+
7							97+	97+	97+	97	94	97+	93	95	92
8								97+	97	97+	97	97+	97+	97+	97+
9									97+	97+	97+	97+	97+	97	96
10										92	94	97+	92	97	93
11											91	97+	95	97	97+
12												95	93	96	92
13													97+	97+	97+
14														93	97
15															84

NEAR-END CROSSTALK COUPLING MEASURED AT PARRY

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	91	88	94	89	94	88	93	97	90	88	84	93	90	87	90
2		95	90	90	95	86	93	95	86	85	94	97	86	89	90
3			90	93	95	90	90	92	90	90	90	92	94	88	90
4				88	95	89	94	92	92	85	92	93	91	97	88
5					94	97	97	94	93	88	91	95	92	90	93
6						90	96	92	93	93	90	96	94	91	94
7							95	96	96	94	94	95	94	91	86
8								92	91	96	93	90	96	94	92
9									97	90	92	95	97	92	92
10										88	86	99	90	94	86
11											91	95	87	89	92
12												88	92	90	96
13													95	94	93
14														92	93
15															82

FAR-END CROSSTALK COUPLING MEASURED AT PARRY

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	91	93	95	84	97	94	96	96	101	88	93	102+	95	89	92
2		89	90	83	93	89	93	102+	89	94	87	93	88	86	85
3			91	101	93	91	93	89	85	94	82	100	101	90	94
4				84	93	101	99	96	86	82	96	92	86	85	96
5					93	87	97	94	99	102+	83	95	95	89	102+
6						94	102+	102+	92	102+	93	102+	90	102+	96
7							94	102	85	89	92	91	91	92	89
8								96	92	102+	91	102+	99	90	88
9									93	94	98	102+	97	96	87
10										86	89	94	93	98	93
11											87	84	88	88	99
12												88	91	88	88
13													91	97	94
14														91	88
15															78

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

CABLE NO. 0-106 — 16 Pairs - 19 Gauge
Runit - Biijiri
7.6 Miles (40,140 Ft.)

Pair No.	Resistance (Ohms) Loop	Resistance (Ohms) Varley	Insulation Resistance (Megohms) Tip	Insulation Resistance (Megohms) Ring	Trans. Loss (db) 1000 cps	Trans. Loss (db) 2500 cps	N & XT Vol. (db)	Remarks
1	722	0.5	200+	200+	6.0	6.5		Rev.
2	723	1.0	200+	200+	6.0	7.2		
3	725	1.0	200+	200+	6.2	6.8		
4	722	0	200+	200+	6.3	6.6		
5	724	1.0	200+	200+	6.3	6.6		
6	722	0.5	200+	200+	6.2	6.6		Rev.
7	669	1.0	200+	200+	10.3	24.0		N.L.
8	725	0	200+	200+	6.2	6.6		
9	722	1.0	200+	200+	6.2	6.6		
10	725	3.0	200+	200+	6.3	6.7		
11	724	0.5	200+	200+	6.3	6.6		
12	723	3.0	200+	200+	6.3	6.7		
13	667	1.0	200+	200+	10.2	24.0		N.L.
14	669	0	200+	200+	10.3	24.0		N.L.
15	667	1.0	200+	200+	10.2	23.0		N.L.
16	722	0	200+	200+	6.0	6.3		

NEAR-END CROSSTALK COUPLING MEASURED AT RUNIT (LEVEL 105)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	94	97+	92	93	97	95	87	88	96	88	91	93	97	94	89
2		82	96	91	83	99	89	90	93	86	88	95	96	97+	93
3			91	96	92	93	96	91	92	97	90	96	97+	97	97
4				93	93	97	92	90	92	90	94	97+	90	97	89
5					91	96	97	89	89	96	93	94	97	96	88
6						97+	97	88	90	97+	97	95	97+	97+	97
7							95	97	96	96	96	97+	97	92	97+
8								97+	90	97+	89	96	97	97+	95
9									91	90	97	97+	97	91	94
10										97	93	95	93	97+	87
11											92	97+	97	92	92
12												95	93	97	88
13													97	97	97+
14														97+	97+
15															97

NEAR-END CROSSTALK COUPLING MEASURED AT BIIJIRI

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	91	95	92	95	95	92	88	86	93	93	95	100	98	95	93
2		88	93	91	89	97	93	97	95	85	88	102+	96	97	97
3			95	93	97	98	98	92	93	97	90	95	102+	95	97
4				93	93	92	90	94	92	95	97	98	94	98	94
5					97	95	98	89	95	97	97	95	98	95	93
6						102	100	89	88	94	95	97	100	102+	99
7							97	102	100	97	95	97	96	96	92
8								97	93	100	92	102	95	102	91
9									93	89	97	100	93	93	95
10										95	89	101	95	100	89
11											91	100	101	94	93
12												94	93	100	91
13													95	98	100
14														91	97
15															91

FAR-END CROSSTALK COUPLING MEASURED AT RUNIT (LEVEL 105)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	94	97+	90	97	97	89	92	80	92	91	94	97	96	94	89
2		88	97	97+	97	97+	88	97+	96	82	93	93	97	97+	97+
3			87	91	95	95	88	85	97	95	93	92	97+	95	95
4				97+	86	91	84	85	83	89	95	97	94	95	83
5					95	91	97	87	82	92	95	92	94	94	85
6						97	88	89	88	96	97+	91	97+	97+	89
7							89	95	97+	97	90	94	95	87	97
8								92	87	96	84	95	97	97+	88
9									91	88	97+	97	94	91	84
10										97	97+	92	90	96	97
11											83	97	95	97+	88
12												97	91	97	83
13													97	93	94
14														93	93
15															91

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

<u>CABLE NO. 0-107</u>
Runit - Biijiri
8 Miles (42,000 Ft.)

16 Pairs - 19 Gauge
88 MH
Non-Loaded

Pair No.	Resistance (Ohms) Loop	Resistance (Ohms) Varley	Insulation Resistance (Megohms) Tip	Insulation Resistance (Megohms) Ring	Trans. Loss (db) 1000 cps	Trans. Loss (db) 2500 cps	N & XT Vol. (db)	Remarks
1	752	0.5	200+	200+	6.7	7.0		
2	755	0	200+	200+	6.7	6.9		Rev.
3	755	0.5	200+	200+	6.2	7.0		
4	754	2.0	200+	200+	6.8	7.0		
5	755	1.5	200+	200+	6.9	7.0		
6	755	0	200+	200+	6.8	7.1		
7	755	0	200+	200+	6.8	7.0		
8	753	1.0	200+	200+	6.8	7.1		
9	756	1.0	200+	200+	6.8	7.1		
10	753	1.0	200+	200+	7.0	7.5		
11	755	1.0	200+	200+	7.1	7.3		
12	755	1.0	200+	200+	7.4	7.6		Rev.
13	699	2.0	200+	200+	11.2	23.4)		
14	699	1.5	200+	200+	11.2	23.3)	5 KC	
15	699	2.0	200+	200+	11.0	23.2)		
16	700	2.0	200+	200+	11.2	23.5)		

NEAR-END CROSSTALK COUPLING MEASURED AT BIIJIRI (LEVEL 110)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	102+	102+	99	100	93	97	91	100	99	95	96	91	102+	102+	100
2		102+	99	90	89	93	89	89	101	95	97	102+	95	96	101
3			100	91	82	100	96	83	101	96	94	102+	94	102+	89
4				91	96	88	94	99	94	96	93	101	97	102	102+
5					100	102+	102+	92	95	96	99	102+	102+	102+	101
6						87	97	94	99	94	96	100	102+	87	102+
7							101	92	99	92	95	102	90	100	89
8								101	99	94	100	99	100	102+	101
9									99	101	102	100	101	96	99
10										97	96	102+	96	82	96
11											79	88	88	102+	102
12												102+	94	102+	97
13													99	101	102+
14														100	96
15															102+

NEAR-END CROSSTALK COUPLING MEASURED AT RUNIT (LEVEL 105)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	97	97	94	94	94	95	90	90	90	96	96	95	97	97	97
2		90	90	92	94	95	87	90	90	91	94	95	97+	97	97
3			97	94	85	96	94	94	88	96	94	97	97	97	97
4				89	90	86	93	92	87	96	91	97	97	97	96
5					95	95	97	92	89	92	95	97	97	94	97
6						94	93	91	87	95	94	96	95	94	96
7							94	92	95	87	89	97	91	97	95
8								87	93	89	96	95	93	97	94
9									93	93	96	96	95	96	97
10										95	95	97	94	97	96
11											94	95	97+	97+	97
12												97	96	97	96
13													97	97	97
14														86	97
15															97

FAR-END CROSSTALK COUPLING MEASURED AT RUNIT (LEVEL 105)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	91	97+	97	90	87	91	86	97	97+	97+	91	93	97+	90	97
2		92	95	97	97	84	85	87	88	91	97+	97	97	97	93
3			93	88	81	92	90	97+	97	94	87	97+	91	97	94
4				97	97	86	91	95	90	97+	97	96	97	97+	97+
5					89	90	91	80.5	97	90	97+	93	97	93	97
6						96	91	97+	90	83	97	92	94	90	91
7							92	85	92	93	95	97+	86	97	87
8								94	88	96	95	89	91	93	94
9									83	90	94	97	91	93	97
10										97	94	95	89	95	94
11											92	91	92	97+	93
12												97+	91	95	93
13													94	97	94
14														94	90
15															97

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

CABLE NO. O-108
Bokan - Biijiri
5.7 Miles (30,840 Ft.)

Pair No.	Resistance (Ohms) Loop	Resistance (Ohms) Varley	Insulation Resistance (Megohms) Tip	Insulation Resistance (Megohms) Ring	Trans. Loss (db) 1000 cps	Trans. Loss (db) 2500 cps	N & XT Vol. (db)	Remarks
1	551	0.5	200+	200+	4.4	5.0		
2	551	2.0	200+	200+	4.6	5.0		
3	555	0	200+	200+	4.6	5.4		
4	551	1.0	200+	200+	4.6	5.8		
5	552	0	200+	200+	4.7	5.2		
6	554	1.0	200+	200+	4.8	5.5		
7	551	0.5	200+	200+	4.8	5.3		
8	554	0	200+	200+	4.6	5.4		
9	552	1.0	200+	200+	4.6	5.5		
10	551	0.5	200+	200+	4.8	5.7		
11	553	0	200+	200+	4.8	5.3		
12	552	1.5	200+	200+	4.8	5.5		
13	514	0	200+	200+	7.5	18.2)		
14	515	0.5	200+	200+	7.2	18.2)	5KC	
15	513	1.0	200+	200+	7.5	17.8)		
16	512	0	200+	200+	7.6	18.5)		

NEAR-END CROSSTALK COUPLING MEASURED AT BOKAN

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	89	97+	89	95	88	90	91	91	88	95	97+	97	97	93	97
2		90	97	88	87	93	96	95	89	97	91	91	91	97	97
3			91	94	97	86	96	96	90	91	89	90	95	95	96
4				96	96	97	86	89	97	93	91	89	97+	97+	91
5					89	95	95	93	88	93	91	94	95	94	97
6						86	91	91	90	94	91	97	96	95	97
7							88	97	90	85	93	97+	95	92	93
8								88	86	90	95	97+	97+	97	89
9									91	97	94	97+	97	96	97
10										78	97+	97	91	97	97
11											97	97+	95	95	97+
12												97+	97	97+	97+
13													96	97+	94
14														95	92
15															97+

NEAR-END CROSSTALK COUPLING MEASURED AT BIIJIRI

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	88	102+	89	91	92	91	91	92	89	92	97	96	97	90	99
2		91	101	92	91	93	101	100	95	96	94	90	91	96	94
3			89	96	97	94	102+	93	95	94	95	91	95	98	97
4				99	98	102+	93	95	92	91	96	92	96	100	91
5					89	99	102+	92	87	96	100	94	96	90	102+
6						83	97	87	94	94	84	100	102+	102+	93
7							86	90	96	86	94	101	101	88	92
8								89	87	90	90	96	94	102+	92
9									92	89	93	96	94	94	102+
10										81	92	95	89	95	94
11											94	102+	95	94	102+
12												102+	96	96	96
13													96	97	91
14														90	88
15															102+

FAR-END CROSSTALK COUPLING MEASURED AT BOKAN

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	93	97+	85	92	90	90	93	86	89	92	93	97	95	89	95
2		88	97+	85	97	93	97+	97	84	89	90	88	92	97	92
3			89	89	97+	89	97+	90	85	82	92	89	97+	97	97
4				97+	95	95	82	97+	88	94	90	88	95	97+	86
5					83	94	97+	93	92	87	94	94	97	90	97
6						91	95	90	92	87	88	97	96	94	91
7							92	95	88	85	95	97+	97	88	90
8								86	93	95	89	97	93	97+	85
9									85	85	97	97+	93	94	97+
10										74	97	89	86	95	94
11											90	97+	92	94	97+
12												97+	95	95	97
13													93	97+	90
14														88	87
15															97+

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

CABLE NO. O-108A
Bokon - Engebi
4.3 Miles (24,300 Ft.)

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	cps	N & XT Vol. (db)	Remarks
1	435	0.5	200+	200+	3.8	4.2		
2	436	0.5	200+	200+	3.8	4.2		
3	436	1.0	200+	200+	3.8	3.8		
4	437	0.5	200+	200+	3.8	4.2		
5	438	1.5	200+	200+	3.9	4.2		
6	435	0	200+	200+	3.8	4.2		
7	437	0	200+	200+	3.8	4.2		
8	437	0	200+	200+	3.8	4.2		
9	406	0	200+	200+	5.5	14.2		NON LOADED
10	404	1.0	200+	200+	5.3	14.2		NON LOADED
11	435	0	200+	200+	3.8	4.2		
12	438	0.5	200+	200+	4.0	4.4		
13	405	0	200+	200+	5.5	14.4		NON LOADED
14	437	1.0	200+	200+	3.8	4.2		
15	435	0	200+	200+	3.8	4.0		
16	405	0.5	200+	200+	5.4	14.2		NON LOADED

NEAR-END CROSSTALK COUPLING MEASURED AT ENGEBI

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	91	101	96	102+	94	97	94	99	102	102+	90	102+	101	96	102+
2		90	102+	98	101	102+	95	88	101	102+	92	97	90	92	101
3			97	93	96	84	88	95	88	91	90	94	90	93	102+
4				90	99	95	92	102+	101	101	89	102+	93	96	96
5					102+	92	95	102+	93	96	97	100	91	94	99
6						90	95	96	102+	97	86	97	96	92	95
7							90	96	91	94	88	102+	95	90	90
8								102+	100	96	90	94	98	91	93
9									102+	101	95	101	102+	89	92
10										82	96	101	90	94	102+
11											95	100	93	99	102+
12												90	95	96	101
13													90	93	93
14														93	96
15															98

NEAR-END CROSSTALK COUPLING MEASURED AT BOKON

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	80	80	80	80	80	81	83	79	78	81	80	78	81	83	78
2		80	81	82	81	81	81	76	78	81	80	88	81	85	78
3			80.5	84	85	81	85	82	74	78	80	79	79	80	78
4				80	80	81	80	76	78	81	79	77	79	79	78
5					80	81	81	78	80	80	79	77	80	78	77
6						79	81	78	79	80	80	79	82	81	81
7							81	79	80	80	81	79	81	80	81
8								80	80	80	85	88	80	81	88
9									80	83	82	81	84	80	80
10										75	84	82	83	86	82
11											82	79	84	83	79
12												82	81	80	80
13													83	86	86
14														80	78
15															79

FAR-END CROSSTALK COUPLING MEASURED AT BOKON

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	97+	95	85	93	90	97+	86	97+	97+	97+	85	97+	94	96	97+
2		93	97+	97+	97+	97	97	86	97+	97+	89	95	94	81	97+
3			97+	91	86	89	85	94	88	97+	89	93	89	97+	97+
4				95	97+	90	90	97	94	97+	95	97+	89	97+	92
5					97	91	97+	97+	86	97+	91	95+	93	97+	97+
6						90	90	93	97+	97+	97	94	97	92	93
7							85	93	87	86	85	97+	97+	97+	91
8								94	93	88	91	92	97+	97+	92
9									97+	95	93	94	97+	85	94
10										76	97	97	89	90	97+
11											83	97+	91	91	97+
12												90	90	87	97+
13													89	90	89
14														97+	91
15															94

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

CABLE NO. 0-109
Bokan - Biijiri
6 Miles (30,540 Ft.)

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	cps	N & XT Vol. (db)	Remarks
1	548	0.5	200+	200+	4.8	6.2		
2	550	2.0	200+	200+	4.8	6.4		
3	549	3.0	200+	200+	4.8	6.4		
4	549	0	200+	200+	4.9	6.8		
5	549	0	200+	200+	4.9	6.2		
6	548	0.5	200+	200+	4.8	6.6		
7	548	1.0	200+	200+	4.8	6.3		
8	548	0.5	200+	200+	4.8	6.6		
9	549	0.5	200+	200+	4.8	6.6		
10	549	0.5	200+	200+	4.8	6.5		
11	548	1.0	200+	200+	4.8	6.2		
12	548	1.5	200+	200+	4.6	6.2		Rev.
13	509	0.5	200+	200+	7.7	18.5		
14	510	3.0	200+	200+	7.7	18.3		
15	509	1.0	200+	200+	7.7	18.4		
16	507	0.5	200+	200+	7.7	18.4		

NEAR-END CROSSTALK COUPLING MEASURED AT BOKON

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	95	97	91	97+	92	86	93	95	90	92	94	91	93	97	97+
2		84	89	96	88	93	95	90	91	97	89	97	97	93	97
3			85	89	89	93	93	94	94	95	91	91	97	97	94
4				83	93	95	97	93	96	95	94	92	95	95	97
5					88	93	89	86	95	89	91	95	93	95	97
6						92	94	97	95	92	90	94	97+	96	88
7							91	90	89	92	93	97	94	96	95
8								88	97	91	97	95	97+	92	93
9									90	92	90	97+	92	93	97
10										94	97	90	97+	97	90
11											92	90	93	96	91
12												92	97	90	88
13													94	97+	97+
14														92	97+
15															97

NEAR-END CROSSTALK COUPLING MEASURED AT BIIJIRI

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	91	94	85	98	82	84	91	97	86	89	94	89	97	96	96
2		88	86	97	90	93	91	86	94	97	92	102	102	96	100
3			86	91	87	96	92	92	100	91	92	92	102+	97	92
4				84	93	96	96	90	102+	98	94	94	93	95	102+
5					88	92	89	87	94	89	89	94	99	94	102
6						86	93	95	101	94	88	101	92	90	94
7							92	94	91	94	88	101	102+	98	92
8								92	95	94	97	93	102+	95	93
9									90	94	94	100	99	92	97
10										88	91	92	102	93	94
11											92	85	89	95	89
12												89	94	88	93
13													96	102+	102+
14														102+	102+
15															92

FAR-END CROSSTALK COUPLING MEASURED BY BOKON

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	95	94	85	95	89	86	94	97+	92	92	97+	90	95	97+	95
2		88	97	93	84	88	90	94	85	94	97	97+	95	97	97
3			91	94	86	92	95	97+	87	97+	95	90	97+	96	93
4				88	97	95	91	88	91	92	89	89	89	95	97+
5					85	97+	85	85	90	85	89	96	97	94	97+
6						84	88	96	97	88	94	97	97	97	92
7							88	89	90	91	86	97	97+	95	92
8								93	94	94	97+	93	97+	96	89
9									83	92	97+	97	93	91	93
10										97+	90	90	97+	94	94
11											91	86	91	91	91
12												95	97+	88	86
13													94	97+	97
14														89	97
15															97

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

<u>CABLE NO. 0-109A</u>
Bokon - Engebi
6 Miles (22,260 Ft.)

