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Armed Services Technical Information Agency

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Date: 3-Feb-54

Signed Richard E. Reedy
OFFICE SECURITY ADVISOR

PROGRESS REPORT ON
HIGH ALTITUDE PLASTIC BALLOONS
CONTRACT NONR-710 (01)
December 22, 1952 to December 3, 1953
VOLUME X
CONFIDENTIAL INFORMATION

Copy No. [illegible]

Confidential Information

PROGRESS REPORT ON
RESEARCH AND DEVELOPMENT
IN THE FIELD OF
HIGH ALTITUDE PLASTIC BALLOONS

This material contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Sections 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.

CONDUCTED UNDER
CONTRACT NONR-710(01), NR 211 002
FOR PERIOD DECEMBER 22, 1952 to DECEMBER 3, 1953
WITH THE
OFFICE OF NAVAL RESEARCH

AND SPONSORED JOINTLY
BY THE ARMY, NAVY, AND AIR FORCE

PREPARED BY THE
DEPARTMENT OF PHYSICS
UNIVERSITY OF MINNESOTA
MINNEAPOLIS 14, MINNESOTA

Confidential Information

Confidential

PROGRESS REPORT ON CONTRACT 710(01)

From December 22, 1952, to December 3, 1953

VOLUME X

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Confidential Information

Section I

INSTRUMENTATION

A. Summary of Work Done on Instrumentation

In the period covered by this report, flights could be divided into four groups as far as the instrumentation was concerned. The first of these was a continuation of the flight constants flights, the second was continuation and expansion of temperature investigations, the third was a program of testing Mylar and cylinder balloons, and the last was the step flights which were the outcome of the flight constants flights. For each of these groups of flights a different gondola was required even though some of the apparatus included in the gondolas was interchangeable. In addition, the normal process of improvement in development continued during this period, so that none of the instruments that were flown in the beginning of the period remained unchanged by the end.

The flight constants gondola, as it was flown at the end of the last report period, was little changed during this time except that a great deal of work was put in on the command receiver and the receiver control circuit, which appeared to be the weakest link in the system. Analysis of results of the flight constants flights flown during the last period showed that the bandwidth of the receiver was very narrow, making it quite selective, and the control filter circuits also had a very narrow bandwidth. The combination of the two resulted in a system which was so selective that extreme difficulty was experienced in operating this system at long range and after the batteries had been partially used or after the equipment had cooled a little. A new receiver was developed with a slightly wider bandwidth and only the minimum necessary equipment, namely an Olland Cycle, a transmitter, batteries, and an antenna, and was encased in a 1" styrofoam box covered with aluminum foil. A separate blowdown timer, flown on some of these flights, consisted of a pocket watch altered for this purpose with batteries, a case, and blowdown squibs and cannon. This weighed about six ounces.

The step flight consisted essentially of a platform which altered its altitude in a predetermined fashion, from which the lift of an ordinary balloon was measured. This presented several problems in instrumentation. Regulation of the rate of ascent, determining the altitude of each step, and timing the ascent and level portion of each step, was one part of this problem, while measuring the lift of the balloon under study and telemetering this information to the ground was another part. The solution was two gondolas, one composed of a ballasting system, flight program timer, and weigh-off device, the other containing altitude measuring devices, flight safety devices, telemetering equipment, and power sources.

Two ballasting systems were developed, one using liquid ballast, the other magnetic ballast, with appropriate programmers for each system. Two types of tensiometers have been flown for measuring the lift of the test balloon, the most recent one an adaptation of the Olland Cycle pulse-time coding system of telemetering linear position. Since the tensiometer and pressure-measuring units were flown in duplicate recently to avoid possible loss of information from equipment failure, the amount of information to be telemetered was more than a single channel telemetering system could contain, and a multiplexing system became necessary. A commutator was developed which

Section I

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Special equipment, developed for the temperature and infrared measurements, is discussed thoroughly in Section I, B and C, and will not be covered here. The gondola control equipment and telemetering was standard at the time and was not changed in any way for these temperature flights.

A program of test-flying balloons of different materials and shapes required development of a small, relatively light-weight gondola with good heat-conserving powers for one to two-day flights. This was done in a gondola frame measuring 1 ft on a side with all the usual apparatus plus a water tank for heat storage. The gondola was encased in a styrofoam box built of two layers of 2" styrofoam with aluminum foil between layers and on the outside. It was possible to make the up and down camera windows smaller than on the large gondola packages because the fit of the box was tight, thus allowing accurate positioning. These were the only openings through the styrofoam, since the antenna dropper was fastened on the outside. There was no contact of the gondola frame with the outside air, suspension being through nylon ropes and with a fiber support for the antenna dropper and flasher. The total weight of this gondola was about 47 lbs as prepared for a two-day flight, without parachute.

A second type of gondola devised for the program of balloon testing was the subminiature gondola which, weighing about 4½ lbs without parachute, was intended for flight on small diameter balloons. This gondola contained only the minimum necessary equipment, namely an Olland Cycle, a transmitter, batteries, and an antenna, and was encased in a 1" styrofoam box covered with aluminum foil. A separate blowdown timer, flown on some of these flights, consisted of a pocket watch altered for this purpose with batteries, a case, and blowdown squits and cannon. This weighed about six ounces.

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In addition to the flight equipment mentioned, some ground equipment has been developed including a portable receiver for station WWV to aid in theodolite tracking, a small portable plastic bell jar for testing pressure-operated equipment away from the laboratory, and an improved proportional reader for reading Olland Cycle records, among other things. Theodolite tracking and recovery arrangements continued to be a responsibility of instrumentation personnel, and the reading of records has become another.

B. Temperature Instrumentation

Two instruments have been used to measure temperatures in the air surrounding the balloon and within the balloon gas itself. Both employ thermistors as the temperature sensing elements, but the first was designed to record the measurements, while the second telemeters temperature information on one or more channels of the multi-channel pulse-coded transmitter. For a description of some of the problems relating directly to thermistor properties, See Volume IX, Section V.

1. The Air Thermistors

Although it is impractical to ventilate the air thermistor except on rapid ascent or descent, one concludes that the temperature error associated with a lack of rapid convection is on the order of 1° and can be neglected. Consequently, for air temperature measurements, one or two thermistors are either mounted on a non-hygroscopic lucite plate attached to the end of an aluminum pole which is attached to the gondola, or are suspended on an 8-ft lead and allowed to dangle below the gondola. In either case, care is taken to assure low electrical leakage and negligible temperature rise from conduction or radiation. Fig. I-1 shows the air thermistor pole mounting for Flight 73.

2. The Balloon Thermistor Droppers

Because of the extreme fragility of the rod thermistors,* it is necessary to protect those mounted in the balloon for gas temperature measurement from breakage during transport, inflation, and launch. During temperature flights, measurements have been taken at seven points within the balloon (cf. Fig. V-2, Volume IX, Section V); the thermistors are suspended at these points by dangling them on leads of appropriate length connected to the balloon fabric.

As shown in Figure I-2, the thermistor is mounted on a small wooden stick of low heat capacity and is surrounded by a wire helix which serves to protect the thermistor from falling against the balloon fabric during ascent and also as a spring to pop apart the two aluminum hemispheres. These hemispheres are held together by wrapping the suspension lead around them; this assembly is then mounted in a pressure-operated dropper (Figure I-3) which releases it at a predetermined pressure, allowing the sphere to unwind and fall off as the thermistor reaches its preassigned coordinate.

The thermistor is dropped into the balloon gas when the balloon has distended sufficiently for it to avoid dropping into the fabric.

---

* Friez Instrument Company, type ML 419/AMT-4

Fig. I-1. Temperature flight at launch showing recording type gondola with air thermistors and I.R. detector.

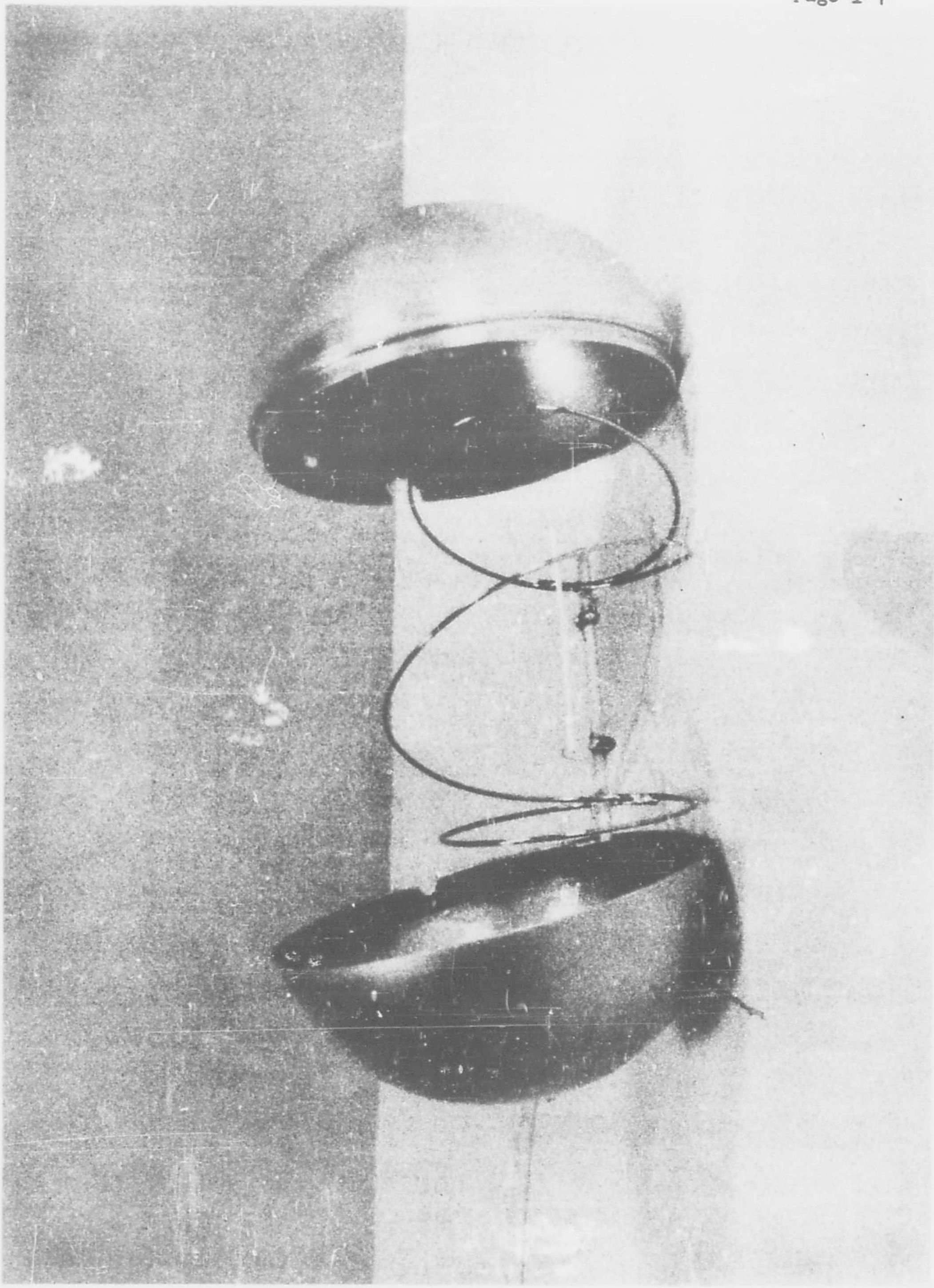


Fig. I-2. Balloon gas thermistor with protective sphere.

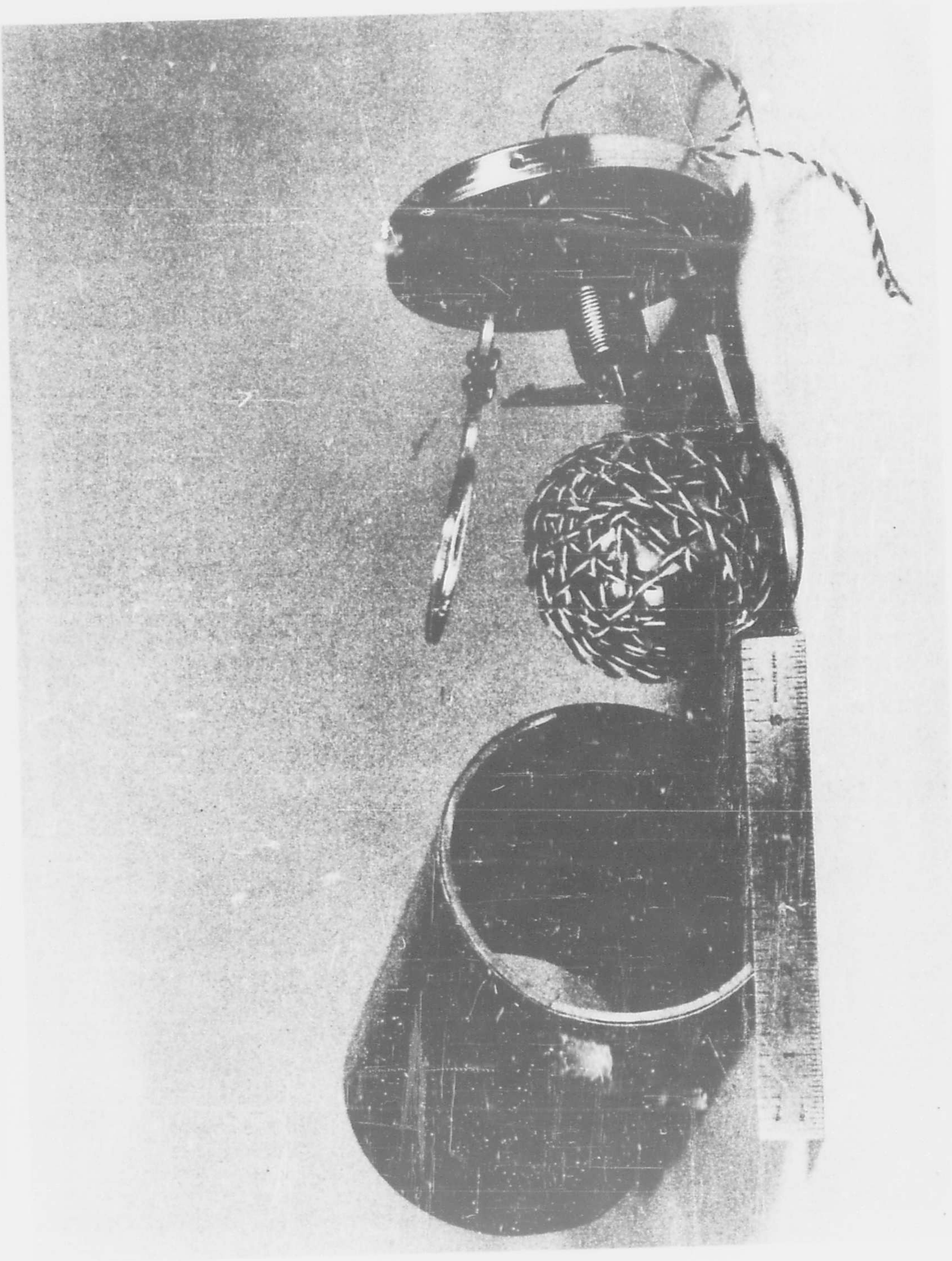


Fig. I-3. Balloon gas thermistor dropper for installation inside balloon.

However, because of the impracticability of calibrating a simple bellows to operate the latch mechanism below a pressure of about 250 mb, some thermistors have been prematurely released and have either broken or read temperatures abnormally high while in contact with the fabric. The temperatures indicated by the thermistors drop abruptly as the sphere falls away, exposing the thermistor to the balloon gas. This is indicated in the temperature plots (Volume IX, Section V) by a dotted line.

The thermistor dropper is mounted in a rigid aluminum cylinder encased in sponge rubber to protect the balloon fabric (Figure I-4) and suspended at a distance of about a foot from the balloon fabric by means of a grommet containing an Amphenol plug for electrical connections. Wires are run down one or more gores of the balloon. A view of the connections at the fabric and a thermistor dropper installed inside the balloon is shown in Figure I-5.

3. The Recorder Voltmeter

Over a moderate temperature range, the resistance-temperature characteristics of the ML 419/AMT-4 thermistor can be expressed approximately by the relation

$$R = R_0 e^{-bT},$$

where R_0 is the resistance at $0^{\circ}C$, b is a constant, and T is temperature in $^{\circ}C$. A choice exists in selecting a parameter to be read with such a characteristic. Supplying the thermistor with a constant current and then measuring the voltage drop

Fig. I-5. Complete dropper mounted in 2-mil double-wall 73' balloon near crown.

across the thermistor results in

$$V = IR_0e^{-bT}$$

$$\frac{dV}{dT} = -bIR_0e^{-bT}.$$

This system gives increasing sensitivity with decreasing temperatures, which is desirable for these particular measurements. Alternative systems which allow sensitivity independent of temperature would take advantage of the logarithmic characteristic.

As shown in Figure I-6, the thermistor constant current is generated by employing a large swamping resistor in series with the thermistor across a fixed voltage stabilized by a voltage reference tube. The 1U4 cathode follower circuit which couples the thermistor voltage to a 0-50 microammeter is independent of supply voltage variations and is not critical to adjust. Adjustments of the circuit are made by applying zero resistance in place of the thermistor and setting the meter current to 50 (full scale), then substituting a 2 megohm resistance (-74°C) and adjusting the grid control to give a reading of 5. It is unnecessary to plot a special calibration of scale vs. resistance since this is done automatically during flight. A typical curve so obtained from Flight 57 is shown in Figure I-7.

4. The Temperature Recorder

The complete recorder unit (Figures I-8, 9, 10, and 11) contains:

(1) an Automatic Electric telephone type stepping switch which selects the thermistor or calibrating resistor to be read;

(2) an instrument panel containing a chronometer, a mercury manometer, two 0-50 microammeters, one of which indicates the thermistor reading and

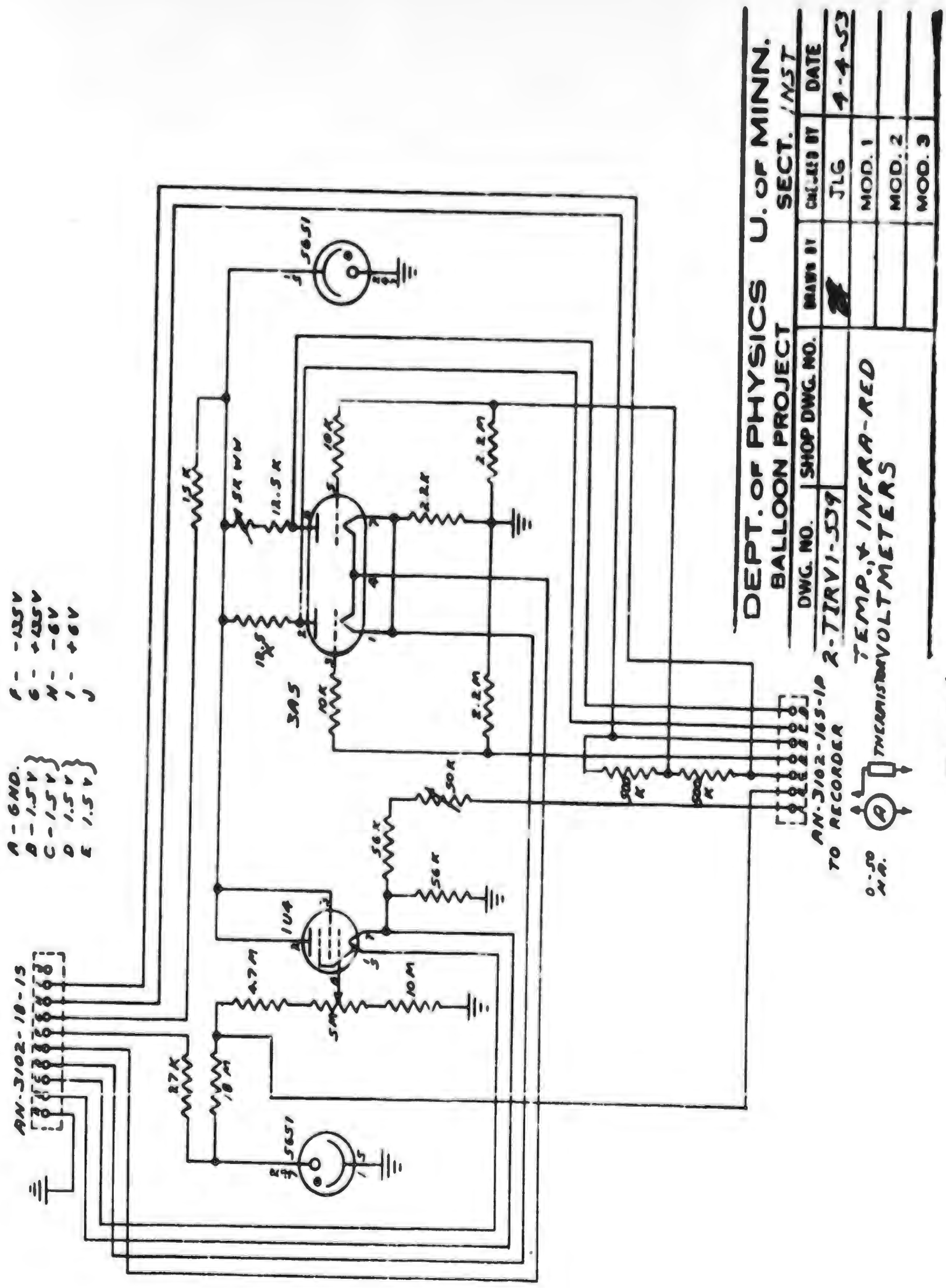

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
2-TIRV1-539
JLG
4-4-53
MOD. 1
MOD. 2
MOD. 3
TEMP. & INFRA-RED THERMISTOR VOLTMETERS
AN-3102-18-1S
TO RECORDER
3A5
1U4
5651

Fig. I-6.

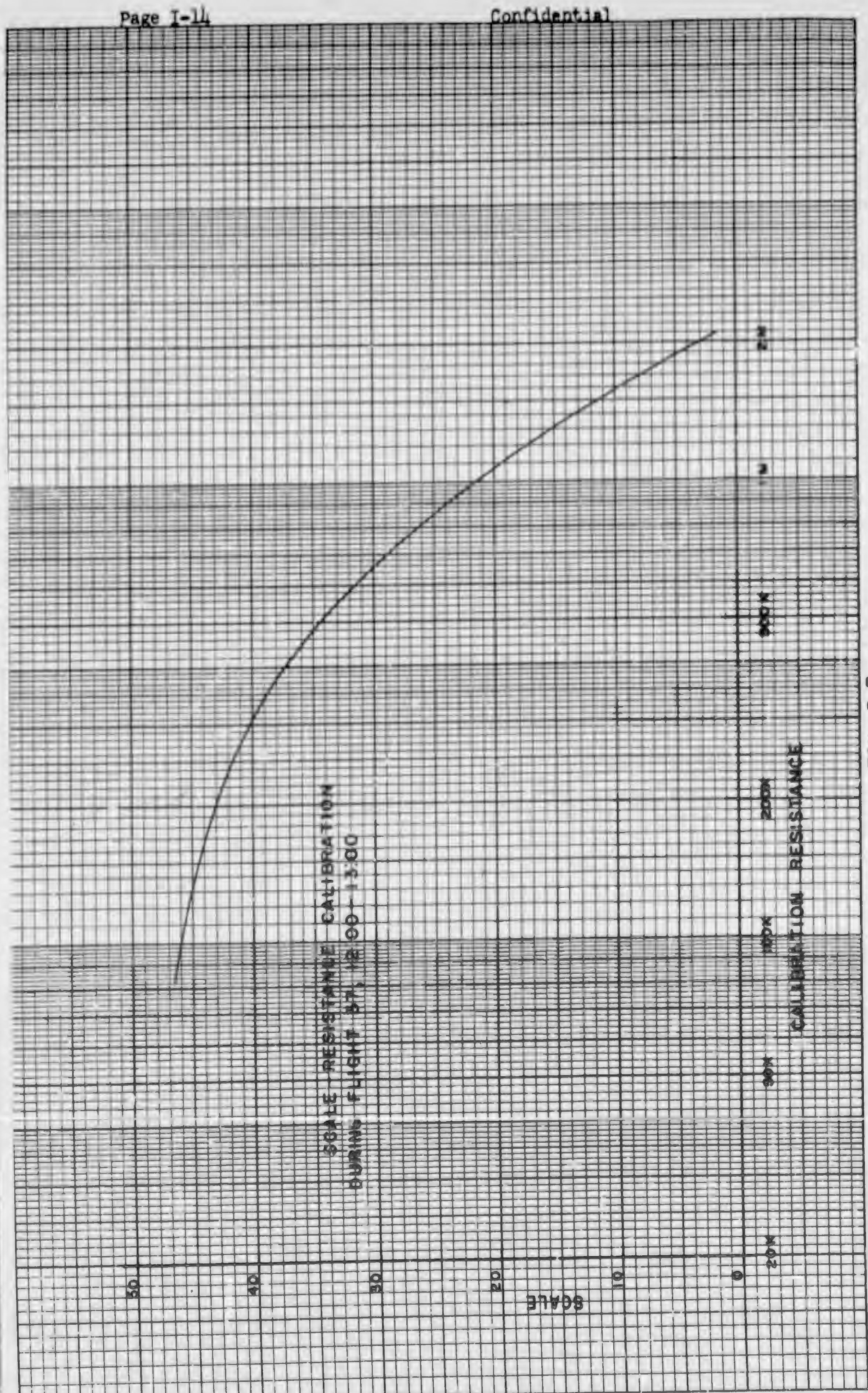

SCALE RESISTANCE CALIBRATION
DURING FLIGHT 37, 12:00-13:00
CALIBRATION RESISTANCE
SCALE
50
40
30
20
10
0
20K
50K
100K
200K
500K
1M
2M

Fig. I-7.

Fig. I-8. Temperature recorder case, closed.

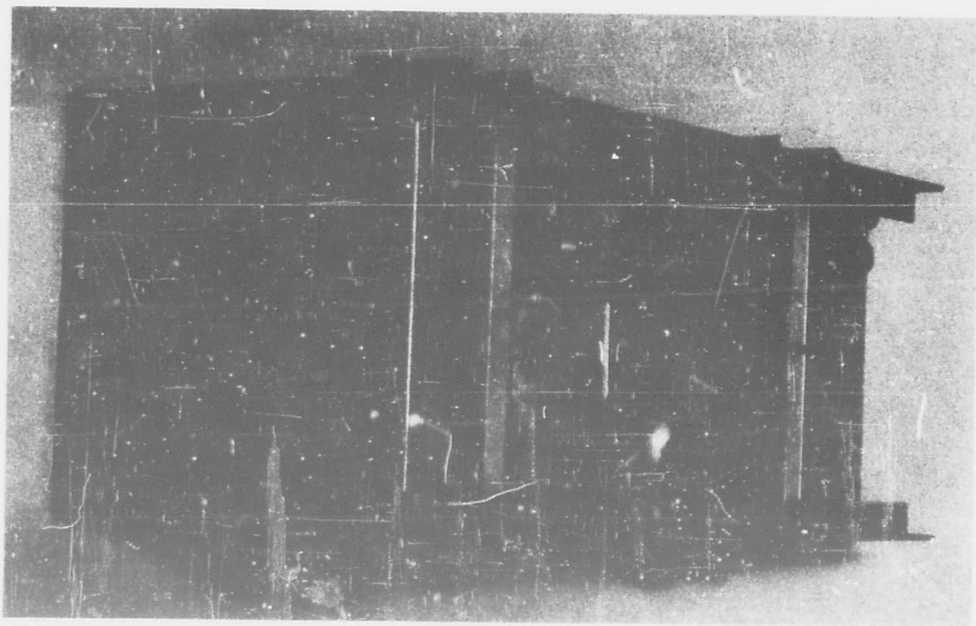


Fig. I-9. Temperature recorder case, open.

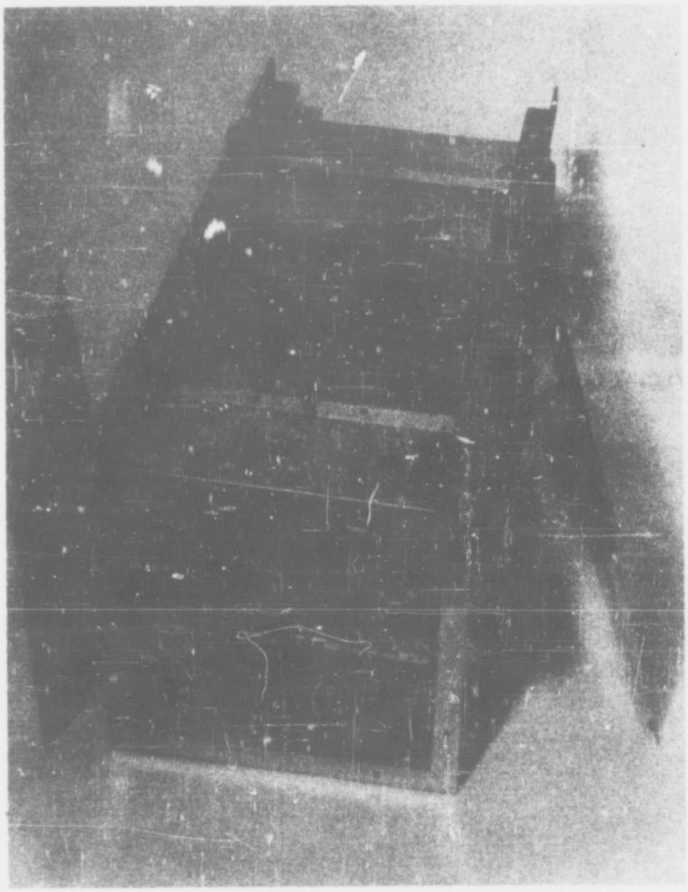


Fig. I-10. Temperature recorder showing instrument panel.

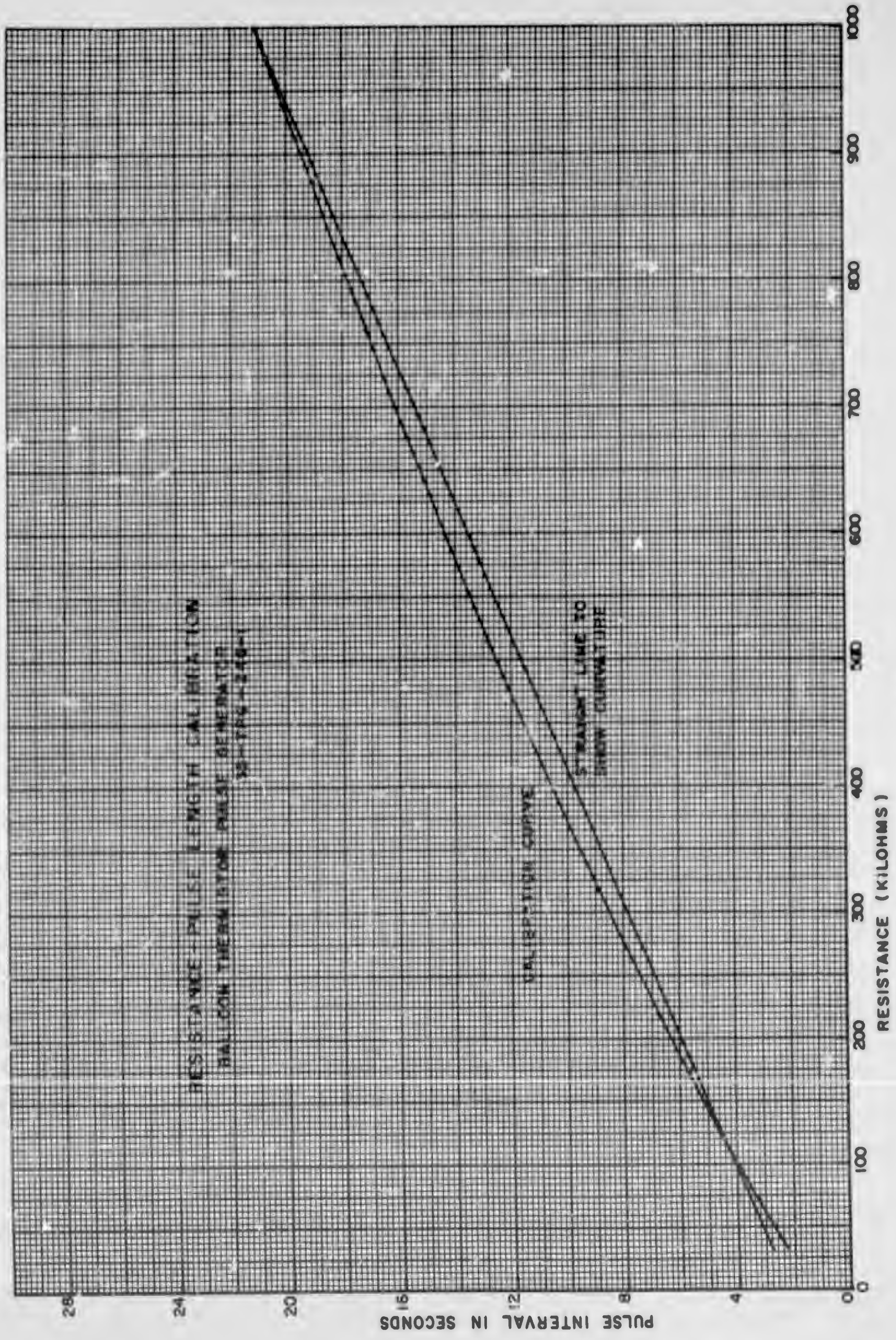

RESISTANCE - PULSE LENGTH CALIBRATION
BALLOON THERMISTOR PULSE GENERATOR
CALIBRATION CURVE
STRAIGHT LINE TO
SHOW CURVATURE
PULSE INTERVAL IN SECONDS
0
4
8
12
16
20
24
28
RESISTANCE (KILOHMS)
0
100
200
300
400
500
600
700
800
900
1000

Fig. I-11.

the other the infrared detector reading, and five indicating lights which positively identify the particular element being read;

(3) a 35-mm camera with an attached switch which synchronizes the stepping switch with the camera frames and turns on two illuminating lights when the shutter is tripped;

(4) a clutch mechanism which connects the camera motor to the camera for the period of one cycle of readings;

(5) a timer which initiates a cycle of readings at predetermined intervals; and

(6) plug connections for air thermistors, balloon thermistors, infrared detector, voltmeters, and power.

All of these are enclosed in a reasonably light-tight box supported on a rigid frame for attachment to the gondola. See Figures I-8, 9 and 10.

The timer which initiates a cycle closes a relay with holding contacts, which in turn energizes the clutch, thus starting the camera. Each revolution of the camera drive trips the shutter, then steps the stepping switch around one position, and repeats. This continues until, after taking the last picture in the cycle, the stepping switch again advances and applies a shutoff voltage to the holding relay, stopping the camera drive and the cycle. The camera motor revolves at 5 rpm, which means that each of the readings in a cycle occurs about 12 seconds apart. The timer can be preset to initiate a cycle every 2½, 5, or 10 minutes, giving a total recording time, since the camera can be loaded with 50 ft of film, of about 5, 10, or 20 hours respectively.

This system allows considerable flexibility in programming thermistor readings, and can be very readily set up for any duration flight. A sample record of the film is shown in Figure I-12.

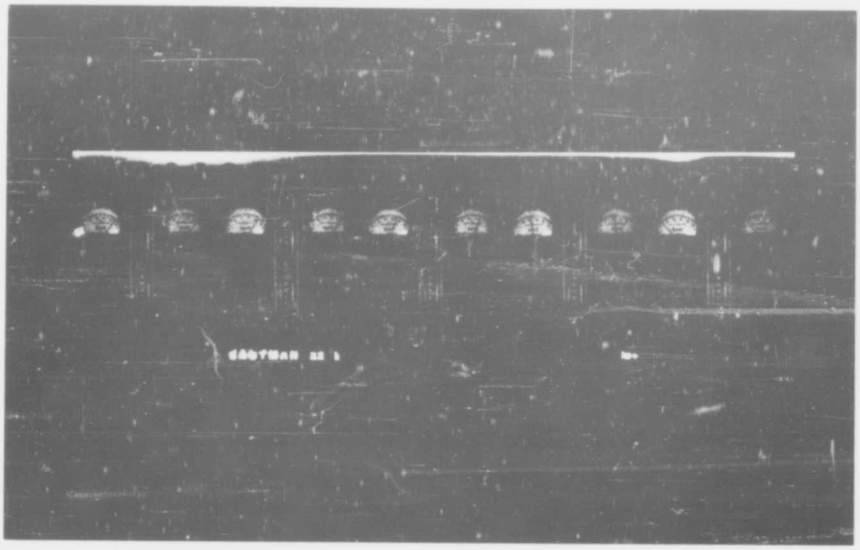


Fig. I-12. Sample film of temperature recorder.

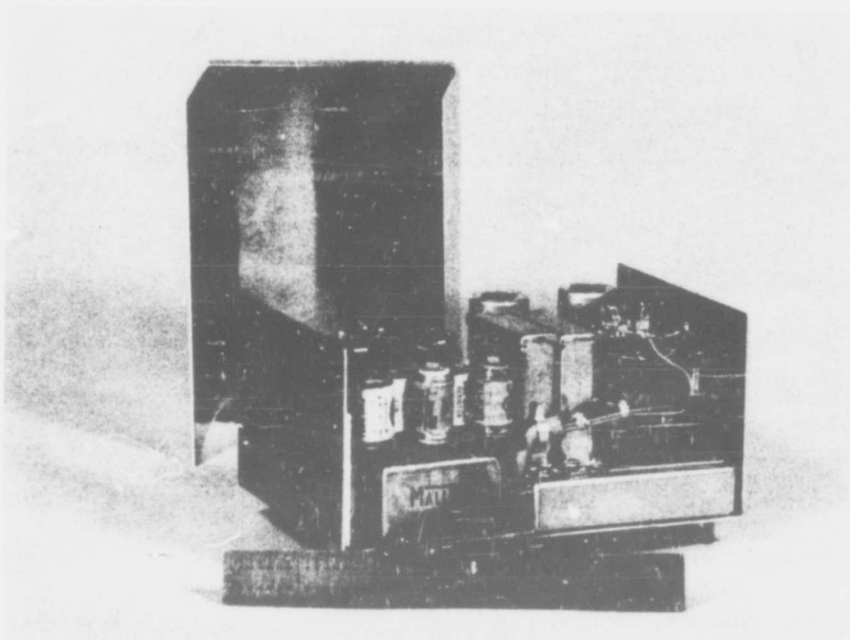


Fig. I-13. Thermistor pulse generator.

5. The Thermistor Pulse Generator

To obtain temperature data in cases where gondola recovery was unlikely, a means of modulating the telemetering transmitter by thermistors was developed.

The thermistor pulse generator (Figures I-13, 14, 15) was designed to key a telemetering transmitter at a repetition rate determined by the resistance of the thermistor. The circuit is a bootstrap relaxation oscillator with approximately linear characteristics.

In the simplified diagram, Figure I-16, pentode V_1 serves as a constant current generator in the charging of capacitor C, whose charging time is determined by the thermistor resistance R. The keying tube, V_2, is normally held nonconducting due to bias from battery B.

The change in voltage across capacitor C as a function of time is given by

$$\Delta E_c = \frac{1}{C}\int_0^t i\,dt,$$

and because of the "bootstrap" action,

$$i = \text{const.} = \frac{E_k}{R},$$

giving

$$\Delta E_c = \frac{E_k}{RC}t.$$

In a typical cycle of operation, C is allowed to charge until V_2 reaches a condition of near zero bias. V_2 then conducts, energizing the relay. One set of contacts discharges C and the other applies a ground to key the telemeter. When C is shorted V_2 is again biased to cutoff and the relay opens. V_1 now begins again to recharge C and repeat the cycle.

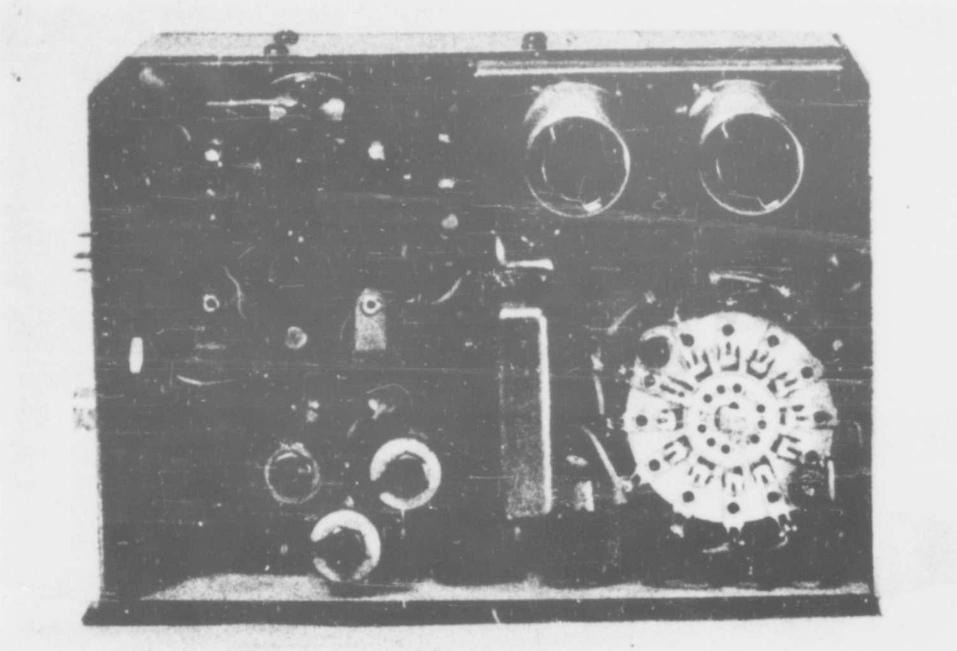


Fig. I-14. Thermistor pulse generator.

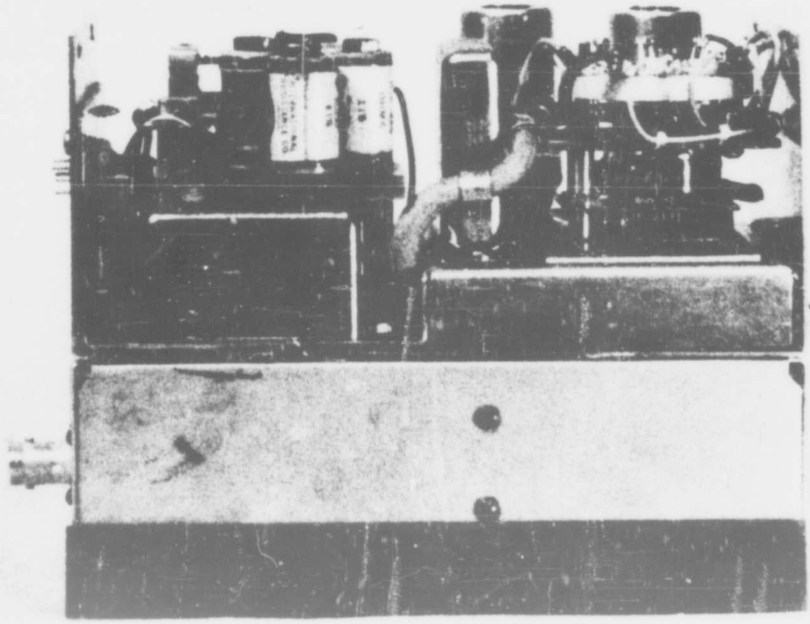
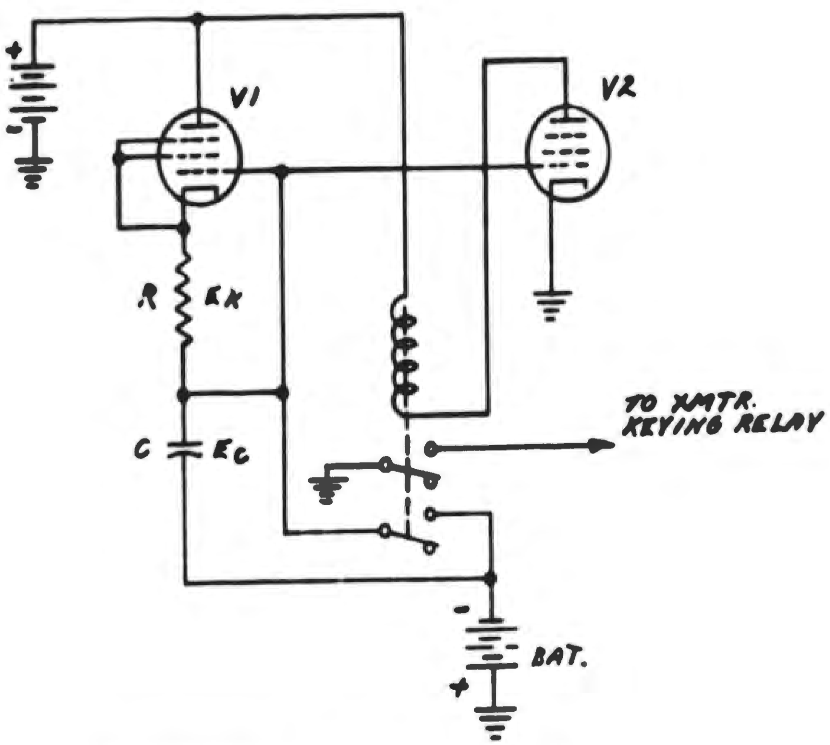


Fig. I-15. Thermistor pulse generator.



A SIMPLIFIED SCHEMATIC OF
THERMISTOR PULSE GENERATOR
BOOTSTRAP RELAXATION OSCILLATOR

Fig. I-16

The resistance of the thermistor increases with decreasing temperature, so a decreasing temperature decreases the repetition rate of the pulse generator. The generator circuit is designed to produce a repetition rate range of from 3 to 20 pulses per minute in the resistance range from 1 megohm to 40 kilohms respectively. The pulse rate is not a perfectly linear function of resistance, as shown in Figure I-17, but the variation is uniform from one unit to another and a standard correction can be applied. To compensate for individual differences in units and voltage changes during flight, two calibration resistors which enclose the typical operating extremes of thermistor resistance are periodically switched into the circuit. See Figure I-18 for the variation of pulse rate with changes in supply voltages.

For selection of readings, a Brailsford 1 rpm motor was modified to rotate a 12-position wafer switch one position each minute. This allows selection of 11 possible functions, two for calibration and the remaining nine for one or more thermistors or other elements. Three unit types have been developed to date -- their circuits approximate the simplified diagram, Figure I-16. The basic differences are in the component values and switching sequences.

Unit 33TPG-220 (Figure I-19) was designed to work with two thermistors, one mounted inside the gondola and the other in the outside air. Two 6BH6's were selected in this circuit for their low heater drain. The charging pentode uses +22½ v screen voltage and a fixed resistor to limit the charging current. The charge capacitor in this unit is 1 mfd. The pulse duration is prolonged by use of a 20 mfd electrolytic capacitor on the plate side of the keying tube.

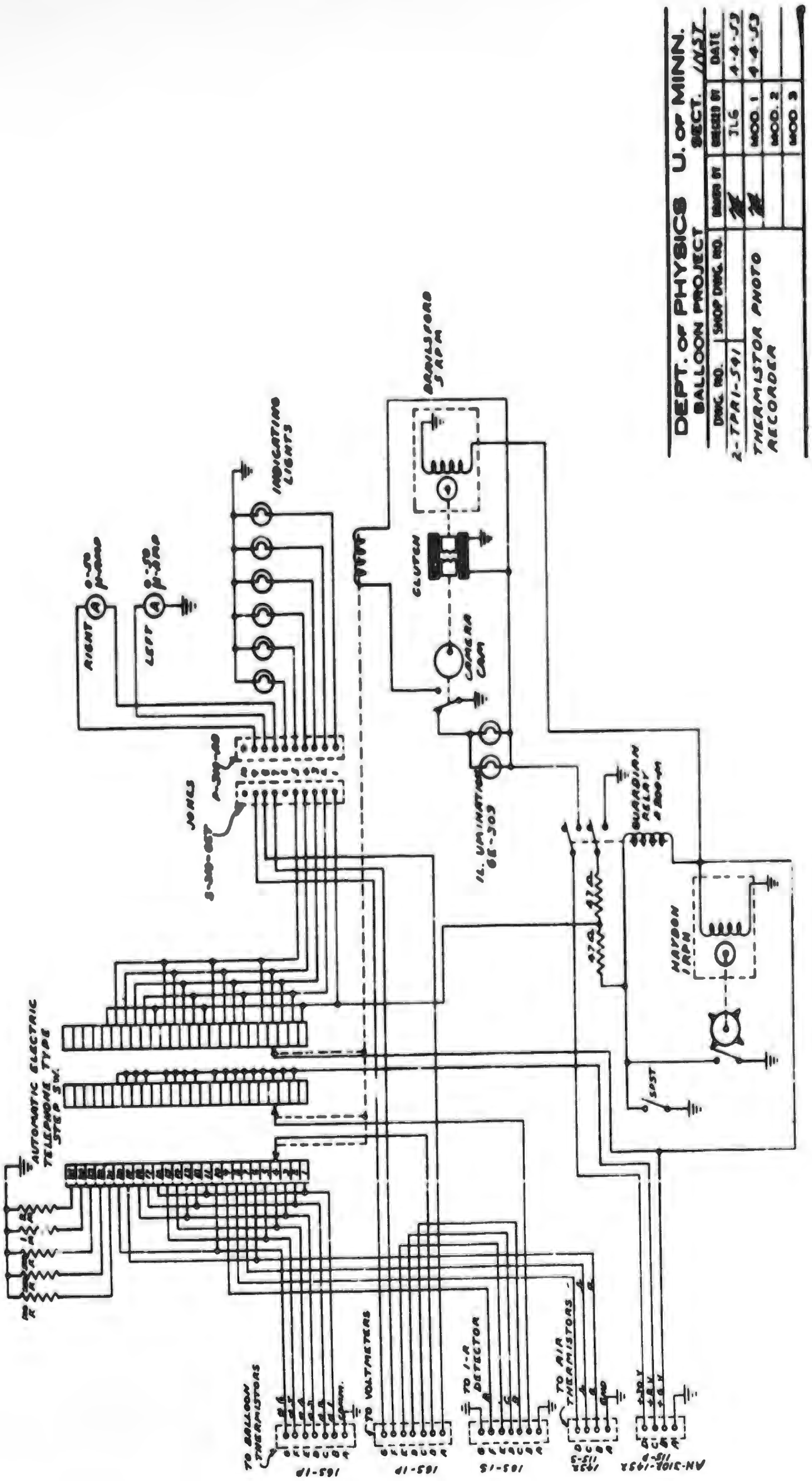

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
THERMISTOR PHOTO RECORDER
INDICATING LIGHTS
CLUTCH
CAMERA CAM
AUTOMATIC ELECTRIC TELEPHONE TYPE STEP SW.
TO BALLOON THERMISTORS
TO VOLTMETERS
TO I-R DETECTOR
TO AIR THERMISTORS

Fig. I-17.

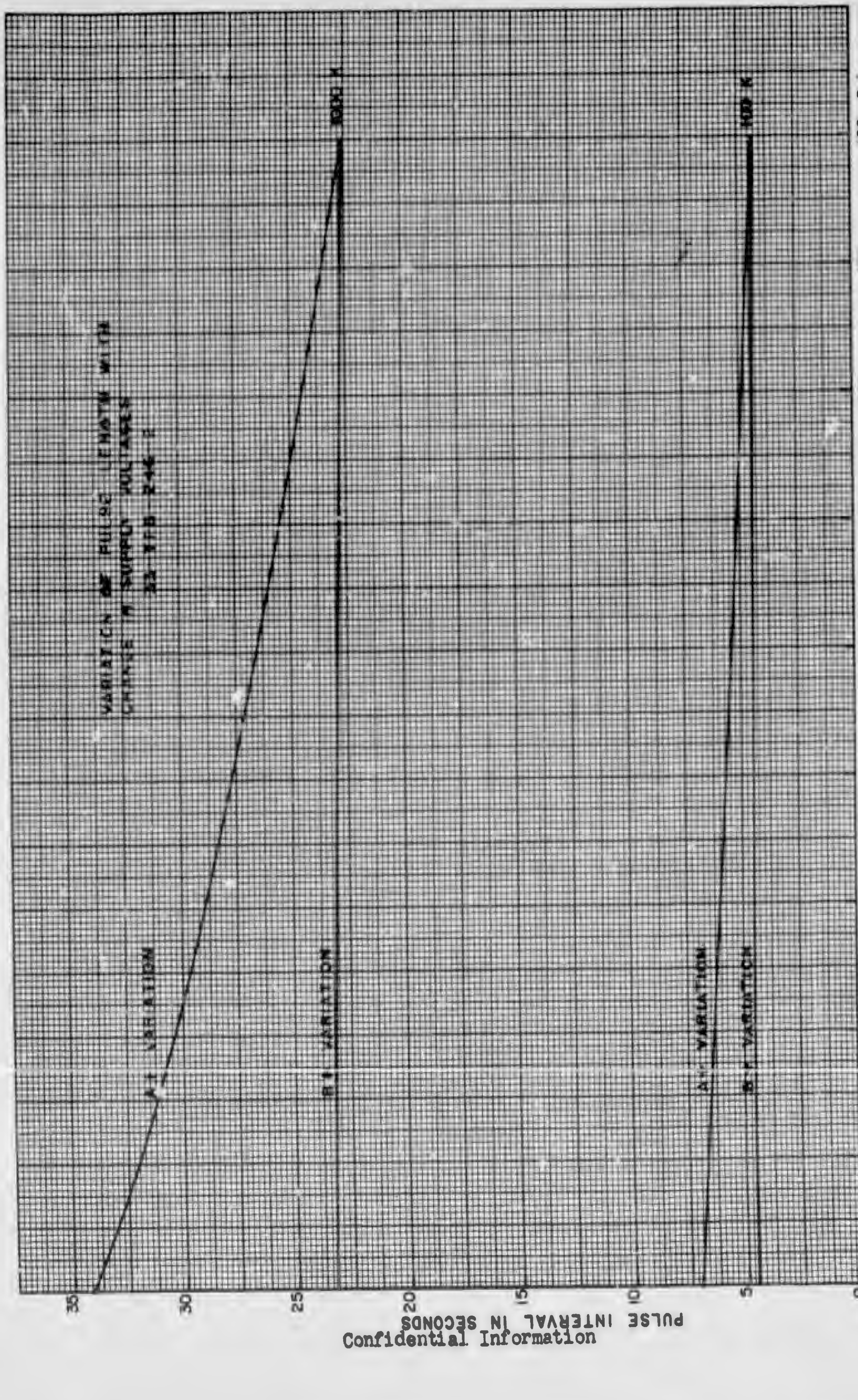

VARIATION OF PULSE LENGTH WITH
CHANGE IN SUPPLY VOLTAGES
A+ VARIATION
B+ VARIATION
1000 K
100 K
PULSE INTERVAL IN SECONDS
0 5 10 15 20 25 30 35
135 140 145 150 155 160 165 170 175 180 B+
5.1 5.2 5.3 5.4 5.5 5.6 5.7 5.8 5.9 6.0 A+

Fig. I-18.

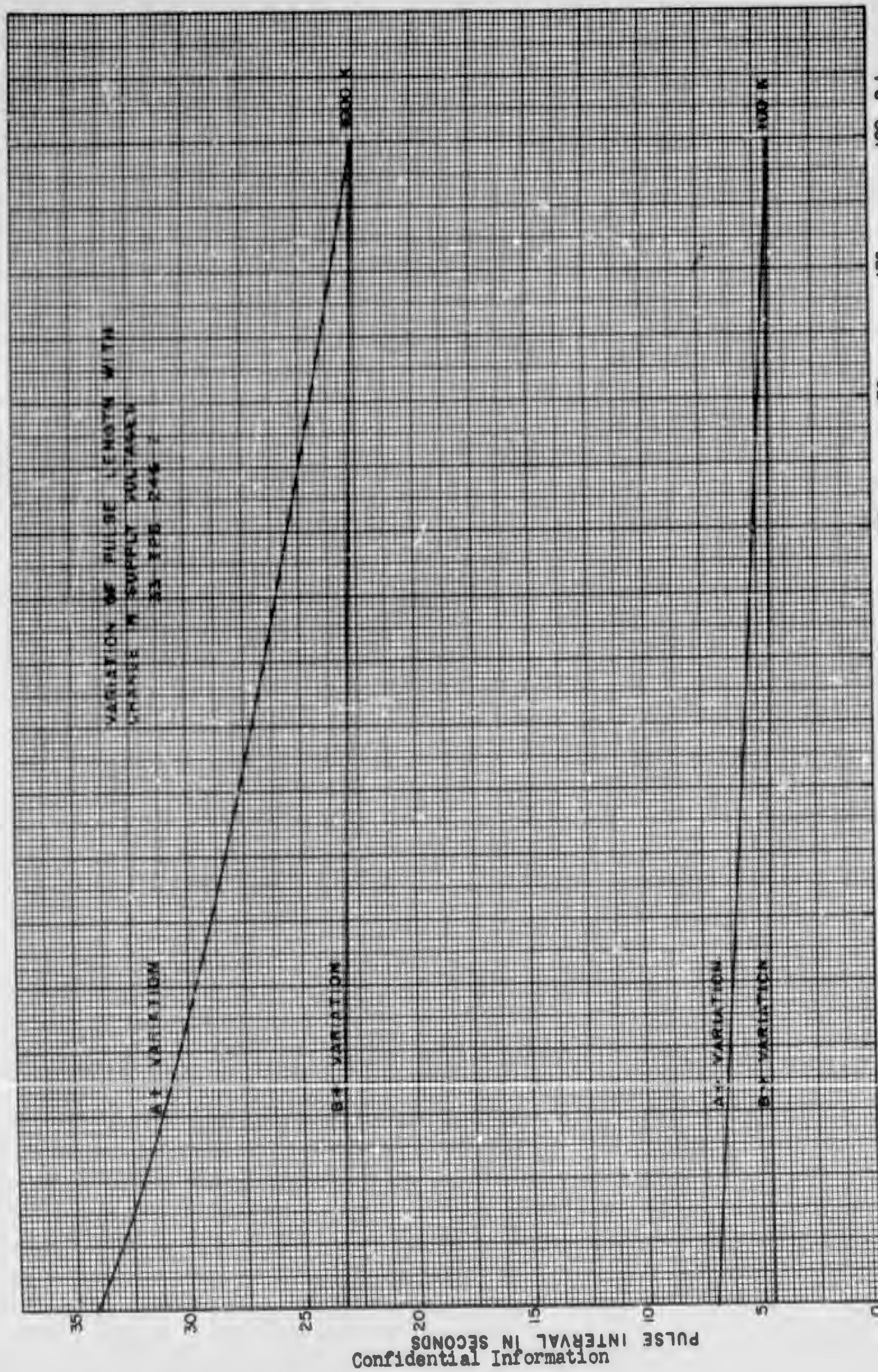

VARIATION OF PULSE LENGTH WITH
CHANGE IN SUPPLY VOLTAGES
A+ VARIATION
B+ VARIATION
1000 K
A+ VARIATION
B+ VARIATION
100 K
PULSE INTERVAL IN SECONDS
0
5
10
15
20
25
30
35
135 5.1
140 5.2
145 5.3
150 5.4
155 5.5
160 5.6
165 5.7
170 5.8
175 5.9
180 6.0
B+ A+

Fig. I-18.

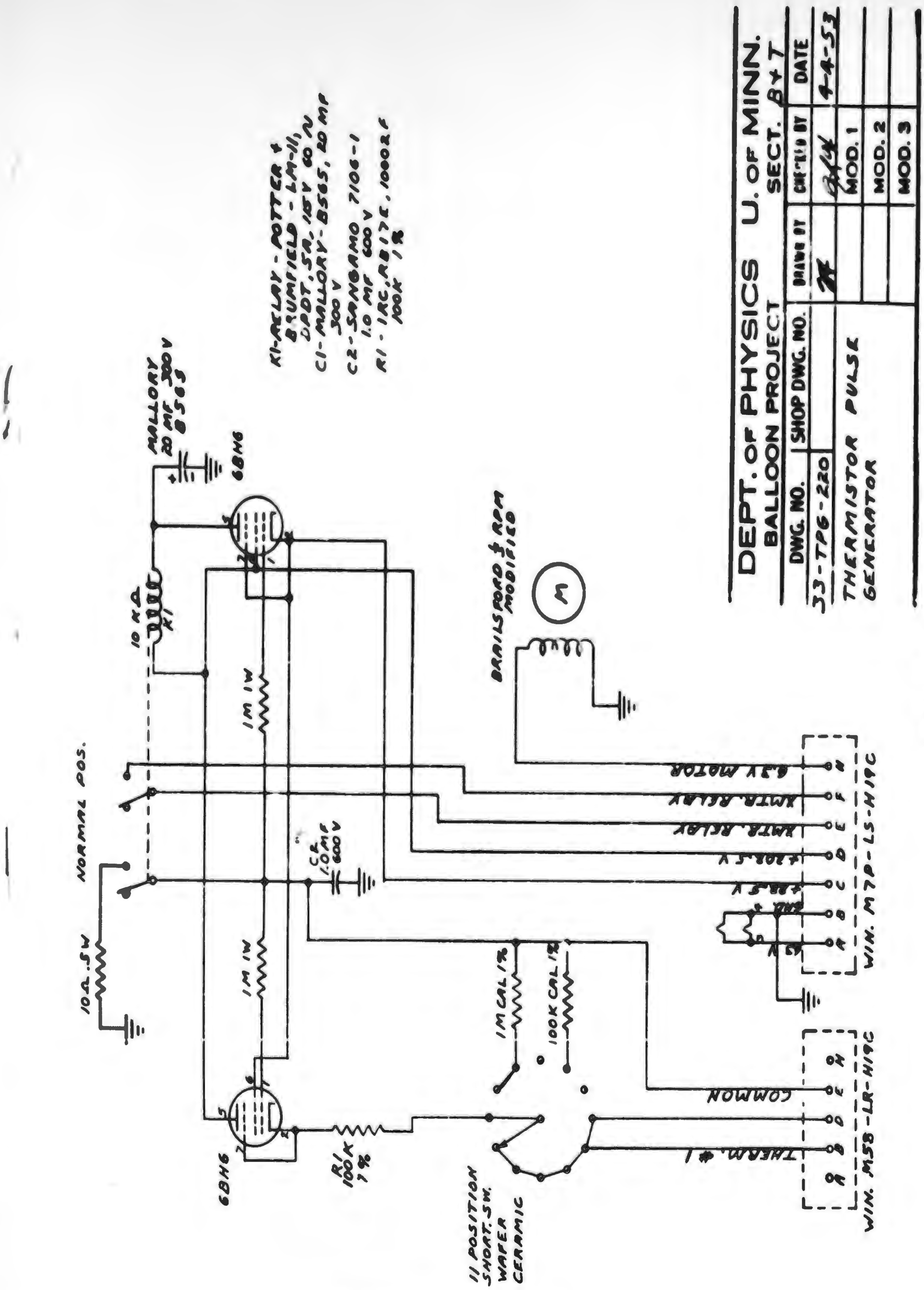

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
SECT. B+T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHK'D BY
DATE
33-TPG-220
4-4-53
MOD. 1
MOD. 2
MOD. 3
THERMISTOR PULSE GENERATOR
6BH6
NORMAL POS.
COMMON
THERM. #1
6.3 V MOTOR
XMTR. RELAY
11 POSITION SHORT. SW. WAFER CERAMIC
BRAILSFORD 4 RPM MODIFIED

Fig. I-19.

Unit 33TPO-228 (Figure I-20) is identical with Unit 220 except for additional components to give infrared detector information on switch positions 5, 6, and 8.

Unit 33TPO-246 (Figure I-21) is designed to operate with a companion transmitter which relays temperature information from the tow balloon to the gondola on load balloon flights. The pulse generator, transmitter, and power supplies are encased in a canvas bag and suspended from the tow balloon. See Figure I-22.

The first two models of the pulse generator have several disadvantages that have been remedied in the redesign of the type presently in use. The effective plate resistance of the 6BH6, when used as the charging pentode, varies to a great degree from tube to tube, which necessitates a good deal of tube selection. In unit 246, this charging tube has been replaced with a 6BJ6, a remote cutoff pentode which operates more uniformly under the conditions of low charging current used in this generator. Along with the tube change, the awkward 22½ v bias battery is replaced with a standard 45 v battery, the 1 mfd capacitor is reduced to 0.4 mfd, the fixed resistor in the cathode circuit of the charging tube is eliminated and the pulse duration is increased to improve readability. In addition to the electronic changes, the relay is modified by adding a pair of contacts to energize the companion transmitter keying relay, and a switch has been added to the thermistor switching assembly to key the transmitter for six seconds while switching between positions. This latter switch clearly defines the pulse groupings and facilitates data read-out.

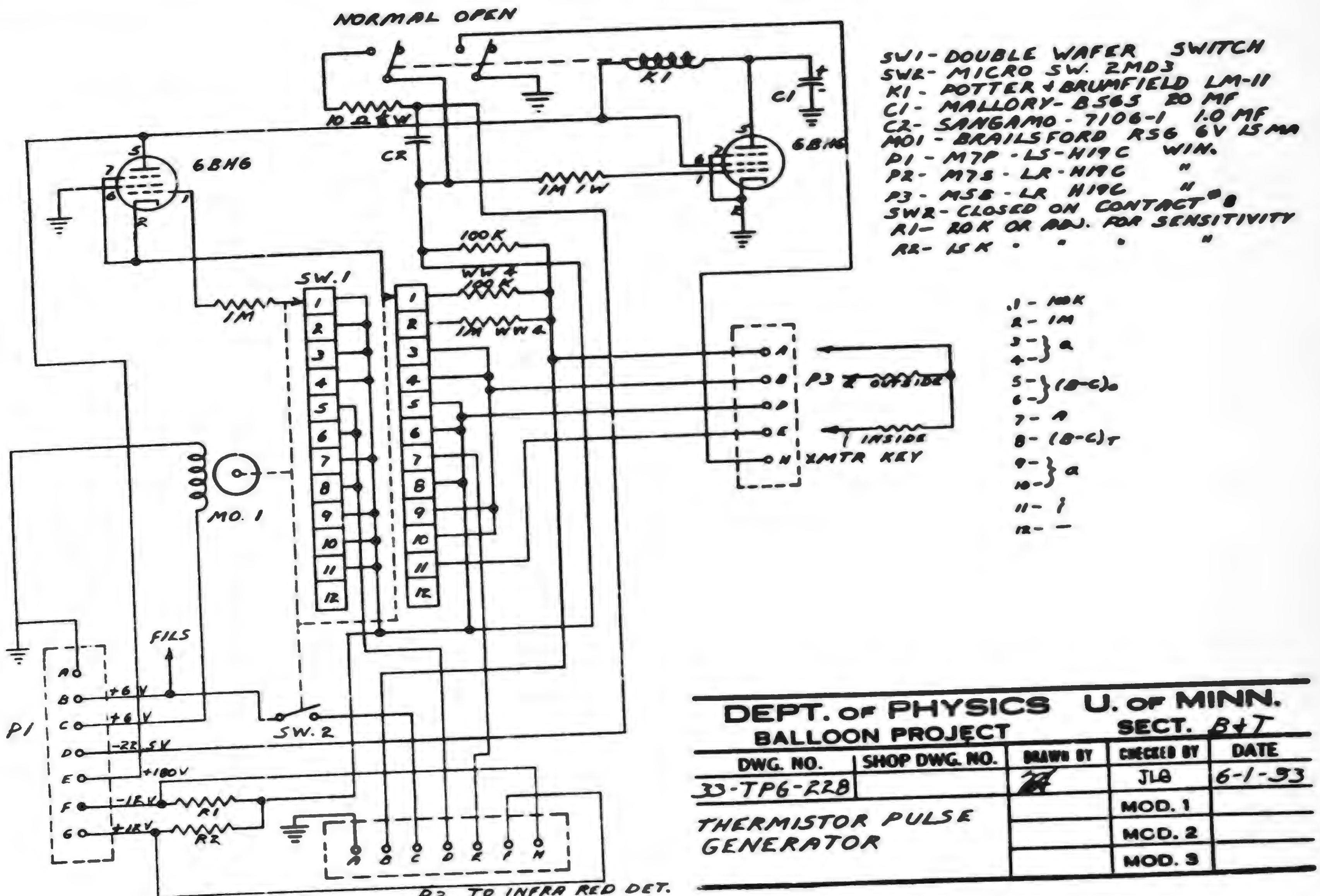

NORMAL OPEN
10 Ω 2 W
CR
1M 1W
6BH6
6BH6
K1
C1
100K
WW 2 100K
1M WW 2
1M
SW.1
MO. 1
FILS
P1
+6 V
+6 V
-22.5 V
+180 V
-18 V
+18 V
R1
R2
SW. 2
P3
OUTSIDE
INSIDE
XMTR KEY
P2 TO INFRA RED DET.
SW1 - DOUBLE WAFER SWITCH
SW2 - MICRO SW. 2MD3
K1 - POTTER & BRUMFIELD LM-11
C1 - MALLORY - BS65 20 MF
C2 - SANGAMO - 7106-1 1.0 MF
MO1 - BRAILSFORD RS6 6V 15 MA
P1 - M7P - LS - H19C WIN.
P2 - M7S - LR - H19C "
P3 - M5S - LR H19C "
SW2 - CLOSED ON CONTACT # 8
R1 - 20K OR ADJ. FOR SENSITIVITY
R2 - 15K " " " "
1 - 100K
2 - 1M
3 - } a
4 -
5 - } (B-C)o
6 -
7 - A
8 - (B-C)T
9 - } a
10 -
11 - ?
12 - —
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B+T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
33-TP6-228
JLB
6-1-53
MOD. 1
MOD. 2
MOD. 3
THERMISTOR PULSE GENERATOR

Fig. I-20.

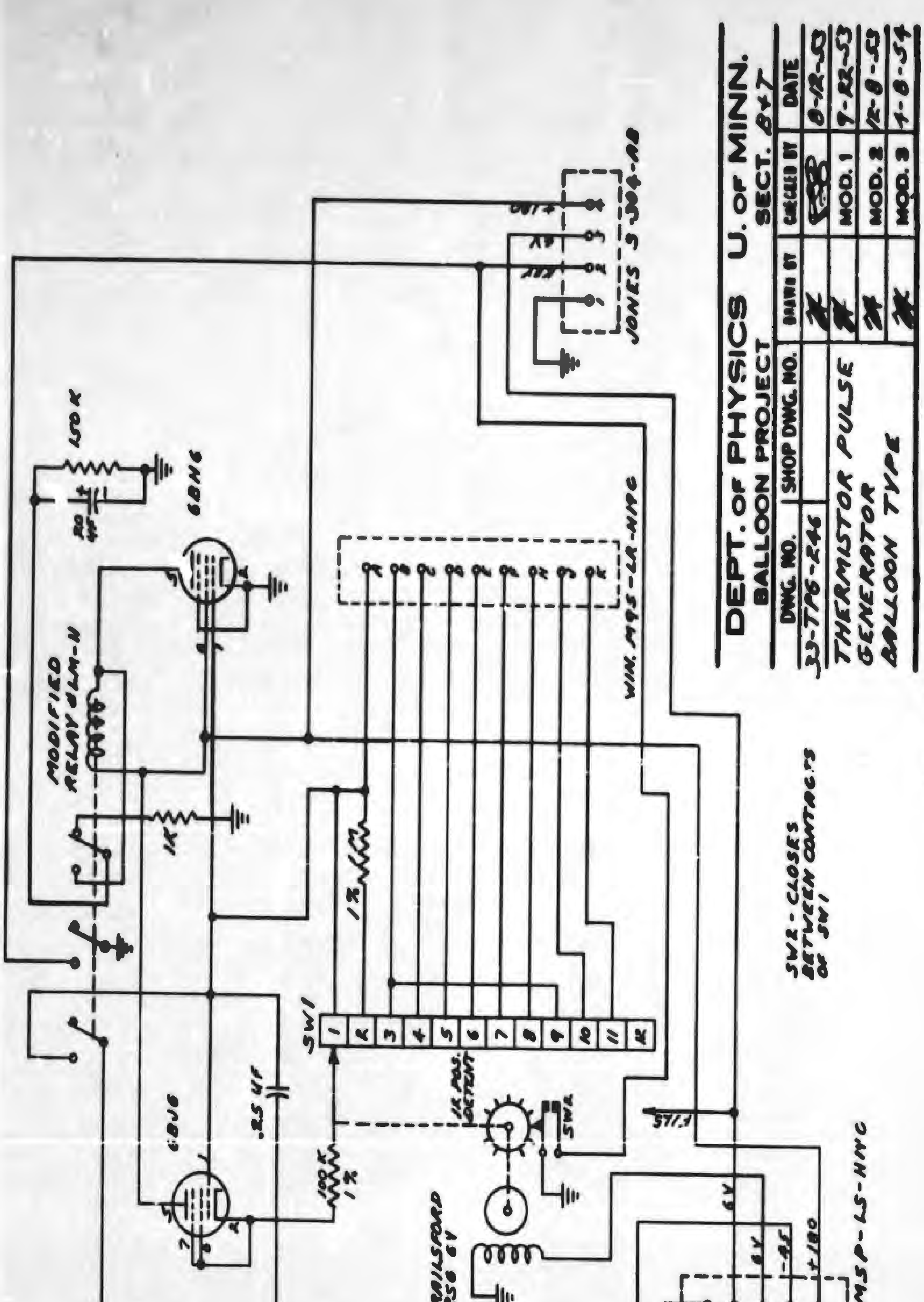

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B+T
DWG. NO. 33-TPG-246
THERMISTOR PULSE GENERATOR BALLOON TYPE
MOD. 1 9-22-53
MOD. 2 12-8-53
MOD. 3 1-8-54
8-12-53
MODIFIED RELAY
SW1
SW2
6BN6
6BJ6
150 K
1K
1 M
100 K
.25 UF
BRAILSFORD
12 POS. DETENT
SW2 - CLOSES BETWEEN CONTACTS OF SW1
JONES S-304-AB
WIN-M9S-LR-HNG
WIN-M5P-LS-HNG
+180
6 V

Fig. I-21.

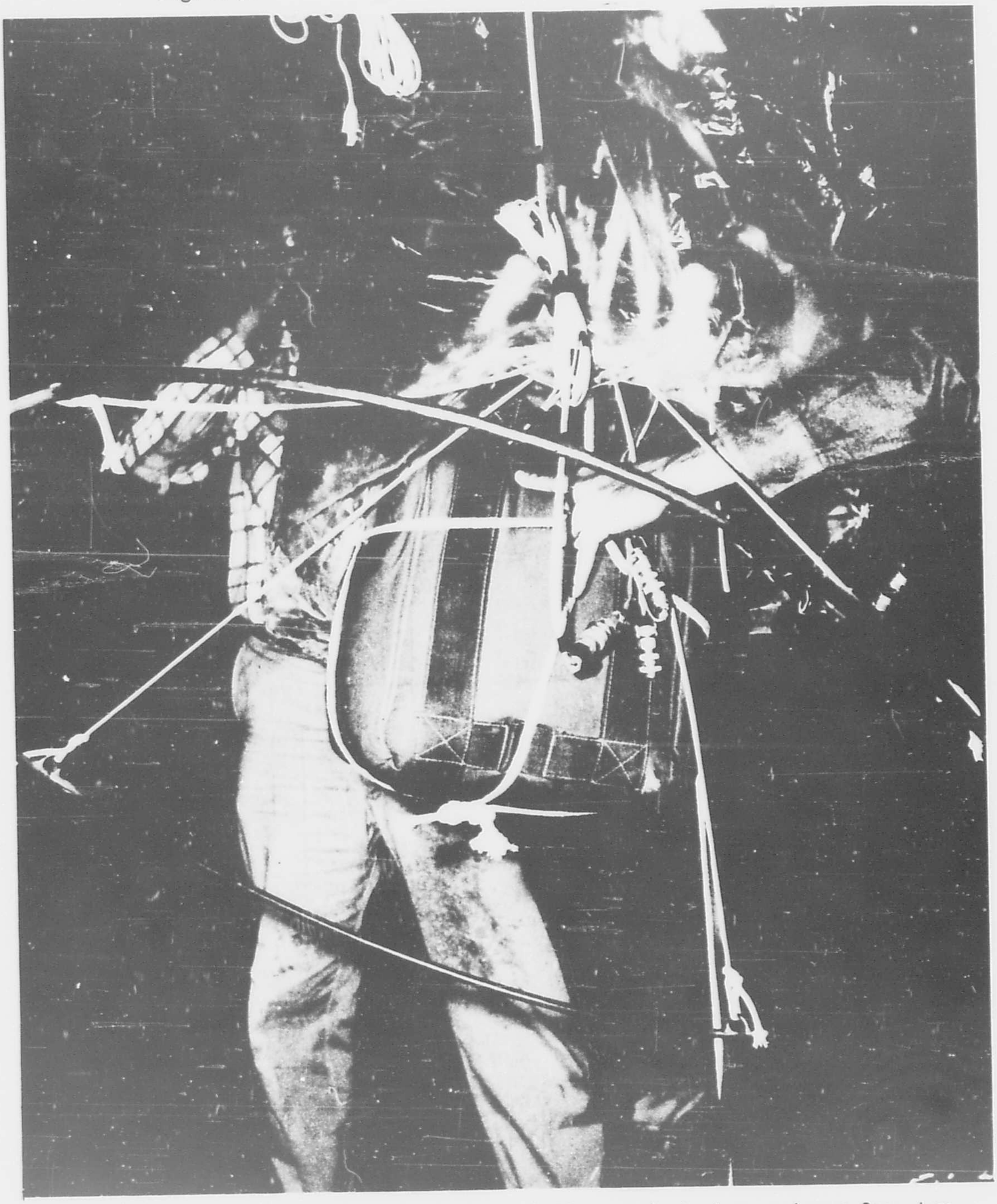


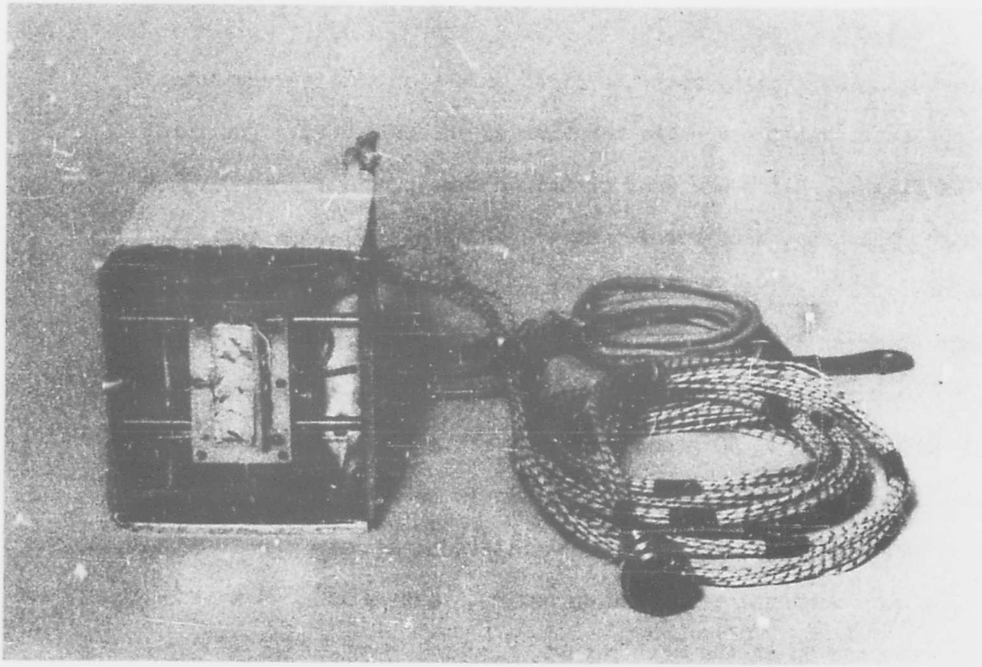
Fig. I-22. Equipment for transmitting balloon and air temperatures from tow balloon during step flights. The package contains a thermistor pulse generator, 10 mc transmitter and batteries. The 10 mc signal is relayed by the main telemetering system.

One major difficulty with the first models of the temperature pulse generator was the erratic behavior of the unit during the first hours of flight. Since the unit contained some circuits operating at very high resistance with respect to the chassis, a leakage resistance due to absorption of water vapor in hygroscopic elements was suspected. Although encasing the units in sealed polyethylene bags with a dessicant effected considerable improvement, the possibility that leakage resistances on the order of 50 megohms could seriously affect the accuracy dictated the redesign of the unit. The newer model pulse generator, flown after Flight 137, is far less sensitive to leakage and is consequently a more accurate telemetering device. The details of this unit will be reported on in the next report.

C. Infrared Measurements

A description of the theory of operation of the infrared detector is given in Volume IX, Section V of this report. Two models of the device have been used to date. The first of these, 2-IRD 1-540, is shown in Figures I-23 and I-24, with the shutter open and closed. The detector block is made of two pieces of brass, heavily silver-plated, such that when assembled they form a tight seal on a window of silver chloride, used as a filter and a pressure window. Two thermistors are mounted in two holes drilled lengthwise through the block; the surrounding space is filled with wax to assure good thermal contact. The third thermistor is mounted behind the silver chloride window on two Stupakoff seals. See Figure I-25.

In this detector, the shutter is made of thin aluminum foil mounted on a wire frame. The frame is attached to a springy brass arm which is



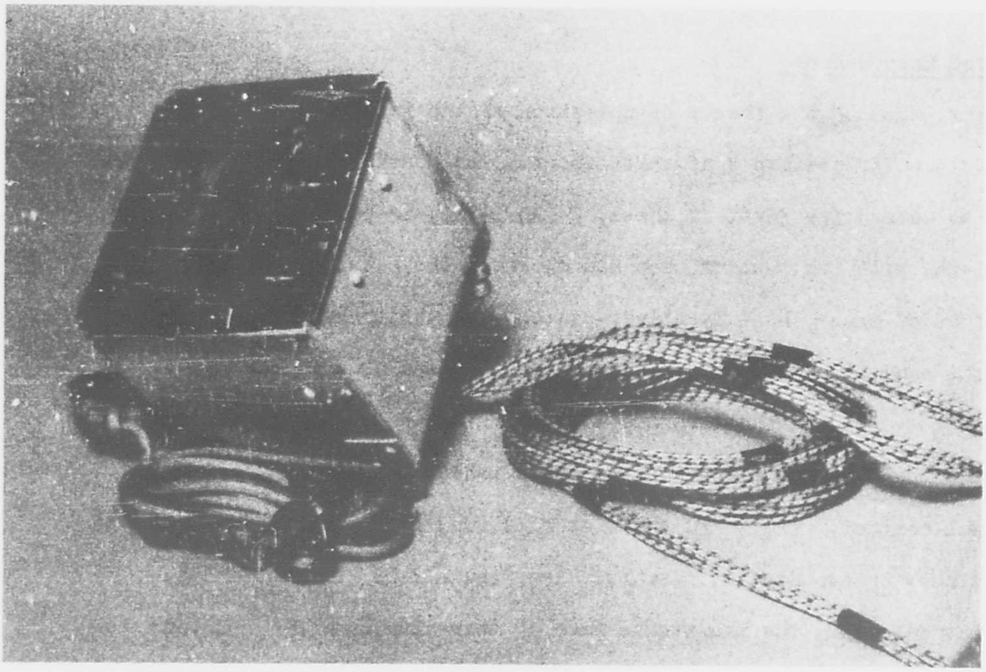


Fig. I-23 (top) and Fig. I-24. Two views of the Model I I.R. detector.

CUTAWAY VIEW OF
INFRA-RED DETECTOR
MODEL 2-IRD-540

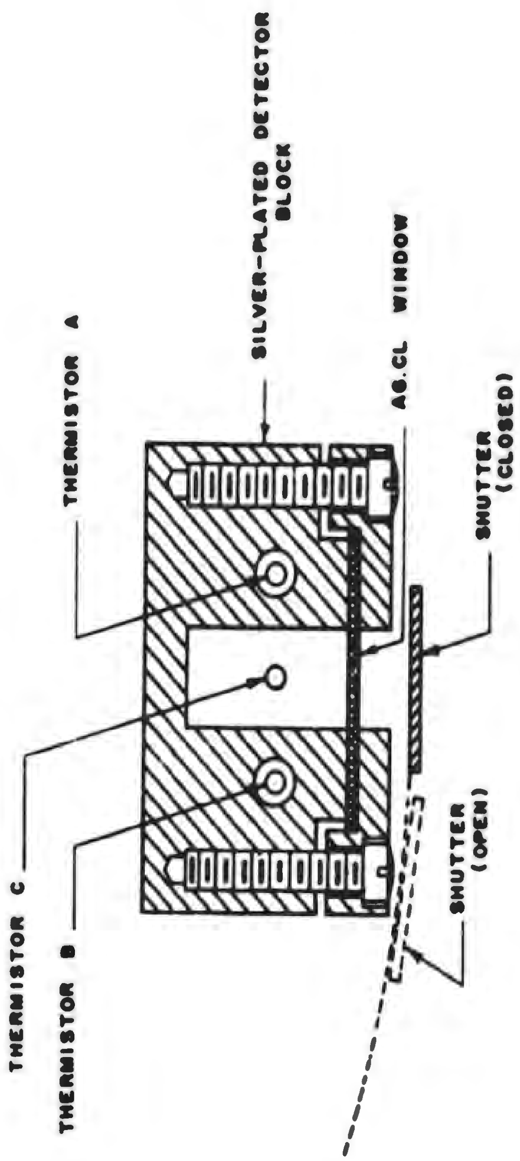


Fig. I-25.

forced to one side as the armature of a modified Guardian relay closes; this movement pushes the aluminum shutter away from the window, exposing the thermistor behind the silver chloride window to the incident radiation.

The block, shutter mechanism, and electrical connections are enclosed in a rigid aluminum box, painted white to minimize solar absorption, and this is suspended beneath the gondola during flight. For the electrical connections, see Figure I-26.

Model 2-IRD 2-547 is a much more compact detector designed to operate from within the gondola or on the frame of the step flight gondola. The two sensing thermistors are bead types,* which have essentially the same characteristics as the rod thermistors but a much smaller thermal lag. The third thermistor is the type used for the other temperature measurements and acts here as a block thermometer. As shown in Figures I-27, 28, and 29, the shutter is made of 0.050" aluminum, mounted on the movable plate of a Ledex rotary solenoid,** which rotates the shutter away from the thermistor cavity. Good thermal contact with the block is maintained in either open or closed position by shaping the shutter so that most of its edge is always in contact with the block wall. During operation, the rotary solenoid is periodically switched on and off and soon reaches thermal equilibrium, the solenoid acting somewhat like a temperature stabilizer.

The voltmeter circuit which measures the voltage output from the detector bridge circuit is shown in Figure I-6. The voltmeter is itself a bridge with a self-balancing feature; a change in voltage between the two

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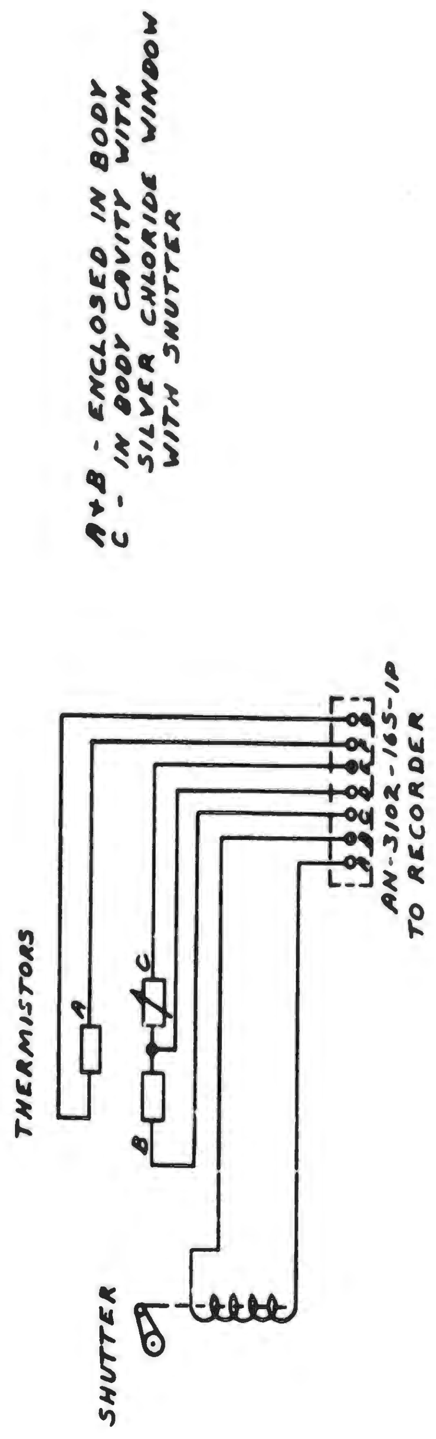
* Victory Engineering Co., Type 51A2.

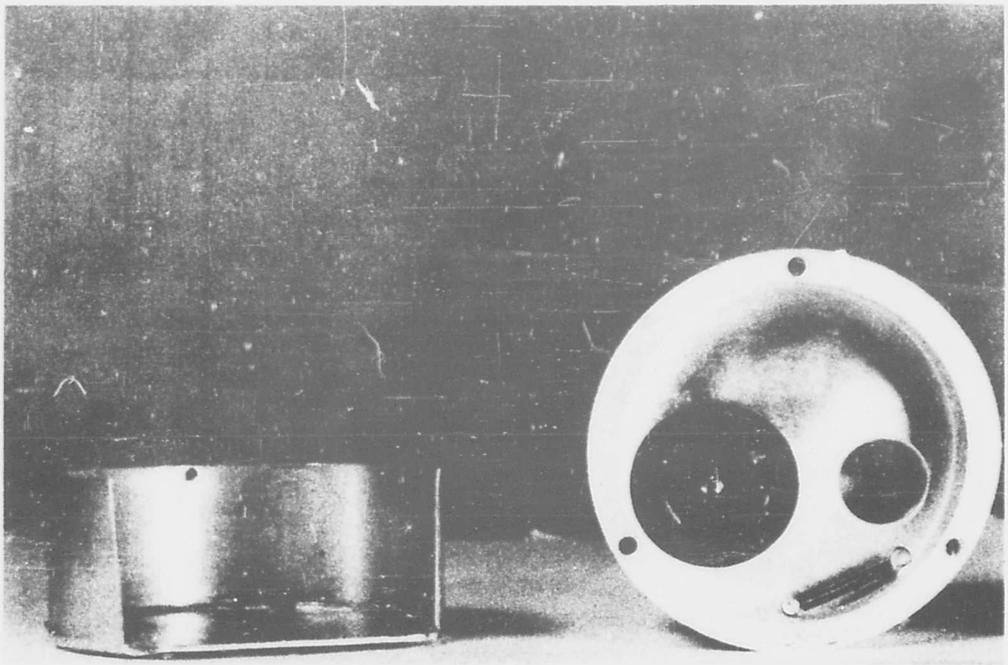
** G. H. Leland, Inc., Type BD2-SR-45-28-X5.



DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
2-IRD1-540			JLG	4-4-53
INFRA-RED DETECTOR			MOD. 1	
			MOD. 2	
			MOD. 3	

Fig. I-26.



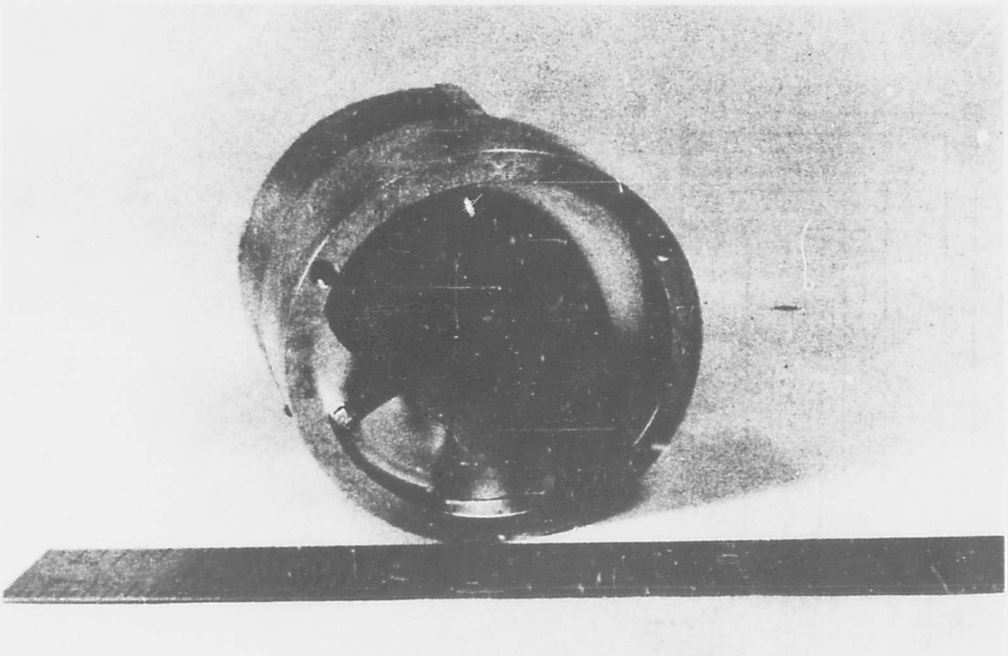


Fig. I-27 (top) and Fig. I-28. Two views of improved I.R. detector, Model II.

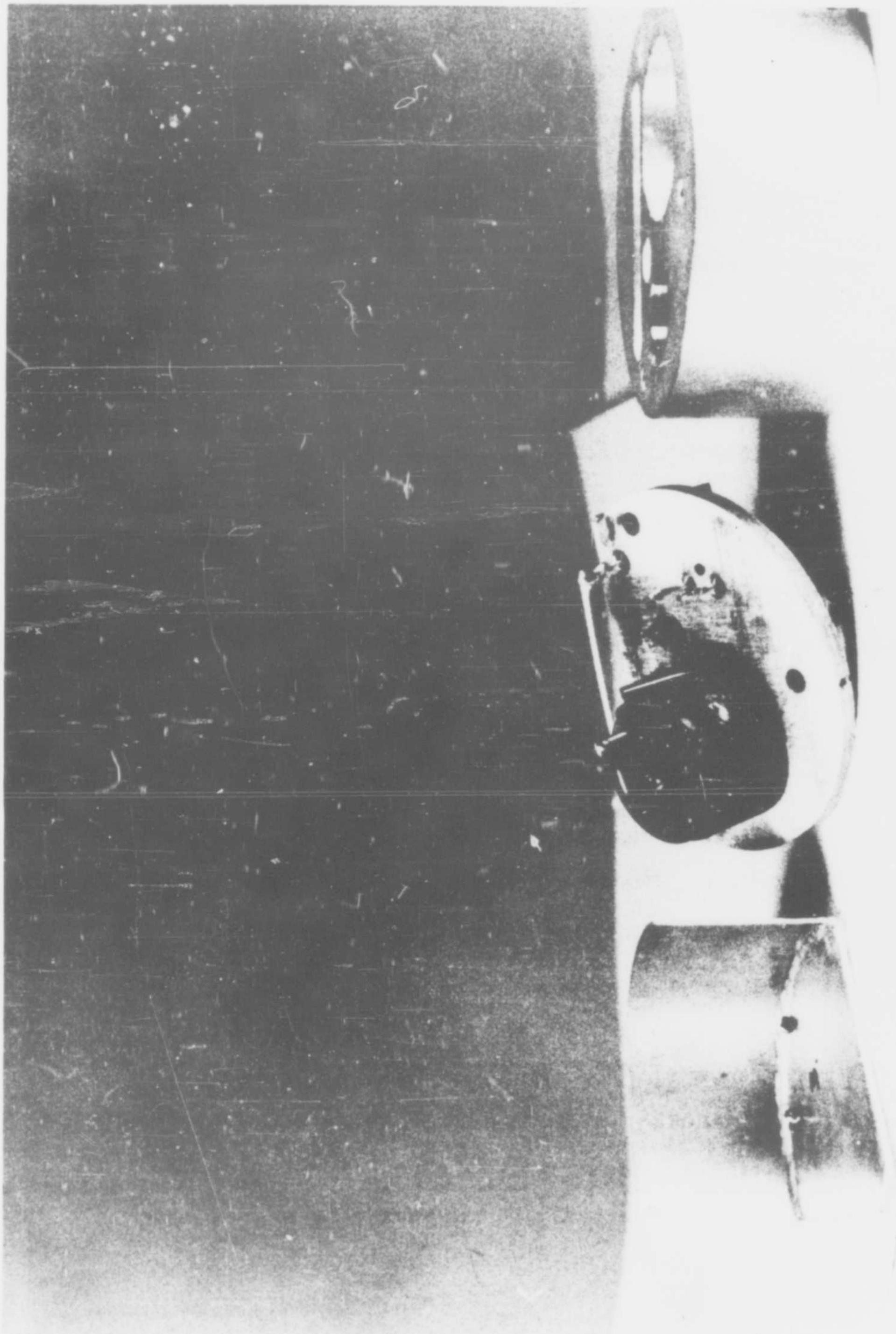


Fig. I-29. Components of Model II I.R. detector.

grids of the 3A5 is reflected in a change in plate currents in the two halves of the tube, which causes a proportional current to flow in the 0-50 microammeter. The characteristic of the voltmeter circuit is very linear and its sensitivity of 0.1 v for full-scale deflection is more than sufficient. The reading of the microammeter is photographed along with the temperature data in the temperature recorder.

On flights after Flight 73, the two models of infra-red detector were flown with the thermistor pulse generator, model 33 TPG-228. The switching circuit in this unit connected the detector bridge output to the grid of the charging tube, thus limiting the rate at which the capacitor can charge. Figure I-30 shows the variation of repetition rate with bias change. Unfortunately, the bias voltage at which the knee in the characteristic occurs depends on the supply voltage and the individual tube. Furthermore, in flight, changes in the temperature of the infrared detector block cause a small zero voltage shift in the thermistor bridge output, which in turn shifts the zero level repetition rate. After trying various circuit modifications on flights subsequent to 73, without being able to justify the accuracy of the data, attempt was abandoned to have the pulse generator telemeter the infrared data and work was begun on a linear null-balance servomechanism.

D. General Instrumentation

Figure I-31 is a table showing the general breakdown of the equipment flown during the period of this report. By using the key, the composition of each gondola can be ascertained. The units are arranged in groups

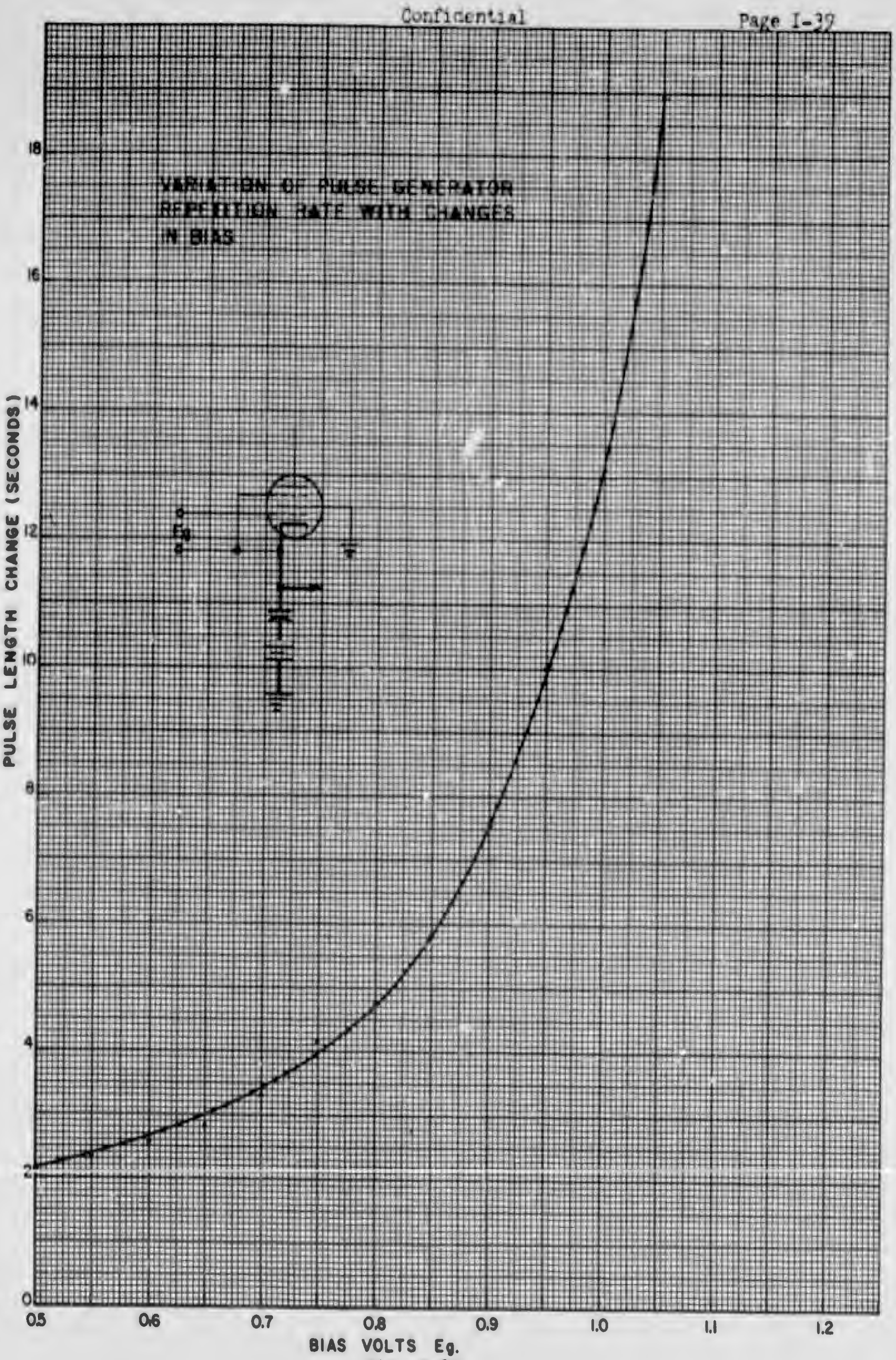

VARIATION OF PULSE GENERATOR
REPETITION RATE WITH CHANGES
IN BIAS
PULSE LENGTH CHANGE (SECONDS)
0
2
4
6
8
10
12
14
16
18
Eg
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
BIAS VOLTS Eg.

Fig. I-30.

SUMMARY OF EQUIPMENT INCLUDED IN GONDOLAS, FLIGHTS 56 - 100

Group	No.	Flight Numbers	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Safety Devices	1	Blinker Beacon	M	-	M	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
	2	Low Altitude Release	B	B	B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	3	Parachutes	24P	24P	24P	6	6	6	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	P	6	6	[illegible]	6	6	6	6	[illegible]
Flight Control	4	Termination Timers	C,V	C	C,V	C	C	[illegible]	C	C	C,V	C,V	C,V	[illegible]	[illegible]	C	I	C	C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	5	Ballast Droppers	C	-	C	-	-	P	P	P	C	C	P	P	[illegible]	[illegible]	-	[illegible]	[illegible]	P	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	6	Ballast Containers	S	-	S	-	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	7	Gas Valves	V	-	V	-	-	-	-	-	V	V	-	-	-	-	-	-	-	-	-	-	-	-	-
	8	Gondola Receivers	[illegible]	-	C	-	-	-	-	-	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Telemetering	9	Transmitters	1746 / 4835	1638	1638 / 4835	1638	1638	1638	1638	1746	1746 / 4835	1746 / 4835	1638 / 4690	1638	1638	1638	10360	1638	1638	1638	1638	1638	1638	1638	3415
	10	Antenna Droppers	2	1	2	1	1	1	1	1	2	2	2	1	1	1	-	1	1	1	1	1	1	1	1
	11	Encoders	S	-	S	-	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-	P
Sensing Devices	12	Olland Cycle	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	13	Tensiometer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	14	Thermistor Interpreters	-	T	-	-	-	-	-	T	-	-	-	T	[illegible]	[illegible]	-	[illegible]	[illegible]	T	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	15	Thermistor Droppers	-	3	-	-	-	-	-	6	-	-	-	[illegible]	-	-	-	-	-	6	-	-	-	-	-
	16	Infra-Red Detectors	-	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	-	-	-	[illegible]	-	-	-	-	[illegible]
Recording	17	Up Camera	O	O	O	O	O	O	O	O	O	O	O	O	O	O	-	O	O	O	O	O	O	O	O,T
	18	Down Camera	O	O	O	O	O	O	O	O	O	O	O	O	O	O	-	O	O	O	O	O	O	O	O
	19	Recording Camera	-	T	-	-	-	-	-	T,I	-	I	-	T	-	-	-	-	-	T	-	-	-	-	-
Structural	20	Gondola Frame	L	L	L	T	T	T	T	L	L	L	L	L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	L	[illegible]	[illegible]	[illegible]	[illegible]	I
	21	Insulation	4	4	4	2	2	2	2	4	4	4	4	4	[illegible]	4L	1	4L	4L	4	4L	4L	4L	4L	4
	22	Cover	C	C	C	C	C	C	C	C	C	C	[illegible]	C	A	A	A	A	A	C	A	A	A	A	C
	23	Gondola Heater	-	-	-	-	-	-	-	-	-	-	[illegible]	-	-	[illegible]	-	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	-
	24	Cosmic Ray Equipment	-	-	-	-	-	-	-	-	-	-	-	P	[illegible]	-	-	-	-	-	-	-	-	-	-

No.	Flight Numbers	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	Blinker Beacon	-	-	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-
2	Low Altitude Release	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-
3	Parachutes	[illegible]	[illegible]	[illegible]	[illegible]	6	[illegible]	P	[illegible]	[illegible]	P	P	[illegible]	[illegible]	[illegible]	P	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	P	-
4	Termination Timers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	I	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-
5	Ballast Droppers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	-	-	-	[illegible]	P	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-
6	Ballast Containers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	-	-	-	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	-
7	Gas Valves	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	-	-	-	[illegible]	-	-	-	-	-	[illegible]	[illegible]
8	Gondola Receivers	-	-	-	[illegible]	-	-	-	-	-	-	-	-	[illegible]	-	-	[illegible]	-	-	-	-	-	-
9	Transmitters	3415	3415	3415	3415	1638	1638	10360	3415	3415	10360	10710	3415	3415 / 10710	3415	10710	1638 / 10710	1638	1638	1638	1638	10710	10710
10	Antenna Droppers	1	1	1	1	1	1	1	1	1	-	-	1	1	1	-	1	1	1	1	1	-	-
11	Encoders	P	V	V	V	-	-	-	V	V	-	-	V	[illegible]	[illegible]	-	[illegible]	-	-	-	-	-	-
12	Olland Cycle	1	1	1	1	1	1	1	1	1	[illegible]	1	1	1	[illegible]	1	[illegible]	1	1	1	1	1	1
13	Tensiometer	1	1	-	-	-	-	-	1	1	-	-	1	1	[illegible]	-	[illegible]	-	-	-	-	-	-
14	Thermistor Interpreters	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	-	[illegible]	[illegible]	-	-	[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	-	-	-	-
15	Thermistor Droppers	-	-	6	-	-	-	-	-	-	-	-	-	3	-	-	[illegible]	-	-	-	-	-	-
16	Infra-Red Detectors	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	[illegible]	-	-	[illegible]	-	[illegible]	-	-	-	-	-	-	-	-
17	Up Camera	O,T	O,T	O	-	O	O	-	O,T	O,T	-	-	O,T	O,T	O,T	-	O,T	O	O	O	O	-	-
18	Down Camera	O	O	O	O	O	O	-	O	O	-	-	O,T	O,T	O	-	O	O	O	O	O	-	-
19	Recording Camera	[illegible]	[illegible]	[illegible]	-	-	-	-	[illegible]	-	-	-	-	[illegible]	-	-	-	-	-	-	-	-	-
20	Gondola Frame	I	I	L	I	[illegible]	[illegible]	[illegible]	I	I	[illegible]	[illegible]	I	I	I	[illegible]	I	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	Insulation	4	4	4	4	4L	4L	1	4	4	1	1	4	4	4	1	4	4L	4L	4L	4L	1	1
22	Cover	C	[illegible]	C	A	A	A	A	C	C	A	A	C	C	C	A	C	A	A	A	A	A	A
23	Gondola Heater	-	-	[illegible]	[illegible]	[illegible]	[illegible]	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	[illegible]	[illegible]	-	-
24	Cosmic Ray Equipment	-	T	[illegible]	-	[illegible]	[illegible]	-	T	T	-	-	-	-	-	-	-	[illegible]	[illegible]	S,P	S,P	-	-

1 — M = Mechanical; S = Sequence Control Programmer; E = External Flasher; A = Automobile Headlight Type

2 — B = Low Altitude Blowdown; S = Sequence Control Programmer

3 — P = Paper Chute; 6 = Six Foot Chute; 8 = Eight Foot Chute; 24P = 24 Foot [illegible]; 24R = 24 Foot Round Chute

4 — C = Camera; H = Haydon Timer [illegible] Dropper; I = Ingersol Pocket Watch; M = Minneapolis-Honeywell Timer; B = Bristol Chart Drive

5 — C = Sequence Dropper, Command; P = Sequence Dropper, Pressure; H = Haydon Hose Dropper; S = Sequence Control Programmer; F = Pressure Follow-up Servo

6 — S = Canvas Sacks; C = Liquid Ballast Cans; 4 = Magnetic Ballast Hoppers with magnetic valve

7 — V = Balloon Valve; B = Liquid Superpressure Valve

8 — C = Command Receiver, Receiver Control Circuit & Distribution Box; L = Loran Receiver; B = Balloon Thermistor Pulse Receiver

9 — 1638 KC; 1746 KC; 3415 KC; 4690 KC; 4835 KC; 10.710 MC; 10.360 MC

10 — Number used

11 — S = Command Signal Coder; P = Princeton Commutator; V = Contact Commutator, Vacuum Tube Pulse Shaper; R = Contact Commutator, Williams Relay Pulse Shaper

12 — Number Used

13 — Number Used

14 — T = Thermistor Photo Recorder & Vacuum Tube [illegible]; G = Thermistor Pulse Generator Located in Gondola; B = Thermistor Pulse Generator Located in Balloon

15 — Number Used

16 — B = Infra-Red Bridge; D = Infra-Red Detector

17 — O = Recording Olland Cycle Pressure; T = Recording Tensiometer Weigh-off

18 — " " " " " " " " "

19 — T = Thermistor Photo Recorder; I = [illegible] Camera Inside Balloon; O = [illegible] Camera Outside Balloon; M = Multichannel Pulse Recorder

20 — L = Large ; T = [illegible] Type; M = Miniature; I = Intermediate; S = Sub-miniature

21 — 4 = 4" Styrofoam; 2 = 2" Styrofoam; C = Cardboard Carton; 4L = 2-2" Layers of Styrofoam with Aluminum Foil Sandwich; 1 = 1" Styrofoam

22 — C = Canvas Cover; A = Aluminum Foil

23 — H = 4" Laminated Styrofoam Box with Aluminum Foil & Thermostatic Heater for Batteries; W = Pressurized Water Tank in contact with Batteries

24 — P = Photon; T = Telescope; S = Single Counter

Fig. I-31.

generally descriptive of their function and will be discussed in that order.

Safety Devices

1. Blinker Beacon

A mechanical oscillator listed as operating the blinker beacon on the early flights of this report was a copy of the Dayco incandescent flasher mentioned in Volume V, Page VII-208. The Dayton Acme Company had gone out of business and therefore it was impossible for us to obtain more of the units which had been used previously. A copy made in the Physics Department shop was used until the Amperite 6F30 flasher tube was brought to our attention by the Tufts Laboratories working under contract with the MOBY DICK project. This flasher tube was incorporated in a unit which was being developed at the same time as a flight control box and which has been called the sequence control programmer. This will be described more fully as a low altitude release, but a wiring diagram is given in Figure I-32 and a picture in Figure I-33.

External flashers were flown on some flights where for one reason or another it was not desirable to power the blinker beacon from the main gondola batteries. These external flashers were a 6F30 tube and battery enclosed in an insulated package and powering a 21 candle power automobile bulb in a lucite protective case. This bulb became standard at the same time the 6F30 tube was first used, whereas previous to that time three General Electric No. 48 bulbs in parallel had been used. Flights 90 and 92 had in addition an external flasher with four sealed beam automobile headlamp filaments connected in series-parallel which were used for tracking by theodolite immediately after launch. This

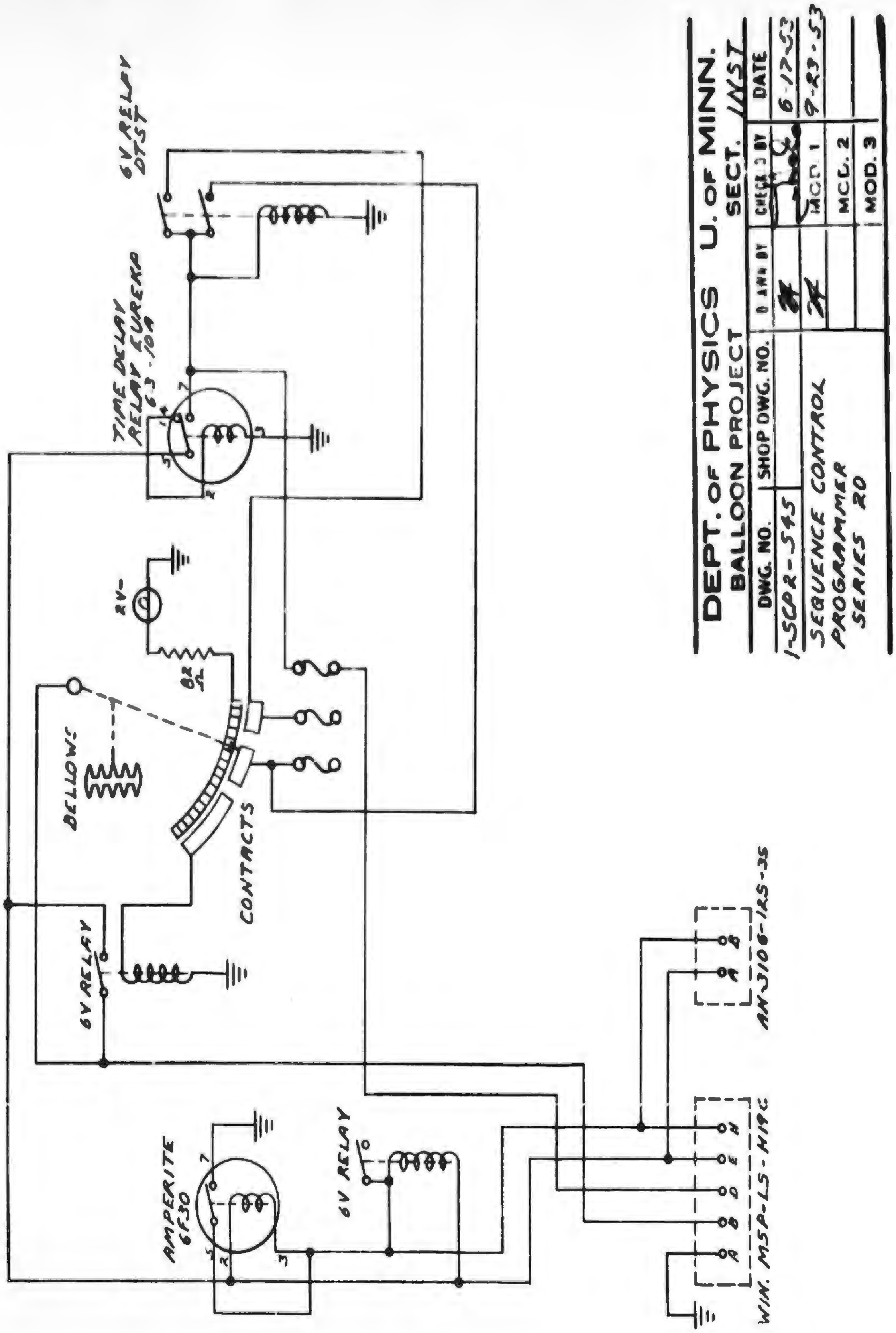

6V RELAY DTST
TIME DELAY RELAY EUREKA 6-3-10A
2V-
82 Ω
BELLOWS
CONTACTS
6V RELAY
AN-3106-12S-3S
AMPERITE 6F30
6V RELAY
WIN. MSP-LS-HIPC
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
1-SCPR-545
6-17-53
MOD. 1
9-23-53
MOD. 2
MOD. 3
SEQUENCE CONTROL PROGRAMMER SERIES 20

Fig. I-32.

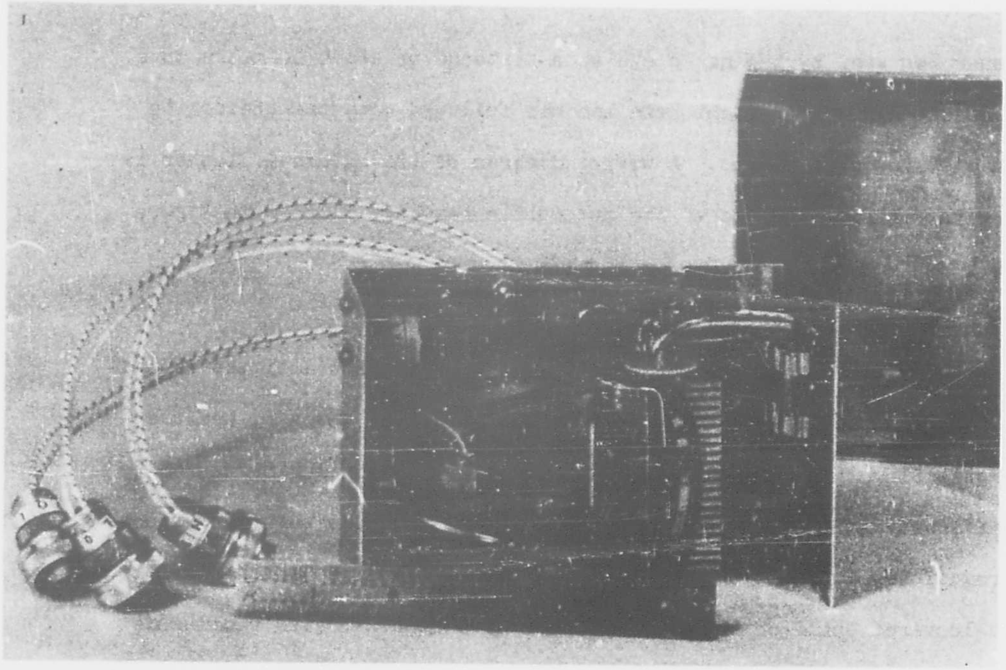


Fig. I-33A. Sequence Control programmer, top view.

