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THE SUPERCONDUCTING CHICAGO CYCLOTRON MAGNET OPERATING MANUAL

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CONTENTS

NOTE: Experimenters and users need to know detailedly only Section I - III.

I. Introduction

The superconducting Chicago Cyclotron Magnet (CCM) is located at the south end of the Muon Lab (Photo 11). This area is equipped with an emergency cryogenic exhaust system, a smoke detector and oxygen level monitors. The magnet iron consists of segmented blocks and has a total weight of 2175 tons. The useful magnetic field volume at 1.5T amounts to $19m^3$.

The magnet dump switch, the mechanical reversing switch and the (20V, 1000A) EMI power supply are located approximately 5m to the north and 1m to the west of the magnet, near and/or on the west wall of the Muon Building. The dump resistor (sized for 200KW continuous operation) is located on the top of the magnet iron.

The liquid nitrogen storage ("blue") dewar is mounted near the upper southwest corner of the magnet iron. The "white" LN_2 buggy and the LHe transport dewars required for cooldown and operation of the magnet should be placed on the floor of the building south of the "blue" dewar. A removable transfer line transfers the LN_2 (during LN_2 precooling) to a permanent transfer line. A removable U-tube connects a standpipe at the end of this transfer line to the top hat entrance (power chimney) of the magnet.

On the south side of the upper magnet iron is a 1.5m (5 ft.) wide x 6m (20ft.) long catwalk installed to provide easy access to the power chimney, the dump resistor, the coil positioning hydraulic system control panel and the "blue" LN_2 dewar.

On the two benches along the west side of the magnet iron yoke, an array of instruments should be set up (as shown in picture 1) such that, together with the instrumentation panel on the west side of the radiation cage (see picture #2), would give readout of the cryogens' boil off flow rates, liquid levels, pressures of both the LN_2 + LHe systems, electrical resistance of the two coils, the support column slider motions, and the thermocouples and strain gages installed in various parts of the magnet.

The Superconducting CCM is a very delicate tool for doing HEP experiments. More detailed information about the magnet is available on an updated magnet description sheet (available from Research Service Cryogenics Group and references (1,2,3).

Section II

<u>How to operate the magnet from the Electronics Control Console</u>

This electronics portion of the operation manual is a synopsis of the complete "Chicago Cyclotron Magnet Electronics and Instrumentation Manual" written by R. Yarema of J. Green. For complete reference, refer to that manual. The purpose here is to provide an easy reference. It is not meant to be complete.

The electrical system is shown in Figure 1. There are four parts: a 20V, 1000A power supply, a mechanical dump switch, a mechanical reversing switch and an air cooled dump resistor. In addition, there is a rack mounted control console (Picture #8).

The power supply operates in two modes, the voltage mode and the current mode. In the voltage mode, the power supply puts a constant voltage on the line charging the magnet with a linear current rise. When within 10% of the set current, the supply switches to a constant current mode from the constant voltage mode and the voltage in the magnet rises exponentially to the set value with a time constant determined by the dump resistor and the inductance of the magnet. This process can be quickened by setting the current set to a higher value and then setting it back down when the desired current is reached. It takes approximately an hour to charge the magnet to full current (880A).

The magnet is discharged via the dump resistor and the current decays with a time constant of $\sim$325 seconds. Once the discharge current falls below 100A, the reversing switch may be thrown, and the power supply then is actually helping to discharge the magnet faster. Note that the warning lights on the magnet would stay on until the current is less than $\sim$0.1A.

The rack mounted control console can be operated locally or remotely (from a porta-kamp outside the Muon Lab, say).

TO TURN "ON" and "OFF" THE MAGNET LOCALLY:

1. Turn the permit key to the right to complete the interlock circuit.

2. The local/remote switch should be in local.

3. The interlock LED's should all be green, if not, press the reset button.

4. The interlock reset LED in status section should be on.

5. Check power supply I set on position 1 of analog section, set to desired power supply current which will be slightly higher than the magnet current when the magnet is fully charged.

6. Push local control "on" push button while holding in the Quench Trip Monitor Inhibit button. Do not release the Trip Inhibit button until the high/low set points LED's have both been off for at least 10 seconds. A spurious trip could otherwise occur. The "Power Supply ON" and "Dump Switch Closed" LED's will be on. The "Imag $>$10A" LED will come on when the magnet is charged to 10A. The "Vmag $>$20mV LED will stay on until the magnet discharges to $<$100ma in dump resistors (.2Ω) which gives a voltage of 20mV.

7. Permit key can now be removed, but if the system faults it will have to be used again to reset the system. The key acts as a control lock out.

8. Flip the alarm reset switch. If the power supply goes off, an ear piercing alarm will occur.

9. To turn power supply off: Push "off" button on front panel. (You may want to disarm the alarm panel first by flipping the alarm switch off).

For Remote operations (possible but have not made provisions for yet), i.e. turning on and off the magnet not from the panel but from a terminal, say in a Porta-Kamp, one should consult the detailed manual and talk to John Green or Ray Yarema.

INTERLOCK SYSTEM

The magnet has an interlock system against the following fault modes:

1. Magnet ground current -- guards against coil short to ground.

2. Magnet overcurrent -- guards against using the magnet at a dangerously high current level.

3. Lower current lead voltage -- guards agains malfunctioning of the AMS lead.

4. Upper current lead voltage -- ditto.

5. Low helium gas flow rate -- guards against in adequate liquid helium supply.

6. High helium gas flow rate -- guards against excessive disturbance, as early warning against possible quench.

7. LHe level I -- guards against low liquid helium level

8. LHe level II -- ditto.

9. Probe I -- gives current flowing through probe I.

10. Probe II -- ditto, except for probe II.

11. Reversing switch door - guard against the leaving of the door on the box for the reversing switch open.

12. External gate -- guards against radiation monitor in the area.

13. Diode Cooling -- guards against the malfunction of the power supply diode air cooling fan.

14. Power Sensor -- guards against the malfunctioning of the power diode in the power supply.

15. Imbalanced voltage between the upper and lower coil of the magnet: guards against possible quench.

Upon the detection of one of these modes, the magnet will discharge automatically.

Again, one should refer to the complete manual for detailed understandings.

III. Safety Considerations of Others

Again, this portion serves as an outline, for more detailed information concerning the safety aspects of CCM, one should refer to the CCM safety Review written by E. Leung, A. Ito and R. Kephart, et al.

Safety Precaution During Cooldown of Warmup

Danger during this phase comes from the existance of cryogens in the area. Sudden loss of vacuum can lead to release of cryogenic fluids inside and outside the Muon Lab. The area of highest potential danger is the basement area (Muon Pit) where the Transrex power supplies are installed. An oxygen monitor is installed in the basement.

1. Personnel working in the CCM area when the magnet is full of liquid helium should have read the operation manual or attended the CCM user's course or obtained a briefing from the CCM operation chief at the time.

2. When working inside the Muon Pit, one should use the buddy system.

3. If any of the oxygen monitors goes off, the procedure is to evacuate the buildings and raise the bay door.

4. Hard hats should be worn especially when working on the aluminum catwalk or above the magnet in the dump resistor area.

Safety Precaution During Power-Up Stage of Magnet

1. Due to the possibility of venting helium into the Muon Lab in the unlikely event of a very serious quench, during the time the magnet is powered, the buildings should be cleared of all persnnel not necessary for the CCM operation, usage of the Transrex power supplies and operation of the experiment itself.

2. Before charging up, magnetic material (tools and bolts, say) should be kept away from the magnet

for they would be sucked into the magnet by strong magnetic field. Cabinets, pumps and other heavy (magnetic or partially magnetic) objects should be well secured.

3. When working inside the magnetic field is a necessary must, one should remove his metallic (if magnetic) belt buckle, pens and other magnetic personal belongings before stepping close to magnetic field volume.

4. Do not run or perform rapid head turning motion when inside the main magnetic field volume, it might lead to dizziness. It may not be advisable for a person with serious heart condition to work inside the main field volume neither.

5. A buddy system should be used when working in the main field volume is necessary.

6. Hard hat is recommended.

Emergency Procedure During Power-Up Status of Magnet

Since a quench if it occurs cannot be stopped externally and the electronics is set to dump the magnet in that event, the response of all personnel to a quench induced dump evidenced by excessive increase in magnet pressure and liquid helium boil-off rate or a burst disk failure should be the following:

1. Immediately leave the building quickly in an orderly fashion.

2. Help to ensure that everyone in the immediate vicinity is able to leave the building safely and be ready to help out if possible.

3. Do no attempt to diagnose the problem from inside the building.

   a. Notify security and fire department to help people from the building.

   b. Alert people in other regions of the Muon area.

   c. Call either Albert Ito, X4940 or Page 942
      Eddie Leung, X4882 or Page 407
      Robert Kephart, X3512 or Page 821

IV. EQUIPMENT OF INSTRUMENTS REQUIRED FOR VARIOUS PHASES:

A. PUMPDOWN:

1. Cryogenics/Magnet Fab. pumping station 1 (consists of a Welch 1397 mechanical pump, a 4" Dia. Edwards Diffusion Pump with a cold trap).

2. Another Welch 1397 mechanical pump (or equivalent).

3. Frederick and Varian ion and thermocouple gauge readouts, two each.

4. 2 small Direct Torr vacuum pumps.

B. COOLDOWN PHASE

1. A Keithley 169 multimeter.

2. A Hewlett Packard 6227B DC power supply.

3. 2 Fluke 8100A Digital multimeters.

4. 2 Hearth Schlumberger strip chart recorders.

5. A digital thermocouple readout (Omega Model 175), calibrated for chromel-constantan E type thermocouple.

6. "White" liquid nitrogen buggy.

7. Activation of the hydraulic system and coil/support movement indicator.

8. Ample LN_2 supply and 5000 L of LHe.

9. Helium gas return line to Meson gas bag (Helium recovery system).

10. Items 3 and 4 as required in Phase A.

C. MAGNET POWER PHASE

1. Above equipment except the "white" LN_2 buggy.
2. EMI power supply.
3. Dump resistor, dump switch and reversing switch
4. CCM Central electronics console.

D. WARM UP PHASE

1. Same as in Phase B except for LN_2 + LHe and vacuum pumps.

E. DORMANT PHASE

1. The Cryogenics/Mag. Fab. pumping station or equivalent.

V. EQUIPMENT SETUP

1. The electronic equipments should be set up in accordance to what is shown in picture 1, 3 and 6. Note that setting up of the strain gage readouts (2 strainsert TN8C strain gage readouts) are not necessary for ordinary runs.

2. Picture #2 shows the radiation cage westside instrumentation panel. On the left side of the alarm loudspeaker (located at the top center of the fence), from top to bottom, are located a Teledyne vacuum readout ("blue" LN_2 dewar vacuum space), a mechanical gauge (giving magnet helium cryostat pressure), three helium gas flowmeters (for steady state He vent, black and white current leads) and below, an oxygen monitor for oxygen content measurement in the basement and roof of magnet. The alarm loudspeaker will produce a very high-pitched sound upon a lack of oxygen in the basement. To the right of this horn-shaped loudspeaker, top to bottom, first is a bell and an amber light for indicating the condition of the helium recovery system in the Meson Detector Building. (The warning light d bell would be activated upon venting of the helium gas bag and a possible malfunctioning gas compressor). Next to it is a helium liquid level indicator for the magnet helium cryostat. Below these are the "blue" dewar level and pressure gauges and three flowmeters (LN_2 shield, He cooldown top hat, helium cooldown far side) used on the LN_2 system.

3. Check and make sure that the interlocks on the CCM central electronics control console are set as below:

I_o = Desired Current $\leq$ 880 amps

INTERLOCK		LOW TRIP	HIGH TRIP
EMERG. SWITCH	ON/OFF		
Rad. Interlock(Magnet Current)			$I_o + 30$
Mag. GND Current			2.5A
Over current (shunt)			$I_o + 20$
Lower lead voltage			∿ 50 mV
Upper lead voltage			∿ 50 mV
Low helium gas flow			4.2 V (100 scfh)
High helium gas flow			12.2 V (500 scfh)
Over current (dump)			930 amp
Helium level 1 (1" helium in reservoir)		0.9 inches	
Helium level 2 (1" helium in reservoir)		8.9 inches	
Probe 1 I			62.9 ma
Probe 2 I			62.9 ma
Over current (relay)			$I_o + 30$
Rev. Switch door	ON/OFF		
External gate	ON/OFF		
Diode cooling	ON/OFF		
Power Trip	ON/OFF		
Quench voltage			set at 75mV

Effect of all trips is to open the dump switch and discharge magnet into dump resistor.

