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US Army Signal Missile Support Agency

MISSILE GEOPHYSICS DIVISION

A HIGH ALTITUDE ACOUSTIC SENSING SYSTEM

By: Willis L. Webb
John W. Coffman
George Q. Clark

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Approved:

for Lloyd White
HENRY F. THOMPSON
Chief Scientist
Missile Geophysics Division

Approved:

Glenn A. Webb
GLENN A. WEBB
Lt Col, Signal Corps
Chief, Missile Geophysics Div

U. S. Army Signal Missile Support Agency
WHITE SANDS MISSILE RANGE
NEW MEXICO

ABSTRACT

Development of an acoustic sensing and telemetering system for use on constant altitude balloons is described. Evolution of the sensors, amplifiers, telemetry techniques, balloons and surface detectors are outlined and the optimum system thus far obtained is presented. Recording and processing techniques applied to the resultant data are enumerated and samples of the processed information are included. Development of the balloon platform used in this application is outlined.

CONTENTS

CONTENTS

CONTENTS

INTRODUCTION

THE FLIGHT OF A SUPERSONIC MISSILE IS ATTENDED BY A NUMBER OF PHENOMENA, AND ONE OF THE MOST NOTABLE IS THE GENERATION OF A SERIES OF PRESSURE PERTURBATIONS. THE INITIAL DISTURBANCE IS CAUSED BY THE SUPERSONIC DISPLACEMENT OF THE AIR MOLECULES AS THEY ARE THRUST OUT OF THE PATH OF THE VEHICLE. THERMODYNAMIC INSTABILITY EXPERIENCED BY THE ENVIRONMENT RESULTS IN THE TRANSFER OF A LARGE AMOUNT OF ENERGY FROM THE MISSILE TO THE AIR. SOME OF THIS ENERGY IS EXPENDED IN IONIZING THE AIR, SOME IS LOST BY RADIATION FROM THE HEATED LAYER, BUT A SIGNIFICANT FRACTION OF THE TOTAL AMOUNT OF ENERGY LOST BY THE MISSILE IS CONVERTED INTO PRESSURE CHANGES WHICH MOVE AWAY FROM THE POINT OF ORIGIN AT THE LOCAL SPEED OF SOUND.

SMALL SCALE PROTUBERANCES ON THE SURFACE OF THE MISSILE MAY GENERATE ADDITIONAL SHOCK FRONTS, BUT THE SECOND MAJOR SOURCE OF PRESSURE PERTURBATION ENERGY IS THE CLOSING SHOCK WHICH IS OBSERVED AFTER THE PASSAGE OF THE MISSILE. THIS INSTABILITY IS CAUSED BY THE RE-ENTRY OF THE AIR OLECULES INTO THE SPACE VACATED BY THE MISSILE. THE MOLECULES MOVE INTO THIS VOLUME AT THEIR KINETIC VELOCITY, WHICH IS SUPERSONIC, AND A NEW COMPRESSIONAL DISTURBANCE IS GENERATED AS A RESULT OF THE ACCELERATIONS INVOLVED. THE POSITION OF THIS SECOND SHOCK FRONT IS A FUNCTION OF A CHARACTERISTIC LENGTH, WHICH VARIES WITH THE MISSILE SPEED AND THE NATURE OF THE ENVIRONMENT. THE MACH ANGLE OF THE FIRST SHOCK FRONT IS DIRECTLY RELATED TO THE MISSILE'S SPEED AND THE LOCAL SPEED OF SOUND. THE ENERGY ADDED TO THE ATMOSPHERE DURING THE FORMATION OF THE FIRST SHOCK FRONT MAY SIGNIFICANTLY ALTER THE LOCAL SPEED OF SOUND, AND THUS THE MACH ANGLE OF THE SECOND SHOCK FRONT MAY BE DIFFERENT FROM THAT OF THE FIRST.

EXTENSIVE DATA HAS BEEN TAKEN ON THE SURFACE DURING THE FLIGHT OF HIGH SPEED ROCKETS, LARGELY CONFIRMING THE ABOVE DEDUCTIONS. ON OCCASION, HOWEVER, DATA HAS BEEN OBSERVED WHICH COULD NOT BE TRACED DIRECTLY TO THE POINT OF ORIGIN WITH AVAILABLE INFORMATION ON MISSILE TRAJECTORY AND ATMOSPHERIC EFFECTS.

THE FIRST ATTEMPTS TO OBTAIN DATA NEAR THE POINT OF ORIGIN WERE MADE BY ALTERING STANDARD METEOROLOGICAL SOUND EQUIPMENT. A CRYSTAL MICROPHONE WAS USED TO MODULATE AN AN/AMT-4 RADIOSONDE TRANSMITTER, AND THE DATA WAS DETECTED AND RECORDED BY A GMD-1 AND BRUSH RECORDER COMBINATION. THIS SYSTEM WAS CARRIED ALOFT BY A CLUSTER OF THREE RADIOSONDE BALLOONS. TWO OF THE BALLOONS WERE INFLATED TO JUST SUPPORT THE INSTRUMENTATION AT A PREDETERMINED HEIGHT AND THE THIRD BALLOON WAS OVERINFLATED TO OBTAIN AN EARLY BURST. AFTER REACHING THE ALTITUDE OF THE FIRST BALLOON BURST THE EQUIPMENT WOULD FLOAT FOR SOME TIME WITH RELATIVELY SLOW ALTITUDE CHANGES. THIS RATHER COMPLICATED ARRANGEMENT COULD PRODUCE SIGNIFICANT DATA RELATIVE TO EVENT OCCURRENCE, BUT LACKED THE REQUIRED RESPONSE CHARACTERISTICS.

AS FREQUENTLY OCCURS, THE DATA OBTAINED FROM THIS EQUIPMENT OPENED NEW AREAS FOR INVESTIGATION. A MORE ADEQUATE SYSTEM COULD BE EXPECTED TO PRODUCE INFORMATION WHICH WOULD BE USEFUL IN ARRIVING AT AN UNDERSTANDING OF

THE PHYSICAL PROCESSES OF THE ATMOSPHERE AND ITS EFFECT ON A RE-ENTERING MISSILE. THE FOLLOWING OUTLINES THE DEVELOPMENT OF SUCH A SYSTEM.

DEVELOPMENT OF THE CONDENSER MICROPHONE

A CONDENSER MICROPHONE WAS DESIGNED AND FOUR PROTOTYPES WERE CONSTRUCTED FOR THIS APPLICATION (FIG. 1). THIS INSTRUMENT WAS RATHER COMPLICATED IN DESIGN, DIFFICULT TO MANUFACTURE AND COMPARATIVELY HEAVY, BUT IT HAD THE DISTINCT VIRTUE OF DOING AN EXCELLENT JOB IN SENSING THE DESIRED DATA. THE DIAPHRAGM CONSISTED OF A SHEET OF SHIM BRASS WHICH WAS SPACED SOME FOUR THOUSANDTHS OF AN INCH FROM THE PLATE. PROVISION WAS INCORPORATED FOR APPLYING THE PROPER TENSION TO THE DIAPHRAGM. SOME ATTENTION TO THE VENTING OF THE SPACE BETWEEN THE PLATE AND THE DIAPHRAGM WAS REQUIRED, BUT WITH A PROPER BACK-UP CHAMBER THE CALIBRATION DATA PRESENTED IN FIGURE 2 WAS OBTAINED BY PROFESSOR T. G. BARNES AND PROFESSOR H. N. BALLARD, UTILIZING TECHNIQUES DEVISED AT THE SCHELLENGER RESEARCH LABORATORY OF TEXAS WESTERN COLLEGE.

WORKING UNDER CONTRACT WITH THE U. S. ARMY SIGNAL MISSILE SUPPORT AGENCY, WHITE SANDS MISSILE RANGE, NEW MEXICO, PERSONNEL OF THE SCHELLENGER RESEARCH LABORATORIES DEVELOPED IMPROVED PRODUCTION TECHNIQUES WHICH RESULTED IN A SATISFACTORY MICROPHONE WHILE SIGNIFICANTLY REDUCING MANUFACTURING AND CALIBRATING PROBLEMS. A NUMBER OF THE UNITS WERE CONSTRUCTED AND FLOWN IN FLIGHT UNITS WHICH WERE PRODUCED BY THE SCHELLENGER RESEARCH LABORATORY.

PRODUCTION OF THE MICROPHONE WAS INITIATED BY SPACE CORPORATION OF DALLAS, TEXAS, UNDER CONTRACT WITH THE U. S. ARMY SIGNAL MISSILE SUPPORT AGENCY. MR. KENNETH MCCRUM SUGGESTED AND IMPLEMENTED THE USE OF A MYLAR FILM FOR THE DIAPHRAGM MATERIAL. THE OUTSIDE SURFACE OF THE MYLAR WAS COVERED WITH A THIN METALLIC COATING TO SERVE AS THE FLEXIBLE PLATE OF THE CONDENSER. THE MYLAR FILM WAS, THEREFORE, BETWEEN THE PLATES AND SERVED TO PREVENT SHORTING OF THE POLARIZING VOLTAGE WHEN EXCESSIVE DISPLACEMENTS CAUSED THE DIAPHRAGM TO TOUCH THE PLATE. (SEE FIG. 3.)

THE MYLAR DIAPHRAGM PROVED TO BE AN EXCELLENT ADDITION TO THE SYSTEM. IT WAS RELATIVELY INSENSITIVE TO THE TENSION APPLIED AND THUS SIMPLIFIED THE JOB OF ESTABLISHING AND MAINTAINING CALIBRATION. FURTHER DEVELOPMENT OF THE MANUFACTURING TECHNIQUES, INCLUDING A MYLAR SPACER RING TO PRODUCE THE DESIRED SEPARATION BETWEEN PLATES, RESULTED IN A UNIT WHOSE COST WAS LESS THAN 10 PERCENT OF THAT OF THE ORIGINAL UNITS.

PRODUCTION OF UNITS BY YUBA CONSOLIDATED INDUSTRIES OF SAN CARLOS, CALIFORNIA LED TO THE INCORPORATION OF A MANUFACTURING DESIGN WHICH AGAIN MATERIALLY SIMPLIFIED PRODUCTION. AS IS ILLUSTRATED IN FIGURE 4, THE UNIT CONSISTS SIMPLY OF A PLATE DEPOSITED ON A PRINTED CIRCUIT BOARD WHICH IS PERFORATED TO PROVIDE VENTILATION TO THE BACK-UP CHAMBER WHICH HAD PROVED TO BE ADEQUATE. A MYLAR SPACER RING IS THEN GLUED TO THE BOARD AND A DISC OF COATED MYLAR IS IN TURN GLUED TO THE RING BY USING A JIG WHICH INTRODUCES THE DESIRED TENSION IN THE DIAPHRAGM. THE UNIT HAS EXCELLENT HANDLING

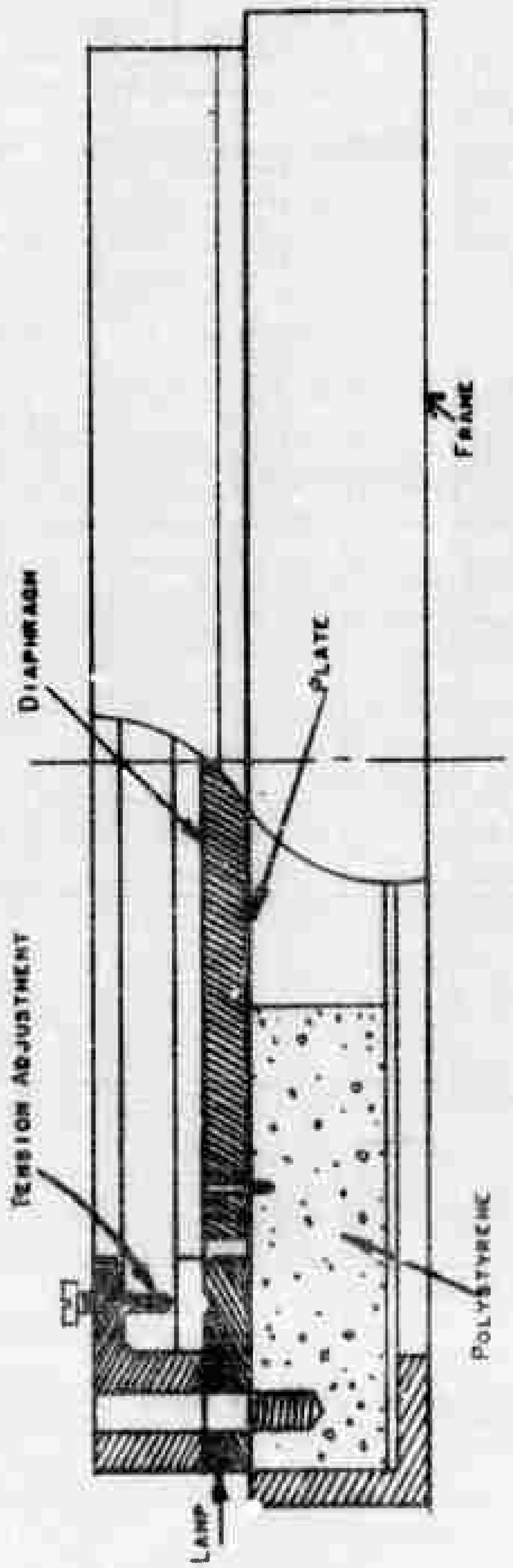

FIG. 1. CONSTRUCTION DETAILS OF THE FIRST CONDENSER MICROPHONE USED IN THE FLIGHT UNITS.