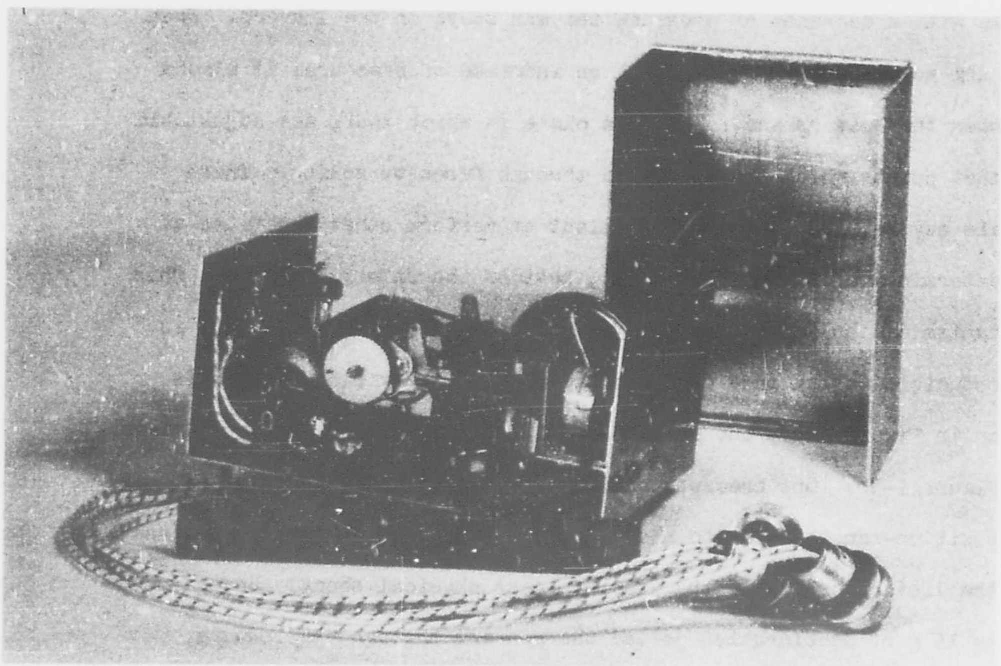
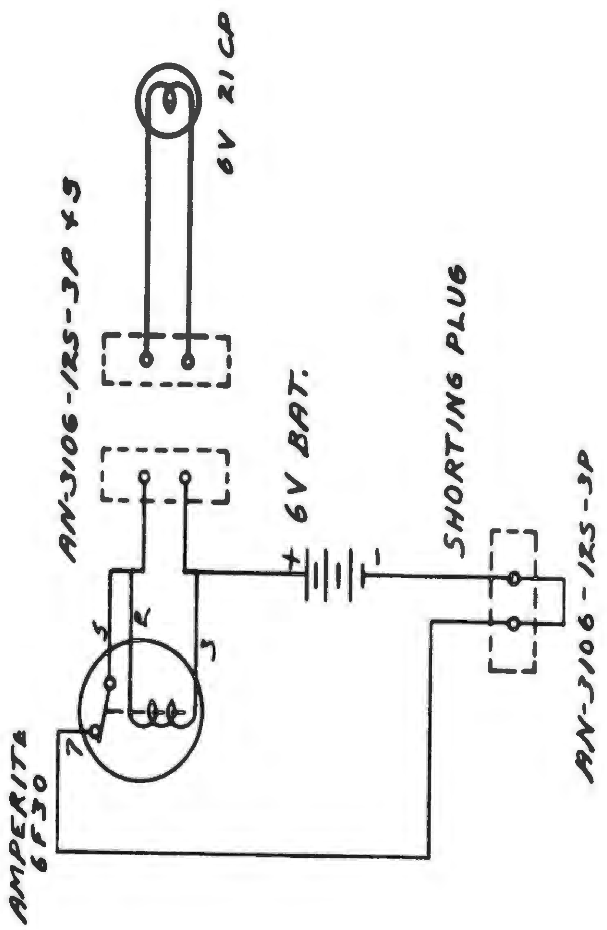


Fig. I-33B. Sequency control programmer, side view.

flasher was seen by the naked eye at a distance of about 40 miles on a cloudless night with slight haze and was followed with the theodolite to a distance of 84 miles. A wiring diagram of the external flasher is given in Figure I-34, and of the automobile headlamp flasher in Figure I-35.

2. Low Altitude Releases

The early flights in this series used the same low altitude release described in the first and second progress reports. However, because one step flight gondola was separated from its balloon during launch by a difficulty in setting this mechanism, and because the setting was not reproducible, another low altitude release was developed which consists of a louvered shelf on which the pen arm of a Bendix-Freize radiosonde bellows assembly #515-307-4 rests. As long as the pen arm moves up the scale with a decrease of pressure the arm stays on the louvers. When the arm moves down the scale with an increase of pressure, it slides between the louvers and falls on a plate in which there are adjustable contact points which are connected through fuses to squibs. These squibs may be used to drop the ballast or perform other functions at predetermined pressures on descent, besides the safety blowdown. This mechanism can be set quite easily to a fraction of a millibar and is reproducible to the same degree of accuracy. The wiring diagram is given in Figure I-32, the picture in Figure I-33, and the shop drawings in Figure I-36. One precautionary note, however, is that this mechanism is position-sensitive as to shock and should be mounted with the plane of the louvered shelf in the axis of least physical shock. Under test, 10 to 15 g of acceleration jolted the pen arm through the louvers,


AN-3106-12S-3P X S
6V 21CP
SHORTING PLUG
6V BAT.
AN-3106-12S-3P
AMPERITE
6F30

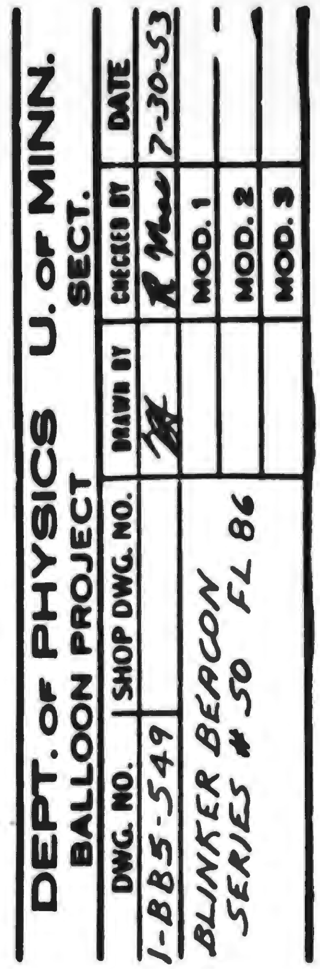

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT.
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
1-BB5-549
7-30-53
MOD. 1
MOD. 2
MOD. 3
BLINKER BEACON
SERIES # 50 FL 86

Fig. I-34.

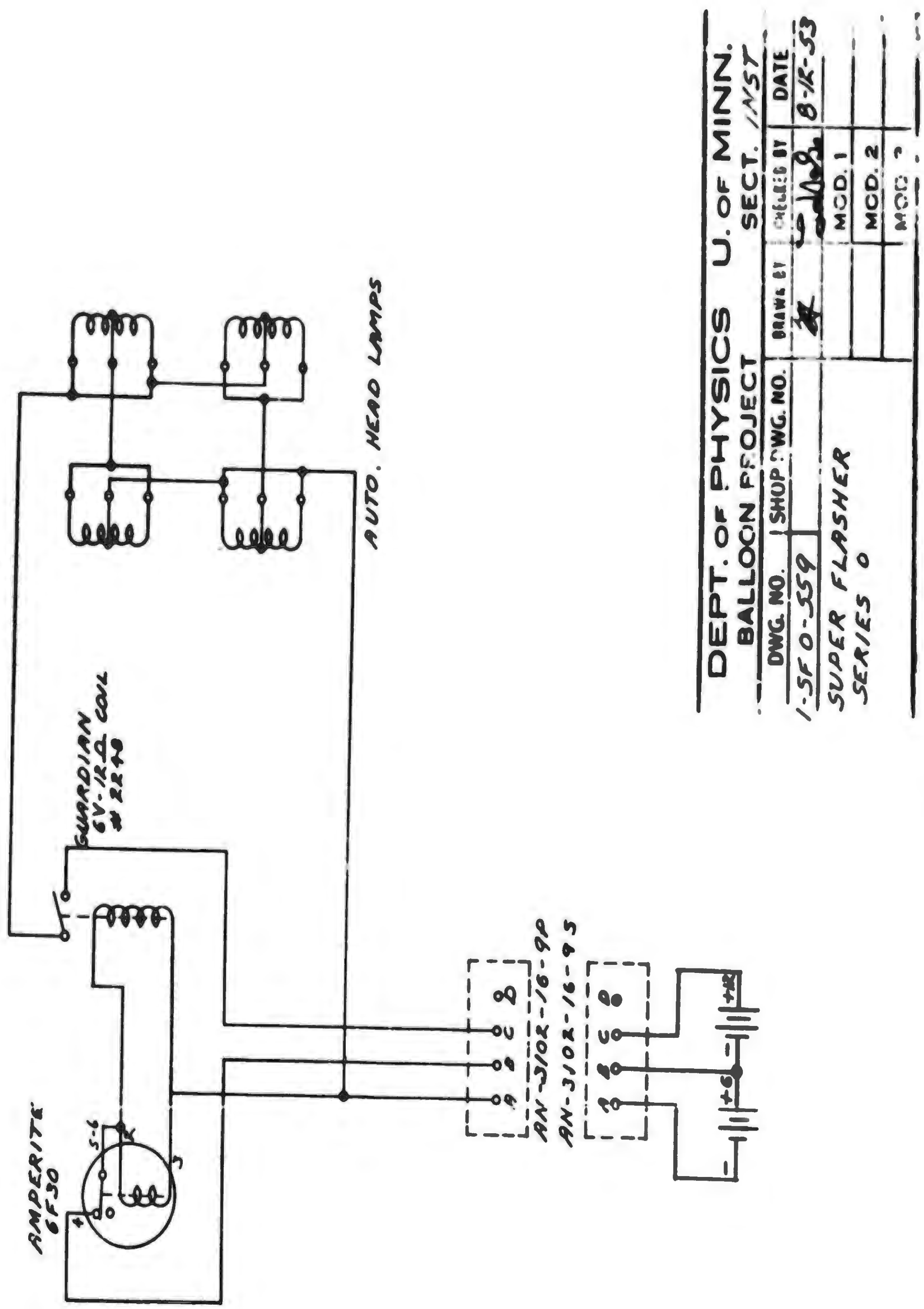

AMPERITE 6F30
GUARDIAN 6V-12Ω COIL
AUTO. HEAD LAMPS
AN-3102-16-9P
AN-3102-16-9S
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
1-SF0-559
8-12-53
SUPER FLASHER
SERIES 0
MOD. 1
MOD. 2
MOD. 3

Fig. I-35.

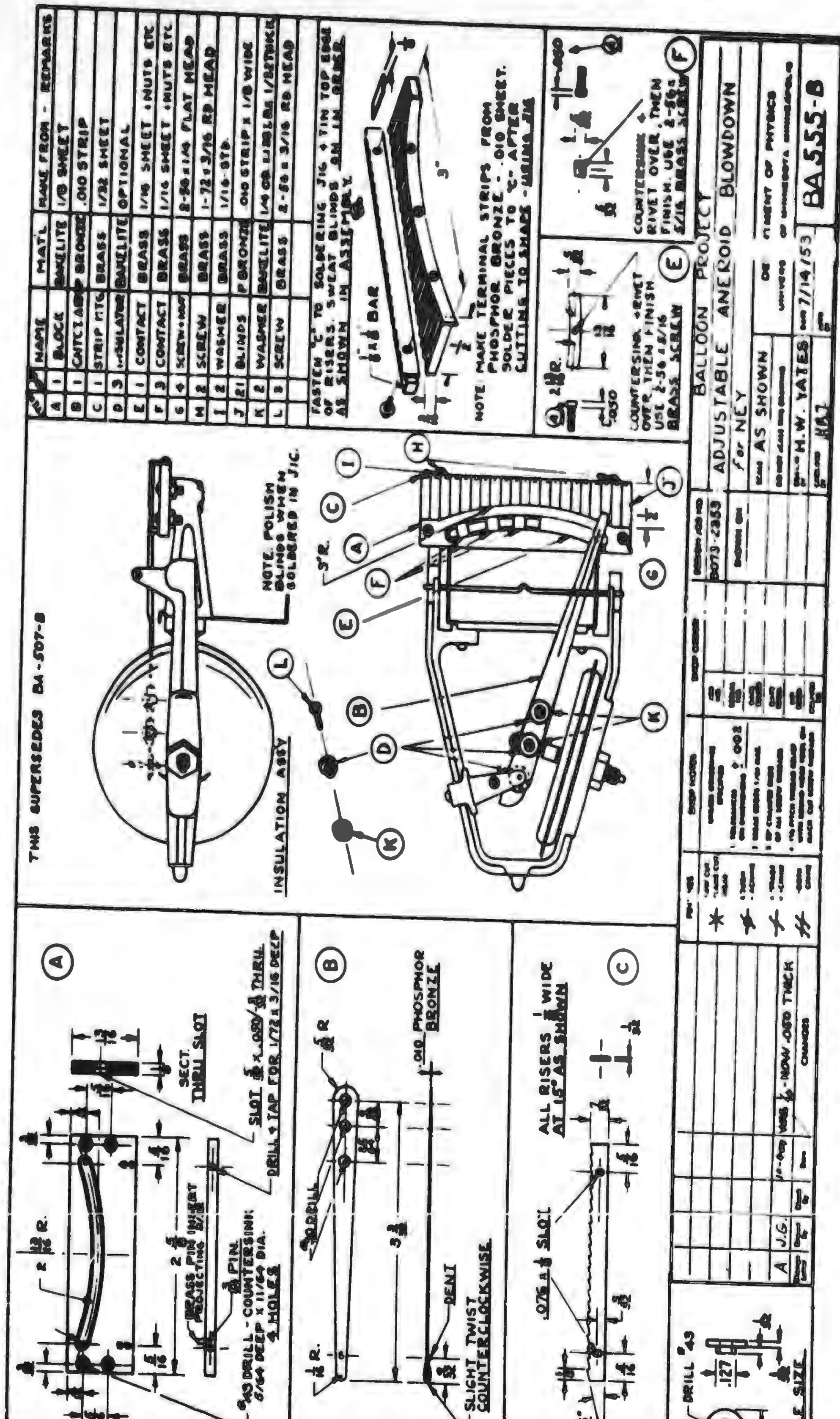

THIS SUPERSEDES BA-507-B
INSULATION ASSY
NOTE: POLISH BLINDS WHEN SOLDERED IN JIG.
BALLOON PROJECT
ADJUSTABLE ANEROID BLOWDOWN
for NEY
AS SHOWN
H.W. YATES
7/14/53
BA 555-B
DOUBLE SIZE

Fig. I-36.

causing what could be, during the flight, a premature blowdown. With this precaution in mounting, this programmer has functioned without mechanical failure.

There have been two human failures associated with this instrument, one when the link pin was unseated from the cup on the bellows as the pen arm was lifted onto the louvered shelf for cocking, and the other failure occurred when, after setting the blowdown altitude and while the unit was still plugged into a power source,the cover of the box was allowed to short the pen arm to ground as it was being put on the box. This burned out the fine flexible wire between the pen arm and 6V supply. A small lamp bulb was then installed in the programmer so as to indicate, even though the box is closed, that the pen arm is on the shelf and that there is current to it.

As can be seen from the wiring diagram in Figure I-32, there are other functions of this sequence control programmer besides operating a flasher and blowdown. It makes up to three pressure-operated ballast drops, unloads the ballast before blowdown, furnishes blowdown warning and delay, and the most recent models contain a blowdown timer.

3. Parachutes

The standard chute used here has been the 24-ft surplus cargo chute in a pack which is released by a ripcord when the load separates from the balloon. The smaller gondolas have been flown on 6 or 8-ft chutes rigged the same way as the larger chute, and the subminiature gondolas have been flown on radiosonde paper chutes rigged open between the balloon and the gondola. The step flights have been rigged differently, however, partly because of the necessity of unloading any liquid ballast that might remain in the tank at the time of release. A 24-ft chute laid in an open cardboard box with a drag chute to pull it out of the box has been used for these flights.

As must be the experience on other projects, it has been found here that the shock of the parachute opening can be the most extreme shock the equipment is subjected to during the course of a flight. We have had heavy rigging rings returned deformed to parallel-sided narrow links by the shock, and 3000-lb test cord snapped by 140-lb loads. We believe it pays to make the parachute rigging extremely heavy to avoid loads free falling.

4. Termination Timers

A number of different types of timers have been used, as shown in line 4 of Figure I-31. The camera blowdown described in Volume V has been changed substantially and will be described in the section of this report on cameras. The low voltage blowdown described in Volume V, Page VII-211, was not changed during this report period. It was finally discontinued because replacements for the sensitive relays used for this purpose could not be found.

Minneapolis Honeywell S414 A1X1 timers have been flown several times during this period with the precaution that they be kept warm. They are always flown in parallel to eliminate the possibility of failure. Another timer made from an Ingersol pocket watch ($3.50) was flown on the subminiature flight. A 2-56 screw was set in the plastic crystal and a sliver of spring bronze was soldered to the head of the screw inside the crystal. This sliver was so bent that it contacted the hour hand once every 12 hours. The minute hand was cut short. These watches ran with no special preparations, even though buried in dry ice overnight, a test applied to all such timers before flight.

The project received on property transfer from General Mills a number of Lux chart drive 8143 clockwork motors and timers such as those flown on N ONR 875 (00) project. These Lux chart drives were altered slightly for our purposes by substituting different microswitches and new mountings, and have been used in several of our flights. The most recent model of the sequence control programmer contains one of these Lux timers.

The last type of termination timer used during this period was a Hayden chronometric motor, 5700 series, which was used as a hose dropper on the step flights. The lag screw which was driven by the Hayden motor continued on after the last hose had dropped to close a microswitch causing blowdown. Since the rotational speed of this model of motor is constant to within 1/10 of 1%, the timer could be set very accurately by positioning the microswitch along the track of the lag screw. Fig. I-37 is a picture of this hose dropper, and the flight termination microswitch can be seen at right in the front.

Flight Control

5. Ballast Droppers

The sequence ballast droppers, both command and pressure-operated, listed in line 5, Figure I-31, were the same as those described in Volume V, pages VII-214-218. Both of these units operated in the manner in which they were intended. The pressure-operated sequence ballast dropper was replaced,however, by the sequence control programmer ballast dropper, since this new instrument had several advantages over the old one. The programmer, Figures I-32, I-33, and I-36, was able to unload ballast just before blowdown and thereby protect the parachute from destruction due to overloading in case of balloon failure at lower altitudes. In addition, the danger of the programmer not firing because the balloon did not reach arming altitude was lessened, since arming altitude was continuous stepwise all during the ascent.

The step flight hose dropper, Figures I-37, I-38, and I-39, is mentioned under the description of the termination timers. A lag screw which is driven by a Hayden chronometric motor moves to the right in the picture, Figure I-37, and when it moves past the slots in the base plate the metal tabs to which the hoses from the ballast cans are attached drop off the end of the screw, through the slot in the base plate,and fall free. This device is not adjustable, obviously, and the timing for the hose drops must be machined in when the slots are located by the shop.

The pressure follow-up servo, Figures I-40, I-41, and I-42, is basically a single pole double throw switch, the armature of which is the pen arm of a radiosonde bellows assembly and the two fixed contacts of which are mounted on a block traveling on a motor-driven lag screw. When the pressure decreases, the pen arm touches one of the contacts which operates the motor and drives the traveling block so as to follow the movement of the pen arm. When the pen arm stops moving up, the motor stops. If the pen arm moves in the other direction because of increasing pressure, it touches the other contact and the valve releases magnetic

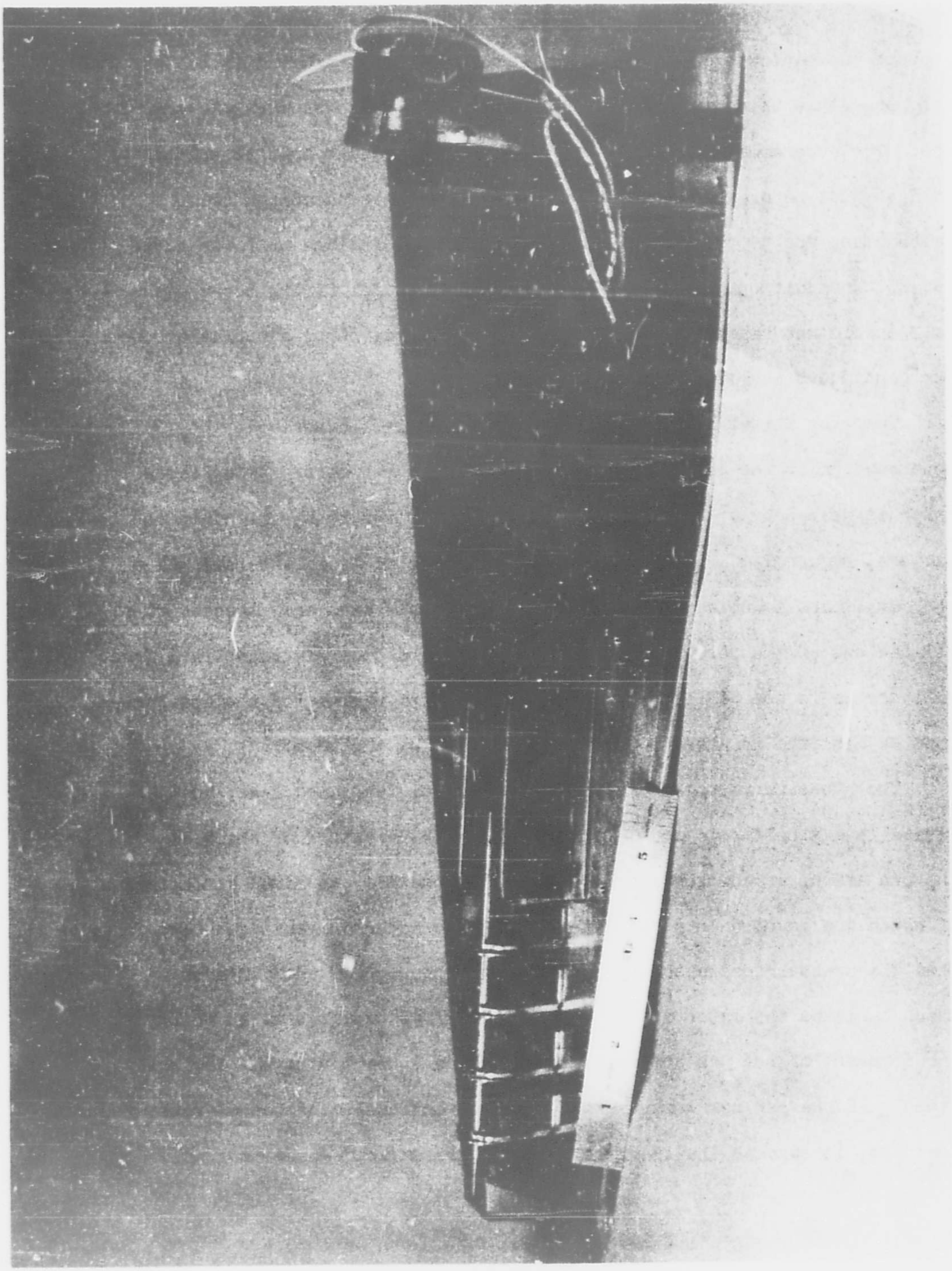


Fig. I-37. Hose dropper and timer. Four hose tabs showing on the left, with flight termination switch showing on the right. Cover in background.

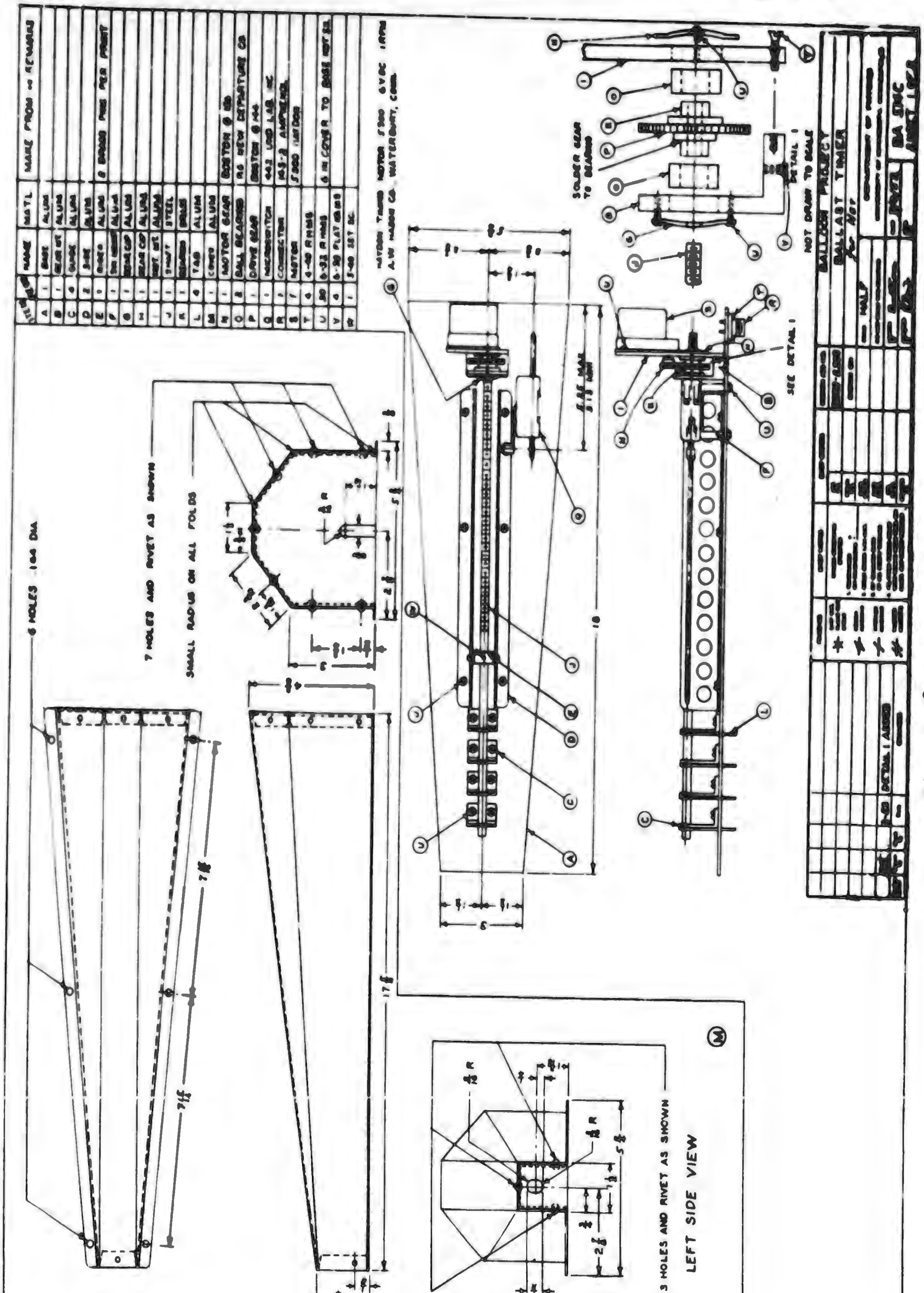

BALLOON PROJECT
BALLAST TIMER
NOT DRAWN TO SCALE
SEE DETAIL I
DETAIL I
SOLDER GEAR TO BEARING
6 HOLES .144 DIA
7 HOLES AND RIVET AS SHOWN
SMALL RADIUS ON ALL FOLDS
3 HOLES AND RIVET AS SHOWN
LEFT SIDE VIEW

Fig. I-38A.

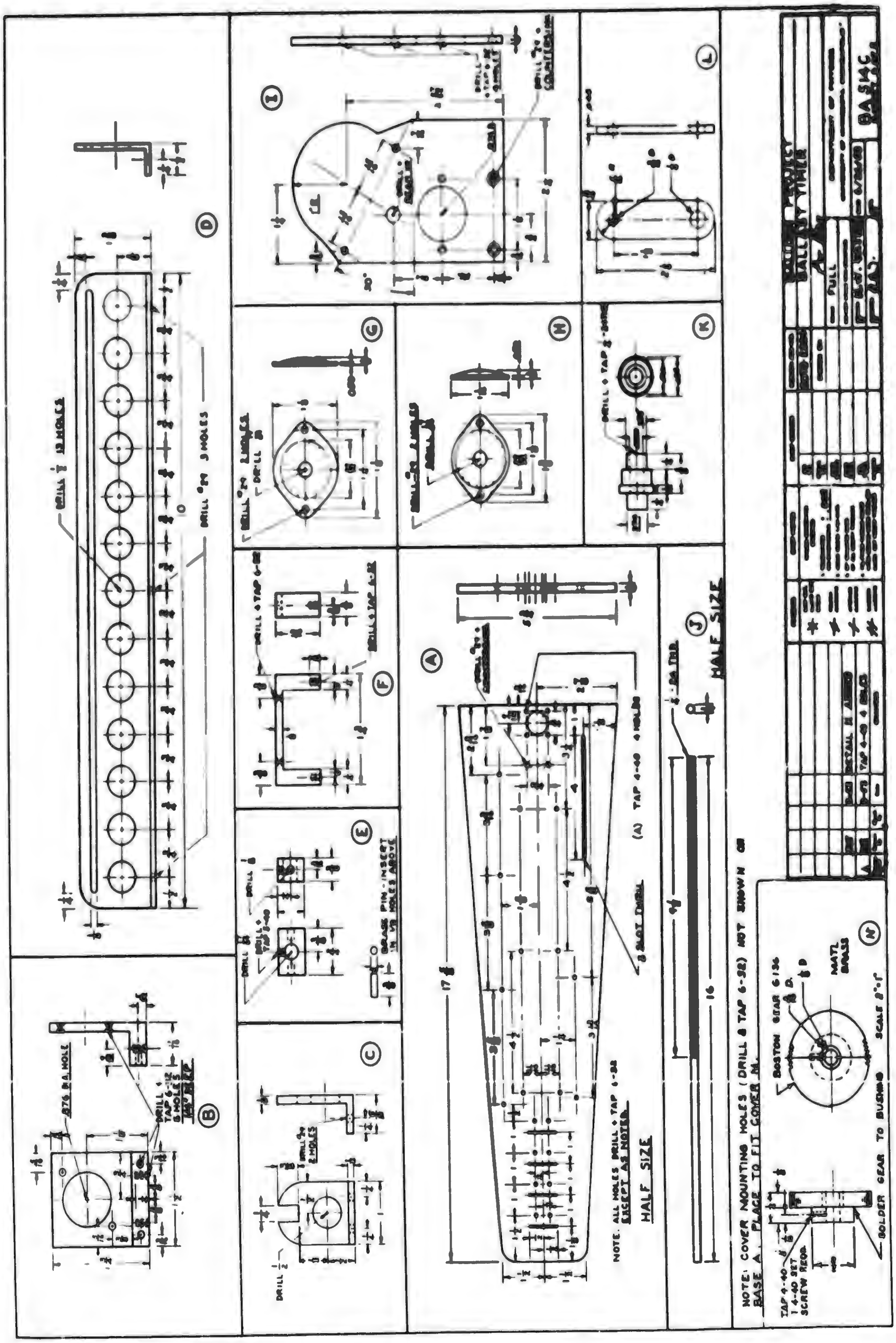


Fig. I-38B.

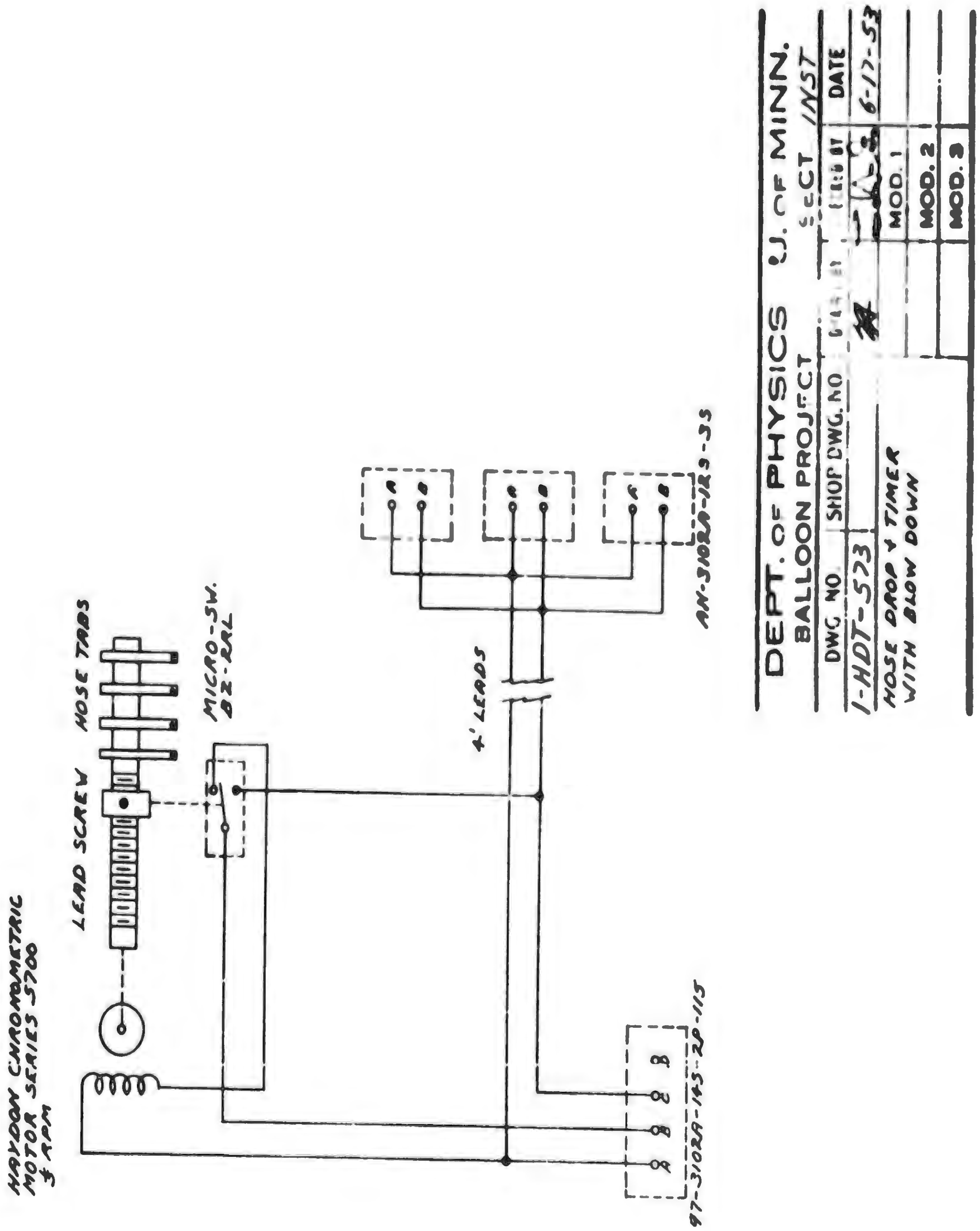

HAYDON CHRONOMETRIC MOTOR SERIES 5700
LEAD SCREW
HOSE TABS
MICRO-SW. BZ-2RL
4' LEADS
AN-3102A-12S-3S
97-3102A-14S-2P-115
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
SECT INST
DWG NO.
SHOP DWG. NO
DATE
1-HDT-573
6-17-53
HOSE DROP & TIMER WITH BLOW DOWN
MOD. 1
MOD. 2
MOD. 3

Fig. I-39.

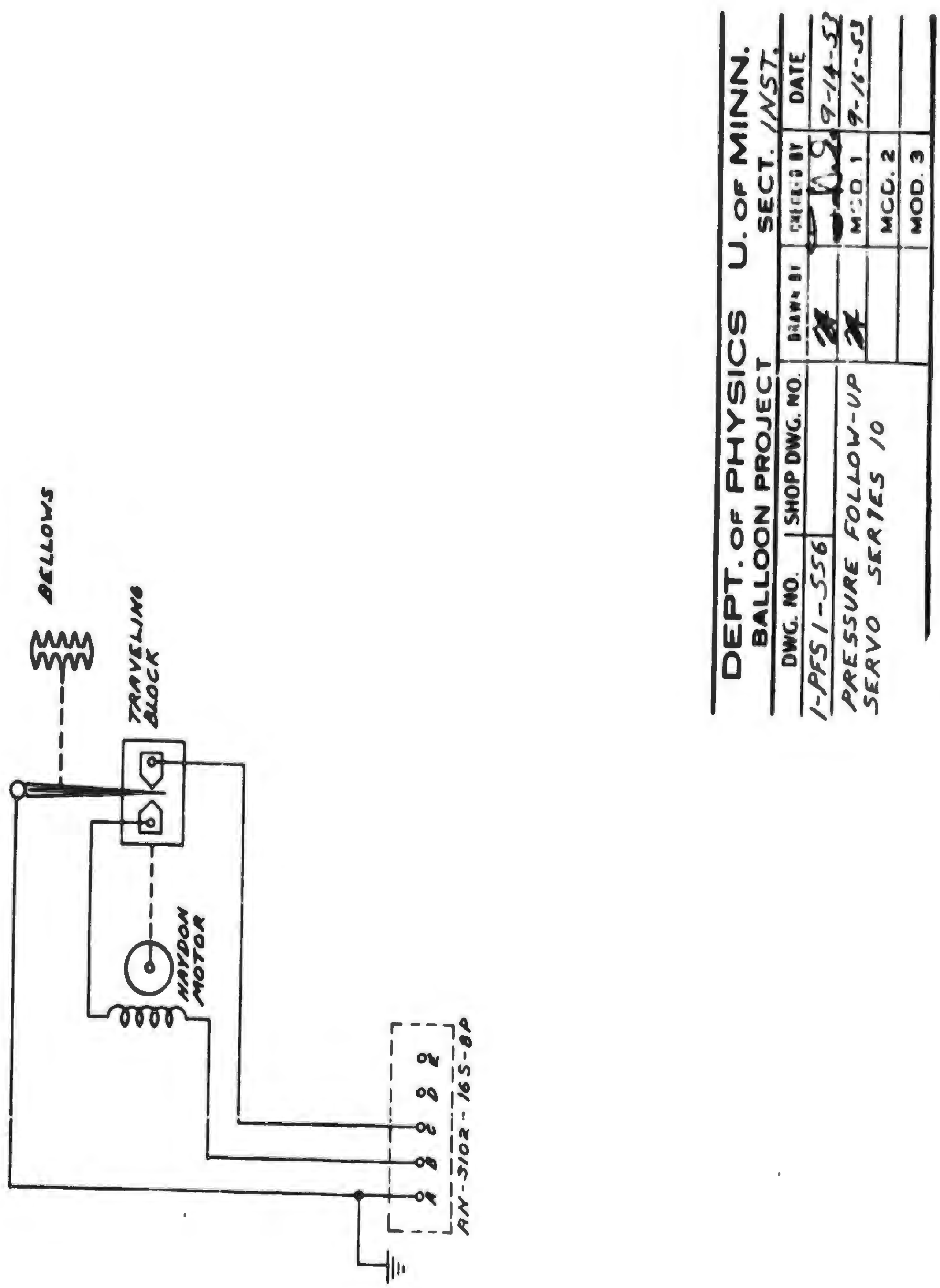

BELLOWS
TRAVELING BLOCK
HAYDON MOTOR
AN-3102-16S-8P
A
B
C
D
E
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST.
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
1-PFS1-556
9-14-53
MOD 1
9-16-53
MOD. 2
MOD. 3
PRESSURE FOLLOW-UP
SERVO SERIES 10

Fig. 1-40.

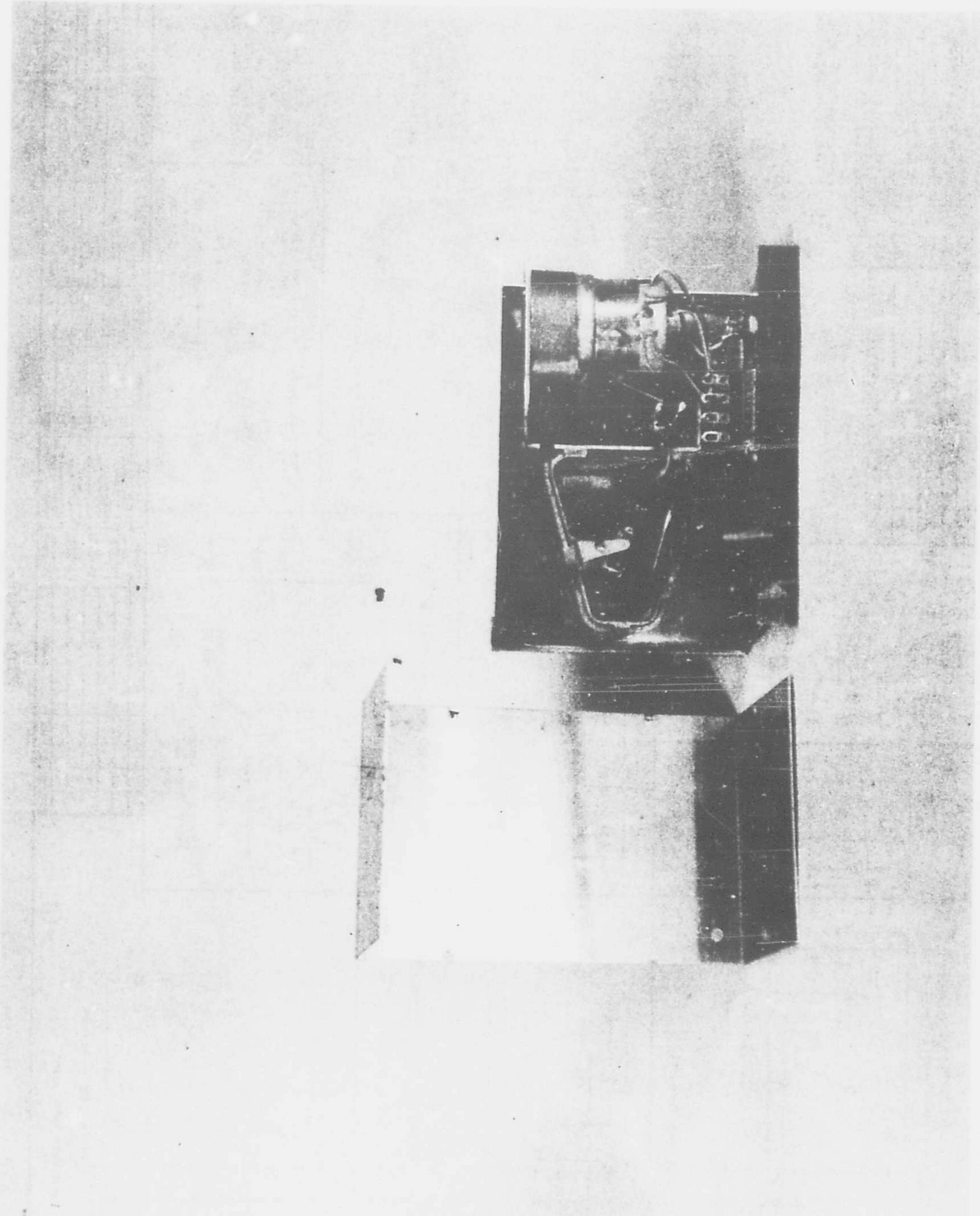


Fig. I-41. Pressure follow-up Servo. Top view.

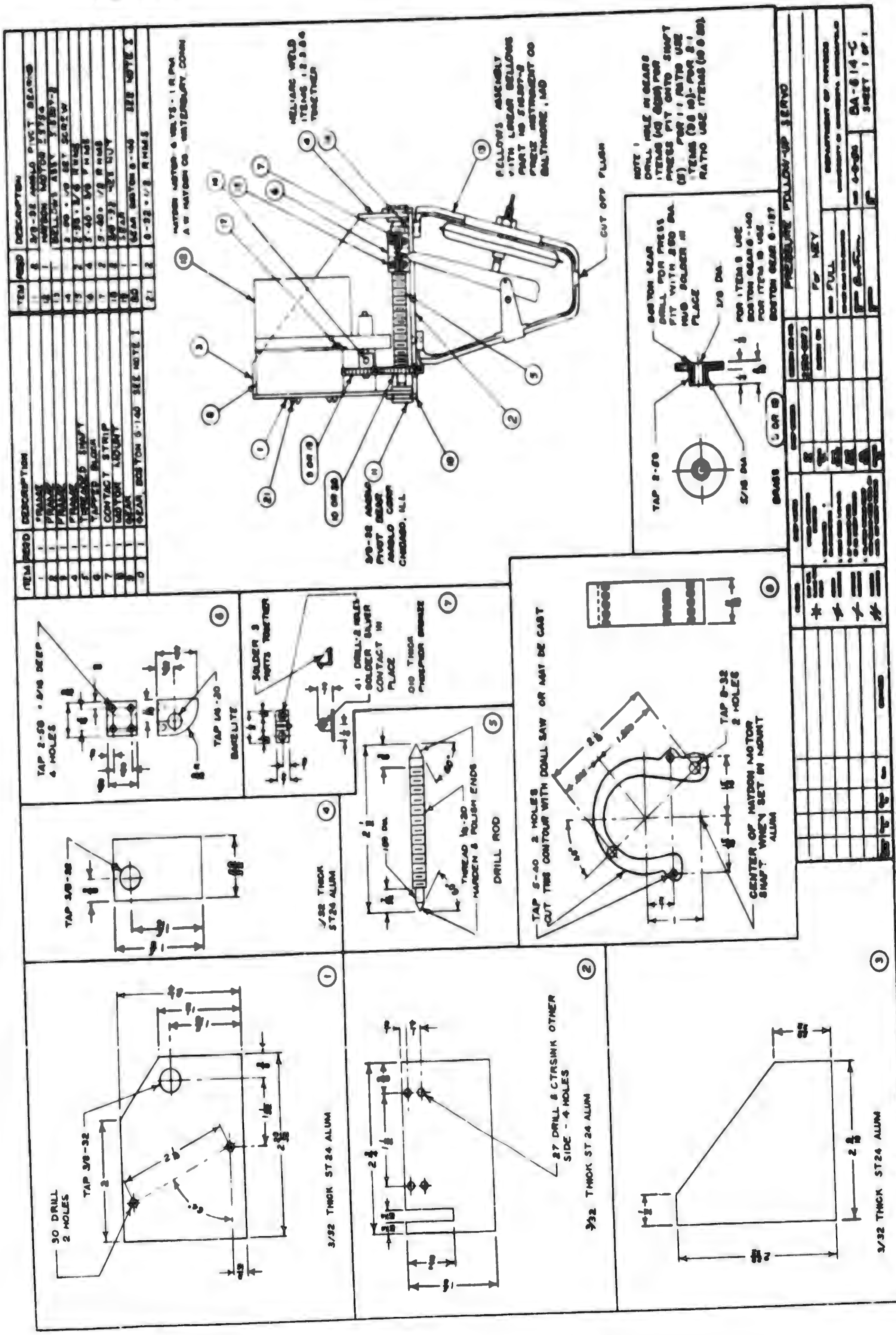

PRESSURE FOLLOW-UP SERVO
BA-614-C
3/32 THICK ST24 ALUM
DRILL ROD
BAKELITE
CUT OFF FLUSH

Fig. I-42.

ballast from a hopper. This device was intended to keep a balloon from losing altitude once it reached altitude, and on the one flight where it has been used it worked as intended.*

6. Ballast Containers

Three types of containers for ballast were used during the period for dropping both liquid and magnetic shot ballast. Three different types of ballast response were required. The ballast sacks described on Page VII-218, Volume V, were used for discrete ballast release. For small ballast drops on the order of four pounds or less, a small (3" x 10") ballast sack was used which also had a pointed bottom, although it was found that the explosive force of a 2-grain squib was enough to disintegrate the whole end of the sack.

Experience has shown that the squib line must be securely fastened to the outside of the ballast sack, because in transporting the sacks or in the rush attending the actual launching the sacks are lifted by the most convenient handle,which often happens to be the squib line. If the squib is pulled into the center of a mass of shot it is cushioned by the shot to such an extent that the sack is unaffected by the explosion and no ballast is dropped. Doubling over the neck of the ballast sack and the squib line leading out of it,and tying it by its supporting cord in this position, also helps prevent its being pulled loose.

The second type of ballast container used during this period was the same magnetic ballast hopper mentioned in Volume V, Page VII-218. It was

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* Note in proof -- this device has been used on numerous flights since #100 with success.

modified slightly for easier manufacture and a shop drawing is given in Figure I-43.

This type of container is desirable where ballast is to be released at a rate constant and independent of the amount remaining in the container, the weight released to be determined by the time duration of the drop. The magnetic valve used in conjunction with the hopper is an improved version of the previous magnetic valve, and a shop drawing is given in Figure I-44.

The third ballast container used during this report period was the liquid ballast tank used for the step flights. A rate of ballast release which would be approximately a constant fraction of the gross load remaining was desired for the step flights, and liquid ballast was thought to be the best material. However, after lengthy experimentation it was found practically impossible to attain true exponential flow, and a close approximation using a square root relationship was finally accepted. It should be mentioned that a variety of flow-governing devices was tried before this solution was accepted. It was thought that capillary flow from a decreasing head of liquid in a tank would be an easy solution, but investigation revealed that the capillary length necessary was on the order of an earth diameter. In this investigation, besides the capillary tube, a bundle of rods (the interstices acting as capillaries), a cylinder of round shot, glass wool between screens, tightly woven orlon and cotton over an opening, and various orifices in metal plates were tried. These devices gave essentially the same flow rate except for the glass wool and orlon, which acted more like filters than the others and as they strained dirt out of the liquid the rate of flow became slower. Even this filtering

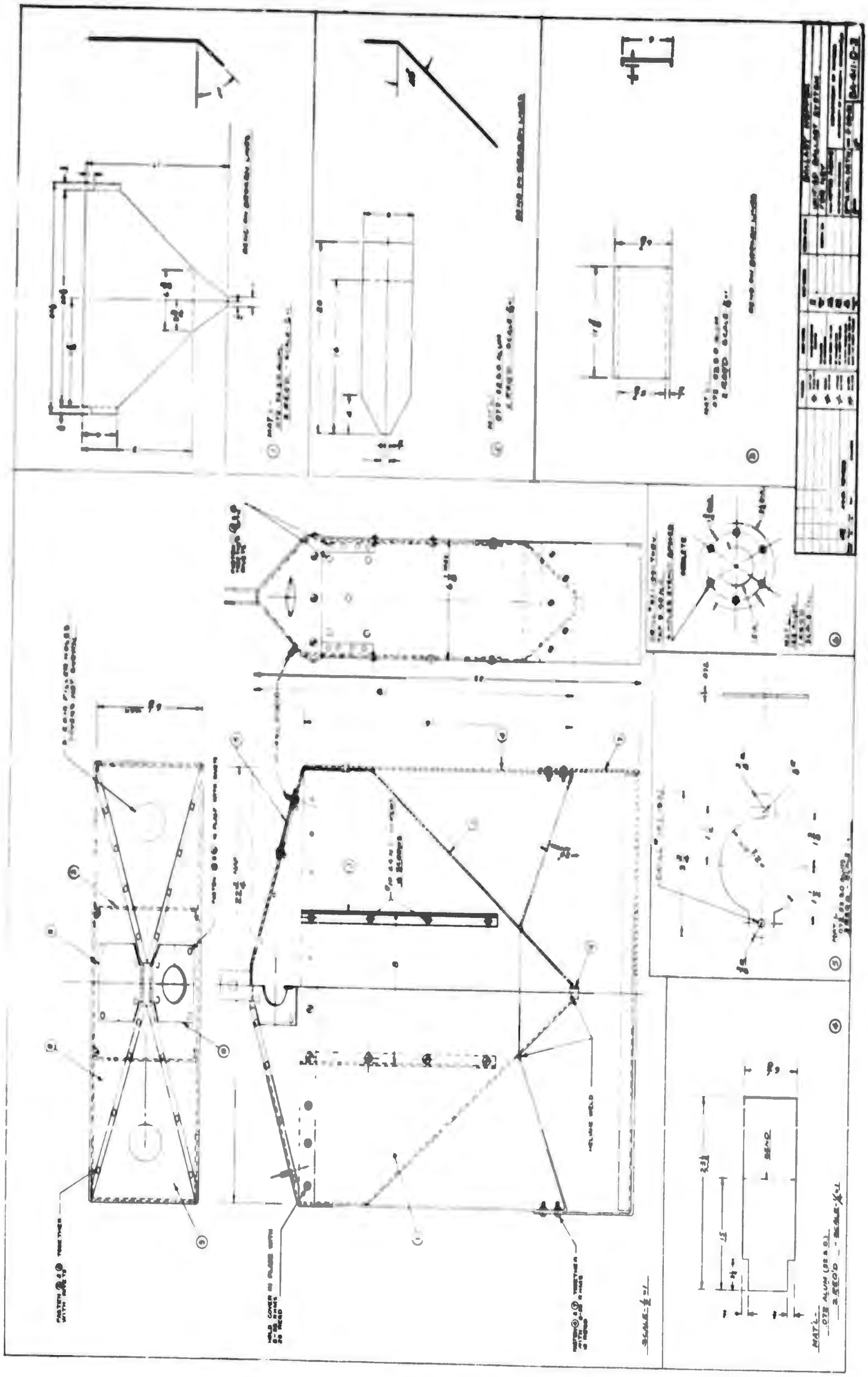


Fig. I-43A.

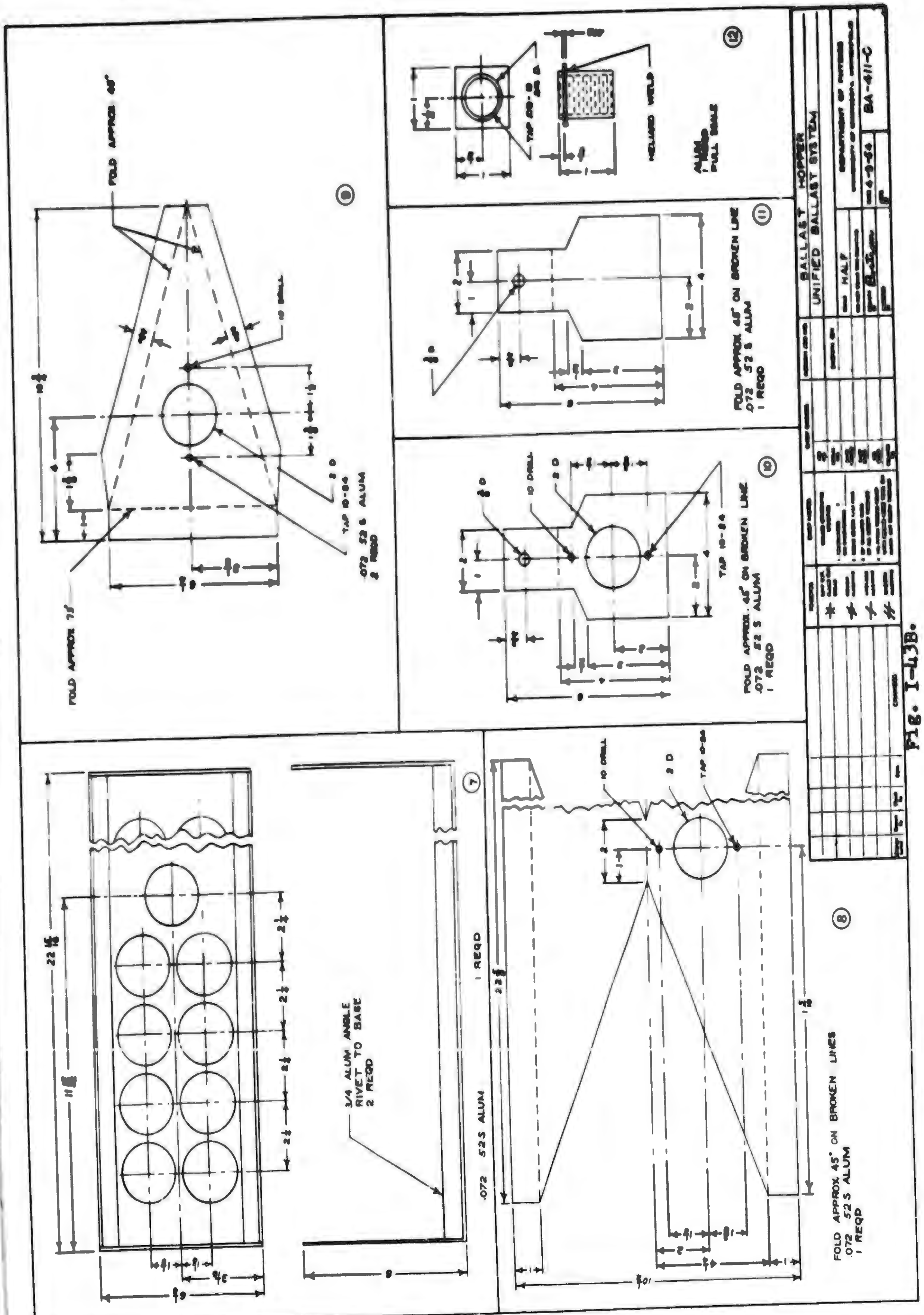

BALLAST HOPPER
UNIFIED BALLAST SYSTEM
HALF
BA-411-C
FOLD APPROX 45°
FOLD APPROX 75°
10 DRILL
TAP 10-24
.072 52S ALUM
2 REQD
FOLD APPROX 45° ON BROKEN LINE
.072 52S ALUM
1 REQD
HELIARC WELD
FULL SCALE
3/4 ALUM ANGLE
RIVET TO BASE
2 REQD
.072 52S ALUM
1 REQD
FOLD APPROX 45° ON BROKEN LINES
.072 52S ALUM
1 REQD

Fig. I-43B.

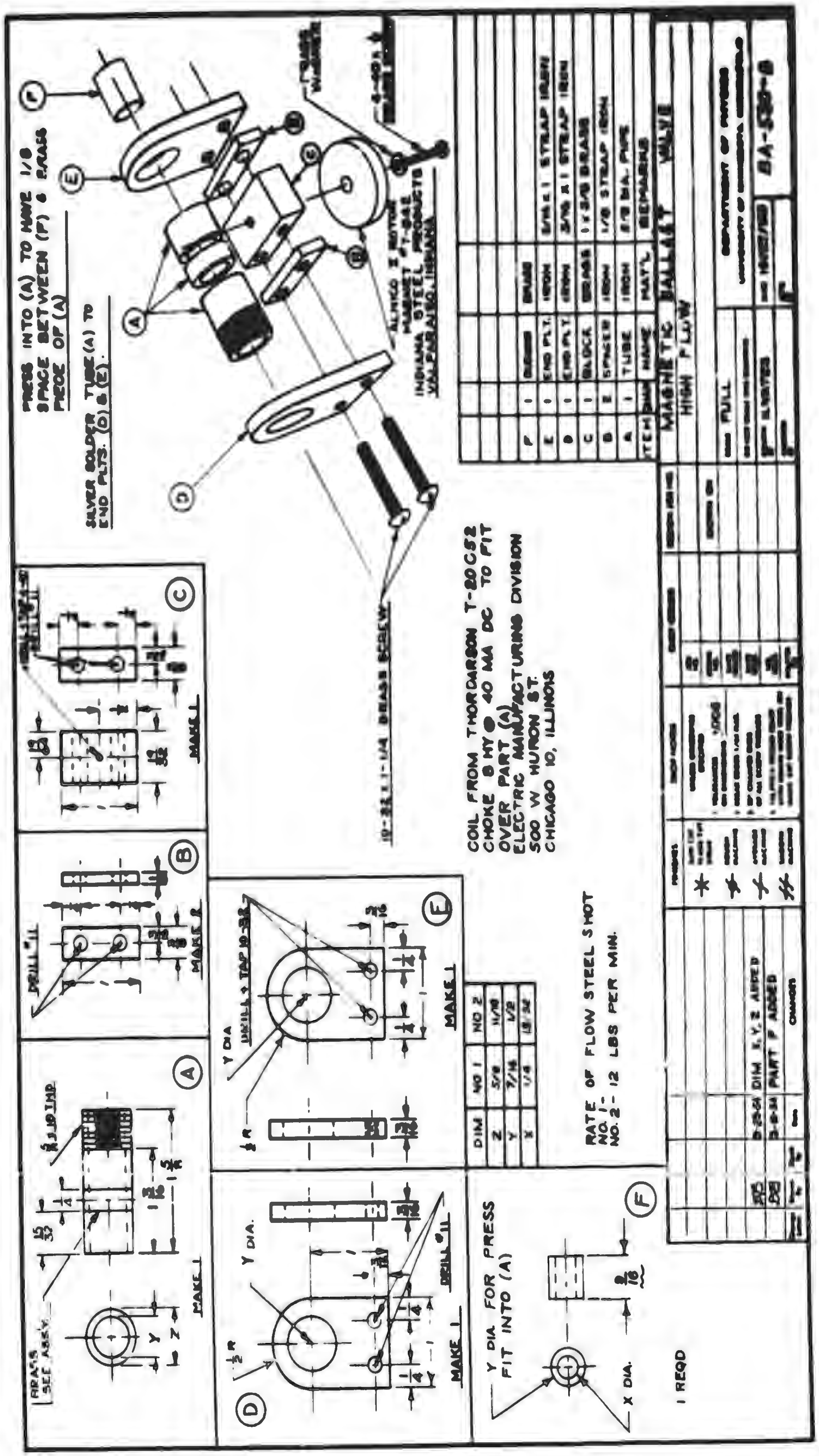
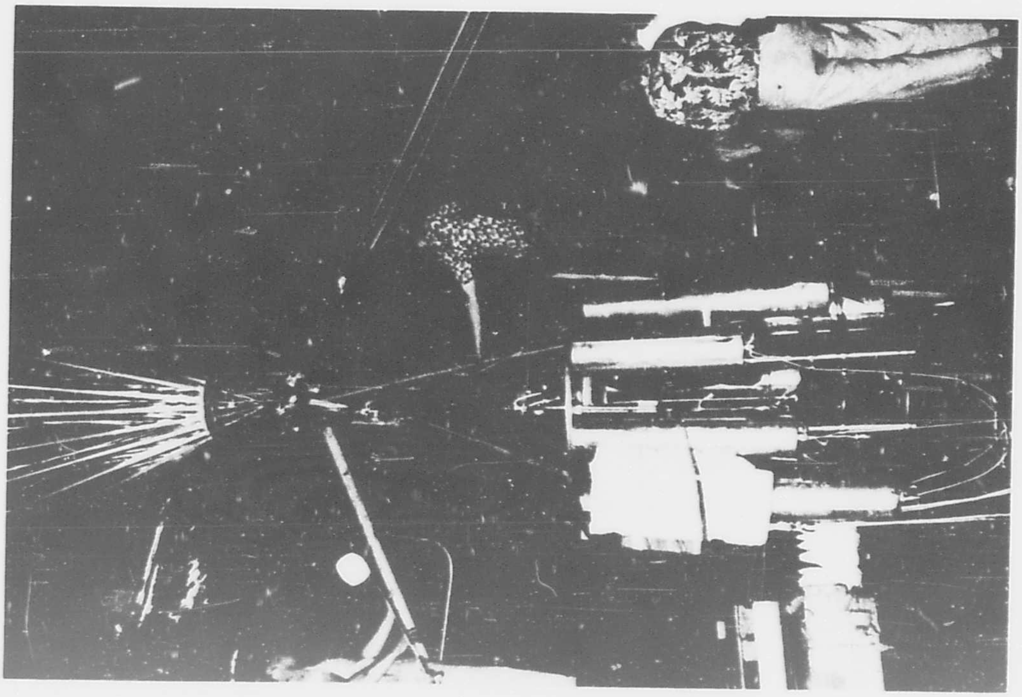

PRESS INTO (A) TO HAVE 1/8 SPACE BETWEEN (F) & PIECE OF (A)
SILVER SOLDER TUBE (A) TO END PLTS. (D) & (E)
10-32 x 1-1/4 BRASS SCREW
COIL FROM THORDARSON T-20C52
CHOKE 8 HY @ 40 MA DC TO FIT
OVER PART (A)
ELECTRIC MANUFACTURING DIVISION
500 W. HURON ST.
CHICAGO 10, ILLINOIS
RATE OF FLOW STEEL SHOT
NO. 1 -
NO. 2 - 12 LBS PER MIN.
MAGNETIC BALLAST VALVE
HIGH FLOW
MAKE 1
1 REQD

Fig. I-44.

action was non-reducible and therefore unusable. The majority of testing was done with water for reasons of safety and convenience, and all of these devices were tried with and without aerosol in the water. Final calibration, of course, was done with the ballasting material used, Skelly-S.

The final form of the step flight ballast container (Figures I-45, I-46) was a large ring supporting eight cylindrical tanks connected in opposite pairs (to maintain balance) with four hoses which were dropped by the hose dropper described previously in this report. The diameters of all the tanks were the same, but the length varied depending on the amount of ballast to be dropped on each step. The head of pressure for each orifice was determined by the length of hose from the orifice to the bottom of the tank plus the depth of liquid above the bottom of the tank. The parameters of the system could be predicted with reasonable accuracy, but the final size of the orifice was determined for each flight by experimentation. The dimensions of the system for a typical flight are given in the table in Figure I-47. A detailed discussion of the theory of the liquid ballast dispensers is given in Volume IX, Section VI.

The hoses used on this ballasting mechanism were several orders of magnitude larger in diameter than the orifices at the end so as to prevent the friction of the liquid in passing down the hose from affecting the flow rate. The use of these hoses dictated that they be made of a material unaffected by organic solvents, one which was strong enough to withstand the shock of dropping suddenly, and, most important, a material was needed which retained flexibility at low temperatures. Fire hose, flexible auto



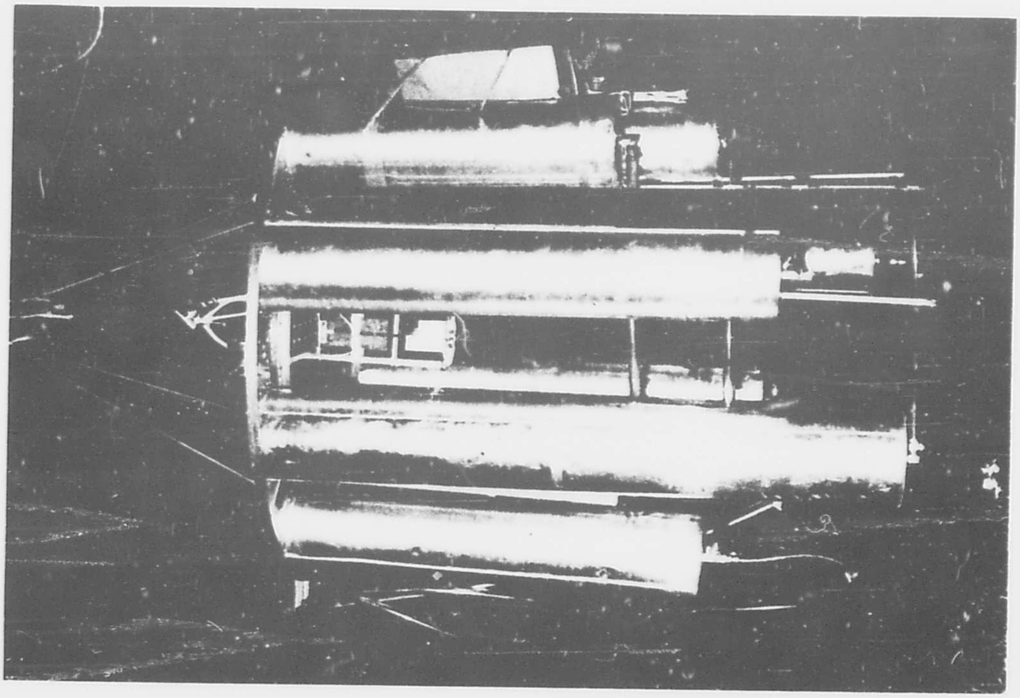


Fig. I-45. Liquid Ballast Tanks

A. Fully rigged, attached to lead balloon, showing position of gondola, parachute, and styrofoam float.

B. Before rigging, showing hoses attached to dropper one side, parachute box on other side, and tensiometer in the middle.

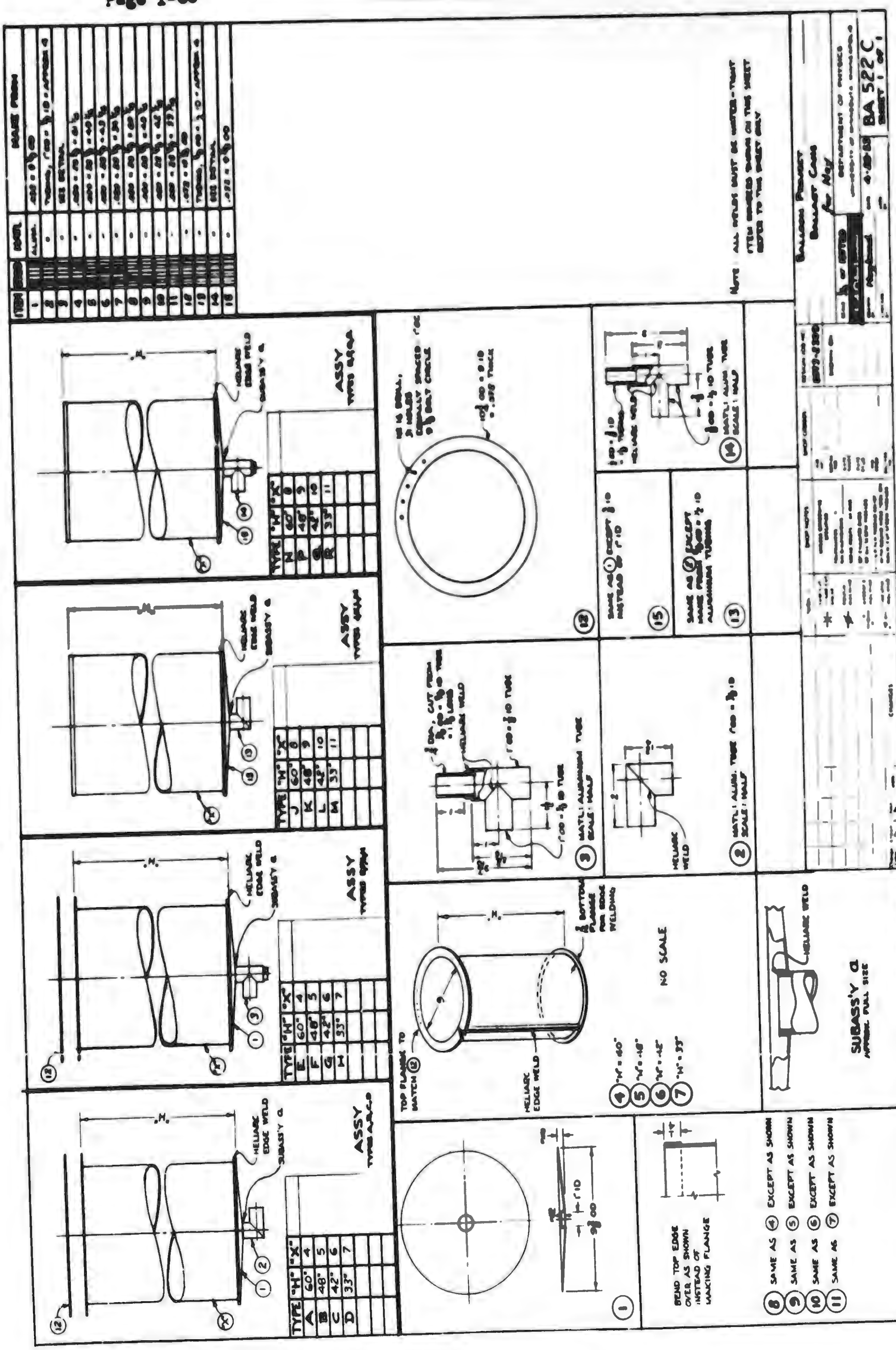


Fig. I-46A.

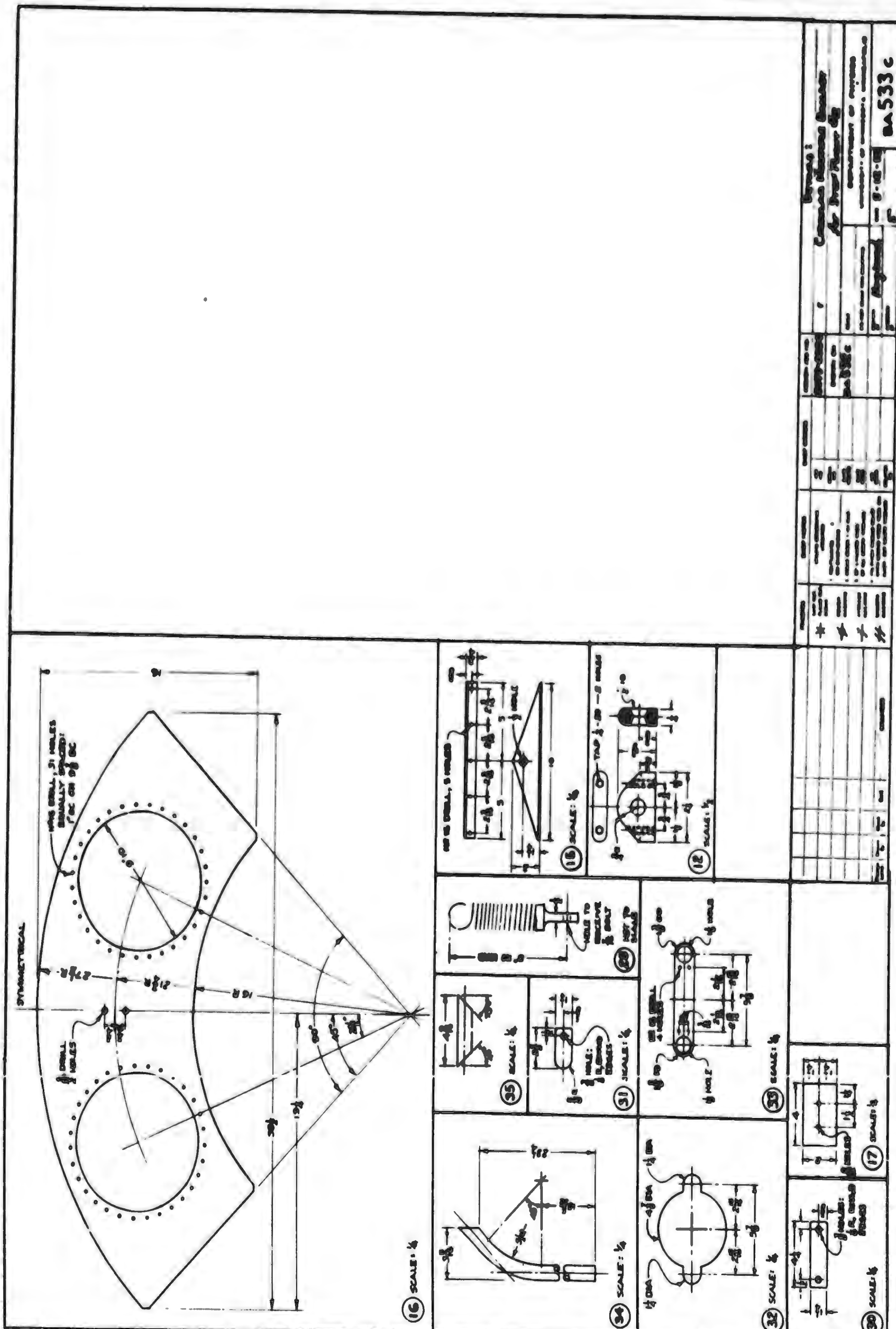


Fig. I-46B.

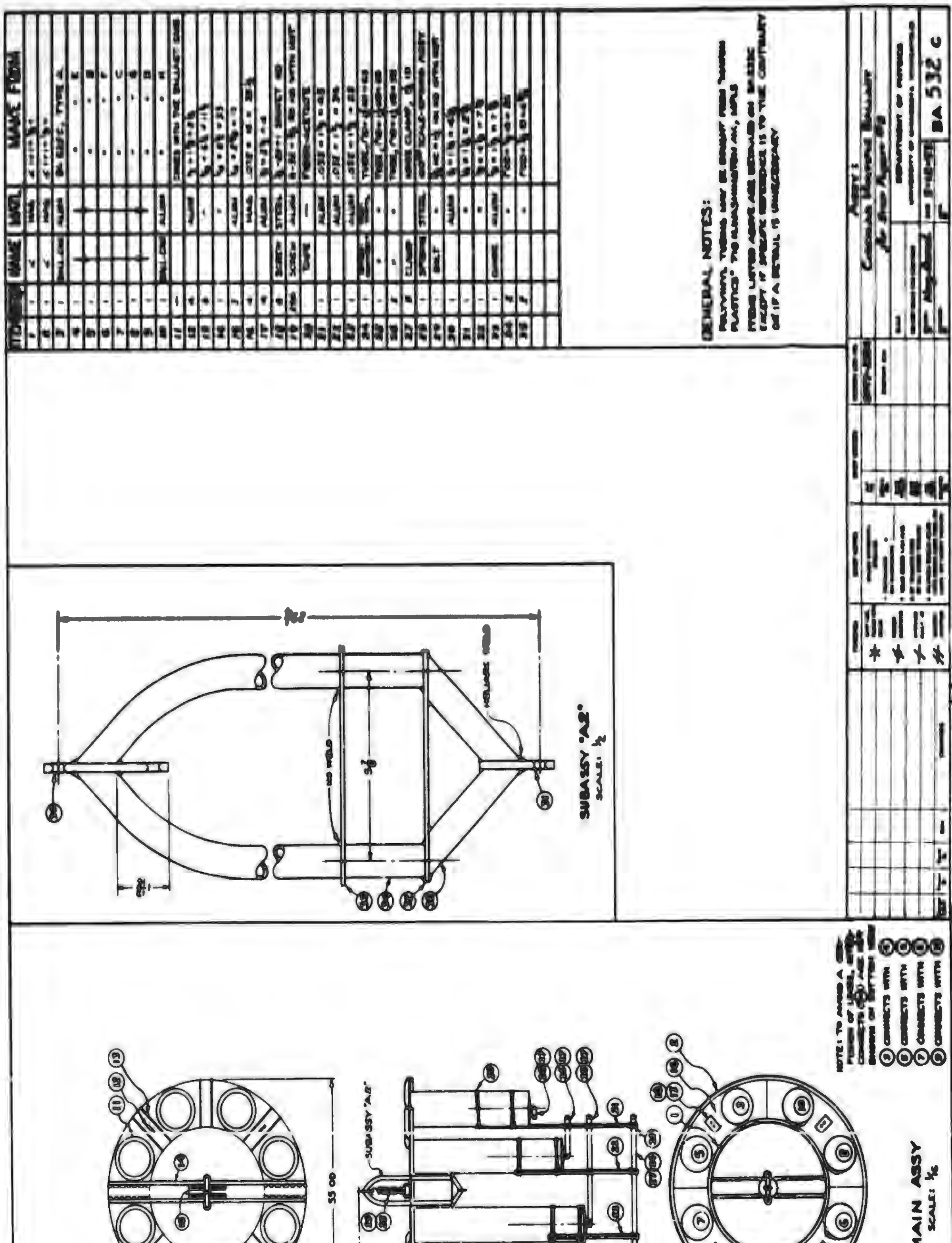


Fig. I-46C.

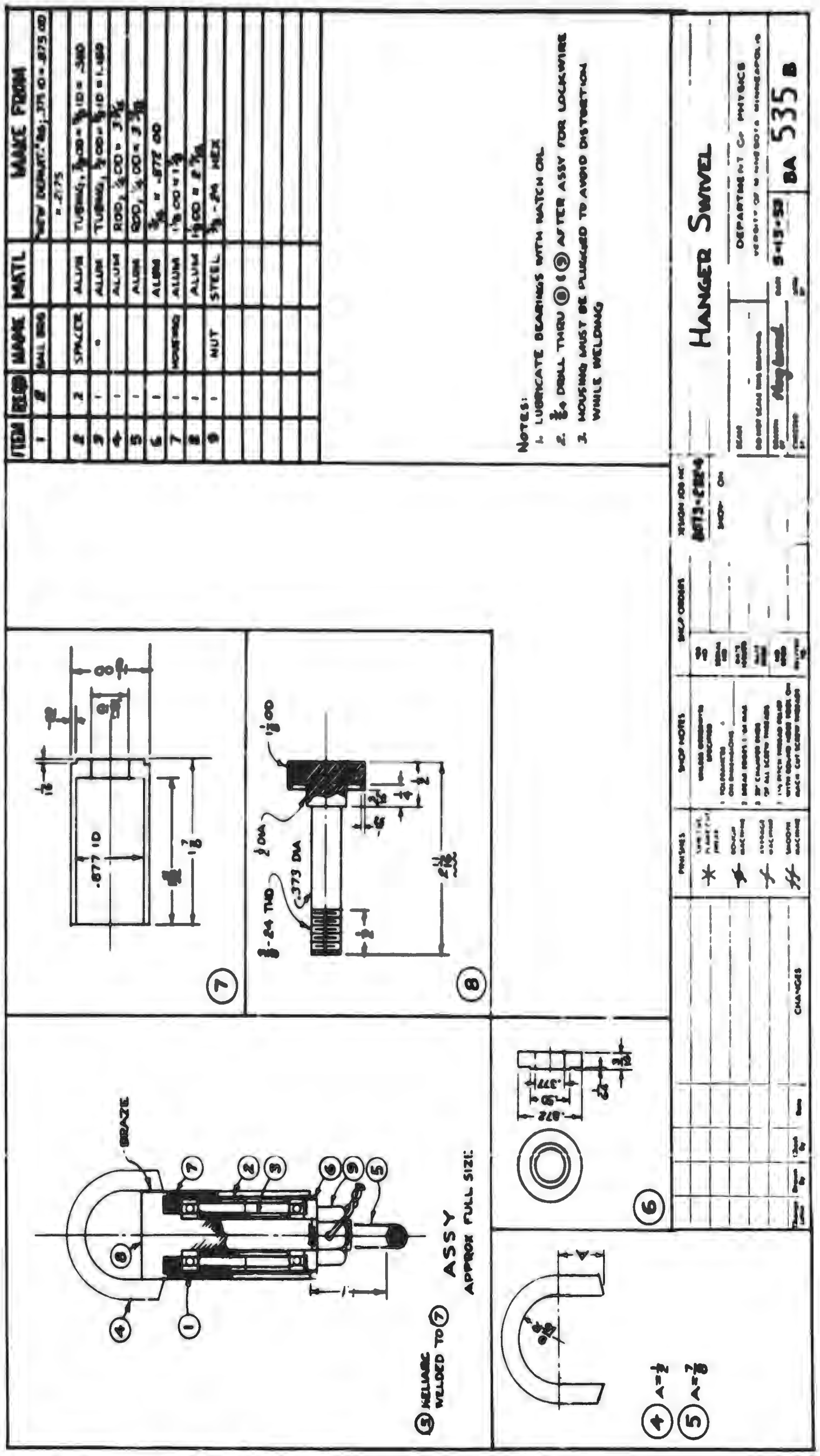

HANGER SWIVEL
DEPARTMENT OF PHYSICS
BA 535 B
NOTES:
1. LUBRICATE BEARINGS WITH WATCH OIL
3. HOUSING MUST BE PLUGGED TO AVOID DISTORTION WHILE WELDING
ASSY
APPROX FULL SIZE
BRAZE

Fig. I-46D.

BALLAST DIMENSIONS FOR FLIGHT 79

Step	Weight of Kerosene Dropped	Height of Kerosene in each Can	Length of Hose (3/4" Dia)	Area of Orifice	Time to Drain
14-24 K	172 lbs.	3.74 ft.	3.71 ft.	0.216 in.	20' 32"
24-34 K	128	2.78	2.57	0.195	20' 39"
34-44 K	112	2.44	1.44	0.206	20' 40"
44-54 K	72	1.57	0.88	0.186	20' 43"

Fig. I-47.

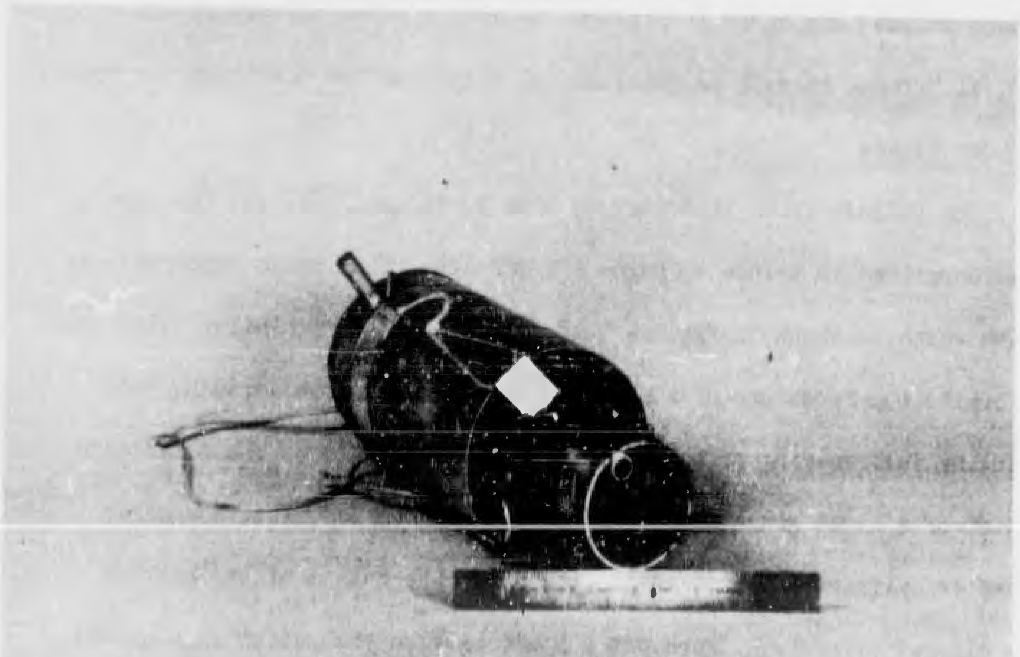
heater duct, 5-mil poly tubing, rubber hose, and neoprene hose were among the different types of tubing tested before tygon tubing was finally accepted. Even this is not a perfect solution, because it was found that the tygon has a tendency to deform permanently if bent sharply, and on several occasions leaking fractures have developed at sharp bends. This trouble has been eliminated by inserting loosely wound wire springs inside the hose at the point of greatest expected curvature.

When it was observed that the fourth hose on two flights apparently did not drop properly, it was suspected that tygon had the property of gradually becoming stiff at low temperatures, even though laboratory testing and manufacturers' specifications did not reveal this behavior. This conclusion and its solution were not reached until the end of the report period, and since it involves an entirely new ballasting and control system, it will be discussed at length in the next progress report.

7. Gas Valves

The balloon valve indicated on line 7, Figure I-31, was the same as that described in Volume V, Pages VII-222-224. The liquid superpressure valve which is shown in Figures I-48 and I-49 was a regulating valve used to create superpressure of a predetermined value in the balloon, yet allowing full valving of any pressure above that value. The valve consisted of a light gauge aluminum can with an open top, with a smaller diameter cylinder fastened inside, to which the bottom of the balloon was clamped directly. There was a space between the bottom edge of the cylinder and the bottom of the can for the valving of gas. A volume of

Fig. I-48. Liquid Superpressure Valve.
A. Side view, showing inflation tube to the left.



B. Top view, showing steel wool packed inside the valve.

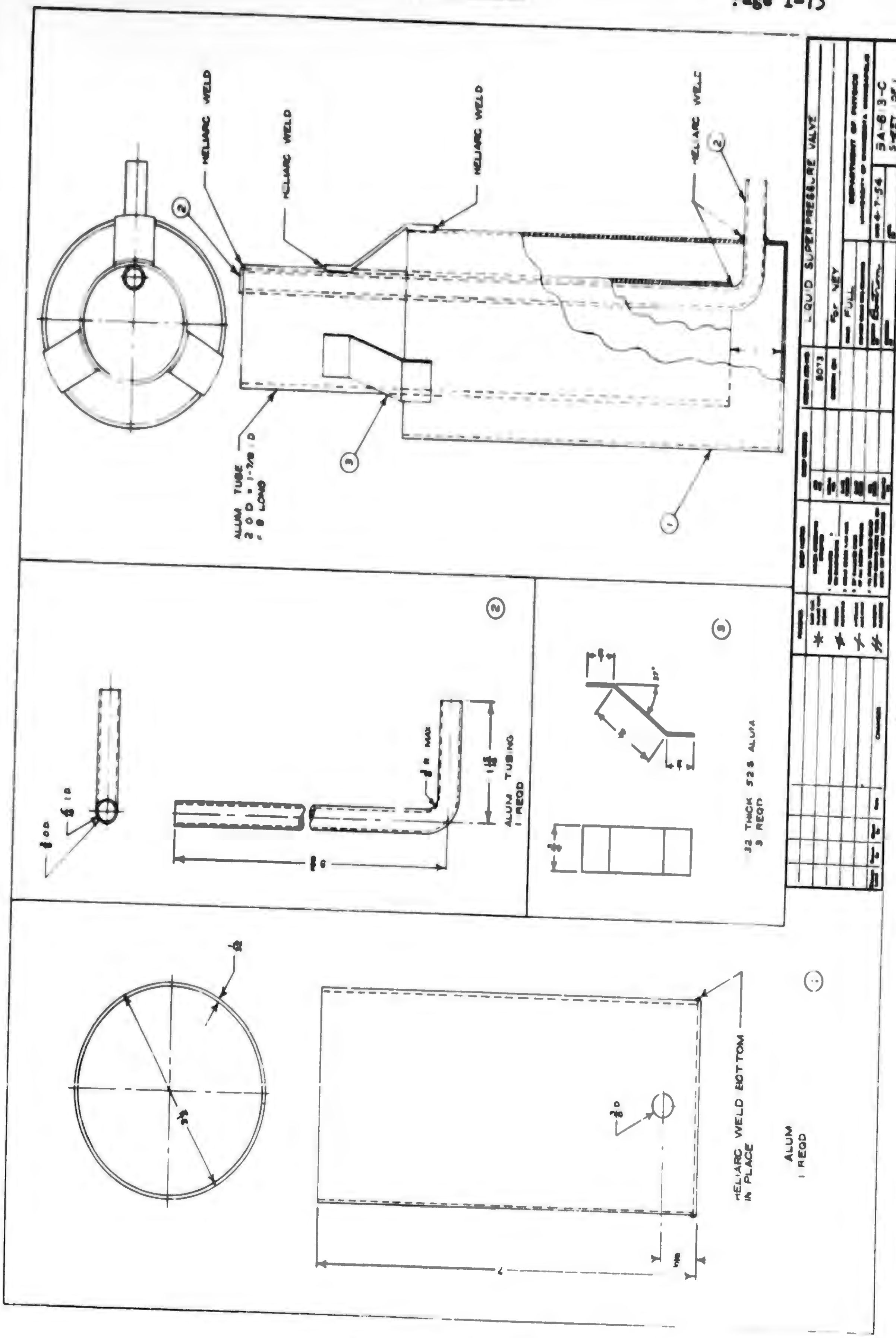

HELIARC WELD
HELIARC WELD
HELIARC WELD
HELIARC WELD
ALUM TUBE
LIQUID SUPERPRESSURE VALVE
FULL
ALUM TUBING
1 REQD
32 THICK 52S ALUM
3 REQD
HELIARC WELD BOTTOM
IN PLACE
ALUM
1 REQD

Fig. I-49.

liquid (Skelly S) was poured into the can to a level above the bottom edge of the cylinder proportional to the superpressure desired. This level was determined for each balloon by experimentation. The space between the can and the top of the inner cylinder was packed loosely with coarse steel wool in order to catch any drops that might splatter as the gas bubbled through the liquid. These drops were then returned to the reservoir, thus maintaining the liquid level and the total weight of the valve. Because the balloon was attached directly to the cylinder, an inflation tube was needed, which in the illustrative model was built into the valve. This was plugged with a cork when the balloon was released to prevent the entrance of air.

The calibrating of these valves was made simpler by the use of a Brailsford Differential Pressure Telemeter, Brailsford & Co., Inc., Milton Point, Rye, New York. This instrument, originally developed for the Signal Corps, is a lightweight D.C. Servo, intended for flight on Piebald balloons, which transforms a positive differential in pressure between atmospheric and one side of a diaphragm into a shaft rotation. A calibrated dial mounted on the output shaft allows the pressure to be read directly up to 10 mb, the total range of the instrument. The scale was periodically checked against the reference manometer used for the calibration of the project pressure equipment and was found to be very accurate even after several months of relatively rough usage.

Telemetering

8 and 9. Receivers and Transmitters

These are discussed in this report, Section II, Volume X.

10. Antenna Dropper

The antenna dropper shown in Figures I-50 and I-51 is changed in several details from the dropper mentioned in the last progress report. The latch arm now has a roller as a latching surface in order to prevent possible sticking due to sliding friction between the aluminum latch and the spring steel striker plate. The illustration shows a dropper made for use with the smaller 3415 KC antennas. All antenna droppers which were flown in the interior of the gondolas have been enclosed in a ¼" plywood box in order to insulate the gondola equipment from contact with the outside air. When the droppers were flown external to the gondola, they were fastened unprotected on the flasher light arm. This proved to be inadvisable, for on one flight when there was a strong ground wind requiring a short run with the gondola, the knee of one of the ground crew struck the dropper, releasing the antenna on the ground. In this case no permanent damage was done, since the random winding of the antenna ball allowed it to unwind rapidly without tangling. On another occasion, when a large appendix was used on the balloon, it was seen to wind around this unprotected antenna dropper immediately after release. Since no radio signal was received from that flight, it was deduced that the antenna dropper was prevented from operating by the appendix.

11. Encoders

The encoders mentioned in Line 11, Figure I-31, served two different purposes. The Command Signal Coder, mentioned in Volume V, Pages VII-238

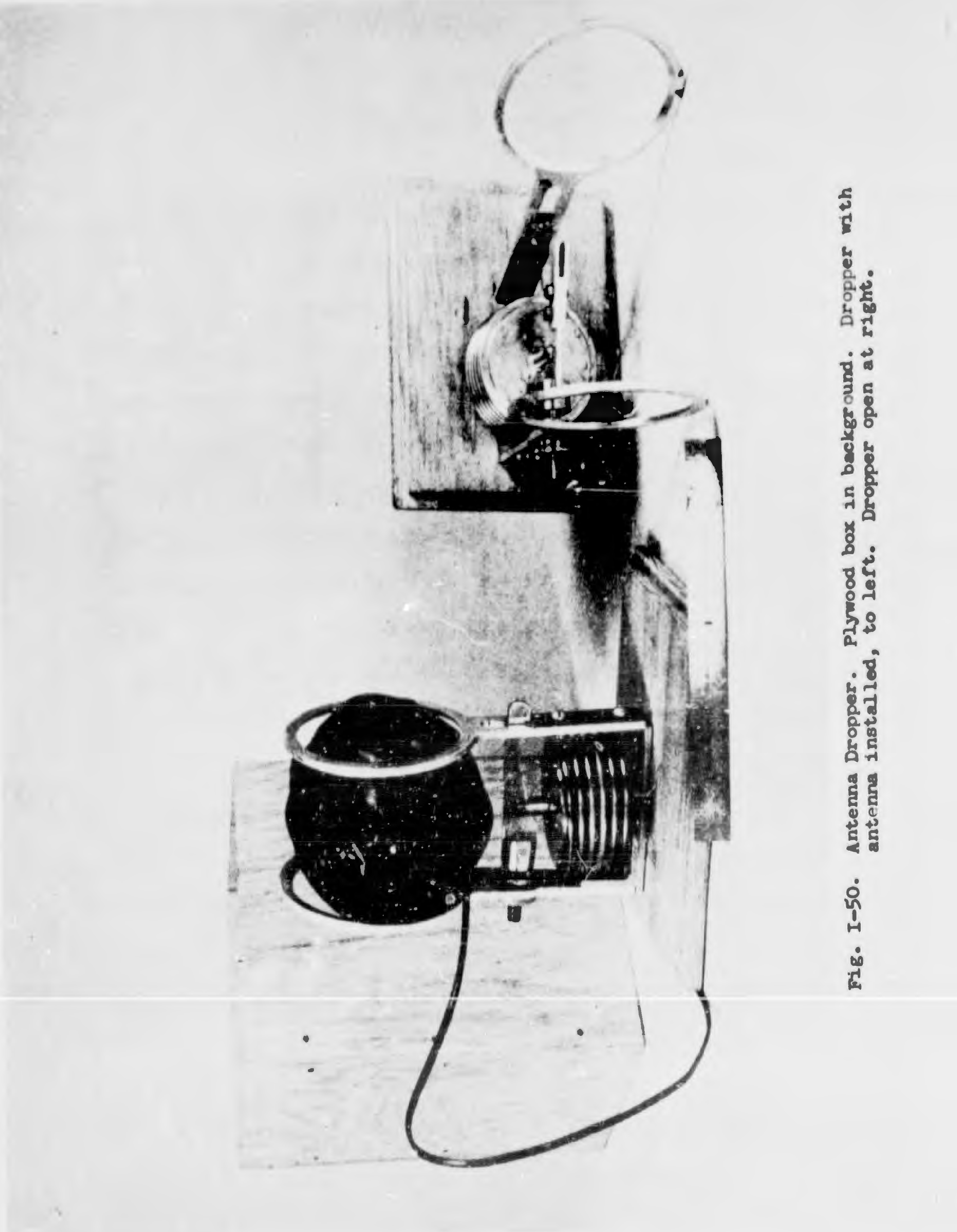


Fig. I-50. Antenna Dropper. Plywood box in background. Dropper with antenna installed, to left. Dropper open at right.

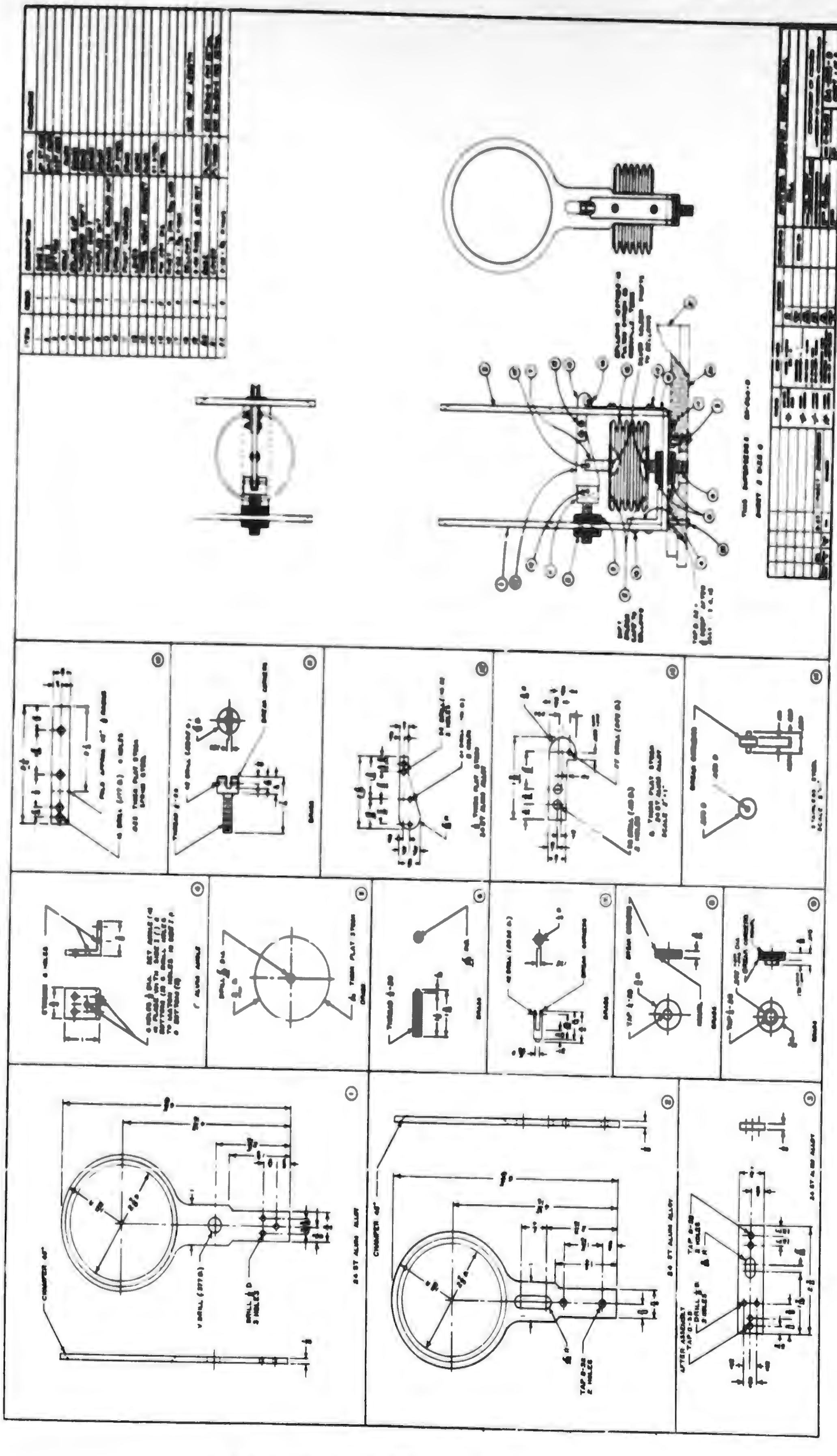


Fig. I-51A.

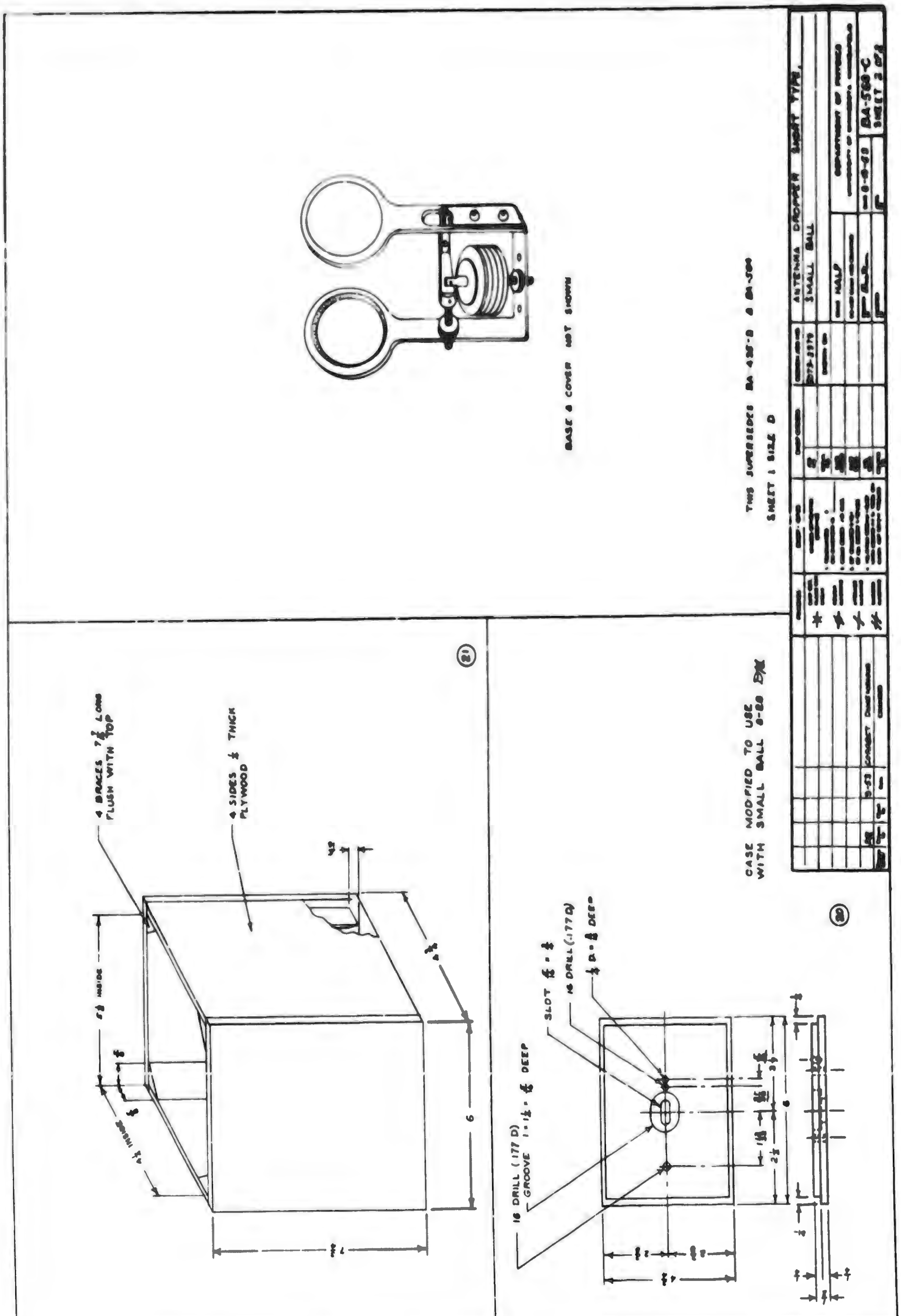

4 BRACES 7⅞ LONG FLUSH WITH TOP
4 SIDES ¼ THICK PLYWOOD
BASE & COVER NOT SHOWN
CASE MODIFIED TO USE WITH SMALL BALL
ANTENNA DROPPER SHORT TYPE, SMALL BALL
SHEET 1 SIZE D

Fig. I-51B.

to VII-240, generated a coded signal which keyed the transmitter and indicated operation of several different command instruments in the gondola. This instrument was unchanged from the description given in the last progress report.

The other type of encoder used during this report period was a multiplexing commutator which repetitively keyed the transmitter with the information from several different sensing devices in the step flight gondola. A pulse, differentiated in time duration from the information pulses, was included every cycle on which the decoding equipment was synchronized so that the signal could be read out the same way it was fed into the encoder. This type of multiplexing is particularly easy to adapt to pulse code modulation such as this project uses. A commutator repetitive rate was chosen which was short with respect to the shortest expected information pulse length (15-20 RPS compared to 1 sec), so that information loss and inaccuracy would be minimized.

The first commutator used was based on a mechanism built by the Applied Science Corp. of Princeton, N. J., Model #2-30S-5M, consisting of a motor-driven arm riding on a number of closely spaced contacts. The whole assembly was packed in grease for lubrication. A vacuum tube pulse-shaping circuit was used to convert the pulses into square waves of the proper voltage to key the transmitter. A picture and schematic of this instrument are shown in Figures I-52 and I-53. Several serious faults were found with this apparatus which resulted in a change in design. The motor of the commutator constantly varied its speed, making synchronization of the ground equipment extremely difficult. In addition, the constant wear of the contact points and wiper arm suspended metal

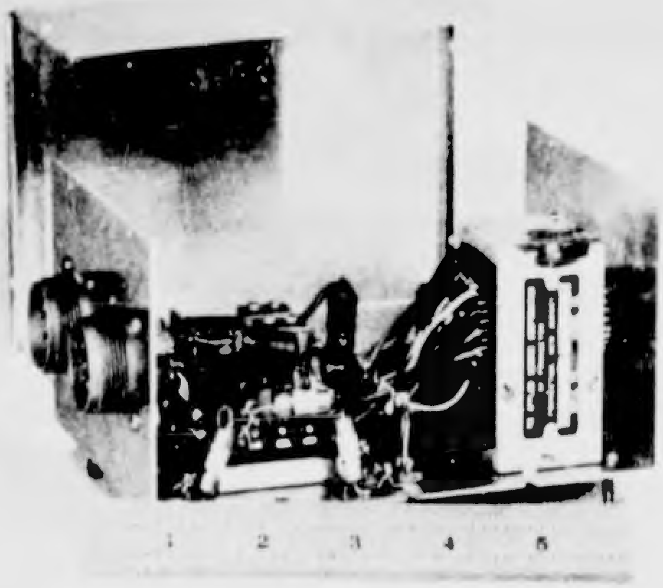
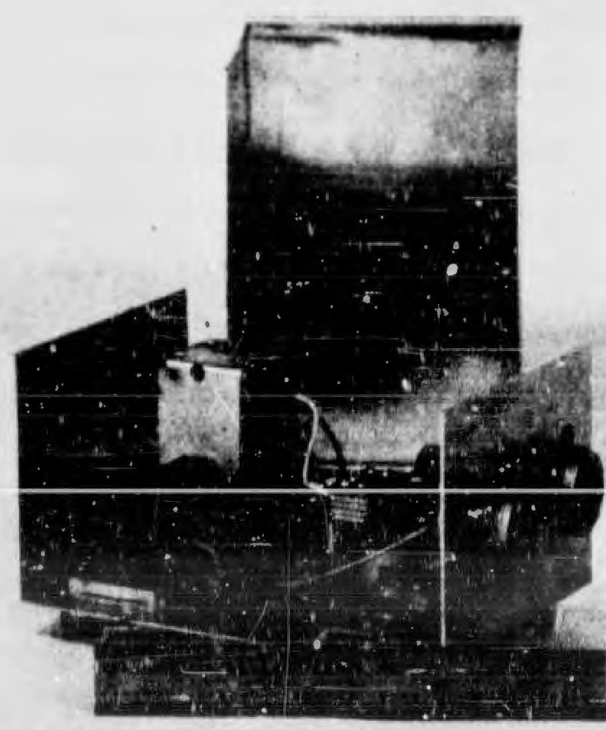


Fig. I-52. Commutator, Princeton Type.
A. Right side view



B. Left side view

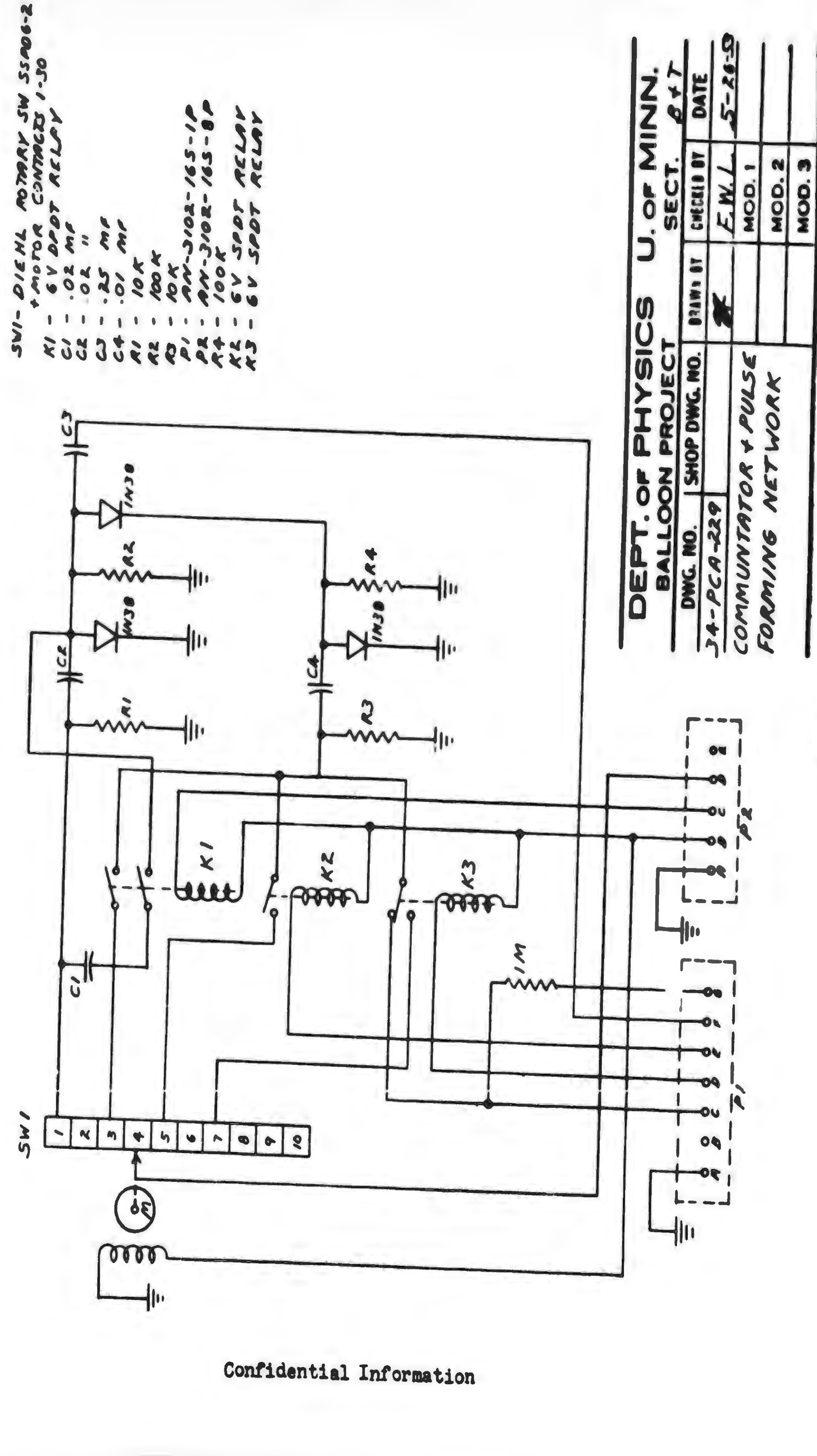

SW1 - DIEHL ROTARY SW SSPO6-2
+ MOTOR CONTACTS 1-30
K1 - 6V DPDT RELAY
C1 - .02 MF
C2 - .02 "
C3 - .25 MF
C4 - .01 MF
R1 - 10K
R2 - 100K
R3 - 10K
P1 - AN-3102-16S-1P
P2 - AN-3102-16S-8P
R4 - 100K
K2 - 6V SPDT RELAY
K3 - 6V SPDT RELAY
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B+T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
34-PCA-229
E.W.L.
MOD. 1
MOD. 2
MOD. 3
COMMUNTATOR + PULSE FORMING NETWORK
SW1
C1
C2
C3
C4
R1
R2
R3
R4
1N38
K1
K2
K3
1M
M
P1
P2

Fig. I-53.

particles in the grease around the contact points and the keying of each channel became very ragged after the commutator had been used a short time. As use continued, the metal particles from each contact spread to the next, so that keying one channel resulted in the keying of the adjacent channels. Cleaning, rinsing,and changing the grease solved this problem temporarily. Actually this commutator was designed for use in rockets, where short-time operation is required. For long-duration balloon flights the commutator problem is more severe.

Because of these difficulties with the Princeton commutator, the instrumentation section developed another type. It consisted of a motor-driven cam which closed pairs of contacts located around the axis of the cam. A motor with a more constant speed was used, and since there was only a very slight rubbing movement intended as a cleaning action between contacts, there was little conducting dirt associated with the contacts, nor was there the preserving grease medium. This commutator was used with two different types of pulse shaping networks, one using subminiature vacuum tubes and the other Millisec relays. A schematic of the former is given in Figure I-54, and a picture and schematic diagram of the latter are given in Figures I-55 and I-56. There appeared after use to be little basic difference in the performance of these two pulse-shaping networks.

The contact type of commutator (Shop Drawings are given in Figure I-57) also had some serious faults which should be mentioned. At the speed at which the contacts were driven it was found that there was a good deal of contact bounce which resulted in uneven pulse shape. This was helped but not eliminated by giving the rear contact a very stiff mounting, bending the ends of the contact mounting leaves at an angle, and locating small

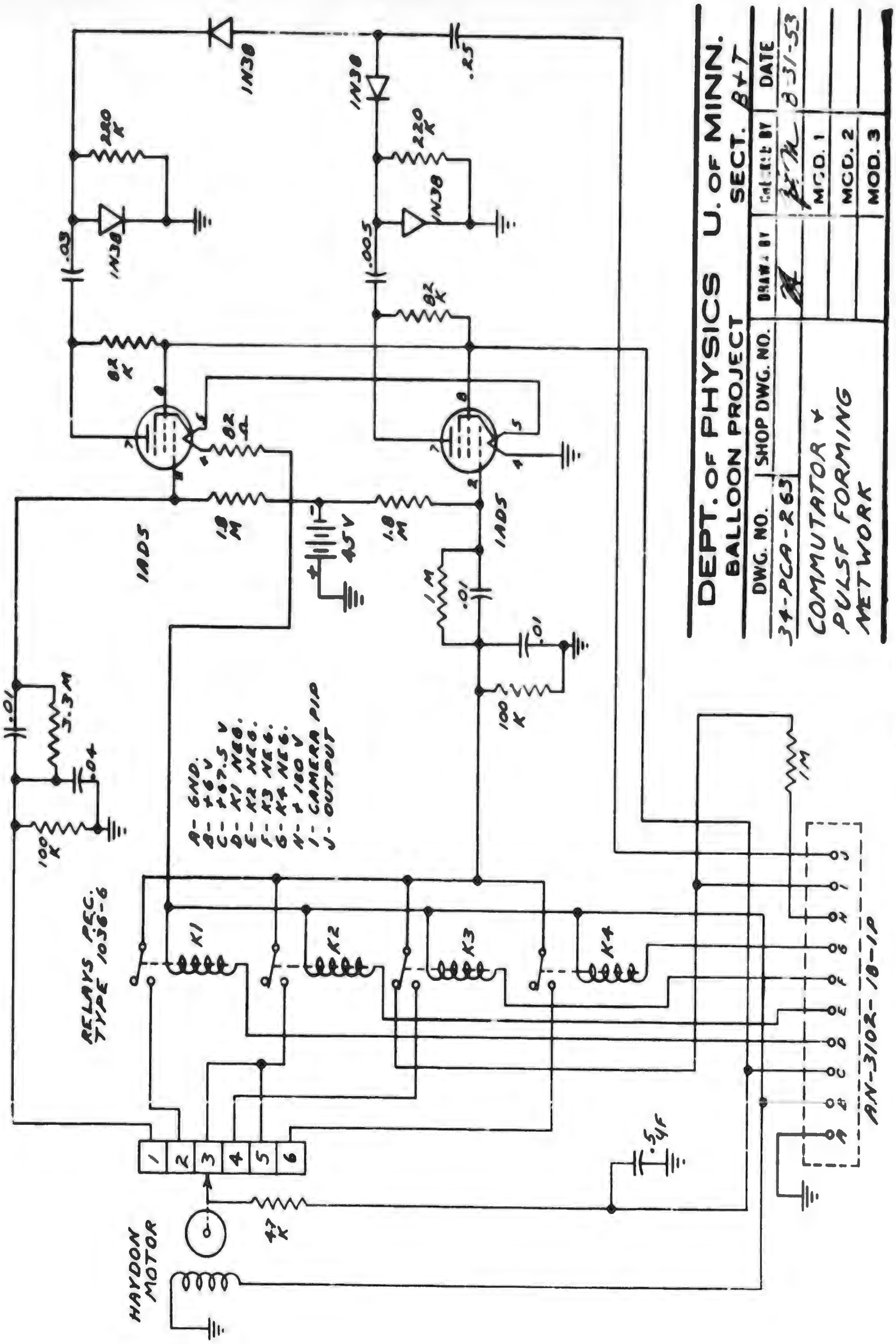

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
SECT. B+T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
34-PCA-263
8-31-53
COMMUTATOR + PULSE FORMING NETWORK
MOD. 1
MOD. 2
MOD. 3
A- GND.
B- +6V
C- +67.5V
D- K1 NEG.
E- K2 NEG.
F- K3 NEG.
G- K4 NEG.
H- +180V
I- CAMERA PIP
J- OUTPUT
RELAYS PEC. TYPE 1036-6
K1
K2
K3
K4
HAYDON MOTOR
AN-3102-18-1P
1AD5
1N38
45V

Fig. I-51.

