ARGONNE NATIONAL LABORATORY
P. O. Box 299
Lemont, Illinois

ADVANCED DESIGNS OF MAGNETIC JACK-TYPE CONTROL ROD DRIVE

by

Joseph N. Young

Reactor Engineering Division

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INTRODUCTION

The magnetic jack is a device for positioning the control rods in a nuclear reactor, especially in a reactor containing water under pressure. Magnetic actuation precludes the need for shaft seals and eliminates the problems associated with mechanisms operating in water.

This report covers the developments made since the writing of a previous report, ANL-5768 (December 1957). The index at the end of this report covers this report and also ANL-5768.

LITERATURE RELATING TO THE MAGNETIC JACK

J. N. Young, Magnetic Jack - A New Control Drive Mechanism, Nucleonics, 15 (6), 118-123 (June 1957).

J. N. Young, Design and Performance Characteristics of Magnetic Jack-Type Control Rod Drive, ANL-5768 (December 1957).

Westinghouse Magnetic Rod Drives Description (advertisement), Nucleonics, 17 (6), 129 (June 1959).

Patent number 2,803,761, which is the improved type discussed in this report.

Patent number 2,831,990, which is the mechanical gripper type.

Annual Technical Progress Report AEC Unclassified Programs Fiscal Year 1959, NAA-SR-3850, page IV-12 thru IV-16 (Atomics International).

J. D. Howell, OMR Control-Safety Rod Component Development Tests, NAA-SR-3172 (Atomics International) (September 1959).

The following drawings may be obtained from the Technical Information Service Extension, P. O. Box 1001, Oak Ridge, Tennessee, attn: Engineering Sales:

AEC No.	Price	ANL No.	
CAPE-34-21	$2.48	RE-1-18892-F	control rod
CAPE-34-22	0.32	RE-1-17892-B	connection
CAPE-34-23	0.32	RE-1-17893-B	(round rod, small
CAPE-34-25	0.16	RE-1-17895-A	diameter type)
CAPE-34-26	0.16	RE-1-17897-A	March, 1956
CAPE-34-36	0.16	RE-6-19155-A	
CAPE-34-30	0.32	RE-1-19093-B	control and
CAPE-34-31	0.32	RE-1-19096-B	power supply,
CAPE-34-32	0.16	RE-6-19125-A	(relay type)
CAPE-34-33	0.16	RE-1-19126-A	Oct. 1956
CAPE-34-34	0.16	RE-6-19127-A	
CAPE-34-35	0.16	RE-7-17995-A	

BRIEF DESCRIPTION OF THE MAGNETIC JACK*

The magnetic jack control rod drive is an hermetically sealed system which eliminates the problems associated with mechanisms operating in water. It consists of a pressure shell, four sets of external stationary magnet coils (hold, grip, lift, pull down) and one internal moving part (armature) that imparts linear motion to a cluster of rods (drive rods).

The drive rods fit loosely in the center of the jack. Applying current to the hold coils causes the rods to adhere to the wall of the pressure shell; the application of current to the grip coils causes the rods to adhere to the bore of the armature. Energizing the lift coil moves the armature to the top end of the chamber and energizing the pull down coil moves the armature to the bottom end of the chamber. Thus, by switching the coils off and on in the proper sequence, the drive rods are moved in steps. If only the hold coil is energized, the rods are held firmly in position. De-energizing all of the coils allows the rods to drop, thus scramming the reactor.

Although the usual step length (about 0.1 in.) is set in assembly by the amount of axial clearance that the armature has in the chamber, the rods may be moved in extra large steps in the down direction and in extra fine steps (about 0.006 in.) in either direction. The large step length is accomplished by dropping and catching the rods with the hold magnet. The small step is accomplished by switching off the lift magnet and letting the cushion washer do the lifting. The cushion washer is a stiff belleville spring which is located at the end of the armature.

The only drawback in the use of this rod drive at Argonne has been the lack of a positive and precise position indicator which is required for experimental work. For reactors which are primarily used for the production of power, simple magnetic position indicators are adequate. For experimental work, some fairly precise magnetic position indicators have been developed recently. One is a simple device which requires several operations to obtain a close reading; another is a complicated one which is easy to read.

SUMMARY

There continues to be no mechanical problems with the jack; consequently there have been no basic changes.

