

INSTRUCTION MANUAL

FOR

EPITAXIAL APPARATUS

Contract No. NAS 5-3758 Procurement No. 670-W4678

Westinghouse G.O. A51248HE

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FOR
EPITAXIAL APPARATUS

Prepared By

WESTINGHOUSE ELECTRIC CORPORATION
DEFENSE AND SPACE CENTER
AEROSPACE DIVISION

For

NATIONAL AERONAUTICAL SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
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Introduction

The epitaxial growth of doped single crystal silicon layers on silicon substrates has become an important process in the fabrication of semiconductor devices. Furthermore, the techniques have developed to allow the growth of not only silicon of a variety of doping levels but also layers of many other materials may be formed by the action of heated substrates on gaseous mixtures. At present, the most useful of these other possibilities are the formation of silicon dioxide and polycrystalline silicon layers.

Since the processes are carried out sequentially in the same apparatus by changing the gas mixtures introduced, the operation becomes complex and simultaneous operation of valves by hand is impossible.

Therefore, a process has been developed which utilizes programmer operation of electronic valves for the etching and growth of single crystal silicon, deposition of silicon dioxide, silicon dioxide nucleation site treatment and undoped silicon growth.



Description of Apparatus

General:

Epitaxial deposition is accomplished by custom equipment composed of a gas control apparatus which controls the atmosphere of a reaction tube in which the epitaxial layers are deposited; an electronic programming device which operates the gas control apparatus valves through the desired cycles; and the reaction tube apparatus consisting of a quartz tube placed in an induction heating coil which heats the silicon substrates by means of a carbon susceptor. The reaction tube apparatus and gas control apparatus are in enclosures which permit air to be drawn through and exhausted through an exhaust system.

Gas Control Apparatus:

The proportioning of the different gases which make up the reaction tube atmosphere is accomplished by adjusting needle valves to obtain predetermined flow rates as measured by flow meters. These needle valves and flow meters are mounted on a panel with a graphic display describing the schematic hookups.

In Figure 1, the flow meters are shown in Line 3 and the needle valves are in Lines 2 and 4. The dopant concentration is controlled by further dilution of the doping gas (which is supplied as a 100 ppm dilution) in hydrogen in the following manner:

Diborane is proportioned through meter N-3 and mixed with hydrogen from meter O-3. A small portion of this mixture is passed through meter P-3 by adjustment of needle valves P-4 and P-2. This mixture is further



reduced by mixing with more hydrogen from meter Q-3. The final amount of dopant mixture is admitted to the main flow line through meter R-3 by adjustment of needle valves R-2 and R-4. Arsenic and phosphorus dilution is done similarly.

A constant amount of vapor for silicon growth is supplied by flowing hydrogen through meter E-3 and bubbling through a container of silicon tetrachloride immersed in a thermal bath of ice and water. This is admitted to the main gas stream with the hydrogen from flow meter F-3. This constitutes the greatest proportion of the reactor tube atmosphere and therefore uses hydrogen from the auxiliary hydrogen purifier reduced in pressure to 15 PSI by pressure reducing valve PVL.

The other gases are admitted directly to the main gas stream in the required amounts by the flow meters and corresponding needle valves.

See Appendix Chart 1 for meter type arrangement and Figure 5 for external gas hookup.

Electrical Control:

The gases are admitted to the reaction tube in the proper sequence by an electronic programmer. This is a rotary stepping relay which is pulsed to each cycle position by variable timers adjusted for the desired interval and by fixed interval timers for those cycles which use only one time setting. The sequence is illustrated as follows:



	<u>Time Interval</u>	<u>Cycle Description</u>
	Untimed	Idle Flow
	5 min	Start Cycle
	5 min	Warmup Cycle
T_1	Adjustable Time	Predeposition Etch
	15 sec	Purge
T_2	Adjustable Time	N-Type Silicon Deposition
	15 sec	Purge
T_3	Adjustable Time	P-Type Silicon Deposition
	15 sec	Purge
T_4	Adjustable Time	Silicon Dioxide Deposition
	15 sec	Purge
T_5	Adjustable Time	Bake or Undoped Silicon Deposition
	5 min	Cool Cycle
	5 min	Purge
		End Cycle
	Untimed	Idle
		Flow



For each cycle position, the programmer admits the proper gases by turning on normally closed 2-way valves for the required interval. However, the doping gases are turned on before they are required so the flow may reach equilibrium conditions and permit last minute adjustments if necessary. At the proper cycle, the programmer switches the 3-way valves to flow the doping gases from the exhaust to the main gas stream. See Chart 2.

The electrical schematic is shown in Figures 6 and 7.

Reaction Tube Apparatus:

Gas mixtures from the gas control panel are admitted to the reaction tube and the chemical reaction is induced by the heated silicon wafer surface. By RF induction heating of a quartz covered graphite susceptor, the wafers are brought to 1150°C, a temperature found adequate for all intended processes. See Figures 2 and 5.

Since the reaction depletes the gases as they pass over the silicon wafers, the susceptor is mounted on a sled which tilts the assembly. By spilling the used gases around the sides, a fresh gas mixture is insured for each wafer. Figure 2 illustrates the susceptor assembly.

Gases exhausted from the reaction tube are explosive, corrosive and poisonous and must be adequately disposed. Therefore, connection of the exhaust delivery tube from the reaction tube to an exhaust vent (4" or larger) with a strong flow of air will serve to dilute the gases below the hazardous level and assure that they are all carried from the building.

The enclosure surrounding the reaction tube must protect against the hazards of accidental release of the reaction gases, explosions which may scatter glass, and act to suppress RF fields from the induction coil. This may be accomplished with the enclosure shown in Figure 4.



Operation of Equipment

General:

This specification covers the process method which vapor etches the silicon surface, deposits a layer of doped silicon, deposits a layer of silicon dioxide, treats the oxide surface for adhesion purposes for subsequent processes, and regrows polycrystalline silicon.

Materials:

Silicon Tetrachloride	Anhydrous Hydrogen Chloride
Diborane	Carbon Dioxide
Phosphine	Trichloroethylene
Arsine	CP-3
Hydrogen	95% HNO_3 + 5% HF
Nitrogen	Ice

Equipment:

Optical Pyrometer
Epitaxial Growth Apparatus
Petri Dishes
Stainless Steel Tweezers
Lintless Paper
Cotton Balls



1. Preparation of Equipment

1.1 Silicon tetrachloride temperature bath preparation

1.1.1 Place crushed ice in dewar flask with silicon tetrachloride supply bottle.

1.1.2 Wait 1/2 hour for temperature to stabilize.

1.1.3 Add ice as ice melts. (About every 4 hours)

1.2 Gas Supply Monitoring

1.2.1 Check main tank pressure of :

Arsine in hydrogen

Phosphine in hydrogen

Diborane in hydrogen

Hydrogen chloride

Carbon dioxide

Hydrogen

1.2.2 Renew tanks before pressure drops below 150 psig.

1.2.3 Check that line pressure at gas control panel is 15 psig.

1.3 RF Generator Start-up

1.3.1 Turn on cooling water to RF generator.

1.3.2 Turn on filament power to RF generator.

1.4 Gas Control Panel Preparation

1.4.1 Turn on hand shut-off valves of gases that will be used during the day.

1.4.2 Actuate system purge toggle switch.



1.4.3 Set needle valves for flows shown in manual purge column in Chart 2.

1.4.4 Purge for minimum of 15 minutes.

1.5 Susceptor Preparation

1.5.1 Select a quartz envelope from storage.

1.5.2 Select a graphite susceptor from storage.

1.5.3 Select a quartz susceptor sled from storage.

1.5.3 Assemble per Figure 2.

1.6 Susceptor Cleaning

1.6.1 Remove assembly from sled.

1.6.2 Remove graphite susceptor from quartz envelope.

1.6.3 Place quartz envelope in CP-4 for 1/2 hour.

1.6.4 Clean sled periodically according to step 1.6.3 whenever a deposit is visually apparent.

1.6.5 Rinse quartz envelope in demineralized water at least 5 times.

1.6.6 Dry and store envelope and sled in storage cabinet.

1.7 Reactor Tube Cleaning

1.7.1 Several similar silicon deposition runs may be made before the reactor tube must be cleaned, otherwise, clean after each run.

1.7.2 Immerse reactor tube in 95% HNO_3 :5% HF for 30 minutes.

1.7.3 Rinse a minimum of 5 times in demineralized water.

1.7.4 Dry by draining in a vertical position.

1.7.5 Allow to dry for four hours before using.



2. Apparatus Set-Up

2.1 Information necessary for run set-up.

2.1.1 Etch time (silicon removal is approximately 0.9 μ per minute of etch time)

2.1.2 Thickness of deposited layer

2.1.3 Bulk resistivity deposited layer

2.1.4 Dopant to be used

2.1.5 Oxide layer thickness

2.1.6 Undoped silicon layer thickness

2.2 Determine silicon deposition time from step 2.1.2 and Graph 1.

2.3 Determine oxide deposition time from step 2.1.5 and Graph 2.

2.4 Determine polycrystalline deposition time from step 2.1.6 and Graph 1.

2.5 Determine dopant concentration of reactor tube atmosphere from step 2.1.3 and 2.1.4 and Graph 3.

2.6 Determine dopant dilution flow meter settings from concentrations from step 2.5 and Graph 4. For greatest accuracy, the glass floats of the meters should be kept between 6 cm and 12 cm. See Example in Appendix 1.

2.7 Time Set-up

2.7.1 Set etch timer for interval determined in step 2.1.1.

2.7.2 Set silicon deposition timer for interval determined in step 2.2.



2.7.2.1 If one dopant gas only is used, set other timer to zero minutes.

2.7.2.2 If N and P type gases are used in sequence to obtain two layers, set sequence selector toggle switch to the "N-P" or "P-N" position. Note: By nature, this toggle switch has a center-off position. This position is never to be used.

2.7.2.3 If N on N layers are to be deposited, set the N-type timer for the total time to obtain the combined thickness and manually change meter settings after the proper portion of time has elapsed for the differing layer concentrations (N on N+ for instance). Should the N-type dopant gases be different (phosphorous on arsenic doped silicon, for instance) switch N-type dopant selector toggle switch after the appropriate time has passed and change meter settings if necessary.

2.7.3 Set oxide deposition timer for time in step 2.3.

2.7.4 Set undoped silicon deposition timer for time determined in step 2.4.

2.8 Electric Panel Toggle Switch Set-up.

2.8.1 Purge gas selector switches.

2.8.1.1 For runs not using silicon dioxide deposition cycle, all purge switches should be set to H_2 .

2.8.1.2 For runs using silicon dioxide for a final step, set oxide purge to N_2 , set bake/Si dep. timer to 5 min., set bake/Si dep. toggle selector switch to



bake position, set purge toggle to N_2 and set cool purge toggle switch to N_2 .

2.8.1.3 For runs using silicon dioxide followed by undoped silicon, set oxide purge gas selector switch to N_2 , set bake/Si dep. selector toggle switch to Si-Dep. position (the corresponding purge selector switch is now out of circuit), set bake/Si dep timer to desired time setting and set cool cycle purge gas selector switch to H_2 position.

2.8.2 All "Auto-Manual" toggle switches must be in "Auto" position for automatic operation.

2.8.3 The "Buzzer-Off" switch connects an audible signal to the End Cycle indicator lite when in the "Buzzer" position. However, the "end-cycle" position of the system flows nitrogen over the cold wafers and therefore the wafers need not be removed immediately. In this case, the audible signal may be turned to the "off" position.

2.8.4 The "ON-OFF" toggle switch starts the automatic cycle. Manual operation can be performed only when this switch is in the "OFF" position.

2.8.5 The "SCRAM"-Normal" switch may be used to abort any run, either manual or automatic. This switch turns off all gases except the high flow nitrogen and the main three-way valve continues to flow this nitrogen to the reactor tube. While this switch is actuated, the other electric panel switches may be returned to either "off" or "normal" positions.



- 2.8.6 The "Auto-Manual" switch actuates the main three-way valve for automatic or manual operation.
- 2.8.7 The N-type Dopant switch may select either arsine or phosphine for use as the dopant gas.
- 2.8.8 The N-type Dopant "IN-OUT" switch disconnects the doping gases from operation.
- 2.8.9 The P-type Dopant "IN-OUT" switch operates per step 2.8.8.
- 2.8.10 For 2-layer depositions of different dopant types, the "N-P" or "P-N" positions gives the desired sequence. See step 2.7.23.
- 2.8.11 "System Purge" switch actuates the hydrogen solenoid valves and purges through the silicon tetrachloride bottle. Also, the doping gas and the hydrogen chloride valves are operated to flow gases out the main 3-way valve to the exhaust.

2.9 Flow Meter Set-up

- 2.9.1 Setting of gas flows must be done under operating conditions with the gases at equilibrium. Once this is done, the same gas flows will repeat as long as line pressure remains the same. Therefore, similar runs may be repeated. For runs requiring different atmosphere concentrations, the meters must be pre-set before the silicon is loaded in the reactor tube as follows:
 - 2.9.2 Connect the reactor tube to the delivery tube from the gas panel.
 - 2.9.3 Connect the reactor tube to the exhaust line.
 - 2.9.4 Place "Auto-Manual" switch (beside SCRAM switch) in manual position.



- 2.9.5 Actuate Etch "Auto-Manual" switch to obtain manual operation.
- 2.9.6 When Hydrogen Chloride flow meter B-3 reading has stopped, changing indicating equilibrium conditions, set needle valve B-4 to set the glass ball at 11 cm.
- 2.9.7 Set Hydrogen meter E-3 glass ball to read 9 cm.
- 2.9.8 Set Hydrogen meter F-3 glass ball to read 6 cm.
- 2.9.9 Actuate N-Dep "Auto-Manual" switch to obtain manual operation. Then return Etch "Auto-Manual" switch to Auto position.
- 2.9.10 After equilibrium conditions have been reached, set flow meters H or I, K and M-3 to setting determined in step 2.6. Similarly set meters J and L-3 Needle valves J-2, L-2 should be closed only enough to obtain sufficient back pressure to supply the required flow through the next flow meters.
- 2.9.11 Actuate P-Dep "Auto-Manual" switch to obtain manual operation. Then return N-dep "Auto-Manual" switch to its "Auto" position.
- 2.9.12 Set flow meters N, P, and R and O and Q similar to step 2.9.10.
- 2.9.13 If an oxide run is to be made, operate the "Auto-Manual" switch to obtain manual oxide cycle operation and adjust the carbon dioxide flow to obtain a C-3 meter glass ball setting of 15 cm. See step 2.9.6.