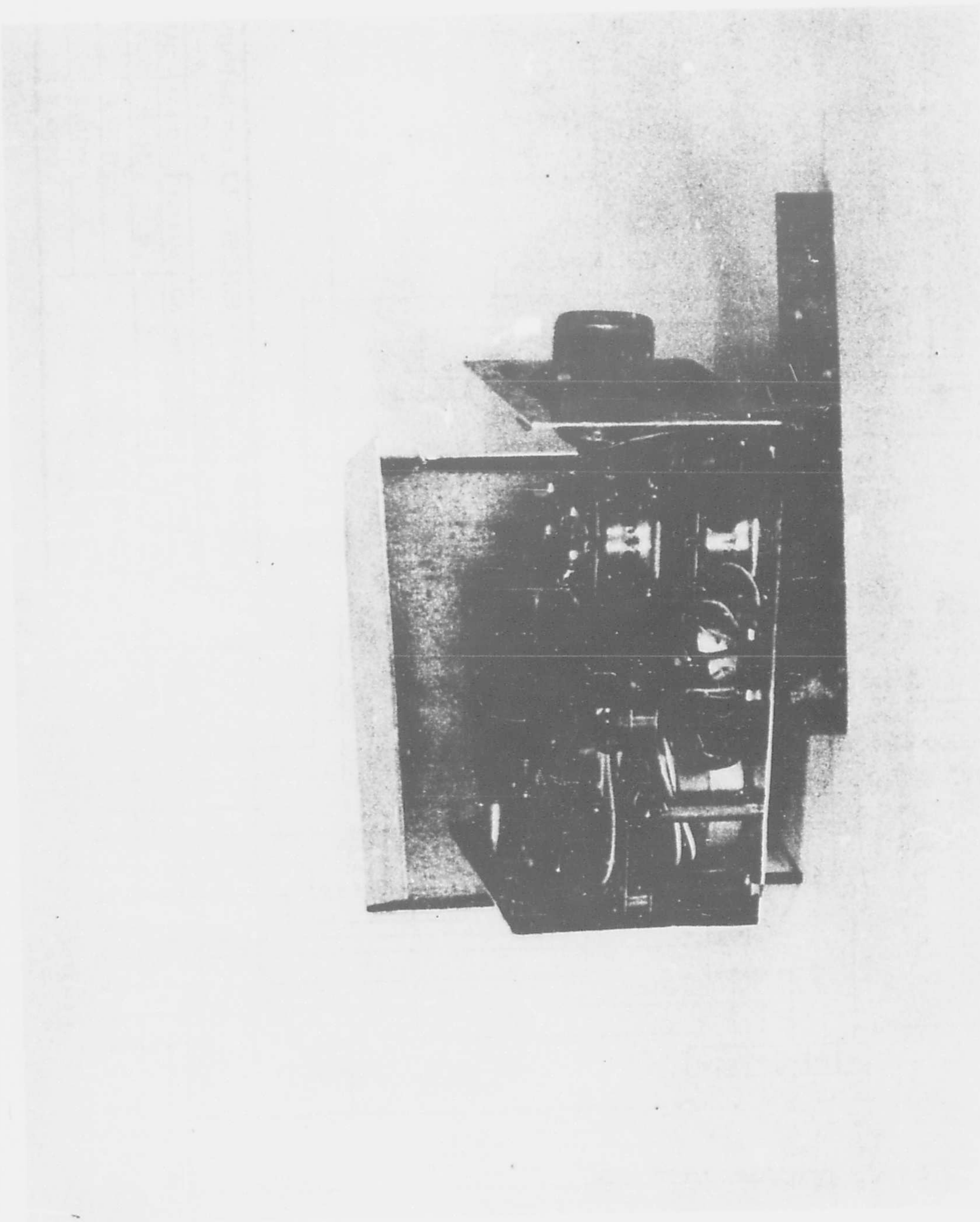


Fig. I-55. Commutator, Millisec Type. Showing motor-driven contactor to the left front.

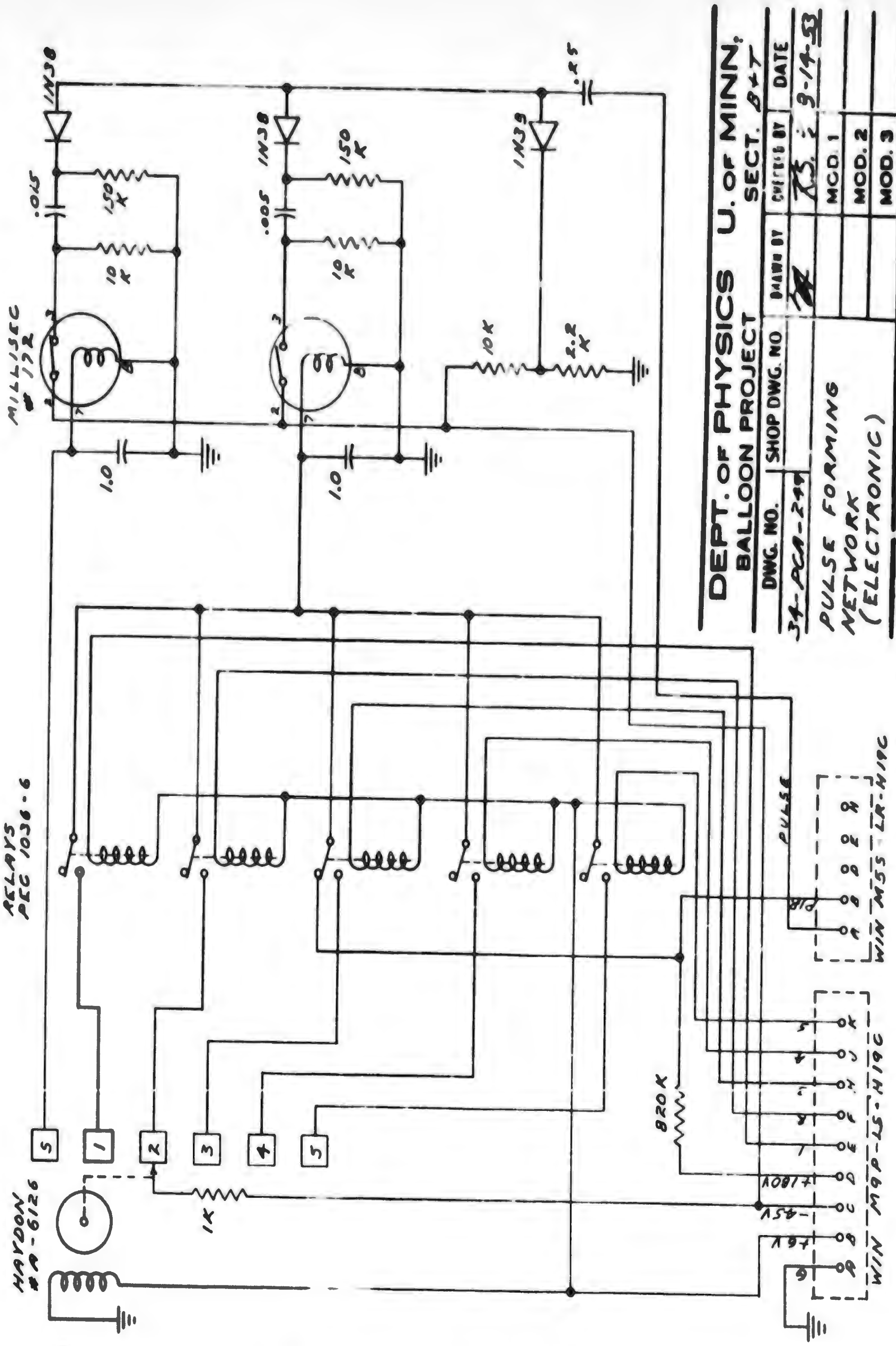

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
9-14-53
MOD. 1
MOD. 2
MOD. 3
PULSE FORMING NETWORK (ELECTRONIC)
RELAYS
1N38
1N39
PULSE
820 K
1 K
HAYDON

Fig. I-56.

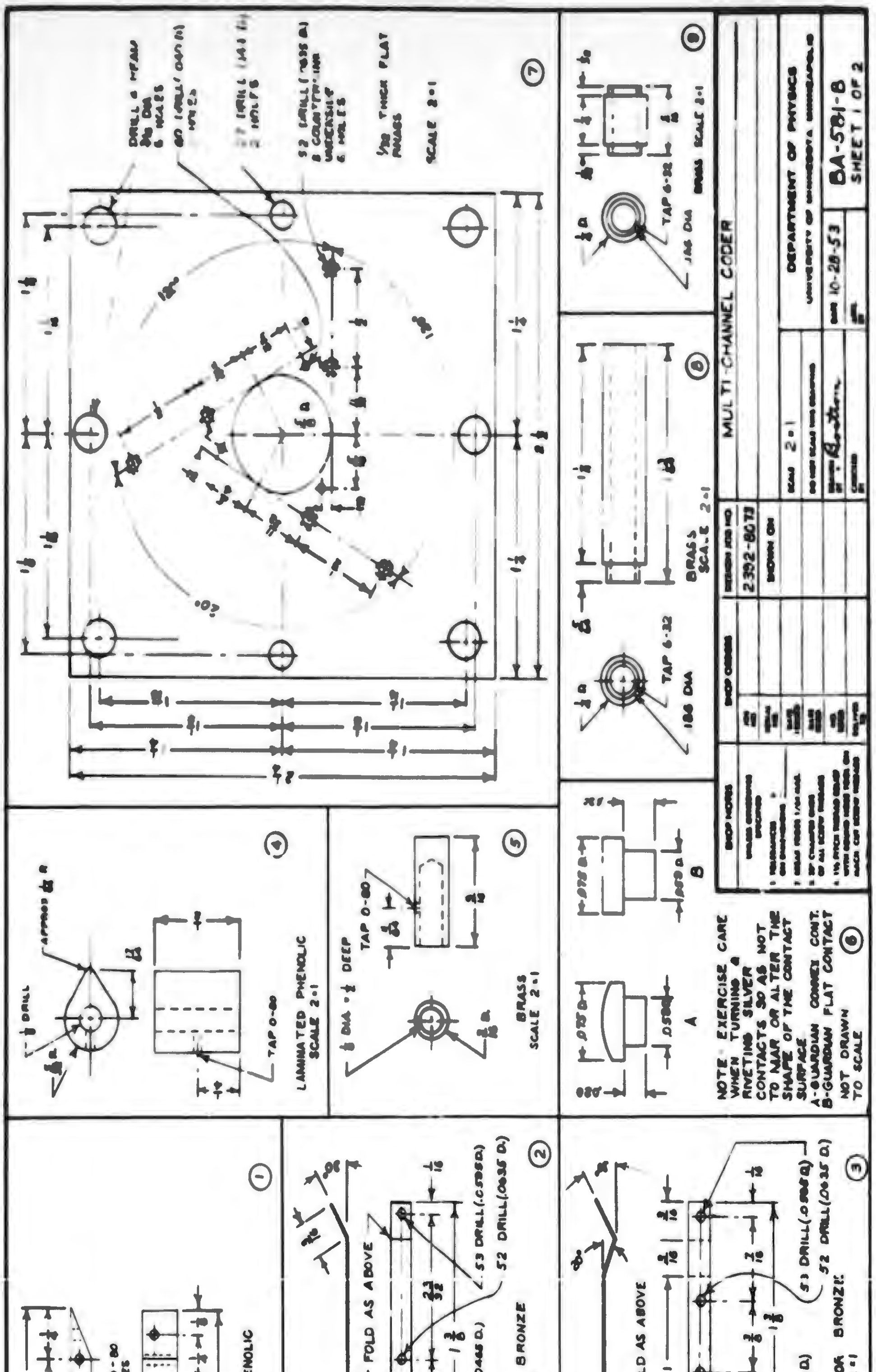

MULTI-CHANNEL CODER
DEPARTMENT OF PHYSICS
BA-581-B
SHEET 1 OF 2

Fig. I-57A.

ITEM	REQD	DESCRIPTION	REMARKS
1	6	BLOCK	
2	6	CONTACT STRIP	
3	6	CONTACT STRIP	
4	1	CAM	
5	1	BUSHING	
6	6 PAIR	SILVER CONTACT	
7	2	PLATE	
8	2	SPACER	
9	4	SPACER	
10	2	SPACER 1/4 O.D. × 1 1/8 LONG	TAPPED 6-32
11	6	PIN .040 DIA × 1/4 LONG	
12	8	6-32 × 3/8 RHMS	
13	4	6-32 HEX NUT	
14	12	0-80 × 3/16 FHMS	
15	25	0-80 × 1/8 RHMS	
16	1	MOTOR 4.5 VDC 900 RPM	MFGD BY HAYDON CO, WATERBURY, CONN

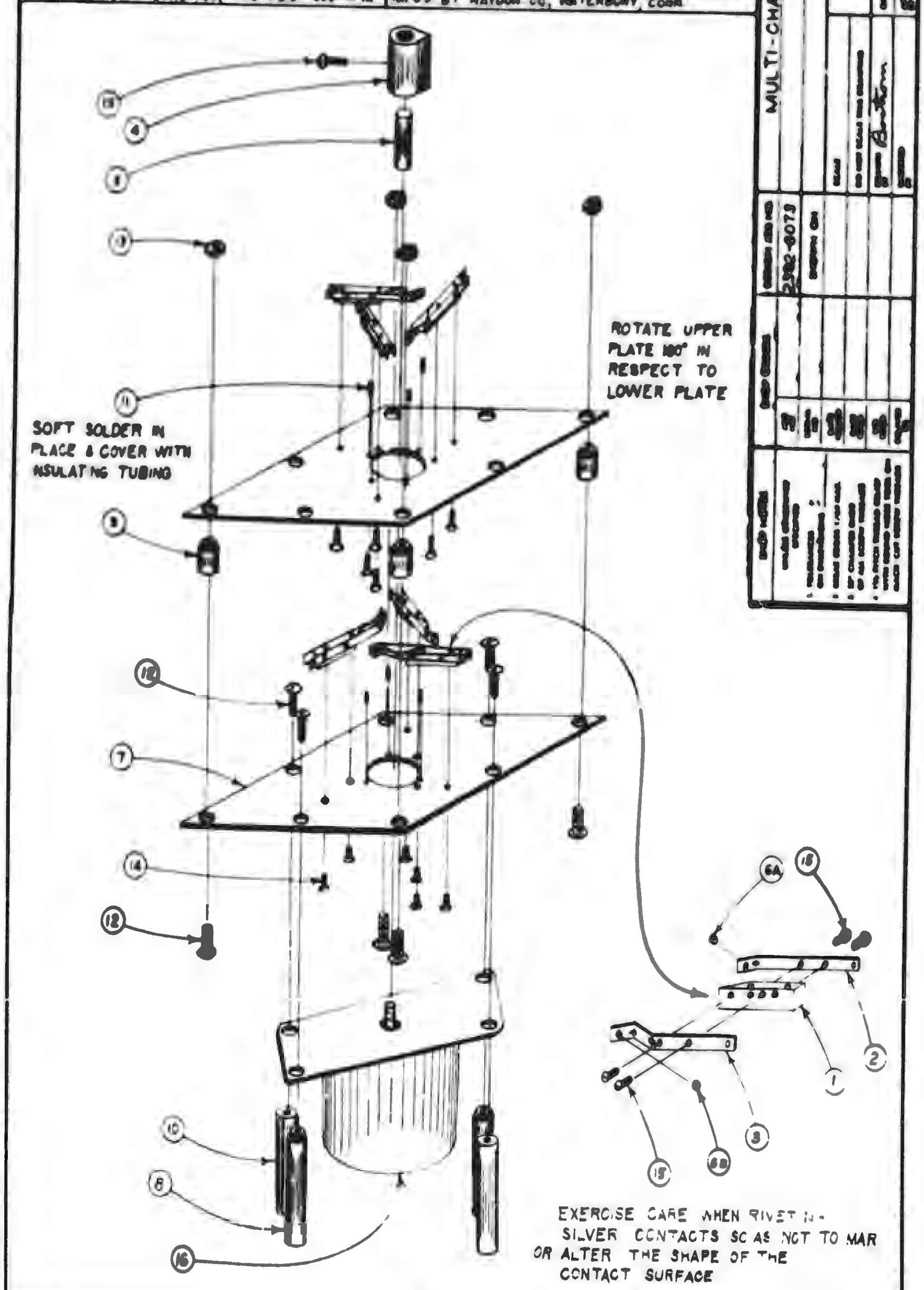


Fig. I-57B.

stop pins behind the driven contact to limit its bounce. Loading the contacts improved the pulse shape but that decreased the motor speed and resulted in uneven drive, since the load on the motor was unevenly spaced. Therefore, though this type of commutator was an improvement over the first type used, it was not the perfect solution.

A third type of commutator, developed but not flown during this report period, has proved to be the most faultless tested here. A picture is given in Figure I-58, shop drawings in Figure I-59, and a wiring diagram in Figure I-60. It consists of a permanent magnet set in the rim of a flywheel rotating within a magnetic shield, which induces pulses in several pickup coils wound around U-shaped poles located around the edge of the flywheel. The voltage pulse generated in the pickup coils is shaped and rectified and is used to key the transmitter directly when circuit is completed through the information-generating equipment. The sync pulse is transformer amplified to differentiate it from the information pulses, and in addition is separated in time spacing from the adjacent channel pulses. The magnetic shorting ring, the function of which is to short out the magnetic field between poles, serves to eliminate a considerable amount of interaction between adjacent circuits, and also shortens the rise and decay time of each pulse, thus increasing the pulse amplitude. In addition, it eliminates the difficulty in starting the motor caused by the permanent magnet locking between the legs of one pole, and evens the running load on the motor, resulting in longer motor bearing life and smoother operation. The flywheel also has a smoothing effect on the drive speed. The case is so constructed that it seals the commutator from the entrance of dirt.

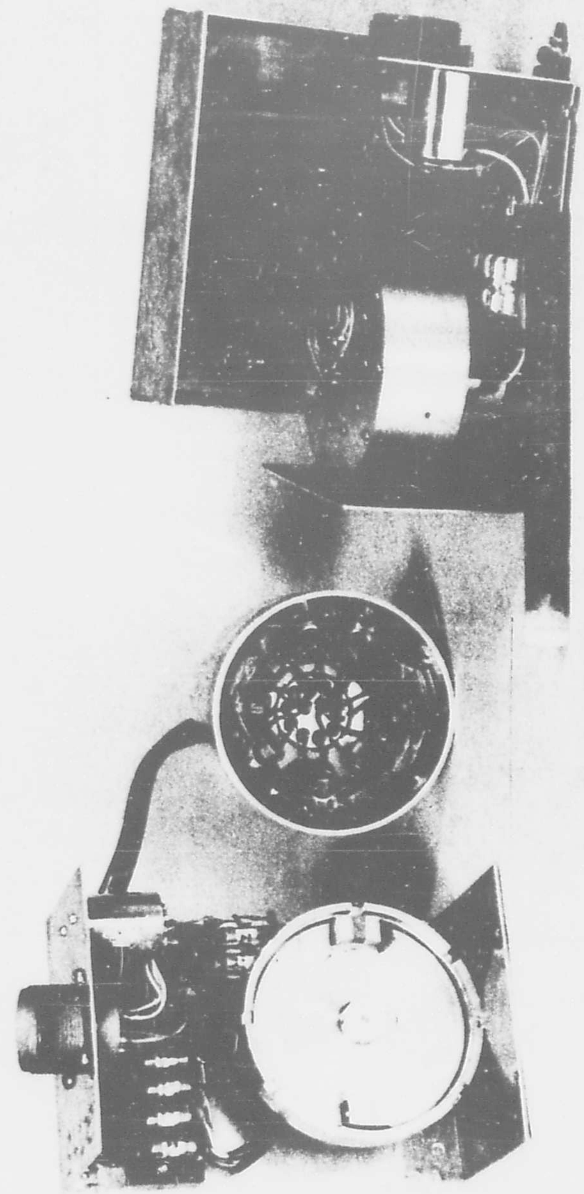


Fig. I-58. Commutator, Magnetic Type. Commutator assembled, at right. Commutator with cover open, at left, showing motor-driven rotor and magnetic shorting ring with pickup poles and coils.

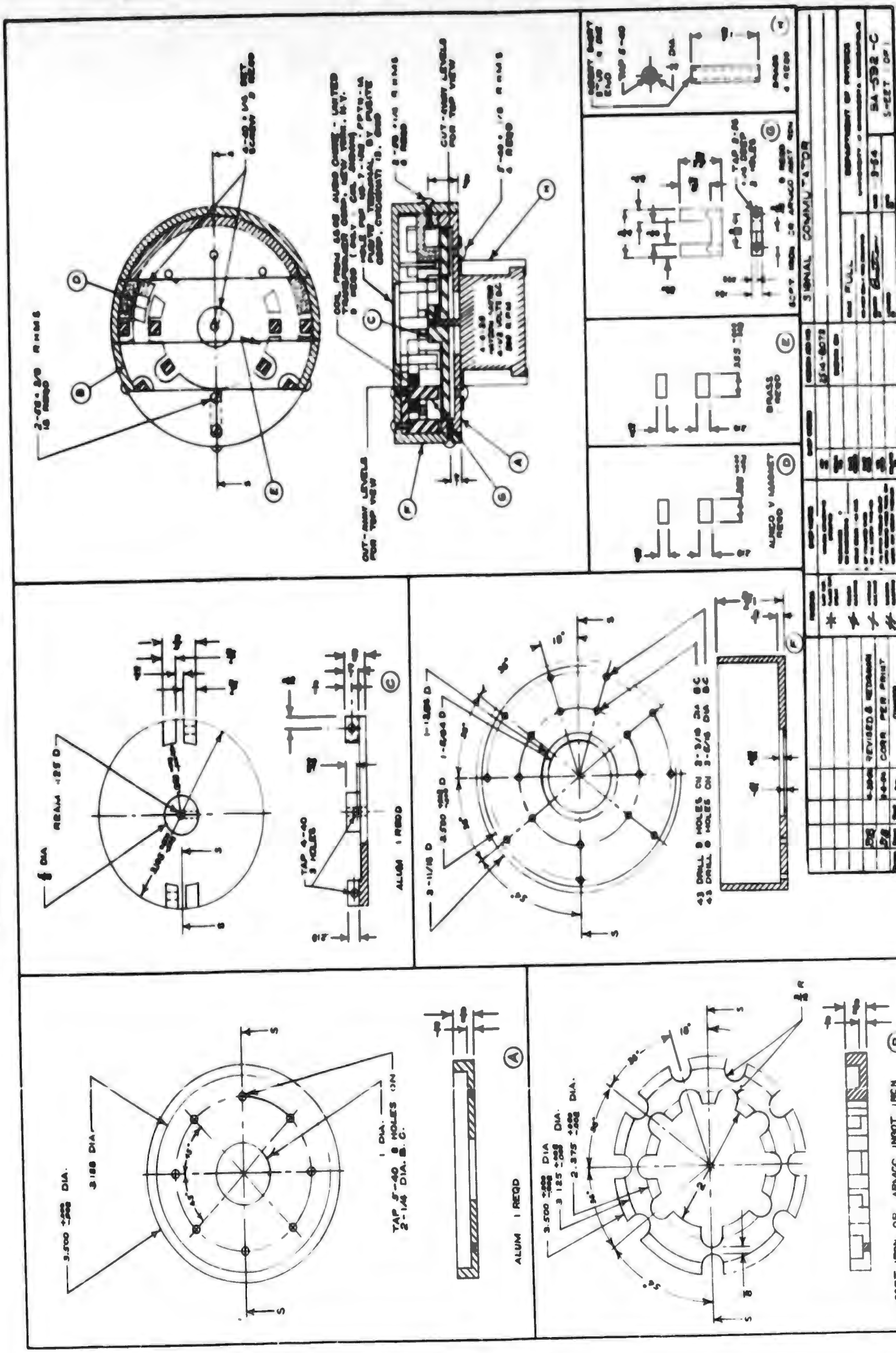

SIGNAL COMMUTATOR
ALUM 1 REQD
TAP 5-40, 8 HOLES ON 2-1/4 DIA. B. C.
SCFT IRON OR ARMCO INGOT IRON 1 REQD

Fig. I-59.

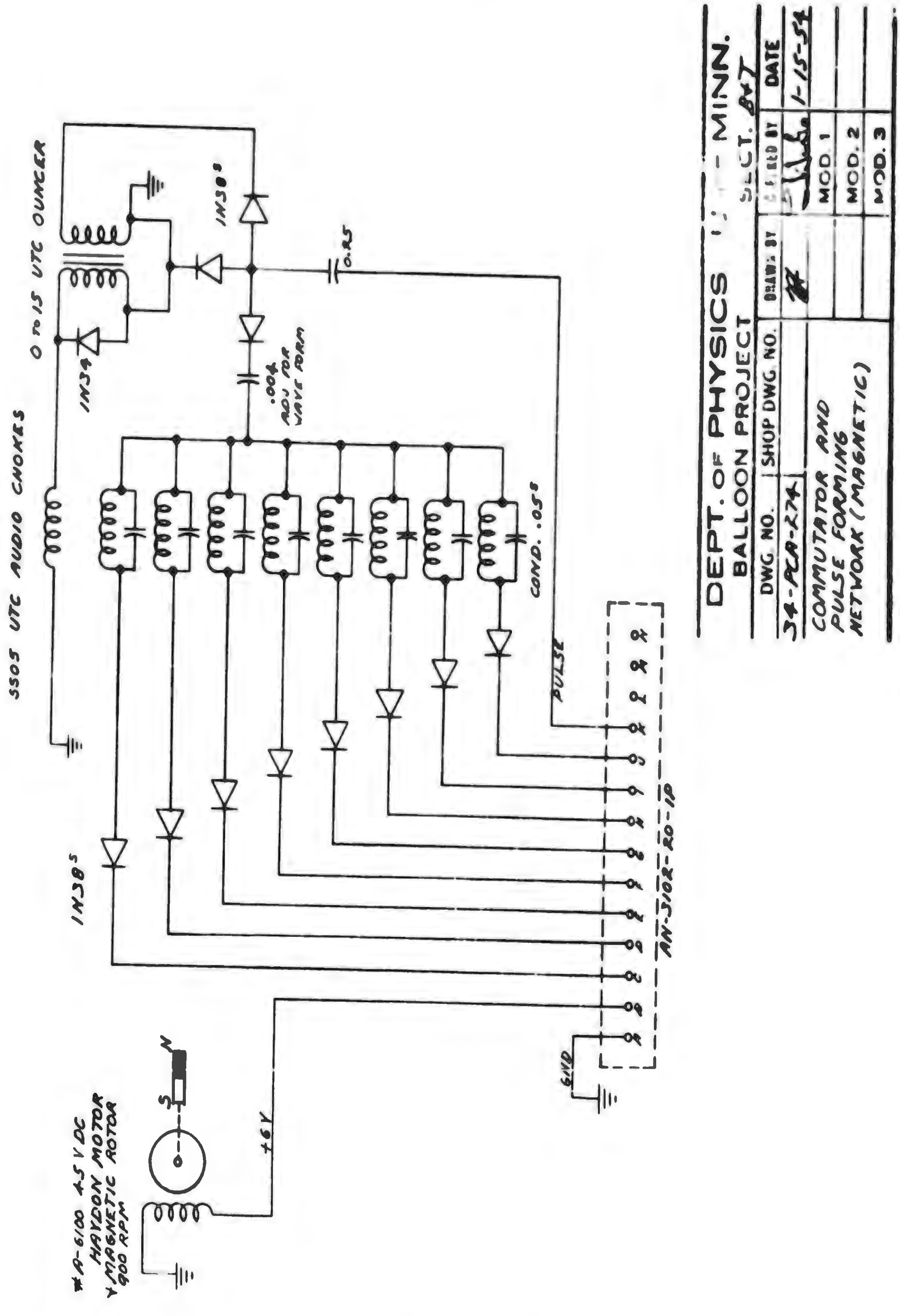

DEPT. OF PHYSICS MINN.
BALLOON PROJECT
DWG. NO.
SHOP DWG. NO.
DRAWN BY
DATE
54-PCA-274
1-15-54
MOD. 1
MOD. 2
MOD. 3
COMMUTATOR AND PULSE FORMING NETWORK (MAGNETIC)
5505 UTC AUDIO CHOKES
0 TO 15 UTC OUNCER
IN34
IN38
0.25
.004 ADJ FOR WAVE FORM
COND. .05
PULSE
AN-3102-20-1P
GND
+6V
A-6100 4.5 V DC HAYDON MOTOR MAGNETIC ROTOR 900 RPM
S
N

Fig. I-60.

Many hours of laboratory testing and several flights have revealed only one failure in this instrument, when a diode opened and caused the loss of the sync pulse during a flight. The speed was constant enough, however, to allow read-out by free-running the decoding equipment, displaying the signal on a scope, photographing the scope, and reading the film. This technique allowed the reader to watch any speed changes and keep track of the channels through the noise.

Sensing Devices

12. Olland Cycles.

The Olland Cycle for pressure measurement was discussed at length in Volume V, Pages VII-259-281, but since then some changes have been made which bear mentioning. A picture is given in Figure I-61, shop drawing in Figure I-62, and schematic in Figure I-63. On several occasions, because of a shifting of the reference arm in relation to the mounting of the bellows assembly, calibration was lost. To remedy this, the reference arm was eliminated and the rotor altered so that the calibration was a function of the machined pattern of the rotor and not of the assembly of the instrument. Two lines parallel to the axis were milled the length of the rotor, from which phase angle to any position on either helix could be read. Two reference lines are necessary because with only one pen arm a differential relay system is not possible and "crossovers", i.e. those points at which the phase angle relationship is zero degrees and the reference and helix are superimposed, become areas of uncertainty. A secondary reference, with such a phase angle displacement from the main reference that under no circumstance can both references be concealed by the helix,

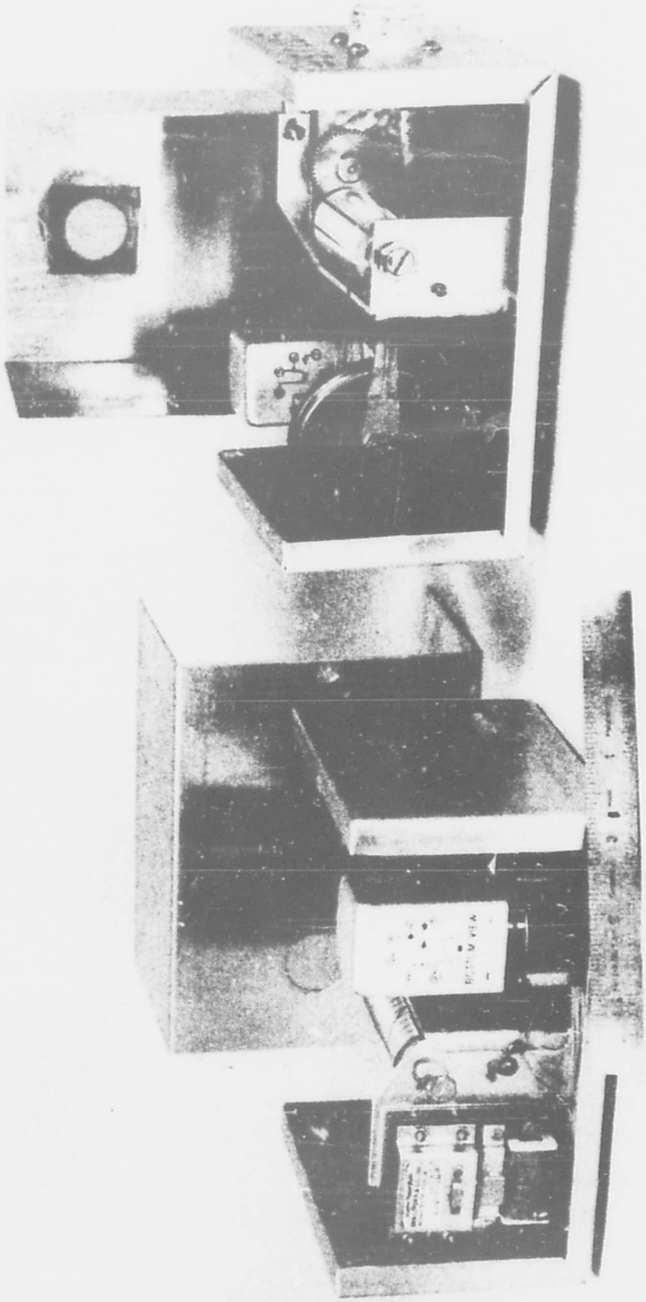


Fig. I-61. Olland Cycle. Right view at left, and left view at right.

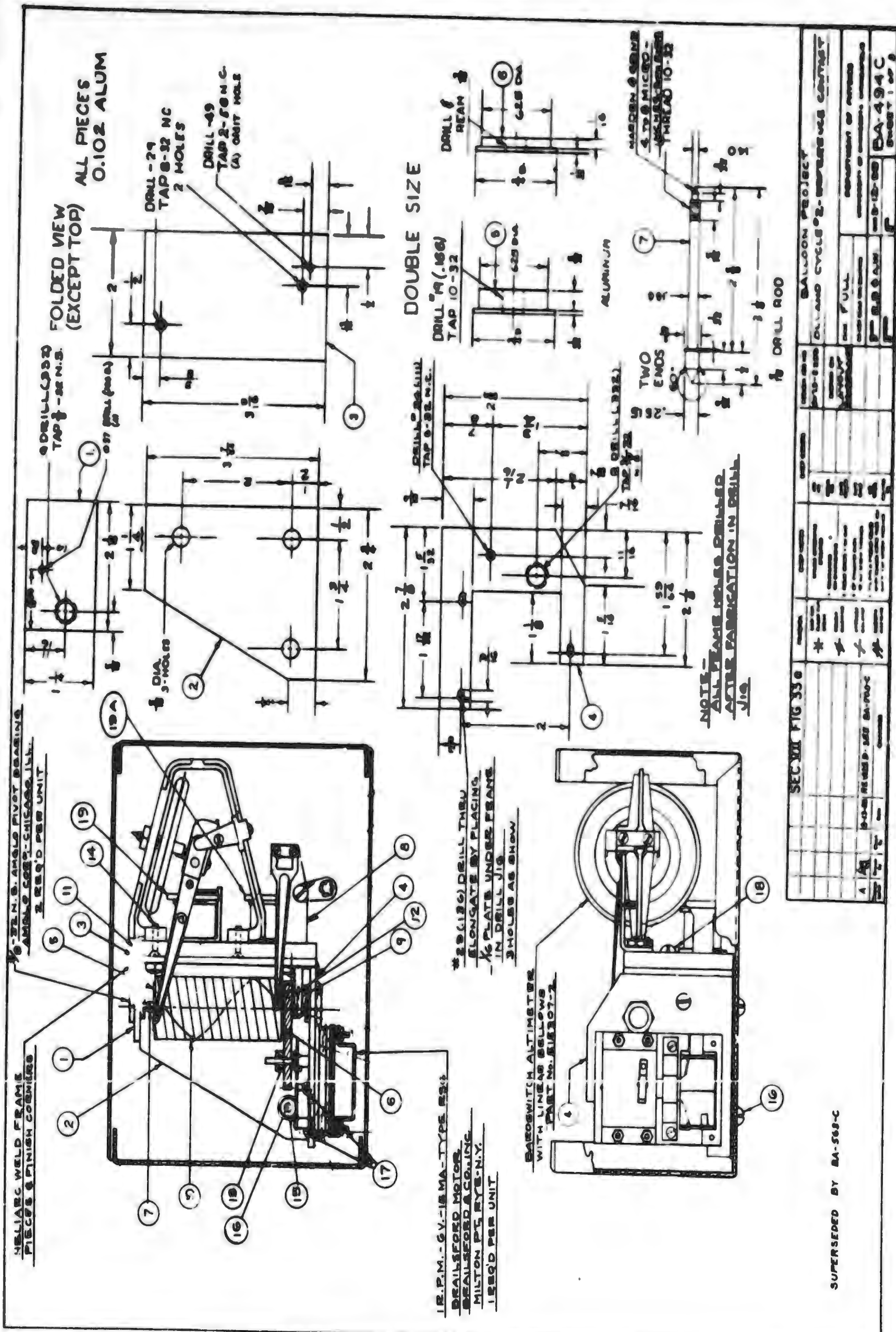

FOLDED VIEW (EXCEPT TOP)
ALL PIECES 0.102 ALUM
DOUBLE SIZE
ALUMINUM
TWO ENDS
DRILL ROD
BAROSWITCH ALTIMETER WITH LINEAR BELLOWS
BALLOON PROJECT
BA-494C
SUPERSEDED BY BA-503-C

Fig. I-62A.

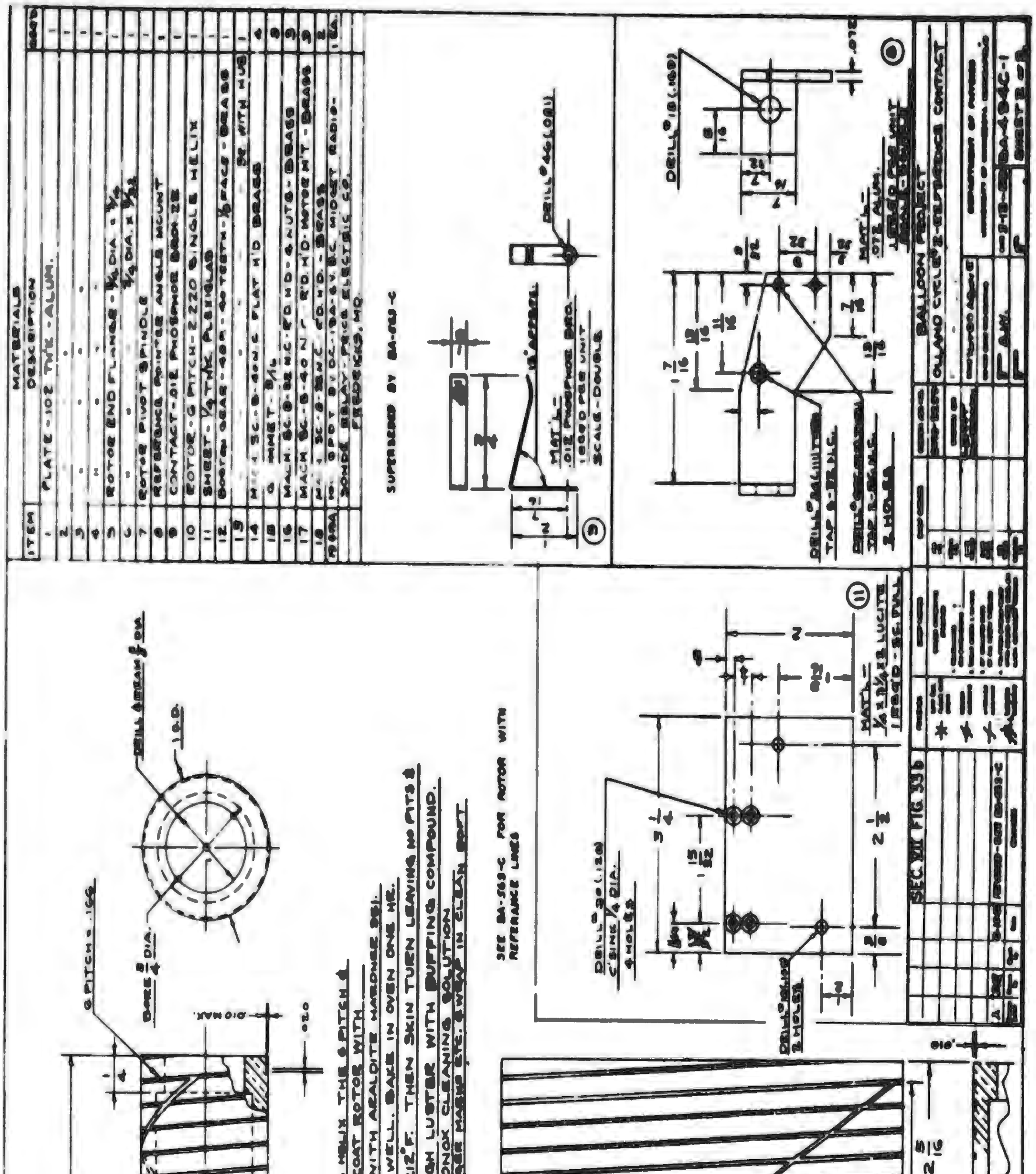

MATERIALS
SUPERSEDED BY BA-293-C
BALLOON PROJECT
SCALE-DOUBLE
SINGLE HELIX PITCH=2.220
ARALDITE
1" DIA. ROTOR
SEC. VII FIG. 33b

Fig. I-62B.

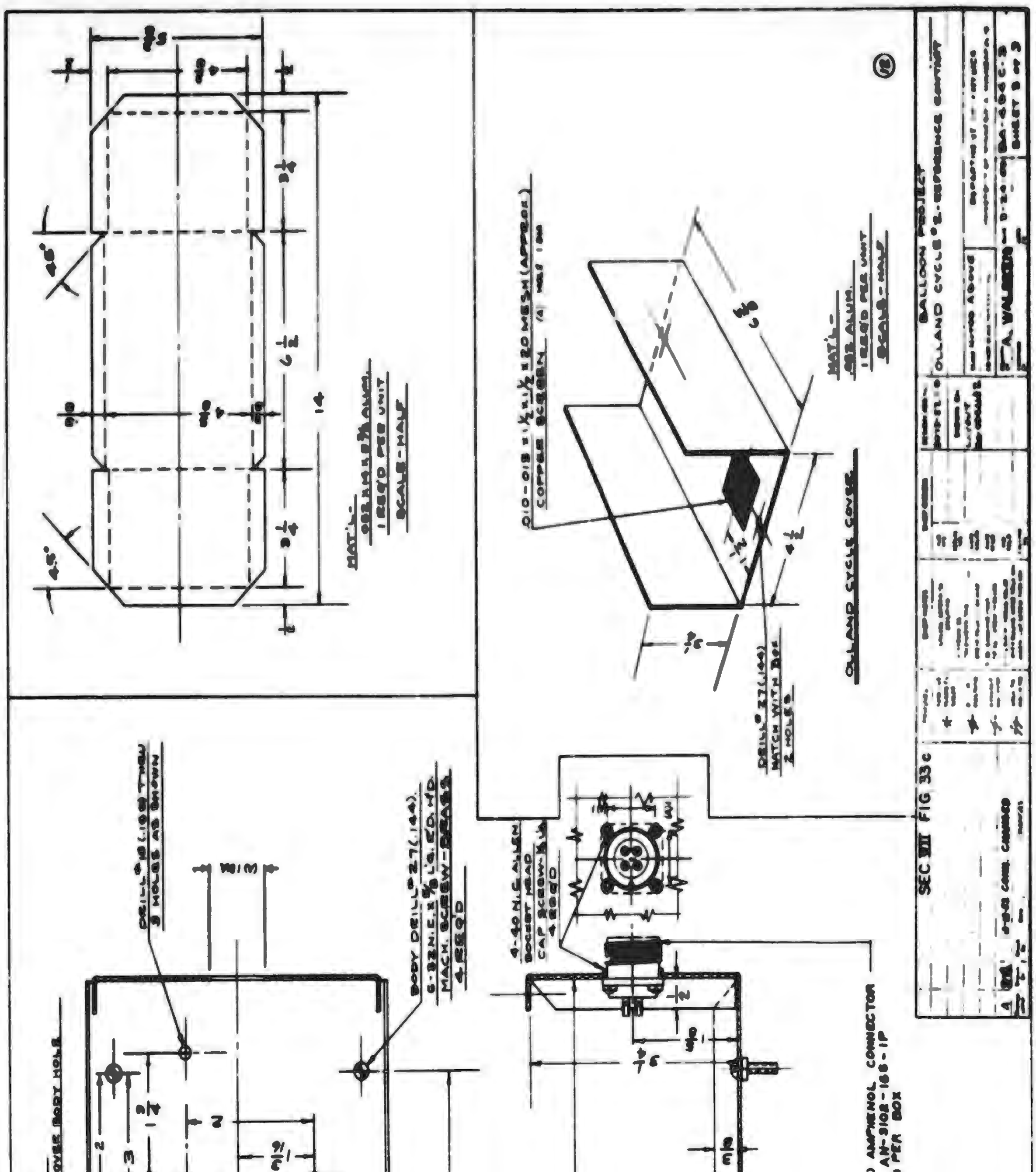


Fig. I-62C.

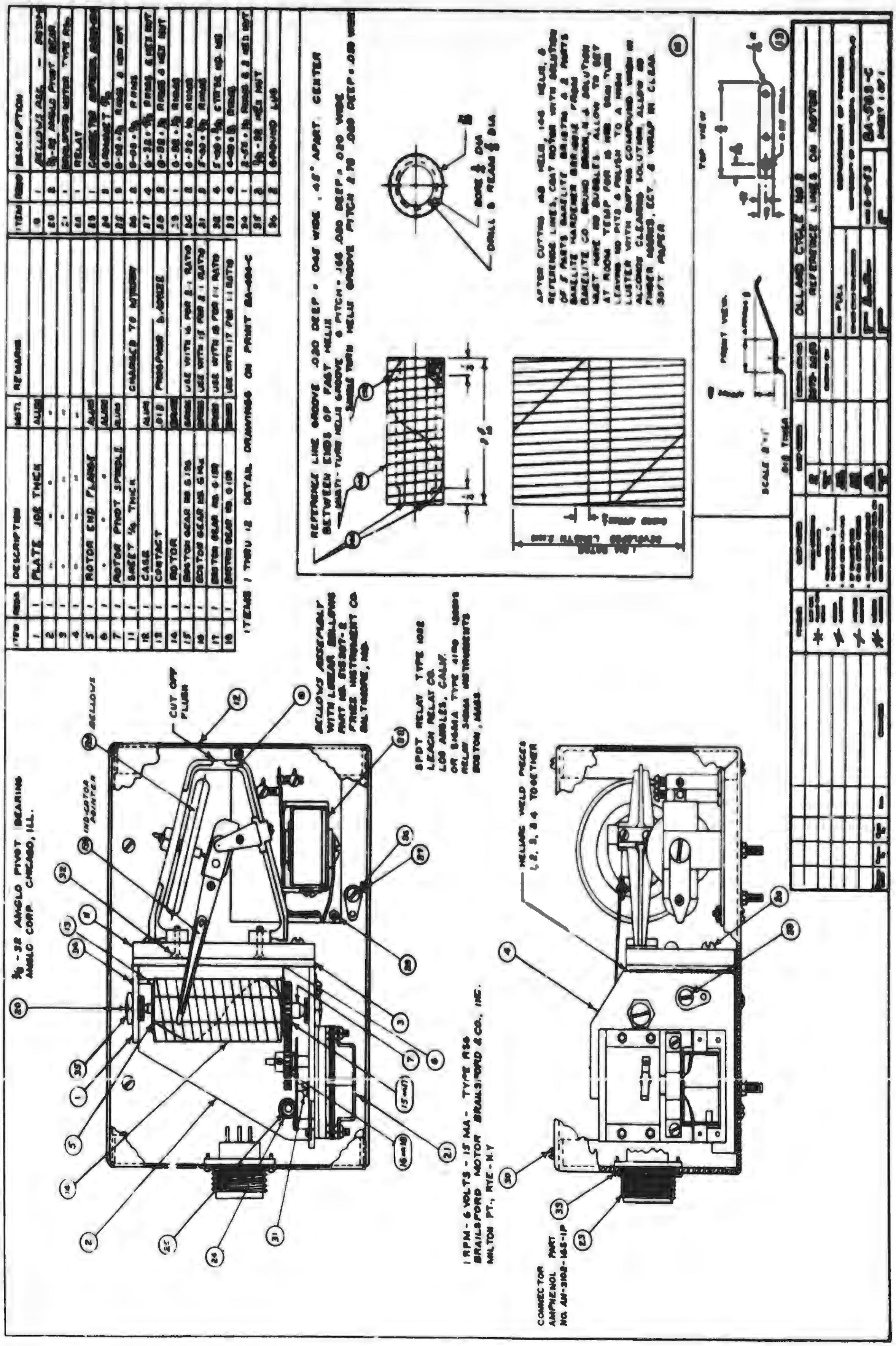

3/8-32 ANGLO PIVOT BEARING
ANGLO CORP. CHICAGO, ILL.
INDICATOR POINTER
BELLOWS
CUT OFF FLUSH
BELLOWS ASSEMBLY WITH LINEAR BELLOWS PART NO. 515207-2 FRIEZ INSTRUMENT CO. BALTIMORE, MD.
SPDT RELAY TYPE 1002 LEACH RELAY CO. LOS ANGLES, CALIF. OR SIGMA TYPE 41RO 12000S RELAY SIGMA INSTRUMENTS BOSTON, MASS.
1 RPM - 6 VOLTS - 15 MA - TYPE RS6 BRAILSFORD MOTOR BRAILSFORD & CO., INC. MILTON PT., RYE - N.Y.
CONNECTOR AMPHENOL PART NO. AN-3102-16S-1P
HELIARC WELD PIECES 1, 2, 3, & 4 TOGETHER
ITEMS 1 THRU 12 DETAIL DRAWINGS ON PRINT BA-404-C
REFERENCE LINE GROOVE .020 DEEP × .045 WIDE, 45° APART CENTER BETWEEN ENDS OF FAST HELIX
MULTI-TURN HELIX GROOVE 6 PITCH .166 .020 DEEP × .020 WIDE
SINGLE TURN HELIX GROOVE PITCH 2.78 .020 DEEP × .020 WIDE
BORE DIA
DRILL & REAM DIA
AFTER CUTTING HELIX, HELIX, & REFERENCE LINES, COAT ROTOR WITH SOLUTION OF 5 PARTS BAKELITE & 2 PARTS BAKELITE HARDENER FROM BAKELITE CO. BOUND BROOK, N.J. SOLUTION MUST HAVE NO BUBBLES. ALLOW TO SET AT ROOM TEMP FOR 16 HRS. THEN TURN LEAVING NO PITS & POLISH TO A HIGH LUSTER WITH BUFFING COMPOUND. WASH IN ALCOHOL CLEANING SOLUTION. ALLOW NO FINGER MARKS, ECT. & WRAP IN CLEAN SOFT PAPER
FRONT VIEW
TOP VIEW
SCALE 2" = 1"
OLLAND CYCLE NO. 2
REFERENCE LINES ON ROTOR
FULL
BA-583-C
SHEET 1 OF 1

Fig. I-62D.

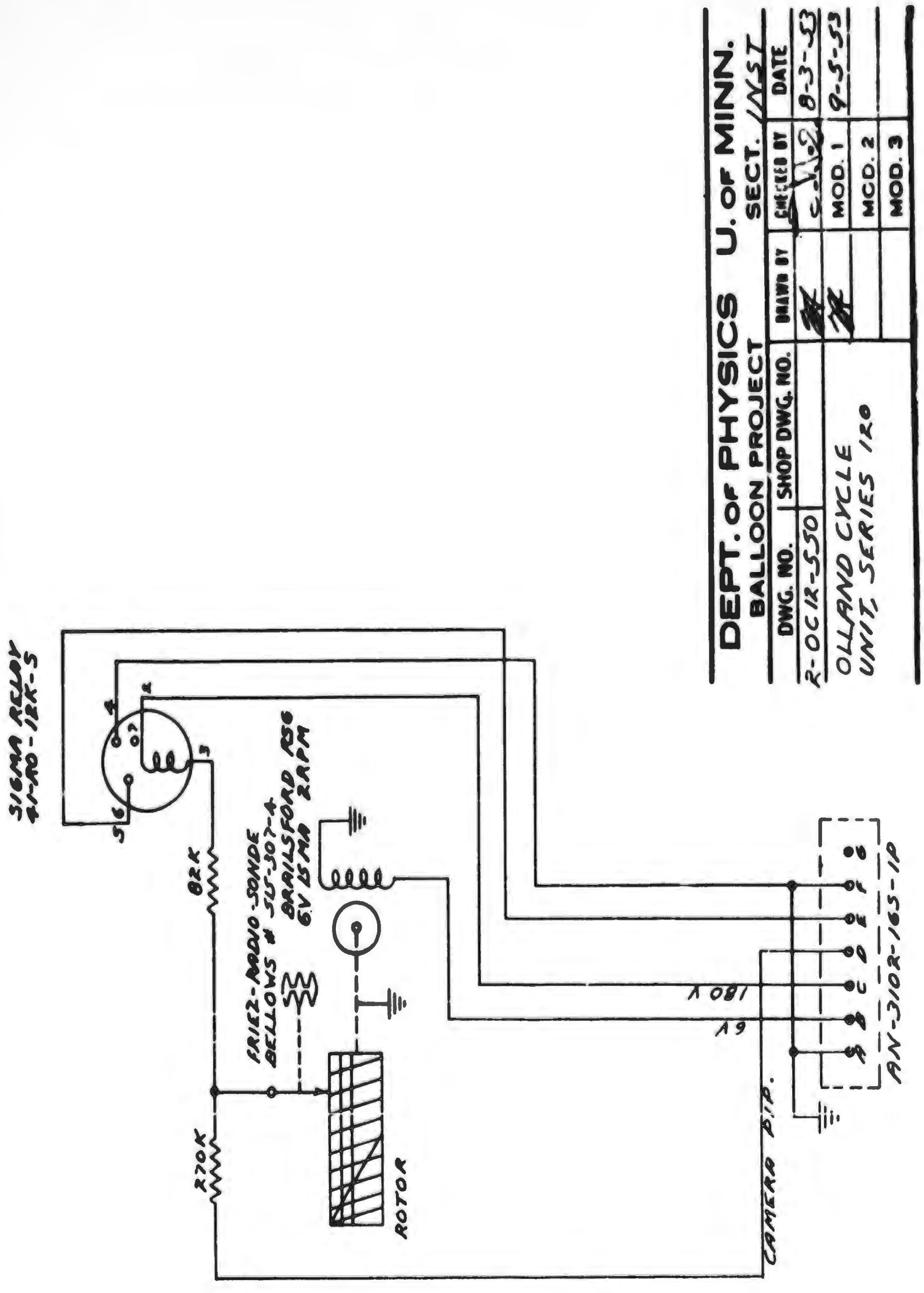

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
SECT. INST
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
2-OC12-550
8-3-53
MOD. 1
9-5-53
MOD. 2
MOD. 3
OLLAND CYCLE
UNIT, SERIES 120
SIGMA RELAY
41-RO-12K-S
82K
270K
ROTOR
FRIEZ-RADIO-SONDE
BELLOWS # SU-307-A
BRAILSFORD R56
6V 15MA 2RPM
180 V
6V
CAMERA B.P.
AN-3102-16S-1P

Fig. I-63.

reduces the equivocality of the crossover area to a minimum. Figure I-64 is a strip chart record of a crossover of a double reference Olland Cycle, illustrating the readable and unreadable portions of the signal.

The Olland Cycle with this change becomes a much more rugged instrument, and once a calibration has been made only a lateral shift of the rotor along its axis in relationship to the bellows assembly mounting will change it. Even then, by determining a few points, a new scale can be fitted to the old curve with no loss in accuracy.

Because of troubles mentioned in the Texas report, Volume VIII, Page II-5, when small corrosive deposits on the rotor caused the loss of information, the circuit was altered to use a higher voltage and a high impedance relay, and the rotor was given a very light silver plating. The relay used, a Model 41 RO 12,000S, Sigma Relay Company, is delivered from the factory with a pull-in current value of about 1.5 milliamps and release at about 0.15 ma. This was altered by bending the armature spring to give a pull-in value of 1.1 milliamps and release of 0.6 ma. In addition, a small tab of phosphor bronze shim was spot-soldered to the underside of the armature to prevent it from sticking to the core of the relay due to residual magnetism.

As can be seen from the wiring diagram, the relay is normally held in, and when the pen arm runs over an insulated portion of the rotor the relay opens, keying ground to pin E. The voltage which exists across the insulation on the rotor then is applied to the recording neon bulbs in the cameras, for direct gondola recording of pressure data. It has been found that no more than two neon tubes can be operated in this fashion,

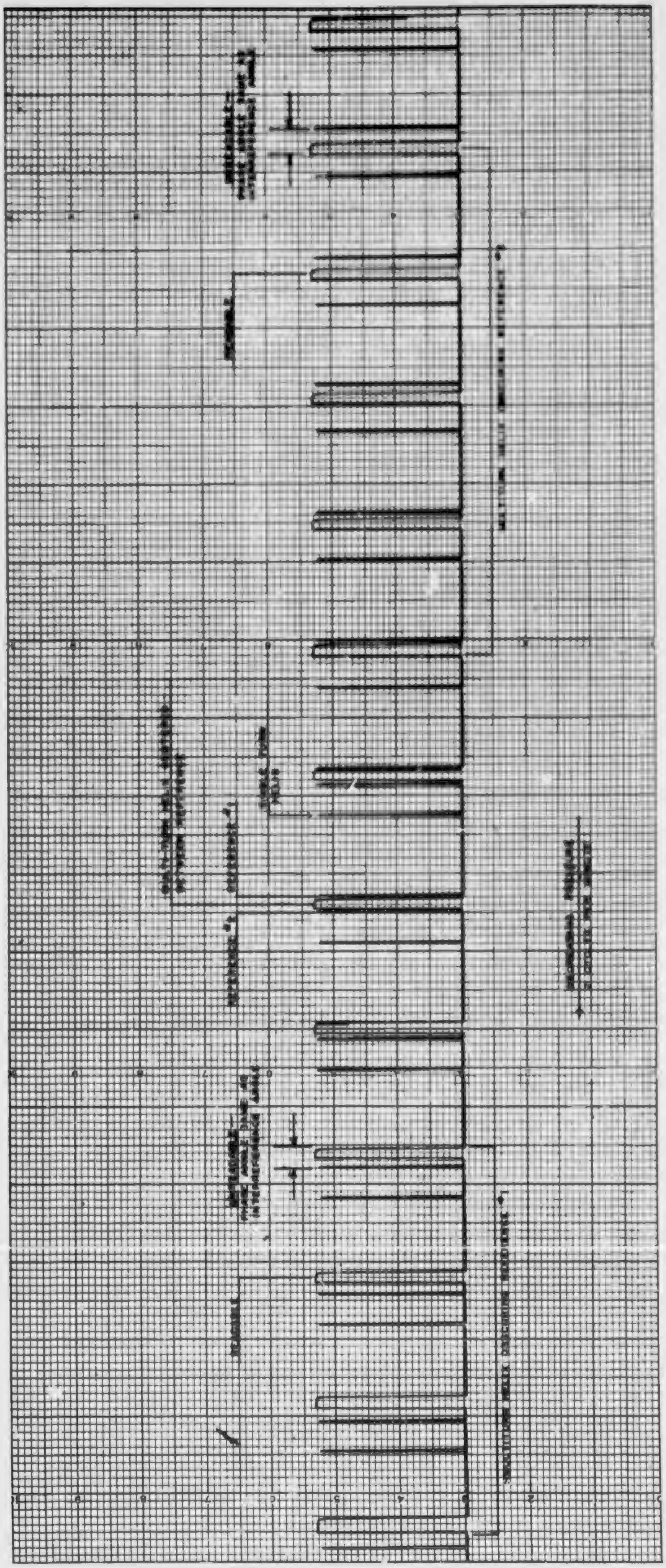


Fig. I-64.

or they will short out the Olland Cycle rotor and key the high impedance relay on continuously.

Preliminary work was done on a high altitude Olland Cycle which bell jar tests indicate is capable of measuring balloon altitude with an accuracy of 45 ft at 102,000 ft, as compared with an accuracy of 210 ft at the same altitude for the standard Olland Cycle. The limit of accurate pressure determination with the Olland Cycle telemetering is the bellows element much more than the telemetering, reading, or calibrating. The new high altitude Olland Cycle uses two bellows, one which gives maximum response below 60 mb and another giving maximum response above 60 mb. Further analysis of this instrument after use will be included in the next progress report.

13. Tensiometers

The tensiometers listed on Line 13, Figure I-31, were of two types. The first was used until Flight 90 and was the same instrument as that described in Volume V, Pages VII-238, 241-243. It was essentially a single-turn Olland Cycle, and because the tension measurements desired were of a smaller order than could be easily resolved, a different instrument was designed which used a standard 11-turn Olland Cycle rotor and an 8-to-1 pen arm ratio. The result was a much more precise record which was readable to about one lb at 300 lbs, or within the accuracy of the calibrating scale, and because ball bearing pivots were used throughout, the reproduceability of the record was greatly improved at the same time.

However, on Flight 91 when this new instrument was first flight-tested, a portion of the record was lost and the decision was made to fly all important sensing devices in duplicate on step flights. Therefore, a double Olland Cycle type of tensiometer has been used since that time. A picture is given in Figure I-65 of this instrument, shop drawings in Figure I-66, and a wiring diagram in Figure I-67.

14, 15, 16. Thermistor Interpreters, Thermistor Droppers, and Infrared Detectors.

These are discussed in Section I, B and C, of this volume.

Recording Cameras

17, 18. Up and Down Cameras

The cameras which this project uses have become such important pieces of equipment, and can be adapted to such a variety of purposes, that a detailed description has been thought desirable. The basic camera was first designed in 1948 as a data recording camera for use in balloon-borne cosmic ray equipment flown by the University of Minnesota Physics Department. In this application it was used with a short focal length lens without a shutter, exposure within the totally enclosed gondola being by strobe flash. Film drive was continuous.

Early in the Balloon Project, when a need developed for an automatic camera, this basic unit was adapted to the purpose by the Physics Department shop. The major change necessary was fitting a shutter drive mechanism to the film drive, and since a longer focal length lens was to be used, a lens tube mounting which also could be used for focusing was devised. Mounting brackets for both up and down positions were also necessary. This is the basic camera described in Volume I, Pages 5-3 and 5-4. Naturally, a considerable amount of improvement and modification has taken

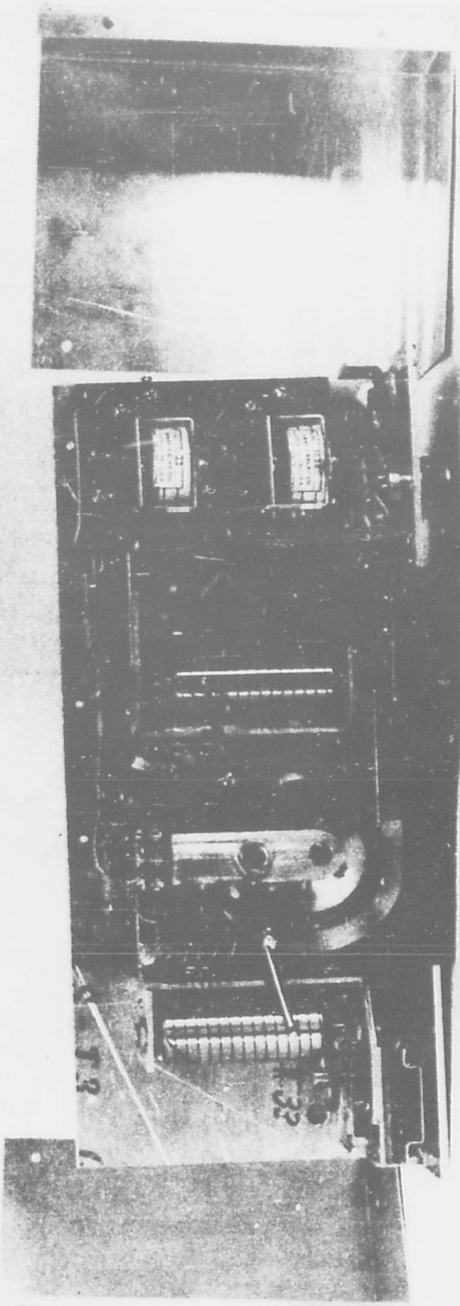


Fig. I-65. Double Tensiometer. Side View.

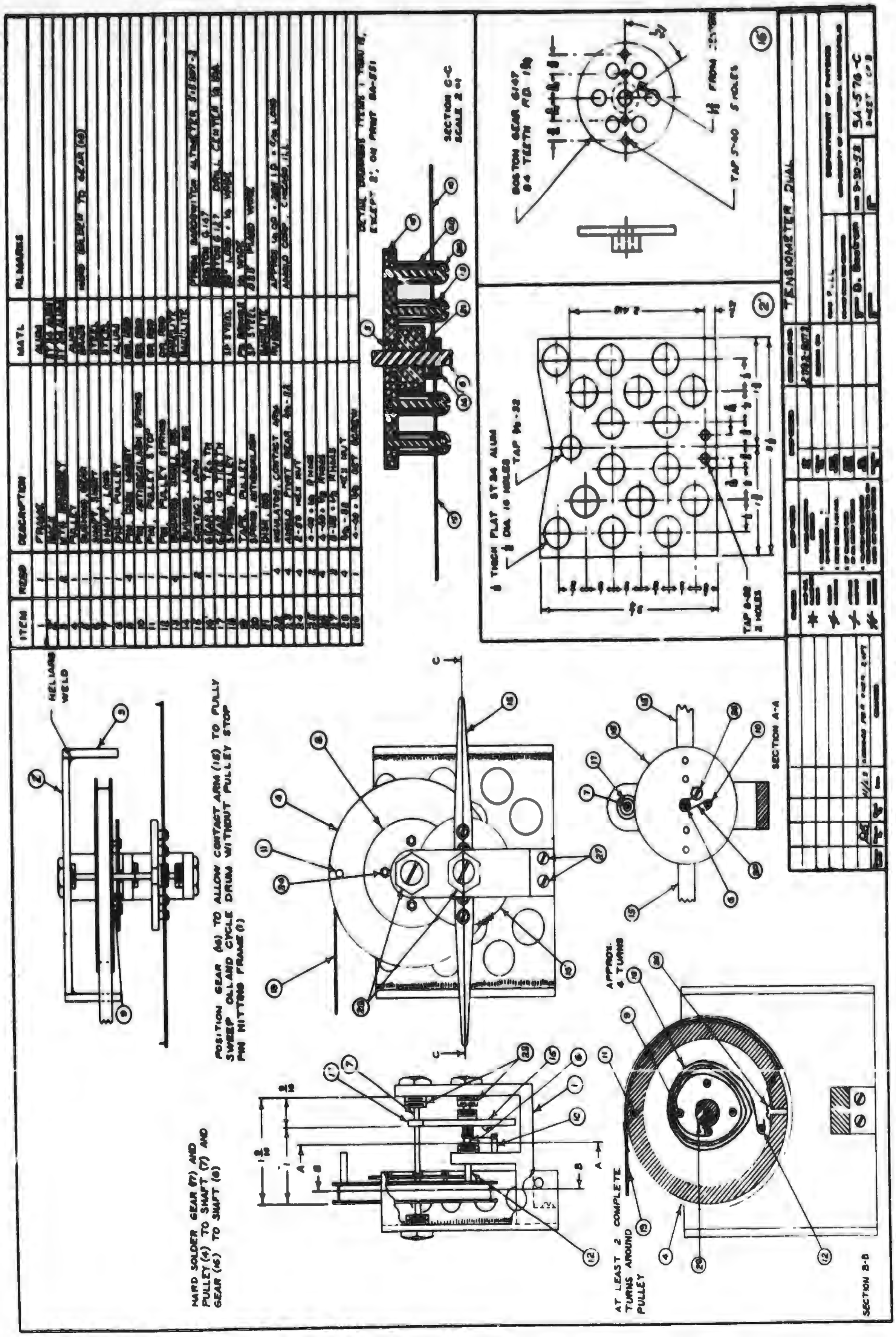


Fig. I-66A.

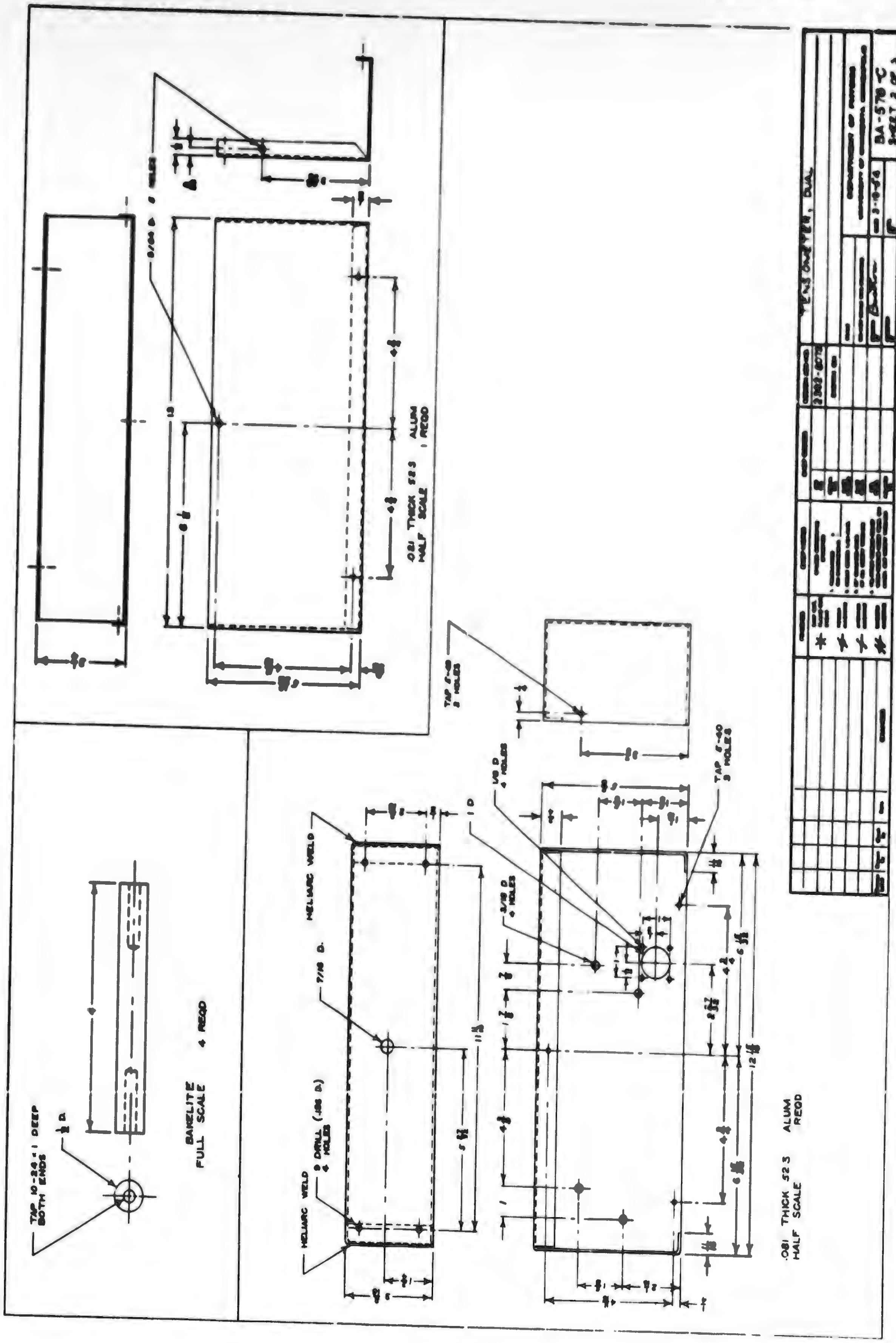

TENSIOMETER, DUAL
BAKELITE
FULL SCALE
4 REQD
ALUM
1 REQD
HALF SCALE
MELIARC WELD
7/16 D.

Fig. I-66B.

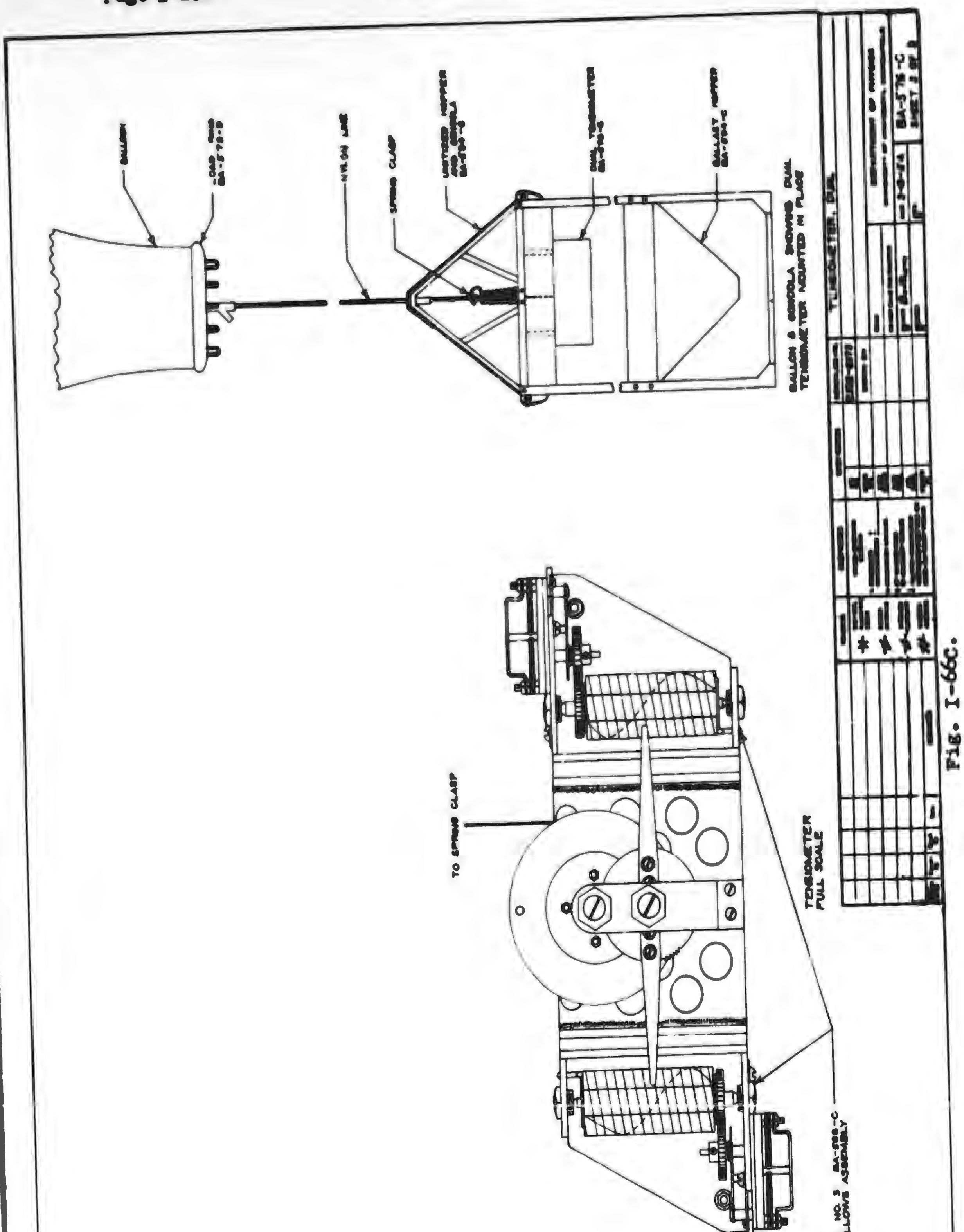

BALLOON & GONDOLA SHOWING DUAL
TENSIOMETER MOUNTED IN PLACE
TO SPRING CLASP
TENSIOMETER
FULL SCALE
WITHOUT BELLOWS ASSEMBLY
TENSIOMETER, DUAL

Fig. I-66C.

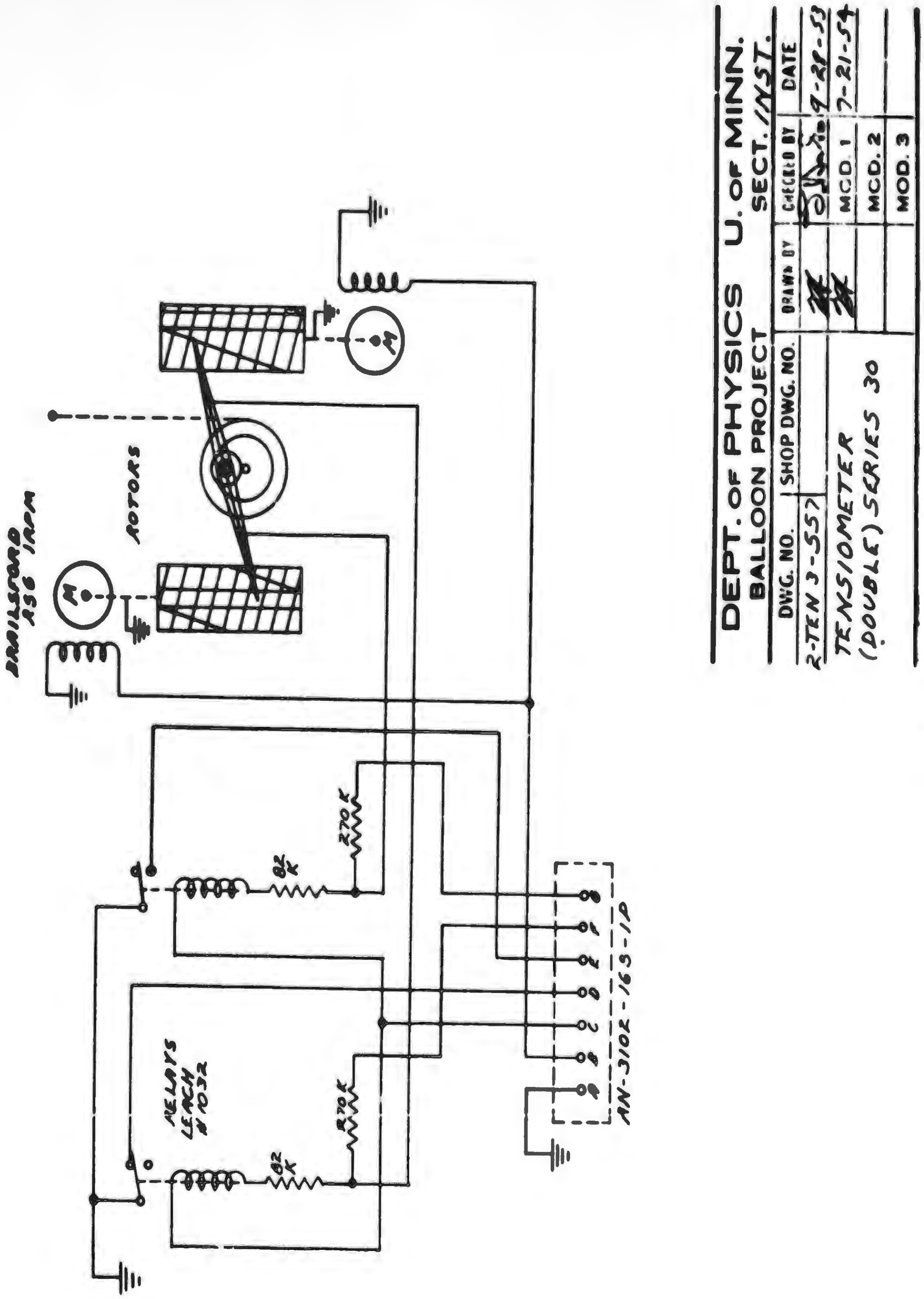

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST.
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
2-TEN 3-557
9-28-53
MOD. 1
7-21-54
MOD. 2
MOD. 3
TENSIOMETER (DOUBLE) SERIES 30
ROTORS
BRAILSFORD
RELAYS LEACH #1032
270 K
82 K
AN-3102-16S-1P

Fig. I-67.

place, some of which was described in Volume V, Pages VII-224, 231-234.

The shop drawings for the current camera are given in Figure I-68, with pictures in Figure I-69, and a wiring diagram in Figure I-70. The basic camera body is a magnesium casting made to Physics Department shop specifications by the R. C. Hitchcock & Sons, Inc., Minneapolis, Minnesota. All machining is done in the Physics Department shop. The lens and shutter assembly are bought from two different companies, that for the down camera from the Bolsey Corp. of America, New York, N.Y., and the lens for the up camera from the Ilex Optical Company, Rochester, N.Y. The motors most commonly used have been Brailsfords of 1, ½, or 1/5 rpm from the Brailsford Company, Milton Point, Rye, New York, but on special occasions Chronometric Haydons were used (The A. W. Haydon Company, Waterbury, Conn.), when need was felt for a more accurately timed film drive.

The most recent modifications that have not been mentioned in the last progress report are a new felt gasketed light-tight back to eliminate the need for taping the back of every camera against light seepage, and a new light-sealed lens tube. The previous lens tube allowed a light leak between the tube and its barrel when the set screw to hold the tube was tightened. This seal was accomplished by fitting a felt ring in a slot milled in the inside wall of the barrel. A filter retaining ring which fitted inside the lens tube to hold the filters was also added. A new telemetering recording tube has been included which requires less alteration of the camera casting. It is a tube which takes the place of an idler roller over which the film passes as it leaves the film storage spool

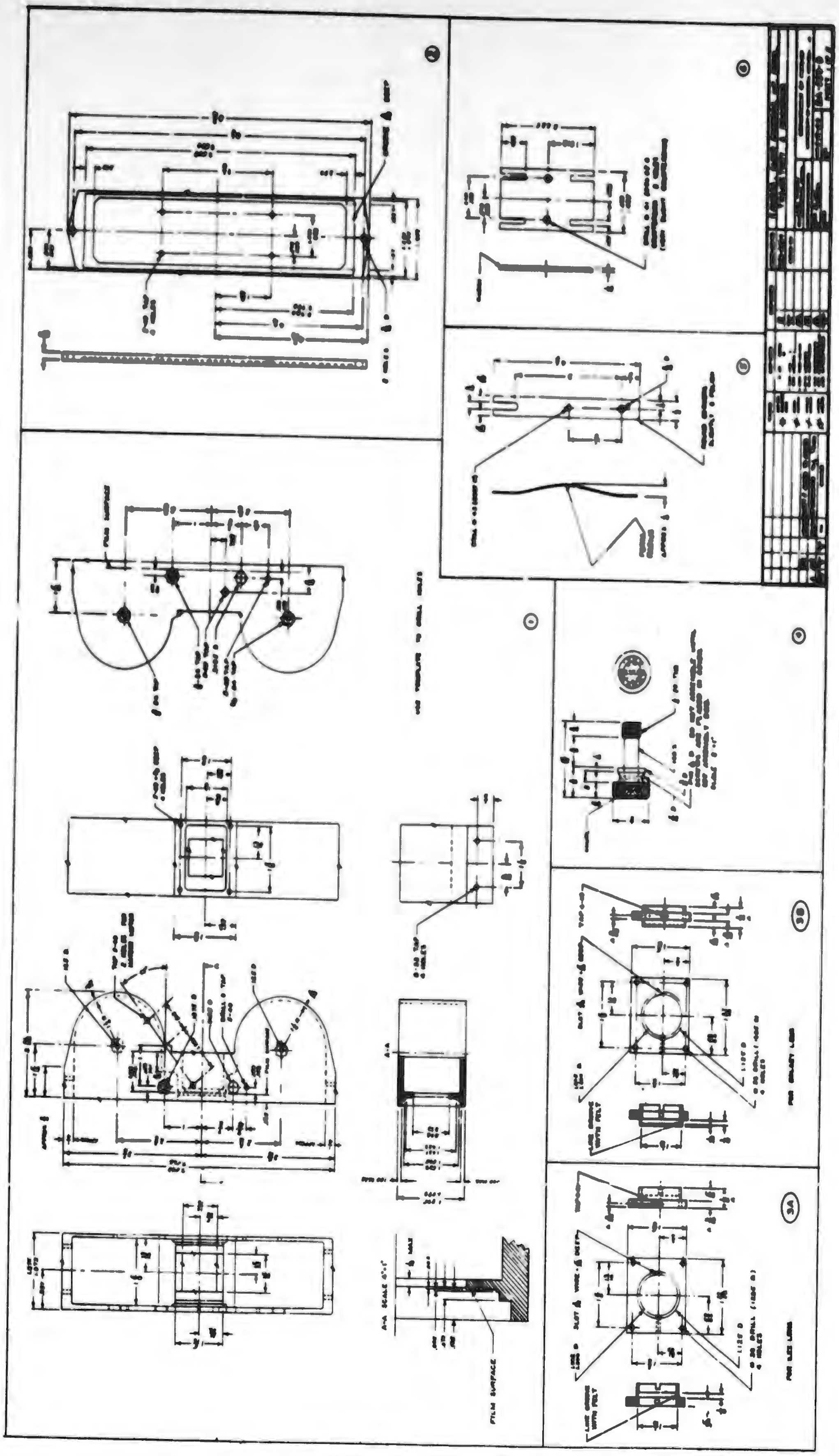


Fig. I-68A.

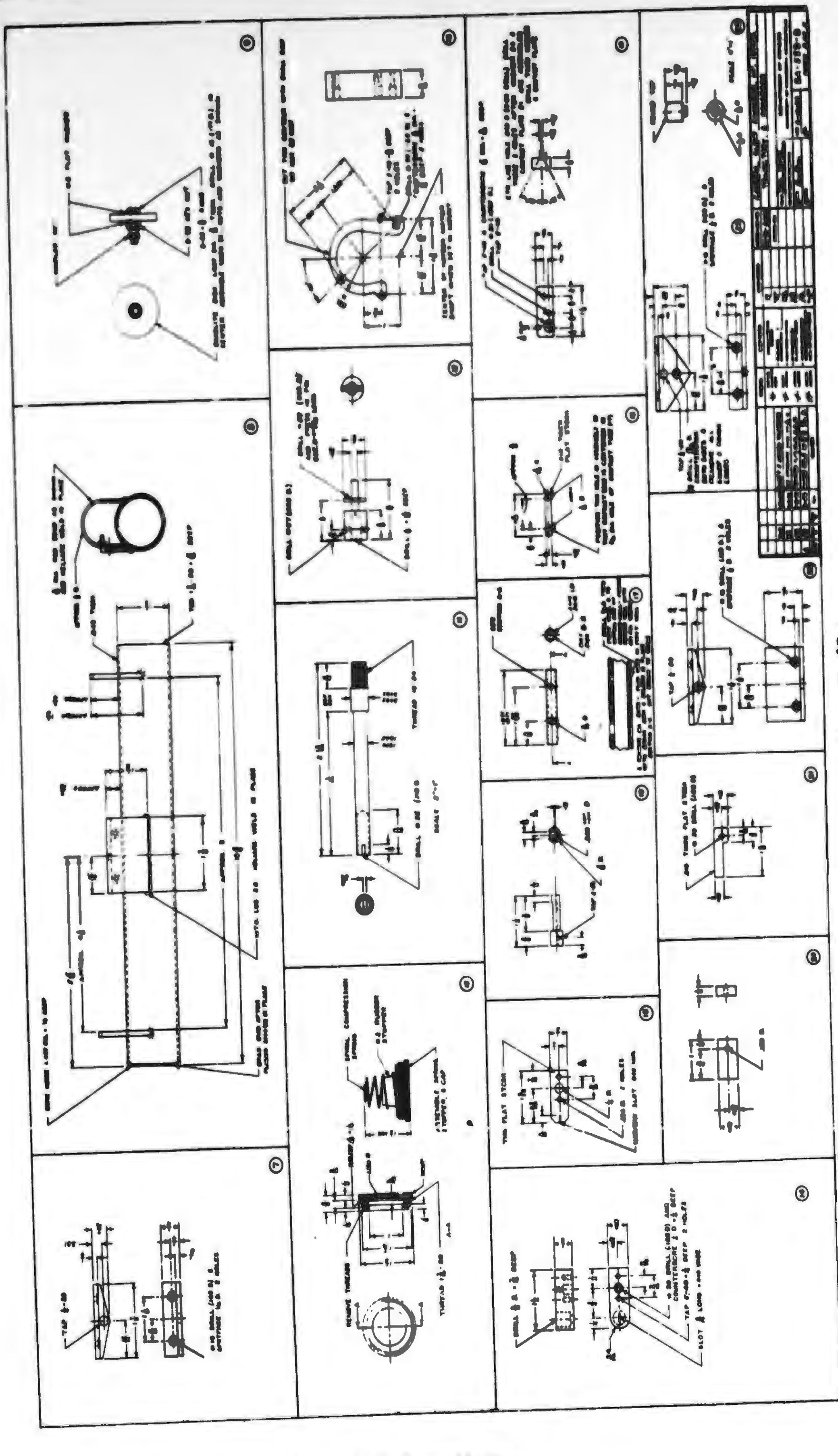


Fig. I-68B.

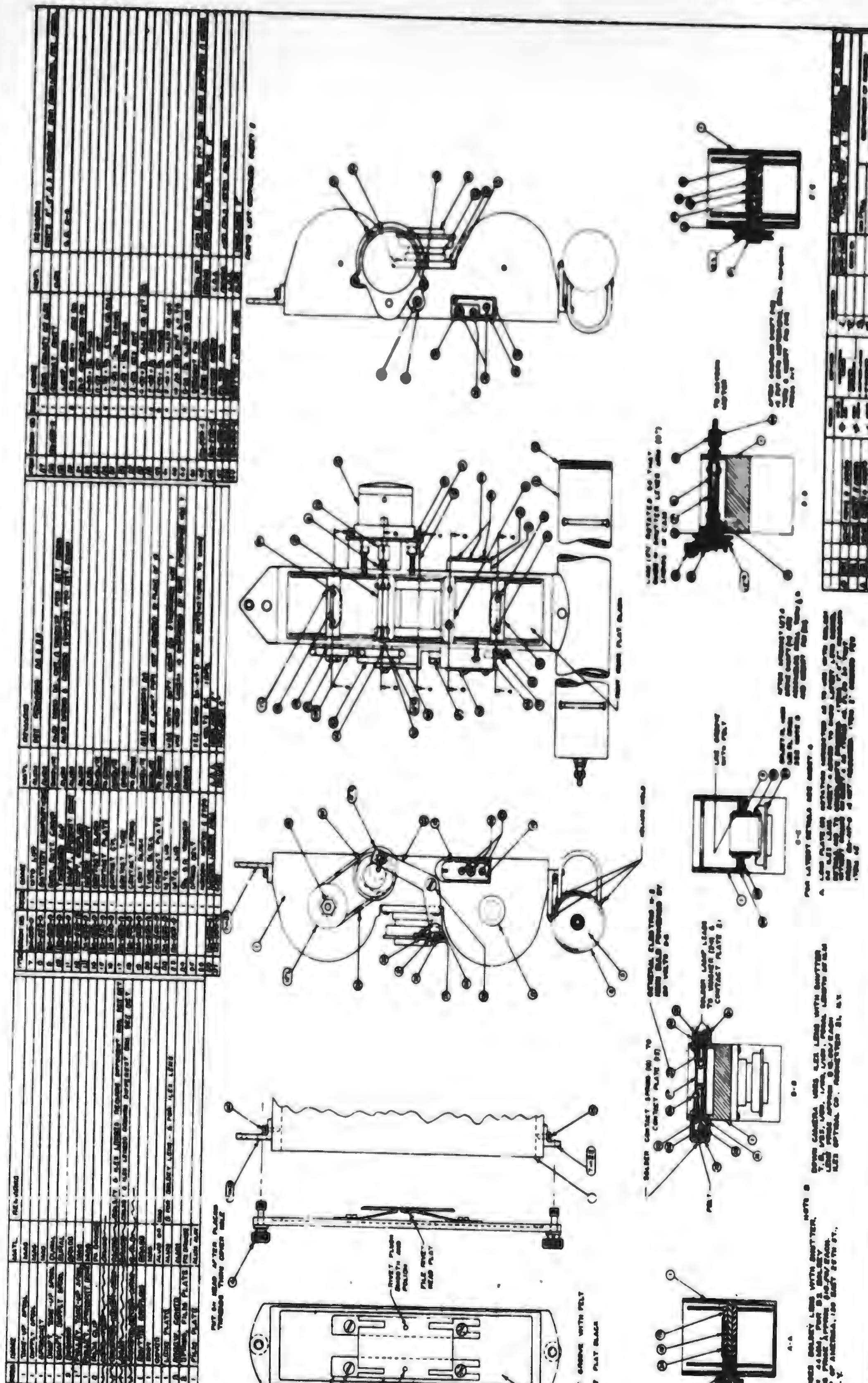


Fig. I-68C.

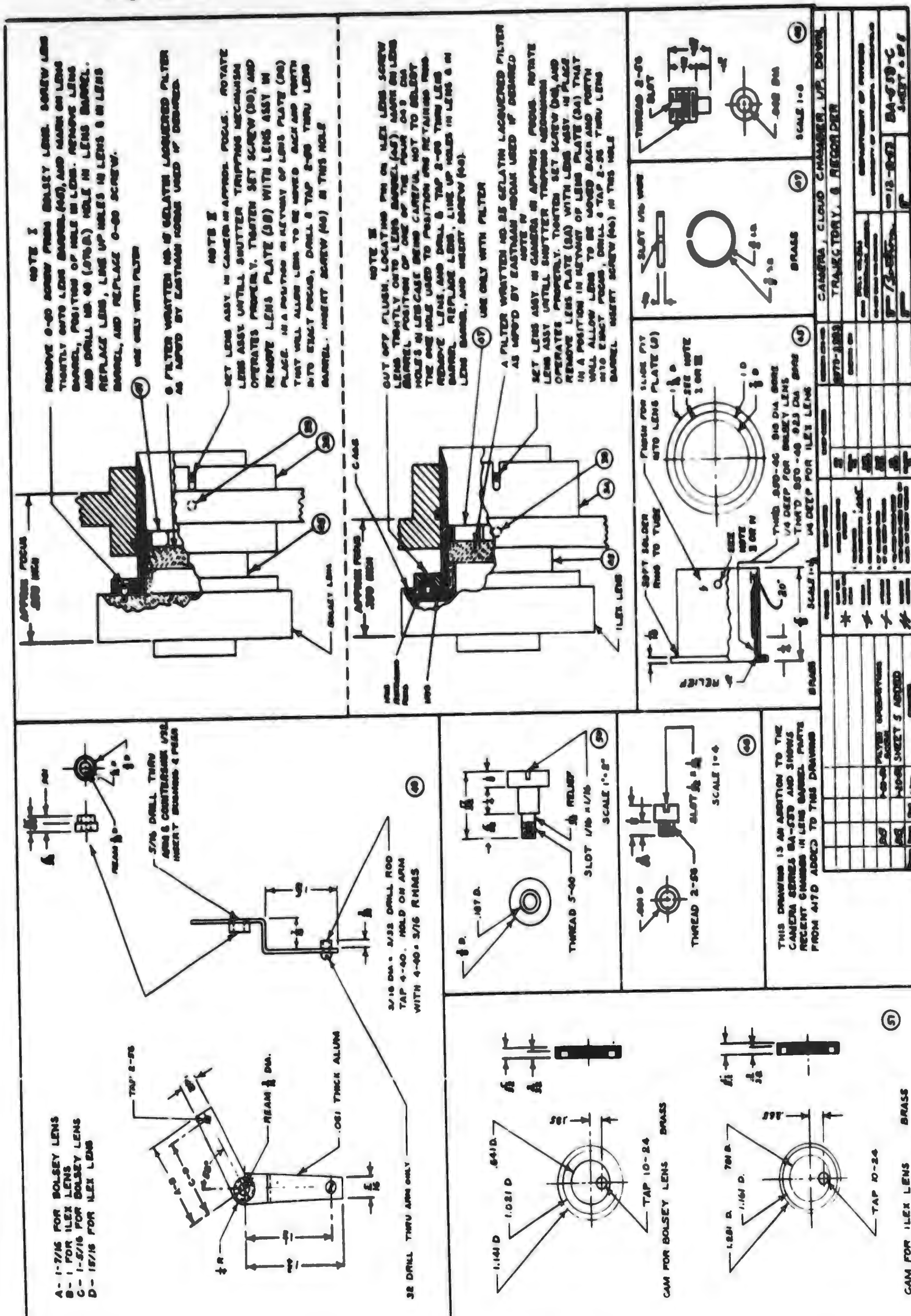


Fig. I-68D.

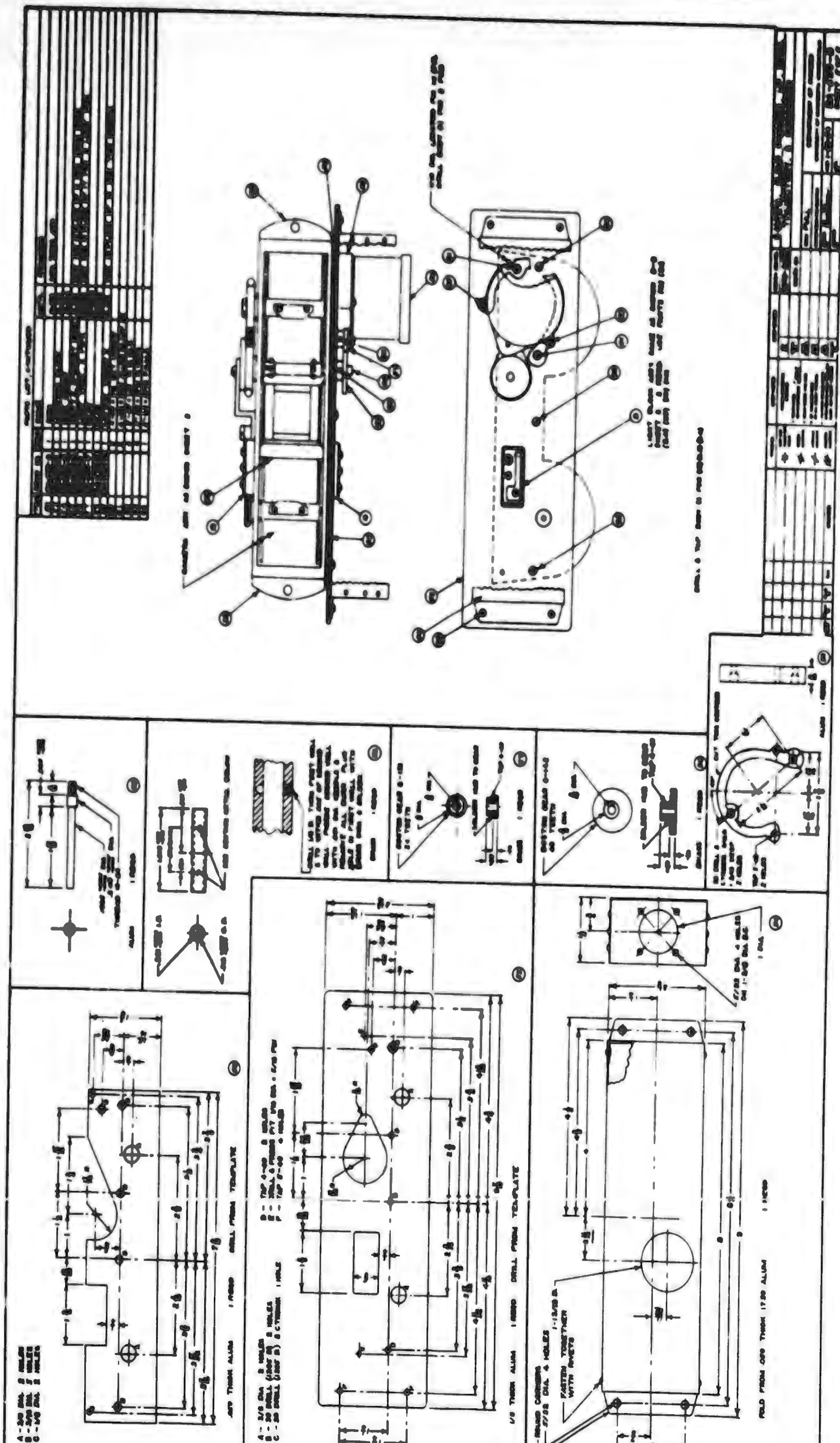


Fig. I-68E.

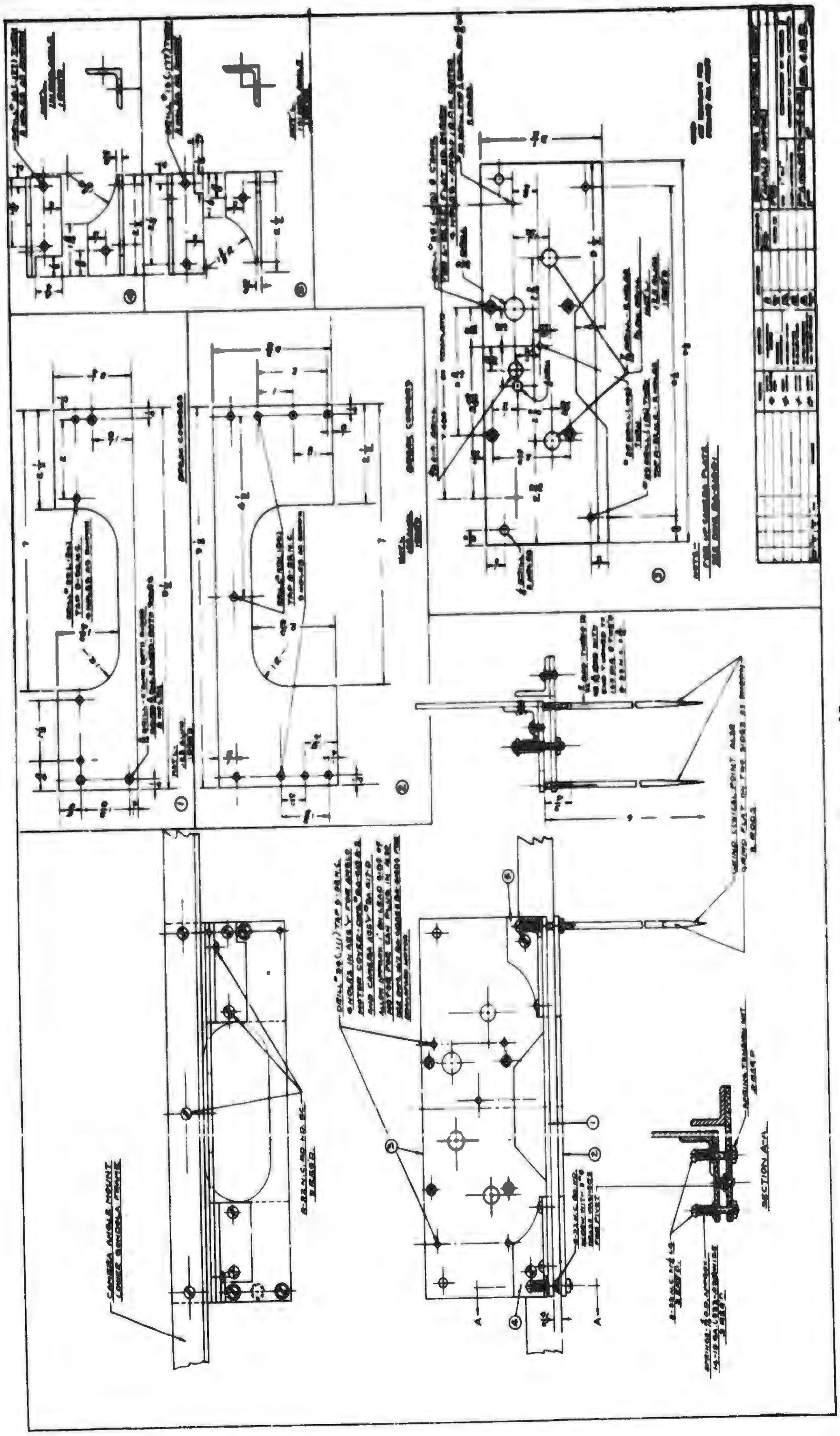


Fig. I-68F.

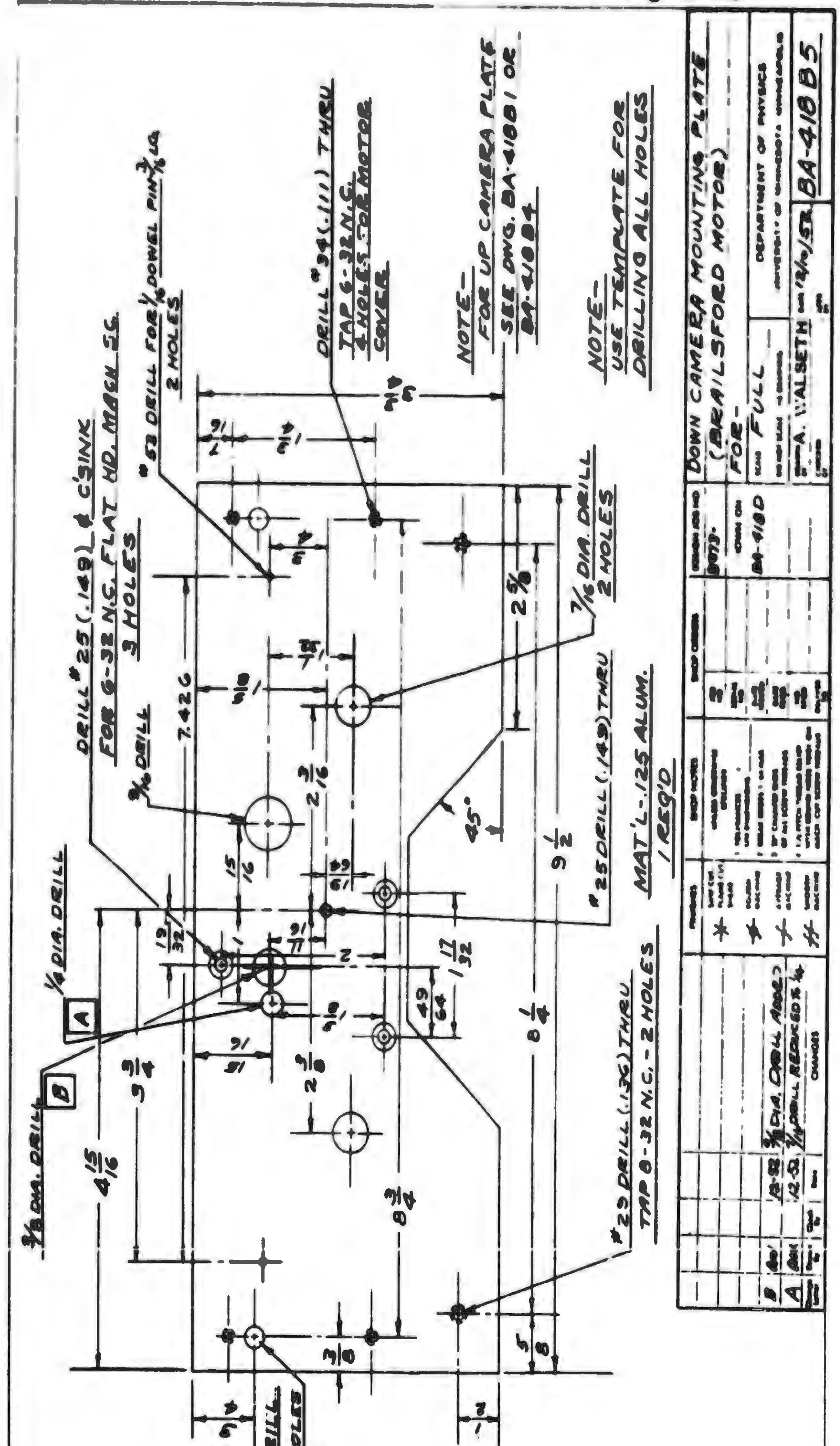

DOWN CAMERA MOUNTING PLATE
(BRAILSFORD MOTOR)
FOR-
FULL
DEPARTMENT OF PHYSICS
A. WALSETH
BA-418B5
BA-418D
NOTE-
USE TEMPLATE FOR
DRILLING ALL HOLES
NOTE-
FOR UP CAMERA PLATE
SEE DWG. BA-418B1 OR
BA-418B4
DRILL #34(.111) THRU
TAP 6-32 N.C.
4 HOLES FOR MOTOR
COVER
#53 DRILL FOR 1/16 DOWEL PIN 3/16 LG
2 HOLES
DRILL #25(.149) & C'SINK
FOR 6-32 N.C. FLAT HD. MACH. SC.
3 HOLES
9/16 DRILL
7/16 DIA. DRILL
2 HOLES
#25 DRILL (.149) THRU
MAT'L-.125 ALUM.
1 REQ'D
#29 DRILL (.136) THRU
TAP 8-32 N.C. - 2 HOLES
1/4 DIA. DRILL
3/8 DIA. DRILL
1/4 DRILL
2 HOLES
7.426
45°

Fig. I-680.

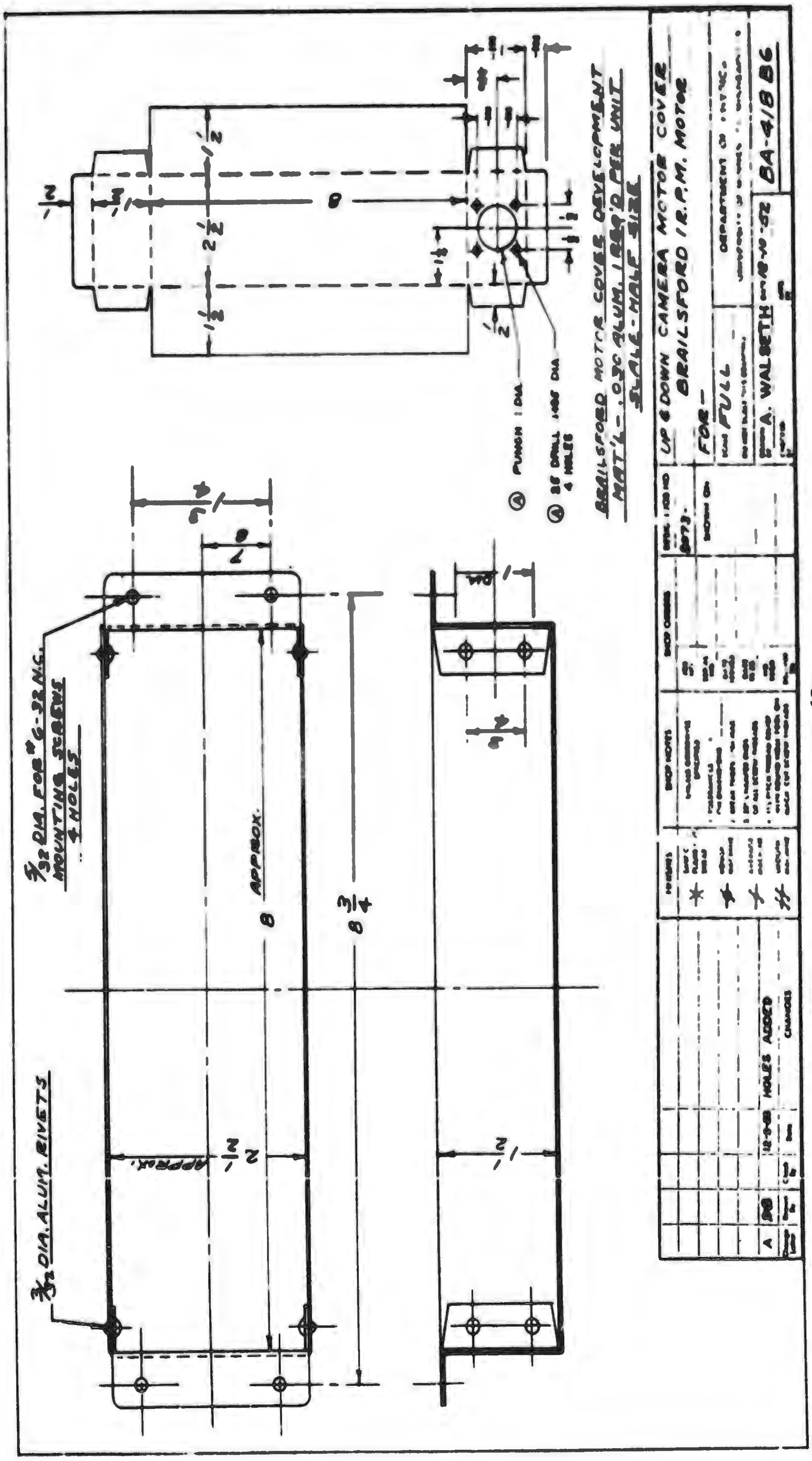

BRAILSFORD MOTOR COVER DEVELOPMENT
MAT'L - .030 ALUM. 1 REQ'D PER UNIT
SCALE-HALF SIZE
PUNCH 1 DIA.
3/32 DIA. ALUM. RIVETS
5/32 DIA. FOR #6-32 NC. MOUNTING SCREWS 4 HOLES
APPROX.
UP & DOWN CAMERA MOTOR COVER
BRAILSFORD 1 R.P.M. MOTOR
FOR-
FULL
A. WALSETH
HOLES ADDED

Fig. I-68H.

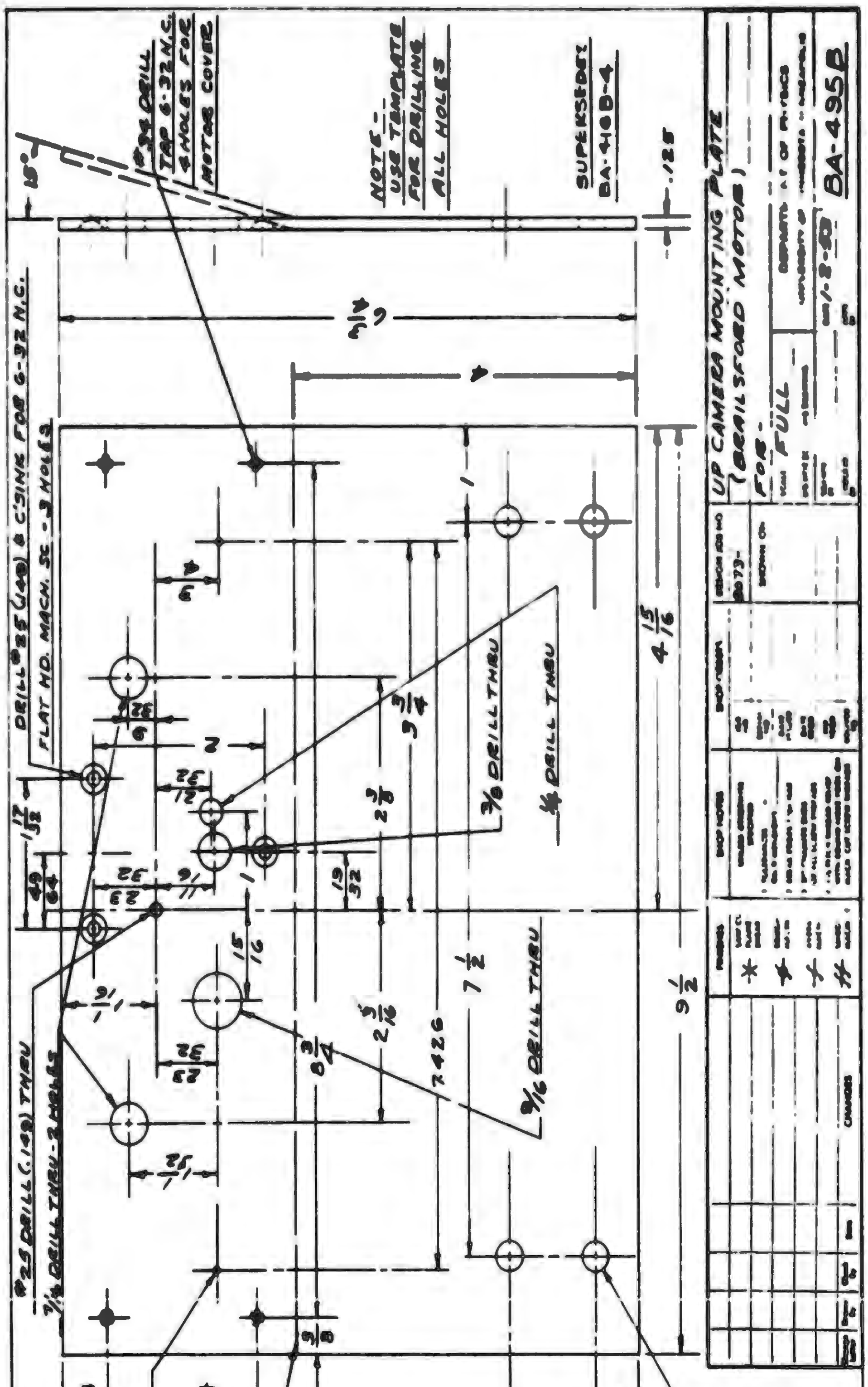

UP CAMERA MOUNTING PLATE
(BRAILSFORD MOTOR)
FOR -
FULL
BA-495B
SUPERSEDES:
BA-495B-4
NOTE -
USE TEMPLATE
FOR DRILLING
ALL HOLES
#34 DRILL
TAP 6-32 N.C.
4 HOLES FOR
MOTOR COVER
DRILL #35 (.100) & C'SINK FOR 6-32 N.C.
FLAT HD. MACH. SC. - 3 HOLES
#25 DRILL (.149) THRU
3/8 DRILL THRU
1/4 DRILL THRU
9/16 DRILL THRU
DRILL 3/8 DIA.
4 HOLES
BEND 15°
MAT'L -
.125 ALUM
1 REQ'D
7.426
.125

Fig. I-68I.

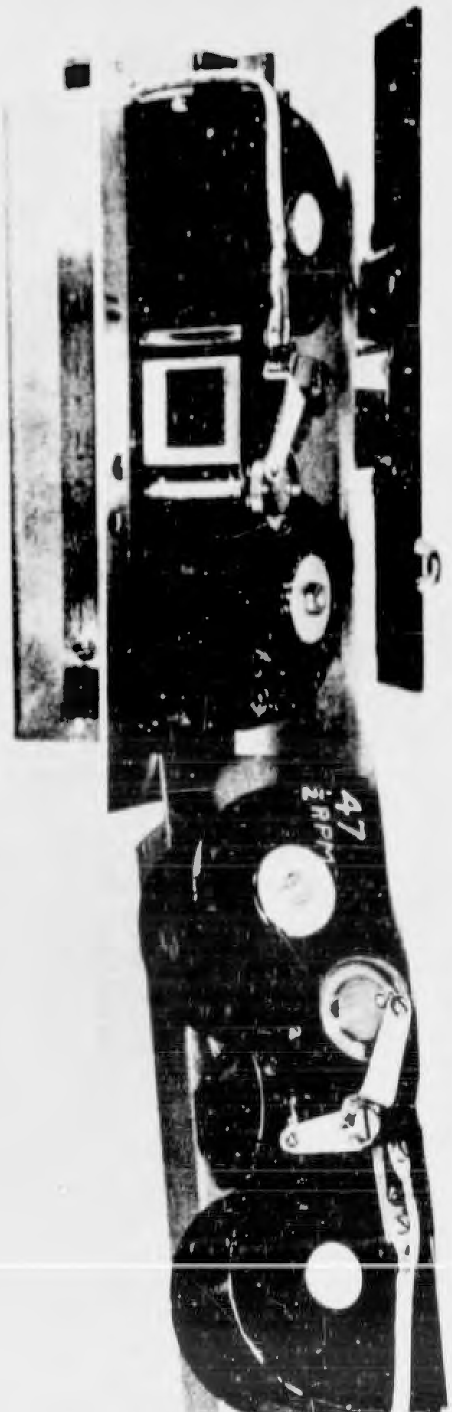


Fig. I-69A. Up Camera. Front view at left. Back view with cover removed at right, showing double telemetering recorder tube to right of film mask.

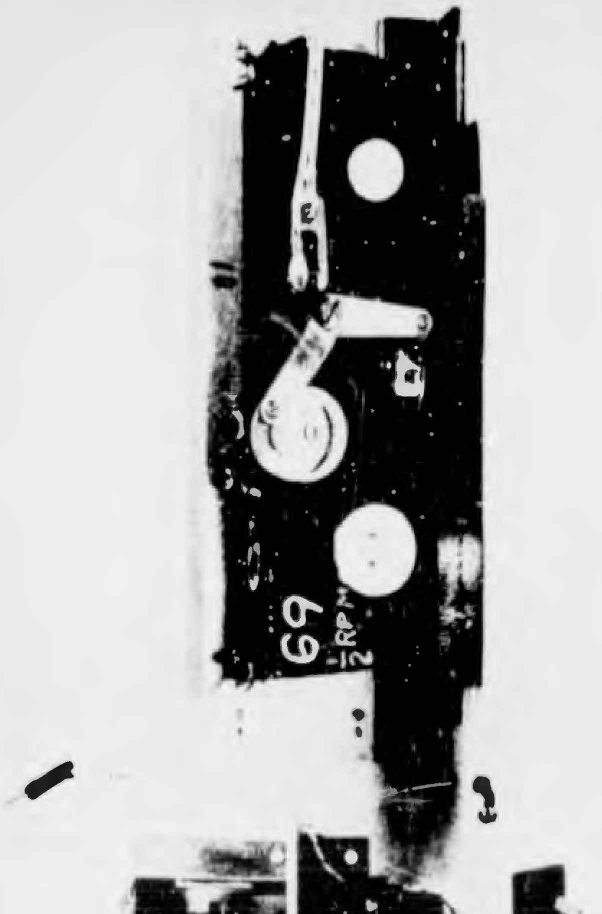


Fig. I-69B. Down Camera. Back view, with back and motor cover removed at right, showing blowdown tube and single telemetering recorder at right of film mask. Side view at right. This camera has a double telemetering recorder instead of blowdown.

