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Polar Automatic Weather Station

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The Polar Automatic Weather Station (PAWS) was developed to meet a need for detailed weather data from polar regions. It telemeters windspeed and direction (1-min averages), barometric pressure, and air temperature via a high-frequency radio link when interrogated by a central station. The accuracy of the telemetered data is as follows: windspeed, ±1 n.mi./h; wind direction, ±5°; barometric pressure, ±1 mbar; air temperature, ±1°F (0.55°C). The PAWS has a radioisotope power generator that can supply power for at least 5 years of unattended operation. A detailed description of the equipment, its operation, and the results of field trials is
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20. Abstract (Continued)

presented. Recommendations are presented for eliminating the problems encountered during field trials.

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POLAR AUTOMATIC WEATHER STATION

INTRODUCTION

Weather information is needed for planning naval operations in the polar regions. In the Arctic, weather data are needed to help plan aircraft flights in support of scientific field parties working for the Naval Arctic Research Laboratory. In the Antarctic. the data are needed to plan air operations conducted by the Naval Antarctic Support Force (Deep Freeze). At present, reconnaissance aircraft and satellites, and a very few manned weather stations, are the only means for obtaining the required weather data. Aircraft and satellites have limitated ability to obtain weather data, and the cost of maintaining manned weather stations in the polar regions is very high. To meet the need for detailed weather data in these regions, the Naval Air Systems Command has sponsored the development of a Polar Automatic Weather Station (PAWS). The present PAWS is powered by a radioisotope power generator (RPG) that can provide useful power for at least 5 years.

Operational conditions in both polar regions include low temperatures, blowing snow, and occasional icing, particularly near the coast. The tundra areas of the Arctic differ from the Antarctic in that summer temperatures are well above freezing, and the tundra becomes so soft that surface travel is virtually impossible and air transportation is limited to prepared runways only. Surface transportation is by means of tractor-drawn sleds (cat trains) that can be used only during the Arctic winter. These are very slow (3 mph, or about 5km/h) and are used mainly to move equipment and supplies that cannot be handled by aircraft. In poth polar regions, surface and air transportation is very limited. This lack of transportation was a major reason for using an RPG to power the PAWS.

Automatic weather stations have been used in the Antarctic for a number of years. These included the AN/GMT-1 (Grasshopper), designed to be delivered by air, and the early models of the PAWS, one of which was powered by an RPG. In addition, the Naval Research Laboratory developed a weather telemetering system for the Atlantic Undersea Test and Evaluation Center (AUTEC) that included automatic weather stations and a central station that interrogated and monitored them. The central station provided automatic data printout, so that a radioman was not needed for the monitoring. Most of the AUTEC system has been in operation for 7 years. Experience with the Antarctic stations and the AUTEC system was drawn on in the development of the PAWS.

Objectives

The goal was to have an automatic weather station, to be deployed in the polar regions, that could operate for 5 years without maintenance. This station would have to be able to telemeter weather data over distances up to 1,000 mi (1,609 km) with accuracy and reliability comparable to those of a manned weather station. It was important to design the equipment so that all of the components were interchangeable, to facilitate field servicing. This applies particularly to sensors and encoders because even in a small

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newtwork the use of individual calibrations for every possible sensor-encoder combination presents difficult decoding problems.

Approach

The PAWS instrumentation incorporated the most proven designs, based on experience in Antarctica and AUTEC. The command receiver had to be redesigned to allow it to work at a wide range of temperatures, and a higher power dual-frequency transmitter and a coupler were developed because it was expected that the PAWS would be communicating over distances great enough that sky-wave propagation would have to be used. The use of the RPG made it necessary to develop a power conditioner to interface it with the battery. The waste heat was used to keep the internal parts of the PAWS from having to operate at temperatures that maybe as low as -100°F (-73°C) in Antarctica. The amount and distribution of insulation had to be adjusted to keep from exceeding the 130°F (54°C) recommended temperature limitation of the RPG if the PAWS were deployed in the Arctic in the summertime.

To assure long-term reliability in the field required testing in the laboratory and a thorough shakedown operation.

DESCRIPTION

The Polar Automatic Weather Station (PAWS) is shown in Fig. 1. It is designed to telemeter windspeed (1-min average), wind direction (1-min average) barometric pressure, air temperature, and reference temperature (for correcting barometer readings) in international Morse code for distances up to 1,000 mi (1,609 km). The PAWS is equipped with two command receivers (operating on different frequencies) and a dual-frequency transmitter so that it responds on the frequency on which it was interrogated.

The PAWS consists of an insulated enclosure mounted on a toboggan. The external instruments are mounted on one end of the enclosure, and the antenna and its coupler are mounted on the other end. All penetrations of the enclosure are sealed to prevent the entrance of snow or rain. The enclosure houses the main instrument package, the secondary instrument package, the RPG, and the battery pack.

Structure

The PAWS structure is made up of main frame, enclosure, toboggan, anemometer support, antenna coupler enclosure, and antenna.

The main frame, shown in Fig. 2, is a welded structure of 3-in (76.2-mm) aluminum channel and a 1/4-in (6.4-mm) aluminum floor plate. It has provisions for mounting the two internal instrument packages, the RPG, and the battery pack. There are also provisions for attaching the main frame to the enclosure by means of 24 bolts located to distribute loading so that the main frame can support the enclosure. This is particularly important during rough handling that could occur during shipping or deployment.

The enclosure is shown in Fig. 3. It is made of 3/4-in (19-mm) marine plywood clad with 0.03-in. aluminum. The inside fiberglass channels are riveted to the plywood

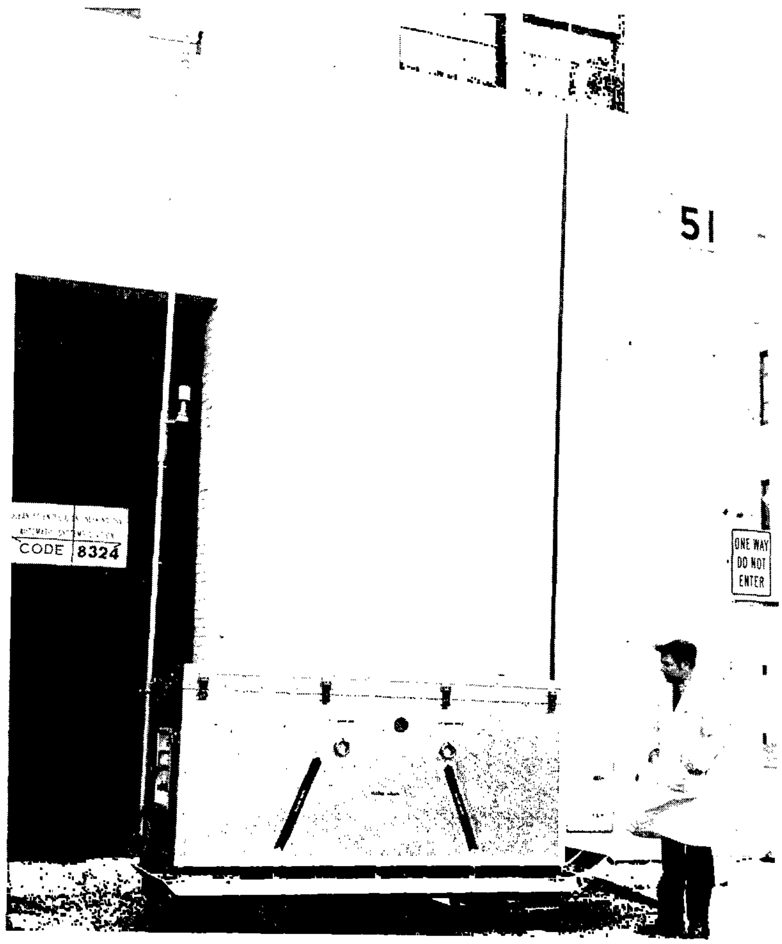
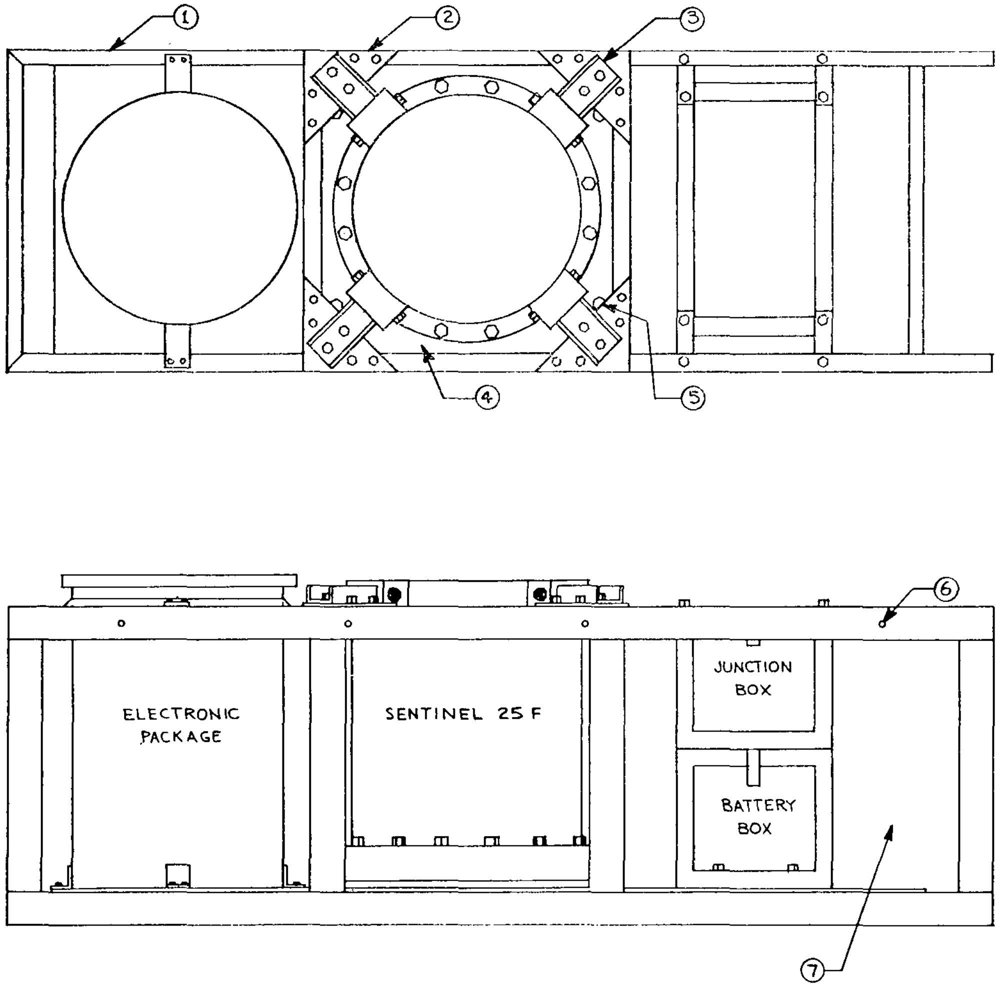


Fig. 1 — Polar Automatic Weather Station



NOTES:

1. ALL FRAME WORK IS 3" x 1.4" ALUM. CHANNEL 6061-T6. CHANNEL IS WELDED INSIDE AND OUT AT ALL JOINTS.
2. GUSSETS ARE ¼" ALUM. PLATE 6061-T6, BOLTED TO CHANNEL IN FOUR PLACES EACH WITH ½"-13 ST. ST. BOLTS.
3. BRACES ARE 3" x 1.4" ALUM. CHANNEL BOLTED TO GUSSETS IN TWO PLACE WITH ½"-13 ST. ST. BOLTS. BRACES ARE BOLTED TO RPG WITH ¾"-10 ST. ST. BOLTS.
4. GENERATOR MOUNTING PLATE IS ½" ALUM. PLATE 6061-T6 DRILLED 16 PLACES TO MATE WITH RPG WHEN COOLING FIN IS REMOVED. FOUR ADDITIONAL HOLES ARE PROVIDED FOR SECURING TO GENERATOR FRAME. GENERATOR PLATE IS SUPPORTED BY THREE 3" CHANNELS PLACED ON 12" CENTERS.
5. FOUR ¾"-10 BOLTS SECURE GENERATOR PLATE TO FRAME AFTER PASSING THRU. FLOOR PLATE.
6. FRAME WORK IS BOLTED TO FIBRE GLASS CHANNEL IN ENCLOSURE BY TWENTY-FOUR ⅜"-24 ST. ST. BOLTS, 4 ON EACH SIDE OF TOP RAILS, 4 ON EACH END THRU VERTICAL CHANNELS AND 4 ON EACH BOTTOM CHANNEL INTO BOTTOM. FASTENING TO FIBRE-GLASS CHANNEL IS ACCOMPLISHED BY RIVETING FLOATING T-NUTS TO INNER SIDE OF FIBRE GLASS CHANNEL.
7. THIS AREA WILL BE UTILIZED FOR STORAGE OF THE COOLING FIN WHEN REMOVED FROM RPG.

Fig. 2 — Main frame assembly

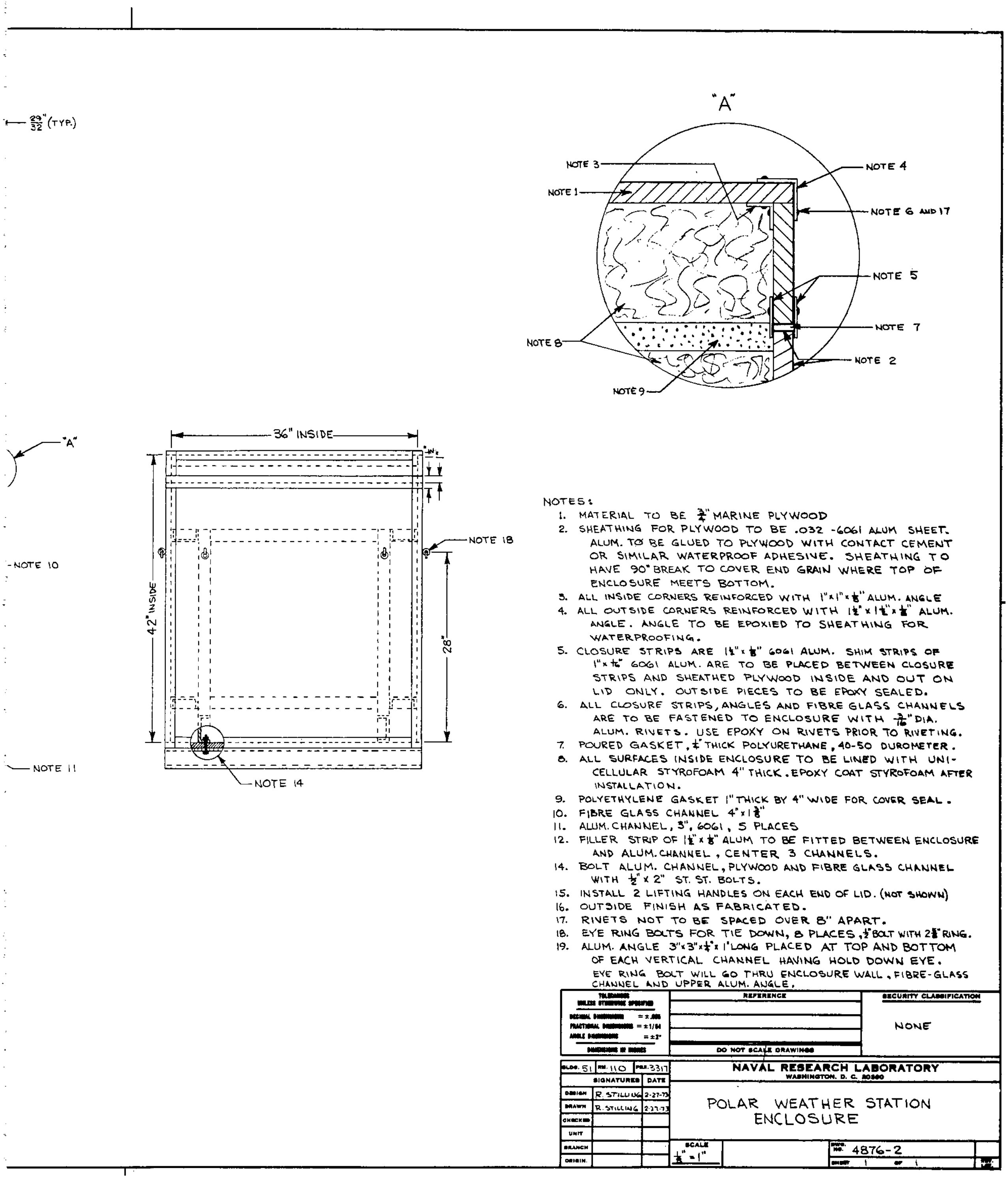


Fig. 3 — Enclosure

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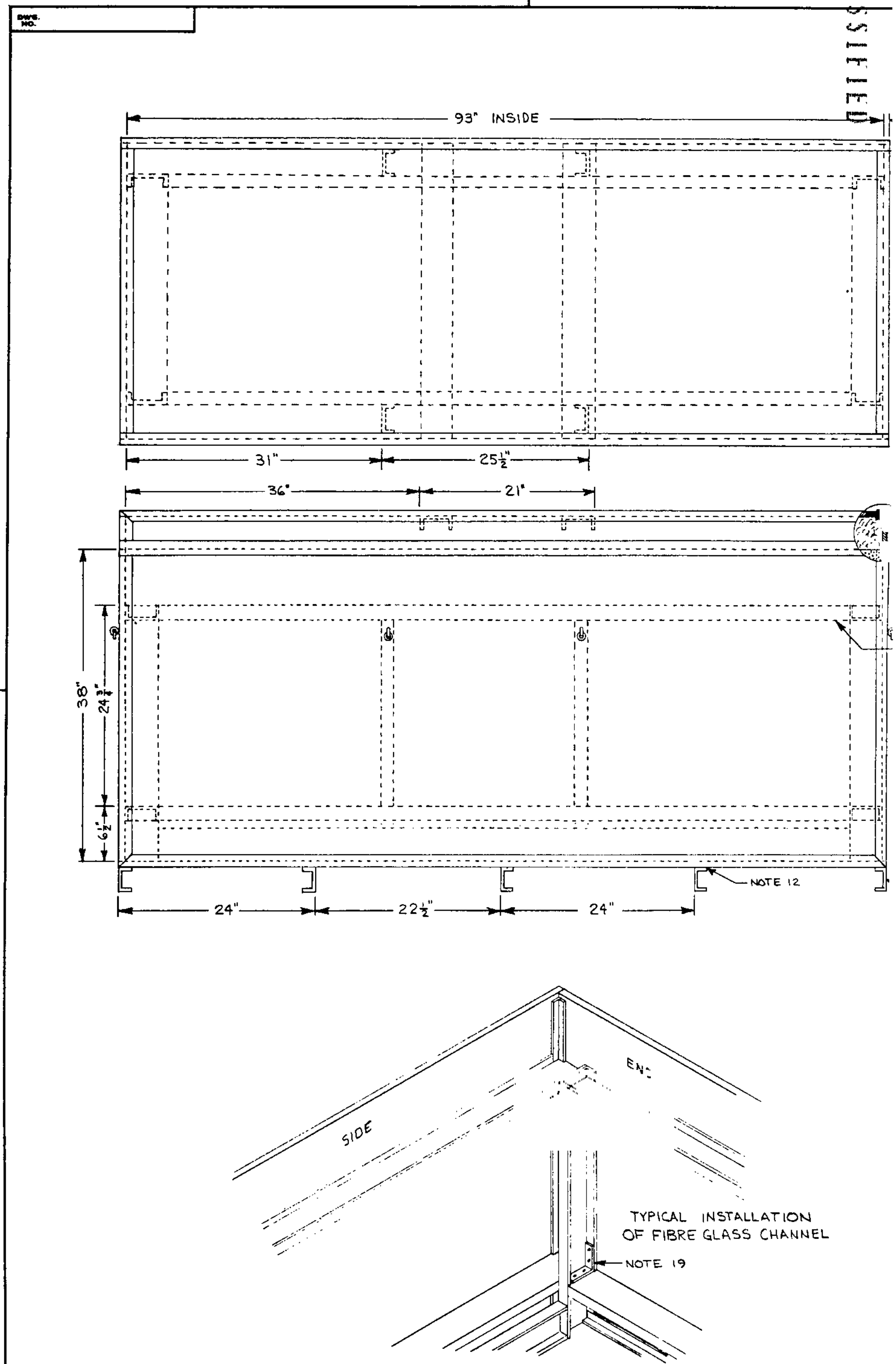


and have provisions for attaching the main frame to the enclosure. The eight tie-down bolt rings on the outside are also attached to the plastic channels. The spaces between the channels are filled with unicellular styrofoam for insulation. There are two aluminum penetration panels, one on each end. The connector panel provides five weatherproof connectors — two for connecting the anemometer and air-temperature sensor cables, and three for test purposes. There are also penetrations for the power switch and the battery and barometer vents. These vents are protected by Teflon filter discs that permit slow venting but keep water or snow from entering. The inside of the connector panel is insulated with urethane foam to keep condensation from forming on the connectors. The antenna cable panel has two stuffing tubes to provide seals where the low- and high-frequency cables enter the enclosure. The inside of the antenna cable panel is not insulated. This provides a cold surface for capturing any moisture that might accidently get into the enclosure should it be necessary to service the PAWS in blowing snow. This was a chronic problem with the automatic weather stations in Antarctica. The 3-in (76.2-mm) channels on the bottom are bolted to the plastic channels and form a skidlike structure for handling the PAWS with a forklift as well as a means of securing the enclosure to the toboggan. The lid is attached to the enclosure with 14 large trunk latches. A double gasket seal is provided to keep out snow or rain.

The toboggan is 1/4-in (6.4-mm) aluminum reinforced with 3-in (76.2-mm) aluminum channels welded in place. It is attached to the enclosure by means of ten 3/8-in (9.5-mm) bolts. A stainless steel towing bridle is provided at the front of the toboggan.