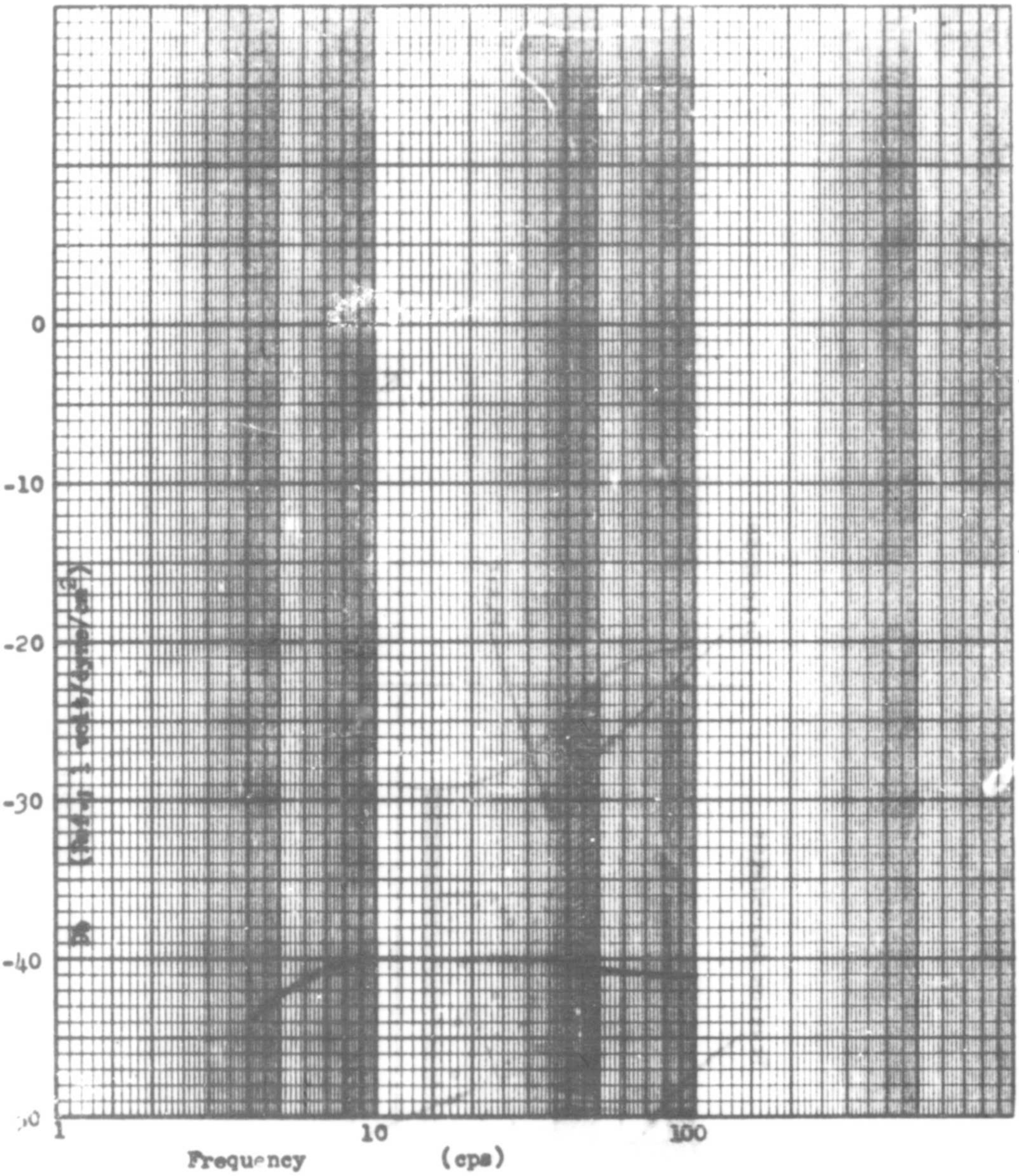

FIG. 2. CALIBRATION CURVE FOR AN EARLY MODEL CONDENSER MICROPHONE.

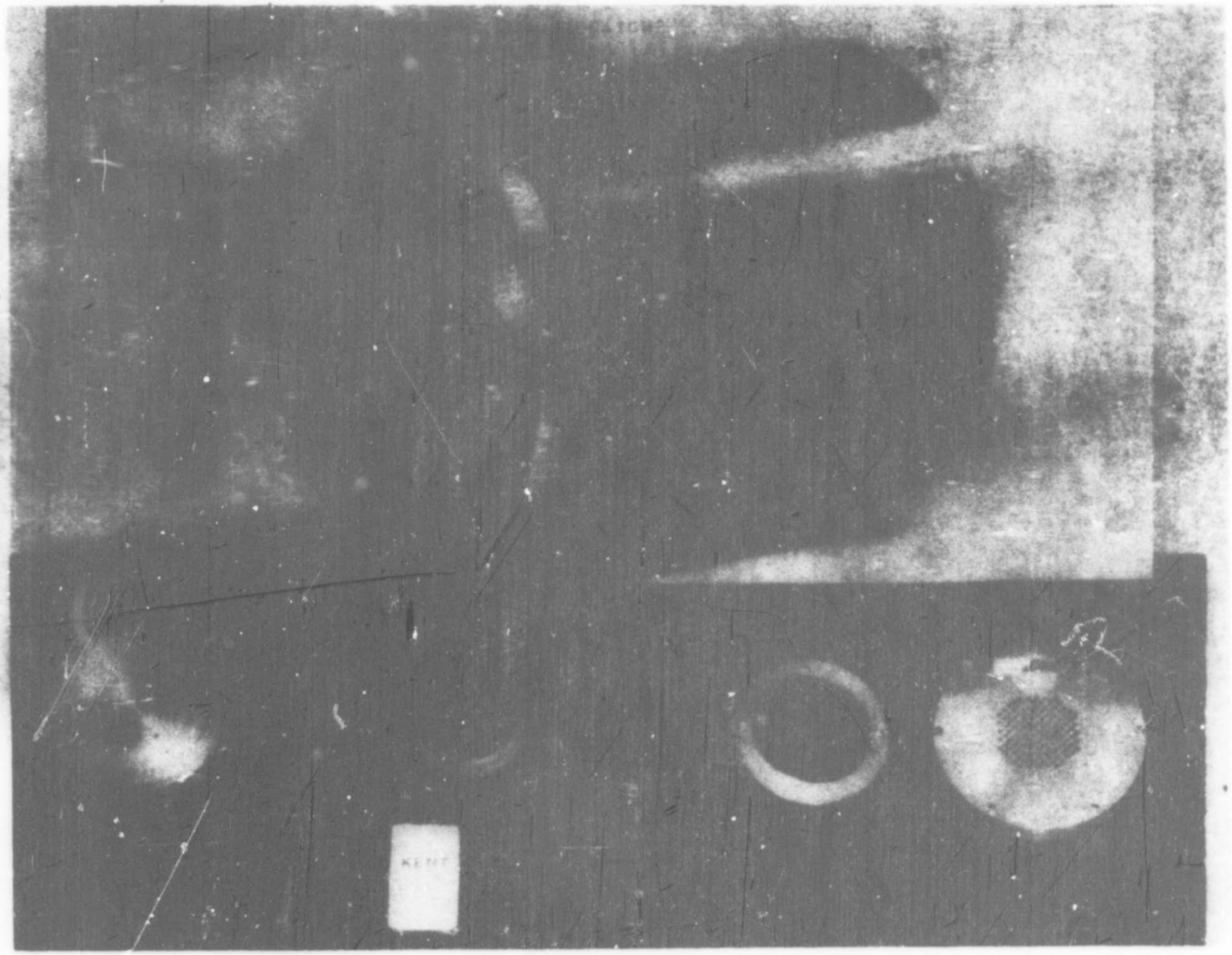

Fig. 3. Condenser microphone and back-up chamber. The lower part of the photograph is an exploded view of the microphone including the Mylar diaphragm incorporated by Space Corporation of Dallas, Texas.

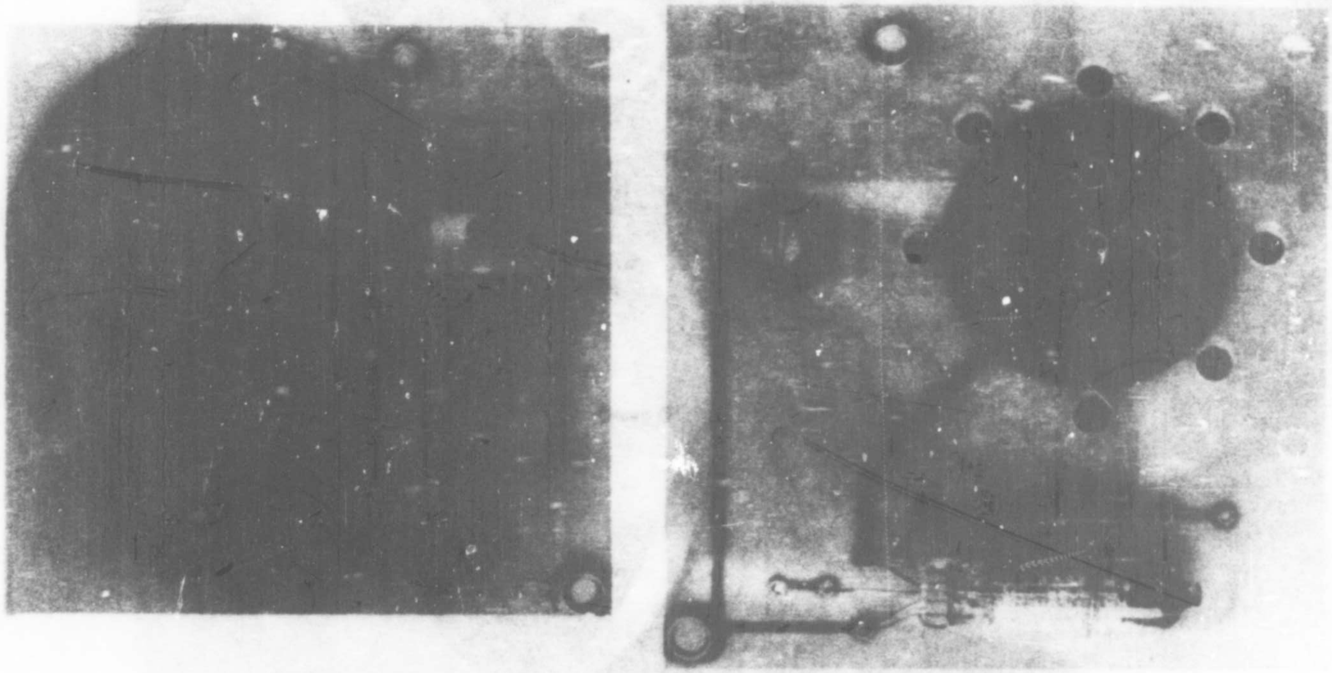

Fig. 4. Details of the Yuba Consolidated Industries of San Carlos, California, microphone construction.

characteristics. The hard tube on the back of the circuit board in Figure 4 is the input tube necessary to maintain the required impedance between the microphone plates.

THE TELEMETRY SYSTEM

The initial flight units were constructed by personnel of the Schellenger Research Laboratory and were designed for optimum operation. One of these units is illustrated in Figure 5. The condenser microphone was mounted in the top of its accoustic back-up chamber. An impedance matching preamplifier was mounted on the base of the microphone, inside the back-up chamber. The amplifier was mounted in the center of the package. Two parallelled radiosonde wet cells formed the basic power supply, while a group of dry cells was used to power the amplifier. Suitable insulation was used to maintain a reasonable operating temperature in the battery compartment. A modified AMT-4 radiosonde transmitter was mounted on the bottom of the package. In this circuit the output of the amplifier was coupled to the cathode of the transmitter tube.

Production of the flight units was begun by the Space Corporation of Dallas, Texas. An immediate effort was made to reduce the dry cell battery requirements by transistorizing the amplifier. A rain cover was devised to protect the microphone from precipitation and other particulate matter encountered during the ascent. This unit is illustrated in Figure 6. One of the circuits developed by the Space Corporation is shown in Figure 7.

Problems associated with the weight and moisture factors led to the development of a styrofoam container for the flight units. This system has a shoe box appearance with separate compartments for the microphone, the battery, and the amplifier transmitter section. (See Fig. 8a and 8b.) The transmitter compartment was provided with a six-volt relay which, at the expense of an eight-milliampere current drain, was held closed until the voltage dropped below a value of 2.5 volts. At that time the relay would open, shorting the remaining voltage across a squib which was arranged to cut the equipment from the balloon and allow it to fall at a rate controlled by the parachute.

A means of maintaining a check on the calibration of the system was also incorporated in the above model. This checking device consisted of an RC circuit which precipitated the firing of a neon tube. The pulse from the neon tube was passed through a matching transformer and applied to the field of a two-inch speaker. An 11-gram weight attached to the diaphragm of the speaker resulted in a decaying oscillation of approximately 100 cycles per second. Questions relative to the performance of the amplifier resulted in the incorporation of a second such circuit with the output of the neon tube placed, through a suitable voltage divider, on the input of the amplifier. The outputs of the two calibration systems were easily distinguishable. They were each designed to fire at preset intervals between 10 and 30 seconds.