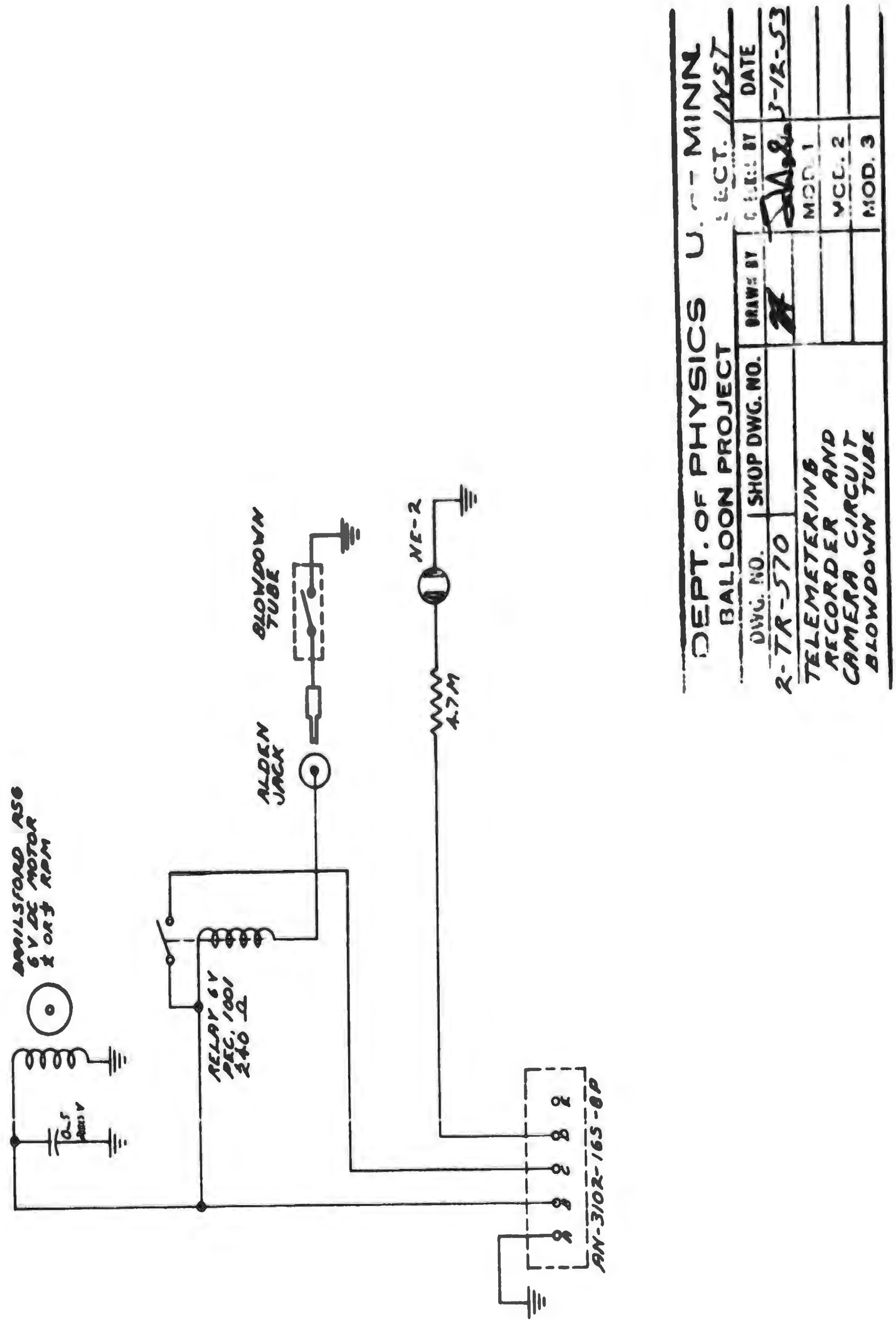

ALDEN JACK
BLOWDOWN TUBE
NE-2
4.7M
AN-3102-16S-8P
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
DWG. NO.
SHOP DWG. NO.
DRAWN BY
DATE
2-TR-570
3-12-53
TELEMETERING RECORDER AND CAMERA CIRCUIT BLOWDOWN TUBE
MOD. 1
MOD. 2
MOD. 3

Fig. I-70a.

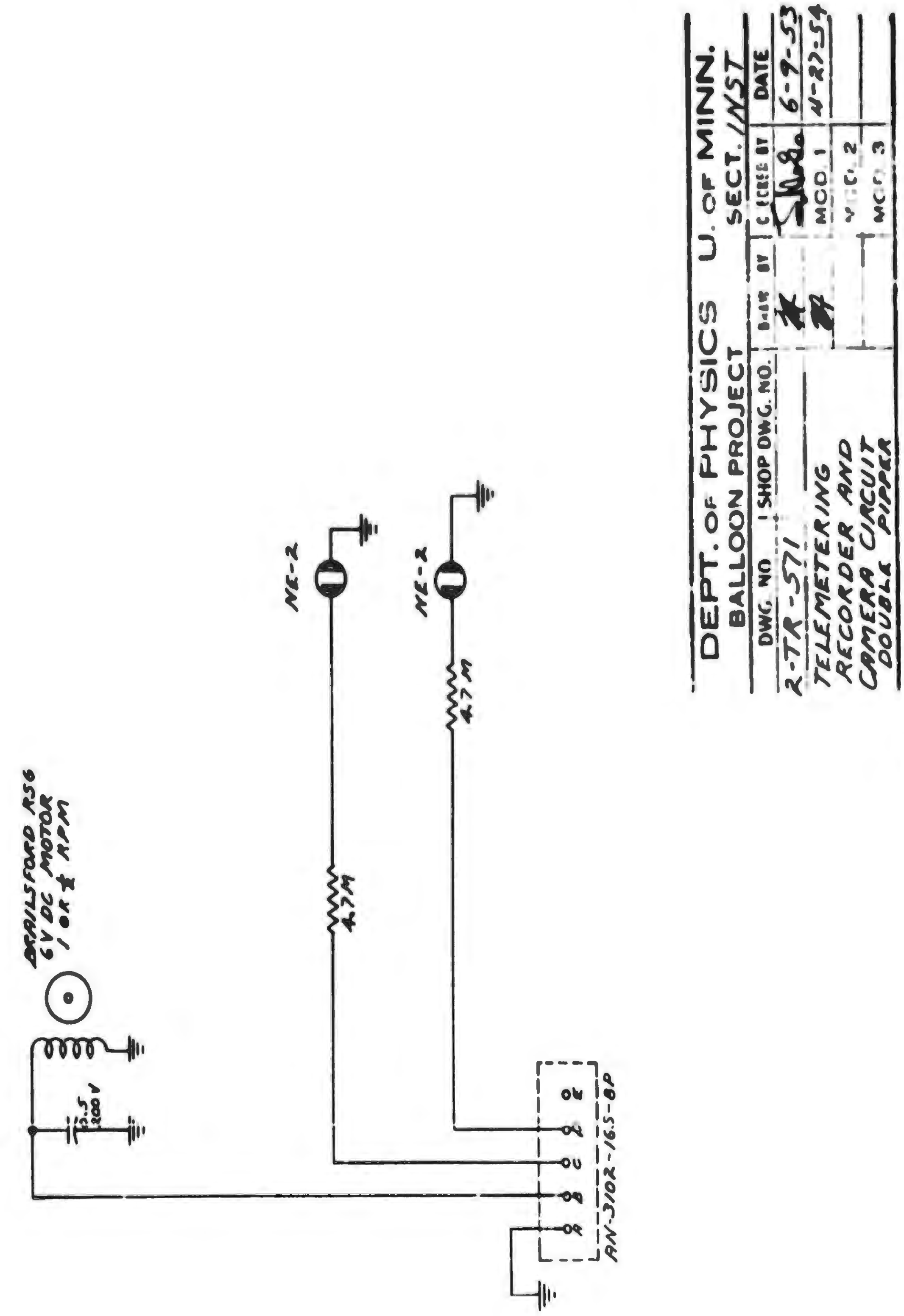

BRAILSFORD RS6
6V DC MOTOR
AN-3102-16.5-8P
4.7M
4.7M
NE-2
NE-2
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
2-TR-571
6-9-53
4-27-54
MOD. 1
MOD. 2
MOD. 3
TELEMETERING RECORDER AND CAMERA CIRCUIT DOUBLE PIPPER

Fig. I-70B.

and allows the inclusion of two telemetering recorder bulbs, one on either side of the picture area. These bulbs record dots and dashes from, e.g. Olland Cycles or other sensing devices. The back pressure plate was extended over the tube to insure the film maintaining contact with the tube.

Another variation of this tube contains a flight termination contact in one end of the tube and a telemetering recorder in the other. This contact is an insulated polished contact which during flight and while the camera still contains film rides on the edge of the picture area of the film. When the end of the film passes, the contact grounds itself on the back pressure plate, thereby signaling flight termination to the Sequence Control Programmer. This type of timer has actually terminated only a few flights even though it has been flown almost as standard equipment in this period, because in most cases flight termination was effected previous to camera blowdown by some other technique. Because of the difficulty of measuring film length in the dark for accurate timing, the camera blowdown has been used mainly as backup, rather than principal timer. To prevent the possibility of the film end not releasing from beneath the clip on the storage spool and the camera avoiding blowdown, a U-shaped notch is cut in the edge of the film approximately 6" from the end, so that a positive blowdown signal occurs at this time.

The mounting plate on which the up camera is fixed tilts the axis of the lens 15° to the vertical in order that the camera lens (which has a cone of acceptance of a little over 30°) will photograph from the center of the bottom of the balloon to the outside edge. This applies to a 60° cone-angle balloon with the camera about 6 ft below the cone apex.

Actually, as can be seen from some of the up camera pictures of the balloon at or near altitude, a slightly shorter focal length and wider cone of acceptance is desirable since the outer edge of the balloon is just out of the field of view. Therefore, this angle has been altered on occasion to better photograph either the duct appendix or the skirt appendix, depending on which was fitted to the particular balloon.

The down camera was made with a flexible mount to allow adjustment so that the lens axis was absolutely vertical. Determination of balloon altitude and trajectory by film measurement is dependent on the camera being perpendicular to the ground, but this perpendicularity has been difficult to maintain after launch because of the packaged ballast drops which put the gondola off balance every time a package is dropped. An example of this behavior is seen in the film trajectory of Flight 69, Volume XI, this report, where after the gondola attained altitude and started rotating, the slight angle of the camera mounting resulted in an apparently staggered trajectory. At 2014 a package of ballast was dropped and the gondola balanced, with the result that the trajectory became smooth.

When the shift was made to the smaller gondolas, there was not enough space for the adjustable mount inside the gondola so the cameras were fastened rigidly to the gondola frame and the whole package was leveled as much as possible by the location of the moveable weights hung on the outside, such as the chute, ballast packages, cosmic ray equipment, etc. This generally requires that the gondola be hung up prior to launch and these weights distributed and fastened in the proper place. The use of a 20-ft plumb line hanging from the camera to determine vertical has eliminated this problem, where there is no danger of fouling with the transmitting antenna.

Figure I-71 shows the elective components usually used in the typical cameras. The choice of motor type, Column 2, depends on the need for accurate timing of the pictures or the telemetered record. Constant speed is highly desirable in recording time-pulse information, since any variation in the recorder speed between reference pulses of the Olland Cycle changes the phase angle relationship of the information helixes. An extreme example of this can be seen in the time-altitude curve for Flight 67, Volume XI this report, which had the additional complication of a very poorly defined light spot. The opposite effect was noticed in reading the camera information for Flight 92, where an error in film speed of less than 12 seconds was found during the 8½ hours for which a telemetered check was available. This camera was driven by a Chronometric Haydon motor.

The choice of drive speed, Column 3, is dictated for the up camera by the film capacity of the cameras and the fact that the essential changes in the balloon of which a photographic record is desired take place in general during the ascent and shortly thereafter. At 1 RPM the maximum film capacity is 10 hours. This is generally enough for the first day of flight. In addition, the spacing of the information pips recorded on the film at 1 RPM is much more accurately read than at the slower drive speeds. The down camera on the other hand is generally required to record flight trajectory as long as the flight is airborne, and for any flight

Fig. I-71. **ELECTIVE COMPONENTS FOR STANDARD FLIGHT CAMERAS**

	MOTOR TYPE	SPEED	LENS	FILTER	EXPOSURE*	TELEMETER RECORDING CHANNELS	TERMINATION TIMER
Up	Brailsford or Haydon Co.	1, 1/2	Ilex	G	1/150 at f16	2	No
Down	Haydon Co. or Brailsford	1/5, 1/2	Bolsey	A	1/25 at f5.6	1	Yes
Horizon	Brailsford	1	Bolsey	A	1/150 at f16	-	-
Crown (Balloon)	Brailsford	1	Ilex	-	1/100 at f8	-	-
Crown (Outside)	Brailsford	1	Bolsey	A	1/50 at f5.6	-	-
Meteorological Tracking	Haydon Chrono.	1	Bolsey	A	1/25 at f5.6	None	Yes

* All exposures reduced to Eastman Background X film or equivalent. (ASA outdoor index = 40)

longer than 10 hours a 1/5 RPM motor is used. This has the advantage of furnishing a telemetered record, even though slightly inaccurate, throughout the entire flight, and for trajectory purposes at the usual altitude and speed of the balloon, pictures were not needed at more frequent intervals than one every five minutes.

A very recent change has been the 1/2 RPM speeds for both cameras. This is a compromise which satisfactorily resolves the various conflicts, except the down camera speeds for flights over 20 hours, and is to be standard in the future.

The lens choice listed in column 4 is dictated by the difference in focal length of the Bolsey and Ilex lens. The Bolsey's focal length of 44 mm makes it a more desirable lens for subjects at a great distance from the camera, whereas the shorter focal length of the Ilex (35 mm) makes it the better lens for closer subjects where the detail is easily apparent and a wider area is to be photographed.

The filters listed in column 5 were chosen, in the case of the down camera, to cut haze without too large a filter factor, and in the case of the up camera to give sharp contrast between the balloon and the sky. An Aero-I filter serves as well as the G listed. The exposures listed were arrived at by experimentation, since no previous information was available. Quite a variety of film types have been tried on this project, including Eastman Commercial Kodachrome, Linograph Ortho, Plus X, Super XX, Infra Red, and DuPont Superior 1. No marked advantage was noted with any of these except, of course, the color advantage of Kodachrome, which was not advisable for routine use because of its narrow exposure latitude.

Infra Red film with a Wrattan 80 filter was too slow for down camera film but with an A filter gave about the same results as Plus X in the down or horizon cameras. Plus X or Background X appeared to be generally equal and more desirable than the others because they balanced a moderate exposure index with relatively fine grain qualities.

The last two columns show that the blowdown tube is usually used on down cameras with one telemetering recorder, and when two telemetering recorders are used they are usually on the up camera. This is done because the faster drive speed makes the up camera a more desirable recording camera, whereas the slower speed of the down camera makes it a more desirable termination timer. The blowdown tube on the meteorological tracking camera was used to separate the camera from the balloon at a given time before the end of the balloon flight.

In addition to the up and down camera positions which have been called standard, this basic camera has been used, as is listed in column 1, in several other applications. Pages VII-233 and 234 of Volume V mention the horizon and crown cameras. The crown camera (Picture, Figure I-72) was used during this report period not only to photograph thermistors hanging inside a balloon at ceiling but also, when hung outside a tow balloon, to photograph the platform balloon below in order to measure the horizontal displacement of one with respect to the other. This was done on two step flights to determine if horizontal displacement was affecting the tensiometer reading.

In addition, a special meteorological tracking camera was developed during this period (picture in Figure I-73) which is intended to furnish

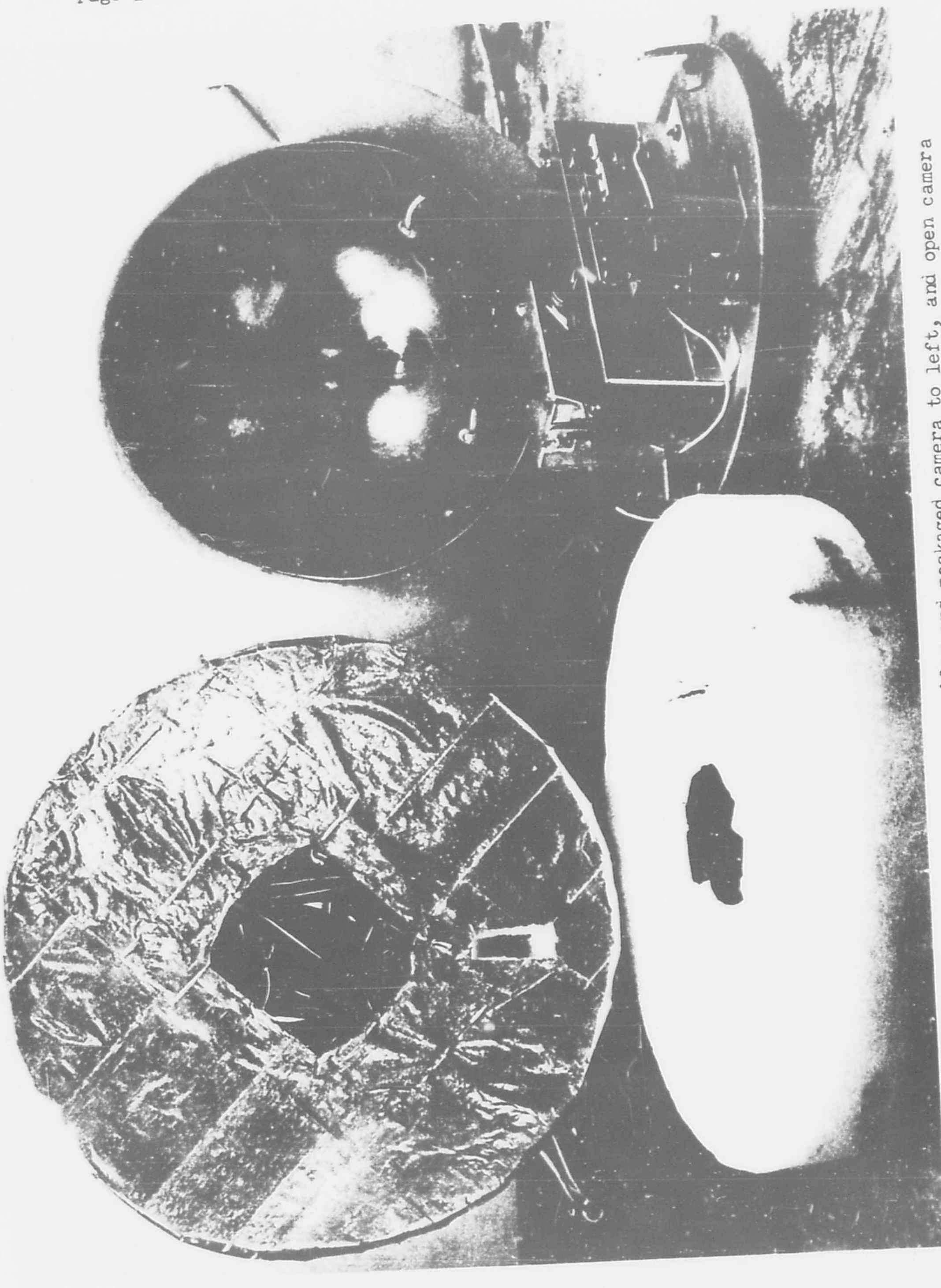


Fig. I-72. Crown Camera, showing assembled and packaged camera to left, and open camera to right.

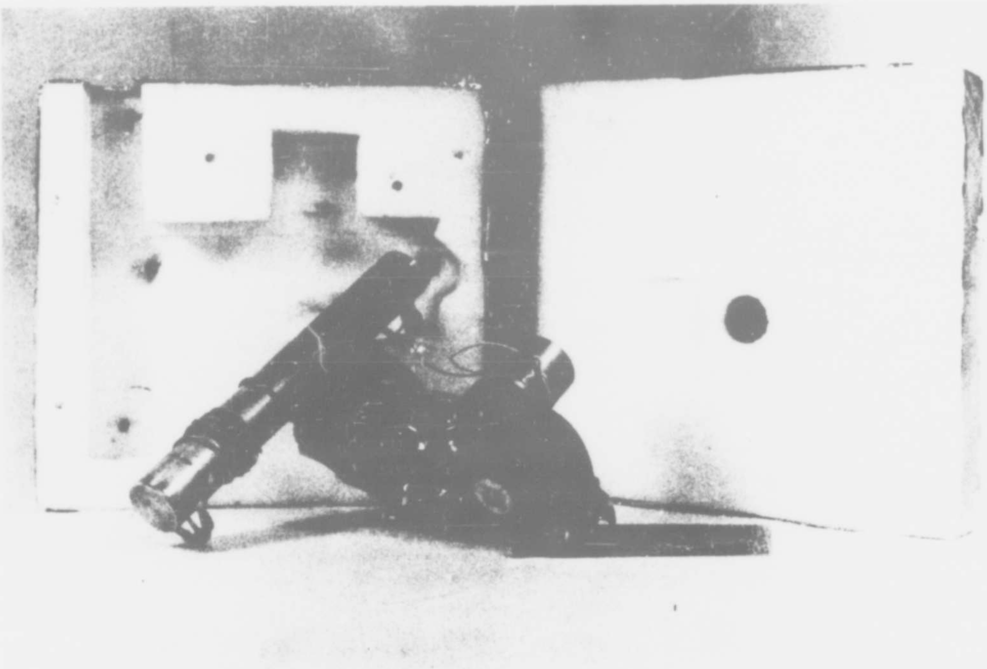
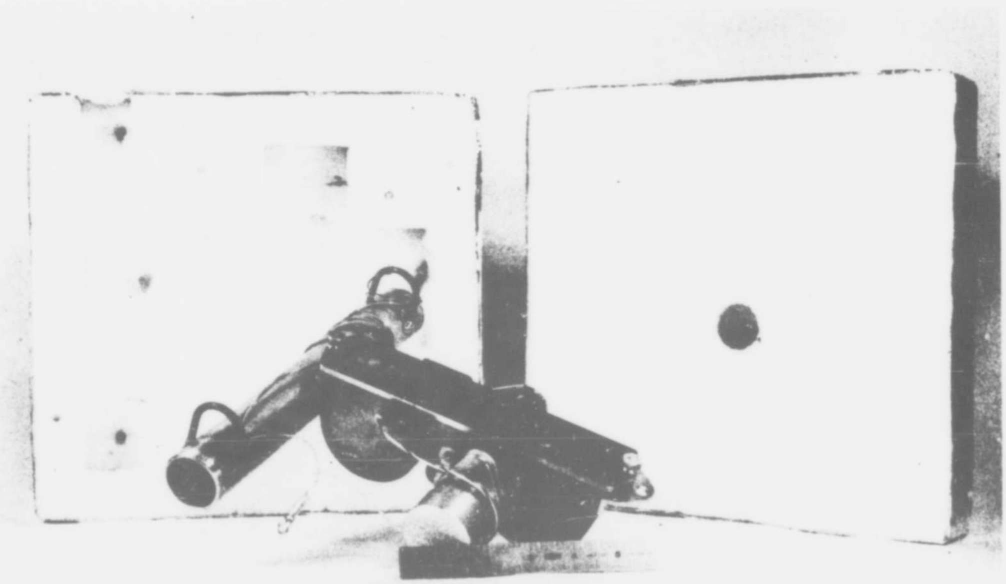


Fig. I-73. Meteorological Camera.
A. Bottom view, showing styrofoam case in background.



B. Top view, styrofoam case in background.

altitude and trajectory information on air mass movements at moderate altitudes. This camera has not been flown during this report period and a description of its use will be deferred.

Another application of the basic camera has been as a data-recording instrument in the photo recording ammeter, Page VII-244, 248-250, of Volume V. In this situation an Ilex lens was used with a lens tube extension resulting in a lens-to-subject distance of about 11 inches. A similar application is in the Thermistor Photo Recorder which is described in this volume in the Temperature Measurements section.

This same camera body fitted with a short focal length lens without a shutter or diaphragm assembly and driven by a 110 V.A.C. synchronous motor is also used as the continuous track oscilloscope camera mentioned in this report, Volume X, Section II, in the description of the Multiplex Decoding equipment. This application is similar in principle to the Photo Recording Ammeter in that the display of information (in this case an oscilloscope) is displayed on one axis,and the film running continuously at right angles photographs a time plot of the information. The lens used is an Eastman HE 23410, 26 mm Anastigmat Copying Lens.

In preparing these cameras for use a few precautions and adjustments have been found to be of great importance to the success of the camera run. Several times small metallic chips left over from the shop have been the cause of camera stoppage and a thorough cleaning is indicated for every camera upon receipt from the shop, followed by a thorough de-burring of all moving parts and tightening of all screws, etc. All moving parts are operated by hand to check tolerance and freedom. One point of particular trouble is the bushings,through which the drive sprocket and the film take-up spool shaft operate. These on several occasions have been found to freeze because of a few thousandths tightness in either radial dimension or bushing thickness. These bearings are then lubricated with molybdenum disulfite, either in a dry powder or in an aqueous solution. This lubricant has been found to be superior to any liquid organic lubricant we were able to find for moving parts of aluminum, after trying between 12 and 15 different substances. Great care was taken, however, not to allow any lubricant to get on the take-up pulleys because a small amount will lubricate the belt so that it will not drive the take-up spool.

The take-up belt (Figure I-74) should be adjusted so that it exerts a pull of between three and four ounces on a film attached to the take-up spool with the motor driving it. If this tension is too tight, the film will slip over the sprockets of the film drive shaft and the pictures will have uneven blank spaces between them. If the tension is too loose, the film will not be pulled off of the film drive sprockets but will follow the sprockets around and jam up under the drive shaft. If the pictures on the film are overlapped, the film storage spool does not revolve freely or the back plate seating is inaccurate. On one occasion when a film refused to pass through a camera it was found that the two small shoulders on either side of the film channel on which the back pressure plate was intended to rest were unevenly milled and the plate was pressing directly against the film. This pressure plate is intended only to keep the film flat between these shoulders and should not press against the film.

The action of the shutter drive should be checked carefully to be sure the limits of travel of the shutter release lever are not being

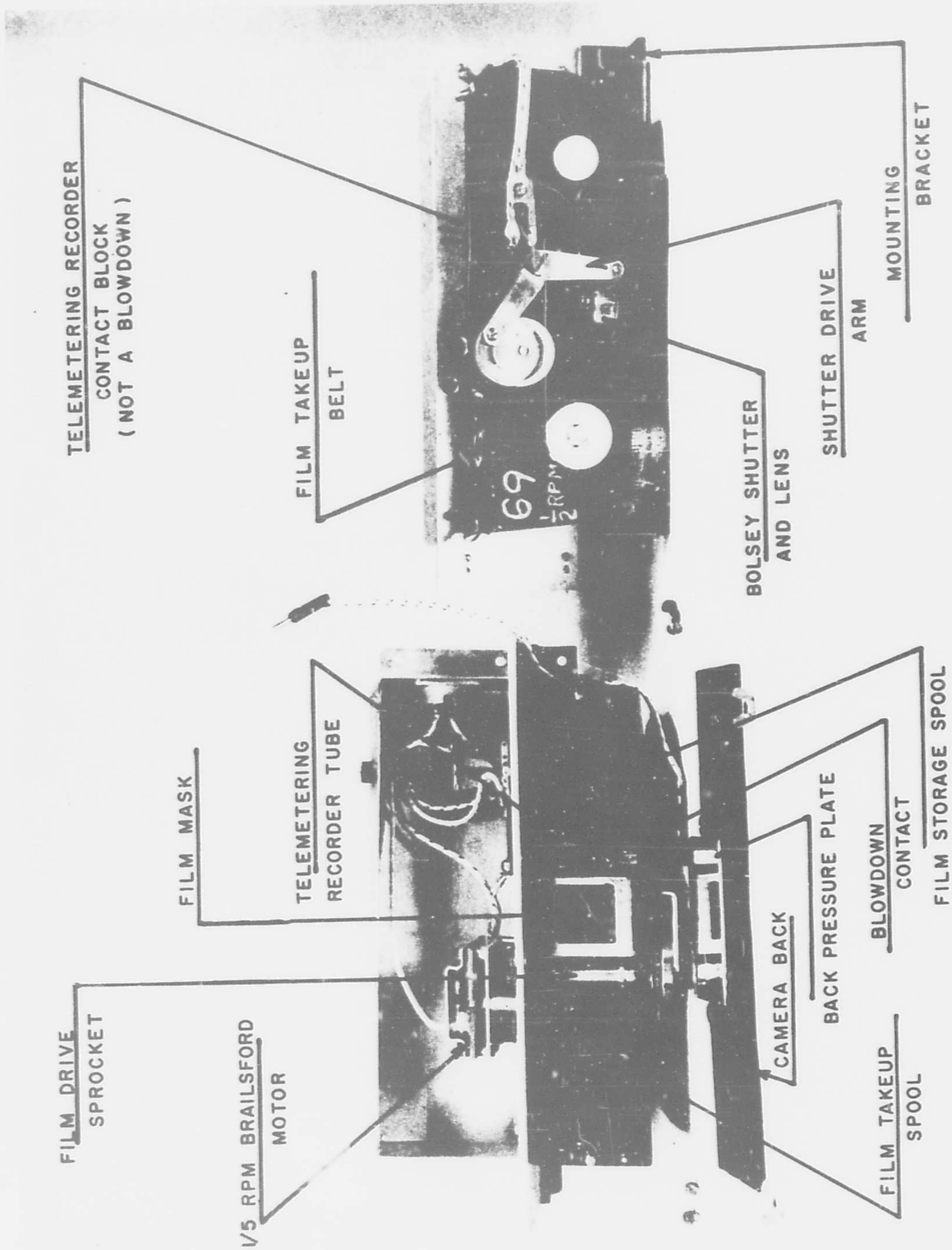


Fig. I-74. Down Camera, with outstanding parts indicated. Cam to the right has double telemetering record instead of blowdown.

exceeded. This adjustment is a matter of rotation of the shutter mechanism in the lens draw tube, which is indexed to the camera body by the clamping screw keyway. Note should be made of the fact that the shutter drive arm used with the Ilex and Bolsey lenses are not interchangeable, and one will overdrive a mismatched shutter assembly while the other will underdrive a mismatch. This whole mechanism--the drive sprocket, film take-up spool, and shutter drive arm--should rotate freely when disconnected from the motor, and this is generally the best way of testing the camera action.

To focus the camera a fine ground glass plate which is slightly narrower than the film width is taped across the mask of the camera after the back is removed, and the shutter is set on "time." With the motor disconnected or the shutter drive arm disconnected, the shutter is opened. This should never be done by the motor because the "time" stop is a racket release mechanism, and the shutter will be damaged if it is driven through a cycle by the motor. The lens tube clamping screw is loosened and the lens tube worked in and out until focus on an object at 40 ft or more is obtained. A window in a semi-dark room is convenient. A jeweler's loupe is an aid in examining the ground glass, but is not necessary. The clamping screw is then tightened, and the focus rechecked. The action of the shutter drive should be reexamined carefully after reassembly to be sure that the focusing did not misalign the drive. This focus is tested before flight on film as will be explained later. The filter is then cut to fit inside the lens tube, and the filter retaining ring inserted to hold it in place.

The telemetering recorders have received a great deal of attention as their importance as a flight performance recording device has become more apparent. On a number of flights when radio attenuation or noise prevented the reception of the entirety of the flight, or in cases of telemetering failure, the cameras have furnished the missing information. The accuracy of this type of record is inferior to the telemetered record, and this inferiority results from four factors. Evenness of motor speed has already been mentioned, but this is only a part of the problem of accurate film drive. It has been observed recently that the film does not move smoothly through the camera but in a series of very fine jerks on the order of a hundredth of an inch in magnitude. This becomes a basic fault in the system when the film is magnified 20-to-1 for reading, and is one that cannot be solved without a complicated film drive mechanism that smooths the film transport before and after it is marked.

The second part of the problem is to insure the ignition of the neon tube at the instant the current is applied to it. A neon tube ordinarily is operated in a lighted place so that its need for gaseous ionization is not generally known. The Tufts laboratory of the MOBY DICK project uses a "keep alive" current through its neon markers, but this did not prove practicable in our cameras. A very careful program of hand picking these General Electric NE-2 bulbs eliminated first those whose envelopes would not fit the tube in the camera body, then those in which the glowing spot on the electrodes moved, and lastly those which lit only after an obvious delay in a darkroom. Then a spot of radioactive watch paint was applied to the envelope of each tube (Sun Ray Radioactive Finishing Kit #25, C. M. Thomsen Co., Minneapolis, Minnesota) and the tubes again checked in a dark room. Final acceptance after these tests amounts to approximately 15 to 20 out of 100 bulbs, but there have been no evidences of lost or delayed pulses with tubes so selected.

The third and fourth sources of error in this recording system are the size and definition of the spot on the film. A large spot or a spot with a fuzzy edge is difficult to read and inaccurate (see the time-altitude record of Flight 67). The size of the spot is principally a function of the size of the hole through which the light passes to the film, and the definition of the spot is a function of the light intensity and the characteristics of the film. The film choice is essentially dictated by other considerations (namely, the grey-scale reproduction of a photographic image), and therefore the definition reinforcement of a contrast film and developer cannot be used. The antihalation backing of all modern films are approximately equal, so that the light intensity is the only variable which can be manipulated in this case. The resistors in series with the neon tubes adjust the intensity of the light to give a spot with a minimum of halation and a relatively sharp profile with the size of the pinhole that we use. These resistors have to be changed with different size pinholes. The pinholes made here have not been measured recently but are currently approximately five ten-thousandths (5/10,000) of an inch in diameter. This is just too small to see on a polished brass surface with the naked eye, and about as small as is advisable for this use because the grain size of the film will not record much smaller. These anpertures are made by drilling a small hole from the far side of the tube almost through the tube wall, perforating the weakened wall with a special steel needle, and then closing the hole by burnishing over it, while a special ball-shaped tool supports the weakened tube wall from underneath.

To prepare the camera for flight after it has been cleaned, checked for action, focused, and the telemetering recorder bulb installed and wired, a foot of film is placed in the camera (all loading being done in total darkness) and the camera is operated from a test-pack of dry cells which plug into the camera terminal. Several pictures containing measured distances are taken from a standard position outdoors on the campus, and the telemetering recorder is manually keyed to simulate both short and long Olland Cycle pulses, plus a special code of short and long pulses. This film is developed as would be a flight film and carefully checked for focus, film drive, and telemeter record. Any defects are repaired and other test films are taken until the camera is satisfactory.

When the flight film is measured and loaded, the same type of test pictures are taken on the film for calibration purposes, in the case of the down camera, and in order to have an exposure and developing guide on every film. The shutter speed and diaphragm opening is set and taped to prevent accidental movement. Development after the return of the film is done in Steinman tanks with Eastman D-25 developer for 22 minutes at 72°F.

These camera films have been noted as the most indestructible things flown here. Several gondolas have been recovered after as much as two weeks in water, both fresh and salt, and though the cameras had to be opened with a hammer and chisel, and the film spool was found to have dissolved from inside the roll of film, an adequate film record was obtainable in all cases. In only one case of a free fall, where the camera was thrown 250 ft by the impact and the body split open, was a film unreadable. Other free falls have occurred where the camera body was bent markedly, but all those records were undamaged.

19. Multichannel Pulse Recorder

As a solution to the problem of compromising the needs of a photo recording camera and a telemetering recorder, a special pulse-recording camera is being developed here. This camera has a number of markers which will record up to nine separate channels of information and has a film storage capacity of 200 ft of 16 mm film, which allows approximately 26½ hours of recording. The film transport speed of 1½ inches per minute is fast enough to record the shortest duration pulses generated in the gondola (by the Thermistor Pulse Generator) and also resolve the close spacing of the pulses from the same instrument, which range between 2 and 25 pulses per minute. A picture of this instrument is shown in Figure I-75, a wiring diagram in Figure I-76, and a shop drawing in Figure I-77. The 200-ft magazine is bought unfinished from the National Camera Exchange, Minneapolis, Minnesota, and is the magazine for their Morton 16 mm Soundmaster camera. The motor is a Haydon Chronometric. Since this camera is still in the process of development, a detailed description will be deferred.

Structural

20. Gondola Frame

The frames listed in Figure I-78 represent a transition from the early "loose fitting" design, which could accommodate almost any size or shape obtainable in all cases. In only one case of a free fall, where the camera was thrown 250 ft by the impact and the body split open, was a film unreadable. Other free falls have occurred where the camera body was bent markedly, but all those records were undamaged.

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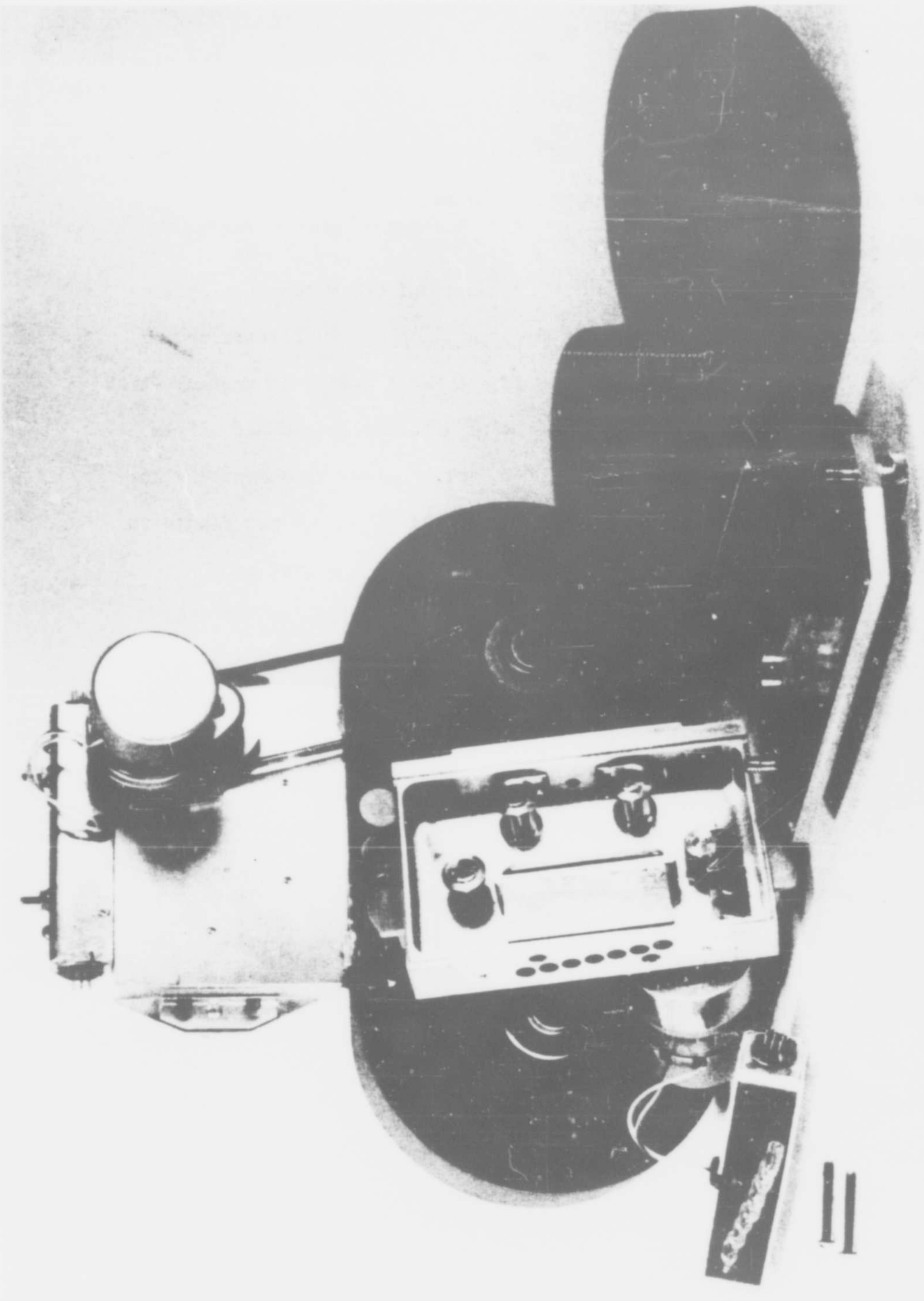


Fig. I-75. Multichannel Pulse Recorder. Assembled recorder in background. Disassembled recorder in foreground, showing marker tubes to left, main cam body in the center, and film magazine to the right.

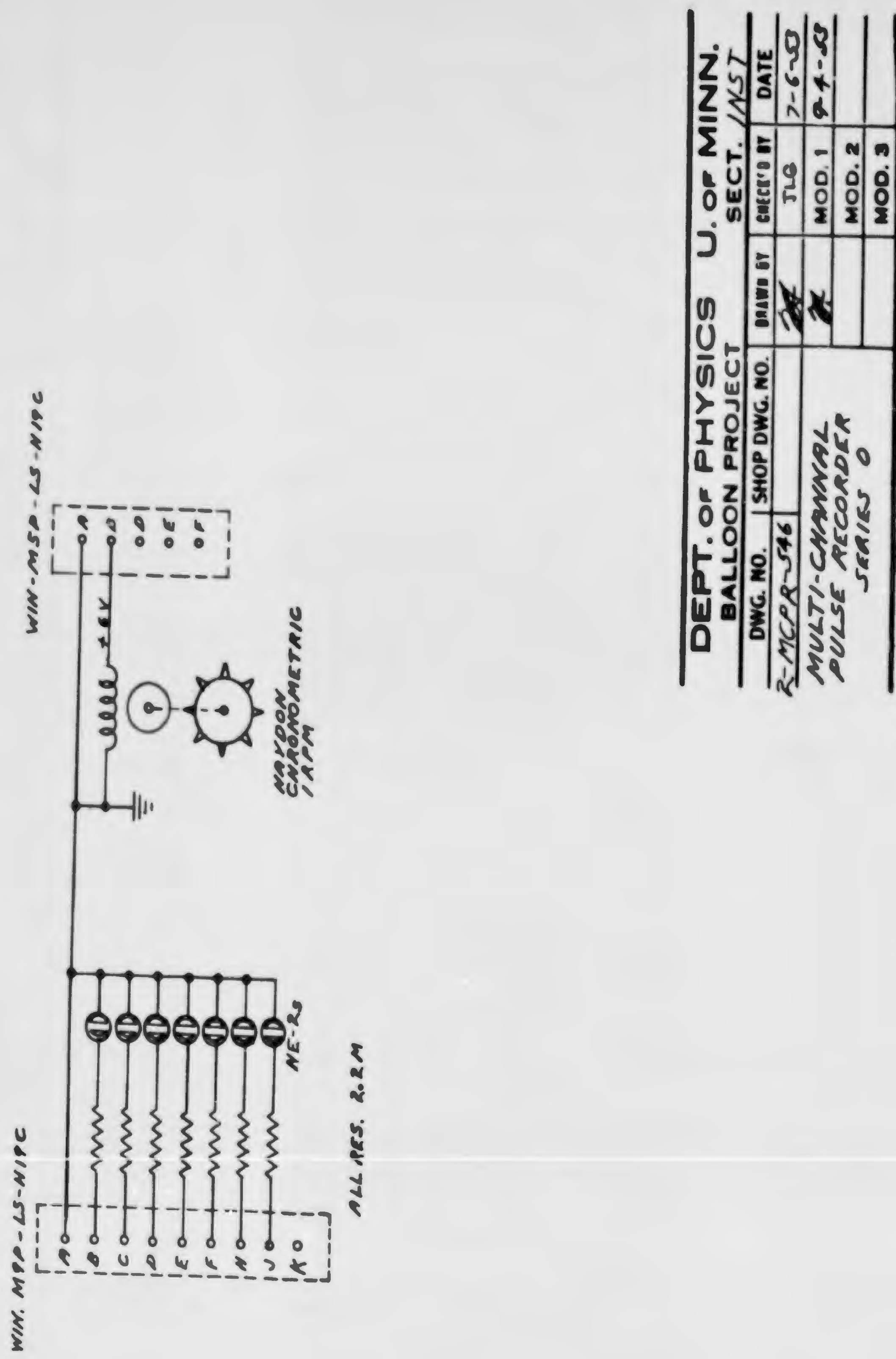

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
SECT. INST
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
R-MCPR-546
TLG
7-6-53
MOD. 1
9-4-53
MOD. 2
MOD. 3
MULTI-CHANNEL PULSE RECORDER SERIES 0
HAYDON CHRONOMETRIC 1 RPM
NE-2s
ALL RES. 2.2M

Fig. I-96.

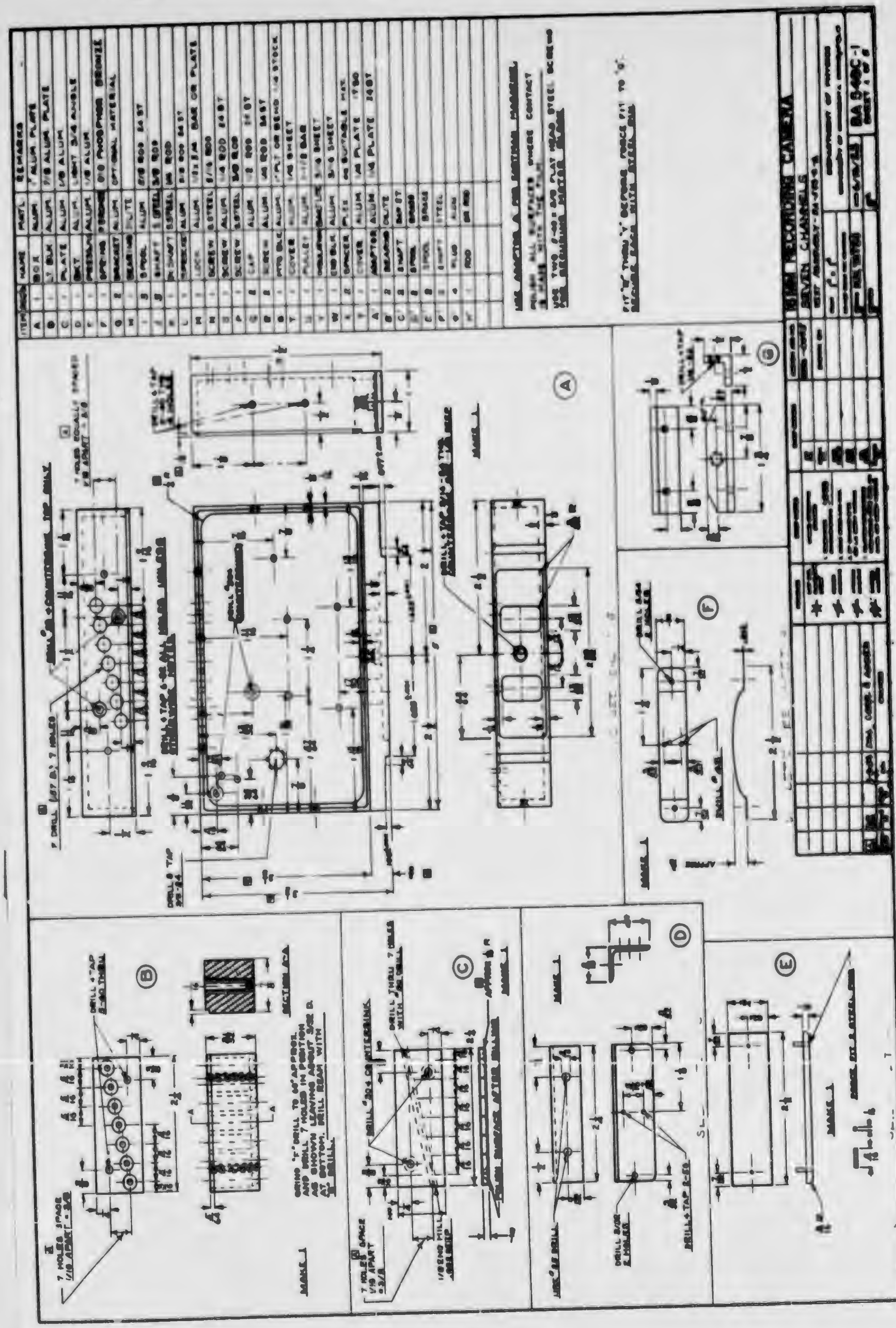


Fig. I-77A.

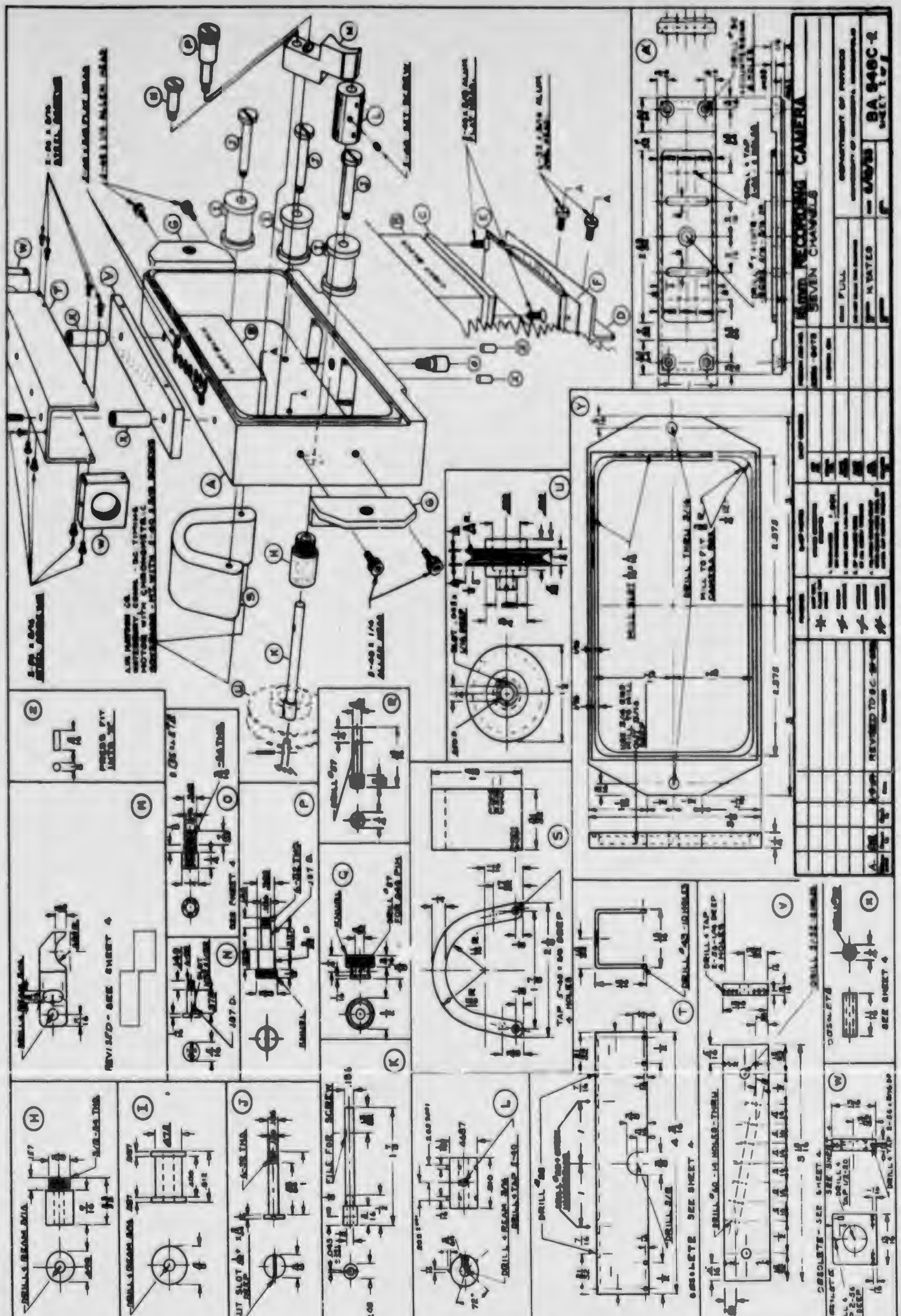


Fig. I-77B.

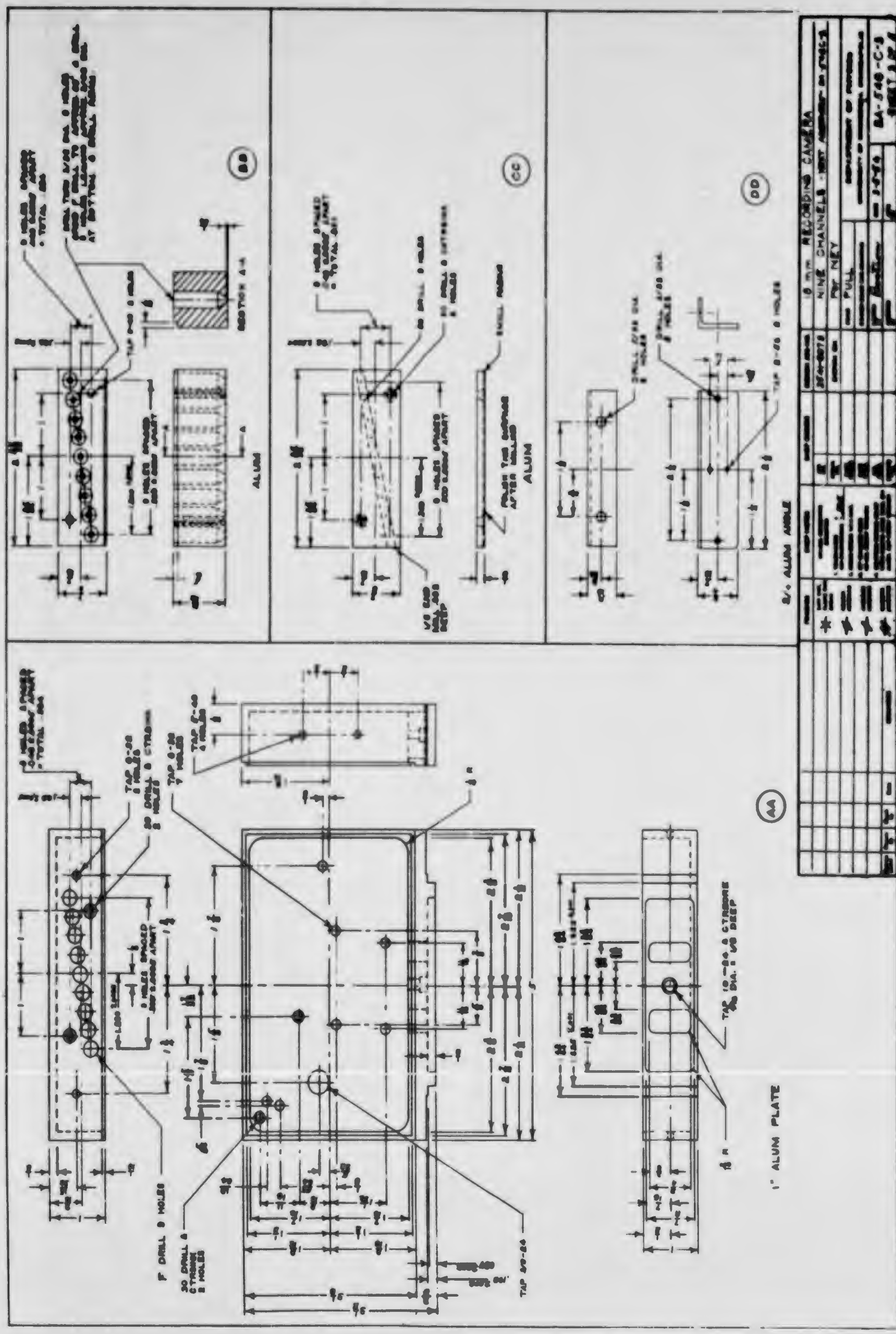

1" ALUM PLATE
ALUM
SECTION A-A
3/4 ALUM ANGLE
16 mm RECORDING CAMERA
NINE CHANNELS

Fig. I-77C.

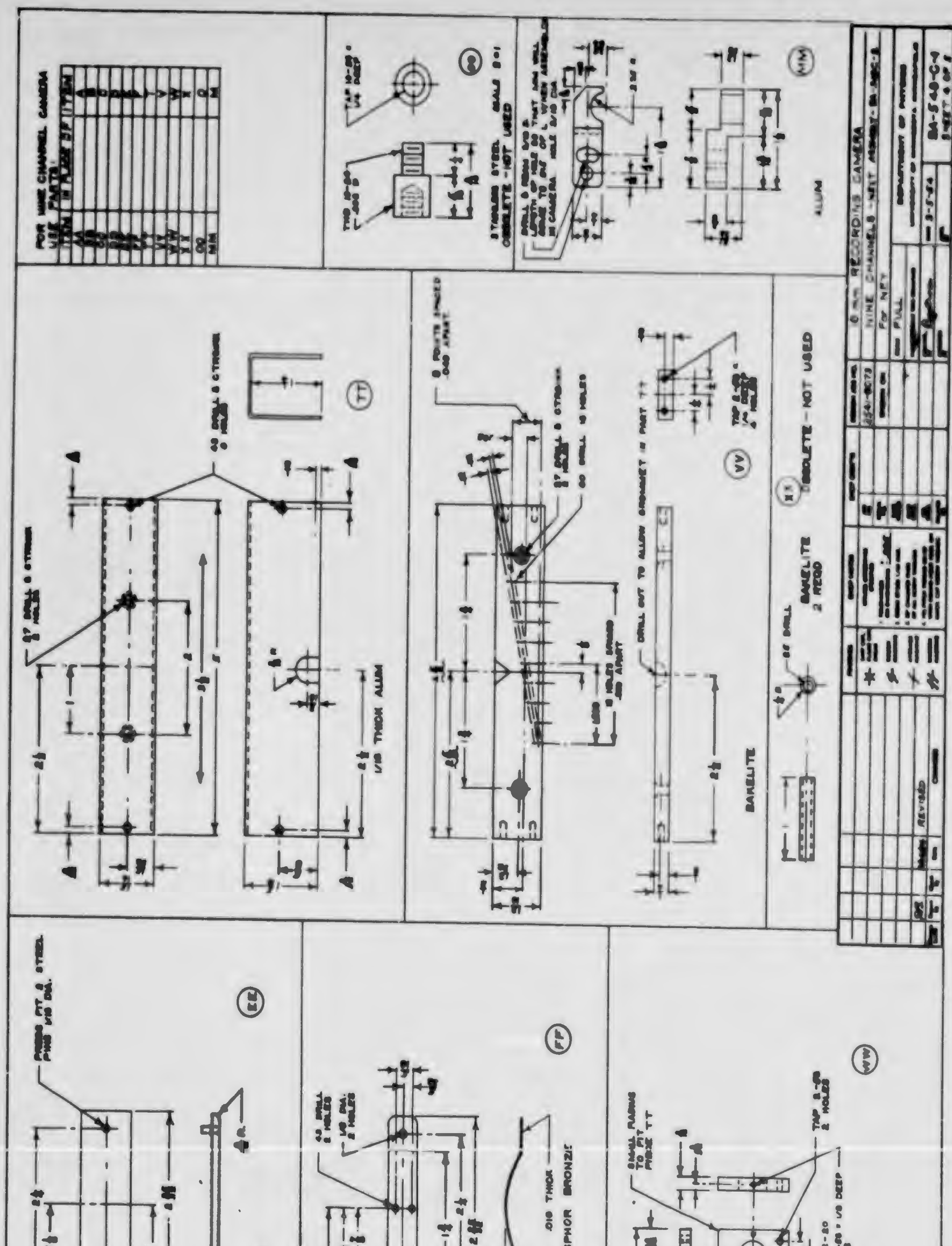

BAKELITE
2 REQD
BAKELITE
OBSOLETE - NOT USED
1/16 THICK ALUM
ALUM
.010 THICK
PHOSPHOR BRONZE
ALUM
2 REQD.
ALUM
8 mm RECORDING CAMERA

Fig. I-77D.

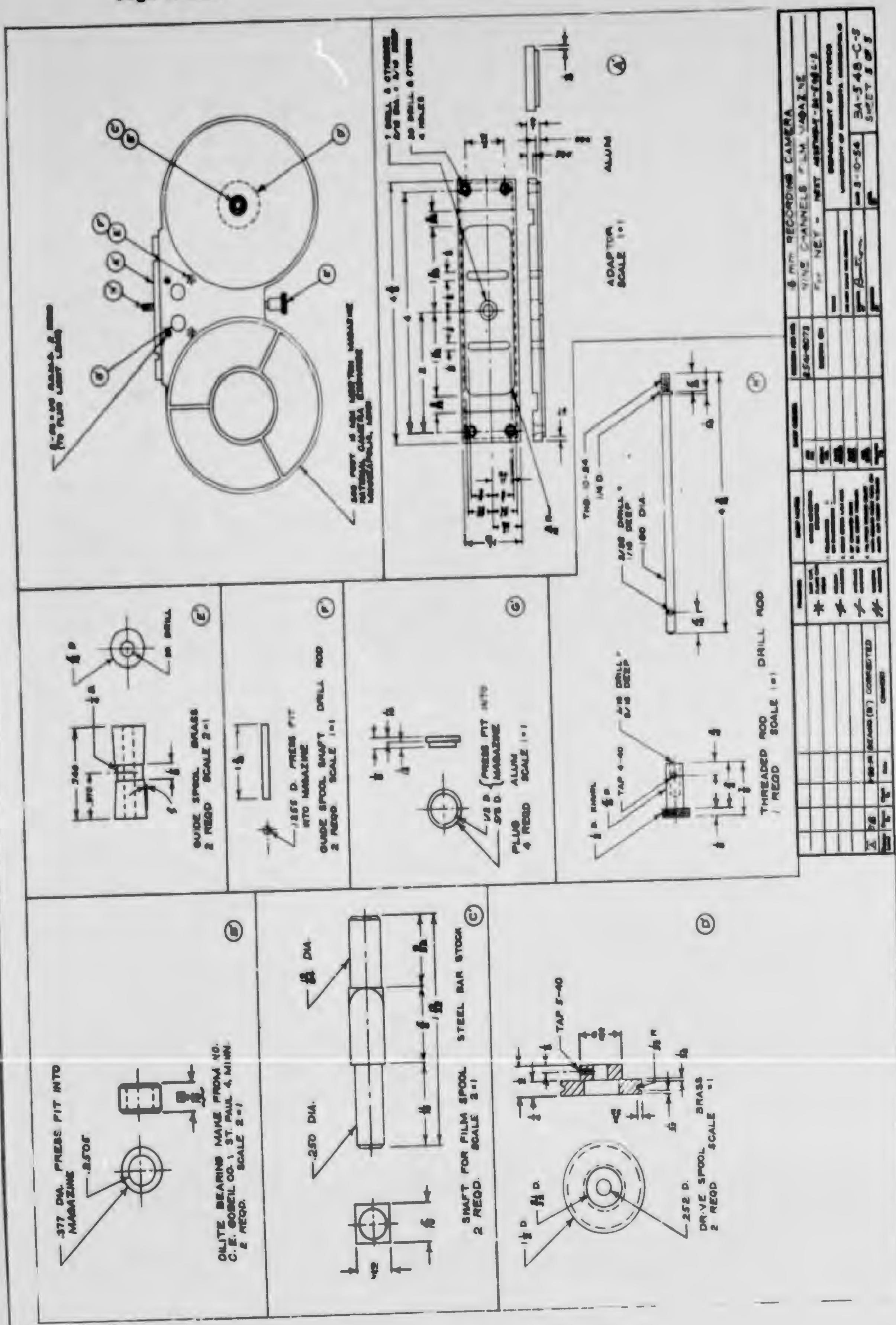

8 mm RECORDING CAMERA
NINE CHANNELS FILM MAGAZINE
34-548-C-8
ADAPTOR SCALE 1=1
ALUM
THREADED ROD 1 REQD SCALE 1=1 DRILL ROD
GUIDE SPOOL 2 REQD SCALE 2=1 BRASS
GUIDE SPOOL SHAFT 2 REQD SCALE 1=1 DRILL ROD
PLUG 4 REQD ALUM SCALE 1=1
OILITE BEARING MAKE FROM NO. C.E. GOBEIL CO., ST. PAUL 4, MINN. 2 REQD. SCALE 2=1
.377 DIA. PRESS FIT INTO MAGAZINE
SHAFT FOR FILM SPOOL 2 REQD. SCALE 2=1 STEEL BAR STOCK
.250 DIA.
DRIVE SPOOL 2 REQD SCALE 1=1 BRASS
.252 D.
TAP 5-40

Fig. I-77E.

CONSTRUCTION OF GONDOLA FRAMES

NAME	BODY CAVITY	MATERIAL	TOP	BOTTOM
Large	24 x 24 x 24	1" AL angle	45° Cap	8" Legs
Texas	12 x 12 x 7	½" AL angle	45° Cap	---
Miniature	12 x 12 x 12	½" AL Angle	------	---
Intermediate	12 x 12 x 18	½" AL angle	45° Cap	8" Legs
Subminiature	6 x 6 x 6	1" Styrofoam	------	---

Fig. I-78.

instrument, to gondolas which were engineered to contain specific components. The smaller, most recent frames, of course, represent a lower proportion of the total weight of the equipment and are therefore more efficient in this respect also. There has been one free fall of this miniature type gondola when the bottom of a prematurely burst balloon tangled the chute, and the gondola kited into a river. In this case the gondola was badly broken up, but it has been the only serious damage done to one of these rectangular frames. A picture of the frame is shown in Figure I-79, and a shop drawing in Figure I-80. As can be noted from the picture, there is no heat conducting path that can lead the heat from the gondola to the outside air, since suspension is by nylon ropes through the four gusset plates in the upper corners of the frame. There are no legs on this frame as there were on the older large style frame, and the antenna dropper and flasher is supported by a nonconducting fiber arm.

21 & 22. Insulation and Cover

Except for one short daytime flight, all the gondolas flown in this period were insulated by Styrofoam, as were the gondolas of the previous report periods. (Page VII-253, Volume V). In designing the more compact gondola, the case was made of two 2" layers with aluminum foil on the outside of each. Since aluminum has better radiation absorbing qualities in the visible spectrum than in the infrared region, it is an excellent material to cover a gondola.

The temperature inside a gondola so insulated has been measured on a number of flights and the graphed results can be seen in this report, Volume XI, where the time-temperature results are presented. Because of

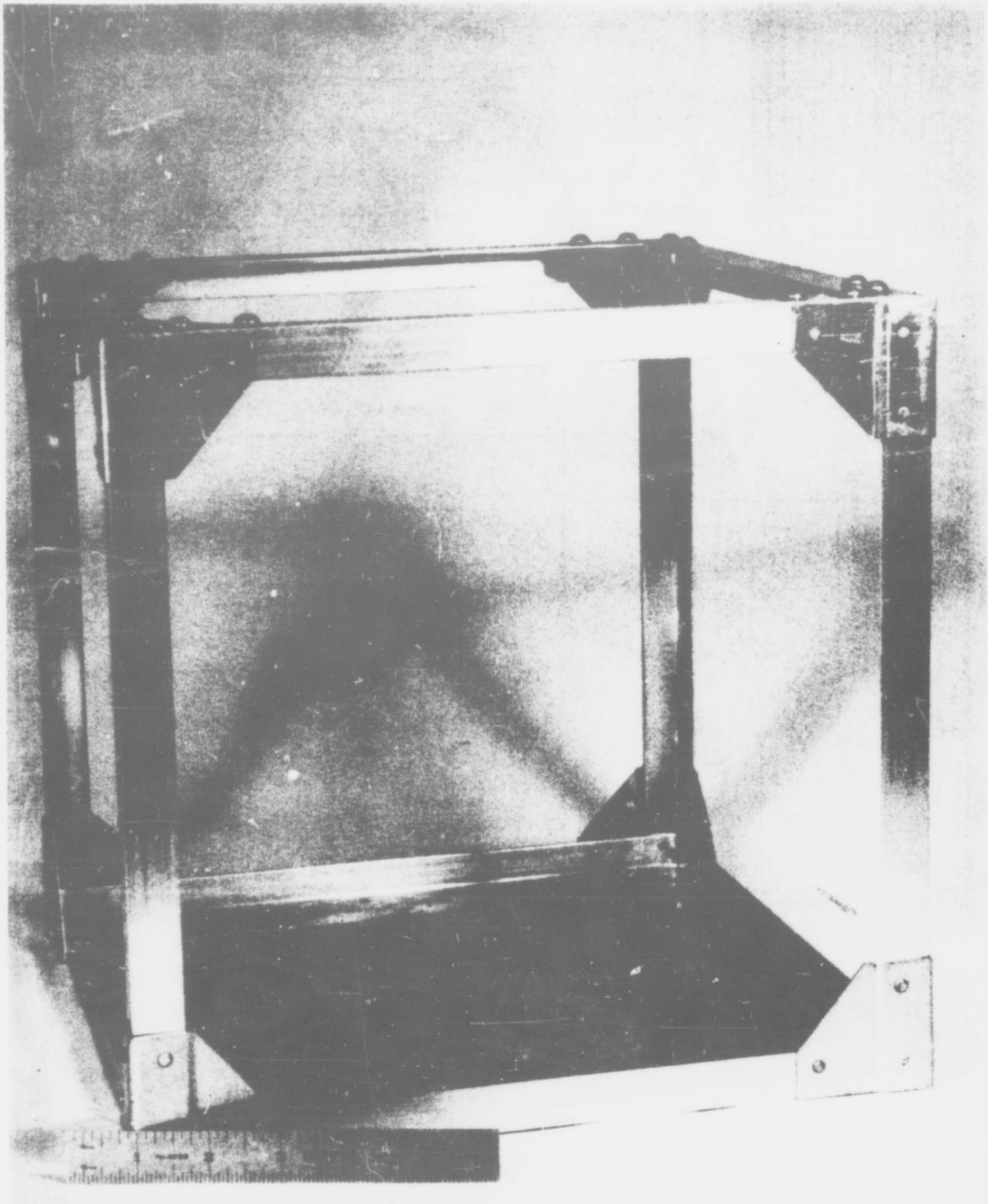


Fig. I-79. Miniature Gondola Frame.

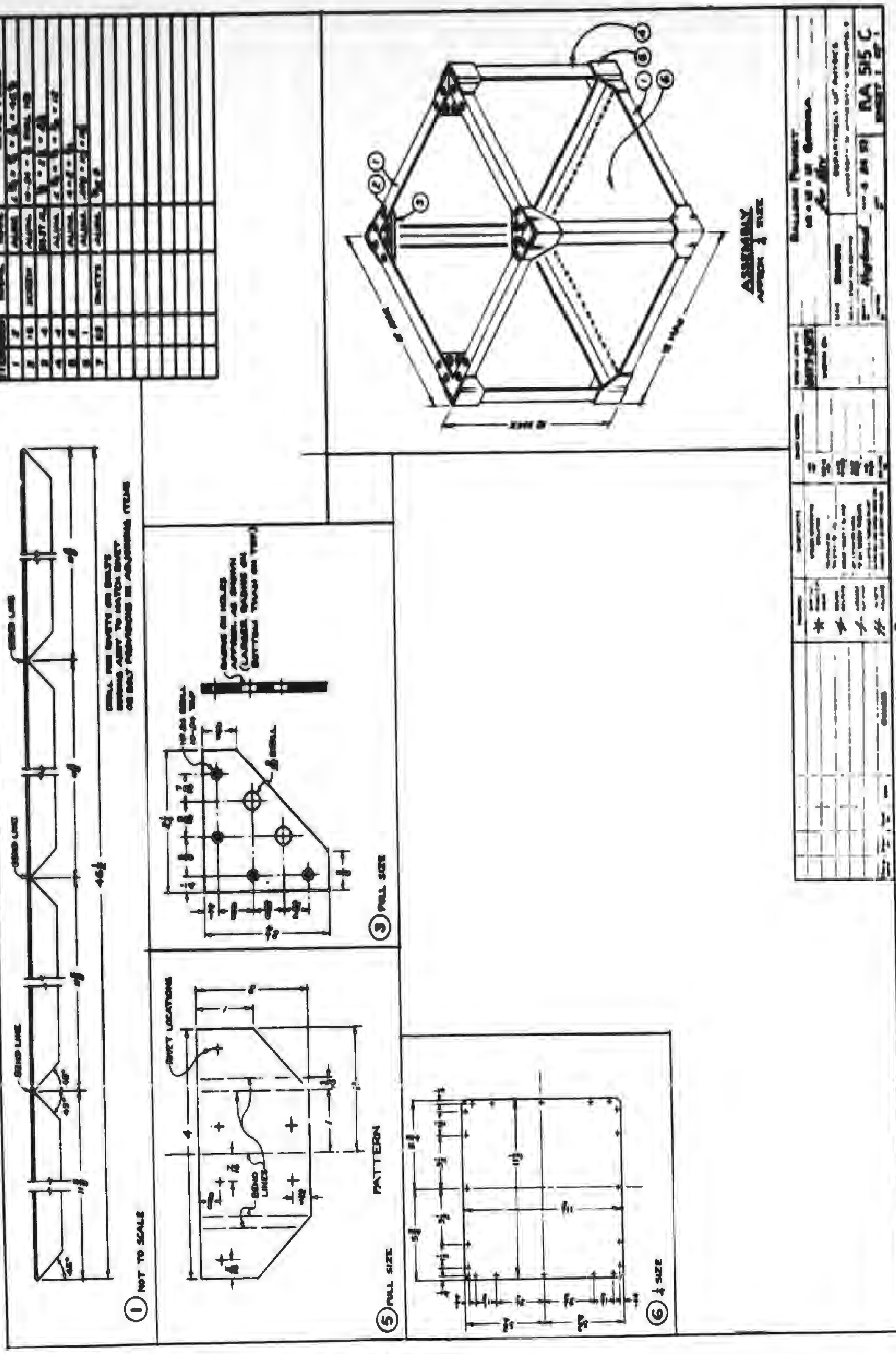

NOT TO SCALE
RIVET LOCATIONS
BEND LINES
PATTERN
FULL SIZE
ASSEMBLY
RA 515 C

Fig. I-80.

the inherent characteristic of the thermistor pulse generator which makes the first hour of readings somewhat unstable, it is more desirable to refer to a longer flight, and therefore Flights 90, 91 or 92 are recommended. It will be seen that the temperature inside the gondola remains very near air temperature at the launch site regardless of the time or length of flight. This is a temperature differential of 65° to 85° across the insulation of the gondola, and about 15 watts continuous heat dissipation.

The styrofoam has qualities in addition to its heat insulation which make it a desirable packaging material. Its shock resistance is very good and short of unreasonably large acceleration it has protected our equipment very well. Its most valuable secondary quality, however, is its buoyancy, and a gondola which lands in water can always be found floating high. Even the heaviest gondola flown here can be supported by the styrofoam in its case (with 256 lbs of lift to spare), as has been proven by the recovery of one which floated 23 days in Lake Michigan.

23. Gondola Heater

When it was suspected that there was a component failure on one flight due to low battery temperature, a special thermostatically controlled insulated battery box was flown. This was, however, given up in favor of the heat engineered gondola with the extra precaution of a water tank in contact with which the batteries were fastened. This tank was designed to keep the batteries above freezing temperatures for two days and nights. The whole system was tested in the cold chamber of the Department of Mechanical Engineering, at -62°F for 72 hours, through the courtesy of Dr.

Richard Jordan. However, as designs changed, the heat output of the transmitter soon became more than this water tank was able to produce and the battery capacity was increased to produce the heat in this fashion instead. The gondola temperature results in the flights cited previously were warmed by equipment heat rather than by a water tank.

Wiring. The wire used on this project has been reduced to two basic types. The glass-insulated wire mentioned in Volume V, Page VII-256, has been used extensively in wiring gondolas and for thermistor leads from the balloon. However, in wiring very small units it proved balky and unmanageable, and extended heat was able to char the insulation. Therefore, Teflon insulated wire #22001-Al, Tensalite Insulated Wire Co., Tarrytown, New York, has been used inside units and in critical areas in gondola wiring. Teflon has no known solvents and therefore is unaffected by battery acid, and since it has an exceptionally high charring point it cannot be damaged by soldering irons. A smaller gauge wire can be used because the danger of damaging the insulation due to overloads is eliminated. Were it not for the high cost, Teflon wire would be used throughout a gondola because of the ease of working with it.

Recovery. An analysis of the recovery of all the flights by the University to date is presented in Figure I-81. The lower recovery percentage of this report period is due in part to the low return on the subminiature gondolas flown on the small Mylar balloons, but two step flights and two temperature flights are also among those missing. During this period no particular effort was made to recover flights that were outstanding (with one exception),

SUMMARY OF PROJECT EQUIPMENT RECOVERY TO DATE

	Flight Nos. Assgnd	Flights Airborn		Recovery			
				Gondolas		Balloons	
		Number	% of Flights	Number	% of Airborn	Number	% of Airborn
1st Report Period	20	18	90.0	18	100.0	13	72.3
2nd Report Period	35	33	94.3	31	94.0	28	84.8
Texas Report	13	13	100.0	13	100.0	10	77.0
3rd Report Period	45	39	86.7	32	82.1	30*	77.7*
TOTAL	113	103	91.2	94	91.3	81*	77.9*

DATA AS OF 24 MARCH 1954.

* Includes one balloon whose gondola is listed as Not Airborn.

Fig. I-81.

reliance being placed instead on local finders. The one exception was a temperature flight for which an extended air search was made and the cooperation of the local sheriff and U. S. Forest Service representatives was obtained, but the equipment was not found until eight months later by hunters in the exact center of the search area. This gondola was the most thoroughly vandalized gondola we have recovered, with every instrument in the gondola being torn or smashed open except the temperature-recording camera, which contained the only irreplaceable information. Some long outstanding flights recovered from the northern woods have shown considerable damage due to porcupines, which chew styrofoam, plywood and even aluminum.

Figure I-82 is a picture of a map kept in the section office which records the recovery points of the first one hundred flights and the Texas flights. The lighter pins show the locations of the balloons, and the darker pins represent gondolas. The generally prevailing winds at each launching site can be seen from the distribution of the pins, but it should be noted that the Pyote, Texas, and Pierre, South Dakota, sites were both used only during the winter months, whereas the Minneapolis site has been used year around, and some of the cluster around the Twin City area represents summer flights which changed direction at altitude and drifted back over the cities, rather than short duration flights. The one pin off the edge of the map represents a balloon that landed in France.

Tracking. A relatively small number of these flights have been tracked by theodolite, since the camera trajectories have been considered adequate. A few night launches were tracked with the aid of the automobile headlight

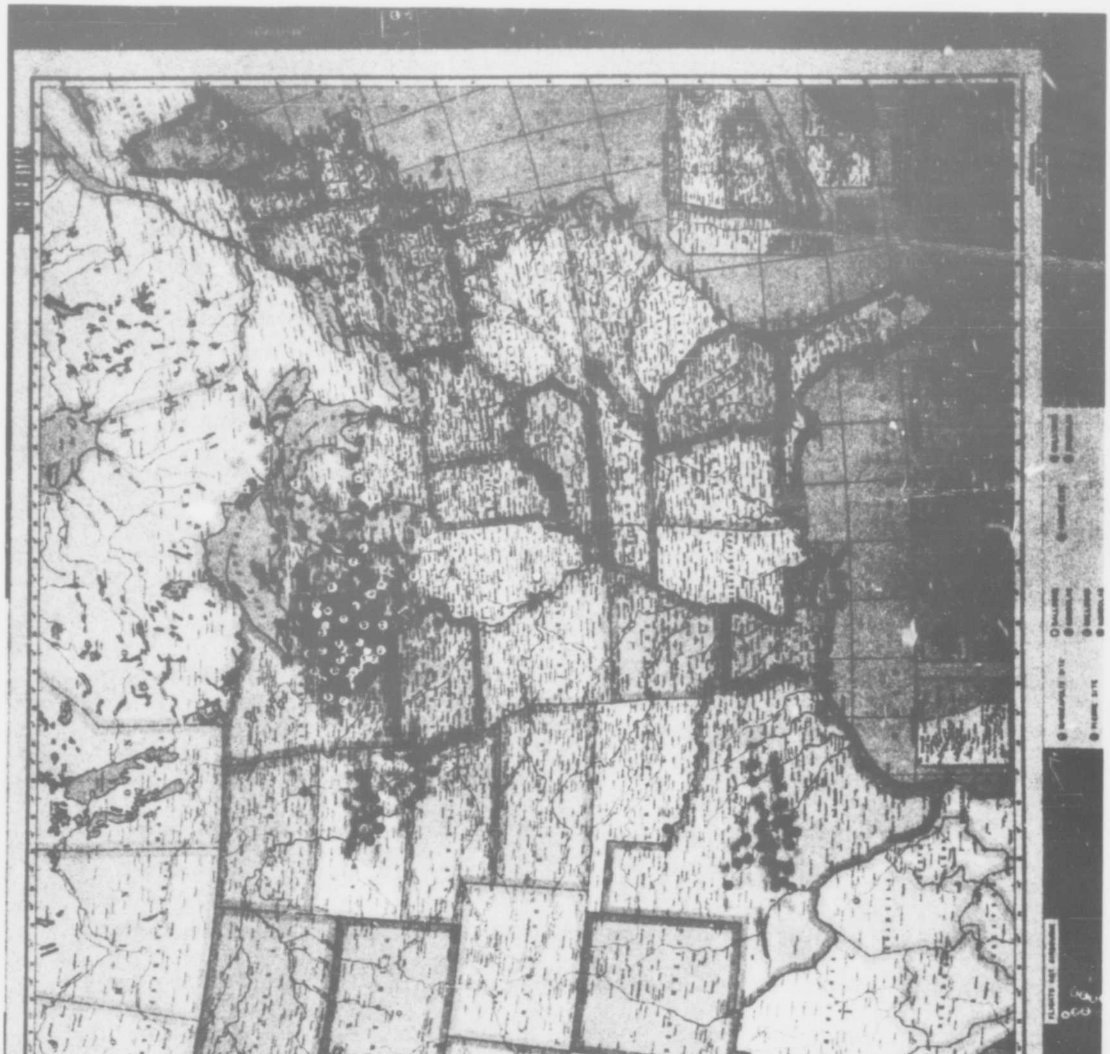


Fig. I-82. Map of recovery points of first 100 flights flown by University of Minnesota Balloon Project and Texas flights.

flasher. An inestimable aid in tracking has been a portable WWV receiver developed in this section, which allows the theodolite operator to take accurate five-minute readings so that the information can be combined with other records with a minimum of error. The use of this receiver, which requires no attention from the operator and gives an audible signal with a one-minute warning, has converted theodolite operation to a one-man job, since previously it was considered necessary to have a second man as a time keeper and recorder. A picture of this receiver is shown in Figure I-83, and a schematic diagram in Figure I-84. This receiver has also been used at launching operations to give accurate time.

Record Interpretation. An increasingly heavy duty of this section has been the reading of flight records and calibrations. As the number of instruments in each gondola has increased, and the accuracy of each was improved, the time necessary to calibrate and read out results has increased until at the end of the report period one fulltime person and two parttime persons were working exclusively on readout.

To aid in this interpretation an improved Olland Cycle Scaler has been developed which increases the speed, accuracy and ease with which Olland Cycle records can be read. Shop drawings are given in Figure I-85 and a picture in Figure I-86. The record shown on the scaler in the picture was a poor but readable record of a multichannel step flight signal which was being read when the picture was taken. The Olland Cycle trace is essentially obscured to all but the most practiced eye, but with the aid of the scaler no difficulty was experienced in reading it.

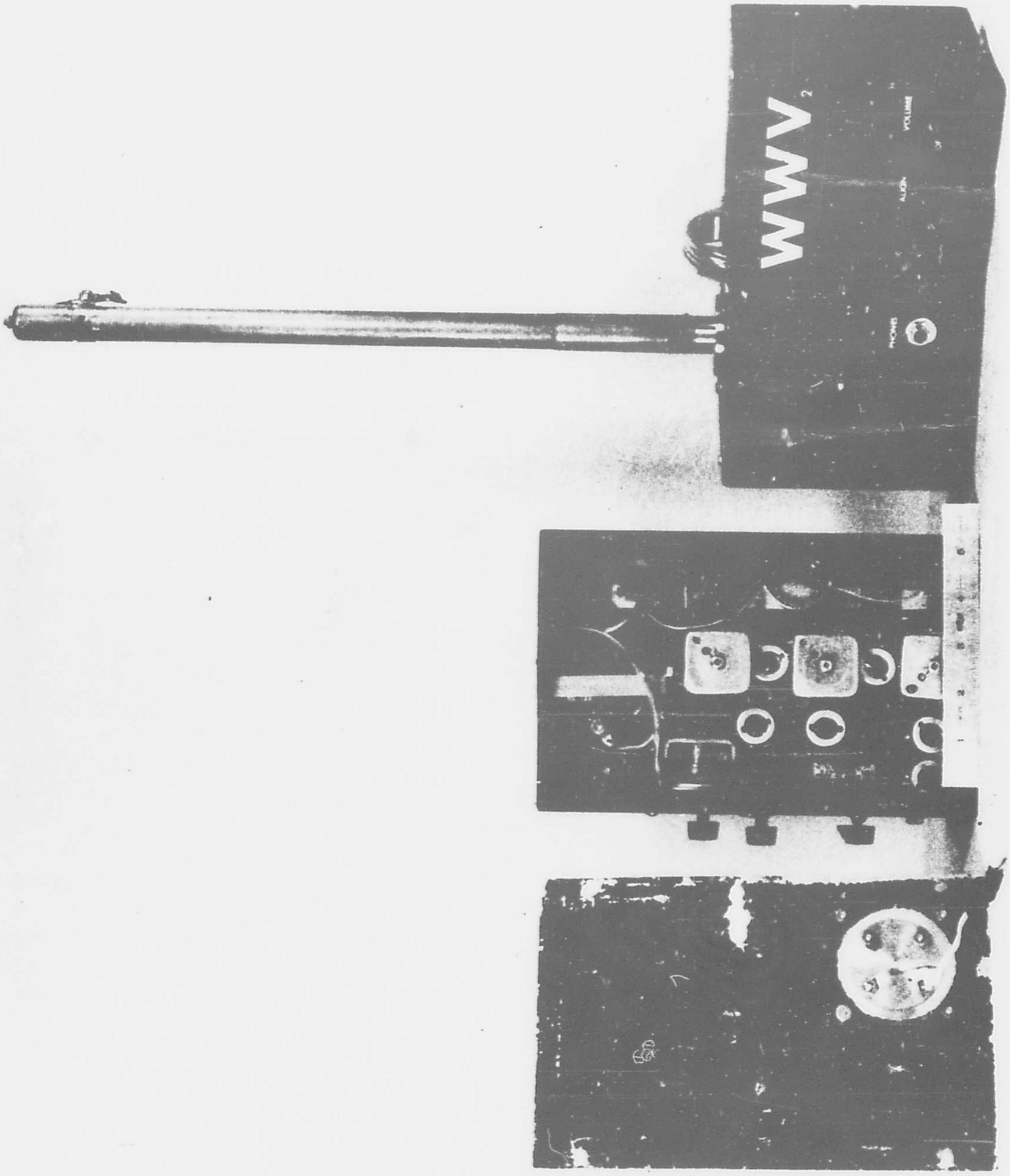


Fig. I-83. WWV Portable Receiver, with cover removed at left, and assembled at right.

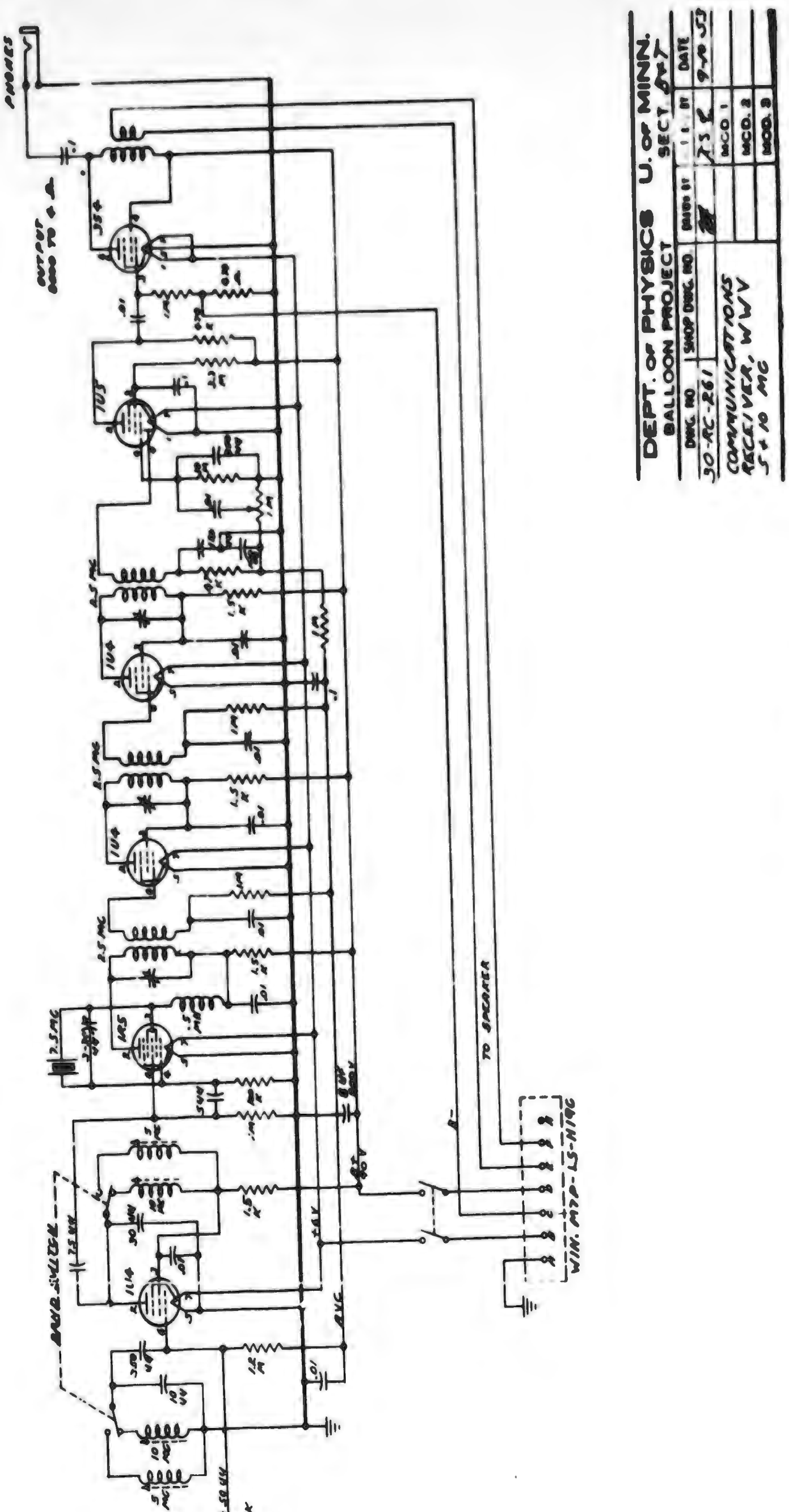

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
30-RC-261
COMMUNICATIONS RECEIVER, WWV 5+10 MC
PHONES
TO SPEAKER
ANT
PIN JACK
BAND SWITCH

Fig. I-84.

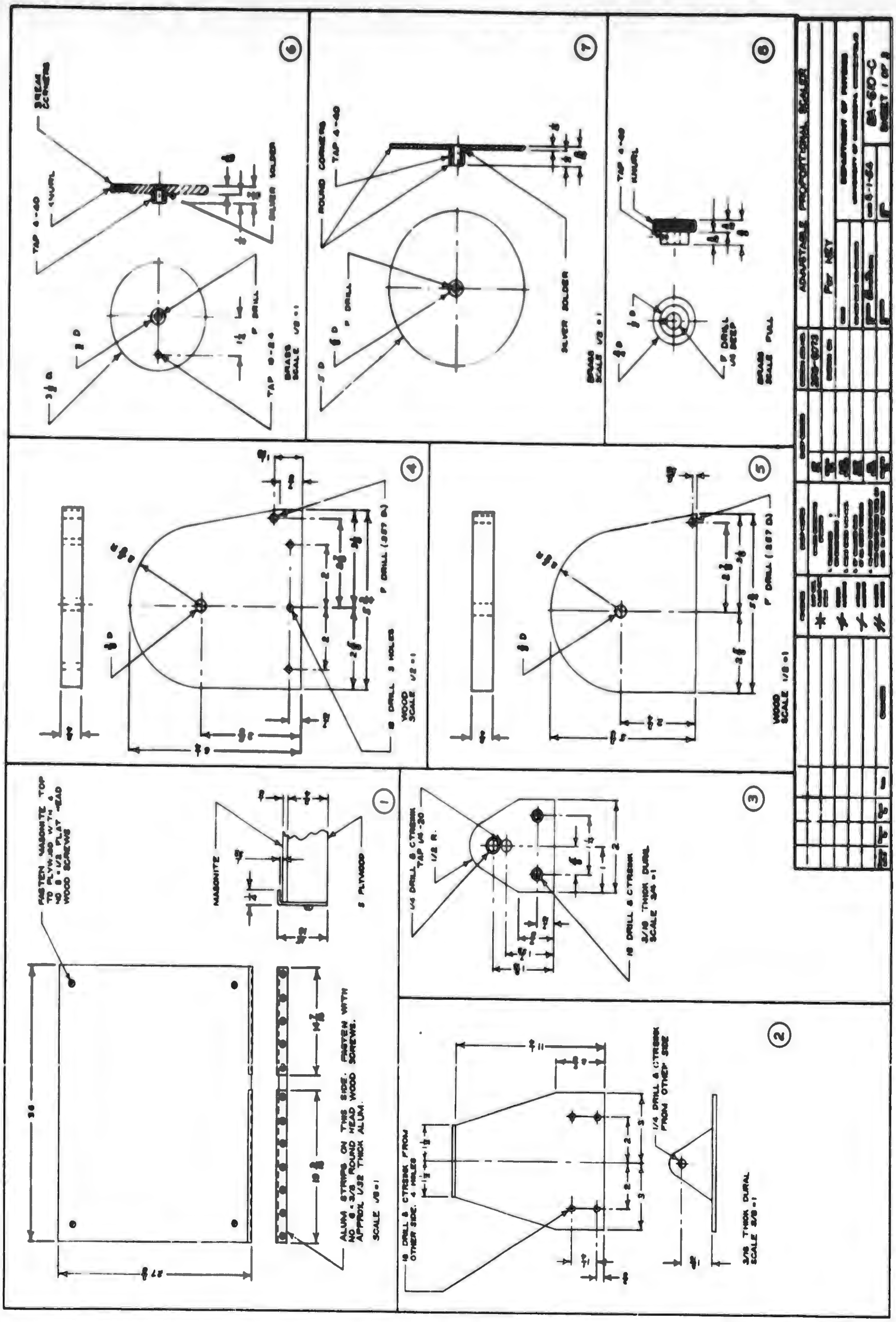


Fig. I-85A.

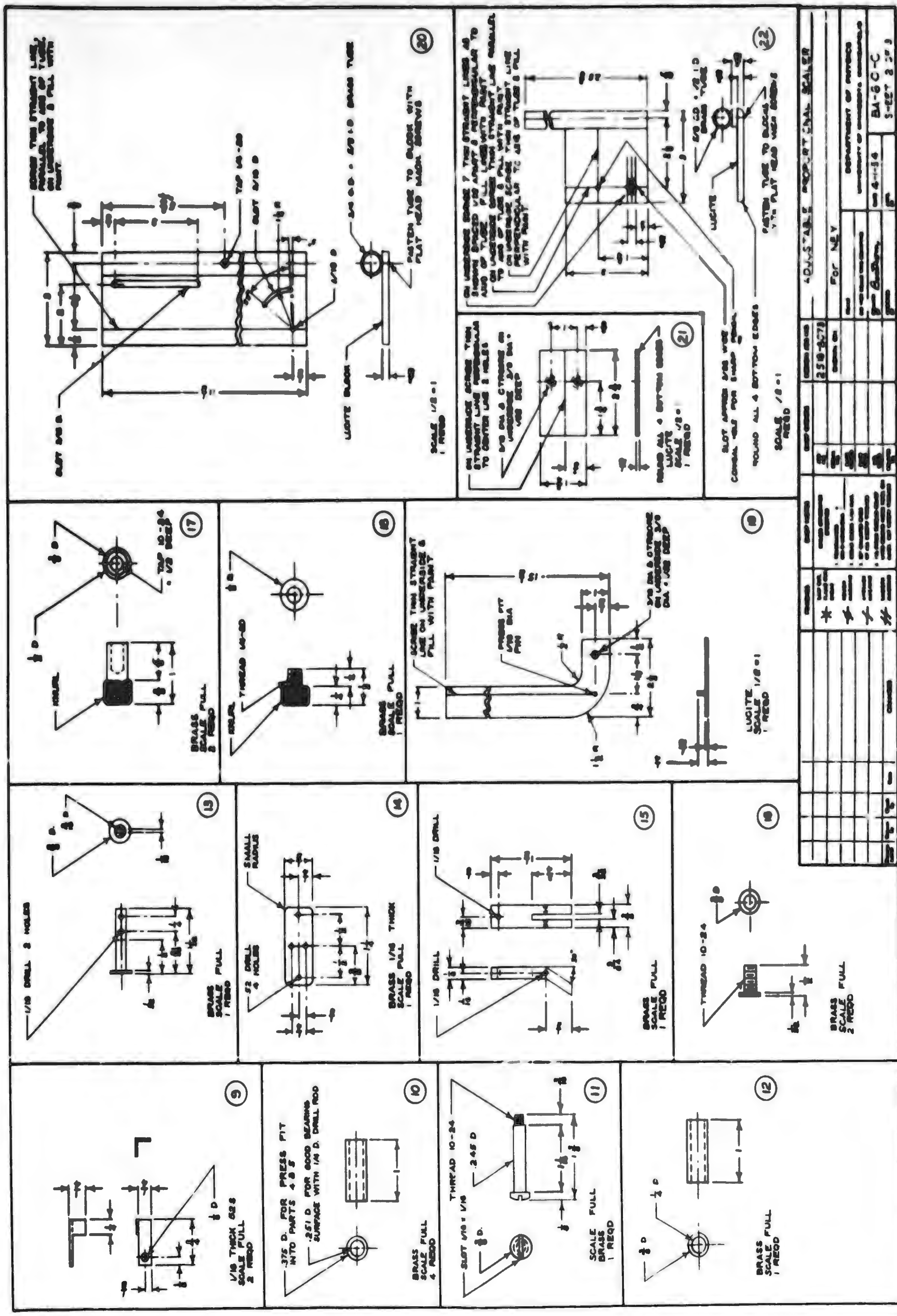


Fig. I-85B.

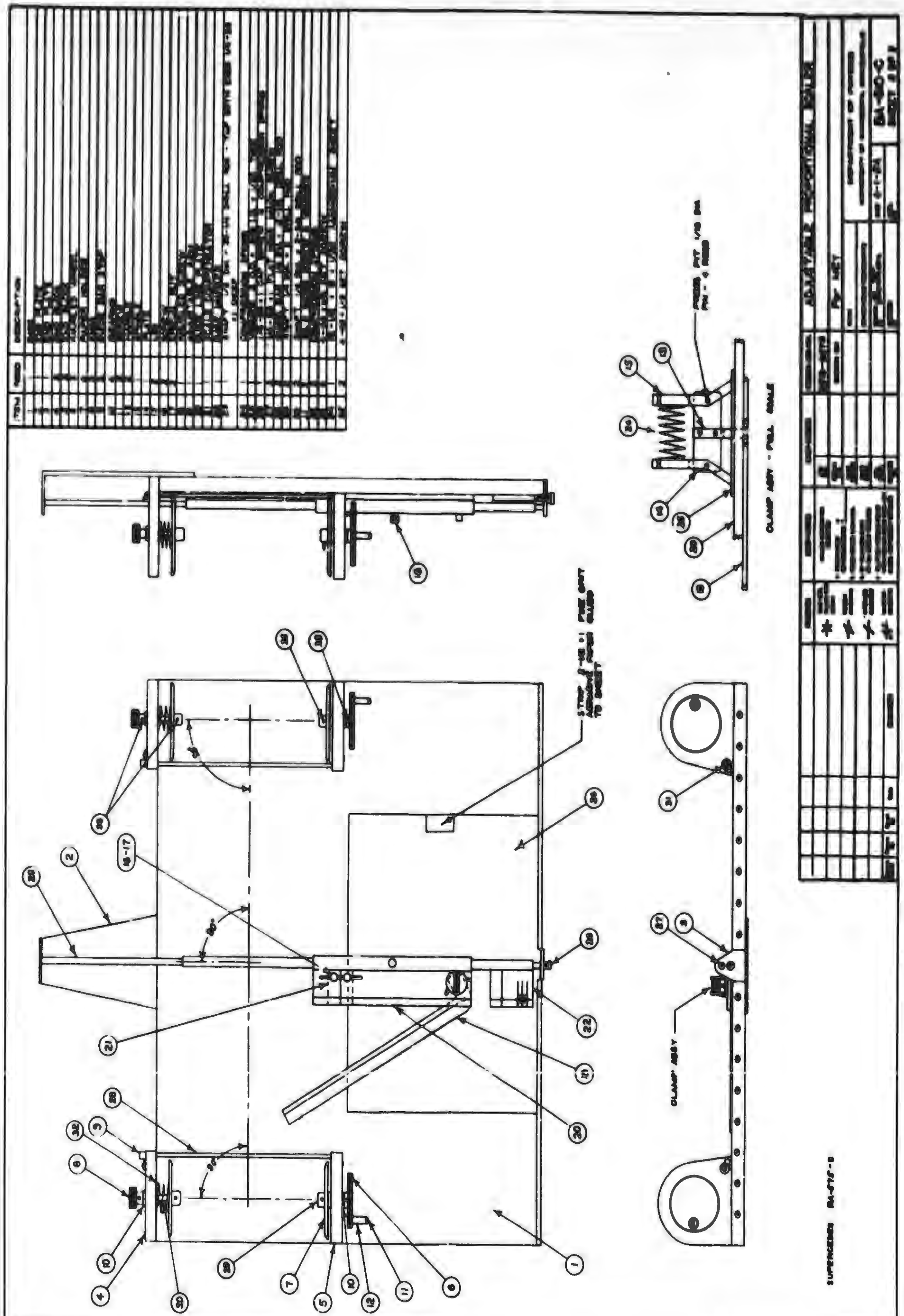


Fig. I-85C.

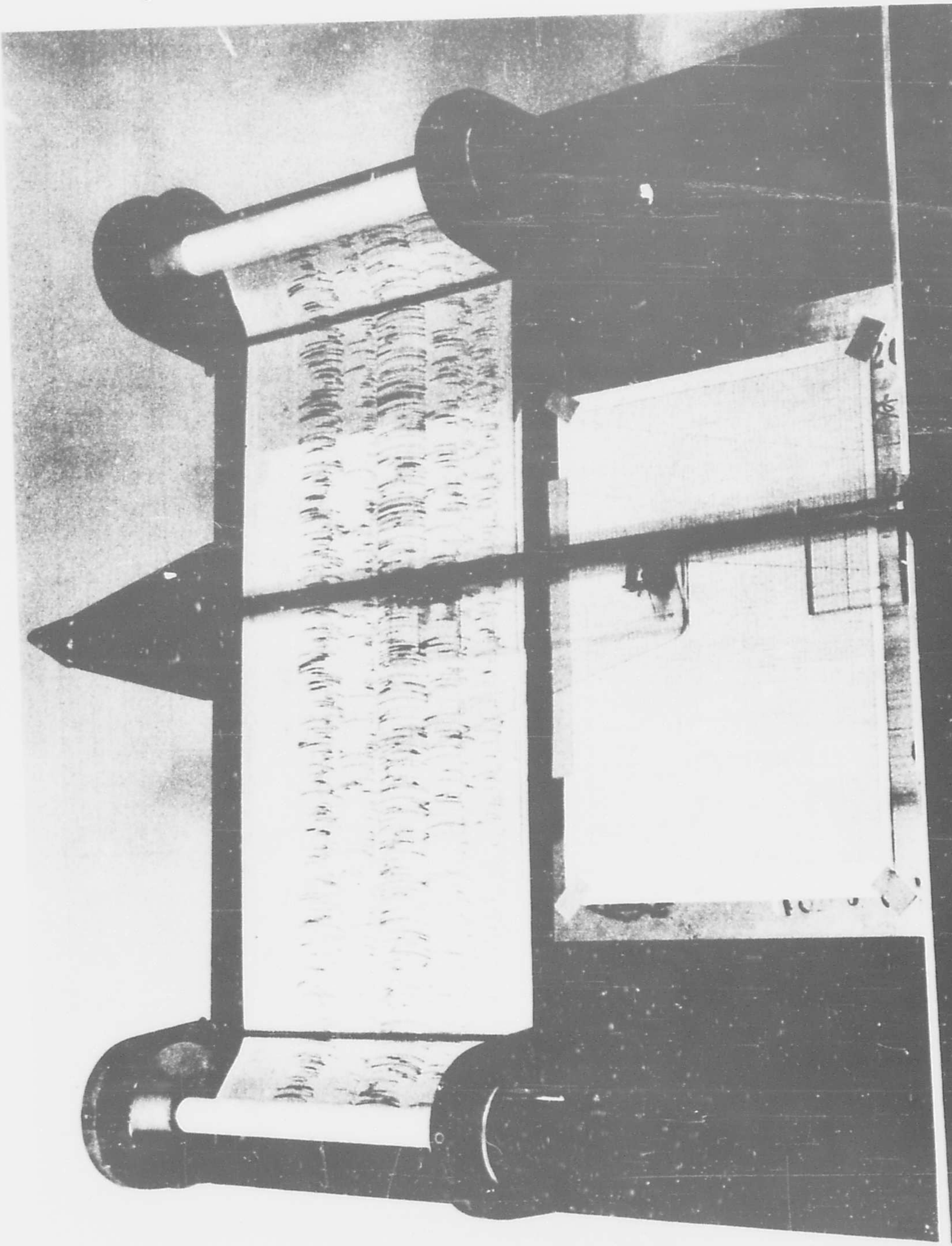


Fig. I-86. Adjustable Proportional Scaler. Strip chart record on rolls at top, scaler reading second channel from bottom, Olland Cycle calibration chart showing at bottom.

The scaler is composed essentially of a vertical scribed line on a piece of lucite and a scribed line on a pivoted arm. An Ollano Cycle reference (see Figure I-64) is moved under the vertical line and the movable arm is adjusted to intersect an arbitrarily chosen base line on the strip chart recording and the next similar reference. The distance between the two scribed lines on the base line represents 360° on the Ollano Cycle rotor. The lucite plates on which the lines are scribed are then moved parallel to the vertical scribed line until the line on the pivoted arm intersects the same base line on the strip chart and the edge of the helix to be measured. The amount of the vertical displacement is proportional to the phase angle displacement of that helix, and is measured on a chart placed below a continuation of the vertically scribed line which has a horizontally scribed line for indexing purposes. This chart, called the "calibration chart" of the Ollano Cycle, is a graphical representation of the helixes of the Ollano Cycle Rotor on a scale expanded 1 to 9 and which is prepared by plotting in the scaler known pressure, or tension, or other type of deflection of the pen arm against phase angle. This phase angle is obtained by evacuating the Ollano Cycle in a bell jar at a constant rate or dropping ballast at a constant rate, and taking pressure or weight readings at regular intervals to establish a pumping or dropping rate curve. The Ollano Cycle pressure or tension phase angle readings are then plotted against the rate curve for the time at which they occurred, giving a phase angle vs pressure or tension plot, when the time element is eliminated.

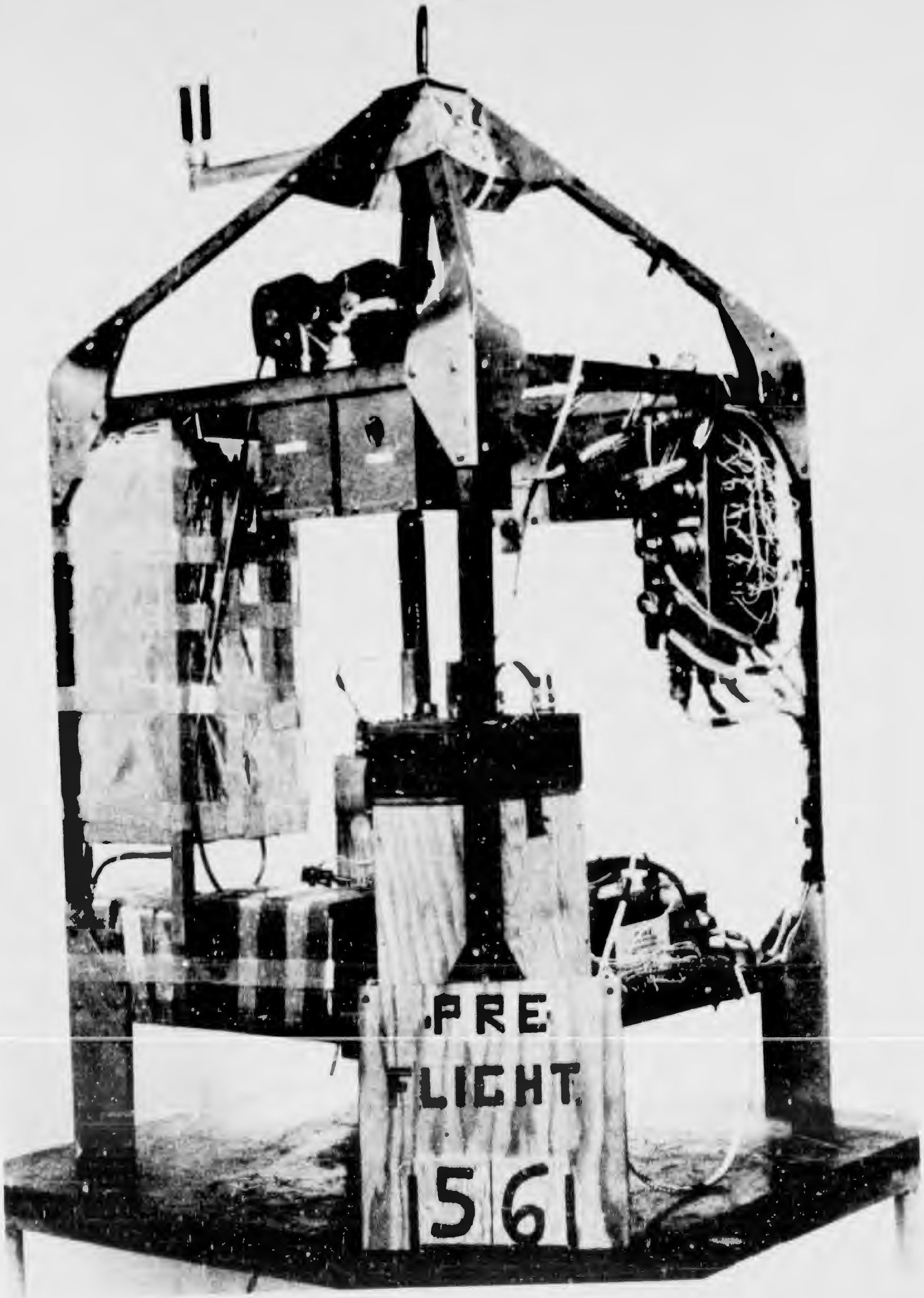
The scaler shown is an adjustable model designed to read any of the six channels recorded by the Brush six-channel Oscillograph, the Leeds & Northrup, or the Esterline-Angus recorder. In addition, compensation is provided for different size graph paper being used for the calibration sheet, and a set of lines furnished to read the second set of references used during cross-overs. A series of lines is necessary because the expanded scale magnifies small inaccuracies in the indexing head used on the milling machine to cut the references. The limits of accuracy of this reader are the width of the ink line being read and the ability to plot fine lines on the calibration chart.

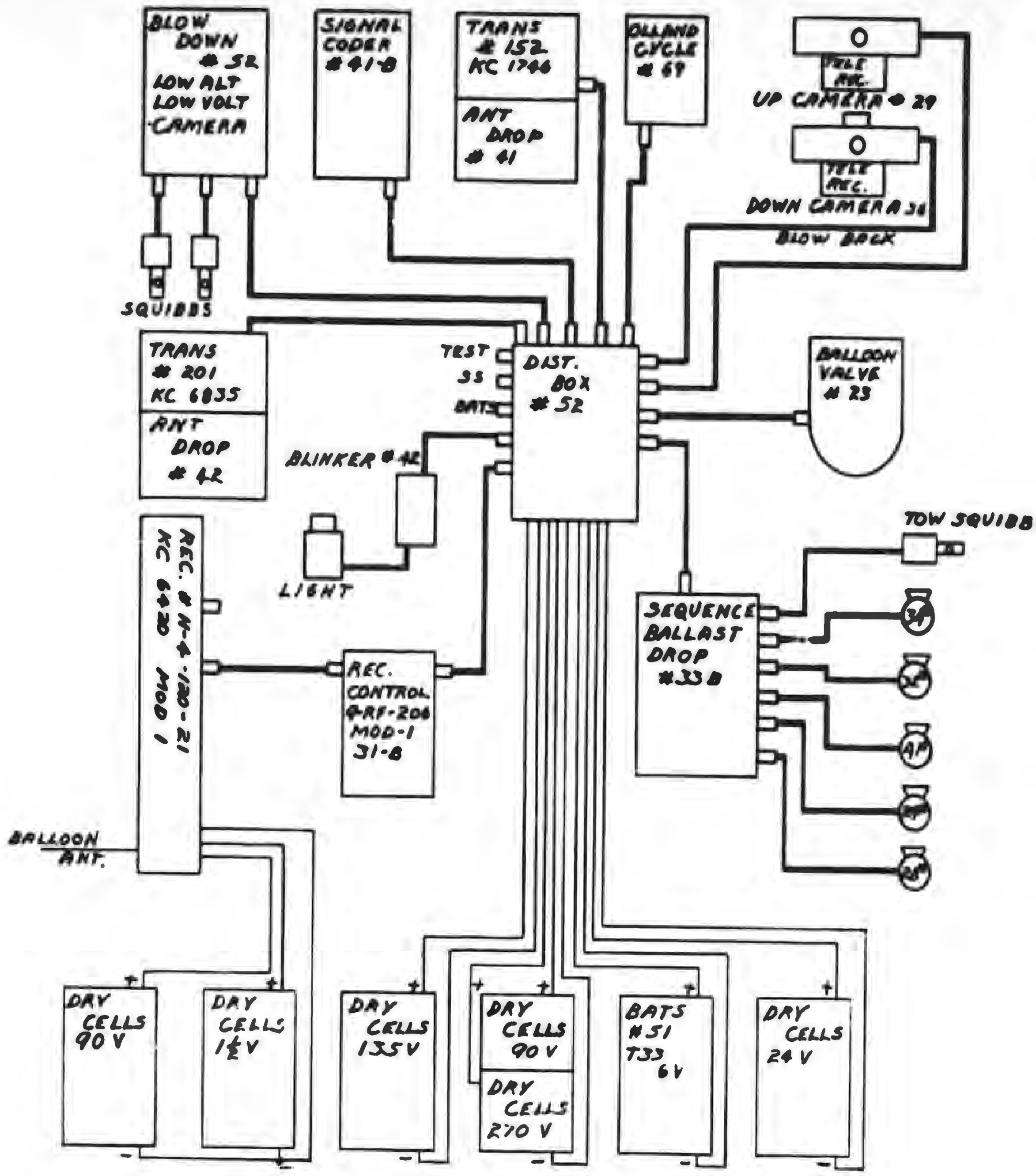
The same adjustable scaler is used to read up and down camera film, scope camera film, or 16 mm recorder film. The film is projected by a strip film projector onto a piece of white grid paper fastened to the scaler board, and the information pips lined up on an arbitrary horizontal grid line which is used as the base line. The scribed reader lines are then used to measure phase angle of the images of the Olland Cycle pips as the film is moved through the projector. Some slight modification of the projector is necessary to allow the projection of the total width of the film, because the ordinary projector is masked too small to include the area where our telemeter recorder prints. A 3-to-4-inch projection lens is necessary to enlarge the film properly, and yet have the projector within reach of the scaler operator.

One precautionary note should be mentioned concerning this scaler. It is a proportional scaler designed for reading proportional displacement of cyclic occurrences, and is highly accurate at reading Olland Cycle type records. However, for reading a record consisting of a linear display of occurrences, it is no more accurate and much more cumbersome than a finely divided ruler. The generation of a calibration curve for a linear display is a very complicated approximation, with a range so limited for most purposes as to be of little value.

E. Block Diagrams and Gondola Pictures

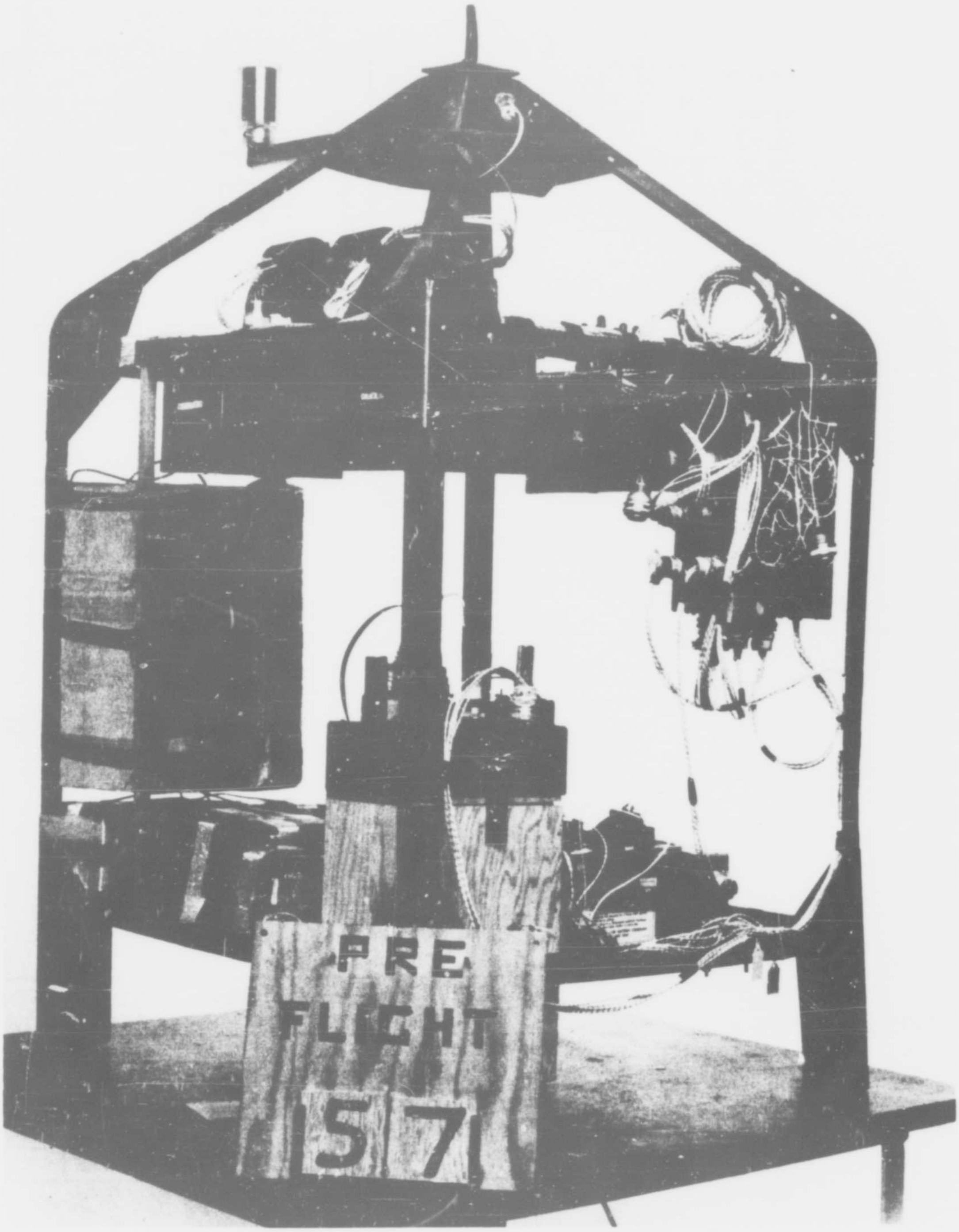
The following pages contain block wiring diagrams of all the gondolas flown during this report period, and photographs of these gondolas where available. The flights differ in details which were determined by the intent of the flight experiment. The component information to be seen on these pages is summarized in the table in Figure I-31.

