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COMMUNICATIONS FOR OPERATION SANDSTONE

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COMMUNICATIONS FOR OPERATION SANDSTONE

By

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Group LAJ-11

May 25, 1948

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I. INTRODUCTION

This report covers the planning and operation of the communication system provided for the Atomic Energy Commission by Joint Task Force Seven during Operation Sandstone. The communications network encompassed Kwajalein, Hawaii, and many points in the United States as well as the Eniwetok Atoll area. Some appreciation of the magnitude of the system can be obtained when it is pointed out that some three hundred eighty-five (385) frequencies were required to provide the eighty-five (85) radio channels used by AEC and the Armed Forces for this operation. One of the primary features of the communications system was the employment of a radiotelephone system (AN/TRC-1) between the important ships and shore locations. This system was connected into the ship and shore telephone switchboards thus reproducing, in miniature, the telephone facilities available between cities in the United States. Other communication systems used by AEC during this operation were: radioteletype and coding systems to provide for the transmission of Atomic Energy Act (AEA) Restricted Data between the forward area and the AEC installations in the United States; radio-intercommunication facilities between the AEC directors and staff offices and the cabins of the Task Force staff section heads and commanders; a "technical radio net" to provide communication to the photographic towers and to back up the radiotelephone system, and special radio nets required by the Radiological, Blast, Neutron, Radiochemistry, and Evacuation Groups.

II. BACKGROUND

A. Scientific Operations Plan

The Atomic Energy Commission tested three (3) atomic weapons at Eniwetok Atoll during the spring of 1948. To support the AEC, the Armed Forces

activated Joint Task Force Switchman (later designated Joint Task Force Seven). Three primary ships were assigned to the operation: USS Albemarle (AV-5) as the Test and Scientific Directors' headquarters, USS Curtiss (AV-4) as the Weapons Assembly Ship, and the USS Mt. McKinley (AGC-7) as the JTF 7 Flagship. Eniwetok Island was the main shore base. The three tests, X-ray, Yoke, and Zebra were conducted in the northeastern part of the Atoll on Engebi, Aomon-Biijiri-Rojoa, and Runit Islands. The test control station was located on Parry Island. Photographic towers were used on Aomon, Runit, Aniyaanii Islands, and on a coral head near the center of the lagoon. Upon completion of the construction phase, the ships proceeded from the West Coast to Eniwetok Atoll and anchored off the first test island (Zero Island). When preparations for the test were complete, the ships moved to a safe location inside the lagoon near Parry Island to observe the detonation. After the test, the ships proceeded to an anchorage near the second Zero Island. This procedure was repeated until the tests were completed.

B. Personnel and Duties

On 23 October 1947, Mr. R. W. Henderson, First Assistant Scientific Director, appointed Mr. Louis A. Hopkins, Jr. of the Sandia Base Branch, Los Alamos Scientific Laboratory, to act in a liaison capacity in communication matters between J-Division and the Armed Forces during the planning and operation phases of Operation Sandstone. The duties of the J-Division Communications Section, LAJ-11, were considered to be:

1. Coordinate the communications requirements of J-Division with the communications staff of Joint Task Force Seven.

2. Coordinate the Atomic Energy Commission communication facilities in the United States with the Armed Forces.

[redacted]

3. Inform the Scientific Director concerning the status and operation of the communication system provided by the Task Force.

4. Advise the Scientific Director in matters relating to communications and operations.

On 7 January 1948, Lieutenant Colonel John P. Scroggs, Signal Corps, of the 38th Engineer Battalion was chosen to aid Mr. Hopkins with this assignment. Lieutenant Colonel Scroggs' primary duty was planning and supervision of the AEC message handling procedures and facilities.

III. DISCUSSION

A. Planning Stage

1. Preliminary Plans

On 27 October 1947, after a general briefing on the purpose and status of the plan for the scientific phase of Operation Sandstone by Mr. R. W. Henderson, a trip was made to Washington, D.C., and Boston, Massachusetts, to determine the communication requirements of the scientific groups based at these locations and to meet the JTF 7 communications staff. It was learned that the Communication Section was headed by Captain (later Commander) C. L. Engleman, USN, with Colonel C. H. Hatch, Signal Corps, as his deputy and in charge of Army communications. Lieutenant Colonel C. A. Smith, USAF, and Lieutenant Colonel J. E. Dupree, Signal Corps, represented the Air Force, and Commander R. J. Schmidt handled Navy communications. The delineation of responsibilities within this staff provided that the Army would supply all ground communications, the Navy all shipboard facilities, and the Air Force all air/ground and point-to-point communications concerning aircraft. Since the communications system planning had been proceeding for approximately one month at this time, the Communications Section was already aware of many

[redacted]

[redacted]

phases of the current scientific plan and were considering means of supplying the necessary communications. At this stage, AN/TRC-1 radiotelephone equipment was being planned as the primary communication network on shore, and SCR-608 (10 channel voice) radio sets as the main voice communication between ships and between ships and shore. Navy type MBF radio sets were to be installed in the cabins of the Technical (later termed Scientific) Directors and the General and Flag Officers of the Armed Forces to provide an intercommunication system for their exclusive use. Plans were being made to provide radioteletype facilities for handling messages between the forward area and the United States.

2. Telephone System

a. AN/TRC-1 Installation

On 28 October 1947, the first consideration was given to the possibility of installing AN/TRC-1 equipment on the three main ships to provide VHF radiotelephone and teletype service between the ships and between the ships and the Army shore system. This installation would permit an individual at any ship's service telephone to dial the ship switchboard and be connected to any telephone on the other two ships or to any telephone on the main shore locations. The need for such a flexible radiotelephone system interconnecting the USS Albemarle (AV-5), USS Curtiss (AV-4), USS Mt. McKinley (AGC-7), Eniwetok Island, Parry (control) Island, and the three Zero Islands (Engebi, Aomon-Biijiri-Rojoa, and Runit) was discussed with the principal scientific personnel concerned during the period 29 October to 6 November 1947. All agreed that this system was highly desirable.

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The first written request[1] for radiotelephone service was made on 12 November 1947. The final requirements for the radiotelephone system were determined during a trip to Washington covering the period of 13 to 21 November 1947. Decision on these final requirements involved estimates of the amount of traffic expected, the existing limitation of four (4) outside line drops on the AVs' switchboards, a possible increase in the number of drops on the AGC-7 switchboard from four (4) to ten (10), personnel and space restrictions aboard ship, planning and installation time for the ships, and the relocation of the main shore relay station from Parry to Eniwetok. The final AEC radiotelephone plan[2] was submitted on 19 February 1948, and contained requests for the following circuits:

(1) AGC-7 and AV-5, 2 channels
(2) AGC-7 and AV-4, 1 channel
(3) AV-4 and AV-5, 2 channels
(4) AGC-7 and Eniwetok, 7 channels
(5) Eniwetok and Engebi, 8 channels
(6) Eniwetok and Aomon, 4 channels
(7) Eniwetok and Runit, 4 channels
(8) Eniwetok and Parry, 8 channels

These circuits required the following AN/TRC-1 installations with associated telephone and teletype carrier and ringer equipment:

(1) AGC-7, 5 sets
(2) AV-4, 3 sets
(3) AV-5, 3 sets
(4) Eniwetok, 9 sets
(5) Engebi and Parry, 2 sets each
(6) Aomon and Runit, 1 set each

This made a total of twenty-six (26) AN/TRC-1 sets of equipment operating within a radius of approximately ten (10) miles. Considerable time was

[1]Secret Letter, Henderson (Hopkins) to Capt. Russell; subj.: "Proposed Communication System for Operation Sandstone", dated 12 Nov. 1947. (Ref.: IAB-Z-5-(26)).

[2]Secret Letter, Henderson (Hopkins) to Capt. Russell; subj.: "Communication Plan for Operation Sandstone", dated 19 Feb. 1948. (Ref.: IAB-JS-11-(125)).

[redacted]

devoted by the JTF 7 Communications Section to the selection of the fifty-two (52) frequencies required in the 70 to 100 megacycle band to provide service free from interference.

The shipboard installations were started during the first week in December 1947 with Lieutenant Commander Ralph L. Hildebrand supervising the AV-5 work at Norfolk, Virginia, and Lieutenant (Junior Grade) Thomas V. Grant supervising the AV-4 and AGC-7 installations at the Terminal Island Naval Shipyard, San Pedro, California. Inspection trips were made to Norfolk on 17 December 1947 and 12-13 January 1948, and to Terminal Island on 18-20 December 1947, 26-27 January, and 17-24 February 1948. All three ships were docked at Terminal Island during the latter period, preparatory to departure in convoy for Eniwetok.

b. Island Telephone Installation

The initial requirements for the island telephone installation were determined during the period 29 October through 10 November 1947. The first written request[1] was forwarded to the Communication Section on 12 November 1947. The final requirements for the land-line telephone system were laid down in a conference held at the Naval Research Laboratory on 16 December 1947, with the following section heads present:

Dr. A. C. Graves, Deputy Scientific Director
Dr. G. K. Hartmann, NOL (LAJ-8)
Dr. E. H. Krause, NRL (LAJ-4)
Mr. H. E. Grier, EGG (LAJ-12)
Capt. C. L. Engleman, USN, JTF 7 Communications Officer

The requirements included:

(1) Eniwetok
  (a) Radiochemistry
  (b) Security
  (c) Others

[1] See footnote, page 7.

(2) Parry
- (a) Control Station (3)
- (b) Telemetering tower (IAJ-8 installation)
- (c) Beach
- (d) Cable terminal
- (e) Guard
- (f) Communications building

(3) Zero Islands
- (a) Top of tower (2)
- (b) Tower base
- (c) Timing station (4)
- (d) 400-ft. station
- (e) 1,000-ft. station
- (f) Gamma "A" station
- (g) Gamma "B" station
- (h) Gamma "C" station (Runit only)
- (i) Photo tower (Aomon and Runit)
- (j) Causeway between Aomon-Biijiri
- (k) Blast building (2)
- (l) Blast footing common
- (m) Blast footings
- (n) Communications building
- (o) Beach or pier

The locations of the Zero Island telephones were plotted on the IAJ-16 maps[3]. The "blast footing common" line was to be terminated on a pair of binding posts in a small box adjacent to each footing, and at a phone in the blast building. The "blast footing" circuit was also terminated in this box and ran to the island switchboard. Thus each blast footing was connected to all other footings on the island and to the blast building with a common circuit and also with a common circuit to the switchboard. Telephones were to be carried by the working parties and connected to the terminal board at the footings being worked on at the time.

c. Ship Telephone Installation

Telephones were already installed in Shops 1, 2, 4, 5, 6, 8, 9, 10, 11, 12, and 15 and the Admiral's cabin and Flag Office on the

[3]Secret Maps, IAJ-11, Nos. MJ-3201C (Engebi), MJ-3301C (Aomon-Biijiri-Rojoa), MJ-3401C (Runit), dated 28 Dec. 1947. (Ref.: IAB-J-218, dated 9 Jan. 1948).

AV-4 and AV-5. Therefore, no modification was required. A request for land-line telephone service to the two AV's, during the period 15 February to 1 March 1948 while berthed at Terminal Island, was made on 15 January 1948 to the Commanding Officer, Terminal Island. Separate lines were requested from the yard switchboard to phones in the Admiral's cabin on each AV and in the Flag Office on the AV-5. Due to a shortage of circuits on the pier, the Flag Office on the AV-5 was made a party line to the Admiral's cabin phone. Arrangements were made with the Fiscal Section JTF 7, to have all AEC long distance calls charged to a special Navy appropriation number. The yard considered this system unworkable so the few calls not made collect were charged to the yard telephone allotment.

3. Teletype System

a. General Plan

Coincident with the decision to employ shipboard AN/TRC-1 radio sets and telephone carrier equipment for radiotelephone circuits between ships and between ships and shore, was the formulation of a plan to use teletype terminal equipment to provide VHF radioteletype communication between ships and between the AGC-7 and Eniwetok joint relay station. Normal shipboard HF radioteletype equipment was to be employed between ships when out of VHF range. During movement to and from the forward area, the AGC-7 was to maintain contact with Pearl Harbor by HF radioteletype and relay messages to the AV-4 and AV-5 by VHF or HF radioteletype.

On 7 November it was decided that all AEC traffic to and from the ships would pass through Los Alamos. This was prescribed to simplify the passing of classified messages from military channels to AEC channels and to provide a central point of control. On 20 November 1947, a request was

submitted to the AEC for a leased line from Los Alamos to the Army Command and Administrative Net (ACAN) major teletype relay station at Sixth Army Headquarters, Presidio of San Francisco. This circuit was required to provide a continuous outlet for traffic to and from the forward area with a minimum of relay points. The activation date was set for 1 March 1948.

b. Teletype Routing Indicators

To provide for proper routing of messages in the ACAN system, Los Alamos, as a tributary of Presidio (UWP), was assigned the routing indicator UWPJ.

The routing indicators assigned the three primary ships were to change as they changed their location. While at Terminal Island Naval Shipyard the local relay station (BWDK) was to be connected to the USS Mt. McKinley (BWDKA) by tie line, and messages for the USS Curtiss (BWDKV) and USS Albemarle (BWDKY) would be relayed by hand from the USS Mt. McKinley.

During the movement to the forward area messages were to be relayed by Pearl Harbor (BHP), 14th Naval District, to USS Mt. McKinley (BHPDA) who would in turn relay to the USS Curtiss (BHPDD) and USS Albemarle (BHPDE). Messages were to be transferred from the ACAN system to Navy system or vice versa, either over tie line between Pearl Harbor (BHP) and Fort Shafter (UHP) or over tie line between Presidio (UWP) and 12th Naval District (BWP) San Francisco.

While in the forward area, Joint Relay Station, Eniwetok (UHPJ) would serve the USS Mt. McKinley (UHPJA) who would relay to and from the USS Curtiss (UHPJD) and USS Albemarle (UHPJE).

The Los Alamos teletype center was to be furnished with a list of names of all AEC personnel on the AV-4 and AV-5 so messages addressed

to individuals in the forward area could be properly addressed for routing. Los Alamos was to be notified in advance of exact time to change ships' routing indicators.

c. Cryptographic Systems

(1) SIGTOT (one-time-tape system)

On 3 November 1947 after a discussion with Mr. W. Moran, AEC Security, and Mr. W. R. Williams, AEC Communications, it was decided to employ the one-time-tape (SIGTOT) cryptographic system for classified message traffic between AEC activities in the United States and the three primary ships. This decision was based on the fact that AEC approved of and had been using SIGTOT for confidential and secret messages; consequently, some trained personnel and necessary equipment were already available. Also SIGTOT is one of the most rapid and secure cryptographic systems.

On 4 November 1947, during a conference with Commander R. J. Schmidt of JTF 7 Communication Section, Commander James Hargraves, Lieutenant J. M. Jones and Mr. John Kelly of the Department of the Navy, it was decided that three (3) SIGTOT equipments would be required on each AV and five (5) SIGTOT equipments on the AGC-7. This would provide necessary coding facilities for a three-way SIGTOT conference between ships. One (1) SIGTOT unit would be used for on-line transmitting to the other two ships simultaneously and the other two (2) SIGTOT units used to receive on-line from each of the other ships. The two (2) remaining units on the AGC-7 could simultaneously be used for off-line encrypting and decrypting other messages while the conference was in progress.

The SIGTOT tapes required for message encryption and conference were ordered on 20 November 1947. This request is summarized in the following table:

[redacted]

[redacted]

	Number of Tapes	Holder of Transmitting Tape	Holder of Receiving Tape
(1)	600	AGC-7	AV-4 and AV-5
(2)	600	AV-4	AGC-7 and AV-5
(3)	600	AV-5	AGC-7 and AV-4
(4)	200	Los Alamos	AGC-7
(5)	200	AGC-7	Los Alamos
(6)	400	Los Alamos	AV-4
(7)	400	AV-4	Los Alamos
(8)	400	Los Alamos	AV-5
(9)	400	AV-5	Los Alamos

Systems (1) through (3) were to be used for both three-way conference and classified messages between ships. Systems (4) through (9) were for use in encrypting messages classified SECRET, CONFIDENTIAL or RESTRICTED, both Military and Restricted Data, originating on these ships and addressed to AEC activities in the United States or vice versa. All such messages would be decrypted at Los Alamos and reencrypted in proper system for relay to the addressee. The number of tapes required was based on an estimate of the amount of traffic plus a large safety margin. Half of the tapes in each system were ordered to arrive by 15 February 1948 and the remaining half to be delivered by 1 March 1948.

(2) SIGPIE (one-time-pad system)

SIGPIE system was requested for use between Edgerton, Germeshausen, and Grier, Inc., (EGG), 202 Hood Building, Cambridge, Massachusetts, and Los Alamos and between EGG and AEC Washington, since EGG had no way of receiving or sending classified information except by courier.

SIGPIE systems were also requested for use between Los Alamos and NOL, Washington, D.C., and between Los Alamos and NRL, Washington, D.C.

[redacted]

They were to be used for high precedence messages which had to be sent during hours when AEC Washington teletype center was closed.

d. Teletype Communication Centers

(1) Hours of Operation

On 2 December 1947, Dr. Froman submitted a request to Mr. Carroll Tyler, Santa Fe Directed Operations, that the Los Alamos teletype center be placed on a continuous operation basis effective 1 March 1948 until completion of Operation Sandstone.

On 15 January 1948 a request was submitted to AEC Washington, D.C. (Mr. Malcolm E. Pitts, Director, Office of Administrative Operations) for the Washington teletype center to remain open from 0600 to 1800 local time, Monday through Friday. This request was later changed to operation from 0700 to normal afternoon closing hour since the working-day time overlap between Eniwetok and AEC Washington, D.C., amounted to only two hours. Message transmission time was estimated to be a minimum of two hours, thus all messages originated at Eniwetok during hours 0800 to 1700 local time would be relayed to AEC Washington by Los Alamos at 0700 Washington, D.C. time and would be delivered to addressee by the time his office opened. Messages from AEC Washington to the forward area would be relayed immediately by each relay point since they would be operating continuously.

Sandia Base teletype center was asked to maintain operating hours 0600 - 1700 local time, Monday through Friday and 0600 - 1200 on Saturday. Also, it was requested that the practice of having an operator on 24-hour call be continued so Los Alamos could deliver urgent messages during off-duty hours.

(2) Message Handling Procedure

Annex C to Test Director's Operation Order 1-48 prescribed the message handling procedure for TG 7.1 classified messages on the AV-4 and AV-5. The Staff Office on each of these ships was to be the accountable office. It would be responsible for preparing necessary typewritten copies of outgoing messages from the originator's rough draft, for maintaining a receipt record of all such messages delivered, and for delivering messages to the ship SIGTOT Officer for encryption after authority for release had been obtained from the Test Director or Scientific Director on the AV-5, or the First Assistant Scientific Director on the AV-4. The SIGTOT Officer was to encrypt the message and then decrypt his encryption to insure that the message was correctly encrypted before sending the scrambled tape to the Ship's Communication Watch Officer (CWO) for transmission. Incoming messages were to be delivered directly to the Staff Office by the SIGTOT Officer as soon as the message was decrypted. The Staff Office would account for the message and deliver the necessary copies to the addressees. The SIGTOT Officer was to maintain a code room file of military classified messages only. All copies of Restricted Data messages were to be delivered to the Staff Office Restricted Data Control Officer's representative for accounting, distribution, and filing.