3. Run Operation

- 3.1 Set up equipment per steps in Section 1.
- 3.2 Set up apparatus per steps in Section 2.
- 3.3 Load susceptor assembly
 - 3.3.1 Assemble susceptor parts. See Figure 3.
 - 3.3.2 Place cleaned wafers on the top center line of the quartz envelope. See Figure 3.
- 3.4 Load reactor tube
 - 3.4.1 Place the loaded susceptor assembly in the reactor tube.
 - 3.4.2 Position at the mid-point of the RF induction heating coil.
 - 3.4.3 Replace end-cap.
 - 3.4.4 Place the exhaust delivery tube in the exhaust port.
- 3.5 Place "ON-OFF" switch on "ON" position.
- 3.6 Monitoring of run (Automatic cycle)
 - 3.6.1 Start Cycle in 5 min. of high flow nitrogen. For flow rates see Chart 2. Main 3-way valve actuates flow to reactor tube.
 - 3.6.2 Warm-up Cycle 5 min. High nitrogen off. High hydrogen on, SiCl_4 by-pass, and RF generator plate on (power to induction coil).
 - 3.6.3 Monitor temperature. Adjust power if necessary to maintain 1150°C .
 - 3.6.4 Etch Cycle - Timer T_1 (Figure 3) Hydrogen on, hydrogen chloride on, doping gases on but 3-way valves flowing to exhaust.
 - 3.6.5 Etch Cycle Purge - hydrogen on, hydrogen chloride off.



- 3.6.6 N-type Deposition Cycle - Timer T_2 , hydrogen on, SiCl_4 flow to tube, N-type doping gases on, N-type dilution stage 3-way valve directed to tube, P-type dilution stage on but 3-way valve flow to exhaust.
- 3.6.7 N-type Deposition Purge Cycle - hydrogen on
- 3.6.8 P-type Deposition Cycle - Timer T_3 , hydrogen on, SiCl_4 flow to tube, P-type doping gases on, P-type dilution stage 3-way valve directed to tube.
- 3.6.9 P-type Deposition Purge Cycle - hydrogen on
- 3.6.10 Oxide Deposition Cycle - Timer T_4 , hydrogen on, SiCl_4 flow to tube, carbon dioxide on.
- 3.6.11 Oxide Deposition Purge Cycle - nitrogen on.
- 3.6.12 Oxide Bake Cycle - Timer T_5 nitrogen on.
- 3.6.13 Undoped Silicon Deposition Cycle (may be used instead of step 3.6.12) timer T_5 , hydrogen on SiCl_4 flow to tube.
- 3.6.14 Cool Cycle - 5 min., hydrogen or nitrogen, RF generator plate circuit off.
- 3.6.15 Purge Cycle - 5 min., nitrogen
- 3.6.16 End Cycle - untime, high flow nitrogen
- 3.7 Return "ON-OFF" switch to "OFF" position.
- 3.8 Unload susceptor assembly from reactor tube.



4. Maintenance of Apparatus

4.1 Stainless steel solenoid valves

4.1.1 Since stainless steel may in time be attacked and corroded both outside and inside the valve, periodic disassembly and acid cleaning may be necessary.

4.1.2 When valves are reassembled, if evidence of leakage is apparent, or annoying solenoid buzz is present, lubricate the plunger with a fluorinated hydrocarbon grease such as "Kel-F" or "Fluorolube".

4.2 Teflon and nylon solenoid valves are assembled and seated at the factory, therefore they should be returned to the factory for any repairs that may become necessary.

4.3 Hand shut-off valves should have periodic leak checks made with a soap solution to insure that the teflon packing is not leaking. Tighten the packing nut until leakage stops.

4.4 Flow meters are of stainless steel construction and the same consideration should be given as in line 4.1.

4.5 The flow meter needle valves depend on "O" rings for sealing purposes. Should these develop leaks, they should be replaced with Viton-A "O" rings of the same size. Lubrication should be with "Kel-F" or similar fluorinated hydrocarbon grease.

4.6 Auxiliary needle valves are constructed of stainless steel with Viton-"A" "O" rings. Maintenance as in 4.5



APPENDIX 1

Parts List

Tube Fittings - Hand valves, stainless steel, brass and polyethelene

Swagelok fittings and Whitey valves

Pihert Valve and Fitting Company

6612 Jefferson Davis Highway

Richmond 34, Virginia

Pressure Reducing Valve - Model No. 39 line regulator

Matheson Company

P.O. Box 85

East Rutherford, New Jersey

Ashcroft Pressure Gages - Model 1000B, 2 $\frac{1}{2}$ " dial $\frac{1}{4}$ " NPT Block connection

0 - 30# range, Flush Mount

M. S. Jacobs and Associate, Incorporated

810 Noblestown Road

Pittsburgh 5, Pa.

Teflon and Nylon diaphragm valves - Valcor Engineering Corporation

365 Carnegie Ave

Kenilworth, New Jersey

Stainless Steel Solenoid Valves - 3 way operation

Automatic Switch Company

Florham Park, New Jersey



Bristol Reset Timer - Series 21

Bristol Motors

Old Saybrook, Connecticut

Atcotrol Dial Timers - Automatic Timing and Controls

King of Prussia, Pa.

Flow Meters and Parts - Brooks Instrument Division

Emerson Electric Company

Hatfield, Pa.

Rotary Stepping Relay - Automatic Electric

Shirley Highway and Edsoll Road

Springfield, Virginia

Gases: Phosphine in Hydrogen - 100 PPM, "A" cylinder, CGA 350

Arsine in Hydrogen - 100 PPM, "A" cylinder, CGA 350

Diborane in Hydrogen - 100 PPM, "A" cylinder, CGA 350

Regulators for above: Model 19-350 Diffusion Resistant metal

diaphragm regulator, with $\frac{1}{4}$ " Tylok Fitting.

Carbon Dioxide, Coleman Instrument Grade - No. 2 cylinder, CGA No. 320

Regulator for CO₂: Model 19-320 Diffusion Resistant metal diaphragm

regulator, with $\frac{1}{4}$ " Tylok Fitting

Silane, Semiconductor grade, No. 3 cyl, CGA 510

Regulator for silane: Model 195-510 Special for doping gas

Regulator for Hydrogen Chloride: Model B15A-330 Corrosion Resistant

Regulator

All above from: Matheson Company, Incorporated

P.O. Box 85

East Rutherford, New Jersey 07073



Hydrogen Chloride, Anhydrous, for semiconductor use from
Frontier Chemical Company
600 Doremus Ave.
Newark 5, New Jersey

Silicon Tetrachloride - Gallon containers - Electronic grade
Anderson Chemical Division
Stauffer Chemical Company
380 Madison Avenue
New York, New York

Graphic Susceptors - Rectangular graphite bars for induction heating purposes.
1 5/8" wide ($\pm 1/8"$) x 1/4" high ($\pm 1/16"$) x 9" long
Ultra Carbon Corporation
P.O. Box 747
Bay City, Michigan 48709



APPENDIX 2

Example: An arsenic doped epitaxial silicon layer 21μ thick and 1Ω cm bulk resistivity.

1. Etch time usually 15 minutes by experience.
2. Deposition time from Graph 1 is 22 minutes.
3. Oxide time is 0 minute.
4. Undoped silicon deposition time is 0 minute.
5. Atmosphere dopant concentration is determined to be 3×10^{-4} ppm Graph 3.
6. From Graph 4, 3×10^{-4} ppm indicates that 5 cm for the glass float of the hydrogen meters J and L and 4.8 cm for the glass floats of the dopant and mixture meters I, K and M.
7. Set etch cycle timer for 15 minutes.
8. Set N-type silicon deposition cycle timer for 22 minutes.
9. Set P-type silicon deposition cycle timer for 0 minutes.
10. Set oxide deposition timer for 0 minutes.
11. Set undoped silicon deposition timer for 0 minutes.

Meter Arrangement:

<u>Location</u>	<u>Brooks Instrument Number</u>	<u>Gas Metered</u>
A-3	R-2-15-B	Idle Nitrogen (Air Curves)
B-3	R-2-15-D	Hydrogen Chloride
C-3	R-2-15-D	Carbon Dioxide
D-3	Not Used	Silane
E-3	R-2-15-B	Hydrogen
F-3	R-6-15-A	Hydrogen
G-3	Any tube suitable	Hydrogen
H-3	R-2-15-AAA	Arsine in Hydrogen
I-3	R-2-15-AAA	Phosphine in Hydrogen
J-3	R-2-15-D	Hydrogen
R-3	R-2-15-AAA	Arsine/Phosphine in Hydrogen
L-3	R-2-15-D	Hydrogen
M-3	R-2-15-AAA	Arsine/Phosphine in Hydrogen
N-3	R-2-15-AAA	Diborane in Hydrogen
O-3	R-2-15-D	Hydrogen
P-3	R-2-15-AAA	Diborane in Hydrogen
Q-3	R-2-15-D	Hydrogen
R-3	R-2-15-AAA	Diborane in Hydrogen
S-3	R-6-15-A	Nitrogen

Chart 1

Gas	Solenoid Valve	Flow Meter	Flow Rate	Meter Setting		Automatic Cycle																
				Float	cm	Idle	Start	Warmup	Etch	Purge	N-Dep	Purge	P-Dep	Purge	Oxide	Purge	Bake/ St Dep	Cool	Purge	End	Scram	
Low N ₂	A-5(N.D.)	A-3	1000 cc/min	Glass	5	x																
HCl	B-5	B-3	205 cc/min	Glass	11				x													
CO ₂	C-5	C-3	315 cc/min	Glass	15																	
SiH ₄		D-3																				
H ₂ to SiCl ₄	E-5	E-3	6000 cc/min	Glass	9			x	x	x	x	x	x	x	x	x	x	x	x	x	x	
High H ₂		F-3	14,500 cc/min	Glass	6			x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Purifier		G-3	Indicator																			
AsH ₃ /FH ₃	H or I-5	H, I, K, M	Use						x	x	x											
H ₂	J-5	J, L	Charts						x	x	x											
B ₂ H ₆	N-5	N, P, R	Use						x	x	x	x	x	x								
H ₂	O-5	O, Q	Charts						x	x	x	x	x	x	x	x						
High N ₂	S-5	S-3	6000 cc/min	Glass	10		x															
	A-1							x	x	x	x	x	x	x	x	x	x	x	x	x	x	
3-Way	F-1																					
Valves	H-1																					
	M-1																					
	N-1																					

Note: A-5 2-way valve is normally open and closes when energized, all other 2-way valves are normally closed and open when energized.

Flow meters H or I, K and M operate in unison with the same setting.

Flow meters J and L operate in unison with the same setting.

Flow meters N, P and R and O and Q operate similarly.