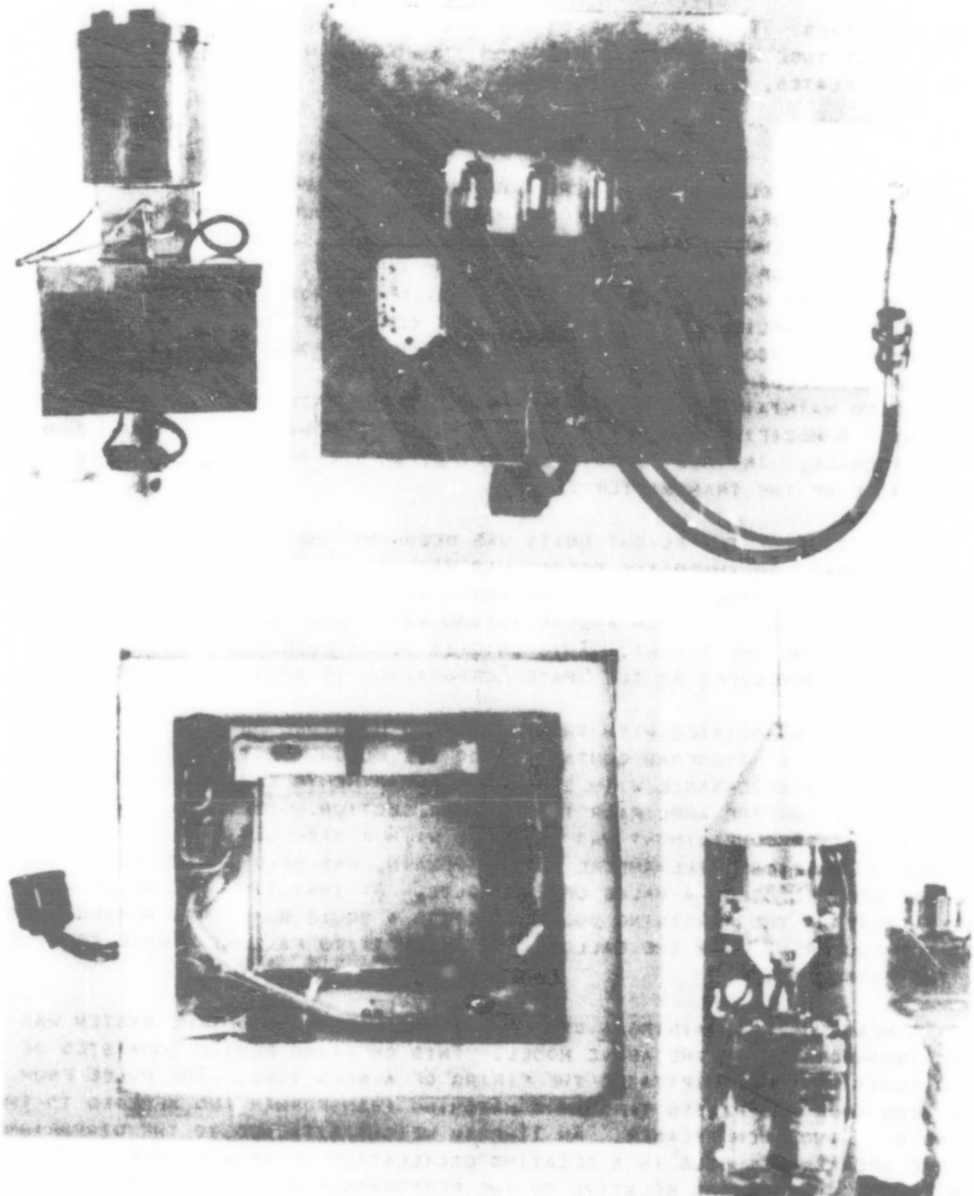

FIG. 5. THE FIRST ACOUSTIC FLIGHT UNIT BUILT BY SCHELLENGER RESEARCH LABORATORY OF TEXAS WESTERN COLLEGE, EL PASO, TEXAS.

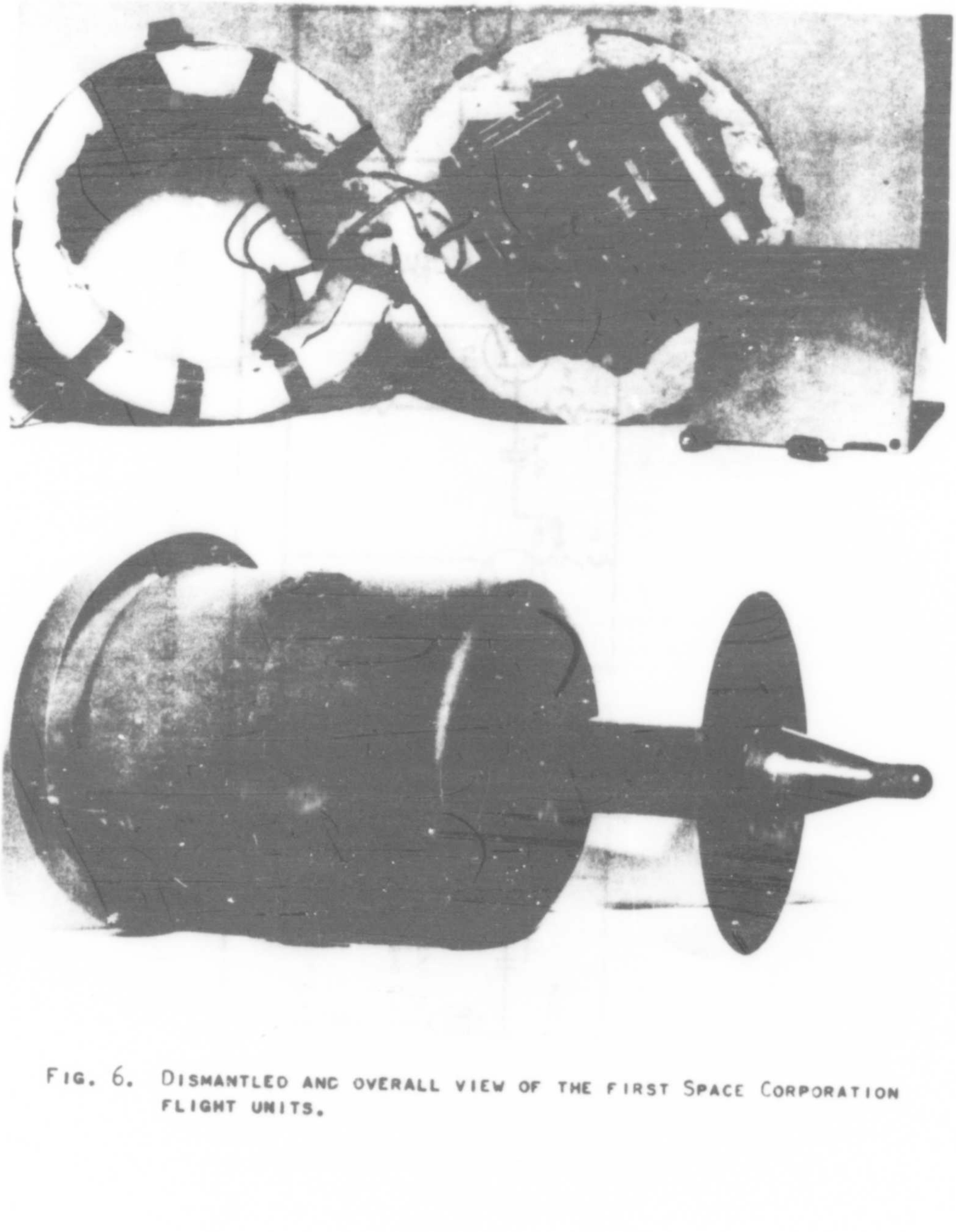

FIG. 6. DISMANTLED ANC OVERALL VIEW OF THE FIRST SPACE CORPORATION FLIGHT UNITS.

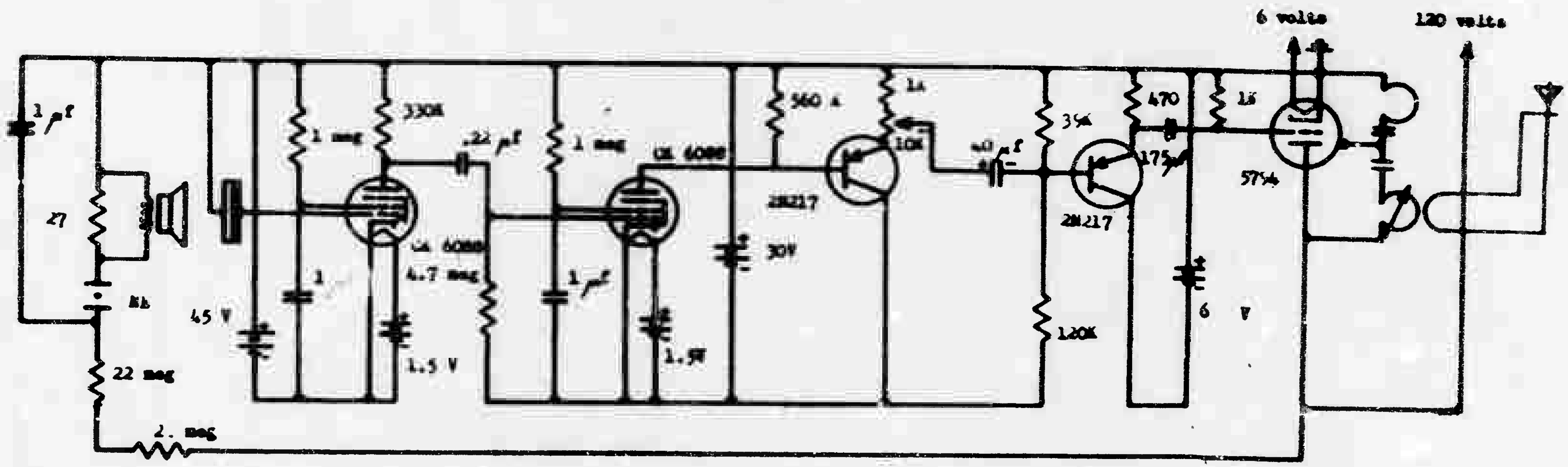

FIG. 7. ONE OF THE CIRCUITS DEVELOPED BY SPACE CORPORATION OF DALLAS, TEXAS.

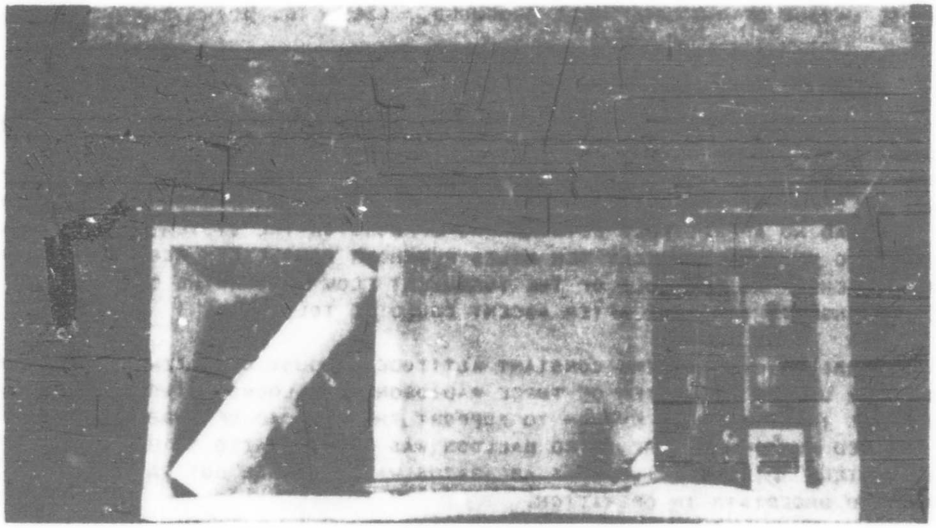

FIG. 8A. STYROFOAM CONTAINER DEVELOPED FOR REDUCTION OF WEIGHT AND MOISTURE.

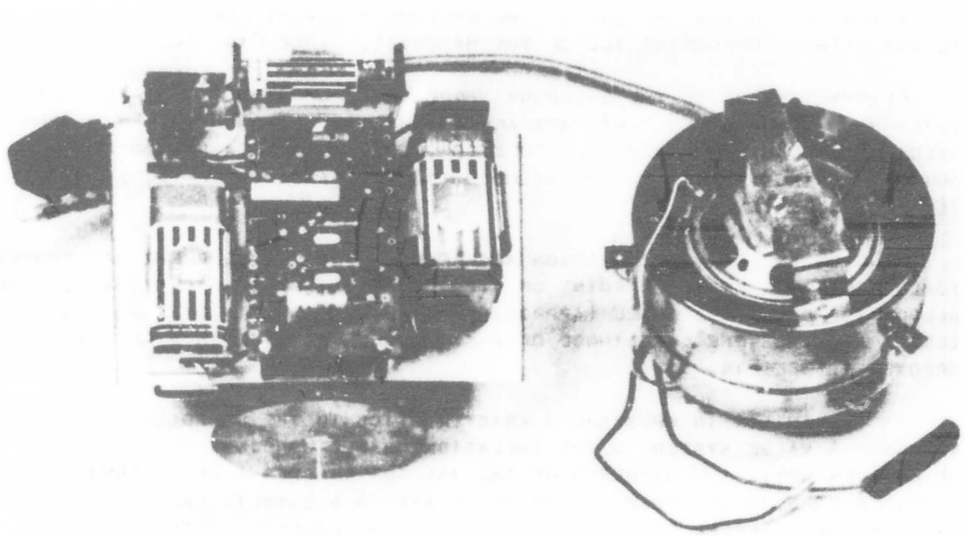

FIG. 8B. THE SECOND SPACE CORPORATION ACOUSTICSONDE MODEL.

The next unit was manufactured by Yuba Consolidated Industries of San Carlos, California. This unit incorporated the condenser microphone illustrated in Figure 4. A number of variations in both the electronics and the physical layout of the unit were produced. (See Fig. 9.)

THE BALLOON PLATFORM

The requirement placed on a suitable balloon platform was that it support the required payload at a desired altitude for a period in excess of one hour. It was not essential that the altitude be maintained accurately or even at a constant value, since relative velocities on the order of one mile per hour had no appreciable detrimental effects on the system. The normal ascent rate of approximately ten miles per hour completely neutralized the acoustic sensor as a result of the turbulent flow around the diaphragm. A slow change in altitude after ascent could be tolerated.

Initial flights of the constant altitude accoustic system were accomplished by use of a cluster of three radiosonde balloons. Two of the balloons were inflated only enough to support the payload of three pounds at the desired altitude. The third balloon was overinflated to burst at approximately 75,000 feet. This apparatus was workable but was rather clumsy and uncertain in operation.

A constant altitude balloon of an extremely simple type was procured from Raven Industries, Incorporated. It consisted of a 3/4 mil laminated tailored cylinder some 18 feet in diameter and 26 feet long. An opening 15 inches in diameter at the base of the cylinder allowed for the escape of any excess helium. A six-inch diameter sleeve was installed approximately ten feet below the top of the balloon allowing for inflation of the balloon without deploying all of the material. (See Fig. 10.)