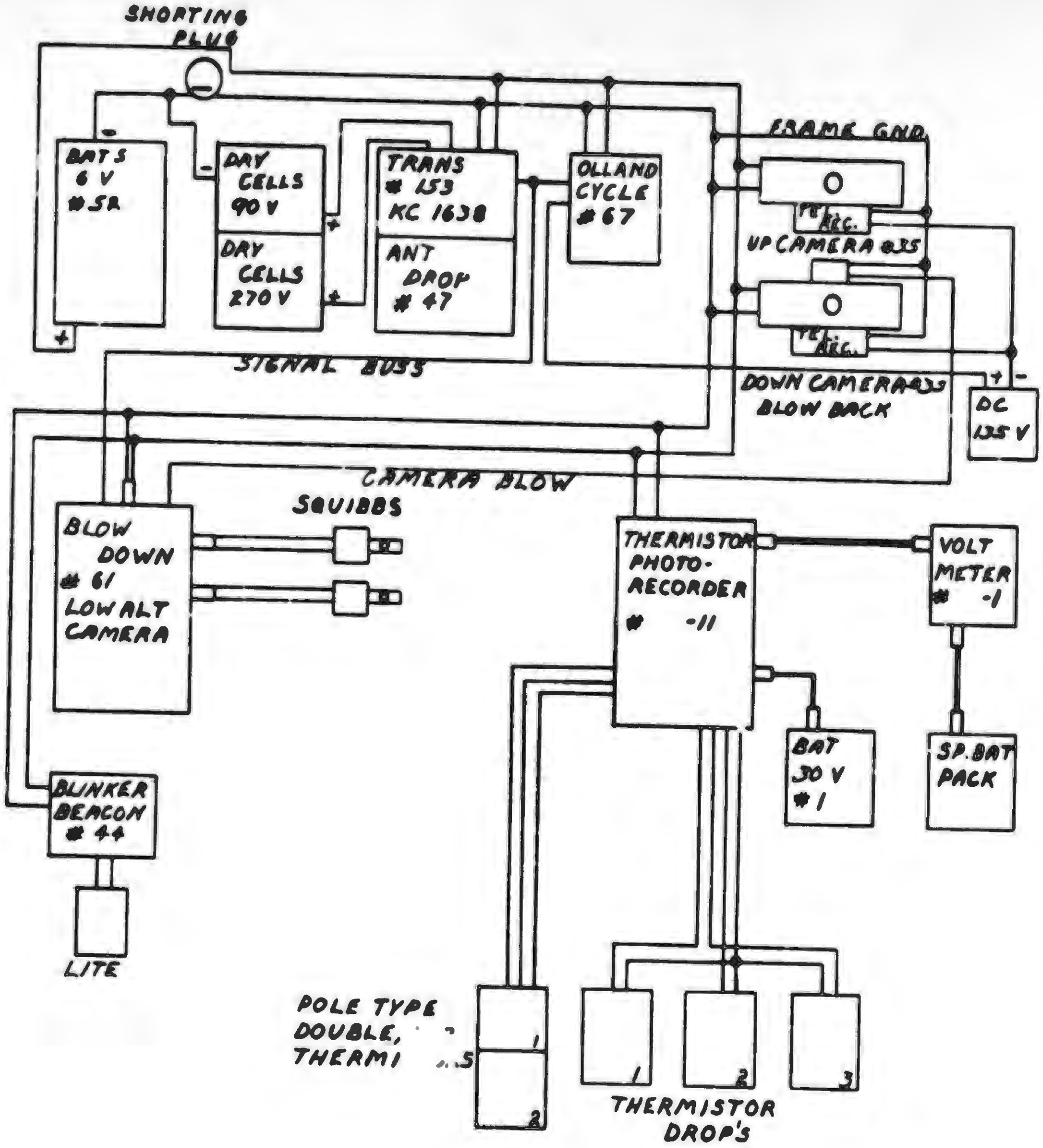

PRE
FLIGHT
56



DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	1-23-53
FLIGHT #56			MOD. 1	
GONDOLA #14			MOD. 2	
			MOD. 3	


PRE
FLIGHT
57



DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST		
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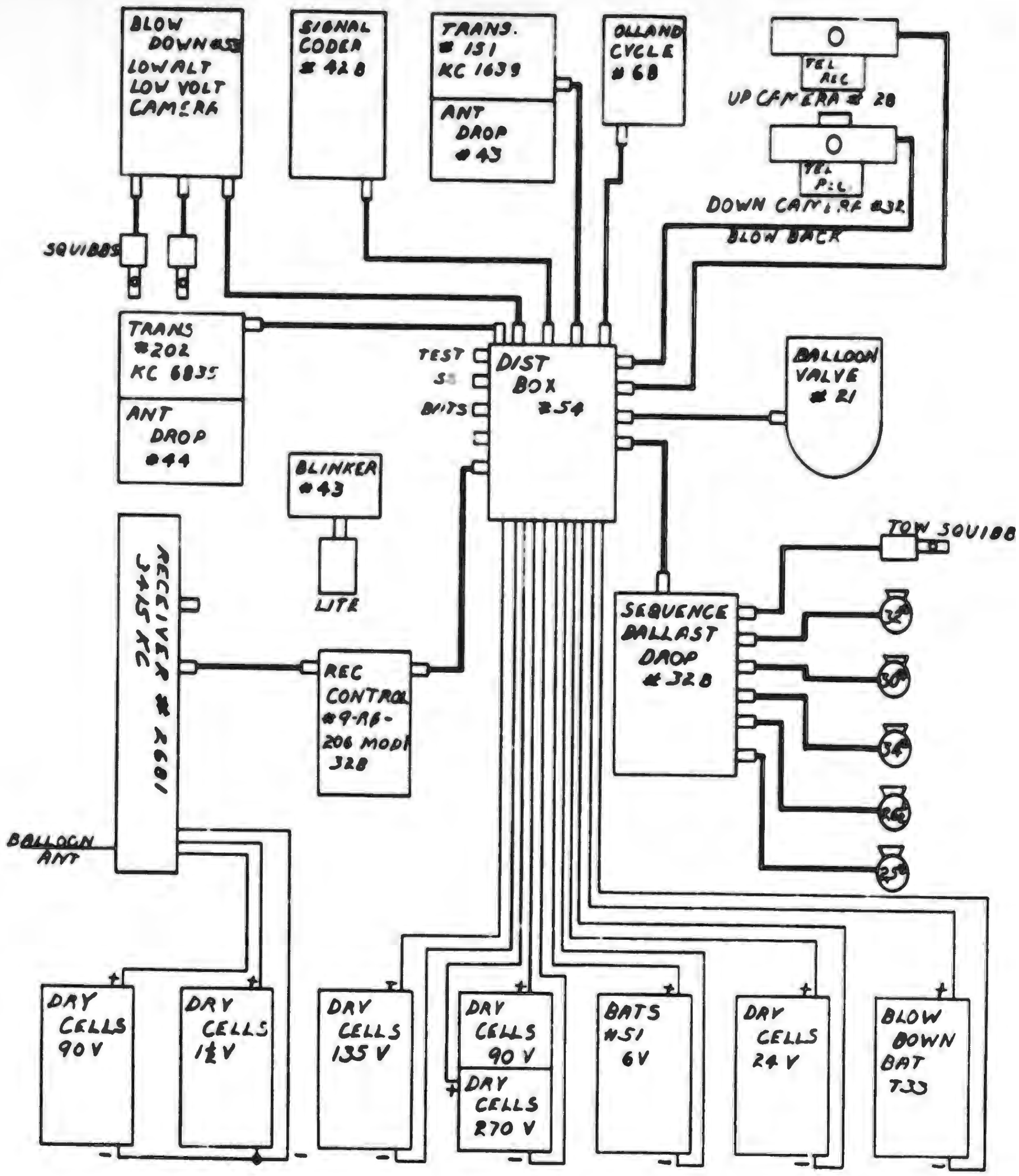
FLIGHT #57 GONDOLA # 8			MOD. 1	
			MOD. 2	
			MOD. 3	


8
PRE
FLIGHT
58

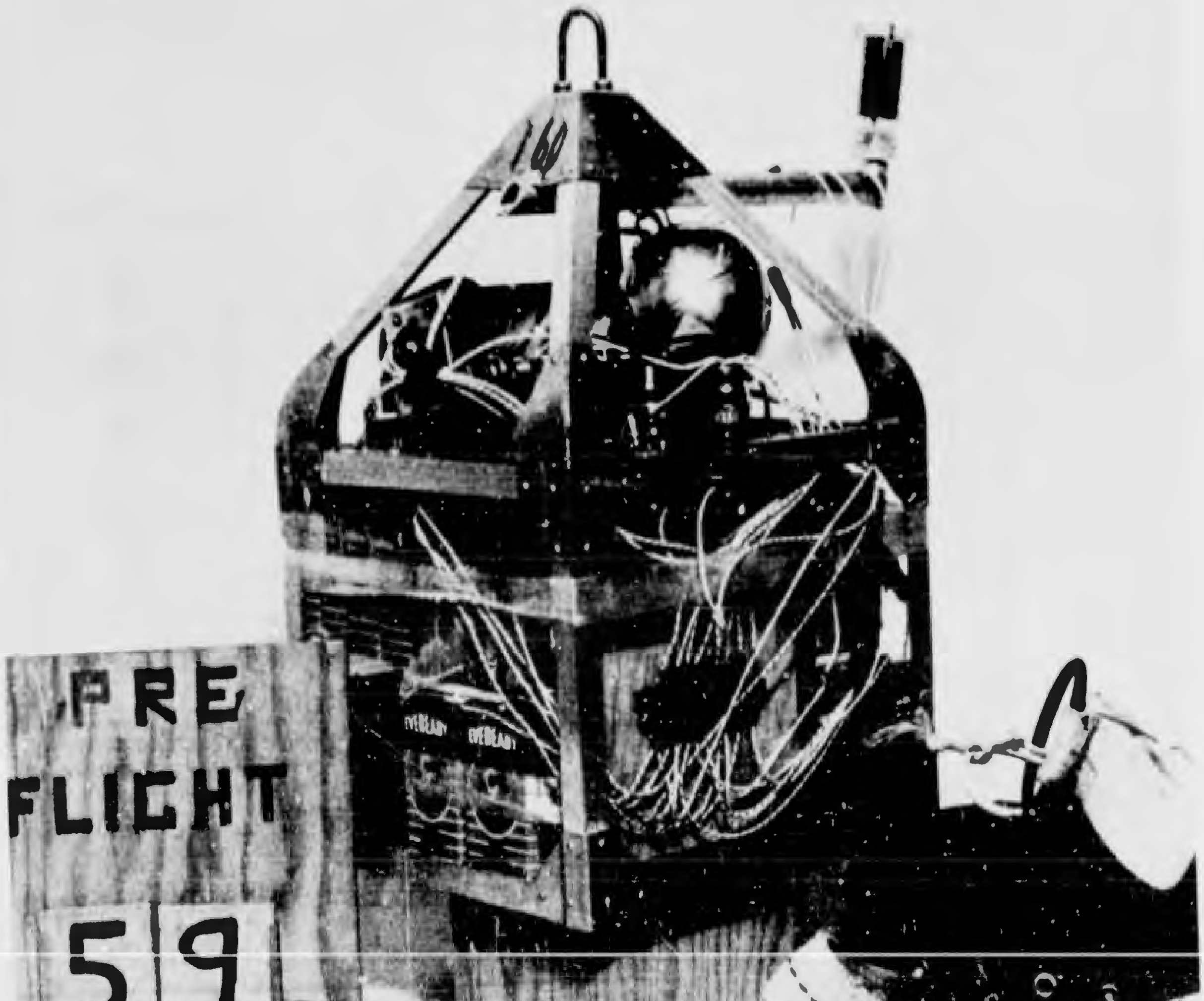


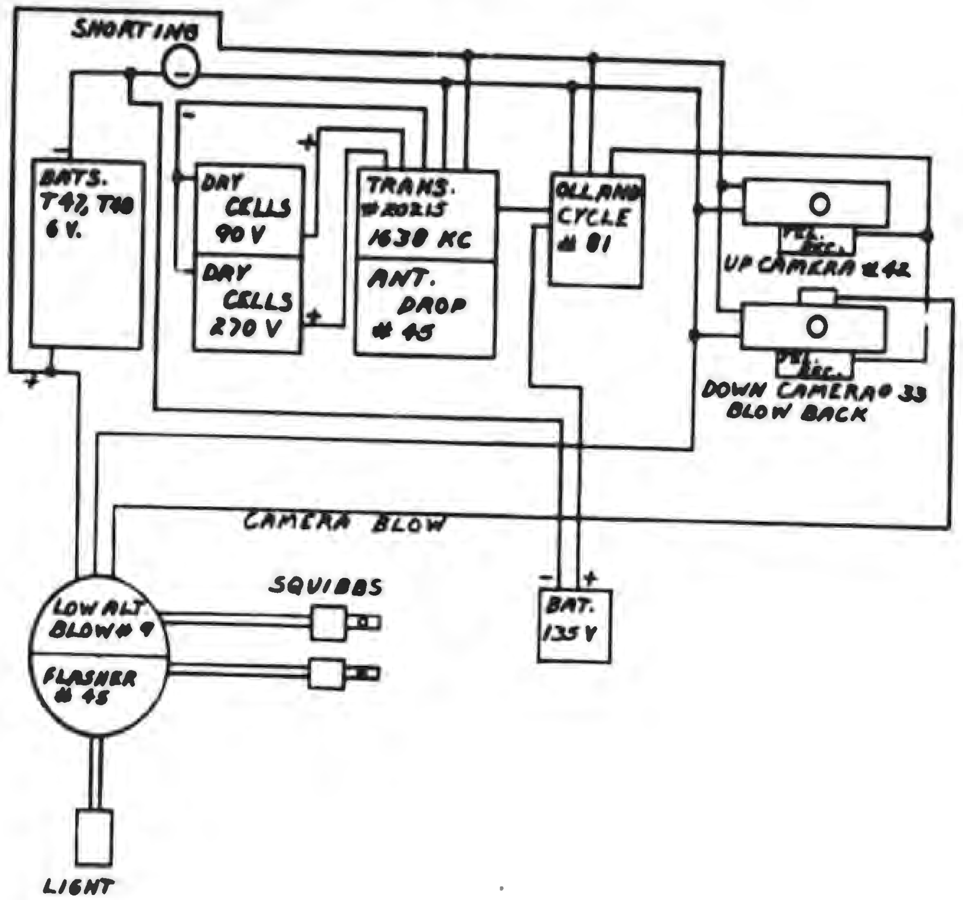
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST.

DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]		1-27-53

FLIGHT #58
GONDOLA #15

MOD. 1	
MOD. 2	
MOD. 3	

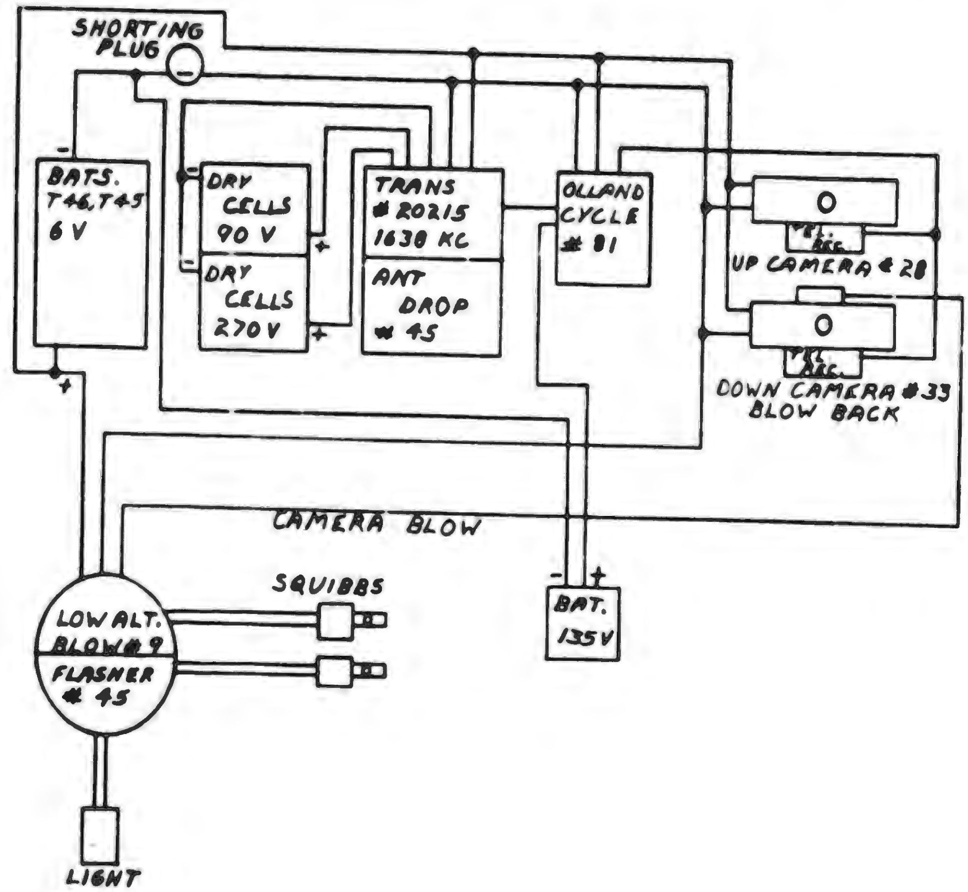

PRE
FLIGHT
59



DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST.

DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				2-12-53
FLIGHT # 59 GONDOLA # 160			MOD. 1	
			MOD. 2	
			MOD. 3	


160
160
POST
FLIGHT
60



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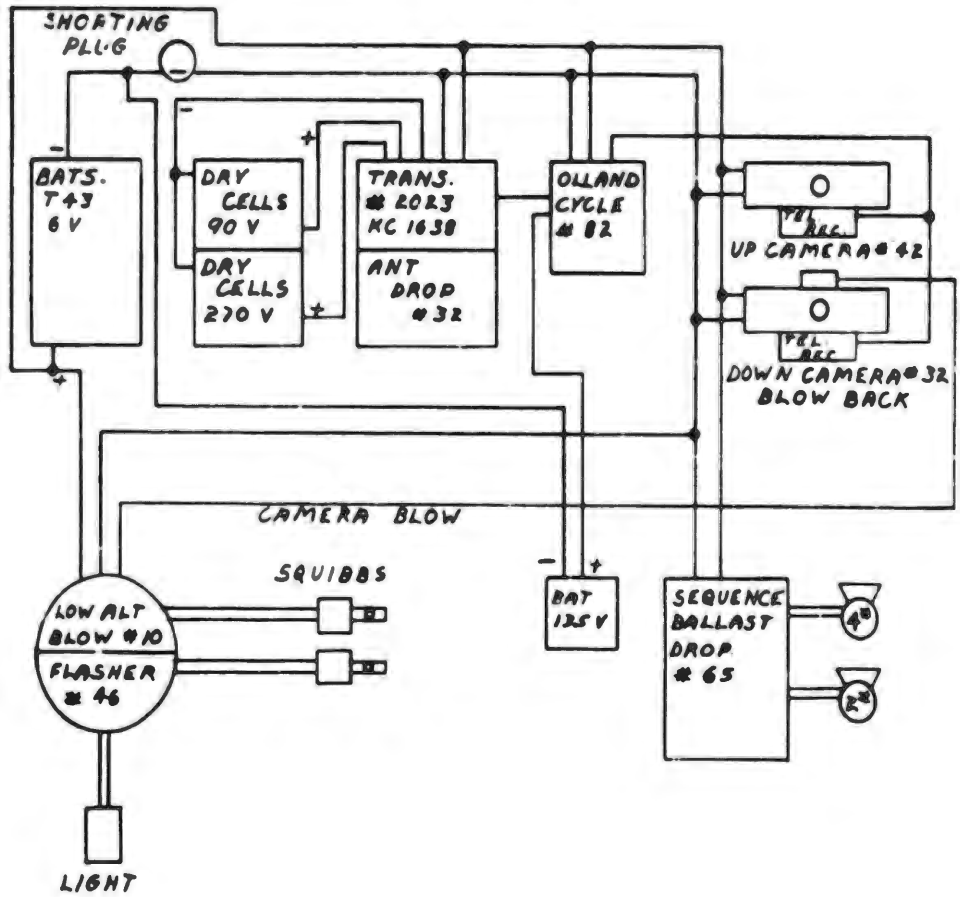
		[illegible]	[illegible]	2-15-53
FLIGHT # 60 GONDOLA # 160			MOD. 1	
			MOD. 2	
			MOD. 3	


PRE
FLIGHT
6



DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST.		
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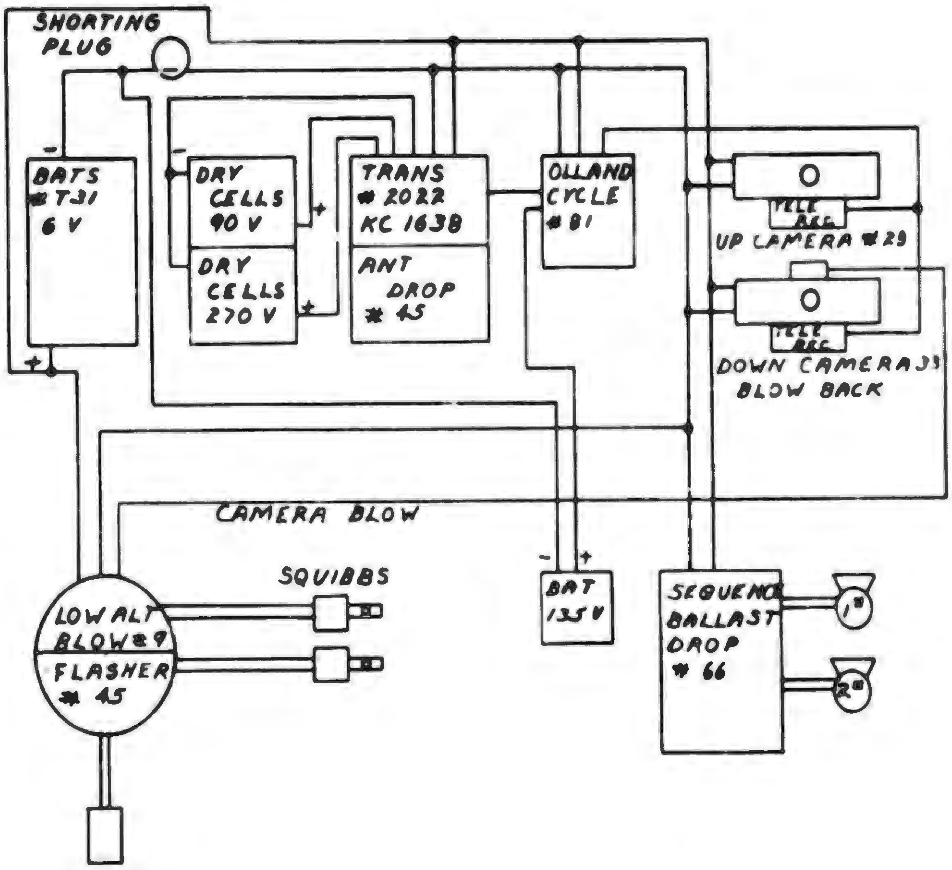
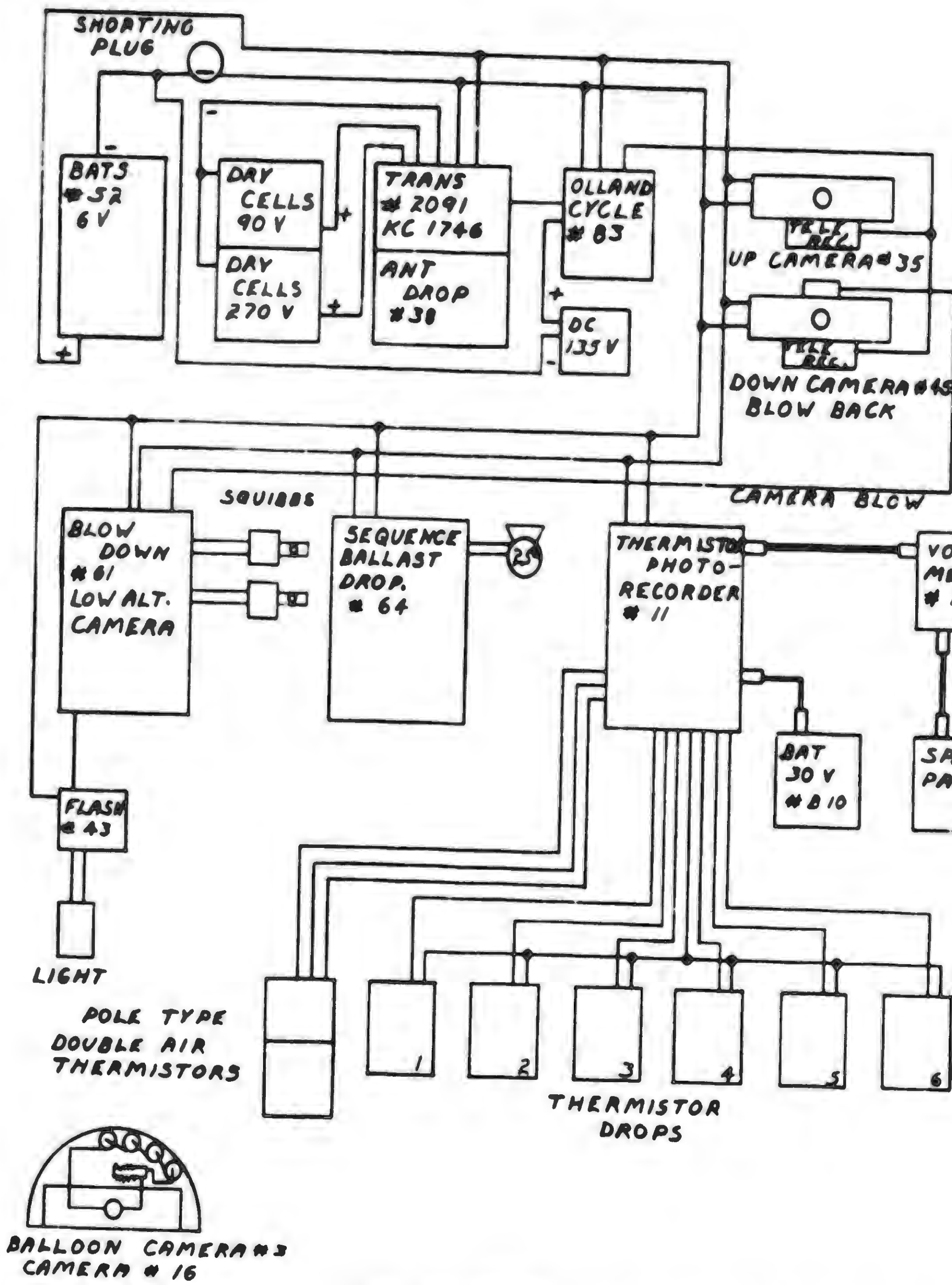
		[illegible]	[illegible]	2-17-53
FLIGHT # 61 GONDOLA # 155			MOD. 1	
			MOD. 2	
			MOD. 3	

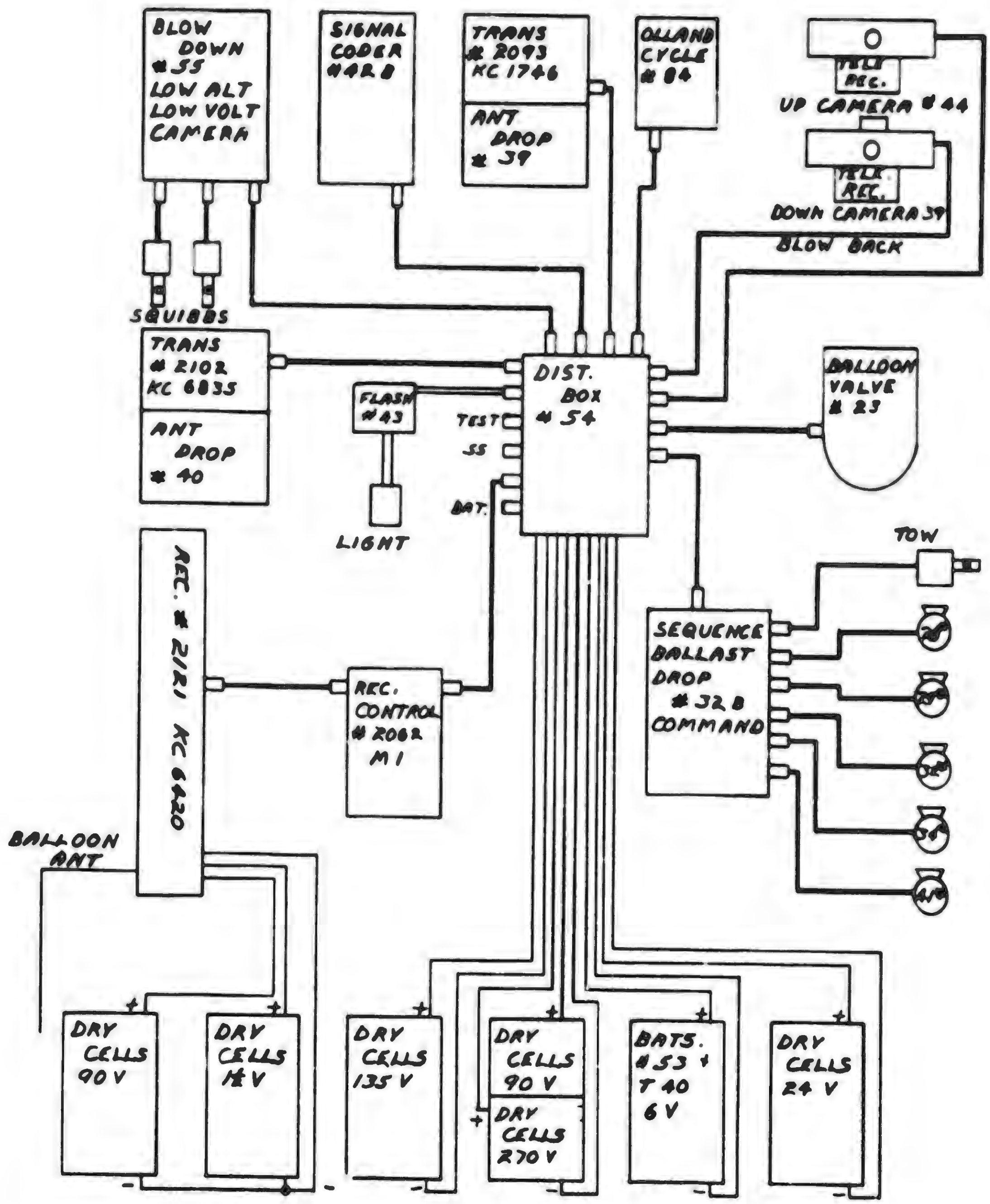


DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT SECT. INST.				
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	2-23-53
FLIGHT # 62 GONDOLA # 160			MOD. 1	
			MOD. 2	
			MOD. 3	



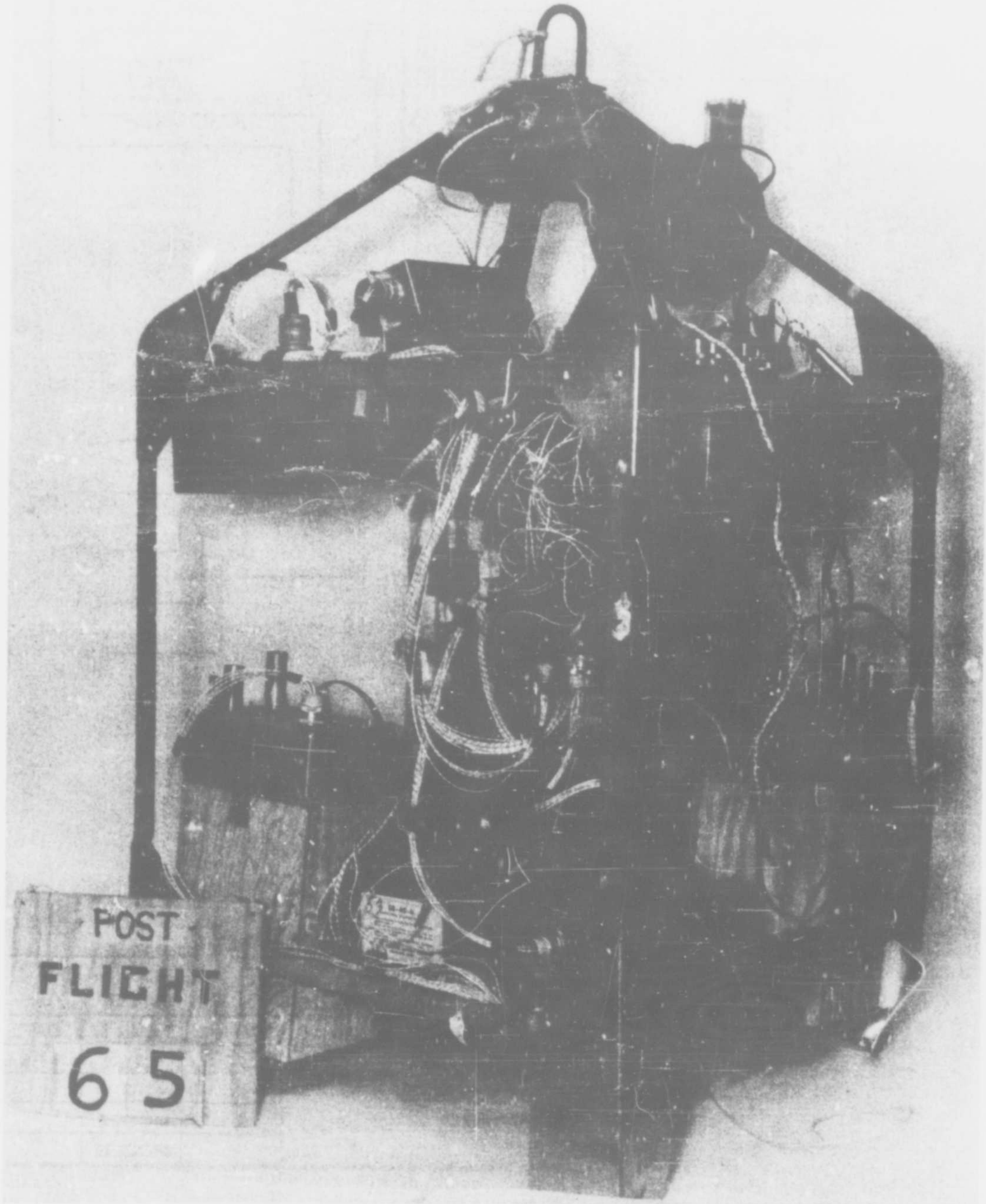
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

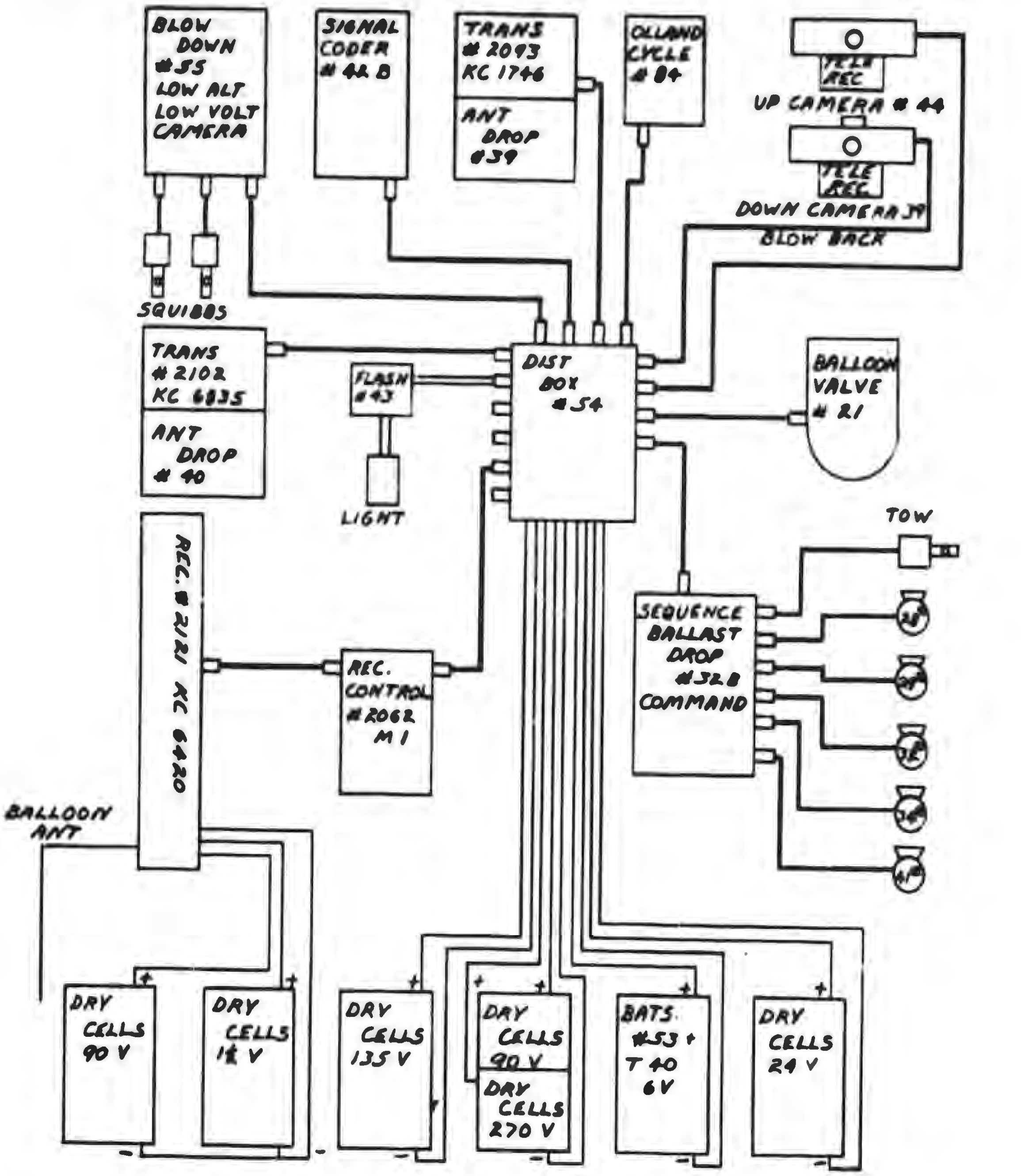
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				2-23-53
FLIGHT # 63 GONDOLA # 8			MOD. 1	
			MOD. 2	
			MOD. 3	



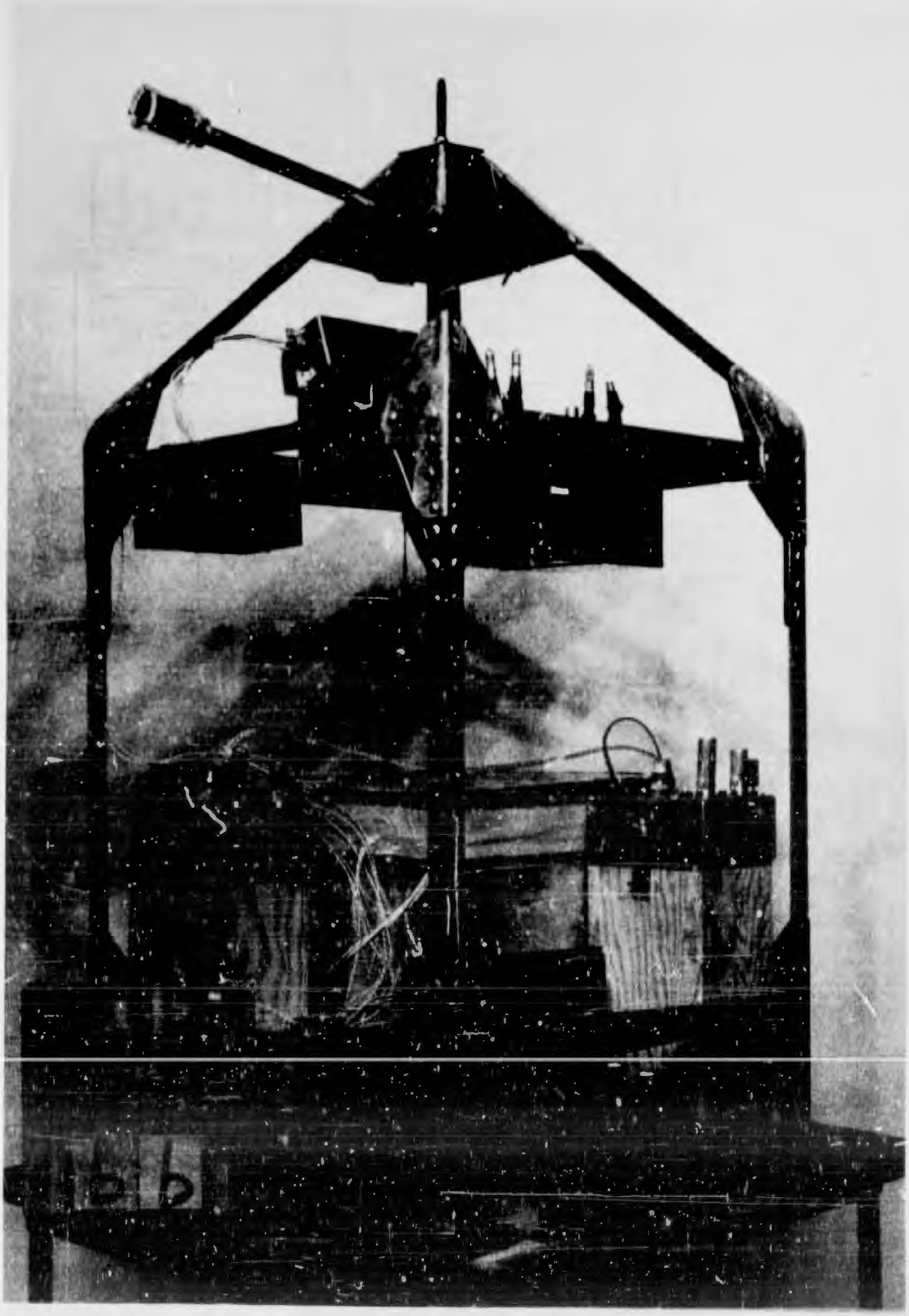
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST.

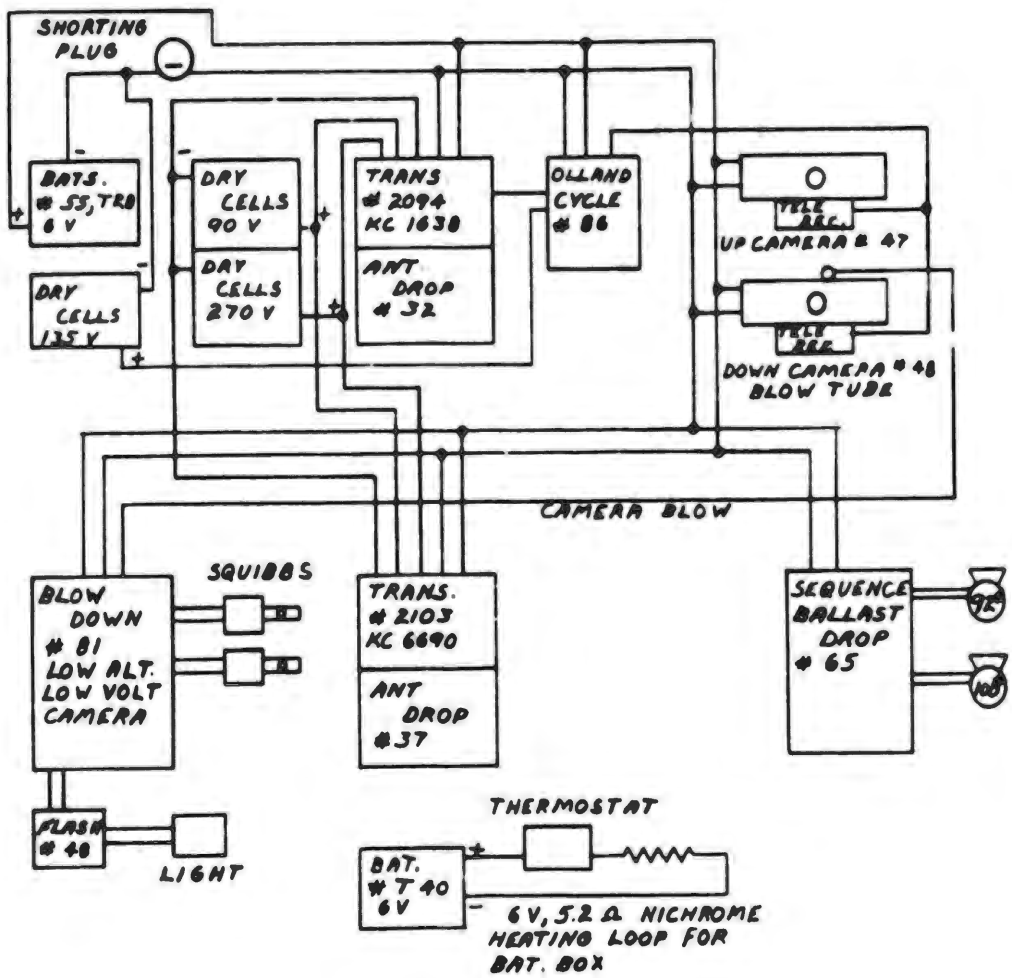
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	2-24-53
FLIGHT # 64			MOD. 1	
GONDOLA # 15			MOD. 2	
			MOD. 3	


POST
FLIGHT
65



DEPT. OF PHYSICS BALLOON PROJECT		U. OF MINN.	SECT. INST	
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	2-25-53
FLIGHT #65 GONDOLA #15			MOD. 1	
			MOD. 2	
			MOD. 3	

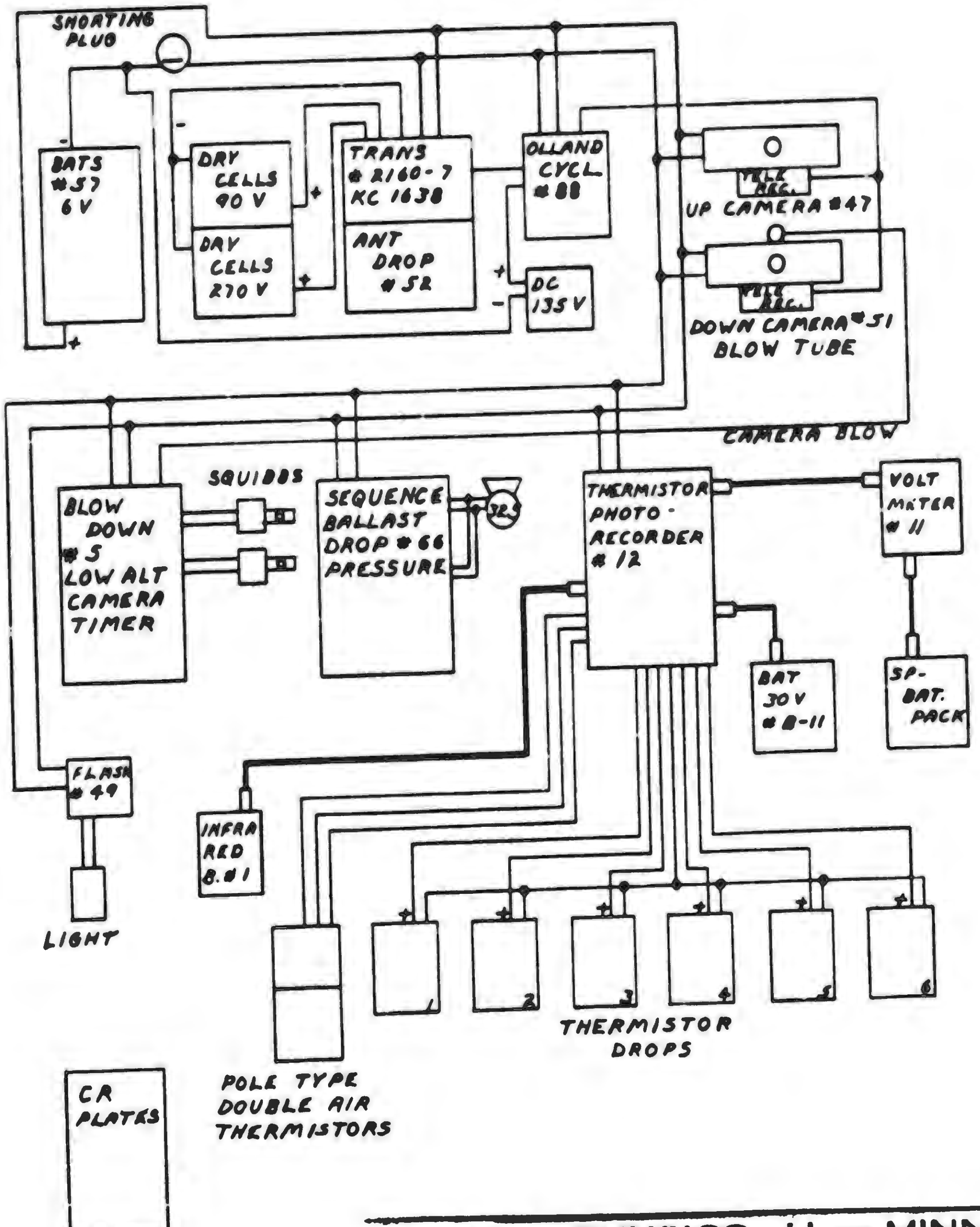




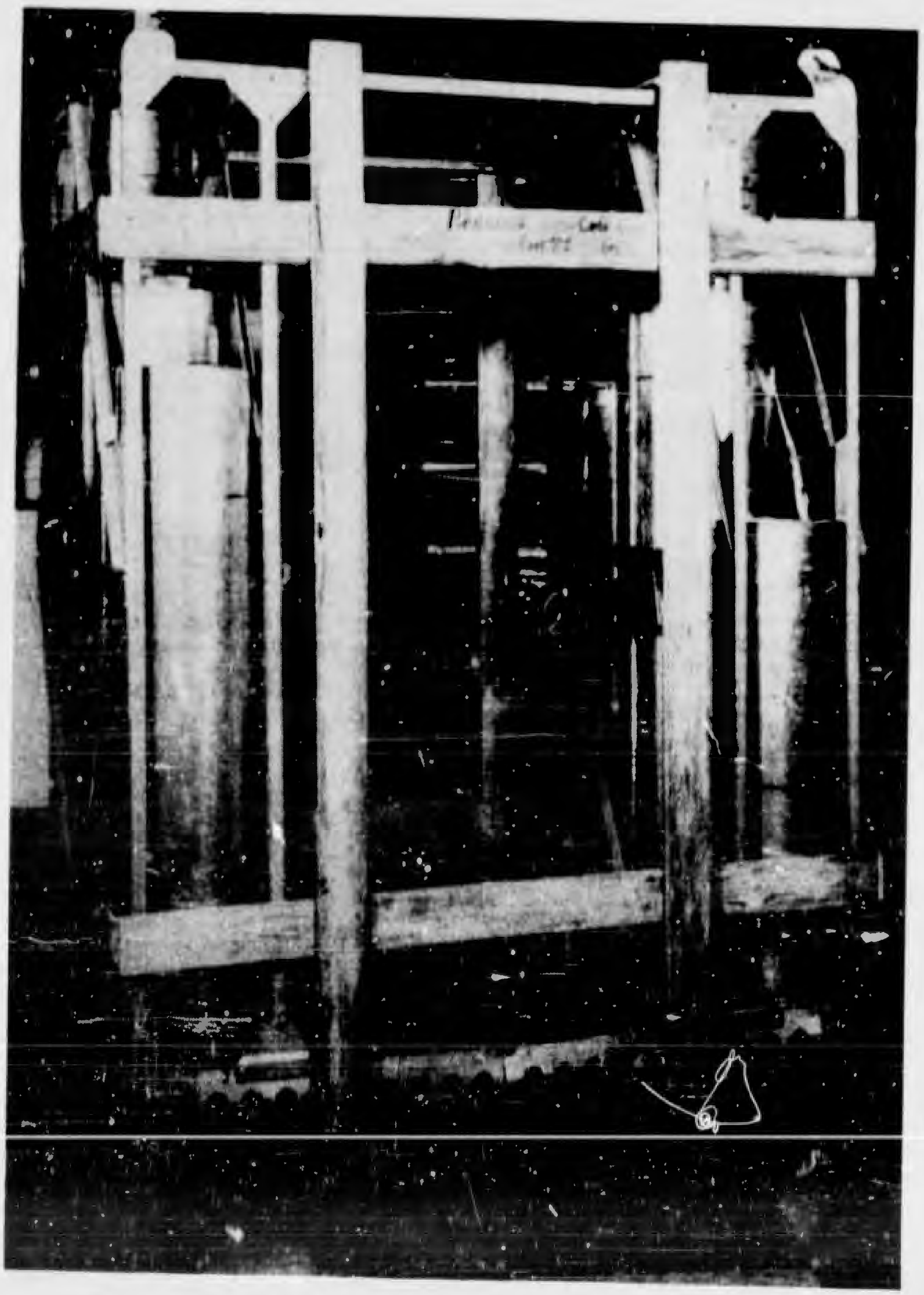
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	3-12-53
FLIGHT # 66 GONDOLA # 2			MOD. 1	
			MOD. 2	
			MOD. 3	

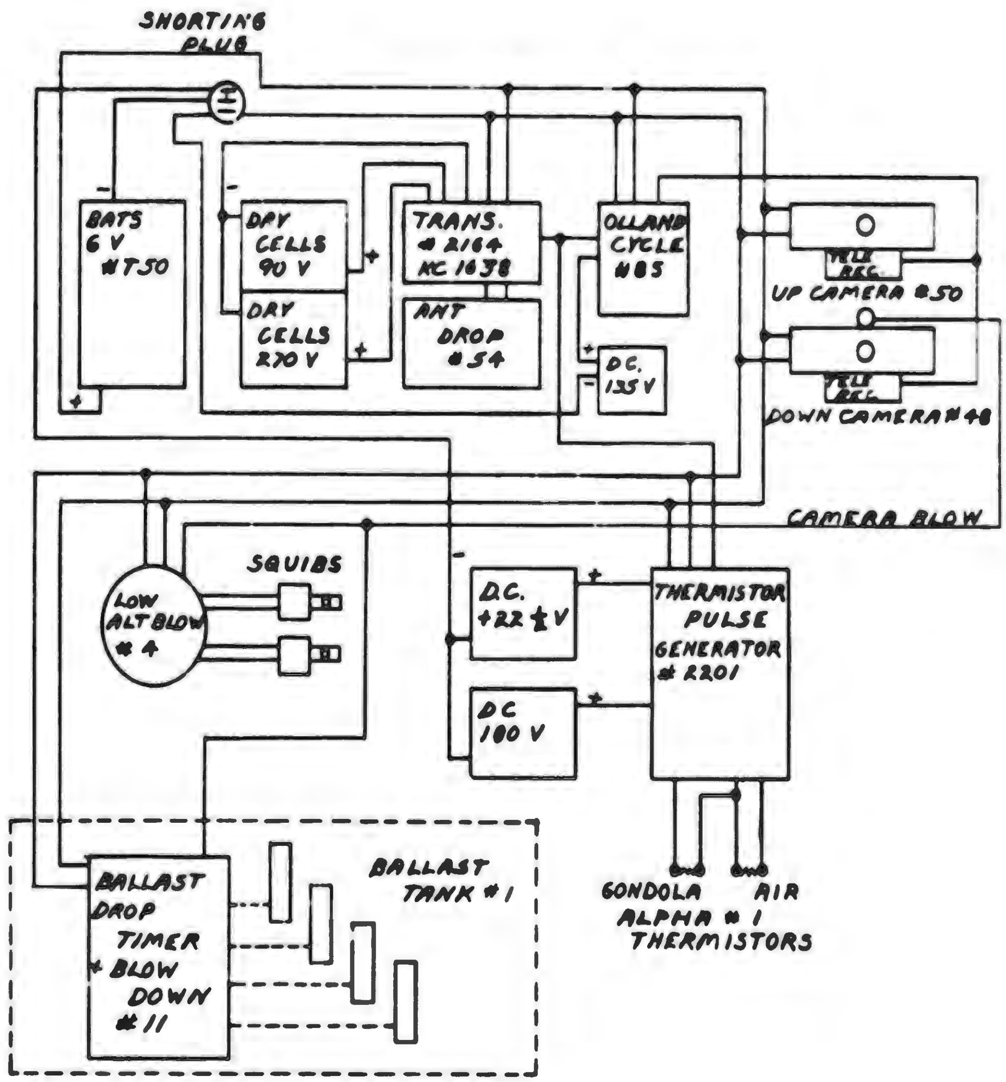

PRE
FLIGHT
67



DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	4-4-53
FLIGHT # 67 GONDOLA # 13			MOD. 1	
			MOD. 2	
			MOD. 3	

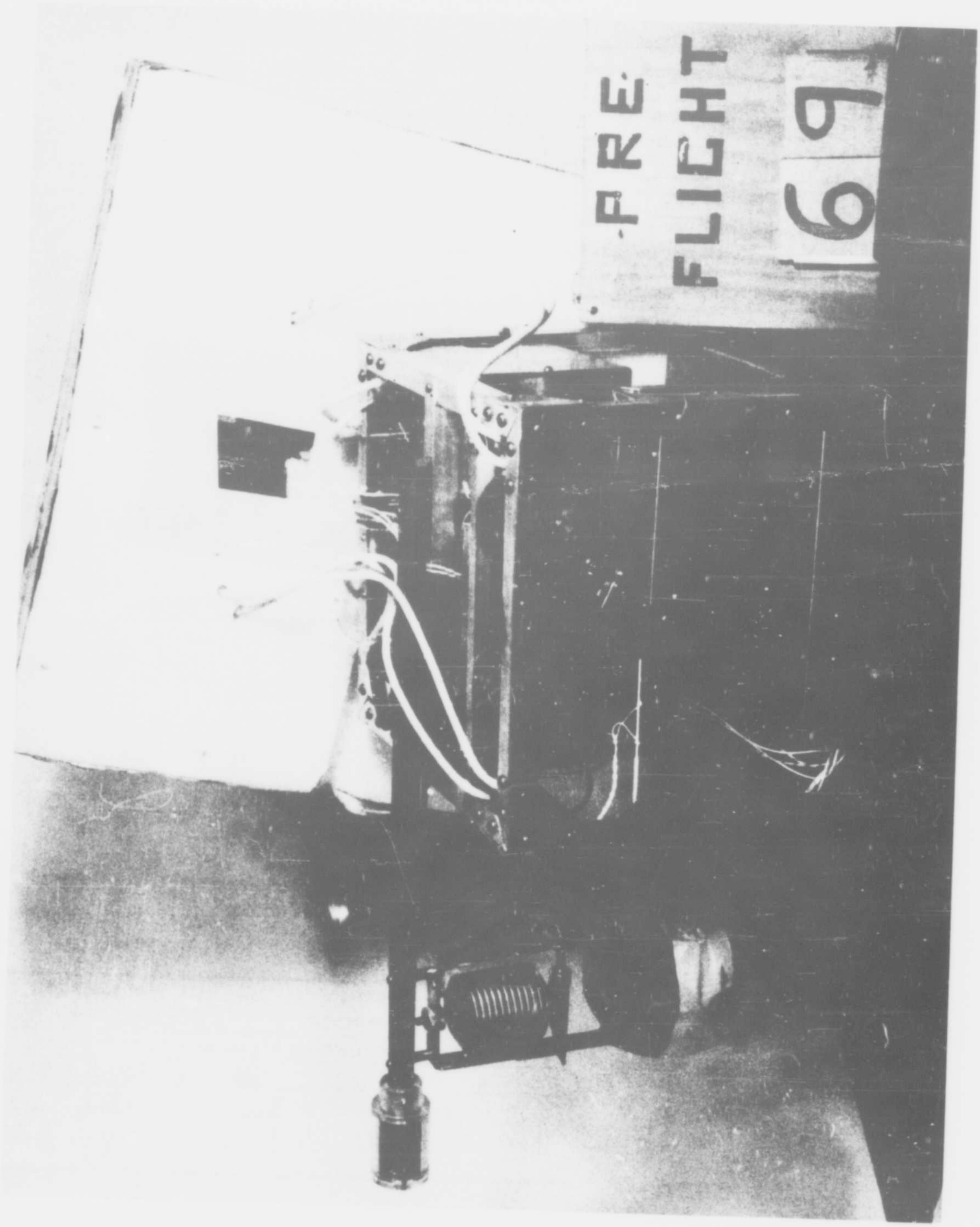


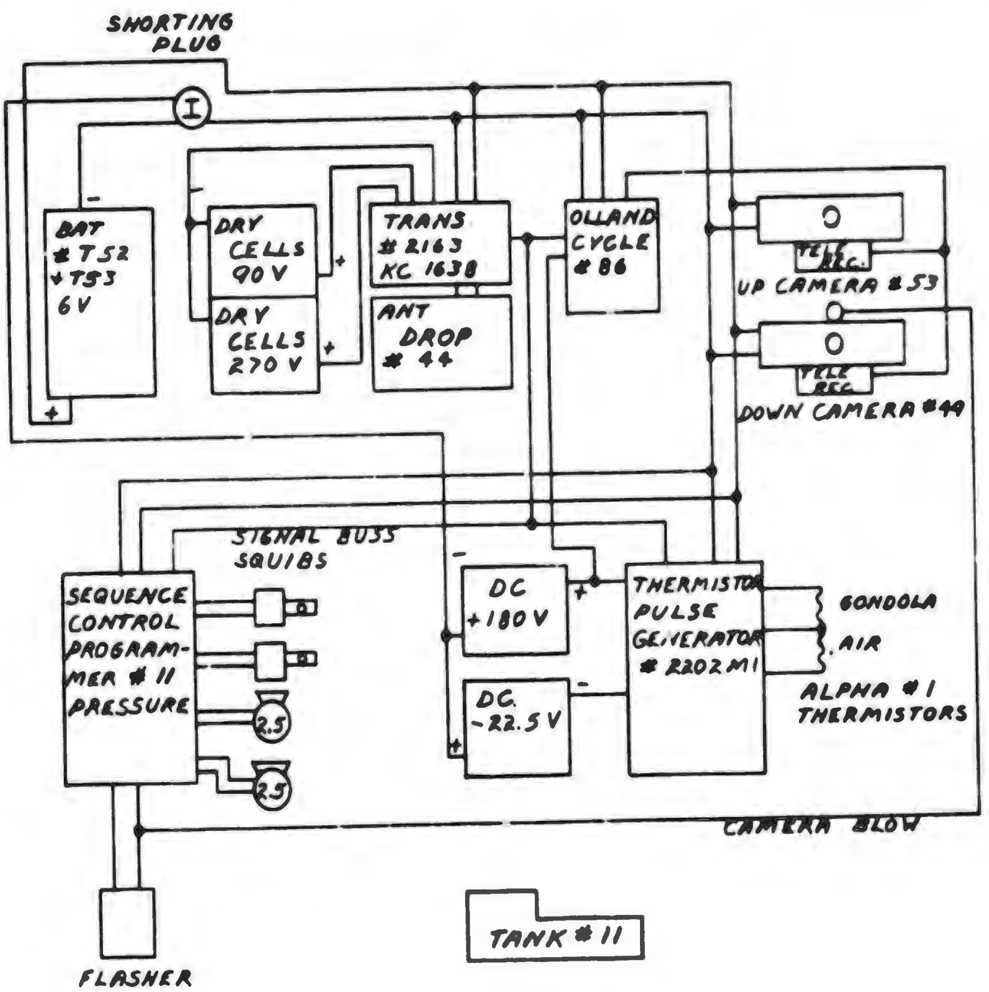
Tanks used on Flight 68, following recovery.



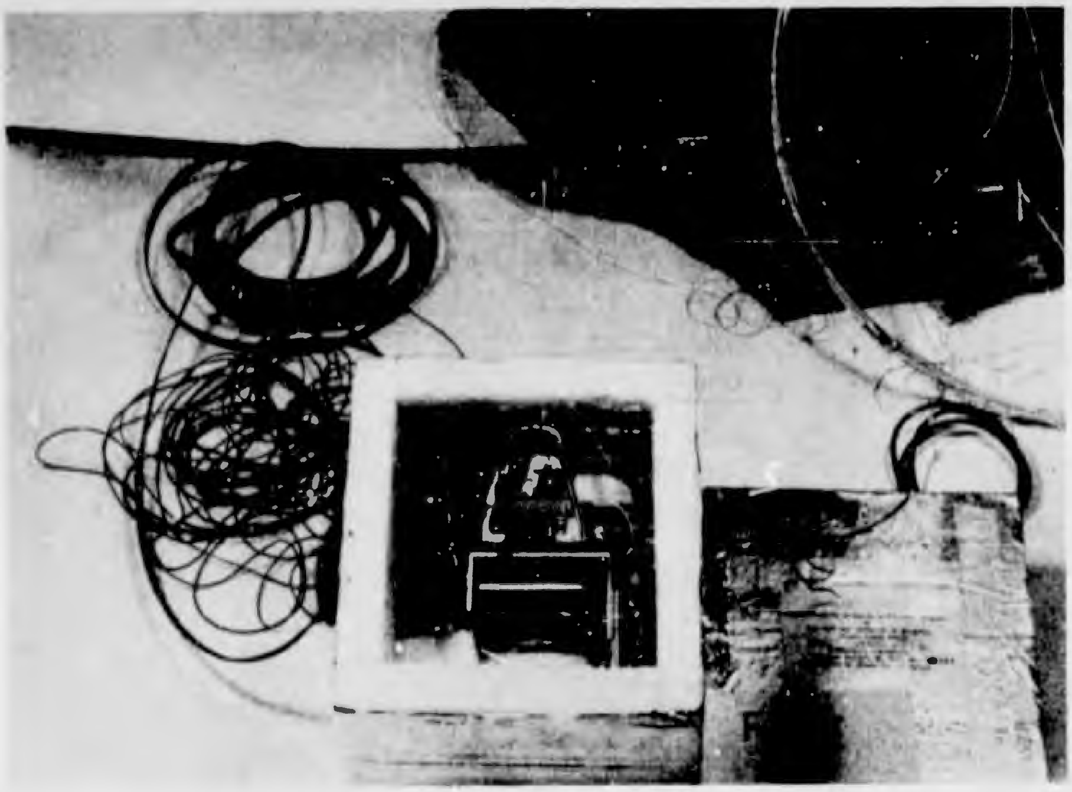
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST.

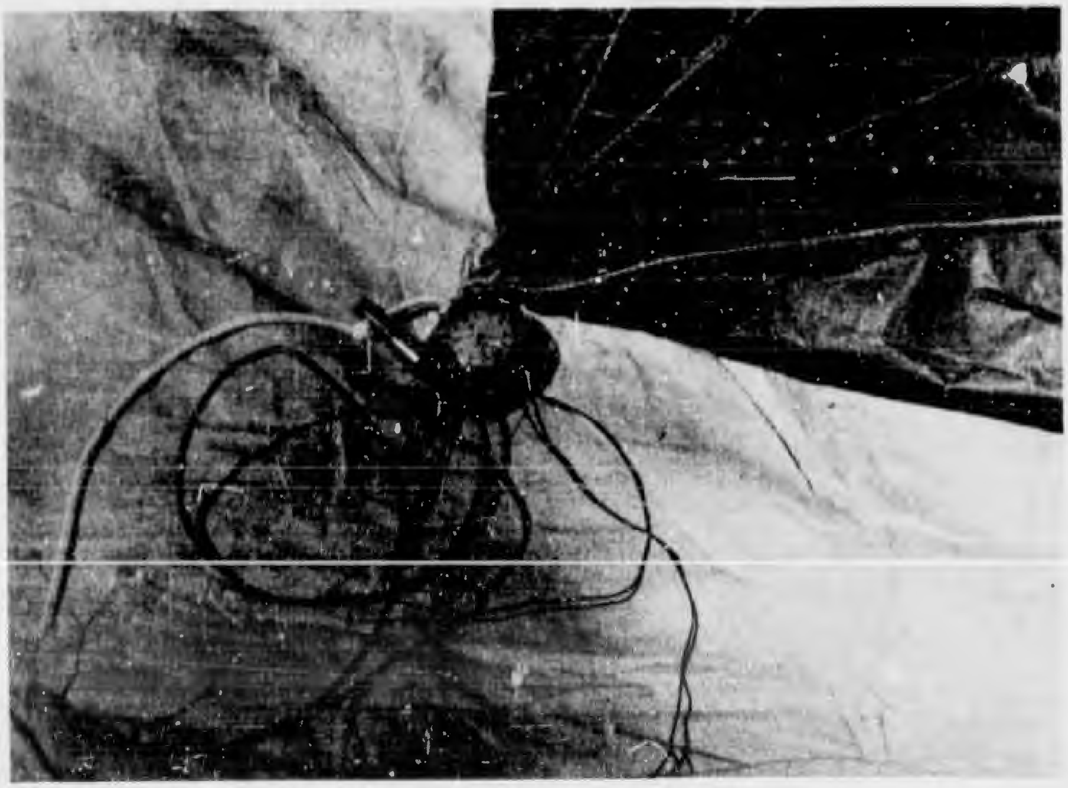
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				4-11-53
FLIGHT # 68 GONDOLA # 170			MOD. 1	
			MOD. 2	
			MOD. 3	

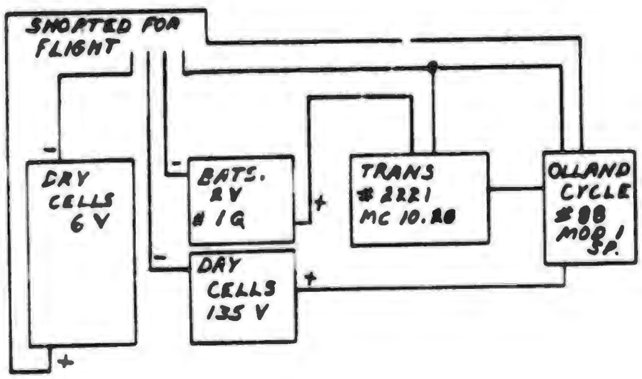

PRE
FLIGHT
69

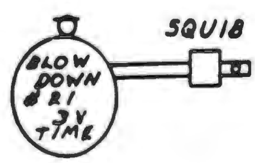


DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST.		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	4-20-53
FLIGHT # 69 GONDOLA # 191			MOD. 1	
			MOD. 2	
			MOD. 3	



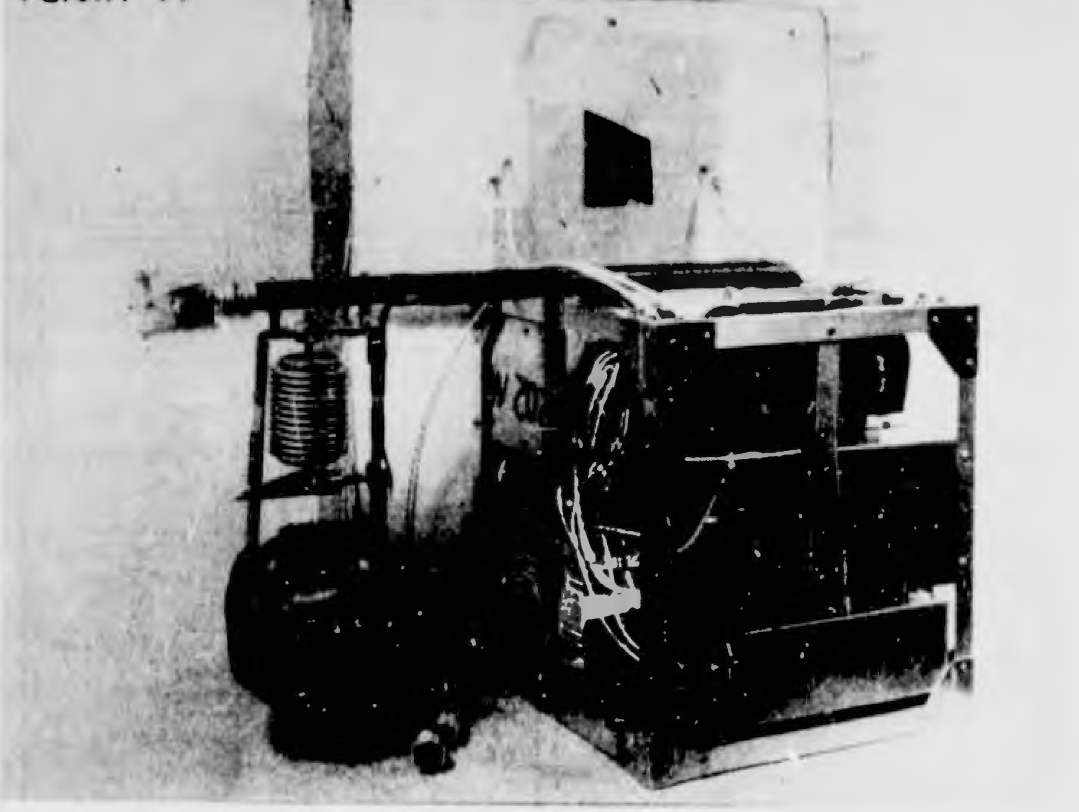




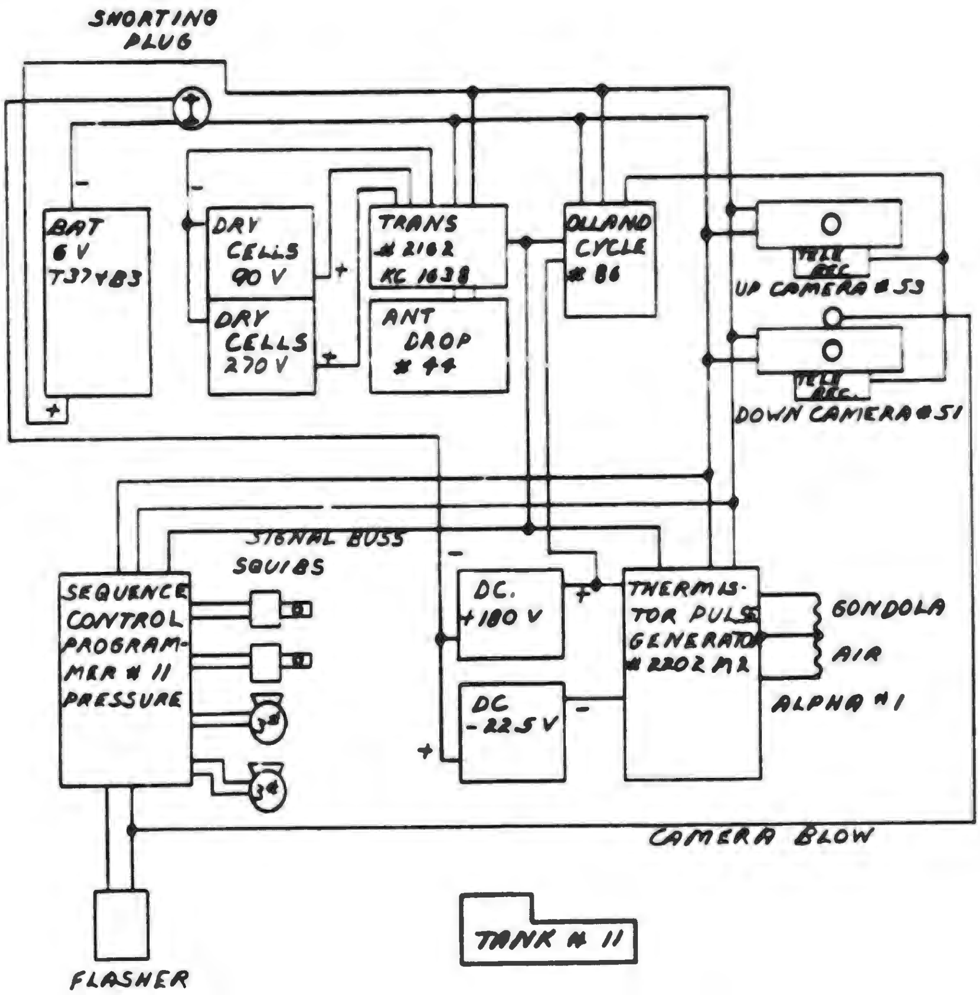


DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				4-27-53
FLIGHT # 70 GONDOLA # 211			MOD. 1	
			MOD. 2	
			MOD. 3	

FLIGHT 71

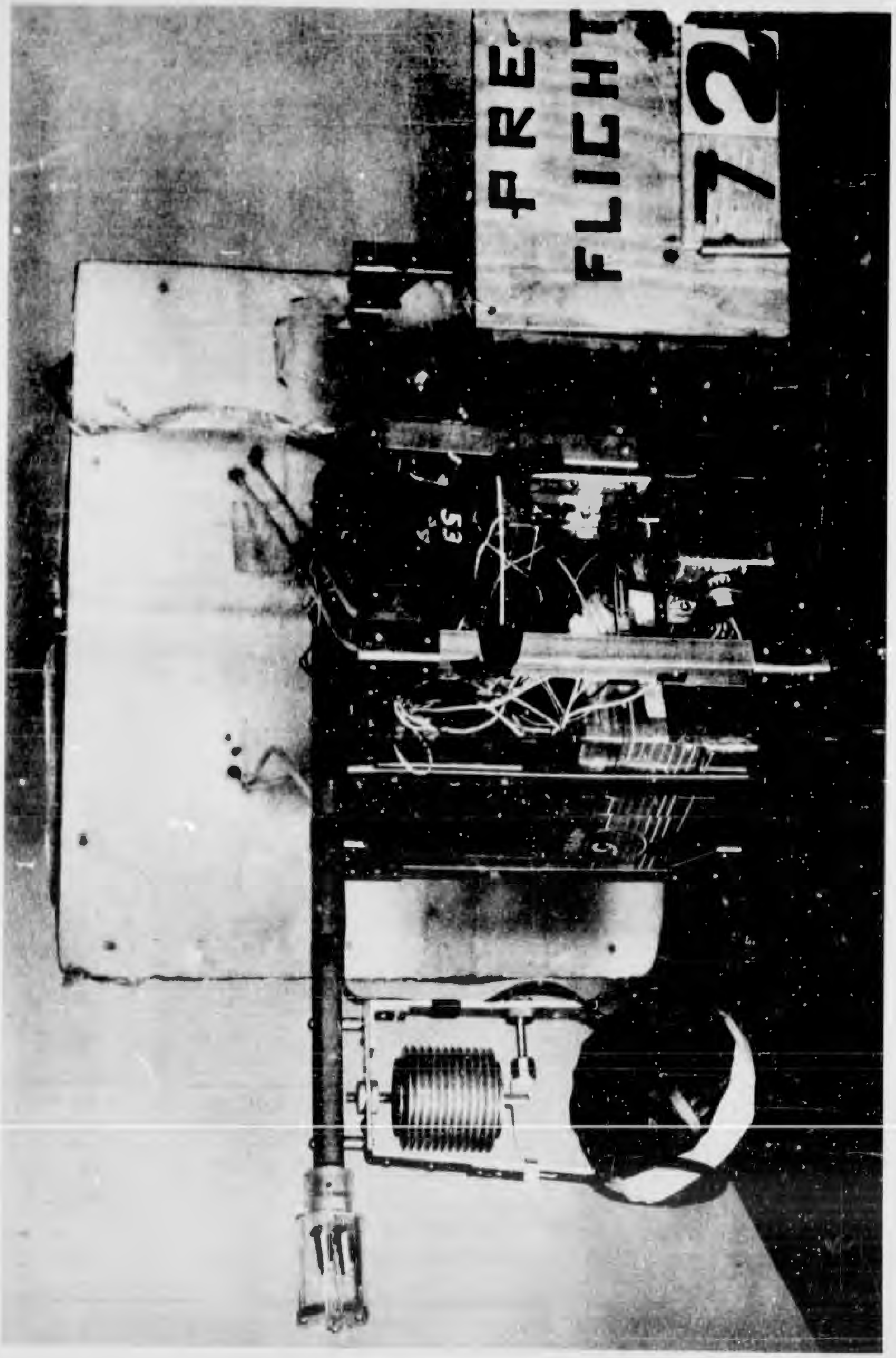


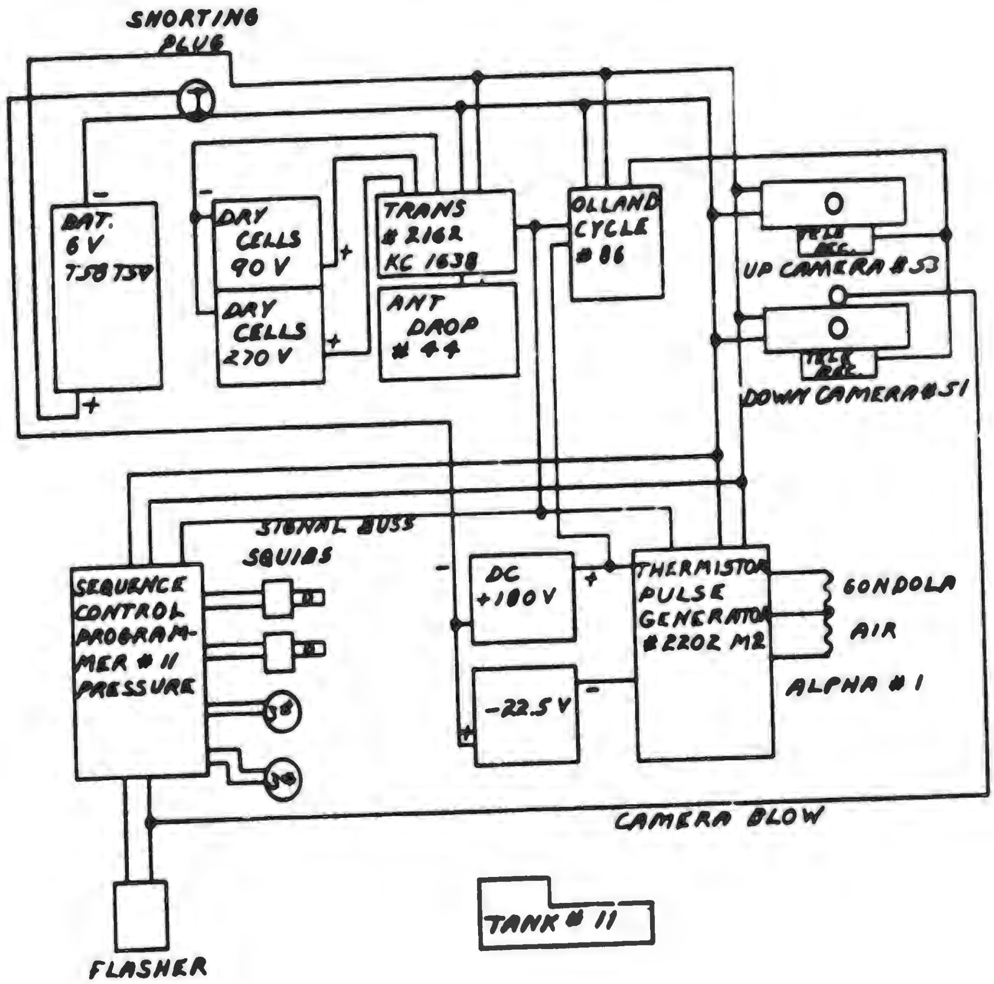
FLIGHT 71



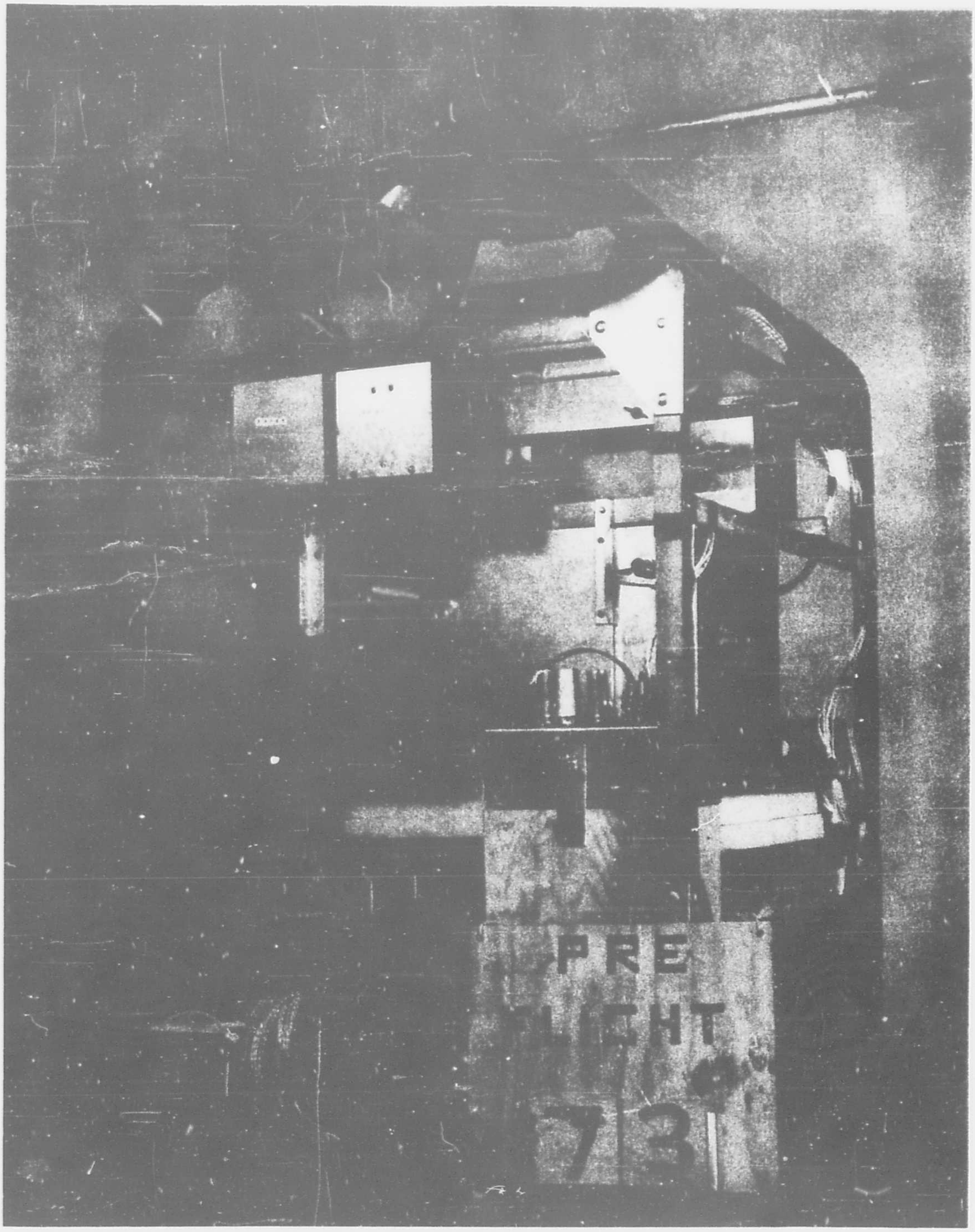
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

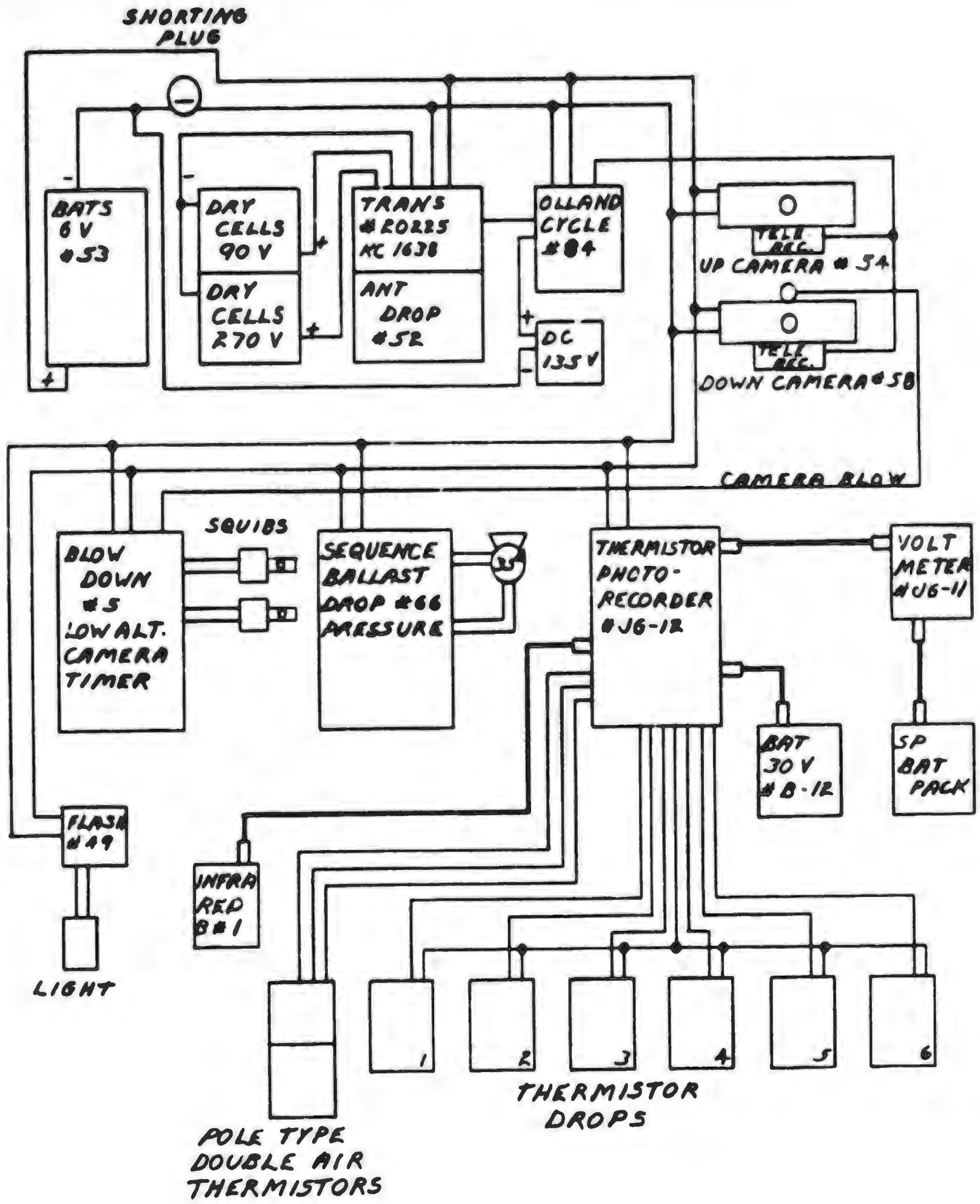
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	5-4-53
FLIGHT # 71 GONDOLA # 191			MOD. 1	
			MOD. 2	
			MOD. 3	


FLIGHT
72



DEPT. OF PHYSICS BALLOON PROJECT		U. OF MINN. SECT. INST.		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				5-6-53
FLIGHT # 72 GONDOLA # 191			MOD. 1	
			MOD. 2	
			MOD. 3	

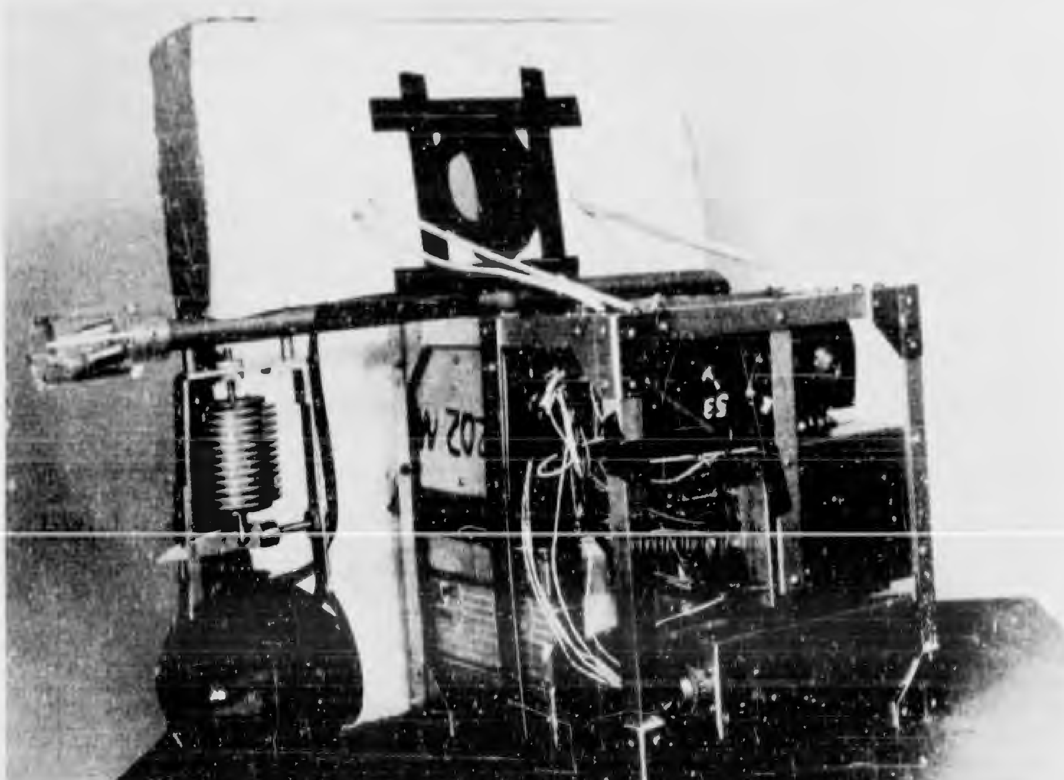

PRE
LIGHT
73

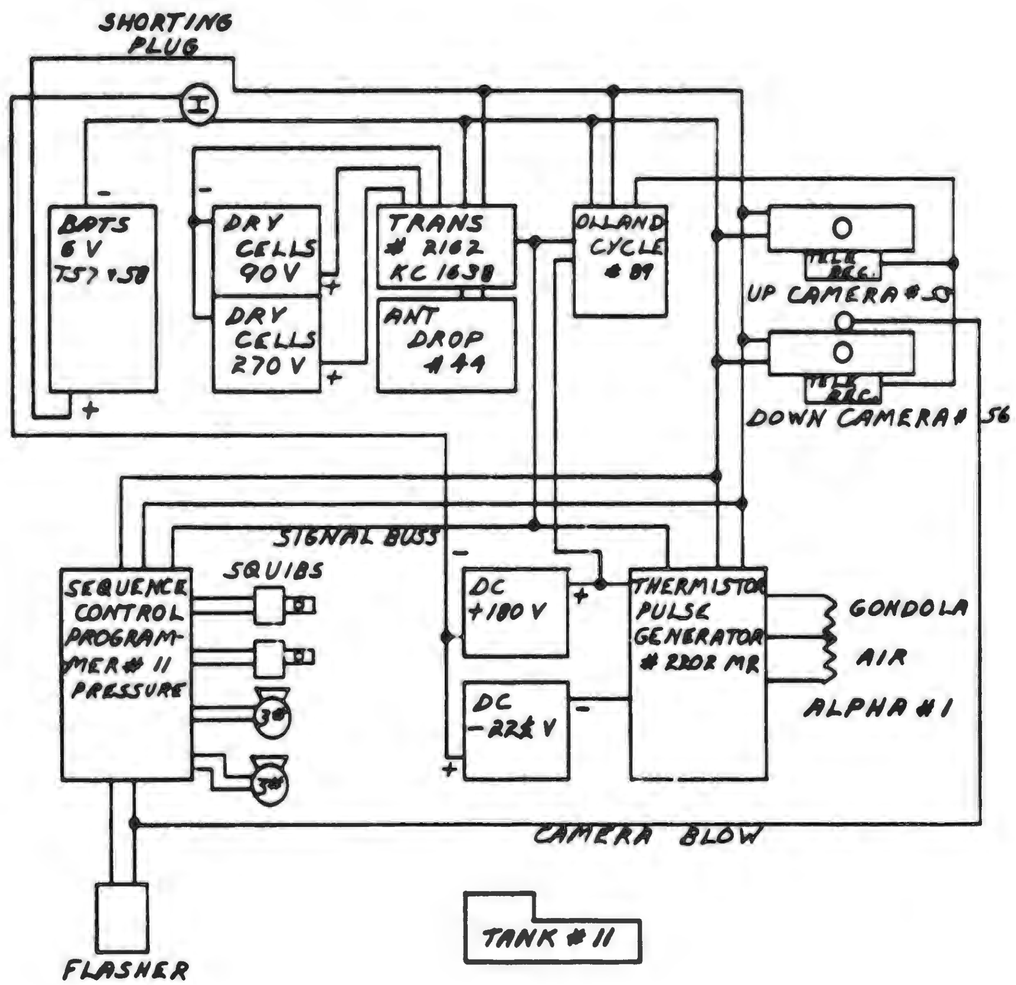


DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

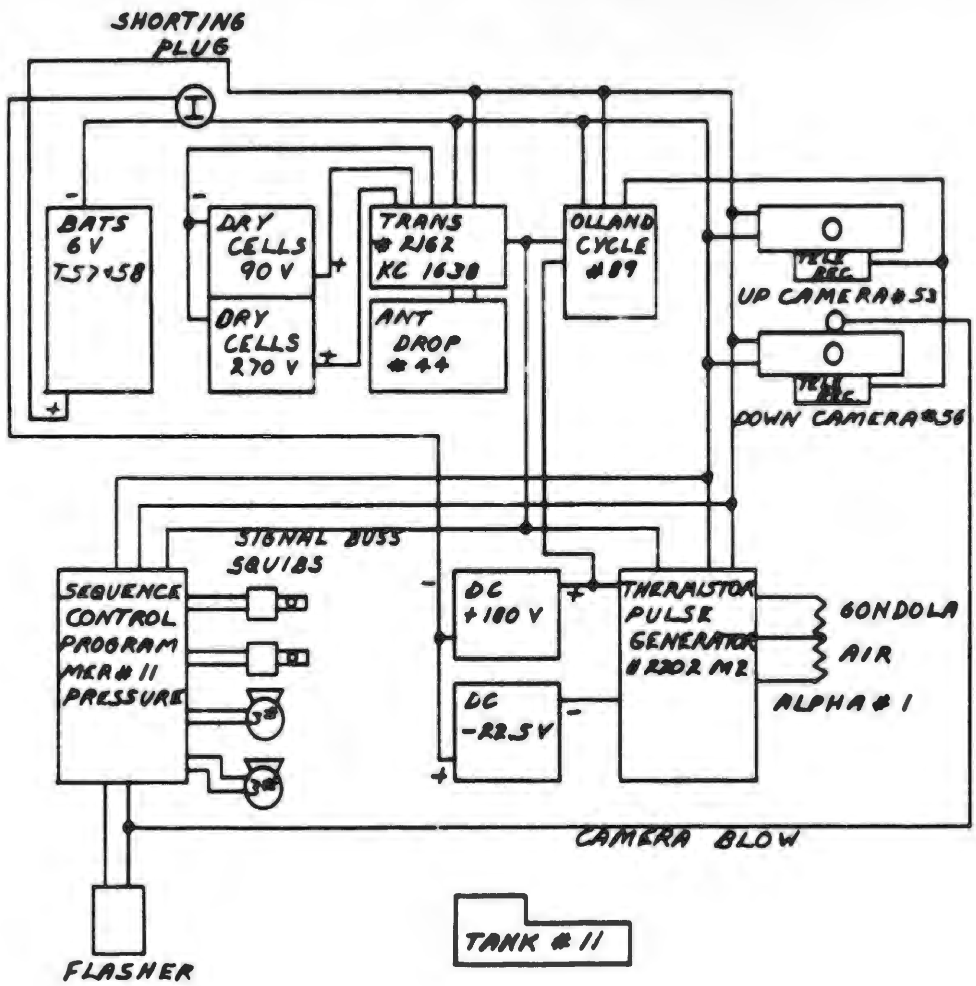
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	5-12-53
FLIGHT # 73 GONDOLA # 13			MOD. 1	
			MOD. 2	
			MOD. 3	


PRE
FLIGHT
74

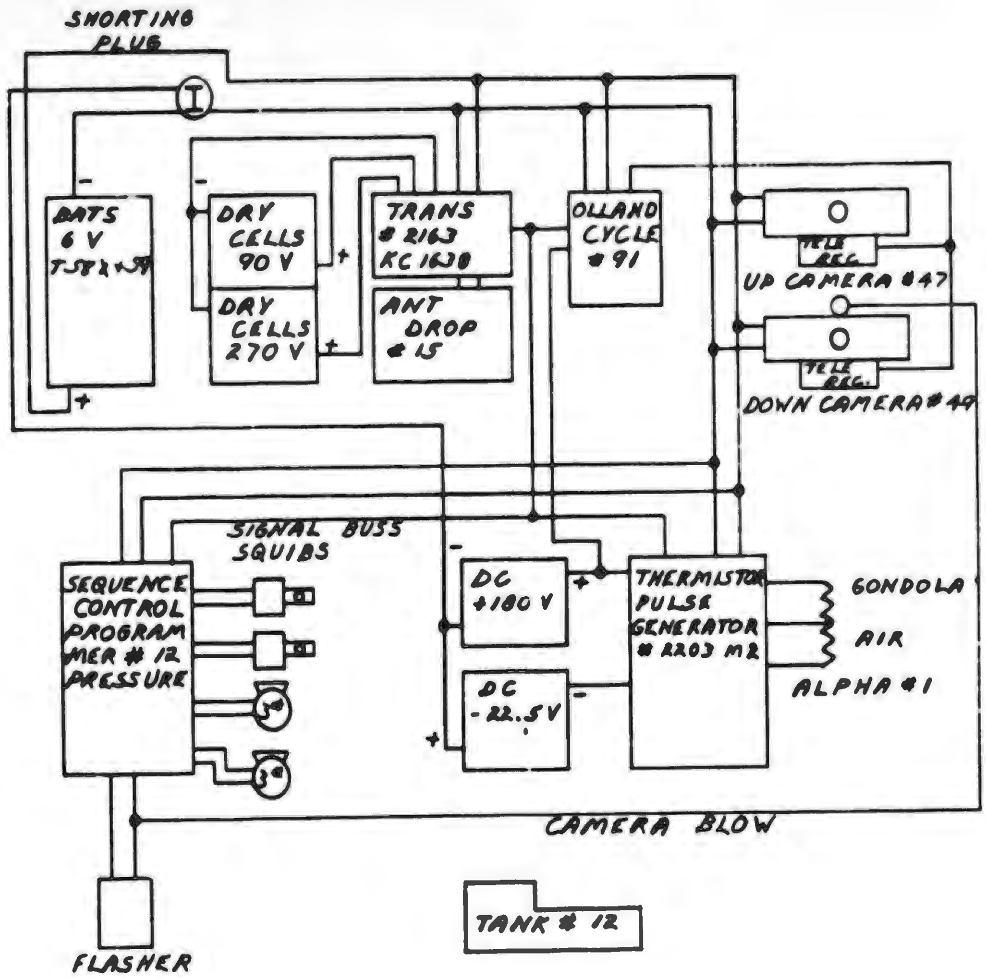




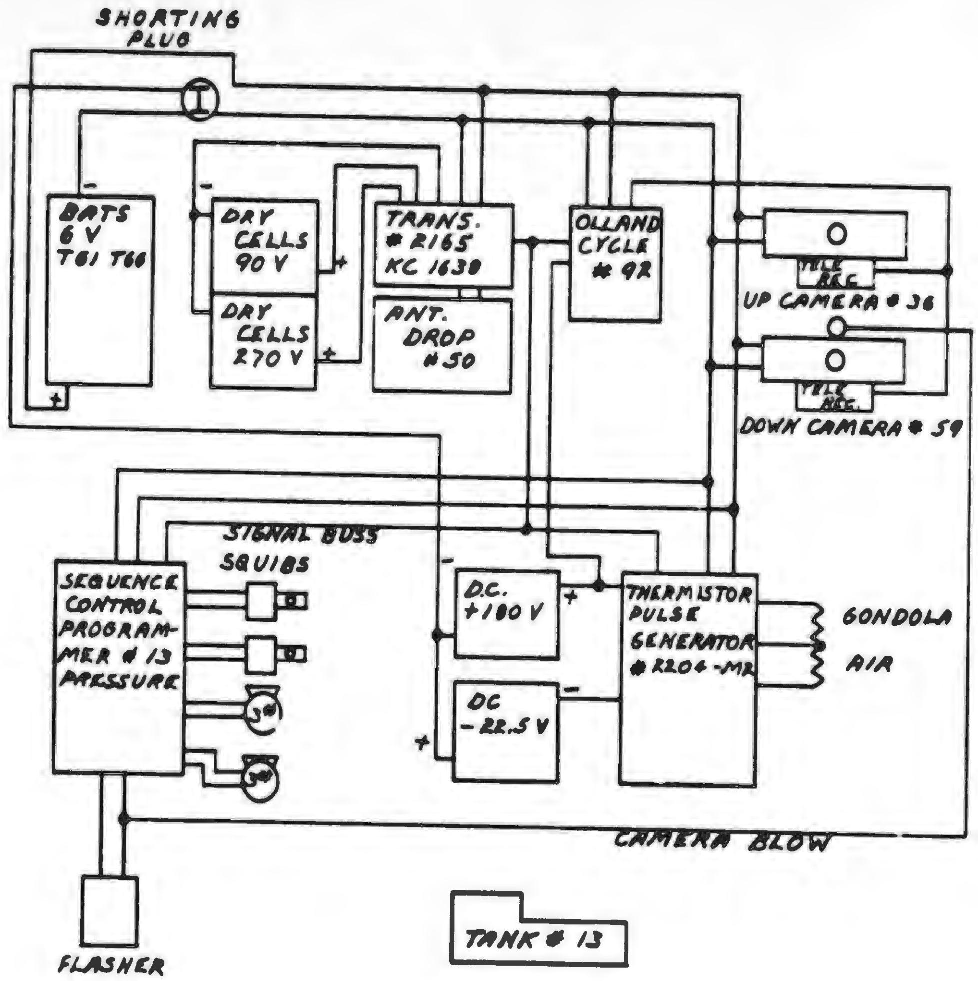
DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT SECT. INST				
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	5-19-53
FLIGHT # 74 GONDOLA # 191			MOD. 1	
			MOD. 2	
			MOD. 3	



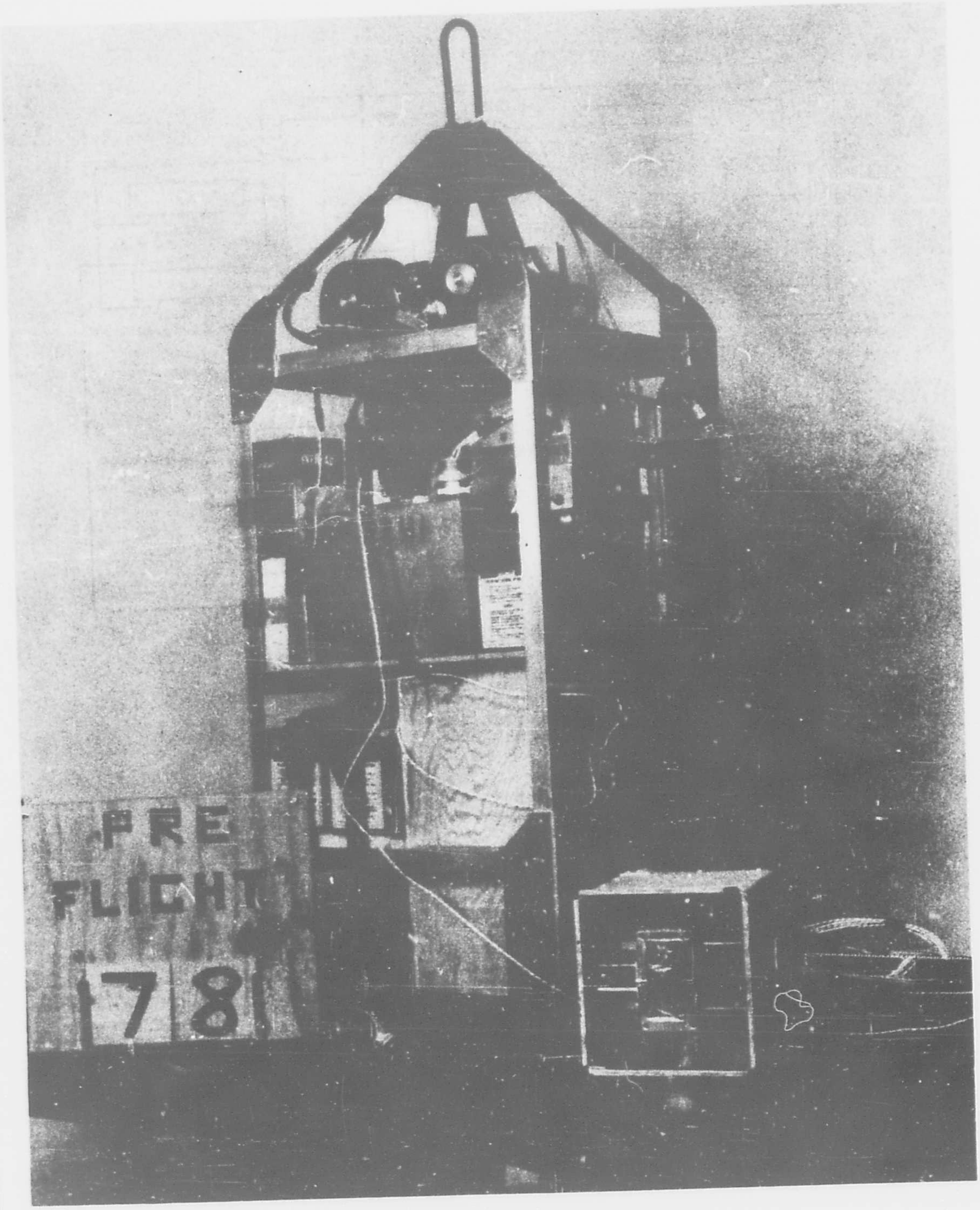
DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT SECT. INST				
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				5-22-53
FLIGHT # 75 GONDOLA # 191			MOD. 1	
			MOD. 2	
			MOD. 3	

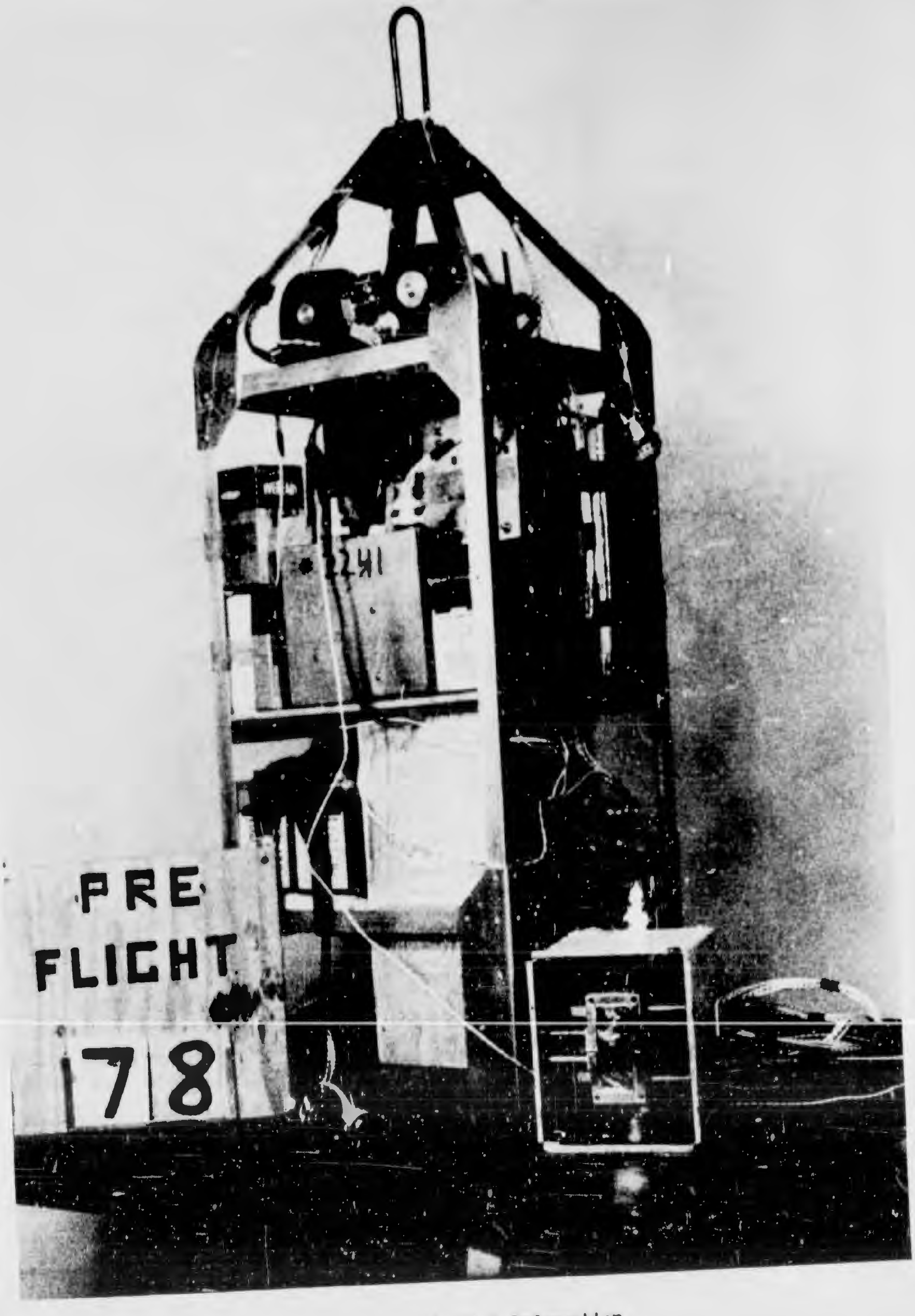


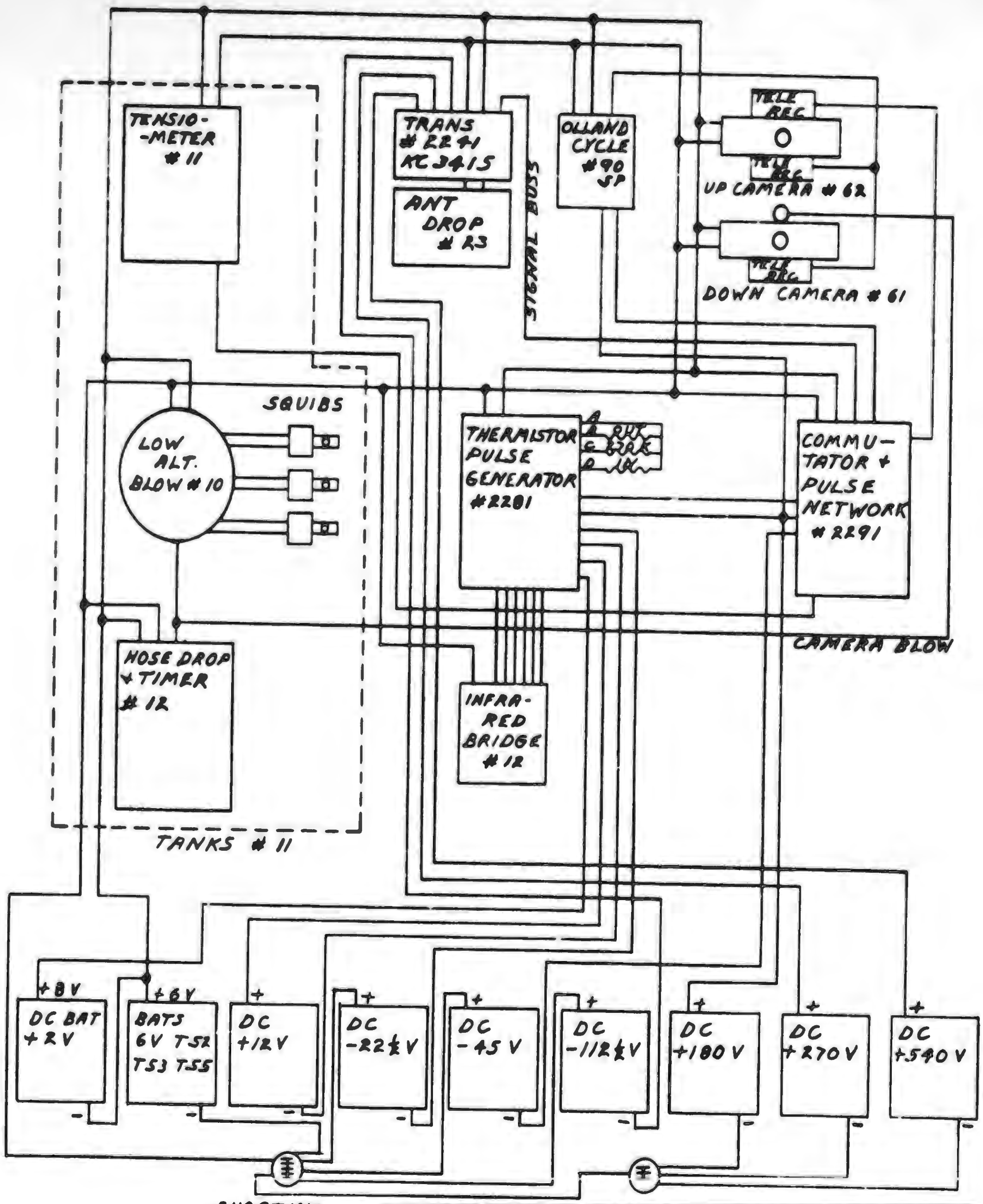
DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	5-26-53
FLIGHT # 76 GONDOLA # 192			MOD. 1	
			MOD. 2	
			MOD. 3	