Jacks #24 and #27 have been modified to provide a more durable coil connection. Instead of fastening the ends of the coil wire to a terminal strip, the coils now have nickel terminal posts which are an integral part of the coil.

*A more detailed description is given in ANL-5768.

Jack #24 was modified further to provide a universal control rod drive for pressures up to 2600 psi. Jack #29 H is the high-pressure version. A short model of the pressure shell of Jack 29 H was pressure tested to destruction (See appendix E).

Jack #29 L is designed for lower pressures. The design for lower pressure makes possible the use of coil sleeves which facilitate installation of preassembled coil assemblies. This is especially desirable for below-the-reactor applications. The internal parts of Jack 29 L were slightly modified to minimize the possibility of radioactive dirt collecting in the jack. A special blow-down valve at the bottom is used to remove the dirt that falls thru the drive. Jack #29 L has been built, tested, and will be installed in EBWR.

Five type #27 magnetic jacks have been built and tested; one of these will be installed in ALPR. Parts are on hand for a sixth unit, which is a spare. This drive system is described in detail in appendix B. It was found necessary to increase the chrome plate thickness of Jack #27 rods from 0.002 in. to 0.006 in. This decreases the amount of residual magnetism so that the rod is freer to drop. Residual magnetism is more of a problem with large-diameter hold magnets such as in Jack #27 than with small-diameter hold magnets such as in Jack #29. It was also necessary to increase the thickness of the nonmagnetic sleeves to reduce the unbalanced radial forces on the armature and thereby reduce wear. The test described on page 90 caused a small amount of wear which indicates that there will be practically no wear with the thicker sleeve. Radial forces are more of a problem with a short-length armature such as in Jack #27 than with a long armature such as in Jack #29.

The following is an approximate manufacturing cost breakdown of the EBWR Magnetic Jack (#29 L):

Coils (unpotted)	$ 180		
Coil shells	1000		
Coil assembly and potting	320		
Coils		$1500	
Parts from Rock Island	2540		
Miscellaneous parts and assembly	460		
Mechanical parts		3000	
Jack			$4500
Commutator switch	129		
Switch motor	21		
Rectifiers	74		
Assembly and miscellaneous parts	276		
Power supply			500
Total			$5000

Left diagram labels:

- $31\frac{15}{16}$"
- $46\frac{5}{8}$"
- $114\frac{3}{4}$"
- $7\frac{1}{4}$" SQ.
- $5\frac{9}{16}$" DIA.
- $4\frac{3}{8}$"
- 1.90" DIA.
- 60" TRAVEL
- $3\frac{3}{4}$"

Right diagram labels:

- 72" TRAVEL
- $4\frac{11}{16}$"
- 127 1/4
- $47\frac{1}{8}$"
- $32\frac{7}{16}$"
- 1.9" O.D. PIPE
- 5 9/16" DIA. COIL
- 2.2" O.D. TUBE
- 1 9/16" I.D. TUBE
- 7 1/4" SQ. COIL
- 4.4" O.D. TUBE
- 3 1/2" I.D. TUBE
- 12" DIA. FLANGE
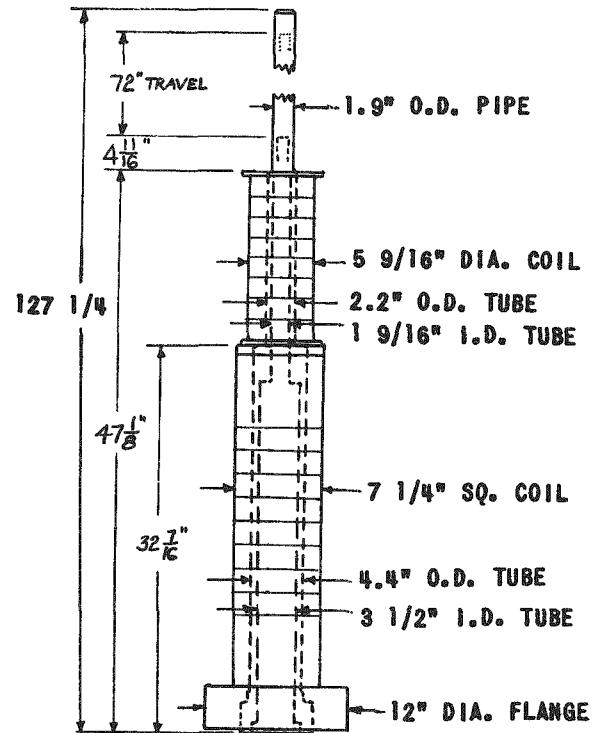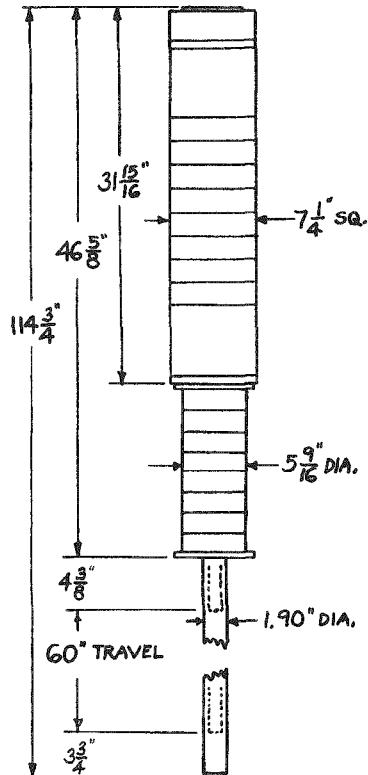
	100°F	350°F
DESIGN PRESSURE P.S.I.	1120	1025
MAXIMUM CAPACITY (f=.45), LBS.	580	490
RATED CAPACITY, LBS.	190	160
POWER FOR HOLDING, WATTS	200	140
POWER FOR MOVING, WATTS	1470	980