Transmission of TOP SECRET messages by teletype had been requested but not yet approved by the Commission by the end of the planning stage. Thus, only RESTRICTED, CONFIDENTIAL, and SECRET messages could be transmitted. To distinguish between AEA Restricted Data messages and non-AEA Restricted Data (Military Classified) messages, it was prescribed that AEA Restricted Data messages include in the text the statement "This is AEA Restricted Data".

(3) Coordination with Teletype Relay Centers

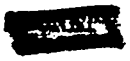
Starting early in December 1947, several visits were made to Los Alamos to discuss details of the message relay plan with Mr. Richard L. Kennedy, Chief of Communications, and Mr. James A. Sugden, Traffic Manager. Additional personnel for 24-hour operation had been hired and were being cleared. During initial operations many errors were anticipated because the new personnel had to be trained on-the-job by supervisors. It was decided that until the ships reached Eniwetok, all messages for Eniwetok or Sandpiper (Fort Shafter) would be sent to AEC Washington and passed by hand to the War Department for relay.

On 26 February 1948, Sixth Army teletype relay center at Presidio of San Francisco was visited. Coordination was effected with Colonel L. C. Parsons, Signal Officer, Sixth Army and his Relay Center Officer, Captain Robert E. Mills. It was decided that in the event the leased line from Los Alamos failed, Presidio would deliver SIGTOT messages by commercial TWX to Los Alamos. However, since Presidio did not have facilities for receiving tape on TWX, all outgoing messages from Los Alamos would be routed through Terminal Island Naval Shipyard teletype center where TWX facilities were available for receiving tape transmissions. Mr. Sugden, Traffic Manager at Los Alamos, was informed of this decision by telephone.

On 1 and 2 March 1948, Mr. L. A. Hopkins, en route to Eniwetok, visited 14th Naval District teletype center at Pearl Harbor and discussed the teletype message routing with Lieutenant Commander J. L. Bishop.

4. Technical Net

The so-called Technical Net, consisting of SCR-608 (10 channel voice) radio sets installed at the important stations within the



[redacted]

Task Force was, until 28 October 1947, considered to be the primary intra-Task Force voice communication system. On this date, the decision to install AN/TRC-1 radiotelephone equipment on the three main ships reduced the Technical Net to a "back-up" status. However, a conference with Colonel (later Brigadier General) P. T Cullen on 5 November 1947 concerning the communication requirements of the Photographic Group (IAJ-7) indicated that this group could best be served by inclusion of the photo towers in this net. The Technical Net was then planned as a primary photo communication network and as a back-up for the radiotelephone system. The final plan[2] called for the following stations:

a. AV-4 (Flag Office)
b. AV-5 (Flag Office)
c. AGC-7 (J-3 and Radiological Offices)
d. CVE-115 (Radiological Office)
e. LSM-250 and LSM-378 (Cable Ships)
f. LSD-19 (Boat Pool Base)
g. LCM (6) (Tank Control Boat)
h. Eniwetok
i. Parry
j. Zero Islands (Engebi, Aomon, and Runit)
k. Photo Towers (Aomon, Runit, Aniyaanii, and the Coral Head)

Each SCR-608 radio set has ten (10) pushbutton-controlled transmitting frequencies and twenty (20) pushbutton-controlled receiving frequencies (two receivers, each having ten channels). It was planned that each of the above stations be assigned to one of eleven (11) receiving frequencies. This frequency would be set up on both receivers and thereafter not changed. The transmitter would be set up on the remaining ten (10) frequencies. If, for example, Station A (assigned frequency No. 1) desired to communicate with Station B (assigned frequency No. 2), Station A would push the button on his transmitter corresponding to frequency No. 2 and call Station B. Station B, hearing Station A

[2]See footnote, page 7.

[redacted]

calling, would push the button on his transmitter corresponding to frequency No. 1, answer Station A and communication would be established. Other stations in the Tech Net could simultaneously carry on conversations on their assigned frequencies. Since eleven (11) frequencies were to be used for seventeen (17) stations, some limitations were inherent in the net. These were reduced to a minimum by assigning all photo towers, the two LSMs, and LCM (6) and Engebi, and Aomon and Runit to common frequencies. The photo towers and LSMs were to be able to transmit on their own receiving frequencies plus nine (9) other channels, thus providing communication between photo towers and between LSMs, but not between photo towers and LSMs. The LCM (6) and Engebi could not communicate directly, nor could Aomon and Runit. With these exceptions, all stations were to be able to communicate with all other stations in the Technical Net.

5. Radiological Net

The initial requirements for the Radiological Net were determined in a conference with Colonel J. P. Cooney of the JTF 7 Staff and Commander F. I. Winant of TG 7.6 on 6 November 1947. It was planned to employ twelve (12) Radiological Safety (Rad-Safe) parties after the shot to determine the radiological conditions on the Zero and nearby islands. These parties would also work in conjunction with the scientific parties returning to the Zero Island to collect data. It was decided to equip each Rad-Safe party with an SCR-300 walkie-talkie to maintain communication with their landing boats. The messages would be relayed from the boats by Navy-type TCS radio sets to the radiological centers on the AGC-7 and CVE-115. Two (2) special SCR-608 circuits were to be provided between the radiological centers, and Tech Net SCR-608s were to be installed in each center. In addition, communication was to be provided

between the radiological centers, helicopters, and a C-47 to be used for the initial radiological survey immediately following the shot.

6. Blast Net

On 4 November 1947, Dr. G. R. Hartmann of NOL stated a requirement for a clear frequency assignment of 150 to 160 megacycles to be used by six (6) blast telemetering equipments. On 14 November 1947, there was a discussion concerning the possibility of employing six (6) channels in the vicinity of 80 megacycles for the same purpose. This was discouraged because of possible mutual interference with the AN/TRC-1 radiotelephone equipment. On 20 November, after talking with Mr. P. E. Shafter of NOL, it was decided to allocate the band from 156 to 180 megacycles for blast telemetering with the understanding that the concentration would be effected in the high end of the band to avoid possible interference from the 100 to 156 megacycle VHF aircraft band. Due to an oversight, no consideration was given at this time to possible interference from the Mark III IFF equipment operating throughout the range of 157 to 187 megacycles.

On 16 December 1947, Dr. Hartmann requested two (2) SCR-300 walkie-talkie nets to aid in the installation and testing of his blast measuring equipment. One net was to have eight (8) SCR-300s and the other was to have thirteen (13).

7. Radiochemistry Net

The communication requirement of the Radiochemistry Group, LAJ-2, was worked out at several conferences with Dr. R. W. Spence and Dr. M. G. Bowman of Los Alamos and Colonel R. G. Butler of the Military Application Division of the Atomic Energy Commission. The first of these was held

with Colonel Butler on 14 November 1947. Briefly, this group planned to operate a radio-controlled tank on the shot island after the test. The tank was to be directed from a helicopter. A spare tank was to be carried in a specially fitted LCM (6). In case the helicopter failed, a second helicopter would be called into service from the CVE-115. If the control equipment also failed in the second helicopter, the tank could be controlled from the LCM where the operator could be voice directed from the helicopter. SCR-300 walkie-talkie communication was planned between the LCM and the party required to start the tank which was located on the Zero Island and protected by a revetment from the blast effects. VHF radio was to be used between the LCM, helicopters, and the CVE-115. The LCM was also to be equipped with an SCR-608 radio set in the technical net for general communication.

8. Neutron Net

The communications required by the Measurement of Neutrons Group, LAJ-3, to aid in the installation and collection of samples from their water and land cables were determined from discussions with Mr. G. A. Linenberger and Dr. W. E. Ogle commencing on 5 January 1948. At this time they planned to employ air-sea rescue boats (AVRs), helicopters, and one of the LSM cable ships during the collection operation. VHF radio communication was to be used between the AVRs, four (4) helicopters, LSM, CVE-115, and AV-5. Twelve (12) SCR-300s were to be provided for miscellaneous use.

9. Time Signal and Evacuation Net

The request for a voice time signal broadcast was received from Dr. Froman on 1 November 1947. The purpose of this broadcast was to inform all land stations, ships and aircraft of the exact time of the test. The original plan was to transmit the voice signals from the AGC-7 after they had

been relayed from the control station on Parry Island over the radiotelephone system. This was later changed to a direct HF broadcast from the control station for reliability considerations.

When it was learned on 15 January 1948 from Captain C. H. Duerfeldt, USN, of the Task Force J-3 Section, that two AVR air-sea rescue boats would be employed to evacuate the final personnel from the Zero Island, a communication circuit was requested between the two AVRs, the control station, and the AGC-7. This circuit was to use Navy-type TCS radio sets and would share one of the frequencies of the radiological net since the Rad-Safe personnel intended to use the AVRs in conjunction with their survey parties only after the test.

It was planned to provide communication to the final personnel on the Zero Island by connecting telephones at the top of the tower, base of the tower, and the timing station in parallel to an unattended AN/TRC-1 system working into the Eniwetok telephone switchboard. The communication equipment left on the island was to be expended at the time of the test.

B. Operation Stage

1. General

The communications supplied by Joint Task Force Seven for Operation Sandstone were, in general, considered excellent. Most of the requirements missed during the planning stage were provided as the need arose.

Many of these additional requirements could have been anticipated if more time had been available for planning. For example, the amount of radiotelephone traffic was underestimated by a factor of about two. The radioteletype AEC message traffic was overestimated by a factor of approximately ten. The following two sections describe in detail the radiotelephone and teletype systems

including statistics and analysis to enable the designers of some future, similar system to form a reasonable estimate of the volume of telephone and teletype traffic. Two major obstacles were overcome during the initial phase of the operation stage. Lack of previous experience by operators and maintenance men was eventually corrected by on-the-job training and special schools on AN/TRC-1 maintenance and teletype message procedure. Technical difficulties, primarily radio interference, were overcome by considerable additional planning and "out-and-try". The Radio-Intercom (MBF) system, not covered in the following sections, provided good service to the Test and the Scientific Directors, their staffs, and the JTF 7 General and Flag Officers. One additional station for Commander Winant of the Radiological Task Group on the CVE-115 was added to the net.

2. Telephone System

a. General

The telephone system provided excellent communication between the three main ships and the five main islands. It was considered the primary feature of the communications system. Due to underestimating the amount of traffic and some technical difficulties, circuits were many times busy or out of service. All personnel, civilian, Army, Navy, and Air Force, however, agreed that the operation was considerably expedited by the radiotelephone system. It is estimated that this system reduced the teletype traffic to and from the USS Albemarle alone by some two million words during the sixteen weeks of the operation. In future operations of this type, it is strongly recommended that radiotelephone service be provided between important ships and between ships and shore. Shore stations should be interconnected by telephone cables to reduce the interference which is practically inevitable in such a large installation.

One of the important arguments for increasing the length of the planning stage is to allow time for operator and maintenance man training on the new types of equipment that are to be used before the operation starts.

b. AN/TRC-1 Installation

(1) Circuits

Upon arrival of the ships at Eniwetok on 16 March 1948 the radiotelephone systems between the AGC-7 and Eniwetok were activated. It was immediately discovered that, although the ship and shore systems worked satisfactorily separately, the marriage of the two systems was hampered by frequency coordination and interference problems. The AV-5 proceeded immediately to anchorage off Engebi Island and was tied in to that island on one of the two systems previously used between Engebi and Eniwetok, when it was found that the 18½-mile range was too great for the normal AGC-7 to AV-5 circuit. When the AGC-7 and AV-4 moved to Engebi on 18 March 1948, the AGC-7 to AV-5 system was reestablished, but the AGC-7 to Eniwetok systems failed. These circuits were reestablished when the AGC-7 and Eniwetok installed vertically polarized beam antennas and used frequencies providing a minimum of interference. The attention of the Communications Section was soon directed to the large amount of telephone traffic between the AV's and Engebi (the first test island). Many of the calls were not getting through the AGC-7 (Washington exchange) and the Eniwetok (Garfield exchange) switchboards due to circuit congestion and technical difficulties. Therefore, direct circuits were requested from the AV-4 and the AV-5 to Engebi. One of the two systems between the two AV's was deactivated and, with an additional CF-1 Carrier Bay procured from the Army, an AN/TRC-1 system was established between the AV-5 and Engebi which provided two direct telephone channels between the switchboards. The AV-4 circuit was patched

around the AGC-7 and Eniwetok switchboards, thus providing one private AV-4 to Engebi circuit through three radio-relay systems. The final over-all radiotelephone system is shown on Figure No. 1. The AV-5 to Engebi system was discontinued at about 1300 on X minus 1 day. After the X-ray shot a system was established between the AV-5 and Aomon-Biijiri. The second set of AN/TRC-1 and CF-1 carrier equipment required at Aomon-Biijiri was one of those previously used at Eniwetok for the system to Engebi. The same procedure was followed for the Yoke and Zebra, AV-5 to Zero Island systems. After Zebra day, during the roll-up period, two channels were patched from the AV-5 through the AGC-7 to Eniwetok. One of these was patched through Eniwetok to Parry Island while the second terminated at the Eniwetok switchboard. One channel from the AV-4 was patched through the AGC-7 to Eniwetok. As the ships departed the lagoon on 21 May 1948, the AGC-7 to Eniwetok systems were deactivated and two circuits activated between each of the three ships. This system, similar to that used on the voyage to Eniwetok, continued in effect until arrival at Oakland, California. The special radiotelephone network used during the three critical periods is described in Paragraph 9, "X, Y, and Z-Day Communications".

(2) Technical Changes

Two important technical changes were made in the radiotelephone system after arrival at Eniwetok. One of these was the use of directional antennas between the AGC-7 and Eniwetok. Since the ship was constantly swinging at anchor, it was necessary to maintain a continuous watch to keep the ship's antennas pointing at Eniwetok some eighteen miles to the south. The second change was the substitution of CF-1 carrier equipment for the CF-7 equipment used on the system between the AV-4 and the AGC-7. In addition to the advantage of providing four channels as compared to the one channel provided

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by the CF-7, the CF-1 is considerably more adaptable to "line-up" when telephone and teletype are to be used on the same radio system. For future operations, all AN/TRC-1 systems should be installed with CF-1 carrier equipments. Either TH-1 or CF-2 teletype carrier systems may be employed in conjunction with the AN/TRC-1/CF-1 combination depending on whether one or four duplex teletype circuits are required. Due to the extensive use of the radiotelephone system on this operation, it is recommended that the Navy immediately undertake the development of equipment to provide radiotelephone service between major ships and with similar equipment now used or under development by the Army and Air Force. The ability, especially during joint operations, to pick up an office telephone and talk to the desired party, whether he is on another ship or at his office on shore, cannot be overemphasized.

c. Island Telephone Installation

An extensive field telephone installation was used by the Engineers on the Zero Islands during the construction phase. As soon as the ditches were dug for the instrumentation cables and general grading completed, the installation of the AEC telephone network was begun. Nearly all telephones were connected to the island switchboard by means of underground cable. It is believed that most of these underground telephone cables on the three Zero Islands will be useable for a future test. The only new requirements were two lines from the top to the base of the Zero tower to aid in operation of the hoists and the addition of a phone at the 600-ft. station. This phone was connected on a party line with the 400-ft. station. The final "Zero Island Communications" are shown on Figure No. 4. Four phones were provided at the timing station so that one or more could be set up on a patched-through circuit to Parry Island or to the other Zero Islands to provide communication for

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checking the underwater cables used for the time signals. This system was not used since Mr. Grier's group found that one of the submarine cable pairs could be used as a party line connecting the control station at Parry Island with the timing stations on all three Zero Islands, thus providing a private system for IAJ-12. If periodic tests are to be conducted at Eniwetok Atoll, it is recommended that underwater telephone cables be laid between the important islands. Radiotelephone equipment would then be used to provide communication between ships, between ships and shore, and to "back-up" the underwater cable system. A high-powered public address system would have been very useful on the test islands to page persons receiving outside telephone calls.

d. Ship Telephone Installation

The automatic dial systems on the three primary ships gave very satisfactory service during this operation. The primary bottleneck for the entire telephone system was the manual switchboards on the AV-4, AV-5, and the AGC-7. The number of telephone channels between ships and between ships and shore was limited by the number of outside line drops on these switchboards. As was mentioned previously, the AV's had four drops and the AGC-7 ten. Normally the Navy uses the manual switchboards only when the ships are alongside a pier, tying the switchboard to the shore station telephone system by means of a cable connection to the nearest available telephone junction box on shore. The AGC-7 system consisted of three separate switchboards, the original four-drop board, plus six-drop and two-drop boards installed at Terminal Island. Each line from the automatic exchange to the manual board had a separate number; ten numbers were listed for the switchboard on the AGC-7 and four numbers on the two AV's. Thus, if one number was busy, a second number was dialed, etc. On the AGC-7 different numbers were required to be dialed to place a call to

the island exchanges and to the AV exchanges corresponding to the switchboard to which the exchanges were connected. In order to relay a call from one of the AV's to Eniwetok, it was necessary for the operator to receive the call on one switchboard, dial one of the numbers connected through the automatic exchange to the switchboard corresponding to the Eniwetok radio channels, and finally place the call to the desired location. In addition, considerable trouble was encountered with the ringing system since the EE-101 ringers used in conjunction with the AN/TRC-1 system were not designed to be employed with the ships' switchboards. This meant that the operators at times had considerable difficulty contacting the desired exchange even though the radio systems were functioning perfectly. The AGC-7 and AV-5 switchboards used a complicated toggle-switch system rather than the normal cord circuits found on most telephone switchboards. This method is not considered satisfactory when a large amount of traffic is to be handled as on this operation. If the AV-4 and the AV-5 are to be used on future tests of this sort or on tactical missions involving good communications with a shore installation, it is strongly recommended that the present switchboards be replaced with modern manual boards having approximately twelve cord circuits, twelve outside lines capable of being connected to the radiotelephone system, and at least thirteen lines (one more than the number of outside lines) to the ship's automatic exchange. These lines should terminate on a "line-finder" system in the automatic exchange so that only one number must be dialed for a ship's phone to be connected to any of the lines to the manual switchboard. The exact number of lines to be installed should be determined by the nature of the operation and the characteristics of available equipment. With trained operators, the extra

line to the ship's exchange could be used to accept requests for calls to be placed as soon as an outside line to the desired location becomes available.

e. Telephone Traffic Analysis

Throughout the entire operation the telephone switchboard operators on the three ships were required to keep a traffic log. This log listed each call by hour with the origin and destination exchanges and whether the call was completed, line busy or out, or no answer. The data were analyzed for the two AVs for the period 20 April through 3 May 1948. Figure No. 2 shows the "Radiotelephone Calls Per Day" for the two ships. The number indicated is the sum of the incoming and outgoing calls which were divided almost equally. During the two weeks, the AV-5 handled 1,850 calls and the AV-4 1,418. This averages 132 calls per day for the AV-5 and 101 calls per day for the AV-4. If it can be assumed that each call corresponds to two messages and each message contains approximately 100 words, the radiotelephone system reduced the amount of message traffic handled by the AV-5 by 26,400 words per day or an estimated two million words for the sixteen weeks of the operation. Proportionally, the telephone system reduced the AV-4 traffic by approximately one million five hundred thousand words. The ratios of peak calls per day to average and minimum to average for the AV-5 were respectively 1.24 and 0.67. Corresponding figures for the AV-4 were 1.42 and 0.43. Figure No. 3 indicates the relation between the "Average Radiotelephone Calls Per Hour", and local time for the two ships. As would be expected, the traffic peaks occur from 0800 to 1100 in the morning and at about 1300 to 1400 in the afternoon. The peaks rise to approximately 11% of the total calls per day or to about 15 calls per hour for the AV-5 and 11 for the AV-4. It was during these peak periods that most of the outside lines were reported as busy to persons attempting to place calls off the ship. During the

two weeks studied, the AV-5 had 81 outgoing line busy reports or 8.3% of the total of outgoing calls. The worst condition occurred between 1000 and 1100 on 2 May 1948, when 12 calls were placed during the hour and 11 calls were turned down because the desired lines were busy. This was the exception rather than the rule, since the largest number of "line-busys" during any other hourly period was two. In one case, 14 outgoing calls were handled during the hour with no reports of "line-busy". Correspondingly, the AV-4 operators reported only 2.5% of the outgoing calls as "line-busy". From these data, during the two-week period, it appears that the AV-4 had satisfactory radiotelephone service. During peak traffic hours on the AV-5, extra outgoing circuits would have been valuable. In an operation of this sort some compromise must be made between designing the system for the peak or for the average load. Extremely well-trained operators could have alleviated the situation by taking orders for calls to be placed when a line was available, similar to the system used by the telephone company. Also, a control system could have been instituted where authority was required from some designated official before the operator would be allowed to place the call. This latter system would have reduced the number of unnecessary calls but it is not recommended except when more severe circuit congestion exists than occurred on this operation.

