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INVESTIGATION OF SOME ELECTRONIC AND MECHANICAL INTERFACE PROBLEMS IN THE AN/TSQ-47 SYSTEM

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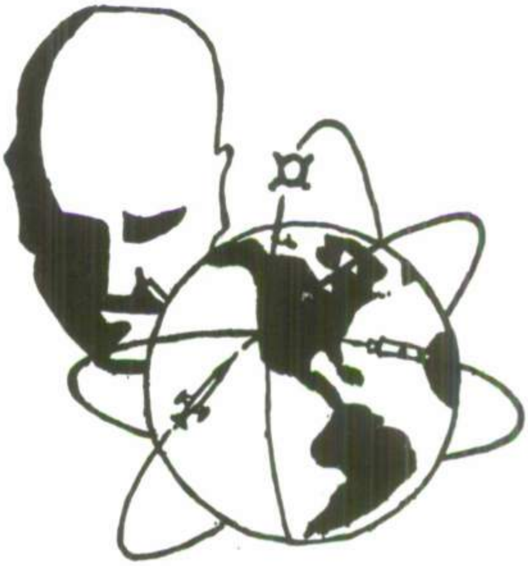

482L SYSTEM

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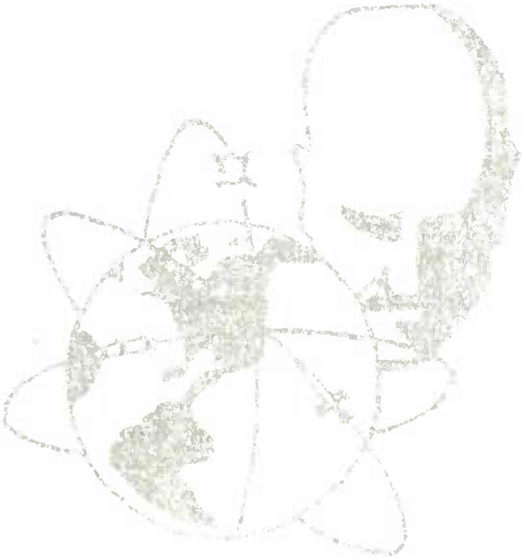

FOREWORD

The work described in this report was performed by the contractor at the customer's facility located at Fort Dawes, Winthrop, Massachusetts. Guidance and technical contributions were received from USAF personnel assigned to this facility. The direction furnished by Mr. Benjamin F. Greene, Jr., Chief, Technical Support Division, 482L Systems Project Office, ESD, is acknowledged and appreciated.

ABSTRACT

This report discusses certain electronic and mechanical interfaces associated with system integration and ground support of the AN/TSQ-47 air traffic control system. Problem areas are defined and suggestions are set forth for improvement and standardization.

Discussions and recommendations for meteorological equipment and a mobile runway lighting system are included.

This report is not complete in that it is supplementary to ESD-TDR-63-601, Investigation of Deployment Problems and Alignment of the AN/TSQ-47 EMS System. It is a continuation of the effort to improve capability and reliability.

This report has been reviewed and is hereby approved.

B.F. Greene, Jr.

B. F. Greene, Jr.
Technical Contract Monitor

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INTRODUCTION

The objective of this report is as follows (from Item 6, Part II-Statement of Work, PR #ES-3-482L-4352 dated 11 October 1962):

Investigate, analyze, and recommend solutions to system integration problems in the AN/TSQ-47 system including, but not limited to:

1. Electromagnetic interference problems between the various radars, microwave links, communication sets, and other radiating devices of the AN/TSQ-47 system.
2. Electronic interfaces between major system components, especially between the microwave links and the radars.
3. Mechanical interface between the AN/TSQ-47 shelters, antennas, pallets, transporters, and aircraft loading systems.

Two additional sections are included, in addition to those prescribed in the work statement:

4. A discussion and recommendations for meteorological equipment; a surface pressure-measuring barometer and a wind direction and wind speed measuring set.
5. A discussion and recommendations regarding a mobile airport lighting system.

Each of the five sections constitute separate entities and they are not interdependent. They cover entirely different areas of AN/TSQ-47 system integration and support.

fundamental frequency itself can cause interference problems if the output power is of such magnitude that it cannot be sufficiently attenuated by the equipment with which it interferes.

B. RACEP interference with VHF receivers.

RACEP is a spread-band system in which voice is converted to coded pulse groups in a time-frequency matrix and processed for transmission at a center frequency of 142 mc with an rf bandwidth of 4 mc at 3 db points. RACEP has an advantage over conventional communications in that it is more secure, provides full duplex operation, and has more flexibility with regard to selective calling of individual stations.

Unfortunately, RACEP has a disadvantage in that it causes interference in VHF air/ground/air receivers operating in the 118 to 151.95 mc range. Obviously, interference would be expected in the 4 mc band centered at 142 mc since this is the RACEP assigned center frequency. However, the interference is encountered over most of the 118 to 151.95 mc range. The interference is most noticeable in the AN/TSW-6 (control tower) where, during modulation of the RACEP transmitter, the VHF receiver squelch breaks and noise, varying in conformance with the RACEP modulation input, is heard at the audio output of the receiver.

I. Interference Measurements

Evidently, no detailed investigation has been conducted to determine the exact nature of the interference. Some suggestions as to measurements that should be made are as follows:

(a) Spectrum analysis of RACEP transmitter output.

The spectrum of the transmitter output should be observed with various modulation inputs such as voice, tones of difference frequencies, etc. A high sensitivity spectrum analyzer with logarithmic amplitude display is recommended in order to see low level sidebands greatly separated from the RACEP center frequency.

(b) Effect of RACEP interference on VHF receiver at various frequencies.

The AGC level should be measured at various frequencies across the band with and without RACEP transmission in order to determine the effect of the interference on the RF and IF sections of the receiver. A more precise measurement could be made by inserting an attenuator in the coaxial cable to the VHF receiver and increasing the attenuation to the point where the squelch is not actuated by the RACEP interference. This would indicate the extent to which the interference must be suppressed at a given frequency in order to prevent false squelch actuation.

(c) Effect of RACEP interference on desired signal.

A test signal should be applied to the VHF receiver at the same time that RACEP interference is occurring. This could be accomplished by applying a signal generator signal, with appropriate matching network, in parallel with the RACEP interference being received via the VHF antenna. For example, a VHF signal (on the frequency to which the receiver is set) modulated 30% by 1000 cps is applied to the receiver and observed and/or measured with and without the RACEP interference. The effect of the RACEP interference on various VHF signal levels could be determined.

II. Possible solutions to RACEP-VHF interference problem.

The following approaches are recommended as possible solutions to the RACEP-VHF interference problem. One, or a combination of the recommended approaches may be utilized, depending upon the extent of interference suppression required.

(a) Reduction of RACEP transmitter power.

Unofficial reports indicate that this approach has already been tried. The RACEP peak power was reduced from 1000 watts to 1 watt. Since the power output of the transmitter was reduced 30 db, the interference could be expected to be reduced by approximately the same amount. This approach is somewhat similar to curing the disease by killing the patient.

(b) Suppression of sidebands with RF bandpass filter.

Although information on the exact nature of the interference caused by RACEP is not available, it is suspected that the main difficulty is a result of sidebands caused by pulsing, at an 8kc rate, the three RACEP carrier frequencies on 141, 142, and 143 mc. A bandpass filter could be used to suppress the sidebands and reduce the interference with the VHF air/ground receivers. Since the RACEP frequency band is fixed, a bandpass filter could be devised which could be inserted in the coaxial cable from the RACEP primary unit to the antenna. This filter would serve a double purpose by reducing the possibility of interference with the RACEP by adjacent VHF channels.

(c) Suppression of RACEP fundamental frequencies with band reject filter.

Since the RACEP transmitter output consists of 1 kw pulses on 141, 142, and 143 mc, and the VHF and RACEP antennas are separated by only a few feet, it is possible that even though the VHF receivers are not tuned to frequencies within the RACEP band the RACEP power is sufficient to cause interference with the VHF receivers. To eliminate this type of interference, a band reject filter could be inserted in the coaxial cable between the VHF antenna and the VHF receiver.

The filter would reject frequencies in the 140 to 144 mc band, but would pass all other frequencies in the operating range of the VHF receivers and transmitters.

(d) Increasing physical separation of RACEP and VHF antennas.

Since the interference is radiated from the RACEP antenna to the VHF antenna, the interference at the VHF receiver will be determined according to the formula:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi R)^2}$$

Where in this case R is the separation between antennas, and P_t is the interference (on the receiver frequency) generated by the RACEP transmitter. G_t and G_r is the gain of the RACEP (transmitting) and the VHF (receiving) antennas respectively. It should be noted that G_t and G_r will depend upon the relative positions of the antennas because of the radiation patterns unless these patterns happen to be spherical, which is unlikely.

If an assumption is made that G_t and G_r remain constant when the antenna separation is changed, R is the only factor in the formula which will change. If the antenna separation is increased by a factor of 10, the interference power into the receiver should be reduced by a factor of 100, or 20 db.

(e) Changing polarization of RACEP antenna.

Both the RACEP and the VHF antennas employ vertical polarization. Since the aircraft which operate on VHF also employ antennas with vertical polarization, it would not be feasible to change the polarization of the VHF antennas used on the ground/air/ground installations. However, the RACEP equipment only communicates with other RACEP within a given TSQ-47 complex, and changing all

RACEP antennas to horizontal polarization would not result in any compatibility problems.

Changing the RACEP antenna to horizontal polarization should result in a considerable reduction in interference with the VHF receivers. Tests would have to be conducted to determine whether horizontal polarization would cause a reduction in the performance of the RACEP communications within the AN/TSQ-47 complex.

(f) Employing hybrid coupler.

A hybrid coupler could be employed to couple the VHF and the RACEP equipment to the same antenna. The hybrid coupler should provide an isolation between VHF and RACEP of at least 30 db, which is the same as is obtained by reducing the RACEP peak power from 1 kilowatt to 1 watt. If additional isolation is required, it cannot be obtained by changing antenna separation or polarization when the hybrid coupler is employed since VHF and RACEP would utilize identical antennas. Additional isolation could be obtained by utilizing filters in conjunction with the hybrid coupler.

(g) Shaping of transmitted pulses.

Photographs showing the shape of the RACEP transmitter pulses are unavailable, but it is suspected that a fairly sharp rise and decay is employed. This results in a number of sidebands displaced in frequency by the repetition rate (8 kc). Utilization of filters, as previously mentioned, reduces the sidebands and consequently increases the rise and decay time of the transmitted pulses. The transmitted pulses could be shaped electronically so as to reduce sidebands. Gaussian shaped or cosine-squared-shaped modulation pulses should produce fewer and lower amplitude sidebands than rectangular-shaped modulation pulses.

Alteration of the transmitted pulse will undoubtedly affect the RACEP reception to some extent. The effect on RACEP performance would have to be weighed against reduced interference with VHF reception.

(h) Blanking VHF receivers during transmission of RACEP pulse.

Since the RACEP transmission consists of a series of short pulses, it should be possible to blank the VHF receiver during the time the RACEP pulse is being radiated from the RACEP antenna. The blanking could be electronically synchronized from the RACEP equipment and should be so devised that no modification of the VHF receiver would be required. This could be accomplished by a solid state device inserted in the coaxial line to the VHF receiver and operating in a manner to cause the receiver input to be grounded when triggered from the RACEP during the time a pulse is transmitted. This device should not operate during VHF transmission.

During reception of normal VHF signals, this electronic switching of the rf input to the VHF receiver might cause a high frequency tone (corresponding RACEP pulse rate) to appear in the audio output. It should be possible to eliminate this tone by using an audio low pass filter on the output of the VHF receiver.

It is important to note that when blanking of the VHF receivers is employed, the receivers should be able to operate within the RACEP frequency band without interference. However, the effect on the RACEP receiver of the VHF transmission in the RACEP frequency band is unknown.

C. Transmissions on VHF guard frequency interfering with UHF guard receiver.

When a VHF transmitter transmits on the VHF guard frequency, the second harmonic causes interference on the UHF guard frequency which is twice the VHF guard frequency. This condition indicates that harmonics are not adequately suppressed in the VHF transmitters, and interference would probably be encountered on any UHF frequency which happened to be twice that of an assigned VHF frequency.

To reduce interference as a result of harmonics from the VHF transmitters, it is recommended that a low pass filter be inserted in the coaxial cable between the transmitter(s) and the antenna. This filter should greatly attenuate all frequencies above approximately 160 mc and should have minimum attenuation and SWR for frequencies below 150 mc.

D. Search radar interfering with microwave.

A test was conducted to determine the effect of the search radar on the microwave reception at the AN/TSW-5. The test was conducted with a separation of approximately 50 feet between the AN/TPS-35 (search radar) and the AN/TSW-5. The 4 ft. microwave antenna was pointed directly at the search antenna. Results indicated that the search radar caused a small amount of interference with the microwave when the separation was 50 ft. When the separation was increased to 500 ft. the search radar did not interfere with the microwave.

To prevent interference with the microwave, it is recommended that a separation of at least 500 ft. be maintained between the AN/TSW-5 and the AN/TPS-35 when the IFR-search microwave link is being utilized.

E. Air conditioner interfering with HF reception.

During field tests, it was found that the air conditioner caused interference with the HF receiver. Since this is broadband type interference, it must be suppressed at the air conditioner. This can be accomplished by shielding ventilation ports, making certain that removable panels are satisfactorily bonded to the housing (installation of fingerstrip around edges may be necessary), filtering input and output leads, and installation of arc suppression devices across relay and switch contacts.

F. RFI Measurements.

Official reports on RFI measurements for subsystems within the AN/TSQ-47 were not available; however, preliminary reports were obtained for the AN/TSW-5 and the AN/TSW-6. The report for the AN/TSW-5 indicates that the interference levels, as measured during Mode #1 Radiated (both broadband and narrowband) and Mode #2 Radiated (with one exception) were above the requirements set forth by MIL-I-26600, and that the conducted interference was within the requirements of MIL-I-26600, with the exception of operation of the microphone key switch. The report for the AN/TSW-6 indicates that the interference levels, as measured during Mode #1 Radiated (both broadband and narrowband), Mode #2 Conducted and Mode #2 Radiated, were above the requirements set forth by MIL-I-26600, and that Mode #1 conducted interference was within the requirements set forth by MIL-I-26600.

From the above it can be seen that both conducted and radiated interference is a problem. It is anticipated that the AN/TSQ-47 contractor can correct the problems with conducted interference and broadband radiated interference (except for the RACEP problem discussed elsewhere), but the narrowband radiated interference could be a serious problem. This interference can be caused by receiver and transmitter spurious outputs, harmonics of spurious outputs, harmonics of the assigned transmitter frequency, and signals on adjacent channels. Except for adjacent channel interference, all of the preceding types of interference are determined by the design of the radio equipment, and except for harmonics of the transmitter, cannot be easily reduced without incorporating equipment of new design. The only remaining alternative is to make judicious frequency assignments within the AN/TSQ-47 complex. This is discussed further in the following paragraphs.

G. Recommendations for further investigation of RFI problems.

Even though there is room for improvement within the AN/TSQ-47 as far as elimination of man-made radio frequency interference is concerned, there is no hope that this interference can be completely eliminated; and even if complete elimination were feasible, the costs would probably be beyond reason for the additional benefits obtained. In addition, the AN/TSQ-47 must be capable of operating in an area where other users of radio and interference generating equipment are present. From the preceding information, it seems that another approach must be included for the solution of RFI problems that may be encountered as a result of the deployment of the AN/TSQ-47 in the field.

Since the number of variables involved in determining all RFI conditions for every possible deployment configuration of the AN/TSQ-47 is so large that manual calculation would require an inordinate length of time, if possible; it is recommended that a computer program be developed. This computer program should be especially tailored for the AN/TSQ-47 to enable RFI analysis and prediction. The program should be so devised that it can include operation of the AN/TSQ-47 in areas where outside sources of RFI are present. With this program, calculations could be made on the present status of RFI conditions within the AN/TSQ-47, and the results of any proposed changes could be calculated in advance. In addition, the program could be utilized in the future to predict RFI problems for any possible deployment condition that will be assigned to the AN/TSQ-47.

SECTION 2

ELECTRONIC INTERFACE PROBLEMS

Since official reports on the Category I testing of the AN/TSQ-47 are not available, the following discussion is based on information obtained from unofficial sources, and from preliminary reports. The succeeding paragraphs will discuss electronic interface problems between major system components and the recommended solutions.

A. Microwave link interface problems.

The following interface difficulties were encountered during field tests of the AN/TSQ-47.

I. IFR-Search Microwave Link.

(a) Excessive overshoot of IFF video at microwave output.

The overshoot of the IFF video measured at the output of the video-trigger demultiplexer at the IFR shelter was found to be 30% with an input pulse rise time of 0.09 microsecond at the opposite end of the link. Specifications call for an overshoot of less than 10 percent with an input pulse rise time of 0.3 microsecond.

To solve the above problem, the microwave link should be retested with an IFF video input pulse of 0.3 microsecond as specified and with proper input terminations. The output should be terminated with the proper resistive load. This test will indicate whether the microwave works properly with the specified input signal and terminations. If it doesn't, the microwave equipment should be repaired or modified as required. Since the microwave performed satisfactorily during factory tests, the difficulty is probably not caused by the microwave.

Assuming results are satisfactory the next step is to test the operation of the microwave link with an input pulse having a rise time of 0.09 microsecond and with the same resistive terminations as before. If the overshoot is excessive, this would indicate that the input pulse rise time is causing the difficulty. This could be resolved by employing a RC network to increase the pulse rise time of the video from the IFF receiver; however, this is not recommended unless the excessive overshoot causes difficulties in the IFF decoder. It is considered worse to degrade the response than to have excessive overshoot, if no other problems result from the overshoot.