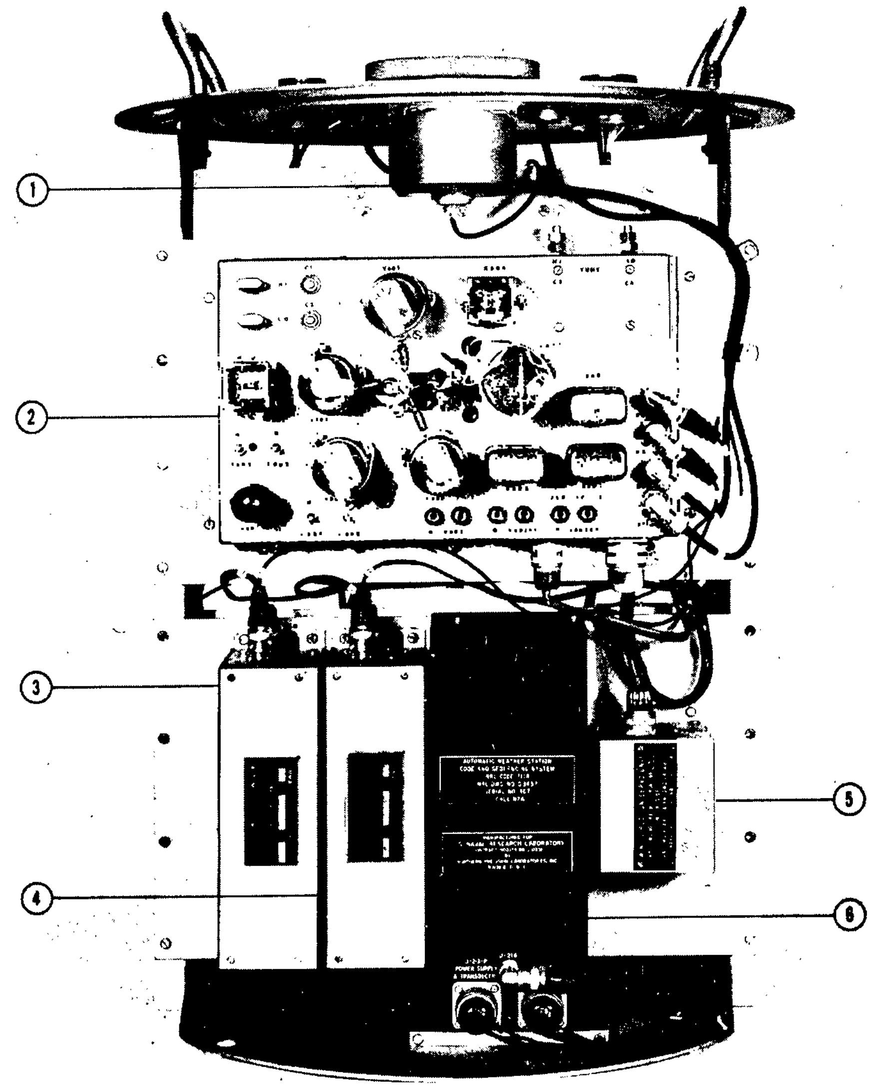
The anemometer support is made of 1-1/2-in (38.1-mm) tubing and is 16 ft (4.88m) long. It is attached to the rear of the enclosure with two brackets. The upper bracket has provisions for alining the support to true north and clamping it.

The antenna and coupler enclosure are attached to the forward end of the enclosure in the same fashion as the anemometer support. The reason for having the coupler enclosure outside the main enclosure is to facilitate final tuning at the deployment site without opening the main enclosure. The cover of the coupler enclosure is attached with trunk latches, and an "O"-ring seal is provided. There are provisions for attaching a ground plane to the bottom of the antenna assembly.

Main Instrumentation Package

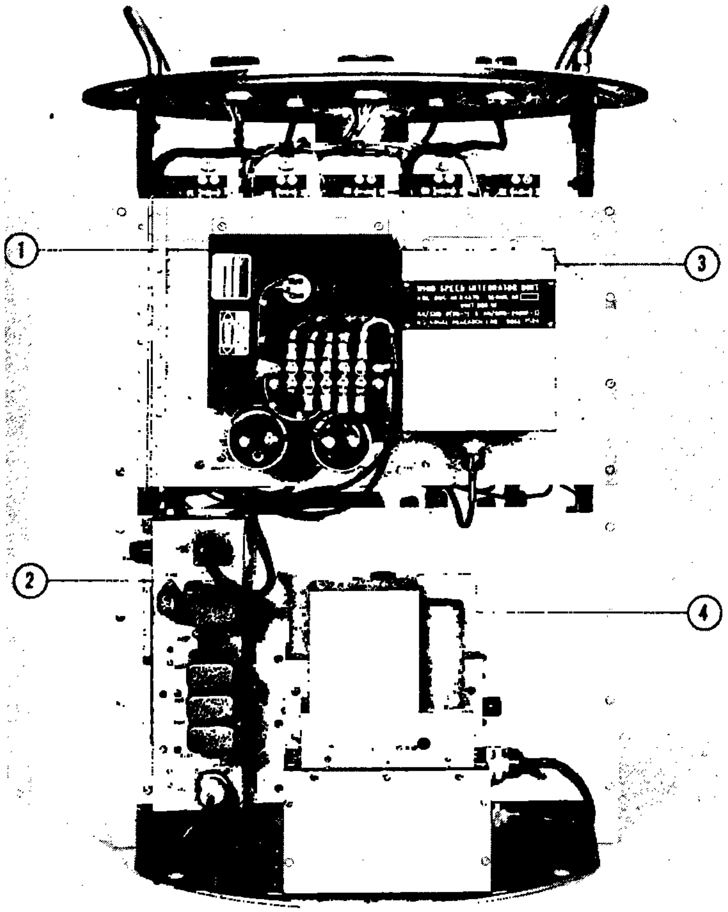
The main instrument package is shown in Fig. 4. It consists of a frame on which are mounted a number of units, housed in an "O"-ring-sealed watertight and gas-tight container. The frame is made up of a base that supports two side rails, four instrument mounting panels (one hinged), and a top deck.

The dual-frequency transmitter is located on the upper panel in the front part of the main instrument package. It is hinged to make its back accessible for servicing. Mounted on the lower panel are the two command receivers, the code and sequencing unit, and the wind-direction servo unit (averager).



1. MANUAL TURN ON COMPARTMENT
2. TRANSMITTER (UNIT 600)
3. COMMAND RECEIVER (UNIT 300) LO-FREQ.
4. COMMAND RECEIVER (UNIT 300) HI-FREQ.
5. WIND DIRECTION SERVO UNIT (UNIT 800)
6. CODE AND SEQUENCING SYSTEM (UNIT 200)

Fig. 4a — Main instrument package



1. D.C. TO D.C. CONVERTER
2. CONTROL UNIT (UNIT 400)
3. WIND SPEED INTEGRATOR (UNIT 900)
4. SERVO ELECTRONICS (UNIT 500)

Fig. 4b — Main instrument package

As shown in the rear view of the main instrument package, the DC/DC converter and the windspeed integrator are mounted on the hinged upper panel, and the control unit and the servo electronics unit are mounted on the lower panel. Behind the upper panel are five terminal strips that provide inter-connection between all of the units in the main instrument package and also serve as nearly 100 test points.

Command Receivers

The command receivers are crystal controlled and are designed to receive a single-tone, modulated, continuous-wave (CW) signal (4 to 16 MHz) which is used to turn on the PAWS. It has two active filters and a resonant reed filter to be sure that it will respond only to the desired tone. To prevent accidental turnon, there is also a built-in time-delay (10 s) circuit so that an occasional signal having the right tone but short duration will not cause turnon.

Transmitter

The transmitter is crystal controlled and has an output of 150 W (CW). It is designed to operate on either of two fixed frequencies in the 4– to 16-MHz band. Switching between frequencies is controlled by external circuitry. It receives 12-V power from the control unit, 750–V plate power from the DC/DC converter, and keying signals from the code and sequencing unit.

Code and Sequencing Unit

The code and sequencing unit is an electromechanical unit that performs the functions of multiplexing, code selection, code generation, and station control. The unit is divided into two essentially separate subunits. These are the code-selector unit (the top part) and the code-generator, call, sequencing, and switch unit (the bottom part). The two subunits are electrically connected and housed in a dust-tight container.

The code selector consists of two code-selection switches, a servomotor, a balance potentiometer, a precision gear train, and a mounting frame. Each of the two code-selection switches consists of a special precious-metal alloy switch pattern on a flush-finish, high-precision printed circuit and a two-brush brush assembly. The gear train connecting the switches to each other and to the servomotor and balance potentiometer is made up of special low-inertia precision gears, a clutch assembly, and a mechanical stop.

The switches are driven by the servomotor (which also drives the balance potentiometer) to a position corresponding to the value of the input to the code-selection circuits. Each of the switch patterns is connected to brushes in the code generator (in the lower part of the code and sequencing unit).

The code-generator, call, sequencing, and switch subunit has three drums: switch vernier, call, and code drum S231; sequencing drum S232; and control drum S233. These drums are driven through a gear train by a 12-V DC governed motor whose output shaft rotates at 24 rpm.

The switch vernier, call, and code drum S231 has three sections, or poles, all insulated from ground. Three sets of brushes are in contact with it. They are spaced around the circumference of the drum so that there is 90° between sets 1 and 2 and sets 2 and 3, and 180° between sets 3 and 1. The switch vernier portion of this drum synchronizes the system properly at the end of each transmission (station turnoff). The call-code section of the drum generates the signal identifying a particular ground meteorological telemeter. The call consists of a letter, a digit, and a second letter. The channel identifier and information code section of the drum has three sets of brushes, causing three letters to be generated for each revolution of the drum. Drum S231 rotates 20 revolutions per station operation, at 17 rpm. The first five revolutions are for generating the station call.

The first pole of drum S232 connects the transmitter to the call-code tracks on drum S231 for the first five revolutions of S231. This pole then connects the transmitter to the information-code tracks for the remaining 15 revolutions of S231.

The second pole of drum S232 allows each sensor channel to be multiplexed in turn and a three-letter data word to be generated for each sensor channel. A data word consists of a letter identifying the channel and a pair of letters representing data. For example, the signal from S232 grounds the B brush of the first-letter brush set on S231 for three revolutions of S231, during which time the B sensor data are being transmitted. Drum S232 will then permit transmission of sensor data on channels V, T, S, and U.

The third drum is the control drum S233, which turns one-fourth revolution for each revolution of the sequencing drum. This drum has three brushes and is used to control station turnoff. All three drums are 1 in. in diameter. All metallic contact surfaces and all brushes are made of precious-metal alloy to prevent corrosion.

Wind Direction Servo Unit

The wind direction servo unit averages the position of the wind vane. The unit is contained in an aluminum flange-mounted chassis and contains a servoamplifier, a servomotor, a control transformer, a gear train assembly, a potentiometer, and a 400-Hz power supply. The power supply and servoamplifier are both solid-state devices. The system functions to position the potentiometer according to the shaft angles of the anemometer transmitter and the compass differential. A slewing rate of 180° in 20s is slow enough to accomplish an averaging function, i.e., to effectively damp out oscillations of the anemometer.

Windspeed Integrator Unit

The output of the windspeed sensor is a train of pulses that are counted by the windspeed integrator. The circuit (Fig. 5) consists of an eight-stage binary counter composed of two integrated circuits; one shapes the input and reset signals, and the other is the actual counter. The outputs of the eight counter stages drive an array of eight relays that connect resistance into the readout circuit, according to the number of input pulses counted during the windspeed averaging time.

Control Unit

The control unit houses seven relays (K401 through K407) that turn the station on, allow the 30-s warmup period, and perform the timing of other major functions to be discussed later. They are all hermetically sealed and are mounted on a 10-by-3 7/8-in. (254-by-98.4-mm) flange-mounted aluminum chassis.

Servo Electronics

The servo electronics consist of five relays that permit sensor data to be applied to a bridge circuit Z501 and a bridge amplifier V501 and V502, also contained in the same unit. A Vibrapack power supply VP501, controlled by a sixth relay, supplies current to the bridge circuit in this unit and to a servomotor in the code and sequencing system during the time of code selection.

DC/DC Converter

The DC/DC converter supplies high voltage for the plates of the transmitter tubes. It converts 24-28V DC to 750V DC and can supply up to 600 mA. It has less than 1% ripple and is regulated to 1% for line and load variations.

Auxiliary Instrument Package

The auxiliary instrument package is shown in Fig. 6. It consists of an "O"-ring-sealed enclosure in which are mounted the pressure transducer, reference temperature sensor, power conditioner, and two terminal strips. On the sides of the enclosure are eight sealed connectors for connecting the auxiliary instrument package to the main instrument package, the RPG, the battery pack, and the PAWS enclosure. There is also a stuffing tube for the power cable to the main instrument package and a barometer vent fitting.

Pressure Transducer

The pressure transducer consists of 6-pin male connector J1701, pressure transducer MT1701, and vibrator motor B1701. These three components are mounted on a 3-1/4- by 6-in. (82.6- by 152.4-mm) aluminum plate. Four 1-3/8-in. (34.9-mm) standoffs are shock mounted to the plate with rubber grommets.

The pressure transducer provides a resistance output that varies as a linear function of applied barometric pressure. The output is obtained by using a pressure-sensitive metal capsule (aneroid cell) to actuate a metal brush (movable element) on a precision wire-wound potentiometer. The total potentiometer resistance is 4,040 ohms ±1%, which is divided into two pressure ranges: Range I-655, to 862 mbar (2,020 ohms), and Range II-862, to 1,068 mbar (2,020 ohms).

The vibrator motor provides controlled vibration to minimize the effect of hysteresis and static friction between the movable element and the potentiometer. When the station is turned on, a vibration is applied to the movable element to eliminate the friction that inhibits the free motion of the movable element.

Reference Temperature Sensor

The reference temperature sensor provides reference temperature for barometric pressure data-correction purposes. It is wound with pure nickel wire and has a temperature coefficient of 5,000 ppm ±10%. The temperature sensor, rated at 1/2 W, is noninductively wound and is used in one leg of a 115-Hz bridge circuit. The resistance of the sensor is 4,000 ohms ±1% at 25K, and is special "Type P" encapsulated.

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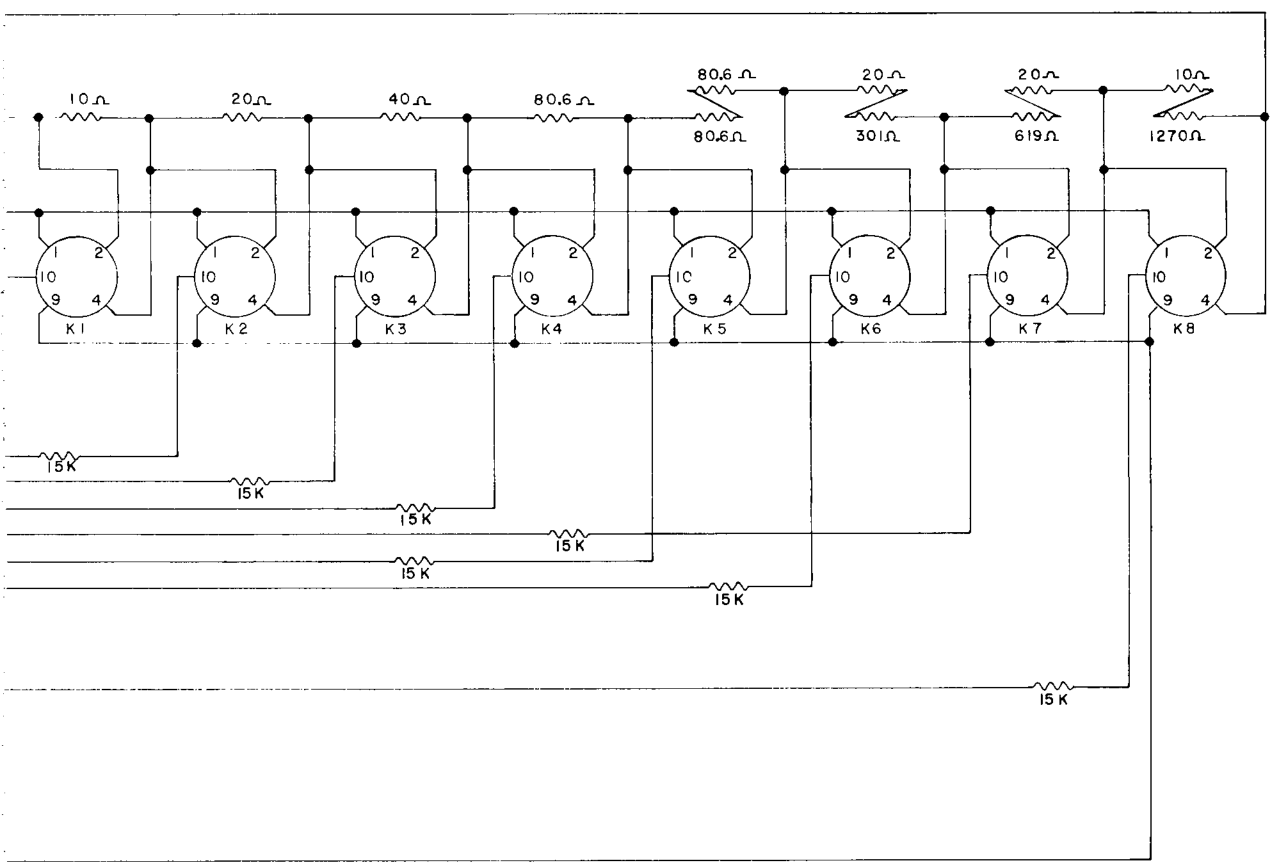


d integrater unit

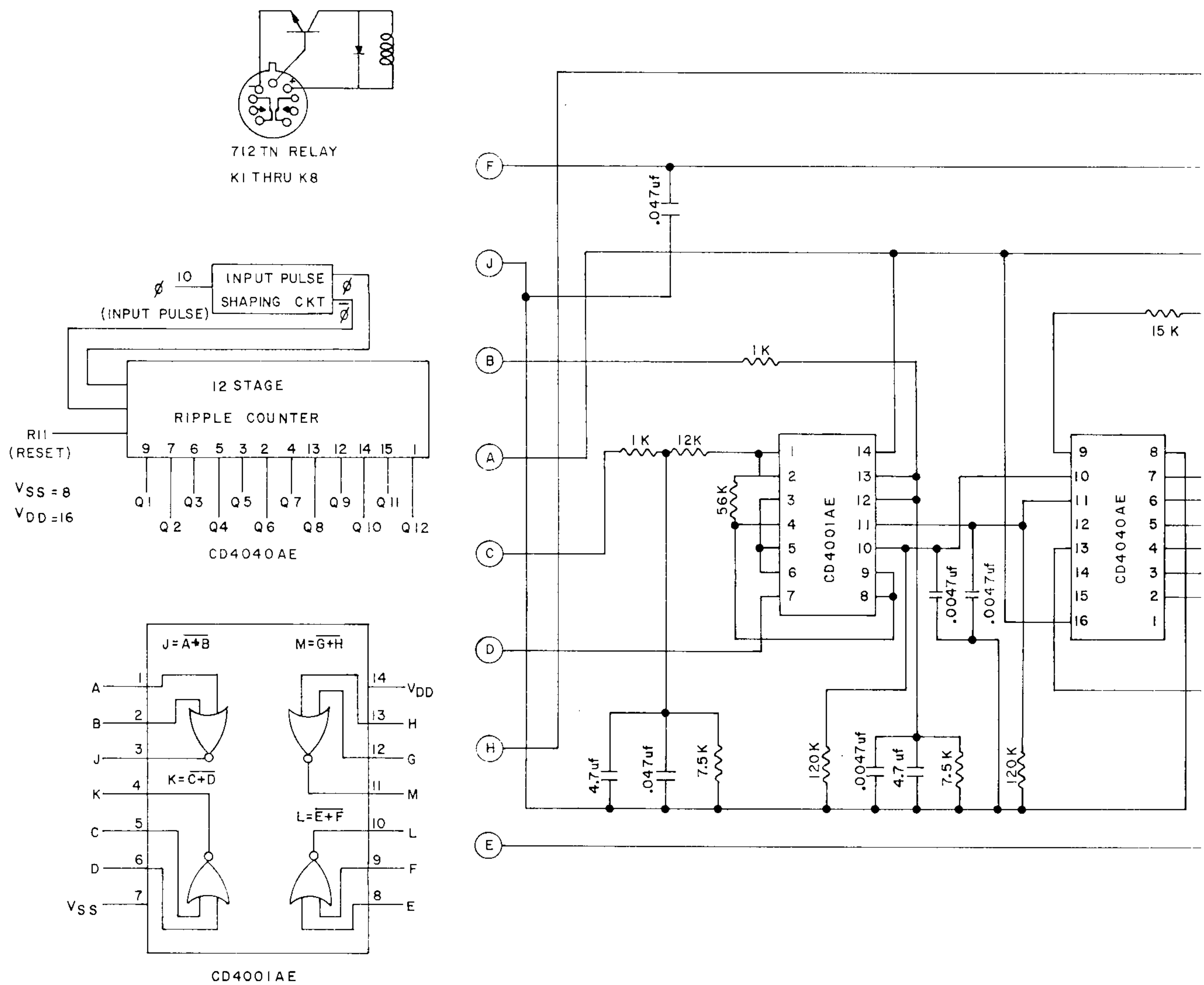
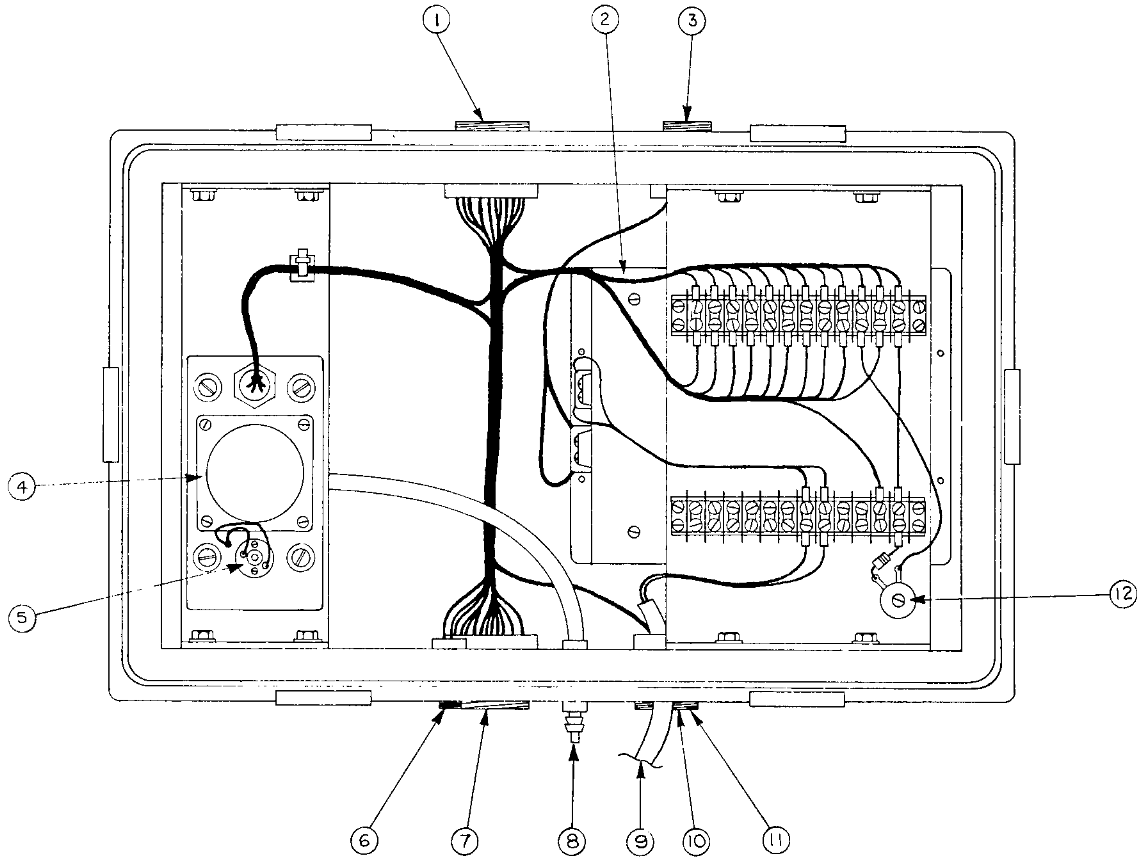


Fig. 5 — Windspee



(1) MAIN INSTRUMENT PACKAGE CONNECTOR
(2) POWER CONDITIONER
(3) RPG CONNECTOR
(4) PRESSURE TRANSDUCER
(5) SHAKER MOTOR
(6) TEMPERATURE SENSOR CONNECTOR
(7) TEST SET CONNECTOR
(8) PRESSURE TRANSDUCER VENT
(9) BATTERY CHARGING CABLE
(10) ANEMOMETER CONNECTOR
(11) ON-OFF SWITCH CONNECTOR (NOT VISIBLE)
(12) REFERENCE TEMPERATURE SENSOR

Fig. 6 — Auxiliary instrument package

Power Conditioner

The power conditioner is a DC/DC converter designed to interface the RPG with the PAWS. It converts the approximate 3-V output of the RPG (when loaded for maximum power) to 28 V to charge the PAWS battery pack. It has zener diodes on its input and output to prevent the RPG's ever having a no-load situation in case of equipment malfunction and protects the battery pack from being overcharged.