Pair No.	Resistance (Ohms) Loop	Resistance (Ohms) Varley	Insulation Resistance (Megohms) Tip	Insulation Resistance (Megohms) Ring	Trans. Loss (db) 1000 cps	Trans. Loss (db) 2500 cps	N & XT Vol. (db)	Remarks
1	404	0.5	200	200	5.0	5.2		
2	403	1.0	200	200	4.8	4.7		
3	404	1.0	200	200	4.8	4.8		
4	402	1.0	200	200	4.8	4.8		
5	404	0.5	200	200	4.8	4.8		
6	404	0	200	200	4.6	4.8		
7	404	1.0	200	200	4.8	4.9		
8	405	0.5	200	200	4.6	4.8		
9	405	1.5	200	200	4.9	4.9		
10	404	0.5	200	200	4.8	4.8		
11	405	0	200	200	4.8	4.8		
12	404	1.0	200	200	4.7	4.6		REV
13	372	0	200	200	6.5	15.0		
14	370	1.5	200	200	6.2	15.0		
15	371	0	200	200	6.5	15.0		
16	371	0	200	200	6.5	15.2		

NEAR-END CROSSTALK COUPLING MEASURED AT ENGEBI

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	101	90	96	88	94	89	93	89	96	99	91	97	102+	96	97
2		94	102+	88	100	87	98	102	93	98	94	102+	102+	102+	96
3			92	96	89	95	93	87	91	87	89	94	96	92	95
4				91	96	98	97	94	93	102+	95	95	93	100	102+
5					93	96	97	89	92	99	85	93	95	102+	94
6						92	102+	97	96	92	90	102	90	94	102+
7							95	96	97	91	102+	91	89	102+	96
8								94	94	91	92	99	94	102+	102+
9									95	90	92	102+	95	96	97
10										91	102+	102+	94	94	97
11											89	102+	96	96	99
12												93	94	91	95
13													102+	96	94
14														101	102+
15															101

NEAR END CROSSTALK COUPLING MEASURED AT BOKON (LEVEL 105)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	97	93	95	89	92	97	94	94	97	97	97	97+	97	95	96
2		97+	97+	93	97	90	97+	95	96	97	97	97	97+	97+	97
3			92	93	94	95	95	88	94	93	92	94	97+	97+	97
4				91	97+	97+	97	93	93	97+	94	96	94	97+	97+
5					94	95	97	94	96	97	89	97	90	97+	97
6						91	97	97	95	91	93	97+	97+	97	97+
7							95	97	97+	92	97+	92	89	97+	97+
8								95	97	91	93	97	97	97+	97+
9									97+	96	94	97+	97	97+	97+
10										96	97+	97+	91	97+	96
11											92	97+	97	95	97+
12												93	94	97	97+
13													97+	96	93
14														97	97+
15															95

FAR-END CROSSTALK COUPLING MEASURED AT BOKON (LEVEL 105)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	97+	93	95	88	91	97	87	97+	90	95	89	97+	97+	95	97+
2		97+	97+	86	97+	85	91	91	88	93	97+	97+	97+	97+	94
3			88	97+	85	93	91	86	94	97	87	92	91	89	92
4				89	97+	97+	97+	88	92	97+	97+	94	90	97	97
5					86	94	97+	91	89	97+	89	93	87	97+	95
6						92	91	89	87	97+	87	97	90	97+	97+
7							87	92	97+	97+	97+	92	88	97+	97
8								96	97+	97	97+	97	94	97+	97+
9									97+	97+	86	97+	97+	95	96
10										86	97+	97+	88	94	93
11											94	97+	97	96	97+
12												91	90	93	95
13													97+	92	92
14														97	97+
15															97+

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

6-17-50

CABLE NO. 2-114

Parry to Japtan
2.5 Miles (15,300 Ft.)

19 Gauge, Non-Loaded

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	5000 cps	N & XT Vol. (db)	Remarks
1	255	2.0	200+	200+	4.0	10.0		
2	253	1.5	200+	200+	3.8	11.0		
3	255	2.0	200+	200+	4.2	10.0	*	R XED R4
4	255	2.0	200+	200+	3.8	10.5	*	R XED R3
5	255	1.0	200+	200+	4.1	10.8		
6	255	0	200+	200+	3.8	10.7		

* NOTE: X approx. 680 ft. from Japtan term.

NEAR-END CROSSTALK COUPLING
MEASURED AT PARRY

	2	3	4	5	6
1	82	94	90	94	88
2		84	87	96	92
3			85	85	97
4				91	91
5					88

NEAR-END CROSSTALK COUPLING
MEASURED AT JAPTAN

	2	3	4	5	6
1	87	93	95	97+	92
2		92	94	97	97
3			92	92	97+
4				96	96
5					95
6					

FAR-END CROSSTALK COUPLING
MEASURED AT PARRY

	2	3	4	5	6
1	80	91	89	99	88
2		85	87	92	89
3			85	85	102+
4				87	90
5					93
6					

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

CABLE NO. 2-115
Parry to Japtan
2.5 Miles (15,180 Ft.)

19 GAUGE, Non-Loaded

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	5000 cps	N & XT Vol (db)	Remarks
1	249	0	200+	200+	4.5	10.7		
2	253	0	200+	200+	4.4	11.0		
3	252	1.0	200+	200+	4.7	10.7		
4	253	0	200+	200+	4.7	11.0		
5	252	1.0	200+	200+	4.7	11.2		
6	253	0	200+	200+	4.6	11.0		

NEAR-END CROSSTALK COUPLING MEASURED AT PARRY

	2	3	4	5	6
1	93	84	99	84	87
2		87	88	82	90
3			87	87	88
4				91	86
5					82

NEAR-END CROSSTALK COUPLING MEASURED AT JAPTAN

	2	3	4	5	6
1	92	91	97	86	93
2		89	97	82	95
3			90	96	89
4				91	86
5					86

FAR-END CROSSTALK COUPLING MEASURED AT PARRY

	2	3	4	5	6
1	92	84	102+	82	87
2		85	89	78	86
3			86	88	85
4				89	83
5					80

SUBMARINE TELEPHONE CABLE 6-20-50
COMPLETION TEST RECORD

CABLE NO. 4-120
Biijiri to Piiraii
2.4 Miles (19 Gauge, Non-Loaded

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	cps	N & XT Vol (db)	Remarks
1	225	0	200+	200+	3.5	8.7		REV.
2	226	0	200+	200+	3.6	9.8		
3	225	1.0	200+	200+	3.7	9.2		
4	225	0	200+	200+	3.8	9.7		
5	225	0	200+	200+	3.7	9.1		
6	224	0	200+	200+	3.7	9.7		

NEAR-END CROSSTALK COUPLING
MEASURED AT BIIJIRI

	2	3	4	5	6
1	93	88	93	.00	86
2		86	94	89	89
3			91	88	92
4				84	91
5					77

NEAR-END CROSSTALK COUPLING
MEASURED AT PIIRAII

	2	3	4	5	6
1	97+	97+	97+	97+	97
2		97+	97+	97+	97+
3			97	94	97+
4				95	91
5					97+

FAR-END CROSSTALK COUPLING
MEASURED AT BIIJIRI

	2	3	4	5	6
1	102+	88	88	102+	83
2		87	102+	89	92
3			94	89	95
4				82	77
5					95

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

6-20-50

CABLE NO. 4-121A
Biijiri to Aaraanbiru
1.25 Miles (9,960 Ft.)

19 Gauge, Non-Loaded

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	5000 cps	N & XT Vol (db)	Remarks
1	166	0			4.3	8.0		
2	167	0			4.7	9.0		
3	166	1.0			4.7	8.0		
4	166	0			4.7	9.0		
5	166	0			4.7	8.0		
6	166	0			4.8	9.0		

NEAR-END CROSSTALK COUPLING
MEASURED AT BIIJIRI

	2	3	4	5	6
1	101	87	88	87	93
2		83	99	85	100
3			87	78	94
4				100	81
5					88

NEAR-END CROSSTALK COUPLING
MEASURED AT AARAANBIRU

	2	3	4	5	6
1	97+	95	94	94	97
2		87	97	91	97+
3			90	83	97
4				97+	90
5					95

FAR-END CROSSTALK COUPLING
MEASURED AT BIIJIRI

	2	3	4	5	6
1	102+	85	85	85	93
2		82	95	84	101
3			85	76	90
4				102+	78
5					85

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

6-20-50

CABLE NO. 4-121B
Aaraanbiru to Piiraai
2.25 Miles (6,360 Ft.)

19 Gauge, Non-Loaded

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	cps	N & XT Vol. (db)	Remarks
1	106	0			2.4	4.0		
2	107	0			2.4	4.4		
3	107	0			2.5	4.2		
4	106	0.5			2.5	4.5		
5	107	0			2.5	4.2		
6	107	0.5			2.6	4.6		

NEAR-END CROSSTALK COUPLING
MEASURED AT AARAANBIRU

	2	3	4	5	6
1	102+	92	92	102+	89
2		97	86	84	84
3			97	102	102+
4				95	79
5					102+

NEAR-END CROSSTALK COUPLING
MEASURED AT PIIRAII

	2	3	4	5	6
1	97+	89	95	97+	90
2		95	87	83	82
3			97+	97	97+
4				94	79
5					97+

FAR-END CROSSTALK COUPLING
MEASURED AT AARAANBIRU

	2	3	4	5	6
1	102+	92	90	102+	86
2		94	84	79	81
3			86	94	102+
4				90	76
5					100

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

6-27-50

CABLE NO. 5-125
Muzin to Engebi
1.3 Miles (6,960 Ft.)

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	5KC cps	N & XT Vol. (db)	Remarks
1	116	0	200+	200+	1.1	3.9		
2	116	0.5	200+	200+	1.1	3.9		
3	116	0	200+	200+	1.2	4.0		
4	116	0.5	200+	200+	1.1	3.9		
5	116	0	200+	200+	1.1	3.9		
6	117	0	200+	200+	1.1	3.9		

NEAR-END CROSSTALK COUPLING
MEASURED AT MUZIN

	2	3	4	5	6
1	94	85	82	90	97
2		84	85	81	97+
3			91	97	91
4				83	86
5					97+

NEAR-END CROSSTALK COUPLING
MEASURED AT ENGEBI

	2	3	4	5	6
1	102	86	85	93	101
2		82	85	80	102
3			92	102	84
4				92	88
5					90

FAR-END CROSSTALK COUPLING
MEASURED AT MUZIN

	2	3	4	5	6
1	97+	82	85	92	97+
2		82	85	82	97+
3			94	97+	83
4				97	87
5					97+

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

6-28-50

CABLE NO. 5-128
Engebi to Teiteiripuchi
4.7 Miles (19,980 Ft.)

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	5KC cps	N & XT Vol (db)	Remarks
1	333	0	200+	200+	4.3	9.9		
2	332	0.5	200+	200+	4.3	9.9		
3	333	0.5	200+	200+	4.3	9.9		
4	332	0.5	200+	200+	4.2	9.9		
5	333	1.0	200+	200+	4.2	9.9		
6	334	0	200+	200+	4.2	10.0		

NEAR-END CROSSTALK COUPLING
MEASURED AT TEITEIRIPUCHI

	2	3	4	5	6
1	87	84	97+	87	95
2		96	80	90	91
3			97	89	85
4				96	91
5					97+

NEAR-END CROSSTALK COUPLING
MEASURED AT ENGEBI

	2	3	4	5	6
1	85	83	98	78	90
2		90	77	89	86
3			92	94	94
4				87	85
5					94

FAR-END CROSSTALK COUPLING
MEASURED AT TEITEIRIPUGHI

	2	3	4	5	6
1	83	81	97+	78	91
2		91	76	87	77
3			95	88	86
4				92	85
5					93

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

CABLE NO. 5-127
Teieiripuchi to Engebi
4.7 Miles (18,720 Ft.)

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	5000 cps	N & XT Vol. (db)	Remarks
1	313	1.5	200+	200+	3.6	9.3		
2	312	1.0	200+	200+	3.6	9.3		
3	315	1.5	200+	200+	3.6	9.4		
4	314	0	200+	200+	3.6	9.4		
5	313	0.5	200+	200+	3.2	9.3		
6	313	1.5	200+	200+	3.8	9.4		

NEAR-END CROSSTALK COUPLING
MEASURED AT TEITEIRIPUCHI

	2	3	4	5	6
1	93	97+	97	83	97+
2		97+	97	97	88
3			94	95	87
4				83	88
5					97+

NEAR-END CROSSTALK COUPLING
MEASURED AT ENGEBI

	2	3	4	5	6
1	89	98	102+	83	91
2		92	99	102	94
3			90	92	90
4				82	86
5					96

FAR-END CROSSTALK COUPLING
MEASURED AT TEITEIRIPUCHI

	2	3	4	5	6
1	91	97	97	81	97
2		96	95	97+	90
3			88	90	87
4				81	84
5					97+

SUBMARINE TELEPHONE CABLE
COMPLETION TEST RECORD

6-28-50

CABLE NO. 5-128
Engebi to Teiteiripuchi
4.7 Miles (19,980 Ft.)

Pair No.	Resistance (Ohms) Loop	Var-ley	Insulation Resistance (Megohms) Tip	Ring	Trans. Loss (db) 1000 cps	5KC cps	N & XT Vol (db)	Remarks
1	333	0	200+	200+	4.3	9.9		
2	332	0.5	200+	200+	4.3	9.9		
3	333	0.5	200+	200+	4.3	9.9		
4	332	0.5	200+	200+	4.2	9.9		
5	333	1.0	200+	200+	4.2	9.9		
6	334	0	200+	200+	4.2	10.0		

NEAR-END CROSSTALK COUPLING
MEASURED AT TEITEIRIPUCHI

	2	3	4	5	6
1	87	84	97+	87	95
2		96	80	90	91
3			97	89	85
4				96	91
5					97+

NEAR-END CROSSTALK COUPLING
MEASURED AT ENGEBI

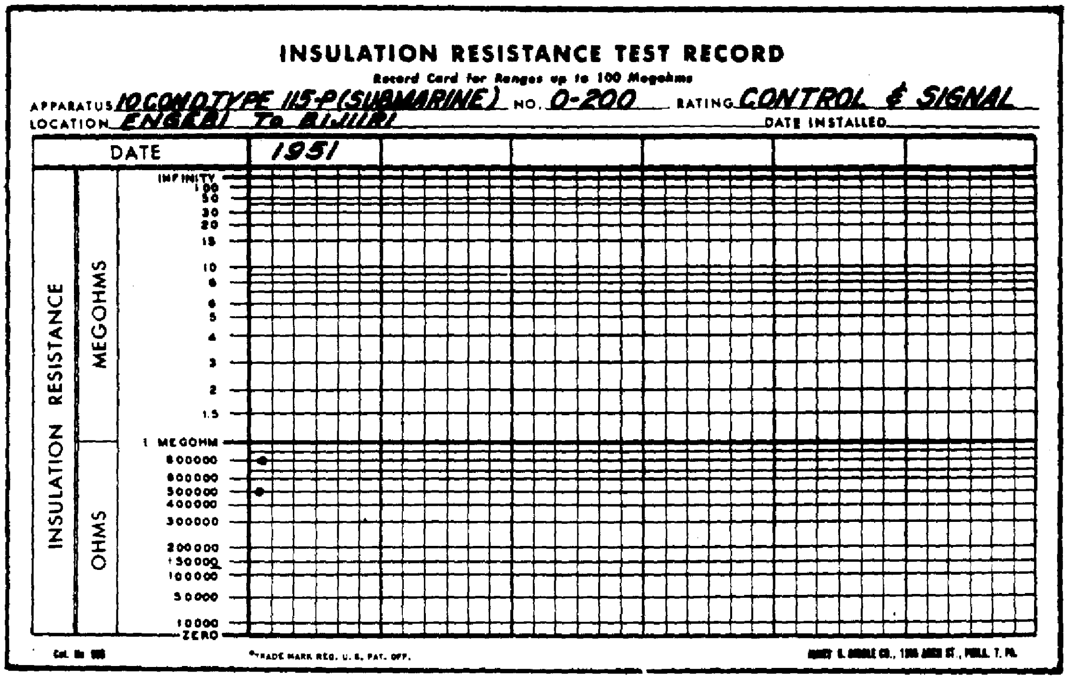
	2	3	4	5	6
1	85	83	98	78	90
2		90	77	89	86
3			92	94	94
4				87	85
5					94

FAR-END CROSSTALK COUPLING
MEASURED AT TEITEIRIPUGHI

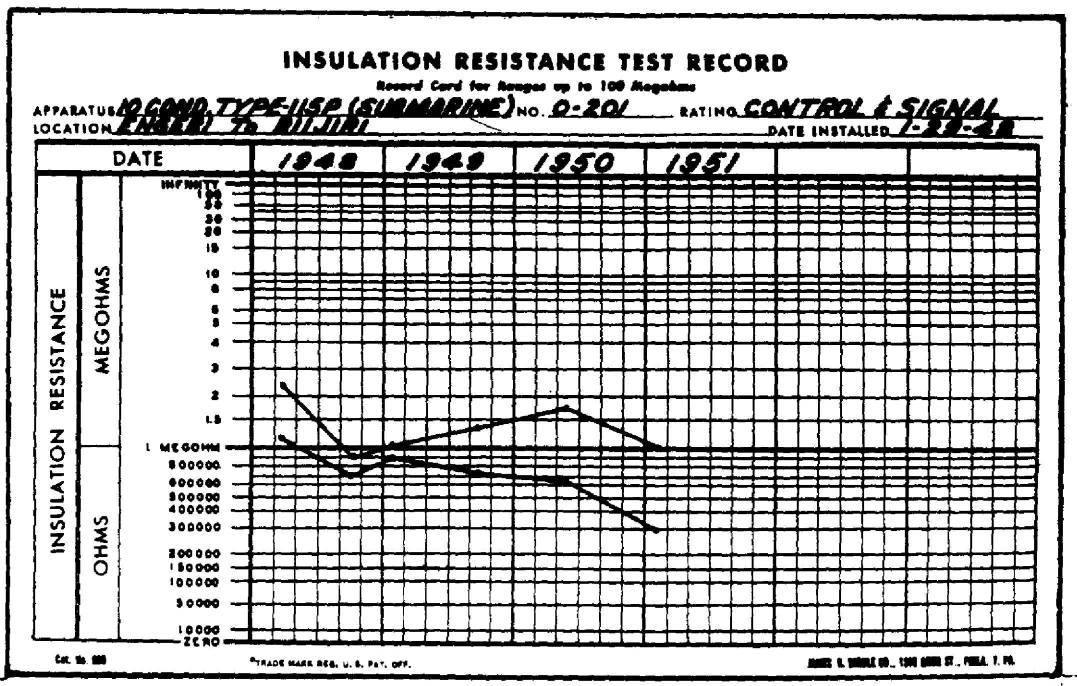
	2	3	4	5	6
1	83	81	97+	78	91
2		91	76	87	77
3			95	88	86
4				92	85
5					93

