AD-A048 021 WEAPONS RESEARCH ESTABLISHMENT SALISBURY (AUSTRALIA) F/G 19/1
DESCRIPTION OF THE W.R.E. STRAND BURNING FACILITIES AND INSTRUC--ETC(U)
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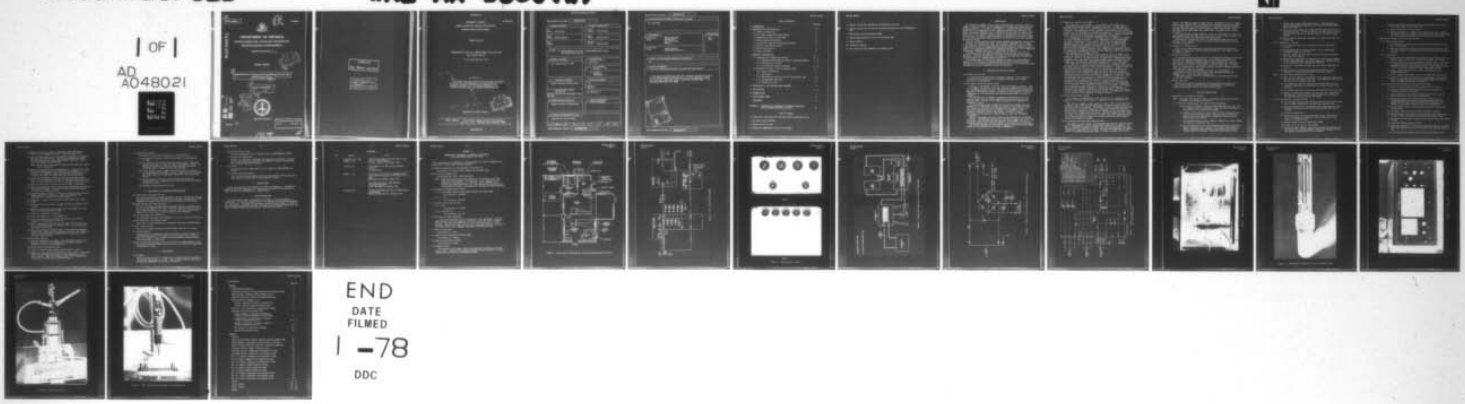

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AUSTRALIA

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

WEAPONS RESEARCH ESTABLISHMENT

SALISBURY, SOUTH AUSTRALIA

MANUAL 1850 (W)

(6) DESCRIPTION OF THE W.R.E. STRAND BURNING FACILITIES AND INSTRUCTIONS FOR USE

(10) W.H. JOLLEY and D.R. KIRK

(11) Jul 77

(12) 28p.

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

Approved for Public Release.

COPY No. 20

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AR-000-908

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DESCRIPTION OF THE W.R.E. STRAND BURNING FACILITIES AND INSTRUCTIONS FOR USE

W.H. Jolley and D.R. Kirk

SUMMARY

This Manual describes the facilities currently available at W.R.E. for the determination of burning rates of solid propellant strands, with particular reference to the [illegible] pressure (20 MPa) bomb. It supersedes WRE Manual 401 [illegible]

Approved for Public Release

POSTAL ADDRESS: The Director, Weapons Research Establishment, Box 2151, G.P.O., Adelaide, South Australia, 5001.

DOCUMENT CONTROL DATA SHEET

Security classification of this page: UNCLASSIFIED

1 DOCUMENT NUMBERS	2 SECURITY CLASSIFICATION
AR Number: AR-000-908	a. Complete Document: Unclassified
Report Number: WRE-MA-1850(W)	b. Title in Isolation: Unclassified
Other Numbers:	c. Summary in Isolation: Unclassified

3 TITLE

DESCRIPTION OF THE W.R.E. STRAND BURNING FACILITIES AND INSTRUCTIONS FOR USE

4 PERSONAL AUTHOR(S):

W.H. Jolley and D.R. Kirk

5 DOCUMENT DATE:

July 1977

6 6.1 TOTAL NUMBER OF PAGES: 28

6.2 NUMBER OF REFERENCES: 5

7 7.1 CORPORATE AUTHOR(S):

Weapons Research Establishment

7.2 DOCUMENT (WING) SERIES AND NUMBER

Weapons Research and Development Wing MA-1850

8 REFERENCE NUMBERS

a. Task:

b. Sponsoring Agency:

9 COST CODE:

10 IMPRINT (Publishing establishment):

Weapons Research Establishment

11 COMPUTER PROGRAM(S) (Title(s) and language(s))

12 RELEASE LIMITATIONS (of the document):

Approved for Public Release

12.0	OVERSEAS	NO		P.R.	1	A		B		C		D		E	

Security classification of this page: UNCLASSIFIED

Security classification of this page: UNCLASSIFIED

13 ANNOUNCEMENT LIMITATIONS (of the information on these pages):

No limitation

14 DESCRIPTORS:

a. EJC Thesaurus Terms: Solid propellant; Burning rate; Test facilities; Manuals

b. Non-Thesaurus Terms: Strand burners; Propellant ballistics

15 COSATI CODES:

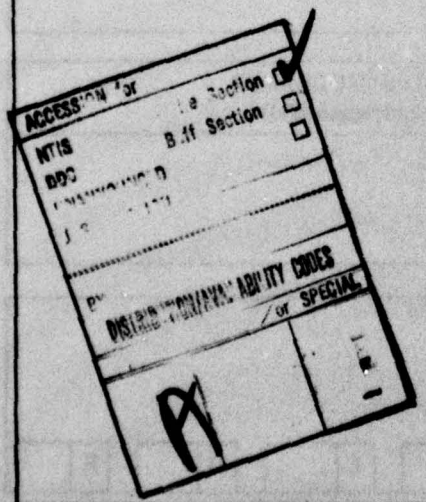
1901
2102

16 LIBRARY LOCATION CODES (for libraries listed in the distribution):

SW

17 SUMMARY OR ABSTRACT:
(if this is security classified, the announcement of this report will be similarly classified)

This manual describes the facilities currently available at W.R.E. for the determination of burning rates of solid propellant strands, with particular reference to the low pressure (20 MPa) bomb. It supersedes WRE Manual 402 (WR&D).



Security classification of this page: UNCLASSIFIED

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1. INTRODUCTION

The Crawford and Hugget strand burning technique(ref.1) has been used for a number of years at W.R.E. for the determination of propellant burning rates at various pressures. It involves the burning of a surface-inhibited strand of propellant in a thermostatted vessel (bomb) pressurized with nitrogen. The strand is mounted vertically and is ignited at the top end by an electrically heated wire. The inhibitor ensures "cigarette" burning and the time for the burning surface to travel a given distance is recorded by an electronic timer, the start and stop pulses being provided by the melting of two wires threaded through the strand.

The W.R.E. facilities have recently been upgraded and expanded and relocated in Building 133, Laboratories Area. The principal components are two bombs (a low pressure one rated to 20 MPa and a high pressure one rated to 70 MPa), a compressor for each, a temperature controlling system for thermostatting the bombs, an instrumentation console for measuring burning times, and a temperature and humidity regulated cabinet for conditioning of strands.

This Manual, while describing the general facilities and total lay-out existing at Building 133, specifically details the low pressure bomb and its operation. Detailed information on the high pressure bomb and its operation are the subject of a separate publication(ref.2).

A third bomb which is fitted with windows to enable the strand burning process to be observed and recorded photographically has been dismantled. Although it has not been re-sited at the new location it could be reconstructed and operated with the information given in reference 3.

2. DESCRIPTION OF THE FACILITIES

2.1 Layout of facilities

A floor plan of Building 133 is given in figure 1. This shows the locations of the various items of equipment and where the relevant activities are carried out.

2.2 Gas supply system and control panels

Nitrogen is delivered to the site in Mk 7A cylinders on pallets. The gas is pumped, as required, into four permanently mounted Mk 12 cylinders to a maximum pressure of 24 MPa. Detailed instructions for operating the compressor (William and James) are displayed in the compressor room and information on its construction and various modifications is given in Appendix I.

Gas from the Mk 12 cylinders is supplied either direct to the low pressure bomb or to the Corblin compressor for pressurizing the high pressure bomb. Details of the Corblin compressor are contained in references 2 and 4.

The distribution of gas to and from the various cylinders and both compressors is controlled via Panel B, located in the compressor room. The flow of gas into and from both bombs and the ballast vessels is controlled via Panel A which is located in the operator's room. A schematic diagram of the gas flow circuit is shown in figure 2. Photographs of the fascias of control Panels A and B are reproduced in figure 3.

Bourdon tube gauges are used to monitor gas pressures at the various locations. A maintenance problem with this type of gauge has arisen with the gauges used for measuring the pressures in the bombs. The use of electronic gauges with a digital display is currently being investigated.

For further information on detailed drawings related to the gas supply system and its pipework circuit refer to Appendix I.