In addition to the above, it is possible that some of the excessive overshoot could be caused by improper termination of the microwave output. To test this possibility, the resistive load should be removed from the microwave output and the equipment (video decoder) should be reattached. The specified input pulse (0.3 microsecond rise time) should be applied at the opposite end. Any overshoot exceeding that obtained when using terminating resistors can be attributed to improper termination provided by equipment attached to the microwave output. If the overshoot is excessive, the difficulty can probably be corrected by inserting a minimum loss matching network. If this proves to be unsatisfactory, the equipment will have to be modified to provide proper input impedance.

Excessive overshoot could also be caused by improper output impedance of the IFF receiver on the input end of the microwave link. This difficulty could also be solved by insertion of a matching network, or modification of the IFF receiver output impedance.

(b) Excessive azimuth error of PPI's in IFR shelter when referenced to indicator at search radar shelter.

The azimuth error of targets on the PPI's in the IFR, when compared to those on the indicator at the search radar, exceeded the specifications. The microwave azimuth data system was rechecked (static test) and found to be within specifications. Evidently, the error is mostly contributed by the indicator(s).

The test procedure used for checking the azimuth error is not considered satisfactorily since comparison is made with the indicator at the search radar which could also have errors. A better method would be to compare the azimuth of the search radar antenna against the azimuth position of the PPI sweep at the IFR shelter. Unfortunately, the search radar antenna is not provided with a 360 degree protractor so that the azimuth position of the antenna can be accurately determined. It is recommended that this item be added to enable more accurate calibration.

The major reason for the azimuth error of the PPI's in the IFR shelter seems to be a result of using a one-speed servo system instead of a two-speed servo system. If greater accuracy is a requirement, the indicator should be modified for two-speed servo operation. The microwave link transmits two-speed azimuth data and has the required outputs to handle two-speed indicators.

(c) Blossoming of PPI display.

At the IFR shelter, when the video gain was increased to enable detection of weak targets on the PPI, blossoming of the display occurred. In addition, a bright spot appeared in the center of the indicator.

The cause of the blossoming was evidently a result of incorrect gain setting at the search radar. This resulted in inability of the operator at the IFR to control the gain for optimum indicator display.

The cause of the bright spot on the indicator is apparently due to inadequate blanking of the radar IF amplifier or the video amplifier during the time when the radar pulse is transmitted. This results in a high level video output during the radar transmitter RF pulse and causes a bright video display at the start of the PPI sweep. Modification of the radar receiver to improve blanking of the IF amplifier and/or video amplifier is recommended.

II. IFR-PAR microwave link.

(a) Excessive overshoot of PAR video at input to microwave.

During Category I tests, the PAR video at the input to the microwave was found to have an overshoot of 15%. This is excessive in view of the fact that allowable overshoot at the output of the microwave is only 10%. Unofficial information recently received indicates that the test was rerun and there was no problem with video overshoot and the original difficulty could not be reproduced.

It is recommended that the test be repeated to the satisfaction of an Air Force observer. It is also recommended that the video be coupled to the oscilloscope by means of coaxial cable only and that a probe not be used. If a probe is used, the compensation adjustment should be carefully checked.

(b) Excessive overshoot of PAR video at output of microwave.

Under the same conditions as in (a), when first tested, the PA.R video at the output of the microwave was found to have an overshoot of 26% when specifications call for an overshoot of not more than 10%. Later when the test was rerun, the overshoot was found to be satisfactory.

The recommendations are the same as for (a) preceding.

(c) Excessive rise and decay time of unblanking gate at input to microwave.

The unblanking gate signal at the input to the microwave was found to have excessive rise and decay time. This gate is generated in the precision approach radar. In view of the fact that this signal is differentiated in the microwave equipment, it is essential that the rise and decay time be rapid enough to generate pulses of proper amplitude in order to cause triggering of a bistable multivibrator on the opposite end of the microwave link.

It is recommended that the rise and decay time of the unblanking gate signal be improved to bring the rise and decay time within the specified value (one millisecond).

(d) Trigger delay problem resulting from regeneration of PAR trigger.

When the PAR video and trigger are transmitting over a microwave channel, the trigger is transmitted at a low level and must be regenerated at the receiving end by means of the VT demultiplexer. As a result of this process, the trigger is delayed approximately 0.4 microsecond with respect to the video. This delay caused by the microwave results in an incompatibility problem when transferring from microwave to cable operation or vice versa, and readjustment of the PAR indicators is necessary.

The recommended solution to this problem is the delaying of the radar trigger over cable by the same amount as the delay over microwave. Adjustable delay lines in the range of 0.4 microsecond and which do not seriously increase the rise time are available. An adjustable delay line is considered necessary since each VT demultiplexer will probably have a slightly different delay time which must be compensated for in order to have interchangeable VT demultiplexers.

(e) Noise on precision DC voltages employed for remote indication of position of PAR elevation scan and azimuth scan antennae.

The PAR supplies precision DC voltages which correspond to the positions of the two antennae. Accurate transmission and reproduction to two of these voltages, elevation position of the elevation scan antenna and azimuth position of the azimuth scan antenna, is extremely important. A great deal of effort was exerted in the design of the microwave equipment to insure that these voltages would be accurately reproduced. The microwave equipment accomplishes this by conversion of the precision DC level to a binary code which is then transmitted and reconverted at the opposite end to an accurate reproduction of the input DC level.

The DC input is encoded into a binary form representing one out of a possible 2048 increments. For example, the range of the elevation scan voltage, when the antenna is set for 11 degrees scan, is 4.5 volts; this means that the elevation scan level is divided into increments of approximately 2.25 millivolts. Encoding is accomplished by the microwave equipment which monitors the precision DC voltage, determines in which increment the voltage falls at a given instant, and transmits a binary code corresponding to this increment. If noise or hum is present during the time the encoding takes place, the DC level will be encoded inaccurately and the reproduced voltage at the opposite end will be in error. Combined noise and hum on the precision DC supplied from the PAR should be less than 1/2 of the voltage increment between two adjacent encoding levels. This means that for the elevation position of the elevation scan the noise and hum should be less than 1/2 of 2/25 millivolts, or less than approximately 1.1 millivolts.

In Category I tests the following levels of superimposed noise and hum on the precision DC levels were recorded at the inputs to the microwave A/D (analog to digital) converters.

(1) Measurement of input to A/D converter; elevation position of elevation scan antenna.

Type noise or hum	Level
1. Radar trigger pulses (magnetron off)	0.8 v peak to peak
Radar trigger pulses (magnetron on)	1.5 v peak to peak
2. Additional pulses of undetermined origin	0.2 v peak to peak
3. 400 cps hum	0.02 v peak to peak

(2) Measurement of input to A/D converter; azimuth position of azimuth scan antenna.

Type noise or hum	Level
1. Radar trigger pulses (magnetron on)	1.0 v peak to peak
2. Additional pulses of undetermined origin	0.2 v peak to peak
3. 400 cps hum	0.02 v peak to peak

For example, from item (1) of the preceding it can be seen that for the elevation position of the elevation scan, the noise resulting from radar trigger pulses is more than 1000 times the acceptable level, the noise resulting from pulses of undetermined origin is approximately 200 times the acceptable level, and the 400 cps hum is approximately 20 times the acceptable level.

The effect of the noise on the remote AZ-EL displays is to cause the targets to appear non-uniform in brightness (venetian blind effect).

The exact cause of the noise and hum on the precision DC levels supplied by the precision approach radar has not been officially determined. The noise and hum could come from inside the radar equipment as a result of capacitive and/or magnetic coupling between wiring and components. It could also be caused by electric and magnetic fields affecting the wiring between the output of the radar and the input to the microwave. Since the precision voltage is referenced to ground at both the radar and the microwave, some of the hum and noise could come from circulating currents in the ground return.

Obviously, specific recommendations for reducing the noise and hum cannot be made without knowing the cause; however, recommendations can be made for reducing or eliminating noise and hum resulting from conditions mentioned in the preceding paragraph.

(1) Hum and noise resulting from capacitive and/or magnetic coupling inside the radar set.

To reduce the effects caused by capacitive coupling of noise and hum into the precision DC circuits, electrostatic shielding of the precision DC circuit wiring and components should be employed. Wire with solid metallic foil shielding is recommended over that with braided shielding. For maximum reduction of interference, double shielding is recommended.

To reduce the effects caused by magnetic coupling of noise and hum into the precision DC circuits, magnetic shielding of the precision DC circuit wiring and components should be employed. Magnetic foil for shielding is commerically available.

It should be possible to combine the functions of electrostatic and magnetic shielding so that one type of foil will accomplish both purposes.

(2) Hum and noise resulting from electric and magnetic fields which affect wiring between radar and microwave.

Electric and magnetic shielding should be employed in the same manner as recommended in (1) preceding. In addition, twisted shielded pairs could be employed provided the return is grounded at only one point. Refer to (3) which follows for additional comments.

(3) Hum and noise resulting from circulating currents in the ground return.

At the radar, one side of the precision DC output is referenced to chassis ground, and at the input to the microwave the precision DC is also referenced to chassis ground. The chassis ground of the microwave and the radar are both connected to shelter ground at different points within the shelter. Unfortunately, referencing of the precision DC to ground at two different points results in a ground loop which can cause noise and hum to appear on the precision DC because of circulating ground currents within the shelter.

The preceding difficulty can be alleviated to a certain extent by a number of approaches as follows:

(1) The microwave analog to digital converter could be redesigned to provide a floating differential input for the precision DC from the radar. The ground return could then be carried back to the radar and the ground loop would be eliminated. In addition, a twisted shielded pair could be employed to further reduce pick-up resulting from nearby electric and magnetic fields.

(2) The radar could be redesigned to provide a floating precision DC output. The ground return could then be carried to the microwave. The results would be the equivalent to those obtained in (1) preceding.

(3) A loss pass filter could be utilized at the input to the microwave analog to digital converter. The filter could be

designed to remove noise and hum, but pass the precision DC. Such filters may cause a following error (as a result of the rate of change of the precision DC and the inductance and capacitance in the filter) and, as a result, may not be satisfactory.

(4) It may be possible to greatly reduce the difficulties encountered as a result of grounding the precision DC returns at more than one point by employing low frequency baluns in each precision DC circuit between the radar and the microwave equipment. A low frequency balun is essentially a close-coupled unity-turns-ratio transformer; however, unlike normal transformers which are magnetically coupled to provide DC isolation between input and output, the balun provides DC coupling from input to output by insertion of a coil in series with a conductor. In this manner, the two coils provide a DC source and return path for the two conductors of a given circuit. The two windings provide magnetic coupling between the conductors, and as long as the currents flowing in the two coils are equal, no reactance drop across the coils results. However, unbalanced currents are attenuated by the open-circuit coil reactance.

Since the balun provides a DC current path it should be satisfactory for coupling the precision DC between the radar and the microwave; and if the open circuit coil reactance is great enough, the balun should attenuate unbalanced hum and noise currents caused by ground loops. If utilized at the output of the radar, the balun will allow twisted shielded pairs to be employed for connection to the microwave with a corresponding reduction in the effects caused by electric and magnetic fields in the vicinity of the wiring.

Low frequency baluns are commercially available, but one of special design may be required to give optimum results.

B. Telephone system interface problems.

Unofficial information indicates that the major difficulty encountered with the AN/TSQ-47 telephone system was 400 cycle hum interfering with telephone communications. This hum resulted from unbalanced telephone lines which, in turn, were caused by improper design of the telephone equipment. The 400 cycle hum is induced on the telephone lines by the 400 cycle power; however, as long as the telephone lines are balanced no interference results.

The problem was caused by the utilization of a local battery telephone impedance matching unit which employed impedance coupling to the line and which was seriously unbalanced when the shelter DC power and the shelter telephone cabling was connected.

In order to isolate the balanced telephone line from the unbalanced equipment, a special transformer was employed. The transformer primary (connected to the telephone line) had balanced split windings which were electrostatically shielded. Dialing was accomplished by connecting the dial contacts in series with, and at the midpoint of, the split windings.

The above modifications have been tested and found to work satisfactorily. All telephone equipment will be modified to incorporate these changes.

C. RACEP interface problems.

The major RACEP interface problem is concerned with radiated interference by the RACEP. This is covered in this report in the section dealing with electromagnetic interference problems (1).

SECTION 3

MECHANICAL INTERFACES

A. Introduction

This section deals with the mechanical interfaces between the various shelters of the AN/TSQ-47 system and the transporters, the pallets associated with the shelters and transporters, and between the system and various methods which may be used to deploy it, in particular C-130A aircraft equipped with the 463L cargo loading system.

Mechanical interfaces are frequently troublesome areas, and almost always involve trade-offs between design ingenuity, applicability in other areas, weight, size, cost, and many other factors. It also sometimes happens that what initially appears to be a remedy for a defect in performance, can trigger the emergency of a series of other complications more prejudicial to performance than the original difficulty. Some examples of trouble spots are briefly outlined.

There are also comments pertaining to the mechanical design of some of the sub-system components, and suggestions for possible improvement.

B. Shelter-Transporter Interface

The transporter was intended to be used by AFCS mobile squadrons for ease in loading, unloading, and transporting the AN/TSQ-47 system shelters from C-130A cargo aircraft to their respective deployment sites. Transporters were envisaged as necessary to protect the equipment within the shelters from shocks and vibrations which might be encountered during system deployment.

Several aspects of transporter performance which fall into the sphere of general requirements were investigated in considerable detail. These performance characteristics were subsequently incorporated into a specification, initially issued as MIL-D-27925 (USAF).

In the following paragraphs there will be set forth some of the considerations pertaining to the interface between shelter and transporter, which is in essence the coupling mechanism, and the various facets which are of importance.

I. Coupling between transporter and shelter.

This constituted one of the troublesome areas of investigation. Transporter manufacturers utilize different methods of attaching their transporters to shelters, and among shelter manufacturers there are many differences in corner structure design, techniques of shelter end wall reinforcement, etc.

Shelter procurement antedated, by a short time, the decision to provide transporters for the AN/TSQ-47 system. Shelter manufacturers are, of course, aware that their product will in all probability be deployed on wheels, so generally provide for this contingency by the additional of pads and reinforced areas on the shelter end walls. RCA engineers specified these areas such that no matter what shelter manufacturer or transporter manufacturer supplied the equipment, the shelters and transporters could be coupled together rapidly, securely, and with a minimum of work. This was to be accomplished by the use of an adapter kit (furnished by the transporter manufacturer) and simple hand tools. It is understood of course that the nature of this kit would depend upon the particular transporter and shelter finally procured.

The compression and lift areas common to all shelters of the AN/TSQ-47 system, with the exception of the AN/TSW-5 shelter, are shown in Figure 1. The AN/TSW-5 compression and lift area configuration is shown in Figure 2.

There was, of course, the consideration that access to the shelters be possible with transporters coupled to them, meaning that no transporter structure impede or prevent opening shelter access doors with the shelters in transport mode. This applied to all shelters of the AN/TSQ-47 system with the exception of the AN/TSW-5.

Another consideration was that no transporter structure interfere with protuberances, access panels and covers extending beyond the skin line of the shelter end walls.

Some confusion, probably due to the 96-inch width of the AN/TSW-5 shelter, contrasted with the 80-inch width of the others, resulted in the compression pads for the AN/TSW-5 being located at the corner posts. Structural reinforcement, in the form of welded pipe, was added at these pad locations. This, of course, required some form of transported adapter, unique to this particular shelter.

Meanwhile, additional complications arose when the estimated weight of the AN/TSW-5 shelter, originally of the order of 9000 pounds, increased to a figure in excess of 12,000 pounds. The transporters for the other shelters of the system are designed for a maximum of 9000 pounds. The possibility was thereupon investigated of transferring certain equipment from within the AN/TSW-5 shelter (in its operational mode), to a pallet or pallets to reduce the shelter weight for transport, but this resulted in a weight reduction of only about 1500 pounds. A reduction in excess of 3000 pounds was necessary to bring the shelter weight to some figure in the vicinity of the 9000-pound transporter capability. The removal to a pallet of additional internally-mounted equipment, such as indicators and power supplies, was not considered practical. This would necessitate the connecting and re-connecting of cables, shock mounts, fasteners, etc., and in addition would invite damage to the equipment in the process of transfer and tie-down to and from the pallet. The set-up time for the sub-system would also be significantly increased.

The solution lay in the issuance of an exhibit, ESSV 63-7, PR ES-3-482L-4556, for the development and test of a wheeled transporter necessary for ground transport of an air-transportable radar control facility weighing 15,000 pounds. This dolly is to be compatible with the AN/TSW-5 shelter, and will be used for its transport in the AN/TSQ-47 system.

It should be mentioned at this point that the 9000-pound transporter was originally intended for use on all shelters of the AN/TSQ-47 system. At the time, the shelters ranged in estimated weight from 4000 pounds to 9000 pounds. It was considered feasible from a procurement cost point of view, from the sound principles of standardization and maintainability, and the very excellent interchangeability feature of being able to utilize any of the dollies with any of the shelters, to use the design as an all-around vehicle for ground transport of the AN/TSQ-47 shelters. It is appreciated, of course, that in the 4000 pound to 9000 pound range of shelter weights, the transporter design could hardly be expected to be tuned to both weight extremes insofar as capability of shock and vibration isolation is concerned. However, a median design was considered adequate, from an engineering point of view, to accommodate shelters with weights within the 4000 pound to 9000 pound range, and perform satisfactorily insofar as the dynamics of shock and vibration are concerned.

The 15,000 pound transporter will of course be uniquely tailored to the AN/TSW-5 shelter, and will not be used for ground transport of any of the other shelters comprising the AN/TSQ-47 system.

The present trend among transporter manufacturers appears to be that of having as "stock" items, a line of vehicles with various load-carrying capabilities, e.g., 3000 pounds, 6000 pounds, 9000 pounds, and then matching as closely as possible one of these transporters to the particular shelter concerned. This probably works out very well when there is only one shelter, but with a complicated multi-shelter system, standardization appears very attractive.