VI. PUMPDOWN

1. Check that the vacuum space has a vacuum of about 100 microns or lower. If not, pump down is required:

   a. Check that the vacuum pump(s) to be used, pumping on itself will reach $\leq$10 microns.

   b. Hook up the pumping station to the upper pump out port and the other 1397 pump to the lower vacuum space. With pumpout valve closed, pump down hose to pump ultimate ($\leq$10 microns).

   c. Start out with the pumping station. Carefully open the pump out valve. If vacuum in the magnet vacuum space is above 500 microns, the valve should be opened very slightly at first (to prevent damage to superinsulation). The valve should be opened only until the pump starts to "gurgle". As the pressure decreases, the valve can be opened more, being careful not be cause violent gurgling in the pump. Repeat the same procedure for the second pump.

   d. The whole pumpdown procedure, assuming that we had kept the vacuum space to be relatively clean, should take no more than 3 to 5 days. During this period, solenoid valves on the pumps should be activated such that a sudden power failure would not cause back streaming of oil into the vacuum space. The cold trap of the diffusion pump should be checked and filled once every 4 hours.

2. While the magnet vacuum space is being pumped down, check the readings on the vacuum of all the jacketed LN_2 and LHe transfer lines. It is recommended that all the vacuum jackets be maintained at 20 microns. If necessary to pump on them, use the small Direct Torr vacuum pump(s), (we had two designated to the CCM operation), after insuring that its ultimate is good ($\sim$1 micron).

3. If the helium cryostat space of the magnet is not filled with a positive pressure of dry gas, one should fill the space with dry helium gas (to ∿2psig) and then pump the space down, first to 500 micron and then 200 microns. Repeat the same procedure once more. This action is to avoid ice formation inside the coils. The magnet is now ready for LN_2 cooldown.

SECTION VII

I. CCM Cooldown and Warm up Scenerio

1. Precool with liquid nitrogen

   a. Both the blue dewar(LN_2 storage tank for the LN_2 system of CCM) and the white buggy are filled up with LN from the LN_2 trailer (outside vendor, e.g. Airco). (cf. Photo 9)

   b. The white buggy is connected through a specially made bayonet and 3/8" transfer line to the LHe cooldown line inside the chimney (that goes all the way to the bottom of the lower coil). Transfer of LN_2 can then be started. LN_2 from the white buggy is used to precool the cryostats and coils of CCM.

   c. The blue dewar is used to provide LN_2 to cooldown the LN_2 system (column & radiation heat shield). The boil-off rate during cooldown should be kept at $\sim$200 SCFH.

   d. The boil-offs from both the LN_2 system and the He cryostat are monitored to control the rate of cooldown. The coil resistance serves as a thermometer to measure the coil temperature at any moment. This resistance is measured by passing a constant current (100 mA) through the coil and measuring the voltage drop across the coils. It is planned to cool down the cryostats with 3500 liters of LN_2 administered uniformly during a period of $\sim$5 days, such that the cooldown rate at any time should be less than 1.3 KW (or equivalent to a resistance (of coil) change of $\sim$ 0.7%/hour). The estimated maximum boil-off rate from the LHe system during nitrogen precooling $<$ 1600 SCFH. During cooldown the position of the columns sliders are carefully monitored by reading the dial indicators.

   e. The above process continues until both systems are filled with liquid nitrogen. Let the coils sit in LN_2 for half to a whole day. During this time we will monitor the boil-offs.

2. Clearing Out the LN_2

The cryostat (LHe system) is then pressurized and the LN_2 is forced out through the LHe cooldown lines. This is possible because this line goes all the way to the bottom of the bottom coil. Helium gas is then passed down the LHe cooldown line to evaporate any LN_2 left behind. This flushing procedure at low pressure (<3 psig) subcools the coil and cryostat to a temperature of approximately 72K. By adopting such a procedure, we require 1500 liters of LHe to further cooldown to 4.2K. (instead of 7000 L if we stop LN_2 precooling at 90K).

3. Further Cooling with Liquid Helium

At around liquid nitrogen temperature, 90% of the material contraction is effected and more than 94% of the thermal energy in the cold mass is removed. Liquid helium is then transferred to the magnet through the U-tube and standard CCM LHe transfer line from 1000 liter dewars provided by our liquefier group (or bought from outside vendors). The transfer rate should be $\sim$ 1000 liter/2 hours at a pressure of $\sim$ 2 psig. It is estimated that $\sim$ 4000 liters is required to cool the cold mass from 80K down to 4.2K and 1500L from 72K to 4.2K. The liquid helium storage volume in the magnet is $\sim$ 2000 liters; so, in about a day or so, if sufficient LHe is available, the magnet could be filled with liquid helium. Monitor the temperatures and boil-offs until the system assumes steady state. It might take two weeks or more to achieve a steady state boil-off because of the substanstial amount of thermal energy still trapped in the support columns.

4. During cooldown, the following are monitored:

a. Resistance of both the upper and lower coils (chart recorder and DVM entries in log).

b. Temperature of heat shields (4 thermocouples).

c. Temperature of intercept on power chimney (1 thermocouple).

e. Temperature of N_2 shield on the electrical interconnecting tube (1 thermocouple).

f. 7 room temperature strain gage readings. (Optional)

g. 4 cryogenic temperature strain gage readings. (Optional)

h. 8 side-load indicator readings

i. 24 column sliding action indicator readings.

A total of 53 readings. These readings should give us a rather detailed cooldown curve and details of the cooldown pattern inside the magnet system.

5. Other Significant Parameters:

Total amount of thermal energy to be removed by LN_2 = 76.4×10^8 J

Total amount of thermal energy to be removed by LHe = 5.0×10^7 J

Electrical resistance of the upper coil at 94 F = 38.2 Ω

Electrical resistance of the lower coil at 88 F = 38.9Ω

6. Warm up:

I. Special Purpose Fast Warmup:

a. Pressurize magnet with cooldown fill extension in and blow out the liquid helium.

b. Break the vacuum with helium gas (to avoid aqueous condensation).

c. Use warm nitrogen gas to warm up the LN_2 system.

d. Use warm helium gas to warm up the cryostat (LHe system) to a temperature of 80K; then use warm nitrogen gas to warm it up to room temperature.

e. One can also keep warm LN_2 gas in the vacuum jacket to speed up the warmup process.

7. Normal Procedure

a. Let remaining LHe boil off naturally.

b. Monitor slider motion and other data twice a day.

c. Turn off LN_2 supply once all LHe is one.

d. Take all readings once a day till totally warmed up.

8. Summary:

a. ∿ 5 days for LN_2 precooling.

b. ∿ 3 days or sitting at LN_2 temperatures.

c. 1 day removal of LN_2 from system.

d. 2 days for filling system with LHe (if LHe is availble).

e. 3 days for achieving thermal equilibrium at 4.2K

f. Ready for doing experiment

g. 2 1/2 weeks for normal gradual warmup

9. CAUTIONS:

The most serious potential problems are listed below:

a. Damage to coil due to thermal stress during LN_2 cooldown. Obviously we should be careful to supply LN_2 to the coil in a controlled manner by measuring the boil-off gas.

b. Damage to column caused by a slider hanging up during cooldown or warmup: It is extremely important to monitor the column positions during cooldown and warm up and take corrective action if they don't move uniformly.

c. Loss of vacuum while the vessel is full of LHe. (Think before you open a valve, etc.)

SECTION VIII
Instruction for Data Taking Analysis During CCM Cooldown

Data Taking

During cooldown, a set of readings has to be taken every two or three hours:

1. The resistance of both the lower and upper coils are read off the blue Fluke Meters (see photo #1). Graph I is used to find the corresponding coil temperature. Both resistance and temperature are recorded on CCM Cooldown Engineering Sheet #1(CDERS #1). The recorders below the meters keeps a continuous record of the resistances to generate the rate of cooling of the coils.

2. The magnet cryostat (can be seen on extreme left side of Photo #2), the LN_2 cooldown boil-off flow rates (indicated by the three flowmeters on right hand side of Photo #2) and the magnet vacuum jacket pressure (Photo #3) are recorded on CCM CDERS #1.

3. Temperature sensor (chromel-constantan thermocouples) readings in the magnet system are readout on the digital thermocouple readout, Omega Model 175 (shown in Photo #4) and recorded on CCM CDERS #2. Their locations are described on CCM CDERS #2A.

4. The upper and lower coil contraction and the support column movements are recorded on CCM CDERS # 3,4, and 5. They are LC #1, 4,7,10, LS #1-12, UC #1,4,7,10, US #1-12 and can be readout directly from the CCM Support/Coil Movement Indicator (the silver box shown in Photo #5). Controls for the hydraulic system are also shown in the same photo.

5. In ordinary runs, this paragraph can be neglected. Strain gauge readings are monitored (when and if necessary in a particular run) with two strainsert TN8C gage readout (Photo #6). Data can be recorded on CCM CDERS 6,7. Locations of the various gages are indicated on CDERS 7A.

Data Processing and Follow-Up Action

a. In ordinary runs this paragraph can be neglected. Plot the temperature of the coils vs. time on CCM CDERS #6 to show the cooldown progress, using data from CCM CDERS #1. This chart is to be posted at a convenient location in the operation center.

b. To achieve the correct cooldown rate, valve adjustments should be made at the white buggy (Photo #7) such that the LN_2 boil-off flow rates would both be $\leq$ 550 + 50 SCFH and the magnet cryostat pressure $\leq$ 3 PSIG. A suggested setting for the white buggy (when the buggy is almost full) is to have the big long stem valve 1/4 turn open, the hydraulic valve fully open and the transfer pressure at the white buggy to be 15-16 psi. (The magnet cryostat pressure reliefs are set for 5 psig, so if the pressure rises above 3 psig, shut off the hydraulic valve at the white buggy and re-adjust the long stem valve and buggy pressure until the pressure falls below 3 psig.

c. Locations for TC #1-9 are described on CCM CDERS 2A. The average temperature from $\frac{TC\ \#7 + TC\ \#5}{2}$ should be kept about the same ($\pm$ 10K) as the lower coil temperature by controlling the LN_2 supply from the blue dewar to the magnet LN_2 system. This can be done by adjusting the LN_2 shield flow (indicating the 3rd meter from right on Photo # 2).

d. From graph II (coil temperature vs. slider motion curve), or directly from graph III (Resistance of coils vs. slider motion curves) if one decides not to have a cooldown progress curve, the expected coil contraction at a given temperature is read-off and recorded in CCM CDERS #8. This shows the theoretical value for the movements.

e. Compare this reading with the linear pot. readings taken earlier in (4). When the average LC readings > the average LS readings by 40 mils. (Similarly for the UC and US readings), activate the hydraulic system to push the sliders in (pushing on all of them at the same time, pressure required in general varies between 700 psig and 1500 psig, time duration 2-5 seconds). The columns should be treated with care. Never force a slider to go in by applying excessive pressure. It is normal for a column to move in under the hydraulic force and then spring back a little. Record another round of the LIN POT readings after the hydraulic action. Enter into CCM CDERS #3,4 & 5, as well as CCM CDERS 8 to compare to the expected value. Fill in one CCM CDERS 8 for each coil and attach them to the log book.

If any column does not respond to the hydraulic system, the column can be checked manually using a torque wrench and bolt. In all cases keep torque less than 100 inch-pounds. If the above procedures fail and any column lags by more than 150 mils from the expected value, stop the cooldown and consult an expert.

Important Points to Note

1. It is important to open up a hardcover log book for each run of the CCM. Date and time all readings taken.

2. Keep all the CDER sheets on a clipboard and keep all data analysis up to date. Good recordkeeping is essential for efficient running of the magnet.

3. Try to interpret the data and observe if there is anything wrong (readings associated for the second cooldown would be available as a guide in a separate black folder). If so, contact whoever is in charge of the operation or persons knowledgeable in the design of the magnet.

CCM Warm-Up

Normal Procedure:

The LHe is allowed to boil off into the He recover system, but with the LN_2 system still providing cooling to insure uniform expansion. From a level of 9.1" in LHe level 2 and 1.3" in LHe level 1, it takes eight days to obtain zero flow in the helium gas flowmeters. The LN_2 system is now turned off and the entire magnet warms up. Readings should be taken approximately twice a day during the helium boil-off period and continue to be taken until coil temperature reaches -50^{o}C (about five more days), at which time most of the coil supports have returned to within 50 mils of their original position and the thermocouple temperature are at 273K ($\sim$0^{o}C). Use the CCM "warmup graph" curves (Graph IV) as a guideline after all the LHe has boiled off. Once again, all the coil supports should return at the same rate to their original positions. Thermocouple Channel 9, the LN_2 inlet, returns to room temperature very rapidly; channels 1,2,3,4 and 8 warmup somewhat more rapidly than channels 5,6,and 7. As the coil temperature rises above -50^{o}C, once a day readings until the magnet returns to room temperature is adequate.