EXHIBIT C

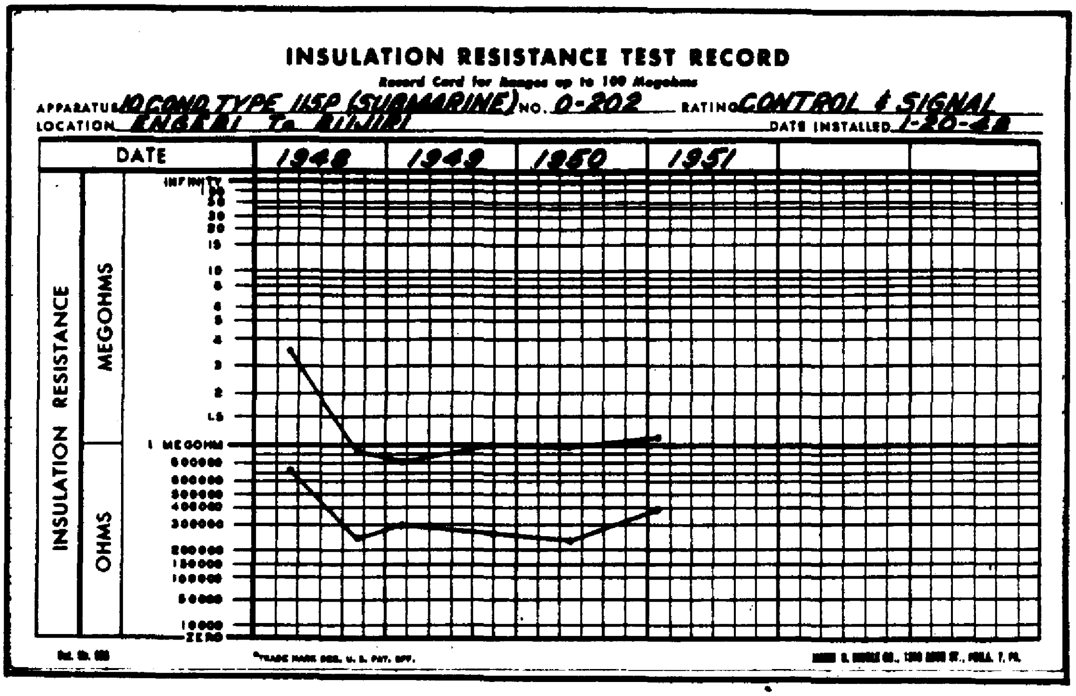
Submarine Control and Signal Test Record

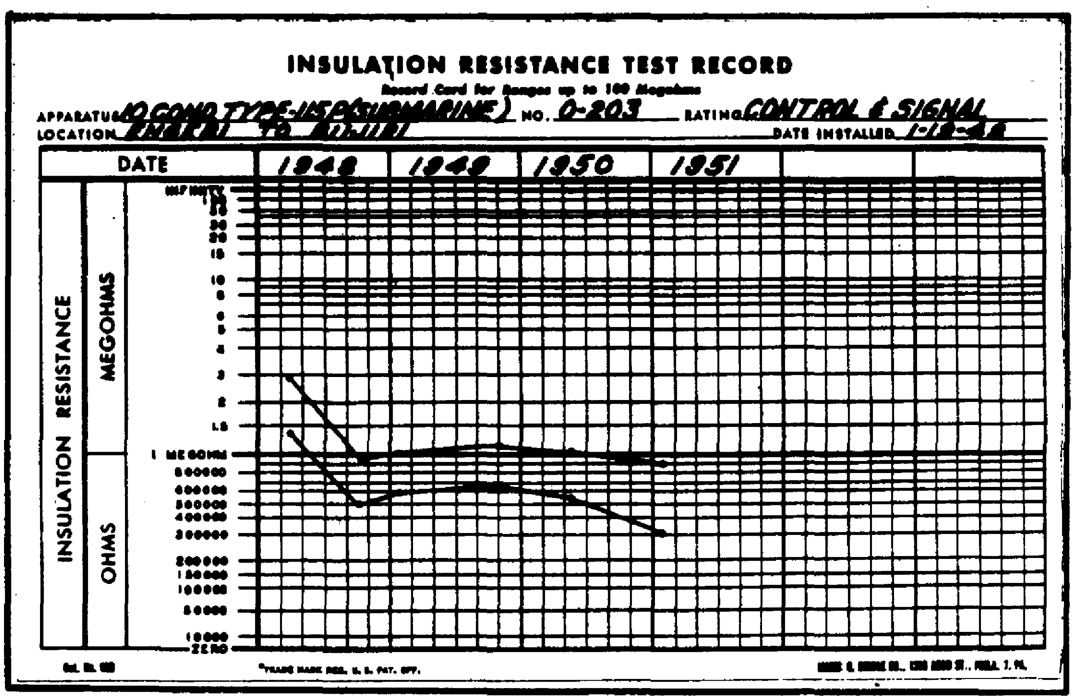


INSULATION RESISTANCE TEST RECORD
Record Card for Ranges up to 100 Megohms
APPARATUS 10 COND TYPE 115-P (SUBMARINE) NO. 0-200 RATING CONTROL & SIGNAL
LOCATION ENGEBI To BIJIIRI DATE INSTALLED
DATE 1951
INSULATION RESISTANCE
MEGOHMS
OHMS
INFINITY
100
50
30
20
15
10
8
6
5
4
3
2
1.5
1 MEGOHM
800000
600000
500000
400000
300000
200000
150000
100000
50000
10000
ZERO
*TRADE MARK REG. U.S. PAT. OFF.



INSULATION RESISTANCE TEST RECORD
Record Card for Ranges up to 100 Megohms
APPARATUS 10 COND. TYPE-115P (SUBMARINE) NO. 0-201 RATING CONTROL & SIGNAL
LOCATION ENGEBI To BIJIIRI DATE INSTALLED 1-29-48
DATE 1948 1949 1950 1951
INSULATION RESISTANCE
MEGOHMS
OHMS
INFINITY
100
50
30
20
15
10
8
6
5
4
3
2
1.5
1 MEGOHM
800000
600000
500000
400000
300000
200000
150000
100000
50000
10000
ZERO
*TRADE MARK REG. U.S. PAT. OFF.


INSULATION RESISTANCE TEST RECORD
APPARATUS 10 COND TYPE 115P (SUBMARINE)
NO. 0-202
RATING CONTROL & SIGNAL
LOCATION
DATE INSTALLED 1-20-48
DATE
1948
1949
1950
1951
INSULATION RESISTANCE
MEGOHMS
OHMS
INFINITY
1 MEGOHM
ZERO

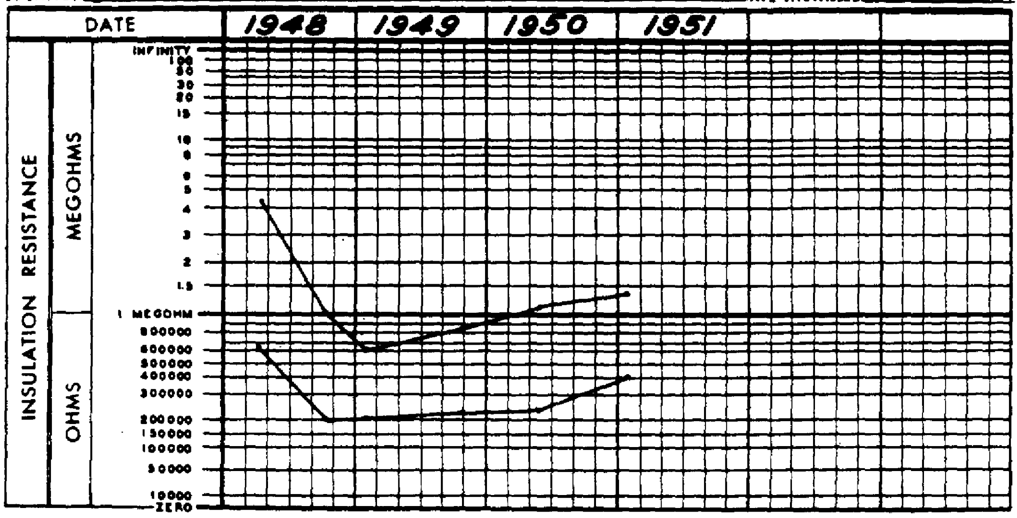

INSULATION RESISTANCE TEST RECORD
APPARATUS 10 COND TYPE 115P (SUBMARINE)
NO. 0-203
RATING CONTROL & SIGNAL
LOCATION
DATE INSTALLED
DATE
1948
1949
1950
1951
INSULATION RESISTANCE
MEGOHMS
OHMS
INFINITY
1 MEGOHM
ZERO

INSULATION RESISTANCE TEST RECORD

Record Card for Ranges up to 100 Megohms

APPARATUS 10 COND-TYPE-115-P (SUBMARINE) NO. 0-204 RATING CONTROL & SIGNAL

LOCATION BIJIRI To RUNIT DATE INSTALLED 1-13-48



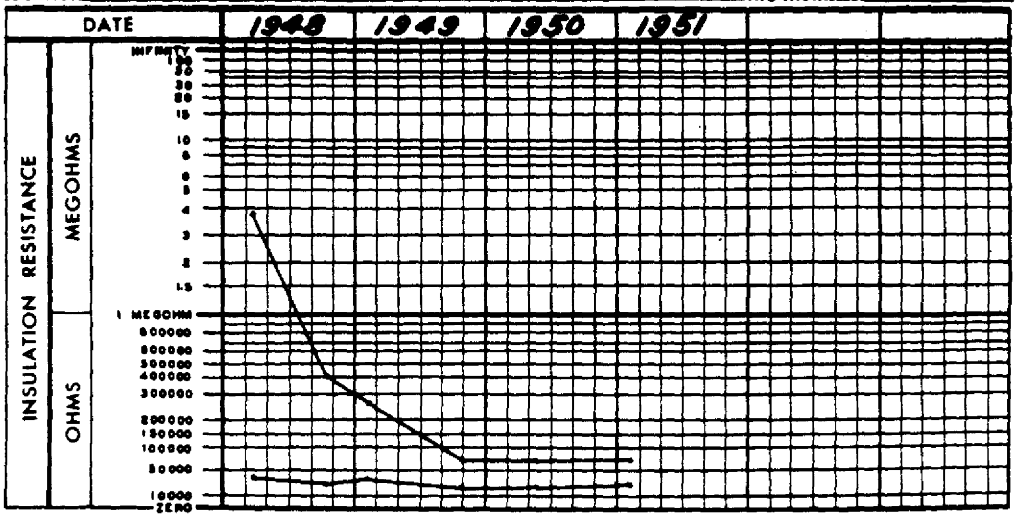
*TRADE MARK REG. U. S. PAT. OFF.

INSULATION RESISTANCE TEST RECORD

Record Card for Ranges up to 100 Megohms

APPARATUS 10 COND TYPE 115P (SUBMARINE) NO. 0-205 RATING CONTROL & SIGNAL

LOCATION BIKIRI To RUNIT DATE INSTALLED 2-24-48



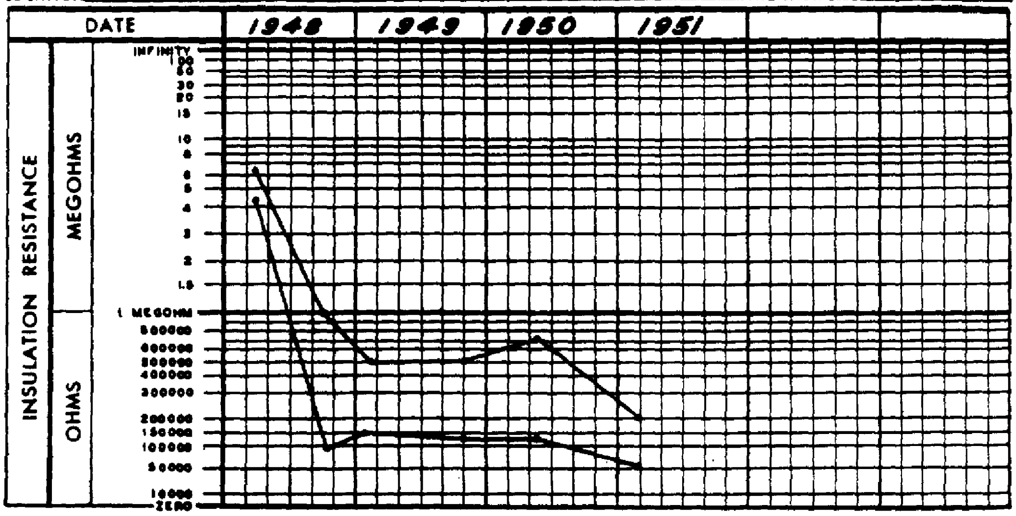
*TRADE MARK REG. U. S. PAT. OFF.

INSULATION RESISTANCE TEST RECORD

Record Card for Ranges up to 100 Megohms

APPARATUS *10 COND. TYPE-115P (SUBMARINE)* NO. *0-206* RATING *CONTROL & SIGNAL*

LOCATION *BIIJIRI TO RUNIT* DATE INSTALLED *1-17-48*



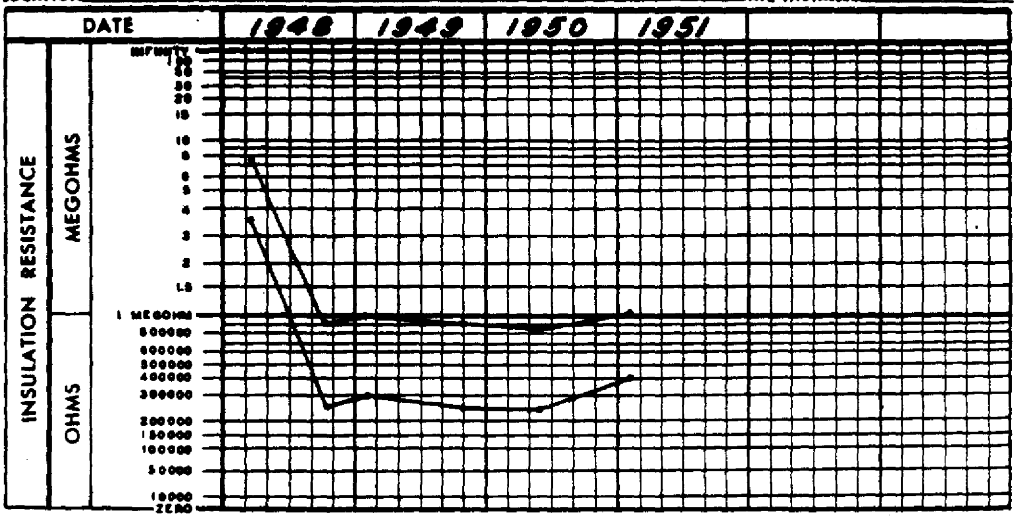
*TRADE MARK REG. U.S. PAT. OFF.

INSULATION RESISTANCE TEST RECORD

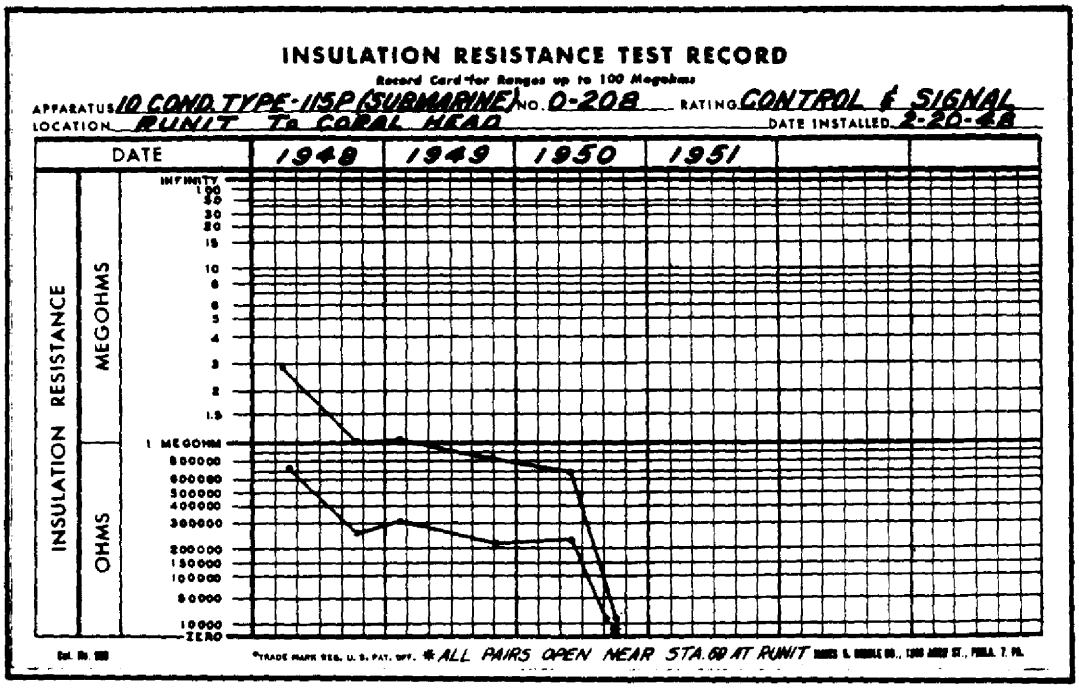
Record Card for Ranges up to 100 Megohms

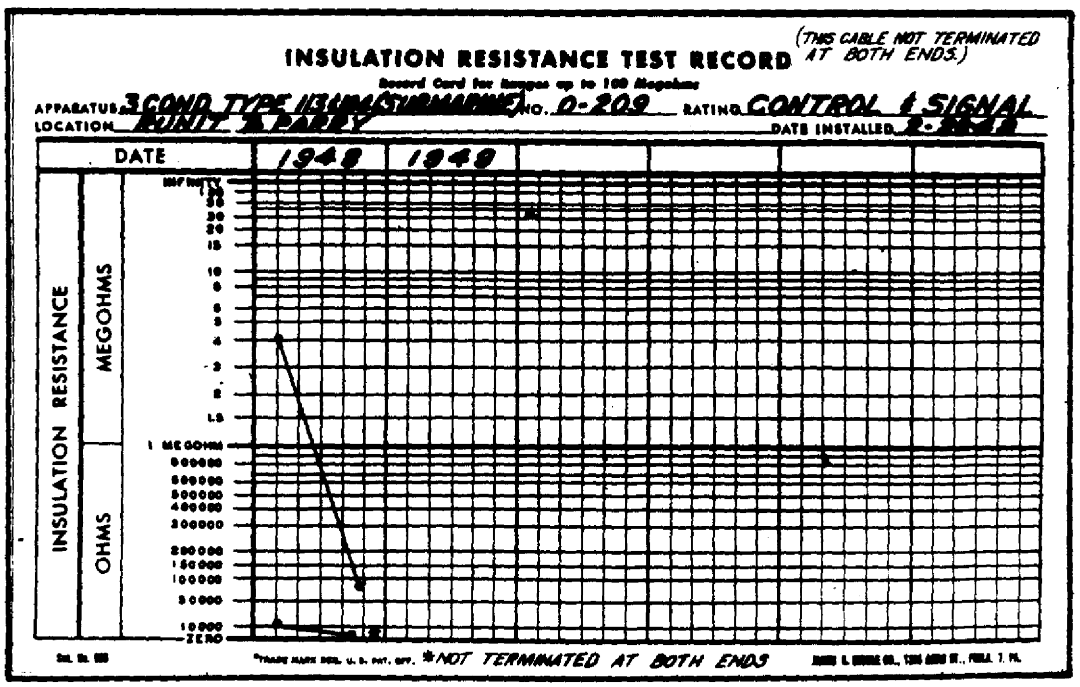
APPARATUS *10 COND-TYPE 115P (SUBMARINE)* NO. *0-207* RATING *CONTROL & SIGNAL*

LOCATION *BIIJIRI TO RUNIT* DATE INSTALLED *1-27-48*



*TRADE MARK REG. U.S. PAT. OFF.