A study was made during the week of 20-26 April 1948 to determine the destination and origin of calls handled by the AV-4. This study is summarized below:

Per Cent	To		From	Per Cent
36.9	122	USS Albemarle	118	34.7
41.3	137	USS Mt. McKinley	146	42.8
9.7	32	Eniwetok	21	6.3
0.9	3	Runit	0	0.0
10.9	36	Aomon-Biijiri*	55	16.2
0.3	1	Parry	0	0.0

*Next test island.

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Similar data should have been analyzed early in the operation to determine the need for special circuits.

3. Teletype System

a. Circuits and Installations

Teletype communication by commercial TWX from Los Alamos to the AGC-7 at Terminal Island was quite satisfactory. This circuit was entirely land-line.

On 29 February 1948, the AGC-7 and AV-4 sailed for Pearl Harbor; the AV-5 and Bairoko (CVE-115) followed on 1 March. Radioteletype communication with Pearl Harbor (BHP) was established by the AGC-7 according to plan; VHF radioteletype communication was established between AGC-7 and AV-4 and HF radioteletype communication between AGC-7 and AV-5. Los Alamos was notified in advance the exact time to change routing indicators.

On 1 March the leased line from Los Alamos to Presidio of San Francisco was activated.

Messages were satisfactorily routed to the ships at sea in accordance with the teletype routing plan. However, SIGTOT scrambled tapes were received so badly garbled they could not be decrypted. A "round-robin" test message sent from the AGC-7 to Pearl Harbor to Fort Shafter to Presidio via ACAN to 12th Naval District San Francisco, to Pearl Harbor via Navy circuit and back to AGC-7 indicated that garbles were apparently occurring in the Navy or Army "long haul" circuit from Hawaii to San Francisco. Since the Army has used SIGTOT over its ACAN circuit for some time and since the Navy does not use SIGTOT, it was suspected that the difficulty lay in the Navy circuit. Presidio relay center was, therefore, requested to route all Los Alamos traffic over ACAN to Fort Shafter for relay. This immediately cleared up much of the garbling.

It was later learned at a conference with the Communication Office of 14th Naval District at Pearl Harbor that the Navy circuit, Hawaii-San Francisco, was a multiplex circuit and did not transmit spaces. For this reason all SIGTOT scrambled tapes were garbled.

On arrival at Eniwetok the AV-5 anchored off Engebi and the AGC-7 and AV-4 anchored off Eniwetok, about 18½ miles from the AV-5 (see Figure No. 6). At this distance the AN/TRC-1 VHF circuits went out and HF had to be used to maintain contact between the AGC-7 and AV-5. Also, when the AGC-7 and AV-4 moved to a position off Engebi, AN/TRC-1 VHF communication between the AGC-7 and Eniwetok went out. VHF communication was re-established when a vertically polarized directional antenna array was installed on the AGC-7 and beamed at Eniwetok.

Due to the constantly changing position of ships at sea relative to each other, it was necessary that AN/TRC-1 antennas be nondirectional. For this reason vertical single element antennas were installed on the three ships. On the AGC-7 and AV-4, in particular, the AN/TRC-1 transmitting and receiving antennas did not have sufficient separation to prevent considerable interference. This made it necessary to keep gain levels quite low. When the ships were within three or four miles of each other, signal strength was great enough for satisfactory communication at low gain levels; however, when the ships were separated by greater distances, the signal-to-noise ratio decreased to the point where teletype reception failed completely. Only by installation of directional arrays, when ships were at anchor, and by separating receiving and transmitting antennas, was it possible to maintain satisfactory AN/TRC-1 communication over distances as great as 18 miles.

To provide for some flexibility in use of SIGTOT equipment and associated teletype equipment, the Bureau of Ships had connected the various equipments into patch panel located in the SIGTOT code room and Radio I on all three ships. This installation permitted either on-line or off-line operation and some flexibility in the use of equipment. However, the patch panels proved to be poorly constructed and caused a great deal of trouble. In several instances mistakes in wiring were encountered such as reversed polarity on patch panel jacks, etc. Also the wiring was so complicated that much unnecessary delay was experienced in setting up circuits. This was especially true on the AGC-7. The experiences of this operation indicated that SIGTOT code rooms should operate off-line for all message traffic and on-line only for teletype conferences.

b. Cryptographic Systems

(1) SIGTOT (one-time-tape system)

(a) Procedure

Navy officers who were to function as SIGTOT coding officers on the three ships had not received previous training in SIGTOT procedures before reporting for duty. Furthermore, clearances were not received for many until after the sailing date. This made it necessary for properly cleared officers of JTF 7 Communication Staff on the AGC-7 and the Communication Officers on the AV-4 and AV-5 to do the work of the SIGTOT Officers until their clearances were received. It also delayed on-the-job training of these officers. Many of the early difficulties experienced with SIGTOT would not have occurred if all SIGTOT officers could have been sent through a joint school to learn the details of message encryption, proper message procedure, and methods of breaking garbles.

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(b) SIGTOT Conferences

Several test and two actual SIGTOT conferences were conducted between ships en route. None of these conferences could be considered completely successful because of circuit difficulties and garbling. The AEC SIGTOT instruction book contained no procedure for conferences, and since no personnel aboard had had previous SIGTOT training or experience, a non-standard procedure had to be devised. Later the Army SIGTOT Instruction Book, SIGSAP-3, which contained the procedure for two-way conferences, was obtained from JTF 7 Army Security Agent Representative. But the two-way conference procedure was not entirely adaptable to a three-way conference. After arrival at Eniwetok no further SIGTOT conferences were conducted between ships since it was quite simple to assemble personnel for conferences on one of the ships.

(c) Garbles

The SIGTOT cryptographic system is an electrical (teletype) system of random substitution. In encrypting a message, impulses from a transmitting key tape are mixed with impulses from the clear text characters to produce a scrambled tape. In decrypting the scrambled tape, impulses from its characters are mixed with impulses from an identical receiving key tape to produce the original clear text letters or characters. If, in the process of relaying the scrambled tape from originator's teletype center to addressee's teletype center, characters are lost or gained or individual characters are changed, the message becomes garbled; that is, it cannot be decrypted automatically so that it exactly reproduces the original clear text.

During the early stages of the operation phase, circuit conditions and equipment adjustment were not sufficiently reliable to prevent excessive garbling. Over 50% of both outgoing and incoming AEC SIGTOT

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messages were garbled seriously. Single-letter garbles usually resulted only in misspelled words and seldom required a message rerun. Messages containing garbles caused by the loss or gain of ten or less characters could usually be broken in an hour or two. Messages so badly garbled they could not be decrypted required that a service message be sent, requesting retransmission of the scrambled tape (rerun) by one or more relay points, or re-encryption of the originating station. This caused delays of from several hours to two or three days.

In an effort to determine the source of garbling, Los Alamos Traffic Manager sent test scrambled tape messages to the relay stations and AV-4 and AV-5, with instructions to return the scrambled tape. The results of these tests were rather inconclusive but indicated that fewer garbles were occurring between Fort Shafter and Los Alamos than in the forward area circuits and teletype centers.

For a period of one week 6-13 April, scrambled tapes transmitted by the AV-5 to Los Alamos and received by AV-5 from Los Alamos were collected and compared with the tapes as received by AGC-7 and the Joint Relay Station at Eniwetok. This comparison indicated that about 20% of the outgoing SIGTOT messages from the AV-5 to Los Alamos were garbled when received by Eniwetok; however, only 5% were garbled beyond decryption. About an equal percentage of incoming messages were garbled between Eniwetok and the AV-5 but only 3% beyond decryption. This information was submitted to Communication Officer JTF 7 with a request that greater efforts be made to improve reliability of local radioteletype circuits.

During the week 2-8 May, of the 61 messages received by AV-4, AV-5, and AGC-7 from Los Alamos, only one was garbled beyond

decryption. Improved circuits and experience of SIGTOT officers had greatly decreased the difficulty with garbles in comparison with the difficulties at the beginning of the operation phase.

AEC SIGTOT tape segment usage (see Figures 8, 10, and 11) was considerably less than anticipated. The USS Albemarle (AV-5) was the greatest consumer but used only slightly more than 10% of the tapes ordered for use with Los Alamos.

(2) SIGABA (Navy ECM)

SIGABA is an electrical cryptographic machine used by the Army, Navy, and Air Forces for encryption of messages classified as high as TOP SECRET. On 24 March 1948, a request was submitted to Communication Officer JTF 7 to provide Los Alamos with SIGABA and joint systems. Since Los Alamos held no joint cryptographic system, it had to send all classified messages addressed to Sandpiper (JTF 7 Headquarters at Fort Shafter, Hawaii) or Eniwetok (when ships were not there) back to AEC Washington to be passed by hand to the War Department for encryption and relay. This caused considerable delay in delivery of such messages and could have been avoided if Los Alamos had been equipped with SIGABA and joint systems. SIGABA was to be used only for encryption of non-AEA Restricted Data messages. At the time of writing this report no answer had been received to this request.

Since SIGABA messages are encrypted into five letter groups, it is much simpler for a teletypewriter operator to determine when and where a garble occurs than in a SIGTOT scrambled tape. Consequently, he can ask for the necessary correction (Rerun) immediately, whereas, with SIGTOT scrambled tape, garbles often cannot be detected until an effort is made to decrypt the message. Also, SIGABA messages are less easily garbled to the

extent that the message cannot be decrypted. For these reasons it is recommended that in any future operation SIGABA and joint systems be furnished Los Alamos for use as mentioned above and as a back-up for SIGTOT.

(3) SIGPIE (one-time-pad system)

On 31 March, AEC issued GM 74 which approved the use of SIGPIE for the encryption of TOP SECRET Restricted Data messages to be transmitted by teletype to and from the forward area. In accordance with this authority SIGPIE systems were furnished to the Test Director (CTG 7.1) on the AV-5 for use in sending such messages to Los Alamos and AEC, Washington. Systems were also furnished the AGC-7 and AV-4 but no requirement for their use was seen since all such messages had to be authenticated by CTG 7.1. These systems were returned.

c. Teletype Procedure

(1) Message Heading Procedure

Los Alamos teletype center experienced considerable difficulty with teletype procedure because it was required to use both the Joint Army-Navy-Air Force Procedure (Joint Tape Relay Procedure, JANP 127) and AEC procedure. The AEC procedure is designed for TWX use where direct connection is made between the originating station and addressee station; consequently, no external heading in clear text other than the cryptographic heading is used. Only an internal heading (encrypted) is used by AEC. On the other hand JANP 127 prescribes the use of an external heading employing routing indicators. No internal heading procedure is prescribed in JANP 127 since all the necessary routing instructions are contained in the external heading. This made it necessary for Los Alamos SIGTOT code room personnel to change all message headings in relaying messages from AEC channels to military channels and vice versa.

An attempt was made to decrease the work of Los Alamos by having the ships use both an external and internal heading. This also was confusing since it required the ships to use one heading procedure for messages to Los Alamos and another for messages to military addressees. No completely satisfactory solution to this problem was found during the period of Operation Sandstone. However, in any operation such as this where different procedures are used, it is apparent that a transition point, such as Los Alamos, must exist and must have personnel trained in both procedures so they can easily and efficiently make the necessary changes from one procedure to the other.

(2) GM 74

When GM 74 became effective on 31 March, it was apparent that its provisions pertaining to CONFIDENTIAL and SECRET messages other than Restricted Data messages (Parts I and II) could not be applied to JTF 7, and the instructions regarding TOP SECRET military non-AEA Restricted Data messages (Part III) could be followed by only TG 7.1. Authority was obtained from AEC (Mr. Del Genio) by Mr. W. Moran (AEC Security Representative on JTF 7 Staff) for JTF 7 to ignore those provisions of GM 74 which were in conflict with the military procedures for handling military classified messages. Restricted Data messages and TOP SECRET military messages addressed to AEC addressees were handled by TG 7.1 in accordance with GM 74.

GM 74 makes no distinction between AEA Restricted Data messages and non-AEA Restricted Data messages except in the classification of TOP SECRET. The Security Annex to JTF 7 Field Order No. 1 specifies, in effect, that all Restricted Data messages will contain the statement "This is AEA Restricted Data" in the text of the message. For joint operations such as Operation Sandstone it is important that GM 74 specify that all Restricted Data messages be designated as such so the military can handle such messages in accordance with AEC Security instructions.

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d. Teletype Traffic Analysis (see Figures 7 to 14 incl.)

(1) Message Traffic

Figures 7 and 9 show the number of words per week (of SIGTOT messages) sent between the ships and Los Alamos during the period 15 February to 15 May 1948. This does not include clear text messages which were estimated to be less than 10 to 15% of the total traffic. The incoming and outgoing word count was very closely balanced with 58,937 words sent from Los Alamos to the ships and 59,059 words originated on the ships for Los Alamos during this period. The peak of the incoming traffic load was about 7,600 words per week and occurred in the week of 18-24 April 1948. The outgoing peak was approximately 7,500 words per week during the period 25 April to 1 May 1948. The AV-5 handled about twice the AEC traffic of the AV-4 and AGC-7 together. The latter two ships' AEC traffic load was approximately equal.

Figures 8 and 10 show the weekly consumption of SIGTOT tape segments corresponding to the word count statistics of Figures 7 and 9. Each roll of SIGTOT tape contains 10,000 Baudot (teletype) characters and is divided into 30 segments, thus each tape segment contains about 333 characters. A summary of the SIGTOT tape segment usage is shown below:

TAPE SEGMENT USAGE WITH LOS ALAMOS

		Ordered Tapes	Ordered Segments	Segments Used*	Per Cent Used
AV-4	Transmitting	400	12,000	234	1.95
AV-4	Receiving	400	12,000	282	2.35
AV-5	Transmitting	400	12,000	1,172	9.78
AV-5	Receiving	400	12,000	1,180	9.83
AGC-7	Transmitting	200	6,000	296	4.93
AGC-7	Receiving	200	6,000	210	3.50

*15 February through 15 May 1948.

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This information can be used in conjunction with the word count data to determine the average number of text words per tape segment. The AV-5 statistics indicate that approximately 33 text words per SIGTOT tape segment can be used as a basis for ordering SIGTOT tapes when planning future operations of this type. This figure includes coded addresses and tape segments accidently destroyed as well as the unused portions of the individual segments.

Figure No. 11 illustrates the SIGTOT tape segment usage between ships. Most of these segments were used during the week of 7-13 March 1948, for the teletype test and actual conferences while the ships were en route to Eniwetok. Since no such conferences were conducted thereafter, only a very small fraction of the tapes on hand were used. The small amount of traffic between ships was due to the extensive use of the radiotelephone system, the Guard Mail system, and the readily available boat transportation.

Figure No. 12 shows the word count per week of incoming and outgoing traffic handled by Los Alamos. During the period 29 February to 15 May 1948, 885 messages with 94,853 words of outgoing and 817 messages with 93,105 words of incoming traffic passed through the Los Alamos teletype center. Each message averaged about 110 words. From 21 April to 17 May 1948, Los Alamos handled 11 incoming and 9 outgoing messages to Mr. Grier's home office in Cambridge, Massachusetts. During the period 1 March to 15 May 1948, 252 messages were sent to and 235 messages were received from AEC, Washington. Also, 40 messages were sent to Sandia Base and 27 messages received from Sandia Base during this period.

(2) Relay Time

Figures 13 and 14 show the distribution of the time required to relay messages between the ships and Los Alamos. The relay time

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plotted is the difference between the message Date Time Group (DTG) and the time the coded message was received by the teletype operator at the addressee station. Figure No. 13, based on 295 messages sent from Los Alamos to the ships during the period 17 March to 2 May 1948, shows that half of the Routine SIGTOT messages were received in less than 3½ hours. Half of the Priority messages and half of the Operational Priority messages arrived in less than 3 hours and 2½ hours respectively. Figure No. 14, based on 127 messages sent from the ships to Los Alamos during the period 21 April to 17 May 1948, shows that the relay time mode for Routine messages occurred between 2½ and 3 hours, while the mode for Priority messages occurred between 2 and 2½ hours. The three Operational Priority messages sent during this period arrived at Los Alamos between 1 and 1½ hours after the Date Time Group was assigned to the messages on the ships. The data indicate that messages were relayed to Los Alamos in approximately one-half hour less time than that required for messages sent to the forward area. The only projected explanation for this is that the date for the relay time to Los Alamos was analyzed only during the last four weeks of the operation and may represent an improvement in the over-all operation of the teletype message relay system.

(3) Leased Line Traffic

The leased line from the Presidio of San Francisco to Los Alamos was in service from 1 March 1948 until the ships returned to the United States at Oakland, California on 4 June 1948. The cost of this facility was quoted as $1,601.13 per month with a $30.00 nonrecurring installation charge. There was no termination charge. Thus, the total cost of this service was approximately $5,100. During the period 1 March to 15 May 1948, approximately 120,000 words were relayed over this line. The cost per word is estimated at

[redacted]

about three cents (3¢) as compared to an estimated TWX cost of one cent (1¢) per word. The line was out of service a total of about 24 hours or less than 1% of the time. The employment of this leased line is believed to be justified by the reliability as well as time-saving advantages over normal TWX service.