Flight testing of the balloons through use of an altitude telemetering system has demonstrated that they are capable of maintaining a six-pound payload at roughly the same altitude (65,000 feet) for a period of seven hours. Barring accidents, the balloon is dependable except at sunset, when it will descend.

A Dewey and Almy Corporation neoprene balloon development has proven highly desirable from the point of view of handling and ascent rate. The balloon is relatively small (approximately eight feet in diameter) at release and thus the likelihood of a successful release in high winds is improved. (See Fig. 11.)

It is similar in physical characteristics to the standard radiosonde balloon. A valve system in the inflation nozzle confines the helium to the balloon until the diameter of the balloon reaches a predetermined value. A cord is attached to the valve and to a diametrically opposite point on the neoprene surface. The top of the balloon lifts the valve when expansion of the neoprene reaches the desired value. The balloon

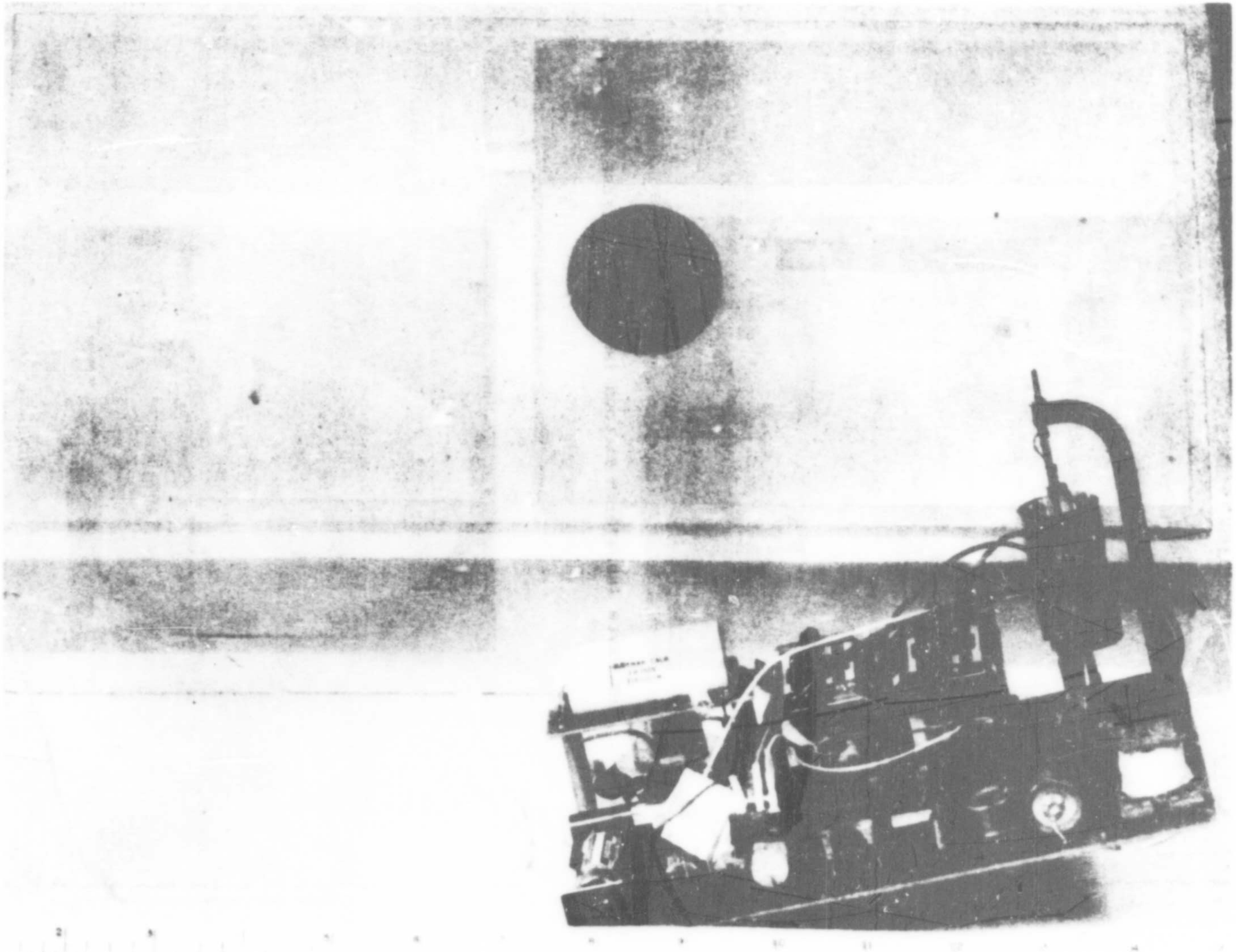

FIG. 9. AN EXPLODED VIEW OF THE YUBA ACOUSTICSONDE.

FIG. 10. THE RAVEN INDUSTRIES BALLOON IMMEDIATELY BEFORE RELEASE.

FIG. 11. THE DEWEY AND ALMY NEOPRENE CONSTANT ALTITUDE BALLOON.

FLOATS AT THAT ALTITUDE AS LONG AS THERMAL EQUILIBRIUM IS MAINTAINED. A SIMPLE METHOD OF ALTERING THE LENGTH OF THE CORD PERMITS SELECTION OF THE CRUISE ALTITUDE OF THE SYSTEM.

As can be noted in Figure 12, one of the chief virtues of the neoprene balloon is its fast ascent rate. It can get a payload into a constant altitude position in less than one hour. This provides an additional three quarters of an hour of operation at altitude.

Also as seen in Figure 12, one of the major problems relative to maintaining instrumentation at a constant altitude centers around the stability of the system at sunset. Thermal changes are such that a loss of altitude is to be expected. The value of this change is determined largely by the absorption properties of the balloon material and the enclosed gas. The polyethylene balloon descends at a relatively slow rate, while the neoprene balloon suffers a considerably greater loss of lift. On the other hand, the mylar balloon shows very little change in altitude between day and night operation.

A number of devices are available which can perform the functions required to maintain stability through sunset. In general, however, they are quite heavy and complicated for the problem at hand. Several possible solutions to this problem are currently being tested.

THE FLIGHT UNIT POWER SUPPLY

The initial power supply devised for the acousticsonde was essentially the same as the battery (BA--259) which is employed in the AN/AMT-4 radiosonde unit. The primary difference is a significant increase in capacity. The unit was designed to deliver 30 milliamperes to a B+ voltage of 120 volts, and 140 milliamperes at an A voltage of six volts for a period of 12 hours.

As is illustrated in Figure 13, the battery is a two layer arrangement of Magnesium - Cuprous Chloride cells. The A cells are 4" x 1-1/2" x 1/8" in size and the B cells are 1-1/4" x 1-1/2" x 1/8" in size. The battery is activated by filling each level with water (65 degrees F) which remains in the battery for two minutes and is then drained. After approximately ten minutes under load the system is in operation.

One of the problems encountered in the use of this battery centers around instability in the electrical characteristics. As is illustrated in Figure 14, the outputs are rather variable from unit to unit and with time after activation. This variability is manifested markedly in the internal impedance curves obtained in the environmental test chamber at the Schellenger Research Laboratory by Professor H. N. Ballard. A high impedance power source leads to feed-back paths which are a bit unusual and require some design attention. (See Figure 15.)

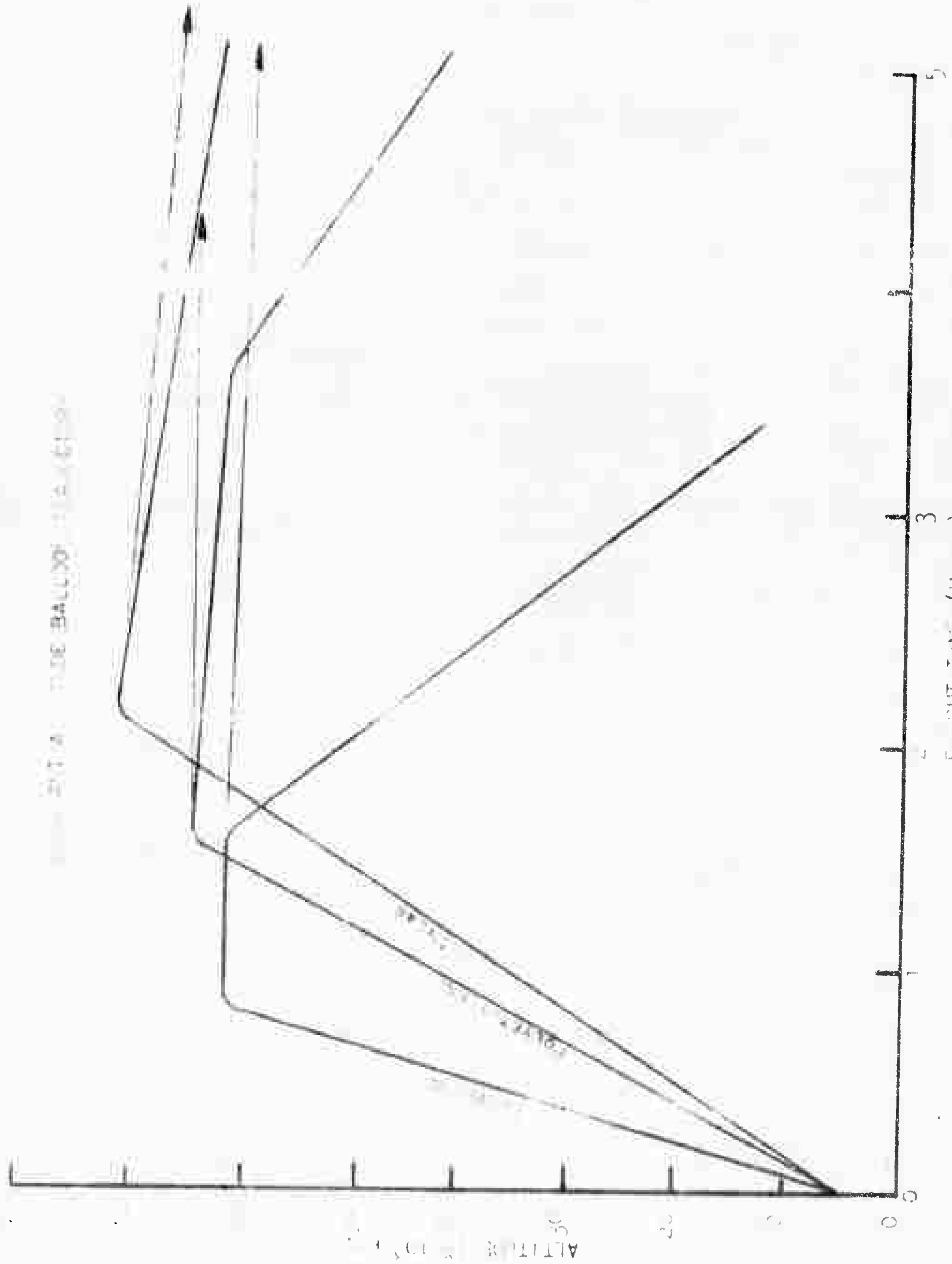

Fig. [illegible]. Altitude-Time [illegible]lots for the Polyethylene, [illegible] and [illegible] Constant Altitude Balloons.

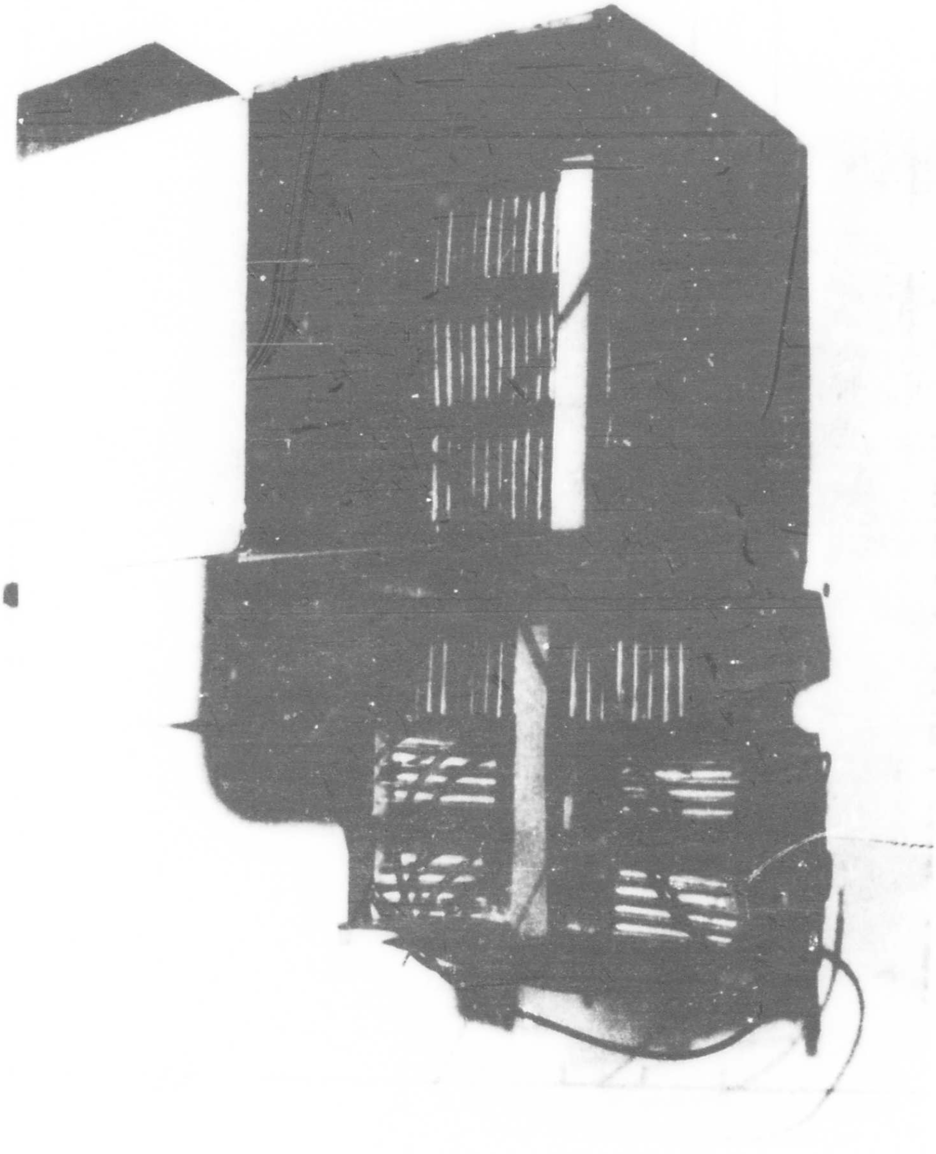

Fig. 13. Magnesium - Cuprous Chloride Battery produced by Eagle Picher Company, Joplin, Missouri.