The weights of transporters presently on the market do not vary with their load-carrying capabilities. This is probably due to type III mobility requirements (generally invoked for these transporters) and the attendant need for "heavy-duty", rugged design of structure, axles, wheels, etc., which automatically establishes a minimum weight threshold. For example, a transporter now on the market with 6000-pound load-carrying capability, and designed for type III mobility, weighs 2500 pounds. A 9000-pound capacity dolly, also designed for type III mobility by the same manufacturer, weighs 2750 pounds, and it is anticipated that the 15,000 pound capacity dolly will not weigh in excess of 3000 pounds.

Eventually, a transporter may emerge capable of carrying loads up to say 10,000 pounds with a suspension system and perhaps even damping characteristics capable of easy and rapid adjustment in the field to match specific shelter weights. Damping appears to have never received too much consideration in transporter design, and resort seems to be made to the natural damping characteristics of air-springs or elastomeric shear and compression mounts. Elastomers, with few exceptions, tend to be temperature-sensitive with regard to stiffness and damping characteristics, particularly as sub-zero temperatures. Continued development work along these lines would perhaps be most appropriate.

This section would not be complete without another remark about the methods presently used to couple dollies to shelters. As stated earlier, different manufacturers of shelters and transporters favor different schemes of accomplishing this. Some standardization in the industry with regard to couplings of this nature would be most desirable. When shelters are procured, for example, followed by the procurement of dollies, adapter kits are furnished with the dollies and these kits are attached to the shelters and become part of them. No other make of transporter can then be used to deploy this shelter without removing the adapter kit and replacing it with another set of adapter hardware compatible with the other make of dolly. These adapter kits are either bolted or riveted to the shelters, and the mutilation of mounting surfaces caused by the attachment of one kit and its subsequent removal, may prejudice the application of another type of kit, or require plugging of holes and other expedients to accomplish in a thorough manner.

Another consideration is that the cost of these kits is of the order of several hundred dollars, and even though a full complement of dollies may not necessarily be procured for a multi-shelter system, each shelter should be equipped with a kit, as it would not be very practical in the field to transfer adapter hardware from one shelter to another in order to be able to transport it.

C. Shelter-463L Interface

It was defined that the AN/TSQ-47 emergency mission support system be compatible with the 463L cargo-loading concept insofar as transportability in the C130A cargo aircraft was concerned. The system shelters are of 80-inch width, with the exception of the AN/TSW-5, which has a width of 96 inches. RCA engineers stipulated that guide rails be designed and affixed to the shelters, these rails to mate with the rails in the C130A aircraft cargo compartment. (The rails in the aircraft may be arrayed in either an 88-inch wide or 108-inch wide configuration.)

In either configuration, the shelter guide rails transmit the shelter load to two longitudinal arrays of rollers. The arrangement also permits locking the shelters in a fore-and-aft direction, and the rail design provides restraint to any sidewise forces which may be encountered in flight.

It is not possible to remove the guide rails from a shelter when the shelter is resting on the ground. It is necessary to raise the shelter either by leveling jacks or with a transporter in order to attach (or detach) these rails. This is considered something of a disadvantage, although not a serious one, and considerable effort was devoted to the search for an alternate design, without much success. The important consideration would seem to be that a shelter with rails attached not be dragged over rocky terrain nor handled in such a manner that damage to the extruded rail sections could occur. A badly damaged shelter rail might prevent the shelter from being loaded in the aircraft due to interference or misalignment with the cargo-compartment guide rails.

An interesting geometric consideration may be appropriate in connection with the design of shelters for air transport, or shelters which may be associated with mission support systems. It is understood that the C-141 Star Lifter (to which the 463L concept is primarily directed) will have guide rails in the cargo compartment spaced 108 inches apart, and there will be no alternative 88-inch spacing arrangement provided. This means that if an 80-inch wide shelter is to be adapted to these guide rails, some form of structure will have to be provided

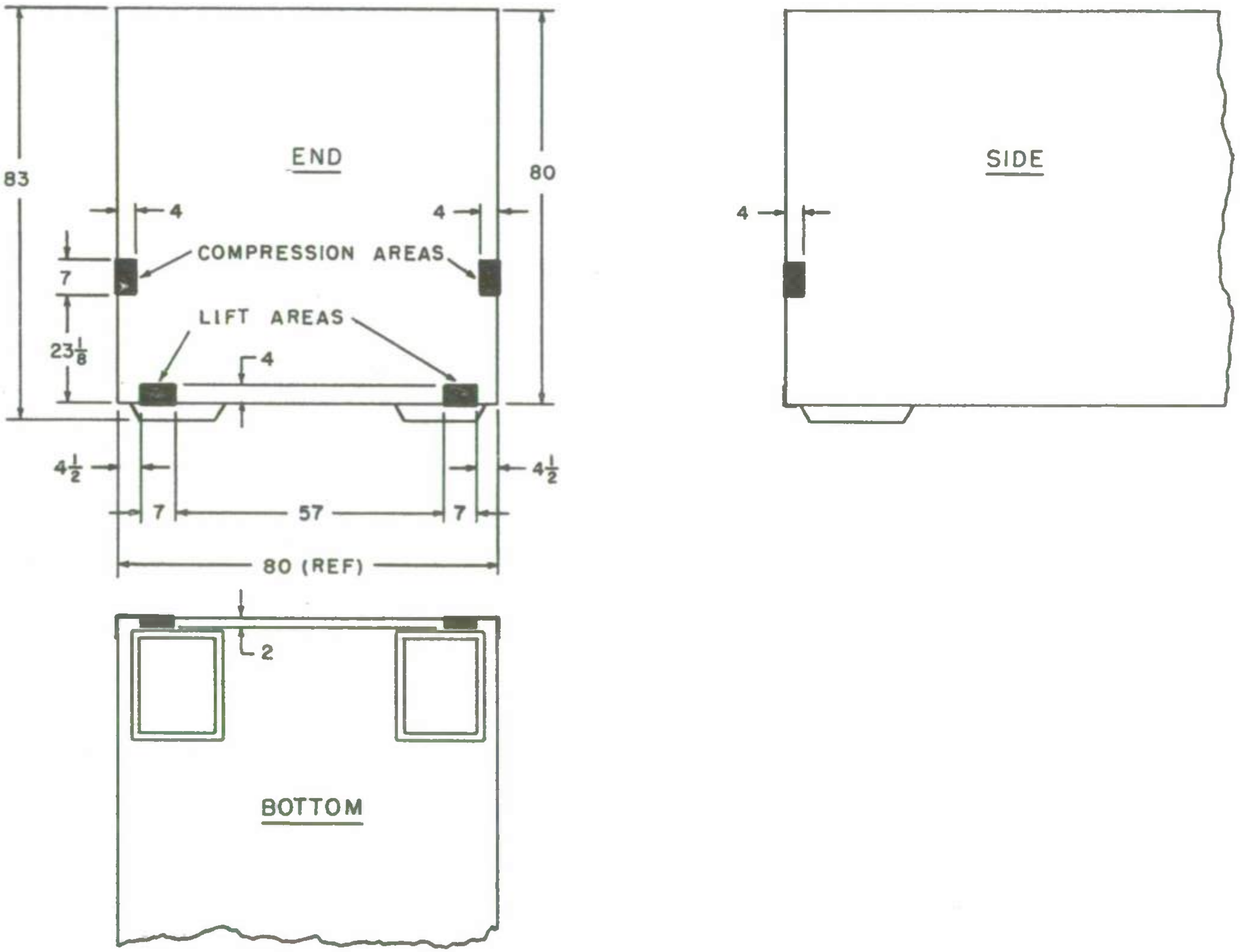

FIGURE 1: Location of Coupling Attachment, AN/TSQ-47 Shelters With Exception of AN/TSW-5

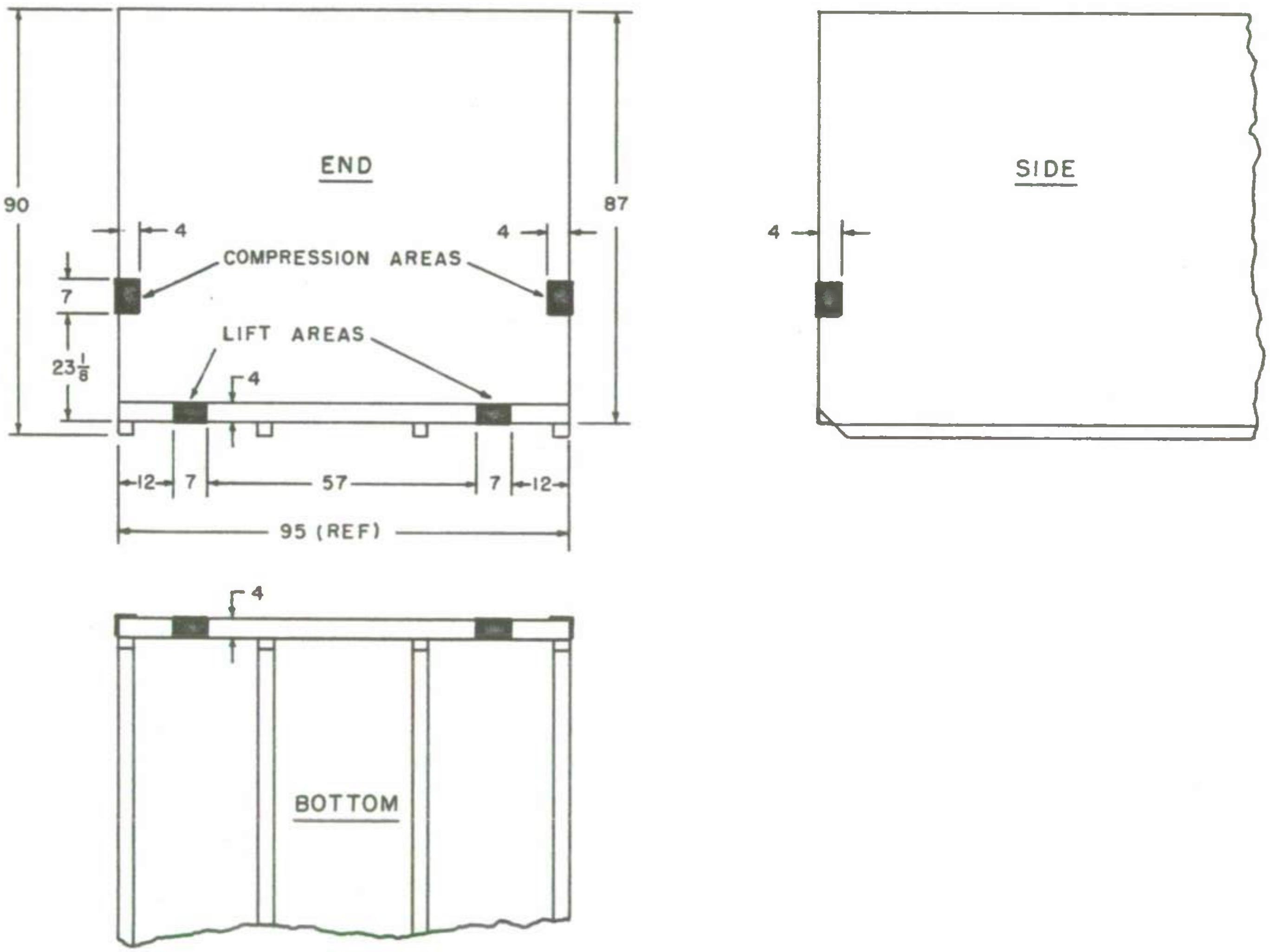

FIGURE 2: Location of Coupling Attachment, AN/TSW-5 Shelter

extending out 14 inches along each side of the shelter.

An alternative arrangement would be to tie down the shelter to a standard 88-inch by 108-inch aircraft pallet, and dispose the pallet in the aircraft with the 88-inch dimension in the fore-and-aft direction. Some 80-inch wide shelters, however, are over 144 inches in length, which would mean a 28-inch (or greater) overhang, both front and rear, on the pallet. Although these pallets are presently designed to carry 10,000 pounds, and most shelters would weigh considerably less than this figure, the overhang may cause difficulties. For example, if the shelters are equipped with iso-skids or similar non-channel type skids, the shelter load would be transmitted to the pallet through the four rectangular pad areas, with the attendant high stresses thereon, rather than in an evenly distributed fashion over the area of the pallet. It is also likely that due to shelter overhang, only a fraction of the rectangular areas of the skids would be in contact with the pallet surface, thereby further increasing the stress.

A rectangle is an "inefficient" way to enclose a given area (the most efficient is a circle), and the greater the ratio of rectangle length to width, the longer the perimeter of the rectangle. In terms of shelters (which have rectangular floor configurations), the closer the rectangle approaches a square (to preserve orthogonality of sides), the smaller the perimeter, and the less the material required for the side walls (assuming equal heights). For example, a shelter having a width of 80 inches and a length of 144 inches has a floor area of 11,520 square inches. If the width was increased to 96 inches, a 120-inch shelter length would yield the same floor area. The perimeter of the rectangle would be reduced from 448 inches to 432 inches (16 inches represents a reduction of 3.5%) and the length reduced 24 inches, a 16.6% reduction.

Although the side-wall material saving is small, the relatively large percentage decrease in length has significance. The bending moment on the fore-and-aft floor beams would be considerably less when the shorter shelter is in transport mode, and this may permit the use of lighter structural members to adequately carry the same load. Another advantage which may accrue is that more shelters could be placed in an aircraft, because fuller use has been made of the available cargo-compartment width.

Standardization of width in shelters which are part of air-transportable systems may be considered appropriate. A choice of say, 96 inches would permit attachment to these shelters of guide rails similar to those presently utilized on the AN/TSW-5. These guide rails would mate with the 463L guide rails in the C-141 aircraft. Runners could also be attached to the underside of the shelters at locations corresponding to the two inboard roller arrays on the C-141 cargo compartment floor. This would distribute the load over the four sets of rollers rather than over just the two outboard rows, as is presently the case for AN/TSQ-47 shelters. For over-the-road transport (with rails removed) the over-all shelter width would be the same as the 96-inch over-all width of the type III mobility transporters presently utilized for the AN/TSQ-47 system.

It is appreciated that the equipment housed within the shelters is the paramount consideration. The sequence of events is generally to make an acceptable, workable layout of equipment, enclosed within a rectangular envelope, followed by trade-offs between available "stock" shelters, center of gravity considerations, convenience of equipment to personnel, location of access doors, and other factors. It is difficult to envisage that the stipulation of a 96-inch width as a standard would prejudice an equipment layout that would be acceptable if packaged in an 80-inch (or some other width) enclosure.

Shelters now are manufactured as "standard" items in various lengths, widths, and heights; see Table I Craig Systems, Inc., Drawing No. SK2318 (Appendix, Fig. 19). Note that for model numbers H-587 and S-141 the lengths and widths are identical, but H-587 has a height of 76 inches versus 73-1/2 inches for S-141. Certainly, there is argument in favor of standardization, particularly for shelters housing equipment and systems which will be deployed by aircraft and transporters.

D. Pallet - 463L and Pallet-Transporter Interfaces

MIL-D-27925A (USAF) specifies that pallet load-carrying capability for the AN/TSQ-47 system shall be 8,500 pounds. It is stipulated further that the pallet be equipped with guide rails such that the pallet may be placed in the cargo compartment of a C-130A aircraft equipped with 463-L guide rails in either the 88-inch or 108-inch wide configuration. The pallet guide rails are to be removable, and only 2 rails (for the 88-inch sides) are to be provided, with the option to be able to attach them to the 108-inch sides as well. When in the aircraft the pallets will therefore be carried in exactly the same manner as the shelters of the AN/TSQ-47 system.

The specification requires that the pallet be provided with structure such that the pallet may be coupled to a transporter. The structure, therefore, must provide attachment points as shown in Figure 1 of this report. (The transporter will couple to the 88 inch sides of the pallet).

A rather important design consideration might be mentioned here. Although the transporter will be coupled to the short sides of the rectangular pallet, requiring that the pallet, fully loaded, be able to withstand the attendant bending loads along the 108-inch length, it must be almost equally rigid in the 88-inch direction. This is because when in an aircraft with 88-inch 463-L rail spacing, it is supported only at the guide rails along the 108-inch sides and the 88-inch width is unsupported between these rails. (The net effect is much the same as if the pallet was being borne by a transporter coupled to the 108-inch sides.)

A somewhat more severe condition accrues when loaded pallets are lifted by sling devices. In this case (with the sling attached at the four corners of the pallet) bending loads prevail not only in the two orthogonal directions, but along the diagonals as well.

If the pallet runner-guide rail design would allow for method of attachment of guide rails to pallets, the same as that presently used for attachment of guide rails to AN/TSQ-47 shelters, utilizing the same extruded section, this would be another step in the direction of standardization of components.

There is an aspect to the use of transporters for the deployment of pallets which is not too satisfactory. This is brought about by the variations in pallet loads. It would not be practical for any one pallet to carry equipment associated with more than one AN/TSQ-47 sub-system. The variation in pallet loads is therefore guide severe. For example, the AN/TSQ-47 search radar antenna sections weigh relatively little, but the envelope dimensions are quite large, and consequently the pallet carrying this equipment may have a gross weight several thousand pounds less than that of a pallet associated with another sub-system, carrying antenna masts, turbine-generators, or other heavy equipment. A transporter which would give a relatively shock- and vibration-free "ride" to a pallet loaded to capacity may give rather harsh treatment to a pallet loaded to only a small fraction of capacity, over the same terrain. This would lend additional emphasis to the need for a "universal" transporter, adjustable in the field, to the specific load being transported. A discussion of this feature is contained in the section "Shelter-Transporter Interface."