External Instrumentation

The external instrumentation consists of the anemometer, air-temperature sensor, and antenna coupler.

Anemometer

The anemometer (Fig. 7), used to measure wind direction and speed, is on the anemometer support. Its overall length is about 10 in. (254 mm), and it consists of an eight-bladed propeller at one end of a 1-in.-diameter (25.4 mm) horizontal housing. A vane attached to the aft end of the housing keeps the instrument facing into the wind. The position of the vane establishes wind direction.

The anemometer is constructed mainly of aluminum alloy. The horizontal housing is approximately 1 in. (25.4 mm) in diameter by 9 in. (228.6 mm) long, exclusive of propeller. The vane attached to the horizontal housing is also of aluminum and measures 5-3/4 by 8 in. (146.1 by 203.2mm). The propeller is a one-piece molding of fiberglass-filled diallylphthalate. The entire unit is "O"-ring sealed. Windspeed is calculated according to the relationship between the rate at which the blades spin and the speed of the wind. A magnetically operated reed switch operates twice per 60 revolutions of the propeller; the necessary calculations are performed in the windspeed integrator unit. Wind direction is determined by the output of a synchro transmitter in the vertical housing.

Temperature Transducer

The sensor element in the air-temperature transducer (Fig. 8) is physically the same as the one used for reference temperature; however, the one situated on the instrument tower is housed in appropriate shielding, both for protection and to maintain accuracy. The sensor is a resistor of pure nickel wire, wound on a slotted bobbin with two radial lug terminals.

The air-temperature transducer is assembled inside a well-ventilated tubular housing. A second ventilated tubular shield is installed outside the first unit, giving a double shield to protect against heating by solar radiation. Two circular cover plates are part of the double shielding. They are separated with spacers to give ventilation and to act as thermal insulators. This unit is mounted on a supporting pedestal that carries the electrical connector. A plug-in unit forms the mounting base for the transducer and makes it easy to install.

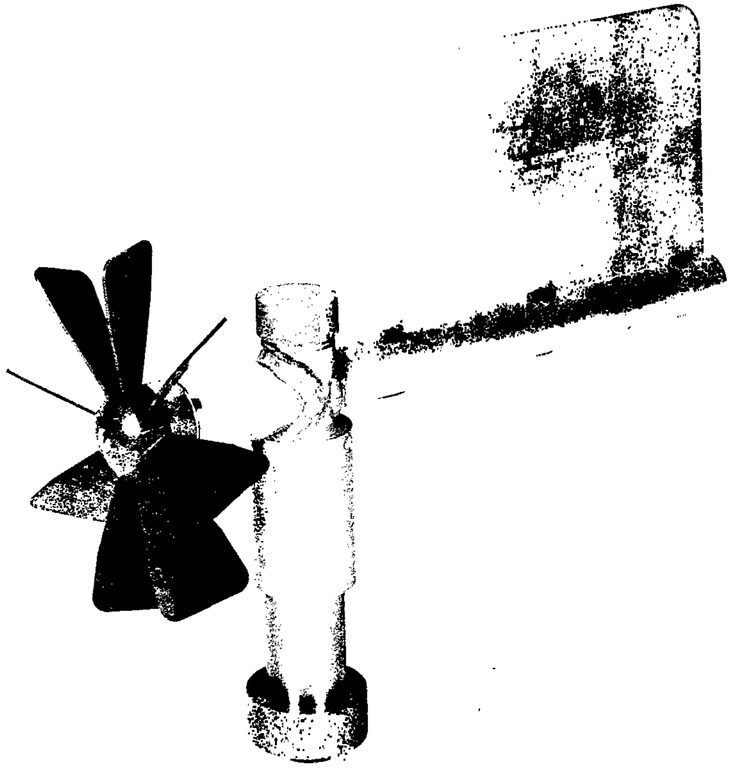


Fig. 7 — Anemometer

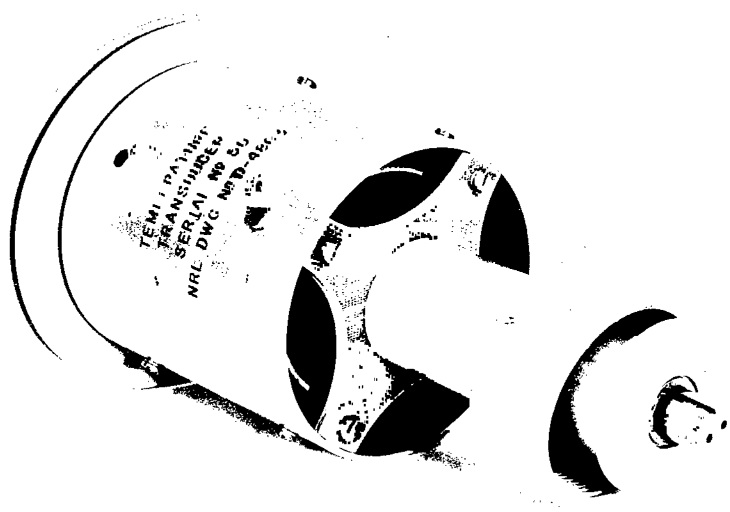


Fig. 8 — Air temperature sensor

Antenna Coupler

The antenna coupler (Fig. 9) simultaneously matches the antenna to two 50-ohm inputs for each communication frequency. Isolation of the low- and high-frequency halves of the coupler is accomplished by two series-tuned circuits, one resonant at the low frequency and the other at the high frequency. In each half of the coupler, the isolation circuits are followed by either a variable inductance or a capacitor, for tuning out the reactance of the antenna, and an adjustable impedance-matching T network. A built-in directional wattmeter monitors forward or reflected power on each frequency with meter switching to select low or high frequency for monitoring.

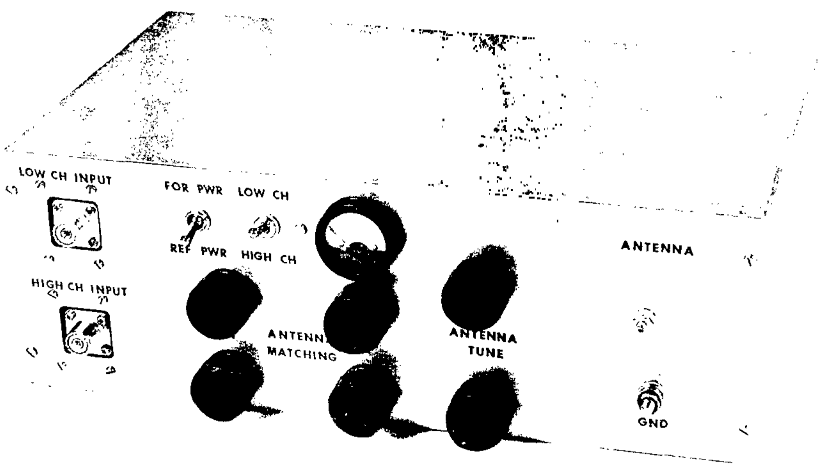


Fig. 9 — Antenna coupler

Radioisotope Power Generator

The radioisotope power generator (RPG) is shown in Fig. 10. It consists of a nuclear heat source inside of a biological shield surrounded by insulation on the sides and bottom, a thermoelectric module for converting about 5% of the heat to electricity, and an outer housing that has fins on the upper end. The fins are removed when the RPG is installed in the PAWS. The RPG housing is 19-3/4 in.(50.2 cm) in diameter and 27.1 in. (68.8 cm) high. Its total weight is 1,400 lb (634.9 kg).

The open-circuit voltage of the RPG is 5.75V DC. However, when the RPG is loaded for maximum power the output voltage drops to 2.9 V, and the load current is 11A.

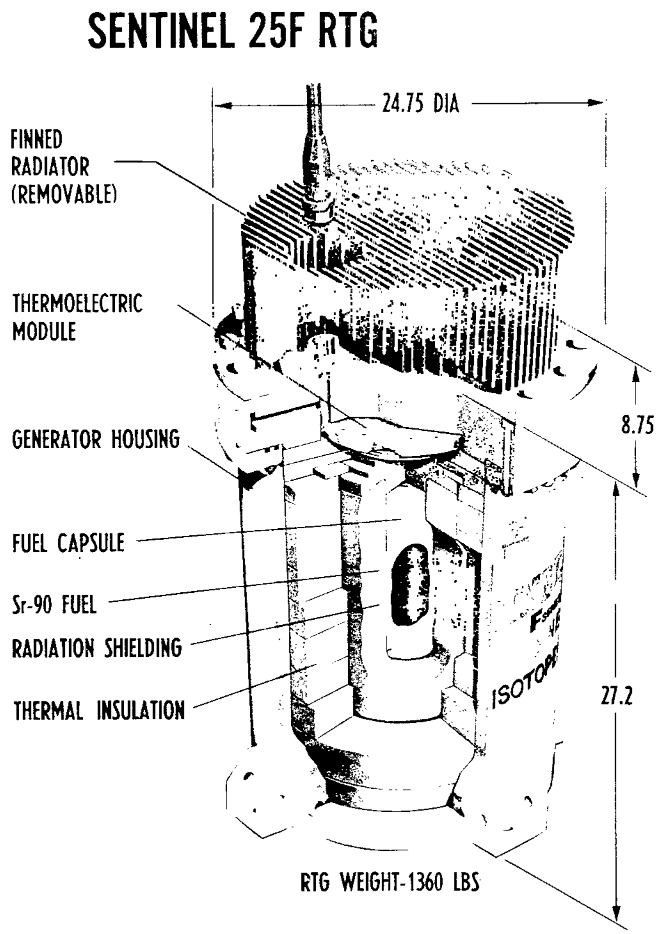


Fig. 10 — Radioisotope power generator

Functional Operation

The Polar Automatic Weather Station is capable of telemetering data by 150-W CW transmitter over distances of hundreds of miles. It contains sensors for measuring reference temperature, wind direction, air temperature, barometric pressure, and windspeed and transmits information derived from these sensors in international Morse code in three-letter groups at 17 groups per minute. This transmitted weather information is monitored by the Central Station for Meteorological Telemetry (NRL Model GKQ-1). The PAWS is operated by a command from the central station.

The received Morse code is converted to weather data by calibration tables. Only one set of tables is needed to convert the data from all PAWS equipments, because all sensors and associated units are standardized and thus interchangeable without recalibration. The accuracy of the transmitted information is equivalent to that of a manned station. In addition to the meteorological information, the PAWS sends its identifying station call.

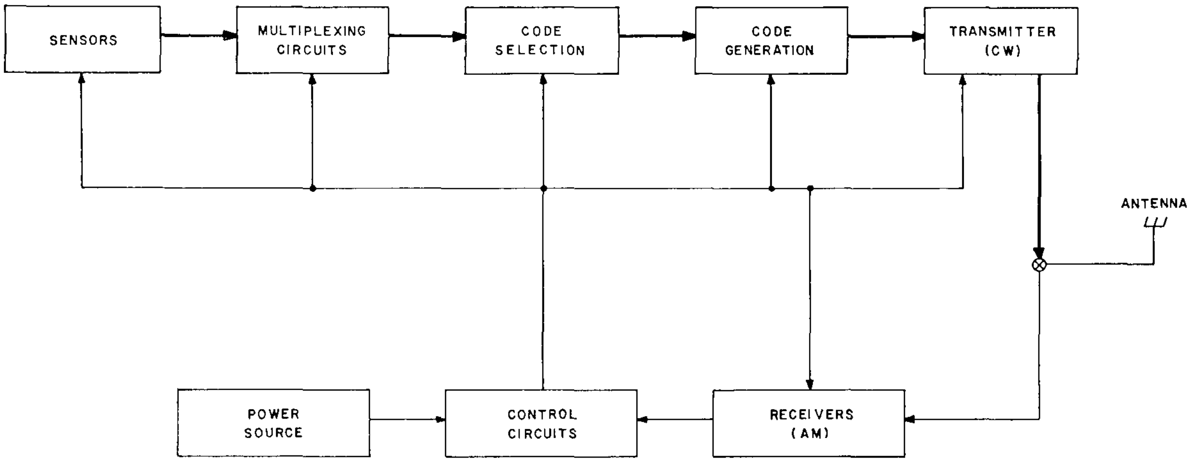


Fig. 11 — Functional block diagram

The basic functions and sequence of operation are illustrated in Fig. 11. The PAWS consists of four weather-sensing elements, multiplexing circuits for connecting each sensor to the code-selector system, a CW transmitter for transmitting meteorological data, two AM receivers for receiving interrogation signals from the central station, and control circuits for programing the sequence of operation.

When the command signal is received from the central station, it begins the operation of a 30-s time-delay relay to allow for equipment warmup. After this 30-s warmup time the control circuits take over, and the station starts its operating sequence. First is the generation of a group of three call letters, which identify the station in Morse code. These letters are repeated five times for a period of approximately 17.5s, after which meteorological data measured by the sensors are transmitted in the following order: reference temperature (degrees Farenheit), wind direction (degrees), air temperature (degrees Farenheit), barometric pressure (millibars), and windspeed (knots).

These weather conditions, as measured by the four sensing elements, are translated into corresponding values of electrical resistance. Through controlled multiplexing circuit relays, these resistances are measured by a self-balancing AC bridge that controls the code selector (which translates the resistance values into letters in international Morse code).

The information code that is generated consists of the coarse letter and the fine letter, which relate the data gathered by a sensor, preceded by a letter designating the channel that is being transmitted. Each sensor is assigned to a particular channel on the code-generating drum so that the received data can be identified accurately. The actual code generation is accomplished by grounding a set of brushes and thus causing certain code letters to be transmitted. The coarse and fine letters are each selected by seven-position switches which are synchronized.

The first letter of each three-letter data group identifies the sensor element. The second and third give weather data, which can be determined from calibration charts that show the numerical values corresponding to the various two-letter combinations. Each three-letter group is repeated three times. After all weather information has been transmitted the station is turned off until reactivated by the interrogation signal.

AUXILIARY EQUIPMENT

Test and Calibration Set

The test and calibration set, Unit 1400, used with the PAWS is shown in Fig. 12. It contains all test equipment and associated circuits for checking equipment onsite. The test set is portable and has a suitcase-like aluminum carrying case 27 in. (68.6 cm) wide, 11-1/2 in. (29.2 cm) high, and 8 in. (20.3 cm) deep. It weighs about 30 lb (13.6 kg).

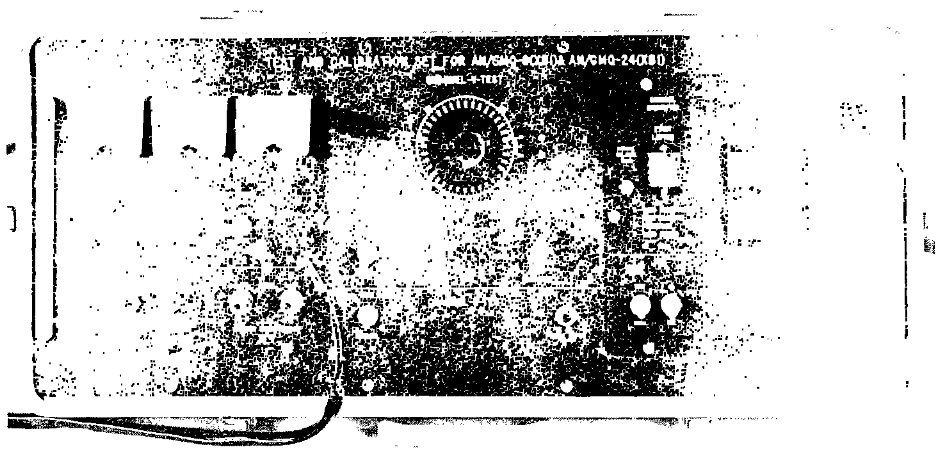


Fig. 12 — Test and calibration set

The left-hand two-thirds of the set can be used independently of the right-hand third, which is used for calibration only. The testing functions are all brought out through cable W1401 and connector J1401, which can be connected to either J101 or 3101. Connector J101 is used when testing the main package only; connector J3101 is used when the main instrument package is housed in the enclosure. The calibration functions are connected via cable W1402 and connector J3102 to J106 only.

The left-hand third of the test and calibration set has testing switches for battery voltage, substitution of channel S and T sensor inputs, and control functions normally derived automatically in the PAWS. The center third contains controls for testing channels V and U, and the right-hand third contains a readout display and associated circuitry, used for calibrating all channels.

Central Station

One of the chronic problems with automatic weather stations in the past has been the interrogation and monitoring of the remote stations by general-purpose transmitting and receiving equipment that is also used for other communication traffic. Using the wrong frequency or monitoring at the wrong time (in the case of timer-controlled stations) have resulted in poor communication reliability. To avoid this, special equipment was designed and built. The central station used to interrogate and monitor the PAWS is shown in Fig. 13. It consists of an interrogation transmitter, an interrogator, a monitoring receiver, a Morse-to-teletype code converter, a teletype printer, and a tape recorder. In normal operation a remote station is interrogated by pushing a button corresponding to the remote station to be interrogated, and the data are automatically printed out by the teletype printer. The recorder is for recording the messages received from the remote station. The central station antenna and antenna coupler are identical to those used on the PAWS except that they are mounted on a 10-ft (3.05 m) tower.

OPERATION

Power System

The power system of the PAWS consists of the radioisotope power generator (RPG), power conditioner, and battery. The system is shown schematically in Fig. 14.

The RPG consists of a 730-W (Sr 90; 107.0 kCi) heat source and a thermoelectric module for converting some of the heat to electricity. The present output power is about 33W (11A, 3V). Electrically, the RPG can be considered as a 5.75-V DC generator with an internal resistance of about 0.25 ohms. When it is used in the PAWS, the fins at the top are removed, and the RPG is inverted and heat-sinked to the main frame. Many radiological safety precautions must be taken during storage, handling, shipping, installation, deployment, and recovery. The generator must be handled carefully because it is rated for only 6-g shock loads. Higher shock loads result in loss of output power, but do not affect radiological safety. The recommended maximum ambient temperature is +130°F (54°C). This affects the enclosure's thermal design.

The power conditioner is a DC/DC converter with zener diodes on the input and output to limit the voltages (2.9-V input, 28-V output). The input zener ensures that the RPG will still have a load even if this unit should fail. (A no-load condition would cause overheating and resultant damage to the thermoelectrics.) The output zener protects the battery pack from overcharging and consequent loss of electrolyte.