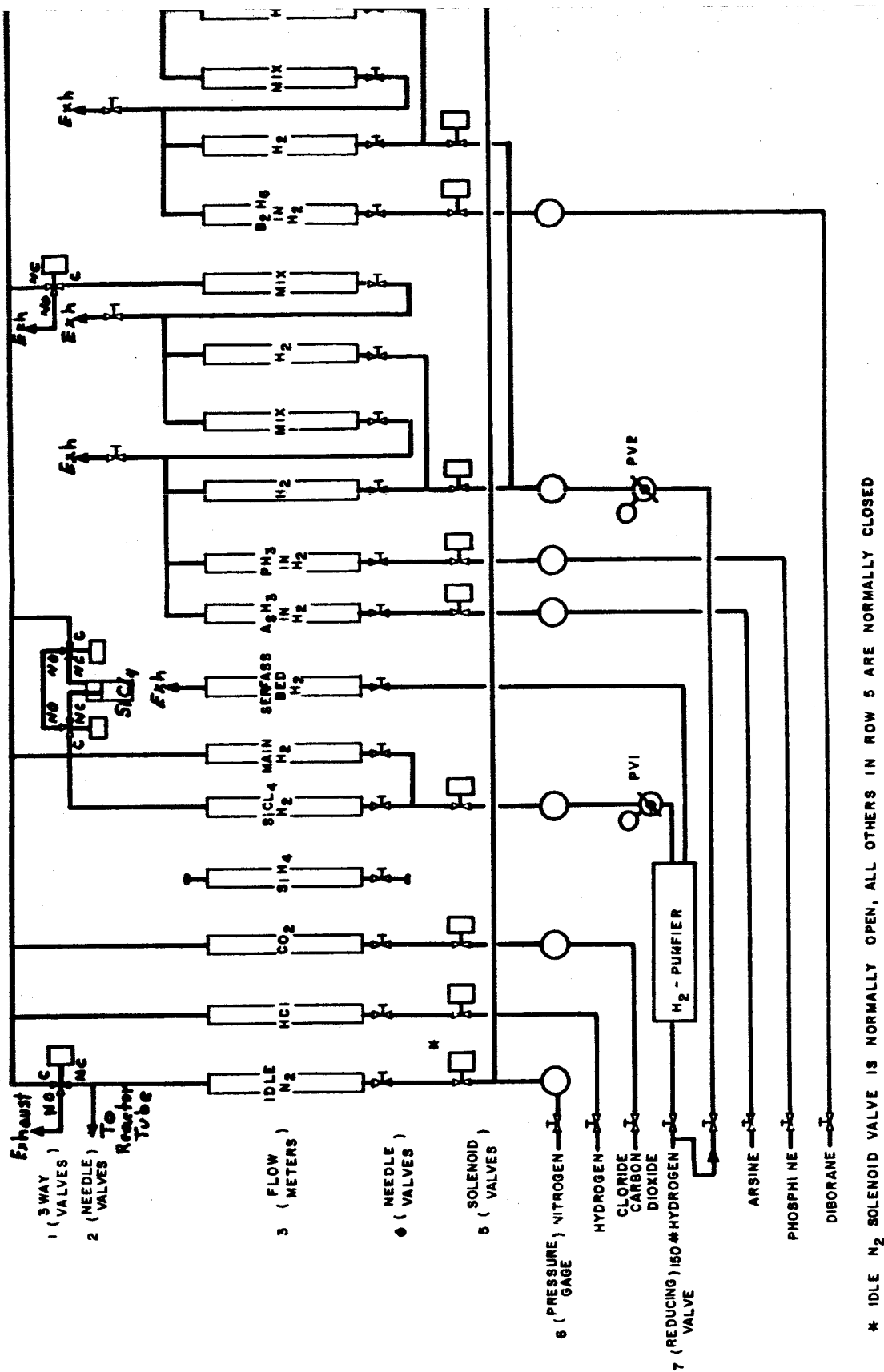


Figure 1. Gas Control Schematic

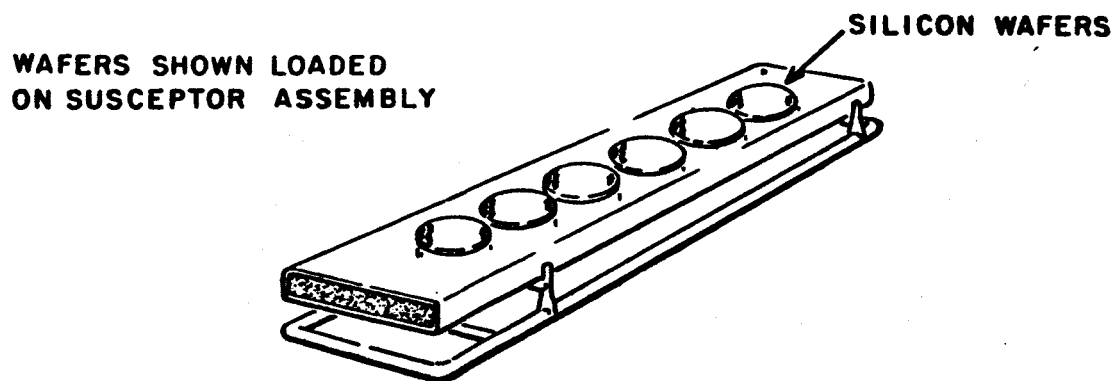
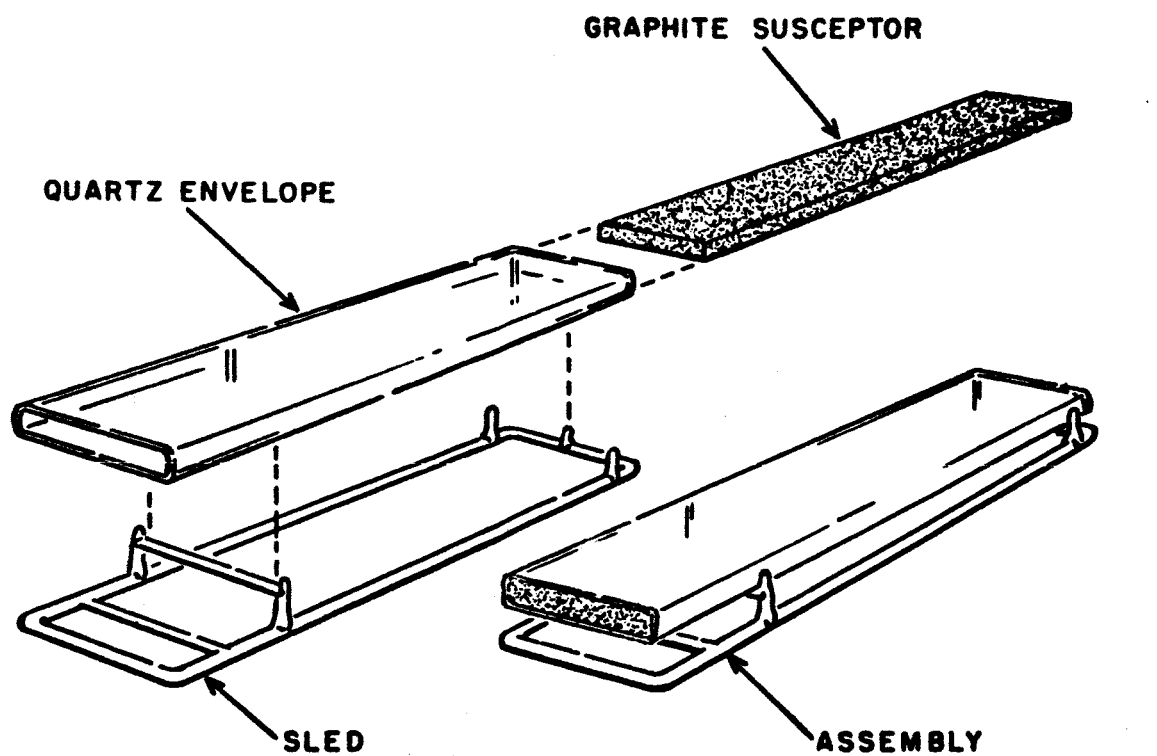


Figure 2. Susceptor Assembly

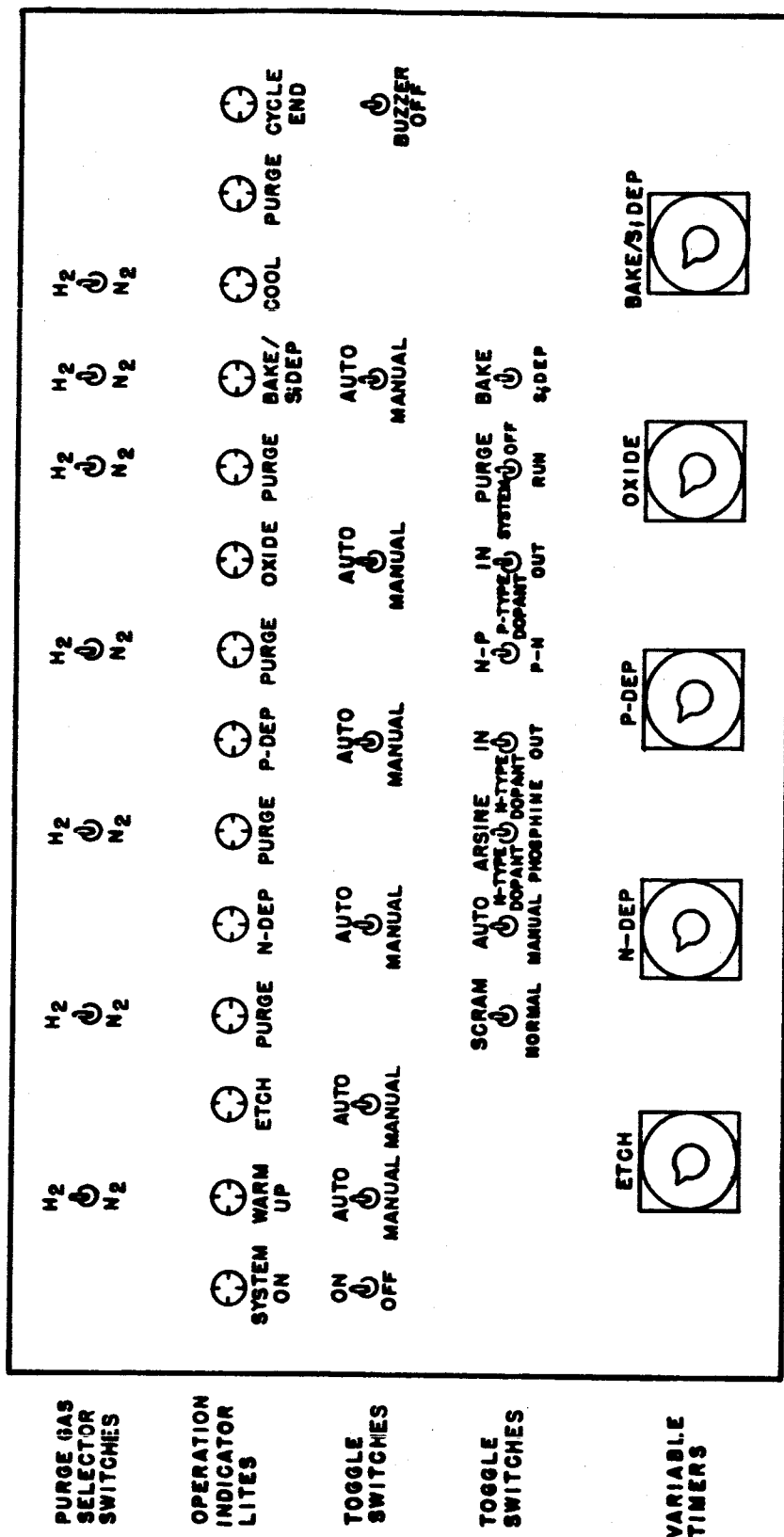
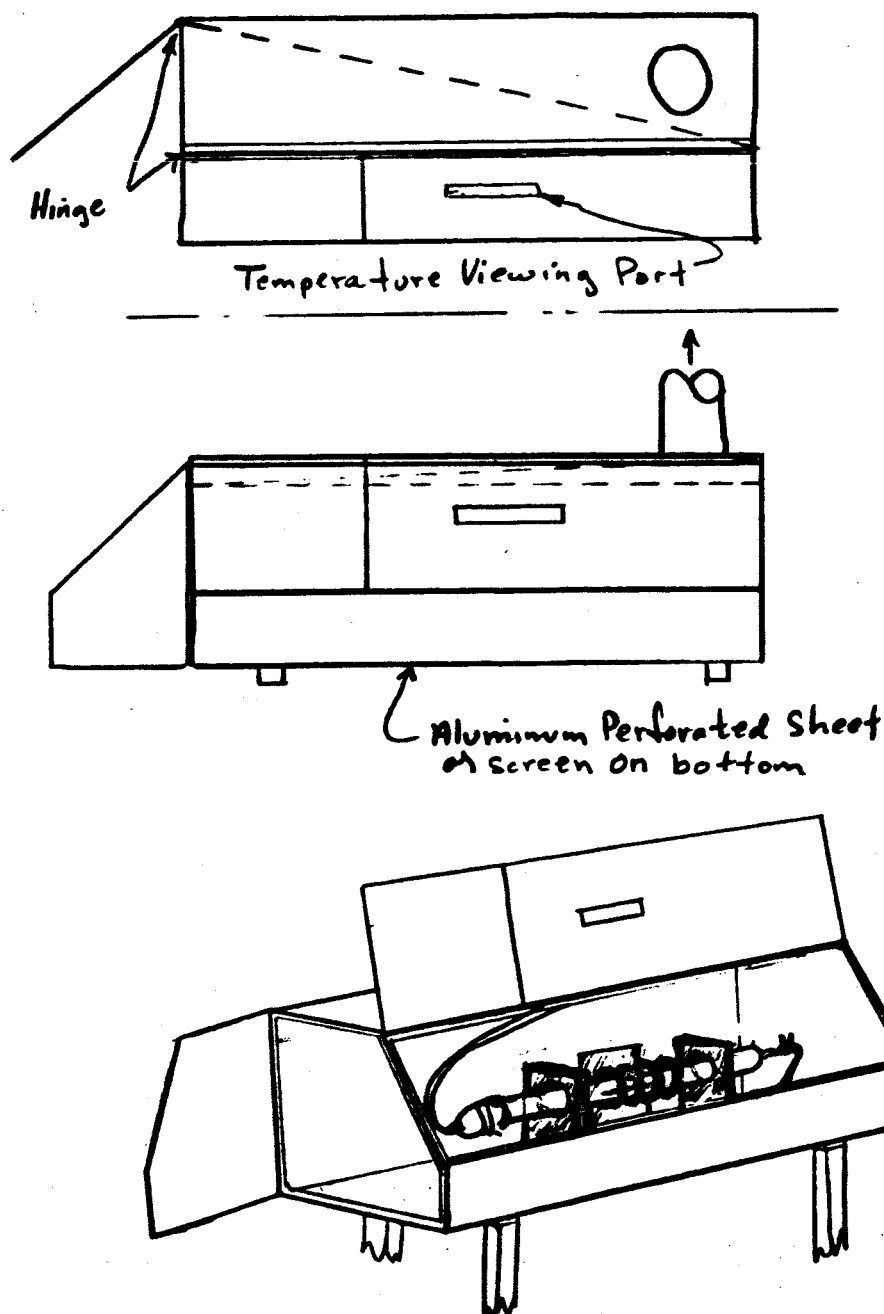
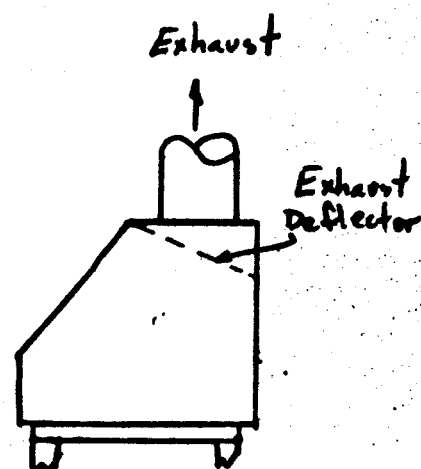


Figure 3. Electric Control Panel



All aluminum construction
All panels grounded with strapping



Top, side & back panels and doors
.090 aluminum sheet.