2.3 Temperature control of the bombs

The temperature of the bombs is controlled by circulating a heat exchange fluid through jackets surrounding each bomb. A pump (Jabsco) recirculates the fluid, a 1:1 glycol/water mixture, from a thermostatted reservoir. The temperature of the reservoir is maintained at the required value by the use of either a 2 kW immersion heater or a cooling coil through which a cold glycol/water mixture is circulated from a separate refrigerated tank. This system is illustrated diagramatically in figure 4.

The temperature of the fluid circulating around the bombs is displayed on a dial thermometer on Panel A. The temperature of the thermostatted reservoir is necessarily 1 to 2 degrees lower than the required bomb temperature since heat is added to the fluid by the circulating pump. The bomb temperatures normally required are 0^{o}, 20^{o} and 55^{o}C. Three mercury contact thermometers set at these temperatures are located in the reservoir and each is connected into a temperature regulating circuit. The appropriate thermometer for the desired temperature can be switched in simply by means of a selector switch.

For 55^{o} operation the heating control circuit, shown in figure 5, is selected by means of the switch on the timing console, where the circuit is housed. With this circuit switched in, whenever the temperature of the reservoir falls below 55^{o}C the heating element supplies heat to raise the temperature. No cooling is required for operation at this temperature.

For operation at either 0^{o} or 20^{o}C cooling only is required since sufficient heat is always liberated from the burning of the strands within the bomb to provide heating. The desired temperature is chosen by means of the selector switch on the control box in the bomb bay. Whenever the temperature of the thermostatted reservoir rises above the selected temperature a relay actuates the pump associated with the refrigerated tank and circulates cold fluid from there through the cooling coil in the thermostatted reservoir until the desired temperature is restored. The refrigerated tank is maintained at -15^{o}C by a 2 hp refrigeration unit controlled by a thermostat unit (Ranco). Another thermostat unit (Honeywell) associated with the circulating pump ensures that the pump will not operate until the temperature of the fluid in the refrigerated tank is down to at least 10^{o}C (or a lower value if desired). The thermostat units are located alongside the control box in the bomb bay. A pressure switch (Ranco) is mounted on the refrigeration unit to switch it off in the event of a drop in Freon pressure. The temperature control circuit for 0^{o} or 20^{o}C operation is shown in figure 6.

2.4 Strand conditioning cabinet

All strands are conditioned at 20^{o}C and 55% rh in a temperature and humidity controlled cabinet (made by Laboratory Thermal Equipment Ltd., U.K.).

The relative humidity in the cabinet is kept at 55% by circulating the atmosphere over a shallow tray containing a saturated aqueous solution of calcium nitrate (A.R. grade). The cabinet is used for conditioning strands both prior to, and after, inhibiting. Inhibited strands are hung from spring clips attached to the roof of the cabinet but the uninhibited ones are placed in a Perspex box containing a saturated aqueous calcium nitrate solution. The purpose of the box is to limit loss of nitroglycerine from the strands and also to prevent their being contaminated with residual solvent from inhibited strands.

2.5 Low pressure bomb and strand mounting heads

The bomb is a heavy walled vessel manufactured from 316 stainless steel and is surrounded by a jacket through which coolant is circulated. The top is internally threaded, to accept the strand mounting head, and a gas connection is provided at the bottom. Through this connection the bomb is linked to the high pressure gas supply line and a ballast vessel via a

filter. The combined volume of bomb, filter, and ballast is 18 l, a volume sufficiently large to limit the pressure rise resulting from strand combustion to about 2% of the operating pressure. The bomb is mounted alongside the high pressure bomb in an alcove formed by blast walls, with a fume extractor fan and hood immediately above them. The bomb set-up is shown in figure 7.

The strand mounting heads currently in use are illustrated in figure 8. Their functions are to support the strand and to carry electrical leads into the bomb to connect with the igniter and timing wires.

References to the drawings for the strand mounting heads and the low pressure vessel, together with its associated filter and ballast vessels, are given in Appendix I.

2.6 Ignition and timing circuits

The circuits associated with the ignition and timing of strands are discussed in detail in a separate publication(ref.5). The timing console is shown in figure 9.

2.7 Strand drilling jig

The strand drilling jig facilitates the accurate positioning of the three holes for the igniter and timing wires. It is shown in figure 10 and consists of a Desoutter automatic feed air drill attached to a gear box which operates three belt driven chucks, correctly spaced for the holes. Each drill consists of a 0.65 mm drill set into a brass shank. A safety cover is provided which, when closed, operates the drill automatically and stops the drill when it is raised.

A previously used, air-operated drill which is used manually in conjunction with a jig for locating the holes has been retained for emergency use. These are shown in figure 11.

The timing wire is 30 S.W.G. tin/lead (63/37), while the igniter wire is 36 S.W.G. nichrome.

2.8 Strand inhibitor

The material used for inhibiting the outer surfaces of strands is a vinyl chloride-acetate copolymer which is manufactured at Explosives Factory, Maribyrnong (E.F.M.) to specification CS5515.

3. OPERATING INSTRUCTIONS

3.1 Preparation of strands for burning

NOTE: Throughout the procedures used in preparing strands for burning do not handle the strands unnecessarily.

3.1.1 Moisture conditioning of strands ("preconditioning")

(a) On receipt of strands visually inspect them and reject any that are cracked, porous or misshapen. Mark the number remaining on the identification label on the package.

(b) Lightly rub the edges of each strand with fine glass paper and wipe off any dust with tissues. Note the date on which this operation was performed on the accompanying "Strand Burning Request and Results Sheet".

(c) If preconditioning is not to commence immediately, rewrap strands and replace in pigeonhole box.

(d) On the nominated day for preconditioning unwrap the strands and spread in an even layer in one of the Perspex boxes provided. Place a cardboard label showing all the strand identification details beside the strands. Close the box and place in the

bottom shelf of the conditioning cabinet. Mark the date on which preconditioning commenced on the "Strand Burning Request and Results Sheet".

(e) After three days remove the strands from the box and place in a corked glass tube. Attach the label to the tube with an elastic band and place the tube in the top shelf of the conditioning cabinet.

(f) After a further three days (minimum) the strands are ready for inhibiting.

3.1.2 Inhibition of strands

(a) Fill the brass tank (total volume 500 ml) with inhibiting solution.

(b) Attach groups of six strands by their ends to the battens provided by means of the clips.

(c) Dip the strands into the tank, ensuring that they are wetted over their full length.

(d) Remove the strands from the tank after 2 s and hang the batten on the frame provided. The excess inhibitor is allowed to drip on to the plastic sheet beneath the framework.

(e) Allow a 20 to 30 minute drying time then repeat paragraphs (c) and (d).

(f) Enter the date on which the strands were inhibited on the appropriate "Strand Burning Request and Results Sheet".

NOTE: (1) Keep tank covered when not in use.

(2) Four coats of inhibitor are given to most propellant compositions but two coats are required for some. The number of coats will be specified by the Officer-in-Charge.

(3) It is important that the solution be discarded after it has served for applying the equivalent of one coat to each of 200 strands.

(4) The strands are ready for drilling 30 minutes after the last dip.

(5) Normally strands to be burned on a given day are inhibited the previous day. In any event strands should not be inhibited more than 35 hours before they are burned.

3.1.3 Drilling and wiring of strands

(a) Cut the small blob of dried inhibitor from the end of the strand with a scalpel and discard into the explosives waste bin.

(b) Open the strand vice by turning the small handle and place the strand in the jig with the cut end flush to the right end of the jig.

(c) Close the strand vice.

(d) Operate the drill by closing the safety cover, allowing the drill to continue operating for a few seconds after it has reached its downward limit.

(e) Release safety cover and remove the strand.

(f) Repeat (a) to (e) for all the strands.

(g) Thread a 120 mm length of igniter wire through the top hole of the strand and a 120 mm length of timing wire through each of the other two holes which are 127 mm apart.

(h) Hang the strand with the end containing the igniter wire down in one of the clamps of a cabinet slide.

(i) Repeat (g) and (h) for all strands.

(j) Attach the label to a clamp on the cabinet slide, then transfer the slide to one of the grooves on the ceiling of the conditioning cabinet allowing the strands to hang there to await burning.

3.2 Burning of strands in the low pressure bomb

3.2.1 Special precautions

(a) All work must be carried out according to the operating instructions listed below.

(b) When the strand burner bomb is pressurized the red warning light over the entrance to the bomb bay must be turned on and no-one is to enter.

3.2.2 Setting-up

(a) Ensure that the high pressure nitrogen cylinders (Mk 12) have an adequate supply of gas for the batch of strands to be burned.

(b) Switch on the power for the temperature control units, including the pump for circulating fluid around the bomb. Select the temperature desired on the setting switch. Ensure that the bomb is at the required temperature before commencing burning.

(c) Switch on the timing console at least 15 minutes prior to commencing burning.

(d) Before commencing burning, switch on the fume hood exhaust fan.