E. C-130A Aircraft - Loading Ramp Interface

MIL-D-27925A (USAF) specifies a frame and inclined plane assembly, termed a loading ramp. This ramp was considered a means for conveniently loading shelters and pallets into C-130A cargo aircraft. The frame is intended to hold the upper end of the inclines plane at the level of the cargo floor within the aircraft. This cargo floor may have a height above the ground of from 34 to 46 inches, depending upon load, tire pressure, etc., and the frame is capable of being raised or lowered to conform to the variation in height.

The C-130A aircraft cargo door is hinged and can be used as a "tailgate" of 123-inch length. When the tailgate is lowered to the ground from a 40-inch cargo floor height, its angle with the horizontal (ground) plane is approximately 13° degrees. With 34-inch cargo floor height, the angle decreases to approximately 10° degrees.

The loading ramp specified in MIL-D-27925A is of 156-inch length (to give a small-angle slope). It is not a completely satisfactory solution, but in the absence of low-boy trailers, cranes, and other appurtenances unavailable at remote air heads, it should aid in the loading and unloading function.

Of particular importance in the design of the ramp is that it be capable of supporting the various shelters, whether they be resting directly on it, or their loads applied through transporter tires. The latter is a more severe case since it is of the nature of a concentrated load moving along the beam (ramp). Where transporters are utilized it is anticipated that the arrays of rollers will be removed from the ramp, and that this will result in a smooth plane surface or else runways for the transporter tires.

F. General Remarks.

I. Loading of Shelters into C-130 Aircraft.

Certain shelters of the AN/TSQ-47 system were taken by truck to L.G.Hanscom Field, fitted out with guide rails, and actually placed in a C-130B aircraft equipped with 463-L rails in the cargo compartment. This exercise constituted part of the test program.

Unfortunately, no transporter nor loading ramp was available for this test. However, a crane and a tractor-lowboy combination were used in the loading operation. The shelters were lifted by the crane, the guide rails attached, and then the shelters lowered onto rollers on the lowboy trailer. The trailer was then backed to the aircraft cargo door, which was in a horizontal position. A cable was attached to the towing eyes of the shelter, and the winch used to tow the shelter into the cargo compartment. The tail of the aircraft was restrained from lowering to the ground by placing chocks under the structure just forward of the cargo door hinge. This lowering of the tail is due to rotation of the fuselage around the main landing gear when heavy loads are placed at the rear of the cargo compartment.

An attempt was made to winch the A/G/A shelter (with guide rails attached) up the aircraft cargo ramp. This was not successful due to the leading edges of the guide rails contacting the rollers on the ramp near the roller center lines. The guide rails should perhaps have a curved ski-like contour on the leading edges, which would probably help in bringing the guide rails onto the rollers. It was also noted that the shelter tended to skew on the ramp due to uneven friction between the two guide rails and the roller arrays and the lack of lateral restraint.

It is anticipated that with the new loading ramp and the acquisition of transporters, the minor problems encountered in the AN/TSQ-47 - 463L compatibility test will be entirely eliminated.

II. Shelter Construction.

During the environmental test program, the AN/TSW-6 sub-system was subjected, among other things, to the rigors of placement in a humidity chamber for 10 days. This is a rather severe test - the temperature is cycled between limits such that there is a great deal of condensation deposited on equipment and fittings within the shelter. A great deal of corrosion resulted, and also what appreared to be galvanic action in areas where dissimilar metals were in contact with each other.

Far more disturbing than the above, however, was delamination of the shelter panels. (The AN/TSW-6 sub-system is housed in a Craig Systems shelter, the side-walls of which are sandwiches comprising aluminum skins 2 inches apart and 2-3 $\#/ft^3$ foamed-in-place polyurethane). There has been a lot of conjecture about the causes of the delamination and about its effect on the structural integrity of the shelter. Tests performed at Craig Systems premises in December 1963 dispelled most of the fears about impairment of structural strength. The shelter floor was loaded with 6000 pounds (uniformly distributed) and dropped from a 6-inch height on each of the four sides of the base, in turn. The instrumentation indicated maximum accelerations varying from 8 to 11 g, and of the order of 10 millisecond duration. Other tests included hoisting of the shelter with the shelter floor supporting a 12,000 pound static load, simulated snowloading of the roof (40 $\#/\text{ft}^2$ evenly distrubited), and teetering of the shelter with diagonally opposite corners supported by raised jacks. Appropriate measurements were made during and after each test, and although there were deflections due to the loading, they were elastic in nature and there was no permanent deformation detactable. Measurement accuracy was of the order of ± 1/32 inch.

The delamination, however, must be considered detrimental. If the structural strength of a shelter does not depend upon the sandwich technique but upon the framework of the shelter, reliance on the benefits of the sandwich would seem rather secondary. Certainly, the shelter is weaker because of delamination; fortunately sufficient strength remains to withstand the rigors of the tests set forth above.

An investigation was made to determine the cause or causes of delamination in the shelter sidewalls. Consultation with an expert in sandwich structures and the field of reinforced plastics brought forth the information that although polyurethane foam is excellent for use in sandwich construction, and performs well under fluctuating temperature, a combination of temperature cycling plus humidity may cause expansion of the foam in places, contraction in others, and of course attendant delamination, not only between foam and skin, but as a breakdown of cohesion within the foam itself.

A second cause could be incomplete curing. By exposure, say, to cycling desert temperatures, the improperly cured portion may continue to cure and perhaps this could result in delamination due to local expansion.

A third possibility is quantitative mismatch of the polymer and activator. This is considered to be critical; too much activator is as detrimental as too little. Subsequent temperature cycling may then cause some of the phenomena mentioned above to occur.

The cause most suspect is exposure to high temperature plus humidity, and this in turn raises the query about how moisture may have entered the panels. This may have come about by penetration at the seams along the sides, edges and corners of the structure, and through fittings, particularly in the floor, when the shelter was exposed to heavy and driving rainfall. An example of this was the AN/TPN-14 shelter, in which walking across the floor would cause water (trapped between the sheet metal and the delaminated polyurethane) to geyser out of the tapped bushings attached to the floor to which equipment had not yet been mounted.

Although foamed-in-place polyurethane is unicellular to a great extent, it is recommended that every effort be made in connection with shelter construction to make all seams and sheet-metal junctures as moisture-proof as possible. Any holes (such as those required for air-conditioning ducts, power panels, fittings, etc.) which penetrate the structure should be equipped with appropriate flanges and designed so sealant may be applied to prevent the inroad of moisture into the structure. Any mounting bushings which are used internally and penetrate the core material should be blind and also thoroughly sealed, even though they do not extend through the outer sheet-metal skin.

SECTION 4

METEOROLOGICAL EQUIPMENT

Two meteorological devices are essential in the support of aircraft operations. One is a surface pressure measuring barometer, the other is a wind direction and speed measuring set.

A. Aneroid barometer.

Two aneroid surface pressure measuring barometers, model ML-102-F, FSN 6660-223-5073, should be included. These barometers will be the portable type with leather carrying cases, and shall have both a "millibar" direct reading scale and an "inches of mercury" direct reading scale. Provision should be made for transit storage of two instruments; one of these will normally be utilized in an operating location, the other is to be considered a spare. In operational status, the barometer shall normally be placed upright in a centrally located position. Provision should be made for temporarily mounting this barometer in a manner allowing easy removal, yet insuring against accidental dislodgement from position.

B. Wind Measuring Set.

An investigation was made of the available military wind measuring sets with emphasis placed upon compatibility with the AN/TSQ-47. Following is a discussion of three sets considered.

C. AN/GMQ-11.

The AN/GMQ-11, Wind Measuring Set, is the device which is being used in the AN/TSW-6 in the present configuration. It was designed to be a permanent installation, operated by 110-120 volt, 60 cycle power. The specification is under the cognisance of the Signal

Corps and the equipment is shown in Figures 3 and 4.

D. AN/GMQ-20.

The AN/GMQ-20 is electrically and physically interchangeable with the AN/GMQ-11. Both units are capable of driving two readouts without resorting to line amplifiers. Both units must be mounted either on the roof of a shelter or on an auxiliary tower structure which is not provided as part of the set. The AN/GMQ-20 specification is under Air Force cognizance.

E. AN/TMQ-15.

The AN/TMQ-15 is designed to be a portable, self-sustained wind measuring set under Air Force cognizance. Whereas the AN/GMQ-11 and the AN/GMQ-20 utilizes an aerovane driven by the wind to generate a voltage, the AN/TMQ-15 is a light chopper device which has less inertia (just the friction of the bearing supporting the three cup anemometer) and correspondingly has higher sensitivity and lower response time. The AN/TMQ-15 comes in three carrying cases, complete with mast, crossarm, guying wire and stakes, remote indicators and cabling, spare parts, and tools. The units can be operated from 110-120 volt, 60 cycle power or from 12 VDC. The 12 VDC is normally supplied by battery packs which weigh 50 pounds and are capable of supplying proper input power for 150 hours continuous operation. However, if 12 VDC is made available (from existing 28 VDC power supplies in the AN/TSW-5) battery packs are not required. The AN/TMQ-15 is shown in Figures 5 through 13.

F. Conclusions and Recommendations.

The conclusions and recommendations of the investigation are as follows:

(a) The AN/GMQ-11 and AN/GMQ-20 are not ideally suited for use with the AN/TSQ-47 because both wind measuring units require 60 cycle power for their 50-60 cycle synchro assemblies; the AN/TMQ-15 can operate from either 50-60 cycle of 12 VDC power.

(b) The AN/GMQ-11 and AN/GMQ-20 are capable of driving one remote indicator without line amplifiers; the AN/TMQ-15 is capable of driving up to four remote indicators over type W-108B telephone cable.

(c) The AN/GMQ-11 and AN/GMQ-20 were designed for permanent installations; the AN/TMQ-15 was designed for mobile applications.

(d) The AN/GMQ-11 and AN/GMQ-20 require a mounting structure which is not included; the AN/TMQ-15 contains its own tower assembly.

(e) If the AN/GMQ-11 or AN/GMQ-20 is mounted on a shelter, they could possibly cause interference with the antenna patterns and communications blind spots. Thus an auxiliary tower assembly may be desirable. The tower assembly of the AN/TMQ-15 can be positioned up to 500 feet from its translator-power supply group, thus eliminating any interference problems.

(f) The AN/TMQ-15 translator-power supply group could be deployed inside the AN/TVN-1 runway lighting van with no modifications to the AN/TVN-1 necessary. Since the AN/TVN-1 is deployed 500 feet from the runway, the indication of wind conditions would not be influenced so greatly by different deployment situations. The J-C 96 type W-108B telephone cable could be routed through the telephone terminal block of the AN/TVN-1 to the remote indicators. One remote indicator could be located in the AN/TSW-6 (which is to be located close to or on top of the AN/TVN-1), and the two remote indicators could be located in the

RAPCON (one at each PAR position.) In the AN/TVN-1, 110 volt 60 cycle power is available (two convenience outlets) to power the translator-power supply group. In the AN/TSW-5 and the AN/TSW-6, 12 VDC would have to be made available from existing 28 VDC power supplies. The only constraint that would be imposed upon the AN/TSQ-47 system is that the AN/TSW-5 be deployed within 10,000 feet of the AN/TVN-1 (assuming that the AN/TVN-1 and the AN/TSW-6 are located virtually in the same place.)

(g) If the AN/TSW-6 is doployed separately, the AN/TMQ-15 translator-power supply can be placed in the shelter and the primary readout panel is utilized. This can be driven by the same 12 VDC source that would have operated the remote indicator.

(h) If the AN/TMQ-15 is used in the AN/TSQ-47 system, no storage space is required inside shelters since the three carrying cases which comprise the AN/TMQ-15 could be easily stored on one of the existing pallets which are not fully loaded.

(i) It is recommended that no wind measuring set or remote indicator be considered as part of the AN/TPN-14. The PAR operator in the AN/TPN-14 has sufficient communications equipment to receive wind information from either the Tower or RAPCON operator. Also, the restriction that the AN/TPN-14 and the AN/TSW-6 be deployed within 10,000 feet of one another (on the same side of the runway) would be imposed upon the AN/TSQ-47.