INSULATION RESISTANCE TEST RECORD
Record Card for Ranges up to 100 Megohms
APPARATUS 10 COND. TYPE-115P (SUBMARINE) NO. 0-208 RATING CONTROL & SIGNAL
LOCATION RUNIT To CORAL HEAD DATE INSTALLED 2-20-48
DATE 1948 1949 1950 1951
INSULATION RESISTANCE
MEGOHMS
OHMS
INFINITY
1 MEGOHM
ZERO
*ALL PAIRS OPEN NEAR STA.69 AT RUNIT


(THIS CABLE NOT TERMINATED AT BOTH ENDS.)
INSULATION RESISTANCE TEST RECORD
Record Card for Ranges up to 100 Megohms
APPARATUS 3 COND. TYPE (SUBMARINE) NO. 0-209 RATING CONTROL & SIGNAL
LOCATION RUNIT To PARRY DATE INSTALLED
DATE 1948 1949
INSULATION RESISTANCE
MEGOHMS
OHMS
INFINITY
1 MEGOHM
ZERO
*NOT TERMINATED AT BOTH ENDS

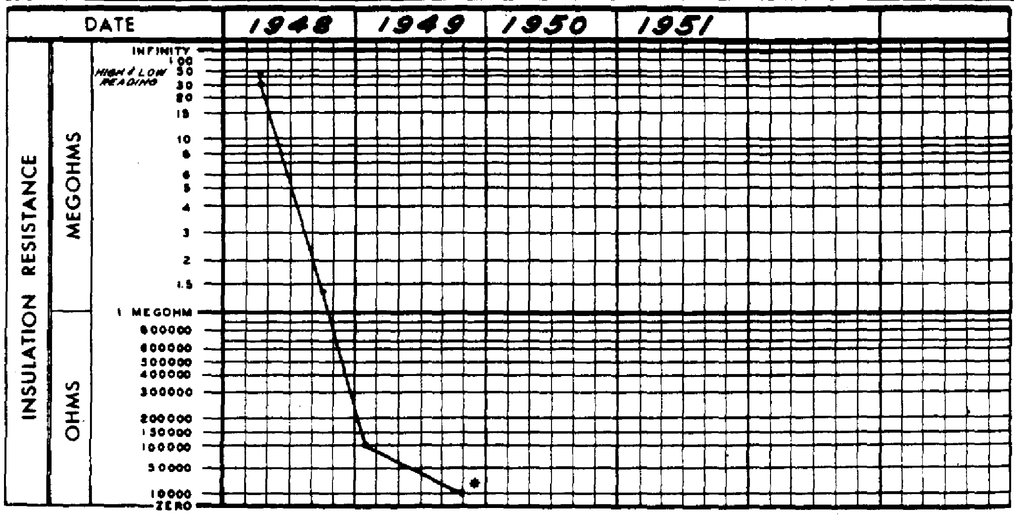
INSULATION RESISTANCE TEST RECORD

THIS CABLE DAMAGED ON BEACH AT RUNIT

Record Card for Ranges up to 100 Megohms

APPARATUS 3 COND. TYPE-113 & 104 (SUBMARINE) NO. 0-210 RATING CONTROL & SIGNAL

LOCATION RUNIT To PARRY DATE INSTALLED 1-30-48



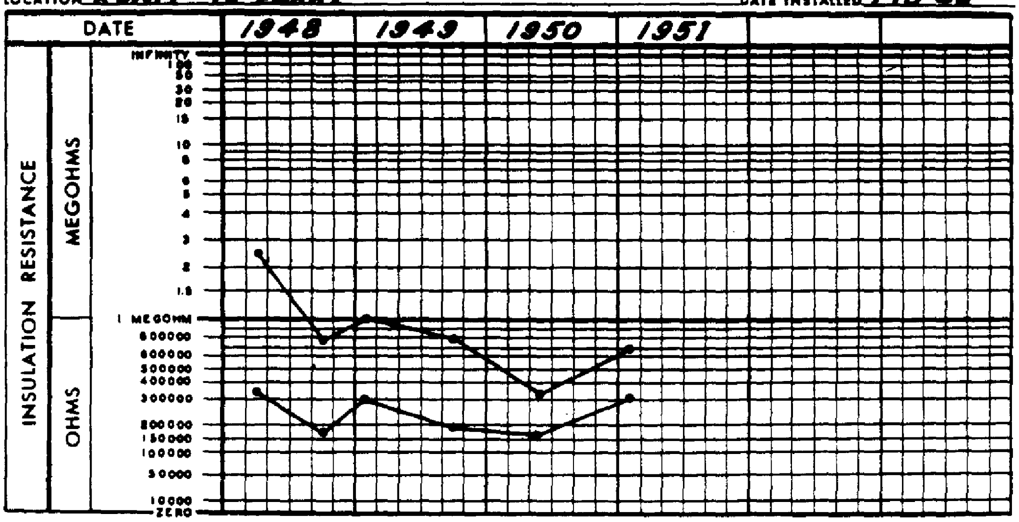
Cat. No. 000 *TRADE MARK REG. U. S. PAT. OFF. * OPEN AT BOTH ENDS JAMES G. BIDDLE CO., 1316 ARCH ST., PHILA. 7, PA.

INSULATION RESISTANCE TEST RECORD

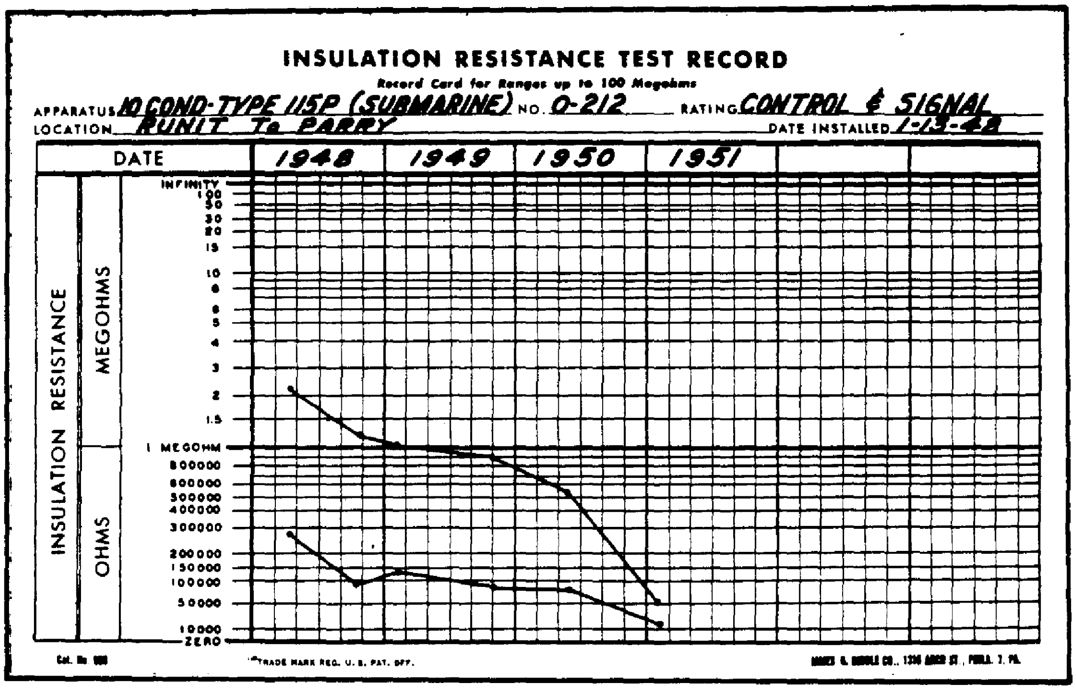
Record Card for Ranges up to 100 Megohms

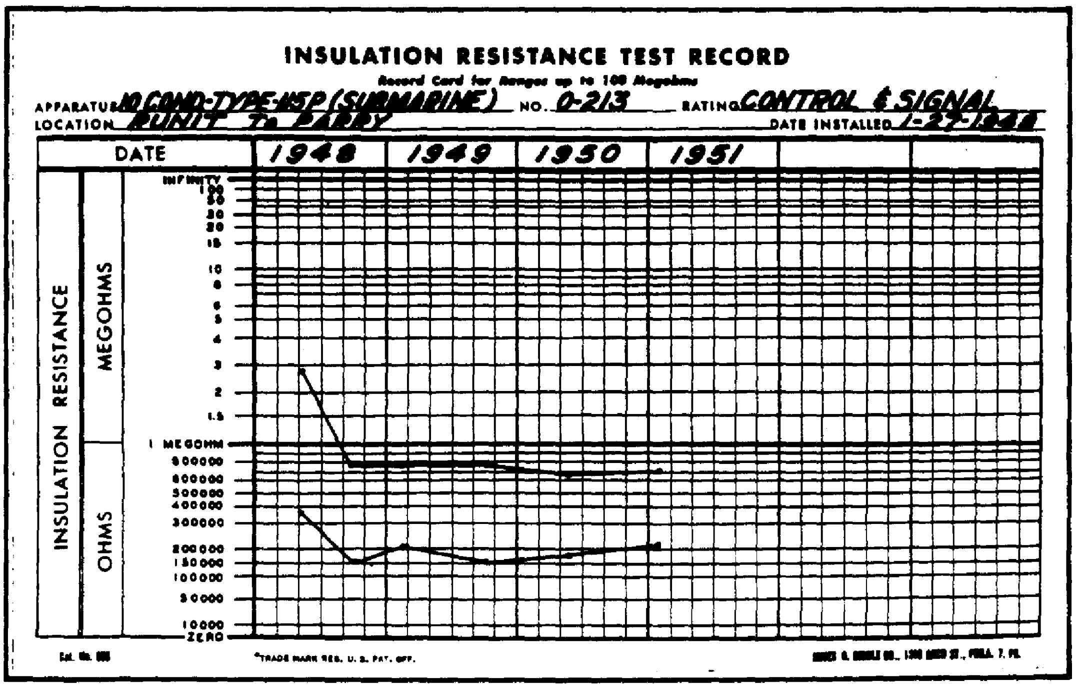
APPARATUS 10 COND. TYPE-115-P (SUBMARINE) NO. 0-211 RATING CONTROL & SIGNAL

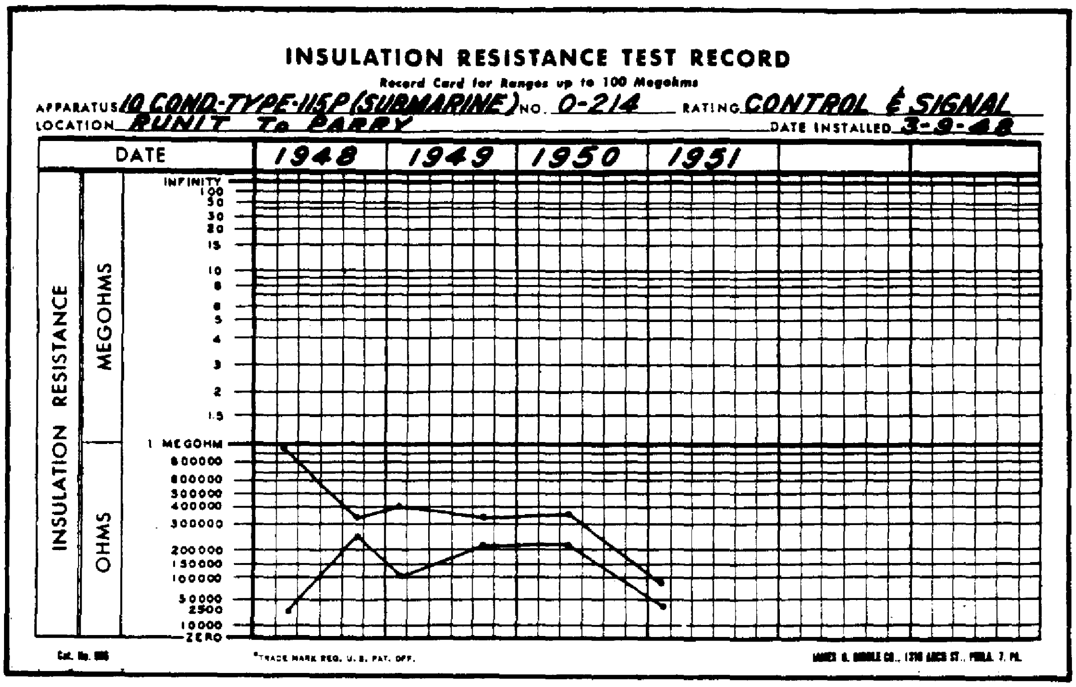
LOCATION RUNIT To PARRY DATE INSTALLED 1-10-48

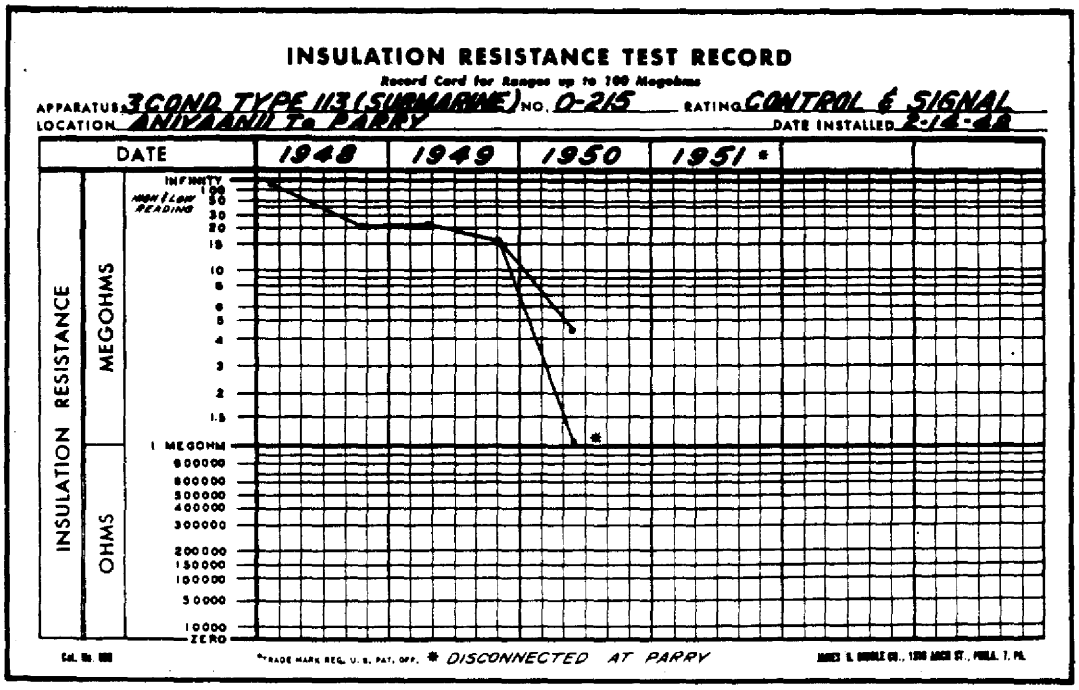


Cat. No. 000 *TRADE MARK REG. U. S. PAT. OFF. JAMES G. BIDDLE CO., 1316 ARCH ST., PHILA. 7, PA.


INSULATION RESISTANCE TEST RECORD
Record Card for Ranges up to 100 Megohms
APPARATUS 10 COND-TYPE 115P (SUBMARINE) NO. 0-212 RATING CONTROL & SIGNAL
LOCATION RUNIT To PARRY DATE INSTALLED 1-13-48
DATE
1948
1949
1950
1951
INSULATION RESISTANCE
MEGOHMS
OHMS
INFINITY
100
50
30
20
15
10
8
6
5
4
3
2
1.5
1 MEGOHM
800000
600000
500000
400000
300000
200000
150000
100000
50000
10000
ZERO
*TRADE MARK REG. U. S. PAT. OFF.


INSULATION RESISTANCE TEST RECORD
Record Card for Ranges up to 100 Megohms
APPARATUS 10 COND-TYPE 115P (SUBMARINE) NO. 0-213 RATING CONTROL & SIGNAL
LOCATION RUNIT To PARRY DATE INSTALLED 1-27-1948
DATE
1948
1949
1950
1951
INSULATION RESISTANCE
MEGOHMS
OHMS
INFINITY
100
50
30
20
15
10
8
6
5
4
3
2
1.5
1 MEGOHM
800000
600000
500000
400000
300000
200000
150000
100000
50000
10000
ZERO
*TRADE MARK REG. U. S. PAT. OFF.


INSULATION RESISTANCE TEST RECORD
Record Card for Ranges up to 100 Megohms
APPARATUS 10 COND-TYPE-115P (SUBMARINE) NO. 0-214 RATING CONTROL & SIGNAL
LOCATION RUNIT To PARRY DATE INSTALLED 3-9-48
DATE 1948 1949 1950 1951
INSULATION RESISTANCE
MEGOHMS
OHMS
INFINITY
100
50
30
20
15
10
8
6
5
4
3
2
1.5
1 MEGOHM
800000
600000
500000
400000
300000
200000
150000
100000
50000
2500
10000
ZERO
*TRADE MARK REG. U.S. PAT. OFF.

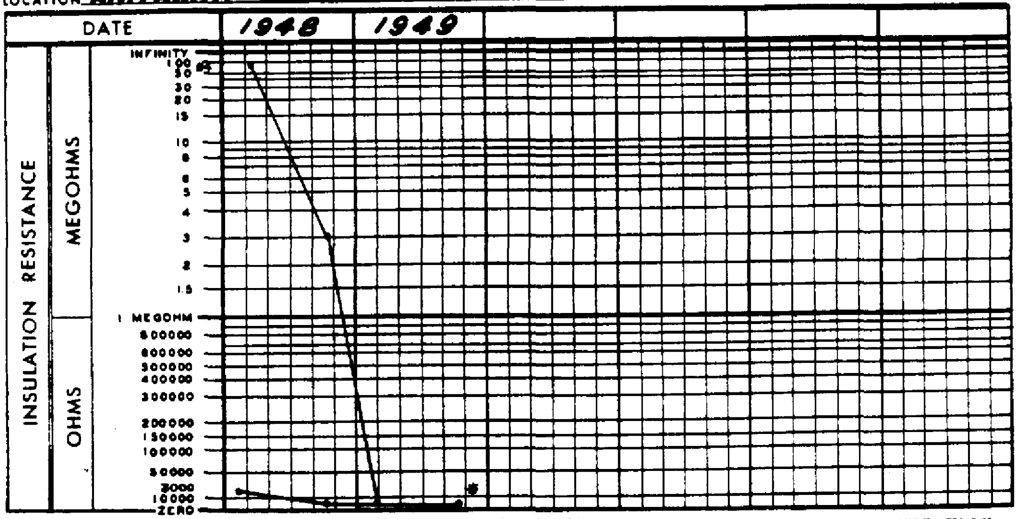

INSULATION RESISTANCE TEST RECORD
Record Card for Ranges up to 100 Megohms
APPARATUS 3 COND TYPE 113 (SUBMARINE) NO. 0-215 RATING CONTROL & SIGNAL
LOCATION ANIVAANII To PARRY DATE INSTALLED 2-14-48
DATE 1948 1949 1950 1951 *
INSULATION RESISTANCE
MEGOHMS
OHMS
HIGH & LOW READING
INFINITY
100
50
30
20
15
10
8
6
5
4
3
2
1.5
1 MEGOHM
800000
600000
500000
400000
300000
200000
150000
100000
50000
10000
ZERO
*TRADE MARK REG. U.S. PAT. OFF.
* DISCONNECTED AT PARRY