(e) Details of the required burning rate measurements and pressures are to be obtained from the "Strand Burning Request and Result Sheet" accompanying the batch of strands.

3.2.3 Operating instructions for the low pressure bomb

(a) Place the strand burner head horizontally in its cradle.

(b) Remove a strand from the conditioning cabinet and check it visually for faulty inhibition.

(c) Insert the end of the strand carrying only one wire into the holder and secure it with the locking screw.

(d) Attach the igniter wire and the two timing wires to the appropriate terminals, ensuring that the timing wires have enough slack for each side to be displaced 5 mm towards the bottom of the strand (using the shaft of a screwdriver).

(e) Trim off excess wire at each terminal and excess strand below fixing screw.

If the ballast tank is not pressurized, proceed as follows :

(f) Check that the inlet valve is closed and that the exhaust valve is open. Check that the valve on the ballast tank is open.

(g) Insert the strand burner head and screw down the retaining collar by hand.

(h) Attach the timing and firing lead.

(i) Check the continuity of each wire by observing that the indicator light for each wire located on the front of the timing console is on.

(j) Switch on the red warning light and close the exhaust valve.

(k) Open the inlet valve slowly to pressurize the bomb and the ballast to the appropriate level. Close the inlet valve.

(l) Set the timing clock to the desired period (normally 5 minutes) and press the start button. After the set period has elapsed the audible alarm will sound and the READY light will come on. Press the audible alarm OFF button.

NOTE: During this timing period a fresh strand should be loaded into a second head.

(m) Recheck the continuity as in paragraph (i). If any light is off follow the Malfunction Drill as outlined in paragraph 3.2.5. If continuity is indicated, adjust the pressure of the vessel, if required, then reset the timer and press the firing button.

(n) At the end of burning, record the time and close the ballast valve. If the timer does not start, or having started, does not stop, follow the Malfunction Drill as outlined in paragraph 3.2.5.

(o) Open the exhaust valve slowly to vent the bomb to atmosphere.

(p) Remove the timing and firing lead from the burner head and unscrew the retaining collar. Take the head from the bomb and immerse it briefly in a bucket of water.

(q) Clean the bomb as necessary. Usually, wiping with the cloth and plunger provided is sufficient. Occasional purging with compressed air is desirable to remove debris.

For subsequent firings, with the ballast tank pressurized, proceed as follows :

(r) Check that the inlet valve is closed and that the exhaust valve is open.

(s) Insert a strand burner head fitted with a new strand and screw down the retaining collar by hand.

(t) Attach the timing and firing lead.

(u) Check the continuity as in paragraph (i).

(v) Close the exhaust valve and open the ballast valve slowly. Continue as in paragraphs (k) to (q).

(w) Before removing the head for the last time vent the ballast as well as the bomb through the exhaust valve. Leave the ballast and exhaust valves open.

(x) After each firing, the burner head is to be cleaned thoroughly using a small brush and warm detergent solution. Give special attention to the terminals and nuts and to the pressure seal. Dry with compressed air.

3.2.4 Closing down operations

(a) Turn off the power to all units. The main power switch on the control circuit for the refrigeration unit may be left on overnight if the occasion warrants it.

(b) Switch off the red warning light.

(c) Close off the gas supply valves on both Panels A and B.

(d) Remove the plug from the bottom of the filter vessel. Pour warm water into the bomb and allow it to drain through the filter into a bucket. Remove any remaining water with compressed air and blow dry for some ten to fifteen minutes.

3.2.5 Malfunction drill

(a) Check the firing lead connections in the control bay.

(b) If a fault is located, rectify and proceed as from paragraph 3.2.3(m).

(c) If a fault is not located, close the ballast valve. Open the exhaust valve slowly to vent the bomb to atmosphere. Remove the timing and firing lead from the burner head and unscrew the retaining collar. Remove the head from the bomb.

(d) If the strand is burnt, immerse the head briefly in a bucket of water and complete paragraph 3.2.3(q). Check the head wiring and the connections on the timing and firing lead, and rectify any faults.

(e) If the strand is not burnt, check the head wiring and the connections on the timing and firing lead and rectify any faults. Discard the strand.

(f) Continue as from paragraph 3.2.3(s).

4. MAINTENANCE OF LOW PRESSURE BOMB EQUIPMENT

(a) High pressure cylinders (Mk 12)

Facilities and Services Group distributes circulars identifying cylinders due for pressure testing. When any of the cylinders forming part of the equipment is listed, action must be taken to deliver it for testing.

(b) High pressure gas lines and valves

Gas lines and valves through which propellant combustion products pass must be tested annually to 31 MPa. All other sections are to be tested to the same pressure at two yearly intervals. The pipe connecting the bomb and the filter vessel is to be replaced every 3 months.

(c) Pressure gauges and thermometers

The calibration of gauges and thermometers is to be carried out annually.

(d) The compressor (William and James)

This unit is to be overhauled at six monthly intervals by PMD Workshop.

(e) The in-line filter

This must be inspected weekly and the element replaced if necessary.

(f) Coolant supplies

Ethylene glycol, of commercial grade (obtained in 44 gallon drum lots), is diluted with water in the ratio one part of glycol to one part of water (by volume). This is added to the refrigerated tank and thermostatted reservoir as necessary.

(g) Any unscheduled maintenance will be carried out by PMD Workshop, except for any part of the timing circuits which will be serviced by Combustion and Explosives Group.

5. PROVISIONING

(a) Nitrogen

Pallets holding four Mk 7A cylinders are available from Gas Section and are usually ordered two at a time. Eight cylinders provide sufficient nitrogen for approximately two days of operation.

(b) Calcium nitrate (A.R.)

Available from Selby's Ltd. Delivery time is approximately 1 month.

(c) Igniter and timing wires

Igniter wire (36 S.W.G. nichrome) and timing wire (30 S.W.G., tin/lead (63:37)) was previously obtained from Explosives Factory, Maribyrnong. Local supplies should be available.

(d) Drills

0.65 mm drills with brass shanks will be supplied by PMD Workshop on request.

(e) Strand inhibiting solution

This is ordered from Explosives Factory, Maribyrnong, quoting specification CS5515. Delivery time is approximately 1 month.

6. WINDOWED BOMB

A full description of this apparatus is given in reference 3. Although the apparatus has been dismantled it is being held by Combustion and Explosives Group and could be reassembled if a demand arises.

7. HIGH PRESSURE BOMB

The high pressure bomb, for operation to 70 MPa, is fully described in reference 2. It forms an integral part of the complete strand burning equipment as it now exists. Although the principles of operation are similar to those of the low pressure bomb there are some differences in operating procedures and the above reference should be consulted for a description of these.

REFERENCES

No.	Author	Title
1	Crawford, H.L. and Hugget, C.M.	"Direct Measurement of Burning Rates by an Electric Timing Method". N.D.R.C. Report A-286, August 1944.
2	Jolley, W.H.	"Development of a High Pressure Strand Burner". In preparation.
3	Napier, I.M.	"Description of the W.R.E. Apparatus Used for Strand Burning and Instructions for its Use". WRE-Manual-401 (WR&D), August 1971.
4		"Test Specification - High Pressure Diaphragm Compressor". W.M.D. Document 51, January 1974.
5	Jolley, W.H.	"Timing Instrumentation for a Crawford Type Strand Burner". WRE-Tech Memo-1755 (W), February 1977.

APPENDIX I

COMPENDIUM OF REFERENCES TO DRAWINGS ASSOCIATED WITH THE STRAND BURNING FACILITIES

The following gives references to Drawing Numbers and other information for various parts of the strand burning equipment.

I.1 Minor new modifications and additions to Building 133

See drawing nos. 91868, 91871, MIRSK 1601 and MIRSK 1602.

I.2 Gas lines and panels etc.

See drawing nos. 91873, 93655 and 95552.

NOTE: Minor modifications were made during the installation of the gas lines and control panels. In some cases, of no consequence, the changes were not marked on the drawings. Where, however, more significant changes were made, e.g. the change from Keelering valves to Hale Hamilton valves, the appropriate drawings have been modified.

I.3 Low pressure bomb and ancillaries

I.3.1 Low pressure bomb, strand mounting heads and water jacket

See drawing no. PD 8348.

I.3.2 Filter

See drawing no. PD 8300.

I.4 Strand drilling jig and vice

I.4.1 Vice

See drawing no. PD 7454.

I.4.2 Drilling jig

See drawing no. PD 7434.

I.5 Williams and James compressor

A full set of drawings for this compressor is not available. There are some drawings held but it appears that some of these may refer to models similar to, but not identical with, the one installed at W.R.E. These drawings, together with some relevant notes which have been made, are held in a file in the P.M.D. Workshop, Building 75 Laboratories Area.

I.6 High pressure bomb

See drawing no. 92489.

I.7 High pressure compressor (Corblin type)

See drawing no. 92510A_0.

I.8 High pressure ballast vessel

See drawing no. 92509.