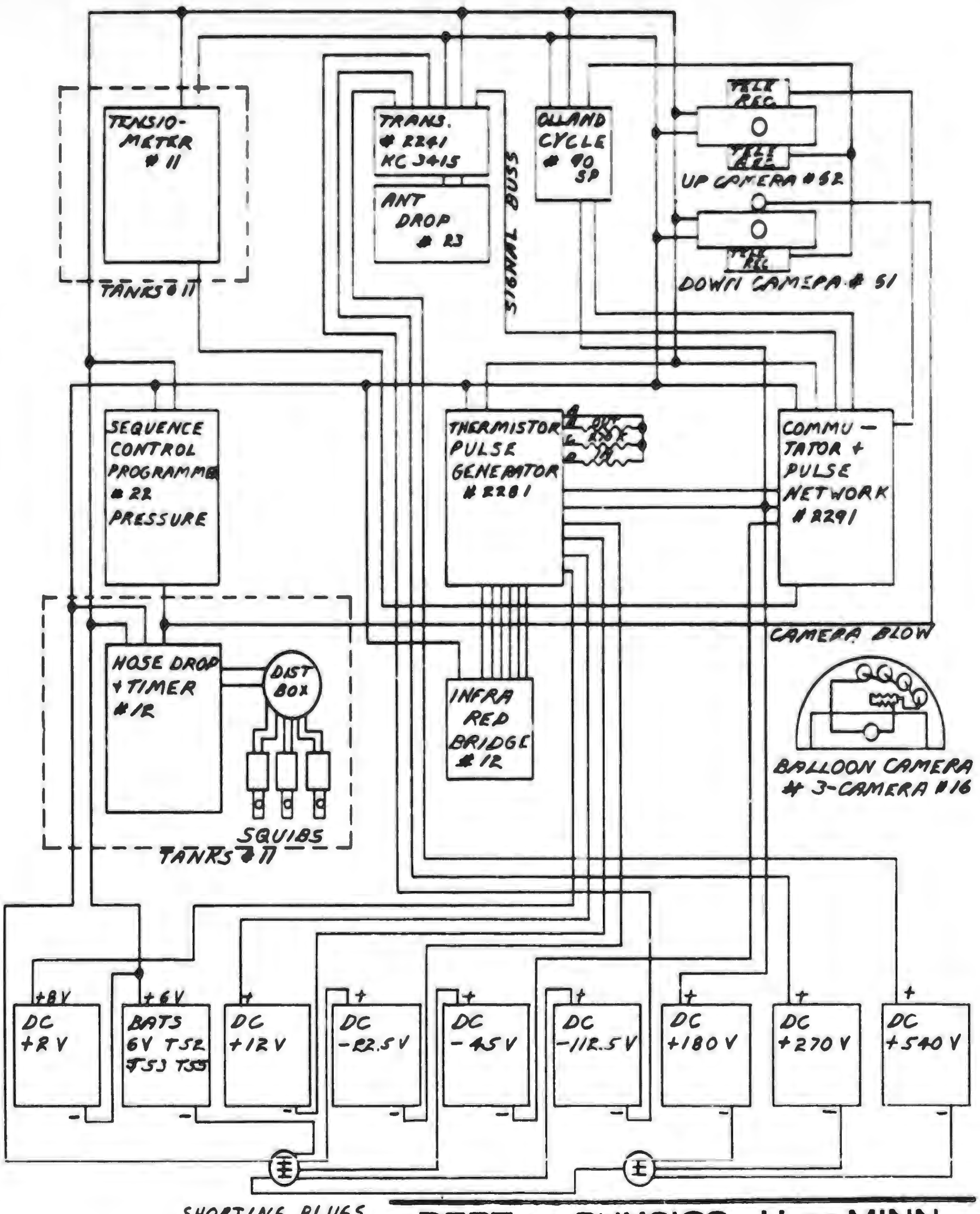
DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT SECT. INST				
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	6-4-53
FLIGHT # 77 GONDOLA # 193			MOD. 1	
			MOD. 2	
			MOD. 3	


PRE
FLIGHT
78

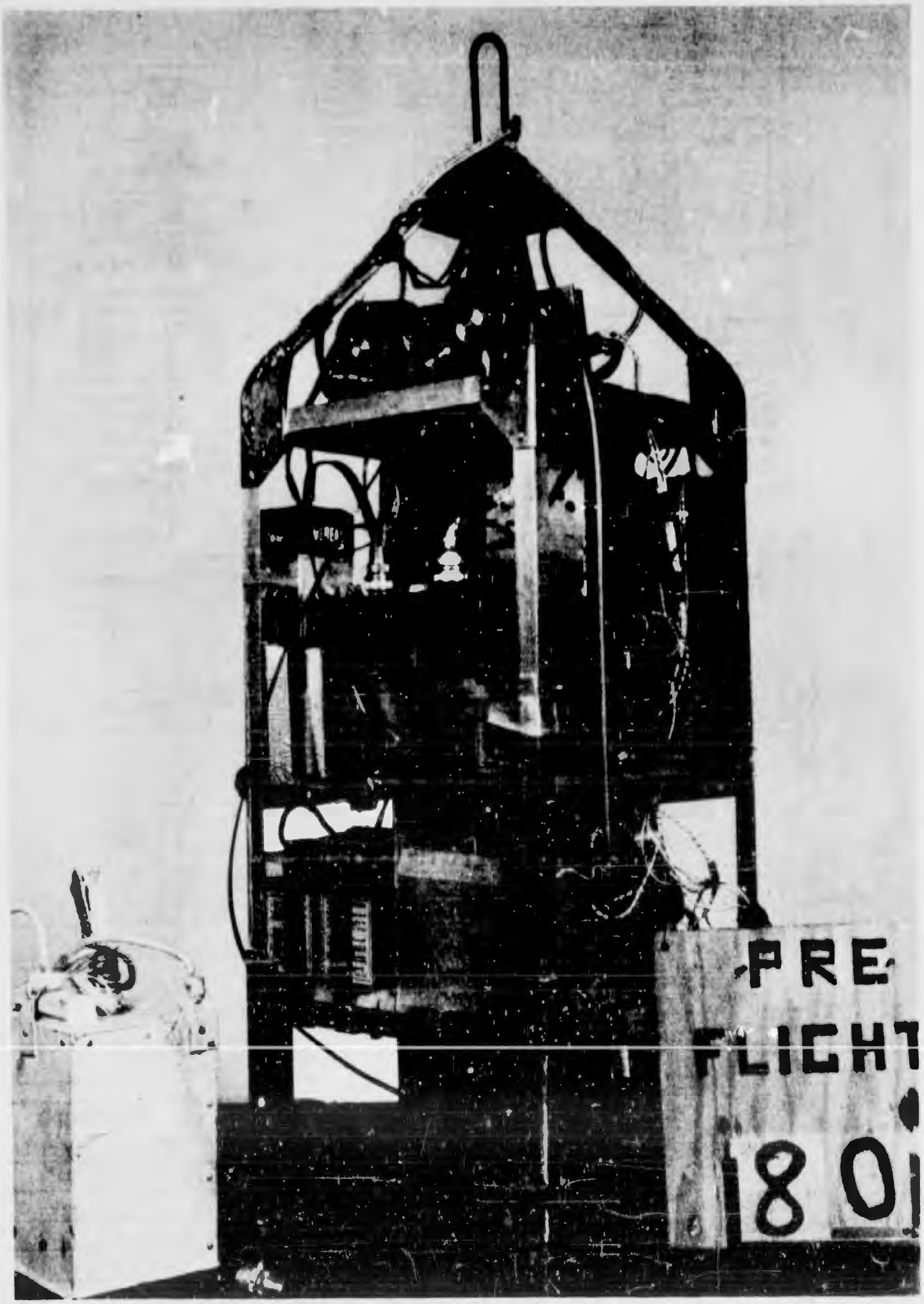

PRE
FLIGHT
78

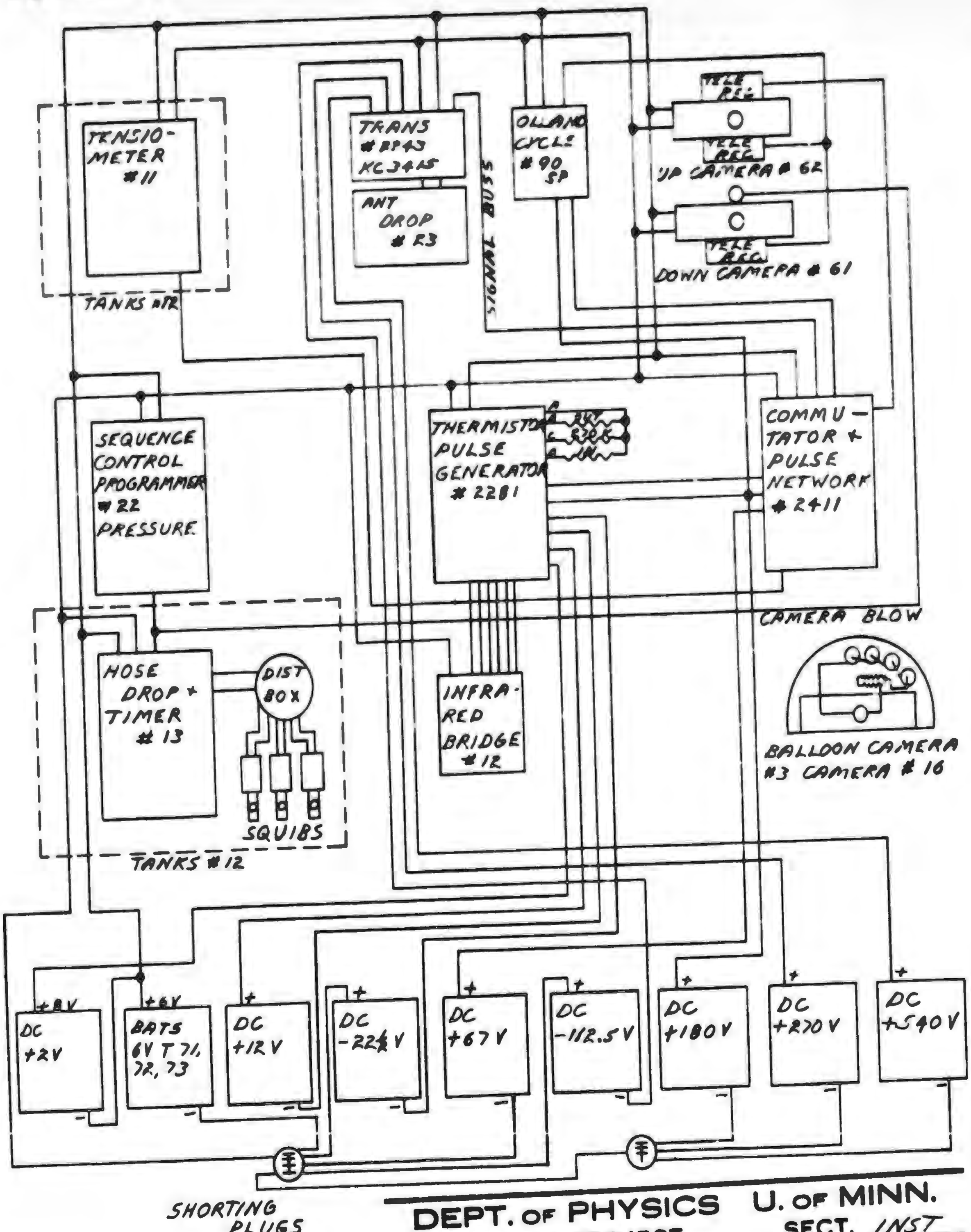


DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	6-9-53
FLIGHT # 78 GONDOLA # 55			MOD. 1	
			MOD. 2	
			MOD. 3	



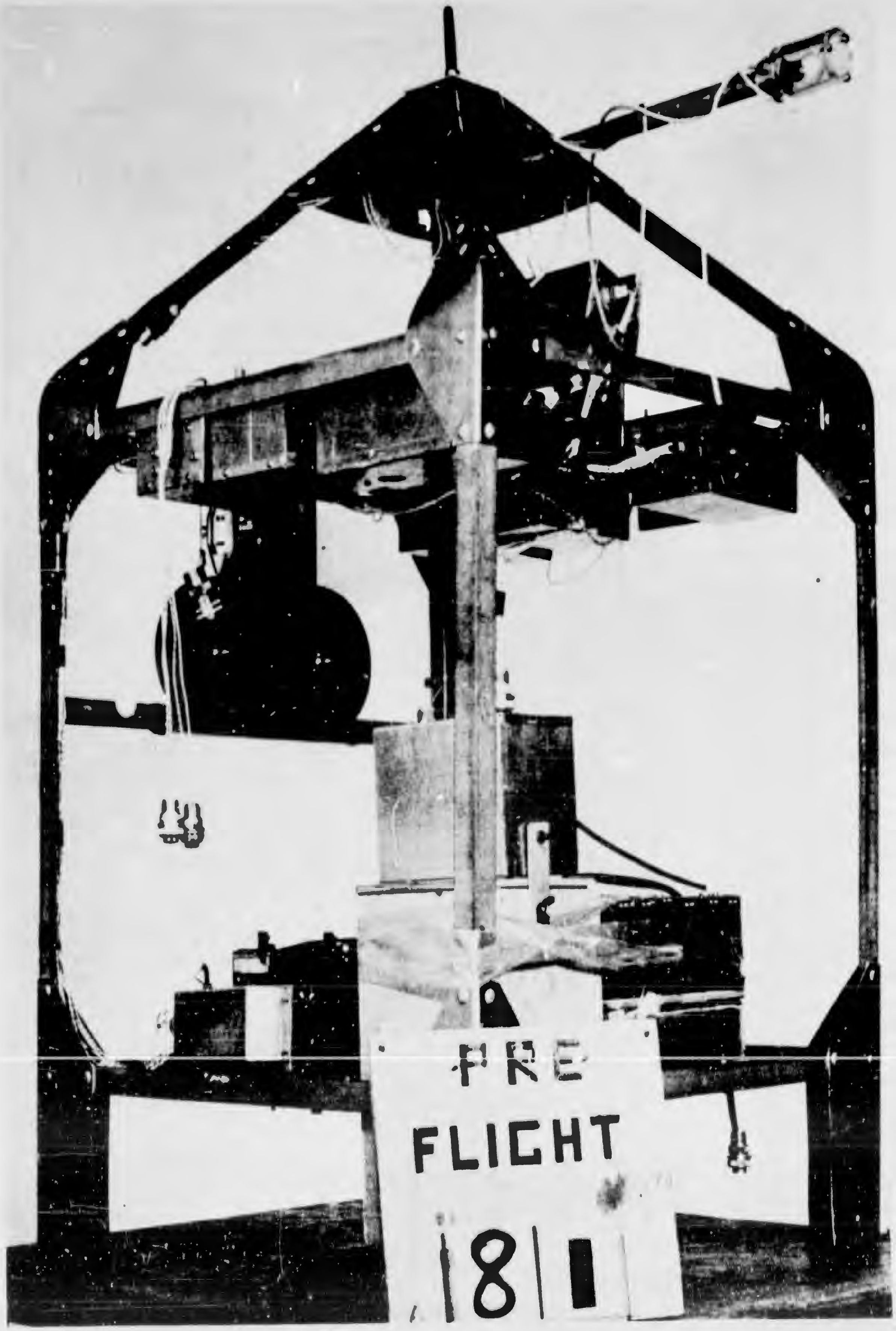
DEPT. OF PHYSICS U. OF MINN.				
BALLOON PROJECT			SECT. INST.	
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	6-17-53
FLIGHT # 79 GONDOLA # 55			MOD. 1	
			MOD. 2	
			MOD. 3	

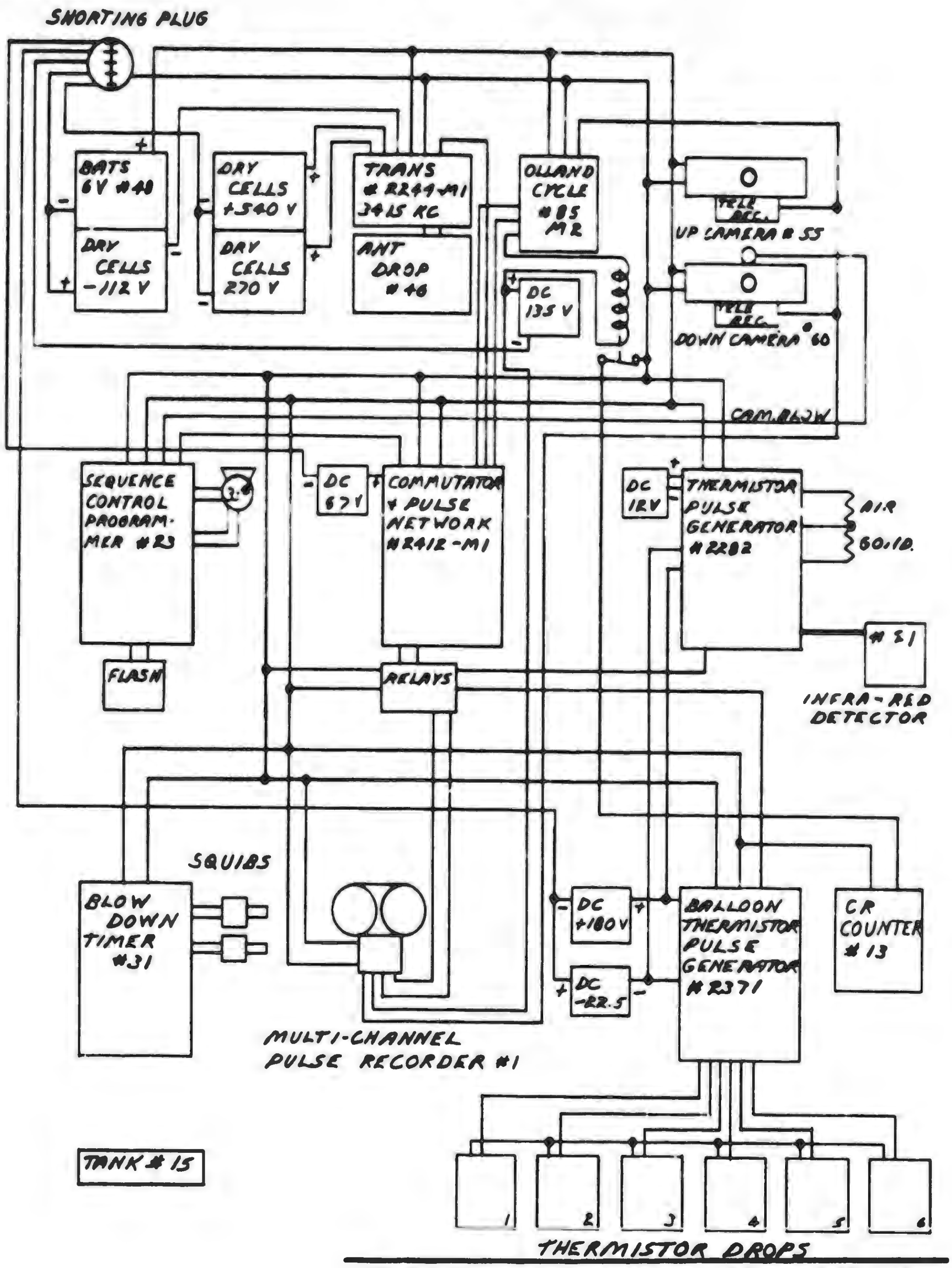

PRE-
FLIGHT
80



DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. *INST*

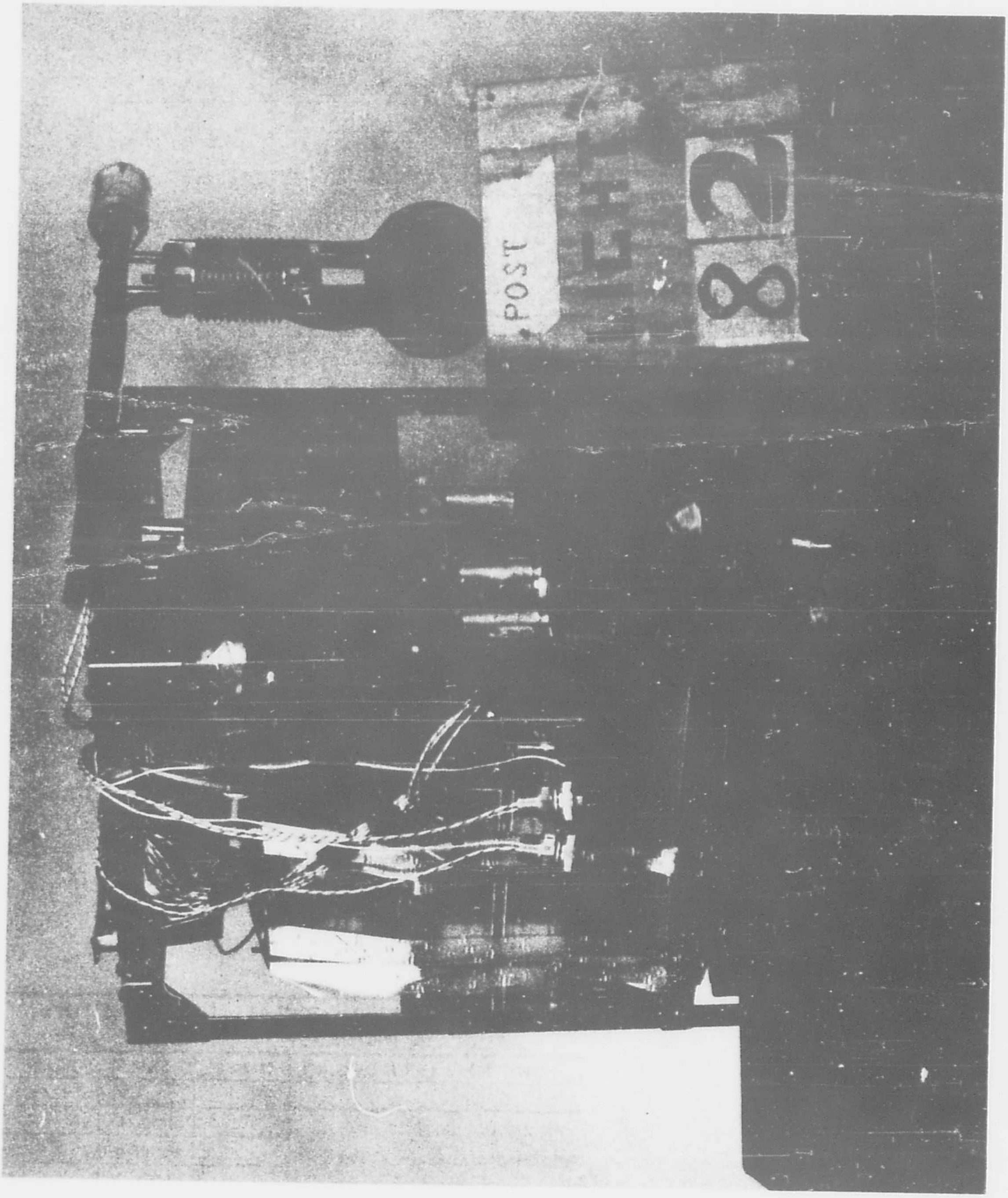
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	7-3-55
FLIGHT # 80 GONDOLA 55			MOD. 1	
			MOD. 2	
			MOD. 3	

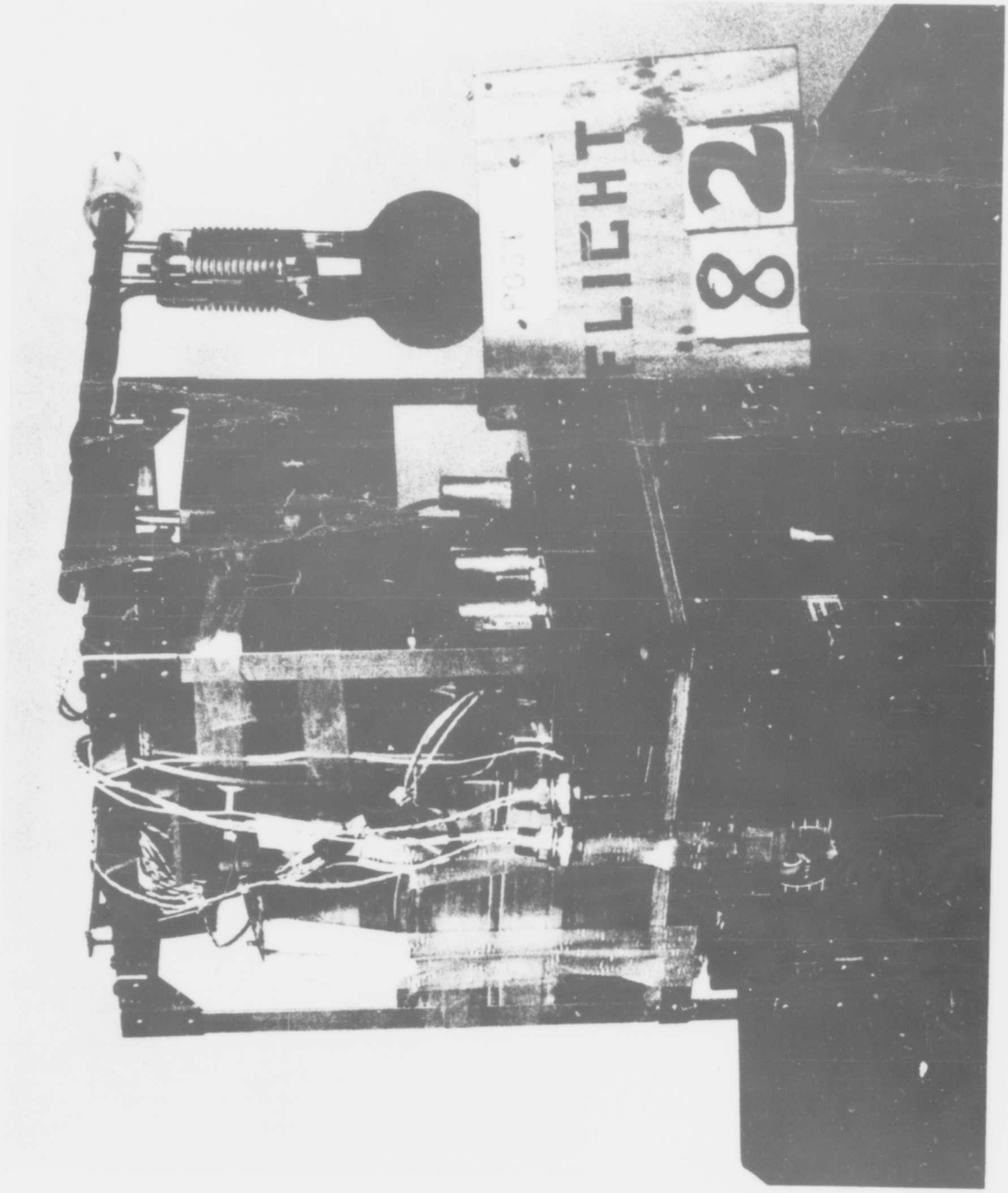

PRE
FLIGHT
18

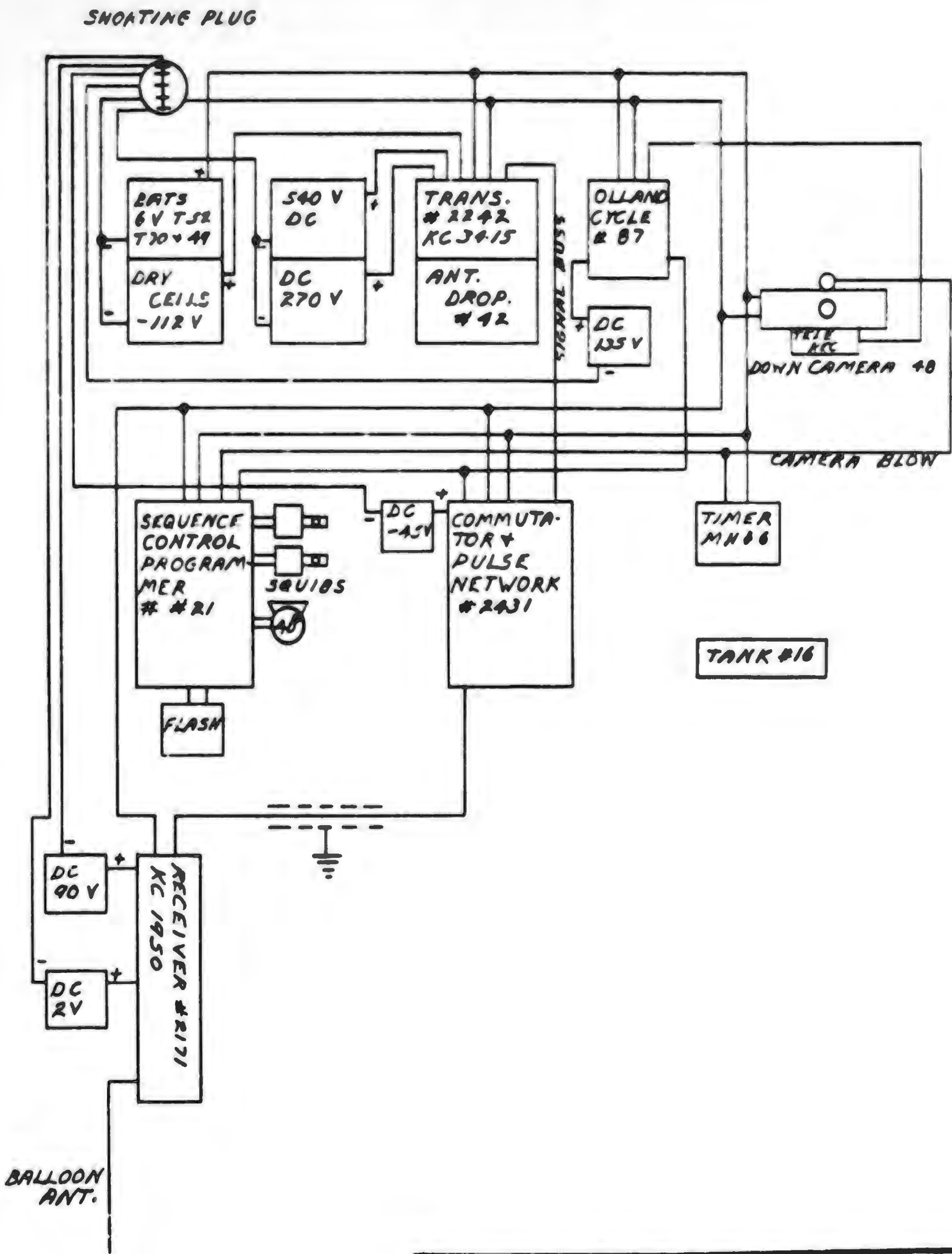


DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST.

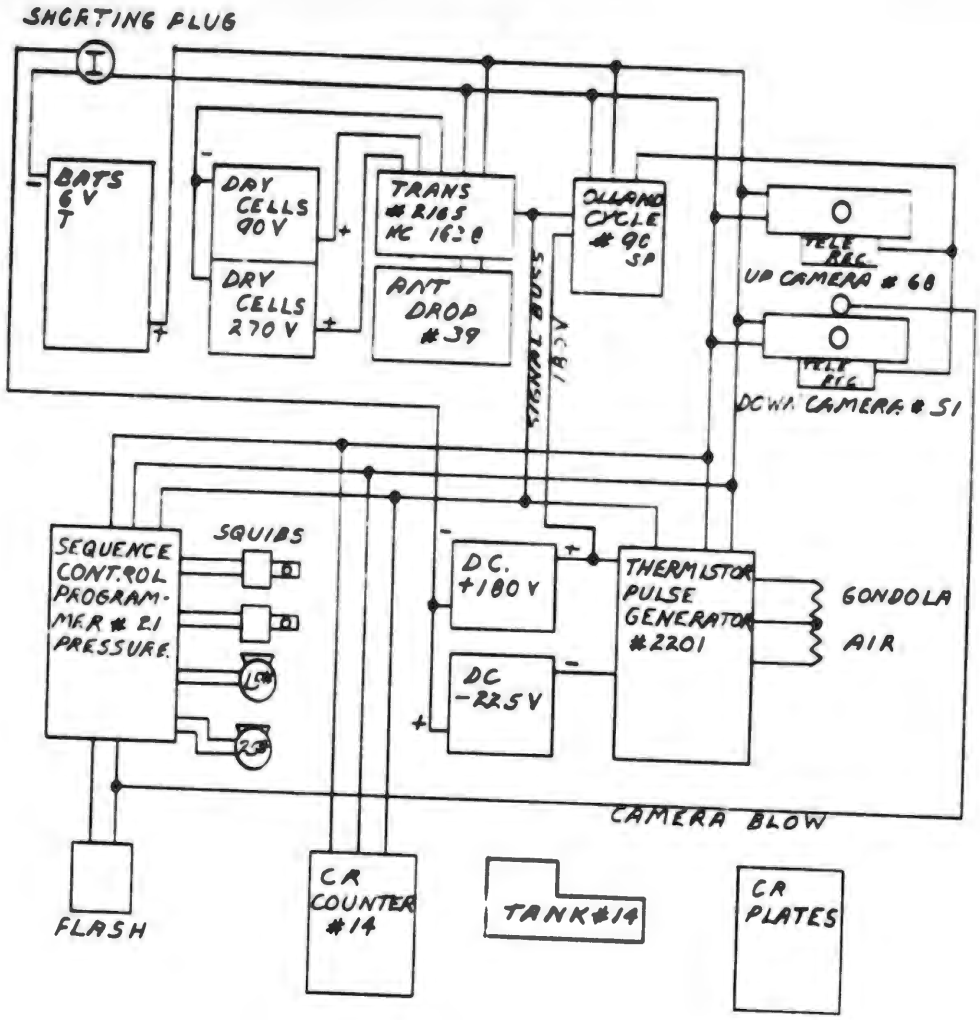
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	7-7-53
FLIGHT # 81 GONDOLA # 19			MOD. 1	
			MOD. 2	
			MOD. 3	


POST


FLIGHT
82

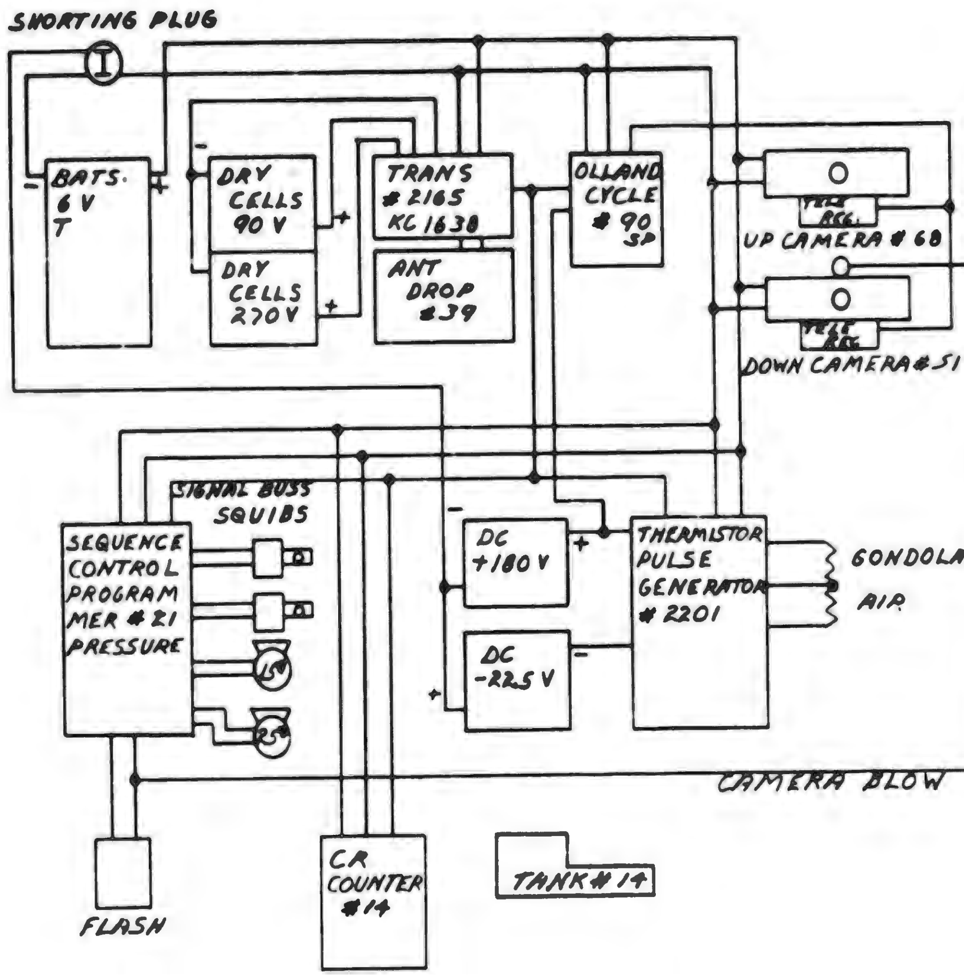


DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				7-11-53
FLIGHT # 82 GONDOLA # X56			MOD. 1	
			MOD. 2	
			MOD. 3	

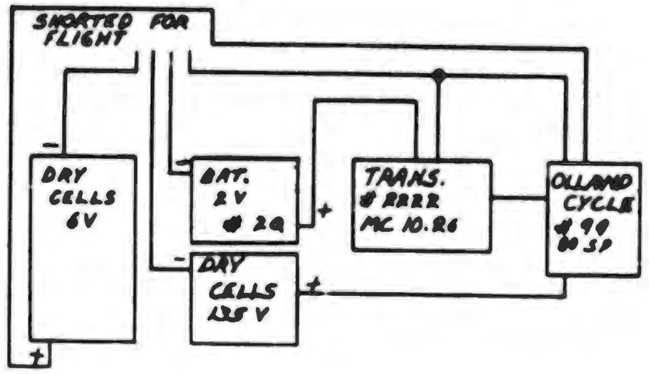


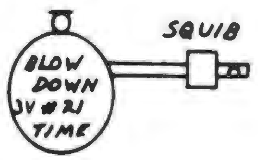
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		JR	S.L.	7-16-53
FLIGHT # 83 GONDOLA # 194			MOD. 1	
			MOD. 2	
			MOD. 3	



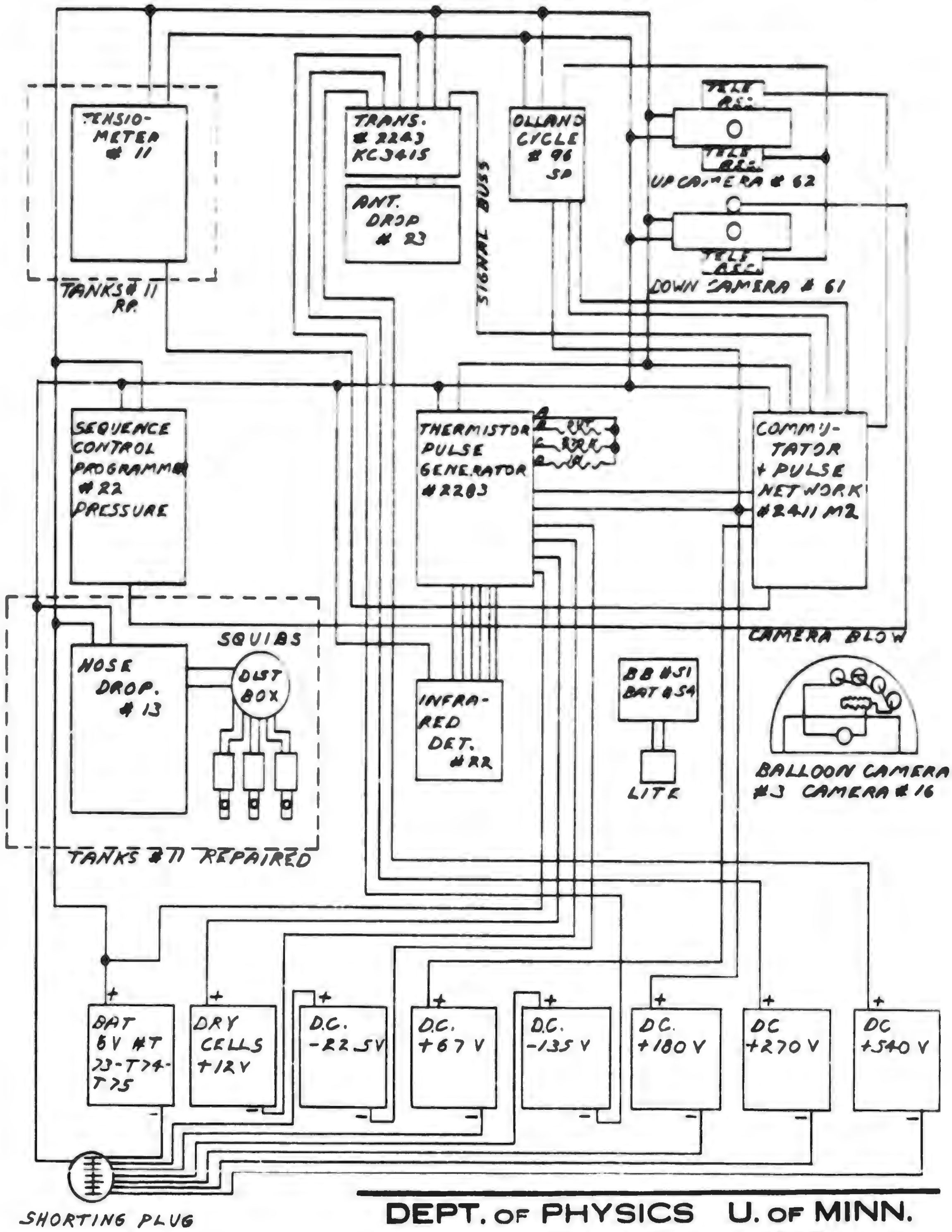
DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	7-23-53
FLIGHT # 84 GONDOLA # 194			MOD. 1	
			MOD. 2	
			MOD. 3	





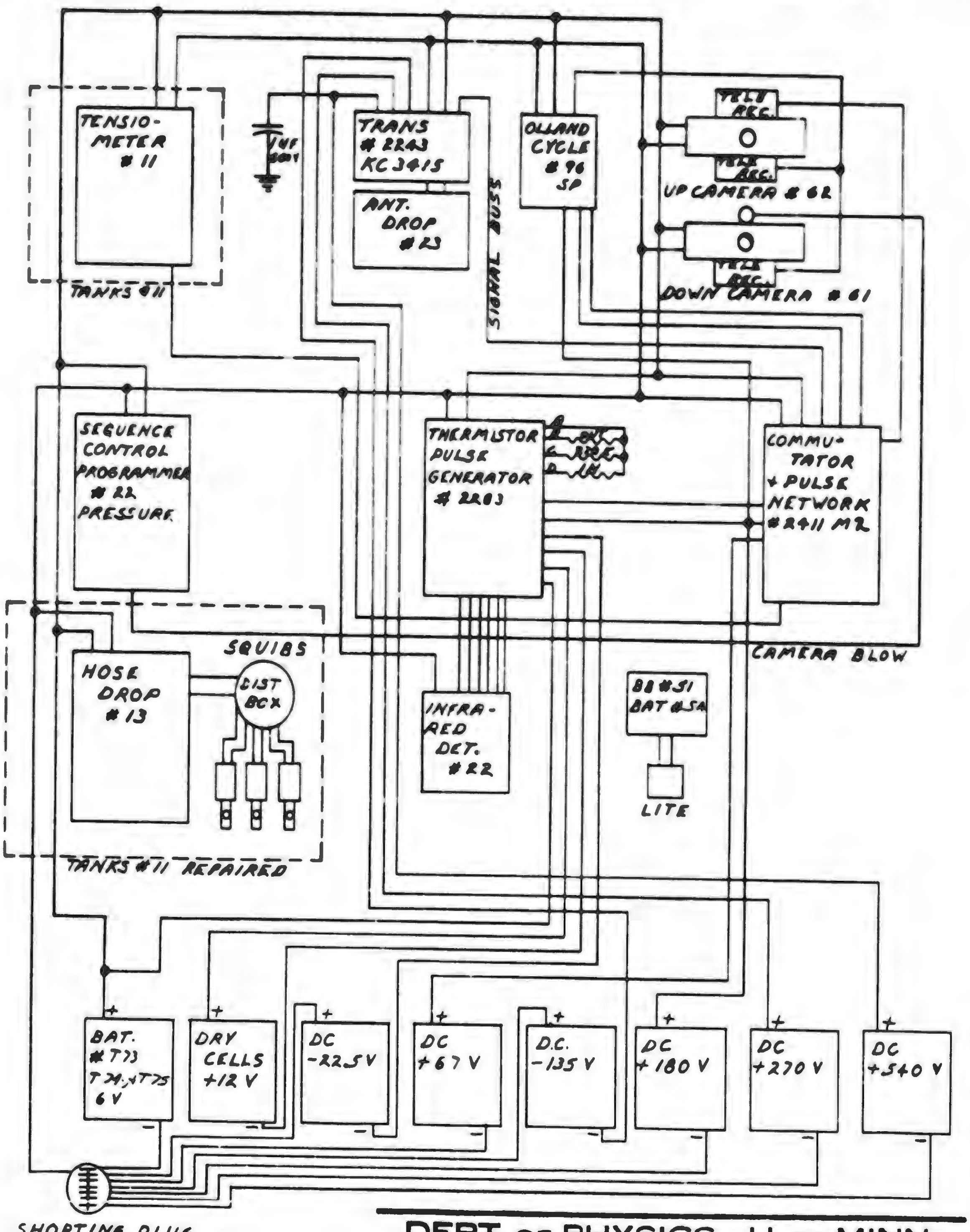
DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	7-24-53
FLIGHT # 95 GONDOLA # 212			MOD. 1	
			MOD. 2	
			MOD. 3	


EVEREADY
244
PRE
FLIGHT
186



DEPT. OF PHYSICS		U. OF MINN.		
BALLOON PROJECT		SECT. INST		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	7-31-53
FLIGHT # 86 GONDOLA # 55			MOD. 1	
			MOD. 2	
			MOD. 3	

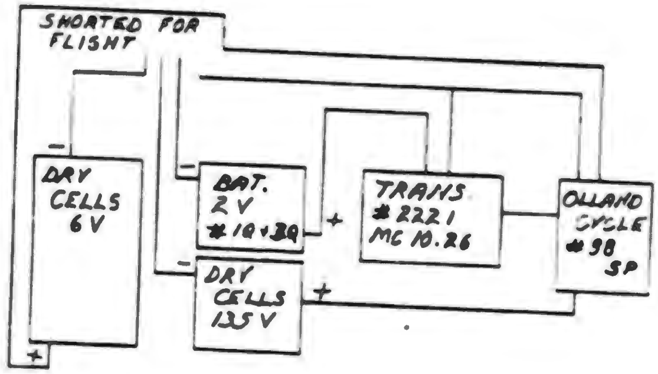

#2243
Modified.
PRE
FLIGHT
87



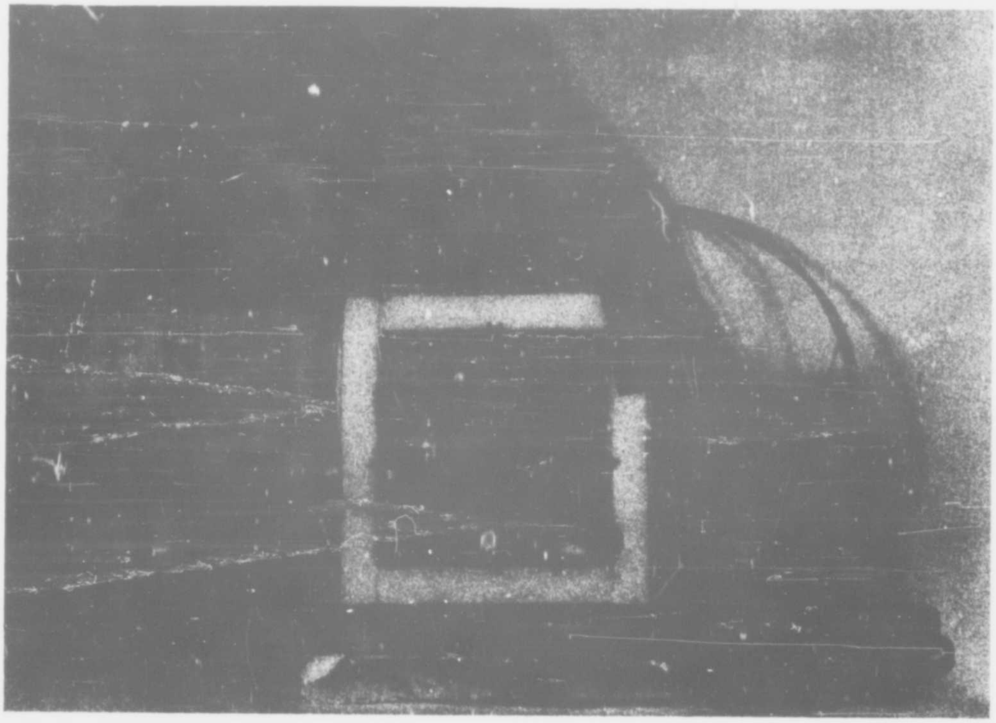
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST.

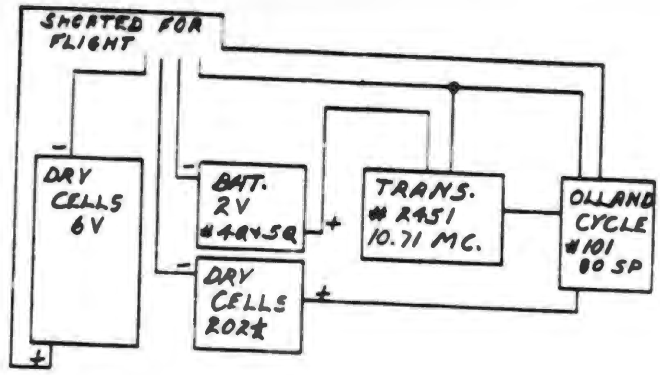
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				8-5-53
FLIGHT # 87 GONDOLA # 55			MOD. 1	
			MOD. 2	
			MOD. 3	


PRE
FLIGHT
8 8

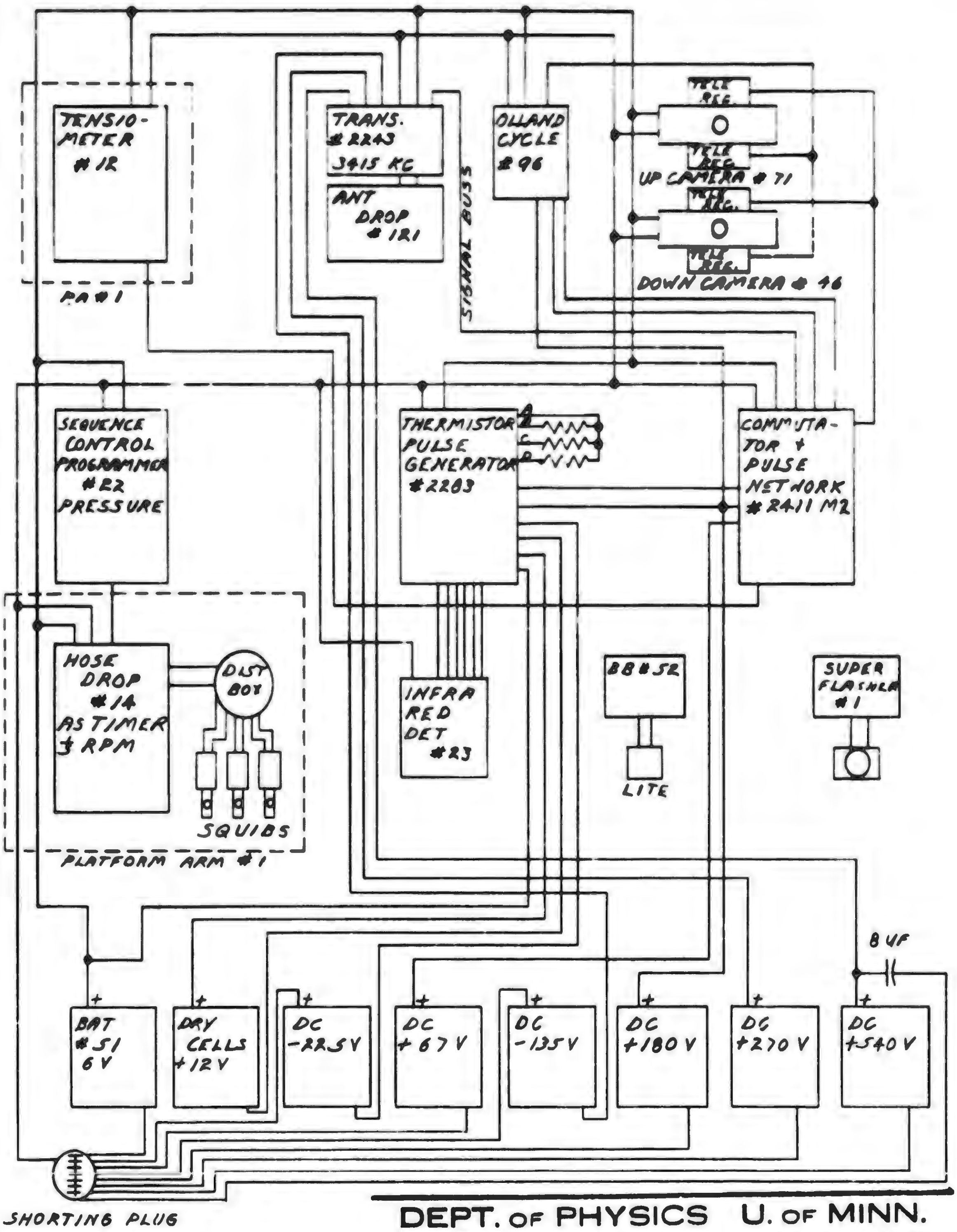


DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT SECT. INST				
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	8-6-53
FLIGHT #88 GONDOLA #213			MOD. 1	
			MOD. 2	
			MOD. 3	



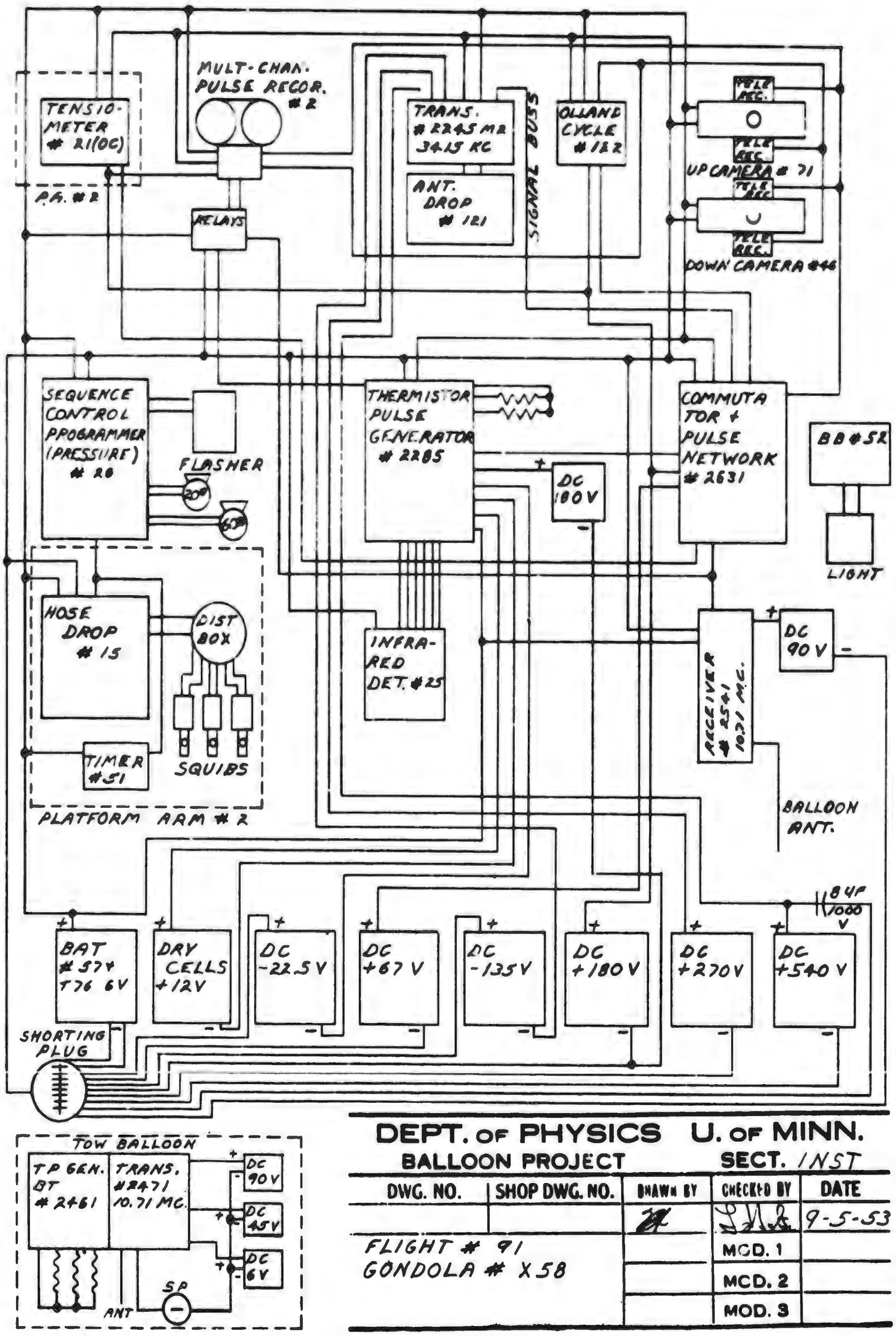


DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT		SECT. INST		
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	8-12-53
FLIGHT # 89 GONDOLA # 214			MOD. 1	
			MOD. 2	
			MOD. 3	

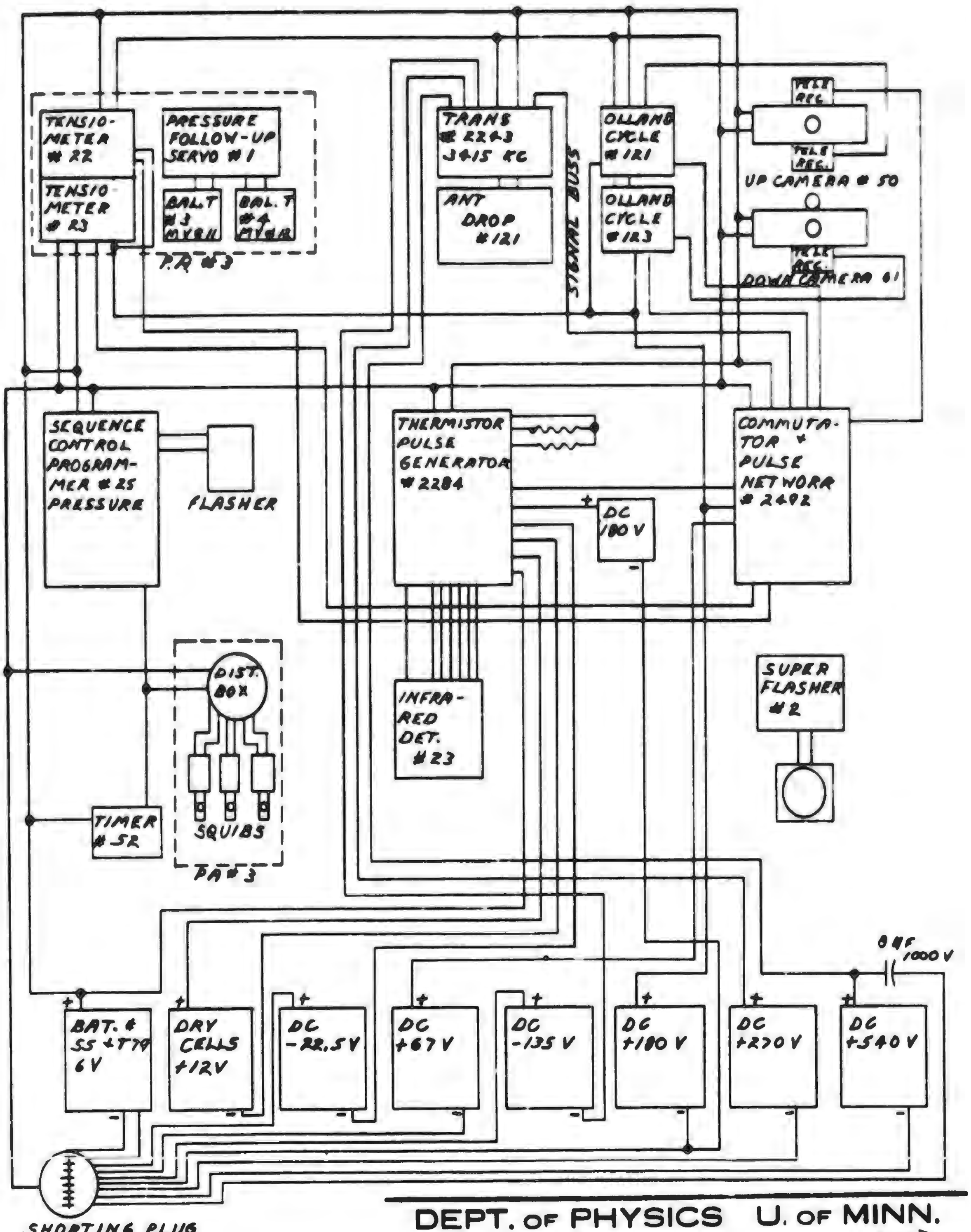


DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

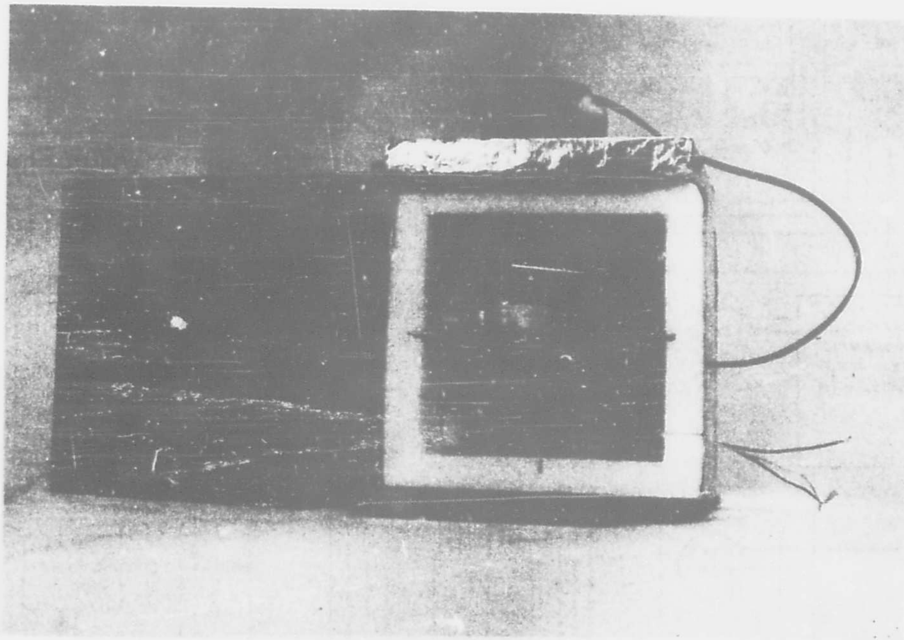
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				8-13-53
FLIGHT # 90 GONDOLA # 61			MOD. 1	
			MOD. 2	
			MOD. 3	

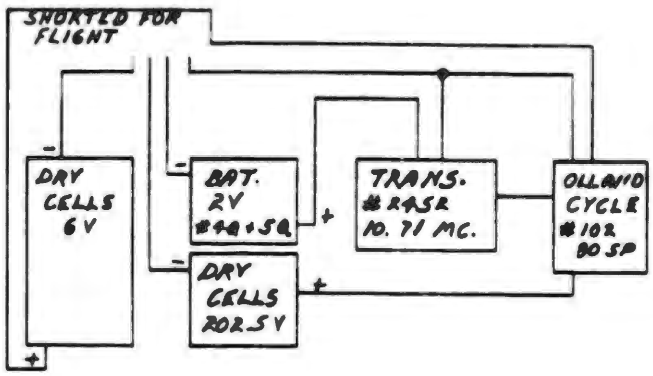

MULT-CHAN.
PULSE RECOR.
2
TENSIOMETER
21(OC)
P.G. # 2
RELAYS
TRANS.
2245 M2
34.15 KC
ANT.
DROP
121
SIGNAL BUSS
OLLAND
CYCLE
122
TELE REC.
UP CAMERA # 71
DOWN CAMERA #46
SEQUENCE
CONTROL
PROGRAMMER
(PRESSURE)
20
FLASHER
THERMISTOR
PULSE
GENERATOR
2285
DC
180 V
COMMUTATOR +
PULSE
NETWORK
2631
BB # 52
LIGHT
HOSE
DROP
15
DIST
BOX
TIMER
#51
SQUIBS
PLATFORM ARM # 2
INFRA-
RED
DET. # 25
RECEIVER
2541
10.71 MC.
DC
90 V
BALLOON
ANT.
8 µF
1000 V
BAT
574
T76 6V
DRY
CELLS
+12V
DC
-22.5 V
DC
+67 V
DC
-135 V
DC
+180 V
DC
+270 V
DC
+540 V
SHORTING
PLUG
TOW BALLOON
TP GEN.
BT
2461
TRANS.
#2471
10.71 MC.
DC
90V
DC
45V
DC
6V
SP
ANT
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
SECT. INST
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
9-5-53
FLIGHT # 91
GONDOLA # X58
MOD. 1
MOD. 2
MOD. 3


PRE
FLIGHT
92



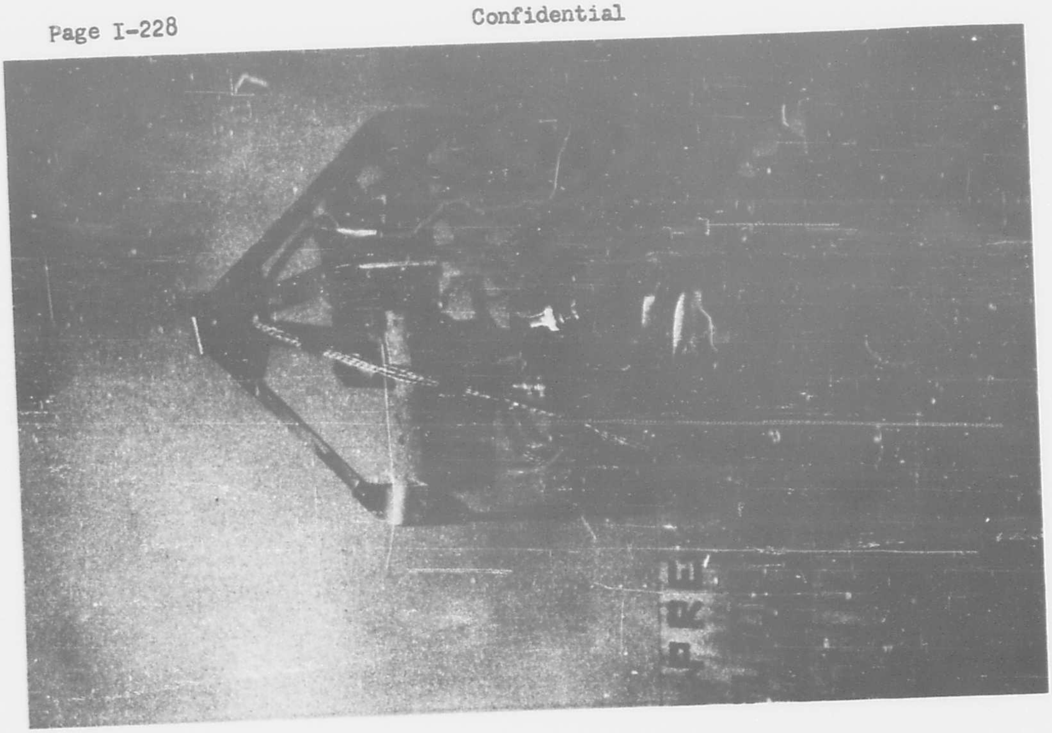
DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT			SECT. INST.	
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				9-16-53
			MOD. 1	
FLIGHT # 92 GONDOLA # 61			MOD. 2	
			MOD. 3	

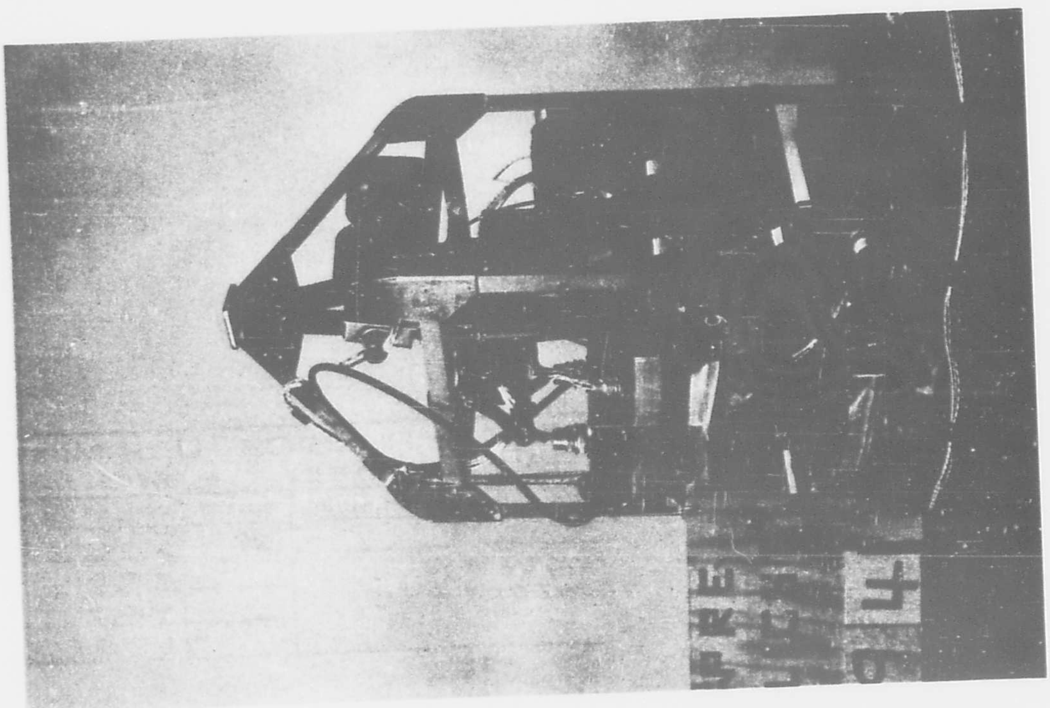


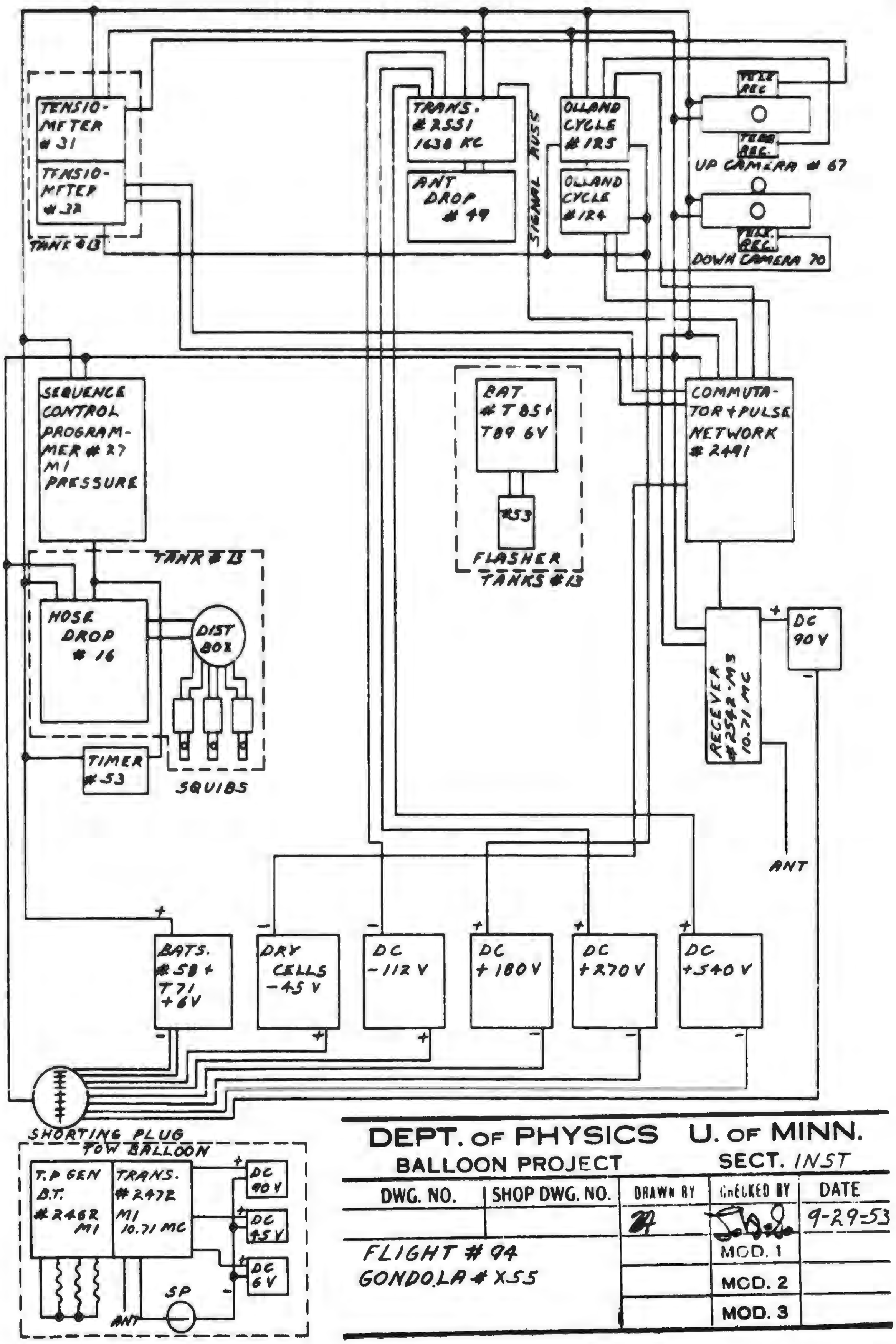


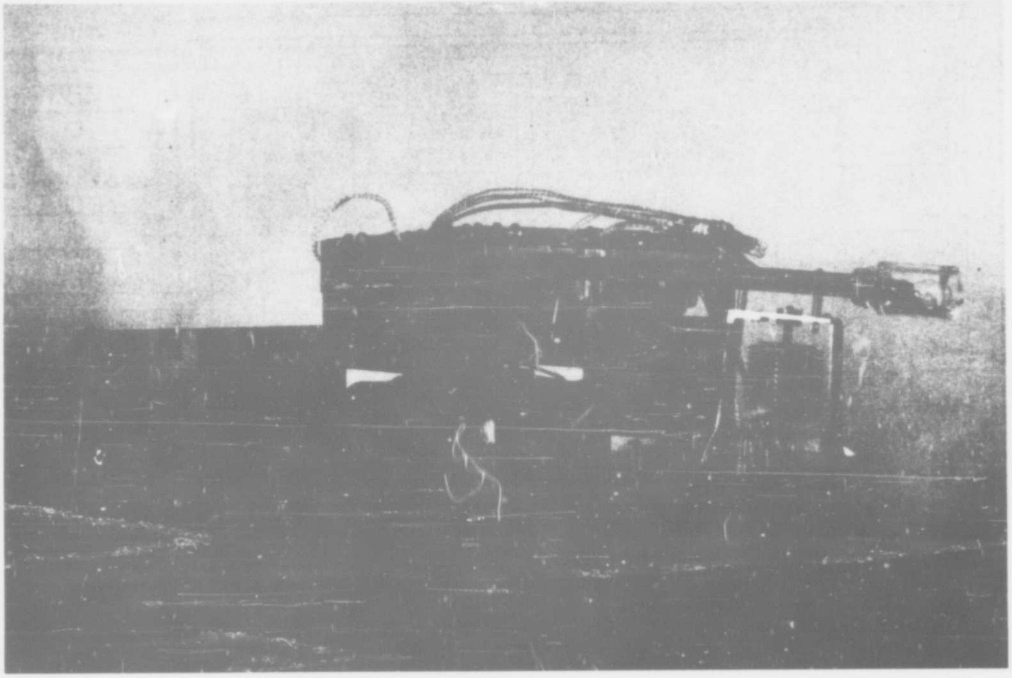
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

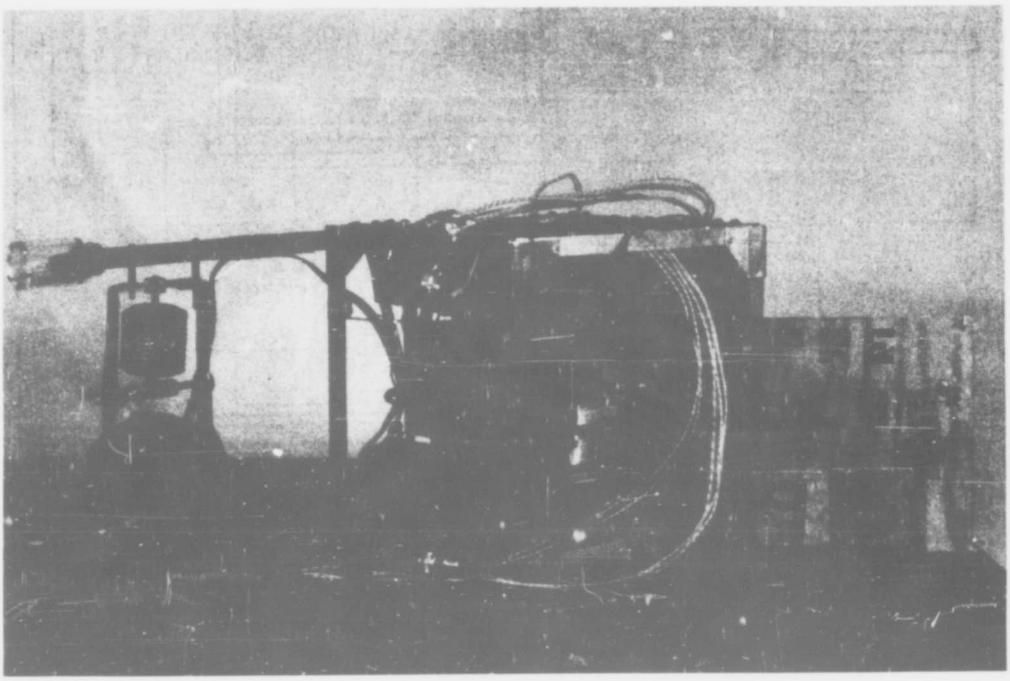
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				9-24-53
FLIGHT # 93 GONDOLA # 215			MOD. 1	
			MOD. 2	
			MOD. 3	

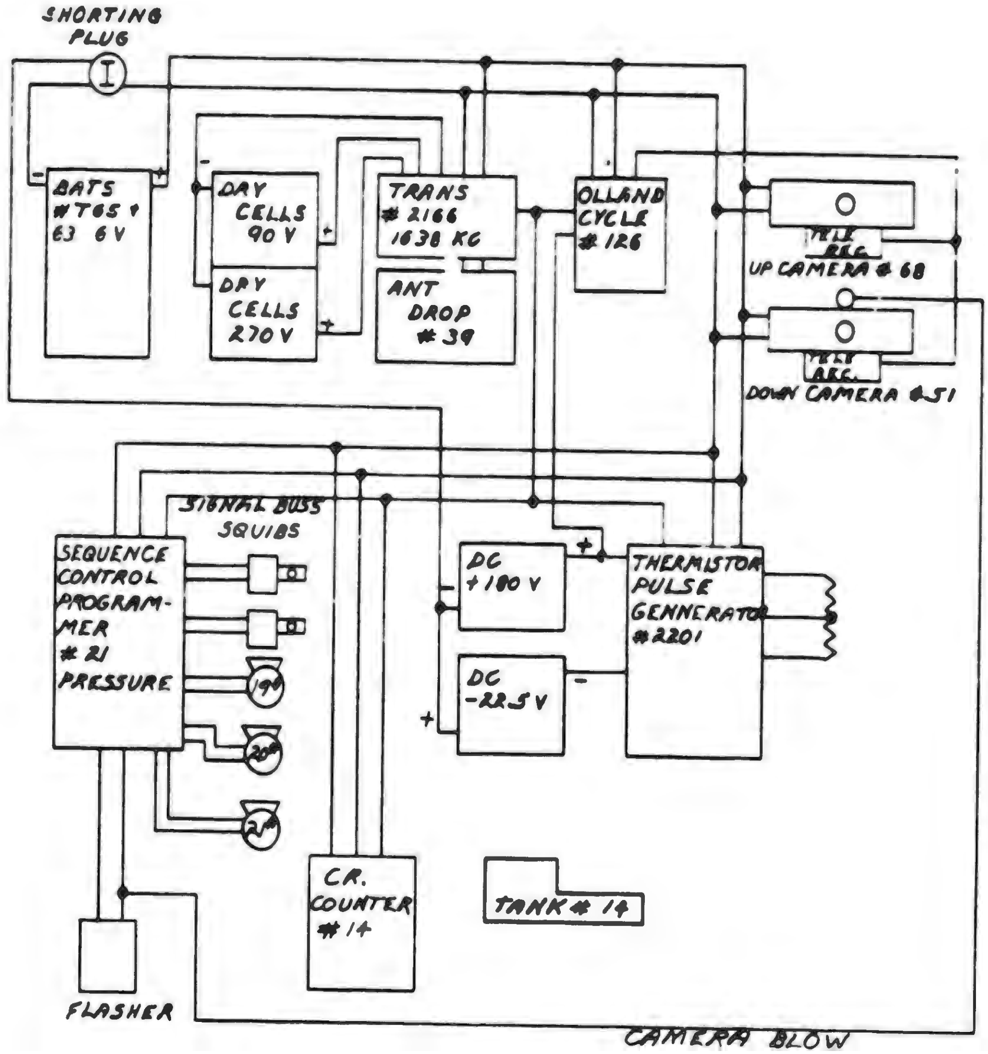





TENSIO-METER # 31
TENSIO-METER # 32
TANK # 13
TRANS. # 2551 1630 KC
ANT DROP # 49
SIGNAL BUSS
OLLAND CYCLE # 125
OLLAND CYCLE # 124
TELE. REC.
UP CAMERA # 67
DOWN CAMERA 70
SEQUENCE CONTROL PROGRAMMER # 27 MI PRESSURE
TANK # 13
HOSE DROP # 16
DIST BOX
TIMER # 53
SQUIBS
BAT # T 85 + T89 6V
53
FLASHER TANKS # 13
COMMUTATOR + PULSE NETWORK # 2491
RECEVER # 2542-M3 10.71 MC
DC 90 V
ANT
BATS. # 58 + T71 + 6V
DRY CELLS -45 V
DC -112 V
DC + 180 V
DC + 270 V
DC + 540 V
SHORTING PLUG
TOW BALLOON
T.P GEN B.T. # 2462 MI
TRANS. # 2472 MI 10.71 MC
DC 90 V
DC 45 V
DC 6 V
SP
ANT
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
9-29-53
MOD. 1
MOD. 2
MOD. 3
FLIGHT # 94
GONDOLA # X55

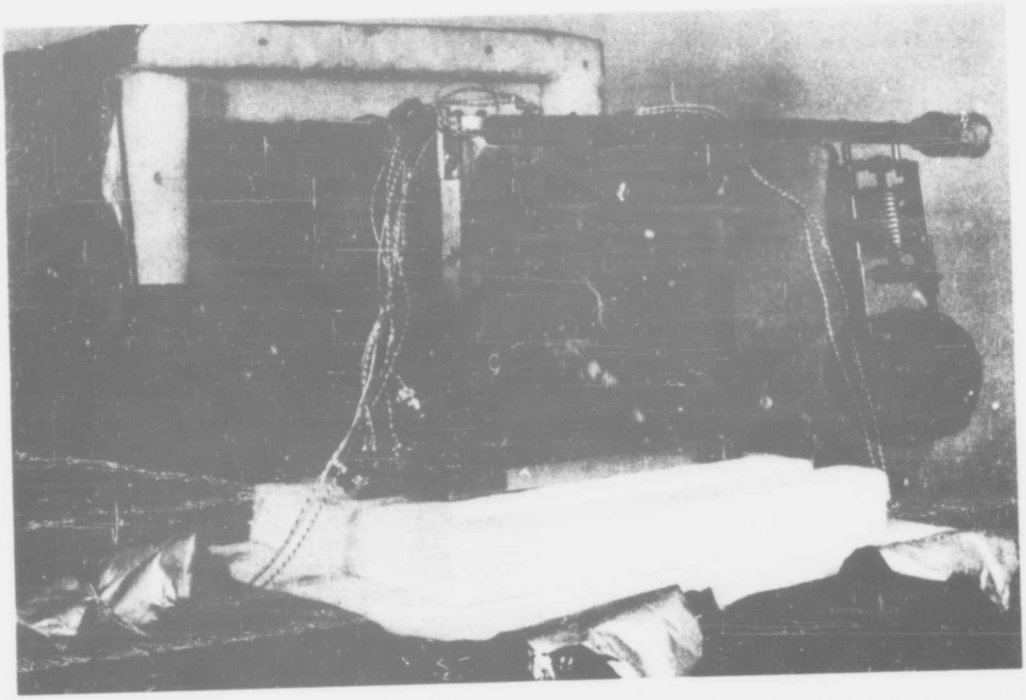


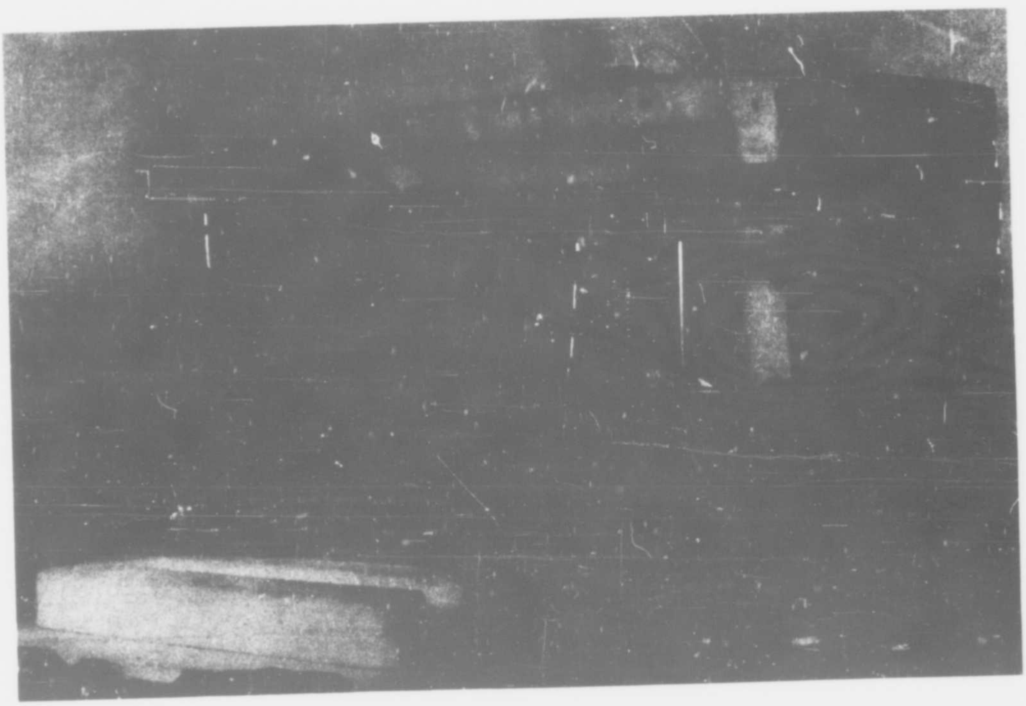


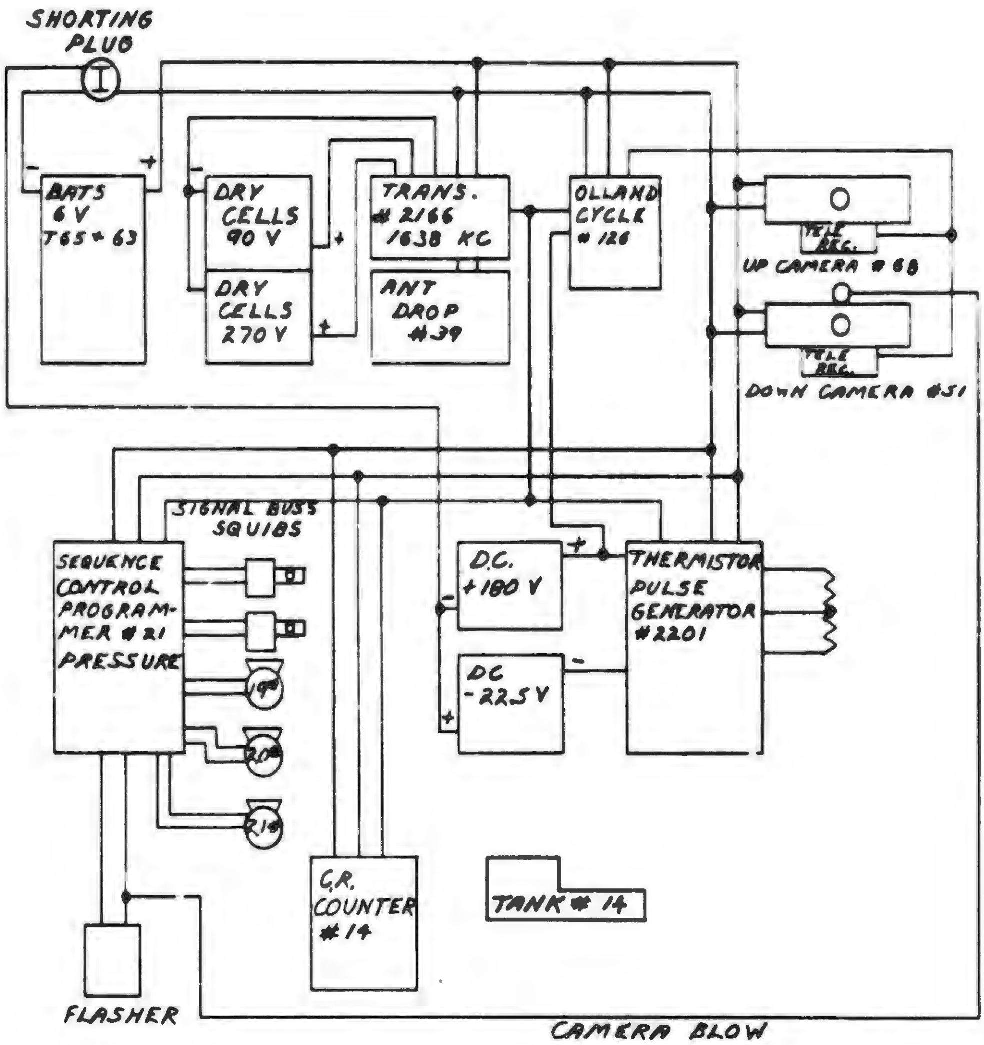


DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

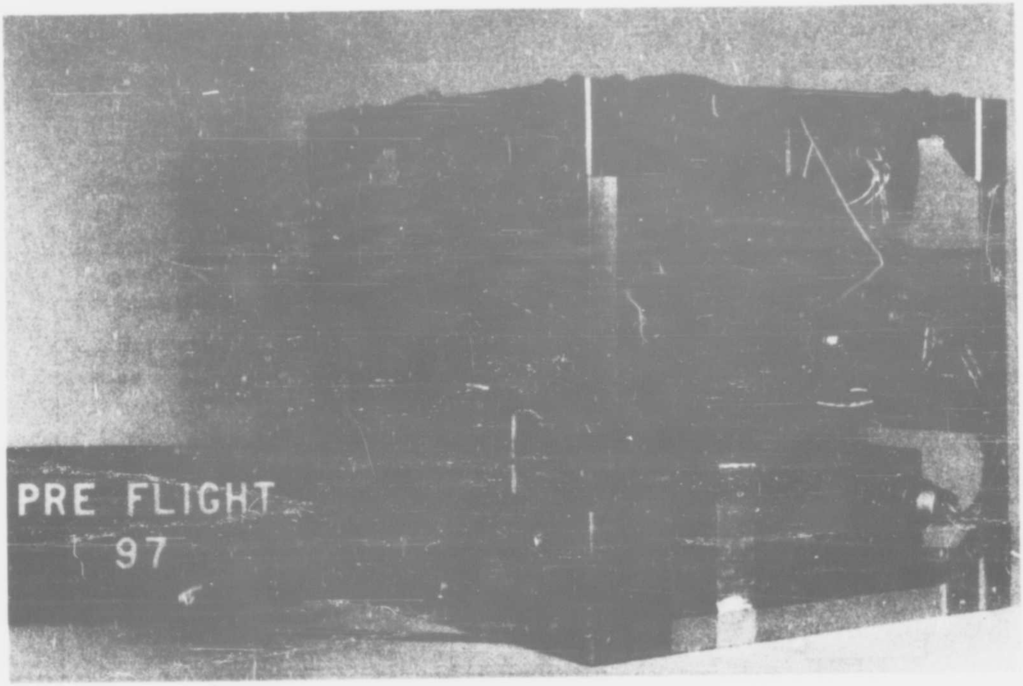
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
				10-2-53
FLIGHT # 95			MOD. 1	
GONDOLA # 194			MOD. 2	
			MOD. 3	

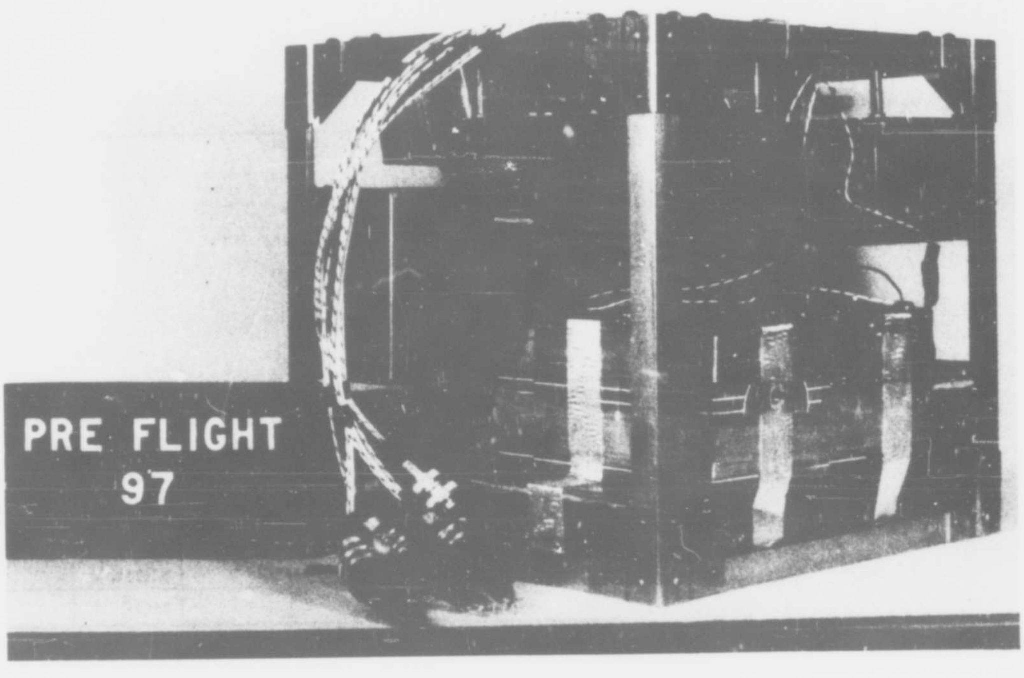


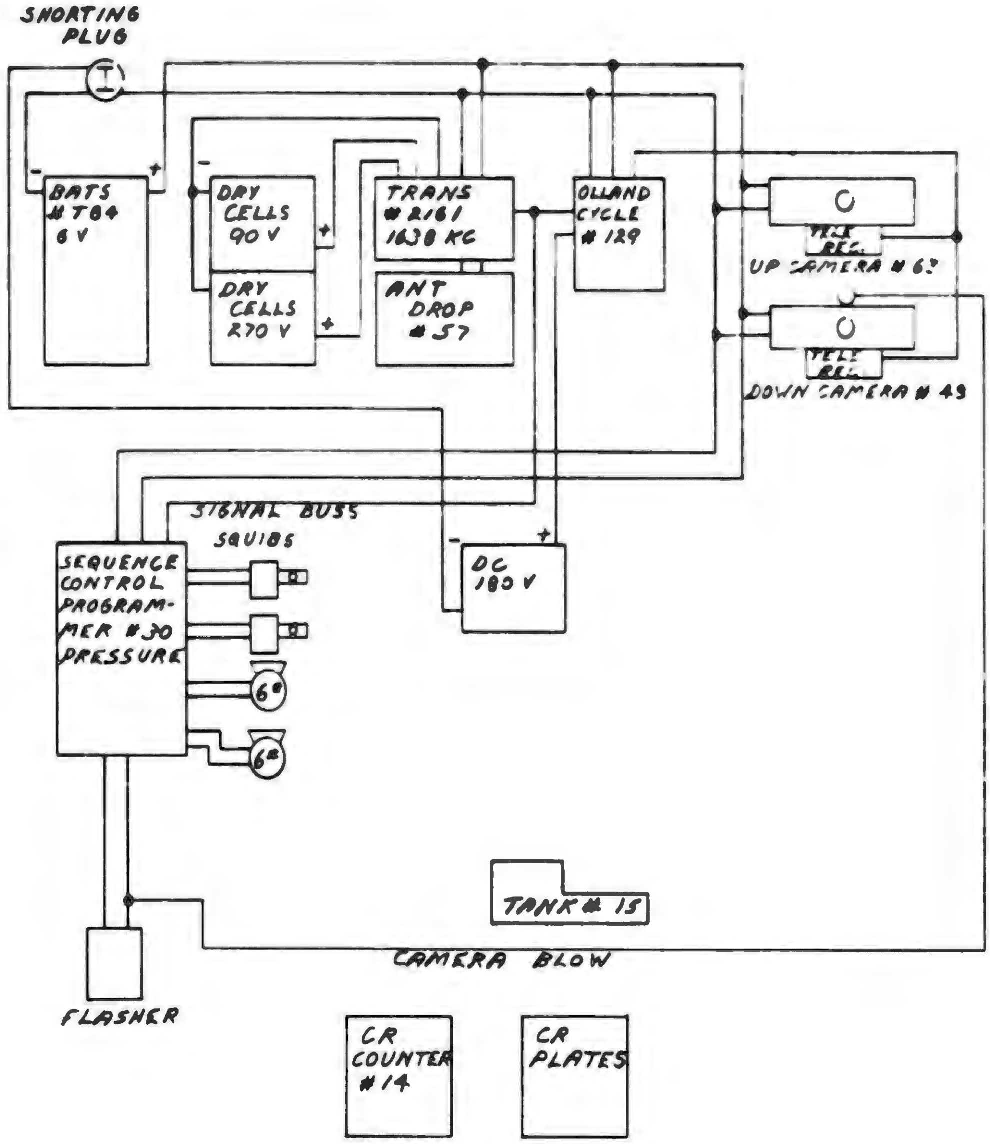




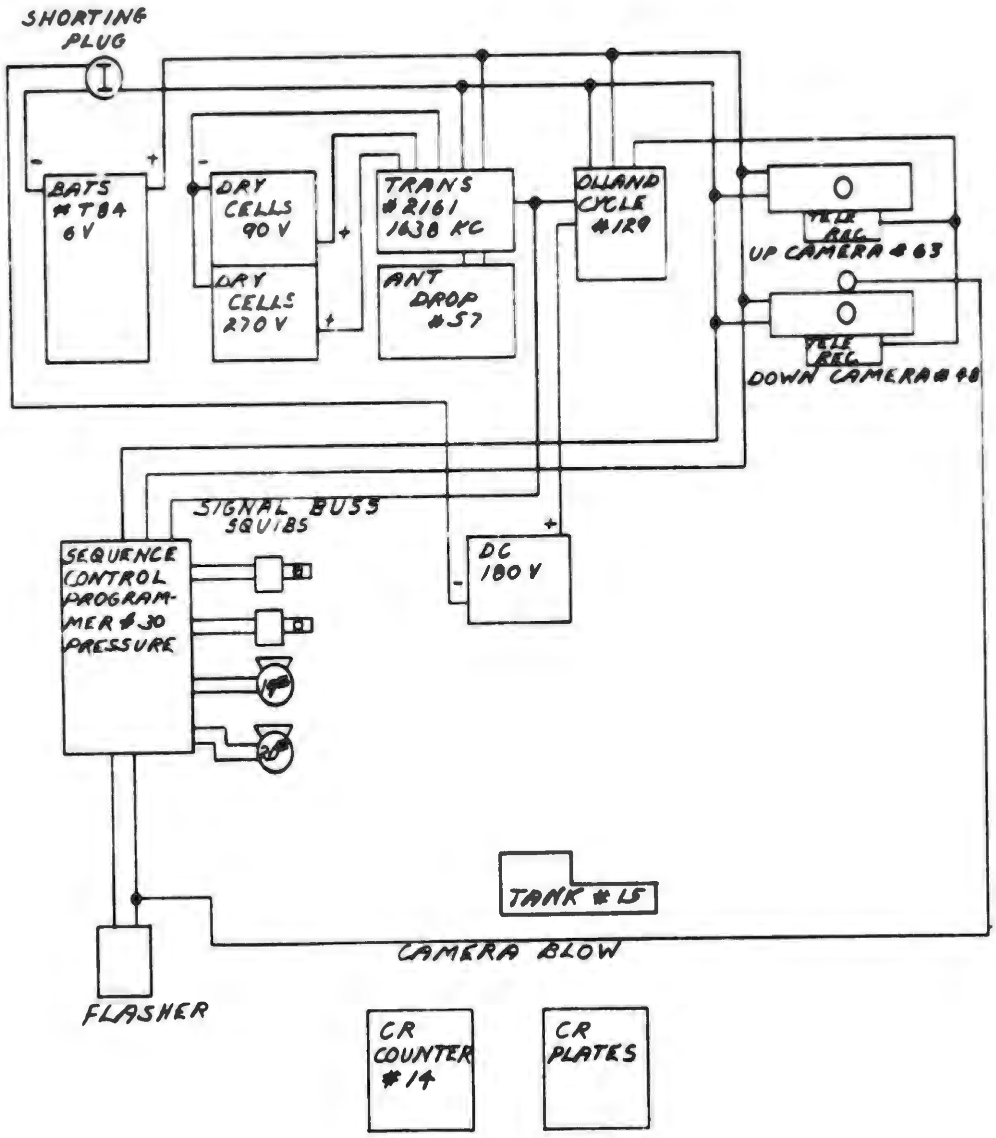
DEPT. OF PHYSICS U. OF MINN. BALLOON PROJECT SECT. INST				
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	10-8-53
FLIGHT # 96 GONDOLA # 194			MOD. 1	
			MOD. 2	
			MOD. 3	


PRE FLIGHT
97


PRE FLIGHT
97

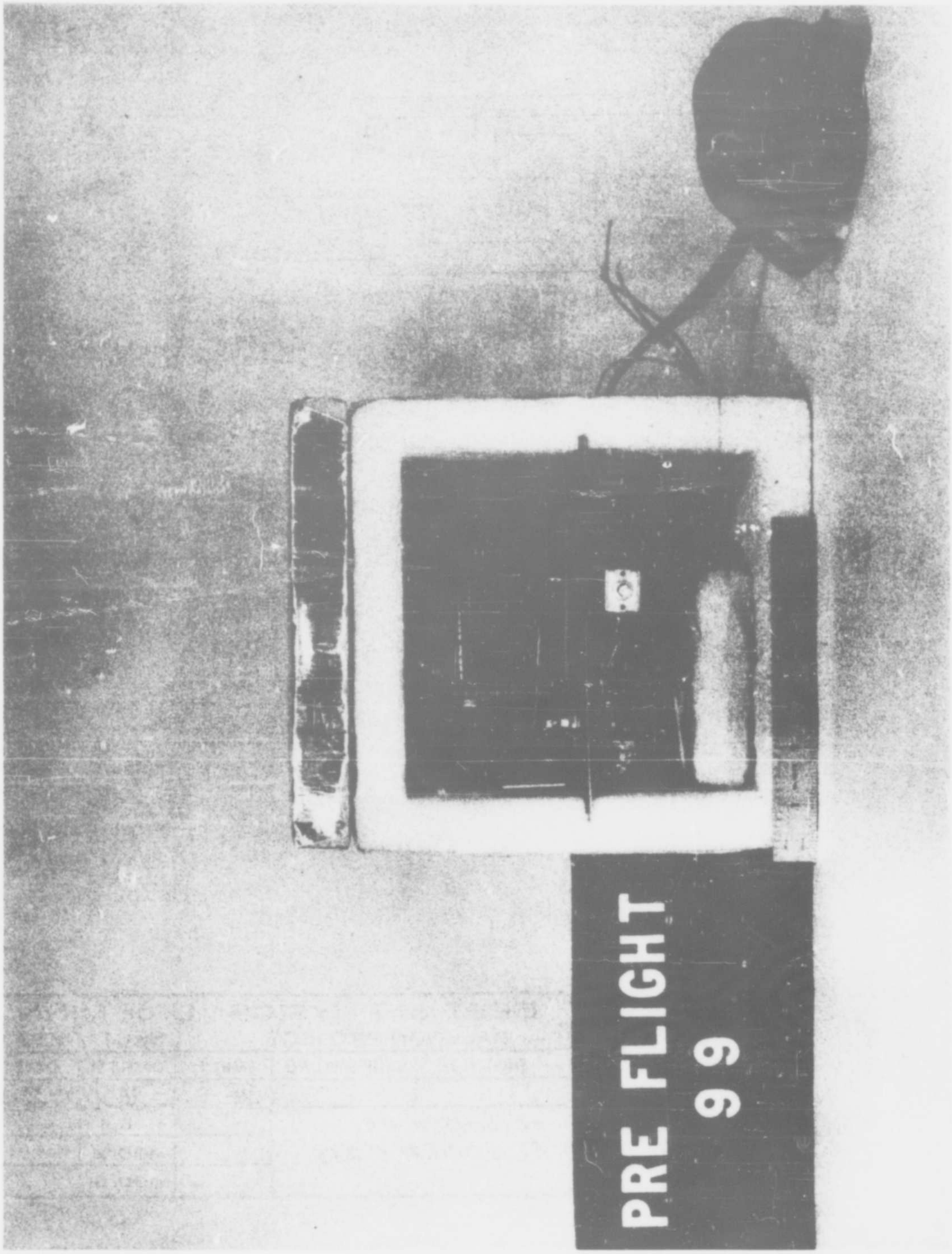


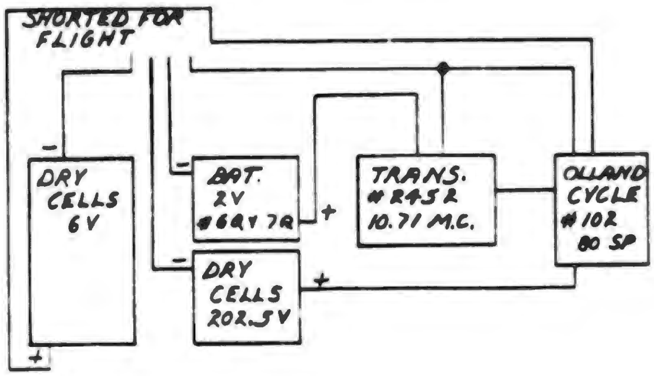
DEPT. OF PHYSICS		U. OF MINN.		
BALLOON PROJECT		SECT. INST		
DWG. NO.	SHOP DWG. NO	DRAWN BY	CHECKED BY	DATE
				10-10-53
FLIGHT # 97			MOD. 1	
GONDOLA # 195			MOD. 2	
			MOD. 3	



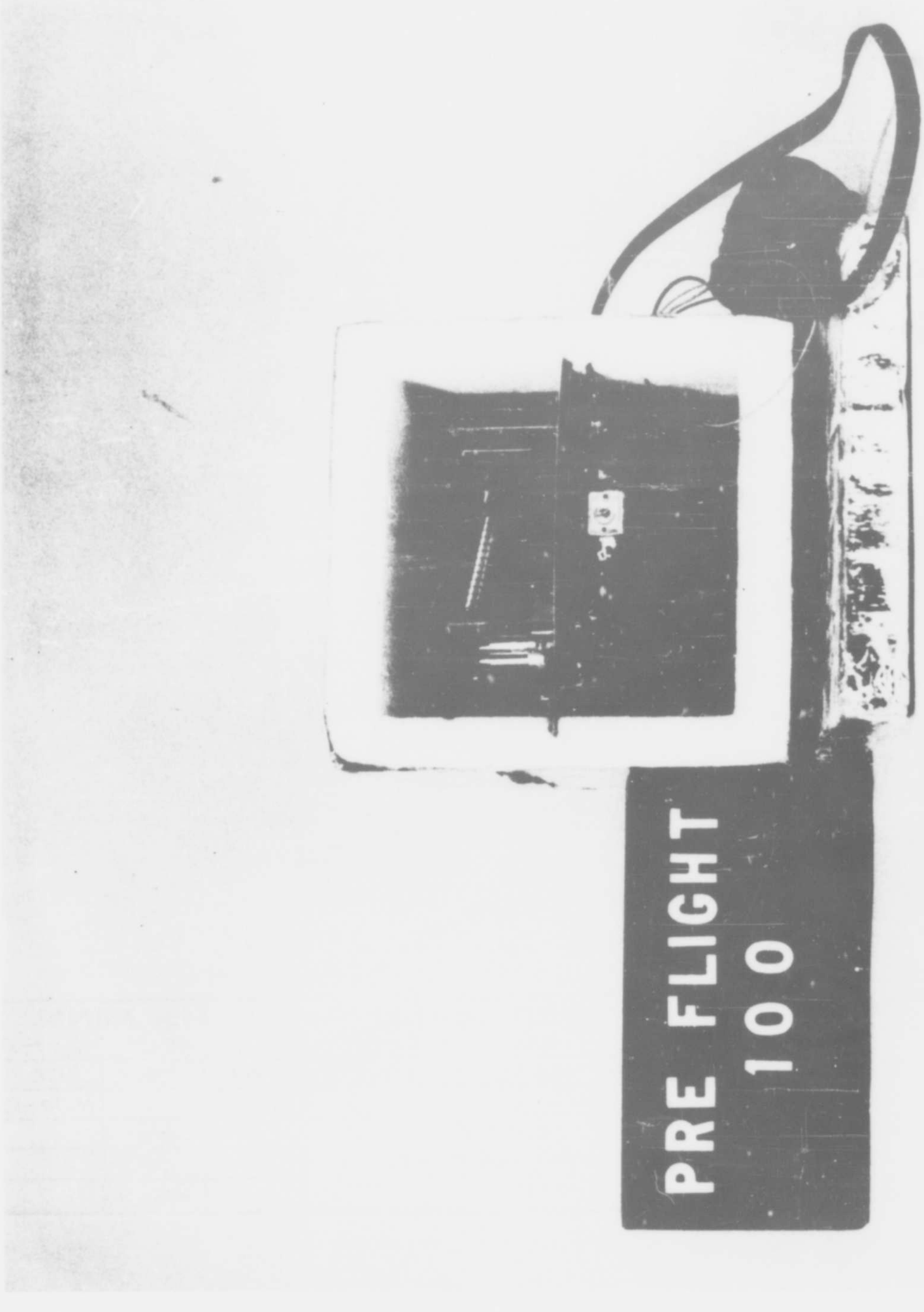
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. INST

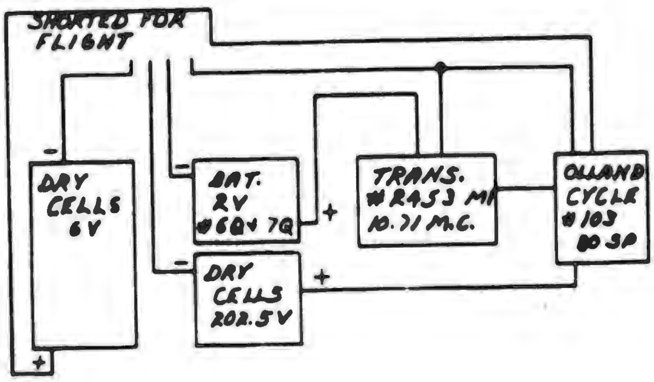
DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[signature]	[signature]	10-29-53
FLIGHT # 98 GONDOLA # 195			MOD. 1	
			MOD. 2	
			MOD. 3	


PRE FLIGHT
9 9



DEPT. OF PHYSICS BALLOON PROJECT		U. OF MINN. SECT. INST		
DWG. NO	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]	[illegible]	11-13-53
FLIGHT # 99 GONDOLA # 215			MOD. 1	
			MOD. 2	
			MOD. 3	


PRE FLIGHT
100



DEPT. OF [illegible] U. OF MINN.
BALLOON [illegible] SECT. INST.

DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
		[illegible]		11-30-53
FLIGHT # 100 GONDOLA # 217			MOD. 1	
			MOD. 2	
			MOD. 3	

Section II

TELEMETERING AND RADIO COMMUNICATIONS

A. Telemetering Encoding Systems

1. Primary Encoding

This encoding system was described in detail in a previous report.[1] Each item of data which is to be handled by the radio-telemetering apparatus is first encoded in this system by the appropriate transducer. The different encoding methods included in this system have in common an inherently narrow bandwidth, because of the relatively long time-constants involved, and also the feature of presenting the data in a pulse-interval type manner. One item of data, after being encoded in the primary system, may be used to directly regulate the keying of a CW radio transmitter in the balloon equipment or may be used to actuate one channel of the multiplex encoder, which is to be described in the succeeding section.

A special Olland Cycle transducer has been developed[2] and used in flights of this series for encoding data which can be reduced to a linear mechanical motion. The two types of data encoded by the Olland Cycle during this series were atmospheric pressure and tension in a cable (in connection with the step-flight program[3]).

The Olland Cycle transducer presents data in such a manner that the relative spacing between pulses contains the information . As may be seen in Figure II-1, there are two reference pulses (A,B) which are used to indicate the speed of rotation of the Olland Cycle rotor, one short pulse (D)

(1) PROGRESS REPORT ON HIGH ALTITUDE BALLOONS, Volume V, P. VIII-341.
(2) Ibid, p. VII-259-281, Volume V.
(3) Ibid, Volume IX, Section VI, Analysis of Step Flights

representing the single (or "slow") helix, and another longer pulse (C) which represents the multiturn (or "fast") helix and which is used for the high accuracy measurement of the data represented.

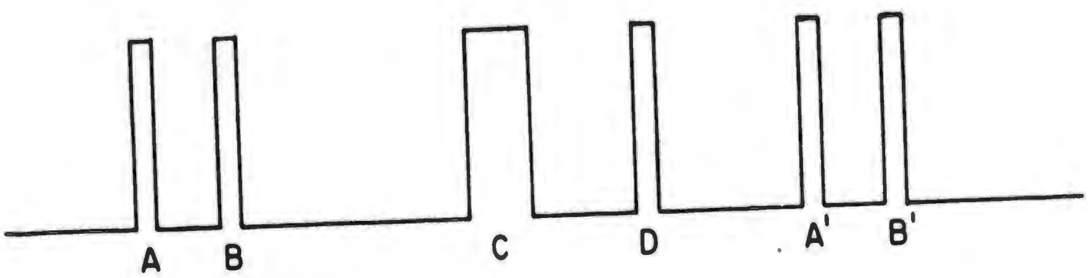


Figure II-1
Olland Cycle - Representative Pulse Spacings

The lengths, on a recorded strip, may be identified as follows:

a. A to A' or B to B' = reference length (R)
b. A to C = 1st "fast" helix length (F_1)
c. A to D = 1st "slow" helix length (S_1)
d. B to C = 2nd "fast" helix length (F_2)
e. B to D = 2nd "slow" helix length (S_2)
f. A to B = reference spacing (D)

If the reference length (R) is considered to be one cycle, or 360°, then the relative spacing of the other pulses may be represented by an angular displacement from the reference pulse (A), so that

$$\theta_F = F_1 \times 360/R = (F_2 - D) \times 360^\circ/R \qquad (1$$

and

$$\theta_S = S_1 \times 360/R = S_2 \quad D \times 360^\circ/R \qquad (2$$

where θ_F = "fast" helix phase angle, and

θ_S = "slow" helix phase angle.

An instrument employing the principle of similar triangles was developed[4] and its use makes it unnecessary to go through the above procedure for evaluating the data represented.

A special encoder[5] of the same general type as the Olland Cycle was used for tension measurement in six of the eight step flights[3] of this series. This encoder produced a single-reference pulse and a single, movable information pulse per complete cycle. The information accuracy inherent in this system was found to be insufficient and the Olland Cycle transducer was used on the last two step flights of the series to attain the desired accuracy in the telemetered tension data.

A special instrument was developed for the encoding of temperature data as represented by the resistance value of thermistors. The instrument and its application are described more fully elsewhere in this volume[6]. In essence, the encoding consists of presenting the value of ohmic resistance of a thermistor or standard resistor by the spacing between signal pulses. These pulses are of approximately one-second duration.

In two flights of the series (91 and 94), primary encoded temperature information was telemetered from the top balloon to the main gondola which was located below the lower balloon[3]. The radio link consisted of a 10.710 mc transmitter in the tow balloon and a receiver located in the lower gondola. The receiver used in Flight 91 lacked sufficient sensitivity and the telemetering of this data was unsuccessful. However, an improved receiver used on Flight 94 gave satisfactory results.

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(4) Ibid, Volume X, p. I-154.
(5) Ibid, Volume X, p. I-101.
(6) Ibid, Volume X, Section I, Temperature Instrumentation.

2. Secondary Multiplex Encoding

In cases where more than one data channel is required, a second encoding system is used before transmission of the data. This system was developed in anticipation of flights where two or more data channels were necessary for the flight analysis. The main factors considered in the development of this system were:

(a) Low band width requirement,

(b) low duty cycle,

(c) adequately high multiplexing rate,

(d) flexibility of channel number, and

(e) simplicity of encoding equipment.

Factors (a) and (b) are necessary to consider in the interests of low peak and average transmitter power requirements. The multiplexing rate (c) must be chosen so that the time between samples in each channel is less than the minimum significant time involved in the primary data encoding.

The multiplexing system developed for use in these flights meets all of the above requirements. The maximum required bandwidth is not greater than 1000 c/sec and the duty cycle has a maximum of 15%. The multiplexing rate chosen is 15 samples per second on each channel. This is high enough so that the data accuracy is not deteriorated and, at the same time, is low enough so that a mechanical commutating system[7] may be used.

In this system, a pulse of 3-millisec duration is emitted at a regular rate (approx. 15/sec). This pulse provides a reference time for identification of the data channel pulses and a reference rate for synchronizing any

(7) Ibid, Volume X, p. I-75, Encoders.

decoding equipment which may be used in the analysis of the signal. As all of the data to be handled is previously encoded in a two-state (off and on) system, each channel is assigned a certain location in time, with respect to the reference pulse, and a pulse of one millisec duration appears in this location when the corresponding channel is in the "on" condition. An oscilloscope display of the signal form may be seen in Figure II-2.

Channel sampling, in this system, is accomplished by a motor-driven magnetic commutator which is described in detail elsewhere in this report[7]. In this system several iron-core coils are located, with proper spacing, in a radial pattern and a permanent magnet is moved through the air gap of each coil in turn, thus inducing current in the coil. If the data channel associated with a certain coil is in the "on" condition as the current is induced, a resulting keying-pulse actuates the telemetering transmitter for the proper one-millisec interval. This commutator has the virtue of simplicity and low power consumption.

A thirty-contact rotating switch[8] was first used in this system. It did not prove to be satisfactory, as the speed of rotation was not sufficiently constant for use in this system.

The magnetic commutator, in use at present, shows a certain degree of instability but with careful selection and ageing, satisfactory operation of these units may be obtained.

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(8) Manufactured by the Applied Science Corp. of Princeton, Princeton, N.J.