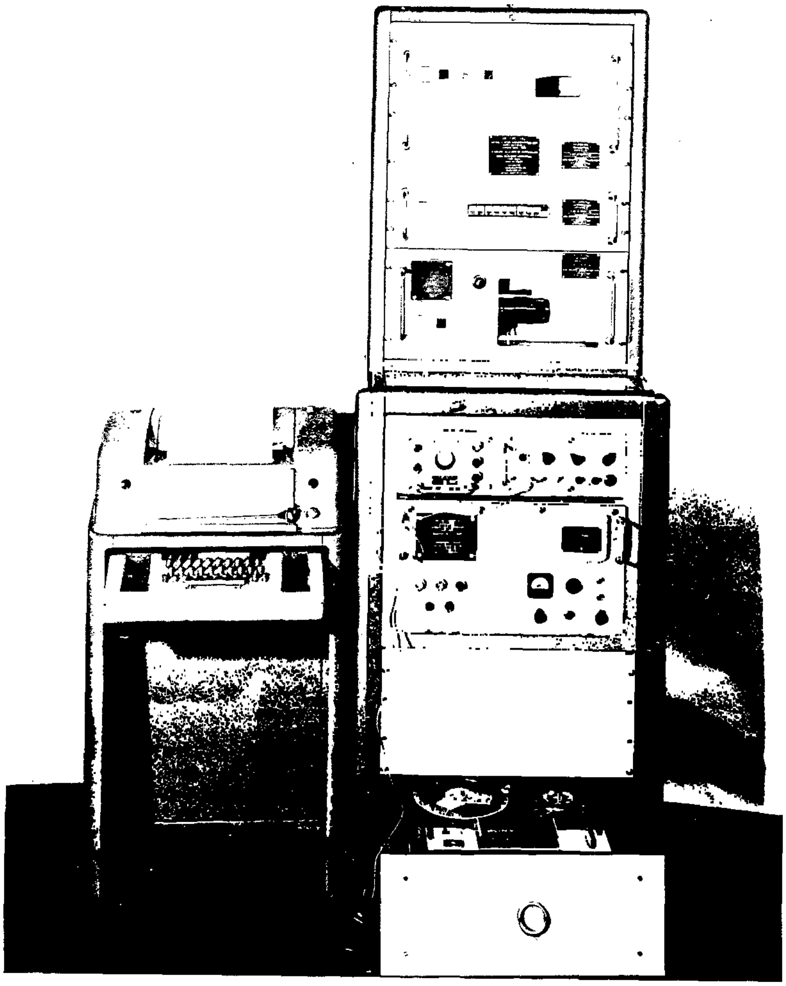


Fig. 13 — Central station console

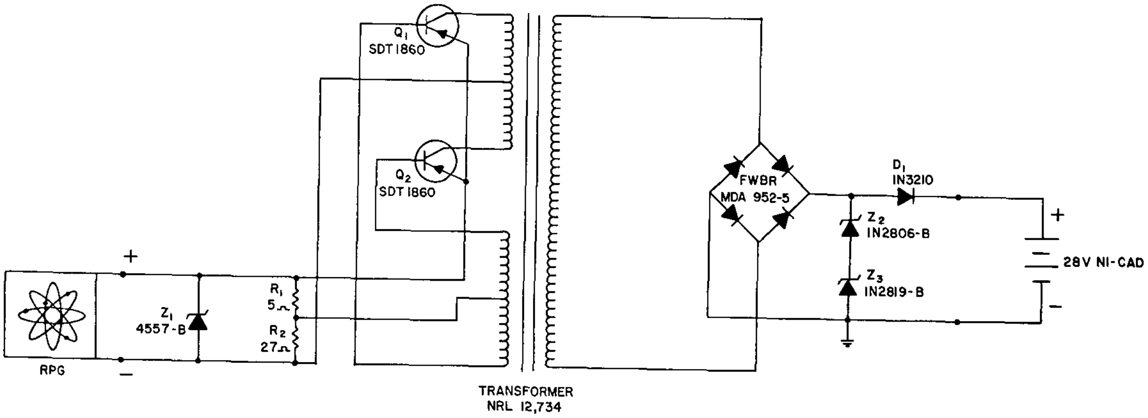


Fig. 14 — Power system schematic

The battery is a 28-V, 40-Ah nickel-cadmium pack. It is mounted in a gas-tight enclosure and vented to the outside of the enclosure. Hermetically sealed connectors and "O"-ring seals are used on the battery enclosure to prevent hydrogen from getting into the rest of the PAWS.

Coding and Sequencing System

The functions of the coding and sequencing system are as follows:

1. Connect the sensors or windspeed and direction averagers to a bridge circuit in the desired sequence.

2. Generate Morse code characters for the station call, sensor channel identifiers, and sensor information letters.

3. Select information letter pairs that correspond to the variables being measured.

4. Key the transmitter to send the station message, consisting of three-letter groups.

A typical message is shown below.

Station call	N7A	Repeated five times	
Reference temperature	BUI	Repeated three times	45.9°F
Wind direction	VMH	Repeated three times	232°
Air temperature	TVI	Repeated three times	-7.6°F
Barometric pressure	SKH	Repeated three times	1003 mbar
Windspeed	UTI	Repeated three times	19 knots

The reason for transmitting the information in letter pairs rather than numbers is to conserve power. The letter pairs require about one-third of the key-down time that numbers would. The call and information groups are repeated to allow the message to be copied when signals are weak or fading.

The PAWS coding and sequencing system consists of the code and sequencing unit and the servoelectronics unit.

Code and Sequencing Unit

The code and sequencing unit is designed to control the selection of each sensor in turn and to translate sensor outputs into a pair of Morse code letters. In addition, it selects and controls the transmission of the station call letters and controls the sequence of events during data transmission. Acting on relay signals from the control unit, it operates automatically from the time control signals turn it on.

The unit consists of two main sections: the code generator and sequencing section and the code-selection section.

The lower part of this unit consists basically of a motor, a gear train, and three drums (Fig. 15). The first drum, S231, has three poles. The first pole is used to control the position of the drum when it stops (station turnoff); the second pole has the call letters of the PAWS on its surface, so that for each of its revolutions the three station call characters are generated; and the third pole contains seven different Morse code letters, each on a separate track. All of the third-pole letter bits are internally connected to the two common tracks. Each letter is contacted by three brushes (located 90° apart) for each revolution of the drum. Code is generated when the bits of a letter pass under a brush that is grounded. The letter appears at the common track as a series of ground-no-ground pulses that correspond in time sequence to the Morse code letter passing under the grounded brush. For each revolution of this drum, the bits of all the letters pass under all three sets of brushes. This means that three letters, which in this system comprise a complete word, are generated.

Although there are only seven different letters on the drum, it is possible to make seven more letters by bridging. Figure 16 shows the actual pattern as it is on the drum. If the B brush is grounded, the letter B is generated. The same holds for letters V, T, I, S, N, and U. However, grounding both the letters B and V at once causes the letter K to be generated. Similarly, the letters W, A, H, D, M, or G may be generated. This makes it possible to generate 14 different letters.

Each word generated consists of three letters. The first letter is determined by which brush of the first-letter brush set is grounded and identifies the channel selected by the second drum, S232. Drum S232 grounds the B brush of the first-letter brush set of S231 for three revolutions, when B-channel sensor data are being transmitted. It likewise grounds the V, T, S, and U brushes of the first-letter brushes of drum S231 as these channels are transmitted. The second letter is determined by which brush or brushes of the second brush set are grounded. They are grounded in accordance with the resistance value of each sensor by coarse-letter selector switch S251. The brushes of the third-letter brush set of drum S231 are also grounded in accordance with the resistance of the sensor, but by the fine-letter selector switch S252.

The second or sequencing drum S232 makes one revolution per transmission. It selects each of the five channels in time sequence, and at the beginning of each channel turns the bridge amplifier on for about 2s. The third or control drum S233 rotates one-fourth of a revolution per station operation and it, in conjunction with the first pole or switch vernier section of S231, turns the station off at the proper time.

The upper part of the code and sequencing unit is the code selector. It consists of a servomotor, a gear train, a potentiometer, and two printed circuit switches, S251 and S252. These switches are the coarse- and fine-letter selector switches and are positioned according to the resistance of a sensor by a simple servosystem.

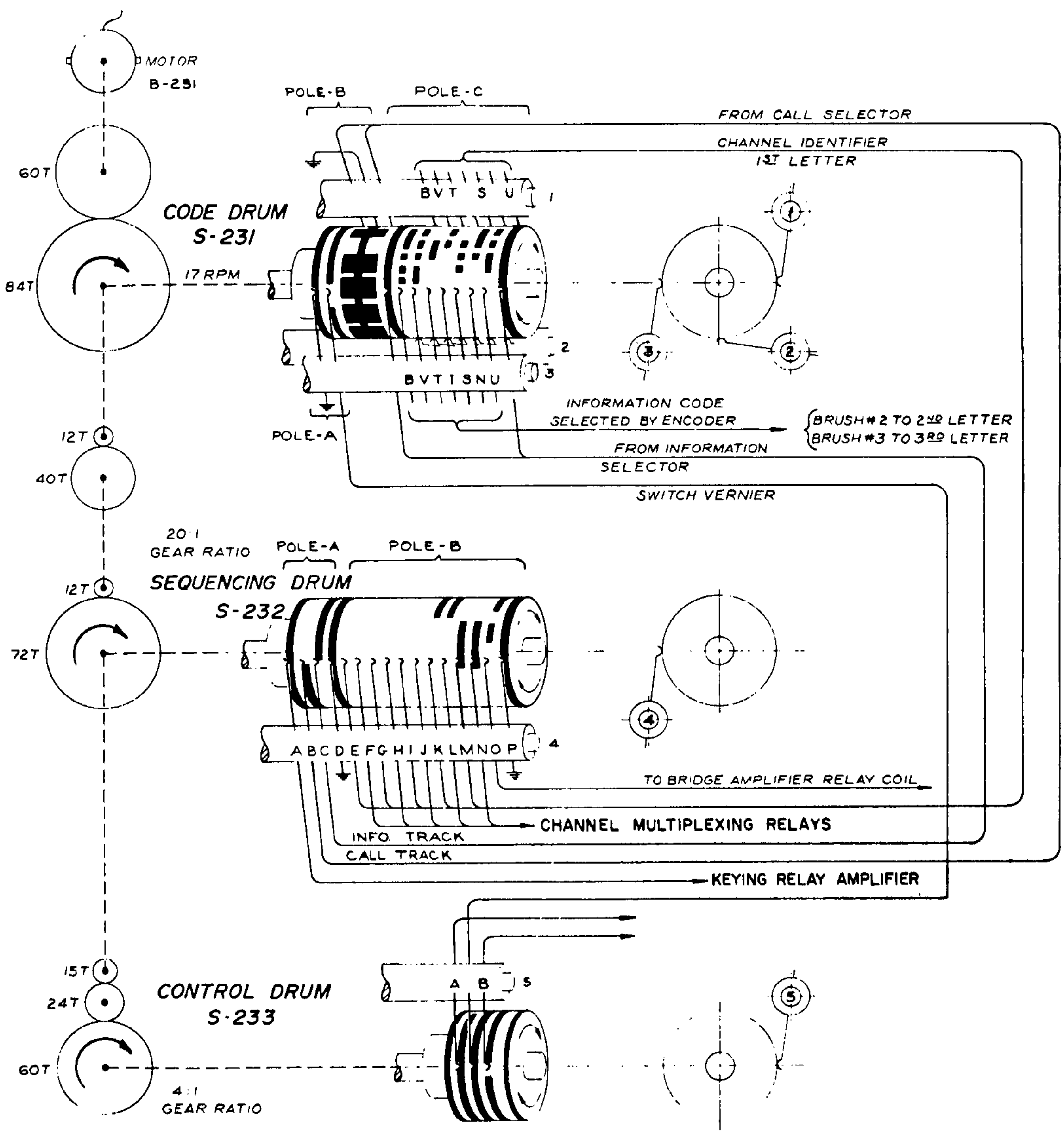


Fig. 15 — Code and sequencing unit

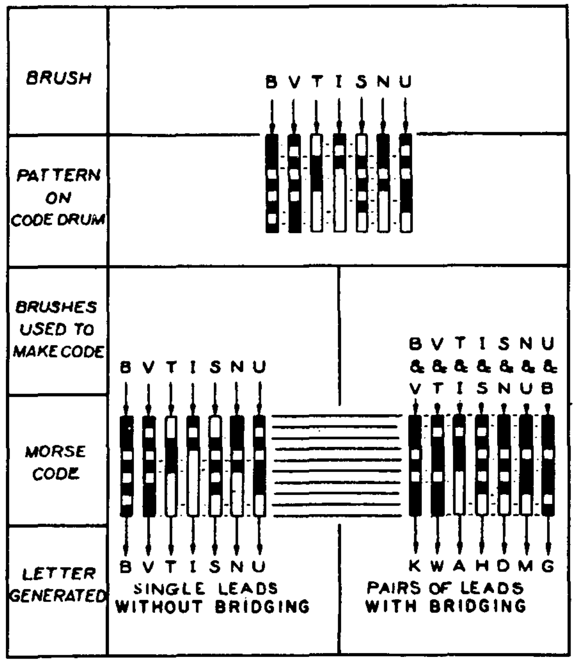


Fig. 16 — Contact pattern on code-generator drum

The switch contacts, shown in Fig. 17, are connected to the code generator in the manner shown by the overall schematic (Fig. 18). Each switch has one brush arm or wiper, and each arm has two contacts. Letters are selected by the wiper grounding the segment or segments that belong to a given letter. Each switch can select 14 different letters, 7 by contacting single letter contacts only and 7 by bridging letter contacts. For example, contacting the I contact causes the letter I to be generated, and contacting the letter T contact causes the letter T to be generated, but contacting, or bridging, both I and T contacts causes the letter A to be generated. These switches do not generate the code letters; they only select the letters that are generated by S231 while S251 and S252 are stationary.

Since each switch can select 14 different letters, the two switches together can select a total of 196 different letter pairs. The progression of the code is shown in Table 1. The switches in Fig. 17 are shown in the lower stop position; they rotate going toward the upper stop. When the fine wiper S252 has rotated 180°, it again goes through all 14 of its letters, but the sequence of the letters is now reversed. The fine wiper goes through its letters 14 times as the coarse wiper goes from the lower stop to the upper stop. With this system of cyclic code progression, coarse letters change when the fine letters H or I are not changing. This arrangement prevents any ambiguity that might result from lost motion in the gear train or tolerances in the switch contacts if the coarse and fine letters were to change at the same time. The code-selecting switches are positioned by a servo-system controlled by the resistance of a selected sensor. Code-selector position feedback is supplied by balance potentiometer R252.

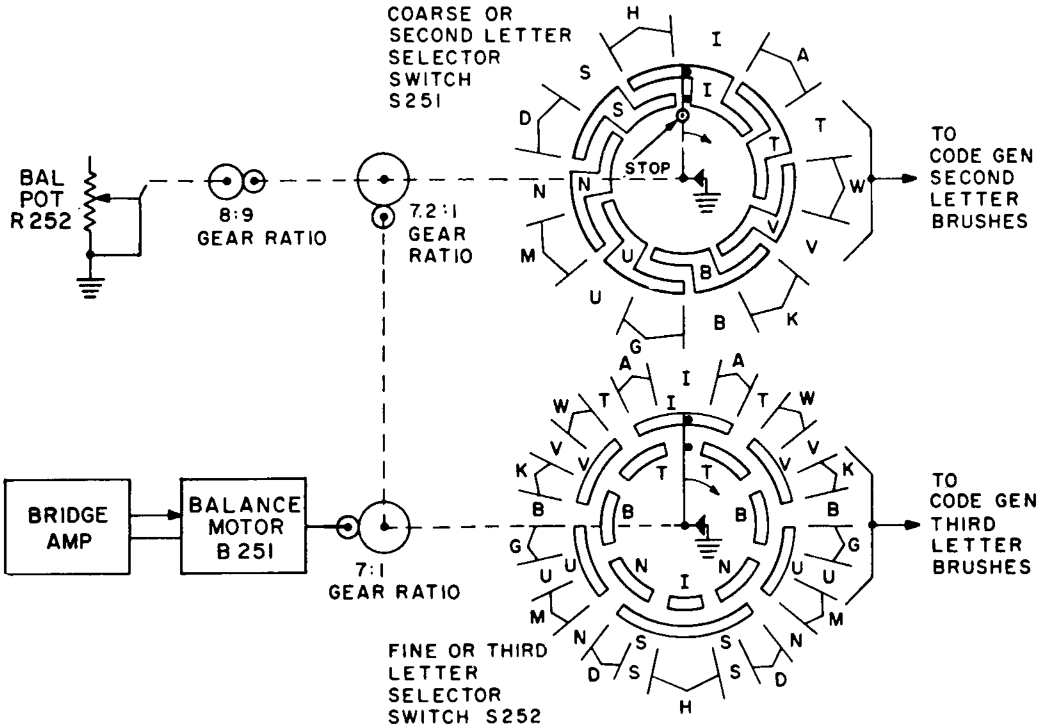
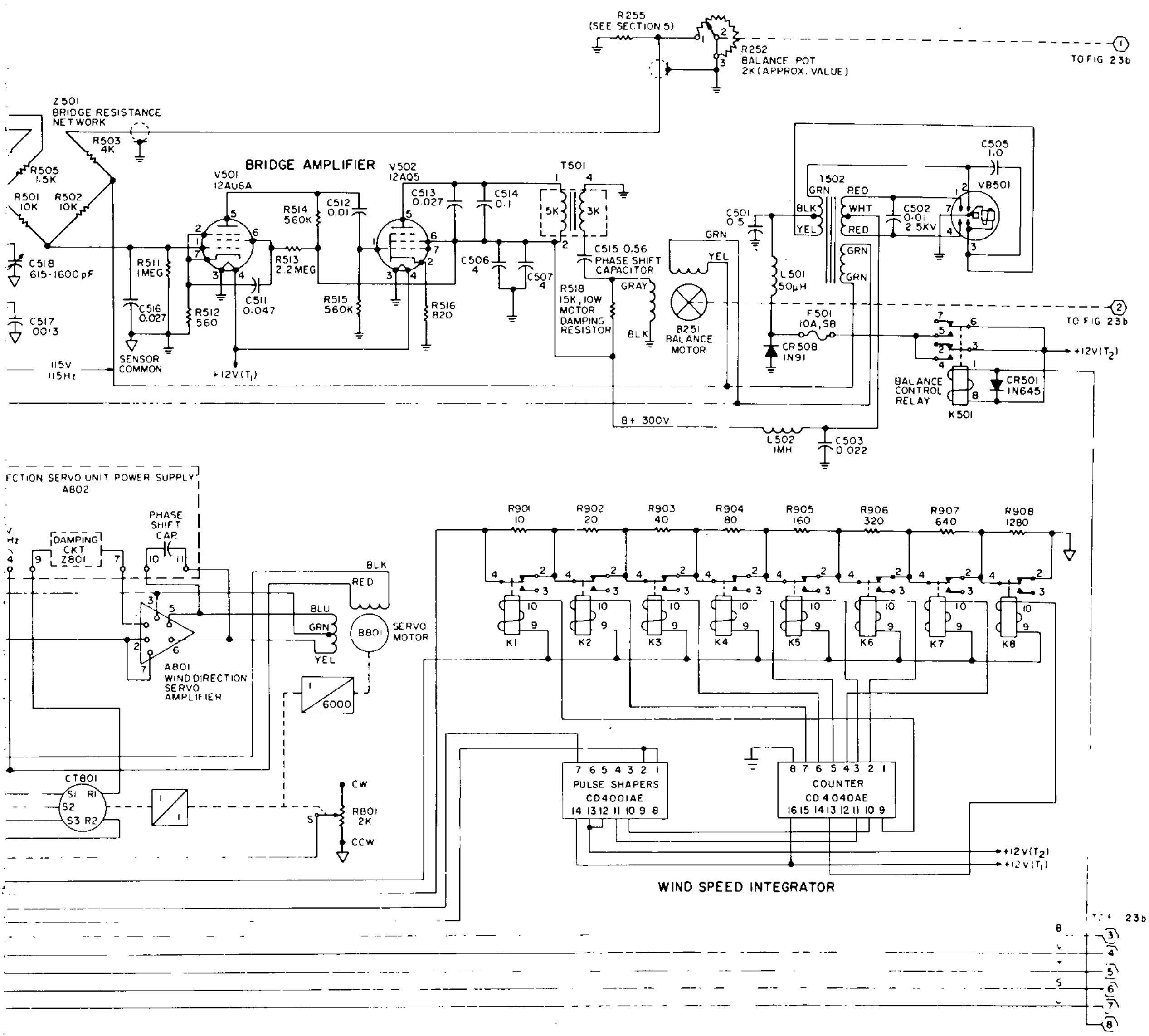


Fig. 17 — Contact pattern on code-selector printed circuit

When the balance potentiometer is driven to zero to match a low resistance in a sensor element or a shorted sensor element, the code-selector gear train may encounter the mechanical stop and will balance, in most instances, not more than one character from the stop. On the other hand, when the potentiometer is driven to a high value of resistance to match a high-resistance sensor or an open circuit in a sensor element, the code-selector gear train may again encounter the mechanical stop. Under these conditions, hunting and pitchoff by the stop (when the amplifier is deenergized) are kept to a minimum by a clutch on the fine-letter selector drive gear.

Servoelectronics Unit

The servoelectronics unit (Fig. 19) contains the relays that select weather sensor data, a bridge balancing network and bridge amplifier, and a vibrator power supply for the bridge. The power supply has a synchronous vibrator, converting +12V DC to 115 V at 115 Hz. A mechanical vibrator is used to get a stable frequency over a wide range of load, voltage, and temperature. Relays K501 through K506 determine the selection of channels in the code selector and apply power to the bridge circuit.