I.9 Windowed vessel

The windowed strand burner bomb was manufactured according to a design from E.R.D.E. Copies of the original drawings are held in a file in P.M.D. Drawing Office, Building 75 Laboratories Area.

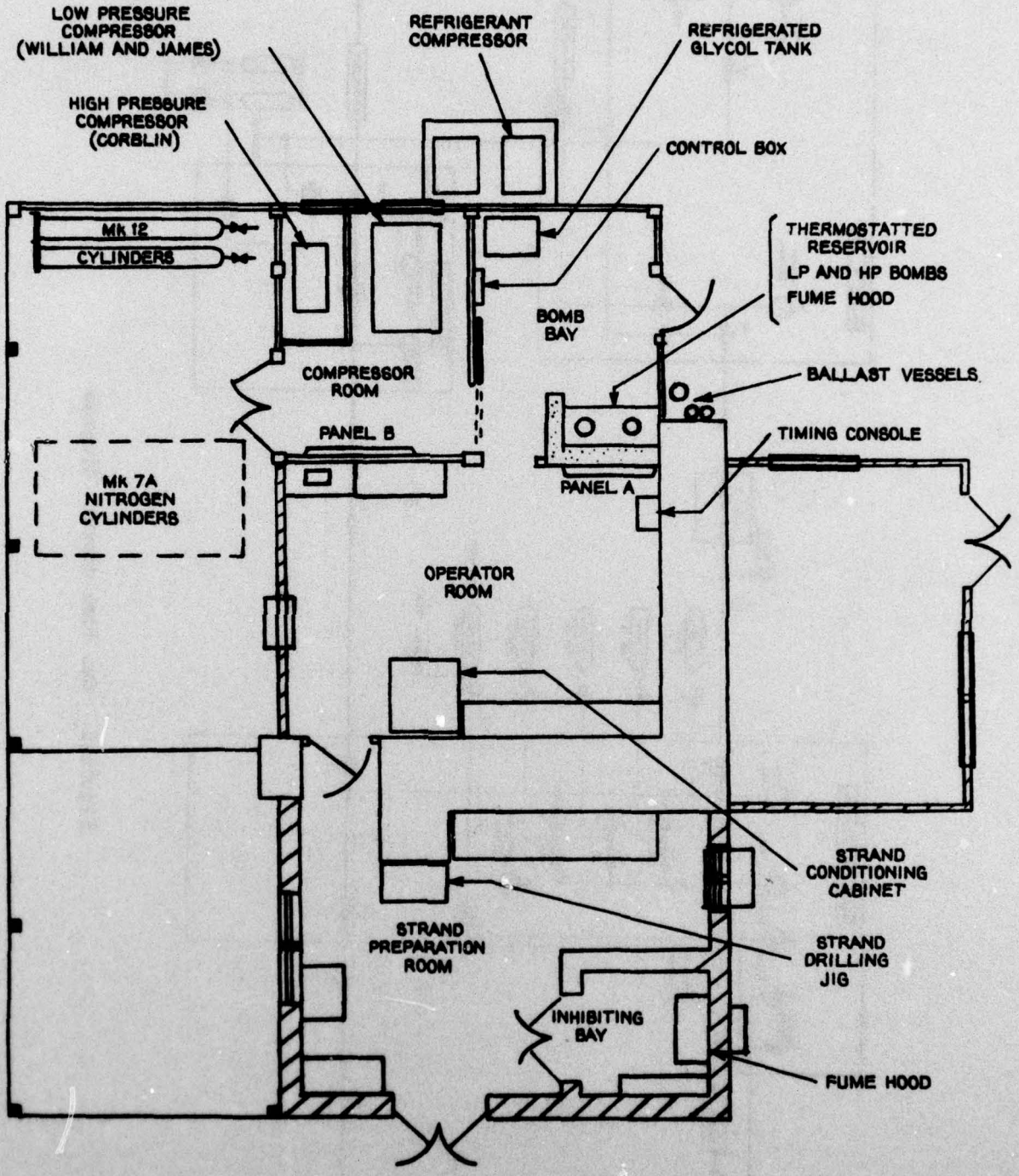


Figure 1. Floor plan of Building 133, housing strand burning facilities

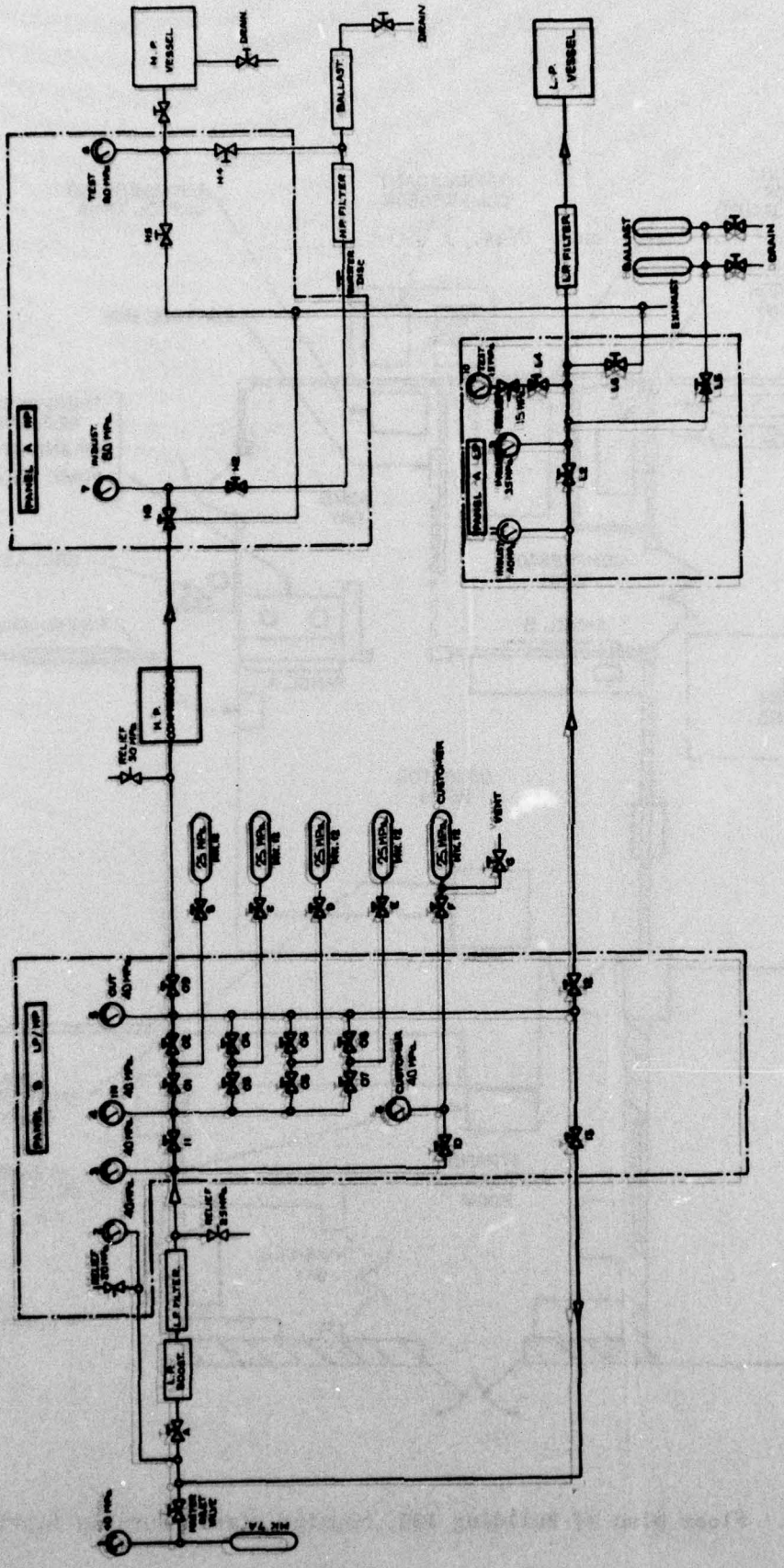
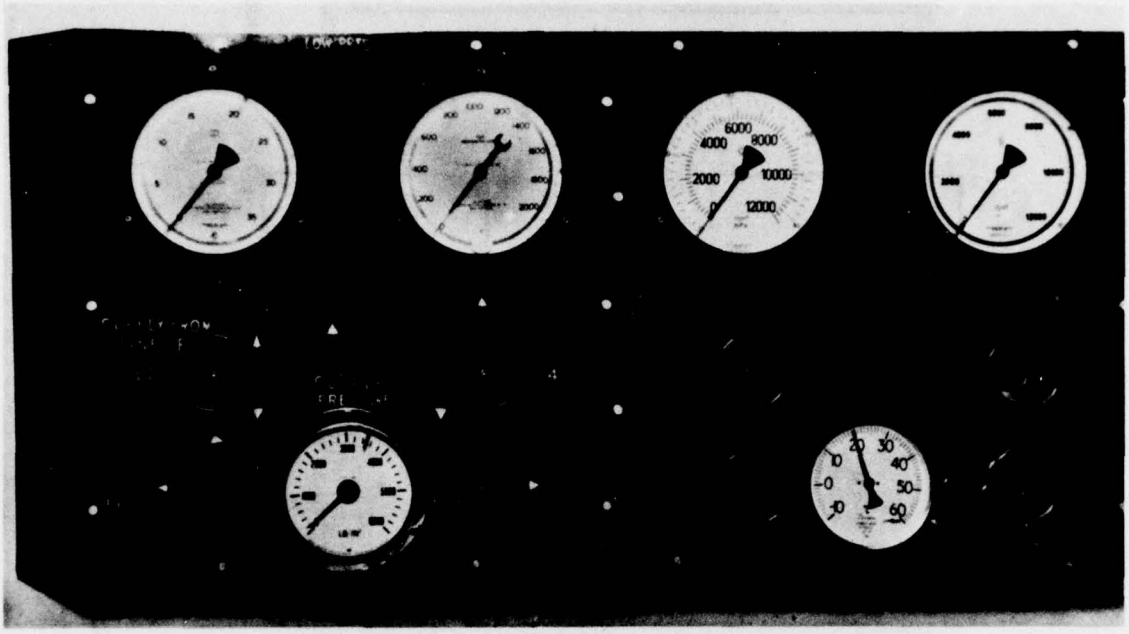
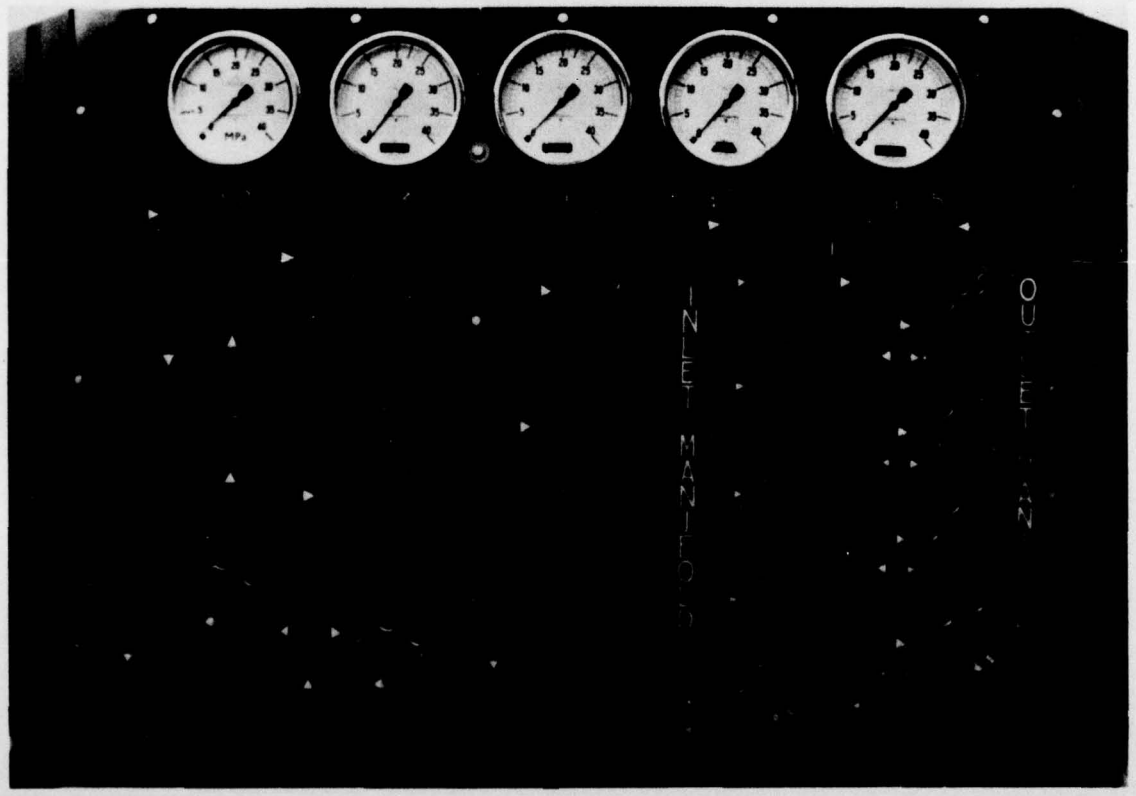