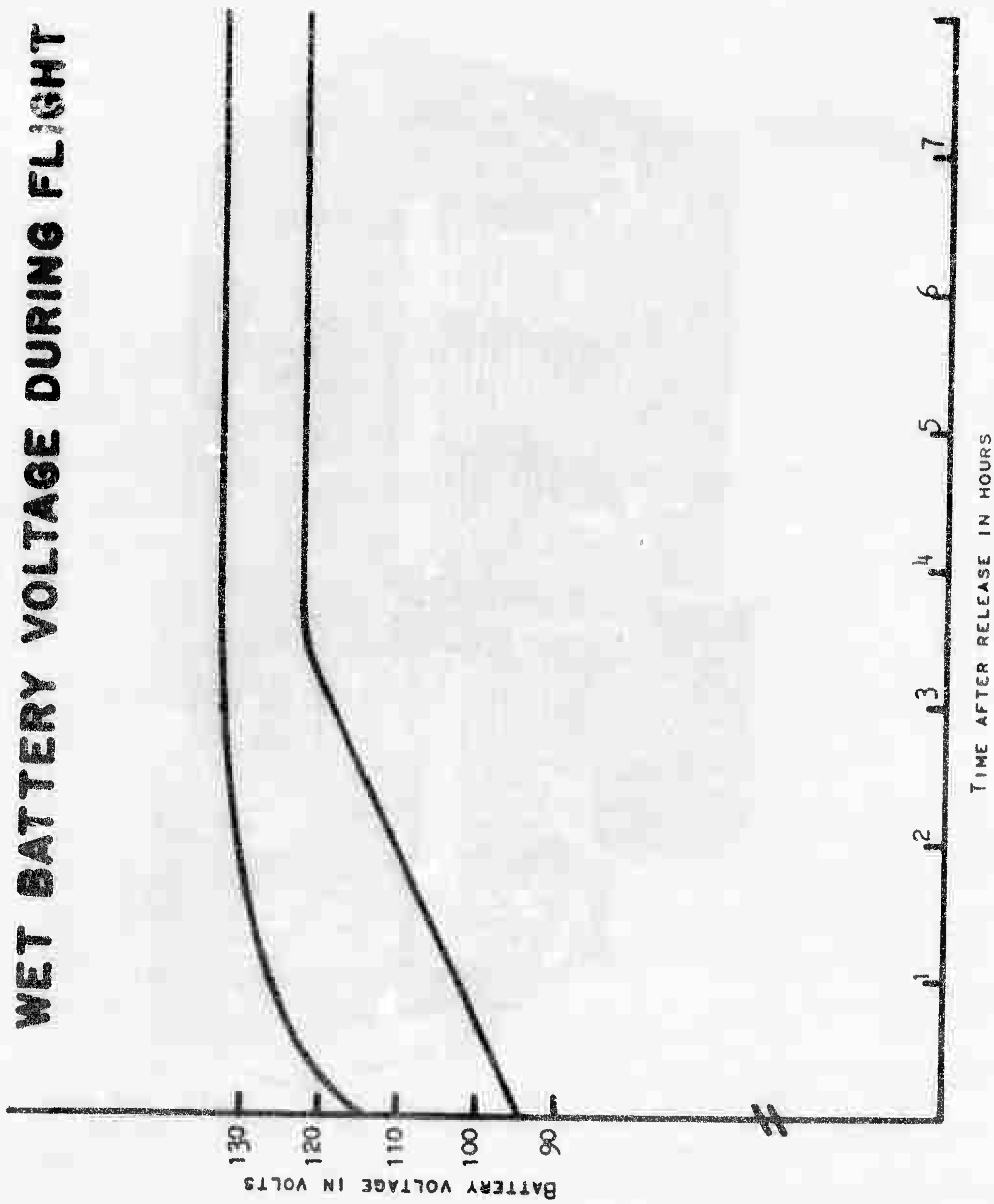

FIG. 14. VOLTAGE OUTPUTS FOR TWO EAGLE PICHER BATTERIES. DATA WAS OBTAINED UNDER FLIGHT CONDITIONS BY USE OF A SUPPLEMENTARY TELEMETRY SYSTEM DEVISED FOR FLIGHT TESTING BY MR. JOHN COFFMAN.

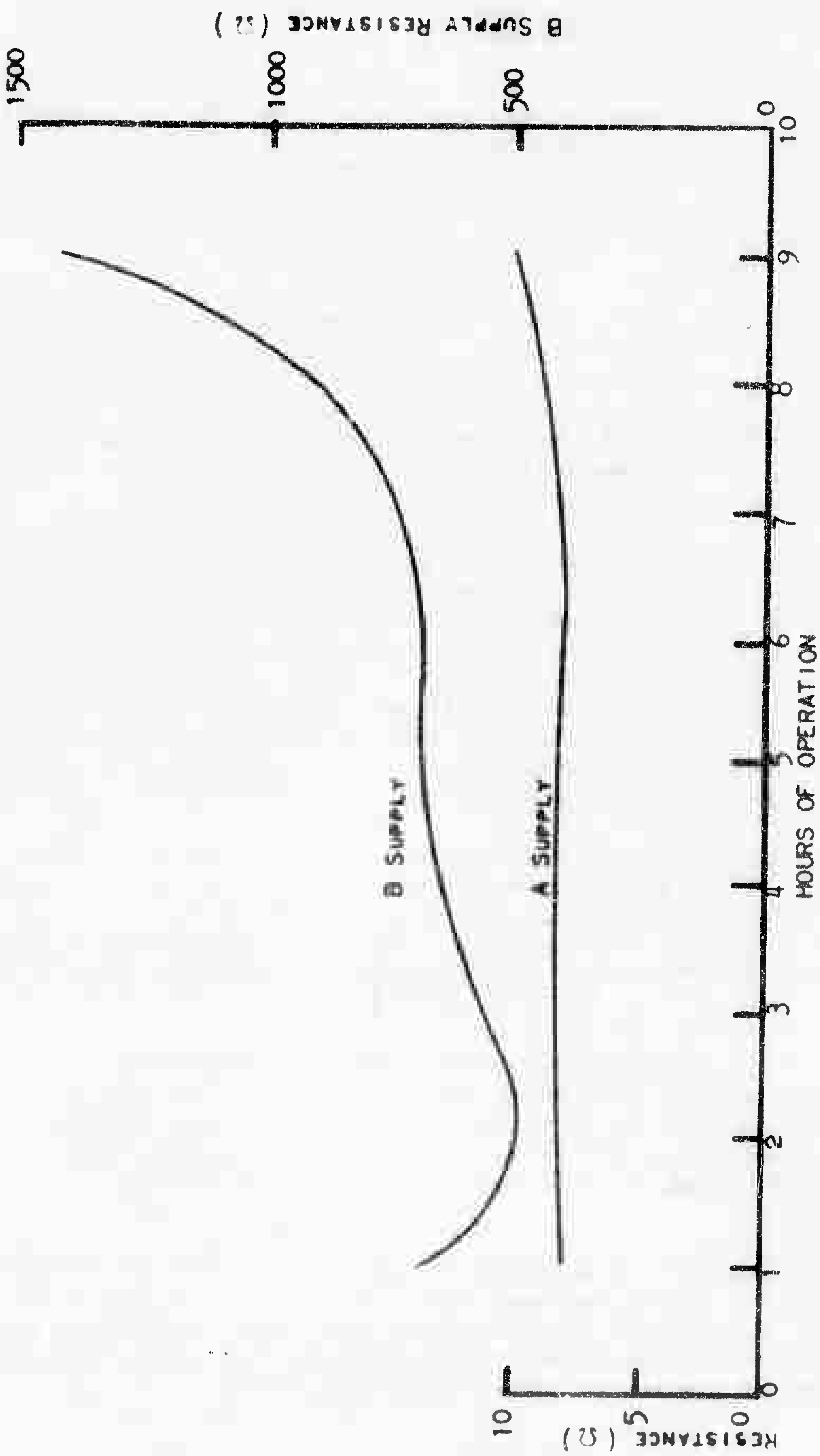

FIG. 15. VARIATION OF INTERNAL IMPEDANCE OF THE WATER ACTIVATED BATTERY UNDER ENVIRONMENTAL TEST CHAMBER EVALUATION.

THE GROUND STATION

THE GROUND STATION IS COMPOSED OF THE RECEIVING AND TRACKING EQUIPMENT AS WELL AS A VARIETY OF DATA HANDLING AND PROCESSING GEAR. AS IS ILLUSTRATED IN FIGURE 16, THE SIGNAL FROM THE BALLOON-BORNE SYSTEM IS DETECTED AND RECORDED DIRECTLY ON ONE CHANNEL OF A SEVEN CHANNEL FM TAPE RECORDER (MANUFACTURED BY AMPEX CORPORATION, REDWOOD CITY, CALIFORNIA). THE DETECTED SIGNAL IS ALSO PASSED THROUGH A SERIES OF FILTERS AND THE FILTERED OUTPUTS MAY BE RECORDED ON ADDITIONAL CHANNELS OF THE TAPE RECORDER.

A VIEW OF THE AMPEX FM TAPE RECORDER IS PRESENTED IN FIGURE 17. THE COMPLETE SYSTEM IS ILLUSTRATED ON THE LEFT, AND INTERIOR VIEWS OF THE THREE RACKS ARE PRESENTED. THE FIRST OPEN RACK CONTAINS THE 75-FOOT LOOP OF ONE-INCH TAPE AND THE SEVEN RECORD AND SEVEN REPRODUCE HEADS. THE CENTER RACK CONTAINS THE ASSOCIATED AM AND FM AMPLIFIERS FOR PROCESSING THE INPUT SIGNALS AND TRANSFERRING THEM TO THE STORAGE RECORDER. THE THIRD RACK CONTAINS THE STORAGE RECORDER, POWER SUPPLIES AND THE AUTOMATIC TURN-ON DEVICE.

THE REMAINING CHANNEL OF THE TAPE RECORDER IS USED TO RECORD THE OUTPUT OF A TIMING UNIT DEVELOPED BY TEXAS INSTRUMENTS, INCORPORATED, OF DALLAS, TEXAS. THE INITIAL RECORDING IS MADE ON A 75-FOOT LOOP OF TAPE WHICH CONTAINS THE INFORMATION FOR A PERIOD OF EIGHT MINUTES WHEN THE SYSTEM IS OPERATED AT ITS NORMAL TAPE SPEED OF ONE AND SEVEN-EIGHTHS INCHES PER SECOND. DURING THE PERIOD IN WHICH THE SIGNAL IS AVAILABLE AN INTEGRATING DEVICE MAKES THE DECISION TO PERMANENTLY STORE THE DATA IN THE STORAGE RECORDER OR TO ALLOW IT TO BE ERASED. A TOTAL OF SOME 12 HOURS OF DATA CAN BE STORED AT THE ONE AND SEVEN-EIGHTHS INCHES PER SECOND TAPE SPEED.

THE RECEIVING AND DIRECTION FINDING SYSTEM CONSISTS OF A GMD-1 ILLUSTRATED IN FIGURE 18. THIS INSTRUMENT PROVIDES A RECORD OF THE AZIMUTH AND ELEVATION ANGLES OF THE TRANSMITTER AS WELL AS A DETECTED OUTPUT OF EITHER AN AM OR FM TELEMETRY SIGNAL. THE DETECTED SIGNAL IS THEN RECORDED ON THE AMPEX FM RECORDING SYSTEM. A SAMPLE OF THE MODE OF PRESENTATION AND THE CODE IS ILLUSTRATED IN FIGURE 19.

THE TIMING UNIT IS LOCATED ON TOP OF THE STORAGE RECORDER RACK. THE TIMER WAS DESIGNED TO PROVIDE AN IDENTIFIABLE PULSE FOR EACH SECOND OF A 36-HOUR PERIOD. THE OPERATOR IS EXPECTED TO INITIATE THE COUNTING SEQUENCE OF THE TIMER AT A KNOWN TIME. THE ACTUAL TIME OF ANY SUBSEQUENT REFERENCE PULSE CAN THEN BE DETERMINED BY COMBINING THE INITIAL TIME AND THE LAPSED TIME.

THE SIGNAL DETECTOR UNIT IS DESIGNED TO ELIMINATE THE WAITING PERIODS BEFORE THE DESIRED EVENT AND AT THE SAME TIME PRECLUDE THE POSSIBILITY OF MISSING THE SIGNAL. A SIMPLE RC CIRCUIT CAN BE USED TO ACTIVATE THE STORAGE RECORDER WHEN SUFFICIENT INCIDENT ENERGY IS AVAILABLE. THE ANALYSIS OF THE DATA CAN, THEREFORE, BE LIMITED TO THE ACTUAL SIGNAL PERIOD.