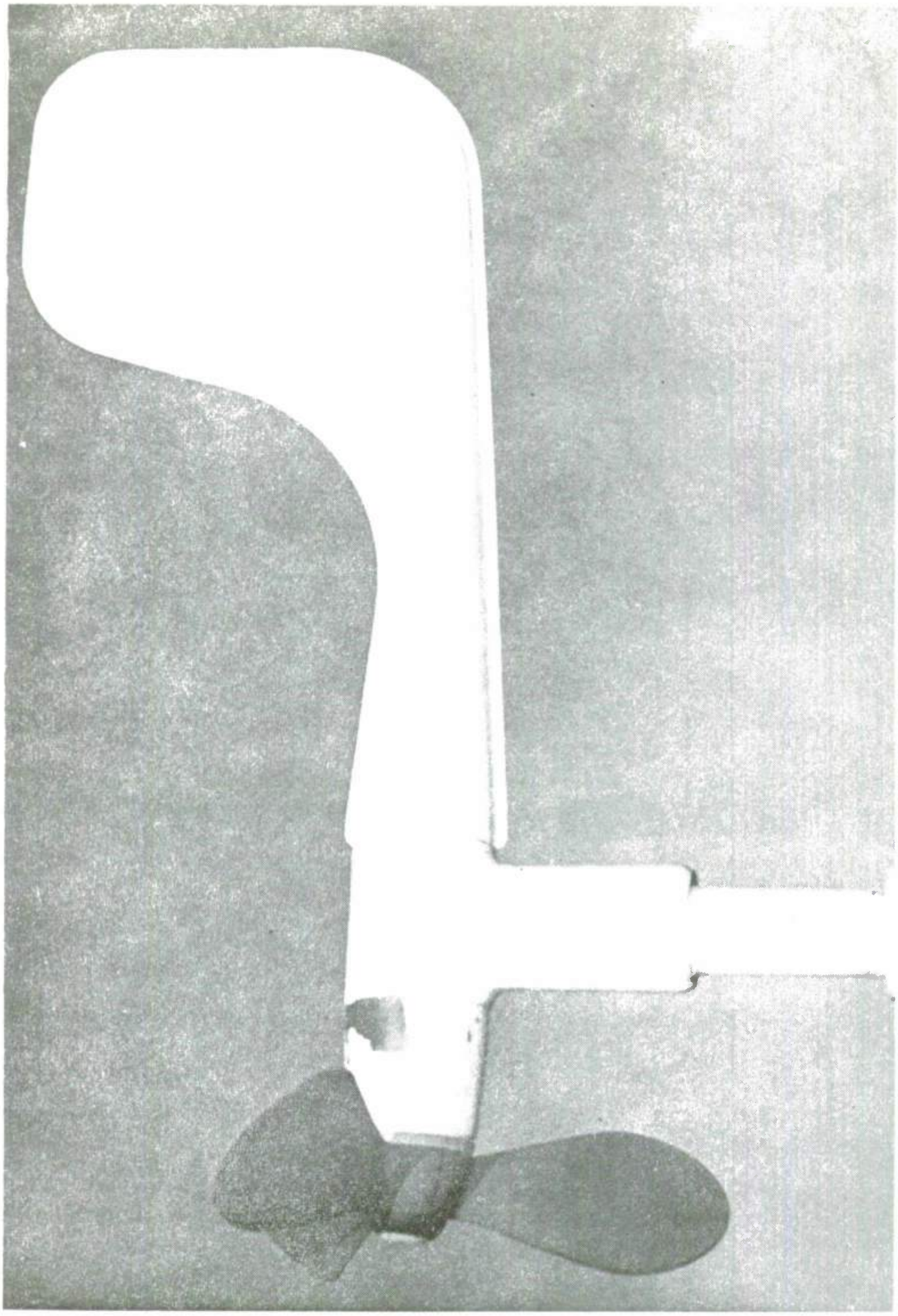

FIGURE 3: AN/GMQ-11 Transmitter Assembly

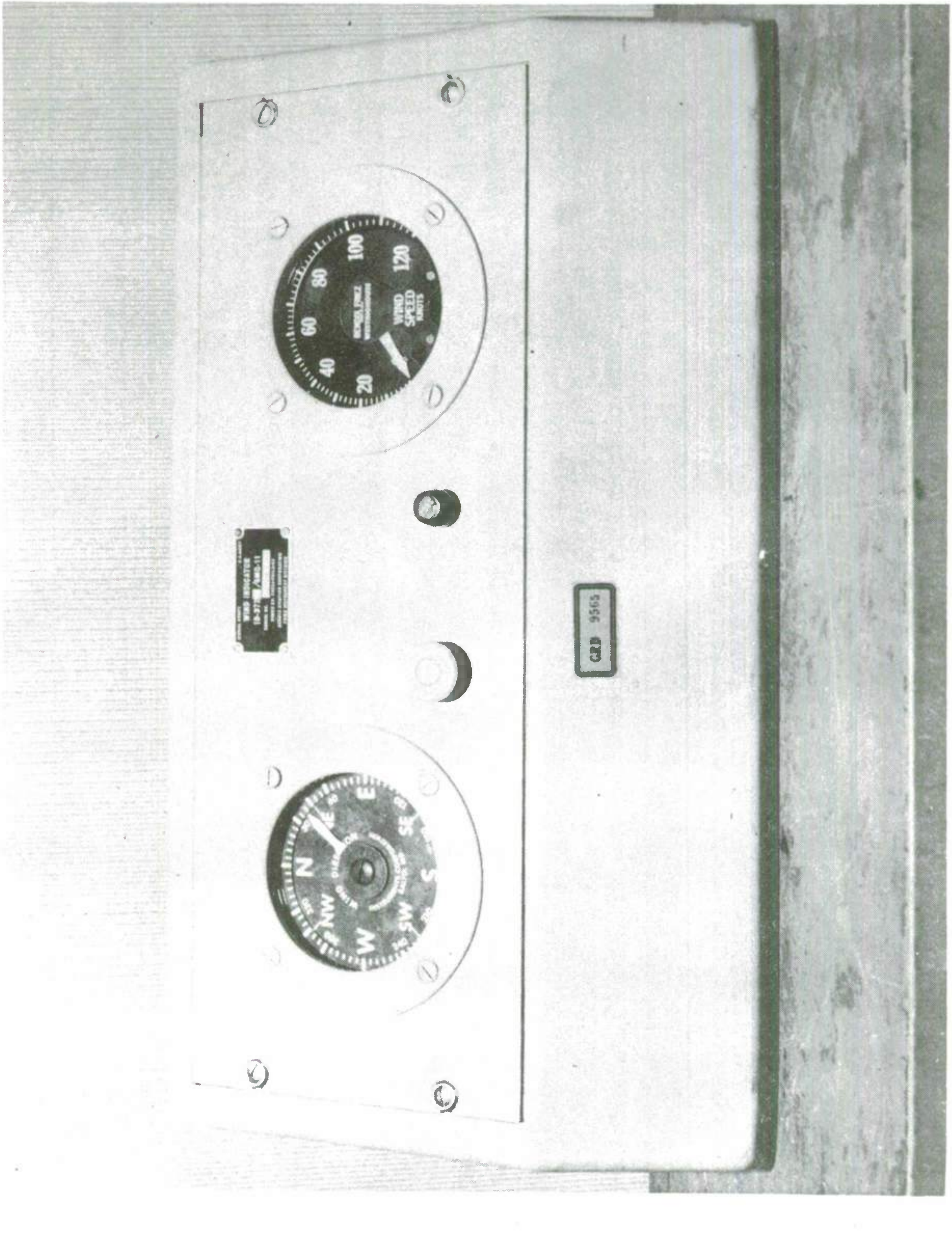

FIGURE 4 : AN/GMQ-11 Indicator Unit

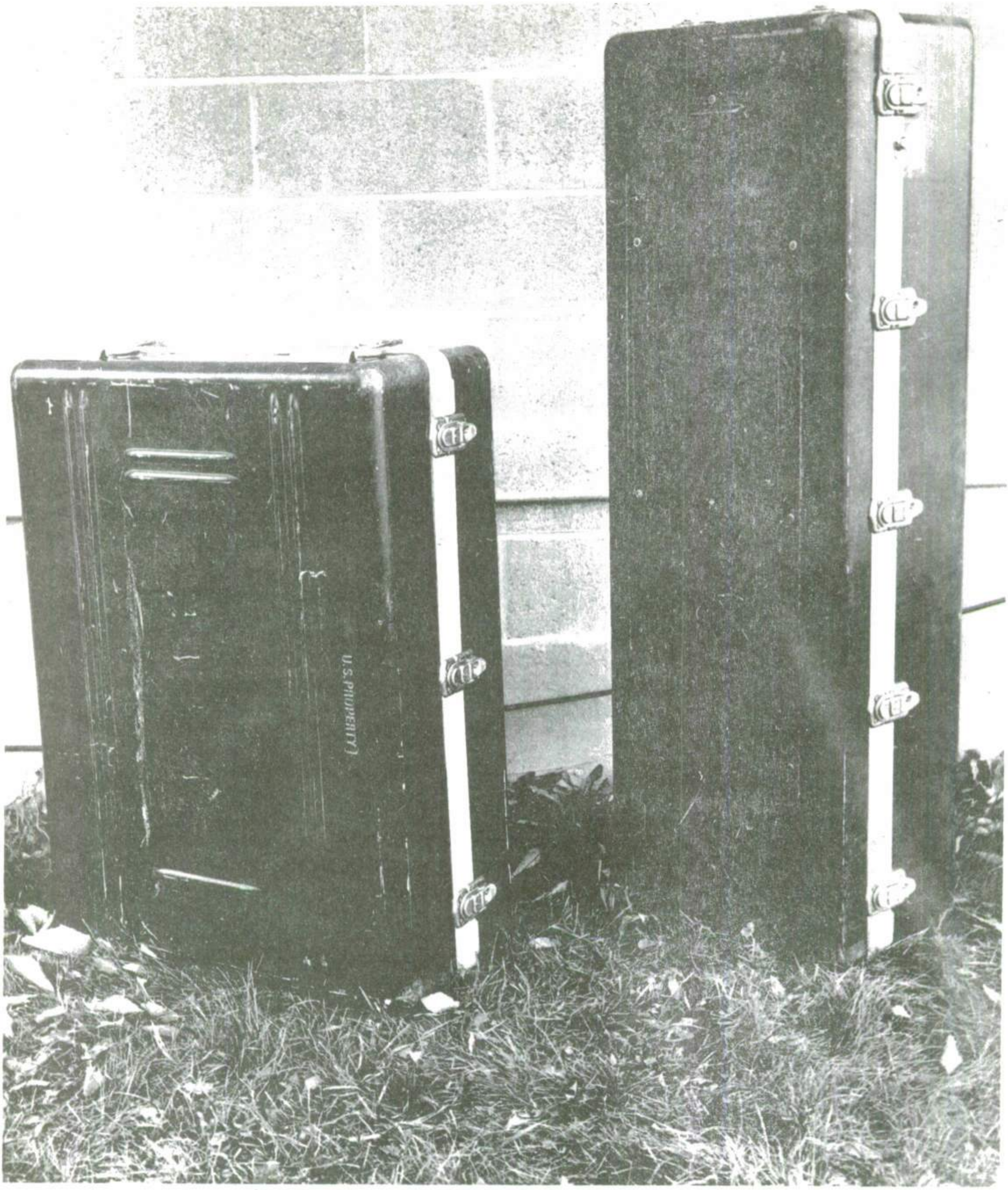

FIGURE 5: AN/TMQ-15 Carrying Cases

FIGURE 6: AN/TMQ-15 Case No. 1

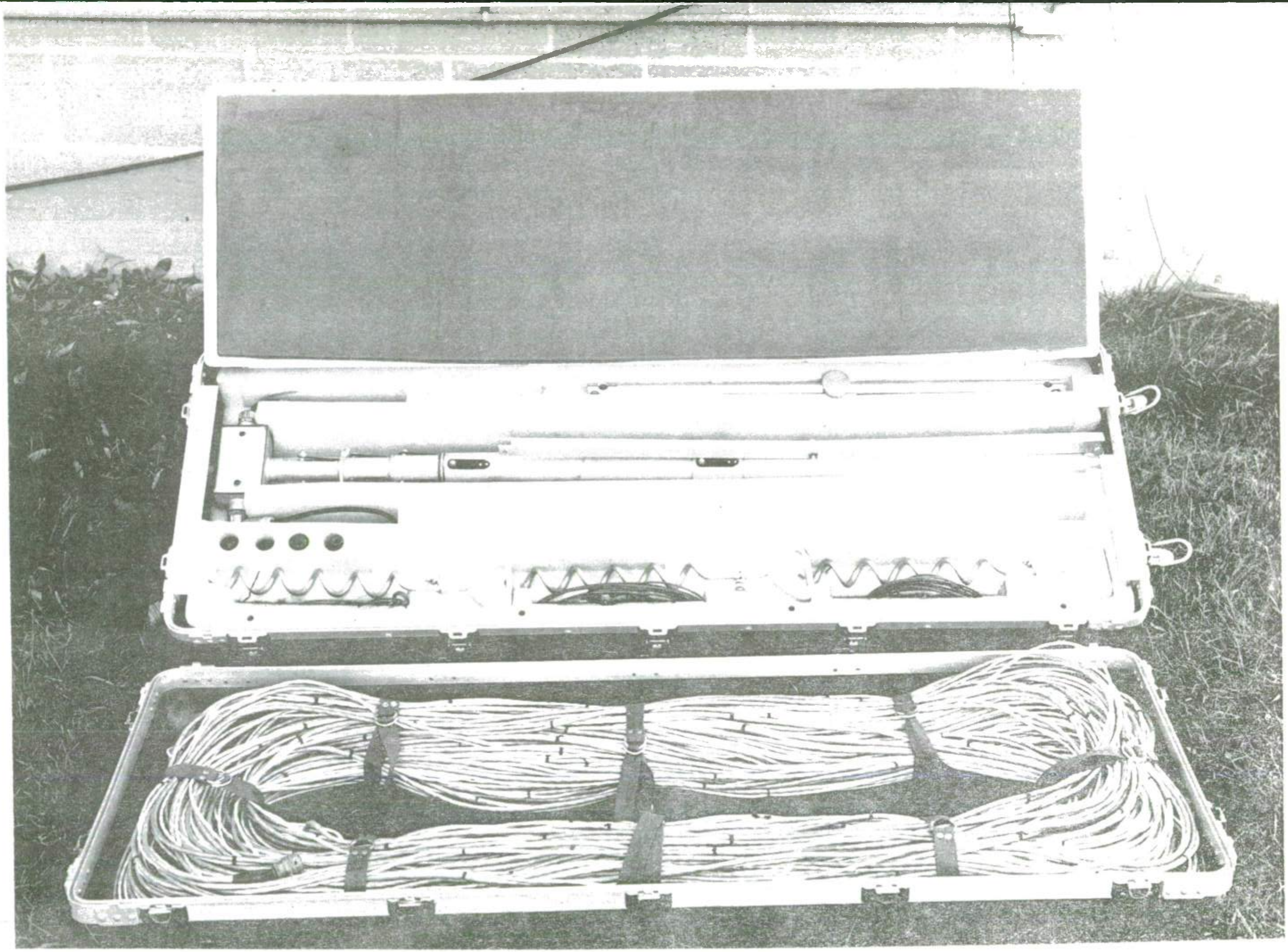

FIGURE 7: AN/TMQ-15 Case No. 2

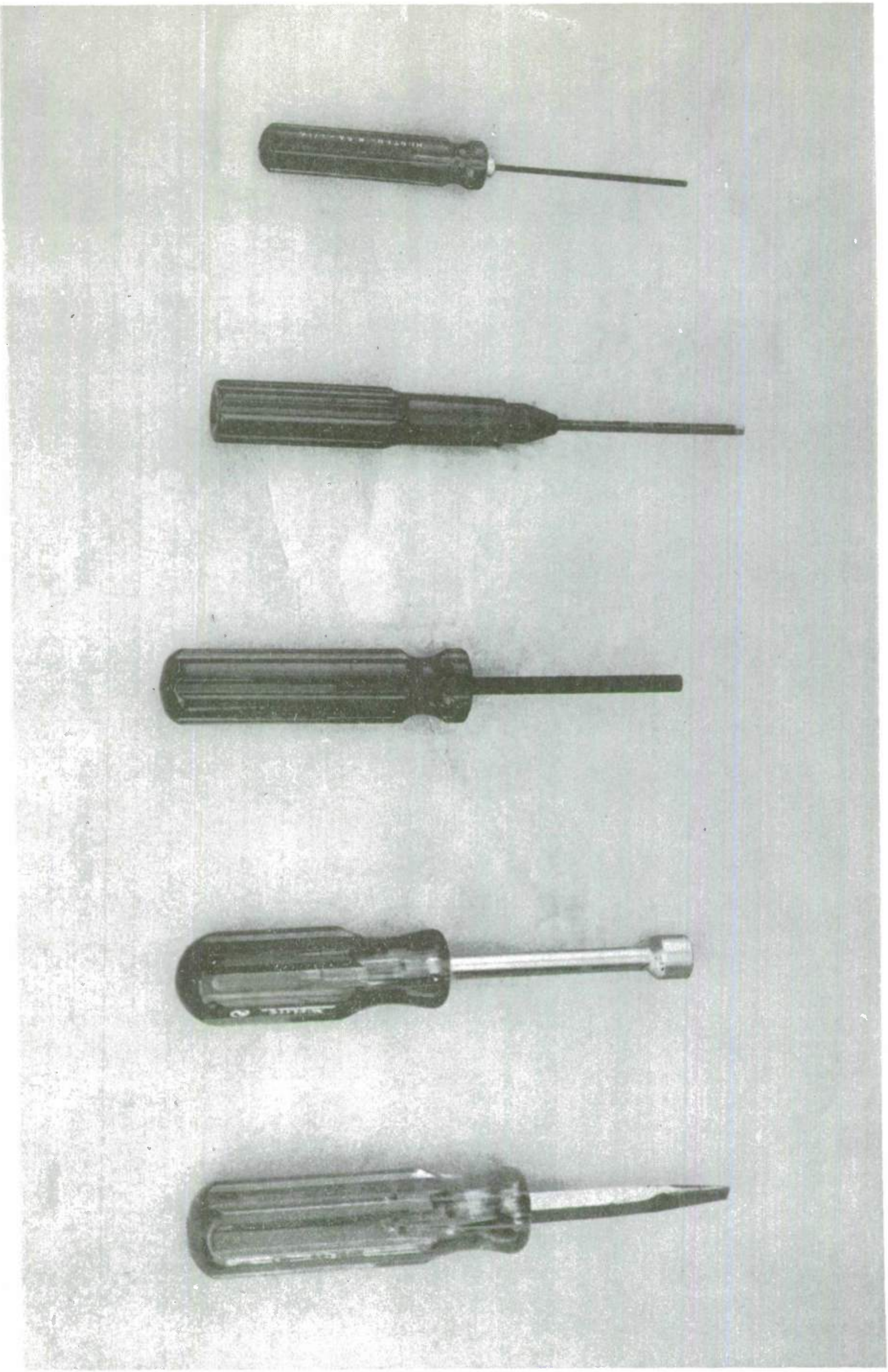

FIGURE 8: AN/TMQ-15 Tools

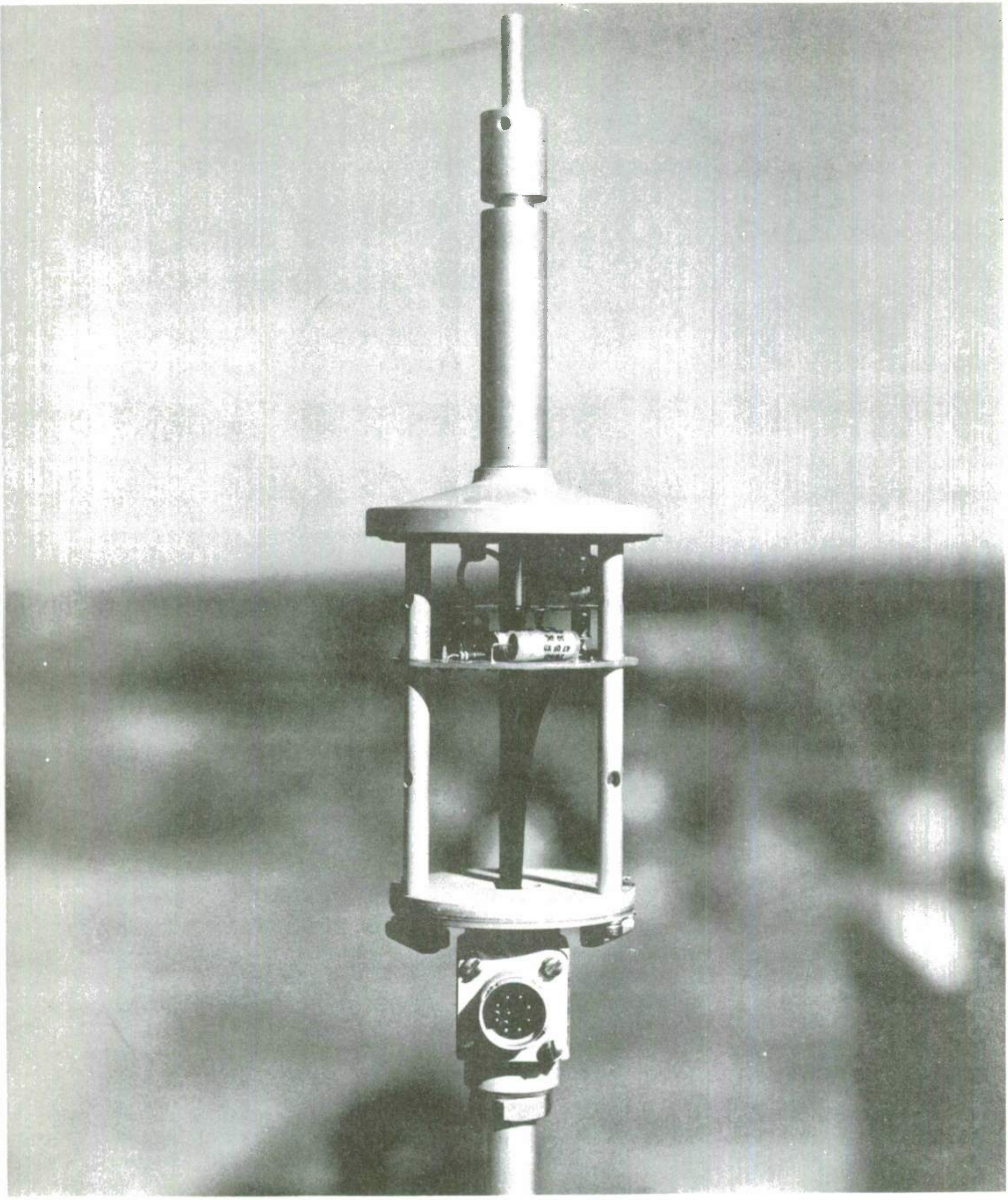

FIGURE 9: AN/TMQ-15 Wind Speed Transmitter

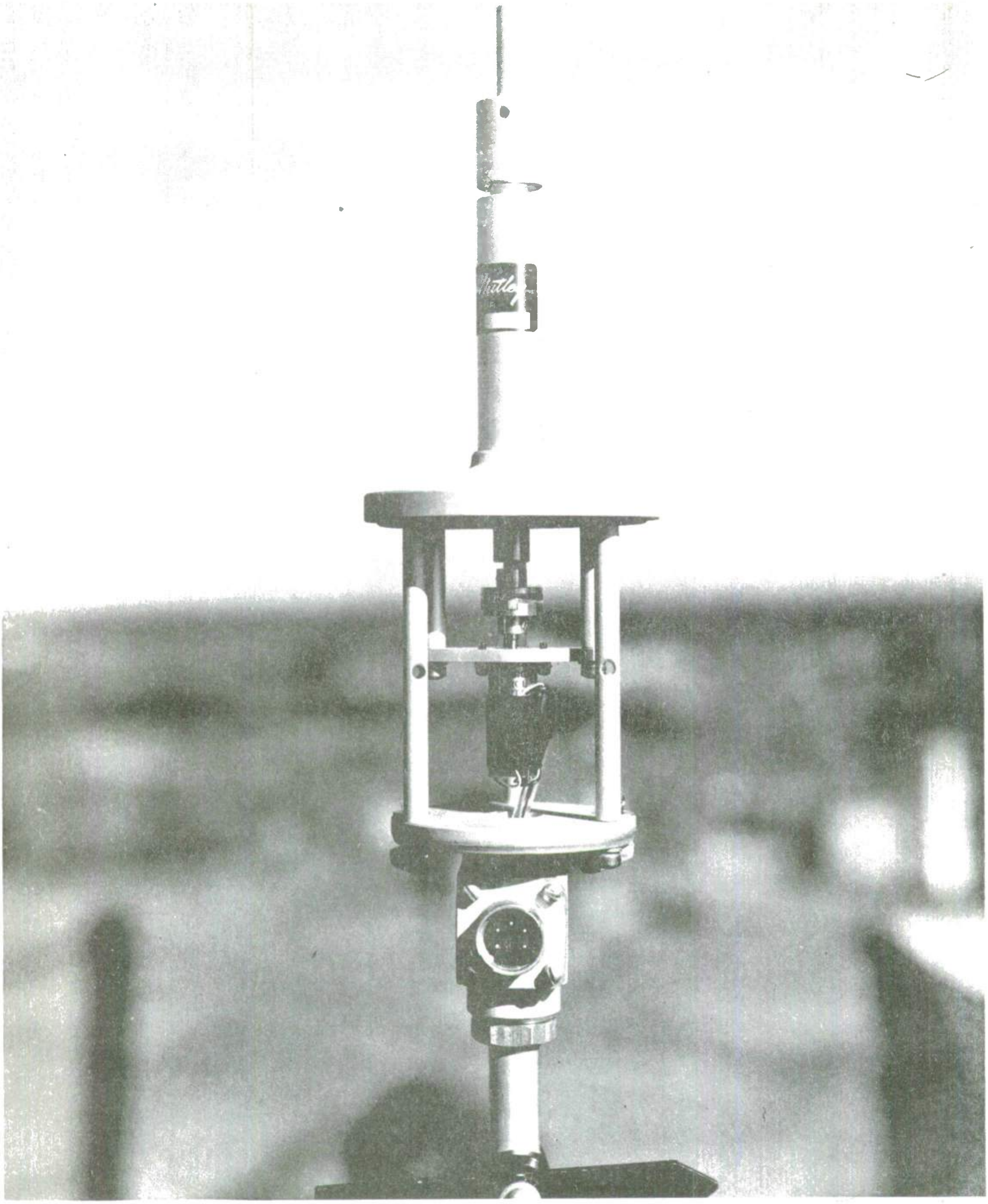

FIGURE 10: AN/TMQ-15 Wind Direction Transmitter

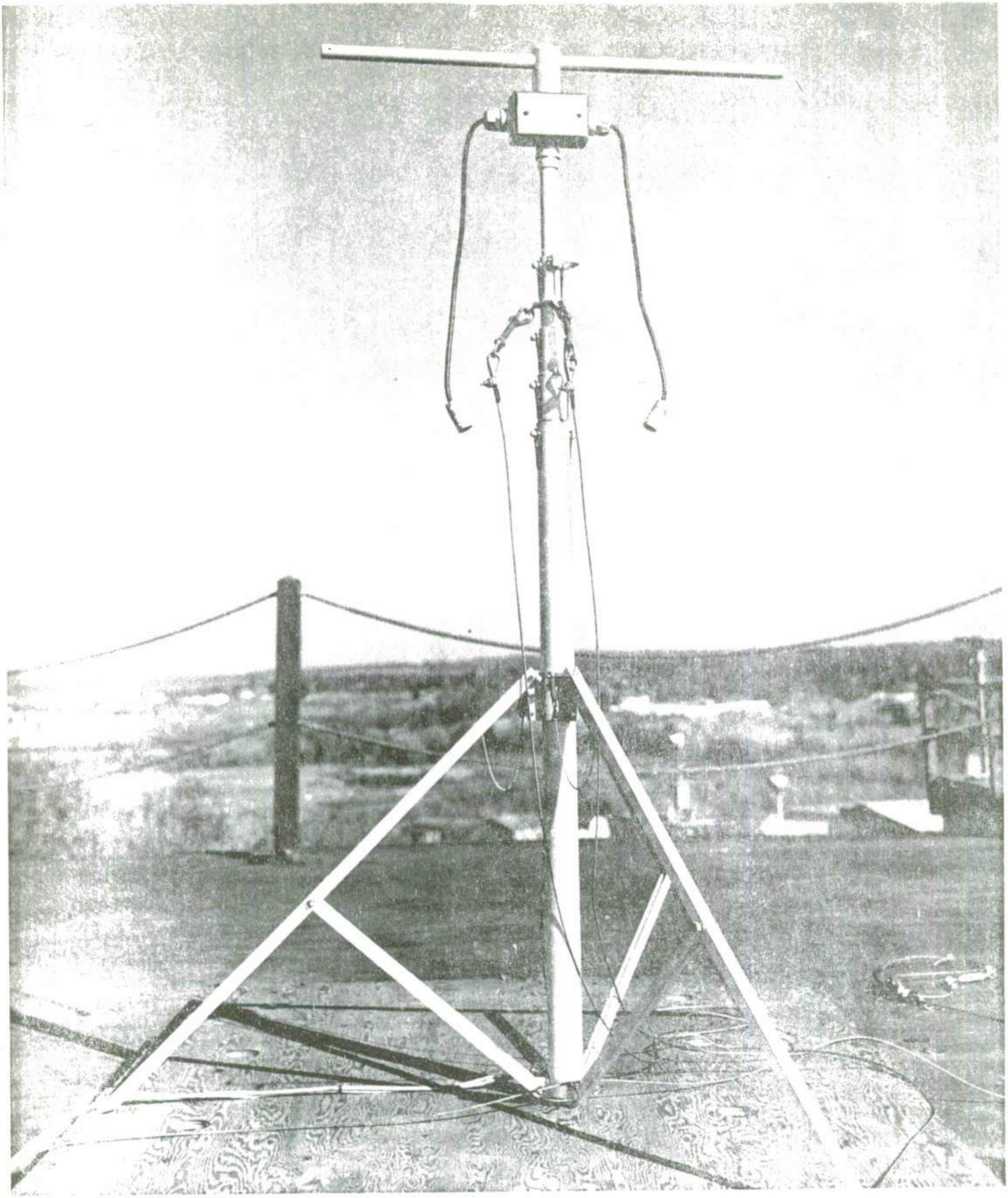

FIGURE 11: AN/TMQ-15 Mast Assembly

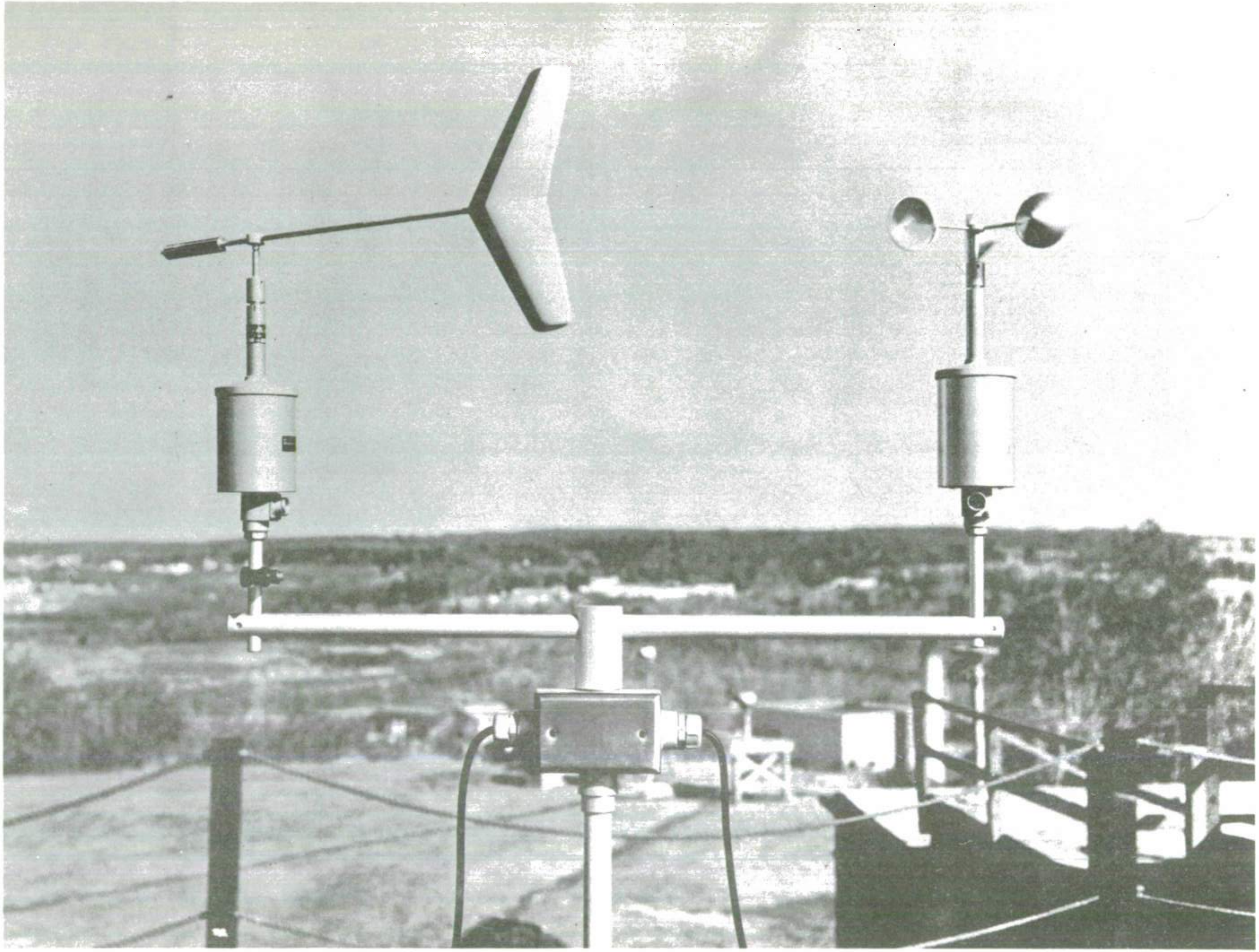

FIGURE 12: AN/TMQ-15 Crossarm Assembly

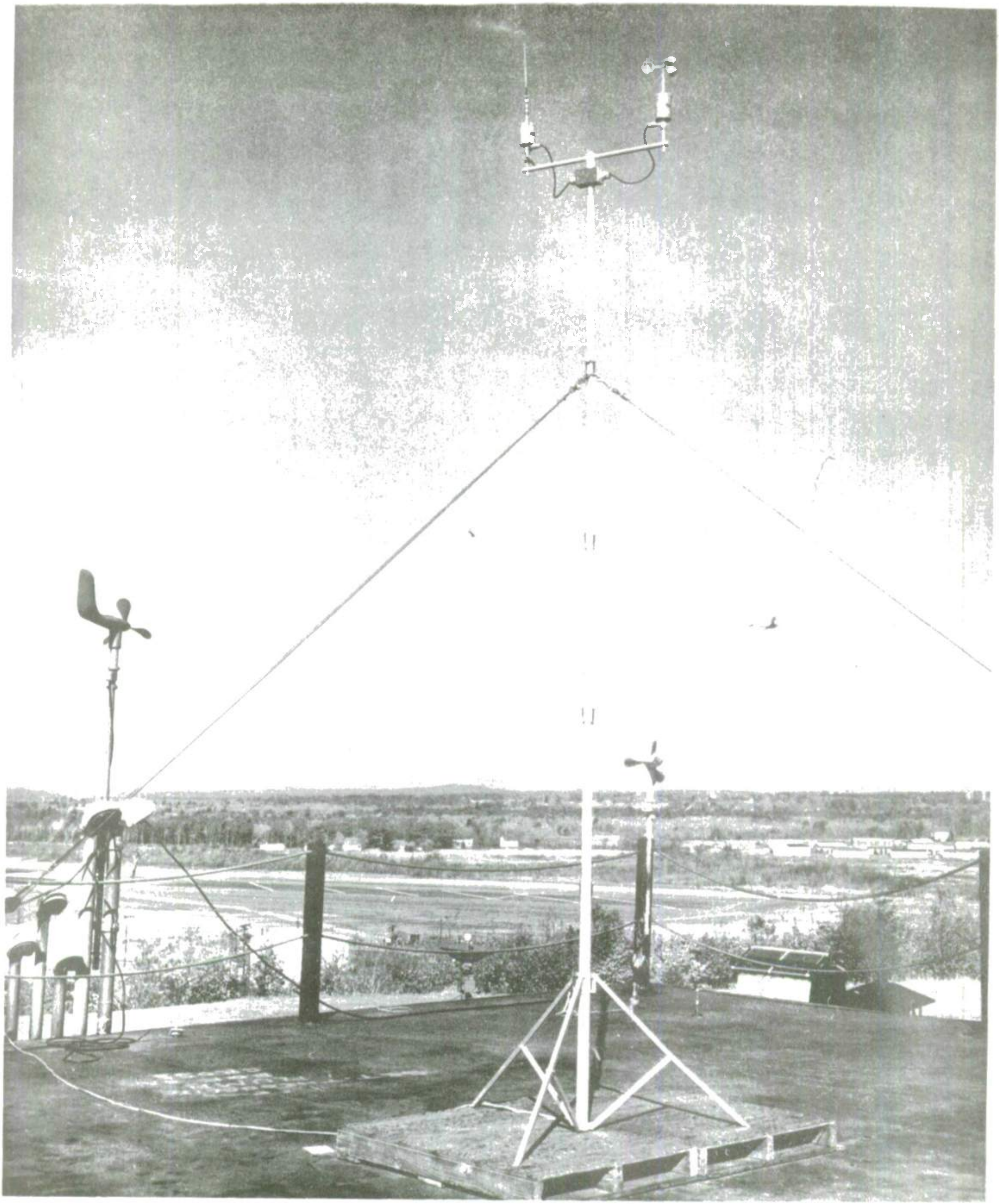

FIGURE 13: AN/TMQ-15 Operational Configuration

SECTION 5

AN/TVN-1 LIGHT-WEIGHT AIR-TRANSPORTABLE AIRPORT LIGHTING SYSTEM

A. Statement of the Problem

A light-weight, air-transportable lighting system is needed as a visual aid for the arrival and departure of aircraft. The system could be deployed in support of an AN/TSQ-47 system or could be deployed independently wherever fixed facilities are not available.

B. Method of Attack

The results of a survey made of the power generation field for the AN/TSQ-47 indicated that the most suitable device for this type of application was a 120/208V, 20KW, 400 cps, gas turbine generator. Since these are being used exclusively in the AN/TSQ-47 system, and since the AN/TVN-1 can be deployed in support of the AN/TSQ-47 system, it was desirable to have compatible or interchangeable power generation equipment. This is most advantageous from a logistics viewpoint. Thus, at first glance, it appeared as though a 400 cps lighting system were desirable. This would afford savings in system weight and cubage over conventional 60 cps lighting equipment. However, the following disadvantages were discovered:

(a) Distributive inductance at 400 cps causes power factor problem which increases the load requirements. Cable inductance can be overcome by double looping of the cable but this doubles cable length and weight.