Figure 2. Gas flow circuit diagram



PANEL A



PANEL B

Figure 3. Control Panels A and B

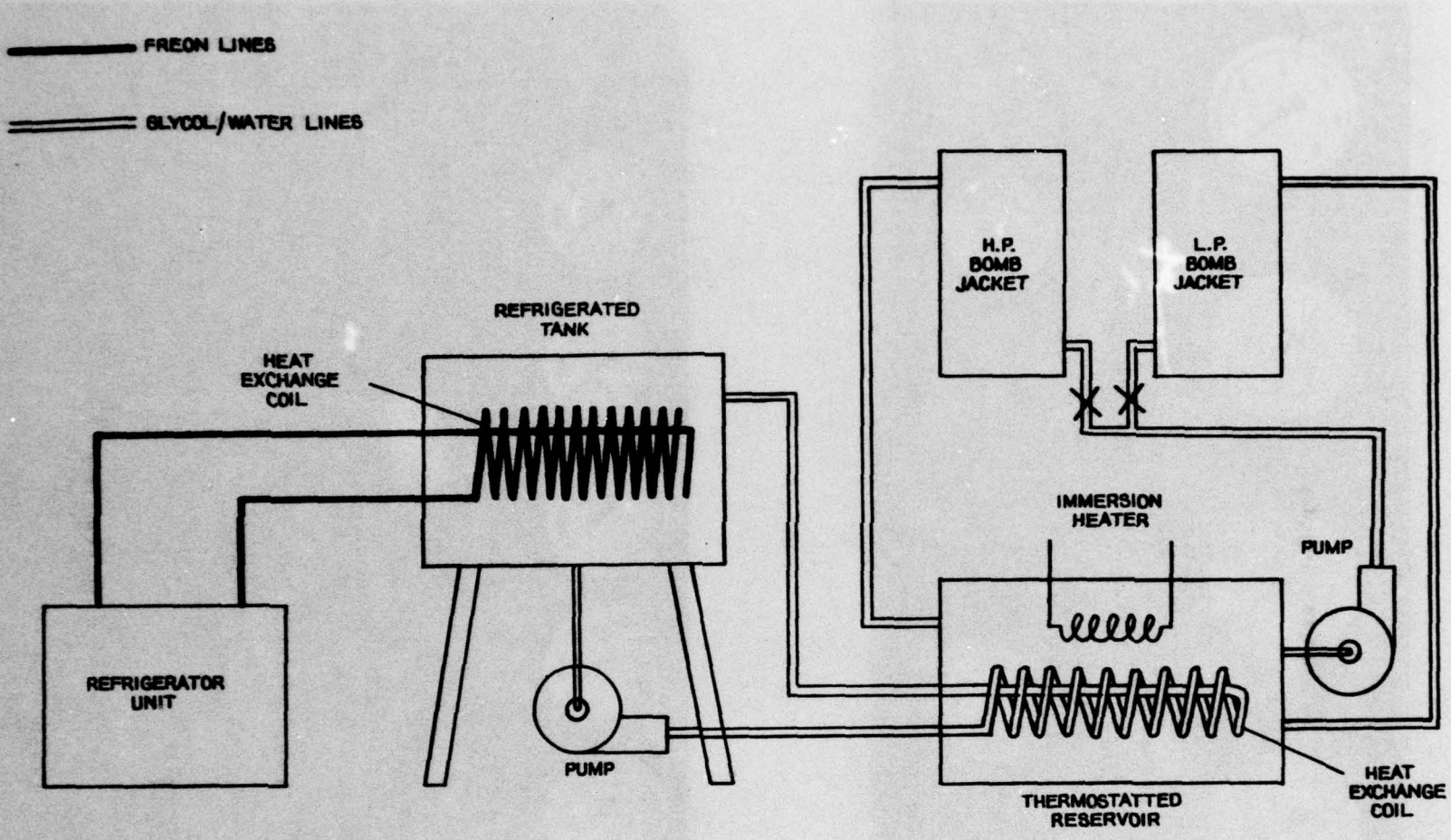


Figure 4. System for temperature control of the bombs

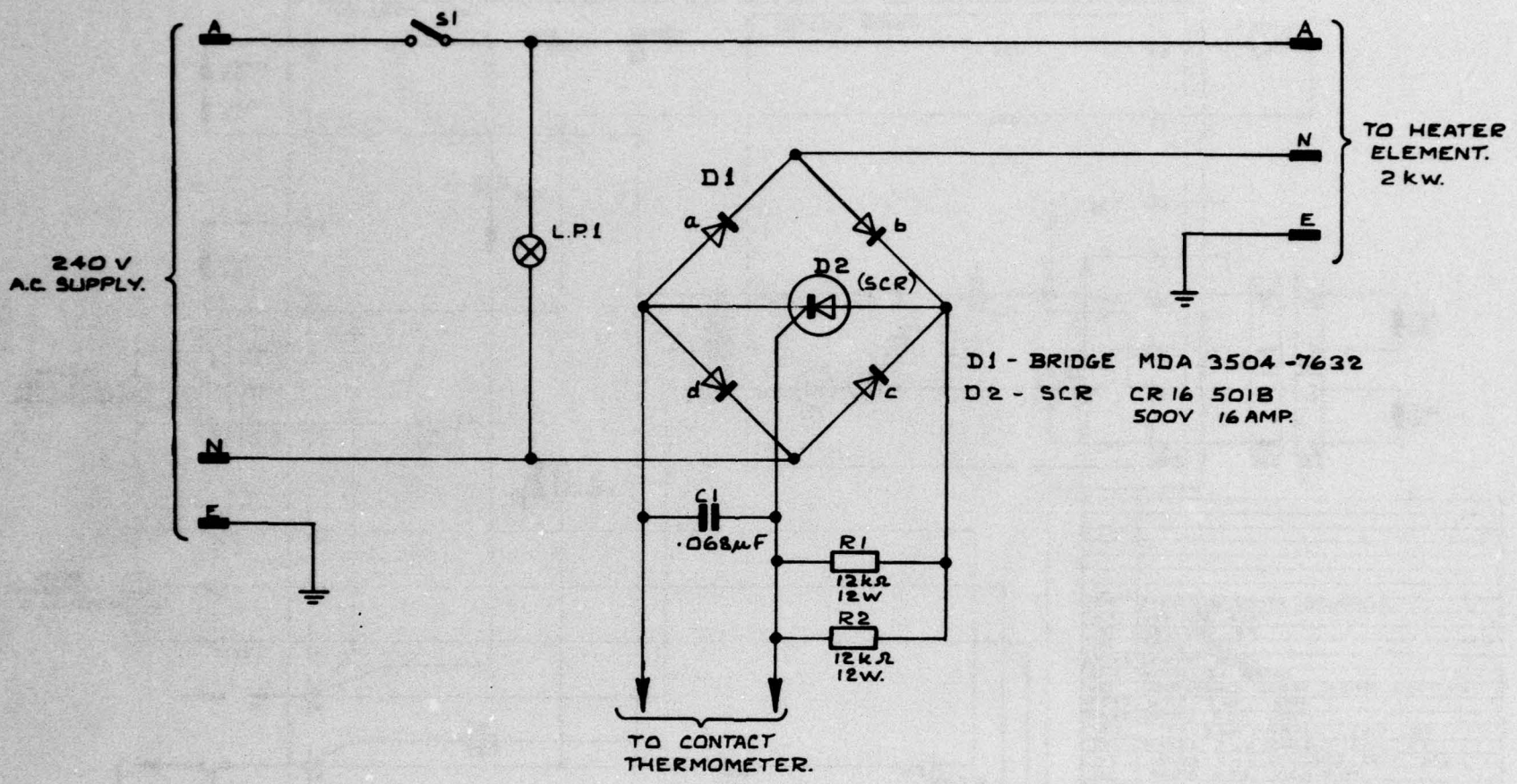


Figure 5. Control circuit for heating the thermostatted reservoir

WRE-MA-1850(W)
Figure 5

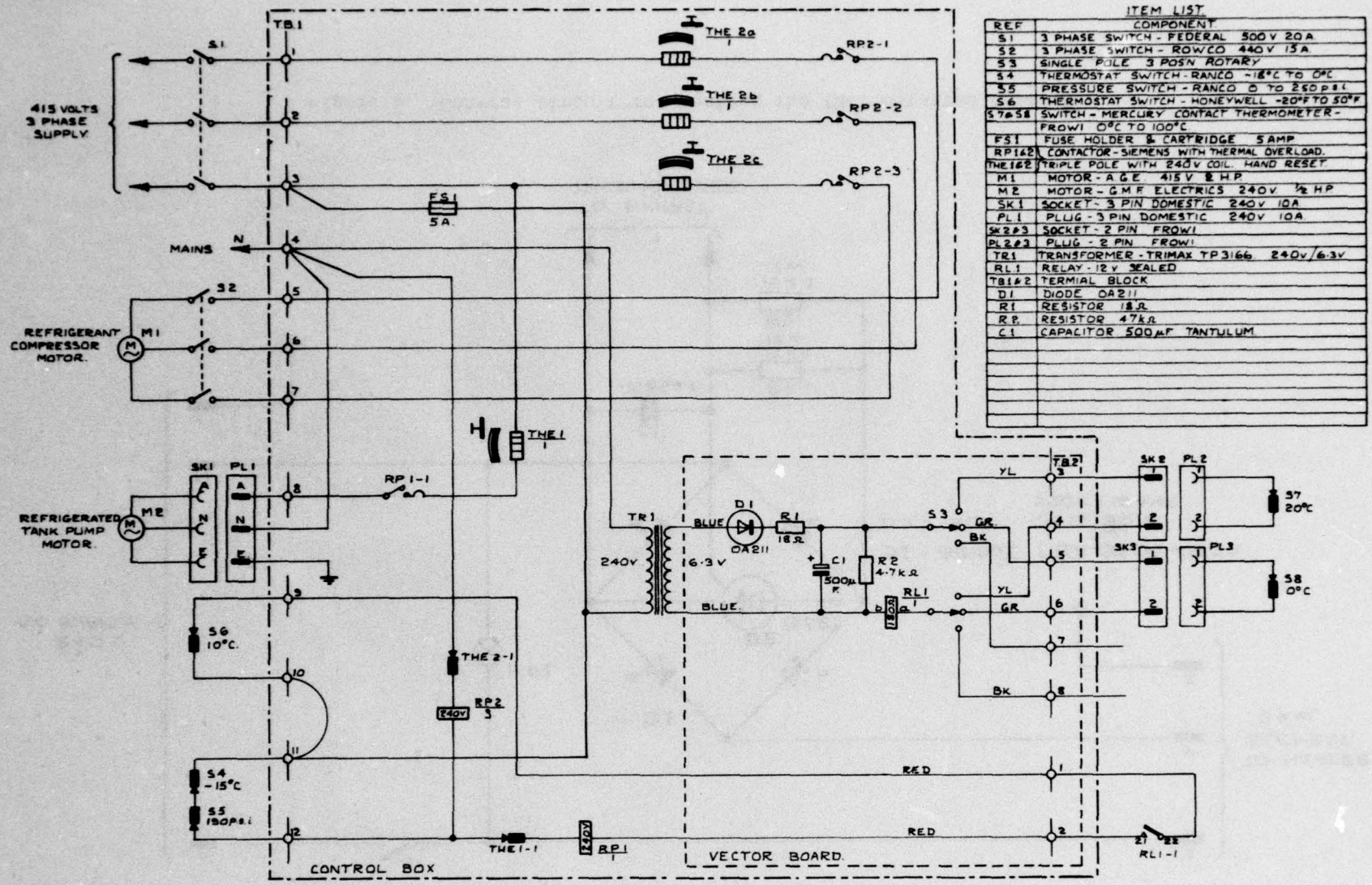


Figure 6. Control circuit for cooling the thermostatted reservoir and refrigerated tank