If a fast warmup is desired, the LHe system can be pressurized through the cooldown fill extension to force the LHe out into a dewar. Next, stop the LN_2 flow and use warm nitrogen gas to blow out the LN_2. Break the shell vacuum with the helium gas to avoid any aqueous condensation. Use warm helium gas to warmup the LHe system to a temperature of approximately 80K, then use warm nitrogen gas to warmup to room temperature. Warm nitrogen gas can also be used to speed up the warmup of the LN_2 system.

SECTION IX

REFERENCES

1. E.M.W. Leung, R.D. Kephart, R.W. Fast and J.R. Heim, IEE Trans. MAG 17, p. 199, 1981

2. E.M.W. Leung, R.D. Kephart, A.S. Ito and R.W. Fast, "The Superconducting Chicago Cyclotron Magnet" Adv. Cryogenic Eng., Vol. 27, 1982.

3. E.M.W. Leung, R.D. Kephart and C.P. Grozis, "A Low Heat Leak Support Structural Member For The Superconducting Chicago Cyclotron Magnet" Advance of Cryogenic Engineering Vol. 27, 1982

CDERS#1

CCM COOLDOWN INSTRUMENTATION

No.	Date	Time	Obs.	Resistance of Upper Coil	Corr. Temp.	Resistance of Lower Coil	Corr. Temp.	Magnet Cryostat Pressure	Cooldown LN_2 B.O. Rate		Magnet Vacuum	Blue Dewar LN_2 Supply B.O. Rate
									(top hat)	(far side)		

MASTER [redacted]

CCM CDERS#2

Thermocouple Readings

[illegible]	Time	channel#1	channel#2	channel#3	channel#4	channel#5	channel#6	channel#7	channel#8	channel#9	channel#10

CCM INSTRUMENTATION

THERMOCOUPLE DIRECTORY   CDERS #2A

Channel #		
1	On top of nitrogen shield (Section 1)	UPPER
2	Between Section 9 & 10 on bottom of nitrogen shield	UPPER
3	On Column #6 nitrogen intercept	UPPER
4	On Pentagonal flange (nitrogen intercept of power chimney)	CHIMNEY
5	Between section 1 and section 12 on bottom of nitrogen shield	LOWER
6	Cryogenic Interconnecting Tube radiation shield	C.I.T.
7.	Between section 6 and 7 on top of radiation shield	LOWER
8	On column #6 nitrogen intercept	LOWER
9	Cooldown nitrogen (2 phase) inlet temperature	
10	Temperature of dump resistor or room temperature during cooldown	

MASTER [redacted]

CCM COOLDOWN SIDE LOAD DIAL/LINEAR POT. READINGS CDEPS # 3

No.	Date	Time	Observ.	D/L	LC-1	LC-2	LC-3	LC-4		UC-1	UC-2	UC-3	UC-4		Remarks		

MASTER [redacted] CCM COOLDOWN COLUMN DIAL/LINEAR POT. READINGS CDERS #4

No.	Date	Time	Observ.	D/L	US-1	US-2	US-3	US-4	US-5	US-6	US-7	US-8	US-9	US-10	US-11	US-12	Remarks

MASTER [redacted] CCM COOLDOWN COLUMN DIAL/LINEAR POT. READINGS CDERS*5

No.	Date	Time	Observ.	D/L	LS-1	LS-2	LS-3	LS-4	LS-5	LS-6	LS-7	LS-8	LS-9	LS-10	LS-11	LS-12	Remarks

MASTER

CCM COOLDOWN STRAIN GAUGE READINGS(STRAINSERT READOUT #[illegible]) CDERS #6

o.	Date	Time	Observ.		ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8		REMARKS			

MASTER

CCM COOLDOWN STRAIN GAUGE READINGS(STRAINSERT READOUT #2) CDERS #7

o.	Date	Time	Observ.		ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8		REMARKS			

STRAINSERT READOUT #1

Channel #	Strain Gauge #	Location
		Fat (300K-77K) G-10 tube, on
1	RS-L-1	Col. #1 of lower coil
2	RS-L-4	Col. #4 of lower coil
3	RS-L-7	Col. #7 of lower coil
4	RS-L-10	Col. #10 of lower coil
		Intermediate stainless steel (∿ 50K) tube, on
5	CS-L-6	Col. #6 of lower coil
6	CS-L-4	Col. #4 of lower coil
		Fat (300K-77K) G-10, on
7	RS-U-4	Col. #4 of upper coil
8	RS-U-7	Col. #7 of upper coil

STRAINSERT READOUT #2

Channel #	Strain Gauge #	Location
1	RS-U-10	Col. #10 of upper coil
2	CS-U-5	Intermediate stainless steel 304 (∿ 50K) tube, on Col. #5 of Upper Coil
		Section 3 Gusset
3	GR-U-3	Upper Coil (right)
4	GL-U-3	Upper Coil (left)
5	GR-L-3	Lower coil (right)
6	GL-L-3	Lower Coil (left)
		Blue LN_2 storage dewar support:
7	BD-T-1	SS304 triangle
8	BD-R-1	SS304 rectangle

ASTEIL

SUPERCONDUCTING CHICAGO CYCLOTRON MAGNET COOLDOWN MONITOR SHEET CDERS #8

(Column Slider Movement)