(b) Under normal operating conditions, a 0.2 amp variation will be induced in the current regulator output due to cable capacitance to ground (based on a 21,000 foot loop calculation), due to capacitive reactance of 1000 ohms at 400 cps versus 26,500 ohms at 60 cps.

This is very critical to the lamp life (100 hour lamp life at 6.6 amps) and the problem is magnified greatly when the cable becomes wet.

(c) IL transformers with open secondaries (burned out light bulbs) will have a heating problem. This is based upon the results of a privately sponsored study conducted by General Electric, Hendersonville, North Carolina, concerning 180 cps and higher frequency lighting systems.

(d) IL transformers with open secondaries become non-linear inductors which, when coupled with the distributive capacitance of the cable at 400 cps, form ringing circuits which induce relatively high currents of certain harmonics. This excess current considerably shortens lamp life and soon another lamp burns out and the situation is worsened, causing chain reaction with all the lamps burning out.

(e) No 400 cps airfield lighting equipment is currently known to be in production.

A survey was made of DC lighting to determine its applicability to runway lighting. It was concluded that a problem exists in attempting to reliably short circuit a burned out lamp, ensuring a series circuit. An arc travels down the stem of a burned out filament. This arc is difficult to sense and before appropriate action can be taken, the arc fuses the base to the fixture and the entire fixture must be replaced. Development is needed in the area of automatically inserting a by-pass resistor at each lamp. Also, no DC airfield lighting equipment is currently known to be in production.

A similar survey was made of 60 cps lighting equipment. It was concluded that no major problem area exists. An open IL transformer creates no serious problem since the circulating current is low due to the capacitive reactance at 60 cps compared with 400 cps.

All necessary equipments exist, are proven items, and are in production, and thus the system is composed of off-the-shelf items whose integration has been proven. From the foregoing discussion it is readily apparent that the factors of proven components, proven circuits, and off-the-shelf availability influenced greatly the decision to use 60 cps lighting equipment.