INSULATION RESISTANCE TEST RECORD

Record Card for Ranges up to 100 Megohms

APPARATUS 3 COND-TYPE-104 (SUBMARINE) NO. 0-216 RATING CONTROL & SIGNAL

LOCATION ANIYAANII To PARRY DATE INSTALLED 2-9-48



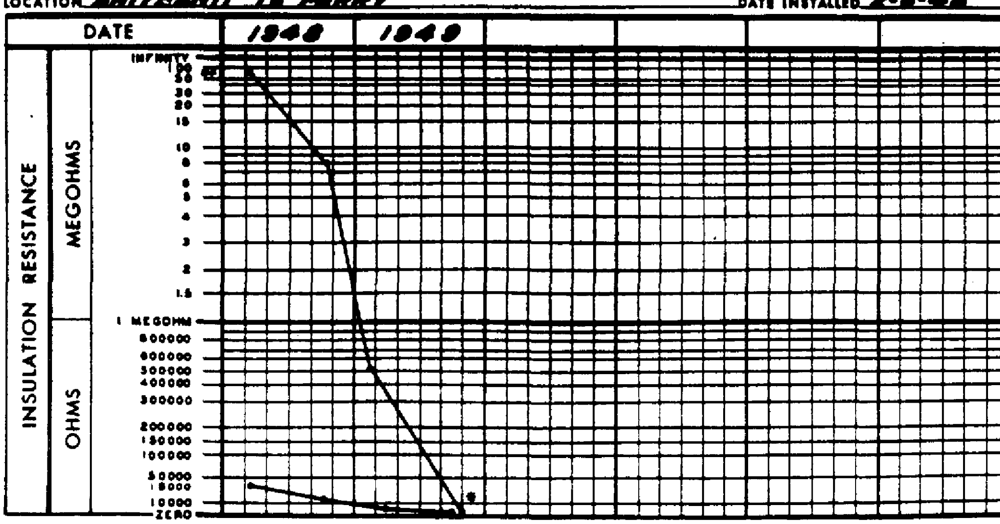
*TRADE MARK REG. U.S. PAT. OFF. * NOT TERMINATED AT PARRY

INSULATION RESISTANCE TEST RECORD

Record Card for Ranges up to 100 Megohms

APPARATUS 3 COND TYPE 104 (SUBMARINE) NO. 0-217 RATING CONTROL & SIGNAL

LOCATION ANIYAANII To PARRY DATE INSTALLED 2-8-48



*TRADE MARK REG. U.S. PAT. OFF. * NOT TERMINATED AT PARRY

INSULATION RESISTANCE TEST RECORD

Record Card for Ranges up to 100 Megohms

APPARATUS 10 COND. TYPE IISP (SUBMARINE) NO. 5-223 RATING CONTROL & SIGNAL

LOCATION ENGEBI To MUZINBAARIKKU DATE INSTALLED

DATE	1951					

INSULATION RESISTANCE — MEGOHMS: INFINITY, 100, 50, 30, 20, 15, 10, 8, 6, 5, 4, 3, 2, 1.5, 1 MEGOHM

OHMS: 800000, 600000, 500000, 400000, 300000, 200000, 150000, 100000, 50000, 10000, ZERO

[illegible] *TRADE MARK REG. U. S. PAT. OFF. [illegible]

INSULATION RESISTANCE TEST RECORD

Record Card for Ranges up to 100 Megohms

APPARATUS 10 COND. TYPE IISP (SUBMARINE) NO. 5-224 RATING CONTROL & SIGNAL

LOCATION MUZINBAARIKKU To KIRINIAN DATE INSTALLED

DATE	1951					

INSULATION RESISTANCE — MEGOHMS: INFINITY, 100, 50, 30, 20, 15, 10, 8, 6, 5, 4, 3, 2, 1.5, 1 MEGOHM

OHMS: 800000, 600000, 500000, 400000, 300000, 200000, 150000, 100000, 50000, 10000, ZERO

[illegible] *TRADE MARK REG. U. S. PAT. OFF. [illegible]

SUBMARINE CABLE TESTS

Instruments:
(1) Megger
(2) Wheatstone Bridge

Temperature
Air (Average) 84°F
Water (average) 82°F

CABLE NO. 0-201 (Type 115-P, 10-Conductor, Engebi to Biijiri, 47,500 ft, laid 1-29-48)

DATE OF TEST	Copper Resistance per Pair (Ohms) AB	CD	EF	GH	JK	Insulation Resistance to Ground per Pair (Megohms) AB	CD	EF	GH	JK	Insulation Resistance to All Conductors per Pair (Megohms) AB	CD	EF	GH	JK
3-16-48	216.8	219.4	219.6	219.2	219.9	2.5	1.7	1.2	1.7	1.9	-	-	-	-	-
10-9-48	218.9	221.6	221.8	221.4	221.1	0.800	0.800	0.600	0.600	0.600	-	-	-	-	-
2-11-49	217.0	219.6	219.9	219.6	219.3	1.000	1.000	.800	.600	.800	-	-	-	-	-
10-31-49	218.5	221.1	221.4	221.0	220.7	1.400	.800	.600	.720	.850	1.500	.900	.720	.820	.900
5-25-50	218	221	221	221	220	1.27	.825	.545	.623	.750	1.27	.773	.675	.675	.750
2-23-51	232	235	235	235	234	1.000	0.300	.300	.300	.300	1.000	.300	.300	.300	.300

CABLE NO. 0-202 (Type 115-P, 10-Conductor, Engebi to Biijiri, 46,800 ft, laid 1-20-48)

DATE OF TEST	Copper Resistance per Pair (Ohms) AB	CD	EF	GH	JK	Insulation Resistance to Ground per Pair (Megohms) AB	CD	EF	GH	JK	Insulation Resistance to All Conductors per Pair (Megohms) AB	CD	EF	GH	JK
3-16-48	210.5	212.4	212.8	213.2	212.3	3.6	1.0	0.79	0.74	0.75	-	-	-	-	-
10-9-48	212.6	214.6	215.0	215.3	214.5	0.900	0.500	0.400	0.250	0.300	-	-	-	-	-
2-11-49	210.8	212.7	213.2	213.8	212.6	.800	.800	.500	.400	.300	-	-	-	-	-
10-31-49	212.2	214.1	214.6	214.9	214.1	1.000	.500	.350	.280	.290	1.400	.520	.400	.340	.350
5-25-50	212	214	214	214	214	.958	.450	.323	.273	.254	.850	.498	.394	.273	.266
2-23-51	226	228	228	228	227	1.200	.550	.400	.400	.400	1.300	.600	.450	.400	.450

CABLE NO. 0-203 (Type 115-P, 10-Conductor, Engebi to Biijiri, 48,400 ft, laid 1-19-48)

DATE OF TEST	Copper Resistance per Pair (Ohms) AB	CD	EF	GH	JK	Insulation Resistance to Ground per Pair (Megohms) AB	CD	EF	GH	JK	Insulation Resistance to All Conductors per Pair (Megohms) AB	CD	EF	GH	JK
3-16-48	218.3	221.8	221.0	222.4	220.9	2.8	1.4	1.45	1.5	1.9	-	-	-	-	-
10-9-48	220.5	223.9	223.2	224.6	223.2	0.900	0.600	0.500	0.500	0.500	-	-	-	-	-
2-11-49	218.6	222.1	221.3	222.8	221.3	1.000	.800	.600	.600	.800	-	-	-	-	-
10-31-49	220.1	223.6	222.9	224.2	222.7	1.200	0.650	0.650	.670	.770	1.300	.720	.720	.780	.850
5-25-50	220	223	222	224	222	1.06	.545	.559	.597	.650	1.06	.623	.647	.647	.697
2-23-51	234	238	237	238	237	.800	.300	.300	.300	.300	.800	.300	.300	.300	.300

CABLE NO. 0-204 (Type 115-P, 10-Conductor, Biijiri to Runit, 42,000 ft, laid 1-15-48)

3-16-48	195.4	197.6	198.1	197.4	197.0	4.2	0.9	0.68	0.63	0.63	-	-	-	-	-
10-9-48	197.2	199.5	199.9	199.3	198.8	0.800	0.300	0.225	0.200	0.200	-	-	-	-	-
2-8-49	195.6	197.9	198.3	197.7	197.1	.600	.300	.300	.200	.200	-	-	-	-	-
10-31-49	196.9	199.2	199.6	199.0	198.5	0.750	0.350	.300	.240	.220	.720	.350	.290	.230	.230
5-25-50	197	199	199	199	198	1.20	.374	.324	.273	.250	.892	.374	.323	.273	.273
2-24-51	213	216	216	215	215	1.300	.450	.400	.400	.400	1.300	.500	.450	.400	.400

CABLE NO. 0-205 (Type 115-P, 10-Conductor, Biijiri to Runit, 38,000 ft, laid 2-24-48)

3-16-48	172.7	172.6	172.6	172.4	172.0	3.7	0.075	0.070	0.075	0.40	-	-	-	-	-
10-9-48	174.4	174.3	173.8	174.1	173.7	.400	0.030	0.27	0.29	0.21	-	-	-	-	-
2-9-49	172.9	172.9	172.4	172.7	172.2	.250	.040	.040	.040	.030	-	-	-	-	-
10-31-49	174.1	174.1	173.6	173.9	173.4	.070	.040	.040	.030	.025	.160	.040	.035	.035	.025
5-25-50	174	174	173	173	173	.120	.030	.037	.032	.027	.120	.030	.040	.032	.027
2-24-51	191	191	190	191	190	200	.070	.070	.050	.050	.200	.050	.050	.050	.050

CABLE NO. 0-206 (Type 115-P, 10-Conductor, Biijiri to Runit, 38,000 ft, laid 1-17-48)

3-16-48	180.2	181.4	181.4	182.1	181.8	6.5	5.0	5.0	4.2	6.5	-	-	-	-	-
10-9-48	182.0	183.1	183.1	183.8	183.5	.500	.150	.100	.100	.095	-	-	-	-	-
2-8-49	180.4	181.6	181.6	182.3	182.0	.500	.200	.150	.150	.150	-	-	-	-	-
10-31-49	179.8	182.8	182.9	183.6	183.3	.500	.190	.140	.130	.120	.750	.200	.150	.140	.130
5-25-50	-	-	-	-	-	.435	.612	.667	.667	.120	.025	.076	.018	.050	.100
2-24-51	198	199	199	200	199	.200	.300	.200	.200	.200	.800	.350	.200	.200	.200

CABLE NO. 0-207 (Type 115-P, 10-Conductor, Biijiri to Runit, 38,000 ft, laid 1-27-48)

3-16-48	179.5	181.7	181.9	181.7	181.6	4.5	4.5	3.5	4.1	7.5	-	-	-	-	-
10-9-48	181.5	183.6	183.8	183.6	183.7	.800	.250	.250	.200	.200	-	-	-	-	-
2-8-49	180.0	182.0	182.2	181.9	182.0	1.000	.500	.500	.300	.300	-	-	-	-	-
10-31-49	213.1	183.2	183.4	183.2	183.3	.900	.320	.290	.260	.290	.900	.310	.300	.290	.300
5-25-50	180	183	183	183	183	.823	.321	.273	.250	.273	.738	.321	.273	.273	.250
2-24-51	197	200	200	199	200	1.000	.500	.400	.400	.400	1.000	.500	.500	.450	.450

SUBMARINE CABLE TESTS (Continued)

Instruments:
(1) Megger
(2) Wheatstone Bridge

Temperature
Air (Average) 84°F
Water (Average) 82°F

DATE OF TEST	COPPER RESISTANCE PER PAIR (OHMS) AB	CD	EF	GH	JK	INSULATION RESISTANCE TO GROUND PER PAIR (MEGOHMS) AB	CD	EF	GH	JK	INSULATION RESISTANCE TO ALL CONDUCTORS PER PAIR (MEGOHMS) AB	CD	EF	GH	JK
CABLE NO. 0-208 (Type 115-P, 10-Conductor, Runit to Coral Head, 44,000 ft, laid 2-20-48)															
3-16-48	200.4	203.4	203.8	203.9	203.4	2.8	1.1	0.75	0.67	0.77	-	-	-	-	-
10-9-48	202.3	205.3	205.7	205.7	205.3	1.000	.450	.300	.250	.250	-	-	-	-	-
2-10-49	200.5	203.5	203.9	203.9	203.5	1.000	.500	.300	.300	.400	-	-	-	-	-
11-12-49	201.7	204.7	205.2	205.3	001.2	.850	.380	.280	.210	.250	.900	.400	.320	.270	.300
5-30-50	204	204	205	205	204	.700	.400	.300	.200	.250	.800	.400	.320	.280	.300
2-27-51	All Pairs Open Near Station #69 at Runit														
CABLE NO. 0-211 (Type 115-P, 10-Conductor, Runit to Parry, 61,000 ft, laid 1-10-48)															
3-16-48	284.8	285.5	286.0	285.9	286.5	2.5	0.70	0.37	0.43	0.38	-	-	-	-	-
10-9-48	287.1	288.0	288.6	288.3	289.3	.700	.300	.175	.175	.160	-	-	-	-	-
2-8-49	285.0	286.2	286.2	286.1	286.7	1.000	.500	.300	.300	.300	1.000	.400	.200	.200	.200
10-29-49	286.9	287.7	288.2	287.9	288.7	.800	.320	.200	.200	.180	.850	.340	.230	.230	.320
5-26-50	286	287	287	287	288	.350	.306	.200	.171	.350	.306	.222	.200	.171	-
2-27-51	292	293	294	294	294	.700	.400	.300	.300	.300	.700	.400	.300	.300	.300
CABLE NO. 0-212 (Type 115-P, 10-Conductor, Runit to Parry, 58,000 ft, laid 1-13-48)															
3-16-48	278.1	278.2	280.0	280.2	279.3	2.2	0.29	0.39	0.28	0.29	-	-	-	-	-
10-9-48	280.5	280.6	282.5	282.7	281.8	1.200	.700	0.175	.090	.090	-	-	-	-	-
2-8-49	278.2	278.3	280.0	280.3	279.6	1.000	.200	.150	.150	.125	1.100	.250	.250	.230	.220
10-28-49	280.2	280.3	282.1	282.3	281.4	.800	.125	.115	.100	.090	.280	.180	.125	.110	.105
5-26-50	279	279	281	281	281	.559	.120	.111	.100	.086	.597	.150	.111	.111	.086
2-27-51	285	295	287	286	286	.500	.200	.200	.150	.150	.500	.200	.200	.150	.200

CABLE NO. 0-213 (Type 115-P, 10-Conductor, Runit to Parry, 57,750 ft, laid 1-27-48)

3-16-48	263.3	264.6	265.8	265.8	266.0	2.6	0.60	0.37	0.42	0.38	-	-	-	-	-
10-9-48	265.7	267.0	268.0	268.0	268.2	.700	.220	.150	.175	.150	-	-	-	-	-
2-8-49	263.5	264.8	265.9	265.9	266.1	.700	.400	.200	.200	.200	.600	.350	.280	.255	.250
10-28-49	265.3	266.6	267.8	267.9	268.0	.700	.250	.180	.180	.150	.700	.270	.200	.200	.180
5-26-50	265	266	267	267	267	.650	.300	.171	.171	.161	.650	.271	.187	.171	.161
2-27-51	270	271	273	273	273	.700	.350	.250	.250	.250	.800	.400	.300	.300	.300

CABLE NO. 0-214 (Type 115-P, 10-Conductor, Runit to Parry, 57,000 ft, laid 3-9-48)

3-16-48	259.1	259.6	260.6	258.9	259.6	0.90	0.80	0.75	0.60	0.025	-	-	-	-	-
10-9-48	261.5	261.9	263.0	261.1	261.9	.330	.250	.275	.250	.260	-	-	-	-	-
2-8-49	259.3	259.8	260.9	259.1	269.9	.400	.250	.300	.300	.100	Tele.	.350	.340	.390	.210
10-28-49	260.6	262.6	262.9	261.0	261.5	.250	.240	.320	.310	.280	.150	.250	.350	.330	.300
5-26-50	260	262	262	260	261	.254	.240	.350	.323	.300	.254	.221	.350	.343	.300
2-27-51	266	267	268	266	267	.080	.080	.450	.400	.350	0*	0*	.450	.450	.400

* Low insulation between AB & CD is approximately 35% of total distance from Parry.

CABLE NO. 5-223 (Type 115-P, 10-Conductor, T-Engebi to T-Muzin, 8,700 ft)

2-27-51	40.1	40.3	40.3	40.2	40.7	2.0	0.6	0.5	0.6	0.6	2.0	0.6	0.6	0.6	0.55

CABLE NO. 5-224 (Type 115-P, 10-Conductor, T-Muzin to T-Kirnian, 7,700 ft)

2-27-51	35.7	36.0	35.8	35.8	36.2	5.0	2.2	2.0	2.2	2.2	3.8	0.9	0.8	1.0	1.0

CABLE NO. 0-200 (Type 115-P, 10-Conductor, T-Engebi to T-Biijiri, 47,000 ft)

2-27-51	209	210	211	210	211	0.8	0.5	0.75	0.5	0.6	0.8	0.5	0.7	0.6	0.7

SUBMARINE CABLE TESTS (Continued)

Instruments:
(1) Megger
(2) Wheatstone Bridge

Temperature:
Air (average) 84°F
Water (average) 82°F

DATE OF TEST	COPPER RESISTANCE PER PAIR (OHMS) A Plus B	A Plus C	B Plus C	INSULATION RESISTANCE TO GROUND PER PAIR (MEGOHMS) A	B	C	INSULATION RESISTANCE TO ALL CONDUCTORS PER PAIR (MEGOHMS) A	B	C
CABLE NO. 0-209 (Type 113, 104; 3.3-Conductor, T-Runit to C-Parry, 6,400 ft, 56,400 ft, laid 2-2-48)									
3-16-48	121.0	121.1	121.1	40.0	1.0	.001	-	-	-
10-9-48	No Test*								
CABLE NO. 0-210 (Type 113, 104; 3.3-Conductor, T-Runit to C-Parry, 5,100 ft, 55,700 ft, laid 1-3-48)									
3-16-48	113.5	113.6	113.5	38.0	40.0	43.0	-	-	-
10-9-48	110.0	109.0	111.2	.000	.000	.000	(Cable damaged on beach at Runit)		
2-8-49	109.2	108.8	110.6	.000	.000	.000	.100	.100	.100
11-12-49	434.0	408.9	109.7	.010	.010	.010	.010	.010	.010
CABLE NO. 0-215 (Type 113, 3-Conductor, Aniyaanii to C-Parry, 30,800 ft, laid 2-14-48)									
3-16-48	57.39	56.94	57.31	102.0	102.0	102.0	-	-	-
10-9-48	57.4	57.4	57.35	20.0	20.0	20.0	-	-	-
2-7-49	57.0	57.0	56.9	20+	20+	20+	10.5	10.5	22.5
10-31-49	[illegible]	[illegible]	-	-	-	-	15+	15+	15+
5-24-50	-	-	-	1.00	2.50	4.50	3.00	1.50	5.00

*Cable not terminated at either end.

CABLE NO. 0-216 (Type 104, 3-Conductor, Ph. Aniyaanii to C-Parry, 41,900 ft, laid 2-9-48)

3-16-48	76.77	76.78	76.79	.030	84.0	84.0	-	-	-
10-9-48	77.4	77.4	77.35	.000	3.0	1.0	-	-	-
2-7-49	68.3	76.45	71.9	.000	.000	.000	.0975	.099	0.100
10-31-49	No Test								
5-24-50	-	-	-	-	-	-	-	-	-

CABLE NO. 0-217 (Type 104, 3-Conductor, Ph. Aniyaanii to C-Parry, 44,900 ft, laid 2-6-48)

3-16-48	83.80	83.82	83.82	84.0	.018	84.0	-	-	-
10-9-48	84.5	84.5	84.65	8.000	8.0	0.010	-	-	-
2-7-49	83.6	82.7	83.72	.000	.500	.000	.110	.150	.110
10-31-49	No Test								
5-24-50	0.20	-	-	.10	.05	-	-	-	-

NOTE: Cables 0-209, 0-210, 0-215, 0-216, and 0-217 not tested in 1951 because they were not terminated at Parry.