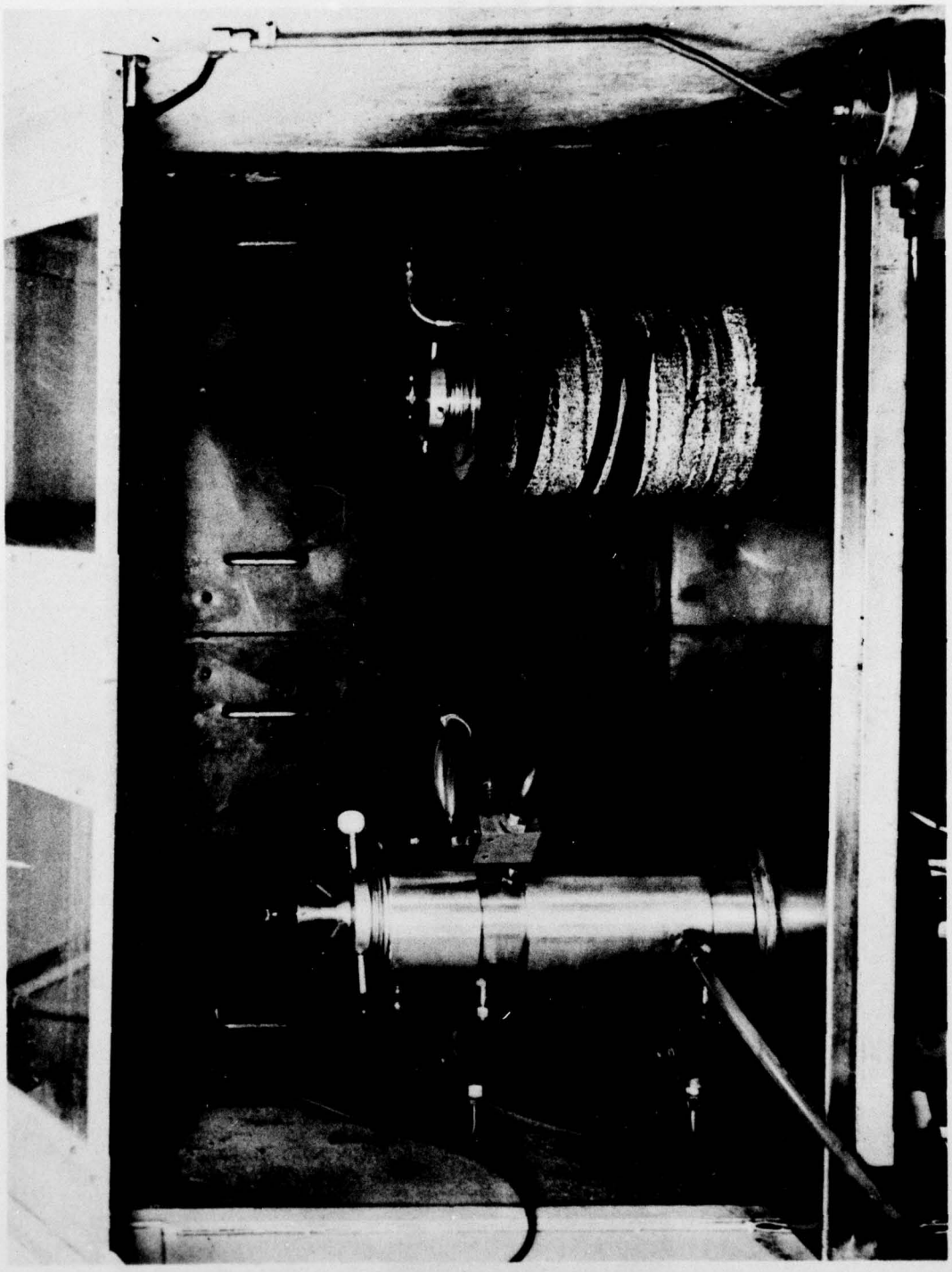


Figure 7. High pressure and low pressure bombs

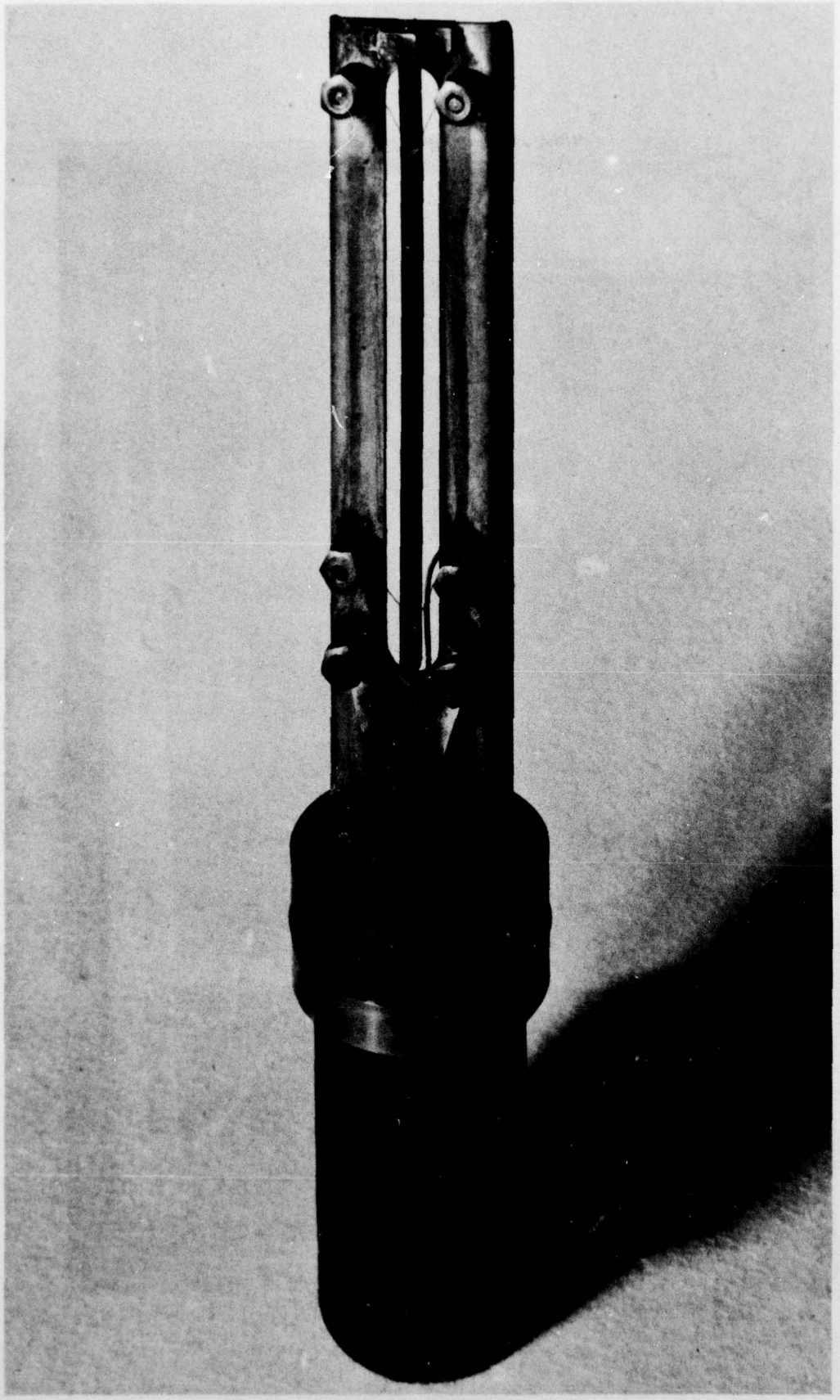


Figure 8. Strand mounting head for use in low pressure bomb

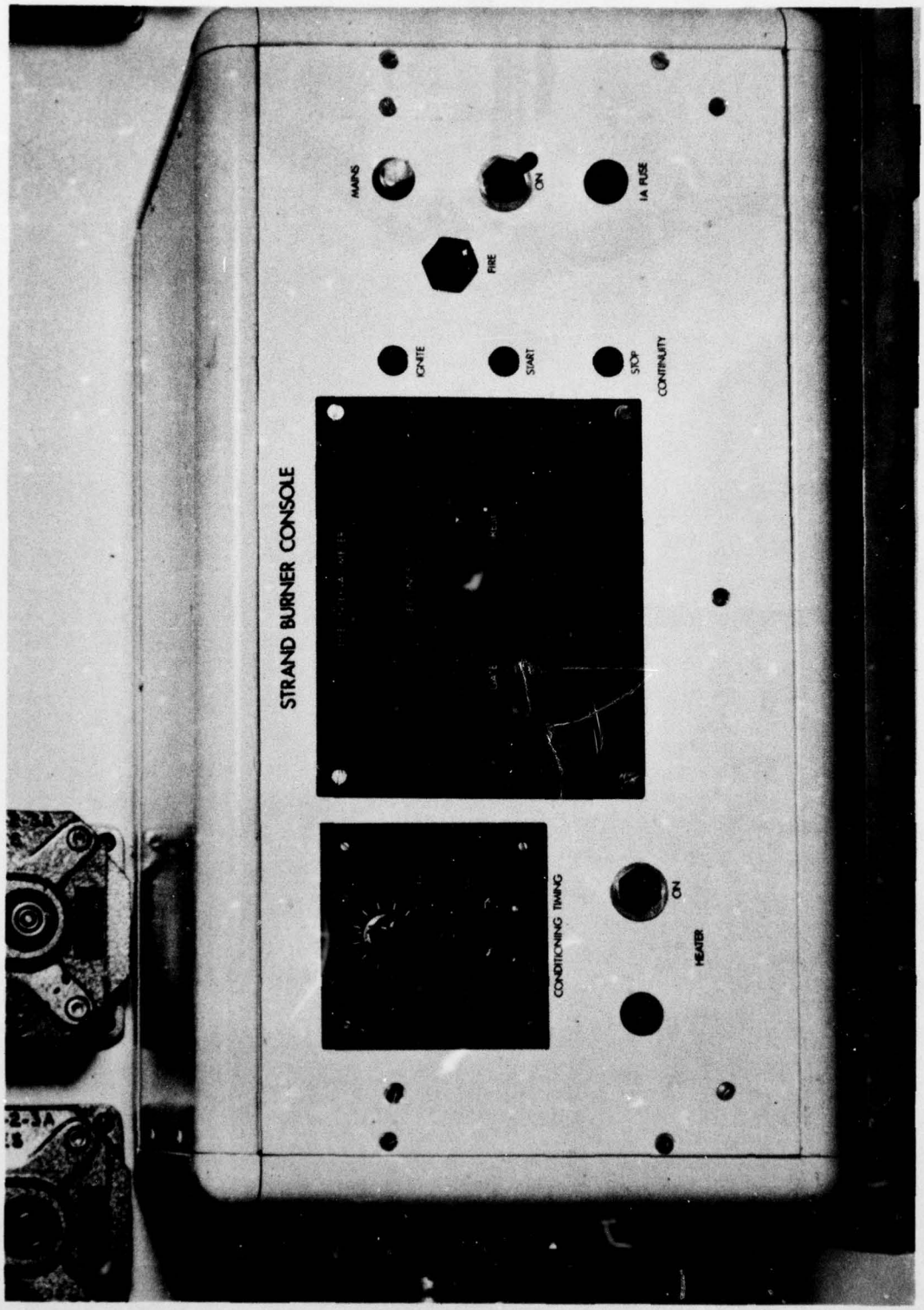