C. Intended Use

The AN/TVN-1 is an air transportable light set to be used for lighting the perimeter of a runway and taxiways. It can be deployed independently or with the Air Traffic Control/Communications system, AN/TSQ-47. When deployed with the AN/TSQ-47, the shelter of the AN/TVN-1 may be used as a stand for the tower, Air Traffic Control Central, AN/TSW-6.

D. Description of AN/TVN-1 Capabilities.

The AN/TVN-1 is designed to provide adequate power sources and fixtures for lighting one airfield runway of 8,500 feet length and 200 feet width, and two airfield taxiways of 1,000 feet length and 200 feet width. The taxiways may be at the same end of the runway, or at the opposite ends, and may extend off the runway at different angles to the runway centerline. The taxiway lights shall define the longitudinal limits of the usable landing area when configured in two straight lines, one at each end of the runway, and perpendicular to the rows of runway lights. High intensity reference lights shall provide flashing lights for use as runway end identifiers. Obstacle lights and reflectors furnish additional marking where desired. A shelter serves to transport the equipment and to act as a workroom when deployed.

E. Configuration.

The AN/TVN-1 is designed to operate in the configurations of

Figure 14 and Figure 15 with interconnections as shown in Figure 16, and with the typical layout described as follows.

The shelter will serve as the base for the AN/TSW-6 control tower if the tower is present. The AN/TVN-1 shelter will be sited on the airfield 500 feet from the runway so it is not a hazard to aircraft, and unloading will proceed (see figure 17). The gas turbines and static converters will be sited about 50 feet from the shelter on the side away from the runway. White lights, runway marker, will be installed as runway lights at 200-foot intervals in two lines, one parallel to each side of the runway and at a distance of 10 feet outside the edges of the full strength pavement. Blue lights, runway marker, will be installed as taxiway lights in the same relationship to the taxiways that the white lights have to the runway. Green lights, runway marker, will be installed as threshold lights in two lines at right angles to the runway, one at each end. Each line of threshold lights will be at a distance of no more than 10 feet beyond the usable end of the runway. The lights will be 35 feet apart except that the innermost lights will be spaced 40 feet on either side of the runway centerline. Red lights, runway marker, will be installed where required to mark obstacles. Runway end identifers will be sited in line with the threshold lights and about 40 feet outside each edge of the usable runway. Figure 18 shows an REI being set up. Reflectors will be sited as required to provide additional, lower grade marking of runways, taxiways, parking areas, ramps, etc. Any lights, fixtures, and cables not in use during a particular deployment will be stowed in the shelter and used as replacements if necessary. During transport, the turbine generators and the static converters will be carried on a pallet. All other parts of the AN/TVN-1 will be packed into the shelter.

F. Description of AN/TVN-1 Components.

Items of equipment to be supplied include the following:

Item No.	Quantity	Description
1	14 each	Light, runway, white lens
2	90 each	Light, runway, blue lens
3	22 each	Light, runway, green lens
4	12 each	Light, runway, red lens
5	138 each	Stake, mounting
6	138 each	Transformer, power
7	138 each	Lamp
8	2 each	Lighting Group, runway end identifiers
9	4 each	Stand, runway end identifier
10	144 each	Reflector
11	2 each	Generator, gas turbine
12	2 each	Converter, static
13	2 each	Regulator, constant current
14	1 each	Shelter
15	as required	Cables
16	as required	Miscellaneous

(a) Runway Lights

The AN/TVN-1 shall contain 84 runway light assemblies which shall be capable of lighting both sides of an 8500 ft. runway with a spacing of 200 feet between lights. The configuration shall be such as to allow the lights to be disposed at 200 foot intervals, in line on both sides of the runway at a distance not to exceed 10 feet from the edge of the full strength paving designated for runway use. A light on one side of the runway shall be capable of being located with respect to its companion light on the opposite side, that a line joining the two shall be at right angles to the runway center line. The lights will be in accordance with Specification MIL-L-7082, with white prismatic lenses.

(b) Taxiway Lights

The AN/TVN-1 shall contain 20 taxiway lights which shall be capable of lighting both sides of two 1,000 foot taxiways or any portion thereof, with a spacing of 200 feet between lights. The configuration shall be such as to allow the lights to be disposed at 200 foot intervals in line on both sides of the taxiway at a distance not to exceed 10 feet from the designated taxiway. A light on one side of the taxiway shall be capable of being located with respect to its companion light on the opposite side, that a line joining the two shall be at right angles to the taxiway centerline. The taxiway lights will be in accordance with Specification MIL-L-7082 with blue omnidirectional lenses.

(c) Threshold lights.

The threshold lights shall consist of 12 lights which shall be capable of lighting both ends of the runway inboard of the runway lights, and not more than 10 feet from the end of the usable runway. The configuration shall be such as to allow the lights to be disposed at 35 foot intervals with a 40 foot gap on each side of the runway centerline. The taxiway lights will be in accordance with Specification MIL-L-7082 with green prismatic lenses.

(d) Obstruction Lights

Obstruction lights will be in accordance with Specification MIL-L-7082 with red omnidirectional lenses.

(e) Mounting stake

One mounting stake will be supplied for each Runway Marker Light. It will be capable of being driven into the ground by use of a mallet without being deformed so that it will accept the clamp assembly of MIL-L-7082 paragraph 3.4.2.4. The mounting stake will be the type that is easy to drive into the ground, and will be of sufficient strength to hold the light assembly rigid in high winds, propellor or jet stream blast without appreciable vibration or movement in any direction. The head of the stake will be tempered steel so that it will not spread when driven into the ground.

(f) Power Transformer (IL)

One 30/45 watt, 6.6/6.6 amp, rubber encapsulated power transformer will be supplied for each Runway Marker Light. These transformers will be essentially in accordance with MIL-T-7641 except that the primary leads will be 39 plus or minus 3 inches long, and the secondary leads will be 60 plus or minus 3 inches long.

(g) Lamp

Each lamp for the light, runway marker, will be a series, clear, 30 watt, 6.6 ampere, T-10 bulb with a C-2V filament, a one and one-half inch light center, and a medium prefocus base in accordance with Type I of MIL-L-6363.

(h) Runway End Identifiers

Two runway end identifier groups will be included in each AN/TVN-1. Each group consists of two condensor discharge light units with associated power transformer and synchronizer. The identification of a runway threshold is assured by placing one flashing light at each end of the threshold as shown in Figure 15. Each unit is installed approximately 40 feet outside the line of the respective runway lights and placed so as not to obstruct the threshold lights. The two units are towed outward at an angle of 10 degrees to provide continuous runway contact during a circling approach while simultaneously assuring reduced intensity at the cockpit since a place approaching the threshold will move steadily out of the major beam. The elevational angle of each unit is set at 10 degrees above horizontal. The combination of intense brillance and the characteristic sharp blue-white flash produced a visual outline of the runway threshold which is a landmark to pilots. Results are far superior to conventional light sources due to the high conspicuity, unmistakable appearance and non-glare characteristics of these lights. Remote control of the flashing light units would normally involve extensive wiring back to the control point. However, the power transformer unit will have a built-in control circuit which utilizes the series runway lighting circuit to perform the control function. To turn the flashing light units ON it is simply necessary to turn the runway lights OFF once then ON again. For remote indication of the light unit operating status, an accessory unit, mounted in the shelter, will operate a jeweled pilot light in unison with the light units. To turn the light units OFF the operation is repeated. With the power and control circuits therefore limited to very simple wiring restricted to the vicinity of the threshold, installation can be effected rapidly.

(i) Runway End Identifier Stand

A lightweight, collapsible metal stand will be included as a mounting platform for each of the four light units. The platform and the stand will be approximately three feet above ground level when in deployed configuration and shall include provisions for quick disconnect type fasteners to securely hold the light unit and keep azimuthal and vertical angle variances to a minimum. This is necessary to ensure that a false indication of threshold is not presented to the pilot.

(j) Reflectors

Reflectors (144) will be supplies to augment the incandescent lighting. A reflector will consist of a retrodirective reflector envelope mounted upon a wire wicket and will be illuminated by the aircraft landing lights.

(k) Gas Turbine Generators

Two gas turbine generators 120/208V 400 cps, 3 phase, 4 wire, 20KW, will be supplied with each AN/TVN-1. These units will be identical to those supplied with the AN/TSQ-47. One unit will be operating while the other unit will be a standby spare.

(l) Static Converters.

Two static converters will be included as part of the AN/TVN-1. Each static converter will accept 3 phase 120/208 volt 400 cycle per second power as furnished by the gas turbine powered generator and convert it to the 60 cycle input frequency of the constant current regulator. The output power will be at least 10.2 kilowatts, 0.8 power factor, 110-128 volts adjustable, single phase 60 cycles per second. One unit will be operating while the second unit will be a spare.

(m) Constant Current Regulator

Two constant current regulators will be included as part of the AN/TVN-1. Each will be designed to operate with an input of 120 volts, 60 cycles, from the static converter. The regulator will be capable of supplying 4KW at 6.6 amps. It will also be capable of supplying the connected loads at various brightness settings (3.4, 3.8, 4.4, 5.3 and 6.6 amps). The regulators will be utilized as shown in Figure 16, with each regulator bearing half of the load.

(n) Shelter

A modified S-141 shelter will be supplied to house the various components of the AN/TVN-1 with the exception of the static converters and gas turbine generators. The AN/TVN-1 shelter, when deployed, will be capable of acting as a base for the AN/TSW-6 tower. The

AN/TVN-1 shelter roof will have load spreading channels to prevent distortion or damage when the AN/TSW-6 is being placed on, or removed from, the AN/TVN-1 shelter. The AN/TVN-1 shelter roof will have recesses or pockets to receive the four iso-skids that are on the bottom of the tower. A ladder will be included to permit access from the ground to the AN/TSW-6 catwalk when the tower is mounted on top of the runway lighting van.

(o) Cables

Cable assemblies of the AN/TVN-1 can be classified in two general categories, power cable assemblies and series lighting cable assemblies. Power cable assemblies consist of all the cabling necessary to interconnect the gas turbine generators, static converters, and the shelter.

The series lighting cable assemblies will be single-conductor, stranded, tinned annealed copper wire with 600 volt insulation of high quality synthetic rubber having a polychloroprene or neoprene sheath with the connectors securely vulcanized to the cable and will be of the following three types:

(1) 140 assemblies of AWG 10 with a length of 207 feet plus or minus 12 inches. These lengths will be used to interconnect the runway lights and taxiway lights (200 foot spacing between lights).

(2) 20 assemblies of AWG 10 with a length of 55 feet plus or minus 6 inches. These lengths will be used to interconnect the threshold lights (35 foot spacing between lights).

(3) 24 assemblies of AWG 8 with a length of 606 feet plus or minus 72 inches. These lengths will be used for a common return from the two runway lighting circuits to the AN/TVN-1 shelter (9000 feet minimum required, depending upon terrain and deployment configuration.)

(p) Miscellaneous

The AN/TVN-1 will also contain, as a minimum, the following miscellaneous items:

(1) A two-line telephone system identical to the system in the AN/TSW-6 tower. It will include control boxes, handsets, calling dials, keys, lamps, ringing circuit with generator, and filters.

(2) A folding chair for use at the workbench.

(3) A utility tool kit containing all special tools and devices necessary for rapidly and accurately assembling, disassembling, siting, aligning, and conducting field level maintenance on the AN/TVN-1.

(4) All test equipment required to perform field level maintenance and operation of the AN/TVN-1 during 30 day deployment without recourse to depot.

(5) Three one-conductor T-connectors to interconnect the two separate series airfield lighting circuits with the single common return circuit.

(6) A fire extinguisher. .