LOW PRESSURE
BOTTOM DRIVE
MAGNETIC JACK
(EBWR) (29L)

	100°F	350°F
DESIGN PRESSURE P.S.I.	2800	2600
MAXIMUM CAPACITY(f=.45), LBS.	580	490
RATED CAPACITY, LBS.	190	160
POWER FOR HOLDING, WATTS	200	140
POWER FOR MOVING, WATTS	1470	980

HIGH PRESSURE
TOP DRIVE
MAGNETIC JACK
(29H)
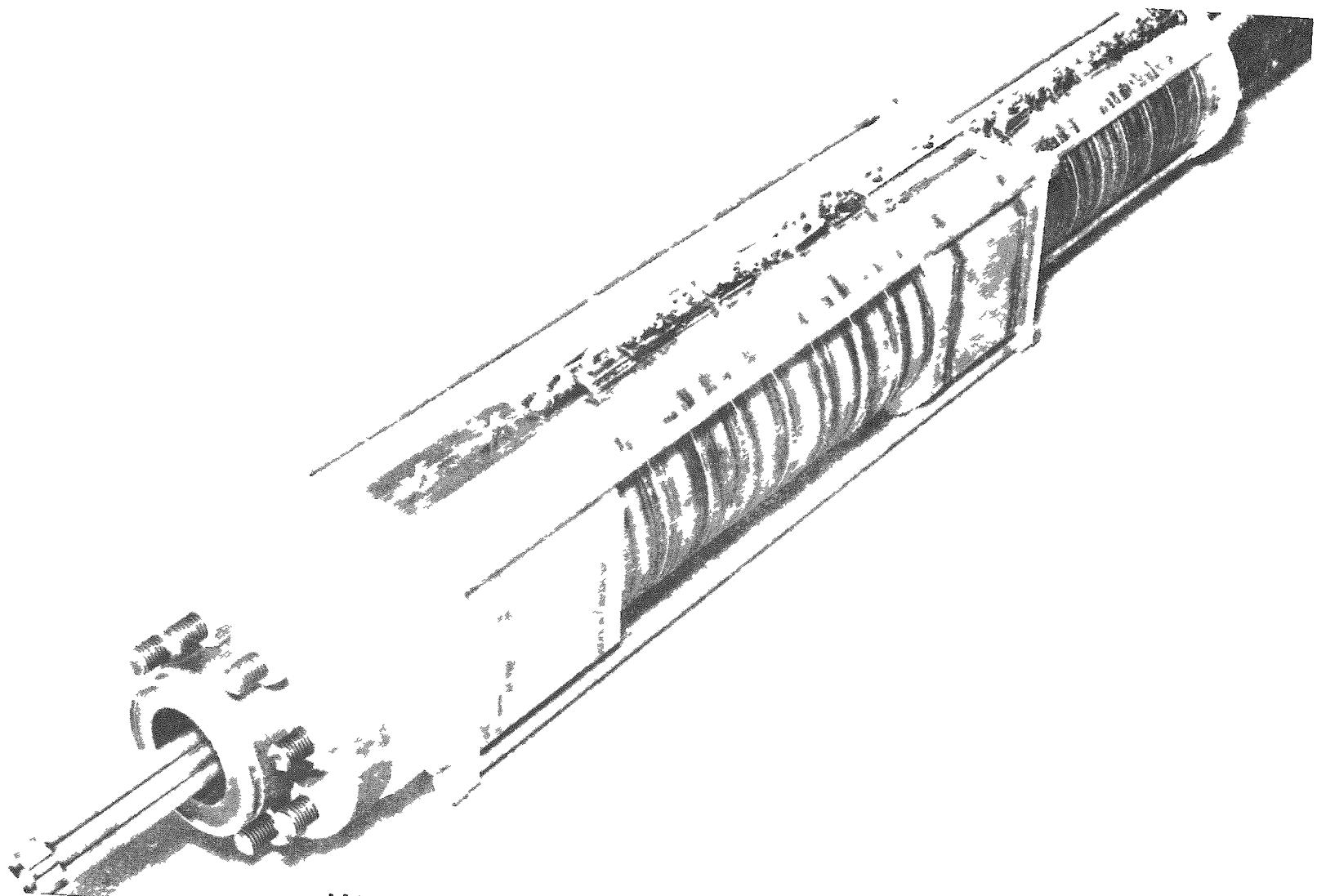
111-7907