Figure 4. Reactor Cabinet

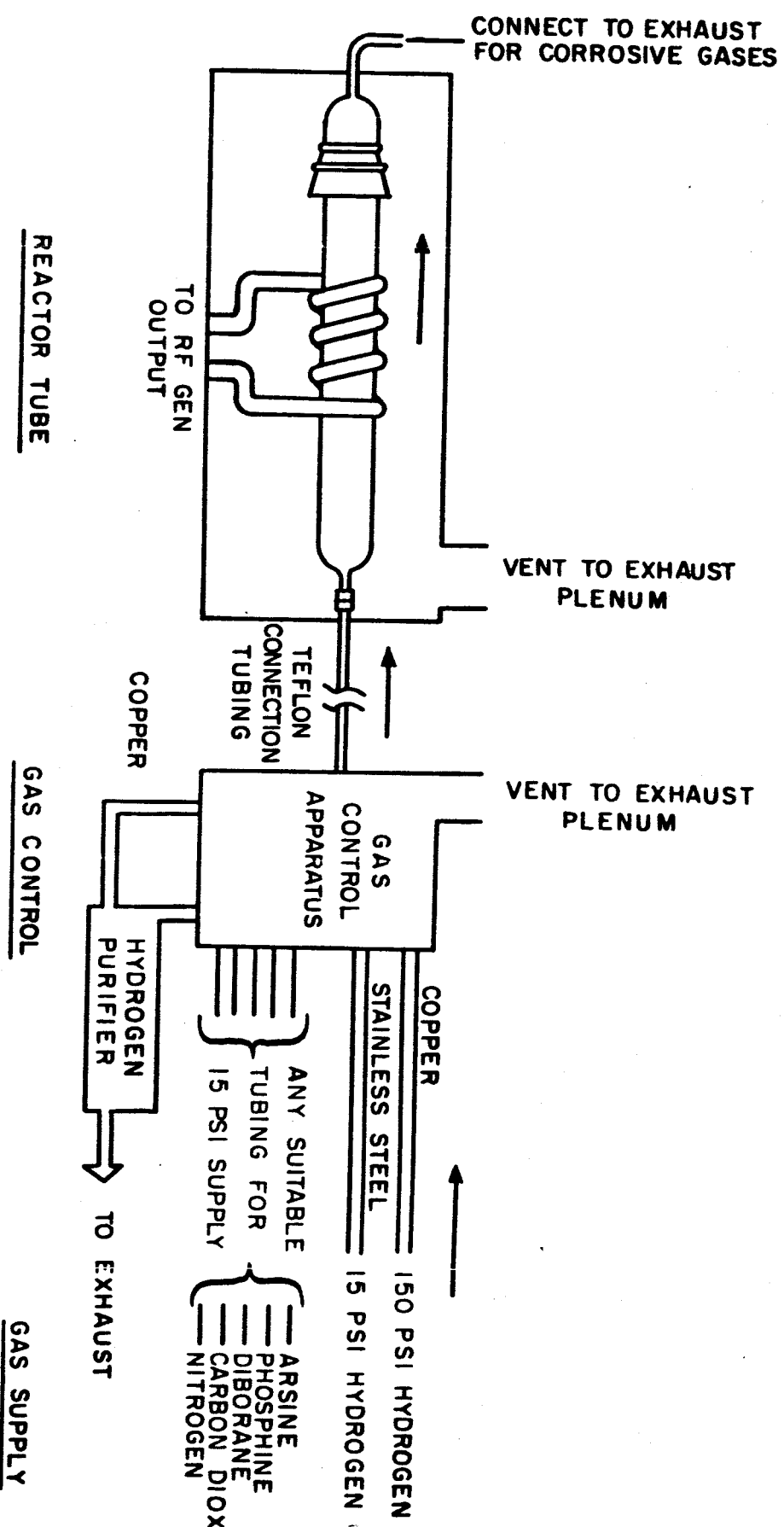
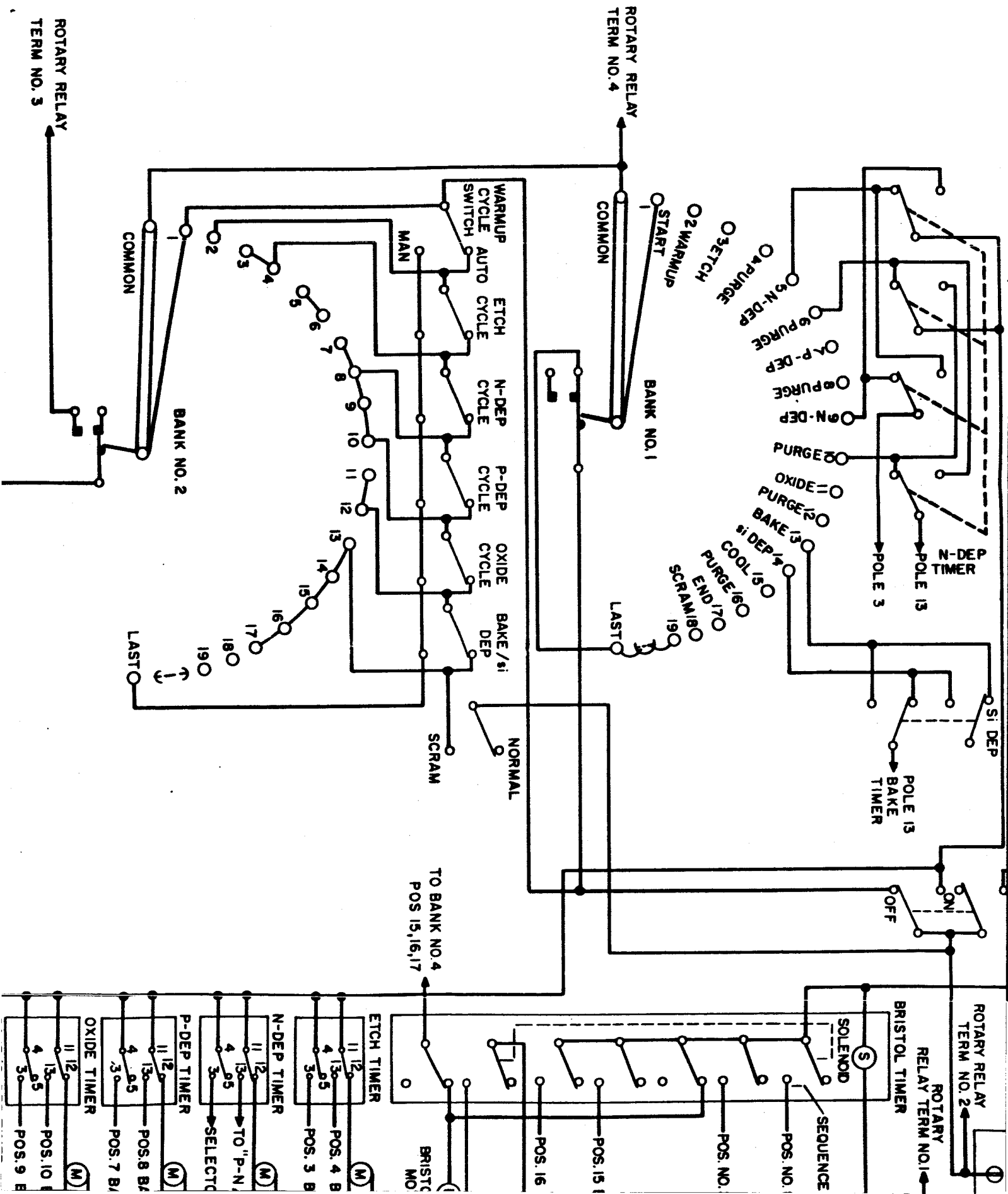
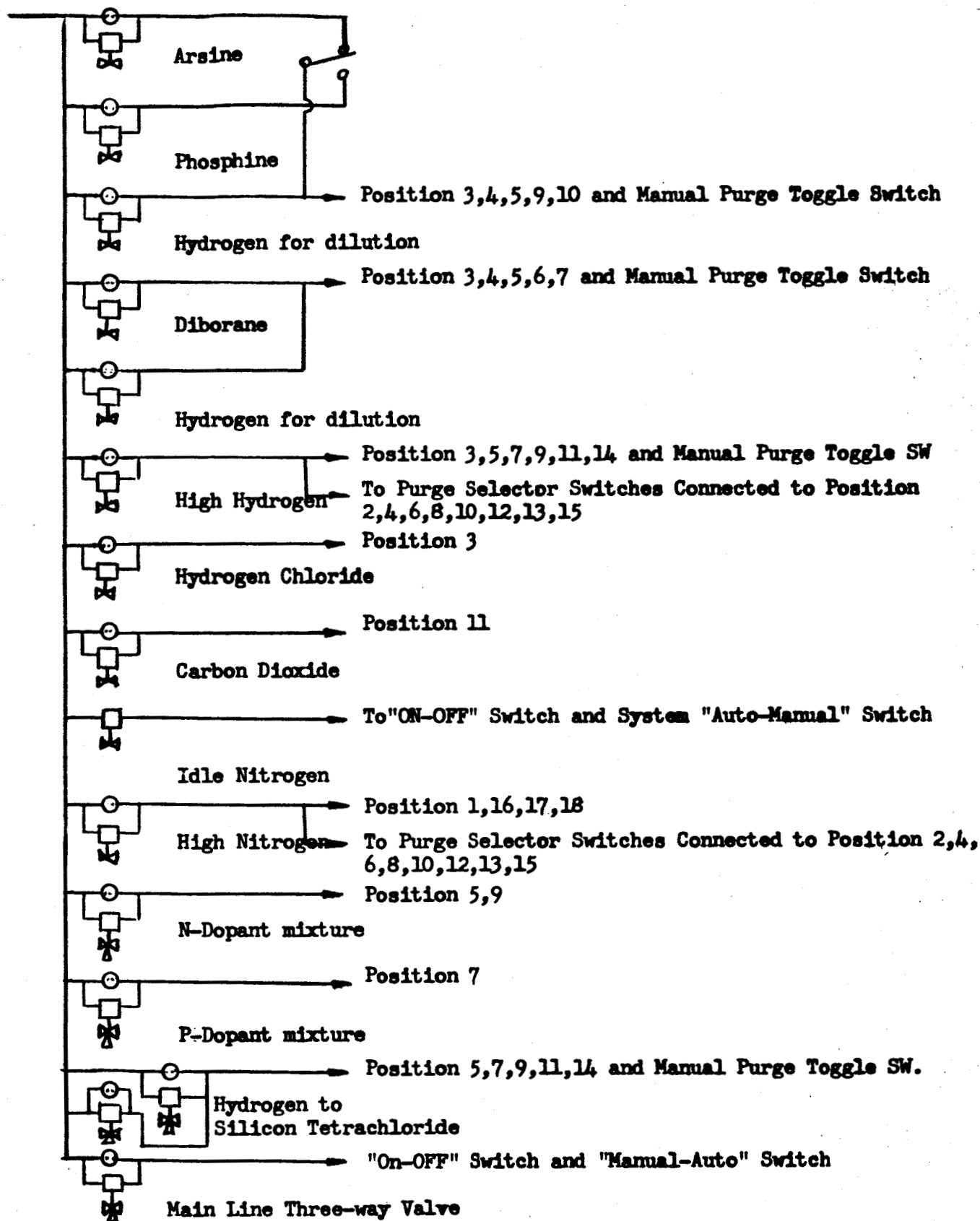


Figure 5. External Gas Connections





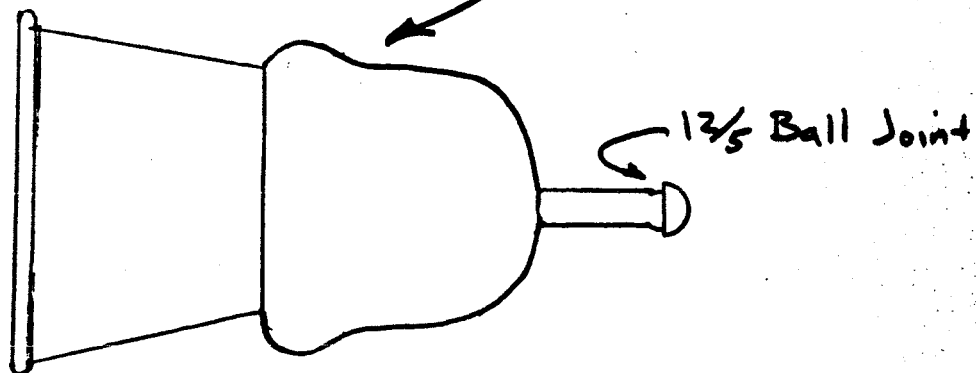
⊙ | Pilot Lite

□ 2 Way Solenoid Valve

⊞ 3 Way Solenoid Valve

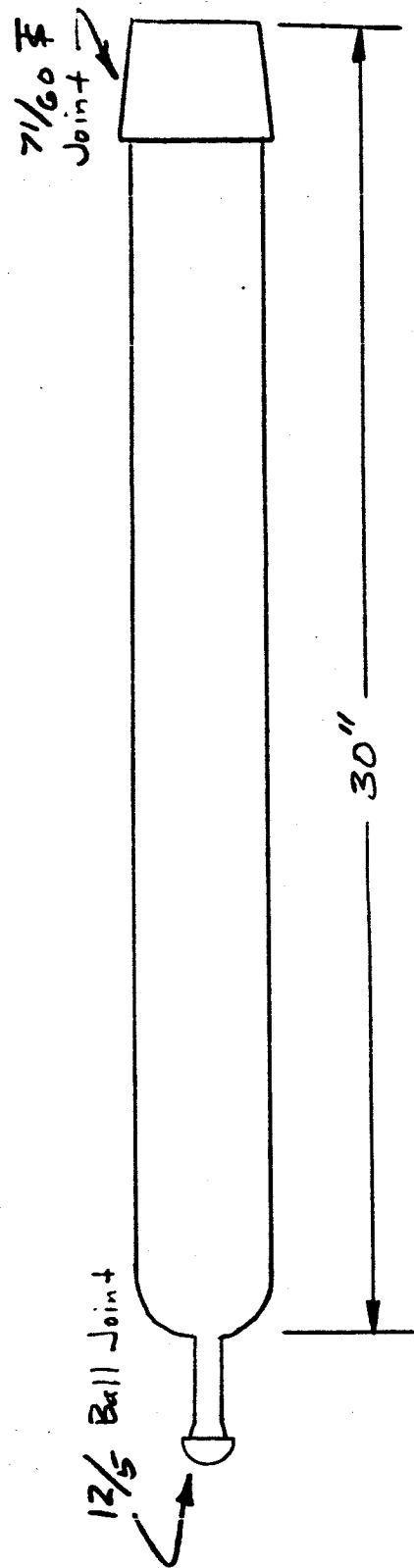
Figure 7. Electric Valve to Programmer Hookup

$7\frac{1}{60}$ Female Φ ground joint



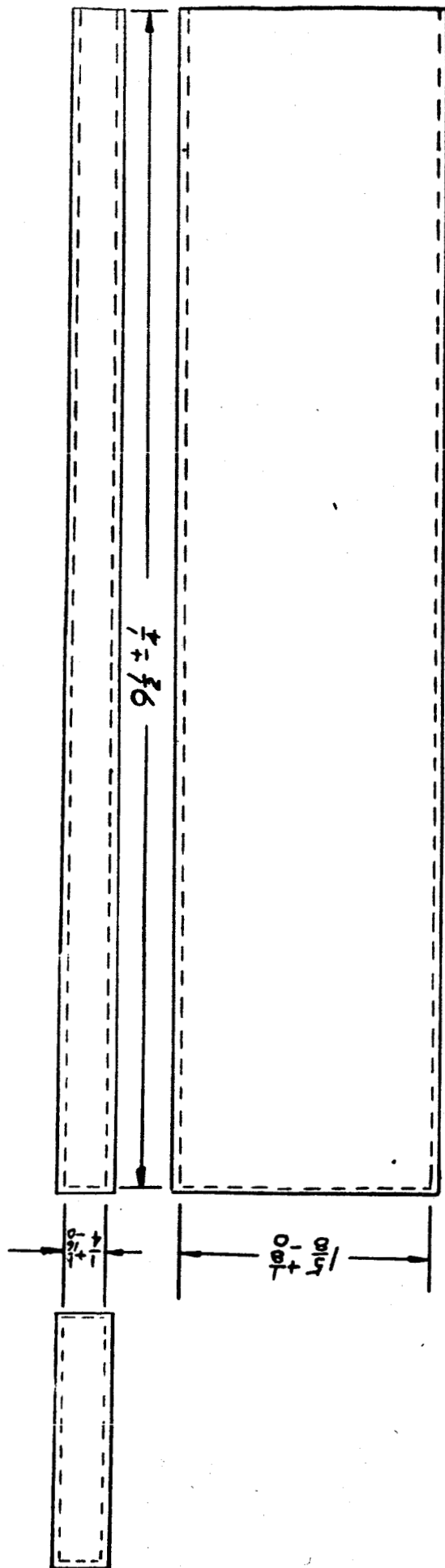
Fabricate from Pyrex components

Figure 8. Reactor End Cap



Make from quartz tubing to fit 71/60 male ♂ ground joint

Figure 9. Quartz Reactor Tube



Note: All dimensions I.D.
Make from clear fused quartz rectangular tubing

Figure 10. Quartz Susceptor Envelope

EPITAXIAL DEPOSITION

Epitaxy Run No. _____ Lot No. _____ Date In. _____
 Project _____ Engineer _____ Date Run _____
 Wafers Rec'd _____ Date Out _____
 Process Control Test Wafers No's. _____ (Remove From Lot)
 Material Source: _____
 _____ Type _____ Ingot No. _____ Resistivity _____

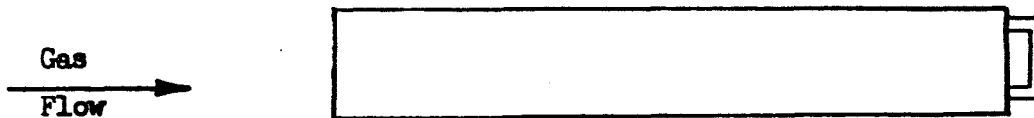
Requirements:

Cleaning: _____

Vapor Etch Time: _____ Surface Evaluation _____
 Requested Rec'd
 Epi. Resistivity _____
 Epi Thickness _____