4. Technical Net

The stations in the so-called Technical Net are indicated on Figure No. 15. The equipment installations on the ships were completed and tested before the convoy departed for Eniwetok. Upon arrival of the Task Force, the shore and LCM (6) Tank Control Boat stations were installed with SCR-608 radio sets provided by the Navy. The original 11 channel plan soon proved to be unworkable due to mutual interference with the 10 meter amateur band and other services. A four channel system was instituted as follows:

Channel No.	Frequency	Stations
1	27.6	AGC-7, AV-4, AV-5, CVE-115
2	27.9	Engebi, Aomon, Runit, LCM (6)
3	30.1	LSM 250 & 378, Eniwetok, LSD-19
4	30.4	All photo towers, Parry

The Tech Net was extensively used, primarily by the Photographic Group, but also by personnel in the AVs' Staff Offices. In many cases when the radiotelephone system was busy or out of service, communication was successful over this facility. Considerable interference resulted from the operation of this net. It was most noticeable as third harmonic radiation into the 70 to 100 Mcs radiotelephone band. It is recommended that on future operations a similar net be planned but using different equipment, preferably on higher frequencies than those used for this operation. Forty to fifty Mcs is worthy of consideration since it was found that SCR-300 walkie-talkies, with about one-half watt

transmitters with the employment of high antennas operating in this range would provide fairly reliable communication throughout the lagoon.

5. Radiological Net

The Radiological Net illustrated on Figure No. 16 gave very reliable service during the operation. Extensive communication was carried out between the radiological centers on the AGC-7 and CVE-115 since the CVE-115 was not included in the radiotelephone net. Additional TCS radio sets were installed in landing boats which preceded the ships returning towards the Test Island after the shot and also in a protected enclosure near the tank dugout to provide direct communication between the radiological personnel returning to the Test Island and the two radiological centers.

6. Blast Net

The SCR-300 walkie-talkie radio sets allocated to the Blast Group were primarily used to provide communication between the Zero Island and the blast telemetering station on Parry Island to aid in lining up the telemetering transmitters and receivers. As was briefly mentioned under the planning stage, no consideration was given to possible interference from the Armed Forces' IFF equipment with the 156 to 180 Mcs telemetering band. Arrangements were made for all unused IFF equipment and all jamming transmitters to be sealed for the duration of the operation. All IFF equipment in use was turned off from minus 30 minutes to plus 5 minutes. No known interference was received from this source. On the night of X minus 1, the telemetering station reported strong interference on one of the six frequencies. The interfering transmitter was identified as an AN/TRC-1 on the AV-5 operating on 84 Mcs. This transmitter, which provided radiotelephone communication with the AV-4 was silenced on X minus 1, X, Y minus 1, Y, Z minus 1, and Z days, and no further interference was reported.

[redacted]

7. Radiochemistry Net

The communications used by the Radiochemistry Group, LAJ-2, differed only slightly from the original plan described in Section III, Paragraph 7, in that a small boat was not required to ferry personnel ashore from the LCM (6) since the landing craft could beach directly on the Zero Island. The system as used is illustrated on Figure No. 17.

8. Neutron Net

The Measurement of Neutrons Group, LAJ-3, used essentially the system discussed previously in Section III, Paragraph 8, and shown on Figure No. 18. The use of the LSM cable ships was eliminated from the operation since collection of the water cable samples could be made by small boats. Direct walkie-talkie communication was provided between the small boats used during the sample installation operation and the AV-5.

9. X, Y, and Z-Day Communications

The special communications set up for the critical times are illustrated on Figure No. 19. The facilities may be divided into five categories:

(1) Three-way radiotelephone
(2) Time signals broadcast
(3) AVR communications
(4) SCR-300 net
(5) Normal communication system

a. Three-Way Radiotelephone

This system was activated at about 1330 on D minus 1 and continued in use until about 0900 on D day. It consisted essentially of AN/TRC-1 systems at the Zero Island, AGC-7, and Parry Island all connected to a patch or control board at the VHF building on Eniwetok. When the AV-5 secured its Zero Island radiotelephone system at about 1300 on D minus 1, the Zero Island

[redacted]

AN/TRC-1 with associated CF-1 carrier equipment was set up in a system with Eniwetok, thus making a total of two Zero Island to Eniwetok systems. Normal telephone service was maintained on the Zero Island until the last personnel left the island at 0200 on D day. At Eniwetok, one channel from each of these systems was connected to drops on a BD-72 switchboard. Also connected to this control board were one channel from each of the two Eniwetok to AGC-7 systems, one channel from each of the two Eniwetok to Parry Island systems, one of the two Eniwetok to Parry Island control station submarine cables, and one line to the main Eniwetok switchboard. The control board operator was responsible for patching in any desired two- or three-way circuits and for testing all circuits every half hour. On the flag bridge of the AGC-7 (headquarters of the Test and Scientific Directors on D minus 1 and D days) were located two EE-8A telephones connected directly to the two special circuits to the Eniwetok control board. These channels were, of course, disconnected from the AGC-7 ship switchboard. At the Parry Island control station, three lines were provided to the Parry Island telephone switchboard, and two submarine cables to Eniwetok. One of these went directly to the Eniwetok control board for use if the two AN/TRC-1 circuits should become noisy or fail. The second cable circuit was used to provide timing signals for the Fitzwilliam Project personnel operating special CW transmitters at Eniwetok. Normal telephone service was maintained continuously on Parry Island except that the two special channels to the Eniwetok control board were reserved exclusively for the use of the control station personnel. The duplication of these and the other facilities was required to insure reliable communications during the critical periods since the Scientific Director stated that the test would be postponed if vital communications should fail. At about H hour minus 30 minutes, the best AGC-7 to Eniwetok and Eniwetok

to Parry circuits were chosen and the corresponding EE-8A telephone on the flag bridge was moved to the location chosen by the Test and Scientific Directors for their viewing point. From this time until about H plus 15 minutes a continuous circuit was maintained to the Parry Island control station. Ringing was not necessary since both phones were guarded continuously during this period. At the time of the shot, the communications equipment which was left on the Zero Island was expended. All equipment on the X-ray test was destroyed. Some of the equipment was salvaged on the Yoke test where the communications building was more distant from the Zero tower, and was used on Runit for the Zebra test.

b. Time Signals Broadcast

Voice Time Signals were broadcasted from the Parry Island control station on JTF 7 Channel No. 707 (3,000 kc). They were transmitted at minus one hour, at minus thirty, ten, and one minutes, and at minus thirty, twenty, and ten seconds. A test broadcast was made preceding the minus one hour signal to allow time for final adjustment of all receivers. This test was acknowledged from the AGC-7 flag bridge on Channel No. 718D. Two SCR-543 radio sets were installed on the roof of the control station. One antenna was used with a double throw switch to allow rapid transfer to the second transmitter if the primary transmitter had failed. The signals were voice relayed by VHF at the combat information center on the AGC-7. The broadcasts were monitored on all ships and aircraft. Arrangements were made so that if either the AGC-7 or the Fitzwilliam personnel on Eniwetok observed any attempt to jam the signals, the control station would be immediately notified and would make simultaneous broadcasts on Channels No. 707 and 718D (3,000 and 5,545 kc).

c. AVR Communications

Three radio channels were provided from the flag bridge of the AGC-7 to the two air-sea rescue boats (AVRs) used to evacuate the final personnel from the Zero Island. Two of these, Channels No. 718C and 718D on 5,205 and 5,545 kc, were controlled from remote position units (RPUs) with monitoring speakers on the AGC-7. Two Navy type TCS radios were used on these channels on each of the AVRs. The third channel was provided by SCR-300 walkie-talkie radio sets operating on Channel No. 415F (47.0 mc). During the final high speed night AVR run from the Zero Island to Parry Island along a course marked by lighted buoys, position reports were made to the flag bridge simultaneously on 5,545 kc and 47.0 mc. These duplicate facilities were installed after communications failed on PX day morning when the TCS receiver on one of the AVRs was accidently detuned when one of the party was thrown against the set during the high speed run. All communications equipment aboard the AVRs was thoroughly checked under operating conditions two or three days before each test. This final AVR run was the most critical time for the communications system during the entire operation. Two TCS sets were installed inside the control station to provide emergency communication with the AGC-7 flag bridge on 5,545 and 5,205 kc in case the radiotelephone system failed. With the single exception of the AVR incident on PX day, all D minus 1 and D day communications were excellent.

d. SCR-300 Net

In addition to the SCR-300s used between the AVRs and the AGC-7 flag bridge, these sets were also employed between the AVRs and the LCVPs used before and after the test to transport personnel between the AVRs and the Zero Island. During the final preparation for the Engebi and Aomon tests the

[redacted]

AVRs could not dock at the island. Consequently, one of the SCR-300s was employed to communicate with the AVRs from the beach. Flashlight signals were used to indicate that communication was desired. This walkie-talkie system also provided emergency communications between the Zero Island and the AGC-7 by relaying messages through the AVRs in the event that the radiotelephone system failed. Since, when not actually under way, the AVR radios were secured to save battery power, it was possible to re-establish communications to the AGC-7, as was required in one case, by calling by radiotelephone from the AGC-7 to the Zero Island beach, attracting the attention of the AVR by flashlight, and then directing the AVR by SCR-300 from the beach to guard the 5,545 kc channel to the AGC-7

e. Normal Communication System

Insofar as was possible, normal communications were maintained on D minus 1 and D days between all manned locations. Communications to the photo towers and the unused Zero Islands were secured as the last personnel were evacuated. The SCR-608 technical net radio set on the Test Island was maintained in operation for emergency use and was expended at the time of the shot. However, use of the technical net during the critical periods was reduced to a minimum to avoid unnecessary interference with other systems, particularly with the radiotelephone. As was mentioned previously, the AV-4 to AV-5 radiotelephone system was secured to prevent interference with the blast telemetering equipment. Telephone service between the two ships was provided by relay through the AGC-7. The ship's telephone on the AGC-7 flag bridge was extensively used by the Test and Scientific Directors to receive final status reports on the various experiments and to report the progress of the final preparations, in code, to personnel on the AVs.

[redacted]

f. Comments

A considerable quantity of communications equipment was destroyed on the Test Island at the time of the shot. Two complete AN/TRC-1 systems with CF-1 carrier bays, a SCR-608, several BD-72 telephone switchboards, and many EE-8A telephones were expended. Although this equipment had been in constant use for several months under severe tropical conditions, it could have been reconditioned. The only justification for this expenditure was the requirement for extremely reliable flexible communications during the critical period. It is recommended that for future tests consideration be given to the installation of submarine telephone cables to provide communication between the islands during critical as well as normal periods. Some care in the location and protection of the cables and terminals should be taken so that the cables could be reused on later tests. This method would eliminate the use of radio equipment on the Test Island, except possibly walkie-talkies to the evacuation boats. More detailed planning by both scientific and communications personnel could reduce to a minimum the amount of communications equipment expended.

IV. CONCLUSIONS

A. Pertaining to the Planning Stage

1. The four-month period allowed for planning is not sufficient for operations of this magnitude when the time required for clearance of personnel as well as operation and maintenance training is included.

2. The quantity of radiotelephone traffic was underestimated by a factor of about two and the amount of teletype traffic was overestimated by a factor of about ten.

[redacted]

3. The plan for routing of AEC teletype messages via military tape relay centers and over the leased line between Los Alamos and the Presidio proved to be satisfactory. The principle of a common relay point (Los Alamos) for AEC messages in the United States was most important.

4. The cryptographic plan should have included SIGABA and joint systems for Los Alamos to be used for handling non-AEA Restricted Data messages. Also, SIGTOT systems should have been provided between Los Alamos and Eniwetok and Los Alamos and Fort Shafter.

5. A definite plan for overcoming the differences between Army, Navy, and AEC message handling procedures should have been formulated during this stage.

6. In general, the over-all communication facility planning was excellent.

B. Pertaining to the Operation Stage

1. The radiotelephone system used on this operation provided good service between the three main ships and the island installations. Although technical difficulties were encountered and the circuits were congested many times by the large amount of traffic, the use of this system tended to aid and expedite the operation more than any other communication facility.

2. The telephone switchboards employed on the AV-4, AV-5, and the AGC-7 were unsatisfactory from both operational and capacity standpoints.

3. The radiotelephone system reduced the amount of message traffic handled by the AV 4 and the AV-5 by an estimated 1.5 and 2.0 million words respectively during the course of the operation.

4. The island telephone installations and the automatic exchanges on the ships gave satisfactory service.

[redacted]

[redacted]

5. The volume of teletype message traffic over the leased line between Los Alamos and the Presidio was about one tenth of that expected and amounted to about 20 messages totaling 2,200 words per day. However, the cost of this service was justified by reliability and time-saving considerations.

6. Garbles occurring during the transmission of AEC messages encrypted in the SIGTOT system caused considerable delay in the delivery of messages in the early stages of this operation. The decrease in the number of garbles as the operation progressed indicates that SIGTOT can be used over well engineered, short range VHF and HF ship-shore and ship-ship systems and over long range shore-based systems if well trained SIGTOT personnel are employed. The use of this encryption system over long range HF ship-shore circuits was not considered entirely satisfactory.

7. The procedures specified in GM 74 for maintaining the security of AEC messages could not be complied with on this operation except in the case of AEA Restricted Data and TOP SECRET messages.

8. The special communication facilities provided for several of the scientific Measurement Groups gave satisfactory service.

9. The duplication of the facilities used for X, Y, and Z-day communications and the expenditure of a large quantity of communications equipment on the Zero Island at the time of the test was justified only by the requirement for extremely reliable communications during the critical periods. No communication failures were experienced on test days.

V. RECOMMENDATIONS

A. Six to eight months should be allowed for communication planning in similar operations. The additional time should result in better system engineering and allow for clearance and training of personnel.

[redacted]

[redacted]

B. Consideration should be given to increasing the radiotelephone facilities employed on future operations of this type.

C. The Department of the Navy should immediately undertake the development of equipment to provide radiotelephone service between major ships and with similar equipments now in use or being developed by the Army and Air Force.

D. The telephone switchboards, especially on the AV-4 and AV-5, should be replaced with larger capacity, more easily operated equipment. The number of outside line circuits to be installed should be considered from the tactical standpoint as well as for use in similar operations.

E. Telephone communication between the main island locations should be provided by a submarine telephone cable system to decrease interference with the radiotelephone system and to reduce the quantity of communications equipment expended on the Test Island.

F. In future operations, all AEC messages should be passed to a central control and relay center such as Los Alamos for encryption, processing and relay to the Joint Task Force or to AEC installations. A military liaison representative and possibly military coding personnel should be placed on duty at the AEC relay center to aid in coordination of military and AEC procedure.

G. In addition to the AEC SIGTOT cryptographic systems furnished between Los Alamos and the ships and between ships, systems should be provided for use with the advance base (Eniwetok) and the JTF Forward Headquarters. Los Alamos should also hold SIGABA and joint systems for transmission of non-AEA Restricted Data messages to military installations.

H. Intensive training should be given to all message handling and coding personnel, both civilian and military, before commencement of the operation phase. Particular attention should be given to obtaining and clearing these personnel very early in the planning stage.

[redacted]

I. Unless a specific requirement exists, no provisions for three-way SIGTOT teletype conferences should be made. However, the two-way SIGTOT tape systems obtained should be authorized for conference as well as off-line message encryption.

J. The SIGTOT and teletype patching installations on the ships should be simplified and improved patch panels installed. Also, the location of equipment in the SIGTOT code rooms should be revised to increase operating efficiency.

K. In view of the high power radio installations being made at Los Alamos, strong consideration should be given to the establishment of a direct radioteletype system with the forward area of the operation.

L. GM 74 should be revised to provide that Restricted Data messages of all classifications be so designated in the text of the message. Also, the classification of all messages should be inserted at the beginning of the message text. Military classified (non-AEA Restricted Data) messages should be handled in accordance with military security procedures, especially on a joint operation.

M. Colonel Carl H. Hatch, Signal Corps, and Commander Russell J. Schmidt, USN, are to be commended for planning and directing the excellent Army and Navy communication facilities provided for the Atomic Energy Commission during Operation Sandstone. These two officers gave unremittingly of their time, energy, and experience toward the success of this operation.

[redacted]

REFERENCES

The following references are available in the LAJ-11 files and should be of value during the planning stages of future operations.

1. Secret Letter, Henderson (Hopkins) to Capt. Russell; subj.: "Proposed Communication System for Operation Sandstone", dated 12 November 1947. (Ref.: LAB-Z-5-(26)).

2. Secret Letter, Henderson (Hopkins) to Capt. Russell; subj.: "Communication Plan for Operation Sandstone", dated 19 February 1948. (Ref.: LAB-JS-11-(125)).

3. Secret Maps, LAJ-11, Nos. MJ-3201C (Engebi), MJ-3301C (Aomon-Biijiri-Rojoa), MJ-3401C (Runit), dated 28 December 1947. (Ref.: LAB-J-218, dated 9 January 1948).

4. Secret, Annex F to Field Order No. 1, 14 November 1947, JTF 7, subj.: "Communications and Electronics Plan", dated 6 February 1948. Also Change No. 1, dated 5 April 1948.