Coil (upper or lower): ______________

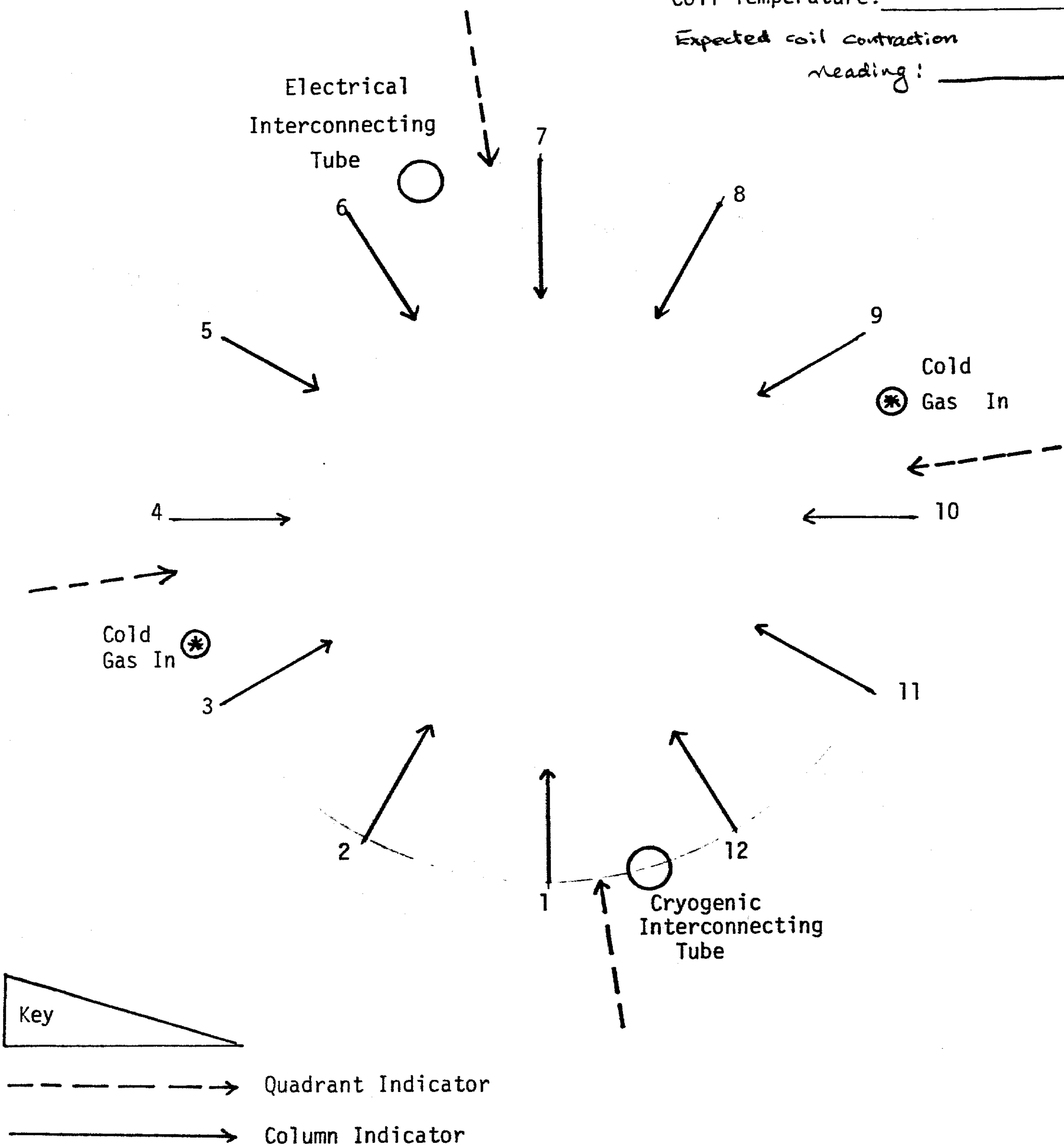
Date, Time: ______________

Observer: ______________ ______

Coil Resistance: ______________

Coil Temperature: ______________

Expected coil contraction reading: ______________

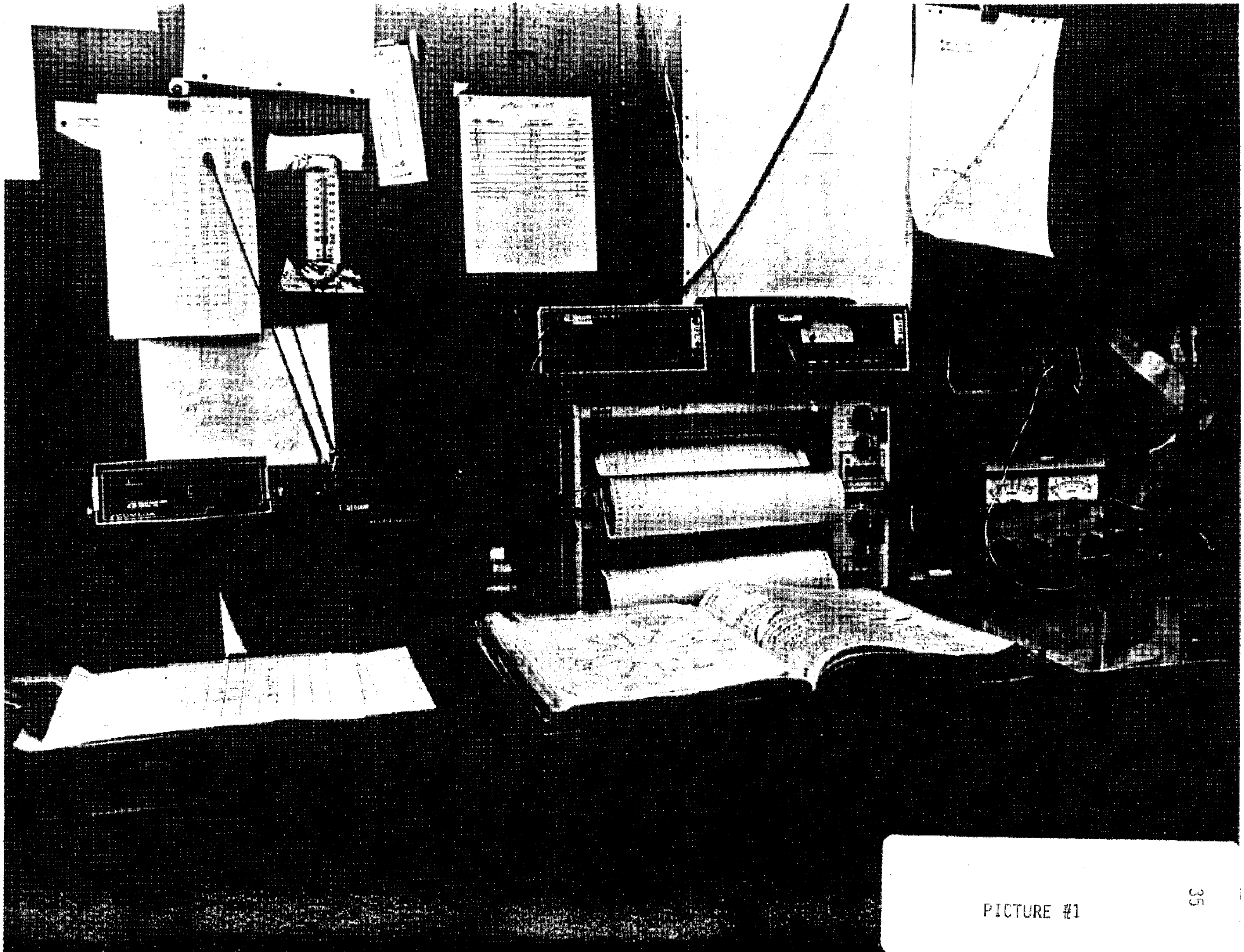


SECTION X

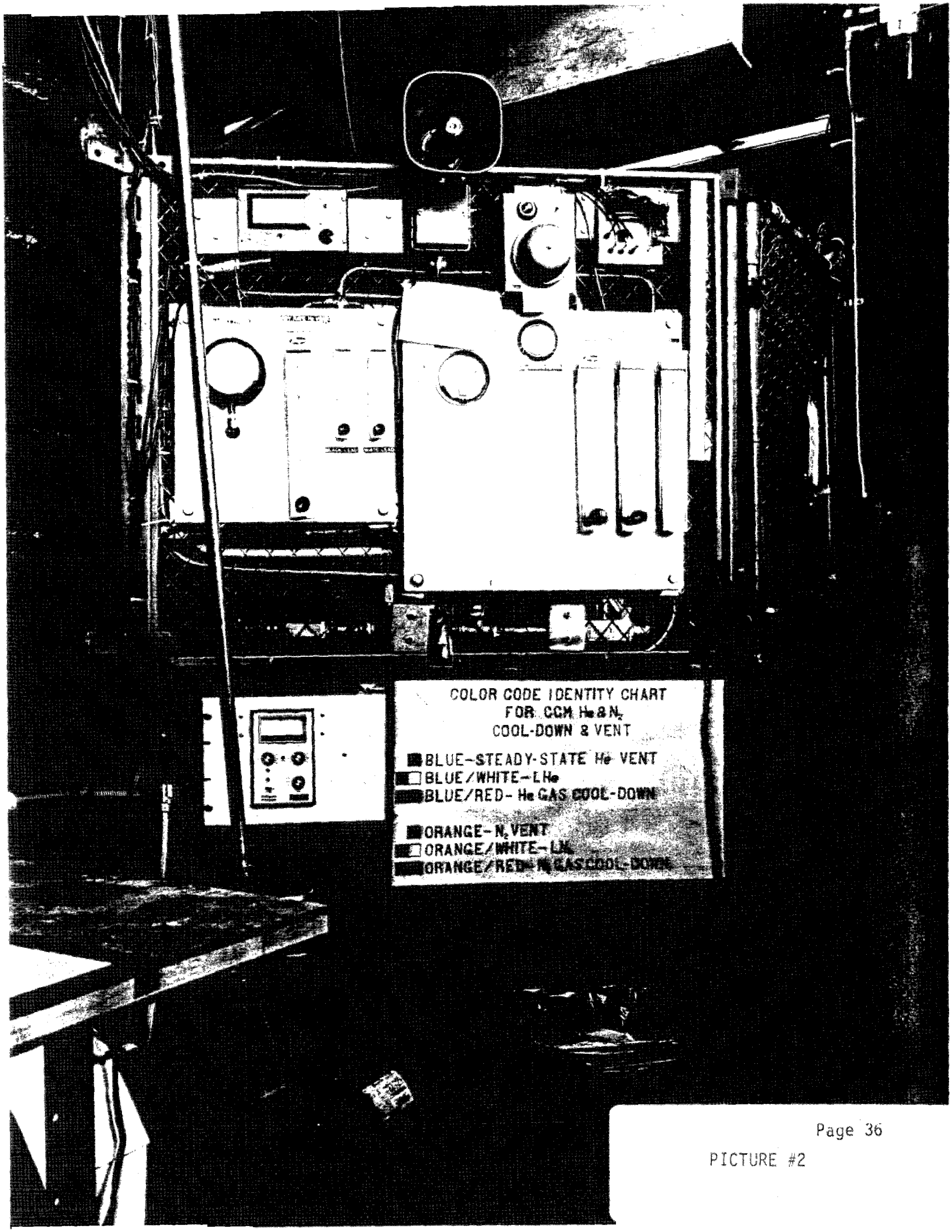
PICTURES

GRAPHS

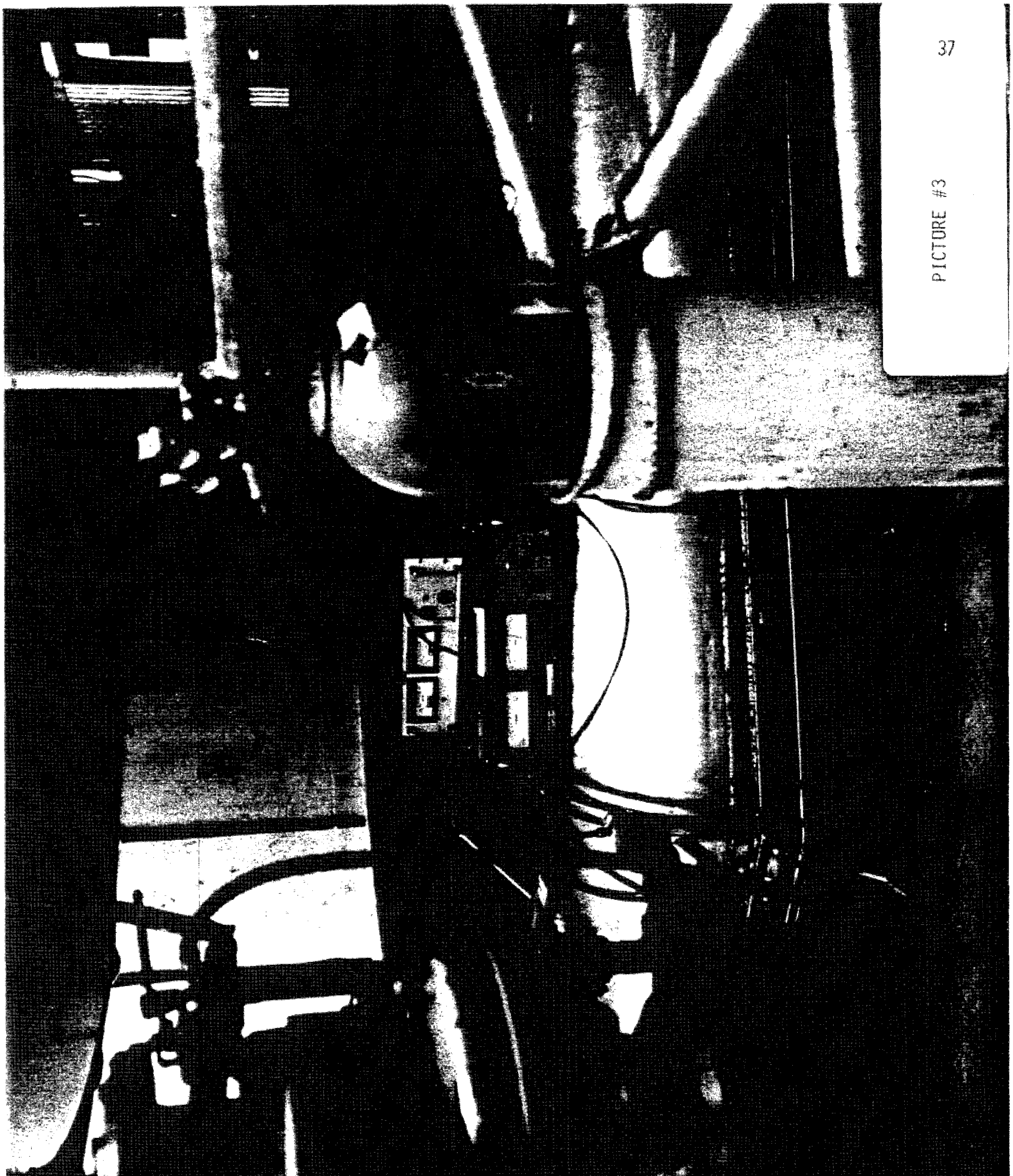
FIGURES



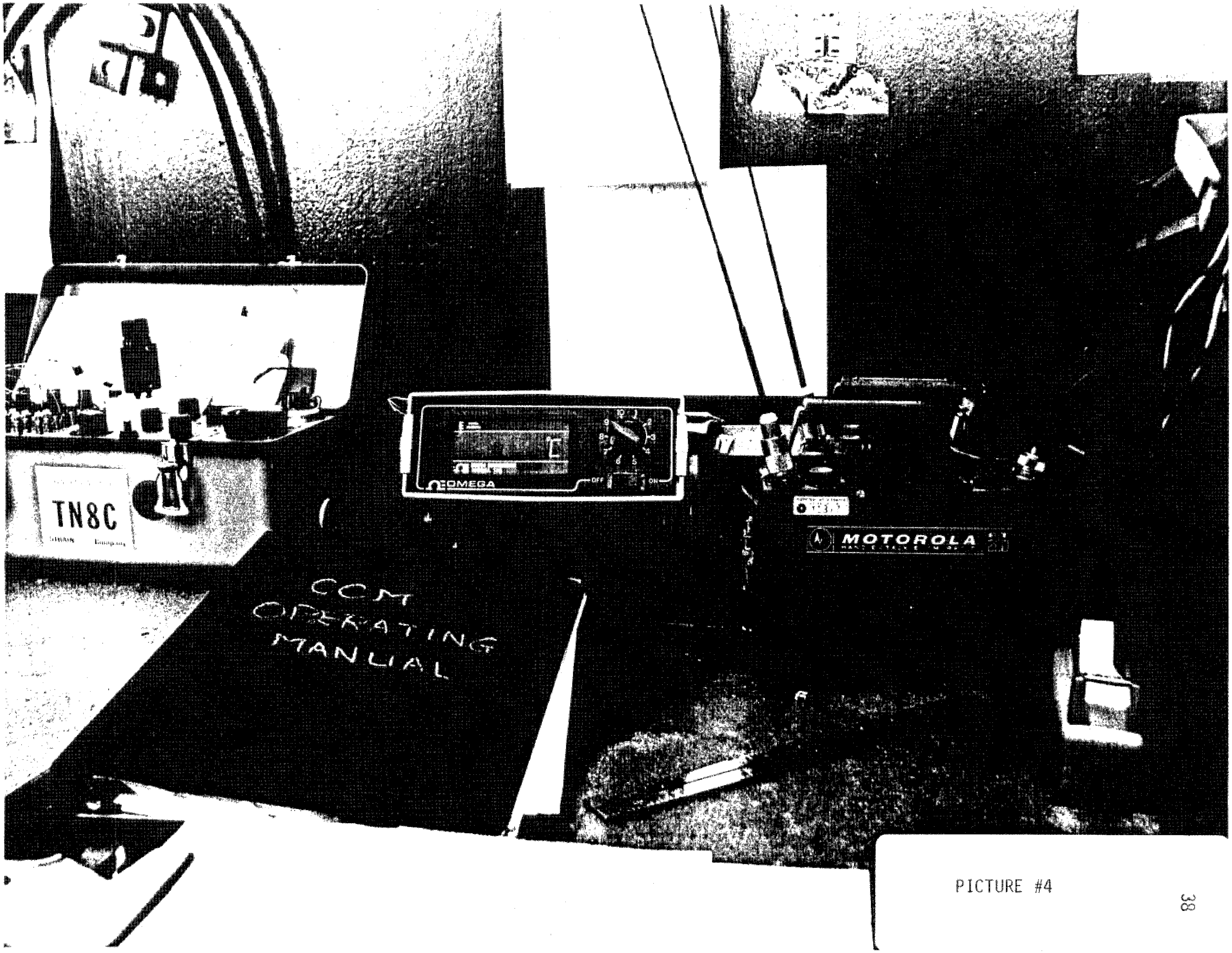
PICTURE #1


COLOR CODE IDENTITY CHART
FOR CCM He & N2
COOL-DOWN & VENT
BLUE-STEADY-STATE He VENT
BLUE/WHITE-LHe
BLUE/RED- He GAS COOL-DOWN
ORANGE-N2 VENT
ORANGE/WHITE-LN2