Operation	Etch	1st Layer	2nd Layer	3rd Layer	Oxide	Bake
Dopant	XXX					XXX
Thickness μ	XXX					XXX
Resistivity Ω Cm	XXX				XXX	XXX
Temp $^{\circ}$ C						
Time Min.						
HCl Flow Cm		XXX	XXX	XXX	XXX	XXX
H ₂ Flow Cm.						
Dopant Flow Cm 1,3,5						XXX
H ₂ Mix Flow Cm 2, 4						XXX
SiCl ₄ -H ₂ Flow						
CO ₂ Flow Cm.		XXX	XXX	XXX		XXX
N ₂ Flow Cm.		XXX	XXX	XXX	XXX	

Wafer Position On Boat



(*) Evaluation Wafer _____

Wafers Rec'd No's _____
 (Incl. Eval. Wafer)

Operator _____

Date _____

Evaluator _____

Date _____

To Spec. No. _____

Comments _____

Figure 11

PRESSURE FACTORS

LBS.	MULT.
0.5	1.014
1	1.03
2	1.06
3	1.09
4	1.12
5	1.15
6	1.18
7	1.21
8	1.23
9	1.26
10	1.29
11	1.31
12	1.34
13	1.36
14	1.39
15	1.41
20	1.53
25	1.64
30	1.74

Figure 12

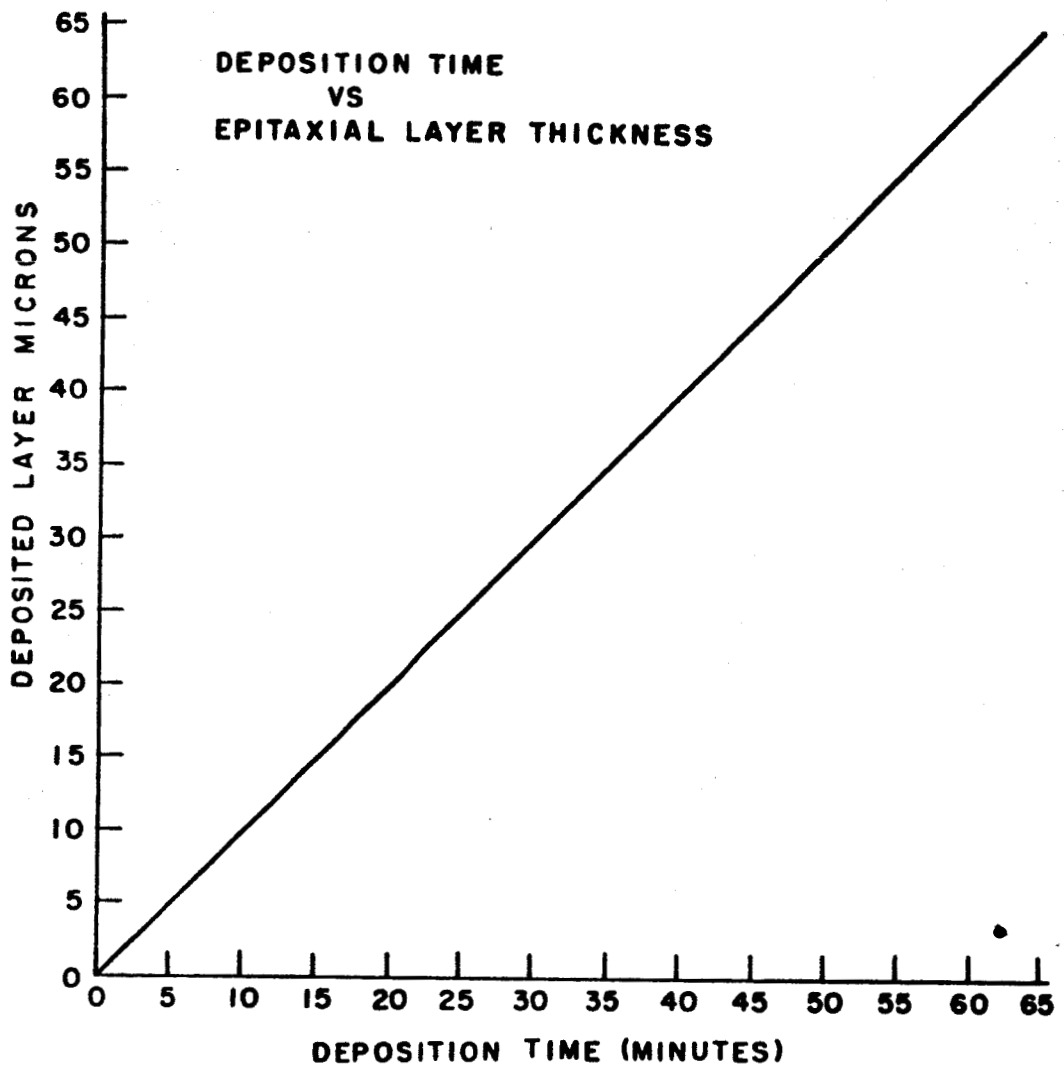
GAS CONVERSION FACTORS

BROOKS INSTRUMENT COMPANY, INC.
MAYFIELD, PENNSYLVANIA

DRAWN	CW	SCALE	DATE	TYPE
TRACED			9-12-52	DATA
CHECKED		DRAWING		
APPROVED		No. UNC-101		

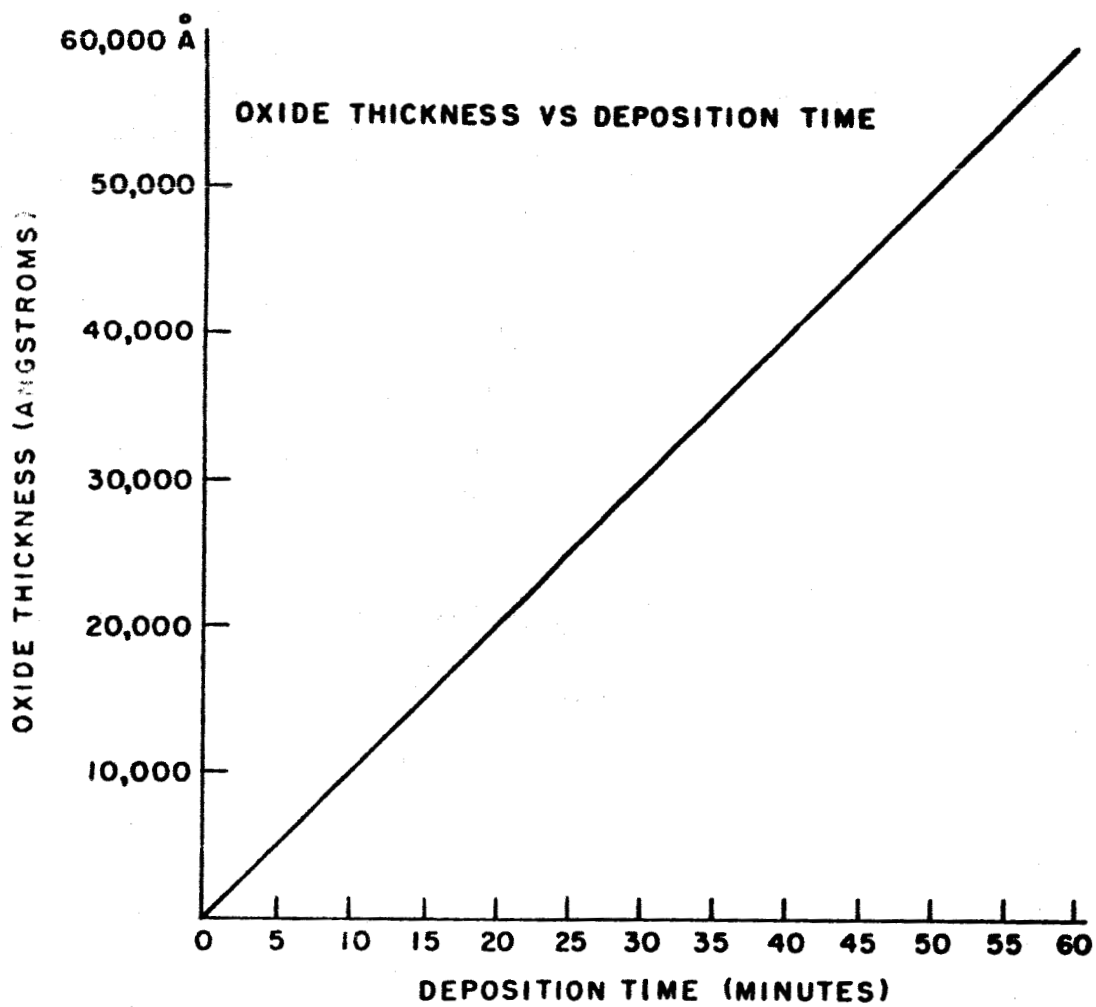
SPECIFIC GRAVITY CORRECTION FACTOR CHART

MULTIPLIER	GAS FOR WHICH METER IS CALIBRATED S.G.															
	HYDROGEN	HELIUM	CRACKED AMMONIA	METHANE	AMMONIA	CITY GAS	ACETYLENE	NITROGEN	AIR	ETHANE	OXYGEN	ARGON	PROPANE	BUTANE	CO ₂	
0.069	1.0	0.71	0.48	0.35	0.34	0.33	0.28	0.27	0.26	0.25	0.22	0.21	0.18	0.21		
0.138	1.41	1.0	0.69	0.50	0.48	0.47	0.45	0.39	0.38	0.37	0.36	0.35	0.32	0.30		
0.294	2.05	1.46	1.0	0.73	0.71	0.69	0.65	0.57	0.55	0.54	0.53	0.52	0.46	0.43		
0.55	2.82	2.0	1.36	1.0	0.97	0.94	0.89	0.78	0.76	0.74	0.73	0.71	0.63	0.59		
0.59	2.92	2.06	1.42	1.03	1.0	0.98	0.92	0.81	0.78	0.77	0.75	0.73	0.66	0.62		
0.62	3.0	2.10	1.45	1.06	1.02	1.0	0.94	0.83	0.80	0.79	0.77	0.75	0.67	0.63		
0.696	3.17	2.25	1.54	1.12	1.08	1.06	1.0	0.88	0.85	0.83	0.82	0.80	0.71	0.67		
0.907	3.62	2.56	1.75	1.28	1.24	1.21	1.14	1.0	0.97	0.95	0.93	0.91	0.81	0.76		
0.967	3.74	2.64	1.82	1.32	1.28	1.25	1.18	1.03	1.0	0.98	0.96	0.94	0.84	0.79		
1.00	3.81	2.69	1.84	1.35	1.30	1.27	1.20	1.04	1.01	1.0	0.98	0.95	0.85	0.80		
1.049	3.90	2.76	1.88	1.38	1.33	1.30	1.23	1.08	1.04	1.02	1.0	0.98	0.88	0.82		
1.10	4.00	2.82	1.93	1.41	1.36	1.33	1.26	1.10	1.06	1.05	1.02	1.0	0.90	0.84		
1.37	4.45	3.15	2.15	1.58	1.52	1.49	1.40	1.23	1.19	1.17	1.14	1.12	1.0	0.94		
1.56	4.76	3.36	2.30	1.68	1.63	1.59	1.50	1.31	1.27	1.25	1.22	1.19	1.07	1.0		
2.06	5.46	3.86	2.85	1.93	1.87	1.82	1.72	1.51	1.46	1.43	1.40	1.37	1.22	1.15		
1.529	4.71	3.32	2.28	1.66	1.61	1.57	1.48	1.30	1.26	1.24	1.20	1.18	1.05	0.97		