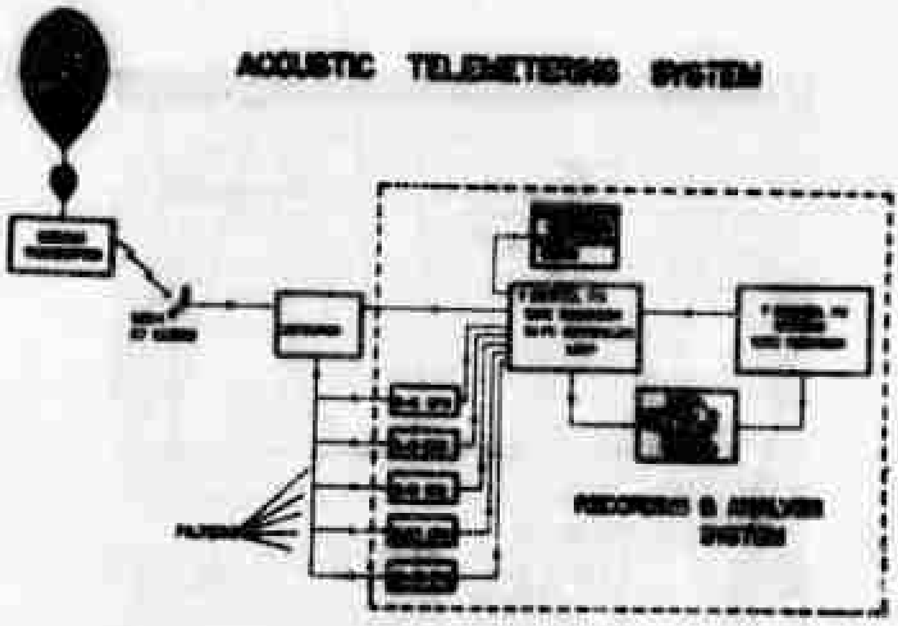

FIG. 16. BLOCK DIAGRAM OF THE INITIAL DATA HANDLING AND PROCESSING SYSTEM.

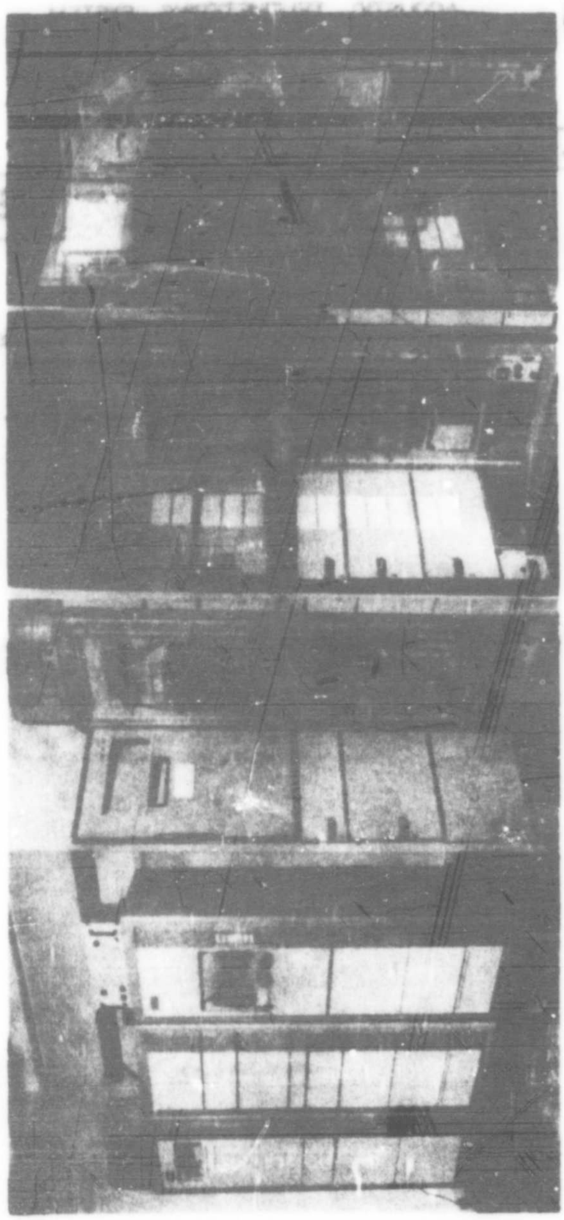

FIG. 17. THE AMPEX FM TAPE RECORDER SYSTEM.

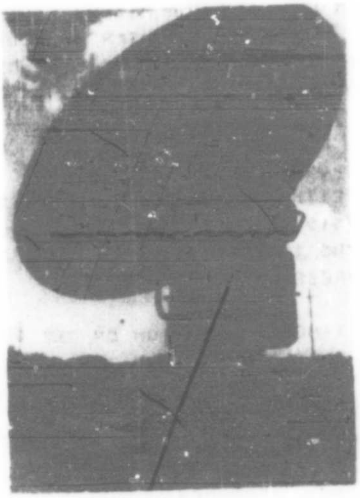

Fig. 18. Radio direction finder and receiving set GMD-1.

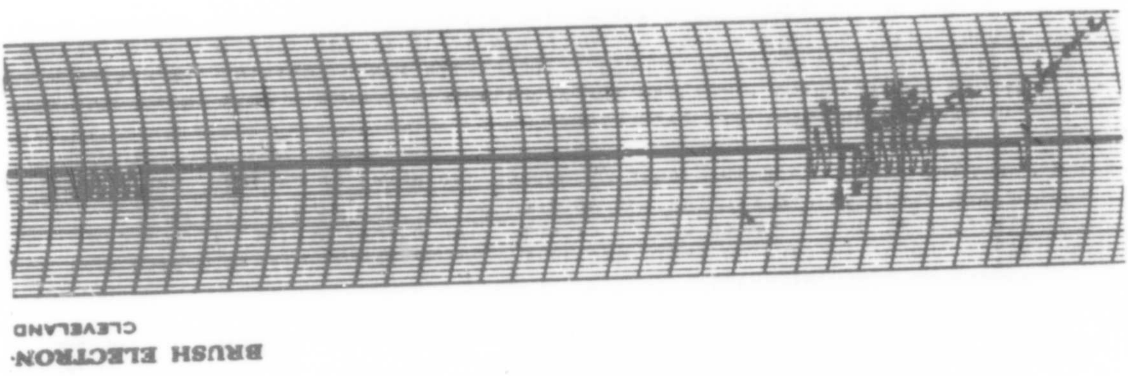

Fig. 19. A sample timing tape with its evaluation.

THE FIRST INSTRUMENT APPLIED IN EVALUATING THE POWER SPECTRA OF THE OBSERVED DATA WAS A KAY ELECTRIC COMPANY VIBRALIZER. THIS INSTRUMENT, ILLUSTRATED IN FIGURE 20, TAKES A 20-SECOND SEGMENT OF SIGNAL AND SCANS IT THROUGH THE USE OF A NARROW BAND SWEEP FILTER SYSTEM TO PRODUCE A DIAGRAM OF THE ENERGY VERSUS FREQUENCY AND TIME. THE INSTRUMENT ON THE RIGHT CONTAINS A 20-INCH DISC, ON WHICH THE SIGNAL IS RECORDED, WHICH IS COUPLED DIRECTLY TO THE DRUM ABOUT WHICH THE RECORD PAPER IS WRAPPED. A STYLUS FITTED TO THE NOTCHED SHAFT IN THE CENTER IS COUPLED TO THE FILTER SCANNING SYSTEM AND AS THE ASSEMBLY TURNS, A TRACE, THE DENSITY OF WHICH IS A FUNCTION OF THE AMOUNT OF ENERGY IN EACH FILTER BAND, IS BURNED ON THE RECORD.

THE INSTRUMENT CAN BE ADJUSTED TO PRODUCE CROSS-SECTIONS OF THE SIGNAL AT SPECIFIC TIMES. THE OUTPUT IS THEN PRESENTED AS A PLOT OF FREQUENCY VERSUS ENERGY LEVEL ON EITHER A LINEAR OR LOGARITHMIC SCALE. THE INSTRUMENT DOES AN EXCELLENT ANALYSIS IN REAL TIME. A SAMPLE OF THE RESULTS OF AN ANALYSIS PERFORMED ON THE TYPE OF DATA OBSERVED DURING THE ASCENT PHASE OF THE BALLOON FLIGHT IS PRESENTED IN FIGURE 21.

THE NEED FOR REAL TIME INFORMATION ON THE POWER SPECTRA OF THE INCOMING SIGNALS HAS LED TO THE DEVELOPMENT OF VARIOUS FILTER SYSTEMS WHICH PROVIDE OUTPUTS DESCRIBING THE TOTAL POWER IN THE SIGNAL OR IN VARIOUS FREQUENCY BANDS. THE FIRST SUCH SYSTEM WAS CONSTRUCTED BY THE SCHELLENGER RESEARCH LABORATORY TO ANALYZE AT 5, 7.5, 10, 12.5, 15, 17.5, 20, 22.5, 25, AND 27.5 CYCLES PER SECOND. THE OUTPUTS OF THESE FILTERS ARE RECORDED ON A BRUSH TYPE MULTIPLE CHANNEL RECORDER. (SEE FIGURE 22.)

THE NEED FOR FASTER ANALYSIS OVER A SHORTER PERIOD OF TIME LED TO THE DEVELOPMENT OF A SYSTEM PRODUCED BY THE ELECTRONICS ENGINEERING COMPANY OF CALIFORNIA. AS IS ILLUSTRATED IN FIGURE 23, THE UNIT ON THE LEFT CONSISTS OF A SIGNAL CONTROL UNIT WHICH SERVES TO ADJUST THE GAIN OF THE SYSTEM TO PLACE THE PROPER ORDINATE ON THE SPECTRAL ANALYSIS. THIS UNIT IS TIED TO THE FLIGHT UNIT'S CALIBRATION THROUGH A FILTER CENTERED AT THE FREQUENCY OF THE BLIPPER CALIBRATION SIGNAL.

ONE OF THE PANELS CONTAINS A TIME SIGNAL GENERATOR WHICH PROVIDES A CODED SERIES OF PULSES EACH ONE HALF MINUTE TO ASSURE IDENTIFICATION OF THE INDIVIDUAL POWER SPECTRAL CURVES. THE CENTER PANEL CONTAINS THE FILTER SYSTEM AND SCANNING MECHANISM AND A SUITABLE RECORDER. THIS INSTRUMENT CAN PERFORM ONE ANALYSIS EACH MINUTE.

THE SECOND RACK IN FIGURE 23 HOUSES TWO BANKS OF FILTERS, ONE SERIES OF ONE TENTH OCTAVE FILTERS AND ANOTHER SERIES OF 1/2 OCTAVE FILTERS CENTERED AT SUBHARMONICS OF 100 CYCLES. THE OUTPUT OF THE FILTERS CAN BE RECORDED DIRECTLY OR THEIR RECTIFIED OUTPUT CAN BE AVERAGED OVER A NUMBER OF TIME INTERVALS.

SAMPLES OF THE TYPE OF ANALYZED RECORD WHICH ARE OBSERVED DURING THE BALLOON ASCENT ARE PRESENTED IN FIGURE 24. THE UPPER CURVE REPRESENTS THE ANALYSIS OBTAINED DURING THE PERIOD BETWEEN THE LINES A AND B ON THE FILTER

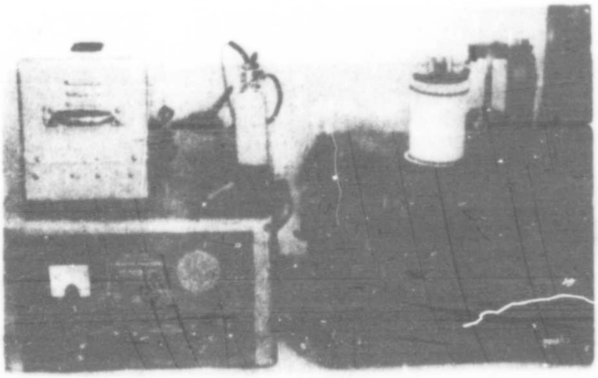

FIG. 20. KAY ELECTRIC COMPANY VIBRALIZER WITH AN ALTEC-LANSING C-3.

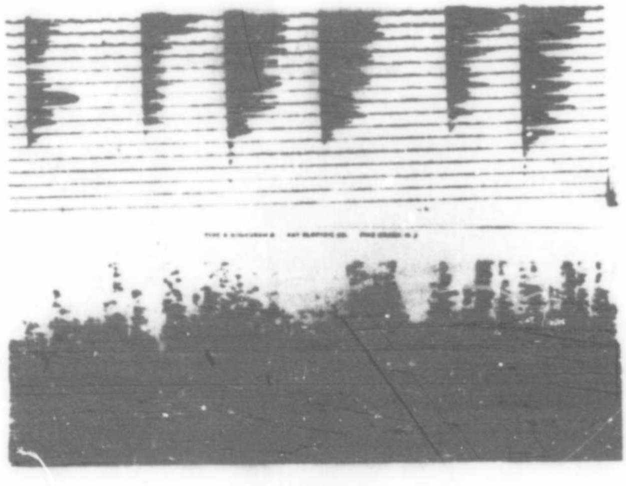

FIG. 21. A SAMPLE OF A KAY VIBRALIZER ANALYSIS OF WIND NOISE AS THE BALLOON ASCENDS.