5. Secret, Test Director Operation Order 1-48, Annex C, "Communication Plan". Also, Change No. 1, dated 27 March 1948.

6. Secret, Communications and Electronics Section of JTF 7, "Historical Report", dated 13 May 1948.

7. Communications and Electronics Section of JTF 7, "Technical Report", to be issued on about 1 July 1948.

[redacted]

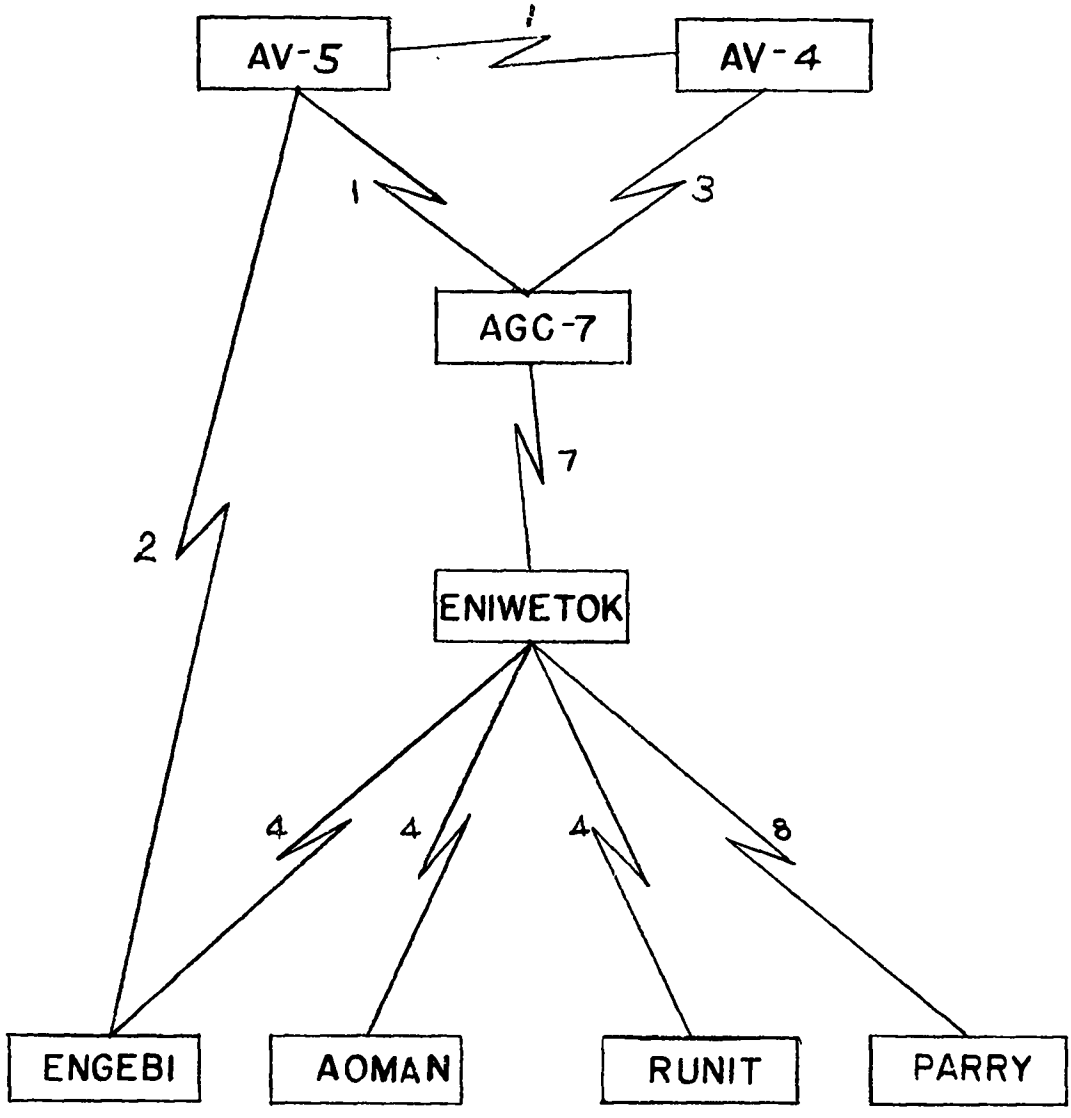
[redacted]

FIGURES

A list of the figure numbers and titles for the drawings included in this report is given below:

[redacted]

[redacted]



[redacted]

DASH NO.	NO. REQ'D	DESCRIPTION
		BILL OF MATERIAL
		TITLE RADIO TELEPHONE OPERATION SANDSTONE

SCALE	ISSUE	DRAWING NO.	SUB.ASS'Y
		6Y20007 A 3	

CHARLES BRUNING CO., LOS ANGELES 12-2-46 1M

FIGURE NO. 1

RADIO TELEPHONE CALLS PER DAY

(20 April to 3 May 1948)

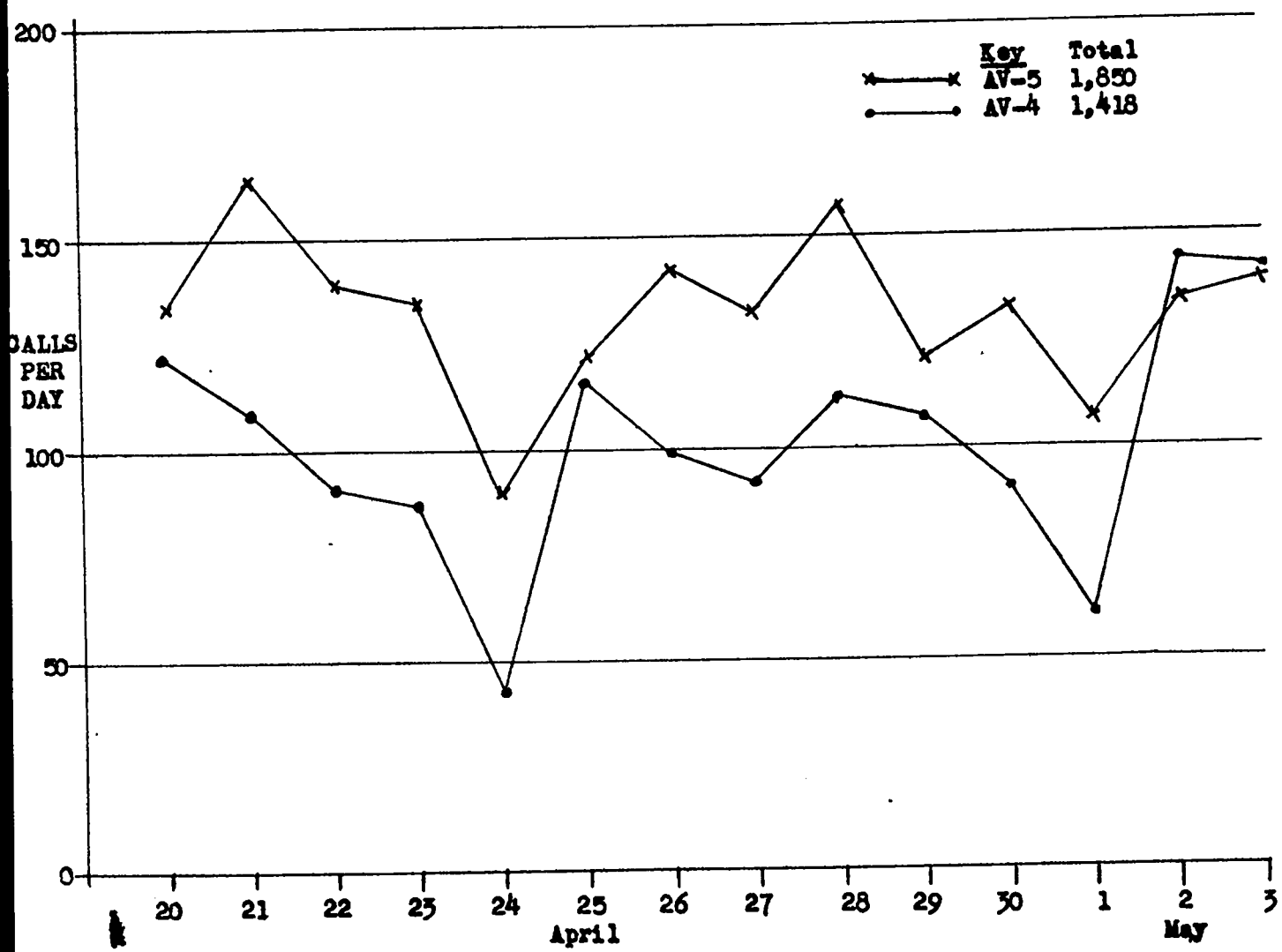


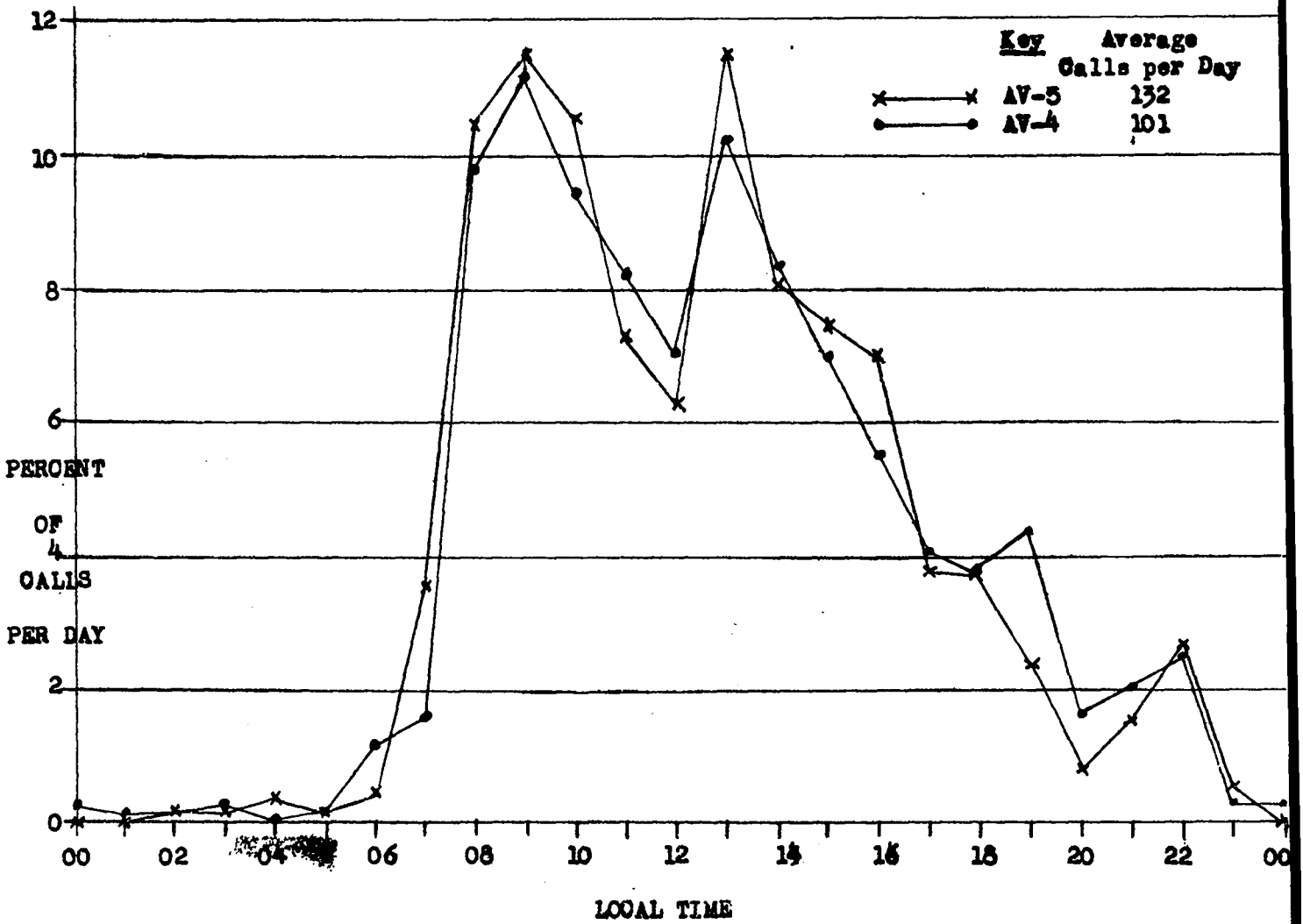
FIGURE NO. 2

[redacted]

AVERAGE

RADIO TELEPHONE CALLS PER HOUR

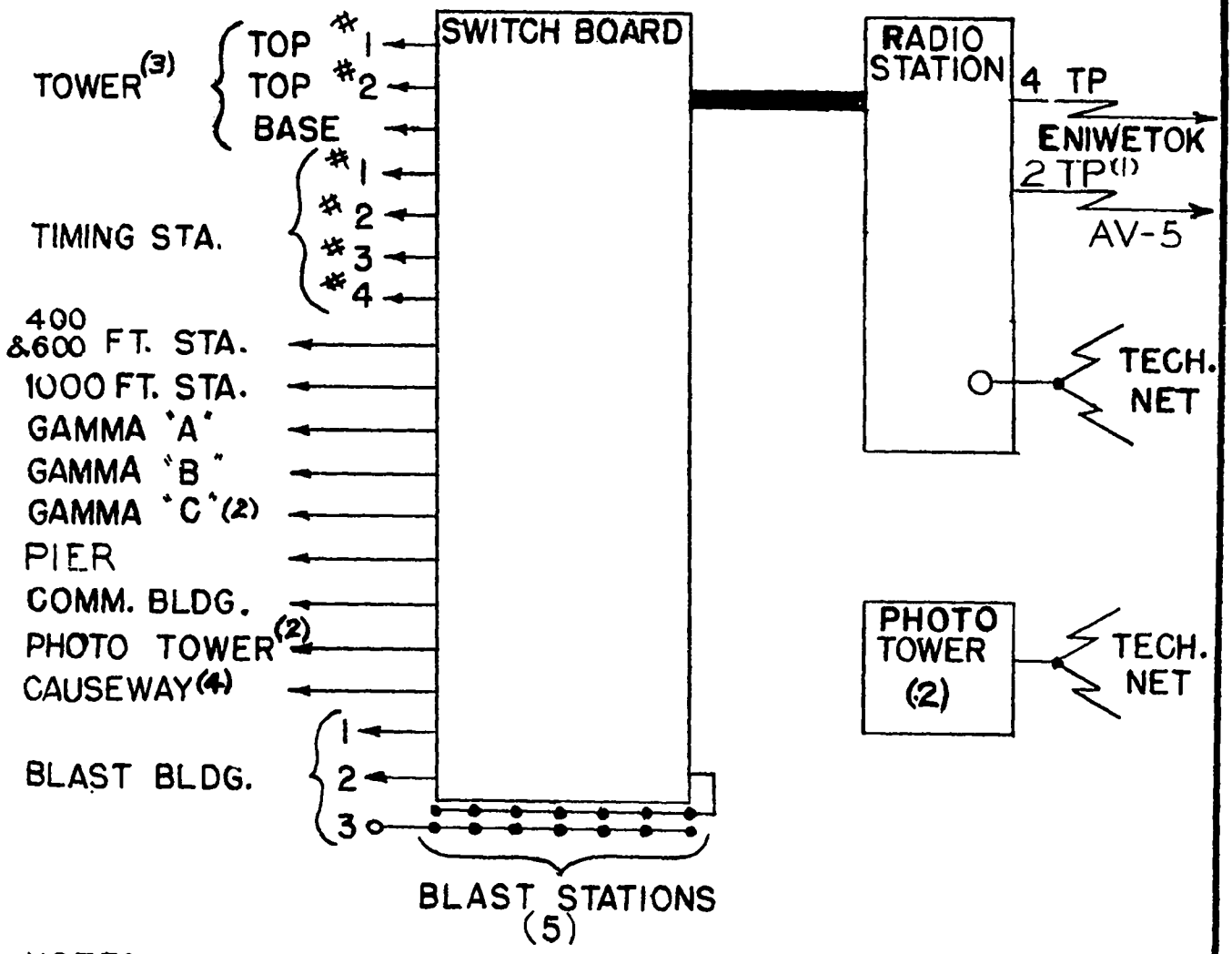
(20 April to 3 May 1948)



[redacted]

FIGURE NO. 3

[redacted]



NOTES:

(1) NEXT SHOT ISLAND
(2) NONE ON ENGEBI.
(3) PLUS TWO LINES TOP TO BASE
(4) NONE ON ENGEBI, RUNIT
(5) CONNECTED IN PARALLEL

[redacted]

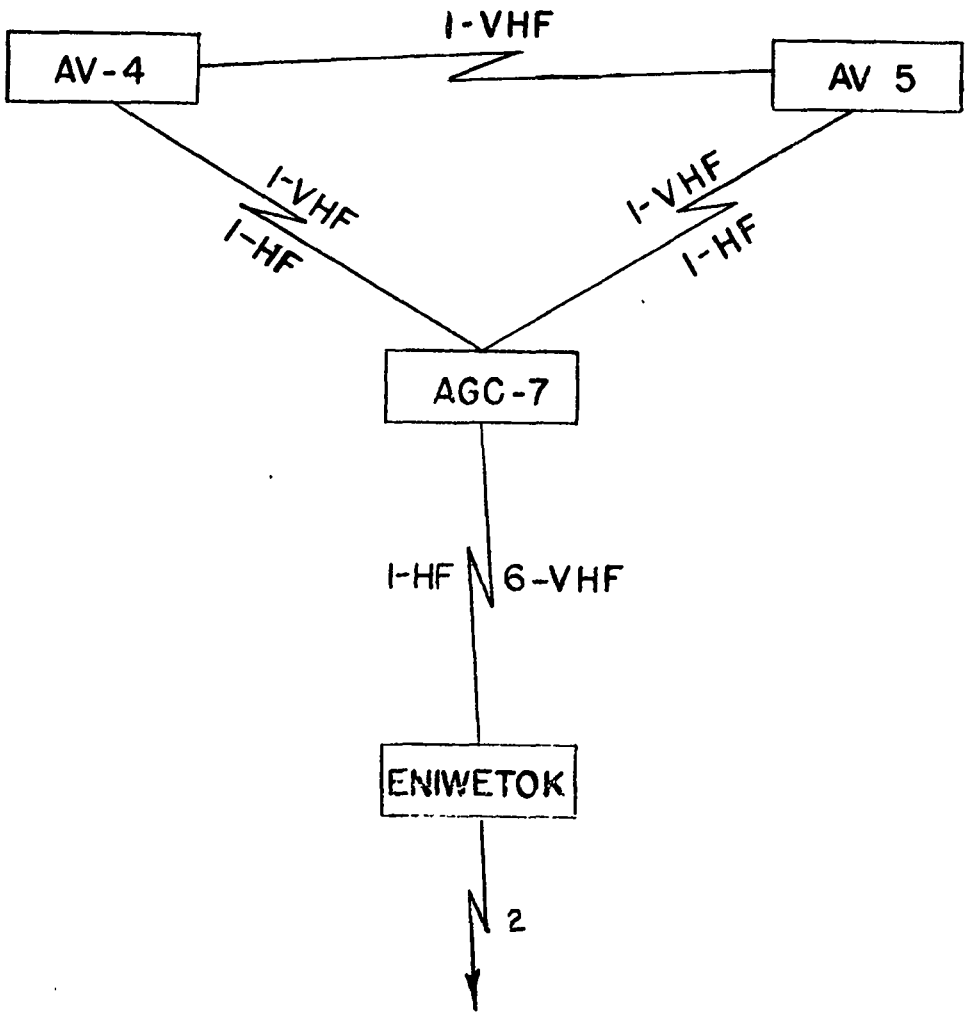
DASH NO.	NO. REQ'D	DESCRIPTION
		BILL OF MATERIAL
		TITLE: ZERO ISLAND COMMUNICATIONS OPERATION SANDSTONE

SCALE	ISSUE	DRAWING NO.	SUB.ASS'Y
		6Y20007 A 13A	

CHARLES BRUNING CO., LOS ANGELES 12-6-46 1M

FIGURE NO. 4

[redacted]



[redacted]

[redacted]