EXHIBIT D

Underground Control and Signal Cable
Test Record

TEST RECORDS
CONTROL & SIGNAL CABLES
(2-Conductor #14 - Underground)

PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	PAIR TO GND.	PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	PAIR TO GND.
SITE "C"											
1	23A	32A	17.31	20	100K	*1	69	1	29.55	50	12
1	32A	32C	--	--	--	*2	69	1	29.16	60	12
1	74A	74B	0.98	1000	300	5	69	12	20.27	80	20
1	74B	74C	1.58	1000	175	6	69	12	20.25	50	15
1	74C	74D	1.22	1000	250	7	69	15	13.85	100	35
1	74E	74D	1.37	1000	250	8	69	15	14.03	100	25
1	74F	74E	1.42	1000	200	9	69	23A	1.57	500	150
1	74F	74G	2.31	1000	150	10	69	23A	1.58	300	150
1	6A	6B	1.14	1000	400	11	69	23A	1.52	1000	300
2	6A	6B	1.07	1000	300	12	69	23A	1.52	750	200
3	6A	6B	1.10	1000	250	13	69	23A	1.53	300	90
4	6A	6B	1.03	1000	300	14	69	23A	1.56	300	125
*1	6A	6B	1.07	1000	350	15	69	26C	31.02	70	13
1	73A	73B	0.45	INF.	INF.	16	69	26C	31.96	30	15
1	73B	73C	4.07	750	125	17	69	26C	31.92	40	10
1	73C	73D	0.39	INF.	1000	18	69	35	30.79	40	12
1	73D	73E	3.56	1000	125	19	69	35	30.30	60	20
1	73F	73G	3.62	750	175	20	69	42	12.04	40	10
1	73G	73H	3.85	750	150	21	69	42	12.22	25	0.1
1	73E	73F	0.31	1000	1000	22	69	50C	8.98	125	50
1	51D	50D	0.78	1000	350	23	69	50C	9.07	125	50
2	51D	50D	0.81	1000	300	24	69	50C	8.97	125	40
3	51D	50D	0.84	1000	500	25	69	50D	24.59	100	40
1	54	50A	1.27	1000	300	26	69	50D	24.90	100	25
2	54	50A	1.25	1000	300	27	69	50D	24.47	80	20
3	54	50A	1.28	1000	300	28	69	54	27.67	60	15
1	51C	50C	0.71	1000	300	29	69	54	27.93	40	15
2	51C	50C	0.69	1000	300	30	69	54	27.66	45	13
3	51C	50C	0.67	1000	500	31	69	55	4.90	150	80
1	51A	50A	1.01	1000	500	32	69	55	4.84	200	100
2	51A	50A	0.79	1000	350	33	69	55	4.81	125	60
3	51A	50A	1.01	1000	500	34	69	57	--	80	25
1	57	50B	1.40	1000	250	35	69	57	--	60	1.5
2	57	50B	1.42	1000	250	36	69	57	--	100	40
3	57	50B	1.38	1000	250	48	69	68	31.68	125	100
1	51B	50B	0.92	1000	350	49	69	68	32.08	40	25
2	51B	50B	0.92	1000	350	50	69	68	31.82	80	80
3	51B	50B	0.91	1000	350	51	69	68	32.08	50	25
1	69	6A	8.82	125	60	52	69	68	32.02	50	25
2	69	6A	8.91	125	50	53	69	68	32.14	45	25
3	69	6A	8.94	200	80	54	69	68	32.20	35	20
4	69	6A	8.97	125	50	55	69	68	32.06	40	20
EXTRA	69	6A	8.84	150	100	*1	69	68	32.03	60	20

*EXTRA

TEST RECORDS (Continued)
CONTROL & SIGNAL CABLES
(2-Conductor #14 - Underground)

PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	INSULATION RES. (MEGOHMS) PAIR TO GND.
*2	69	68	32.13	60	25
*3	69	68	31.17	60	20
*4	69	68	31.49	15	10
*5	69	68	31.41	50	15
56	69	73E	12.69	125	40
57	69	74D	3.13	200	70
58	69	74H	5.65	150	40
59	69	78	--	--	--
60	69	78	--	--	--
61	69	79	15.24	40	10
62	69	79	14.28	35	8
63	69	175	33.44	70	15
64	69	176	31.13	40	7
65	69	177	29.43	30	10
66	69	178	29.06	50	15
67	69	179	14.43	20	0
68	69	180	14.79	60	10
69	69	773	0.78	300	150
70	69	773	0.78	300	150
71	69	4224	19.62	100	30
72	69	4224	19.26	100	30
73	69	4225	5.61	175	60
74	69	4225	5.68	150	60
75	69	4226	5.68	200	50
76	69	4226	5.75	125	40
84	69	100	12.13	40	12

SITE "E" - CABLE TERMINAL "A"

PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	WIRE TO WIRE	PAIR TO GND.
1	69	6323	23.17	35	13
2	69	6323	22.98	30	4
3	69	6323	23.18	40	10
4	69	6323	23.32	17	4
*1	69	6323	23.26	45	12
5	69	6331	21.73	15	4
6	69	6331	22.34	20	4
7	69	6331	22.14	90	25
8	69	6331	22.03	20	5
*1	69	6331	22.14	7	0.2
19	69	6341	22.78	20	6
20	69	6341	23.82	17	4
21	69	6341	22.73	6	0.2
22	69	6341	22.75	10	0.05
37	69	160	27.07	50	15
38	69	161	26.69	100	20

PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	INSULATION RES. (MEGOHMS) PAIR TO GND.
39	69	162	31.79	25	15
40	69	163	27.43	45	12
41	69	164	19.58	100	20
42	69	165	13.23	30	8
43	69	166	1.99	750	150

SITE "E" - CABLE TERMINAL "B"

PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	WIRE TO WIRE	PAIR TO GND.
1	69	6A	5.18	70	20
2	69	6A	5.20	125	55
3	69	6A	5.16	100	50
4	69	6A	5.22	100	25
*1	69	6A	5.25	70	17
5	69	12	16.50	90	25
6	69	12	16.55	60	18
7	69	15	10.36	100	40
8	69	15	10.34	150	30
9	69	23A	0.76	750	250
10	69	23A	0.76	1000	350
11	69	23A	0.76	1000	300
12	69	23A	0.77	1000	250
13	69	23A	0.77	1000	350
14	69	23A	0.75	750	300
15	69	23A	0.75	1000	350
16	69	25	24.81	0.1	0.05
17	69	25	24.93	17	5
18	69	25	24.70	20	5
19	69	25	24.29	8	3
20	69	25	24.56	4	3
21	69	25	24.60	20	5
22	69	26A	23.92	60	15
23	69	26A	23.57	65	15
24	69	26A	23.93	60	15
25	69	35	27.10	60	20
26	69	35	27.10	60	20
27	69	40	--	--	--
28	69	40	14.70	18	0.3
29	69	50B	14.56	20	0.02
30	69	50B	14.68	30	8
31	69	50B	14.72	13	0.02
32	69	50C	5.77	45	0.75
33	69	50C	5.87	35	0.5
34	69	50C	5.84	60	12
35	69	50D	20.67	50	15
36	69	50D	20.76	100	30

*EXTRA

TEST RECORDS (Continued)
CONTROL & SIGNAL CABLES
(2-Conductor #14 - Underground)

PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	PAIR TO GND.
37	69	50D	20.50	100	20
38	69	54	24.43	70	15
39	69	54	24.47	100	25
40	69	54	24.69	100	25
41	69	55	7.28	60	15
42	69	55	7.16	60	15
43	69	55	7.08	60	15
*1	69	55	7.22	60	15
44	69	57	16.33	20	5
45	69	57	16.42	35	8
46	69	57	16.53	10	0
*1	69	57	--	--	--
47	69	68	28.3	50	20
48	69	68	28.3	35	15
49	69	68	28.3	40	15
50	69	68	28.5	60	25
51	69	68	28.2	45	18
52	69	68	28.1	80	60
53	69	68	28.1	125	60
54	69	68	28.3	30	15
*1	69	68	28.3	70	22
*2	69	68	28.3	60	20
*3	69	68	28.0	50	0.5
*4	69	68	27.8	80	20
*5	69	68	27.6	70	20
55	69	70E	5.46	20	6
56	69	73E	15.0	15	0.1
57	69	70R	3.67	300	70
58	69	71C	1.50	200	60
60	69	83A	5.52	60	0.5
61	69	90D	2.90	350	60
62	69	90D	2.91	300	90
83	69	90E	14.56	15	.05
84	69	90E	14.60	28	8.0
85	69	90H	18.65	30	7
86	69	90H	18.74	12	0.2
87	69	90J	10.32	55	15
88	69	90J	10.41	40	10
89	69	75	5.53	80	17
90	69	-	6.56	45	12

SITE "E" - CABLE TERMINAL "C"

PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	PAIR TO GND.
1	69	123	43.06	11	2
2	69	--	43.36	9	3
*1	69	123	25.85	70	17
*2	69	123	25.68	50	9
3	69	131A	26.61	50	10
4	69	--	27.59	30	.05
5	69	132A	17.60	28	7
6	69	--	17.09	28	7
7	69	--	17.01	28	7
*1	69	--	17.24	13	4
8	69	132B	17.66	20	5
9	69	--	17.38	18	5
10	69	--	17.43	20	5
*1	69	--	17.72	15	0.25
11	69	301A	19.03	80	20
12	69	--	18.36	60	0
13	69	--	18.86	100	25
14	69	--	18.70	100	30
15	69	301B	19.96	20	5
16	69	--	19.83	0.7	0
17	69	--	20.06	20	5
18	69	--	19.91	17	4
19	69	301C	10.62	40	10
20	69	--	10.41	30	7
21	69	--	10.66	30	6
22	69	--	10.77	2.5	0.5
23	69	301E	25.38	70	17
24	69	--	26.13	50	12
25	69	--	25.20	80	17
26	69	--	25.66	70	4
*1	69	--	26.16	80	20
*2	69	--	25.94	80	25
27	69	301I	16.13	40	9
28	69	--	16.21	20	5
29	69	--	16.33	25	6
30	69	--	15.82	25	6
32	69	301J	17.56	20	0.1
33	69	--	17.59	20	5
34	69	--	17.47	10	0.05
35	69	--	17.48	30	6
36	69	301K	20.16	10	0.08
37	69	--	20.39	9	0.07
38	69	301K	19.87	0.3	0.1
39	69	--	20.35	15	0.1
40	69	302A	19.57	125	30
41	69	--	19.08	25	30

*EXTRA

TEST RECORDS (Continued)
CONTROL & SIGNAL CABLES
(2-Conductor #14 - Underground)

PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	PAIR TO GND.	PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	PAIR TO GND.
42	69	302B	15.67	25	6	1	32H	32I	2.48	1000	200
43	69	--	15.26	12	0.05	1	32I	32J	2.60	1000	200
44	69	302C	5.97	100	30	1	32J	32K	3.20	125	10
45	69	--	5.89	250	60	1	32L	32K	2.51	60	3
46	69	302D	4.33	400	150	1	51A	50A	0.58	1000	900
47	69	--	4.32	400	100	2	51A	50A	0.58	1000	300
48	69	313	20.58	60	15	3	51A	50A	0.58	1000	300
49	69	--	20.67	20	5	1	51B	50B	0.70	INF.	1000
50	69	--	20.52	14	0.05	2	51B	50B	0.64	1000	300
51	69	423	20.39	25	6	3	51B	50B	0.73	1000	250
52	69	--	20.43	18	5	1	50C	51C	0.70	500	200
*1	69	--	20.53	18	5	2	50C	51C	0.67	500	200
53	69	425	15.24	150	40	3	50C	51[illegible]	0.71	400	150
54	69	--	15.55	125	30	1	50D	51D	0.57	INF.	500
55	69	426	20.19	10	0.03	2	50D	51D	[illegible]	1000+	300
56	69	--	20.26	30	6	3	50D	51D	0.56	500	300
57	69	428	8.43	20	0.05	1	50A	54	1.27	1000	200
58	69	--	8.45	70	16	2	50A	54	1.25	200	.08
59	69	429	1.54	500	200	3	50A	54	1.29	400	125
60	69	--	1.51	300	90	1	85E	70A	0.78	1000	1000
62	69	100	16.77	25	7	1	70A	70B	3.92	100	20
84	69	771	7.41	6	0.1	1	70B	70C	1.47	1000	300
85	69	--	7.38	60	12	1	70C	70D	0.85	INF.	500
86	69	825	10.06	13	2.5	1	70D	70E	0.63	1000	500
87	69	--	10.13	150	40	1	70F	70E	0.64	1000	800
88	69	--	9.99	150	40	1	512	70E	1.48	1000	300
89	69	6312	22.53	20	5	1	70G	70F	0.45	1000	900
1	32L	23A	2.38	100	40	1	70H	70G	0.46	INF.	1000
1	23A	23B	.57	1000+	400	1	70I	70H	0.39	1000+	500
2	23A	23B	.57	1000+	400	1	72H	70I	0.49	1000	400
3	23A	23B	.57	1000+	400	1	70J	70K	0.40	1000	500
4	23A	23B	.57	1000+	400	1	70K	70L	0.37	INF.	1000
5	23A	23B	.57	1000+	400	1	70L	70M	0.53	INF.	1000
6	23A	23B	.56	1000+	400	1	70M	70N	0.39	1000+	800
7	23A	23B	.57	1000+	250	1	70N	700	0.39	INF.	1000
1	26A	26B	7.71	50	13	1	72A	70P	0.44	1000	700
2	26A	26B	7.82	40	9	1	70P	70Q	0.33	INF.	1000
3	26A	26B	7.77	90	20	1	70Q	70R	0.44	INF.	400
1	32A	32B	2.58	500	.05	1	70D	70R	0.44	INF.	300
1	32B	32C	2.22	500	150	1	513	70R	1.52	800	260
1	32C	32D	2.41	1000	150	1	5141	70R	1.16	1000	250
1	32E	32F	2.80	1000	150	1	5142	70R	1.16	1000	300
1	32F	32G	2.93	260	80	1	70R	70S	0.31	1000+	500
1	32G	32H	4.47	400	100	1	70T	70S	0.40	1000+	1000

*EXTRA

TEST RECORDS (Continued)
CONTROL & SIGNAL CABLES
(2-Conductor #14 - Underground)

PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	PAIR TO GND.	PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	PAIR TO GND.
1	72B	70T	0.52	1000*	800	2	90E	90F	0.66	400	200
1	74E	70U	0.42	INF.	500	1	90H	90G	0.76	800	150
1	70U	70V	0.82	250	25	2	90H	90G	0.84	800	150
1	72C	70V	0.46	INF.	400	1	90I	90J	2.12	250	70
1	72C	70W	0.87	INF.	500	2	90I	90J	2.20	250	70
1	70D	70W	0.72	700	150	1	121A	120B	1.01	400	150
1	74G	71B	0.74	INF.	400	2	121A	120B	1.00	400	150
1	5161	71C	0.71	1000	200	1	121B	120C	1.08	275	150
1	5162	71C	0.73	175	55	2	121B	120C	1.06	275	150
1	72F	71C	0.54	800	150	1	121D	120D	.97	300	150
1	5151	71C	0.30	1000	1000	2	121D	120D	.99	300	150
1	71B	71C	0.99	400	100	1	121E	120E	1.00	500	200
1	74H	71D	0.53	400	50	2	121E	120E	1.00	500	200
1	72G	71D	0.55	500	100	1	120A	121A	0.95	400	150
1	700	72A	0.46	1000	400	2	120A	121A	0.96	400	150
1	70U	72B	0.59	1000	600	1	120B	121B	1.06	1000	300
1	71A	72E	0.85	300	0.1	2	120B	121B	1.04	300	150
1	71D	72F	0.98	30	0	1	120D	121C	1.03	300	170
1	85A	73B	0.26	INF.	1000	2	120D	121C	1.01	300	170
1	73A	73B	0.26	1000+	700	1	120E	121D	1.01	300	150
1	73B	73C	0.80	1000	200	2	120E	121D	.96	300	150
1	73C	73D	0.35	INF.	800	1	121C	123	0.65	500	300
1	73D	73E	1.60	400	70	2	121C	123	0.63	500	300
1	511	73E	(Open)	--	--	1	120C	123	0.82	500	300
1	73G	73F	3.39	0.4	0.1	2	120C	123	0.81	500	300
1	73E	73F	0.31	INF.	1000	1	421	423	4.15	100	25
1	85B	73F	0.31	1000+	800	2	421	423	4.12	125	30
1	85C	73G	0.33	INF.	800	1	424	425	6.42	300	80
1	73G	73G	3.98	100	15	2	424	425	6.30	400	100
1	85D	73H	0.77	500	1000	1	427	428	0.31	1000	450
1	70C	74A	0.36	1000+	800	2	427	428	0.33	1000	400
1	85F	74B	0.26	INF.	1000	1	6312	6311	0.72	1000	200
1	70D	74B	0.27	INF.	1000	1	6322	6321	0.89	500	150
1	70J	74C	0.46	1000	500	2	6322	6321	0.84	500	150
1	70W	74F	0.32	INF.	1000	3	6322	6321	0.83	500	150
1	72E	74G	0.72	1000+	400	4	6322	6321	0.82	500	150
1	83B	83A	1.55	1000	250	1	6323	6322	0.97	500	100
1	90A	90B	1.40	125	15	2	6323	6322	1.07	500	100
2	90A	90B	1.42	125	60	3	6323	6322	1.04	500	100
1	90B	90D	24.08	60	13	4	6323	6322	1.02	500	100
2	90B	90D	24.14	50	10	1	6332	6322	0.98	1000	200
1	90C	90D	1.22	1000	300	2	6332	6322	1.12	1000	150
2	90C	90D	1.21	350	125	3	6332	6322	0.99	1000	150
1	90E	90F	0.76	400	200	4	6332	6322	0.93	1000	150

*EXTRA

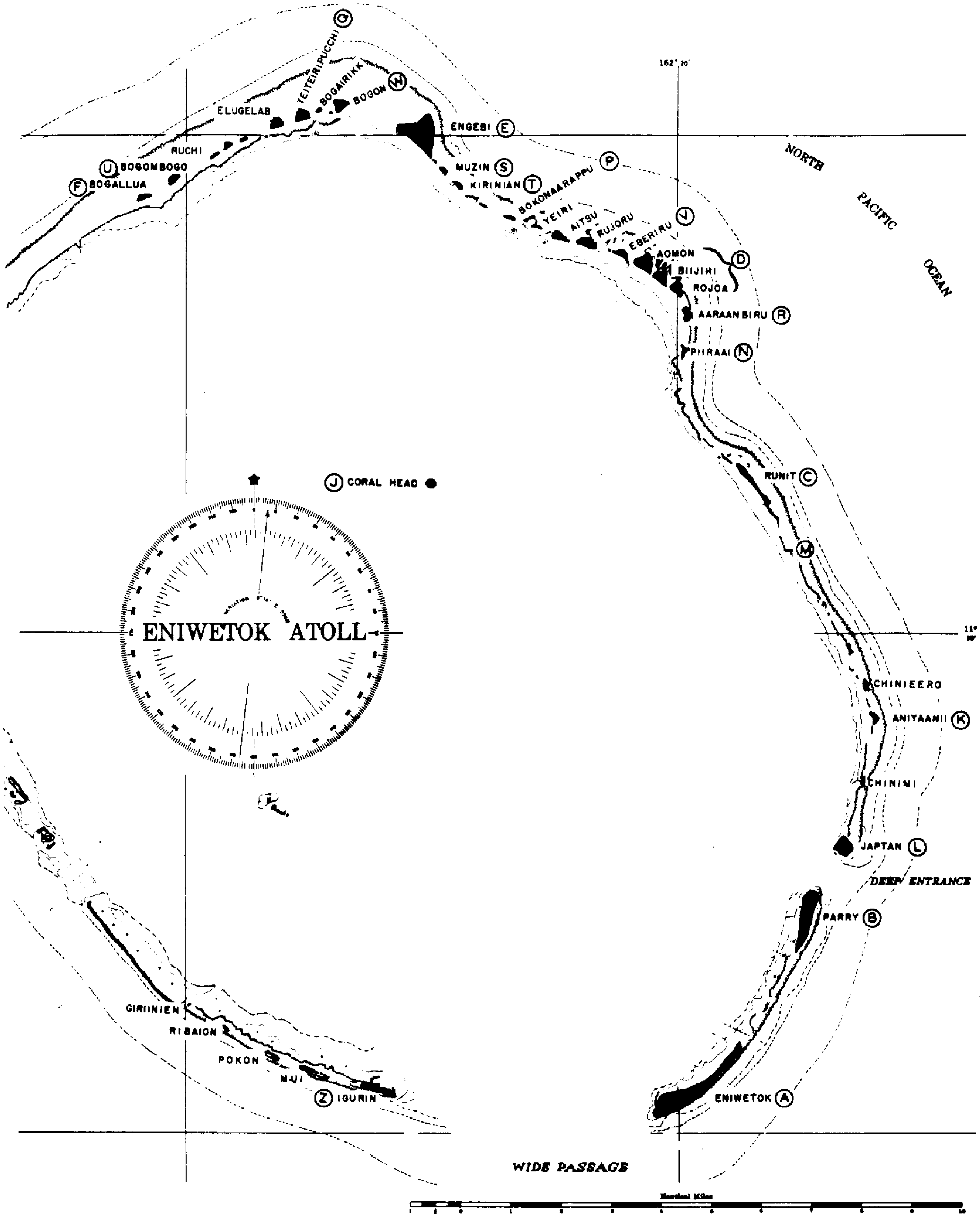
TEST RECORDS (Continued)
CONTROL & SIGNAL CABLES
(2-Conductor #14 - Underground)