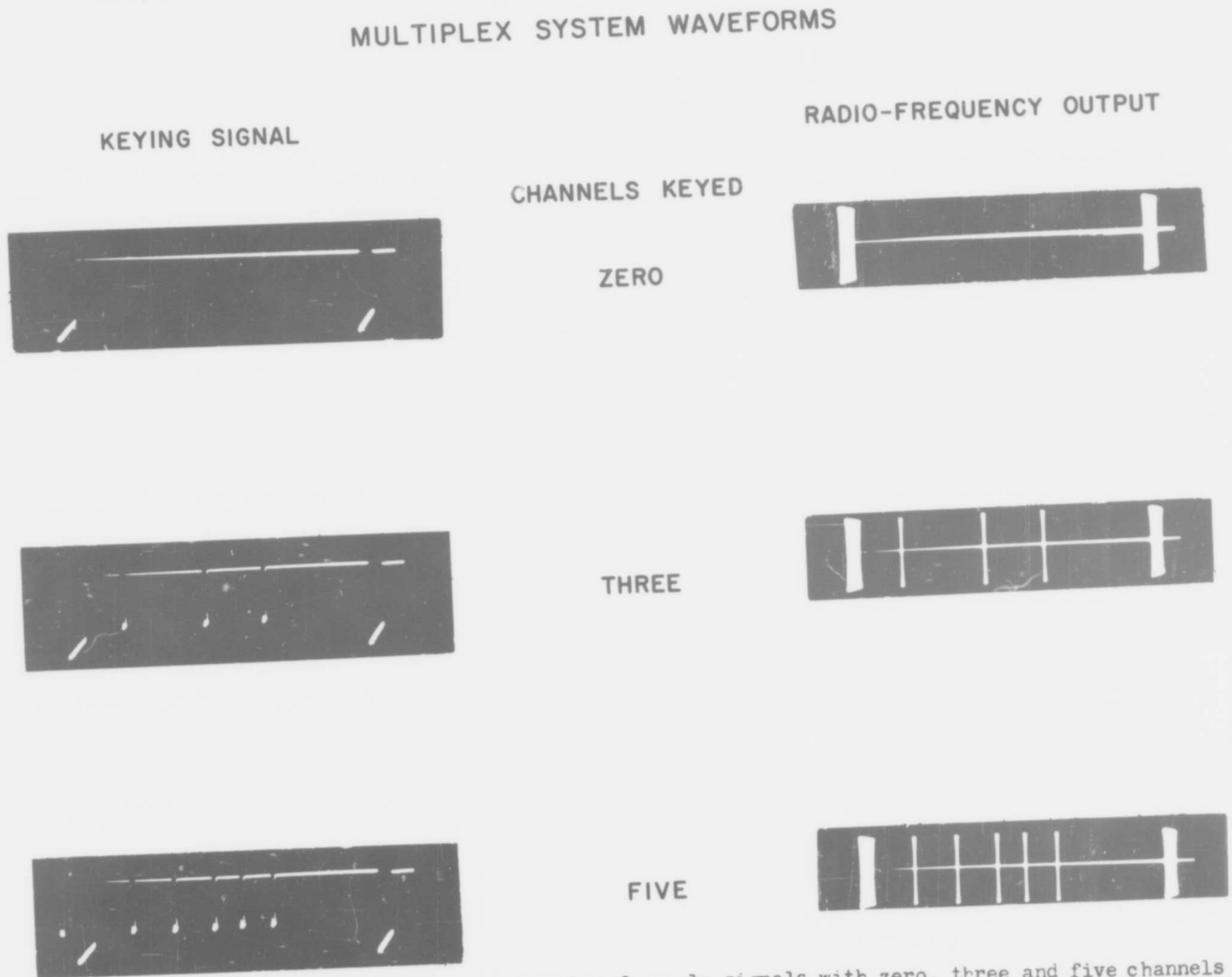


Fig. II-2. Multiplex encoding. Photographs of sample signals with zero, three and five channels activated. The keying signal is that which appears at the grid (pin 7) of the 12A47 in transmitter 32TPE-224 (Fig. II-11a). The R.F. output signal shown is developed across a 72 Ω dummy antenna.

An electronic pulse generator and sampler is being developed and is ready for production for flights. This equipment is more complex and requires a heavier power supply than the mechanical commutator, but produces a signal with an accurately stable repetition rate.

The multiplex encoding system has been used on 11 flights of this series. Use of this encoding system has shown that it is satisfactory for telemetering the data associated with balloon performance, such as air pressure, weight or tension, temperature, and event information.

B. Flight Equipment

1. Transmitters

Several types of transmitters were developed and used in this series of flights. In general, the transmitters used for telemetering primary encoded data are keyed by relays, and those developed for use with the multiplex system are keyed by electron-tube circuits. A series of transmitters, for use with primary encoding, working in the medium frequency range (1638, 1676, 1724 or 1746 KC), were used. The first type (Figure II-3) utilized filament type tubes and was keyed off by reducing the screen potential on the final amplifier. A second type (Figure II-4), with filament tubes and B-minus keying, was then developed to reduce the power supply requirements. The third model (Figure II-5, a,b,c,d), with filament tubes, was designed to reduce the A-supply drain by operating the filaments of the tubes in a series arrangement. This transmitter was used on 13 flights of the series. Another transmitter, with cathode-type tubes, (Figure II-6), was developed for increased reliability, but the A-supply drain was increased

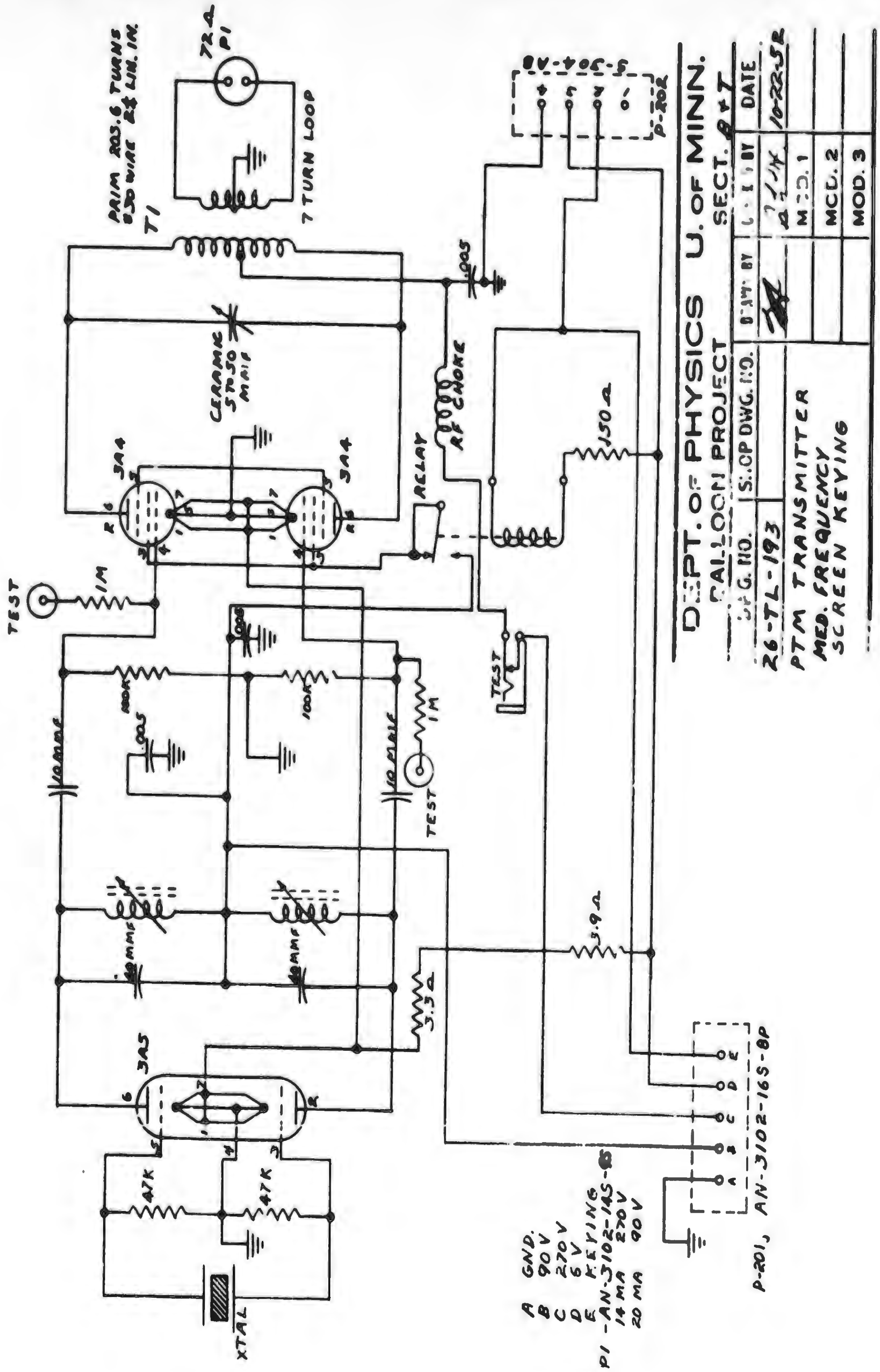

PRIM 203.6 TURNS #30 WIRE 2¼ LIN. IN.
T1
7 TURN LOOP
72 Ω
P1
S-504-AB
P-202
.005
RF CHOKE
CERAMIC 5 TO 50 MMF
3A4
3A4
RELAY
150 Ω
TEST
1M
.005
100K
100K
10 MMF
10 MMF
TEST
1M
TEST
3.9 Ω
3.3 Ω
3A5
47K
47K
XTAL
A GND.
B 90V
C 270V
D 6V
E KEYING
P1 - AN-3102-14S-
14 MA 270V
20 MA 90V
P-201, AN-3102-16S-8P
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
SECT. B+T
DWG. NO.
26-TL-193
PTM TRANSMITTER
MED. FREQUENCY
SCREEN KEYING
DATE
10-22-52
MOD. 1
MOD. 2
MOD. 3

Fig. II-3.

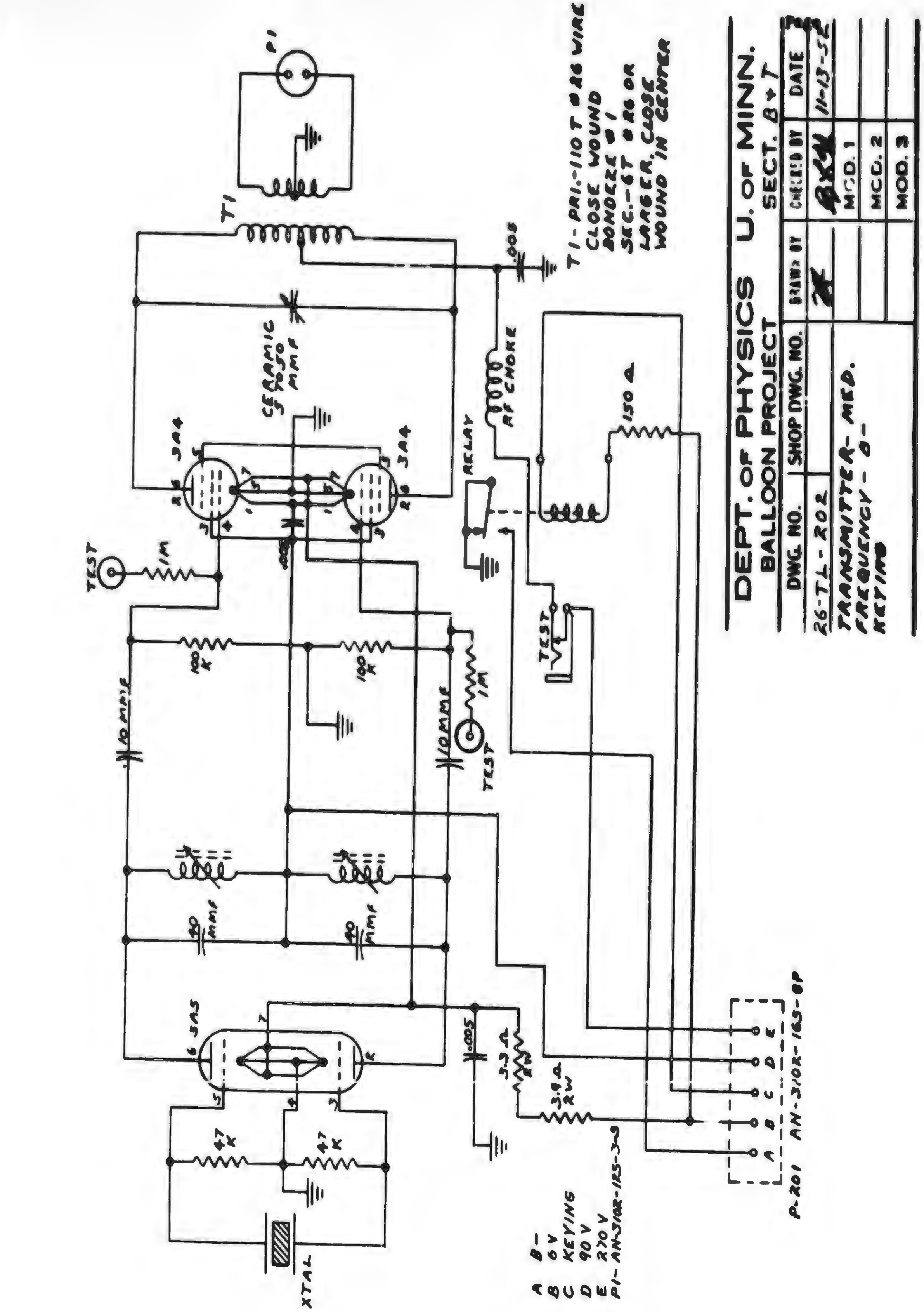

T1
P1
T1 - PRI.-110 T #26 WIRE CLOSE WOUND BONDEZE #1 SEC.-6 T #26 OR LARGER, CLOSE WOUND IN CENTER
.005
CERAMIC 5 TO 50 MMF
RF CHOKE
RELAY
150 Ω
3A4
3A4
TEST
1M
100 K
100 K
10 MMF
10 MMF
TEST
1M
TEST
.005
MMF
MMF
3A5
.005
3.3 Ω 2W
3.3 Ω 2W
4.7 K
4.7 K
XTAL
A B-
B 6 V
C KEYING
D 90 V
E 270 V
P1 - AN-3102-12S-3-S
P-201 AN-3102-16S-8P
DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B + T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
26-TL-202
11-13-52
TRANSMITTER - MED. FREQUENCY - B- KEYING
MOD. 1
MOD. 2
MOD. 3

Fig. II-4.

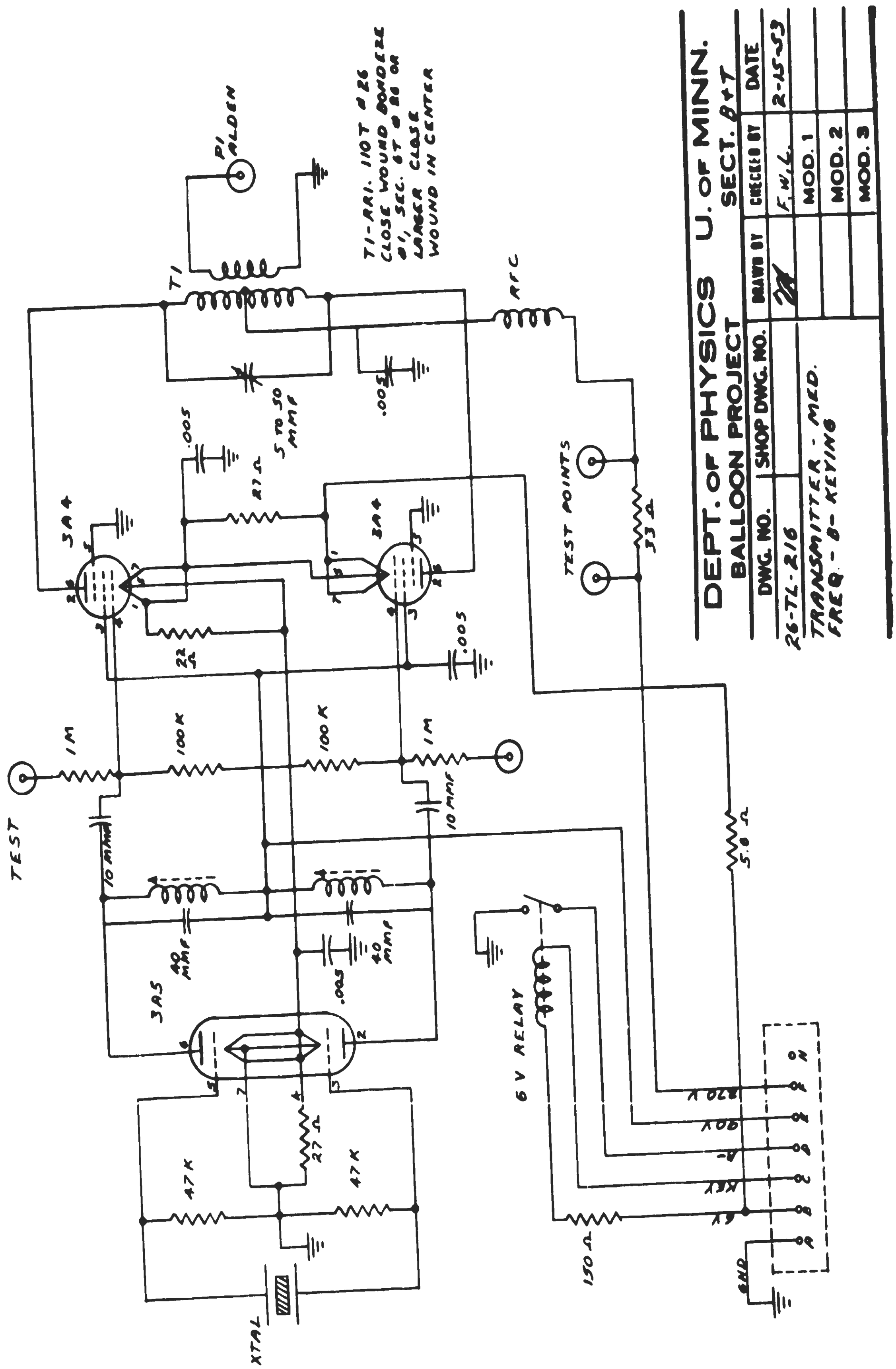

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B+T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
26-TL-216
F.W.L.
2-15-53
MOD. 1
MOD. 2
MOD. 3
TRANSMITTER - MED. FREQ - B- KEYING
TEST POINTS
TEST
XTAL
6 V RELAY
RFC
3A4
3A5
GND

Fig. II-5a.

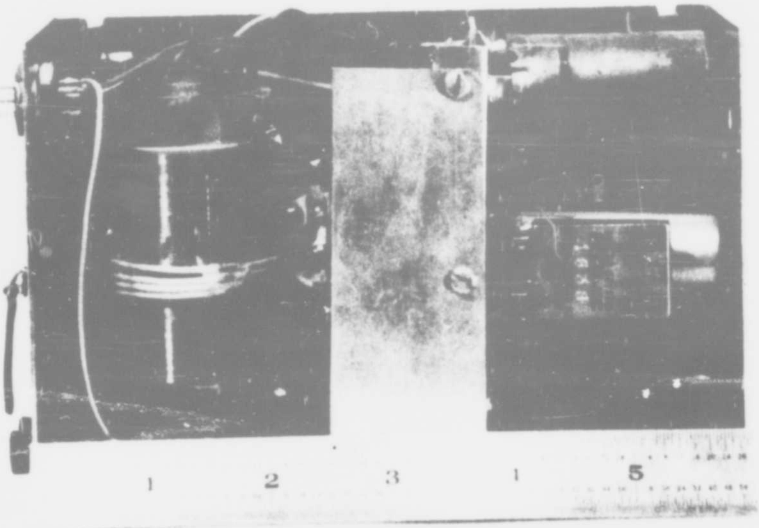


Fig. II-5b. Transmitter - Medium Frequency.
B-Key, End view, cover off. Final tank coil upper center.

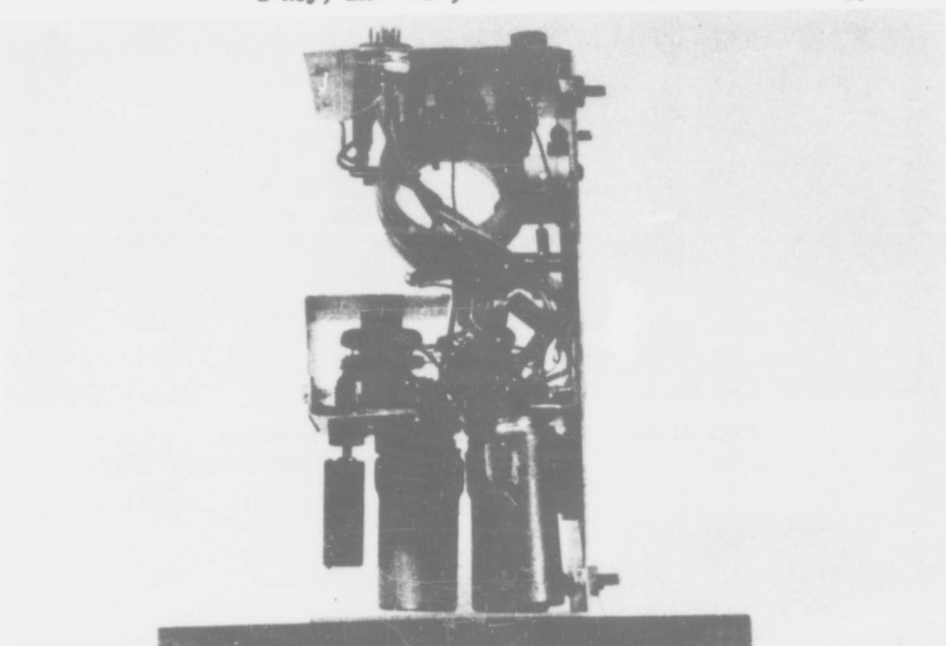


Fig. II-5c. Transmitter - Medium Frequency.
B-Key. Side view, cover off.

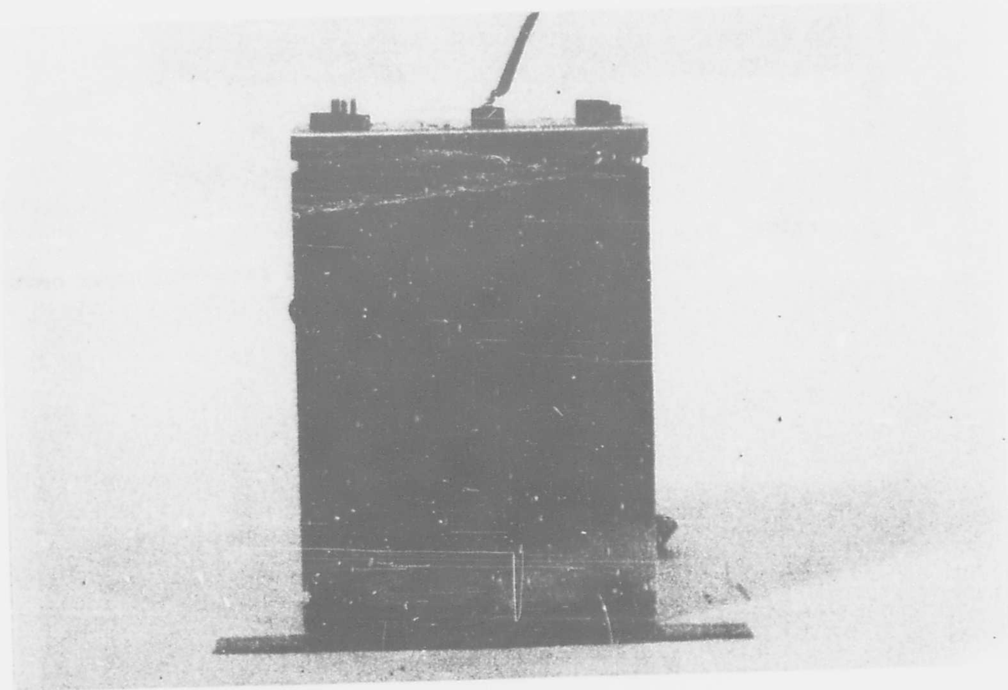


Fig. II-5d. Transmitter, Medium Frequency, B-key. Side view, cover on.

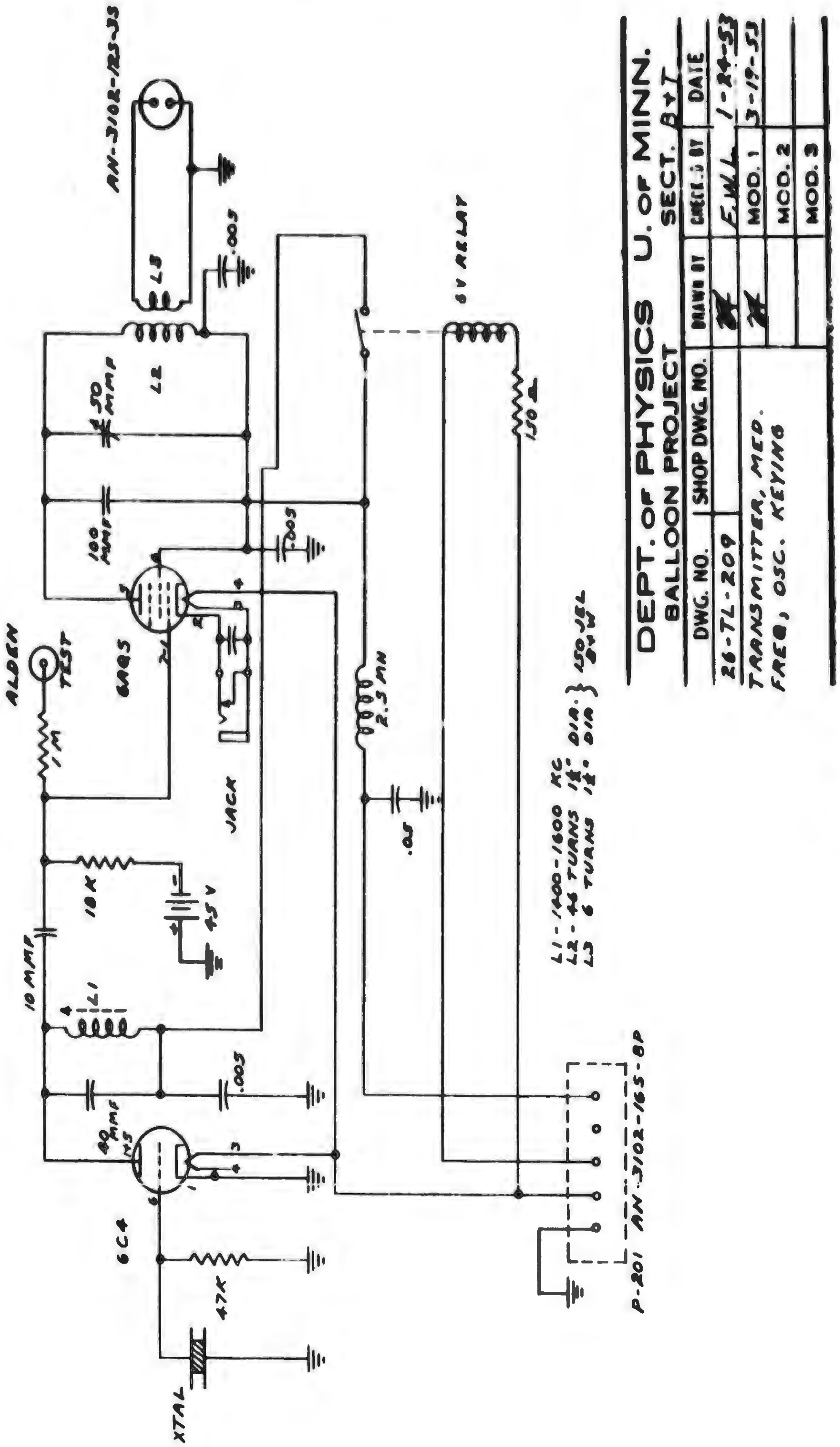

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B+T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
26-TL-209
E.W.L.
1-24-53
3-19-53
MOD. 1
MOD. 2
MOD. 3
TRANSMITTER, MED. FREQ., OSC. KEYING
AN-3102-12S-3S
.005
6V RELAY
L3
L2
50 MMF
150 Ω
100 MMF
.005
2.5 MH
ALDEN
TEST
1 M
JACK
10 MMF
10K
45 V
L1
.005
6C4
47K
XTAL
.05
P-201 AN-3102-16S-8P
L1 - 1400-1600 KC
L2 - 26 TURNS 1¼" DIA.
L3 6 TURNS 1¼" DIA.

Fig. II-6.

and, as the filament-type tubes were operating with unexpectedly good reliability, this transmitter was used on only four flights.

An auxiliary, high frequency (6835 KC or 6690 KC) transmitter (Figure II-7) was used on five flights of the series as a supplement to the medium frequency transmitter.

A special, light-weight series of transmitters in the 10 mc region was developed for use on superpressure flights with small Mylar balloons. The power output of these transmitters is about one watt. The first type, (Figure II-8), at 10.26 mc, consisted of a power oscillator directly coupled to the antenna. The frequency allocation was then changed and a new type of transmitter (Figure II-9) was developed for operation on 10.71 mc. This transmitter used one-half of a type 3A5 as a crystal-controlled oscillator and the other half of the same tube as a power amplifier driving the antenna.

Another transmitter on 10.71 mc (Figure II-10, a,b,c), previously mentioned, was developed for use in telemetering primary encoded temperature information from the tow balloon in step flights to the main gondola. This signal can also be received directly in line-of-sight range. This system was used in two flights of this series.

Special transmitters with electronic keying were developed for use with the recording multiplex encoding system. They were designed to meet the requirements of efficiently developing a high peak power with a low-voltage plate power supply for the final amplifier. It is necessary to maintain low voltages and to use good insulating and spacing techniques in the physical design of the final amplifier of these transmitters in order that they will operate without arcing in the rarified atmosphere encountered in balloon flights. A large part of the solution to this problem is in using fixed

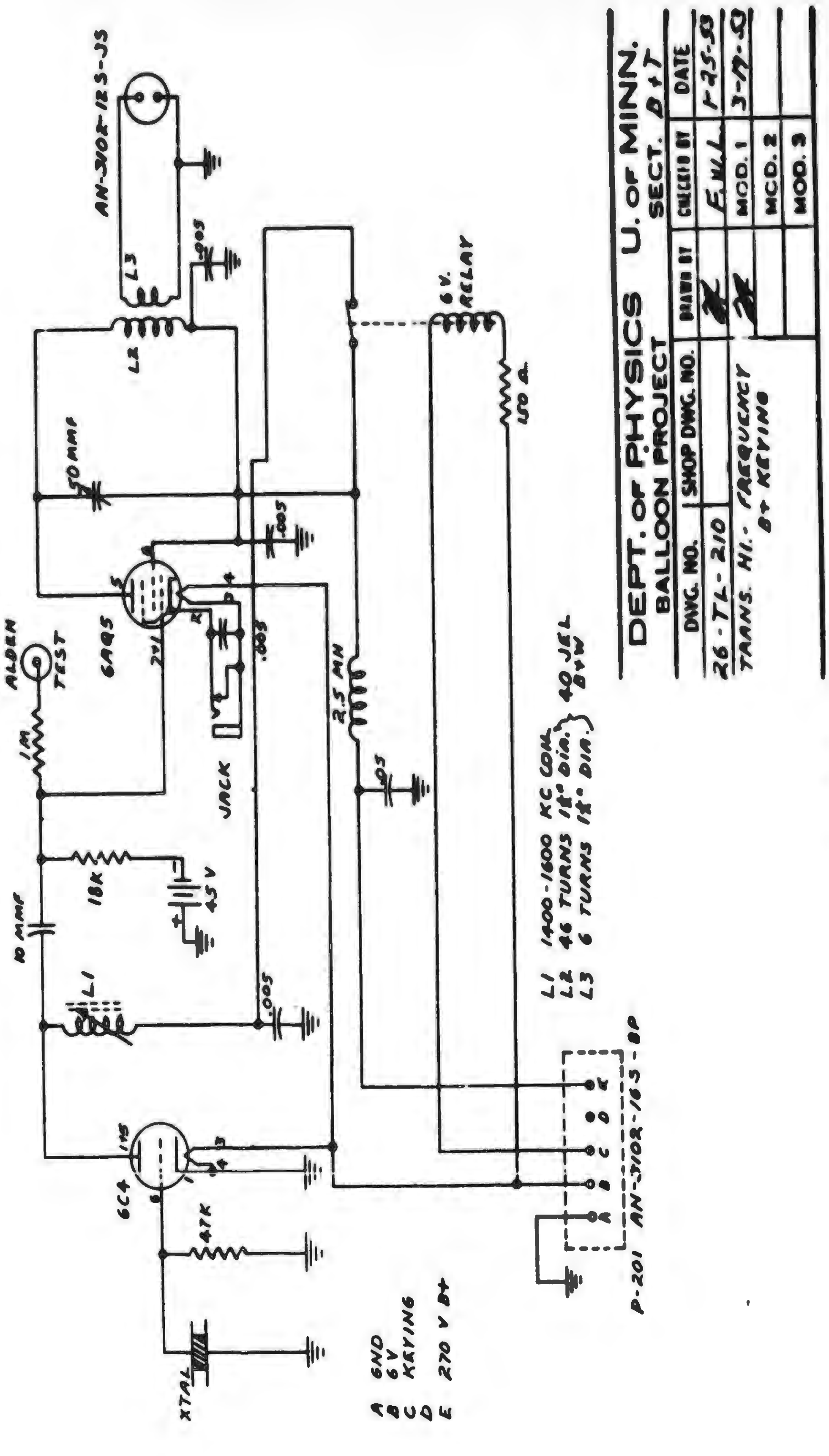

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B+T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
26-TL-210
E.W.L.
1-25-53
MOD. 1
3-17-53
MOD. 2
MOD. 3
TRANS. HI-FREQUENCY B+ KEYING
AN-3102-12S-3S
L3
L2
.005
6V. RELAY
150 Ω
50 MMF
6AQ5
ALDEN TEST
1M
2.5 MH
.05
JACK
18K
4.5 V
10 MMF
L1
6C4
47K
XTAL
P-201 AN-3102-16S-8P
L1 1400-1600 KC COIL
L2 46 TURNS 1/2" DIA.
L3 6 TURNS 1/2" DIA.
40 JEL B+W
A GND
B 6V
C KEYING
D
E 270 V B+

Fig. II-7.

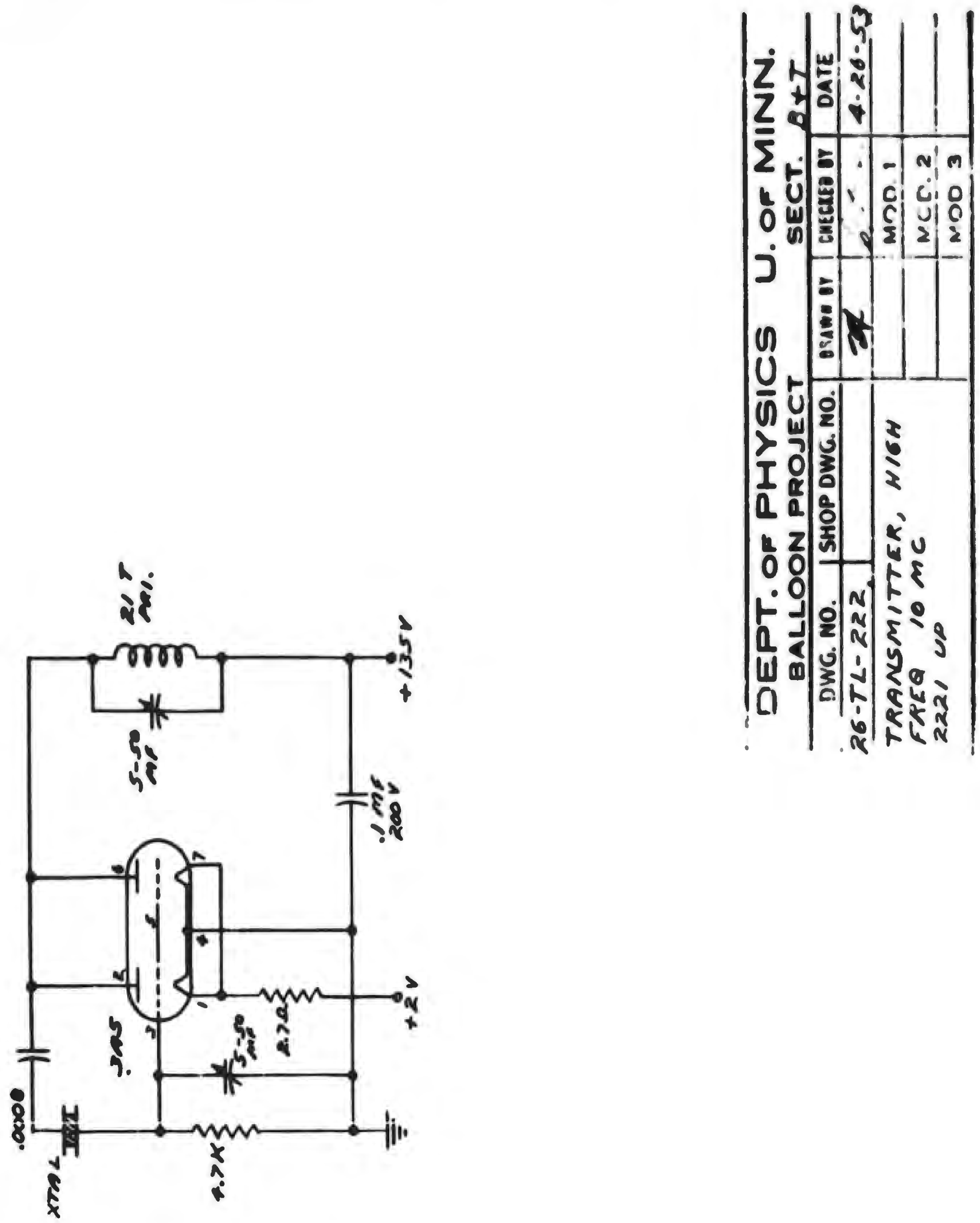
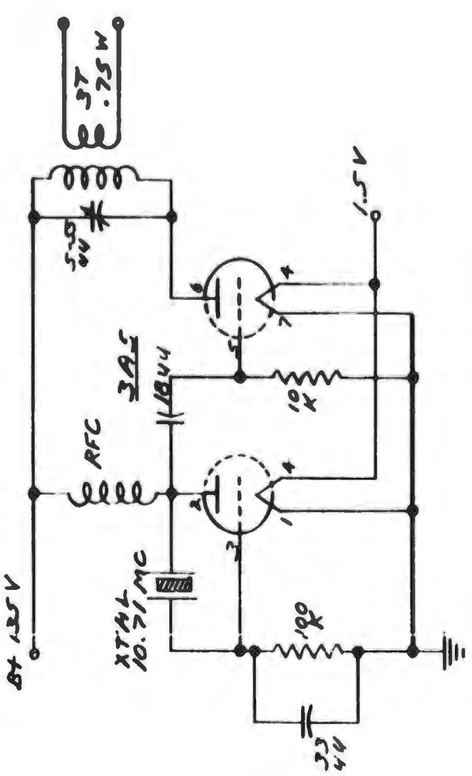

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B+T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
26-TL-222
4-26-53
TRANSMITTER, HIGH
FREQ 10 MC
2221 UP
MOD 1
MOD 2
MOD 3
+135V
+2V
4.7K
XTAL
3A5

Fig. II-8.



DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B+T

DWG. NO.	SHOP DWG. NO.	DRAWN BY	CHECKED BY	DATE
26-TL-245		[signature]	F.W.L.	8-7-53
TRANSMITTER, HIGH FREQ 10 M.C.		[signature]	MOD. 1	11-27-53
			MOD. 2	
			MOD. 3	

Fig. II-9.

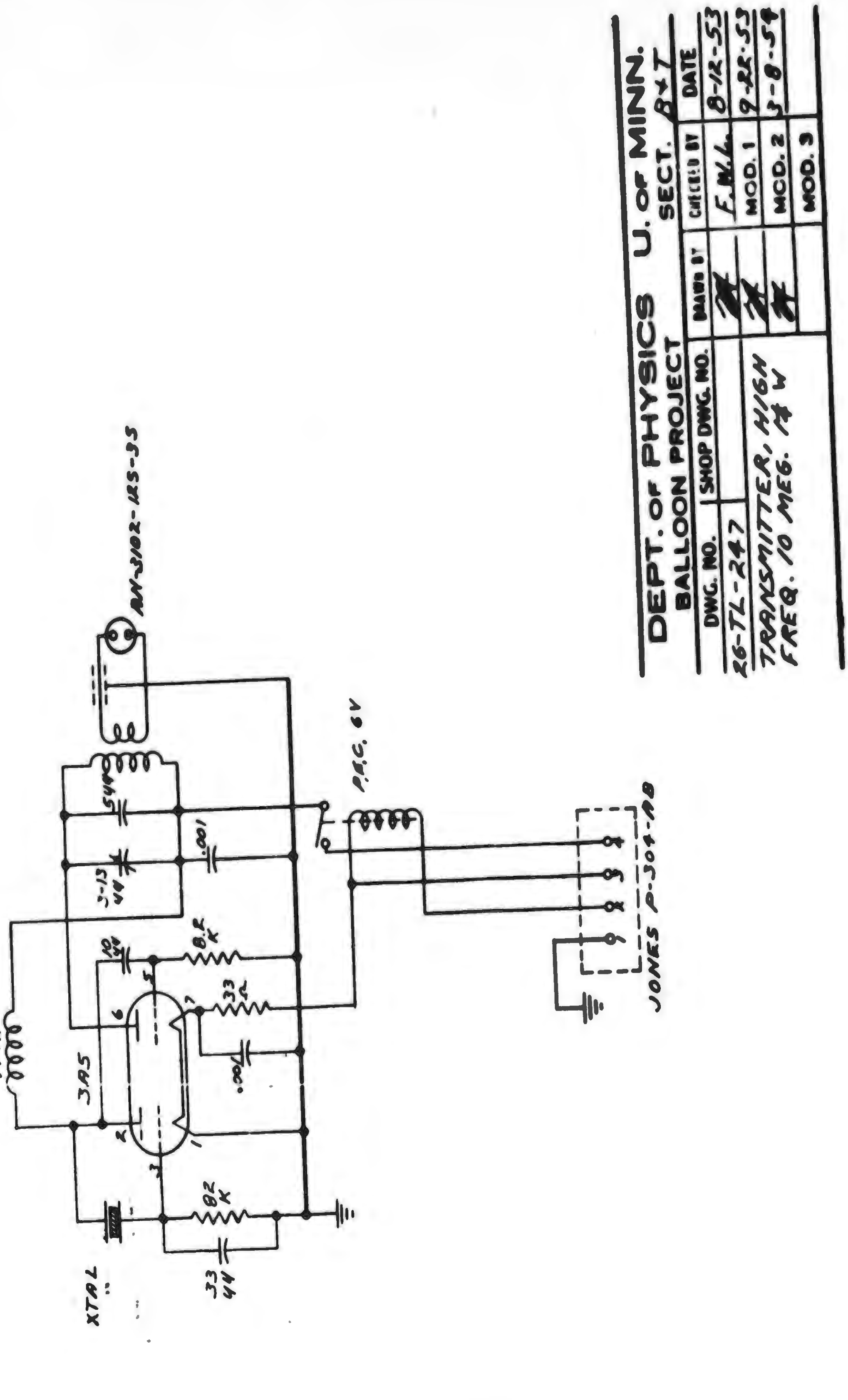

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B&T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
26-TL-247
F.W.L.
8-12-53
MOD. 1
9-22-53
MOD. 2
3-8-54
MOD. 3
TRANSMITTER, HIGH FREQ. 10 MEG. ¼ W
XTAL
3A5
1 MH
JONES P-304-AB
P.R.C. 6V
RN-3102-12S-3S

Fig. II-10a.

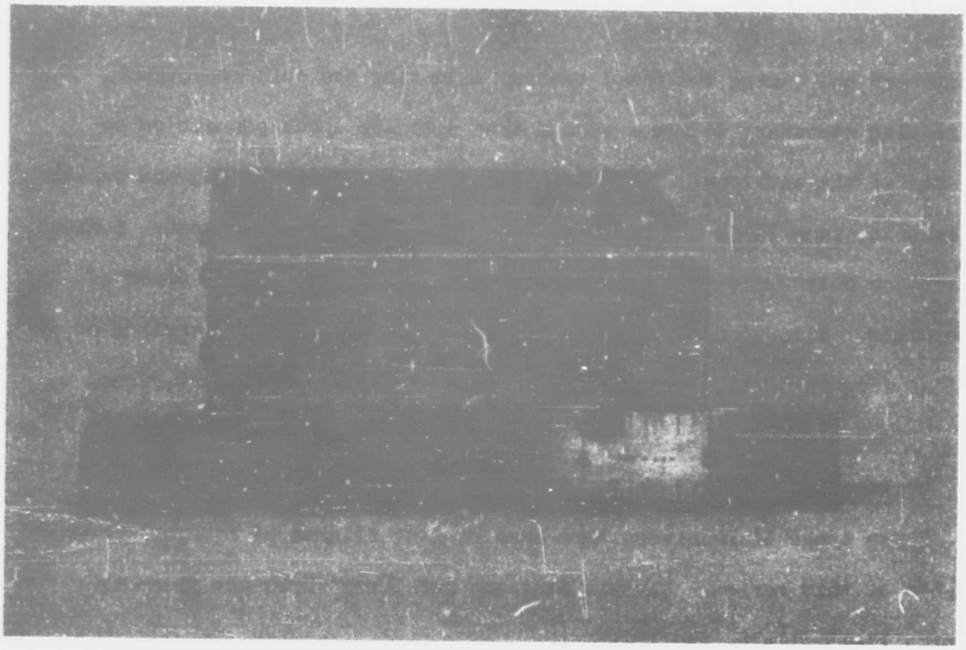


Fig. II-10b. Transmitter, H.F., 10 mc, $1\frac{1}{4}$ W. Outside view.

Fig. II-10c. Transmitter, H.F., 10 mc, $1\frac{1}{4}$ W. Bottom view, showing final tank coil.

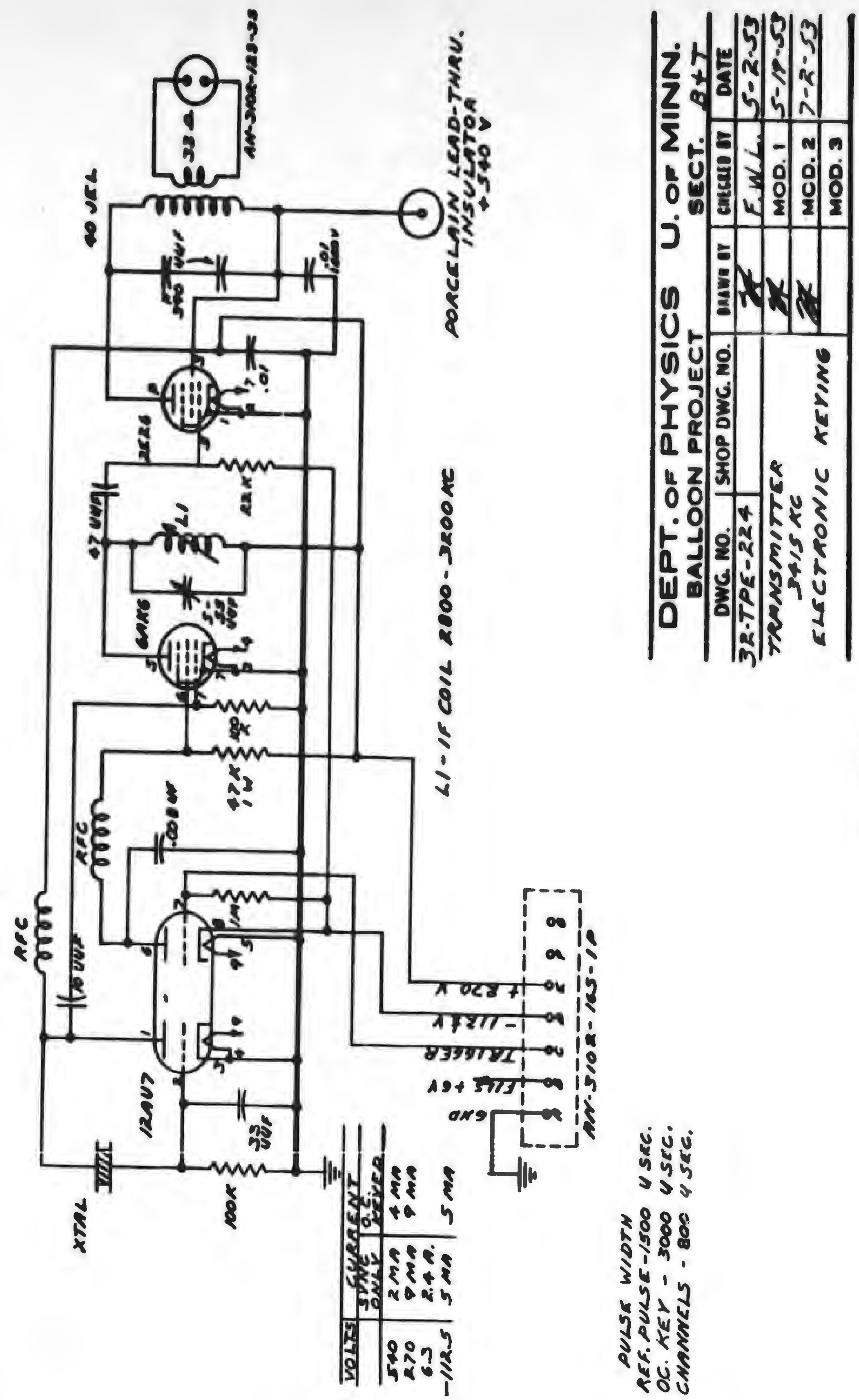
condensers and tuning the final tank by adjusting the coil inductance. It is also necessary to use a vacuum tube with the anode connection on the top of the envelope. These transmitters, as now developed, are capable of inducing from 75 to 115 watts peak power across a matched load. Because of the low duty cycle used, the average power output is in the order of five watts. Circuit diagrams and photographs of two models operating on 3415 KC (Figure II-11, a,b,c,d), and 1638 KC (Figure II-12), are given.

2. Receivers for use in Balloon Flight Gondolas

Three types of receivers were used on four flights of the radio command flights of this series. Circuit diagrams for these units are shown in Figures II-13, II-14, and II-15.

A special receiver (Figure II-16, a,b,c) was developed for use in a test of Loran transponding for balloon tracking. This receiver responded to 1950 KC and featured a wide band, stagger-tuned, I.F. amplifier. The output pulse from the receiver was designed to operate the electronic-keyed pulse transmitter directly.

A three-tube, 10.71 mc, receiver was developed for reception of primary encoded temperature information from the tow balloon in step flights. As the transmission path was short,the receiver was purposely designed to have low sensitivity to prevent keying on interfering signals or noise. The basic design consisted of a single R.F. amplifier, a diode detector, one high-gain voltage amplifier, and a power amplifier which operates a sensitive relay. This relay completes the assigned channel circuit in the multiplex system and, therefore, the temperature data is telemetered to the ground



DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT SECT. B+T
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
32-TPE-224
F.W.L.
5-2-53
MOD. 1
5-19-53
MOD. 2
7-2-53
MOD. 3
TRANSMITTER 3415 KC
ELECTRONIC KEYING
PORCELAIN LEAD-THRU. INSULATOR +540 V
AN-3102-12S-3S
80 JEL
3E29
6AK6
12AU7
XTAL
100K
RFC
L1-IF COIL 2800-3200 KC
47K 1W
22K
AN-3102-16S-1P
+270 V
-112.5 V
TRIGGER
FILS +6V
GND
VOLTS
CURRENT
SYNC ONLY
O.C. KEYER
540
270
6.3
-112.5
2 MA
9 MA
2.4 A.
5 MA
4 MA
9 MA
5 MA
PULSE WIDTH
REF. PULSE - 1500 μ SEC.
OC. KEY - 3000 μ SEC.
CHANNELS - 800 μ SEC.

Fig. II-11a.

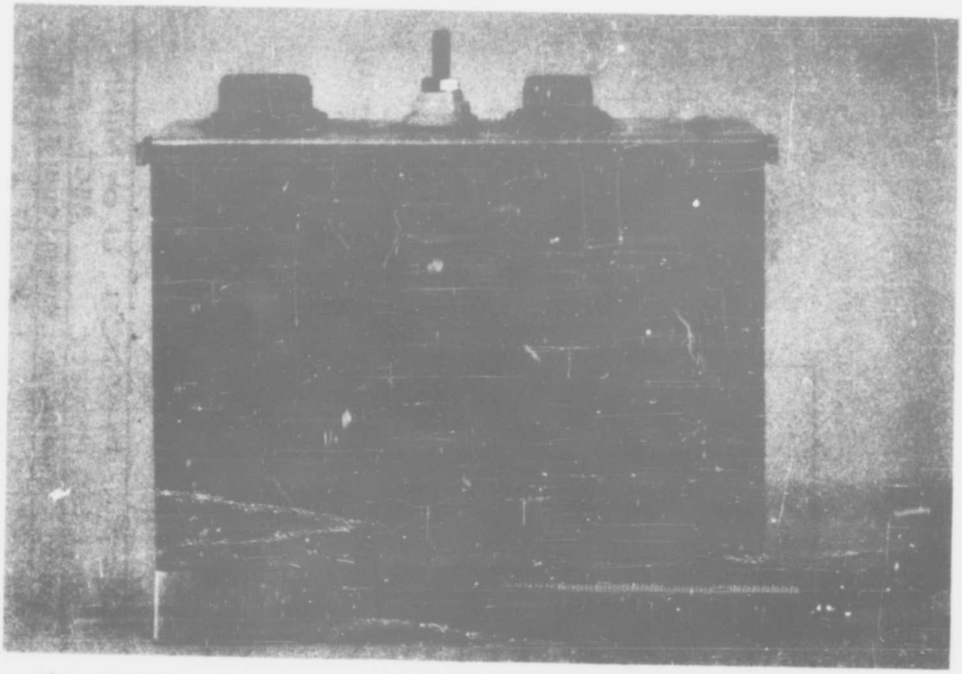


Fig. II-11b. Transmitter, 3415 KC, electronic keying. Outside view.

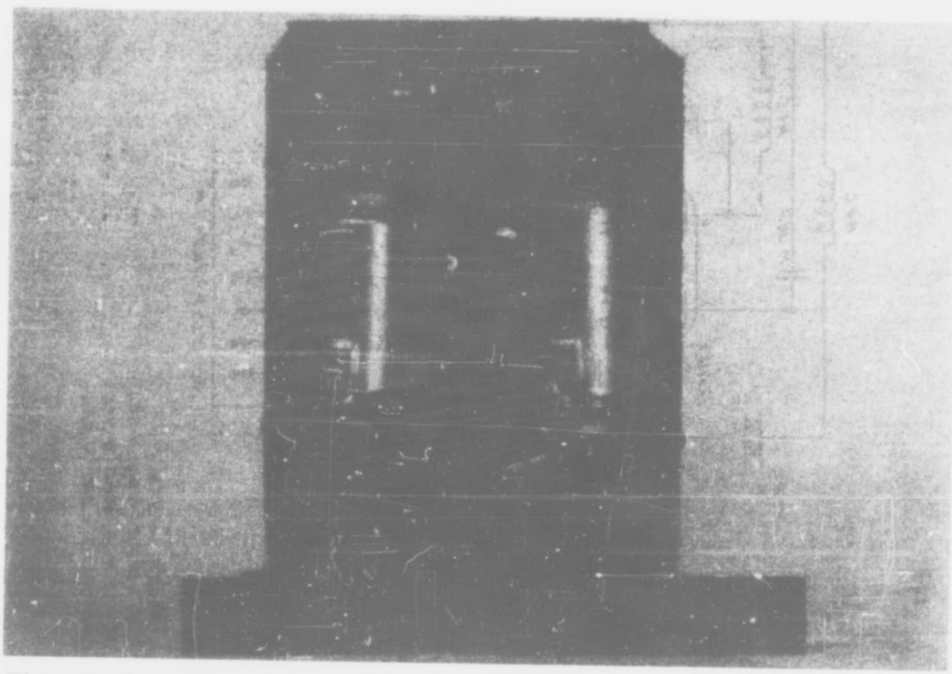


Fig. II-11c. Transmitter, 3415 KC. Electronic keying, side view, cover off. Note final anode connector behind tube at left.

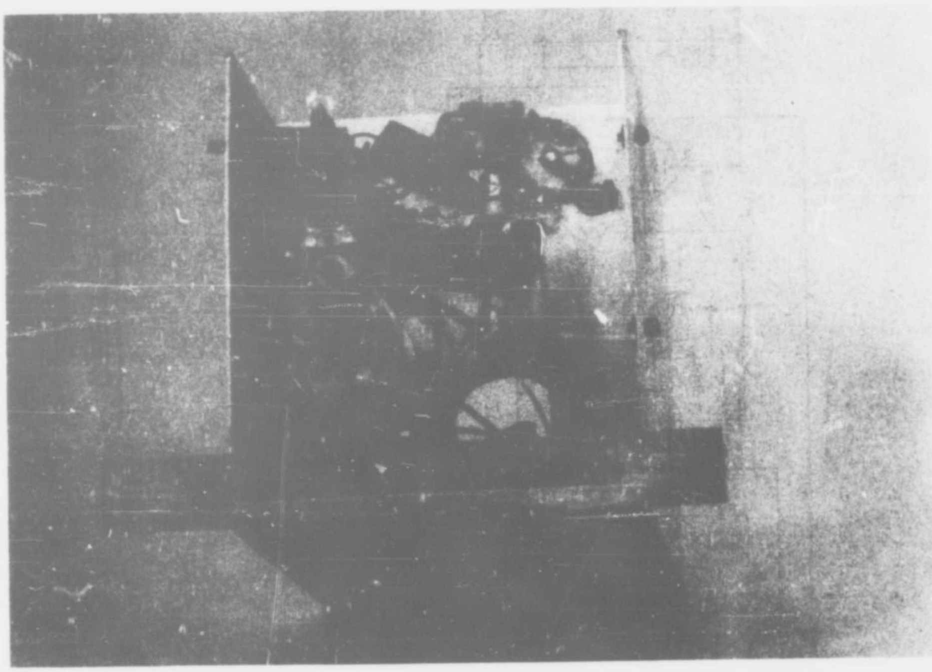


Fig. II-11d. Transmitter, 3415 KC.
Electronic keying - bottom view, cover off.

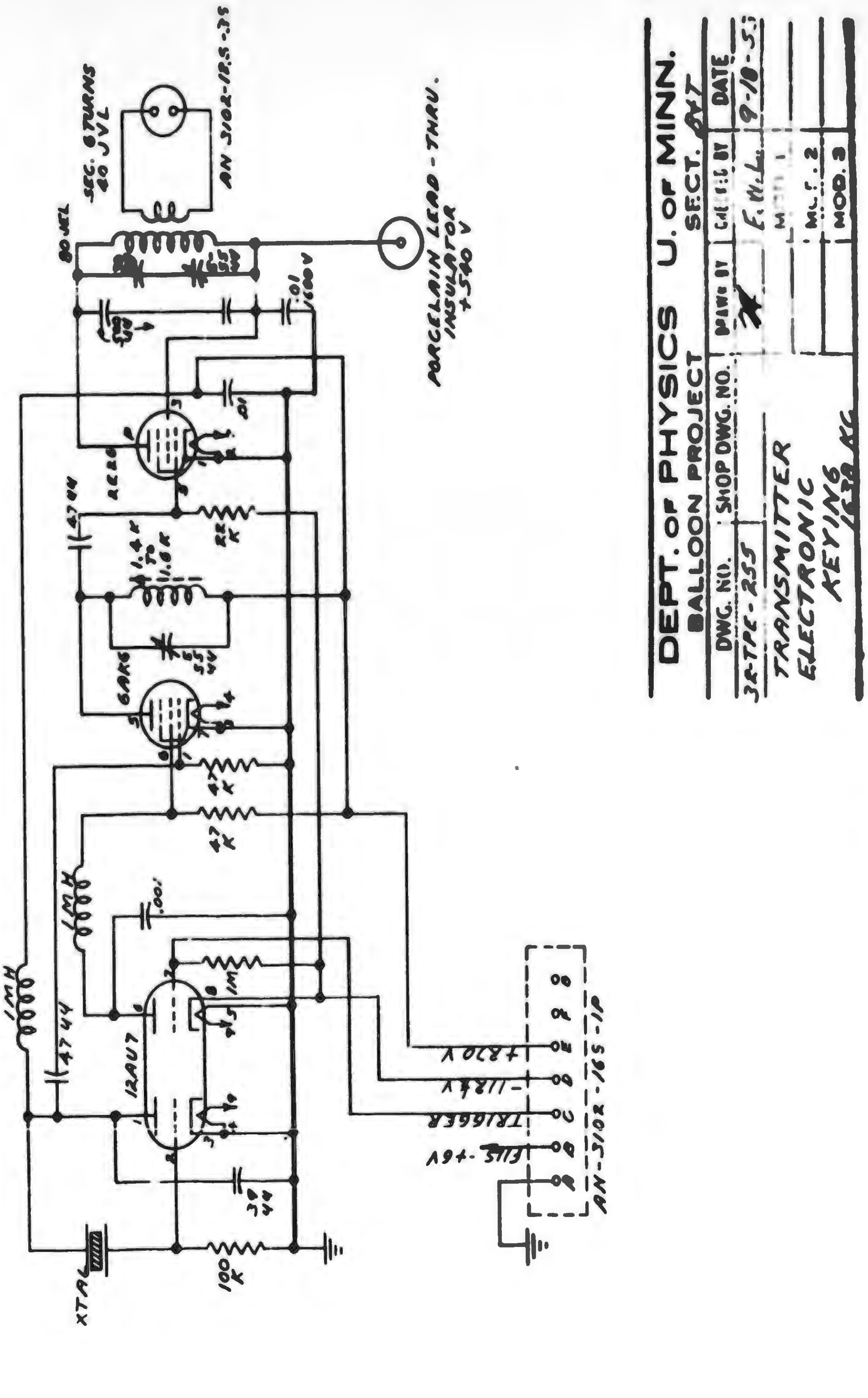

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
TRANSMITTER
ELECTRONIC
KEYING
PORCELAIN LEAD-THRU INSULATOR
12AU7
XTAL
AN-3102-16S-1P
TRIGGER

Fig. II-12.

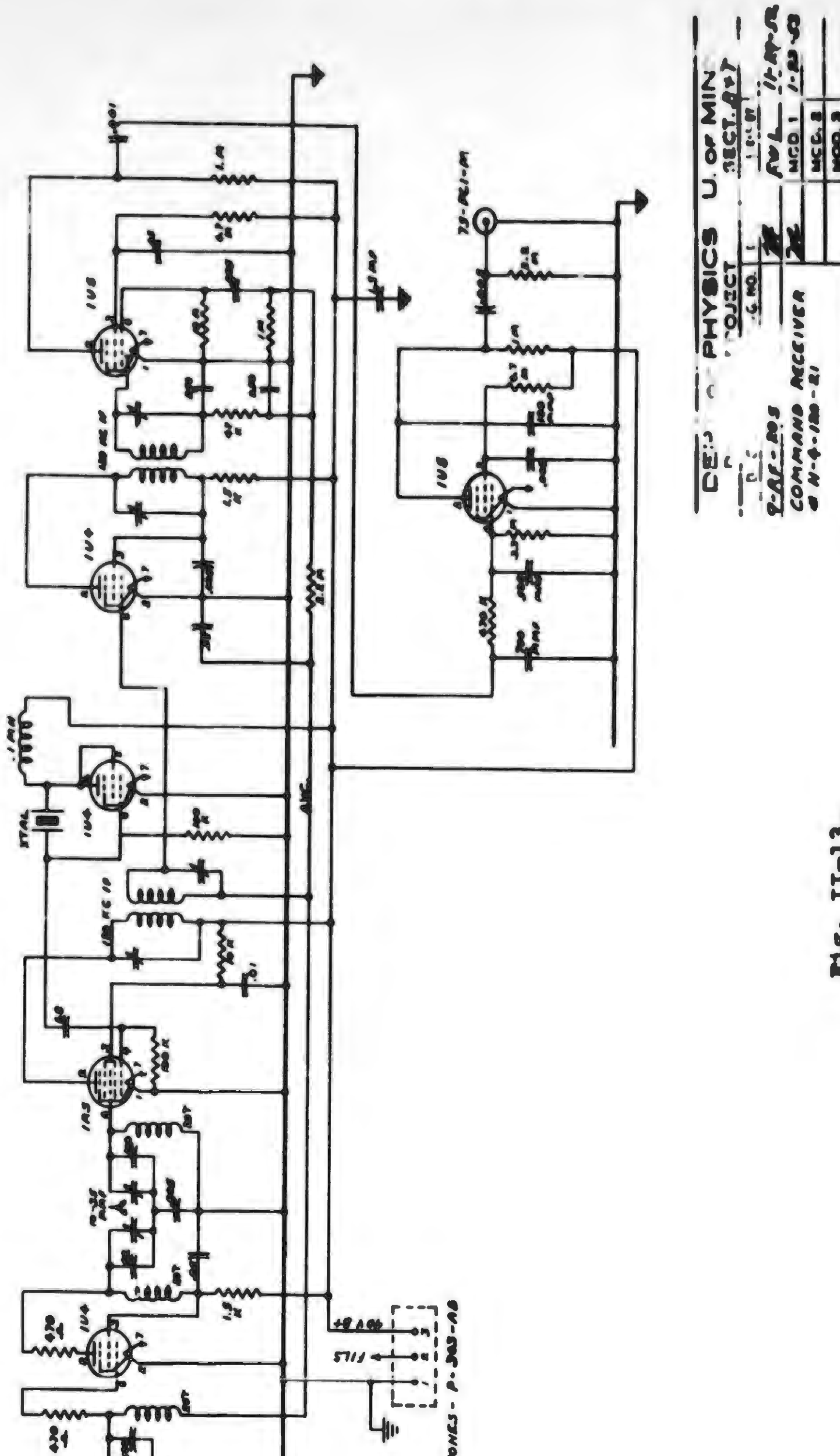

1U4
1R5
1U4
1U4
1U5
1U5
XTAL
AVC
LOW Z INPUT
JONES - P-303-AB
PHYSICS
COMMAND RECEIVER

Fig. II-13.

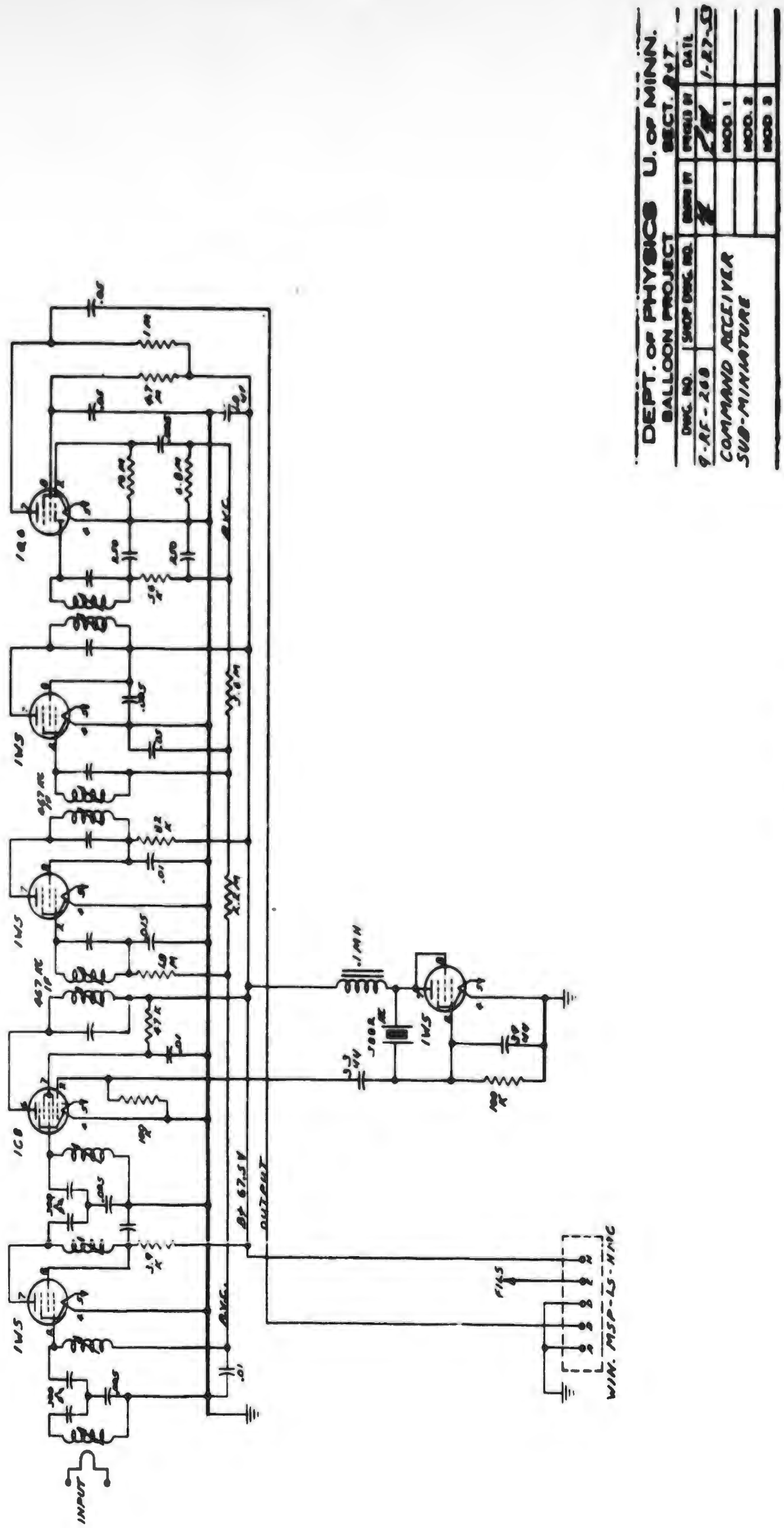

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
COMMAND RECEIVER
SUB-MINIATURE
INPUT
OUTPUT
A.V.C.

Fig. II-14.

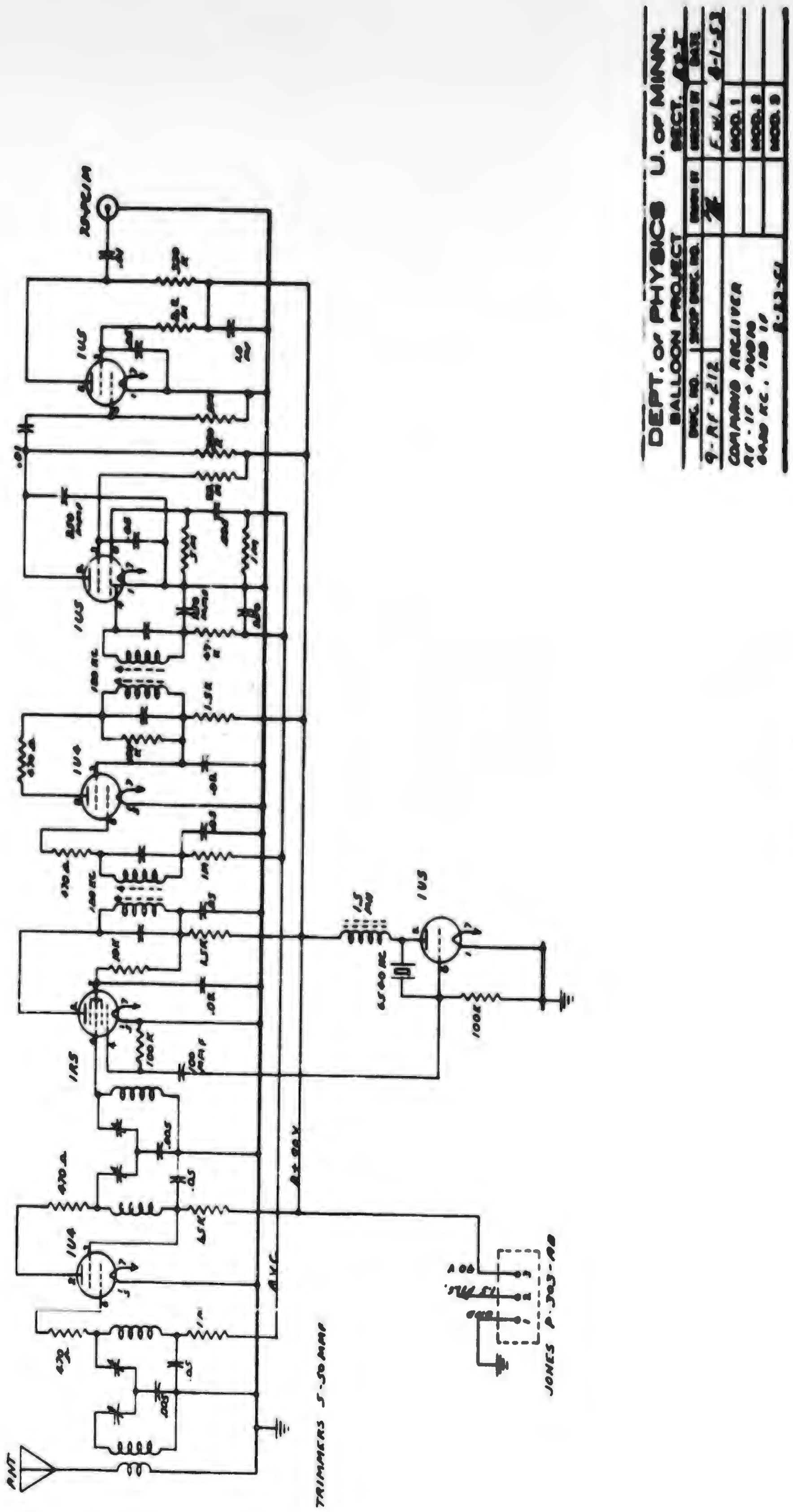

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
9-RF-212
COMPANDO RECEIVER
MOD. 1
MOD. 2
MOD. 3
1U4
1R5
1U5
ANT
TRIMMERS 5-50 MMF
JONES P-303-AB
AVC
B+ 90V
100K
470Ω

Fig. II-15.

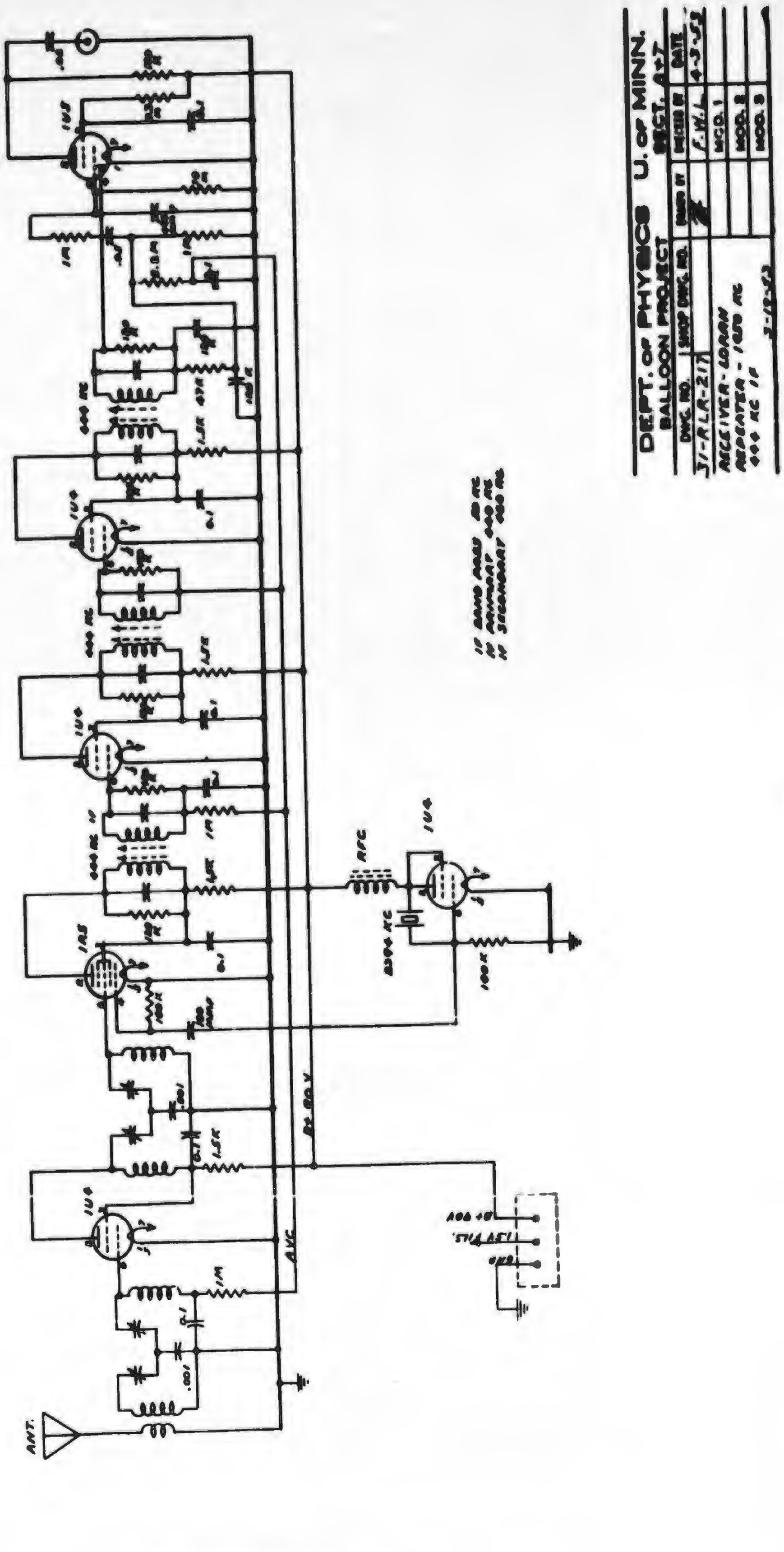


Fig. II-16a.

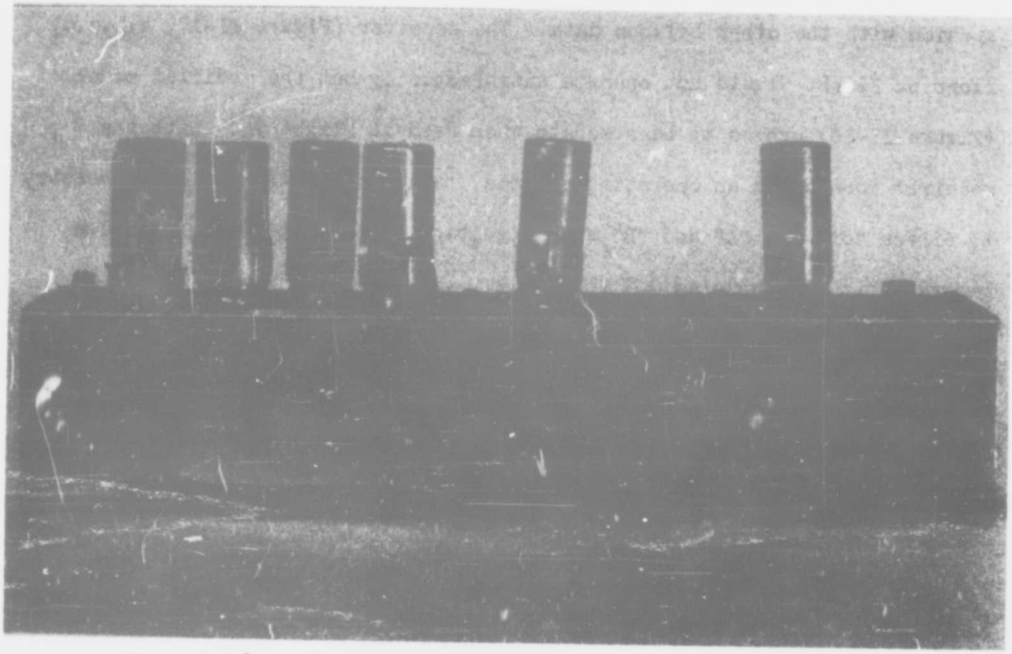


Fig. II-16b. Receiver, Loran Repeater, 1950 KC, 414 Kc I.F.
Side view, showing tuning controls.

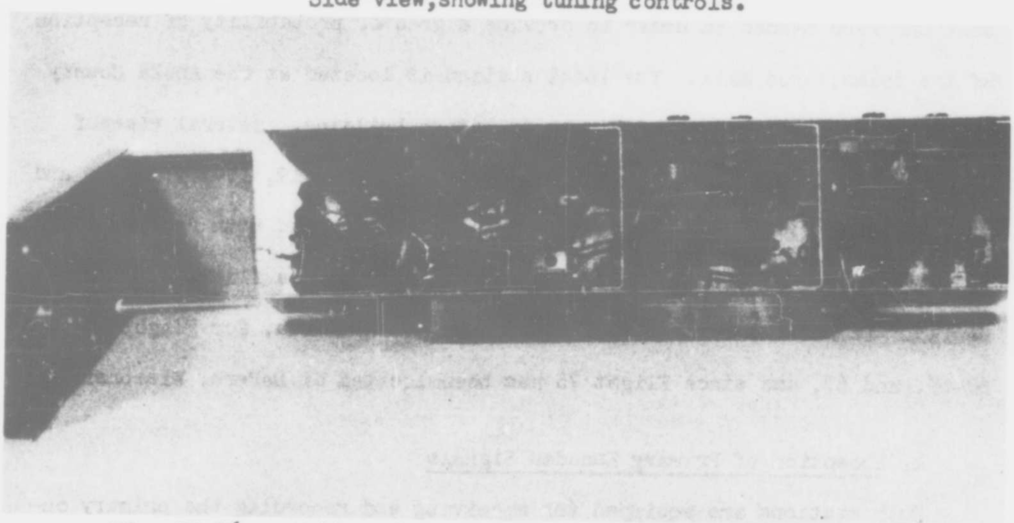


Fig. II-16c. Bottom view, cover off. Right section: R.F.Amp.
Middle Section: mixer stage. Left section: oscillator,
I.F. amplifiers, detector and audio amp.

station with the other balloon data. The receiver (Figure II-17, a,b,c,d) flown on Flight 91 did not operate satisfactorily but the modified model (Figure II-18) proved to be adequate when used in Flight 94. With the receiver mounted in an operating gondola, tests showed that it was necessary to filter both the "A" and "B" supply voltage to prevent keying on noise generated in the gondola.

3. <u>Thermistor Pulse Generator</u>

A circuit for the primary encoding of resistance values was developed and used on 21 flights of this series. This apparatus and its application are more fully described in Volume X, Section I (Temperature) of this report.

C. Operation of Receiving Stations

In most of the operations of this series of flights, two receiving stations were manned in order to provide a greater probability of reception of the telemetered data. The local station is located at the Anoka County Airport in the University of Minnesota office building. Several views of the equipment of this station are shown in Figures II-19, II-20, II-21, and II-22, a & b. A U. S. Navy trailer[9] has been equipped with receiving and transmitting equipment and has been used for most of the flights of this series. It was located and used at Pierre, South Dakota, for Flights 56-59, 62-65, and 67, and since Flight 78 has been located at DePere, Wisconsin.

1. <u>Reception of Primary Encoded Signals</u>

Both stations are equipped for receiving and recording the primary encoded signals. This equipment includes a receiver with a beat frequency

(9) PROGRESS REPORT ON HIGH ALTITUDE BALLOONS, Volume V, p. VIII-375.

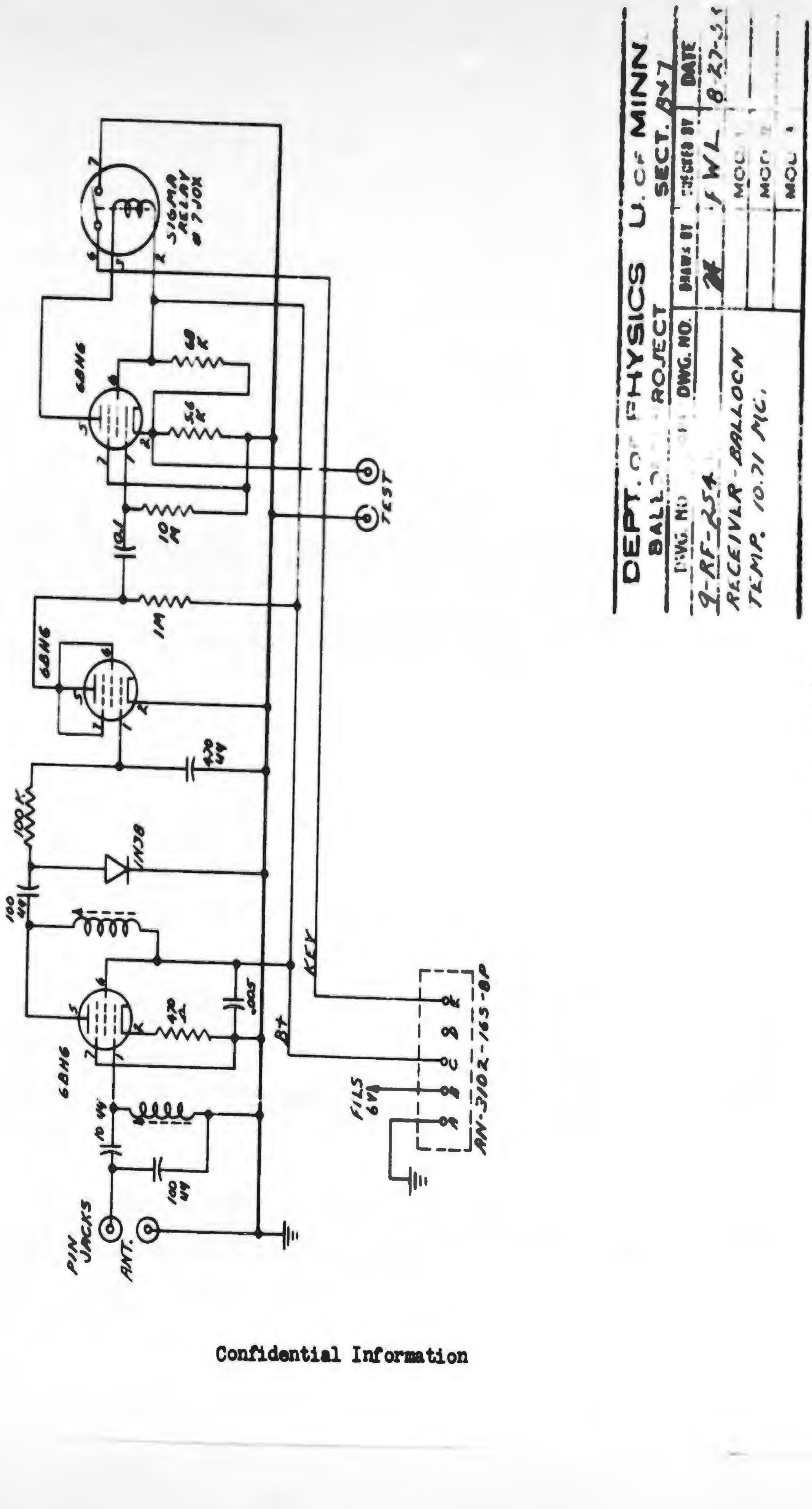

DEPT. OF PHYSICS U. OF MINN.
SECT.
DWG. NO.
DRAWN BY
CHECKED BY
DATE
9-RF-25A
RECEIVER-BALLOON
TEMP. 10.71 MC.
6BH6
SIGMA RELAY #7JOX
TEST
1M
10 M
1N38
KEY
B+
FILS 6V
AN-3102-16S-8P
PIN JACKS
ANT.

Fig.II-17a.

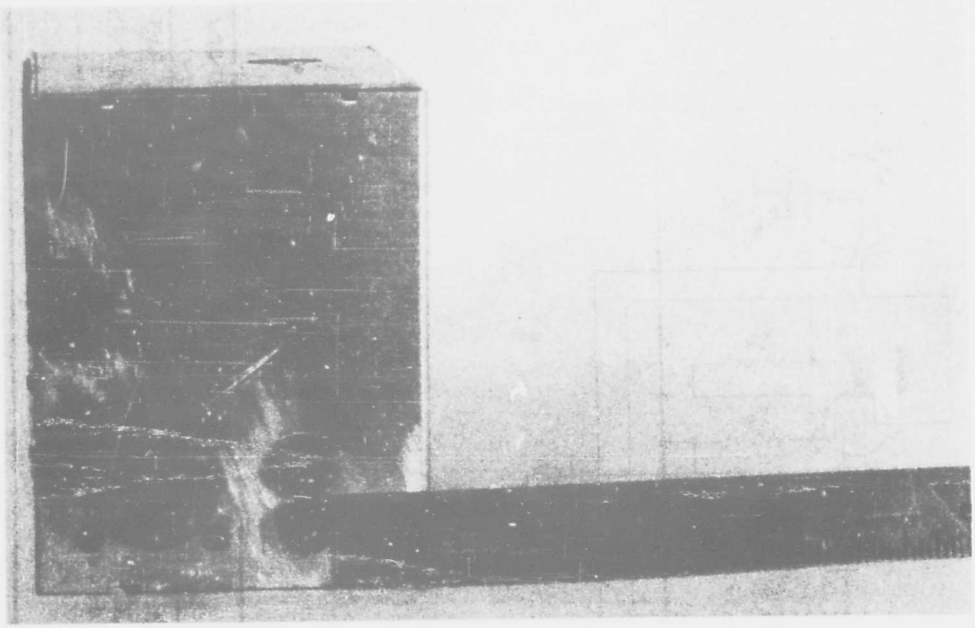


Fig. II-17b. Receiver, Balloon Temperature, 10.71 mc.
Top view showing connecting plugs.

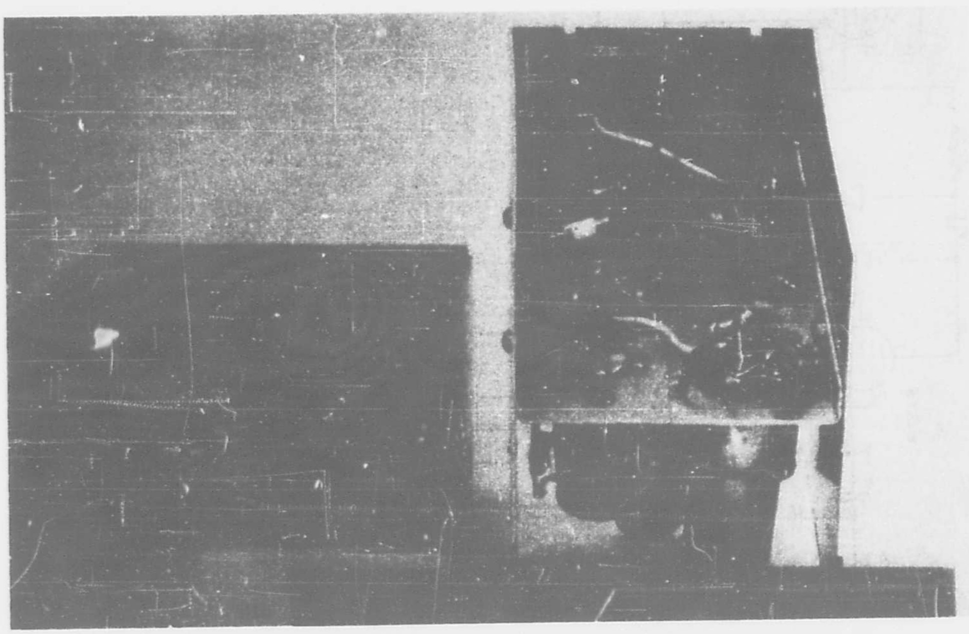


Fig. II-17c. End view, cover off, showing circuit wiring.

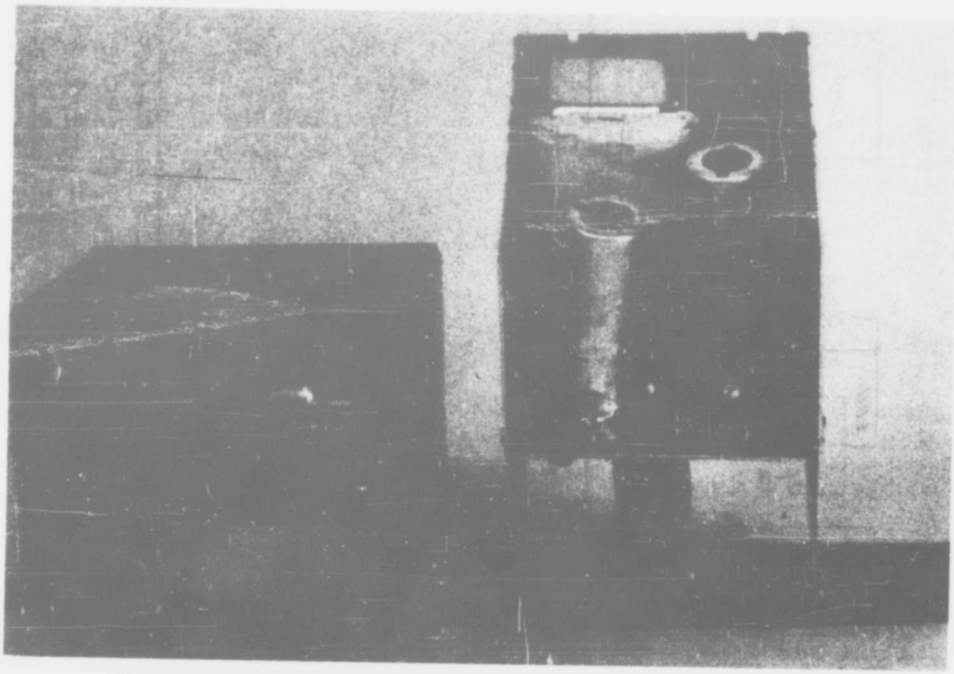


Fig. II-17d. Receiver, Balloon Temperature, 10.71 Mc. End view, cover off, showing tube and relay arrangement.

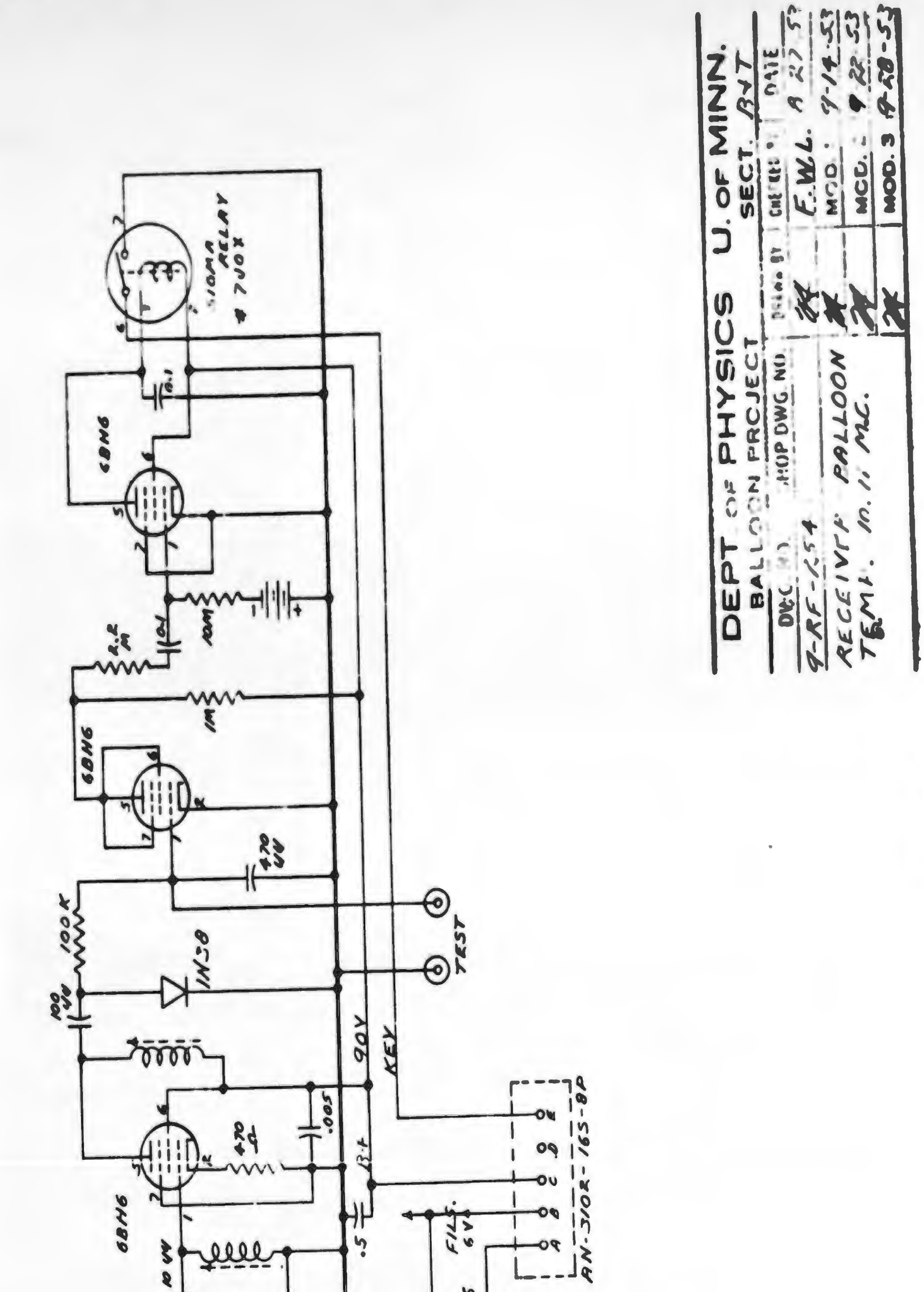

DEPT OF PHYSICS U. OF MINN.
BALLOON PROJECT
SECT. BYT
F.W.L.
RECEIVER BALLOON
PIN JACKS
ANT
TEST
KEY
90V
B+
6BH6
1N38
100K
1M
10M
FILS. 6V
AN-3102-16S-8P

Fig. II-18.

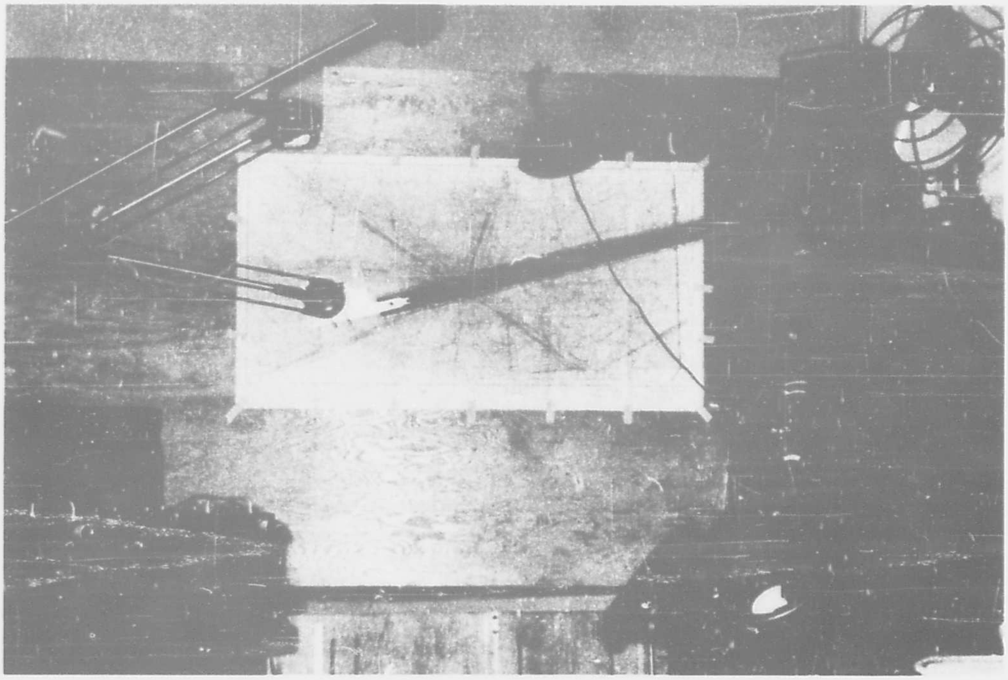


Fig. II-19. Anoka Airport Station. Lower Left: transmitter control center--Plotting Board; Lower Right: D.A.Q. Radio Direction Finder; Upper Right: L.M. Frequency Standard.

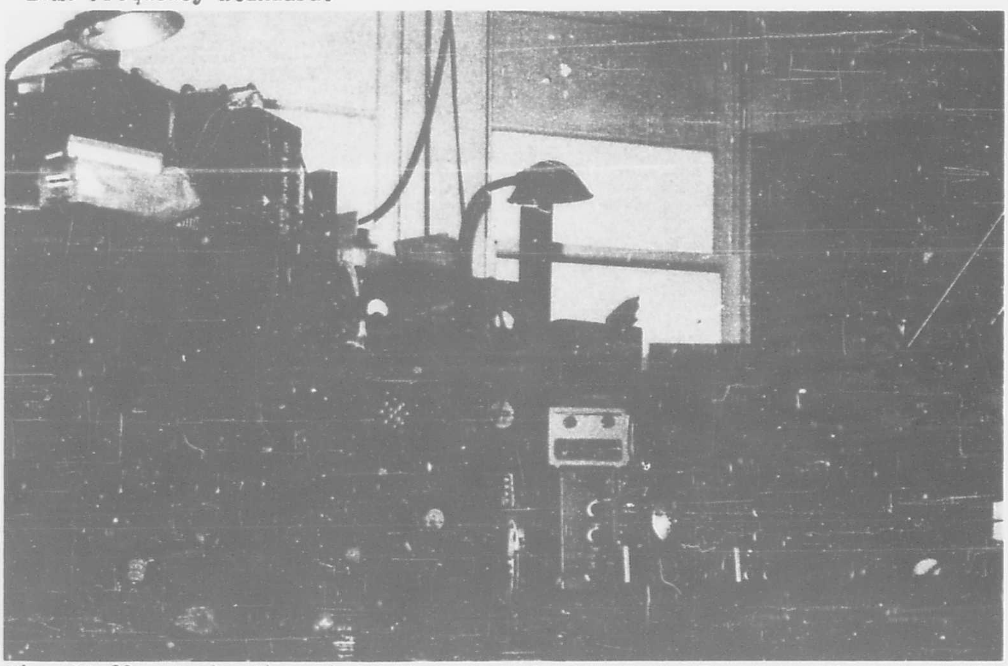


Fig. II-20. Anoka Airport Station. LowerL: Panoramic Receiver; Upper L: V.H.F. Transceiver Model 522; Lower L Center: Hammerlund Receiver; Middle L Center: 11-channel tone generator; Upper L Center: power supply; Lower R Center: HRO-50T1 Receiver; Lower L: Transmitter control.

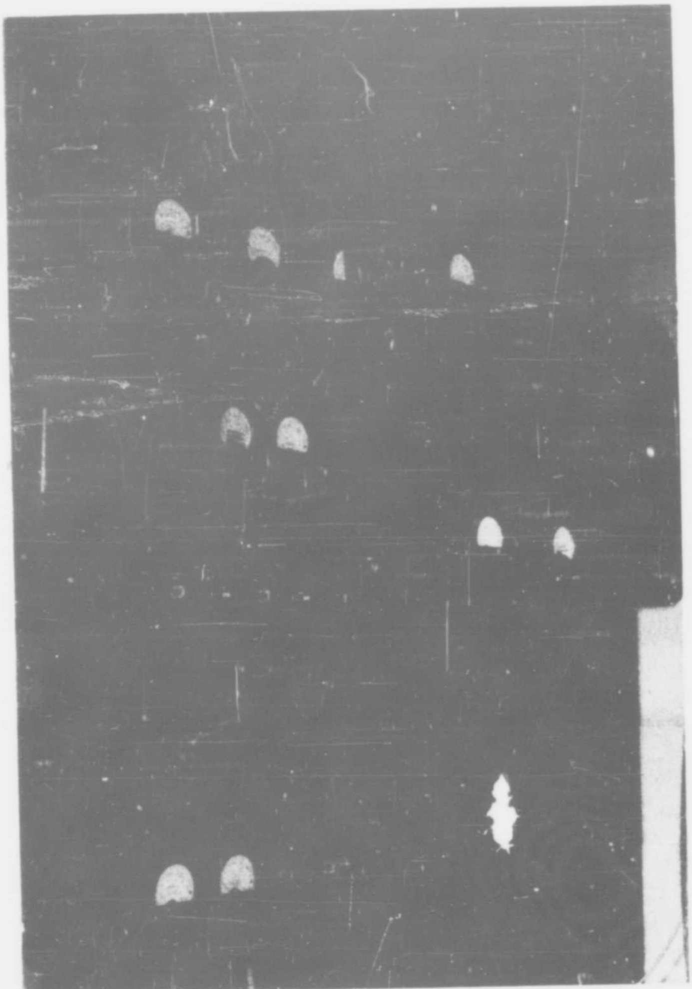


Fig. II-21. High frequency communications transmitter. Located in basement of tower building.

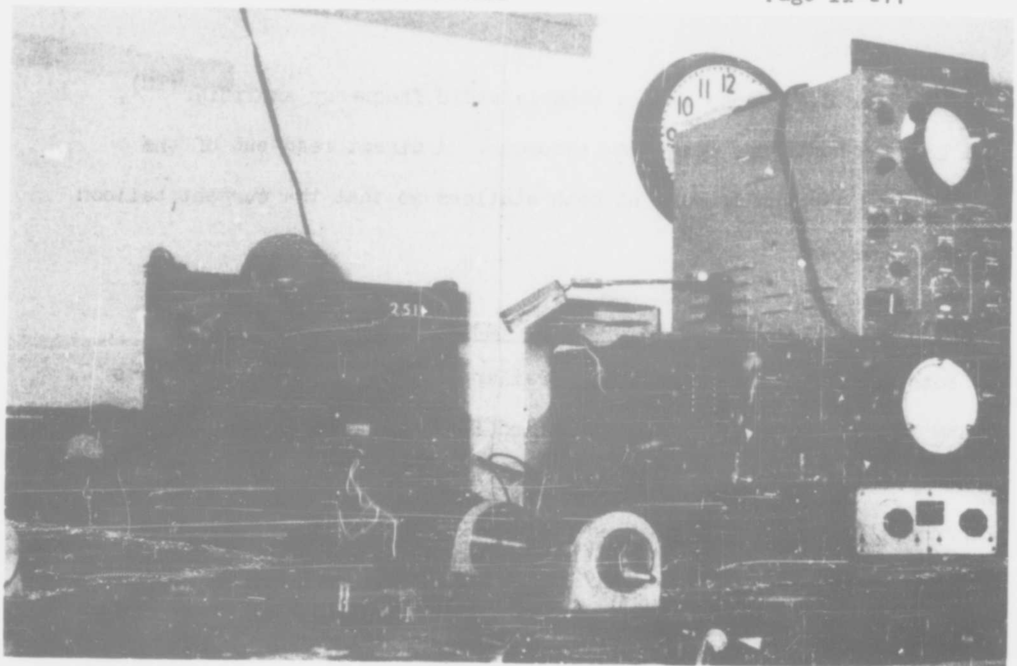


Fig. II-22a. Anoka Airport Station. Lower L: part of tuned audio amplifier; Lower L Center: receiver (see Fig.II-23a,b,c); Upper L Center: special experimental receiver; Lower Center & L: Data readout board; Lower R: Loran receiving equipment, model DAS; Upper R: Dumont oscilloscope.

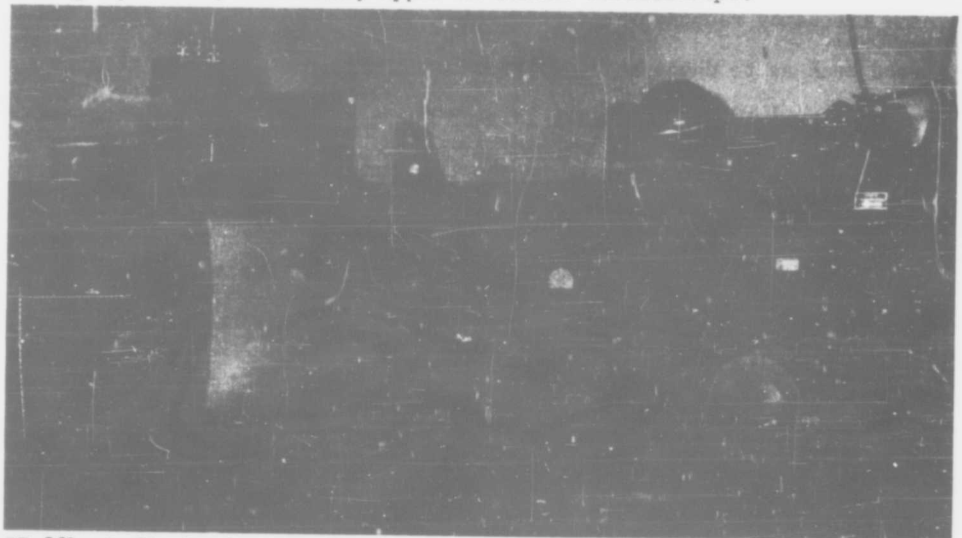


Fig. II-22b. Left: Leeds & Northrup single channel recorder; Lower Center: Data readout board; Upper C: tuned audio amplifier (see Footnote 10, p. II-278); Lower L: receiver (Fig.II-23a,b,c); Upper L: special experimental receiver; Extreme Left: part of Model DAS Loran receiving equipment.

oscillator for C.W. reception, a tunable audio frequency amplifier[10], and a Leeds & Northrup, Speedomax recorder. A direct read-out of the pressure data is usually made at both stations so that the current balloon altitude is known.

2. Reception of Multiplex Encoded Signals

Both the local station and the trailer are equipped with receivers (Figure II-23, a,b,c) especially modified for reception of the pulse-type signal produced by the multiplex encoding system. A 15-minute signal interrupter (Figure II-24) is used in both locations to provide an accurate time mark on all the telemetering records.

a. Magnetic Tape Recording

In the trailer station, the signal, after passing through the interrupter, is then recorded on magnetic tape. It was found that the low frequency response characteristics of the magnetic tape recorders were such as to cause a large overshoot after each pulse. As this is undesirable, a carrier system is used for magnetic tape recording. In use, the multiplex signal (from the 15-minute interrupter) is fed into the 5 KC signal generator (Figure II-25) where it is imposed on the carrier as amplitude modulation. In this system, the modulation is all in the upward (or higher power) direction and is not linear modulation such as is used in voice communication systems. The negative-going signal pulses are applied to the cathode of the tuned output amplifier tube and therefore tend to increase the output level by reducing the grid to cathode bias of this stage.

This carrier system is in use in both stations at present. The

(10) Ibid, Volume V, p. VIII-345 &Figure VIII-3.

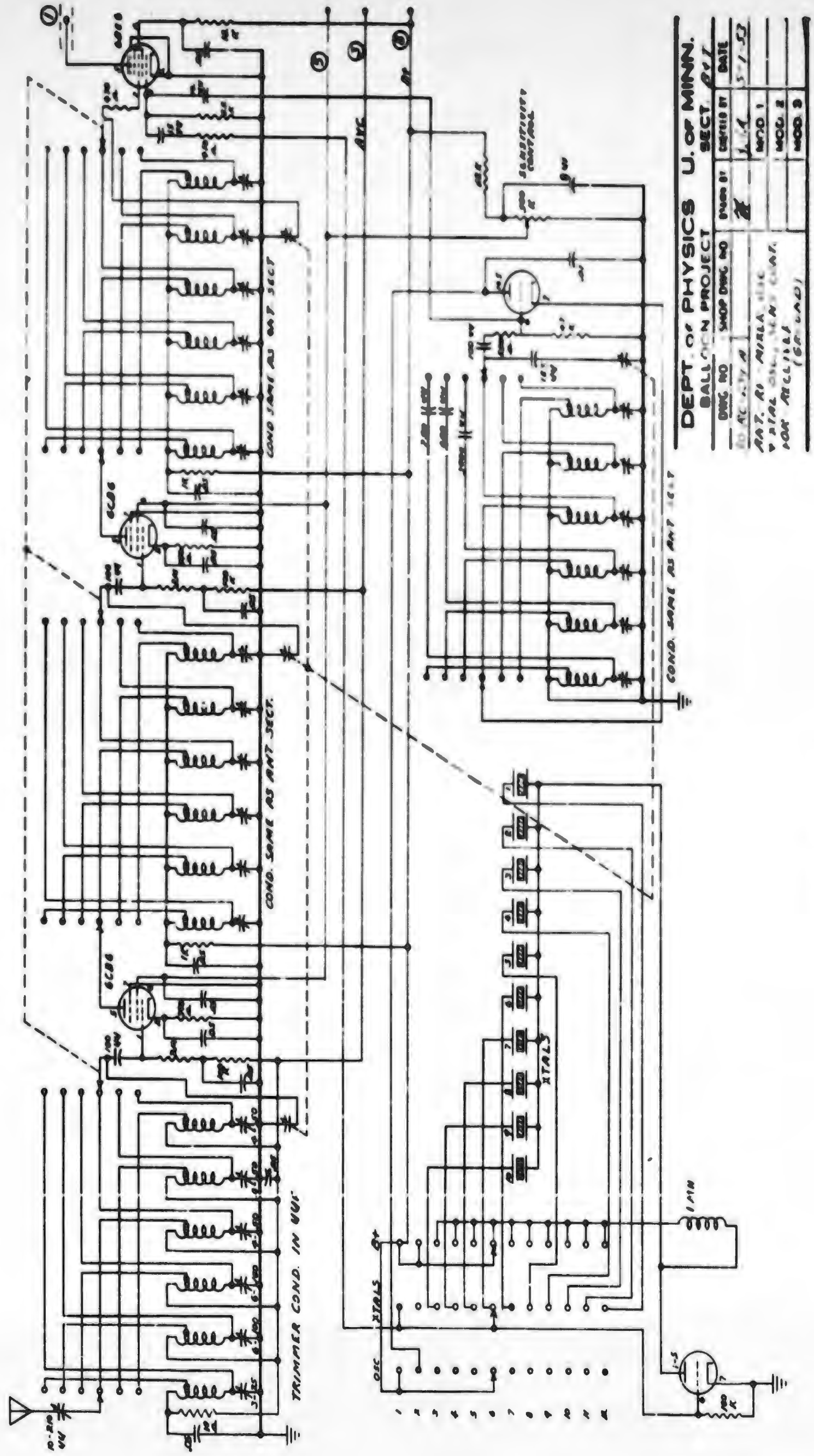

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
SECT.
AVC
6CB6
6CB6
SENSITIVITY CONTROL
COND. SAME AS ANT. SECT.
COND. SAME AS ANT. SECT.
COND. SAME AS ANT. SECT.
TRIMMER COND. IN UUF
XTALS
OSC
B+

Fig. II-23a.

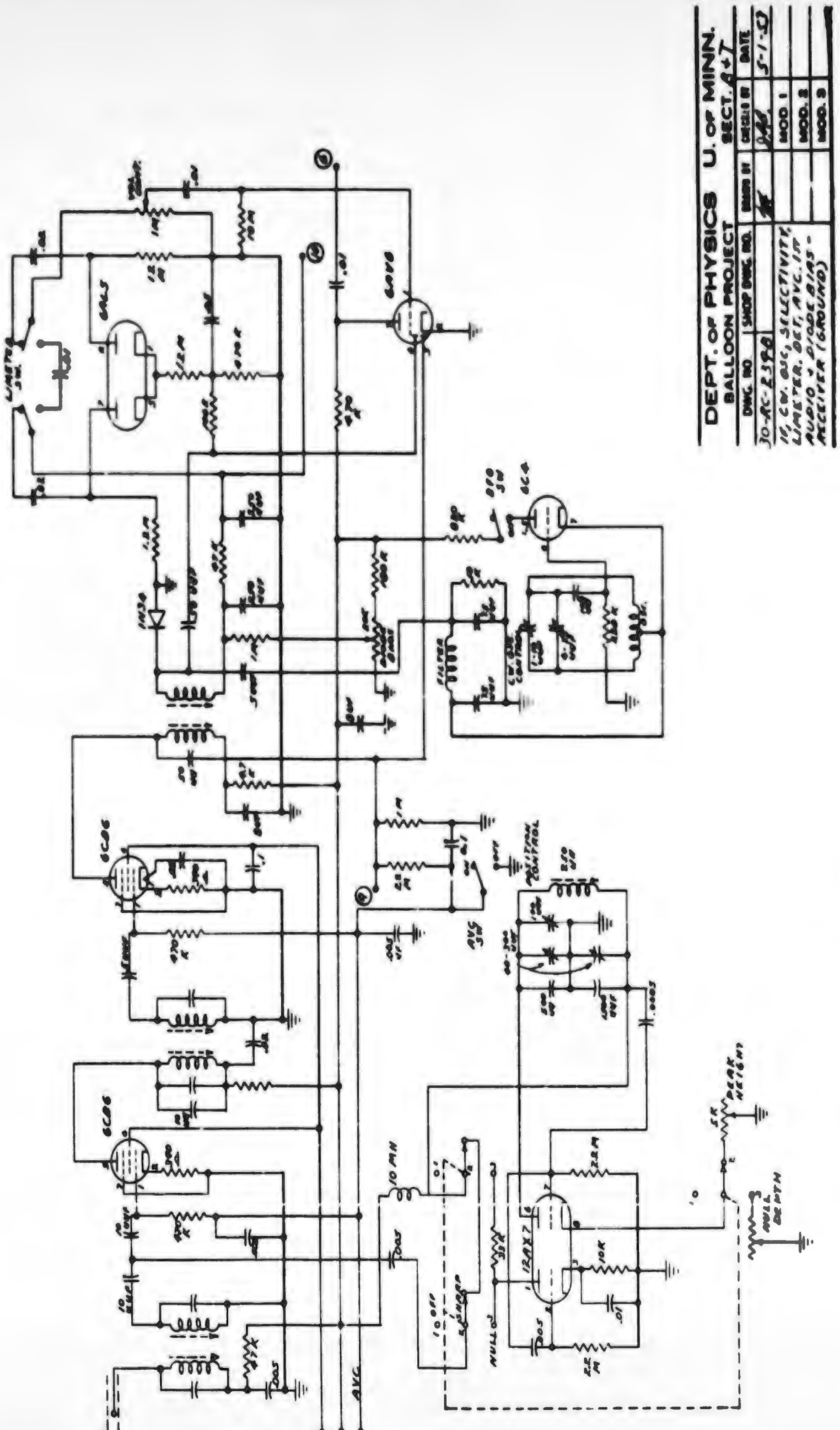

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
6CB6
6CB6
6AL5
6AV6
6C4
12AX7
1N34
AVC
FILTER
PEAK HEIGHT
NULL DEPTH

Fig. II-23b.