R255
(SEE SECTION 5)
R252
BALANCE POT
2K (APPROX. VALUE)
TO FIG 23b
Z501
BRIDGE RESISTANCE
NETWORK
R503
4K
R505
1.5K
R501
10K
R502
10K
C518
615-1600pF
C517
.0013
BRIDGE AMPLIFIER
V501
12AU6A
V502
12AQ5
R514
560K
C512
0.01
C513
0.027
C514
0.1
T501
5K
3K
R511
1MEG
R513
2.2MEG
C516
0.027
R512
560
C511
0.047
R515
560K
R516
820
C506
4
C507
4
C515 0.56
PHASE SHIFT
CAPACITOR
R518
15K, 10W
MOTOR
DAMPING
RESISTOR
GRN
YEL
GRAY
BLK
B251
BALANCE
MOTOR
SENSOR
COMMON
115V
115Hz
+12V(T1)
C501
0.5
T502
GRN
BLK
YEL
RED
WHT
RED
GRN
GRN
C502
0.01
2.5KV
C505
1.0
VB501
L501
50µH
F501
10A, SB
CR508
1N91
TO FIG 23b
+12V(T2)
BALANCE
CONTROL
RELAY
K501
CR501
1N645
B+ 300V
L502
1MH
C503
0.022
FCTION SERVO UNIT POWER SUPPLY
A802
PHASE
SHIFT
CAP.
DAMPING
CKT
Z801
BLK
RED
BLU
GRN
YEL
B801
SERVO
MOTOR
A801
WIND DIRECTION
SERVO
AMPLIFIER
6000
CT801
S1 R1
S2
S3 R2
CW
R801
2K
CCW
R901
10
R902
20
R903
40
R904
80
R905
160
R906
320
R907
640
R908
1280
K1
K2
K3
K4
K5
K6
K7
K8
7 6 5 4 3 2 1
PULSE SHAPERS
CD4001AE
14 13 12 11 10 9 8
8 7 6 5 4 3 2 1
COUNTER
CD4040AE
16 15 14 13 12 11 10 9
+12V(T2)
+12V(T1)
WIND SPEED INTEGRATOR
23b

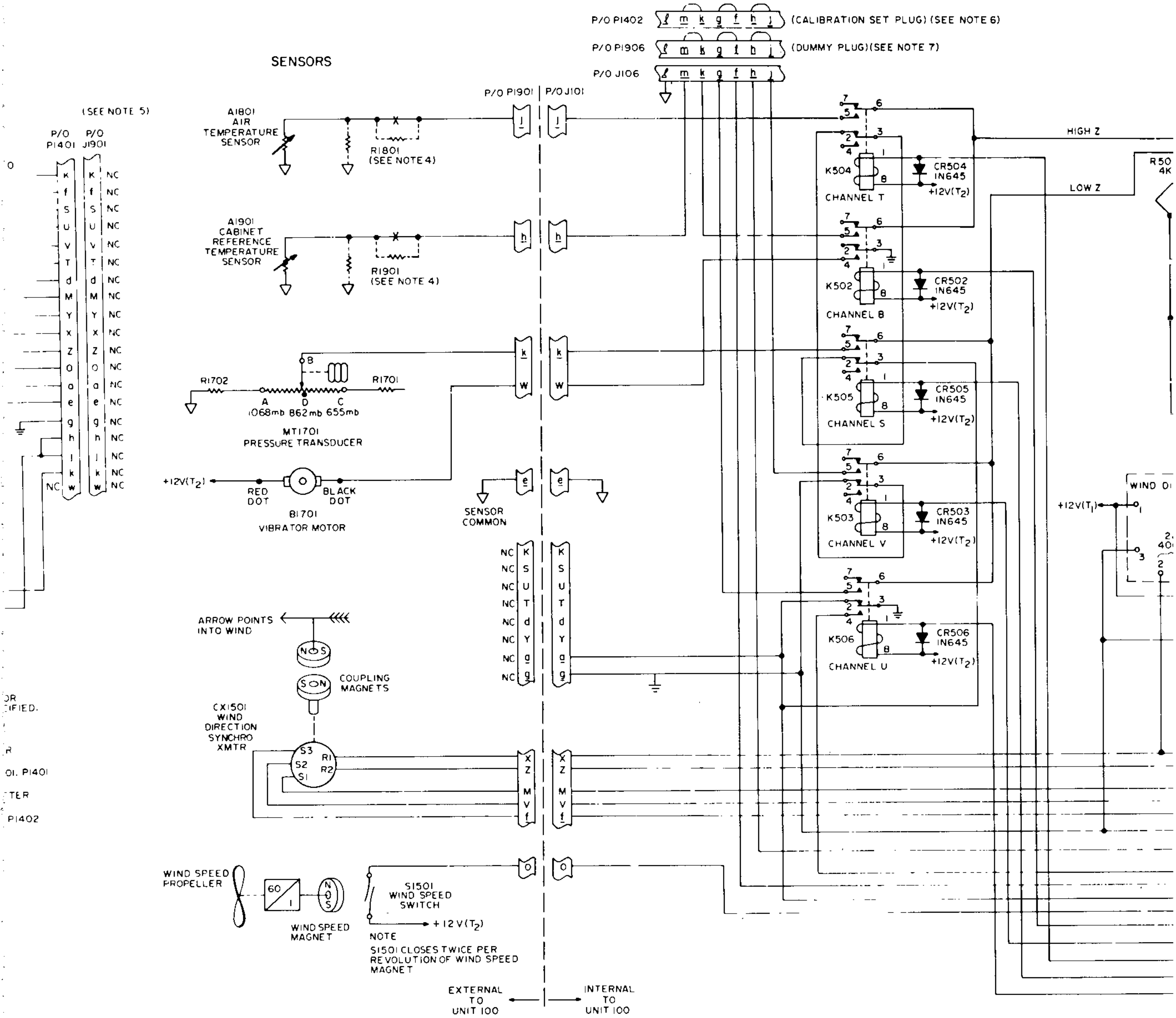
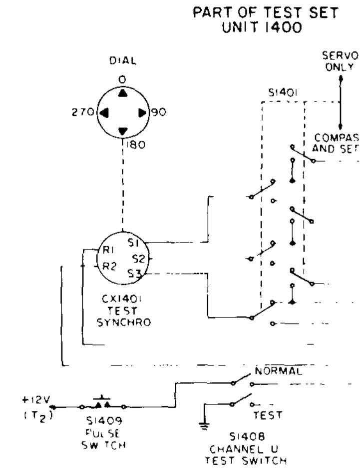
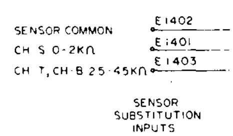


Fig. 18a — Overall schematic diagram



NOTE
TEST SET GROUND IS THROUGH P1401
PIN I AND +12V(T_2) IS THROUGH P1401
PIN L.



NOTES:

1. ALL RESISTOR VALUES ARE IN OHMS AND ALL CAPACI
   VALUES ARE IN MICROFARADS UNLESS OTHERWISE SP
2. ALL RELAYS ARE SHOWN DEENERGIZED.
3. SYMBOL ▽ INDICATES SENSOR COMMON.
4. RESISTORS R1801 AND R1901 CAN BE EITHER IN SERIES
   PARALLEL TO MAKE THE SENSORS INTERCHANGEABLE.
5. TEST SET CONNECTOR P1401 IS SHOWN CONNECTED TO J
   ALSO MATES WITH J101 (AFTER REMOVAL OF P1901).
6. TEST SET CONNECTOR P1402 MATES WITH J106 ONLY (
   REMOVAL OF DUMMY PLUG P1906).
7. DUMMY PLUG P1906 MUST BE CONNECTED TO J106 (WH
   IS NOT CONNECTED) FOR NORMAL OPERATION.

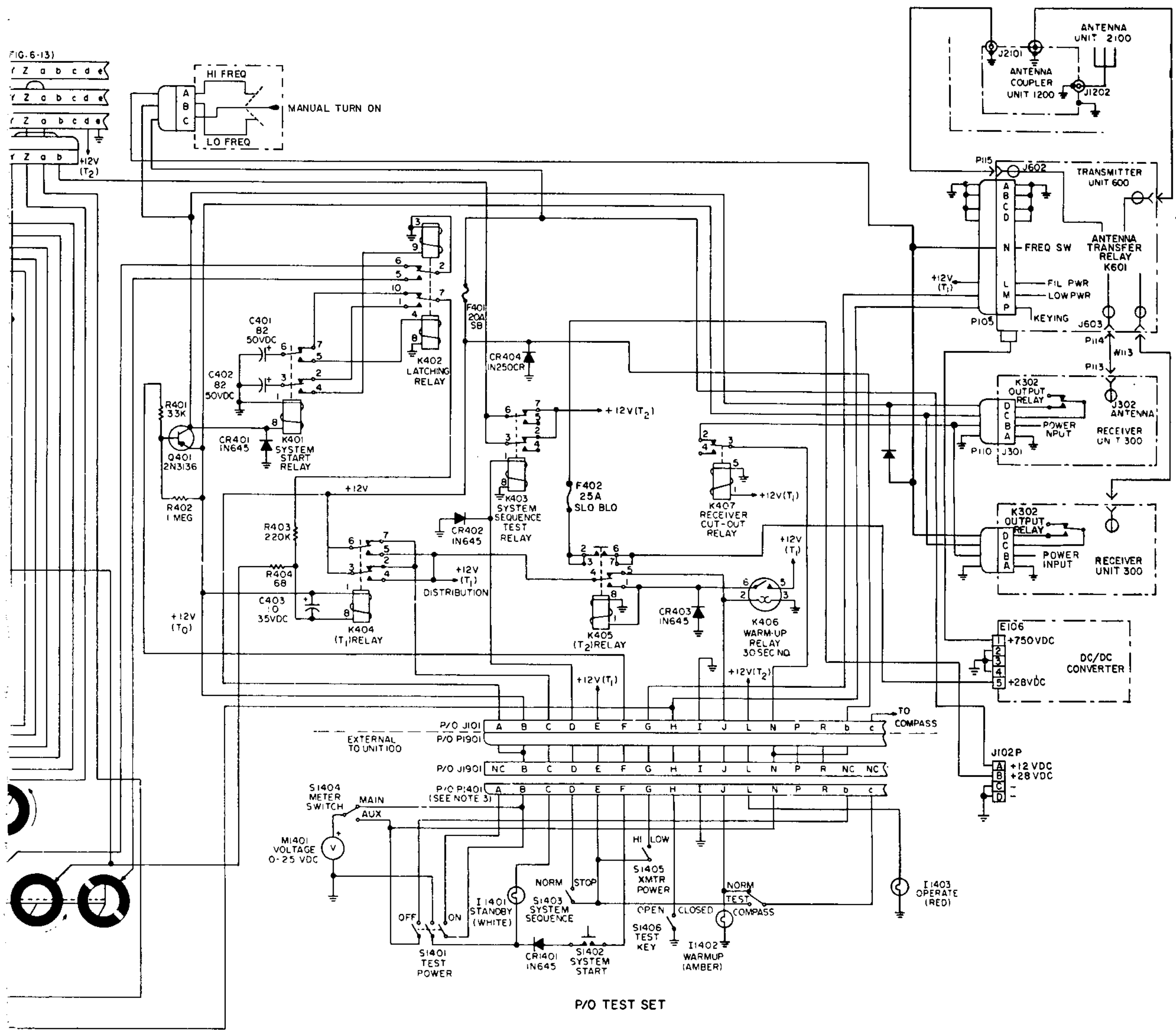


FIG. 6-13)
HI FREQ
LO FREQ
MANUAL TURN ON
+12V (T2)
ANTENNA UNIT 2100
J2101
ANTENNA COUPLER UNIT 1200
J1202
P115
J602
TRANSMITTER UNIT 600
ANTENNA TRANSFER RELAY K601
FREQ SW
FIL PWR
LOW PWR
KEYING
P105
J603
P114
W113
P113
K302 OUTPUT RELAY
J302 ANTENNA
POWER INPUT
RECEIVER UNIT 300
P110
J301
E106
+750VDC
DC/DC CONVERTER
+28VDC
J102P
+12 VDC
+28 VDC
C401 82 50VDC
C402 82 50VDC
R401 33K
Q401 2N3136
CR401 IN645
K401 SYSTEM START RELAY
R402 1 MEG
K402 LATCHING RELAY
F401 20A SB
CR404 IN250CR
+12V(T2)
K403 SYSTEM SEQUENCE TEST RELAY
CR402 IN645
F402 25A SLO BLO
K407 RECEIVER CUT-OUT RELAY
+12V(T1)
+12V
R403 220K
R404 68
C403 10 35VDC
+12V (T0)
K404 (T1)RELAY
+12V (T1) DISTRIBUTION
K405 (T2)RELAY
CR403 IN645
K406 WARM-UP RELAY 30 SEC NO
+12V(T2)
TO COMPASS
P/O J101
EXTERNAL TO UNIT 100
P/O P1901
P/O J1901
P/O P1401 (SEE NOTE 3)
S1404 METER SWITCH
MAIN
AUX
M1401 VOLTAGE 0-25 VDC
HI LOW
S1405 XMTR POWER
NORM STOP
I 1401 STANDBY (WHITE)
S1403 SYSTEM SEQUENCE
OPEN CLOSED
S1406 TEST KEY
NORM TEST COMPASS
I 1403 OPERATE (RED)
I 1402 WARMUP (AMBER)
OFF ON
S1401 TEST POWER
CR1401 IN645
S1402 SYSTEM START
P/O TEST SET

m

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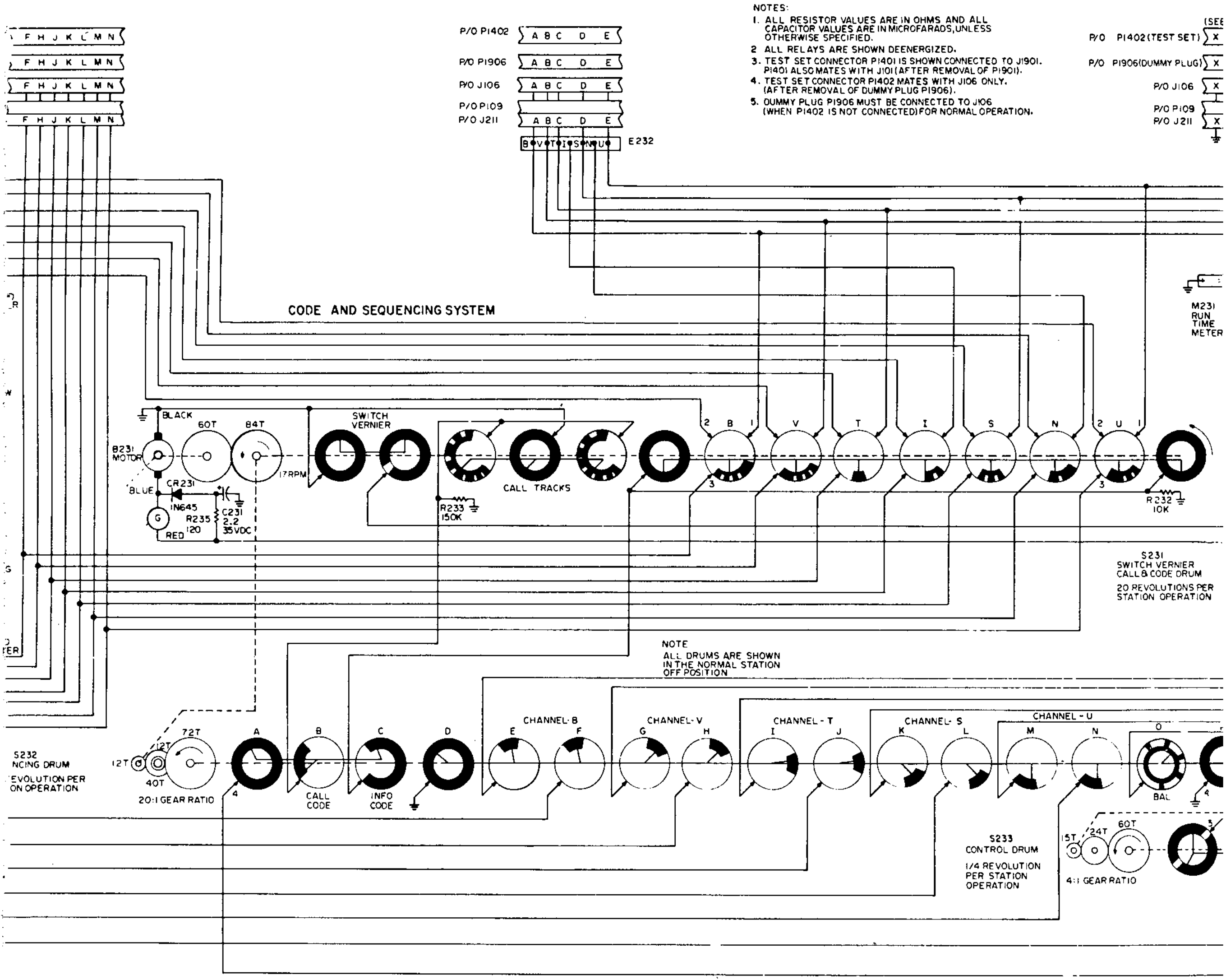

Fig. 18b — Overall schematic diagra

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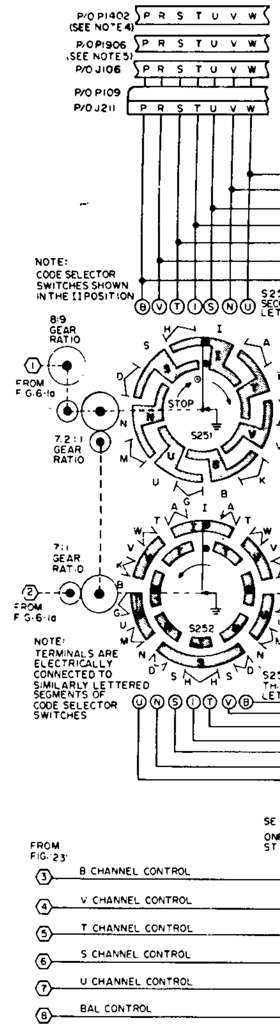

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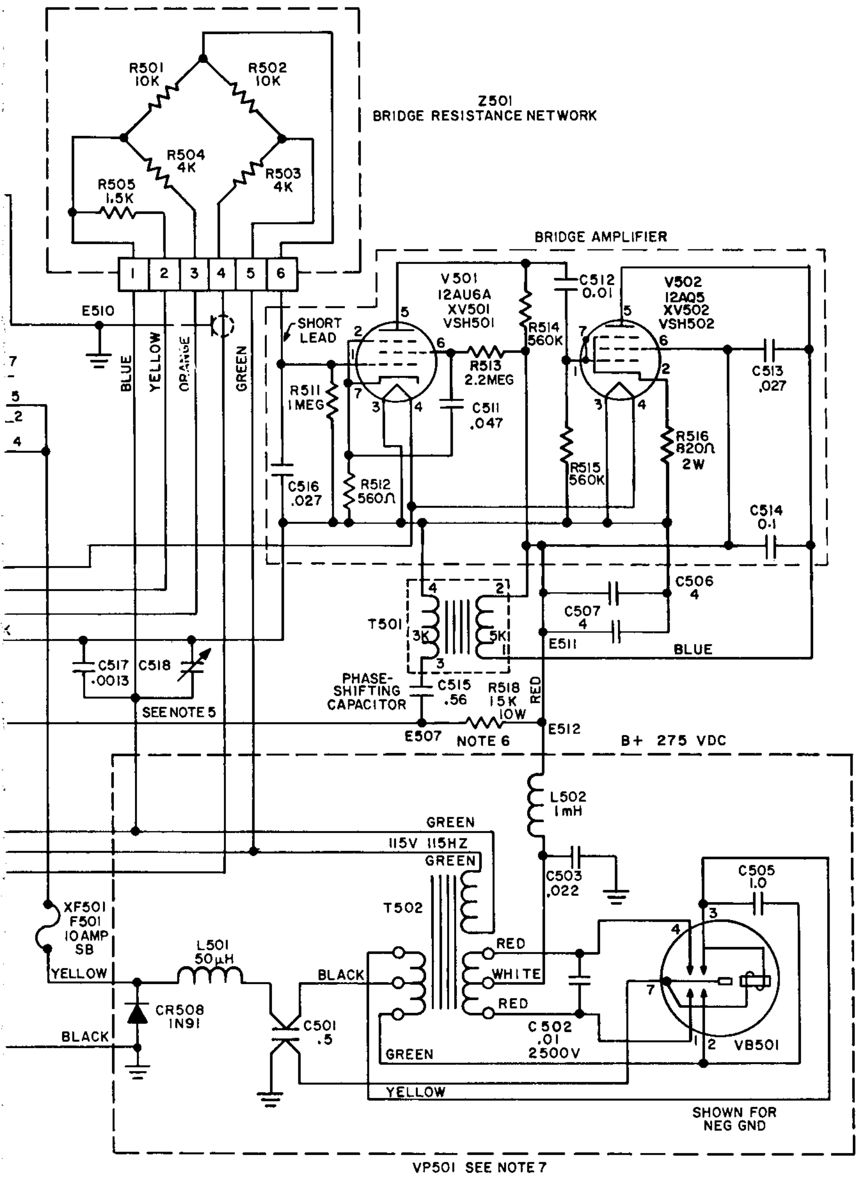

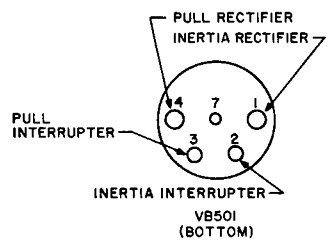

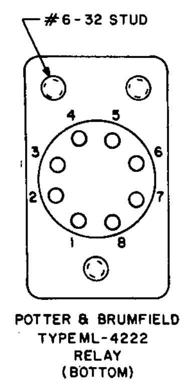

NOTES:

1. ALL RESISTORS ARE 1/2W EXCEPT R516-2W AND R518-10W.
2. ALL CAPACITOR VALUES ARE IN µF.
3. ALL DIODES ARE TYPE IN625 EXCEPT CR508-IN91.
4. ALL RELAYS ARE TYPE ML-4222.
5. ADJUST VALUE OF C518 TO GIVE MINIMUM VOLTAGE AT E507 WHEN ASSEMBLED IN SYSTEM WITH CODE AND SEQUENCING SYSTEM (UNIT 200) WITH UNIT IN NORMAL OPERATING CONDITION AND AT BALANCE WITH AN INPUT OF 1000 OHMS IMPEDANCE CONNECTED TO ONE OF THE LOW IMPEDANCE CHANNELS. FOR DETAILS SEE INSTRUCTION MANUAL.
6. R518 PROVIDES THE DESIRED AMOUNT OF DIRECT CURRENT IN THE FIXED PHASE OF THE CODE SELECTOR SERVO MOTOR FOR DAMPING.
7. FOR MODIFICATION OF THIS UNIT SEE NRL DWG 4868.
8. FOR LOCATION OF BRIDGE AMP COMPONENTS ON TB502 SEE NRL DWG 4868.