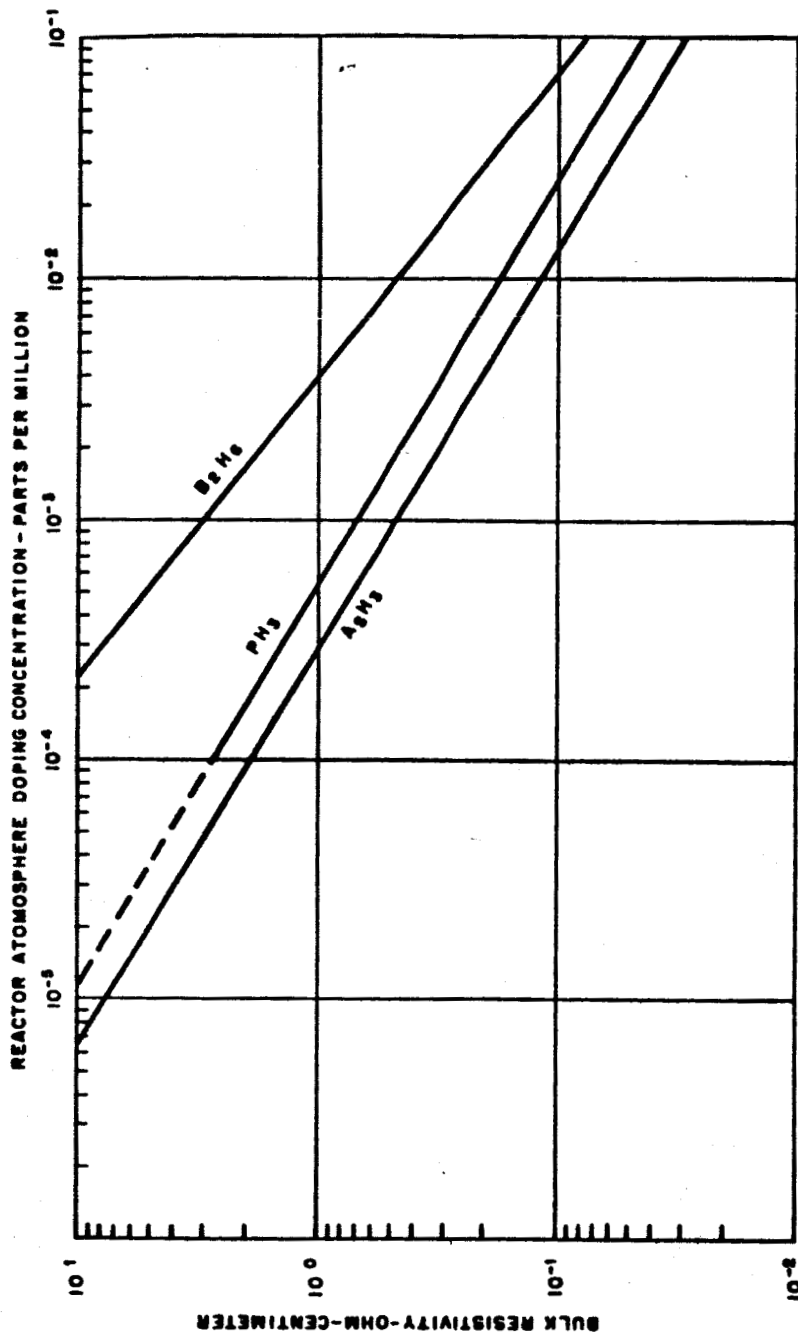


GRAPH /

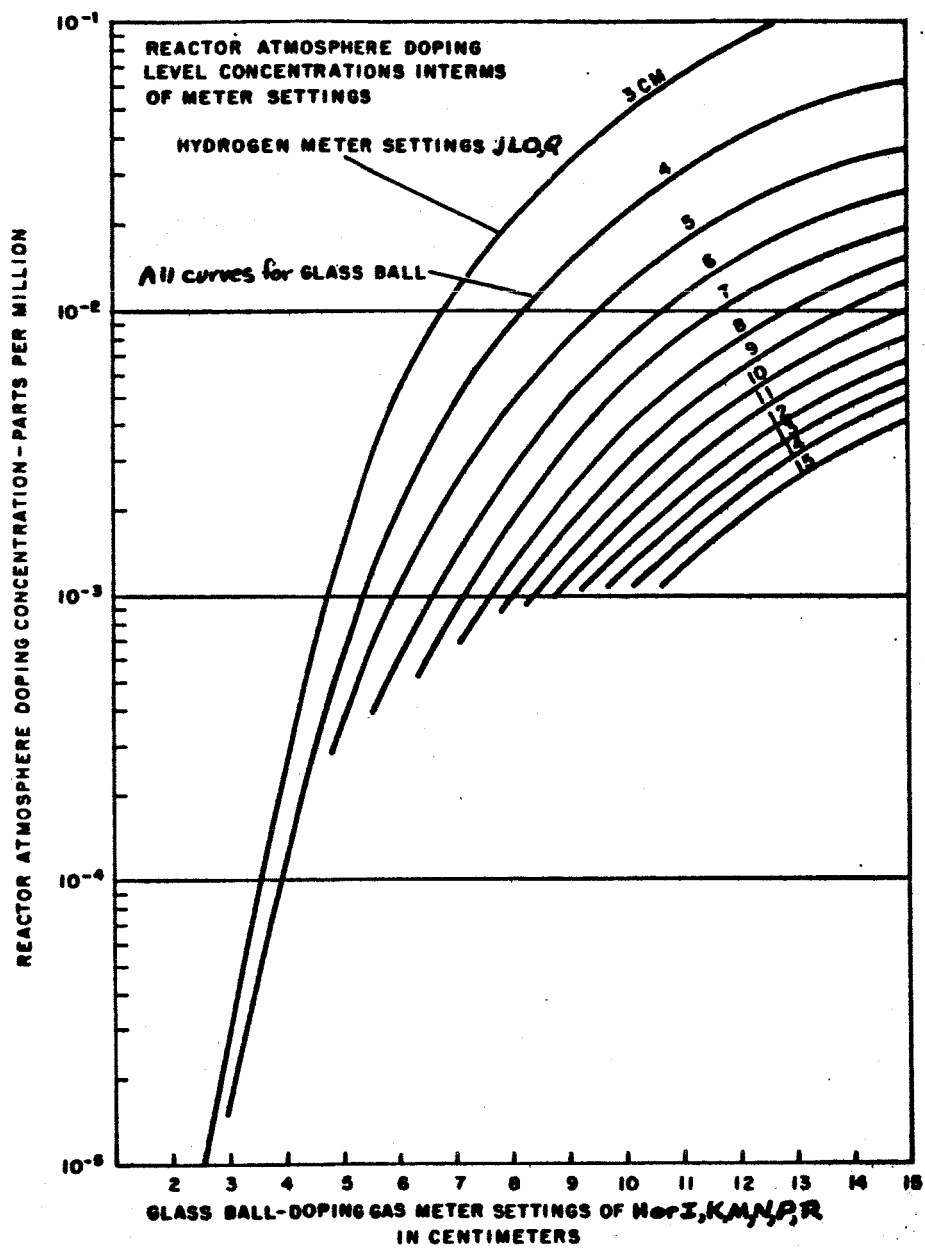
G-1



GRAPH 2



GRAPH 3



GRAPH 4

150



F. R. O. K. S.
INSTRUMENT COMPANY, INC.
MATFIELD, PENNSYLVANIA

CALIBRATION CURVE

TUBE R-2-15-B

FLUID GLASS

SERIAL NO.

100

500 MILLIMETERS

0

500

1000

1500

2000

SEMI-AIR AT 10°F AT 147 PSIA

GRAPH 5

150



BROOKS
INSTRUMENT COMPANY, INC.
MATTHEW, PENNSYLVANIA

CALIBRATION CURVE

R-2-15-B

STN. 572

TUBE

FLANGE

SERIAL NO.

100

EXHAUSTION

50

1000

2000

3000

4000

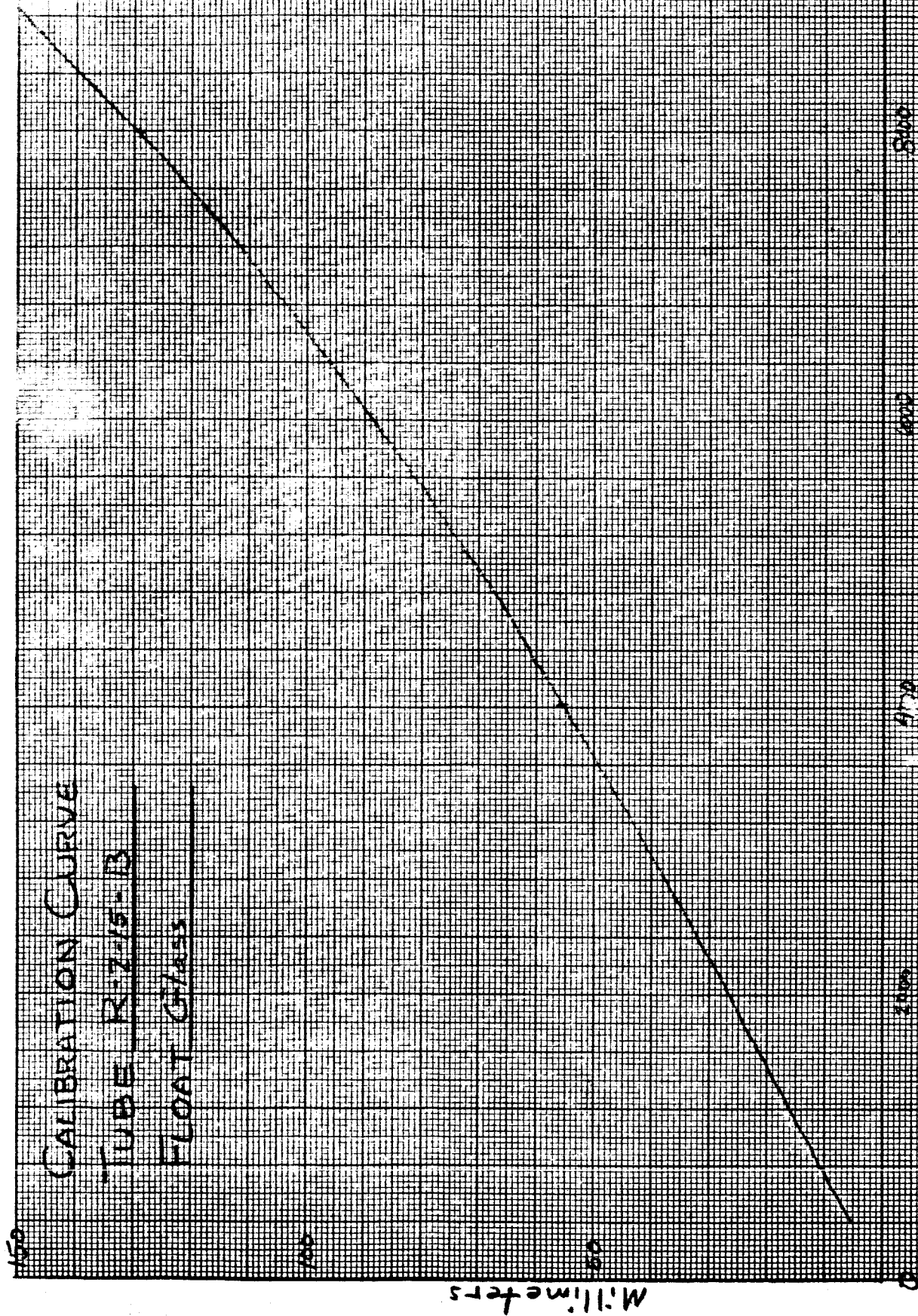
5000

FEEDING AIR AT 70°F & 14.7 PSIA

GRAPH 6

1-12-62

2B-A3



CALIBRATION CURVE

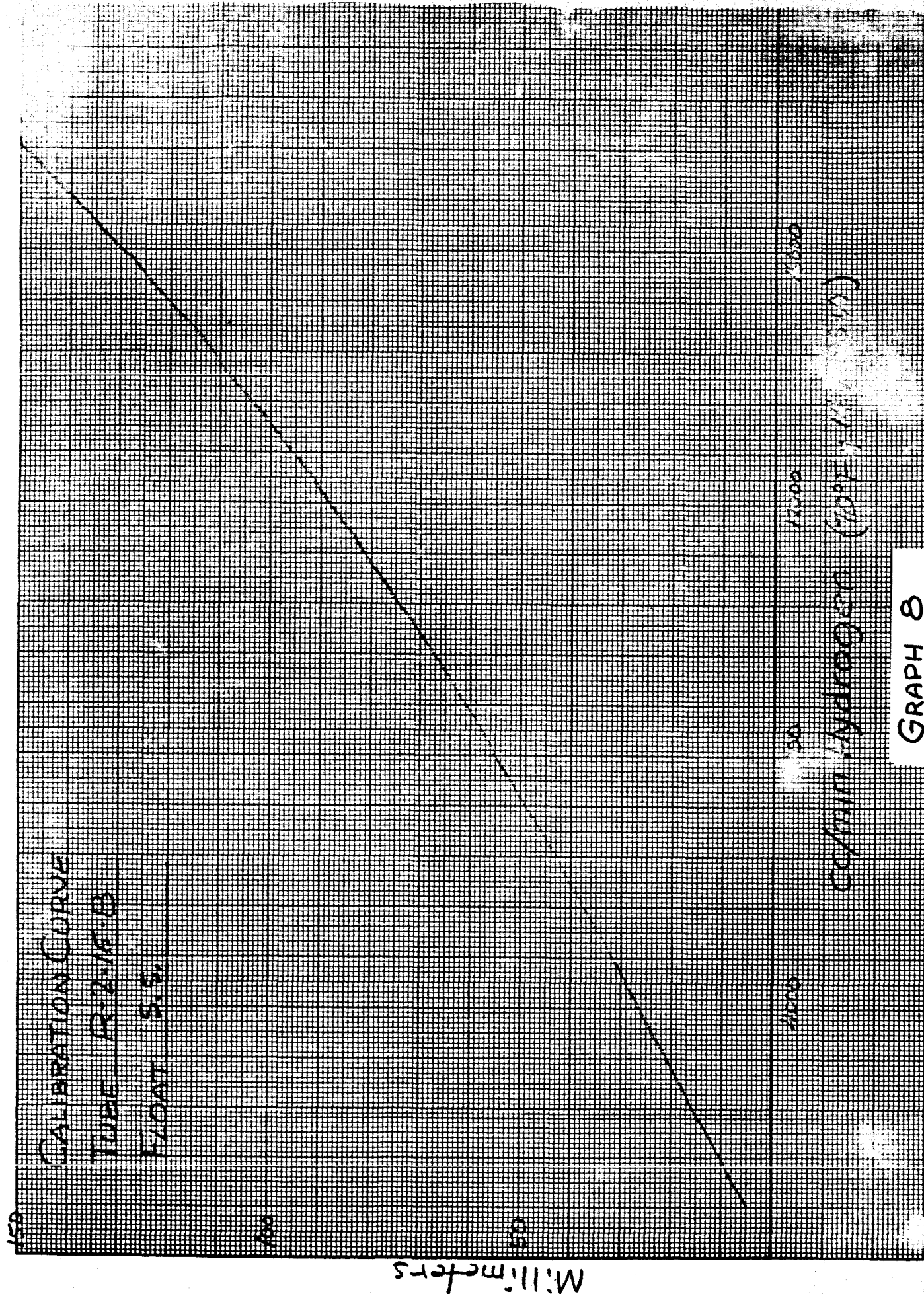
TUBE R-7-15-B

FLOAT Glass

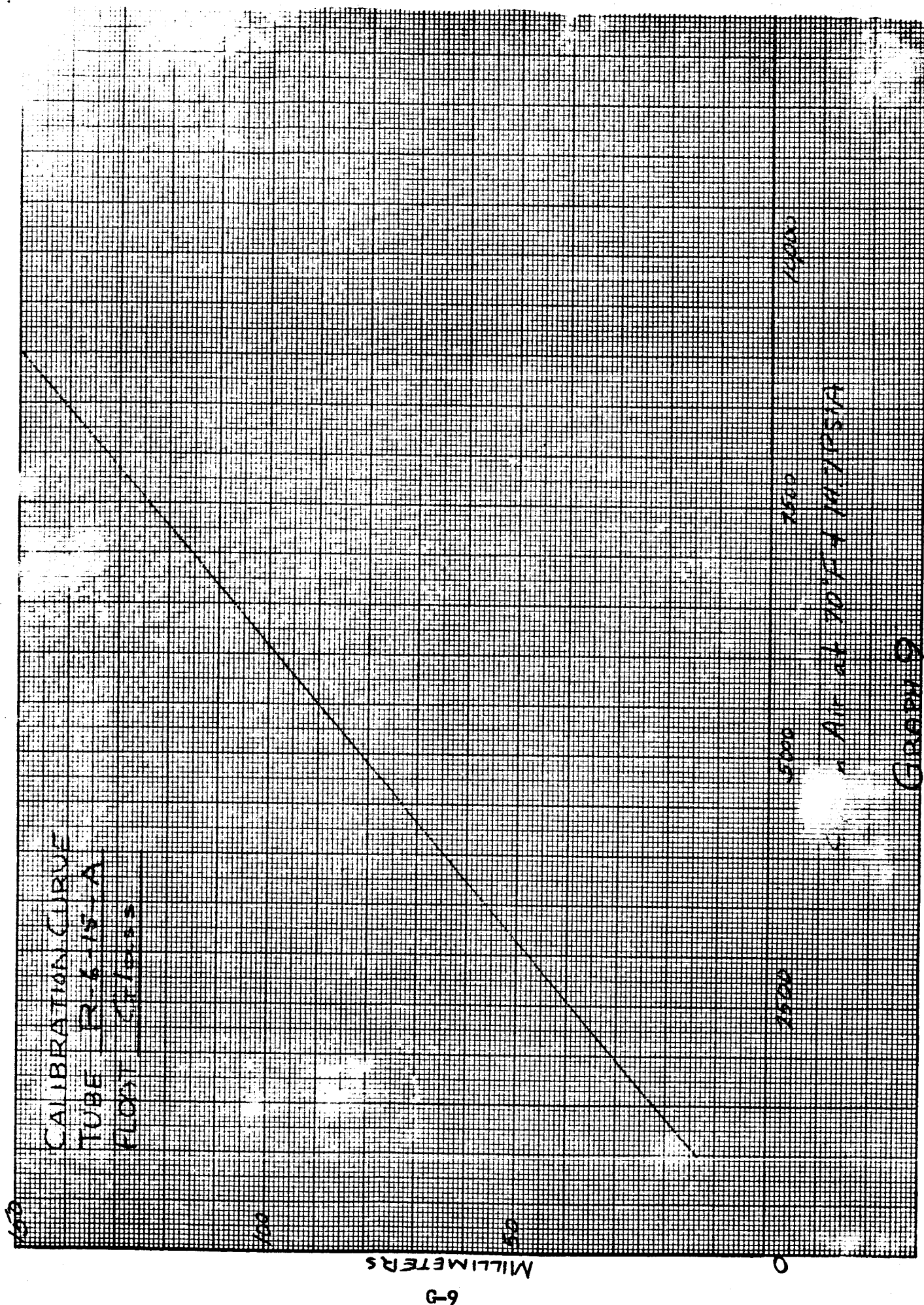
cc/min Hydrogen (70°F @ 14.7 PSIA)