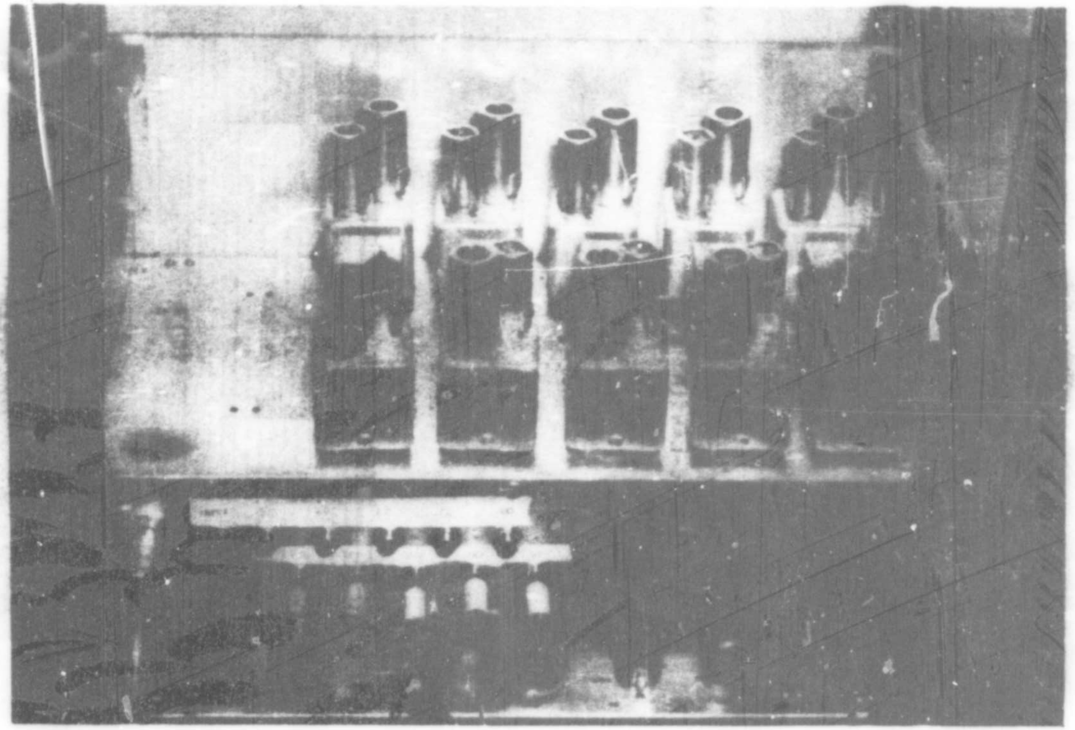

Fig. 22. The channel filter network for real time analysis.

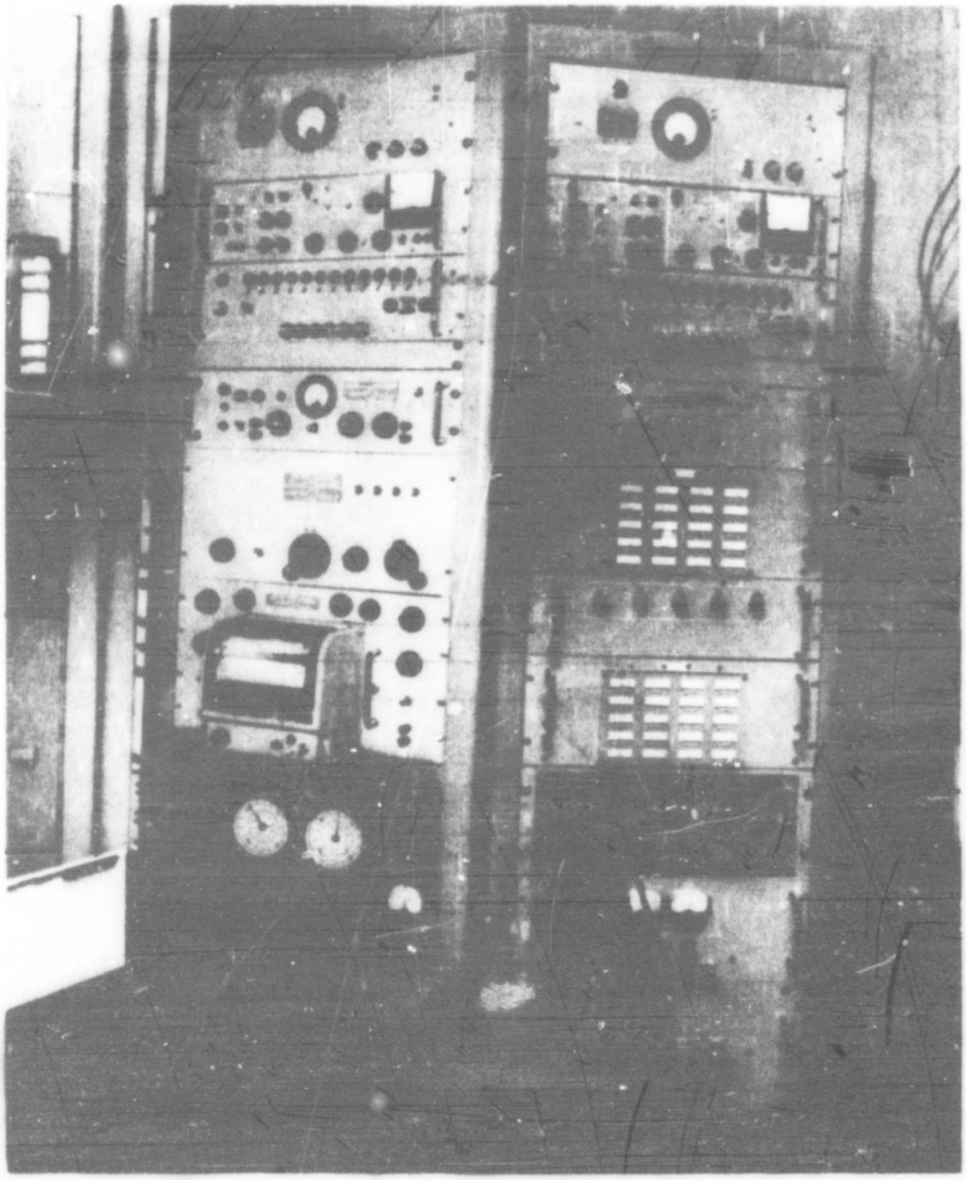

FIG. 23. SPECTRAL ANALYSIS EQUIPMENT PRODUCED BY ELECTRONICS ENGINEERING COMPANY OF CALIFORNIA.

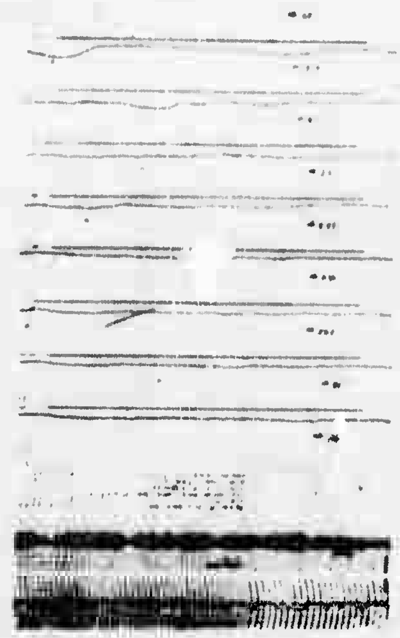

FIG. 24. POWER SPECTRAL ANALYSIS FROM THE VARIABLE AND THE FIXED FILTER SYSTEM.

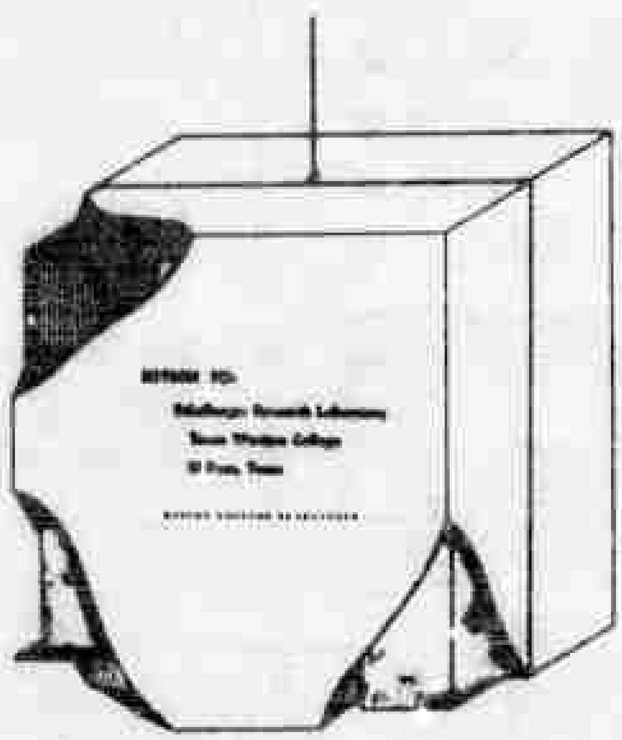

FIG. 25. DRAWING OF A PROPOSED NEW PACKAGING AND LAYOUT DESIGN FOR THE FLIGHT UNIT.

OUTPUT CURVES. AN AVERAGE OF THE FILTER OUTPUT CURVES OVER THAT TIME INTERVAL SHOULD PRODUCE VALUES WHICH CORRESPOND TO THE VALUES OF THE UPPER CURVE AT THE CENTER FREQUENCY OF EACH OF THE FILTERS. THE MERITS OF THE DIFFERENT ANALYSIS SYSTEMS WILL DEPEND LARGELY ON THE USE TO WHICH THEY ARE APPLIED.

CURRENT DEVELOPMENT

THE TELEMETRY SYSTEM DESCRIBED ABOVE WAS DEVELOPED FROM EXISTING SIGNAL CORPS EQUIPMENT. A NUMBER OF PROBLEMS HAVE BEEN ENCOUNTERED IN ADAPTING THE GMD-1 SYSTEM TO THE MODULATING TECHNIQUES UTILIZED AND IN OBTAINING THE DESIRED RANGE OF COMMUNICATIONS. THE FOLLOWING MATERIAL OUTLINES A FEW OF THE MORE PROFITABLE APPROACHES TOWA CIRCUMVENTING THESE DIFFICULTIES.

A NUMBER OF IMPROVEMENTS HAVE BEEN INCORPORATED IN THE UNIT PICTURED IN FIGURE 25. FIELD HANDLING OF THE BATTERY HAS BEEN ELIMINATED BY PLACING IT ON ONE LEVEL IN A WATER TIGHT CHAMBER. THE FLIGHT CREW IS ONLY REQUIRED TO POUR INTO THE CHAMBER A CERTAIN AMOUNT OF THE ACTIVATING SOLUTION AND, AFTER THE CORRECT AMOUNT OF TIME, DRAIN THE SOLUTION OUT. THE PORTS CAN BE SEALED TO MAINTAIN A HIGH RELATIVE HUMIDITY IN THE CONTAINER AND PREVENT EVAPORATION OF THE BATTERY'S MOISTURE.

THE FLIGHT UNIT IS DESIGNED TO BE ATTACHED TO THE BALLOON SYSTEM BY SIMPLY TYING THE SUPPORT CORD TO THE BALLOON. THE CUT-DOWN RELAY IS ACTIVATED ON ASCENT BY THE ACTION OF A PRESSURE CELL SO THAT THEREAFTER EITHER A LOW BATTERY VOLTAGE (A BATTERY LESS THAN 2.5 VOLTS) OR A DESCENT TO BELOW A PRE-SET ALTITUDE (45,000 FEET) WILL INITIATE THE CUT-DOWN PROCEDURE. A SQUIB IN A CUT-DOWN CANNON IS FIRED IN EITHER CASE BY THE REMAINING CURRENT FROM THE A BATTERY TO CUT THE CORD ENCIRCLING THE FLIGHT UNIT. A KNOT IN THE CORD JUST INSIDE THE LOWER EDGE OF THE RIGHT SIDE OF THE BOX WILL CAUSE THE UNIT TO INVERT. THE BOTTOM OF THE PARACHUTE COMPARTMENT (LOWER RIGHT) IS FIRMLY ATTACHED TO THE CORD AND IS PULLED FREE AS THE UNIT ROTATES. A SMALL PIECE OF TAPE ATTACHED TO THE CARDBOARD BOTTOM AND TO THE TOP OF THE MYLAR PARACHUTE DEPLOYS THE PARACHUTE BEFORE PULLING FREE.

A PHOTOGRAPH OF ONE OF THE ELECTRONIC UNITS BEFORE IT WAS INSTALLED IN THE FLIGHT CONTAINER IS ILLUSTRATED IN FIGURE 26. THIS UNIT PROVIDES A TELEMETRY SYSTEM FOR THE MICROPHONE TO THE GROUND RECORDER WHICH IS FLAT WITHIN ONE DB FROM ONE HALF CYCLE TO ABOVE 200 CYCLES PER SECOND. WITH THIS FLIGHT UNIT THE ENTIRE GROUND GMD-1 SYSTEM OPERATES AT OPTIMUM EFFICIENCY.

THE ELECTRONIC CIRCUITRY UTILIZED IN THE EARLY FLIGHT UNITS PLACED CERTAIN LIMITATIONS ON THE FREQUENCY RESPONSE OF THE OVERALL SYSTEM, AS DID THE USE OF MODULATION TECHNIQUES FOR WHICH THE GROUND DETECTOR WAS NOT DESIGNED. AN EFFORT WAS MADE TO IMPROVE THE TELEMETRY CHARACTERISTICS BY DESIGNING MODULATION CIRCUITRY WHICH WAS COMPATIBLE WITH THE GROUND SYSTEM AND AT THE SAME TIME PERMIT COVERAGE OF THE ENTIRE DESIRED FREQUENCY BAND. A SIMPLE DEVIATION OF THE PULSE TYPE OF TELEMETRY UTILIZED FOR METEOROLOGICAL DATA TRANSMISSION WAS DEVISED BY MR. GEORGE CLARK AND IMPLEMENTED BY MR.

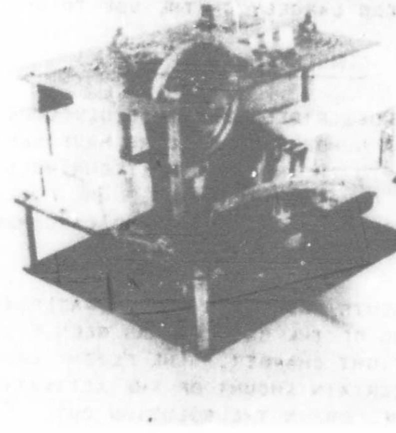

FIG. 26. INSTRUMENTATION SECTION OF THE FLIGHT PACKAGE UTILIZING THE PULSE MODULATION TECHNIQUE.