es unit schematic diagram

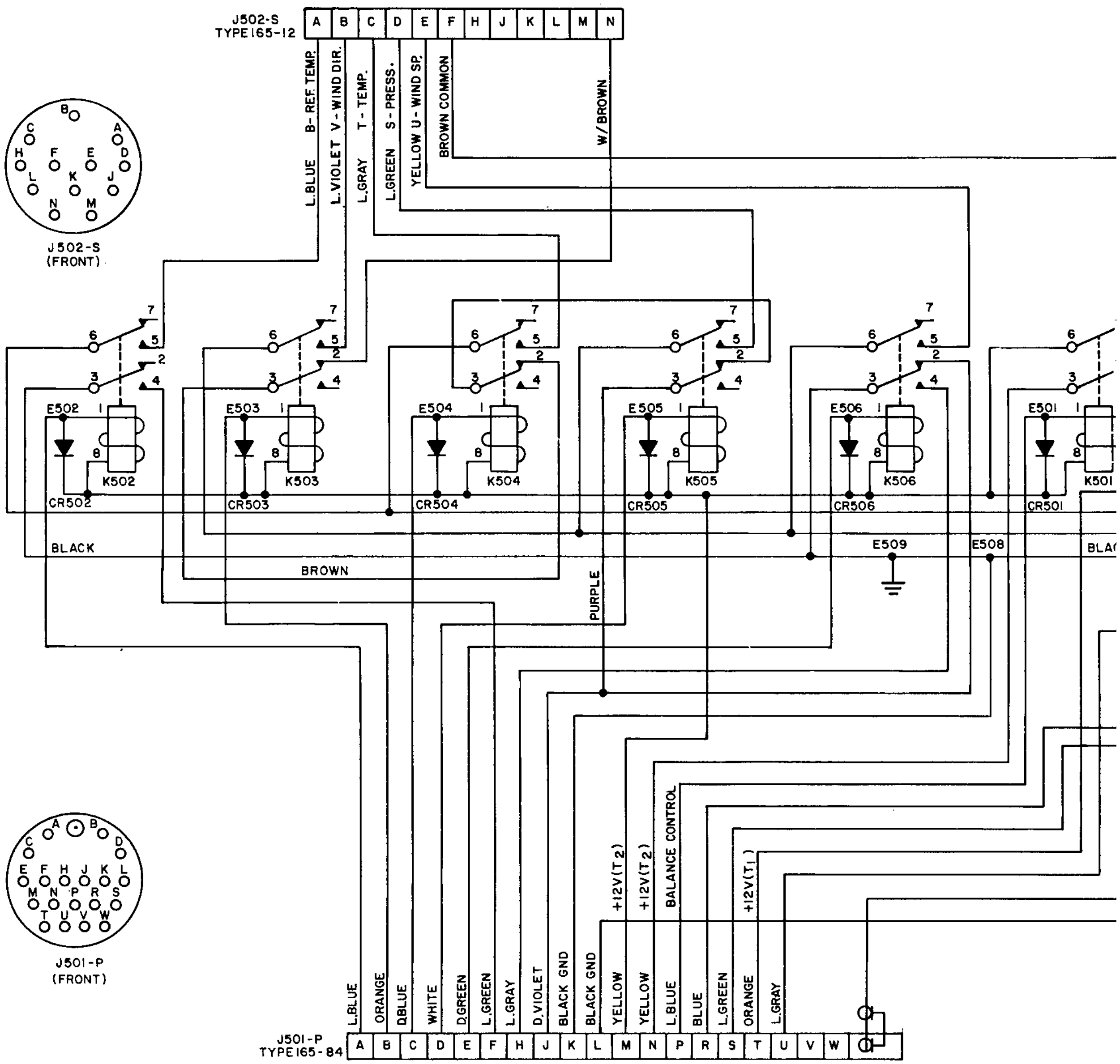

Fig. 19 — Servoelectron

Table 1 — System Letter Combinations

*1st letter channel identification (S232)
2nd letter (S251)
3rd letter (S252)

Lower Stop	H I							
								← Changeover point
	I I	T I	V I	B I	U I	N I	S I	
	I A	T A	V A	B A	U A	N A	S A	
	I T	T T	V T	B T	U T	N T	S T	
	I W	T W	V W	B W	U W	N W	S W	
	I V	T V	V V	B V	U V	N V	S V	
	I K	T K	V K	B K	U K	N K	S K	
	I B	T B	V B	B B	U B	N B	S B	
	I G	T G	V G	B G	U G	N G	S G	
	I U	T U	V U	B U	U U	N U	S U	
	I M	T M	V M	B M	U M	N M	S M	
	I N	T N	V N	B N	U N	N N	S N	
	I D	T D	V D	B D	U D	N D	S D	
	I S	T S	V S	B S	U S	N S	S S	
	I H	T H	V H	B H	U H	N H	S H	
								← Changeover point
	A H	W H	K H	G H	M H	D H	H H	
	A S	W S	K S	G S	M S	D S	H S	
	A D	W D	K D	G D	M D	D D	H D	
	A N	W N	K N	G N	M N	D N	H N	
	A M	W M	K M	G M	M M	D M	H M	
	A U	W U	K U	G U	M U	D U	H U	
	A G	W G	K G	G G	M G	D G	H G	
	A B	W B	K B	G B	M B	D B	H B	
	A K	W K	K K	G K	M K	D K	H K	
	A V	W V	K V	G V	M V	D V	H V	
	A W	W W	K W	G W	M W	D W	H W	
	A T	W T	K T	G T	M T	D T	H T	
	A A	W A	K A	G A	M A	D A	H A	
	A I	W I	K I	G I	M I	D I	H I	
								← Upper Stop
							I I	

*First letter channel identification is selected by sequencing drum S232.

The bridge used to measure the resistance of the sensor element chosen operates on 115 V at 115 Hz and requires a current of approximately 16mA. It has an output impedance of about 7,500 ohms and generates a signal of not more than 10 V into an open circuit. The bridge consists of two fixed legs and two variable legs; the variable legs are composed of fixed resistors in series with variable resistors. At balance the combined resistance of the fixed resistor and the variable resistance of the weather sensor in that leg is equal to the combined resistance of the fixed resistor and the balancing potentiometer in the adjacent leg.

The fixed resistors in the variable legs have a temperature coefficient of 0.002% per degree Celsius, as do the fixed legs of the bridge. Their resistance values were chosen to limit the current through the sensor element to 8 mA, as well as to accommodate two varieties of sensor elements.

The system is designed to accommodate either 0- to 2,000-ohm elements or 2,500- to 4,500-ohm elements, and it may be adapted for use with other inputs by appropriate signal-conditioning equipment. A 4,000-ohm ± 0.1% resistor with a temperature coefficient of 0.002% per degree Celsius is used in series with low-impedance elements. With these elements, this leg of the bridge will vary from 4,000 to 6,000 ohms. A 1,500-ohm ± 0.1% resistor with a temperature coefficient of 0.002% per degree Celsius is used in series with high-impedance elements. This is usually in the form of a resistance element that is sensitive to temperature. With such an element, this leg of the bridge will also vary from 4,000 to 6,000 ohms.

The fixed resistor in series with the balancing potentiometer in the other leg of the bridge circuit is 4,000 ohms ± 0.1% with a temperature coefficient of 0.002% per degree Celsius. This potentiometer is located in the code selector and is driven by the gear train of the code selector. It is a rotary potentiometer with synchro mounting for ease of adjustment. Its compensated resistance is 2,000 ohms with a temperature coefficient of 0.002% per degree Celsius. This resistance covers 310° of shaft rotation; the mechanical rotation is unlimited (no stops). The potentiometer has a 0.5% linearity and a resolution of better than one part in one thousand. The resistance of the potentiometer is varied by the gear train to match the resistance of the "unknown" leg of the bridge. This leg of the bridge will vary from 4,000 ohms, for the lowest value the balance potentiometer can have. This combination matches the full range of the sensor to the full range of the code selector, 196 characters, thus giving about 10 ohms of resistance and about five wire turns on the potentiometer for each of the 196 characters encoded. Capacitor C518 compensates for stray capacitance which can cause excessive quadrature error voltage.

The bridge amplifier converts the bridge signal to a form capable of driving the servomotor. The amplifier consists of two resistance-coupled stages. The first stage employs a 12AU6 pentode voltage amplifier tube whose grid receives the output signal from the bridge circuit. The grid resistor for the 12AU6 is 1 megaohm, and this is essentially the input impedance of the amplifier. This stage amplifies the input signal to the level required to drive the power stage.

The second, or power, stage uses a 12AQ5 beam-power output tube. The plate of this tube is coupled to the control field of the servomotor through an output transformer, which matches the impedance of the 12AQ5 tube to that of the servomotor control field.

The 115 V at 115 Hz, applied to the bridge circuit and to one field of the two-phase servomotor, are derived from the same source. Therefore, to operate the two-phase servomotor, the voltage applied to the control field from the output transformer has to have a phase shift of 90 electrical degrees with respect to the applied source. This is accomplished with a phase-shifting capacitor in series with the output transformer.

Some direct current (approximately 14mA) is allowed to flow through the control winding of the servomotor, providing a degree of magnetic damping, to keep hunting to a minimum. This current flows from the B+ to the control field of the servomotor, after the phase-shifting capacitor, through a 15-kilohm, 10-W resistor.

The bridge voltage, the servomotor voltage, and the B+ voltage of the amplifier are applied by the balance-control relay K501. The filaments of the tubes are energized when the station is turned on and remain energized as long as the station is on. This relay, controlled by sequence drum S232, energizes these circuits for 2.0 s for each variable. The circuit "on" time is limited to 2.0 s to keep the code selector from varying characters during transmission, to conserve power, and to minimize heating of the sensor elements.

A bridge unbalance signal of 20m V is required to drive the servomotor. A change of 4 ohms in the variable leg is sufficient unbalance in the bridge circuit to cause the motor to move. The motor rotates the balance potentiometer through a gear train in the direction necessary to balance the bridge circuit, thus reducing the voltage applied to the grid of the 12AU6 tube to nearly zero. The servomotor simultaneously encodes the weather variable.

Control System

The control system (Fig. 20) of the PAWS controls station turnon, warm-up time, and distribution of power during times T_0, T_1, and T_2; disconnects the receivers during station operate times T_1 and T_2; and controls station turnoff. The control system involves the output relays of the two command receivers, the control unit, the control drum, and the the vernier track on the code generator drum in the code and sequencing unit.

The command receivers are described in the section on the communication system. The main point is that when either of them is interrogated an output relay closes to cause the control unit to turn on the station, and when the station comes on, power to both receivers is cut off by the control unit. In addition, when the high-frequency receiver is interrogated, the transmitter is switched to high-frequency operation.

The code and sequencing unit has already been described. The main point to be mentioned here is that two of the drums, S231 and S233 (Fig. 20), affect station turnon and station turnoff.

NOTE: Part of the tester is shown in Fig. 20. The tester is used during checkout of the station. It is not really a part of the PAWS.

The control unit is an assemblage of relays that supply voltages to the units at the proper times. When K101 is actuated, it causes K402 to change state and thus causes,

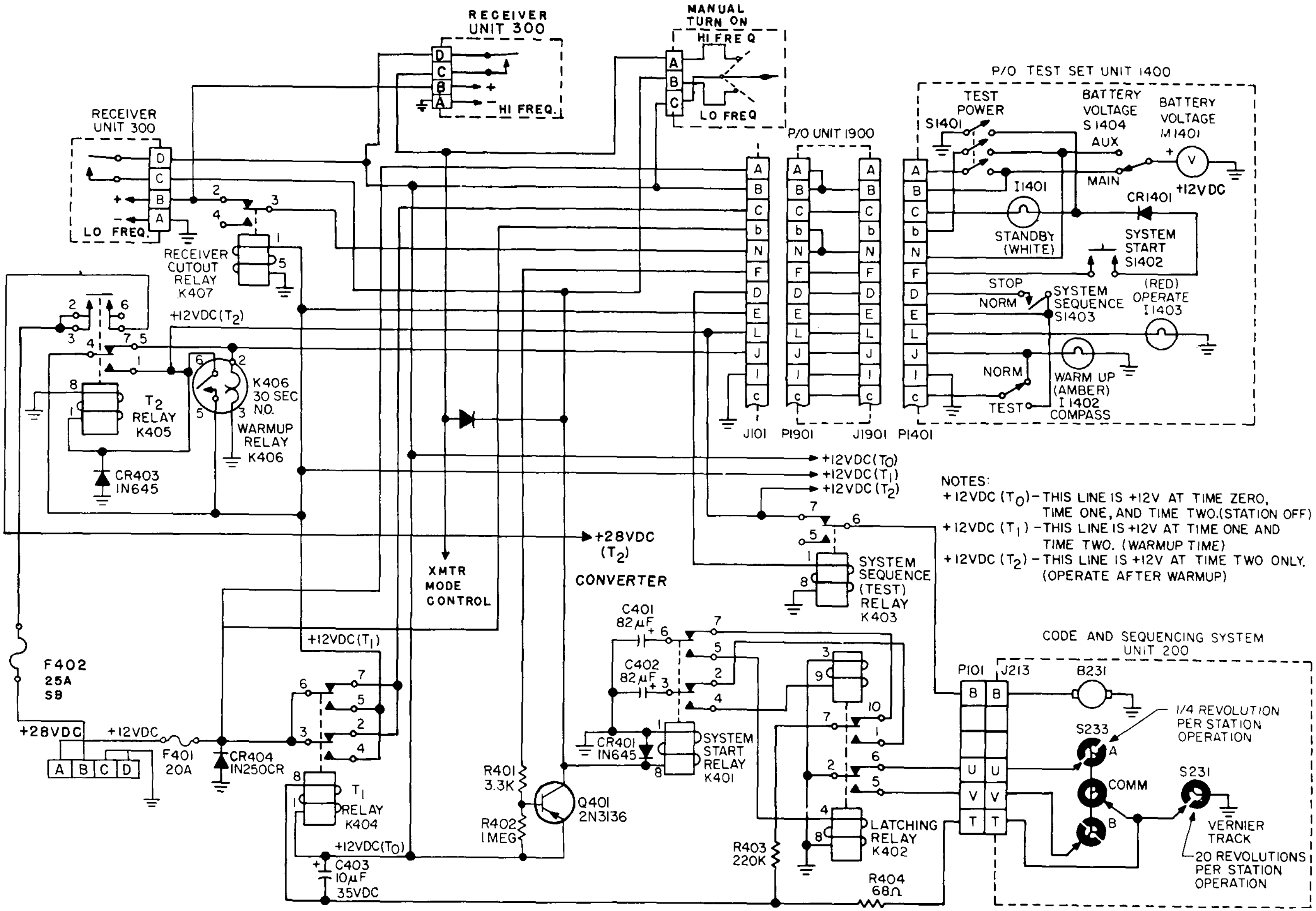

Fig. 20 — Control system. Part of the tester is also shown

through connections in the code, a sequencing unit to actuate K404, which applies power (at T_1) to thermal time-delay relay K406, the servoelectronics unit, the transmitter filaments and relays, and receiver cut-out relay K407. When time-delay relay K406 closes, it actuates the main power relay K405, which supplies 12 V to all 12-V (T_2) lines. It also supplies 28 V to the DC/DC converter.

Station Turnon

A cycle of operation is begun when the solenoid of K401 is energized by either command receiver (+12 V directly to pin 8 of K401) or by the test set (applying +12 V to the base of Q401). When the high-frequency receiver is interrogated, the frequency control relay in the transmitter is actuated in addition to K401.

Warmup Time

The lines marked "+12 V (T_0)" in Fig. 20, have +12 V on them all the time. The "turning on or starting" of the equipment is termed time T_1; when K404 operates, the lines marked "+12 V (T_1)" have +12 V on them. Relay K401 pulls in for a short time (less than 1 s if either receiver out relays K302 closes). With relay K401 closed, capacitor C401 discharges through contacts 6 and 5, which in turn energize the solenoid of latching relay K402 through pins 4 and 8. Capacitor C402 will discharge at the next station turnon, thus energizing relay K402 in the opposite direction. C401 and C402 alternately charge through the coil of K404 and discharge through the coils of K402.

Since pin 8 of relay K402 is grounded, a ground path now exists through contacts 2 and 5 of K402 to drum track B of control drum S233, through the common drum track to pin 8 of the T_1 relay K404. Pin 1 of relay K404 is already at +12 V (T_0), this causes its solenoid to pull in, starting the warm-up time and disconnecting the receivers by the operation of relay K407. This is accomplished when the +12 V DC is fed through contacts 3 and 6 to contacts 4 and 5 of relay K404, respectively. Now +12 V (T_1) is applied to pin 2 of warm-up relay K406.

Operate Time

Relay K406 is thermally activated to close after about 30 s. At this time contacts 5 and 6 of relay K406 close and apply +12 V (T_1) to contact 1 of T_2 relay K405, thus energizing its solenoid and electrically latching itself. The +12 V (T_2) is also applied through contacts 1 and 4 of K405 to drive motor B231 in the code and sequencing system, which starts to turn drums S231, S232, S233. At time T_2, 28 V is applied to the DC/DC converter through contacts 2, 3 and 6, 7 of K405.

Station Turnoff

At control drum S233 (Fig. 20), the two brushes associated with drum tracks A and B, which are connected to contacts 6 and 5 of latching relay K402, are alternately grounded from one station operation to the next. Since each of these drum tracks is segmented into two parts, a completed circuit exists only through the common drum track for less than one-fourth revolution of S233. This, in effect, functions as the "coarse" station turnoff control and allows the vernier track, which is in parallel with the control drum, to operate as the "fine" turnoff control. Control drum S233 turns one-fourth revolution for each revolution of sequencing drum S232, which turns one revolution per station operation. This synchronizes the system properly at turnoff for the next transmission.

Test and Calibration

When the test and calibration set, Unit 1400, is used, system sequence test relay K403 is energized by operating SYSTEM SEQUENCE switch S1403. This removes +12 V (T_2) from drive motor B231 in the code and sequencing system and transfers sequence interruption control to the test and calibration set.

Wind Direction Servo Averaging Time

At the start of the 30-s warm-up time, +12 V (T_1) is applied to the wind direction servo unit, Unit 800, to average the output of the position-varying synchrotransmitter CX1501, in the anemometer, with respect to control transformer CT801 and wind-direction potentiometer R801.

Windspeed Integration Time

After the 30-s warmup +12 V (T_2) is applied to the magnetically operated reed switch S1501 in the anemometer. The windspeed pulses that are developed are fed to the windspeed integrator unit, Unit 900. Here they are counted by the flip-flop stages in the binary counter to produce an output resistance proportional to the number of pulses occurring during a 1-min interval.

Communication System

The PAWS communication system receives interrogation signals from the central station, turns the station on and selects the transmitter frequency to be used, and transmits the encoded weather data back to the central station.

The communication system block diagram is shown in Fig. 21. The heavy lines represent RF connection between the various units that make up the system. The light lines represent control and keying signal connections, and the dotted lines are power connections. The functions indicated in the control unit and the transmitter refer to the relays that perform those functions.

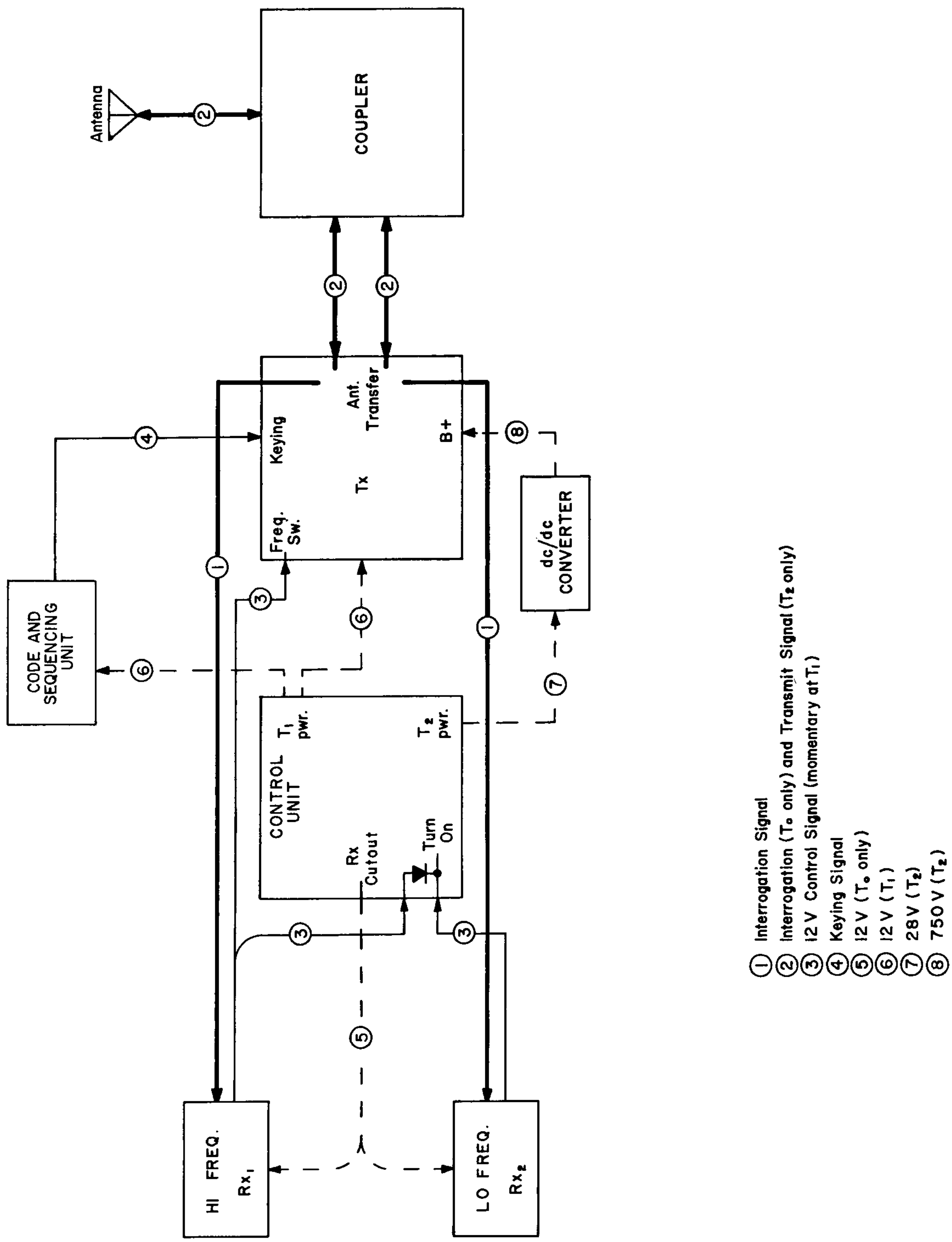

Fig. 21 — Communication system

The interrogation signal picked up by the antenna passes through the coupler and the NC contacts of the antenna changeover relay to the command receiver that is being interrogated. After a 10-s delay, the PAWS is turned on and a transmission cycle begins. As soon as the station comes on, power to both receivers is cut off by the control unit and the antenna changeover relay disconnects the receivers from the antenna and grounds their input. When the high-frequency receiver is interrogated, it actuates the frequency-switching driver relay in the transmitter in addition to turning on the station.