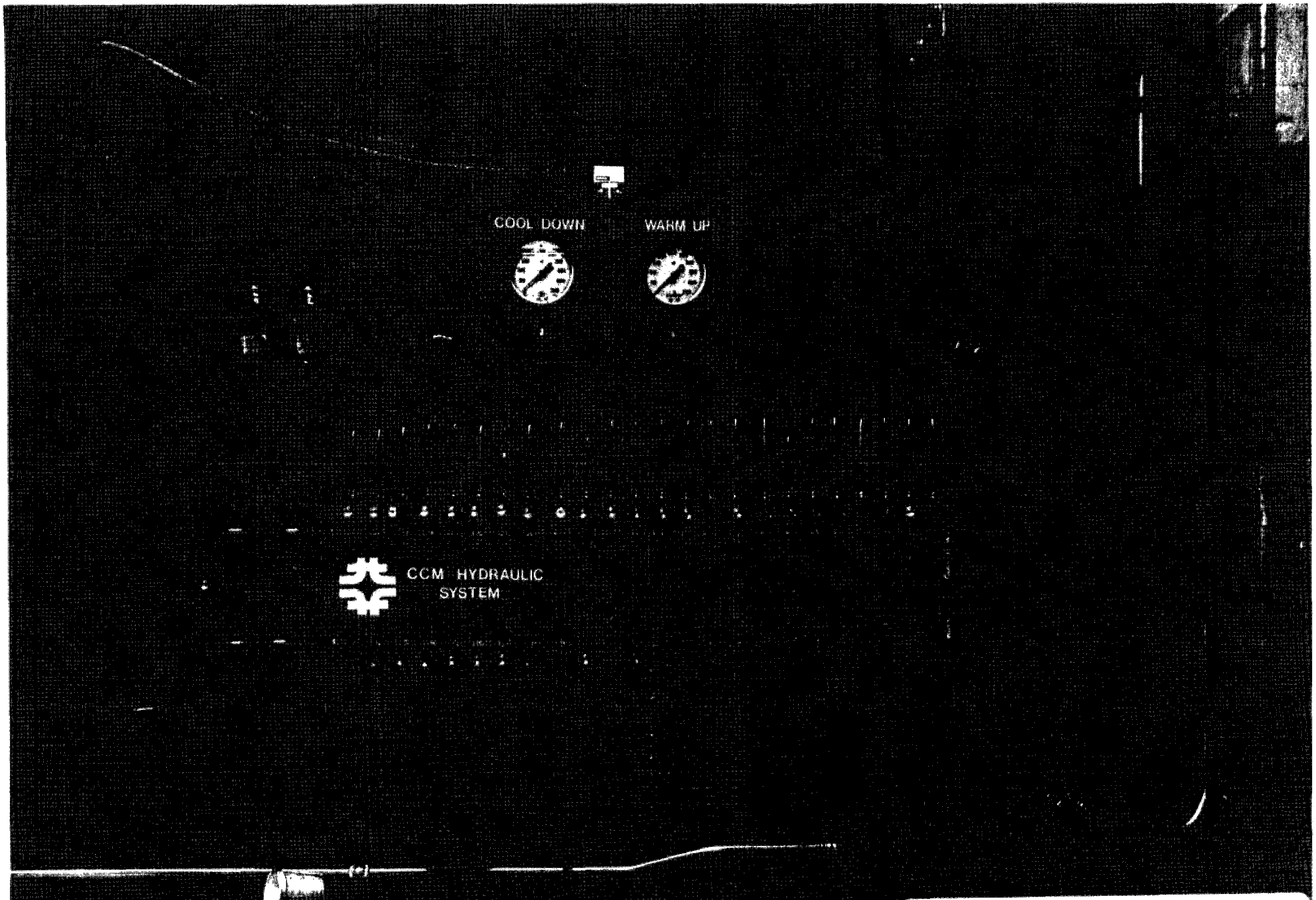
PICTURE #2



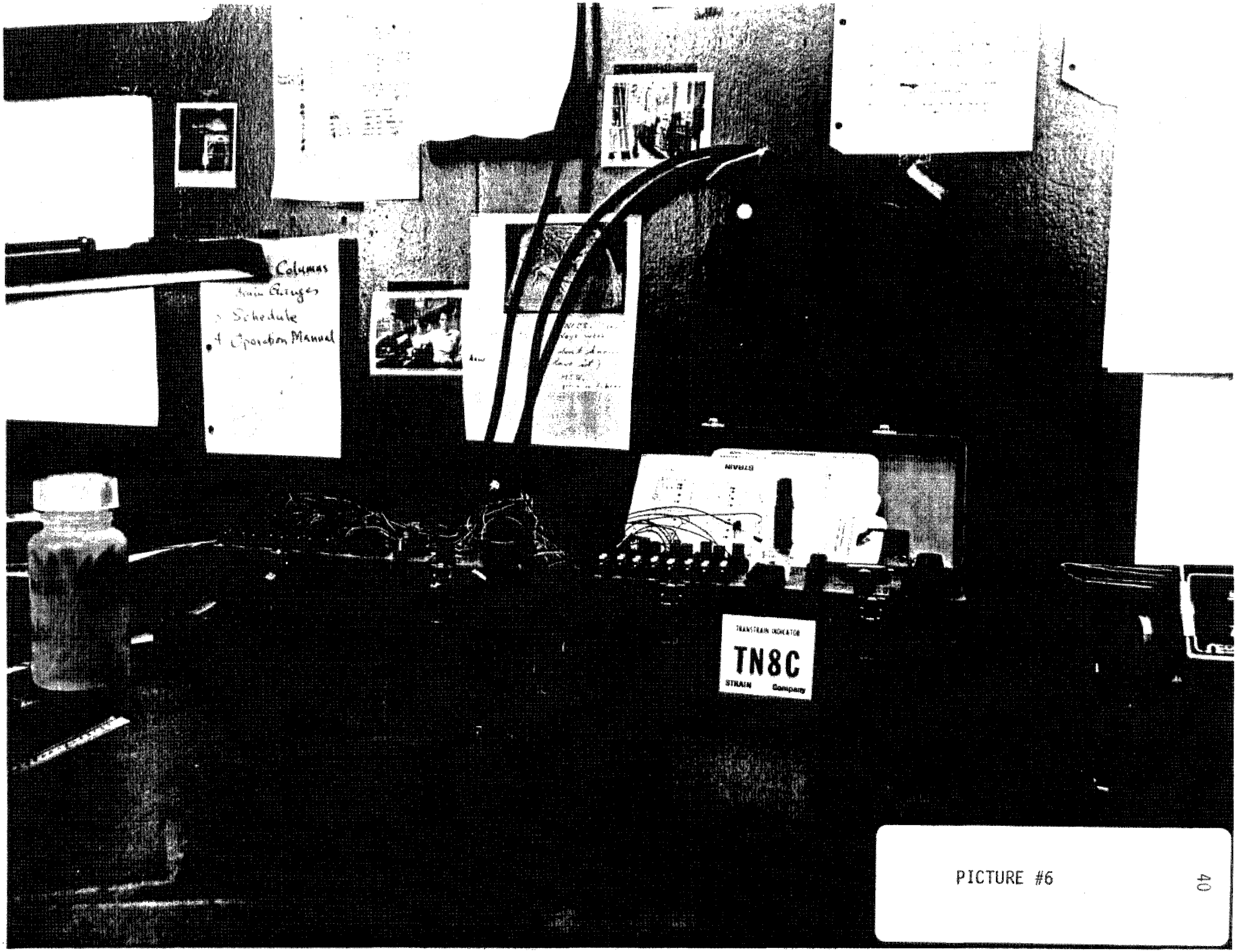
PICTURE #3



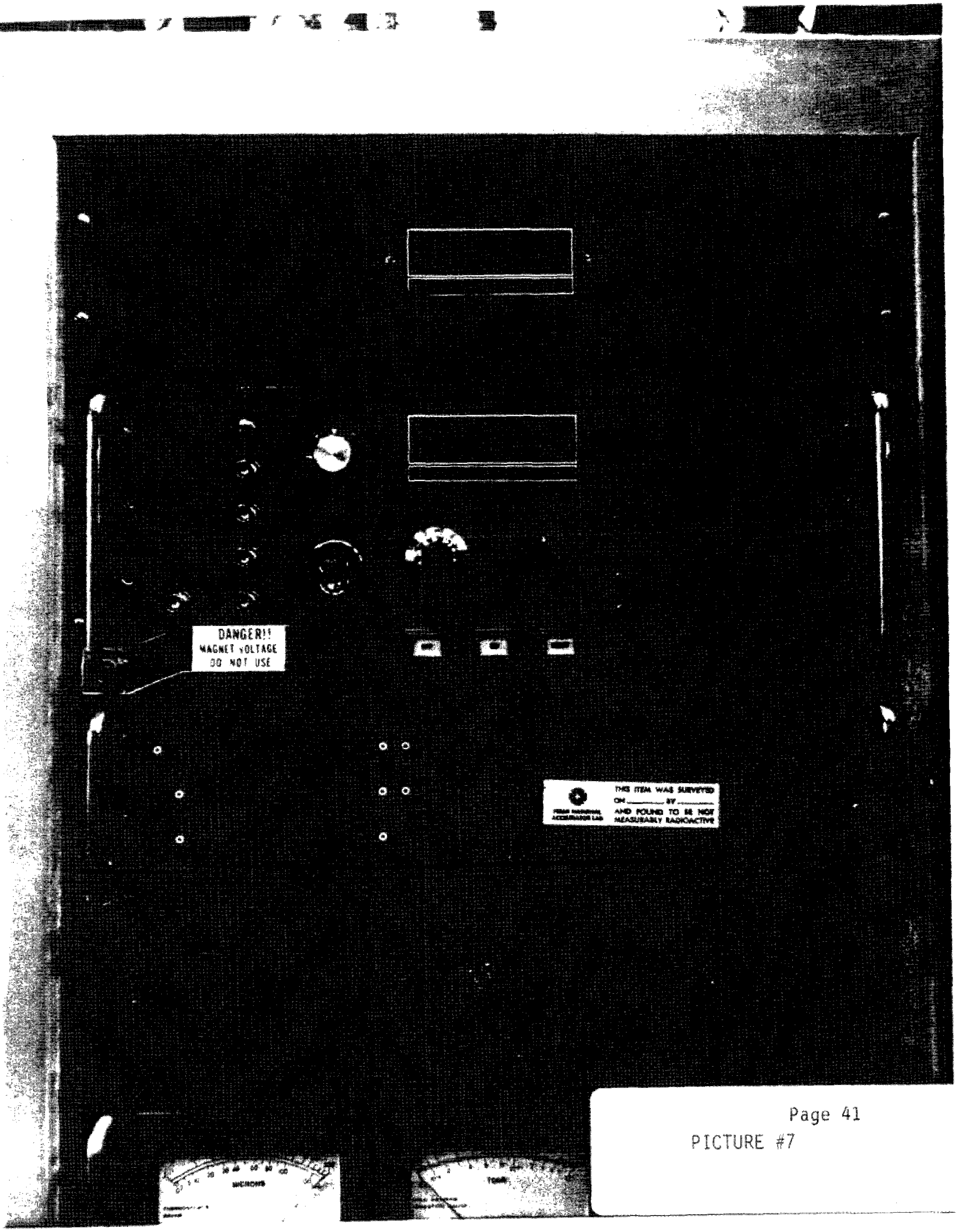
PICTURE #4



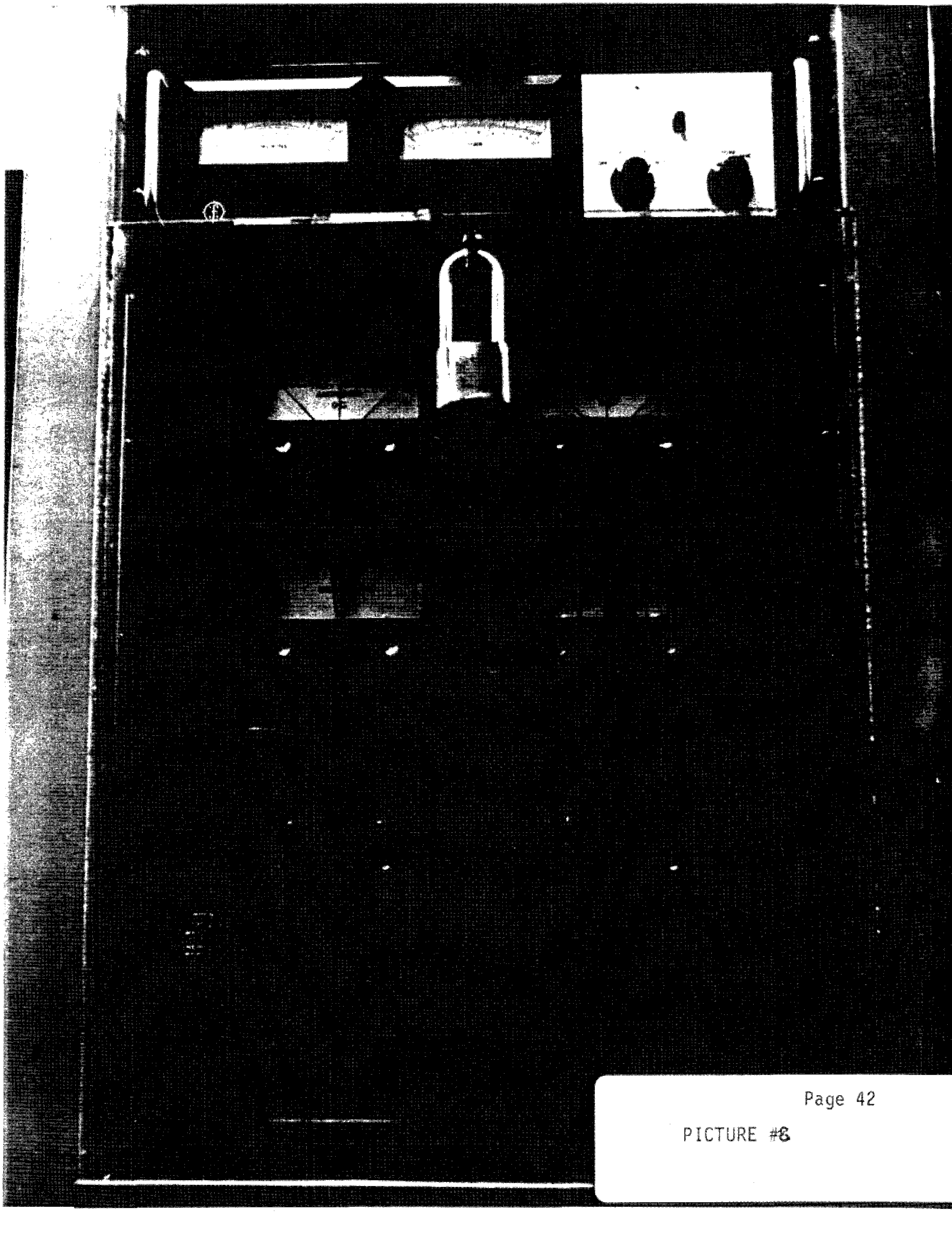
PICTURE # 5


Columns
Schedule
Operation Manual