Figure 9. Timing console

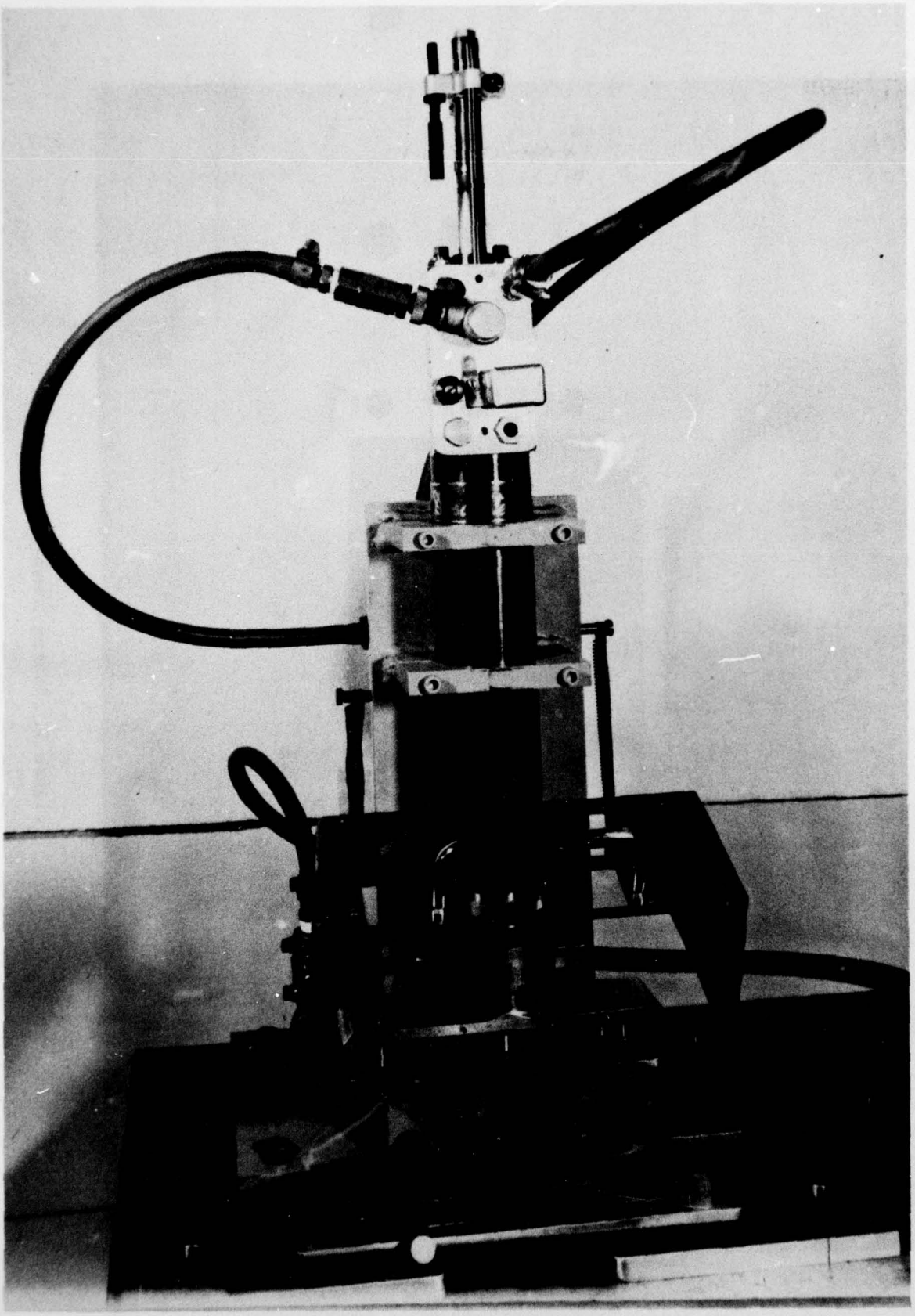


Figure 10. Strand drilling jig

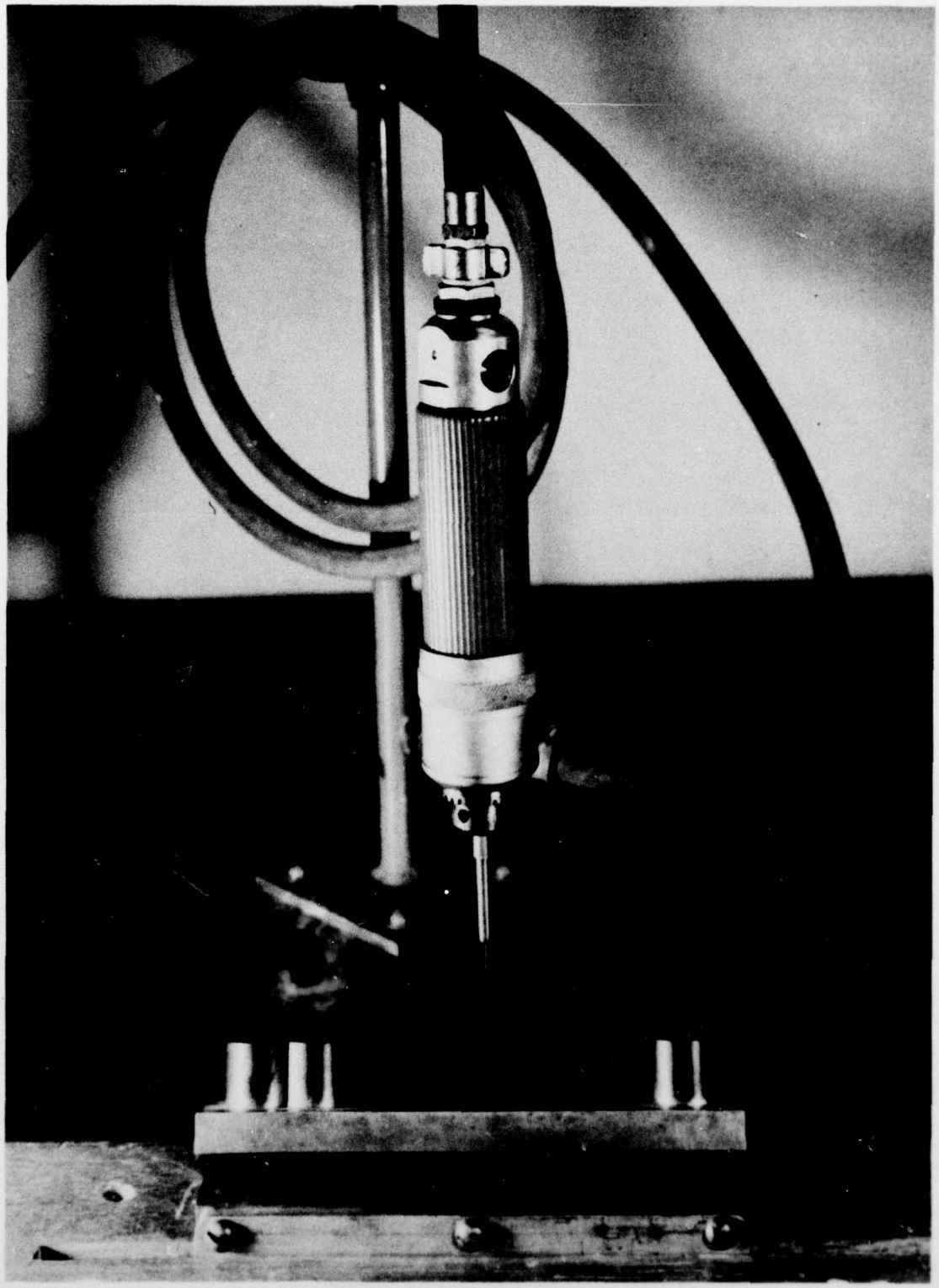


Figure 11. Old strand drilling equipment for emergency use

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