While the station is transmitting, its output passes through the proper half of the coupler to the antenna. At this time the transmitter is keyed by the code and sequencing unit. The DC/DC converter supplies plate voltage to the transmitter while it is in operation.

At the end of the transmission cycle, the control unit cuts off power to all the operating units and restores power to the receivers. With the power to the transmitter cut off, its antenna changeover relay connects the antenna to both receivers again.

Command Receiver

The command receivers are designed to receive a single tone (275 to 500 Hz) modulated RF signal (4-16MHz), used to turn on the remote station from the central station. The receiver is a superheterodyne, single-conversion AM receiver, designed with temperature compensation so that it can operate from -50°F (-45°C) to +150°F (66°C). It has a bandwidth of 1.5 kHz and a sensitivity of 15 μV for a 10-dB signal-plus-noise ratio.

The receiver (Fig. 22) consists of a five-band RF amplifier, crystal-controlled local oscillator, mixer, IF amplifiers, audio detector, two active filters, resonant reed filter, tone detector, pulse shaping and amplifying circuits, control amplifier, level detector, relay drivers, and relay. The output (relay contacts closing) provides turnon of the operating control and sequencing circuits of the main instrument package.

The antenna is coupled into a 4- to 16-MHz, 5-band, 20-dB-gain RF amplifier. Bands are selected by rotary switch SW1, which coarse tunes for a band by selecting taps, for impedance matching, on RF coils L1 and L2, and selecting tuning capacitors for RF amplifier Q1, with input L1 and output L2 tank slug tuning for frequency adjustments. The RF output (TP-1) signal is coupled to the two inputs (bases) of mixer stage U1 across L3, with crystal-controlled-oscillator output U2 (TP-2) coupled to the emitter of the mixer stage. The oscillator is crystal controlled for stability and is temperature compensated, with crystal tuning by C33 and oscillator gain adjusted by R12. The oscillator crystal frequency is 455 kHz higher than the received RF signal; thus the output of the mixer is the 455-kHz 1F signal.

The IF signal is coupled and by the first IF transformer T1 to the input of the IF amplifier stage (U3), with gain controlled by R14. The output of the IF amplifier is coupled and tuned, by the second IF transformer T2, to the audio detector stage. Because of the extreme temperatures in which this receiver is designed to operate, diode temperature compensation is used throughout the receiver. However, it was necessary to use both thermistor and diode temperature compensation in the base biasing network of the audio detector (U4).

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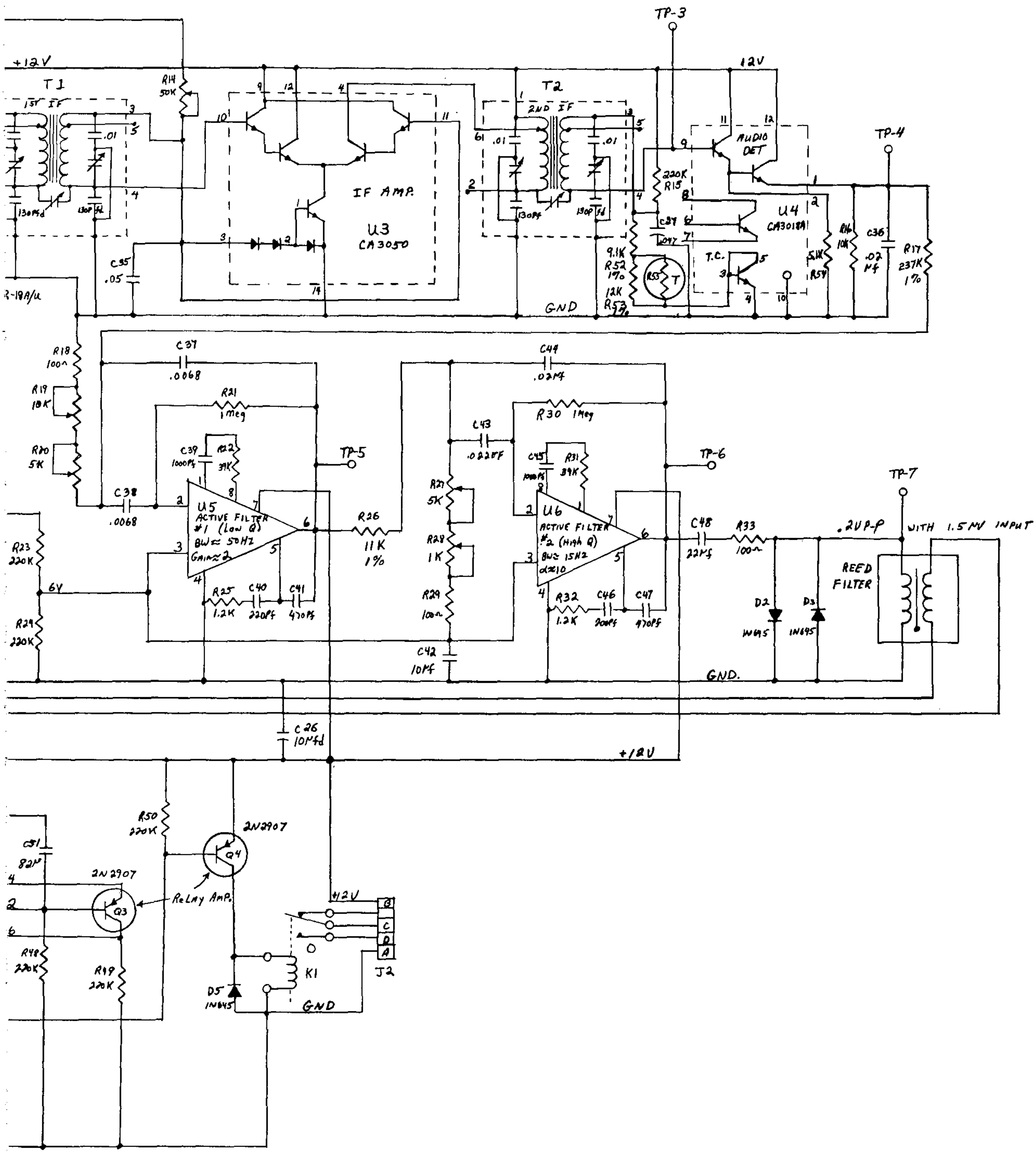

Fig. 22 — Command receiver

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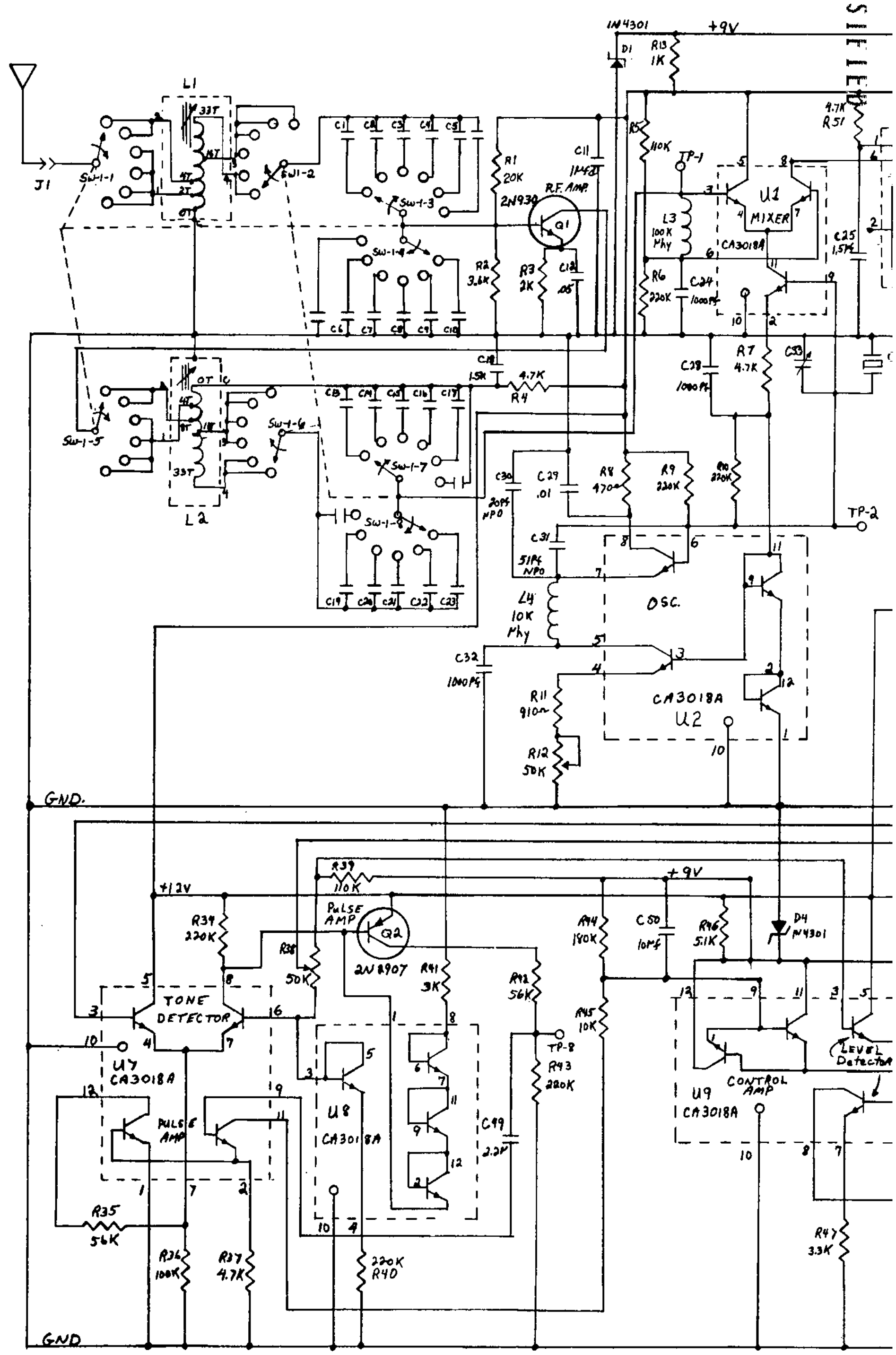


The output of the audio detector is the detected tone frequency (275 to 500 Hz) transmitted from the central station and is referred to in the rest of this description as the reed filter tone. This tone signal is coupled through fixed gain resistor R17 to the input of the first active filter (U5). The first active filter is adjusted by setting the tone-modulated RF input signal for a tone frequency of 15 Hz below the reed filter tone frequency and adjusting R19 and R20 for maximum output. The first active filter output is coupled to the second filter input U6 through fixed gain resistor R26. The second active filter is adjusted by setting the tone-modulated RF input signal for a tone frequency of 5 Hz above the reed filter tone frequency and adjusting R27 and R28 for maximum output. The fixed 100 ohm resistors R18 and R29 are in the input of the active filters, to prevent the inputs from being shorted to ground and burning out the integrated circuits. The filter should now be tuned to pass the reed filter tone frequency at a maximum level and narrow bandwidth. It has been determined by laboratory tests that the tone level should be set at 0.2 V P-P at TP-7, the reed filter input; this is set by gain control resis tor R14.

Diodes D2 and D3 are limiting diodes used to prevent damage to the pulse circuits from large input signal levels. The resonant reed filter will only pass tone frequencies within 1% of the frequency of the filter.

The output of the resonant reed filter is coupled into one input of differential amplifier type tone detector U7 and, through R38 (pulse-shape control), into the other input of the tone detector. The output of the tone detector is coupled to pulse amplifier and shaper circuit Q2. At TP-8 the waveform observed should be a symmetrical square wave; R38 is adjusted to shape the pulse durations so that the positive and negative pulses are of equal duration.

The symmetrical square wave is coupled to another stage of amplification and then into control amplifier circuit U9. R48 and C51 form the RC charge time constant, which determines the turnon time delay of the relay. C51 charges to a voltage to bias Q3 on, which drives Q4 on to apply 12 V DC to the coil of output relay K1.

After the tone-modulated RF signal is removed from the receiver input, the time delay before relay K1 is turned off is determined by the discharge time constant of R44 and C50, hence the time required for the bias of the control amplifier to drop low enough to bias the transistor off. The receiver stays on at all times except while the remote station is transmitting; thus it is ready to receive the next turnon signal.

Transmitter

The transmitter in the main instrument package is a 150-W continuous-wave (cw) transmitter (Fig. 23) that can be operated at any frequency between 4 and 16 MHz. It uses the triode section of a triode-pentode as an oscillator (crystal-controlled), with the second half functioning as a conventional buffer amplifier operating into a 6146A beam power RF amplifier that drives three 6146A beam power RF amplifiers in parallel, to give an RF power output of up to 200 W (150W nominal).

Antenna changeover relay K601 disconnects both receiver inputs and shorts them to ground when the PAWS is transmitting. At the same time, it connects the antenna to the output of the final amplifier in the transmitter. The low-power relay is used to reduce power, during initial transmitter tuning, by inserting a 200-kilohm resistor into the plate circuit of driver stage V602. Keying relay K603 is in the cathode circuits of the buffer, driver, and final stages. These tubes conduct only when the keying relay is closed. K603 is driven by the keying amplifier to reduce the amount of current the code-generator brushes of the code and sequencing unit will have to handle. For frequency changing, K604 changes taps on final tank coil L611 and tuning capacitors C3 and C4. In addition, K605 changes the tank coils in the buffer and driver plate circuits. K604 and K605 are driven by K606 in order to reduce the amount of current that the output relay in the high-frequency receiver will have to handle. When K606 is not energized, the transmitter operates on the low frequency. When K606 is energized, the transmitter operates on the high frequency.

Antenna Coupler

Each half of the dual-frequency coupler (Fig. 24) is connected to the antenna through a pass/isolate circuit that is resonant (low impedance) at the desired frequency and nonresonant (high impedance) at other frequencies. This keeps the high-frequency half of the coupler from loading the antenna when transmitting on the low frequency, and vice versa. With 1,400 ohms isolation, the adjustments of the two halves of the coupler are independent of each other.

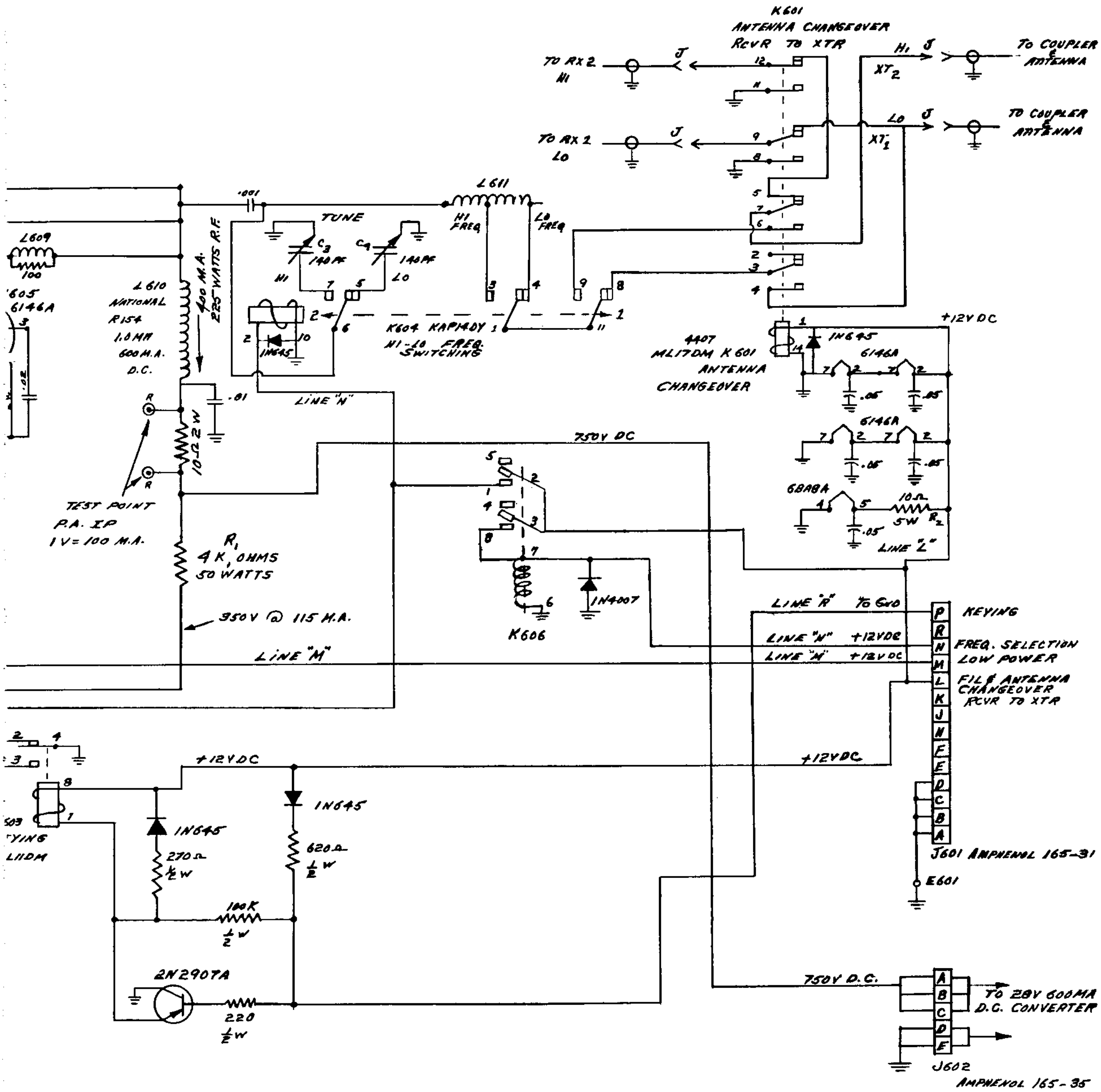
The antenna's capacitive reactance at low frequencies is tuned out by L1202 for frequencies up to 7 MHz and above 13 MHz (where the antenna is inductive). For the high frequencies (7 to 13 MHz), C1207 is used to tune out the inductive reactance of the antenna. At frequencies of 7 to 13 MHz on the low-frequency part of the coupler, L1202 has to be replaced with C1203. Also, for frequencies above 13 MHz, for the high-frequency part of the coupler, C1207 has to be replaced by L1205 because the antenna reactance is capacitive.

The T networks in the two halves of the coupler are designed to match the resistive component of the antenna impedance to the 50-ohm lines. This antenna resistance varies from 14 ohms at 4 MHz to 1,300 ohms at 13 MHz and then drops to 156 ohms at 16 MHz.

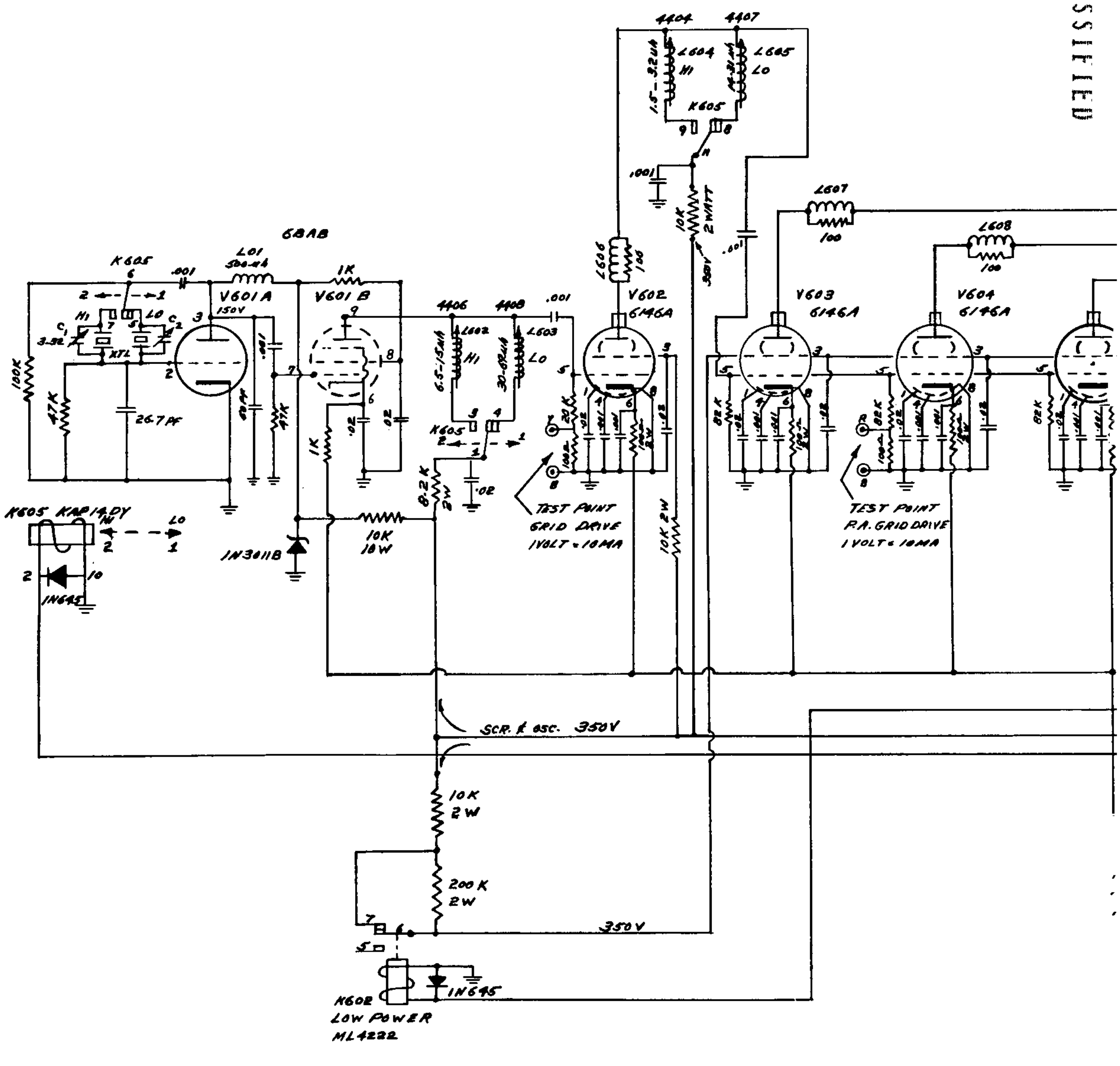
The directive couplers and the meter circuit are designed to indicate the forward and reflected power to or from the antenna, when the coupler is being tuned. The coupler is properly tuned when the forward power is a maximum and the reflected power is a minimum.