TRANSTRAIN INDICATOR
TN8C
STRAIN Company

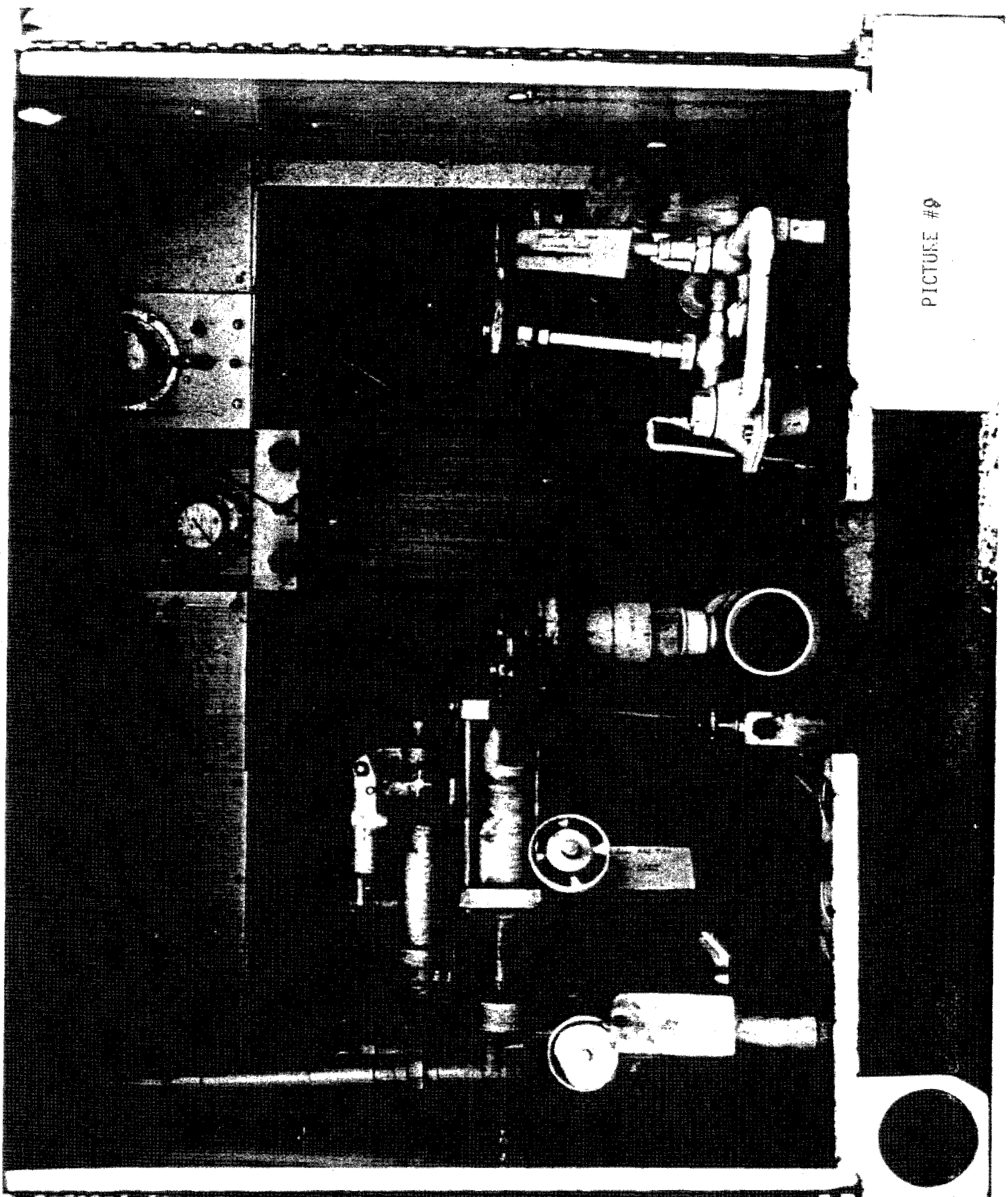
PICTURE #6


DANGER!!
MAGNET VOLTAGE
DO NOT USE
THIS ITEM WAS SURVEYED
ON ______ BY ______
AND FOUND TO BE NOT
MEASURABLY RADIOACTIVE

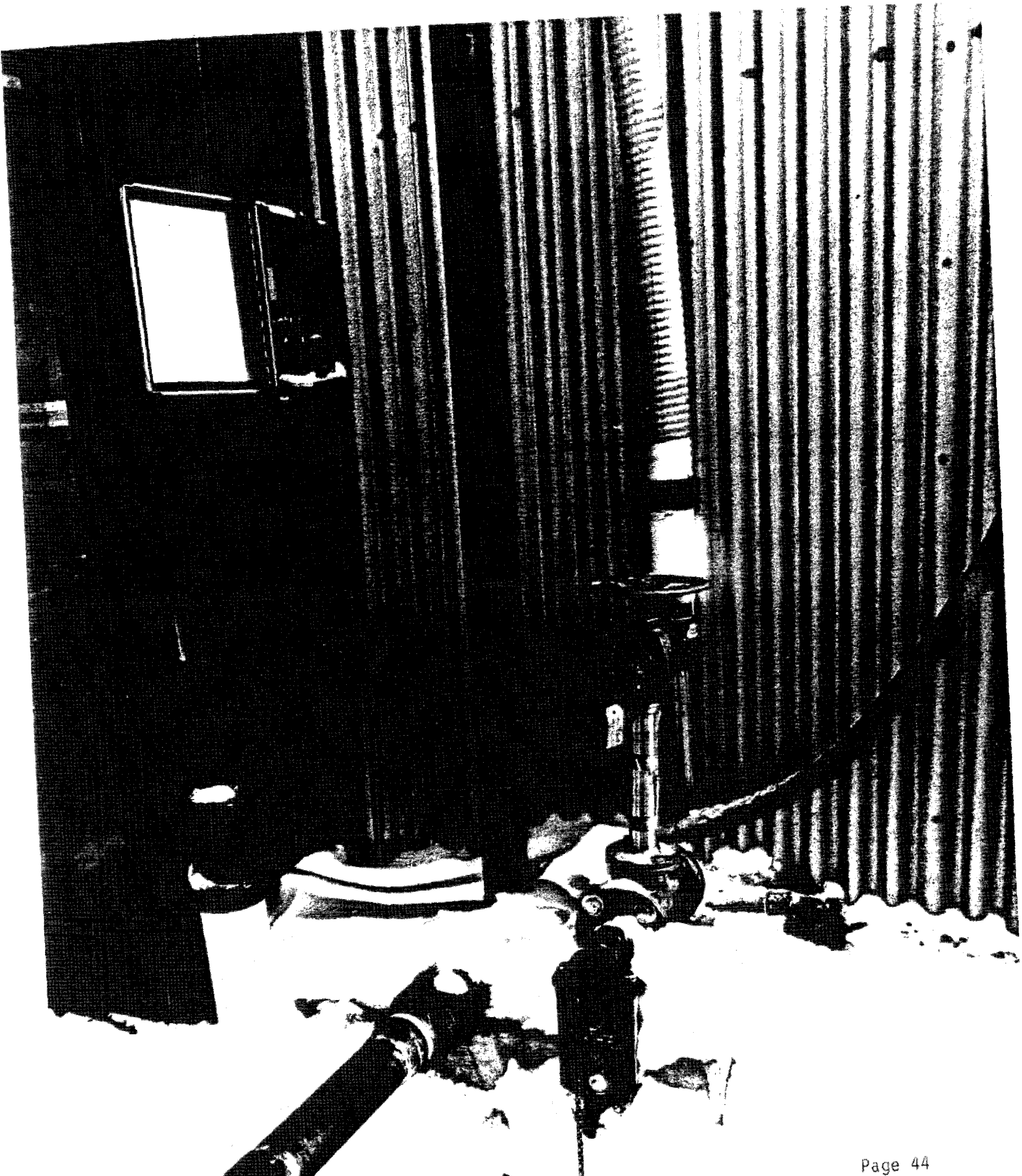