DASH NO.	NO. REQ'D	DESCRIPTION
		BILL OF MATERIAL

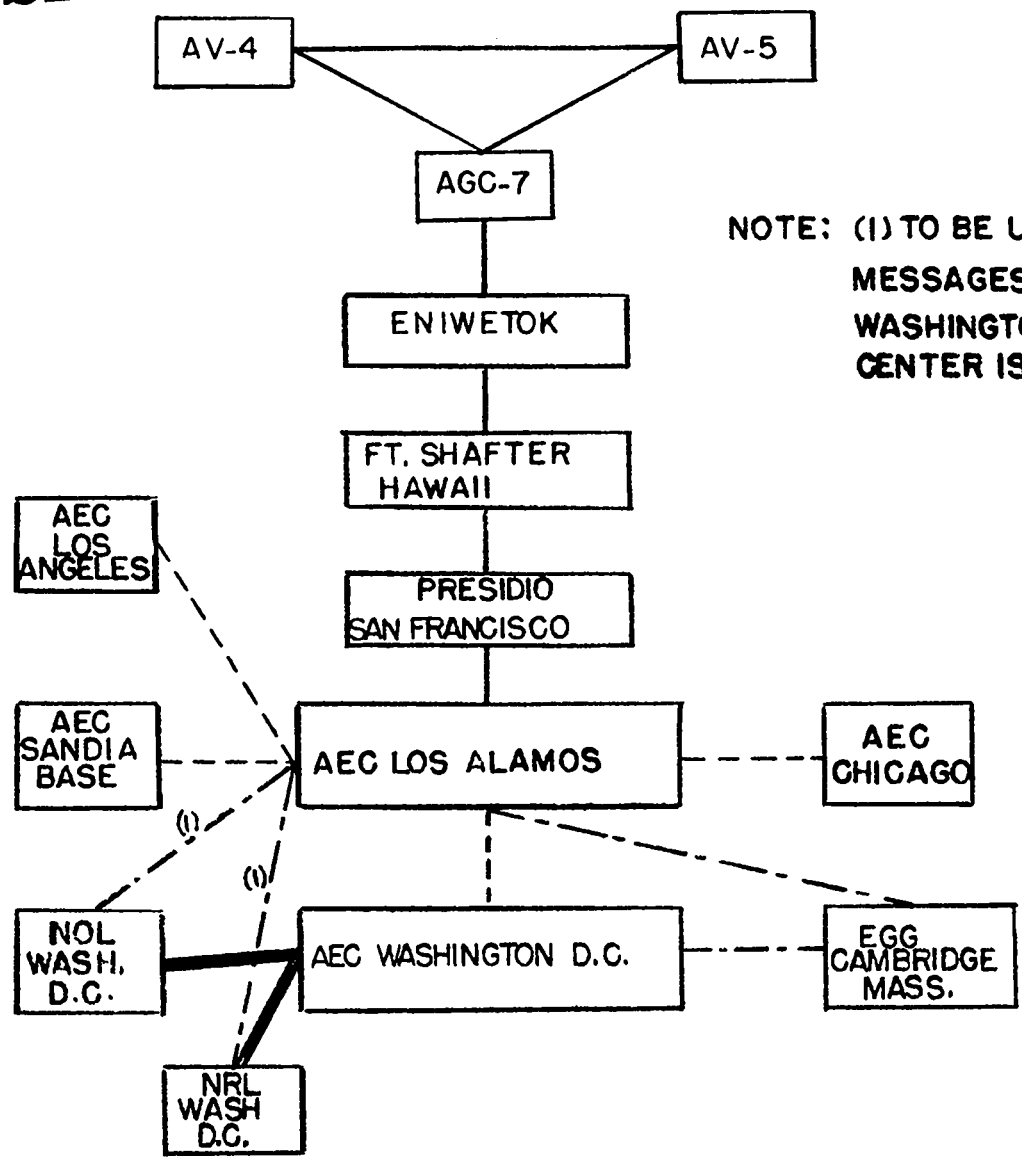
TITLE
RADIO TELETYPE
OPERATION SANDSTONE

SCALE	ISSUE	DRAWING NO.	SUB.ASS'Y
		6Y20007 A 4	

CHARLES BRUNING CO., LOS ANGELES 12-2-46 1M

FIGURE NO. 5

SECRET



NOTE: (1) TO BE USED FOR URGENT MESSAGES WHEN AEC WASHINGTON D.C. TELETYPE CENTER IS CLOSED

——— RADIO TELETYPE OR WIRE CHANNEL
– – – – – – COMMERCIAL TWX
——— WESTERN UNION (USING ONE-TIME PAD CRYPTO SYSTEM)
▬▬▬ COURIER

SECRET

DASH NO.	NO. REQ'D	DESCRIPTION
		BILL OF MATERIAL

TITLE
AEC COMMUNICATION CHANNELS
(16 MARCH TO COMPLETION OF-)
OPERATION SANDSTONE

SCALE	ISSUE	DRAWING NO.	SUB.ASS'Y
NONE		6Y20007 A-19	

CHARLES BRUNING CO., LOS ANGELES 12-3-48 1M

FIGURE NO. 6

SECRET

WORD COUNT PER WEEK
OF INCOMING SIGTOT MESSAGES
FROM LOS ALAMOS TO SHIPS

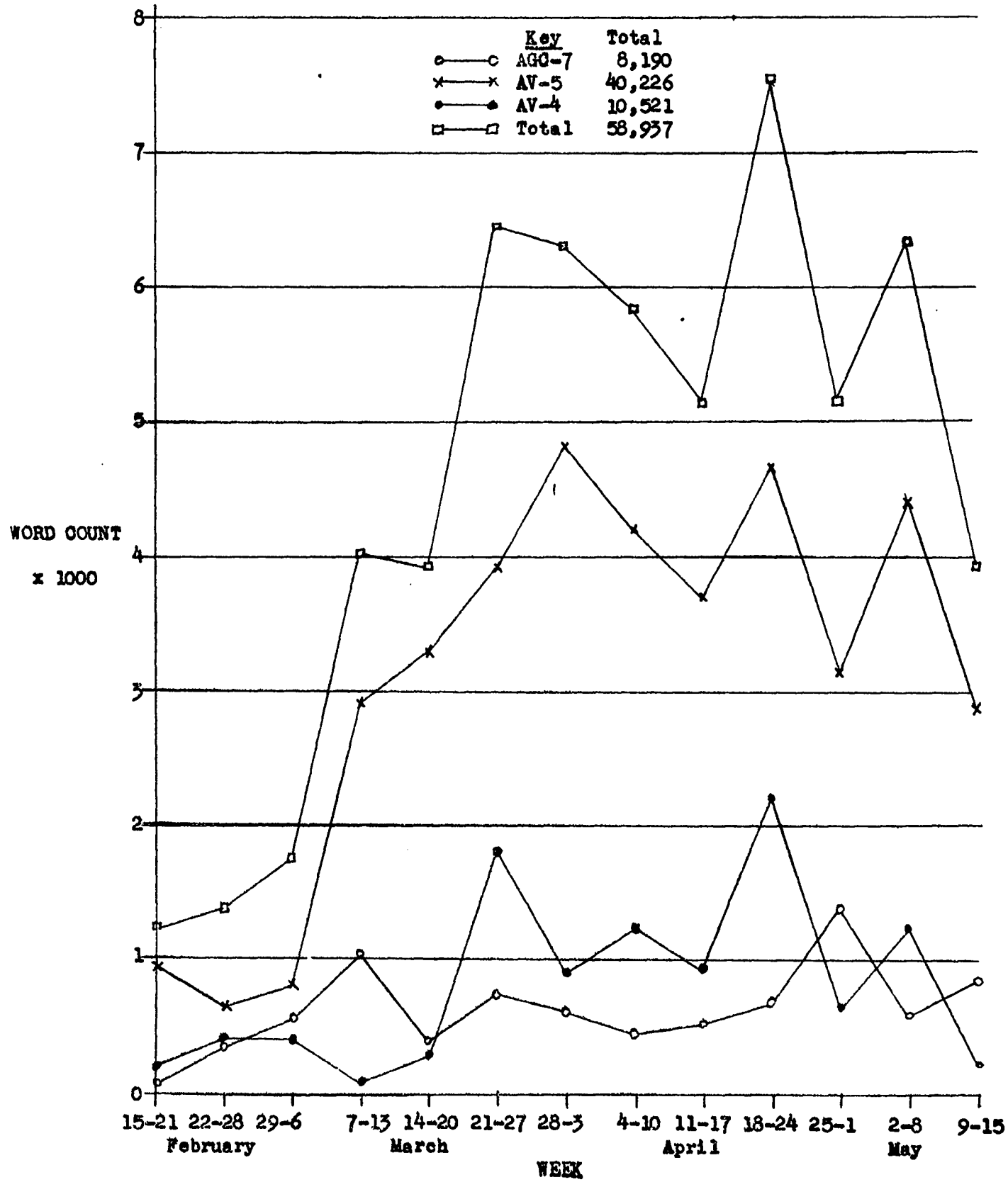
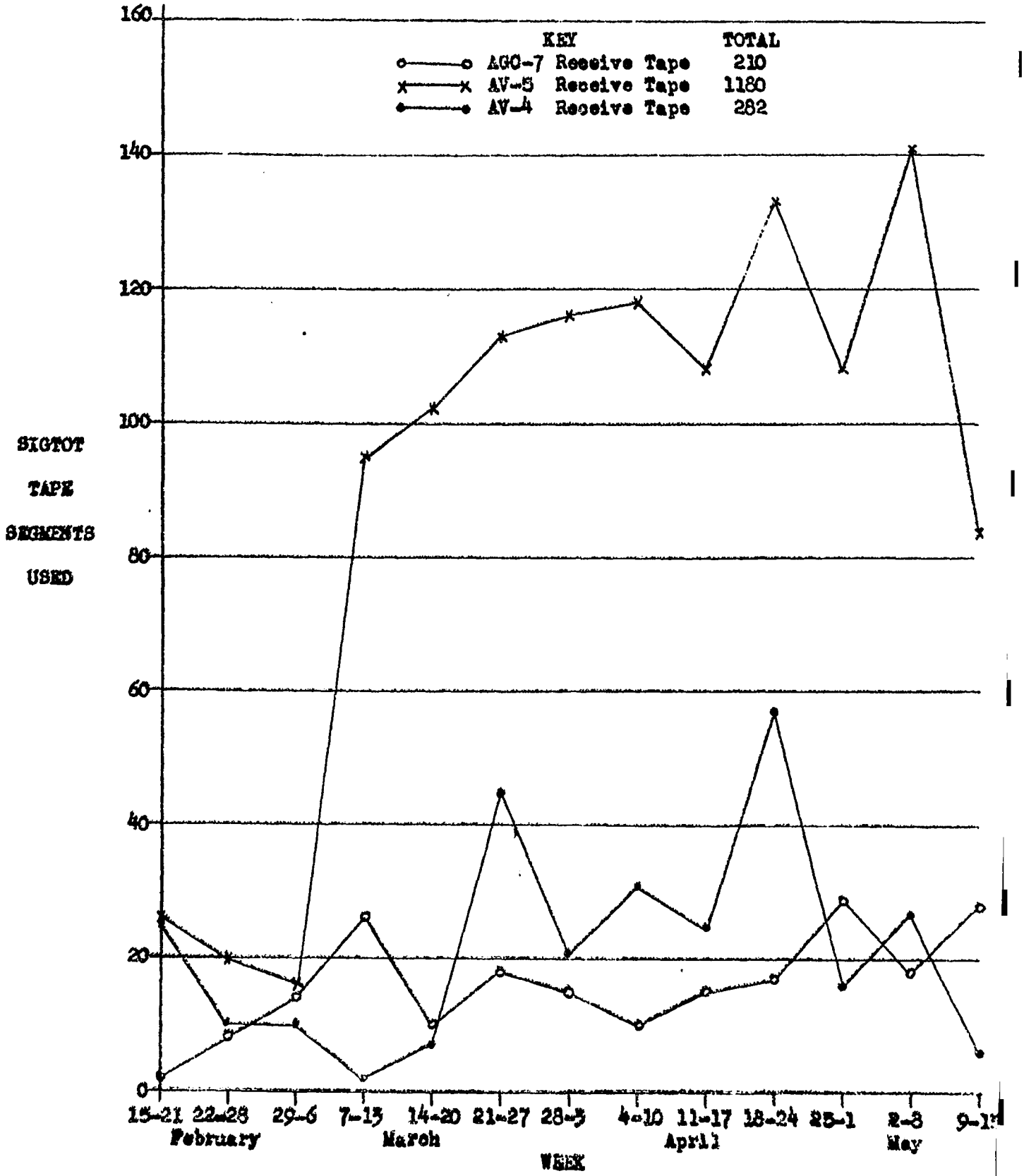


FIGURE NO. 7

SIGTOT TAPE SEGMENT USAGE
FOR INCOMING MESSAGES
FROM LOS ALAMOS TO SHIPS



[redacted]

FIGURE NO. 8

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WORD COUNT PER WEEK
OF OUTGOING SIGTOT MESSAGES
FROM SHIPS TO LOS ALAMOS

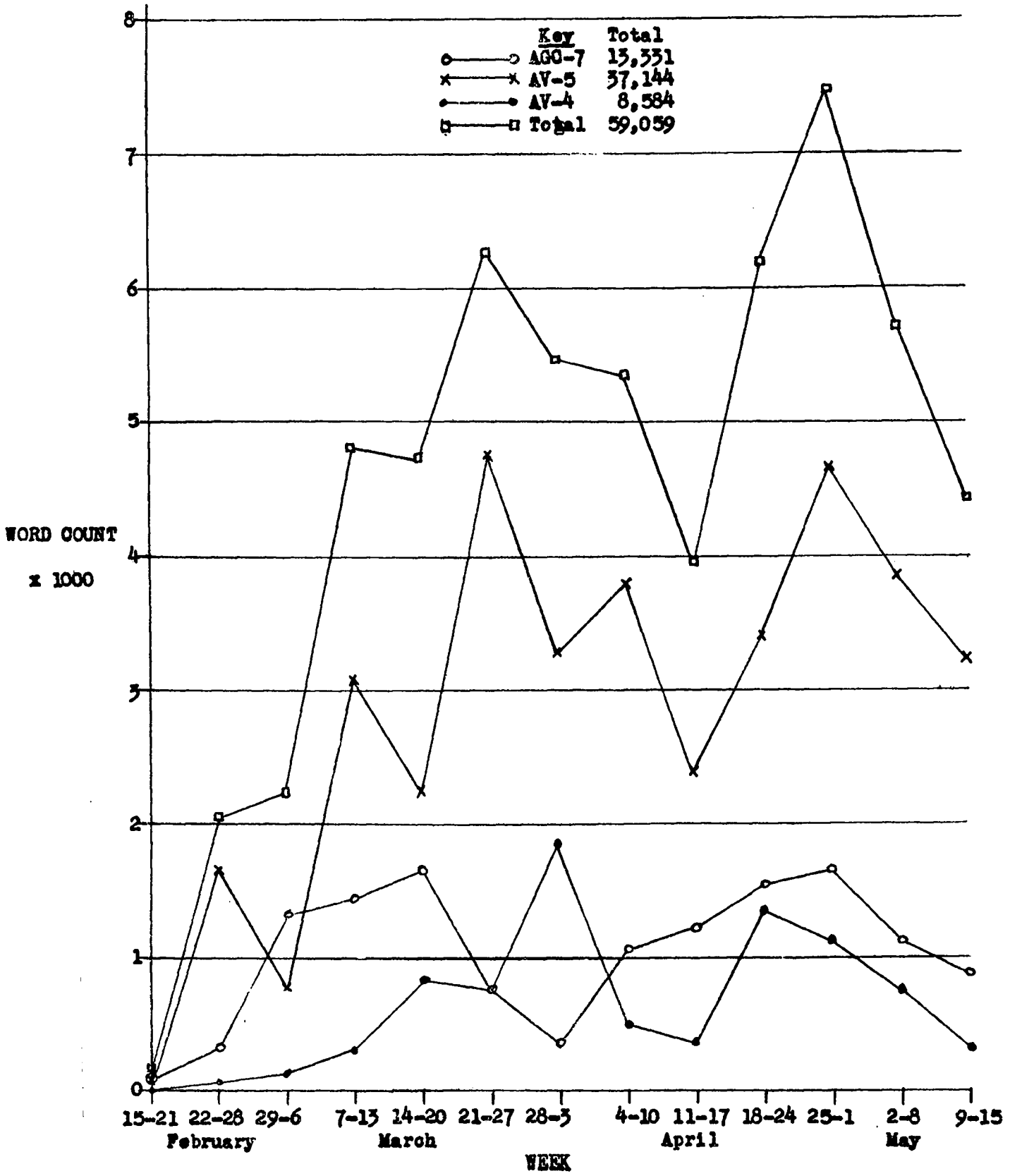
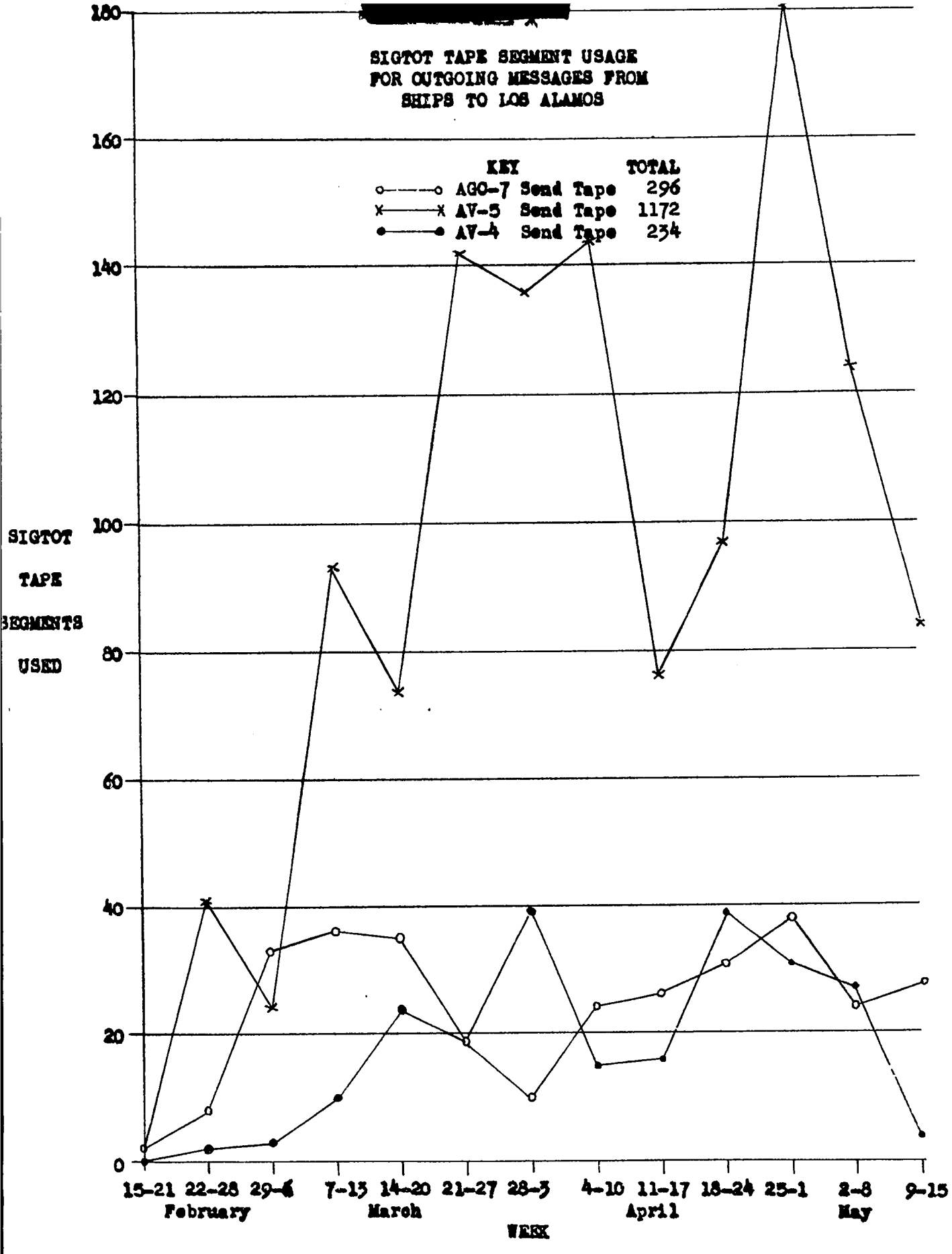
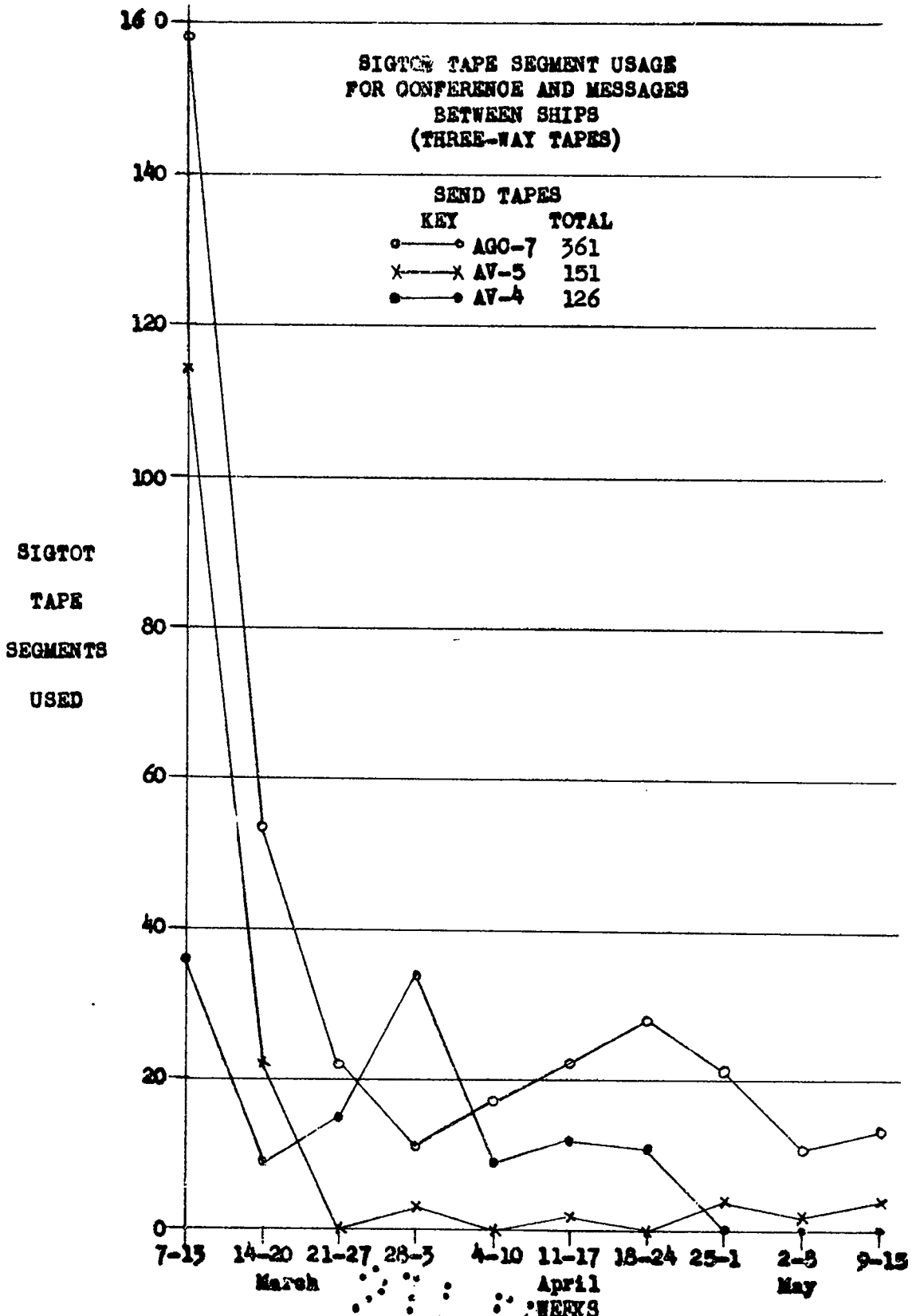