Overall Schematic Diagram

The essential details of the various units that make up the PAWS and their interconnections are shown in the overall schematic diagram in Fig. 18. This diagram also shows the essential details of the test and calibration set and connections to the PAWS during checkout operations.



Transmitter



\- NOTES -

ALL RESISTORS 1 WATT UNLESS OTHERWISE NOTED

USE PARALLEL MODE CRYSTAL CR-18/U
OR CR-62/U LOAD CAP. 32.0 PF

L_2 L_3 L_4 L_5 SELECTED FOR FREQ ASSIGNED

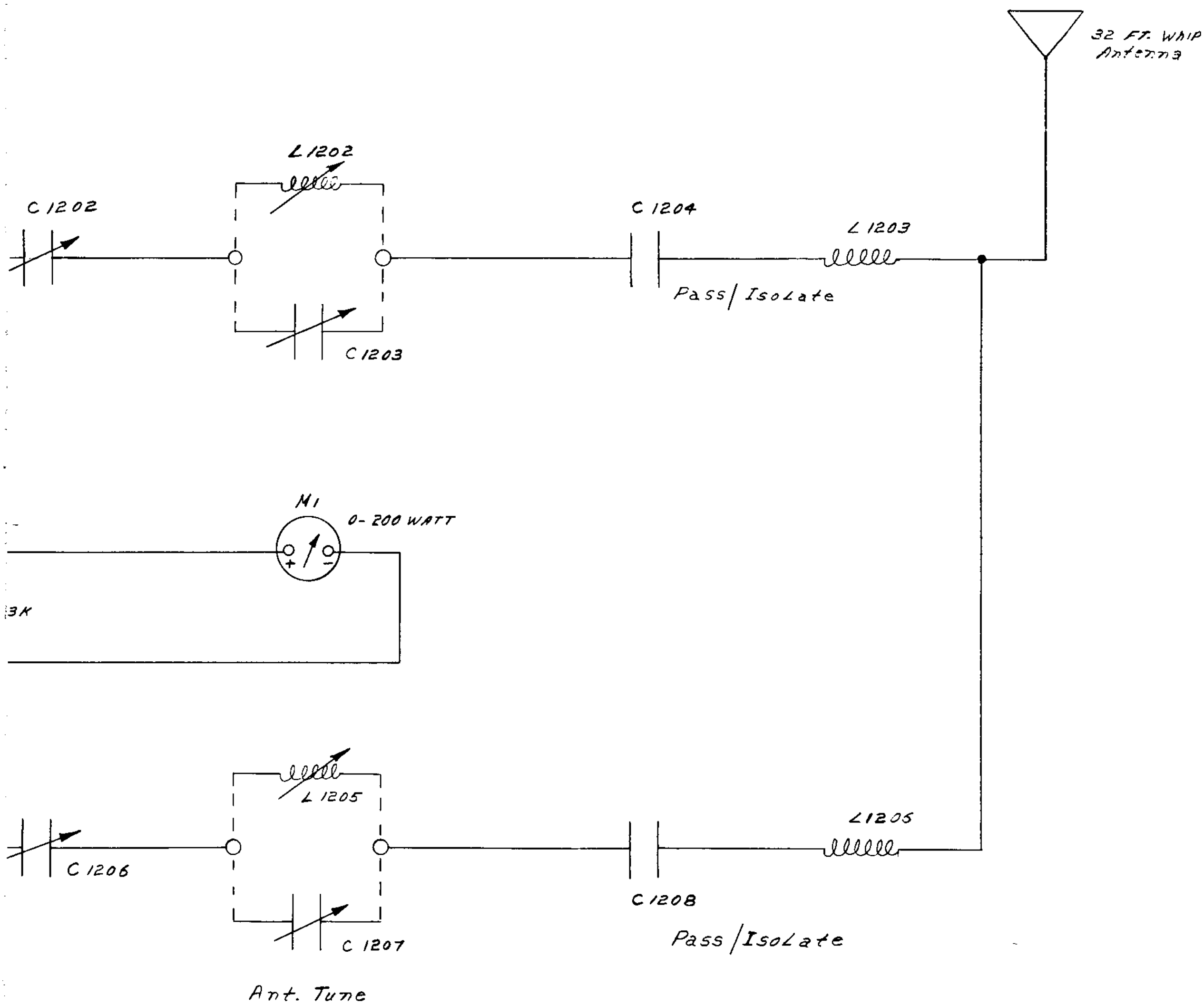
LINE "R" - OPERATES KEYING RELAY BY MAKING GND THROUGH DRUM BRUSHES IN CODE GENERATOR

LINE "M" - MANUAL SWITCHING THROUGH TEST UNIT TO LOW POWER LEVEL WHEN TUNING & LOADING

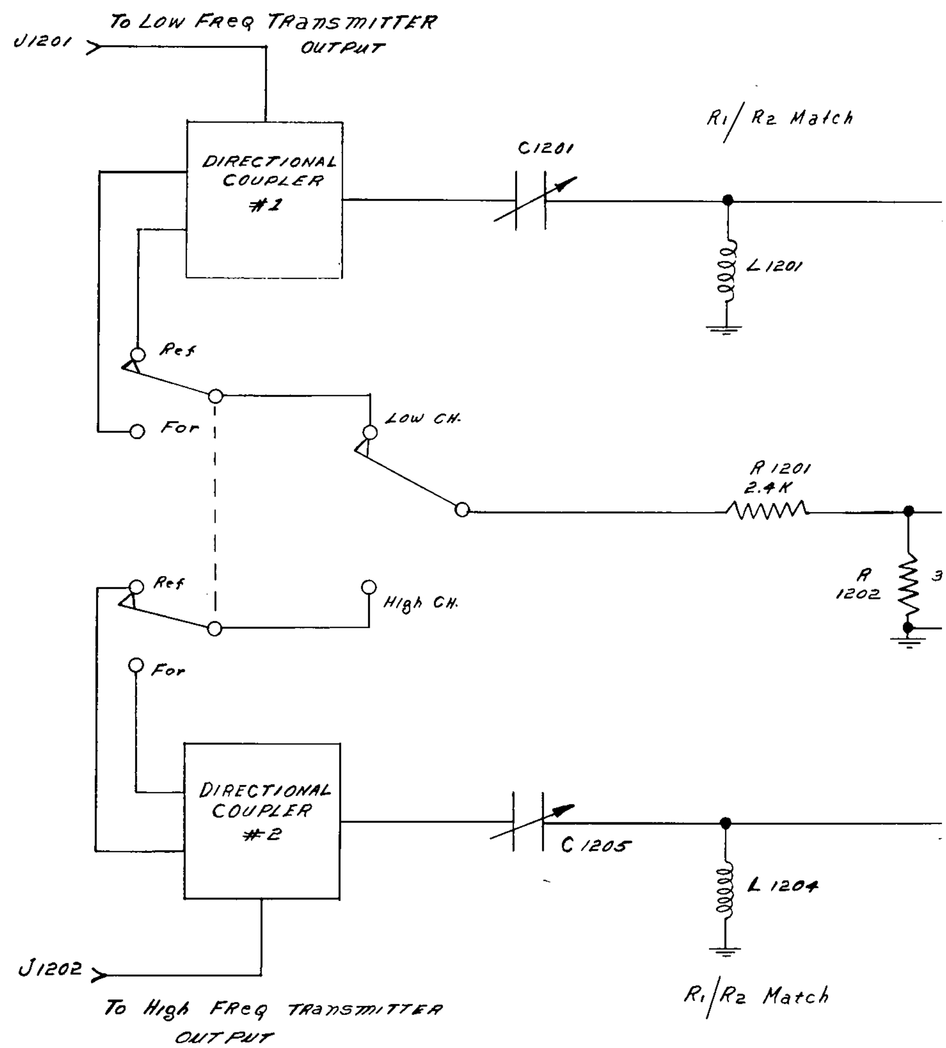
LINE "L" - ACTUATED BY Rx_1 OR Rx_2 DURING STATION WARM UP AND TURN ON THROUGH RELAYS K401 & K404 - MODE CHANGE, RECEIVE TO TRANSMITT

LINE "N" - ACTUATED BY Rx_2, THEREBY CHANGING TO HIGH FREQ. Mode OF OPERATION

Fig. 23 -



;. 24 — Antenna coupler



– Note –

Component Values Determined
By Frequency Assignment

Fi

PERFORMANCE

Laboratory Trials

Laboratory trials of the PAWS were conducted without the RPG by operating it from a 3-V DC power supply. During these trials, the antenna was simulated with a dummy load and the station was turned on manually. This arrangement served to test all phases of the operation of the PAWS except the command receiver, the anemometer, the wind-speed integrator, and the wind direction servo unit.

During these trials the PAWS was operated a minimum of four times a day for one month. The following things were observed:

Battery voltage

Accuracy of barometric-pressure, air-temperature, and reference-temperature data

Transmitter power.

The battery voltage measurements indicated that the power system was able to keep the battery essentially fully charged at all times. The observed accuracy of the data on barometric pressure, air temperature, and reference temperature indicated that the coding and programing functions were being performed satisfactorily. The periodic transmitter power measurements indicated that the DC/DC converter and transmitter performance were satisfactory.

Trials at Ft. Belvoir

The PAWS was moved to Ft. Belvoir, Virginia, and was mated with the RPG for initial field trials. These trials lasted for 6 weeks. During this time, the PAWS was interrogated a minimum of four times a day by the central station, located at the Naval Research Laboratory. For this operation it was necessary to have the lid of the PAWS enclosure raised about 4 in. to provide ventilation and keep the RPG from overheating because the ambient outside temperature was 60° to 70°F (33° to 39°C).

During these trials, all phases of the PAWS operation were checked and appeared to be satisfactory. The telemetered data were reasonably close to values reported at National Airport, except for wind. The Navy Nuclear Power Unit at Ft. Belvoir is in a very sheltered location so the anemometer exposure was very poor. The power system was able to keep the battery fully charged.

An unexpected problem did arise, however. Some other activity was using the same frequency and was able to interrogate the PAWS and to interfere with the NRL monitoring equipment. The unexpected signals were exactly on the PAWS frequency and were very strong (3000 μV). The tone frequency was close enough to turn on the PAWS. Fortunately, the PAWS power system had sufficient reserve to provide power for all the extra transmissions.

Alaskan Trials

The PAWS, RPG, and central station were shipped to the Naval Arctic Research Laboratory (NARL), Barrow, Alaska for field trials in the Arctic during the 1974-1975 winter. Installation of the equipment was done in mid-August. The central station was located in the main laboratory building at NARL, and the PAWS (with the RPG) was located southeast of camp.

At first, spontaneous turnon and some difficulty with interrogation were experienced. The main instrument package was returned to NRL, and the trouble was found to be in the command receivers. They were modified to eliminate a tendency to oscillate. This reduced the sensitivity somewhat, but the compromise was considered acceptable. The 19μV required for PAWS turnon is less than the 20 μV that the central station needs to obtain satisfactory printout of the telemetered data. (The interrogation and telemetering transmitters have the same power.) The main instrument package was then returned to NARL and installed in the PAWS. At that time it was found that the interrogator in the central station was inoperative. This was corrected, and the system finally went into operation on November 2, 1974.

While working on the PAWS and central station during this phase of the field trials, researchers observed that, due to the freezing of the tundra, the antenna grounding characteristics changed between August and October. This was indicated by a substantial change in the antenna coupler tuning at the central station antenna and to a much smaller extent in the PAWS antenna coupler tuning. The central station counterpoise was lying on very wet ground and was partly immersed in puddles, whereas the PAWS counterpoise was lying on relatively dry ground.

During the field trials, the PAWS was interrogated twice a day, and data were compared with weather data reported by the NOAA weather station about 1 mi (1.6km) northeast of the PAWS and by the Barrow airport about 3 mi (4.8km) southwest. These data, obtained during the latter part of November, are shown in Fig. 25. It is evident that the windspeed data are noticeably lower than those reported by the manned stations and that there also is little agreement in wind direction. It should be mentioned that heavy hoarfrost was observed in camp during the time these data were taken.

There is reasonable agreement between the PAWS data on air temperature and barometric pressure and those reported by the two manned weather stations.

The PAWS continued to operate until late in December, at which time it failed to respond to interrogations. Due to the weather, the PAWS was not visited until mid-February. At that time the anemometer was found to have been immobilized by hoarfrost and the antenna was so weighted down with hoarfrost that its tip was within 5 or 6 ft (1.5-1.8m) of the ground. Interrogation was simulated by means of a test switch, but the PAWS still failed to respond. The low temperature, -40°F (-40°C), and high winds prevented making repairs at that time.

Early in March, the PAWS was again visited. The transmitter was replaced, but this failed to correct the problem. In mid-April the PAWS was again visited. The 12-V battery

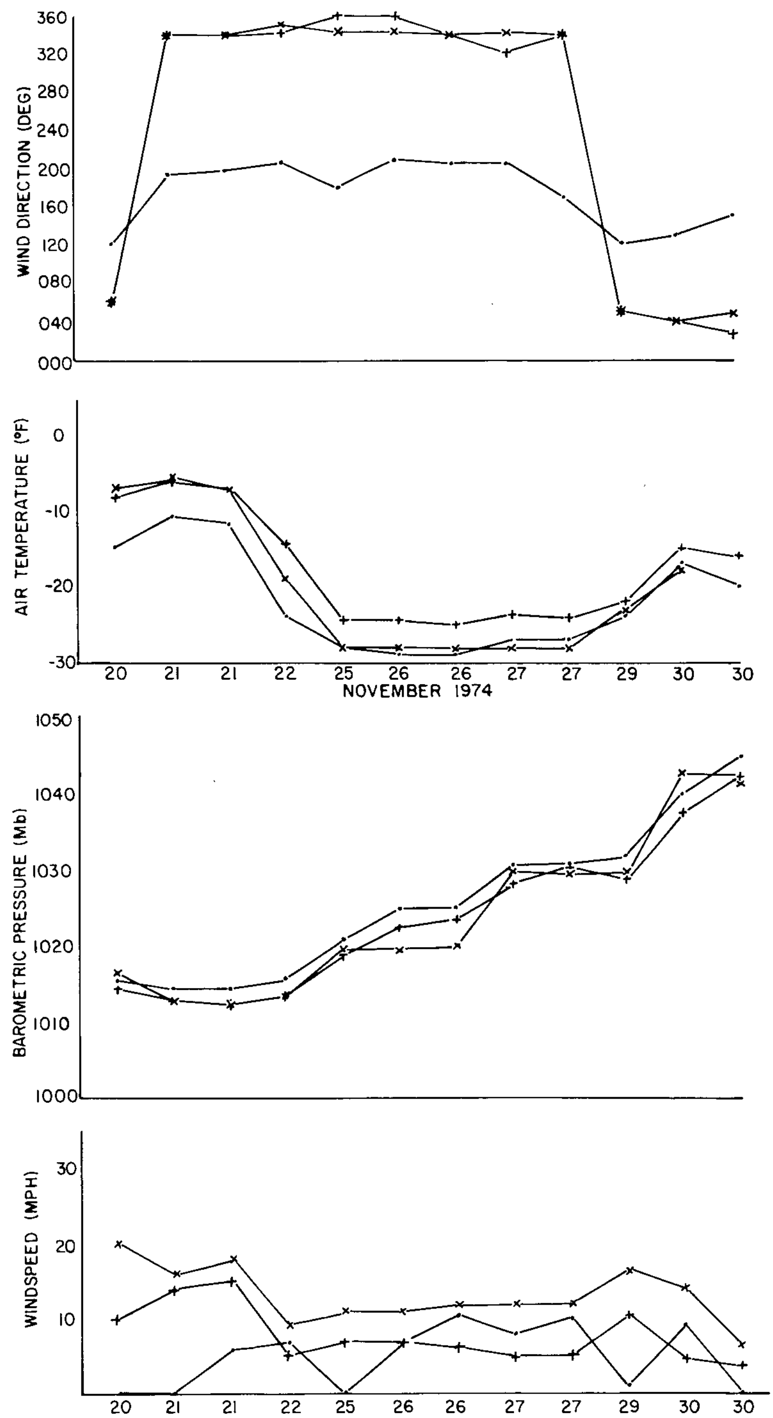


Fig. 25 — Comparison of NOAA (x), Barrow Airport (+), and PAWS (.) weather data

connection was down to 6V, and the 28-V connection was down to 20V. Multimeter measurements showed that the 12-V pin on the power receptacle read a resistance of 3.25 Ω, which indicated that the filaments in the transmitter and the servoelectronics unit were on. This was because the T_1 relay K404 was stuck in the "on" position; the resulting current through the filaments ran down the battery. The power plug was left disconnected to allow the battery to be recharged by the generator. Late in April, the PAWS was again visited. The battery was found to be fully charged. The control unit (containing K404) and the windspeed integrator were replaced. Field trials were resumed and are continuing.

It should be mentioned that when the PAWS was visited during these field trials condensation was evident on the antenna cable panel (on the enclosure), which was supposed to capture it, but there was no evidence of other condensation.

Sensor and Coding Accuracy

The Polar Automatic Weather Station was calibrated to determine the accuracy of the telemetered data. The calibration procedure was planned so that any errors could be analyzed to separate error attributable to the sensors from that caused by the code-selection system.

The accuracy of the telemetered data is determined by the resolution of the sensors, the resolution and repeatability of the coding system, and temperature effects on the coding system. It was not necessary to consider voltage effects on the coding system because the RPG keeps the battery fully charged at all times. Since the coding system is common to all information channels, it seems natural to consider its performance first.

The set of 14 coarse and 14 fine letters used by the coding system was described earlier. The 196 combinations of coarse and fine letters result in an intrinsic coding resolution of 0.51% of full scale. The resistance resolution observed in tests of the coding system was 10.2 ohms regardless of temperature. This corresponds to 1 mba on the barometric-pressure sensor, 0.7 nmi./h on the windspeed sensor and averager, 1.8 degrees on the wind direction sensor and averager, and 1°F (0.55°C) on the temperature sensors. The repeatability of the coding system was ±0.5 fine letter or ±5 ohms.

The range and overall accuracy of telemetered data and the contributions of the various parts of the system to the error are shown in Table 2.

The effect of temperature on the calibration of the windspeed integrator, wind direction averager, and code selector was measured and found to be negligible. However, the barometer is somewhat temperature-sensitive. The following corrections were found to be adequate to bring the data to within ±1 mbar of the proper value:

Reference Temperature	
110° - 130°F (43° - 54°C)	Add 2 mbar
90° - 110°F (32° - 43°C)	Add 1 mbar

60° - 90°F (16° - 32°C)	use values given
40° - 60°F (4° - 16°C)	subtract 1 mbar

Table 2 — Ranges and Error Analysis of Data

Sensor	Range	Coding System Resolution	Coding System Repeatability	Sensor Resolution	Sensor Hysteresis	Estimated Overall Accuracy
Barometric Pressure	862-1068 mbar 655-862 mbar	1 mbar	1 mbar	0.5 mbar	±0.5 mbar	±1 mbar
Windspeed	0-133 n.mi./h	1 n.mi./h	1 n.mi./h	0.7 n.mi./h	0	±1 knot
Wind Direction	000-360 deg	1.8 deg	1.8 deg	0.4 deg	0	±4 deg*
Air Temperature	-60°-30°F (-51°-1°C)	1°F (0.6°C)	1°F (0.6°C)	Infinite	0	±1°F (0.6°C)
Reference Temperature	-60°-130°F (-51°-54°C)	1°F (0.6°C)	1°F (0.6°C)	Infinite	0	±1°F (0.6°C)

*This includes four accumulative alignment tolerances.

CONCLUSIONS

The results of the various tests conducted on the Polar Automatic Weather Station indicates the following:

1. The sensors and coding system of the Polar Automatic Weather Station are capable of accuracies comparable to those of manned weather stations.

2. The Polar Automatic Weather Station can be used throughout the year in most Antarctic locations with the present amount of insulation. However, in the Arctic, the insulation should be removed completely to keep from exceeding the temperature limitation of the RPG during the summer months.

3. The T_1 relay in the control unit is inadequate and should be replaced with a relay having contacts capable of handling at least 10 A.

4. The amount of hoarfrost encountered in northern Alaska can completely immobilize the anemometer. However during 11 years in which Grasshopper and early versions of the Polar Automatic Weather Station were deployed in Antarctica, only one instance of hoarfrost was reported.

5. The central station proved to be very convenient and permitted the interrogation and monitoring of the Polar Automatic Weather Station by nontechnical personnel.

It is recommended that any future development effort include the following:

1. Explore the possibility of using the 700 W of waste heat from the RPG, by means of a heat pipe, to protect the anemometer from hoarfrost.

2. Modify the central station to include a dual-frequency transmitter and receiver to improve communication reliability.

3. Modify the control system to accommodate additional information channels. (It appears that doubling the number can be accomplished easily.)

4. Develop additional sensors to increase the utility of the Polar Automatic Weather Station.

It appears that the present Polar Automatic Weather Station could serve a useful purpose in Antarctica.