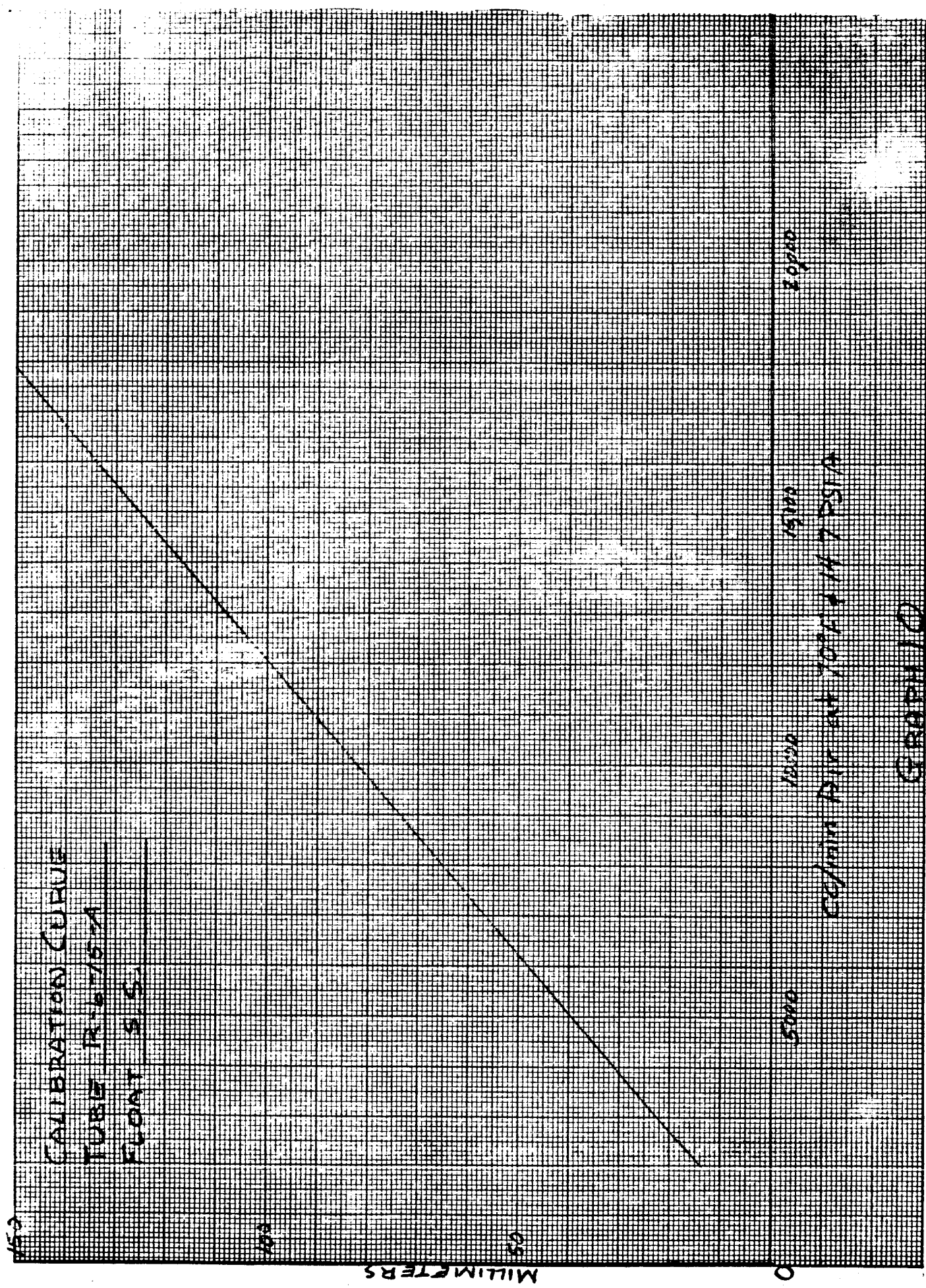
GRAPH 7

Millimeters



GRAPH 8





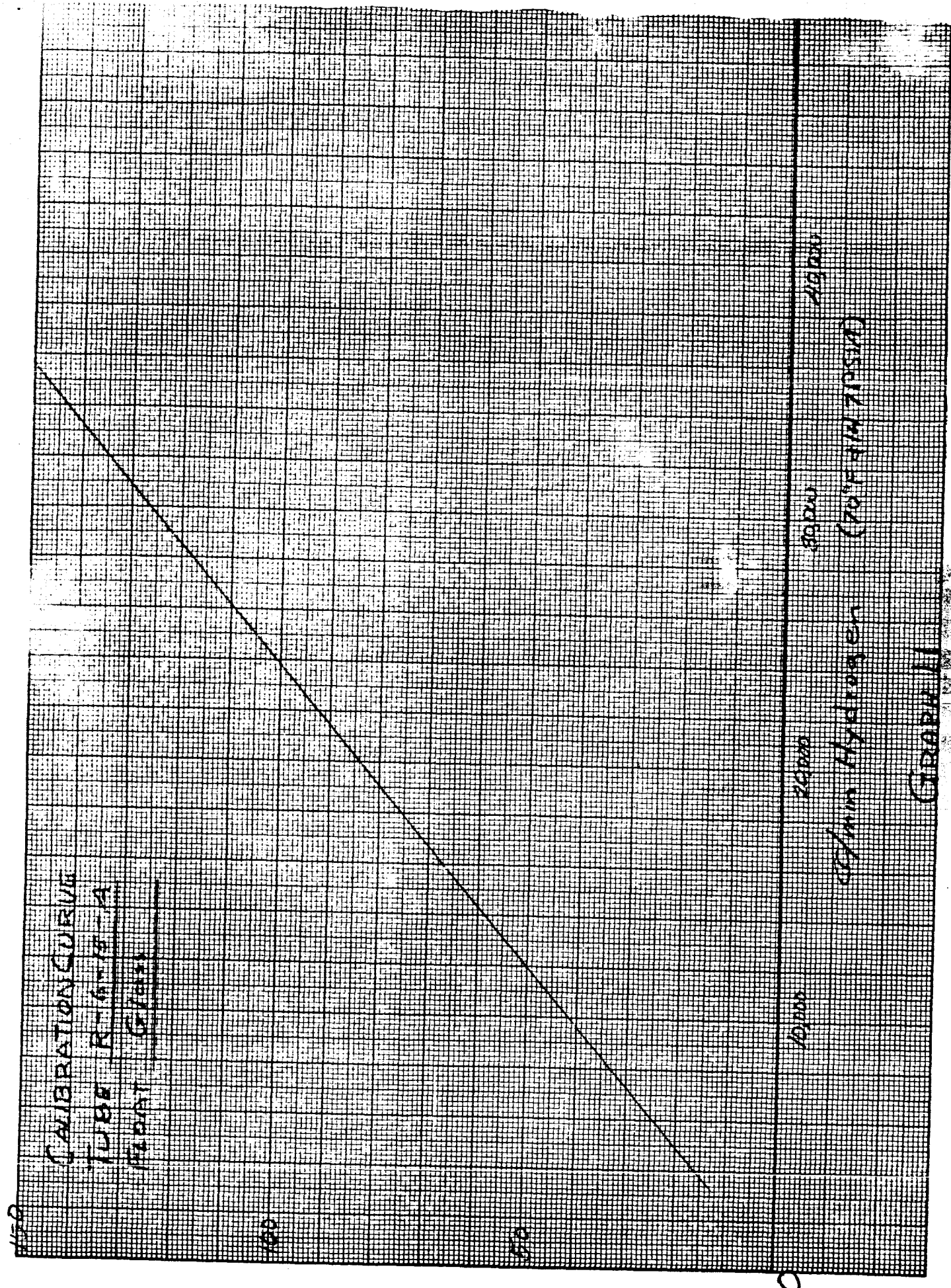
CALIBRATION CURVE
TUBE R-6710-A
FONT S.S.

COPIES AT 1000 FT. 7.551A

GRAPH 10



10 T. CEN. ER 13
15 CM.
KEUFFEL & ESSER CO.



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 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

46° 53'

N 111° E

KEUFFEL & ESSER CO.

150

100

50

0

MILLIMETERS

CALIBRATION CURVE

TUBE R-615-A

FLIGHT S.S.

5000

6000

7000

COAL HYDROGEN (7000 F. 1/117)

GRAPH 12

BROOKS
INSTRUMENT COMPANY, INC.
MAYFIELD, PENNSYLVANIA

CALIBRATION CURVE

TUBE A-2-13-AAA

FLUID GLASS

SERIAL NO.

6-13
MILLIMETERS

60mm AIR AT 70°F ± 0.1°F PSIA

GRAPH 13

7-25-62

AM-A

150



BROOK
INSTRUMENT COMPANY
MATRIC, PENNSYLVANIA

CALIBRATION CURVE

TYPE **H-2-13-AAA**

FLUID **57.57**

SERIAL NO.

100

50

MILLIMETERS

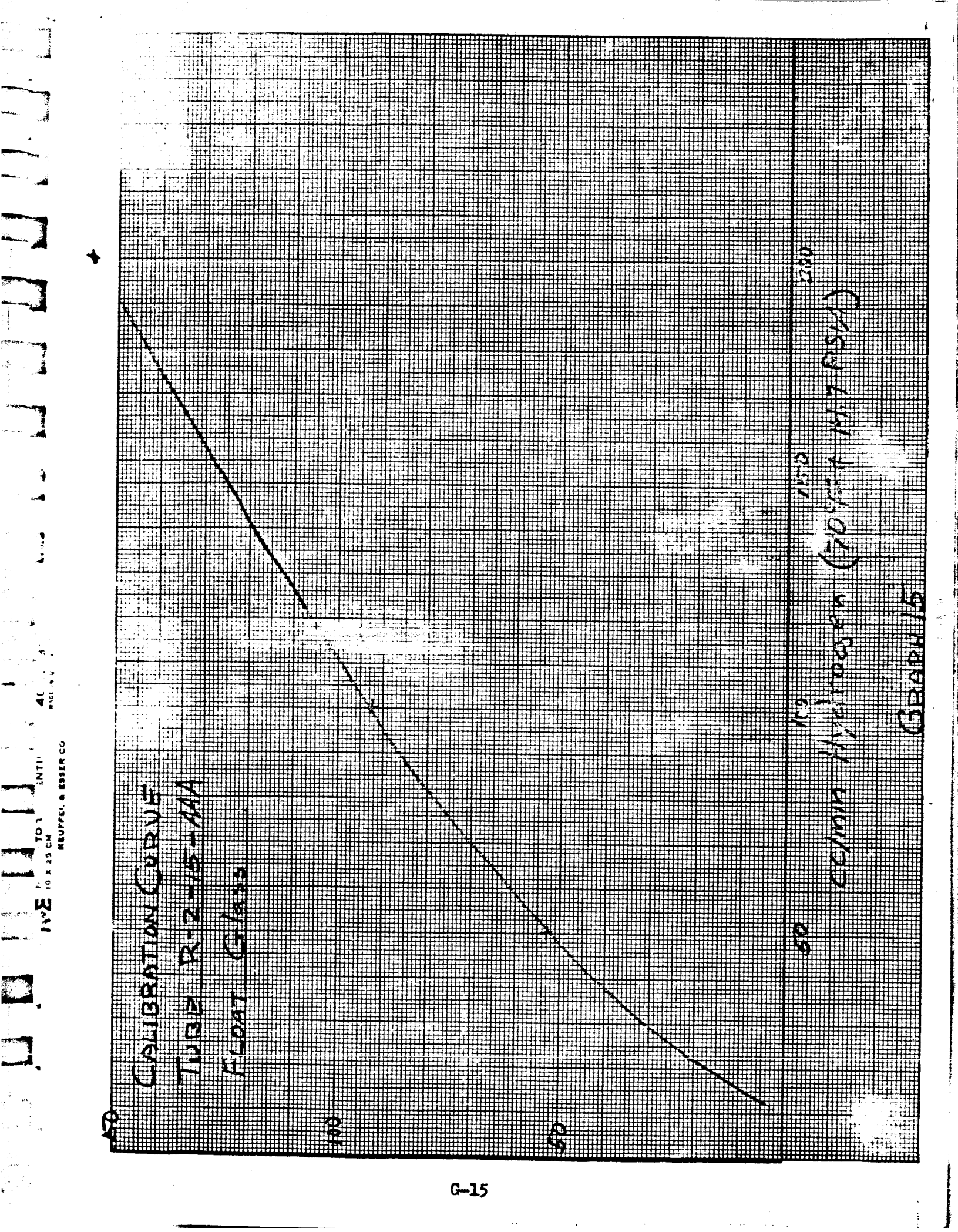
50

100

150

CCMM AIR AT 70°F & 14.7 PSIA

GRAPH 1A



CHILDRS CORP.