PICTURE #7



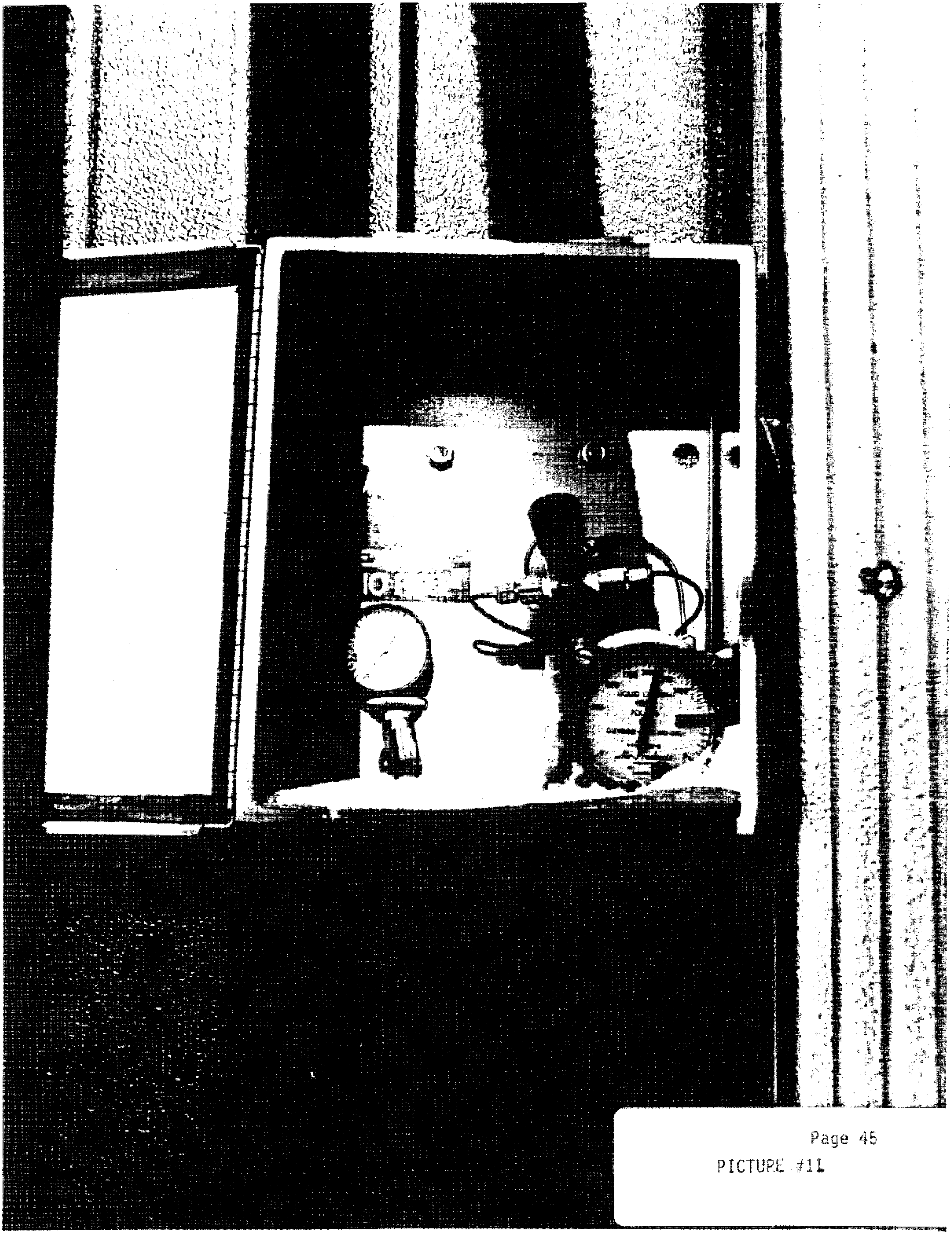
PICTURE #8



PICTURE #9



PICTURE #10



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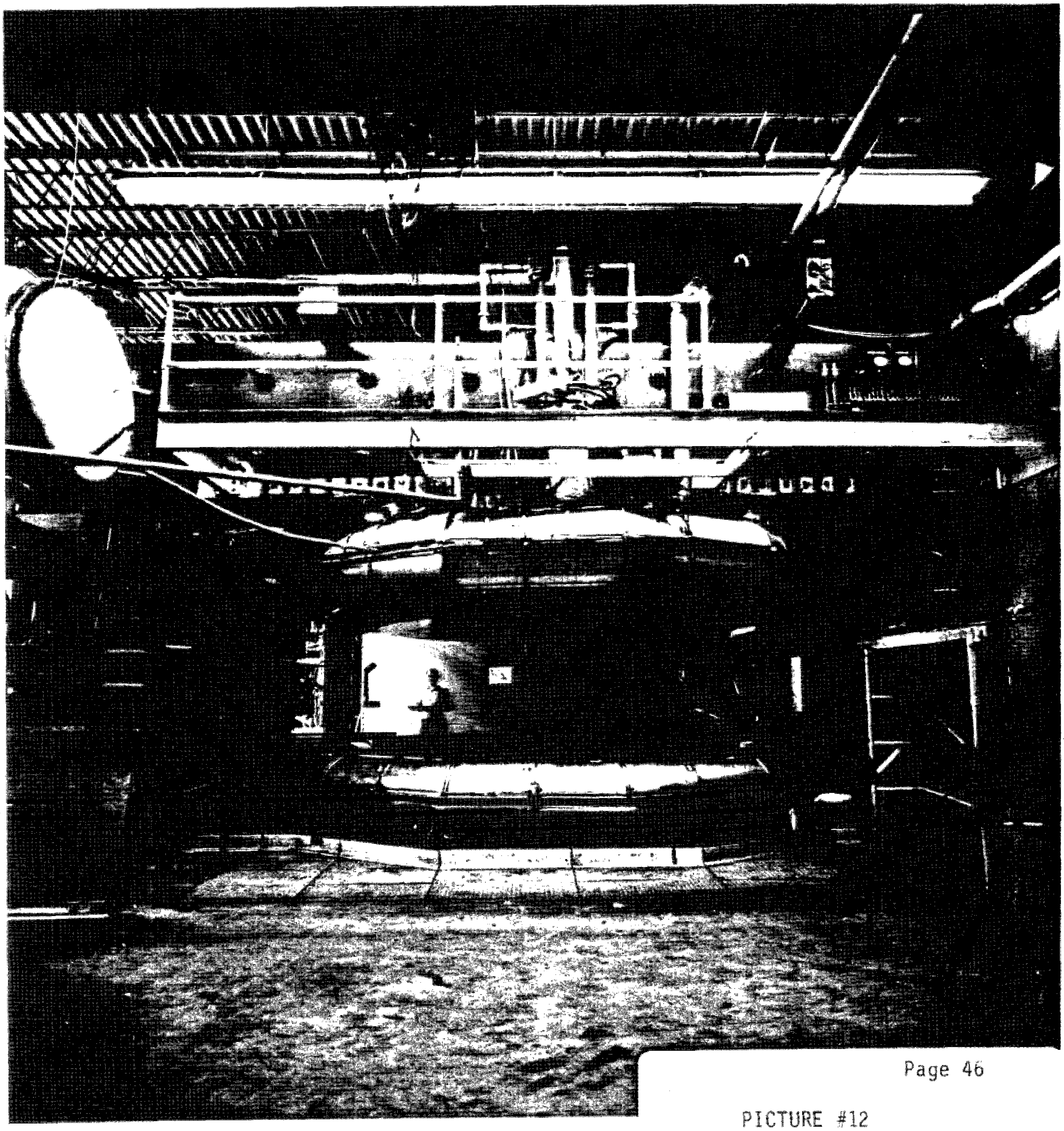
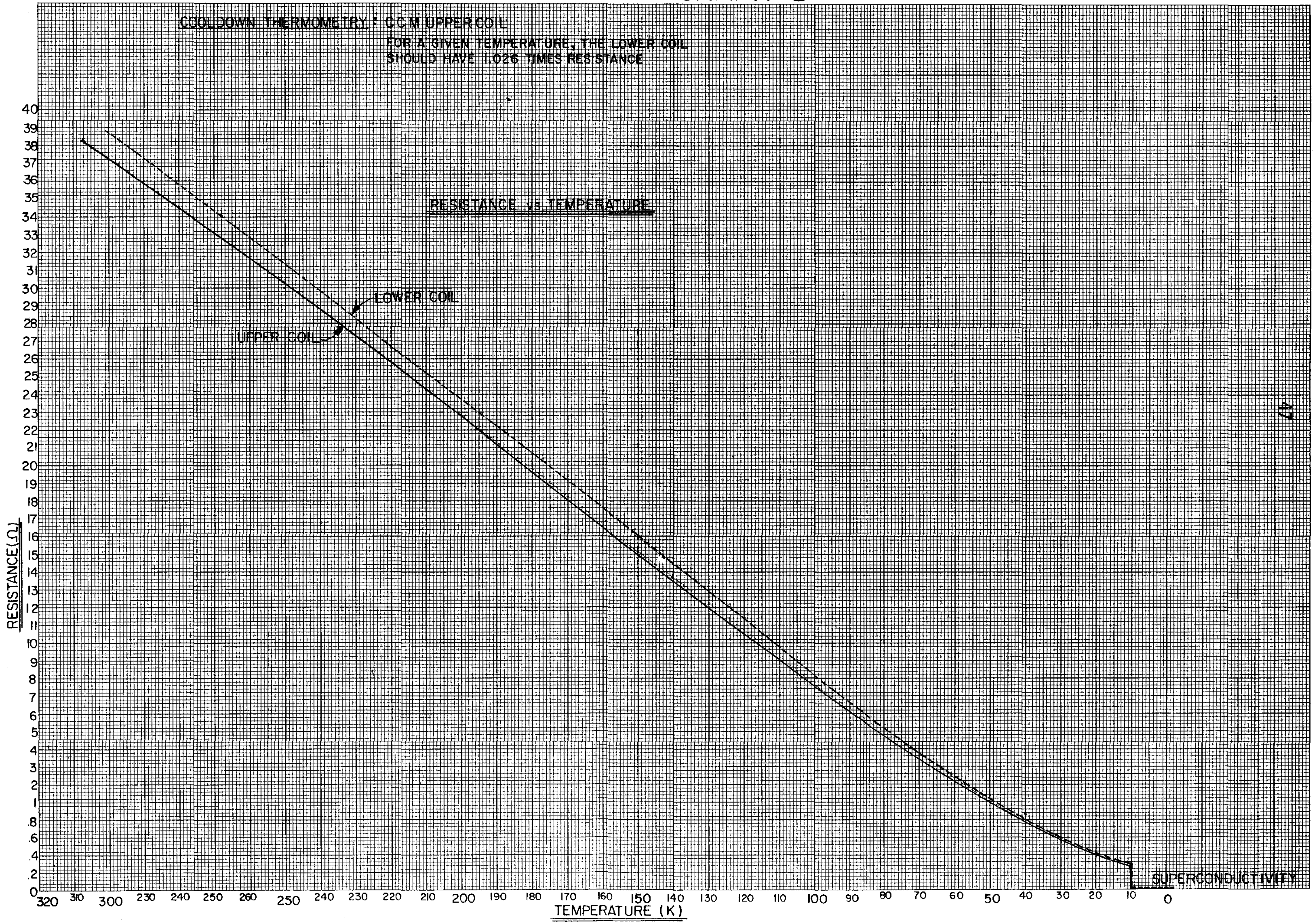
PICTURE #11