PAIR NO.	FROM STA.	TO STA.	LOOP RES. (OHMS)	INSULATION RES. (MEGOHMS) WIRE TO WIRE	INSULATION RES. (MEGOHMS) PAIR TO GND.
1	6342	6341	1.56	200	100
2	6342	6341	1.60	450	15
3	6342	6341	1.60	*INF.	300
4	6342	6341	1.66	500	90
1	6A	6B	0.90	350	150
2	6A	6B	0.91	350	125
3	6A	6B	0.91	350	125
4	6A	6B	0.89	350	125
SITE "S" - TO STA. 101					
1	41	101	2.83	200	40
2	41	101	2.80	90	2
3	76	101	3.00	140	30
4	76	101	3.03	175	50
5	--	--	--	--	--
6	--	--	--	--	--
7	301D	101	2.36	150	15
8	301D	101	2.37	400	100
9	301D	101	2.36	10	2
10	301D	101	2.44	15	3
11	301F	101	4.12	500	110
12	301F	101	4.10	400	110
13	301F	101	4.09	400	110
14	301F	101	4.10	400	110
15	301G	101	3.97	150	30
16	301G	101	3.97	15	5
17	301G	101	4.05	150	30
18	301G	101	4.03	20	2
19	301H	101	1.93	60	15
20	301H	101	1.90	125	1.0
21	301H	101	2.02	700	150
22	301H	101	1.88	200	60
23	302E	101	2.39	1000	250
24	302E	101	2.81	1000	175
25	302F	101	3.68	150	40
26	302F	101	3.62	110	30
27	302G	101	4.40	100	30
28	302G	101	4.33	100	30
29	302H	101	4.87	70	0.1
30	302H	101	4.85	100	30
31	302J	101	2.39	400	100
32	302J	101	2.38	400	100
33	302K	101	3.15	200	40
34	302K	101	3.20	150	40
35	302M	101	2.86	200	50
36	302M	101	2.81	0.03	1.5
37	302N	101	1.84	400	150
38	302N	101	1.87	500	150
39	302P	101	1.04	800	300
40	302P	101	1.14	1000	300
41	302Q	101	1.47	1000	250
42	302Q	101	1.41	400	100
43	302R	101	1.23	250	100
44	302R	101	1.06	400	150
45	518	101	1.95	500	150
46	623	101	2.65	400	100
47	623	101	2.72	400	100
48	623B	101	4.30	200	70
49	623B	101	4.31	200	70
50	623B	101	4.28	150	20
51	624B	101	2.93	300	150
52	624B	101	2.92	500	150
53	826	101	0.99	500	150
54	826	101	0.98	500	150
55	826	101	0.97	500	150
*1	826	101	0.99	500	150
*2	826	101	1.0	500	150
*3	826	101	0.99	400	150
56	4210	101	3.00	100	2
57	4210	101	2.99	175	50
58	4211	101	4.21	175	45
59	4211	101	4.16	175	40
60	5171	101	3.45	125	30
1	5182	518	0.29	INF.	1000
1	5172	5171	0.27	1000+	1000+
1	5173	5171	0.28	1000+	1000+
1	5174	5171	0.26	1000+	1000+
1	4212	4211	0.23	1000	500
2	4212	4211	0.23	1000	500
1	4212A	4212	0.22	1000	500
2	4212A	4212	0.23	1000	500
SITE "T" - TO STA. 101					
1	77	T101	0.75	500	150
2	77	T101	0.75	400	150
3	78	T101	7.33	15	3
4	78	T101	7.41	30	4

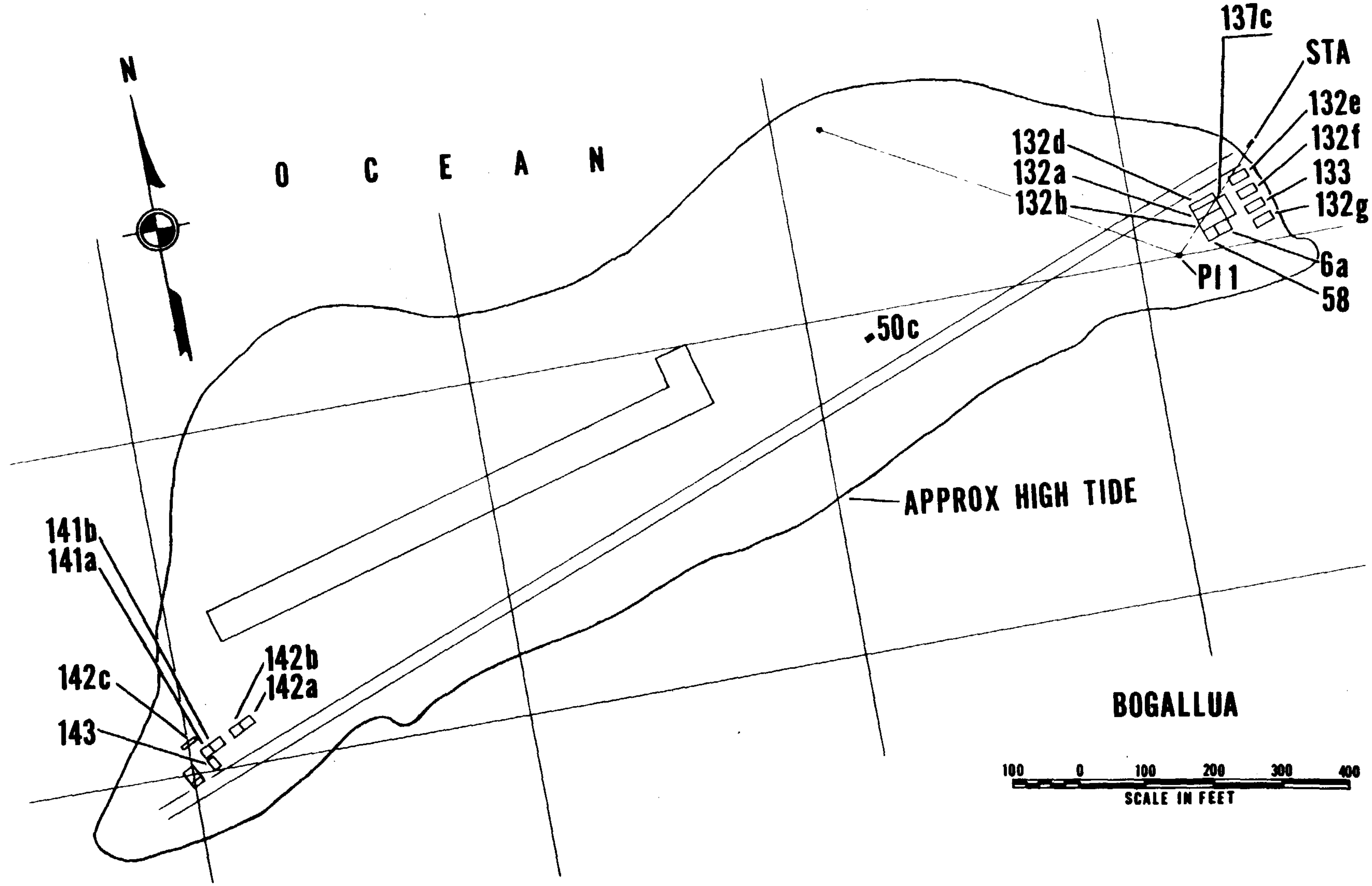
*EXTRA

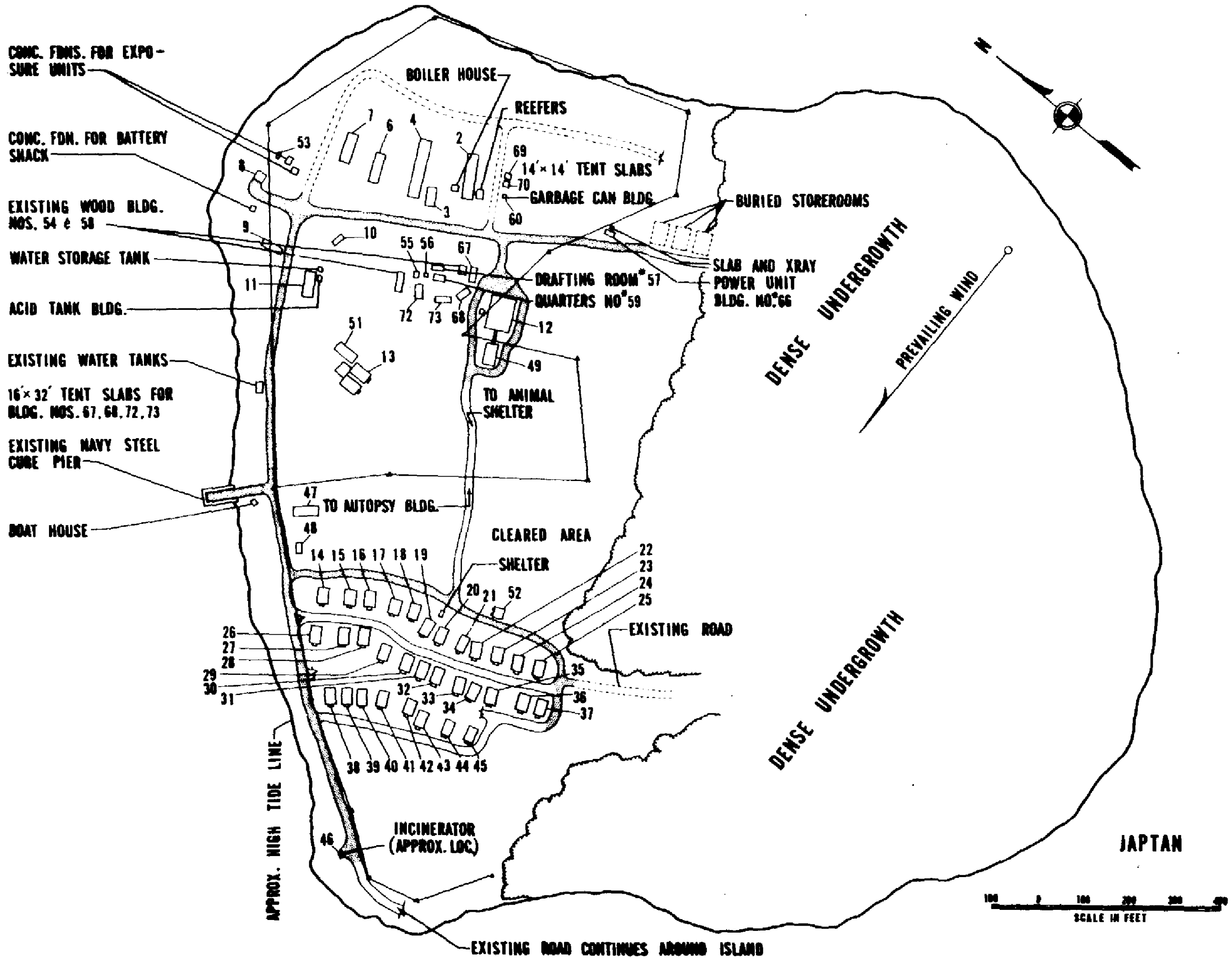
EXHIBIT E

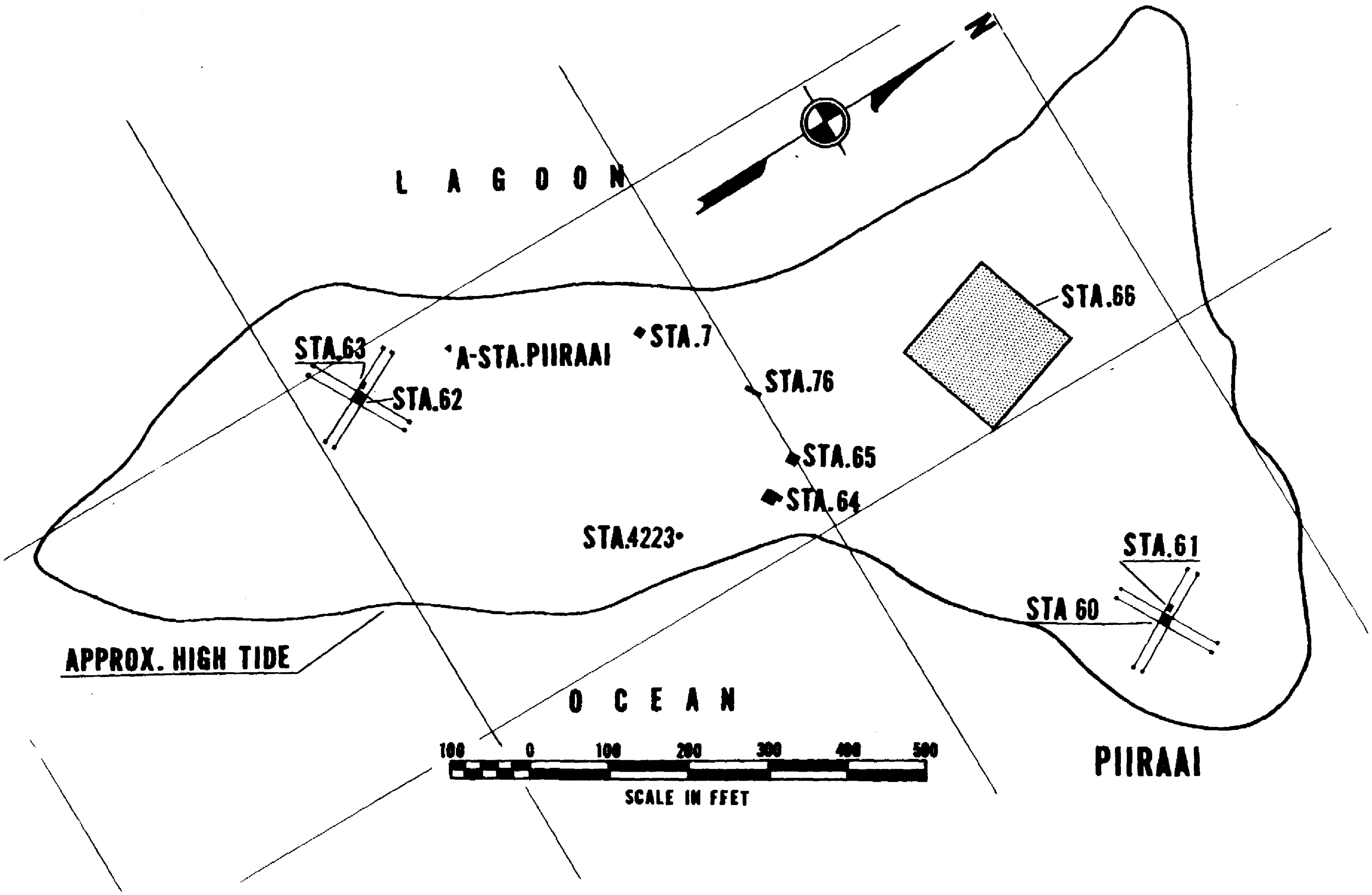
Maps



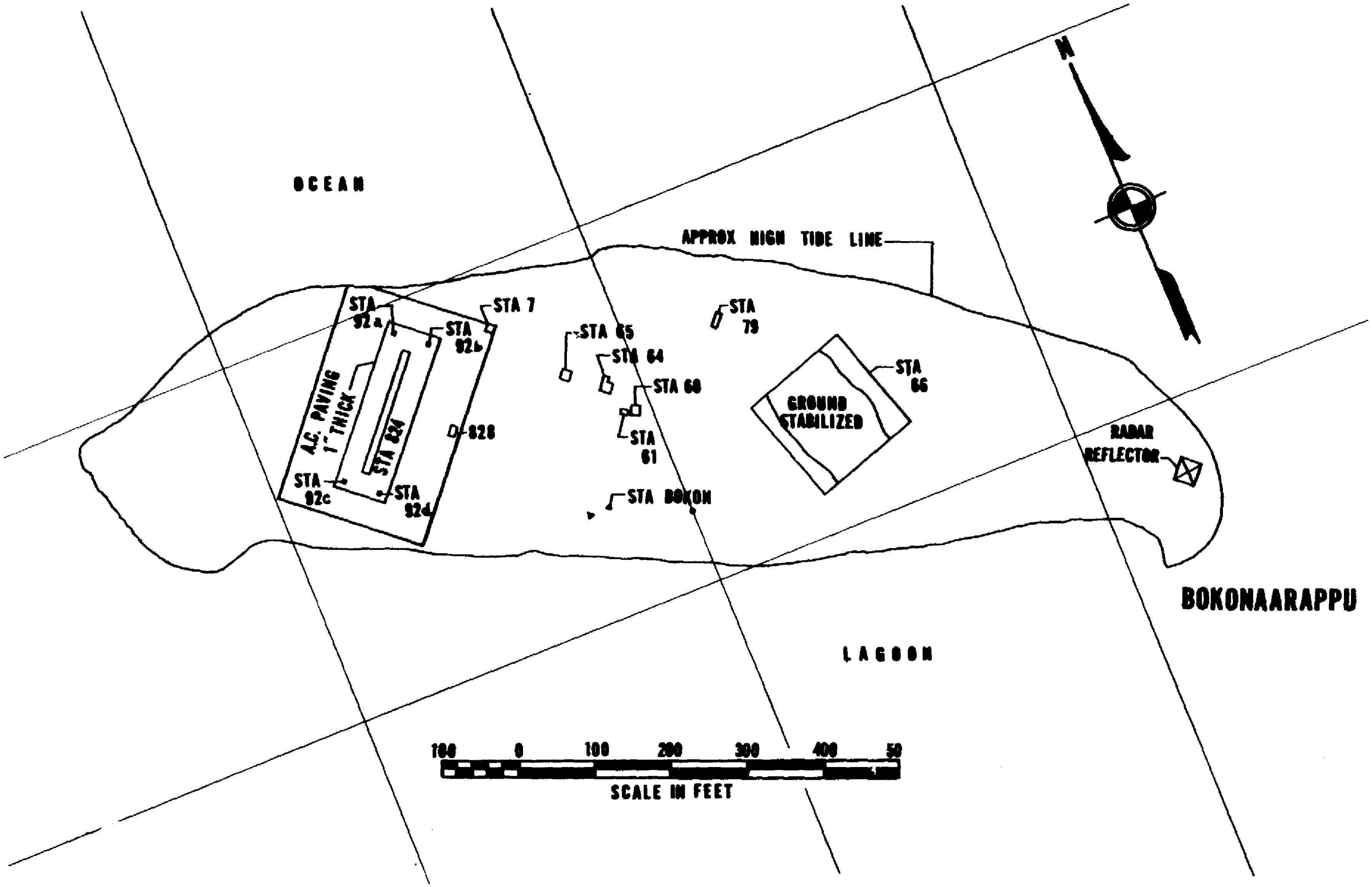
ENIWETOK ATOLL
NORTH PACIFIC OCEAN
162° 20'
11° 30'
ENGEBI E
BOGON W
BOGAIRIKK
TEITEIRIPUCCHI G
ELUGELAB
RUCHI
U BOGOMBOGO
F BOGALLUA
MUZIN S
KIRINIAN T
BOKOMAARAPPU P
YEIRI
AITSU
RUJORU
EBERIRU V
AOMON
BIIJIRI
ROJOA
D
AARAANBIRU R
PIIRAAI N
J CORAL HEAD
RUNIT C
M
CHINIEERO
ANIYAANII K
CHINIMI
JAPTAN L
DEEP ENTRANCE
PARRY B
ENIWETOK A
WIDE PASSAGE
GIRIINIEN
RIBAION
POKON
MUI
Z IGURIN