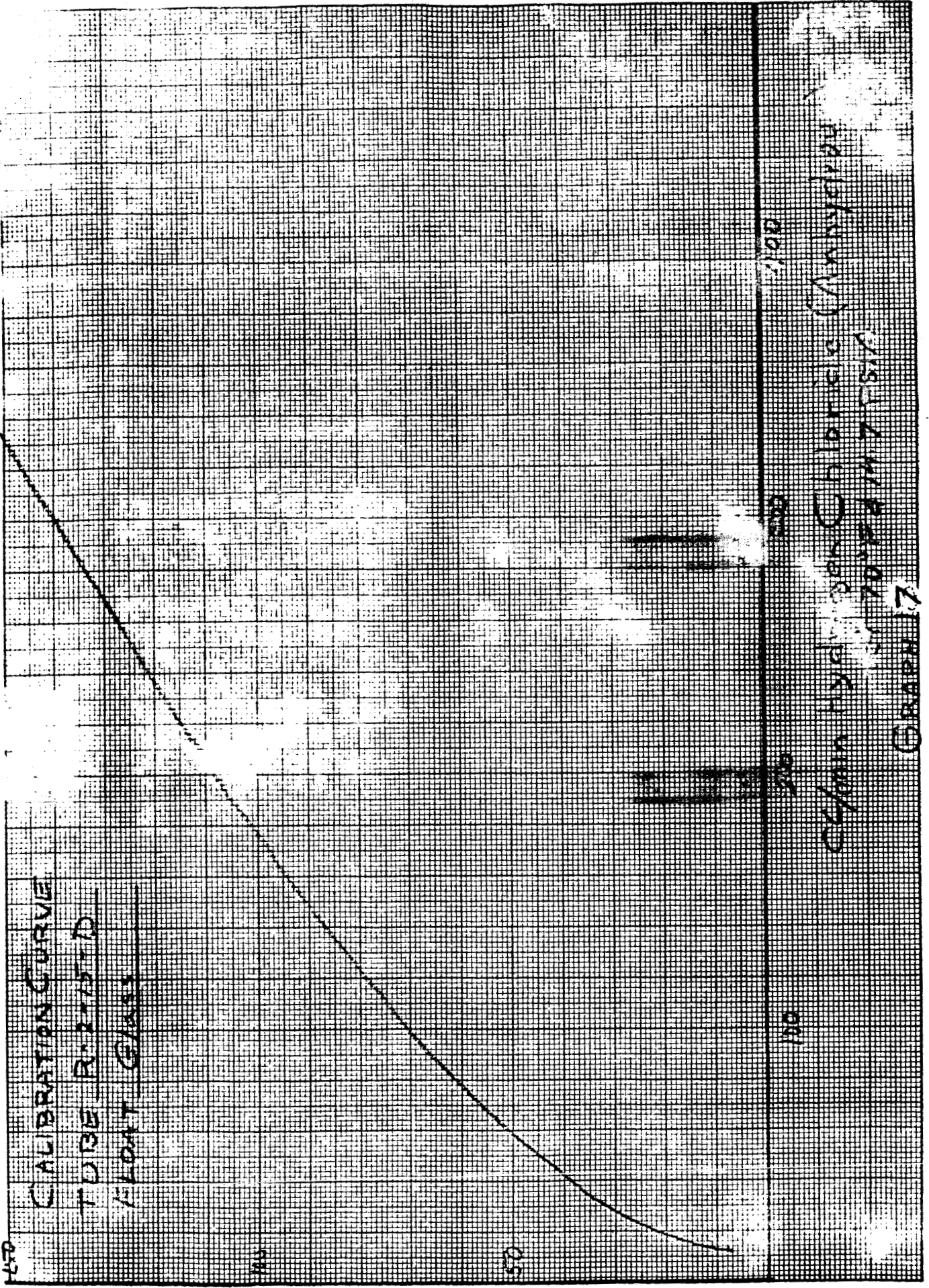
TUBE R-2-15-A/A

Alex S. S.

cc/min Hydrogels (100°F, 147 PSI)

Graph 16

CALIBRATION CURVE
TUBE R-2-15-D
1-LOAT @/ass



Cefam Hydrogen Chloride (Anhydrous)
1000 mg 75%
GRADE 17

THE OF FIVE

A



00-70374147951A
GRADE 18

BROOKS
INSTRUMENT COMPANY, INC.
MAYFIELD, PENNSYLVANIA



CALIBRATION CURVE

TUBE R-2-15-D

FLOAT GLASS

SERIAL NO.

100

50

100

300

500

60 MM AIR AT 70°F & 14.7 PSIA

GRAPH 19

MILLIMETERS

150



BROOKS
INSTRUMENT COMPANY, INC.
HAYFIELD, PENNSYLVANIA

CALIBRATION CURVE

TUBE *A-2-15-0*

FLOAT *ST. ST.*

SERIAL NO.

100

MILLIMETERS

50

200

400

600

800

1000

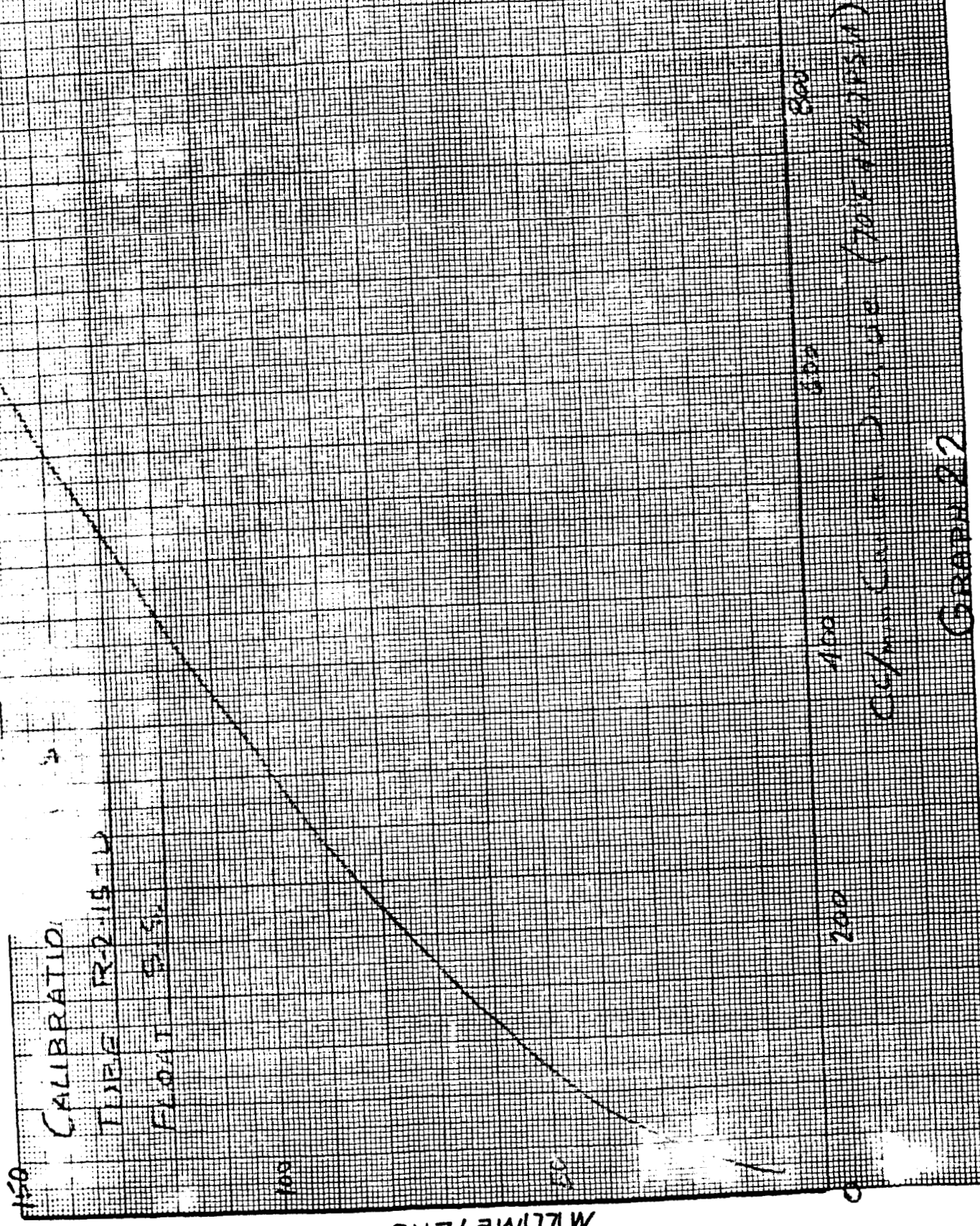
SEMIN AIR AT 70°F & 14.7 PSIA

GRAPH 20

6-27-63

20-A3

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 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100
 KODAK SAFETY FILM
 46
 111

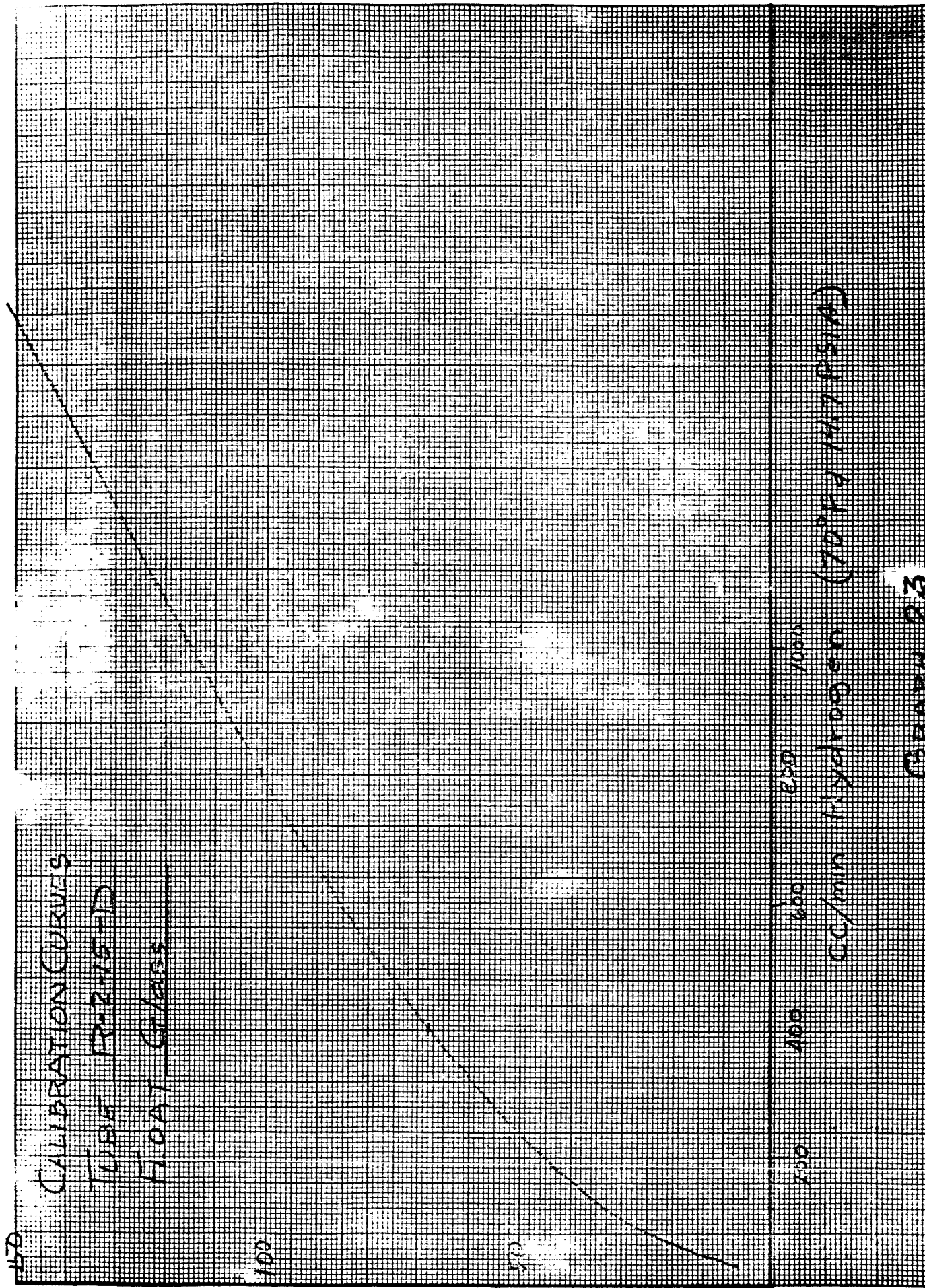


CALIBRATION
 TIME R-2-15-12
 FLOAT 8-30

66/100 Calibration 200/100 (70/100 14/100 5/100)

GRAPH 22

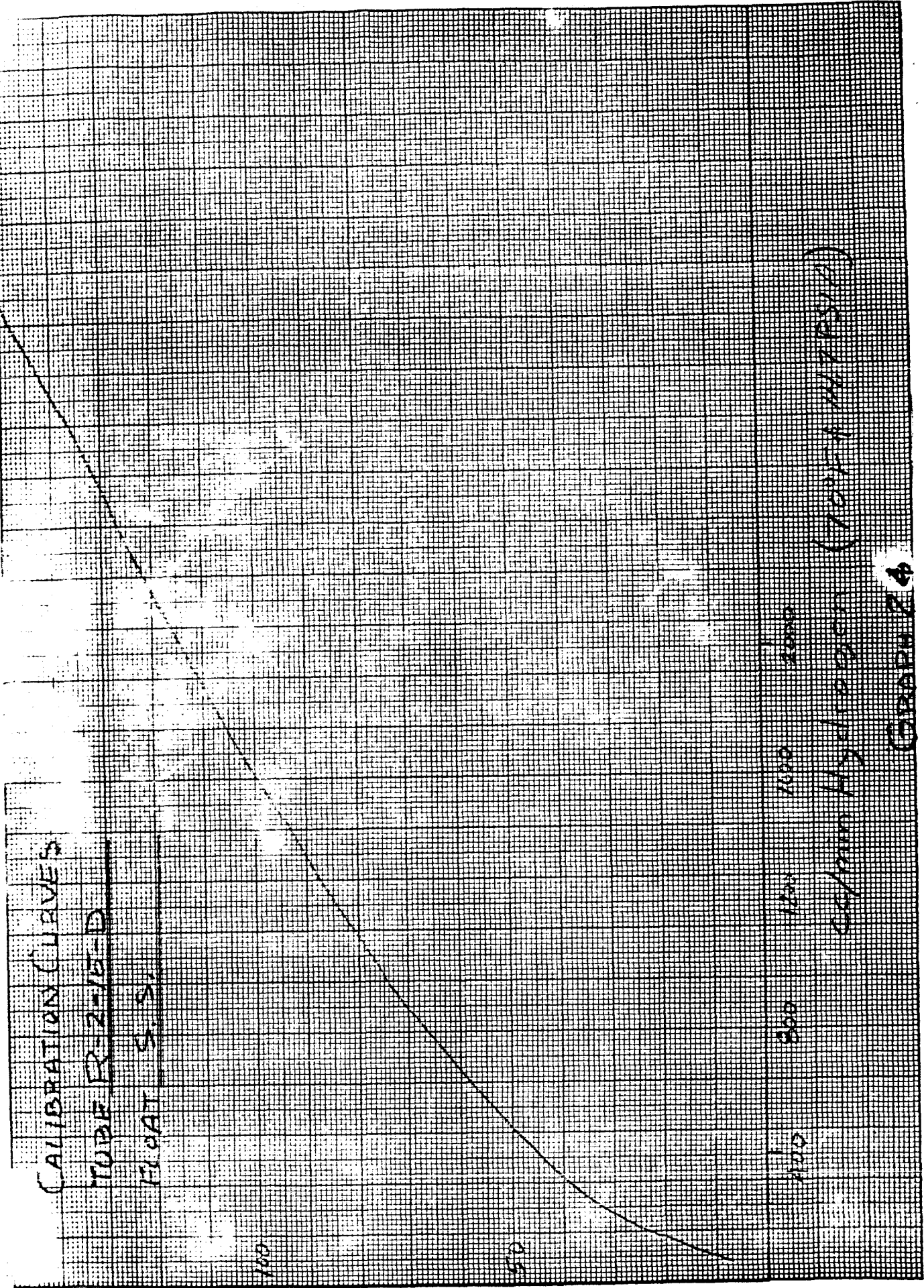
IC TO TITIM 46
 19 100
 REUFEL & ESSER CO.



MILLIMETERS



TO TOTAL
46
KEUFFEL & ESSER CO.



G-24
MILLIMETERS

GRAPH 24