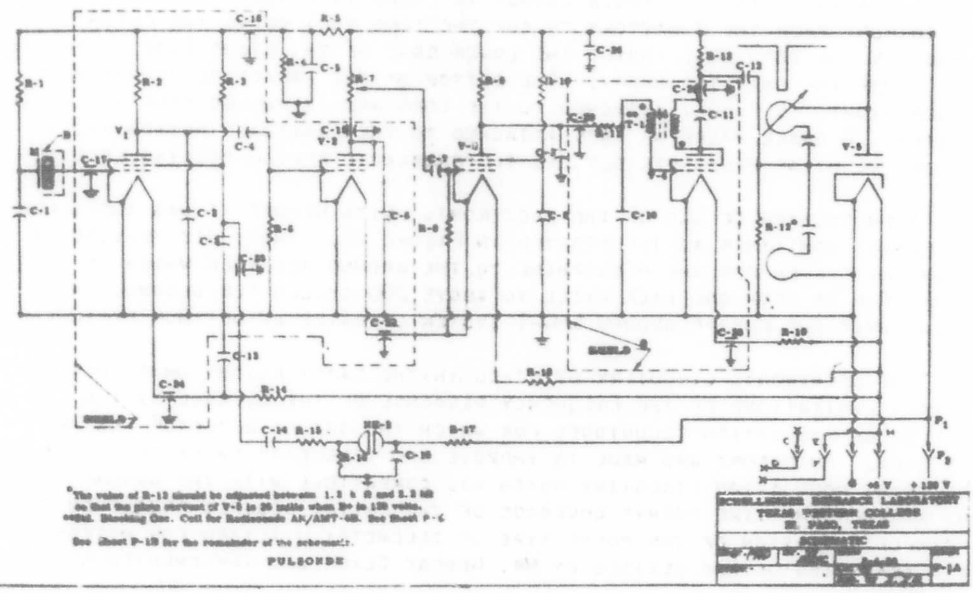

FIG. 27. CIRCUIT DIAGRAM OF THE PULSE MODULATED FLIGHT UNIT DESIGNED BY MR. GEORGE CLARK AND MR. CARLOS MACDONALD.

Carlos MacDonald. The repetition rate of the subcarrier blocking oscillator was increased to 3,000 cycles per second to obtain the desired frequency response. The circuit parameters are illustrated in Figure 27.

The need for greater mobility in obtaining research data has led to the development of mobile stations which can be flown to desired sites. A GMD-1 receiver is used with a portable antenna system (see Fig. 28) and a Precision Instrument Company FM tape recorder. (See Fig. 29.) This system has proven efficient for short periods of observation at remote points.

A balloon drifts with the wind as it floats at constant altitude. Under the more favorable wind conditions encountered, the balloon-borne transmitter will stay within line of sight of the ground station for the entire life of the batteries. Under the more unfavorable conditions one may experience, the transmitter goes over the radio horizon before reaching altitude and never gets back into the field of view. One can use a remote release point or a number of strategically placed GMD-1's, but the system becomes quite complicated. The following is an attempt to obtain extended ranges from a single station.

The Ramo-Wooldridge Corporation designed a system with the objective of extending the life of a flight unit to 24 hours. (See Fig. 30.) One requirement placed on such a system is that it maintain communications over a range of at least 600 miles. This is accomplished by use of sky wave propagation in the 3.5 to 10 megacycle frequency range. The flight unit is interrogated 91.3 times per second to determine the range from the ground station to the balloon. A phase relating technique permits evaluation of the azimuth direction of arrival of the return pulse. The acoustic data is imposed on the flight unit carrier about 90 percent of the time.

A view of the flight unit is presented in Figure 31. This item was designed and built by Texas Instruments, Incorporated, of Dallas, Texas. A two-watt transmitter, a sensitive receiver, pulse generating circuitry and provision for changing frequencies at sunset and sunrise are included. The power supply is designed to provide operation of the unit for a 24-hour period.

The ground station for the long range communications sytem was designed and fabricated by the Ramo-Wooldridge Corporation of Los Angeles, California. (See Fig. 32.) A 200-microsecond pulse is sent to the balloon unit by the 100-watt transmitter (BC 610). The return from the balloon transmitter is then detected with receiver unit R 390 and the travel time of the exchange is evaluated by the unit on the left. The DF section of the ground station is not shown.

The system is designed to maintain communications with the balloon over a 600-mile range. Experimental data will be obtained on a series of test flights to establish the feasibility of the technique and to evaluate the background noise level which will be encountered.

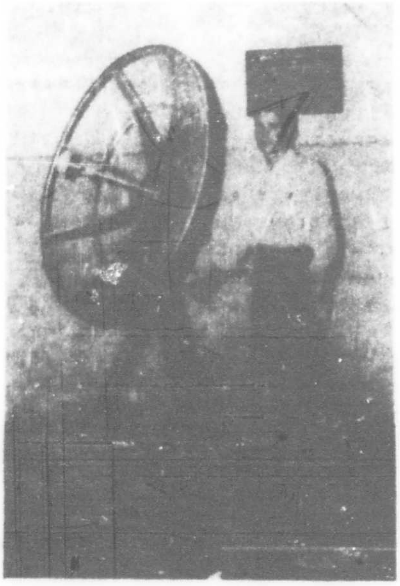

FIG. 28. PORTABLE ANTENNA SYSTEM DEMONSTRATED BY MR. JIM BETTLE.

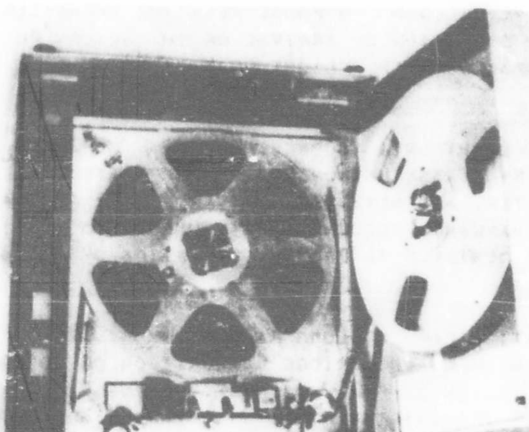

FIG. 29. PRECISION FM TAPE RECORDER USED IN MOBILE INSTALLATIONS.

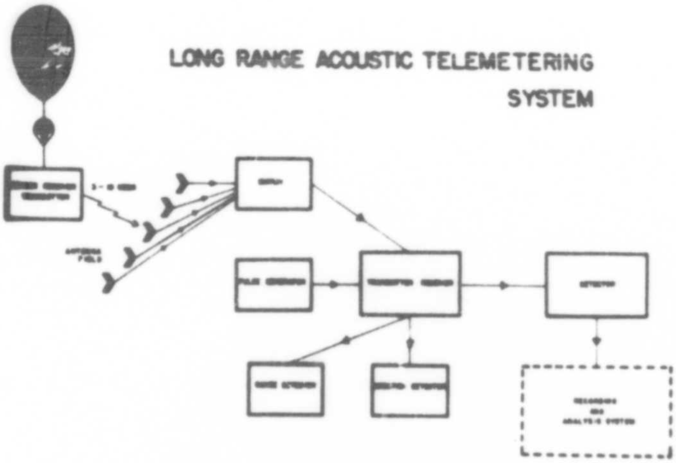

FIG. 30. BLOCK DIAGRAM OF THE LONG RANGE TELEMETRY SYSTEM DESIGNED BY RAMO-WOOLDRIDGE CORPORATION.

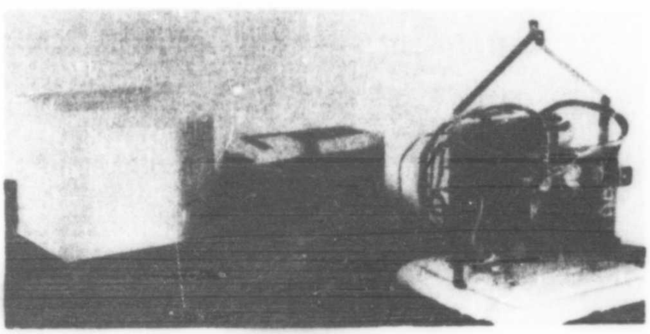

FIG. 31. THE FLIGHT UNIT DESIGNED AND PRODUCED BY TEXAS INSTRUMENTS, INC., OF DALLAS, TEXAS.

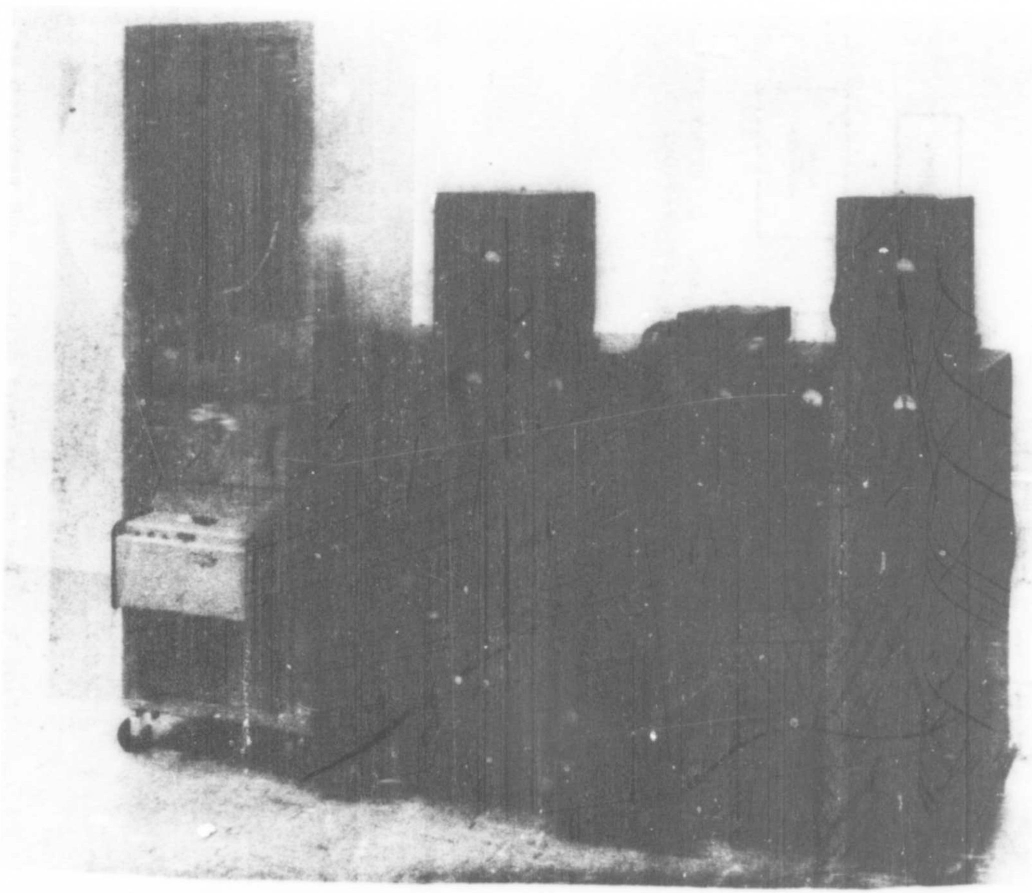

FIG. 32. THE LONG RANGE TELEMETRY GROUND STATION DESIGNED BY RAMO-WOOLDRIDGE CORPORATION.

CONCLUSION

THE SYSTEMS AND TECHNIQUES DESCRIBED ABOVE REPRESENT A FIRST APPROACH TO A DIFFICULT PROBLEM. THE DEVELOPMENT OF RESEARCH AND TESTING TECHNIQUES HAS PROCEEDED CONCURRENT WITH THESE INITIAL SOLUTIONS TO THE DATA ACQUISITION AND PROCESSING PROBLEMS. AN IMPROVED CAPABILITY IS THEREFORE AVAILABLE TO APPLY TOWARD SOLVING THE PROBLEMS WHICH CURRENTLY ARE, OR CAN BE, EXPECTED TO IMPEDE PROGRESS.

OF IMMEDIATE SIGNIFICANCE IS THE FACT THAT INSTRUMENTATION IS NOW AVAILABLE WHICH CAN BE USED TO OBTAIN DATA OF SUFFICIENT FIDELITY TO PERMIT SERIOUS STUDY OF THE ATMOSPHERIC PRESSURE DISTURBANCES GENERATED BY MISSILE FLIGHTS. ONE MAY EXPECT THAT ANALYSIS OF THE POWER AND FREQUENCY COMPOSITION OF SUCH SIGNALS WILL PROVIDE NEW INSIGHT RELATIVE TO THE GENERATION AND PROPAGATION OF BALLISTIC DISTURBANCES. SUCH STUDIES ARE ACTIVELY UNDER WAY.

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Number	Title	Date
1	Air Force Aerobee 65	10 Jul 56
2	Air Force 66	13 Jul 56
3	Naval Research Lab Aerobee 42	13 Jul 56
4	Air Force Aerobee 68	24 Jul 56
5	Air Force Aerobee 64	3 Aug 56
6	Air Force Aerobee 70	17 Aug 56
7	Naval Research Lab Aerobee 46	17 Aug 56
8	Naval Research Lab Aerobee 33	17 Aug 56
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11	Signal Corps Aerobee 35	6 Sep 56
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16	Air Force Aerobee 76	20 May 57
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22	Naval Research Lab 31	4 Dec 57
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24	Air Force Aerobee 83	20 Jun 58
25	Air Force Aerobee 89	20 Jun 58
26	Naval Research Lab Aerobee 41	23 Jun 58
27	Air Force Aerobee 78	23 Jun 58
28	Air Force Aerobee 92	10 Jul 58
29	Air Force Aerobee 82	28 Jul 58
31	Air Force Aerobee 85	4 Aug 58
32	Naval Research Lab Aerobee 51	8 Aug 58

Number	Title	Date
33	Nike Cajun MG 5	[illegible]
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36	Air Force Aerobee 87	22 Aug 58
37	Air Force Aerobee 84	2 Oct 58
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