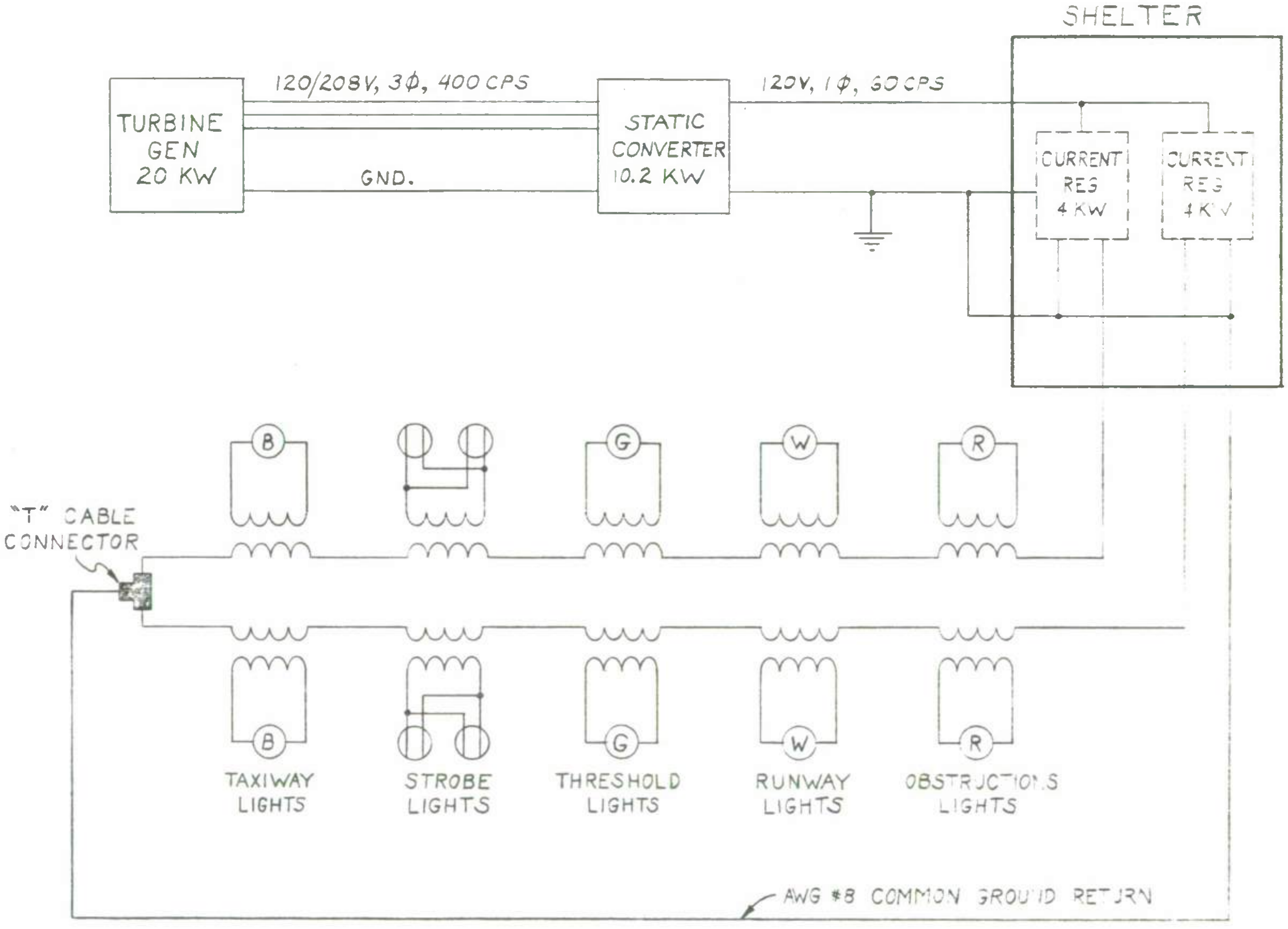

FIGURE 14: AN/TVN-1 Typical Deployment Configuration

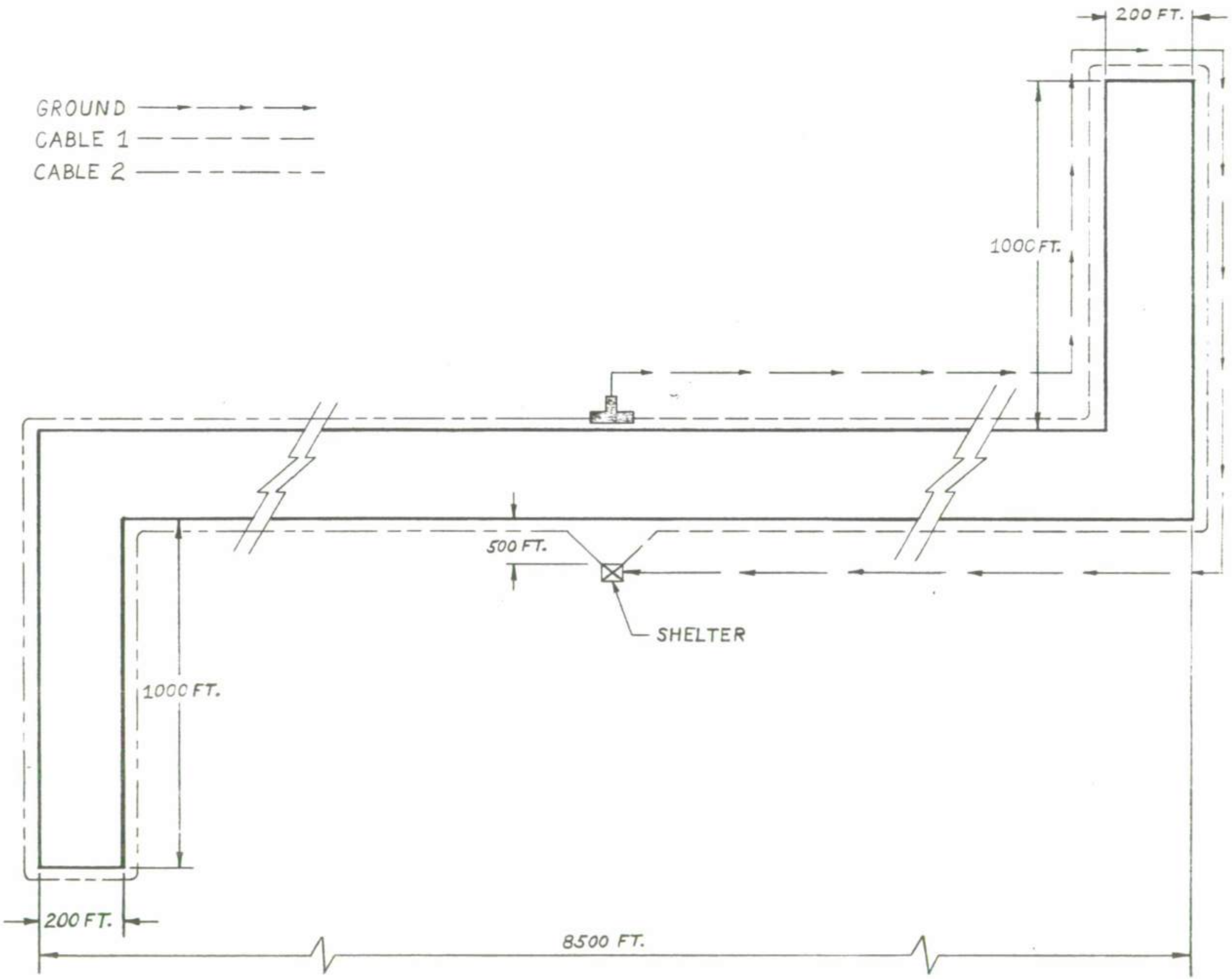

FIGURE 15: Runway and Configuration

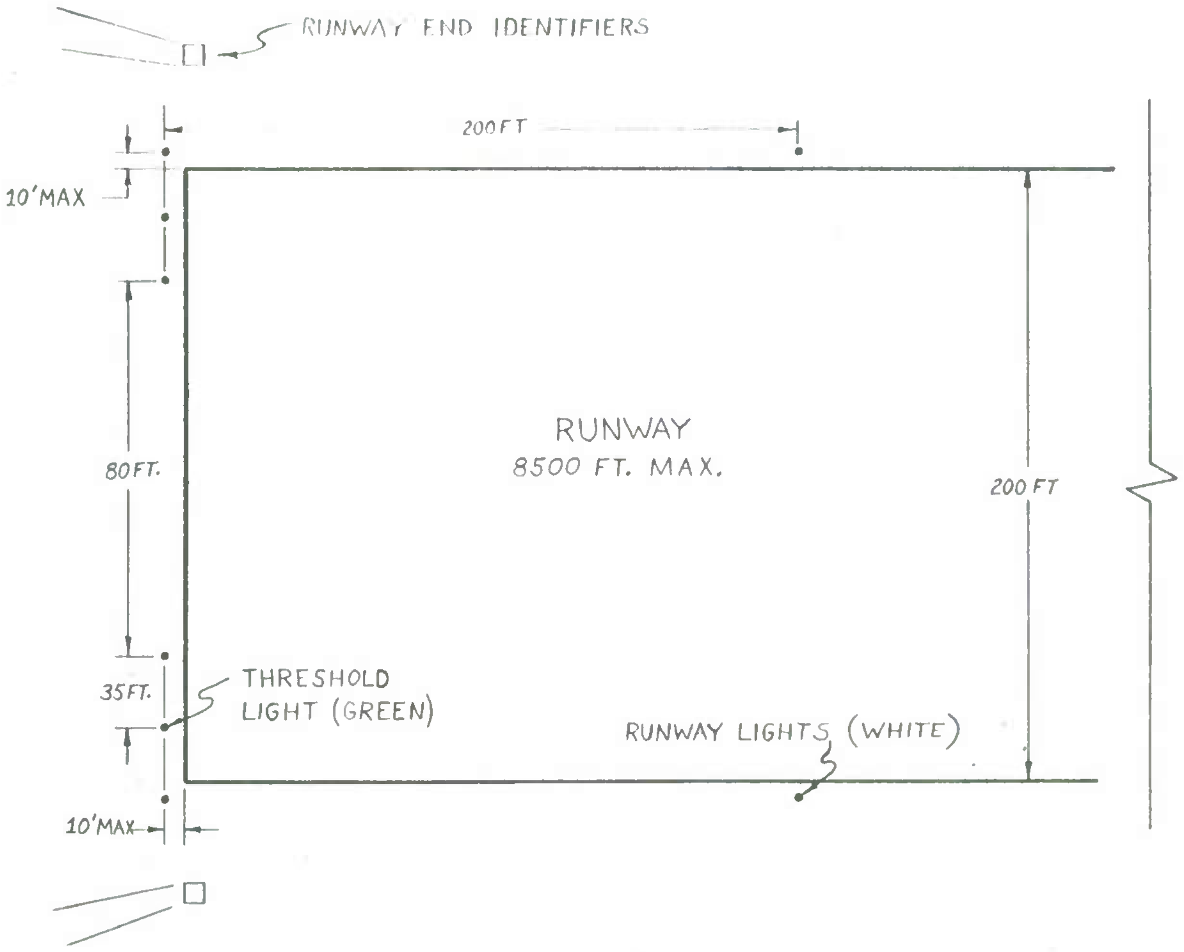

FIGURE 16: AN/TVN-1 Typical Deployment Interconnections

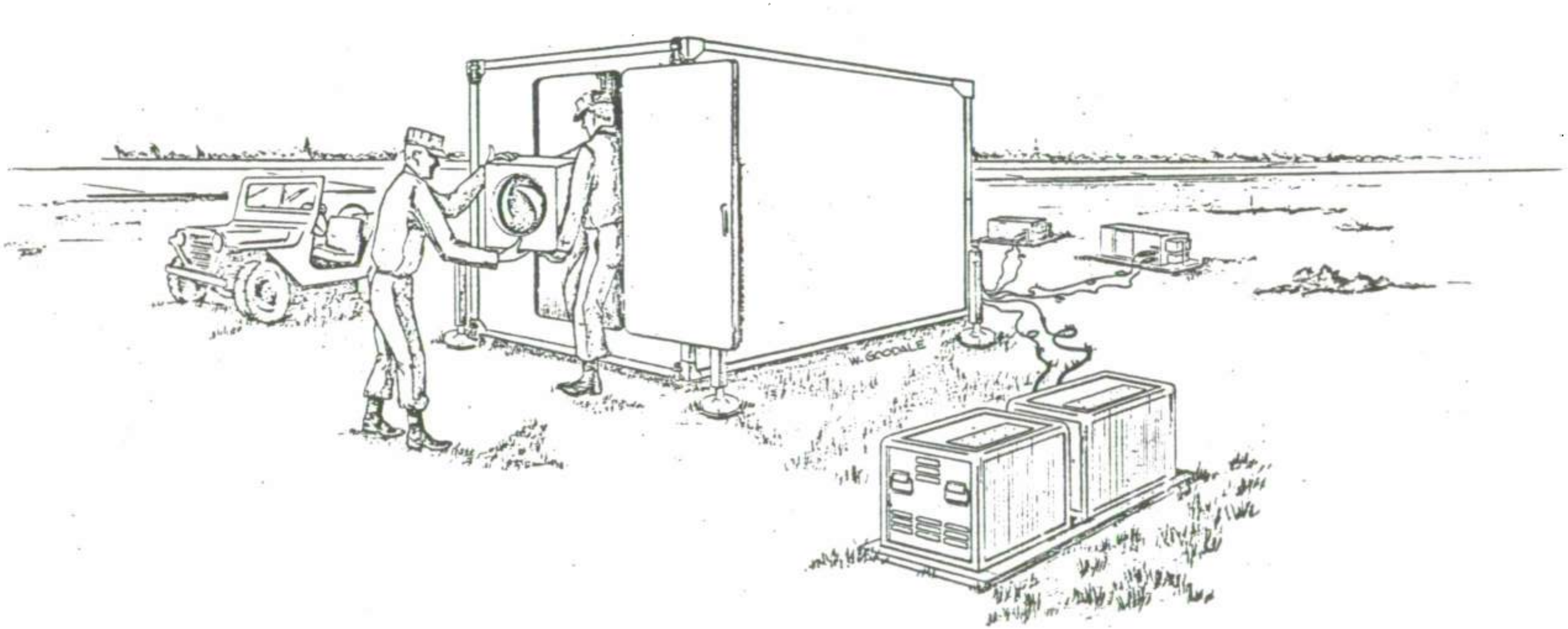

FIGURE 17: AN/TVN-1 UNLOADING

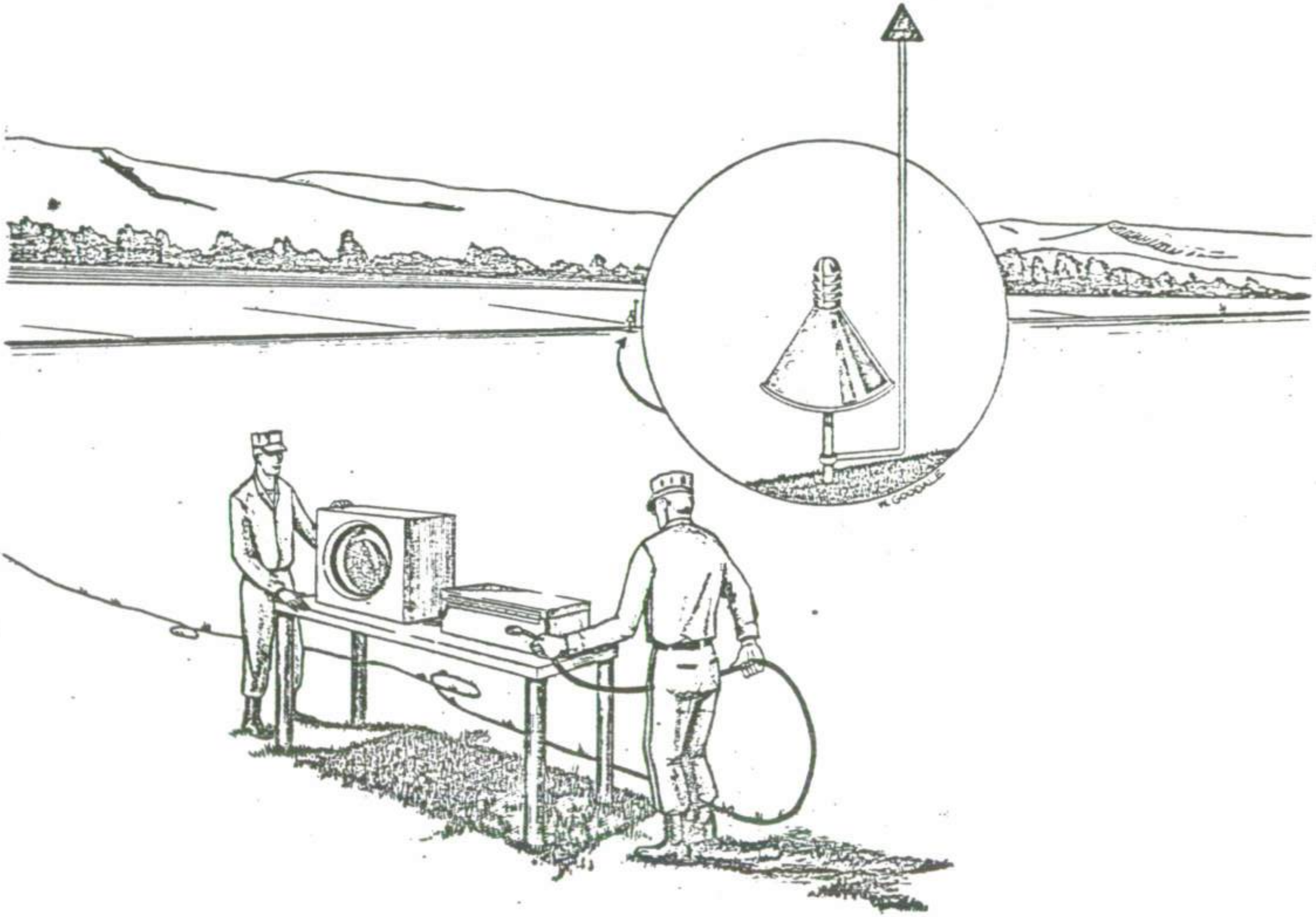

FIGURE 18: REI AND RUNWAY LIGHT SET-UP

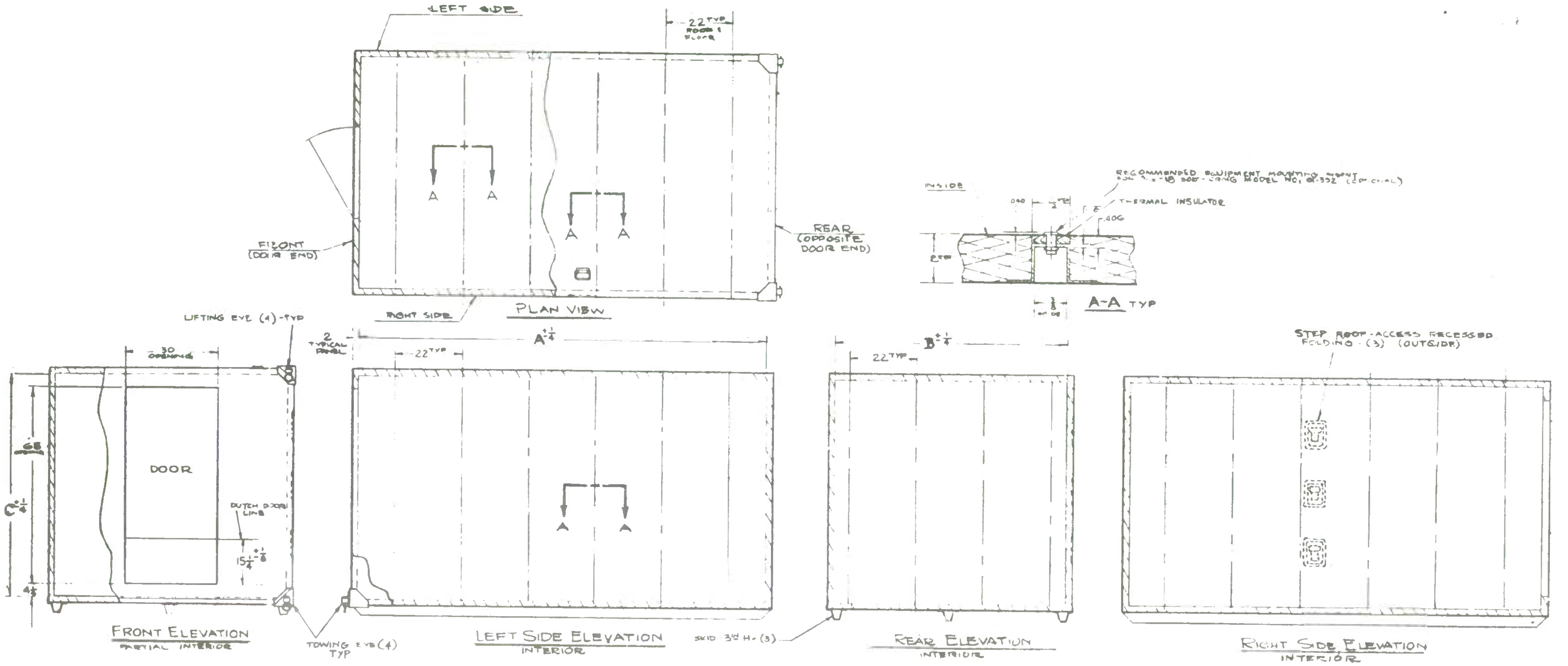

TABLE I - SHELTER

MODEL NUMBER	INSIDE DIMENSIONS IN INCHES			WEIGHT (LB)	RATED PAYLOAD (LB)	DWG NUMBER
	LENGTH	WIDTH	HEIGHT			
	A	B	C			
H-581	76	76	76	860	3600	
H-583	96	76	73.5	1060	5000	
H-584	102	76	76	1020	5000	
H-586	152	76	73.5	1300	5000	
H-587	134	76	76	1200	5000	
S-141	134	76	73 ½	1200	5000	DSK 2724
H-376	140	84	79	1600	10000	DSK 4155
H-382	184	76	79	2300	8500	DSK 4446
H-895	142	76	73 ½	1280	5000	DSK 4448
H-898	240	103	82 ¾	6500	26,000	

NOTES;

1- TABLE I SHOWS CURRENT STANDARD MODELS

2- SHELTER DESIGN CAN BE SUPPLIED WITH ANY COMBINATION OF INSIDE DIMENSIONS LISTED BELOW:

WIDTH	60" TO 90
HEIGHT	60 TO 90
LENGTH	60" TO 312"

3- FOR MAXIMUM OVERALL DIMENSION (APPROX) ADD $4\frac{1}{2}$ TO WIDTH ADD $7\frac{9}{16}$ TO HEIGHT ADD $9\frac{1}{4}$ TO LENGTH

4- STANDARD DOOR OPENING SHOWN MAY BE SUPPLIED WITH A FULL DOOR OR A DUTCH DOOR

5- SHELTER DESIGN - MEETS PERFORMANCE REQUIREMENTS OF MIL-S-52059 (SIG C) AMEND. 2

6- SHELTER — CAN BE SUPPLIED WITH CRAIG SHOCK-ABSORBING SKIDS - MODEL NO 6-515

7- SHELTER — CAN BE SUPPLIED TO PROVIDE RF SHIELDING UP TO 60 DB ATTENUATION FREQUENCY RANGE FROM 150 KC TO 10,000 MC

8- DRAWING NUMBER INDICATES SPECIFICATION SHEETS FOR MODELS LISTED

TITLE
CRAIG SERIES OF STANDARD SQUARE-CORNER SHELTER DESIGNS

Craig Systems, Inc.
LAWRENCE, MASS.

DRAFTSMAN	DATE	B. R. NO.	SIZE	DRAWING NUMBER	ISSUE
	JAN 62		B	SK2318	F
APPROVED					

REF DSK-2318

FIGURE 19: Craig Series of Standard Square Corner Shelter Designs

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