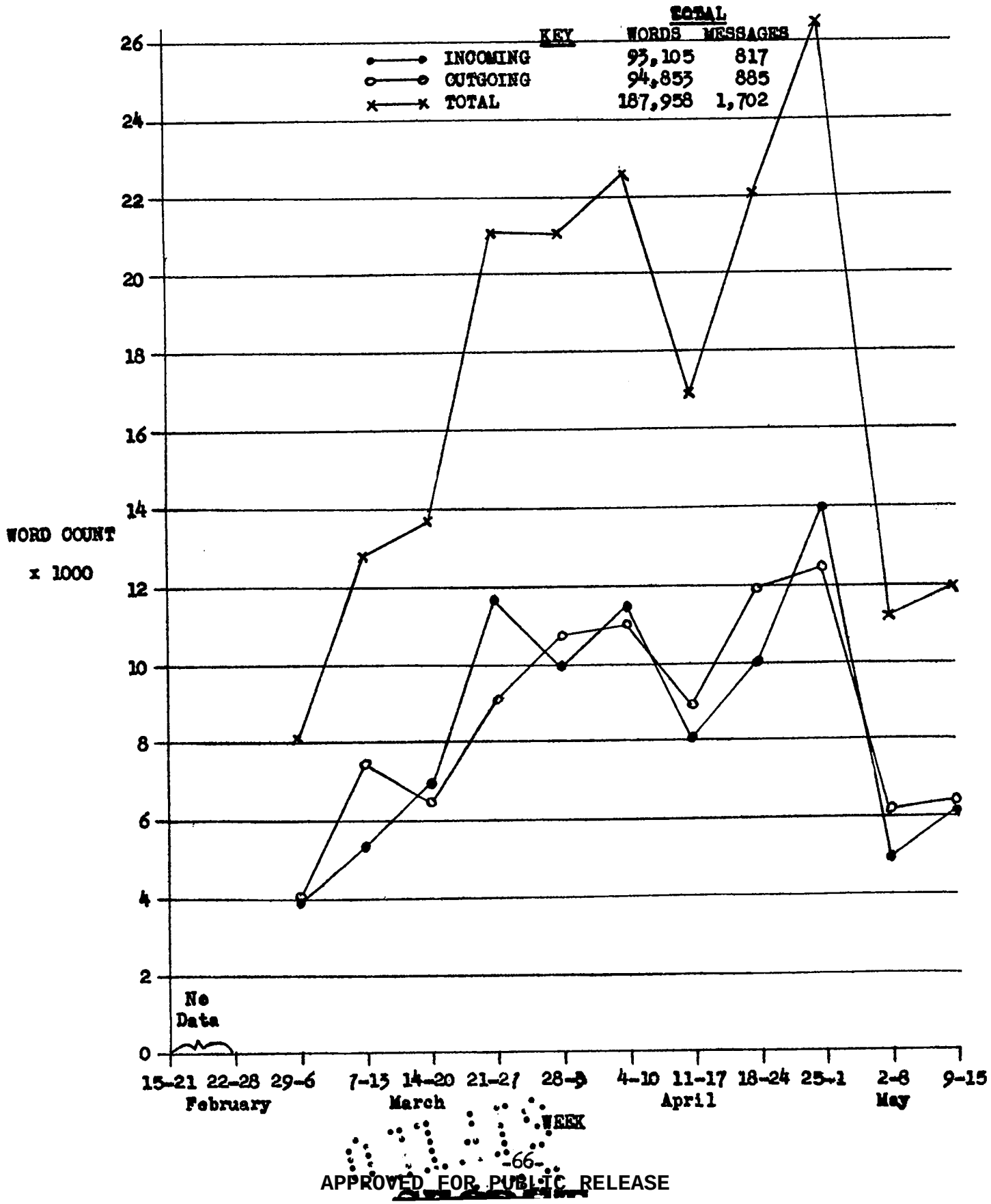
FIGURE NO. 19

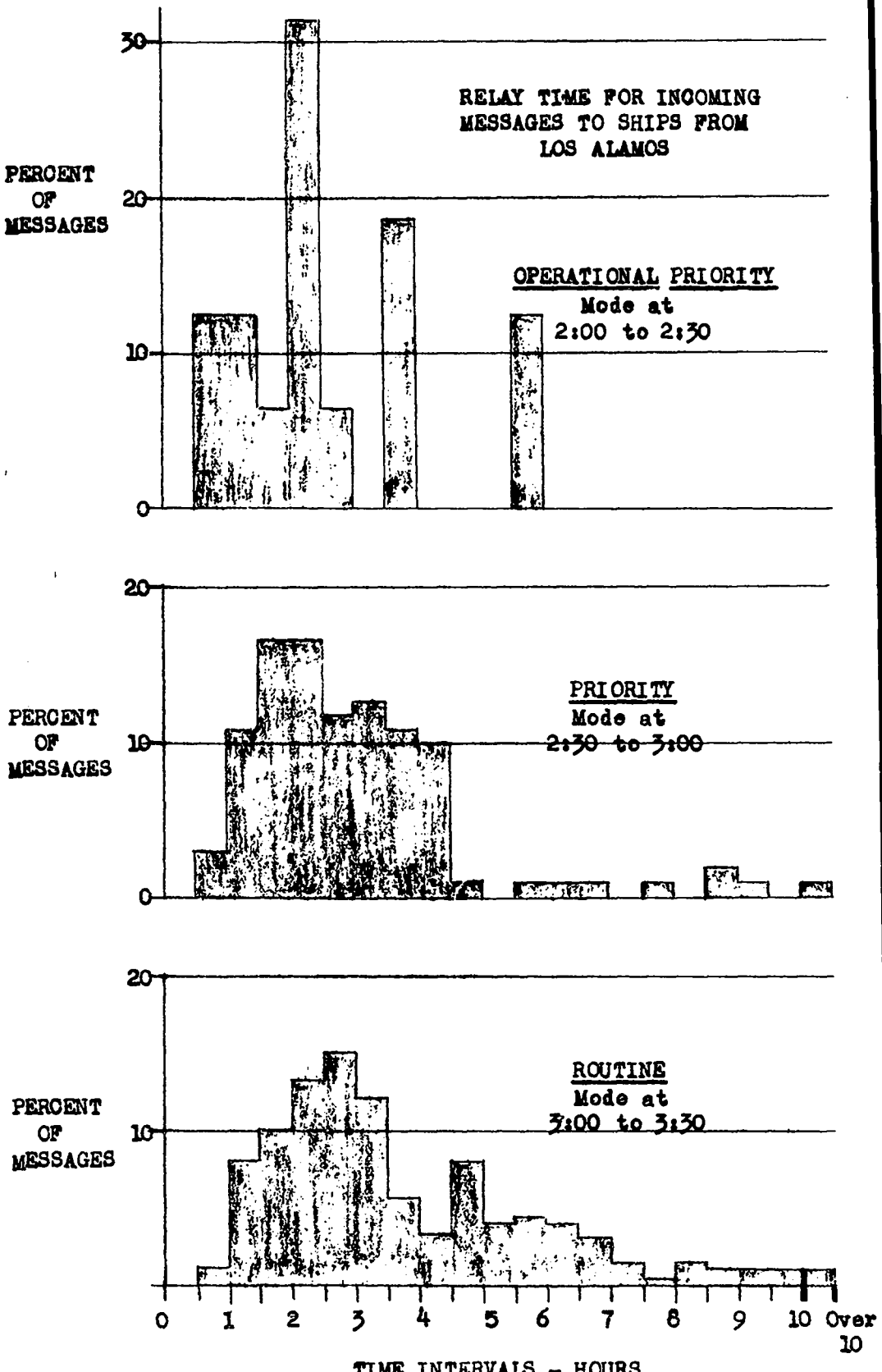

SIGTOT TAPE SEGMENT USAGE
FOR OUTGOING MESSAGES FROM
SHIPS TO LOS ALAMOS
KEY
TOTAL
AGO-7 Send Tape 296
AV-5 Send Tape 1172
AV-4 Send Tape 234
SIGTOT TAPE SEGMENTS USED
180
160
140
120
100
80
60
40
20
0
15-21 22-28 29-6 7-13 14-20 21-27 28-3 4-10 11-17 18-24 25-1 2-8 9-15
February
March
April
May
WEEK

[redacted]



LOS ALAMOS WORD COUNT
PER WEEK



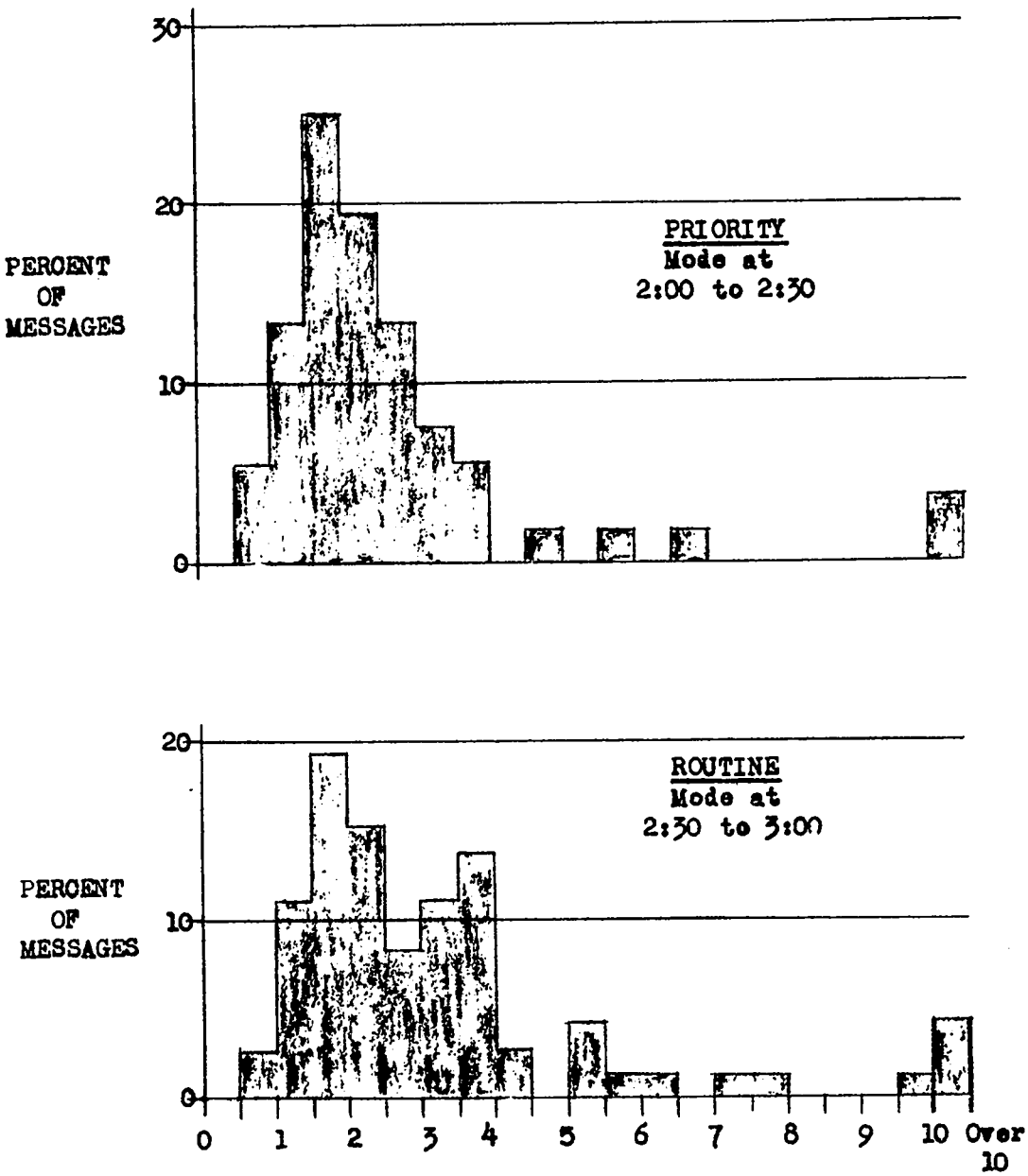


Note: Based on 295 messages from 17 March to 2 May 1948.