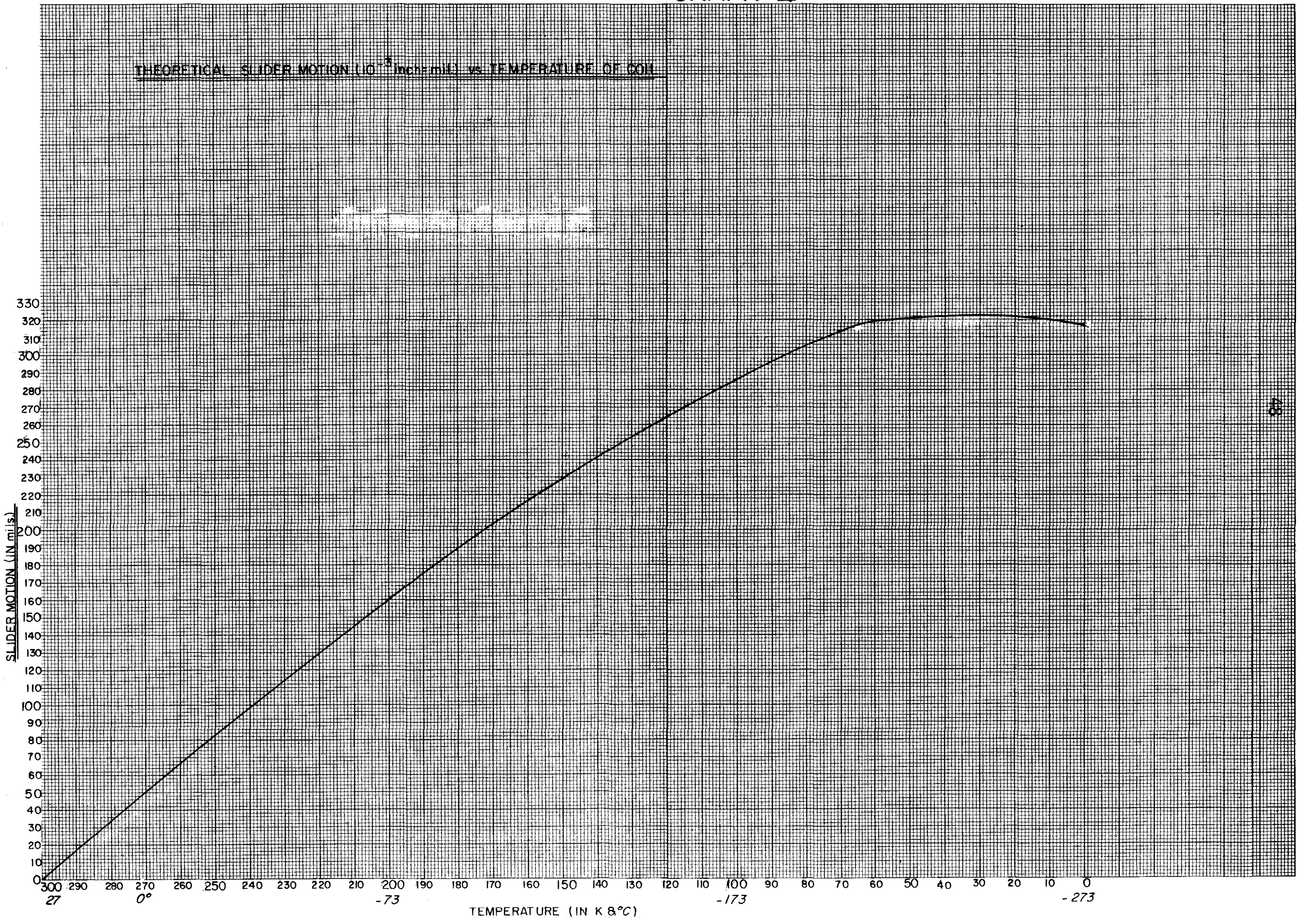


PICTURE #12

GRAPH - I

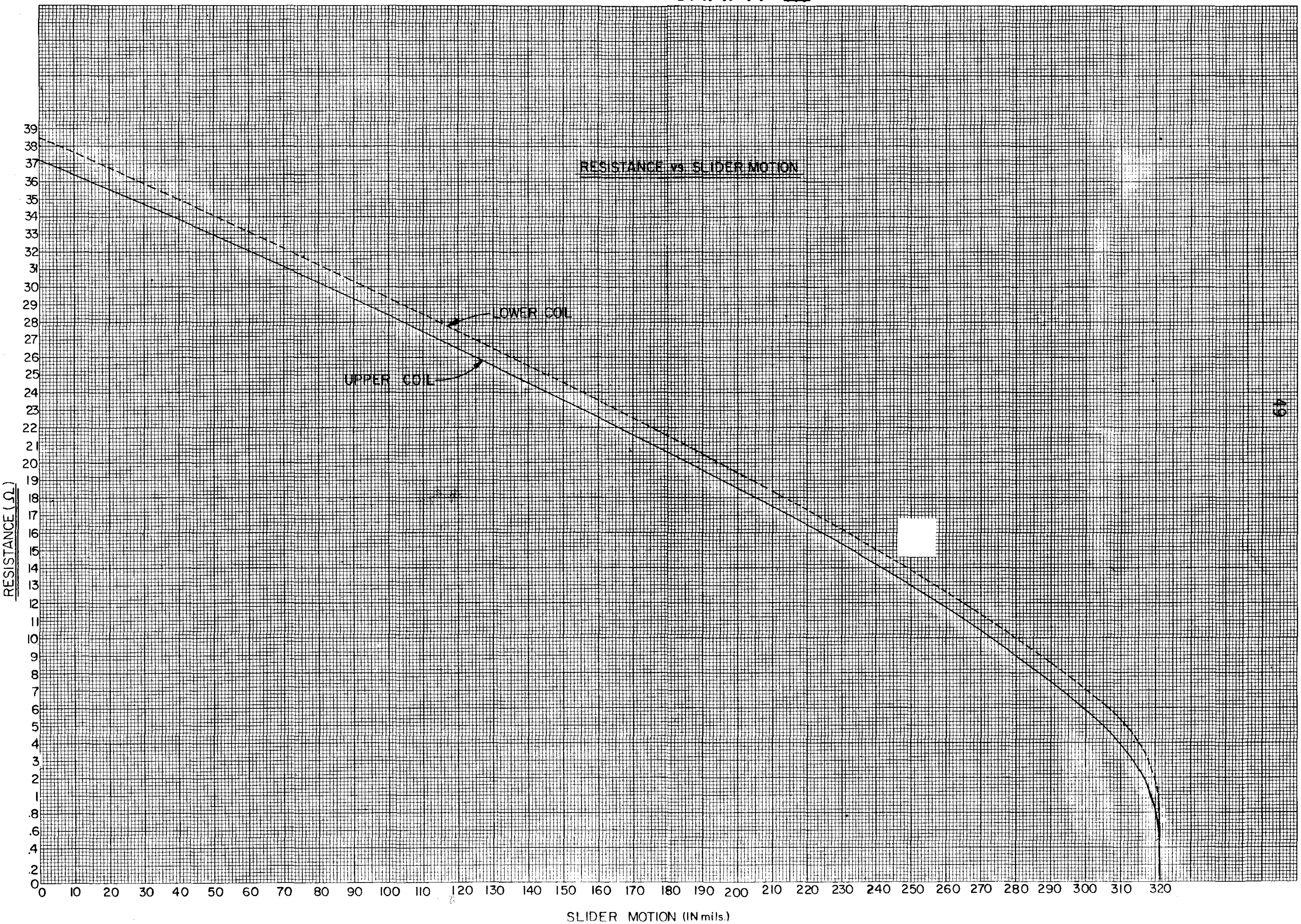

COOLDOWN THERMOMETRY : C C M UPPER COIL
FOR A GIVEN TEMPERATURE, THE LOWER COIL SHOULD HAVE 1.026 TIMES RESISTANCE
RESISTANCE vs TEMPERATURE
LOWER COIL
UPPER COIL
SUPERCONDUCTIVITY
RESISTANCE (Ω)
TEMPERATURE (K)

GRAPH - II



THEORETICAL SLIDER MOTION (10^{-3} inch = mil) vs. TEMPERATURE OF COIL
SLIDER MOTION (IN mils)
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
300 290 280 270 260 250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
27 0° -73 -173 -273
TEMPERATURE (IN K & °C)

GRAPH- III



RESISTANCE vs SLIDER MOTION
LOWER COIL
UPPER COIL
RESISTANCE (Ω)
0 .2 .4 .6 .8 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320
SLIDER MOTION (IN mils.)

GRAPH IV

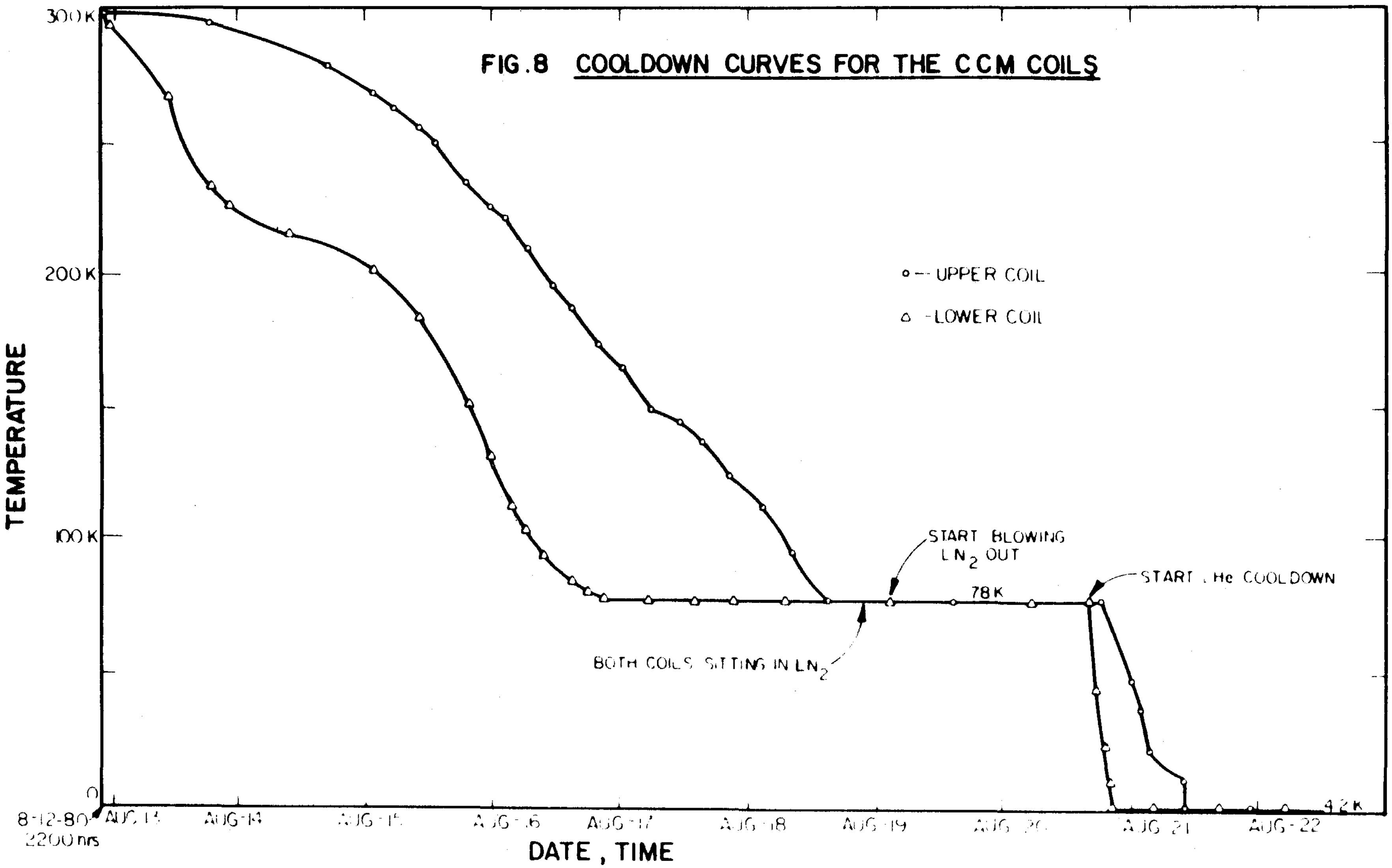


FIG. 8 COOLDOWN CURVES FOR THE CCM COILS

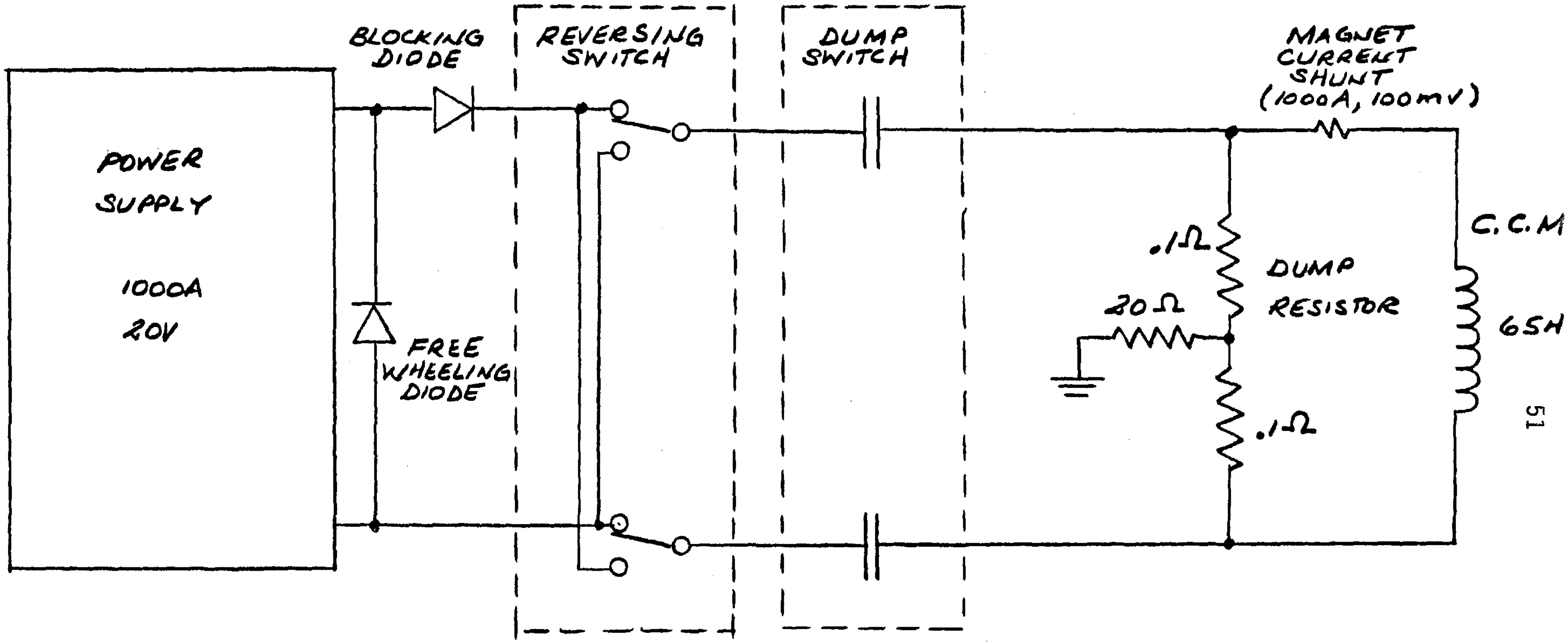


FIGURE 1 - SIMPLIFIED POWER SCHEMATIC