N
O C E A N
137c
STA
132e
132f
133
132g
132d
132a
132b
6a
PI 1
58
50c
APPROX HIGH TIDE
141b
141a
142c
143
142b
142a
BOGALLUA
100 0 100 200 300 400
SCALE IN FEET

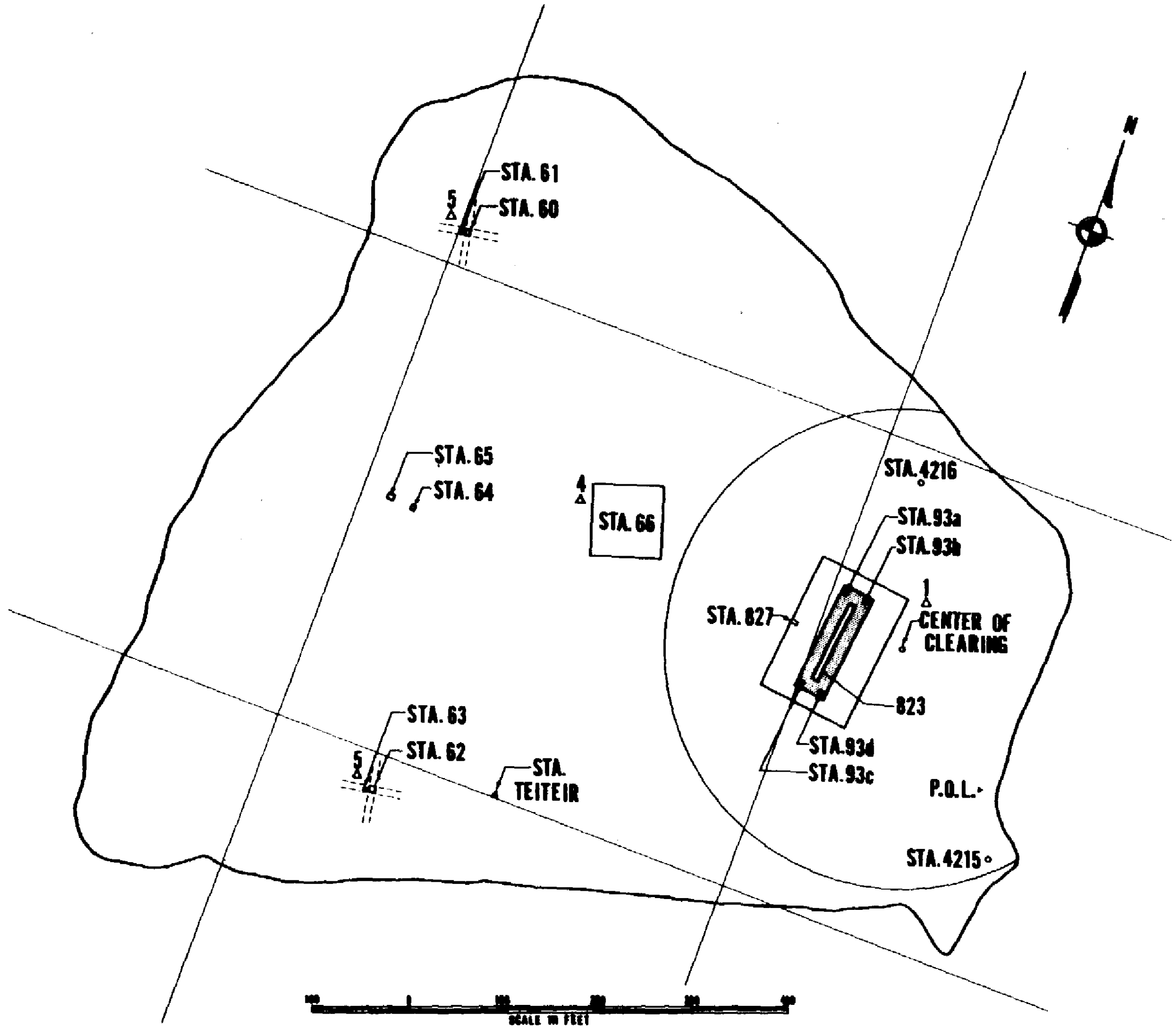

CONC. FDNS. FOR EXPO-SURE UNITS
CONC. FDN. FOR BATTERY SHACK
EXISTING WOOD BLDG. NOS. 54 & 58
WATER STORAGE TANK
ACID TANK BLDG.
EXISTING WATER TANKS
16'×32' TENT SLABS FOR BLDG. NOS. 67, 68, 72, 73
EXISTING NAVY STEEL CUBE PIER
BOAT HOUSE
BOILER HOUSE
REEFERS
14'×14' TENT SLABS
GARBAGE CAN BLDG.
BURIED STOREROOMS
SLAB AND XRAY POWER UNIT BLDG. NO. 66
DRAFTING ROOM #57
QUARTERS NO. 59
TO ANIMAL SHELTER
TO AUTOPSY BLDG.
CLEARED AREA
SHELTER
EXISTING ROAD
INCINERATOR (APPROX. LOC.)
APPROX. HIGH TIDE LINE
EXISTING ROAD CONTINUES AROUND ISLAND
DENSE UNDERGROWTH
DENSE UNDERGROWTH
PREVAILING WIND
N
JAPTAN
SCALE IN FEET



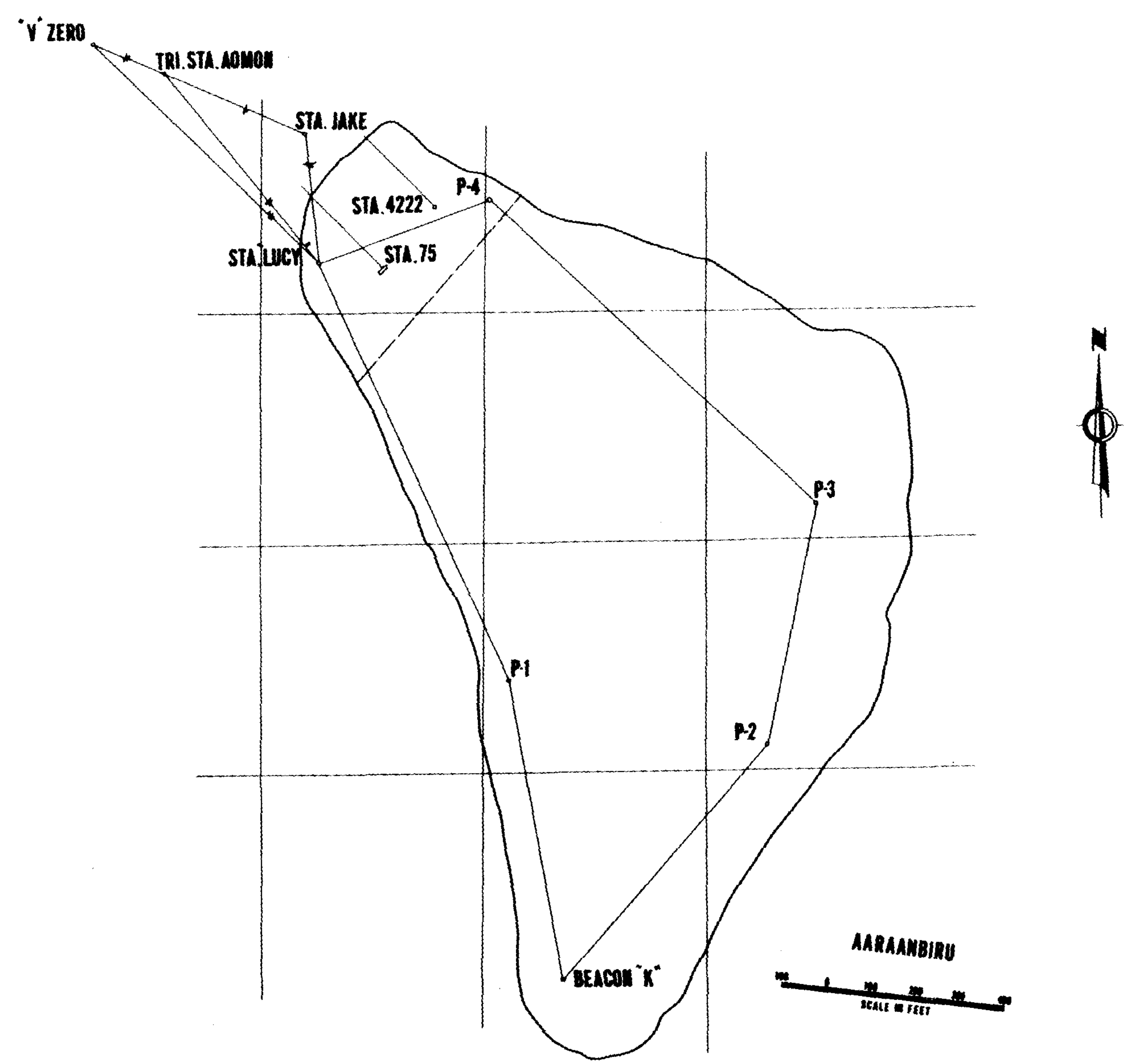
N
LAGOON
STA.66
STA.7
STA.63
A-STA.PIIRAAI
STA.76
STA.62
STA.65
STA.64
STA.4223
STA.61
STA 60
APPROX. HIGH TIDE
OCEAN
100 0 100 200 300 400 500
SCALE IN FFET
PIIRAAI

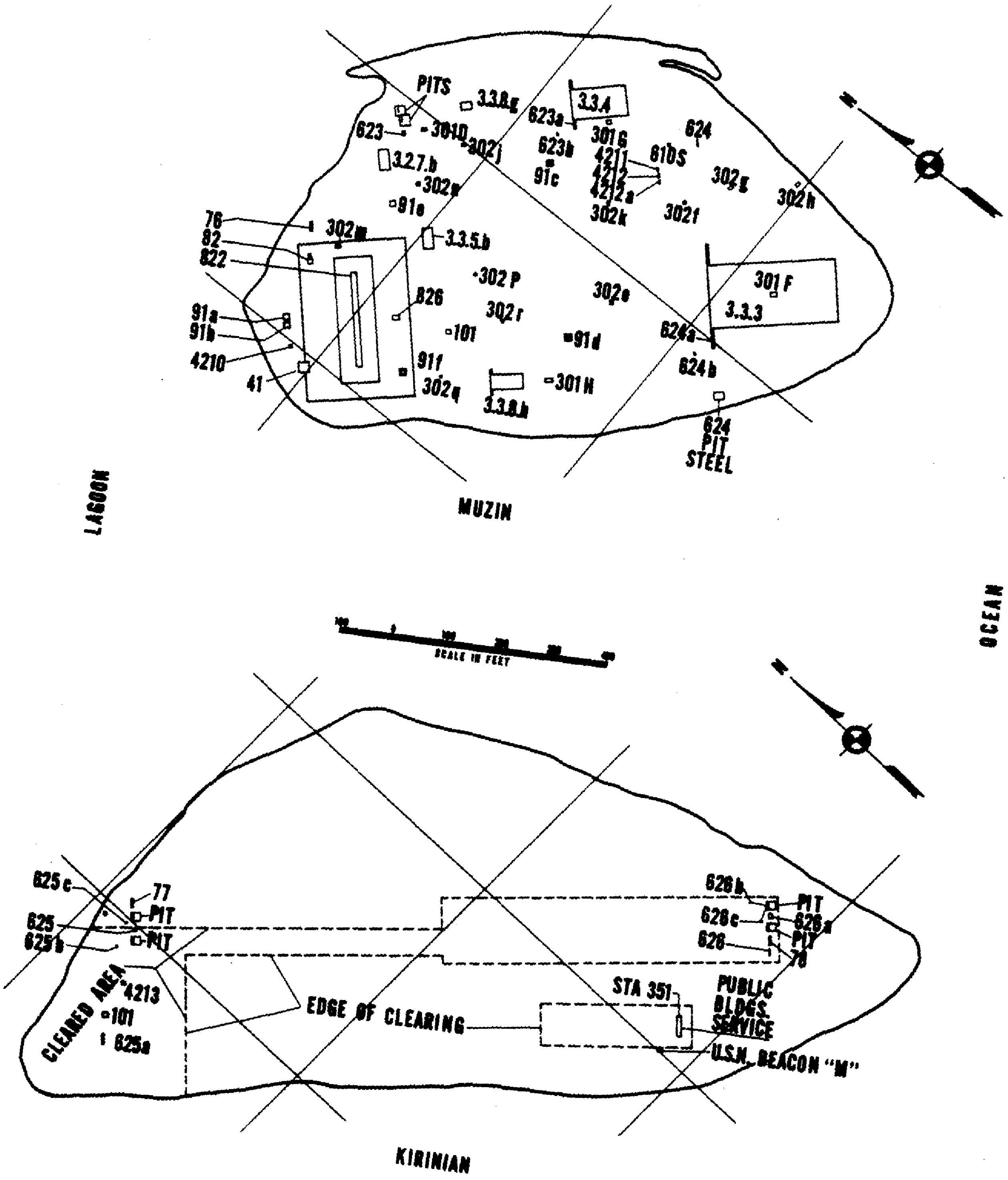


OCEAN
APPROX HIGH TIDE LINE
N
STA 92a
STA 92b
STA 7
A.C. PAVING 1" THICK
STA 824
828
STA 92c
STA 92d
STA 65
STA 64
STA 60
STA 61
STA BOKON
STA 79
GROUND STABILIZED
STA 66
RADAR REFLECTOR
BOKONAARAPPU
LAGOON
100
0
100
200
300
400
50
SCALE IN FEET

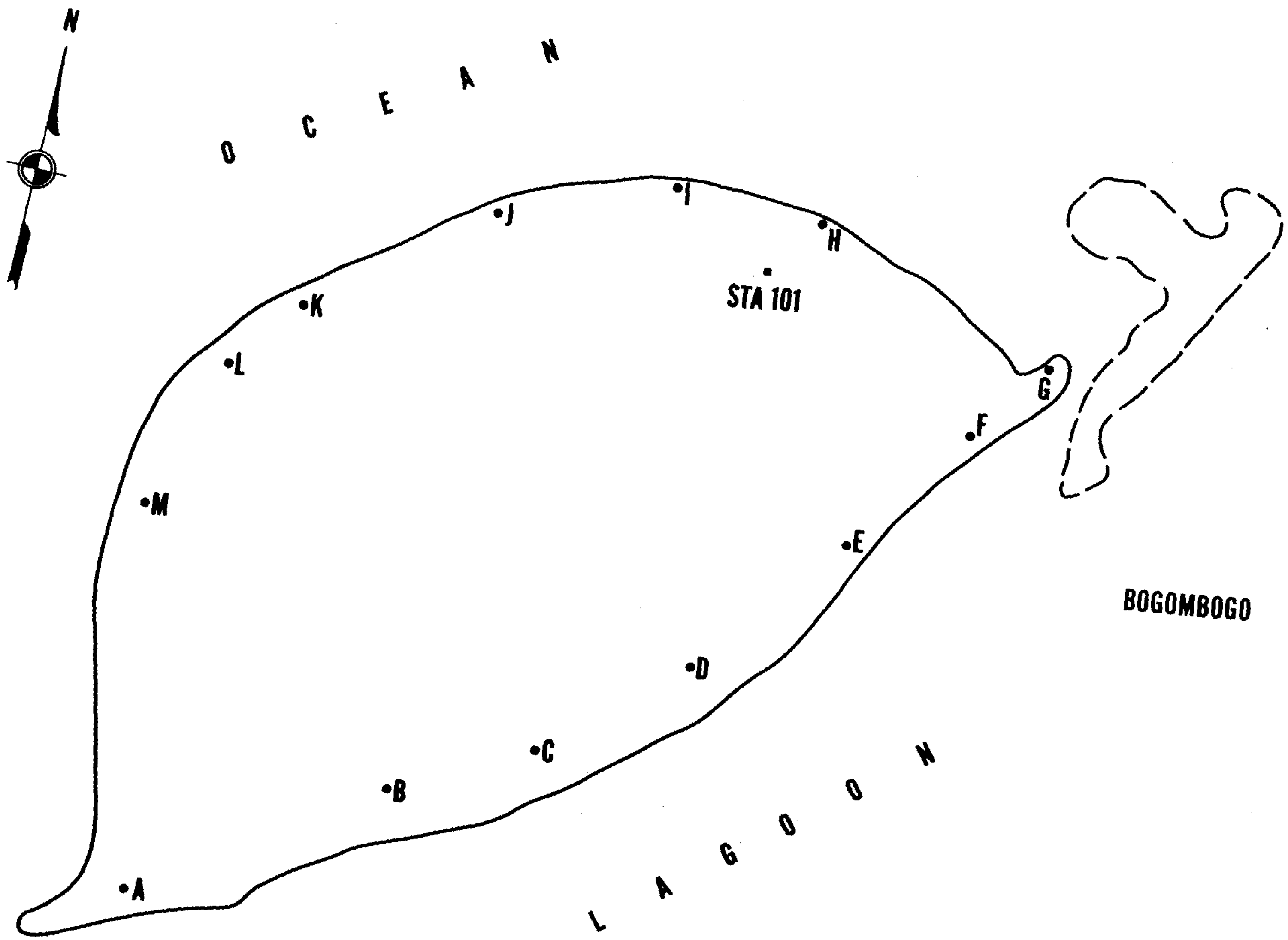


Teiteiripucchi Island


"V" ZERO
TRI. STA. AOMON
STA. JAKE
STA. 4222
P-4
STA. LUCY
STA. 75
P-3
P-1
P-2
BEACON "K"
AARAANBIRU
SCALE IN FEET
N


PITS
3.3.8.g
623a
3.3.4
623
302j
3.2.7.b
302n
91e
623b
91c
301G
624
4211
4212
4212a
302k
302f
302g
302h
76
82
822
302m
3.3.5.b
302P
826
302e
301F
3.3.3
91a
91b
4210
41
101
302r
91d
624a
624b
91f
302q
3.3.8.h
301H
624
PIT
STEEL
MUZIN
LAGOON
OCEAN
SCALE IN FEET
625c
77
PIT
625
625b
PIT
626b
PIT
626c
626a
626
PIT
78
CLEARED AREA
4213
101
625a
EDGE OF CLEARING
STA 351
PUBLIC
BLDGS.
SERVICE
U.S.N. BEACON "M"
KIRINIAN

[redacted]



[redacted]