[redacted]

RELAY TIME FOR OUTGOING MESSAGES TO LOS ALAMOS FROM SHIPS

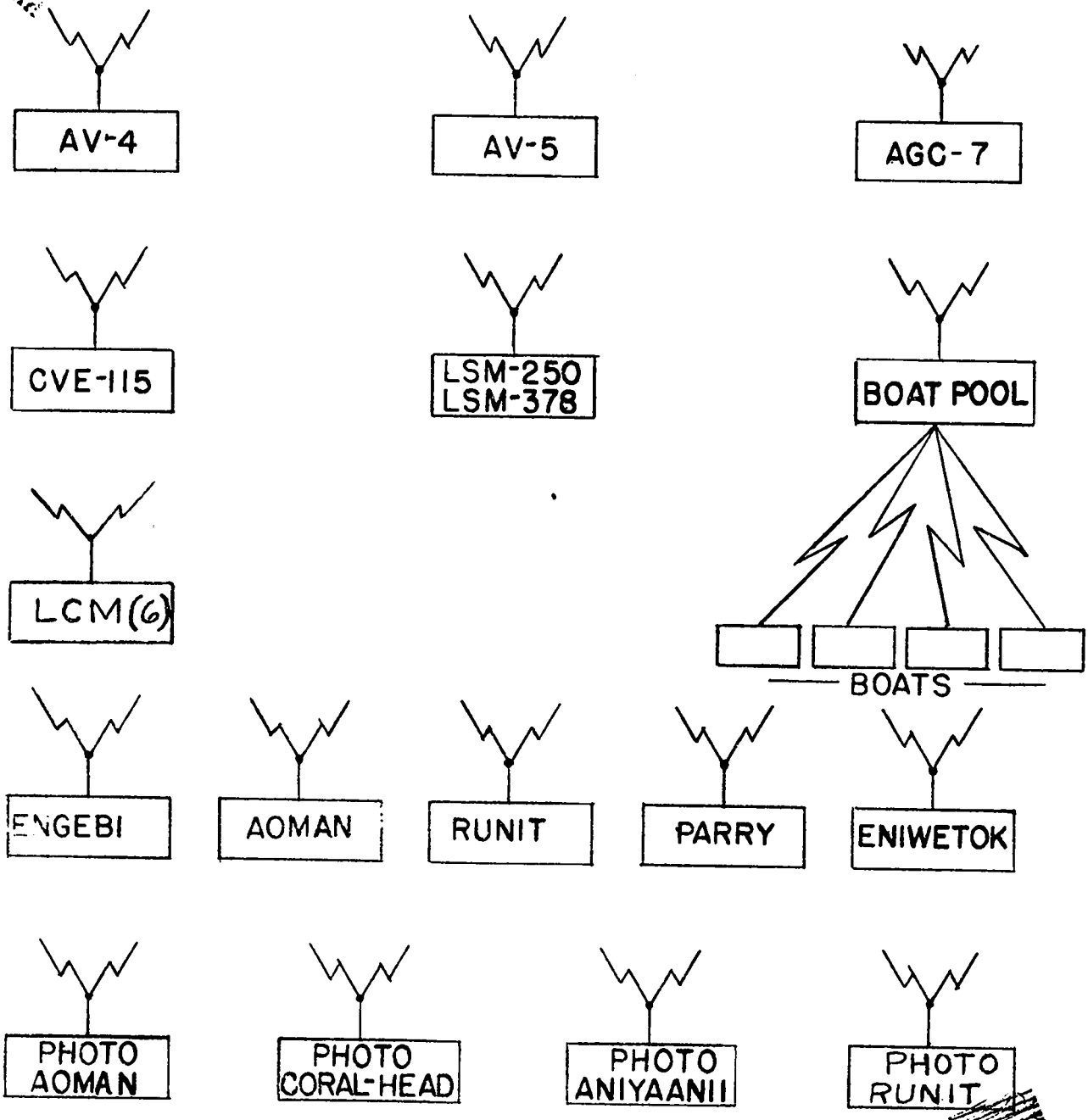
OPERATIONAL PRIORITY
Three messages
1:00 to 1:30



Note: Based on 127 messages, 21 April to 17 May 1946

[redacted]

UNCLASSIFIED



[redacted]

DASH NO.	NO. REQ'D	DESCRIPTION

BILL OF MATERIAL

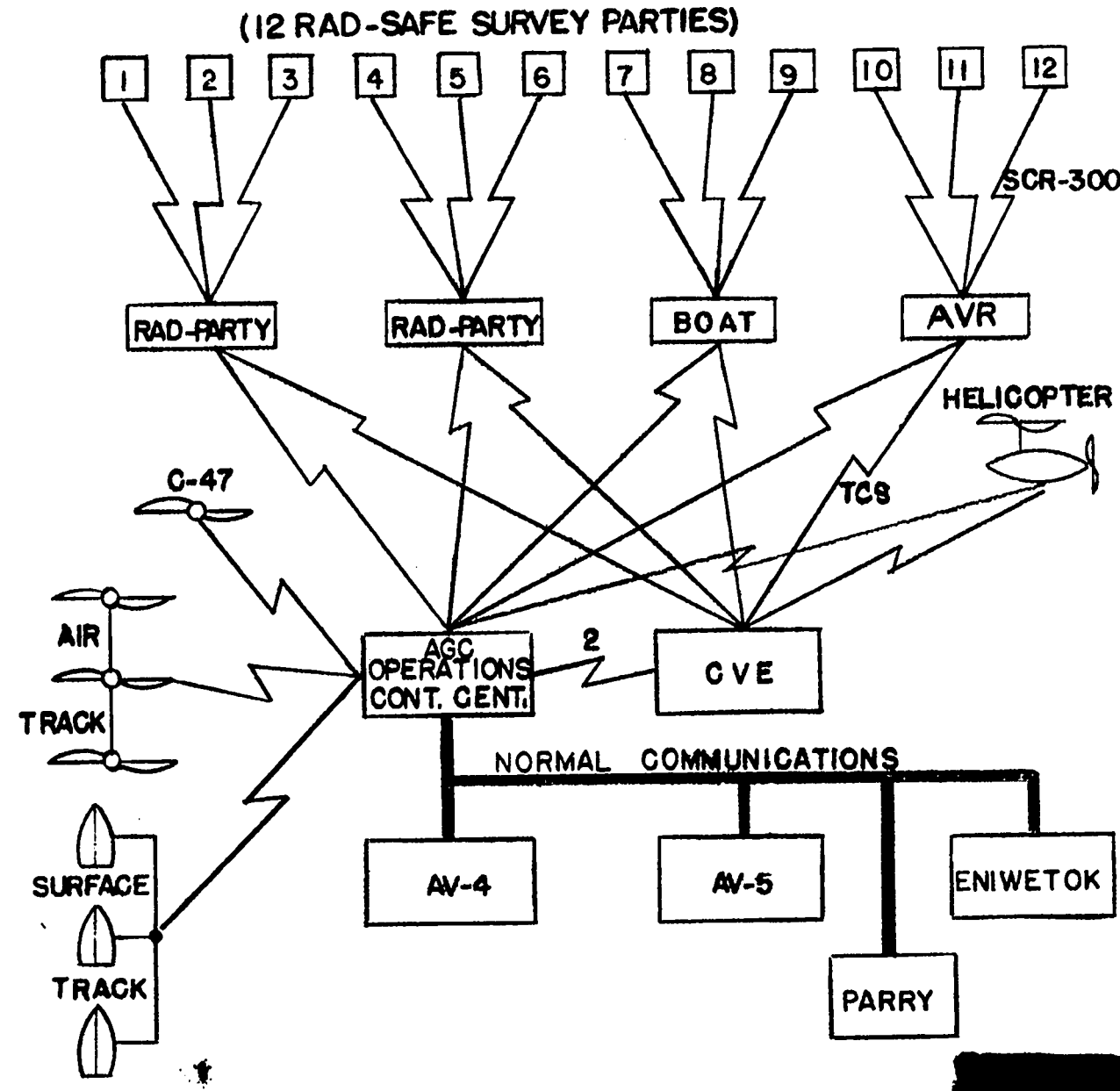
TITLE
TECHNICAL NET
OPERATION SANDSTONE

SCALE	ISSUE	DRAWING NO.	SUB.ASS'Y
		6Y20007 A 5	

UNCLASSIFIED

CHARLES BRUNING CO., LOS ANGELES 12-8-46 1M

FIGURE NO. 15



DASH NO.	NO. REQ'D	DESCRIPTION
		BILL OF MATERIAL

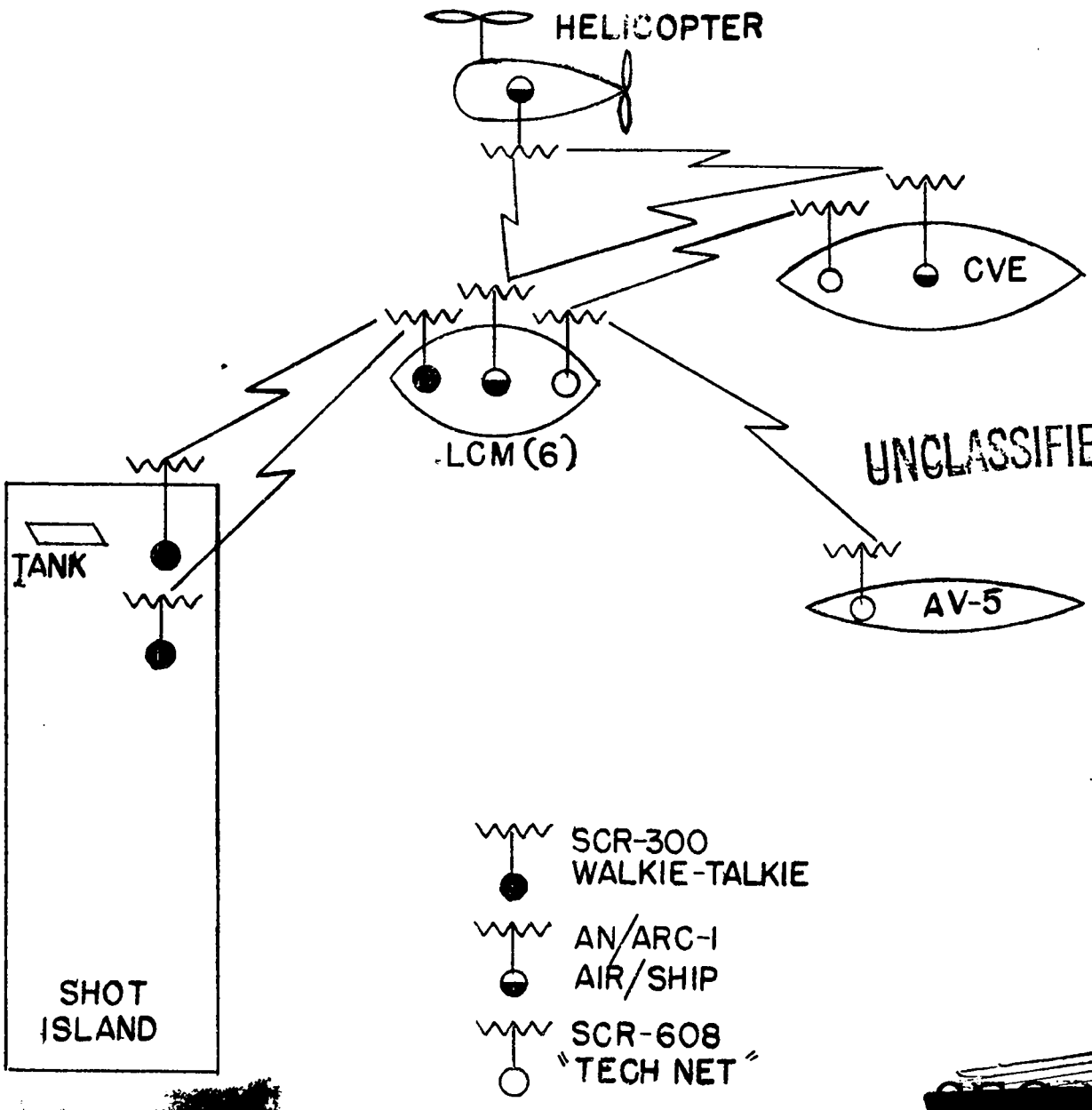
TITLE

RADIOLOGICAL RADIO NET - OPERATION SANDSTONE

SCALE	ISSUE	DRAWING NO.	SUB.ASS'Y
NONE		YS11112A-7	

CHARLES BRUNING CO., LOS ANGELES 12-3-46 1M

FIGURE NO. 16



DASH NO.	NO. REQ'D	DESCRIPTION

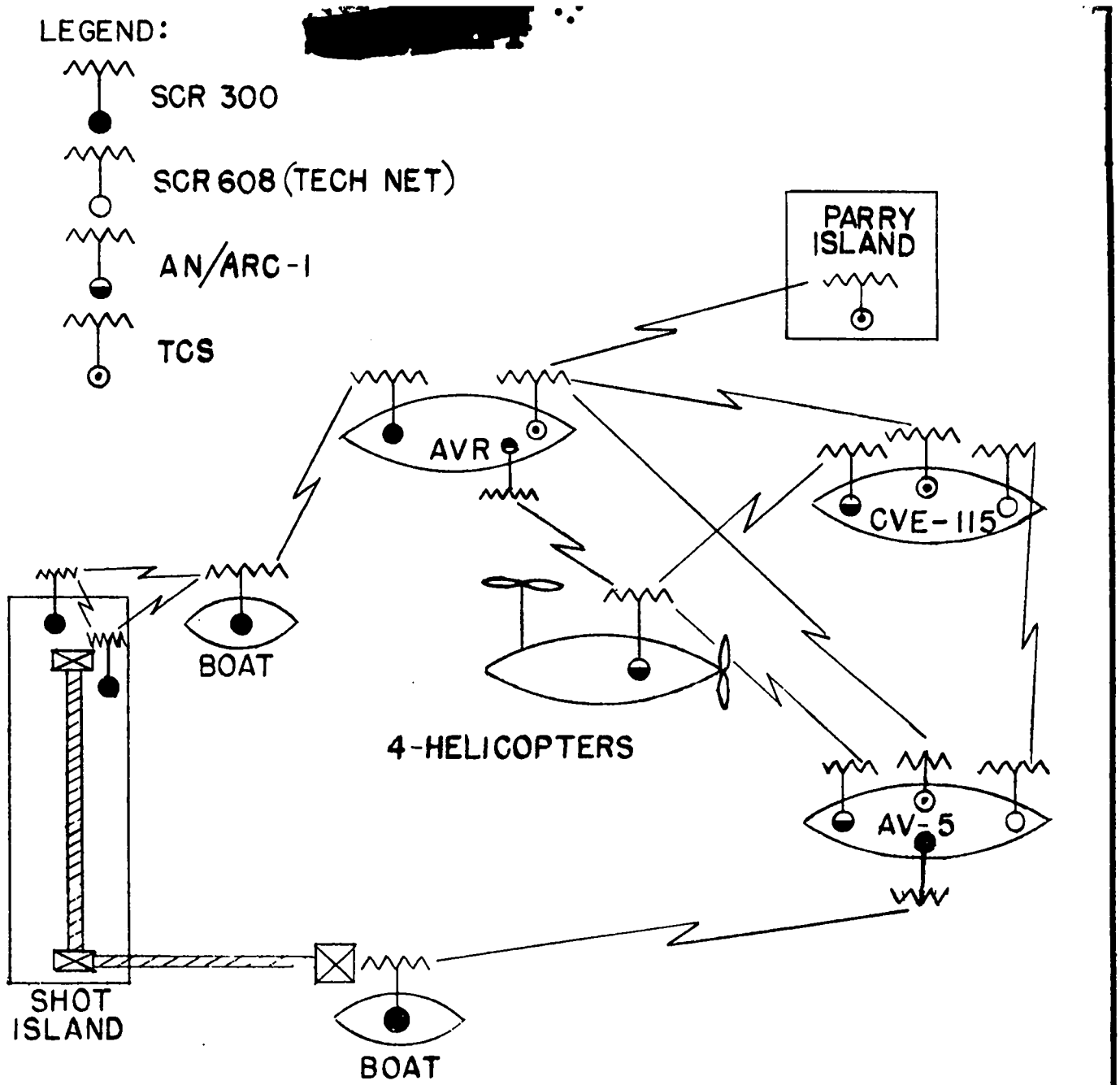
BILL OF MATERIAL

TITLE
RADIO CHEM TANK NET
OPERATION SANDSTONE

SCALE	ISSUE	DRAWING NO.	SUB.ASS'Y
NONE		6Y20007 A 17A	

CHARLES BRUNING CO., LOS ANGELES 12-9-46 1M

FIGURE NO. 17



[redacted]

DASH NO.	NO. REQ'D	DESCRIPTION
		BILL OF MATERIAL

TITLE

NEUTRON NET

OPERATION SANDSTONE

SCALE	ISSUE	DRAWING NO.	SUB.ASS'Y
		6Y20007 A18A	

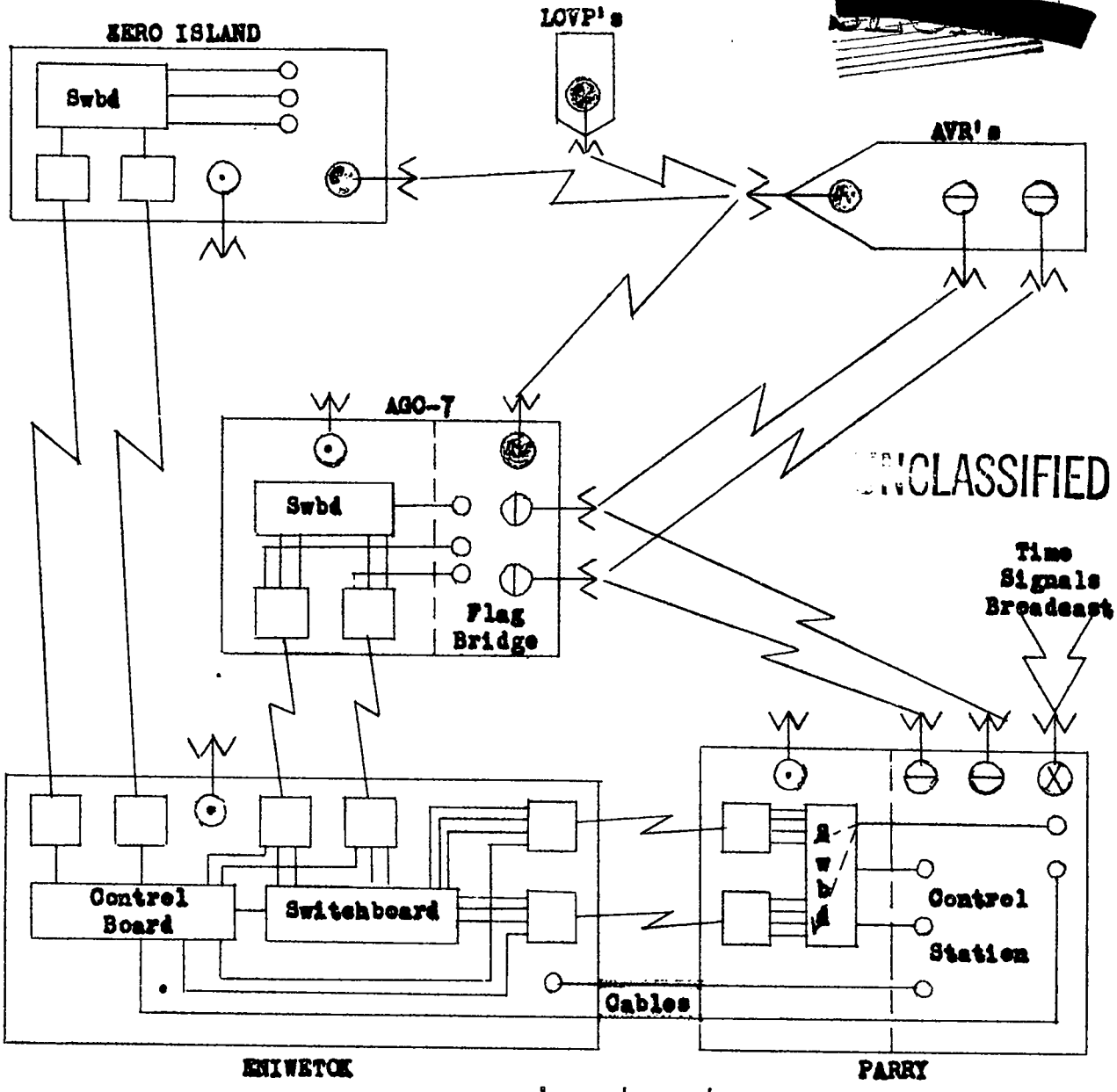
CHARLES BRUNING CO., LOS ANGELES 12-8-46 1M

FIGURE NO. 18

LET.	WAS	DATE	BY

AN/TRC-1 & CF-1 | SCR-608 Tech Net | Navy TCS | SCR-300 | SCR-543 | Phone

SYMBOLS



UNCLASSIFIED

FRACTIONAL TOLERANCE ± 1/64 UNLESS OTHERWISE NOTED

FINISHES	GROUP REPR.	GROUP NO.		BY	DATE
Af GROUND			LAYOUT OR SKETCH		5/18 1948
			DRAWN		
Bf SMOOTH MACHINE			CHECKED		
			PROJ. ENG.		
Cf ROUGH MACHINE			APPROVED FOR CONST.		

DIETZGEN 198M AGEPROOF

DASH NO	NO REQ'D.	DESCRIPTION
		BILL OF MATERIAL
		TITLE: X, Y and Z-Day Communications

SCALE	ISSUE	DRAWING NO.	SUB.ASS'Y.
		A	

FIGURE NO. 19