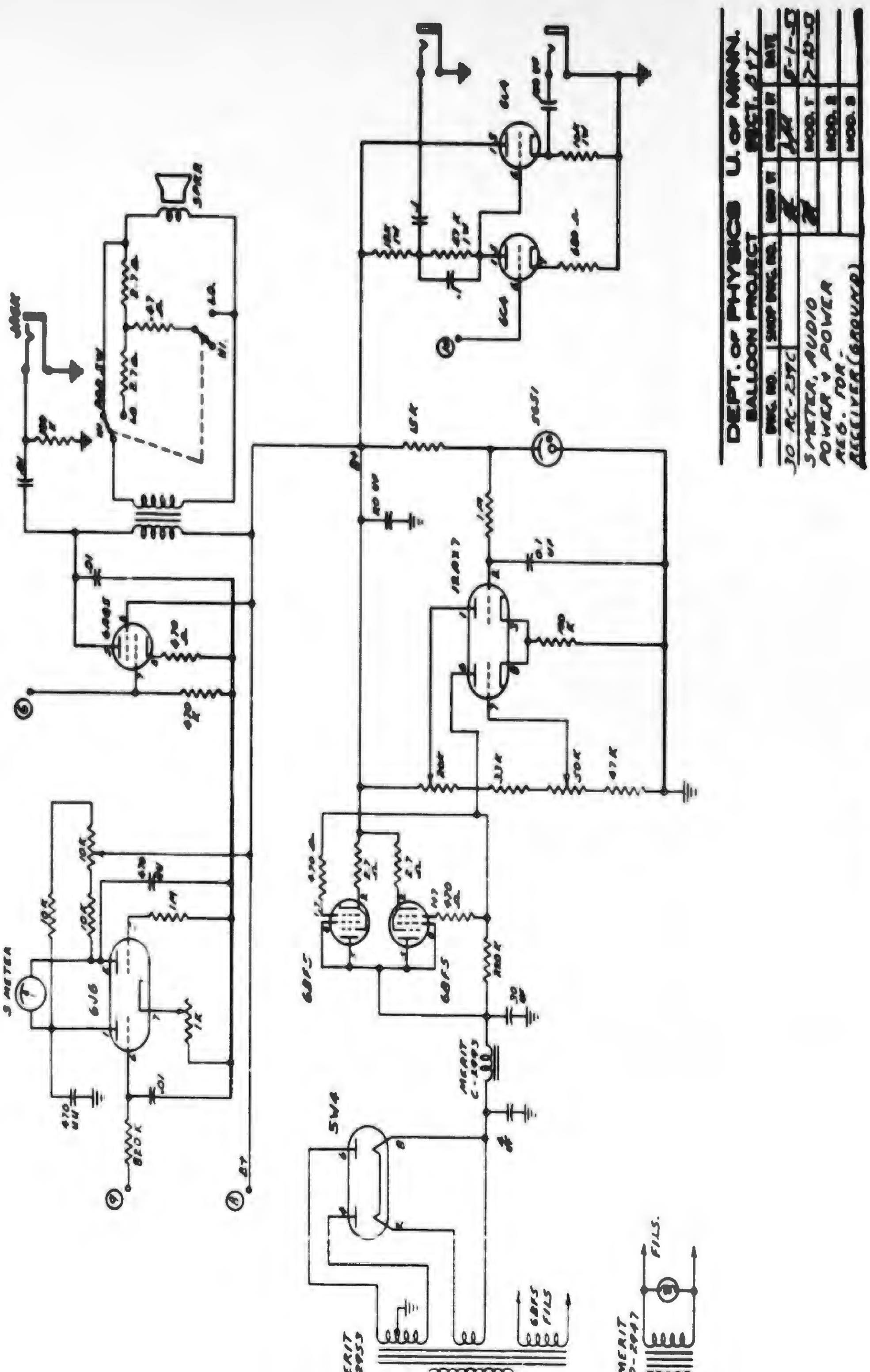

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
S METER, AUDIO POWER & POWER REQ. FOR RECEIVER (GROUND)
S METER
6J6
6BF5
5V4
12AX7
6C4
SPKR
MERIT P-2953
MERIT P-2947
115 V AC
ON VOL CONT.
FILS.

Fig. II-23c.

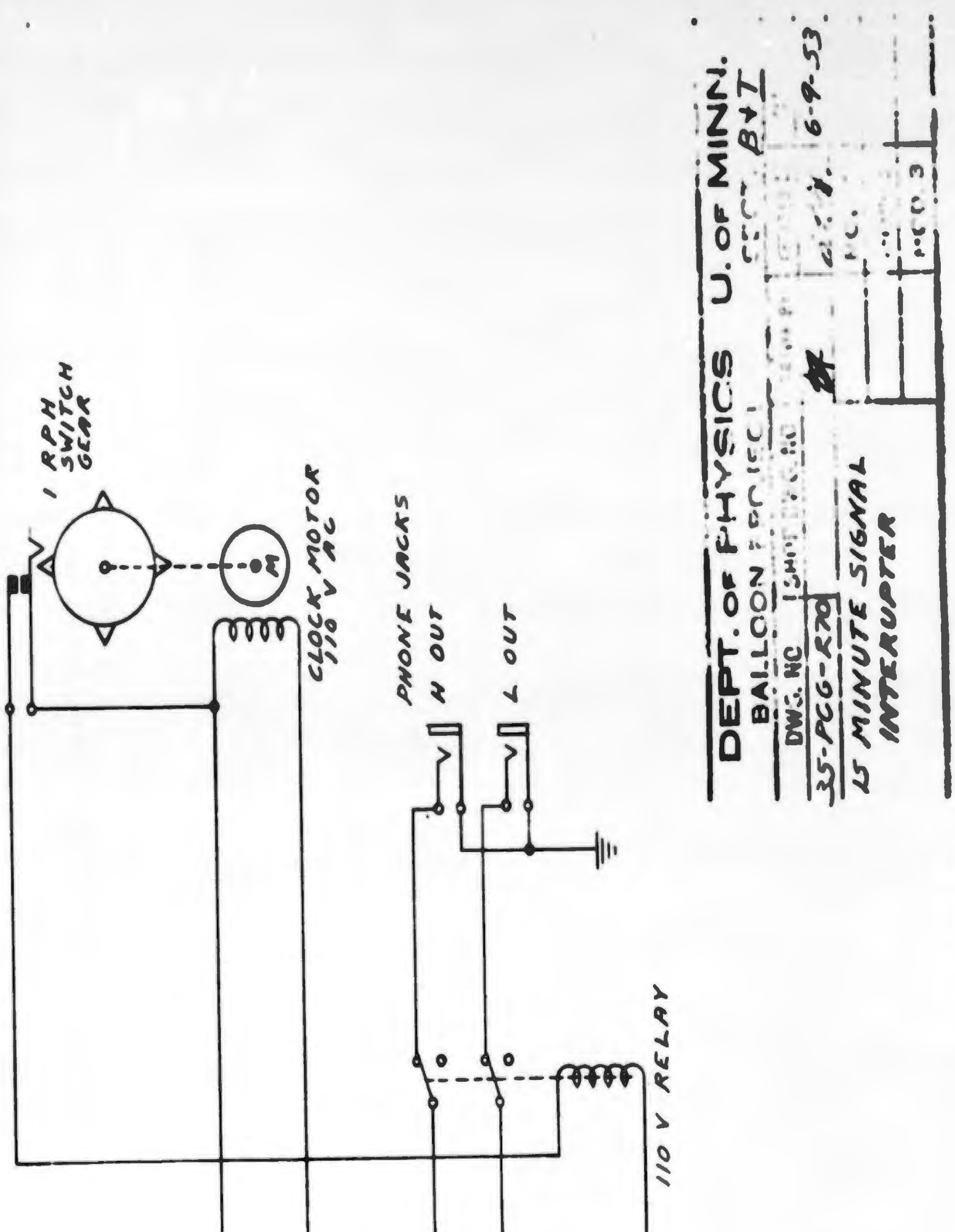

1 RPH SWITCH GEAR
CLOCK MOTOR 110 V AC
PHONE JACKS
H OUT
L OUT
110 V RELAY
110 V AC
H IN
L IN
DEPT. OF PHYSICS U. OF MINN.
35-PCG-R70
15 MINUTE SIGNAL INTERRUPTER
6-9-53

Fig. II-24.

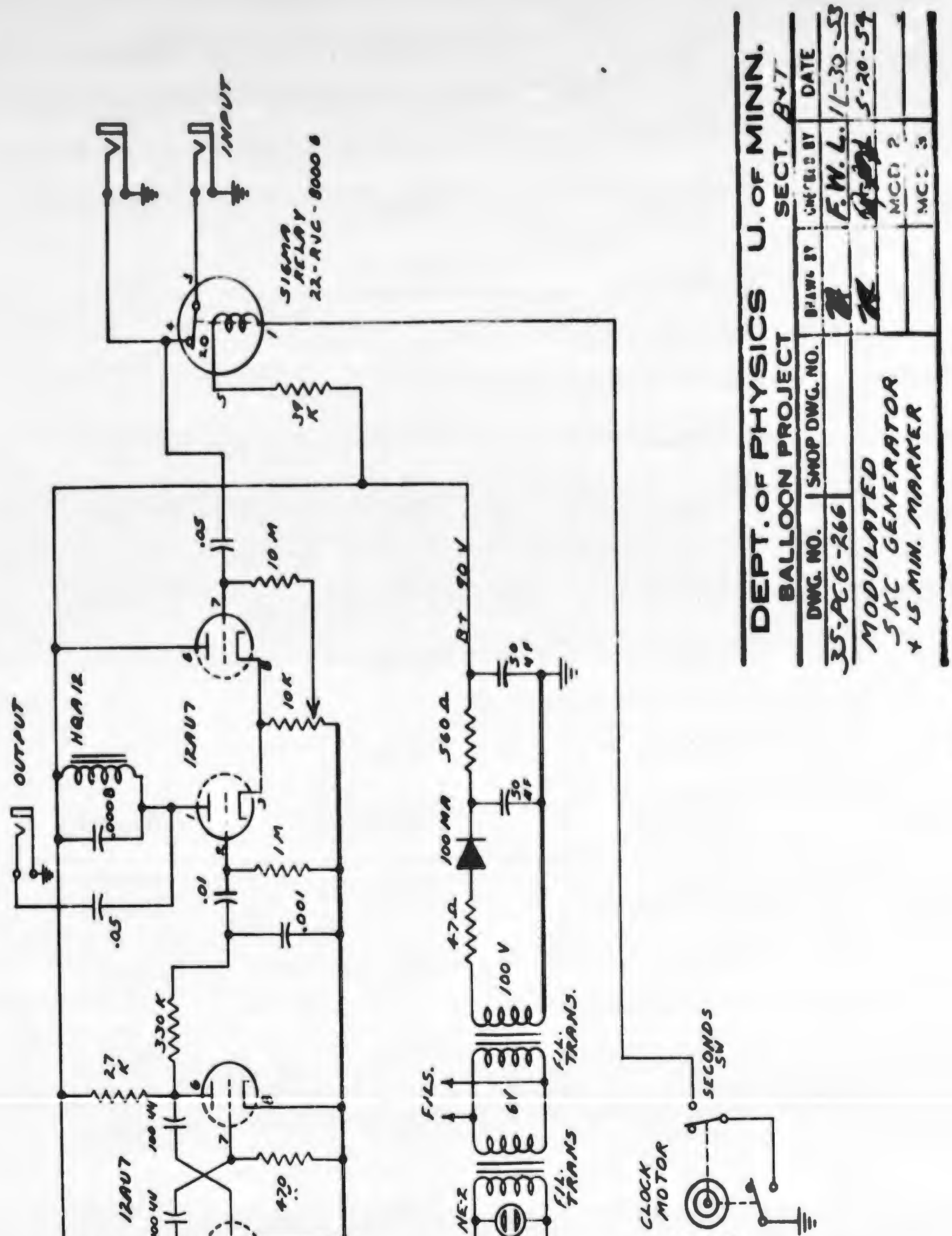

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
SECT. BNT
DWG. NO.
SHOP DWG. NO.
DRAWN BY
CHECKED BY
DATE
35-ACG-266
F.W.L.
11-30-53
5-20-54
MODULATED
5KC GENERATOR
+ 15 MIN. MARKER
SIGMA RELAY
22-RNC-8000 G
INPUT
OUTPUT
12AU7
B+ 90 V
100 V
110 V AC
FIL. TRANS.
CLOCK MOTOR
SECONDS SW
15 MIN. SW

Fig. II-25.

modulated carrier is then recorded at a tape speed of 7½ in/sec. The trailer station is not equipped, at present, to decode the signal, and the main purpose of this station is the production of the magnetic tape recording which is later played back and decoded at the Minneapolis station or in the laboratory.

The magnetic recordings from flights are preserved so that the original data from any flight is always available.

b. Simultaneous Multiplex Decoding and Recording

As may be seen (Figure II-26, a & b) the Anoka Airport station is equipped both for magnetic tape recording and direct decoding of the multiplex signal. Six of the channels may then be currently decoded if desired.

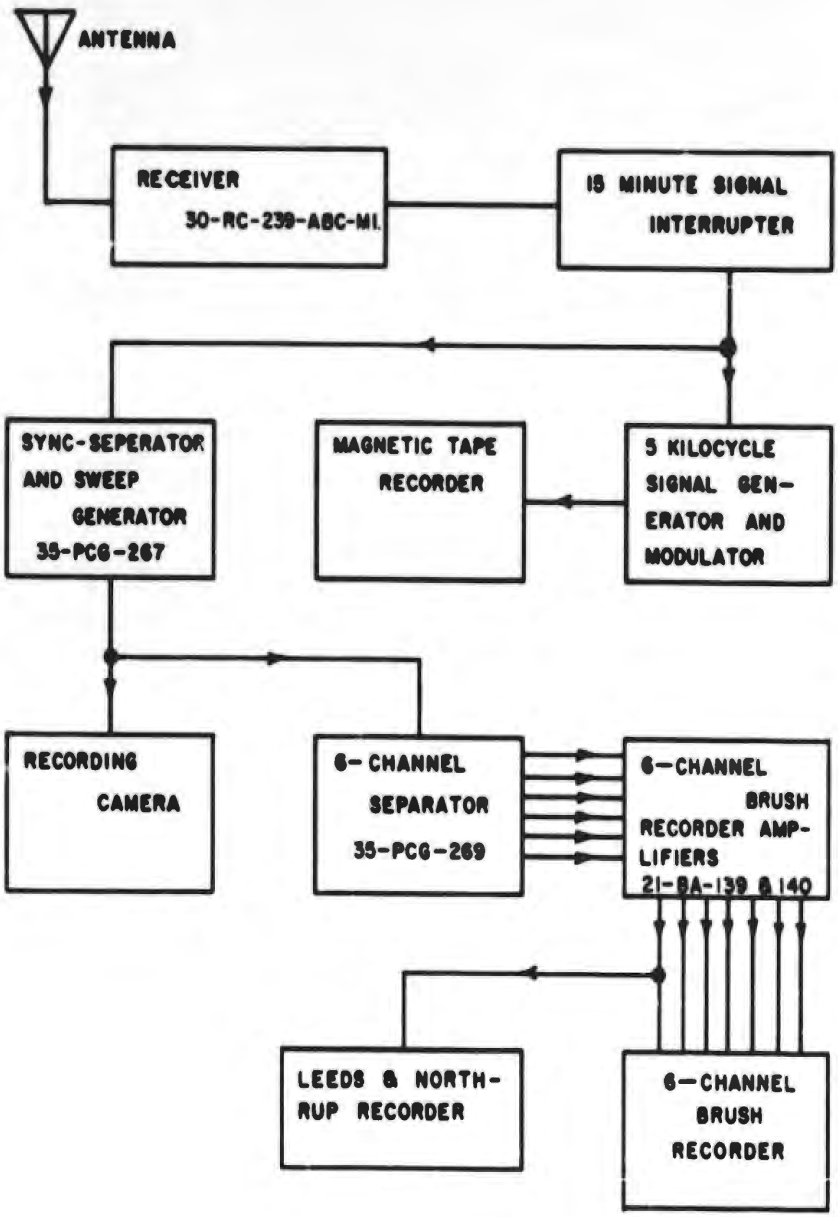
The multiplex decoding equipment as used during this series of flights produced three types of record:

(1) Synchronized film record (Figure II-27),

(2) six-channel, simultaneous, strip-chart recording (Figure II-28),

(3) single-channel strip-chart recording for current data read-out. (Figure II-29).

The main unit of the multiplex decoding equipment is the sync-separator and sweep generator (Figures II-30, II-31). The unit, as shown, is the first working model and has been in use in all of the operations using multiplex encoding. There are still refinements to be made in the circuitry, but in general the apparatus has operated satisfactorily. The block diagram, (Figure II-31), with wave forms will help one to follow the signal through the various circuits if so desired.



MULTIPLEX DECODING SYSTEM
BLOCK DIAGRAM

Fig. II-26a.

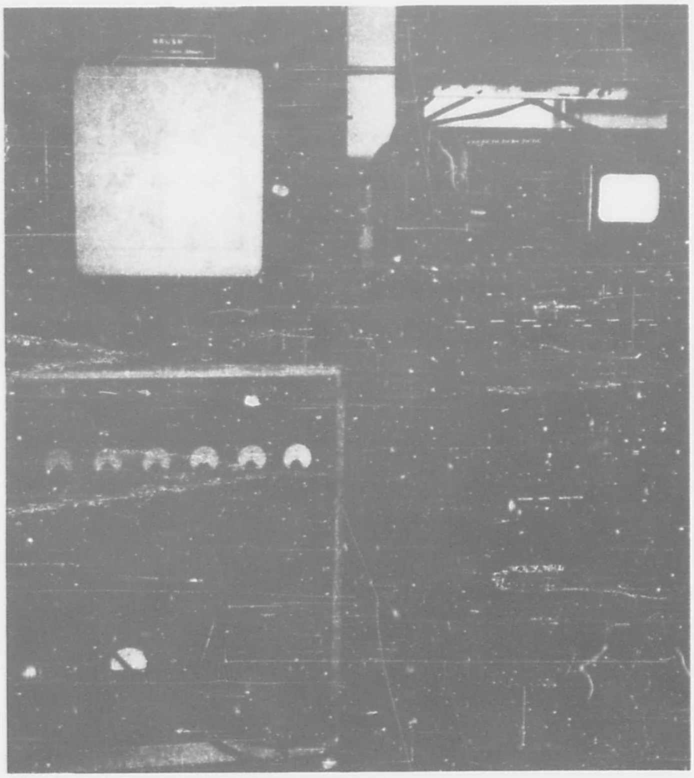


Fig. II-26b. Multiplex Decoding Equipment Racks

Upper Left: 6-channel Brush Recorder
Lower Left: Brush Amplifiers (Fig. II-35,a,b,)

Right side: Top: 6-channel separator (Fig. II-32)
Second: Dual scope unit with camera attachment. (Fig II-34)
Third: Dual scope amplifier (Fig. II-33)
Fourth: Sync separator and sweep generator (Figs. II-30,31)
Fifth & Bottom: Power supplies for above equipment.

Fig. II-27. Synchronized Film Record.

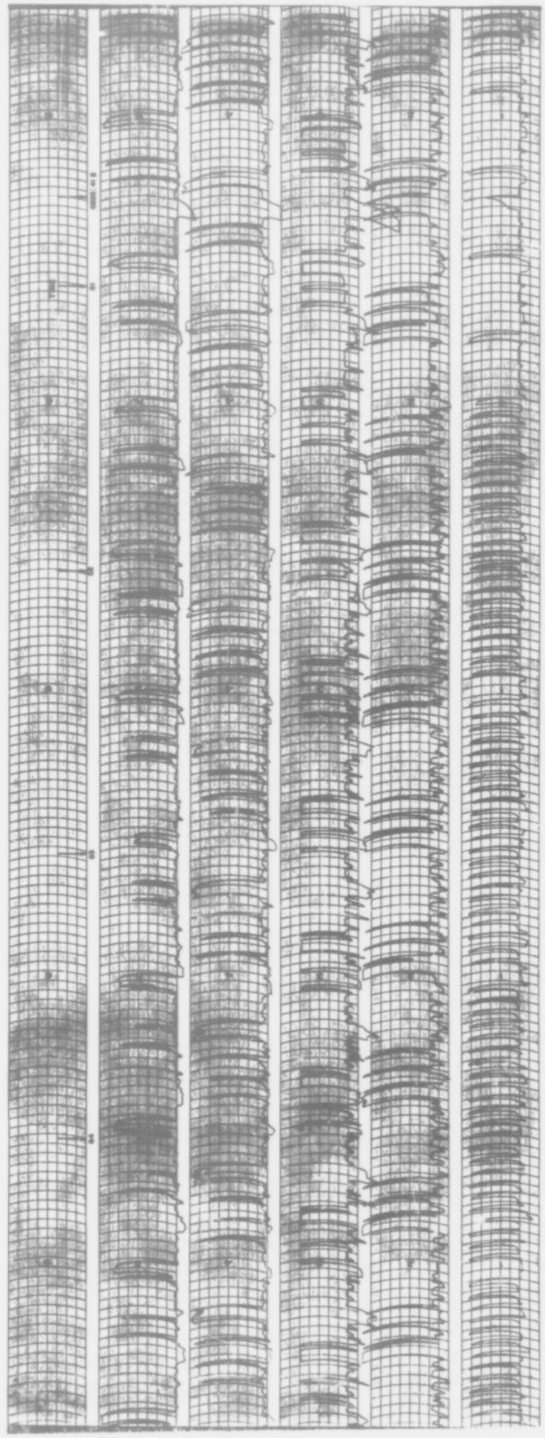


Fig. II-28. 6-channel, simultaneous, strip-chart recording.

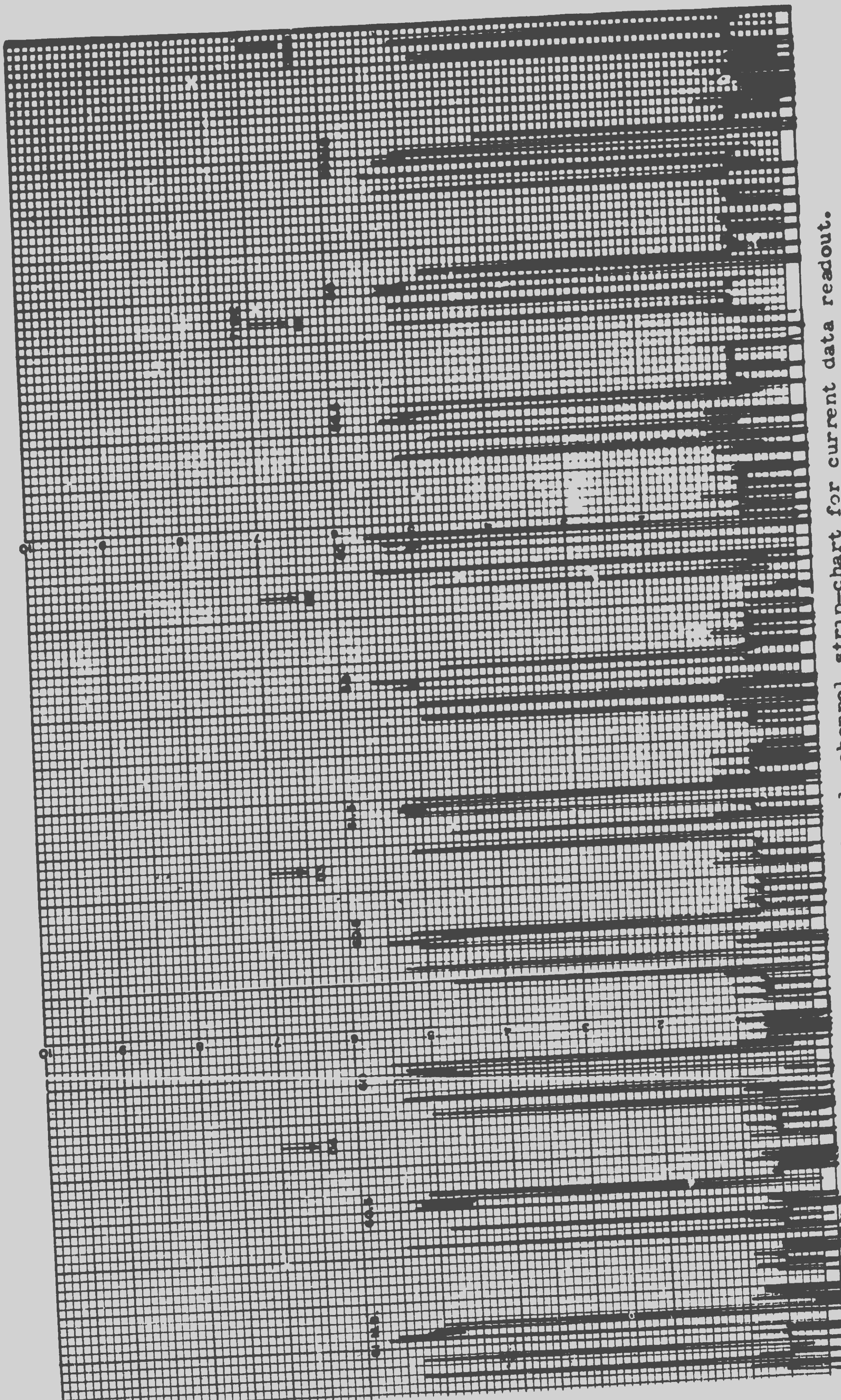


Fig. II-29. Single channel strip-chart for current data readout.

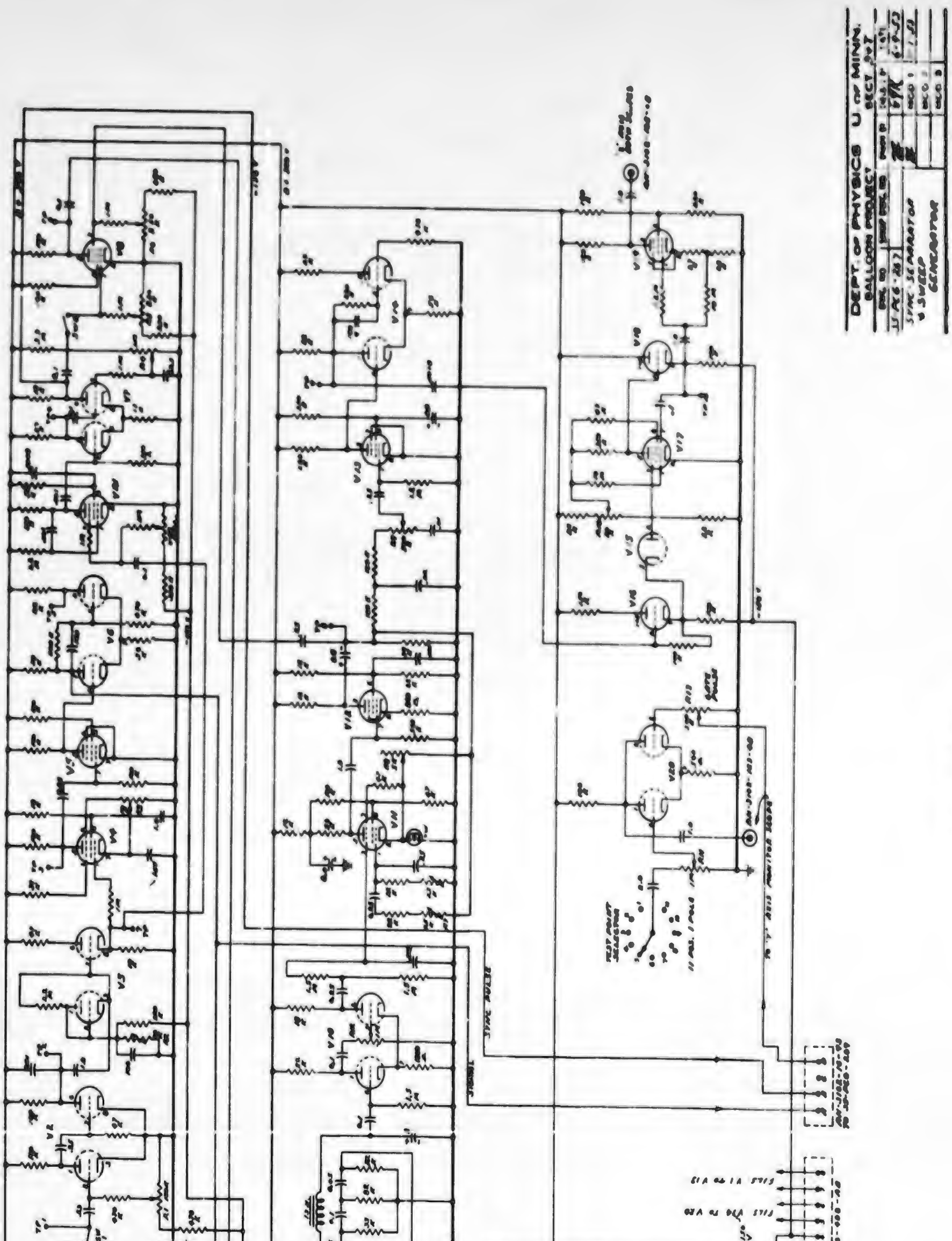

DEPT. OF PHYSICS U of MINN.
BALLOON PROJECT
SYNC SEPARATOR
& SWEEP
GENERATOR

Fig. II-30.

SYNC-SEPARATOR + SWEEP GENERATOR
BLOCK DIAGRAMS WITH WAVE-FORMS

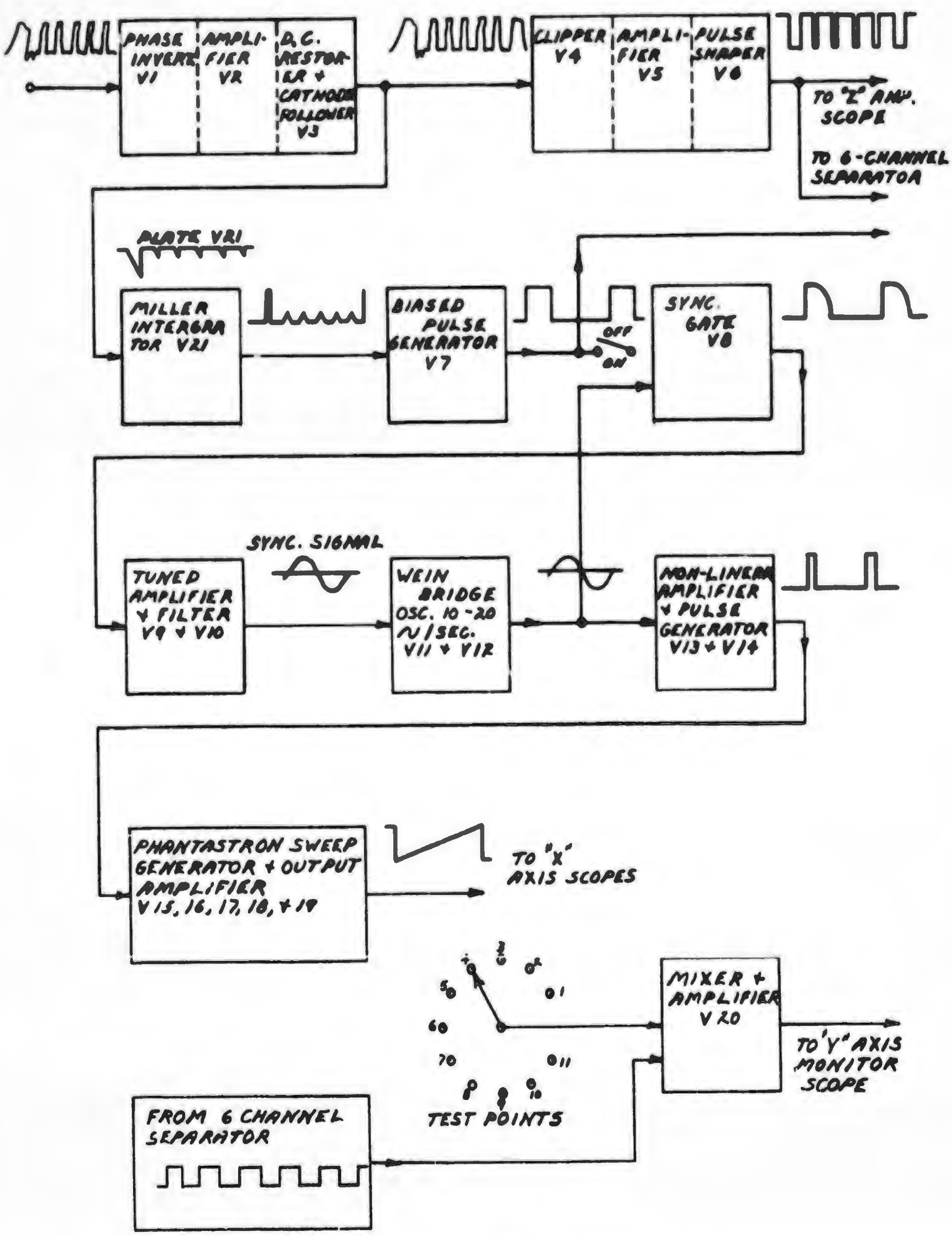


Fig. II-31.

The primary purposes of this unit are to provide:

(a) a synchronized horizontal sweep for cathode-ray-oscilloscope observation and camera recording,

(b) sufficient amplitude of signal for pulse-brightening on the camera oscilloscope, and

(c) a separated reference pulse for synchronizing the six-channel separator circuits (Figure II-32).

A dual scope unit, associated with the decoding equipment, provides a means of camera recording and monitoring the signal and other wave forms derived from the original signal. This equipment consists of two scope-amplifier units (Figure II-33); two five-inch cathode ray tubes (Figure II-34), one with a P-11 phosphor for photography and the other with a long persistence, P-7, screen for visual observation; and the associated power supplies which are not shown.

A saw-tooth waveform, synchronous with the multiplex signal, is applied to the horizontal amplifier input of one of the scope amplifiers (Figure II-33). The D.C.-stabilized output signal from this amplifier is coupled to the horizontal deflection plates of both cathode-ray tubes.

The shaped signal output from the anode of V6 (Figure II-30) is coupled to the "Z" axis input of the camera section of the scope-amplifier unit. The intensity control on this unit is adjusted so that the spot appears only with application of sufficient signals. A continuous strip film record is made at a film rate of 1½ in/min.

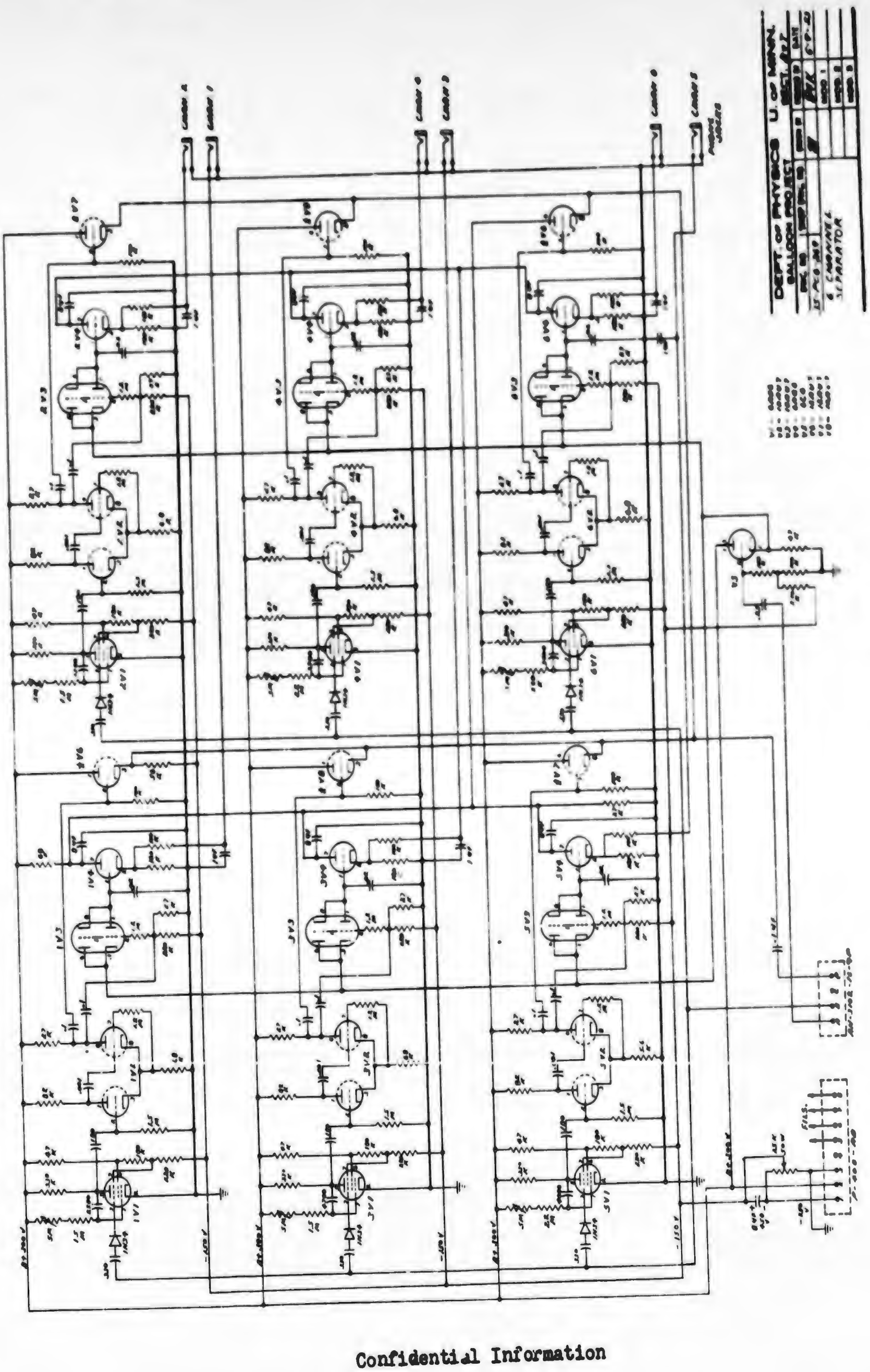

DEPT. OF PHYSICS
U. OF MINN.
BALLOON PROJECT
6 CHANNEL SEPARATOR

Fig. II-32.

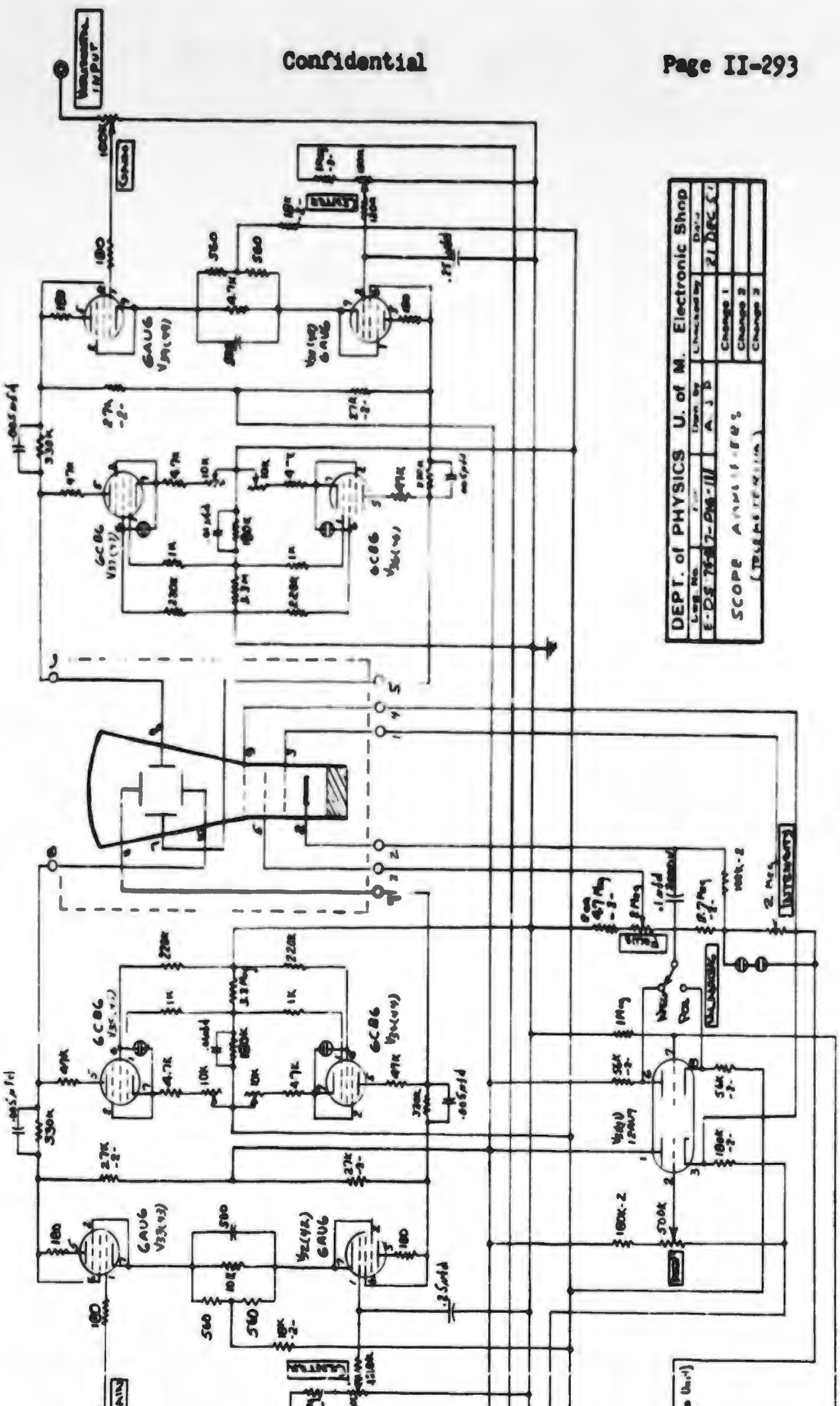

VERTICAL INPUT
HORIZONTAL INPUT
GAIN
6AU6
6CB6
Z AXIS
DEPT. of PHYSICS U. of M. Electronic Shop
SCOPE AMPLIFIERS

Fig. II-33.

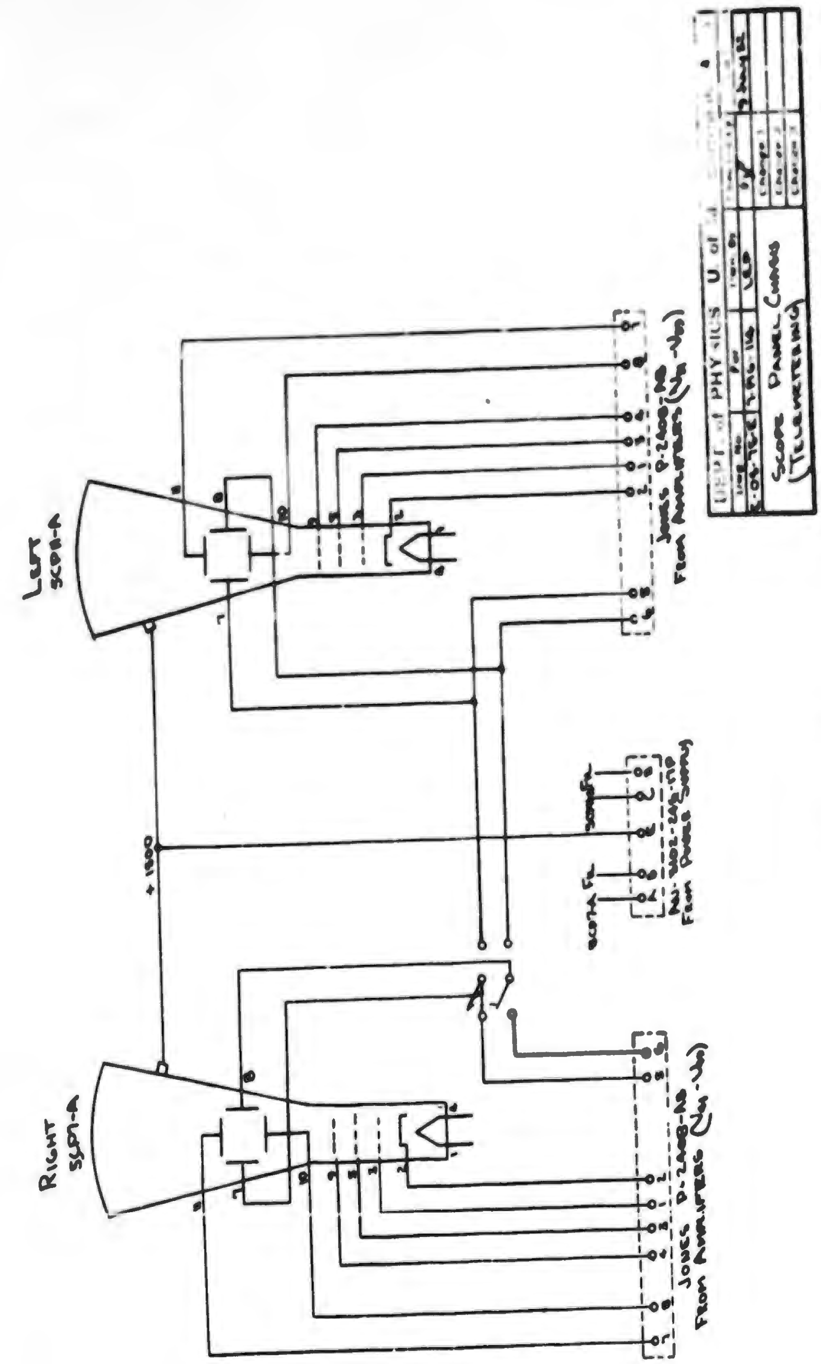


Fig. II-34.

The signal which is observed on the monitor scope comes from the anode of V20 (Figure II-30) and is amplified and D.C.-stabilized by the vertical amplifier (Figure II-33) associated with this unit. The signal to be monitored is chosen by positioning the 10-pole test-point selector switch (Figure II-30) as desired by the operator.

The six-channel separator unit (Figure II-32) consists of six similar units, one for each channel. The positive going sync-pulse, from pin six of V-7 (Figure II-30), is coupled, in common, to V-1 of each channel unit. The tube (V-1) in each channel, and its associated circuit, are used to provide an adjustable delay between the incoming, common, sync-pulse and the individual output pulse. The differentiated anode wave form of V-1 acts as a trigger for the monostable multi-vibrator circuit (V2) which generates a pulse of about 5 ms duration. This positive pulse is coupled to the grids of V3, which are normally biased below plate current cutoff, and also to the grid of the triode gate-pulse-mixer (either V6, 7, or 8) stage. All of the gate pulses are developed across the 56 K, common cathode load resistor of the mixer stage. These pulses are then mixed with one of the test point signals in V20 of Figure II-30 and appear on the monitor scope as negative going notches in the trace. The delay time of circuit V1 of each channel may then be easily adjusted to the correct value for coincidence with the desired signal channel pulse. The complete multiplex signal appears on the grid and cathode of the common circuit, V5, of this unit and is directly coupled to pins 3 and 6 of V3 in each channel.

The circuits V3 and V4 of each channel act as gated, peak-reading voltmeters. The action of the charging circuit for the .02MFD condenser, on the grid of V4, is dependent on the voltage on this condenser and the instantaneous potential applied to pins 3 and 6 of V3 when a positive gate-pulse is applied to the common control grids. It can be seen that,due to the limiting action of the 12-megohn resistor in series with grids 2 and 7, these grids will assume a potential value equal to the most negative of either cathode 3 or 8 when activated by a large positive voltage from the circuit of V2. Therefore, that triode section of V3 which has the most negative, instantaneous cathode potential will be in a conducting state and the voltage appearing at the grid of V4 will be approximately the same as that applied to pins 3 and 6 during the gate time. This gate appears once per cycle at the multiplexing rate and, as V3 is biased below cutoff during the remainder of the period, the voltage assumed by the 0.02 MFD condenser during one gate time will remain essentially constant until the next gate. The signal output, as appears at the cathode of V4, is consequently a close approximation to the original primary encoded signal before multiplexing.

The separated signal from each channel is then fed into the input of one of the six-channel Brush amplifiers (Figure II-35, a,b). These amplifiers drive the pens of the six-channel Brush recorder and a strip-chart ink recording is made of the various data channels simultaneously. The paper feed is adjusted to produce a rate of 6 in/min. If single-channel recording is desired, a Leeds & Northrup "Speed-O-Max" recorder input is connected in parallel with the pen armature of the desired channel.

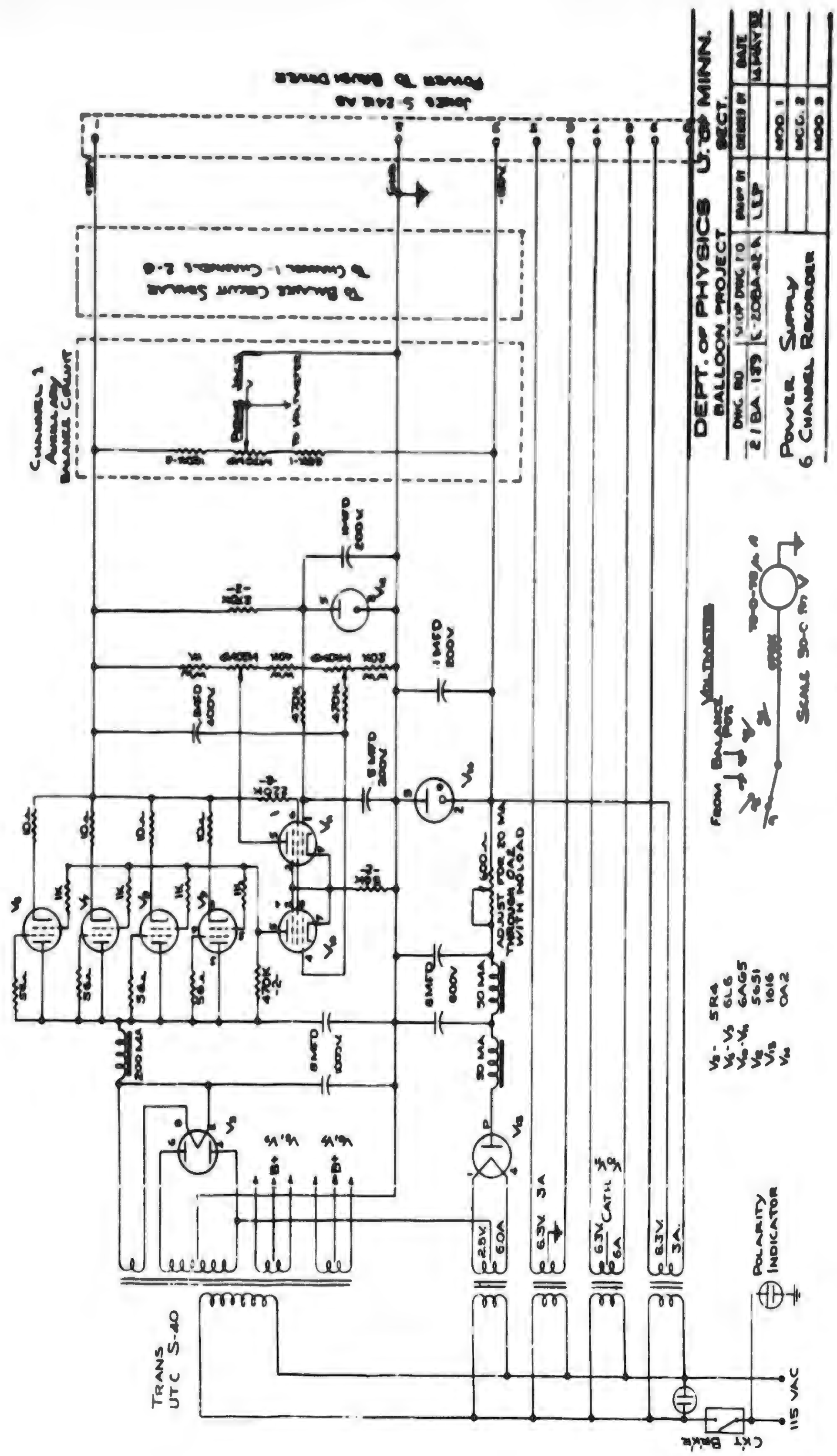

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
POWER SUPPLY
6 CHANNEL RECORDER
TRANS UTC S-40
115 VAC
POLARITY INDICATOR

Fig. II-35a.

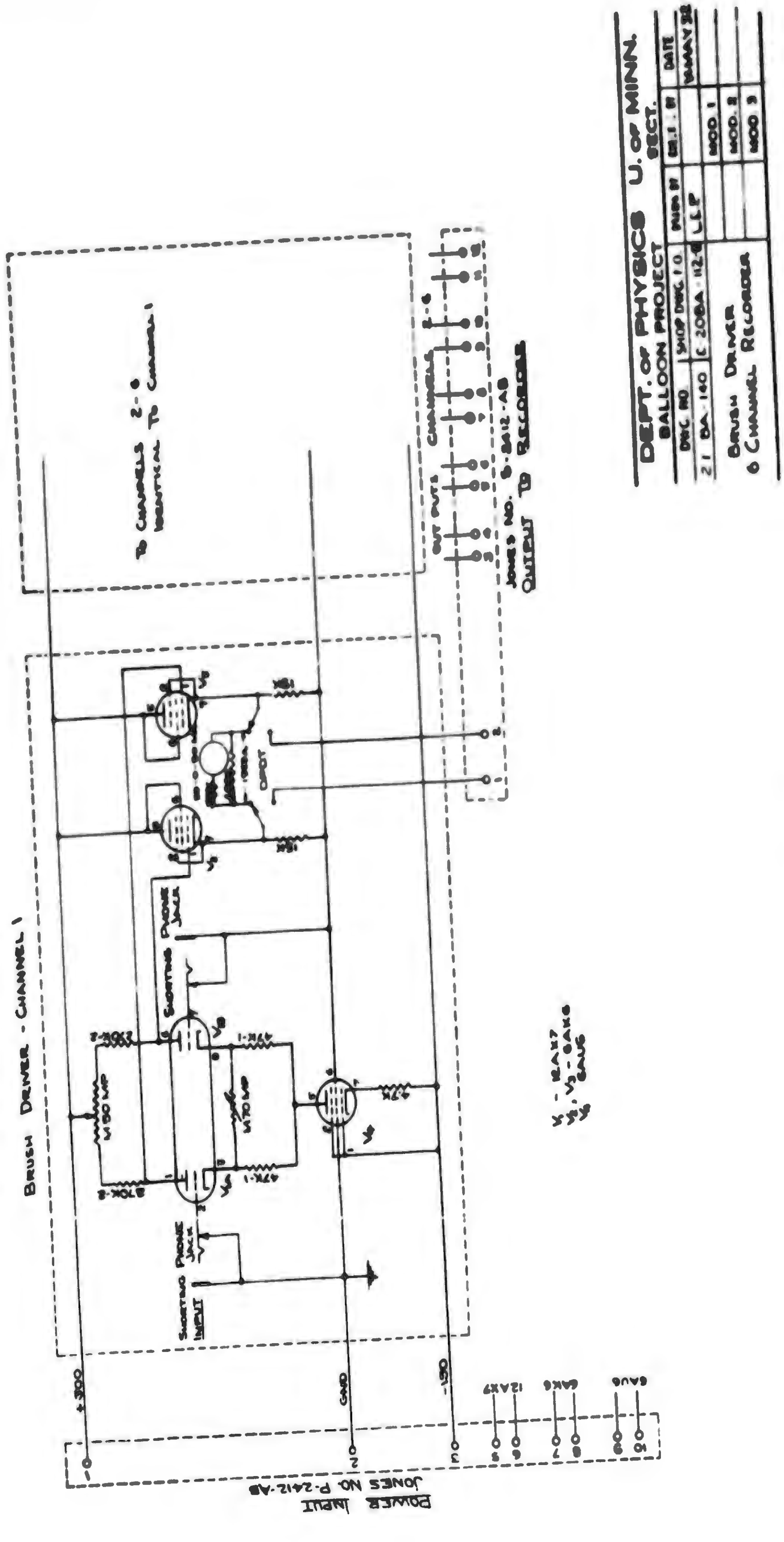

DEPT. OF PHYSICS U. OF MINN.
BALLOON PROJECT
BRUSH DRIVER
6 CHANNEL RECORDER
BRUSH DRIVER - CHANNEL 1
TO CHANNELS 2-6 IDENTICAL TO CHANNEL 1
JONES NO. S-2412-AB
OUTPUT TO RECORDER
POWER INPUT
JONES NO. P-2412-AB
+300
GND
-150
SHORTING PHONE JACK
INPUT

Fig. II-35b.

3. Communications

As communications between the mobile trailer station and the Anoka County Airport station are desirable and necessary during flight operations, both stations are equipped with transmitters operating on either 3415 KC or 6420 KC. These transmitters are capable of handling voice, C.W. code, or M.C.W. code. With the trailer station located at DePere, Wisconsin, it has been found necessary to install a plug-in telephone to insure continuity of communications during operations. The distance between stations in this case is 350 miles and neither of the two available voice frequencies will operate at this short range during winter nights.[11] The lower frequency, 3415 KC, is often used for telemetering and is therefore unavailable for communications.

4. Special Portable Receiving Equipment

A light-weight battery-power portable receiver and recorder unit has been constructed (Figure II-36, a & b) and was used occasionally in the flights of this series. This equipment can be carried by one man and is easily transportable in a light aircraft or automobile.

The receiver is crystal-controlled and, by insertion of the proper plug-in coils, may be tuned to any of the assigned frequencies in the M.F. and H.F. bands. A low-power, simple strip-chart recorder, with a regulated D.C.-motor drive, was constructed for use with this unit. This recorder is used for ink recordings on primary encoded signals. When used for receiving multiplex telemetering, a battery-operated magnetic tape recorder is used in conjunction with the receiver.

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(11) Ibid, Volume X, This section, p. II-308.

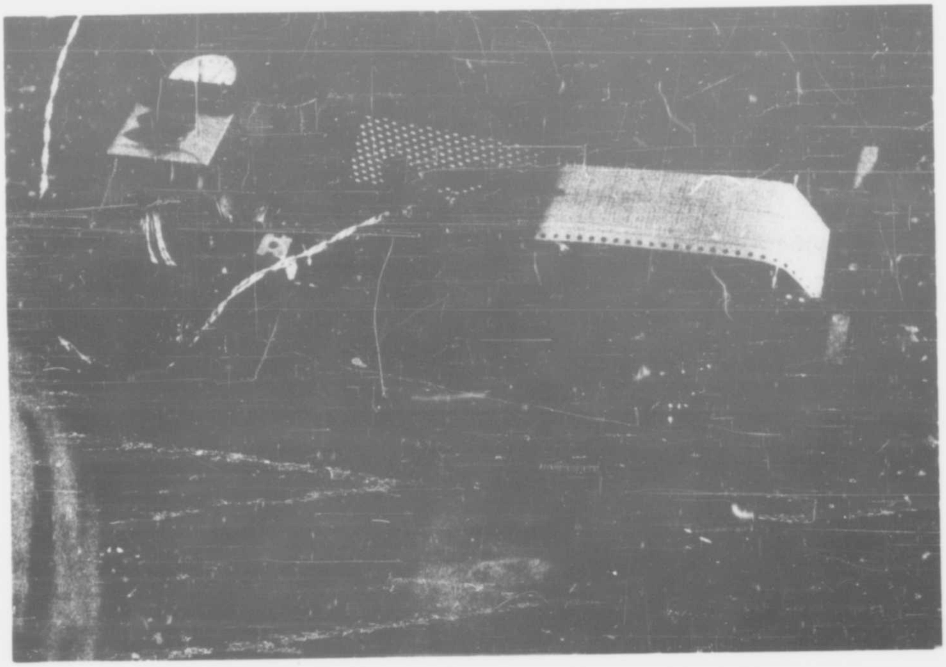

Fig. II-36a. Portable Receiver and Recorder Unit.
Slant view showing control knobs.

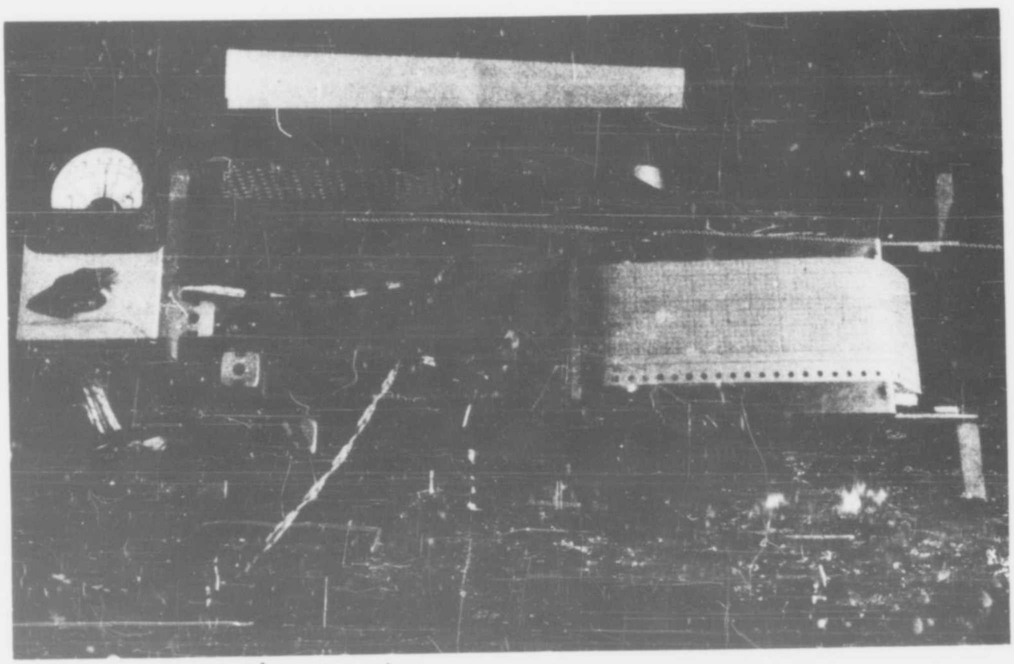

Fig. II-36b. Top view.

D. Investigation of Loran Tracking[12]

It was desired to investigate the problems concerned with a balloon-tracking system utilizing the already-existing and operating Loran hyperbolic navigational system. This system, as used for direct navigation of aircraft and surface vessels, has been shown to have a high degree of reliability and accuracy in the covered zones.

The basic plan of operation, for this series of tests, was to use a fixed-tuned receiver on the Loran frequency used in the area of the flight and to retransmit the Loran signal received on the frequency used for telemetering. A slow operating commutator was used to switch the transmitter modulation from Loran repeat to the multiplex encoded series of pulses. This system would permit balloon altitude, temperature, and other desired data to be telemetered, as well as to furnish position information.

At the ground receiving station, the Loran-modulated signal was converted from the balloon transmitter frequency to one of the Loran frequencies and observed on standard U.S.N., Model DAS-1, Radio Navigation Equipment. The position lines for the balloon were then computed and plotted in the normal manner.

1. Equipment

The receiver for Loran signals, which was c ried by the balloons, was previously described (Figure II-16, a,b,c) in this report. The retransmission frequency chosen was 3415 KC and a converter (Figure II-37) from 3415 KC to 1750 KC was constructed and used so that the signal could be observed in the normal manner on standard Loran indicator equipment.

(12) For an explanation of the Loran system design and operation, see "Loran", Vol. 4, Radiation Lab. Series, M.I.T., McGraw-Hill Book Co., Inc. NYC 1948.

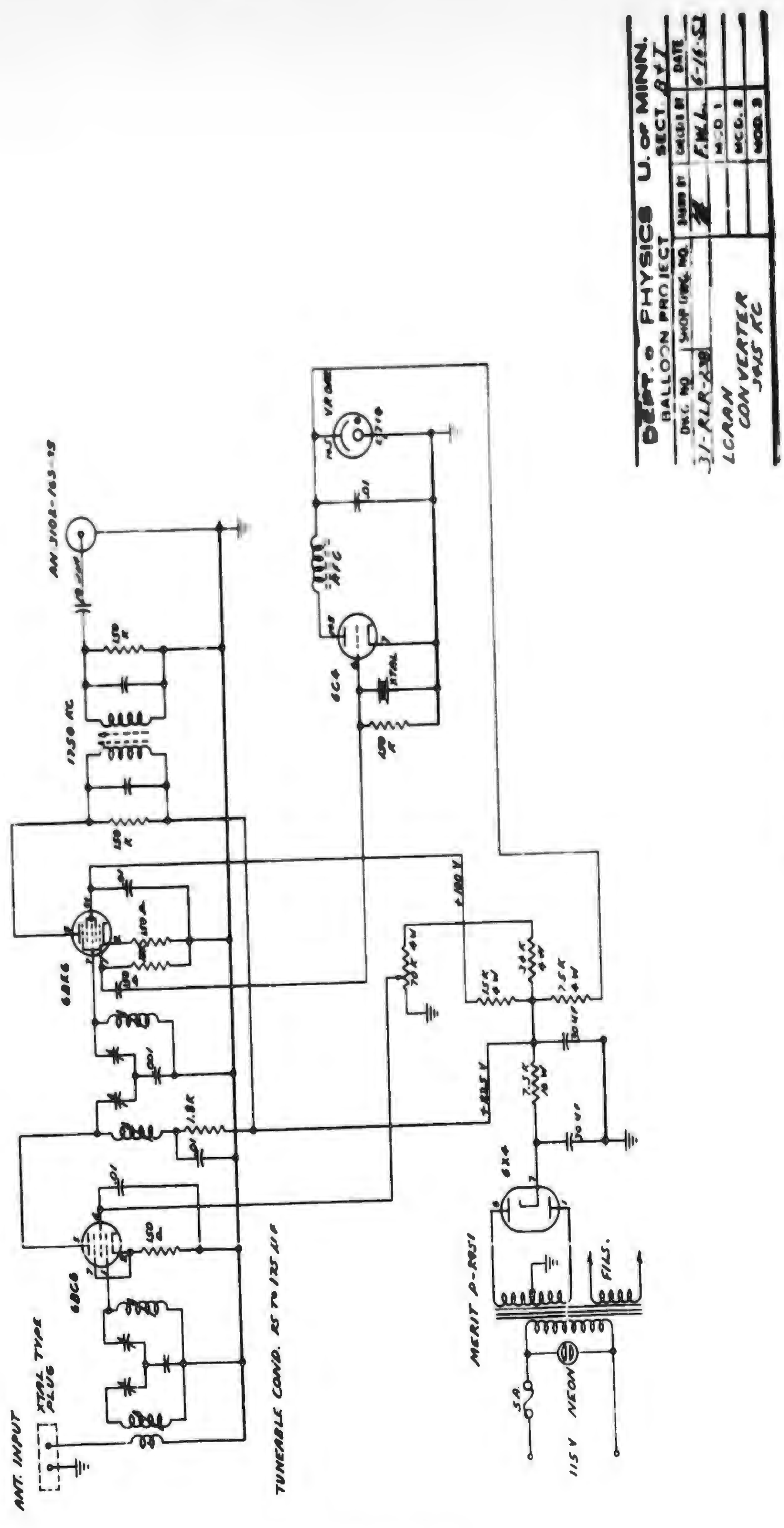
DEPT. of PHYSICS U. of MINN.
BALLOON PROJECT
LORAN CONVERTER
ANT. INPUT
XTAL TYPE PLUG
115 V
NEON
FILS.

Fig. II-37.

2. <u>Methods of Transponding</u>

There are two principal methods available for the retransmission of Loran signals:

(a) linear, in which the transmitter is modulated with the signal as received without clipping, limiting, or other distortion; and

(b) strong-signal triggering, in which the transmitter is modulated only by signals which exceed a certain predetermined amplitude.

The method (a) is capable of furnishing an undistorted relay of the Loran signal at the balloon location. However, the receiver must necessarily have sufficient bandwidth to prevent distortion of the Loran pulses (in the order of 75 KC) and, as a result of this bandwidth requirement, the noise output from atmospherics and artificial interference will be large. The noise output from the receiver will be retransmitted, in a linear system, along with the desired Loran pulses.

As the bandwidth requirements for the balloon-to-ground link are the same as those from the originating Loran stations to any ship or aircraft using Loran navigation, the peak power requirements for reliable reception are very nearly the same as they are for direct Loran at the same distance. The peak power output from Loran stations now in use is from 100 to 1000 kilowatts. As the power requirement for the same distance usually is less at 3415 KC than at Loran frequencies, the power required for this type of retransmission would be at least 10 KW peak for the same coverage.

For line-of-sight reception of the signal from the balloon, the power required would be low and this system should give reliable fixes with approximately the same accuracy as an original signal at the balloon location.

However, the transmitter power requirement for long distance reception appears to be excessive with the power sources and transmitters now available.

The method described under (b) above has certain advantages over method (a) in that the amount of noise retransmitted may be reduced by clipping the receiver output and by eliminating the need for the excessive bandwidth used in a linear system. With a triggering system, the original pulses are not retransmitted as received but are used to initiate operation of a pulse-generating device, such as a monostable multivibrator, which forms the modulating wave-form for the transmitter. It is no longer necessary to preserve the original pulse length specifications in this system, if less than the original Loran accuracy can be tolerated. The bandwidth of the ground receiving equipment may be correspondingly reduced, with an increase of pulse-length from the transponder, and, consequently, the peak transmitter power required for reliable reception is reduced.[13]

The principal objection to the above system is that the original wave-form as received at the balloon location is not available at the indicator and the operator is not easily able to determine which of the pulses of the ground-wave and sky-wave train is utilized to trigger the transponder. The accuracy of the hyperbolic lines obtained under these conditions is consequently very poor.

3. Test Flight

Loran tracking was used on Flight 82. The flight was launched before sunset and because of a faulty balloon descended about 2½ hours after sunset.

The atmospheric noise level on the date of this flight was unusually high due to the presence of thunder storms in the region. During daylight

(13) See Appendix I, this Section, for a discussion of this statement.

hours the skywave signal on 1950 KC from the Atlantic chain of Loran stations undergoes a large attenuation in the D-layer and is received here only occasionally and then with a marginal signal strength. Because of this effect, the transponded Loran signals for the first hour of the flight were almost totally unreliable, although the transmission link from balloon to ground was good. During,and after, sunset the signal from the balloon underwent strong fading and was not usable. This condition, along with the excessive atmospheric radio interference, continued until approximately 0400, 11 July, GMT, at which time the signal-to-noise ratio began to increase and it was possible to recognize Loran stations on the DAS-1 indicator,but the signal was not sufficiently good for time readings. The balloon soon descended (0440 GMT) and ended the test.

The results (Figure II-38) from this test flight were inconclusive and the operation was not considered to be successful.

4. Conclusions

However, some conclusions may be reached concerning the operation of this tracking system. These are based on several ground tests and observations of transponded Loran pulses under various conditions, as well as theoretical considerations of the radio transmission paths concerned, the pulse shapes and bandwidths involved, and the expected or desired accuracy. On the basis of the above factors, the following conclusions seem to be indicated:

(a) Linear retransmission of the signal (and noise) output from the balloon receiver is required for tracking in areas where the Loran ground wave is not predominant and where there may be multiple sky waves. This factor is necessary for proper pulse identification by

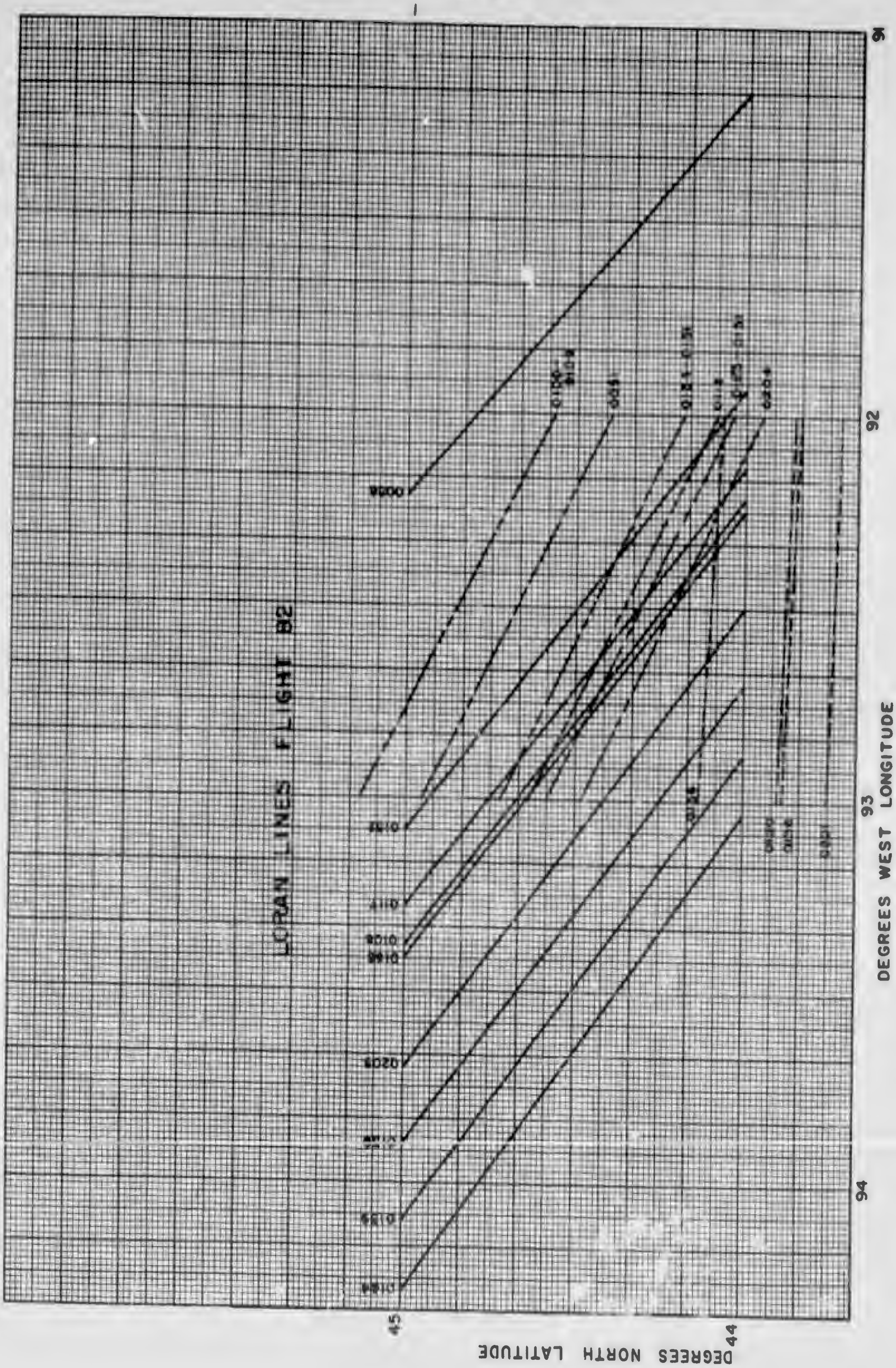
LORAN LINES FLIGHT 82
DEGREES WEST LONGITUDE
92
93
94
DEGREES NORTH LATITUDE
45
44

Fig. II-38.

the operator at the ground station. This type of transponding is normally unsuitable, for reasons given in the previous discussion, except where the relay link to the ground observer is short and reliable, i.e. line-of-sight, in which case the transmitter power requirement is low and very little noise will be added in this transmission link.

(b) Under conditions in which the Loran signals at the balloon receiver consist of the ground wave or the first E-layer wave only, the strong signal triggering system may be used. This system would be efficient with respect to the amount of equipment and modulating power required to be carried by the balloon, as pulse-type modulation can be accomplished in a low-power stage of the transmitter. However, if the balloon-to-ground link is over line-of-sight range,the output power requirement would be large unless pulse stretching and lower bandwidth were used. In the latter case, the reading accuracy would necessarily be reduced. This system would not,it seems, be suitable for tracking balloons over long trajectories.

(c) If the low frequency Loran(14) system were operating, this problem would present fewer difficulties. The pulse lengths employed (200 μ sec) in this system are suitable for retransmission in a narrow band (8 to 12 KC) system and, therefore, reduce the maximum required power from the balloon transmitter. In addition, the various sky-wave and ground-wave pulses overlay in this system to form a single pulse. This condition allows the practical use of a triggered transponding system with all its inherent advantages without introducing as much error as in the standard Loran system. Another advantage of L.F. Loran is that the base lines between stations are long and the stations are fewer, which conditions,

(14) L. F. Loran is described in detail in "Loran" (same as (9)). Apparently this system has been tried, but at present there are no L. F. Loran systems in operation.

respectively, aid in obtaining accurate fixes and reduce the complexity of the transponded signal.

In summary, the results of this study indicate that standard Loran relaying is, in general, not suited for use in balloon tracking unless the special conditions of either a short relay-link from the balloon to the ground indicator or a short path from a Loran triplet to the balloon (a steady ground-wave signal) are fulfilled. If transmitting equipment capable of large (10,000 watts peak) power output were developed along with suitable power supplies, the relay link from balloon to indicator could be greatly lengthened. One alternative to this problem is to use transponding frequencies in the short wave region of the high frequency band (> 10 mc) and employ several tracking stations suitably located for long-range reception.

E. Radio Propagation Predictions

Some of the work done concerning radio propagation as applied to telemetering problems from balloons was previously discussed.[15] Since the time of the last report, some refinements and changes have been made in the computation of predictions and the use of the radio propagation prediction data issued by the Central Radio Propagation Laboratory, National Bureau of Standards, Washington, D. C.

1. Prediction of Disturbed Conditions

In order to aid in the planning of particular flights, the "Advance Forecast of Radio Propagation Conditions" (CRPL - J series), issued bi-weekly, are utilized in an effort to avoid long-range flights during periods of disturbed radio propagation conditions. This service of CRPL includes 25-day advance forecasts as well as for the first seven days after issue of each

(15) PROGRESS REPORT ON HIGH ALTITUDE BALLOONS, Volume V, p. VIII-355-360.

bulletin. In addition, the short-term forecast and current propagation conditions as broadcast by radio station WWV[16] are monitored for the 24 hours preceding an expected long-range flight. It has been the practice to avoid flying when condition "3" or lower is expected.

2. Prediction of Required Power and Minimum Skip

The "Basic Radio Propagation Predictions" (CRPL series D, N.B.S.) for each month is used to make up a set of curves for the particular month, giving the predicted power requirements[17] for each hour of the day for various distances and frequencies (Figures II-39, II-40, II-41). The frequencies chosen are those close to assigned frequencies for this project (1.7, 3.5, 6.5, and 10 mc). The curves are based on a skip point in the west zone at 45° N. latitude. An hourly plot of minimum skip distance for these frequencies (except 1.7 mc) for each month is made as an aid in determining the desired frequency for each flight in view of the expected time-altitude function and expected lateral velocities (Figure II-42).

The predicted power requirement for a certain time and distance is an average value for the month and is not expected to agree exactly with experimental data on any given day.

3. Evaluation of Predictions

It is difficult to make absolute measurements of signal strength without special equipment for this purpose. However, several flights of this series were studied to compare the predicted time of signal failure with that actually realized. The results of this study are shown in Figures II-43, II-44, II-45 and II-46. In all of these charts a horizontal broken line

(16) CRPL, National Bureau of Standards, "Description of Radio Propagation Forecast Services, CRPL-RWS-21", Washington, D.C., Oct 5, 1953.
(17) Based on 3KC Voice communications with a zero d b service factor.

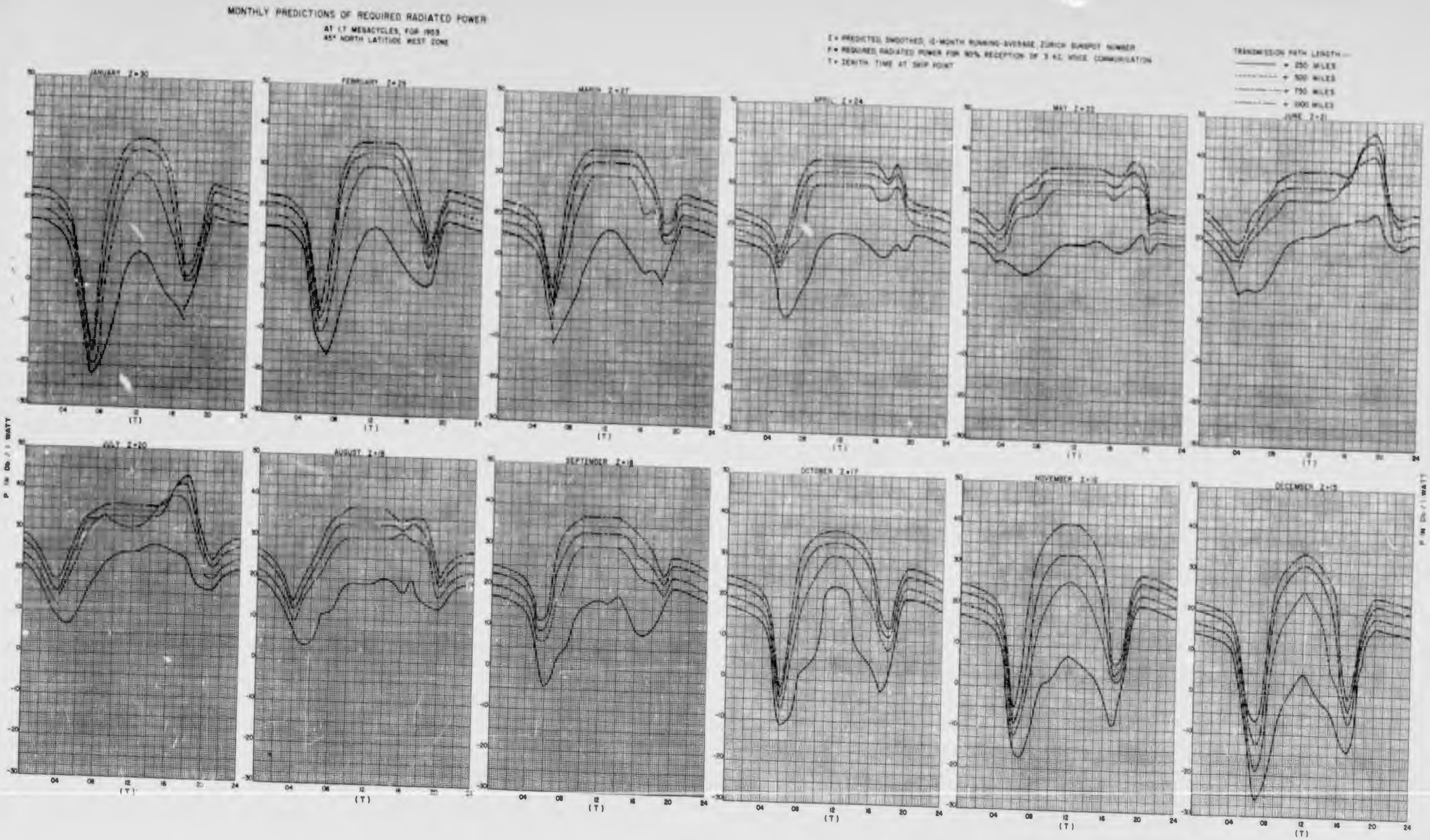
MONTHLY PREDICTIONS OF REQUIRED RADIATED POWER
AT 17 MEGACYCLES, FOR 1953
45° NORTH LATITUDE WEST ZONE
Z = PREDICTED SMOOTHED, 12-MONTH RUNNING-AVERAGE ZURICH SUNSPOT NUMBER
P = REQUIRED RADIATED POWER FOR 90% RECEPTION OF 3 KC VOICE COMMUNICATION
T = ZENITH TIME AT SKIP POINT
TRANSMISSION PATH LENGTH —
= 250 MILES
= 500 MILES
= 750 MILES
= 1000 MILES
JANUARY Z=30
FEBRUARY Z=29
MARCH Z=27
APRIL Z=24
MAY Z=22
JUNE Z=21
JULY Z=20
AUGUST Z=18
SEPTEMBER Z=18
OCTOBER Z=17
NOVEMBER Z=16
DECEMBER Z=15
P IN DB / 1 WATT
(T)

Fig. II-39.

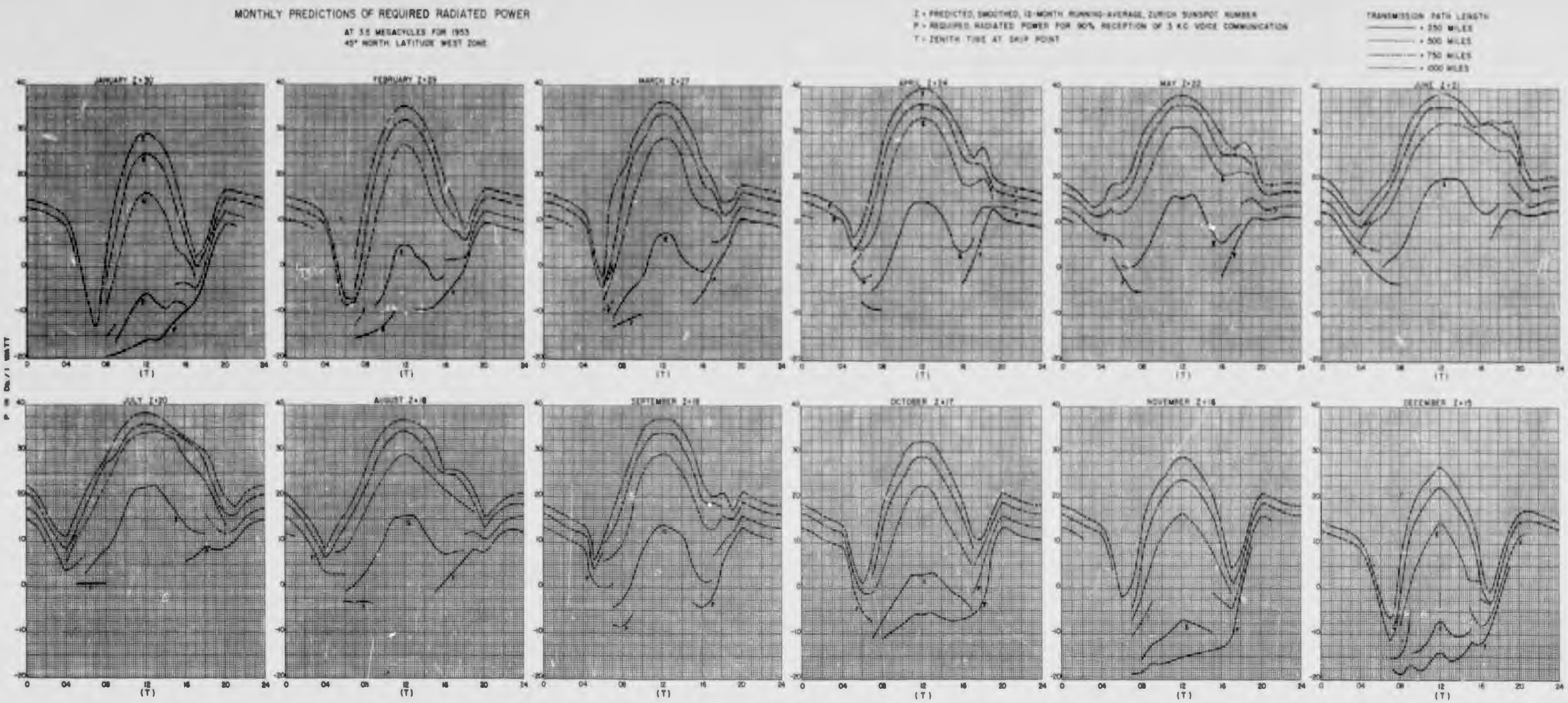
MONTHLY PREDICTIONS OF REQUIRED RADIATED POWER
AT 3.5 MEGACYCLES FOR 1953
45° NORTH LATITUDE WEST ZONE
Z = PREDICTED, SMOOTHED, 12-MONTH RUNNING-AVERAGE, ZURICH SUNSPOT NUMBER
P = REQUIRED RADIATED POWER FOR 90% RECEPTION OF 3 KC VOICE COMMUNICATION
T = ZENITH TIME AT SKIP POINT
TRANSMISSION PATH LENGTH
= 250 MILES
= 500 MILES
= 750 MILES
= 1000 MILES
JANUARY Z=30
FEBRUARY Z=29
MARCH Z=27
APRIL Z=24
MAY Z=22
JUNE Z=21
JULY Z=20
AUGUST Z=18
SEPTEMBER Z=18
OCTOBER Z=17
NOVEMBER Z=16
DECEMBER Z=15
P IN Db/1 WATT
(T)

Fig. II-40.

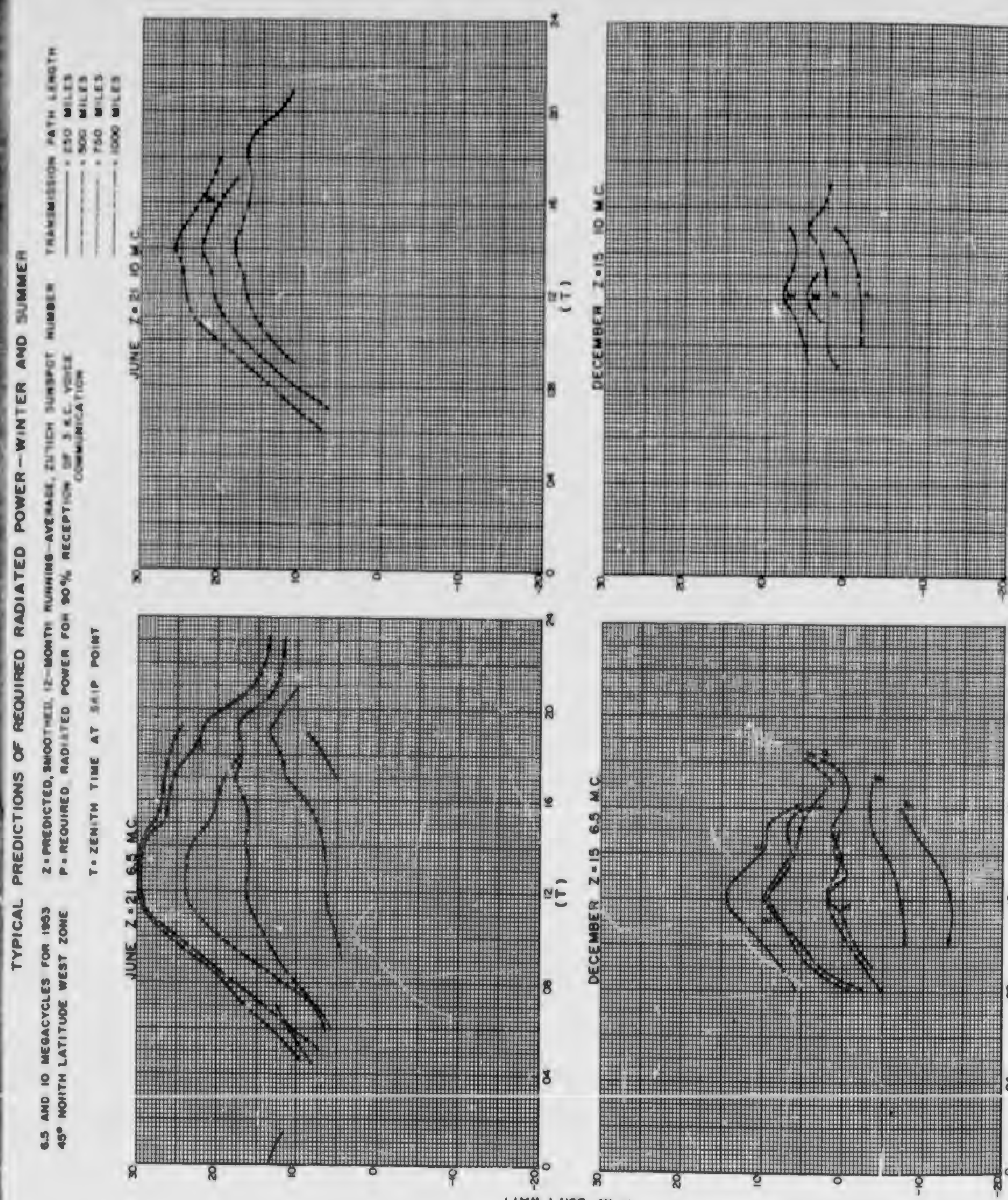
TYPICAL PREDICTIONS OF REQUIRED RADIATED POWER—WINTER AND SUMMER
6.5 AND 10 MEGACYCLES FOR 1953
45° NORTH LATITUDE WEST ZONE
Z = PREDICTED, SMOOTHED, 12-MONTH RUNNING-AVERAGE, ZURICH SUNSPOT NUMBER
P = REQUIRED RADIATED POWER FOR 90% RECEPTION OF 3 K.C. VOICE COMMUNICATION
T = ZENITH TIME AT SKIP POINT
TRANSMISSION PATH LENGTH
= 250 MILES
= 500 MILES
= 750 MILES
= 1000 MILES
JUNE Z=21 6.5 MC
JUNE Z=21 10 MC
DECEMBER Z=15 6.5 MC
DECEMBER Z=15 10 MC
P IN DB/1 WATT
(T)

Fig. II-41.

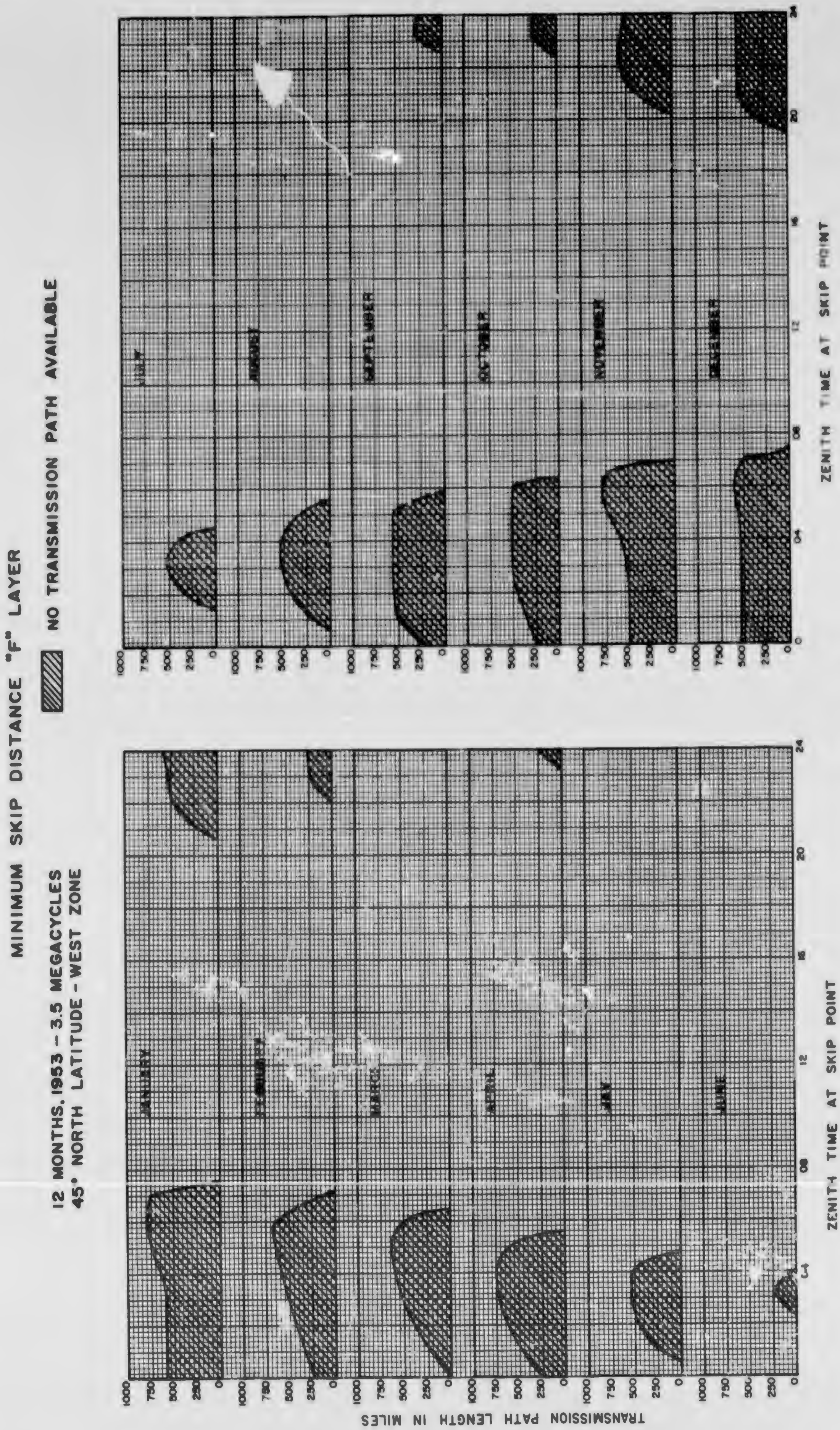
MINIMUM SKIP DISTANCE "F" LAYER
NO TRANSMISSION PATH AVAILABLE
12 MONTHS, 1953 - 3.5 MEGACYCLES
45° NORTH LATITUDE - WEST ZONE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
TRANSMISSION PATH LENGTH IN MILES
ZENITH TIME AT SKIP POINT

Fig. II-42.

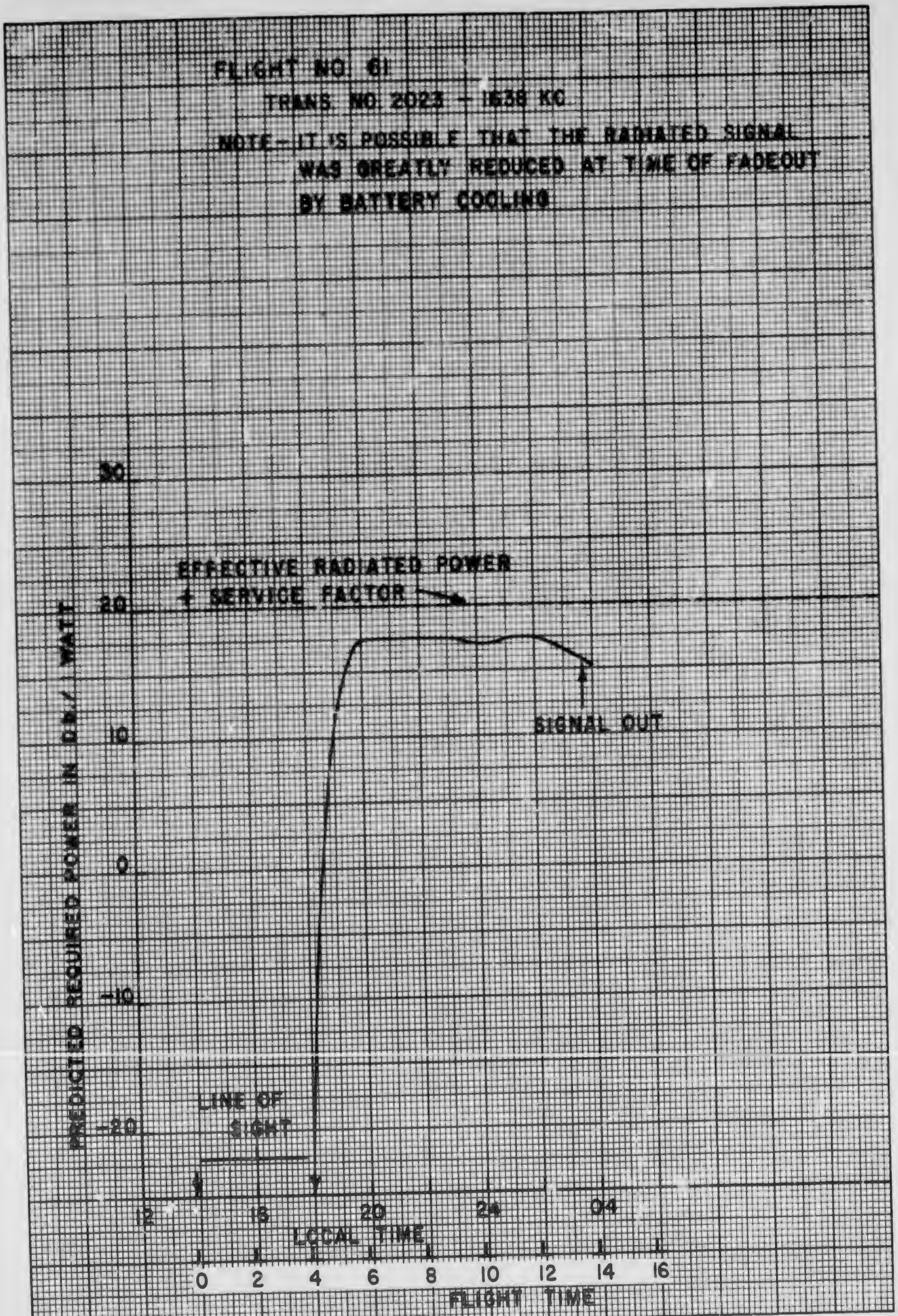
FLIGHT NO. 61
TRANS. NO. 2023 - 1638 KC
NOTE - IT IS POSSIBLE THAT THE RADIATED SIGNAL WAS GREATLY REDUCED AT TIME OF FADEOUT BY BATTERY COOLING
EFFECTIVE RADIATED POWER + SERVICE FACTOR
SIGNAL OUT
LINE OF SIGHT
PREDICTED REQUIRED POWER IN DB/ WATT
30
20
10
0
-10
-20
12
16
20
24
04
LOCAL TIME
0
2
4
6
8
10
12
14
16
FLIGHT TIME

Fig. II-43.

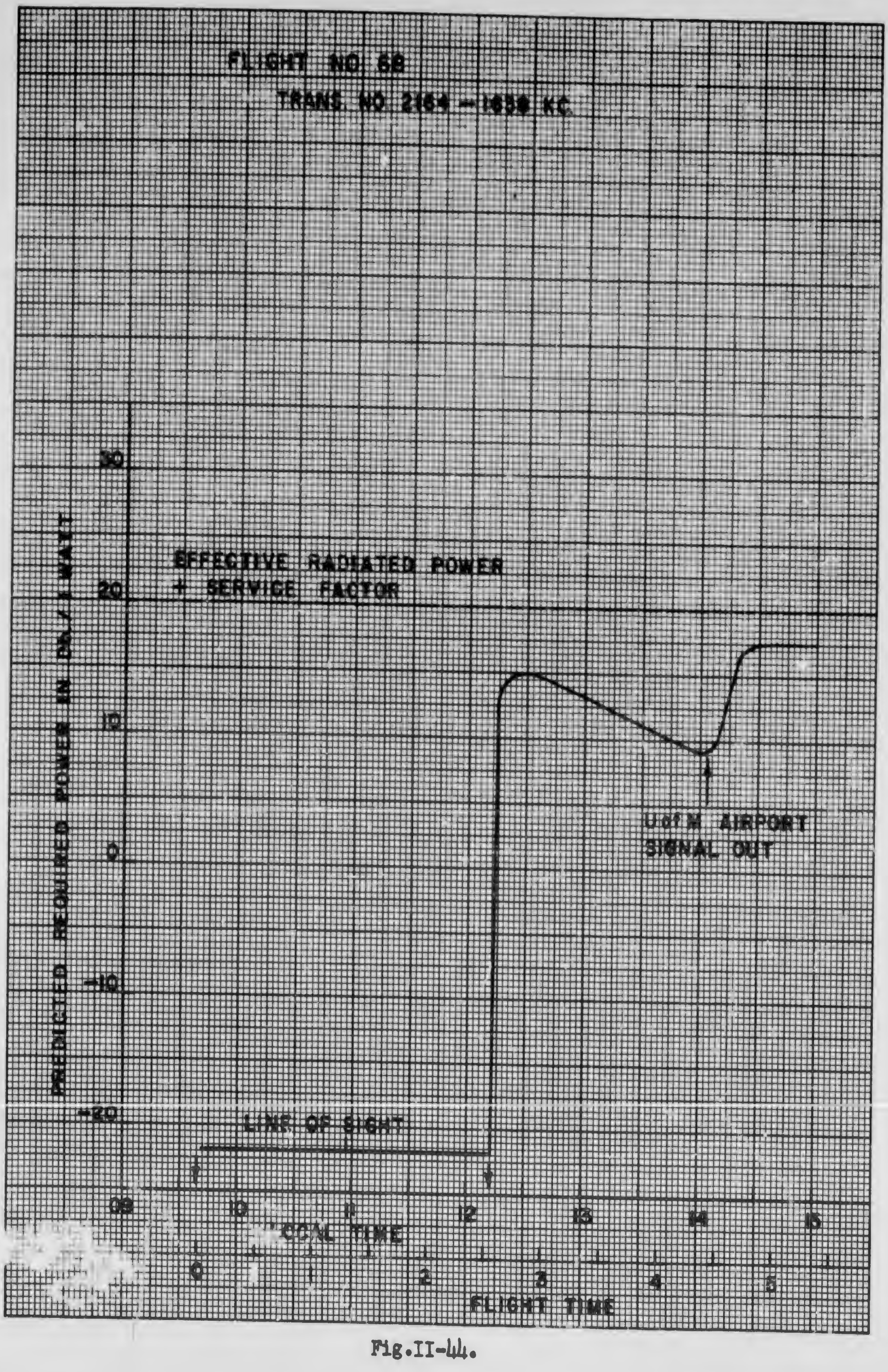
FLIGHT NO 68
TRANS NO
PREDICTED REQUIRED POWER IN
30
20
10
0
-10
-20
EFFECTIVE RADIATED POWER
+ SERVICE FACTOR
U of M AIRPORT
SIGNAL OUT
LINE OF SIGHT
09
10
11
12
13
14
15
LOCAL TIME
0
1
2
3
4
5
FLIGHT TIME

Fig.II-44.

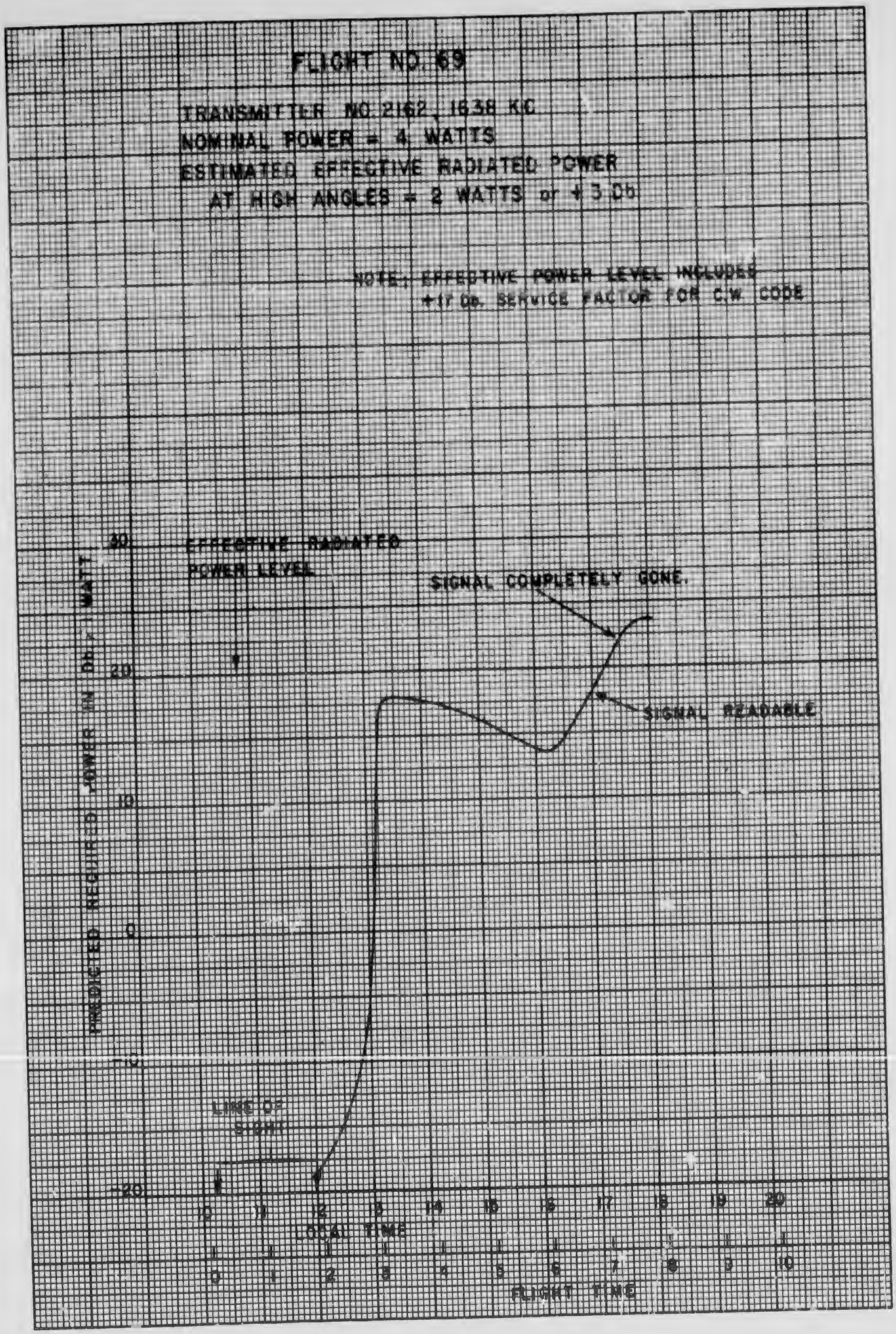
FLIGHT NO. 69
TRANSMITTER NO 2162, 1638 KC
NOMINAL POWER = 4 WATTS
ESTIMATED EFFECTIVE RADIATED POWER
AT HIGH ANGLES = 2 WATTS or + 3 Db
NOTE: EFFECTIVE POWER LEVEL INCLUDES
+17 Db. SERVICE FACTOR FOR C.W. CODE
EFFECTIVE RADIATED
POWER LEVEL
SIGNAL COMPLETELY GONE.
SIGNAL READABLE
LINE OF
SIGHT
PREDICTED REQUIRED POWER IN Db / 1 WATT
30
20
10
0
-10
-20
10
11
12
13
14
15
16
17
18
19
20
LOCAL TIME
0
1
2
3
4
5
6
7
8
9
10
FLIGHT TIME

Fig. II-45.

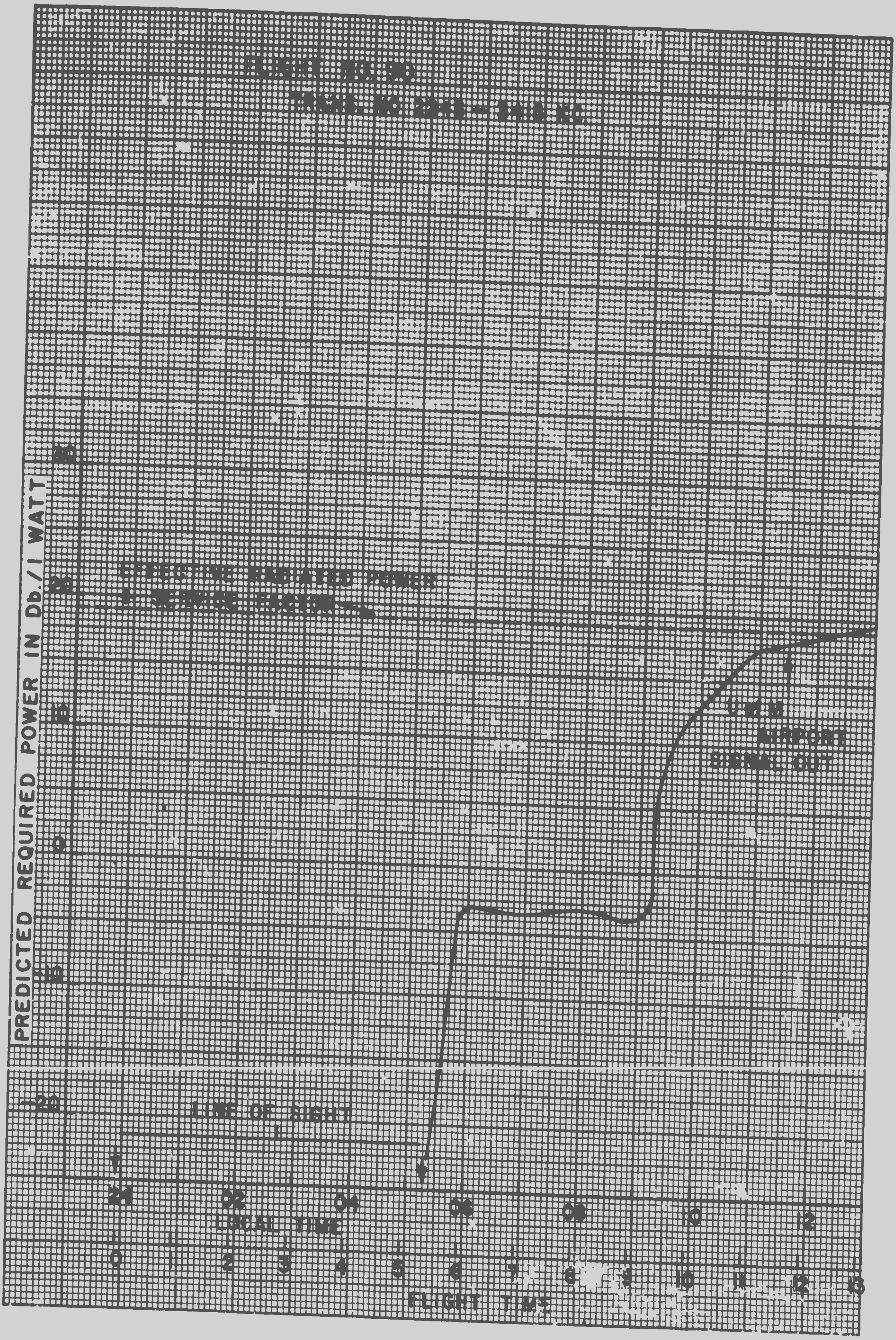
PREDICTED REQUIRED POWER IN Db./1 WATT
EFFECTIVE RADIATED POWER
AIRPORT
SIGNAL OUT
LINE OF SIGHT
24
02
04
06
08
10
12
LOCAL TIME
0
1
2
3
4
5
6
7
8
9
10
11
12
13
FLIGHT TIME

Fig. II-46.

is used to indicate the estimated effective radiated power. This includes a factor (service factor) which is a function of the bandwidth of the signal and the effective filtering (for example, a slow C.W. signal, with crystal filtering in the receiver, would be more easily read than a voice-modulated signal with the same input signal level at the receiver). The estimate of this factor is one of the largest sources of error in these comparisons. In each case the assumption was made that one-half (or -3db) of the available signal power was radiated.(18) In some cases involved, the radiated power did not remain constant as assumed, but decreased as a function of time because of dry-battery dissipation and cooling. For Flights 61, 68 and 69, where primary coding was used, an effective power of +3db was assumed with a service factor of +17db for C.W. code. The effective peak radiated power for Flight 90, using multiplex encoding, was assumed to be +14db and an estimated service factor of +5db was used.

The solid line curves on the charts represent the power required for 90% reception, as would be predicted for the local time shown and the corresponding radio path length(19) involved in each particular flight.

The arrow and the words "signal out" near the end of each plot indicate that at the time in question and under the conditions shown there was no longer a useful signal received at the station involved. Before this time, in each case, a useful signal was received from the beginning of the flight.

It is not presently possible to make a detailed explanation of the various results known. In each of the cases except Flight 68 (Figure II-44)

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(18) Subsequent comparative radiation tests indicate that this figure is not correct and the losses were much greater.

(19) This is not shown on charts. The path length in each case was determined as a function of local time from tracking data which included pictures of the earth taken from the balloon, theodolite tracking, and/or estimates of wind velocities at the appropriate altitudes.

the difference between the estimated radiated power and predicted required radiated power at the time of signal failure was less than 5db, which value lies within the normal ± 6db variation expected 80% of the time.[20] Therefore, the correlation in these cases appears to be reasonably good. As all of the differences between predictions and signals realized are of the same sign, it appears that the estimate for effective radiated power was too large in each case.

The poor agreement (11db) between the predicted requirements and radiated power at time of signal failure in Flight 68 (Figure II-44) may possibly be explained by the fact that the predicted required power value increased to a value within the normally expected ± 6db variation within 15 minutes after signal failure. Therefore a small error in the flight trajectory or a small local variation in the "D" layer absorption would account for this seemingly large difference.

Although the power requirement predictions made in this manner may show large errors at any particular time, their value lies in showing the average required power for the period of the prediction and enables one to provide for flight equipment with sufficient but not excessive power output.

(20) PROGRESS REPORT ON HIGH ALTITUDE BALLOONS, Volume V, p. VIII-357, 359.

APPENDIX I

The relationship, in a communication system, between signal-to-noise ratio, bandwidth, and information capacity is given by Shannon's equation:[1]

$$C = W \log_2 \left(\frac{P+N}{N}\right) \quad (1)$$

where C is information capacity in bits/sec;[2]

W is bandwidth of system, in this case (Loran pulses) determined by the filtering in the indicator system;

P is average signal power at indicator; and

N is average noise power at indicator (in this simple example, assume that $\frac{dn}{df} = N_0$, then $N = N_0 W$).

From Equation (1) we obtain

$$\frac{P}{N} = (2^{C/W}-1) \quad (2)$$

and, substituting for N,

$$P = N_0 W \, (2^{C/W}-1). \quad (3)$$

If we now increase the length of each transponded Loran pulse so that

$$T_1 = kT_0 , \quad (4)$$

where k is a constant,

T_1 is new pulse length, and

T_0 is original pulse length,

we may then readjust the filters in the receiver-indicator system so that the bandwidth is smaller and, as a result, obtain a better signal-to-noise ratio than with the wide-band filters necessary for the original pulses.[3]

1 Claude E. Shannon and Warren Weaver, The Mathematical Theory of Communication, U of Ill Press, Urbana, 1949.
2 P.M.Mackay, The Nomenclature of Information Theory, Transactions of the I.R.E. Report of Proceedings, Symposium on Information Theory, London, Feb 1953.
3 Chance, Hulsizer, MacNichol, Williams, Electronic Time Measurements, Rad Lab Series, Vol 20, p. 199, Sect 7-13, McGraw-Hill, New York 1949.

If we assume (as is not always the case) that filtering for optimum signal-to-noise ratio is used in the I.F. amplifiers of the receiver, the bandwidth "W" will be such that

$$W = \frac{1.2}{T} \qquad (5)$$

As the error in measurement of the time between pulses is proportional to the rise time of the signal,[4] and as the rise time of the pulse as displayed on the indicator is inversely proportional to the bandwidth of the receiver filter,[5] it may be concluded that the error in the time measurement is increased, in a noise-free system, when the system bandwidth is decreased. An increase in error (or uncertainty) of the time measurement corresponds to a decrease in the capacity "C" of the system. Therefore it may be stated that, in this particular case and in an assumed noise-free condition,

$$\frac{C}{W} = A_o, \text{ where } A_o \text{ is a constant.}^{6} \qquad (6)$$

Now, if noise is added to the system (as is always the case), the information capacity "C" is reduced or at least not increased, with "W" remaining constant. Therefore we obtain the inequality

$$\frac{C}{W} \leq A_o \qquad (7)$$

in any real case.

Then, substituting Equation (6) into the variable factor of (3), the inequality

$$(2^{C/W}-1) \leq (2^{A_o}-1) \qquad (8)$$

is obtained. As A_o is a constant, we may write $(2^{A_o}-1) = B_o$, a constant.

4 Ibid, p. 40, Sect 3.2.
5 Valley & Wallman, Vacuum Tube Amplifiers, Rad Lab Series, Vol 18, pp 88, 274-277, McGraw Hill, New York, 1948.
6 Where $A_o < \infty$, as there are definite limitations on the maximum accuracy of the measuring equipment, with perfect signals.

Then Equation (3) may be written as an inequality,

$$P \leq B_0 N_0 W. \qquad (9)$$

The quantity "B_0" is a limiting value and is therefore independent of the bandwidth "W". The noise power per cycle "N_0" is obviously not a function of bandwidth. Therefore, under the above stated conditions the maximum value of average power required is a linear function of bandwidth.

Then, substituting from Equations (4) and (5) into inequality (9), we obtain the inequality

$$P \leq \frac{1.2\ B_0 N_0}{kT_0} \qquad (10)$$

So it follows, that, if the Loran pulses are increased in length ("K" increased), the average transmitted power may be decreased if a corresponding decrease in bandwidth and time measurement accuracy accompanies the above pulse length increase.

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