EBWR MAGNETIC JACK (29L)

The control system has been simplified and designed so that existing reactor controls may be used to control the magnetic jack (see page 15 and appendix B). A new feature is a switch located on the control panel for switching from the usual coarse step of about 0.1 in. to a fine step of about 0.006 in.

The power supply has been simplified and made smaller by using a commutator-type switch instead of the cam-operated microswitches and relays, and by using silicon rectifiers (see page 16) instead of selenium rectifiers (appendix B). The silicon rectifiers are more efficient, smaller and cheaper but not quite as reliable as the selenium rectifiers. The control and power supply fit on a 17 x 10 in. chassis and a 19 x 7 in. panel (see page 15).

Three new variations of the magnetic position indicator were built and successfully tested (see appendix D). One is an automatic version of the position indicator described in ANL-5768. The rod position is read directly on a meter which has dial numbers which automatically change when the rod moves from one 3-in. coil range to the next. The second one gives linear indication on a long-scale DC milliammeter. This is accomplished by special spacing of the coils. The third one consists of two selector switches, a meter and a series of coils with one-inch spacing. The first selector switch reads tens of inches, the second selector switch reads inches and the meter reads tenths of inches. Another meter is used across the series of coils to give the approximate position.

TEST RESULTS

Test results, in addition to those shown below, are listed in the Table of Contents.

The curves on page 17 show decreased lift slippage as the effect of removing the last trace of lubrication and of forming an iron oxide film. This occurs after a new jack is run for a while. This test was made on the EBWR jack (#29 L) at room temperature and with water open to the atmosphere. The measurements were taken while the jack was cold, but, during most of the operating time, the jack was at about 180F.

A series of tests were made to determine the equilibrium temperatures of the drive with various cooling methods. The tests were made with the ALPR jack (#27-2) mounted on a vessel containing water at 422°F (300 psig). To simulate a boiling reactor, the top half of the vessel contained saturated steam. To simulate a pressurized reactor, the water level was raised so that there was little or no steam space. A truly pressurized system might give slightly lower drive temperatures. The ambient temperature was 80°F. The cooling water was 0.10 gallons per minute of 100°F water injected at the flange just below the drive. The hold coils were turned

III-7505

FRONT VIEW

III-7510
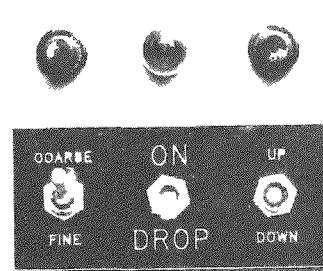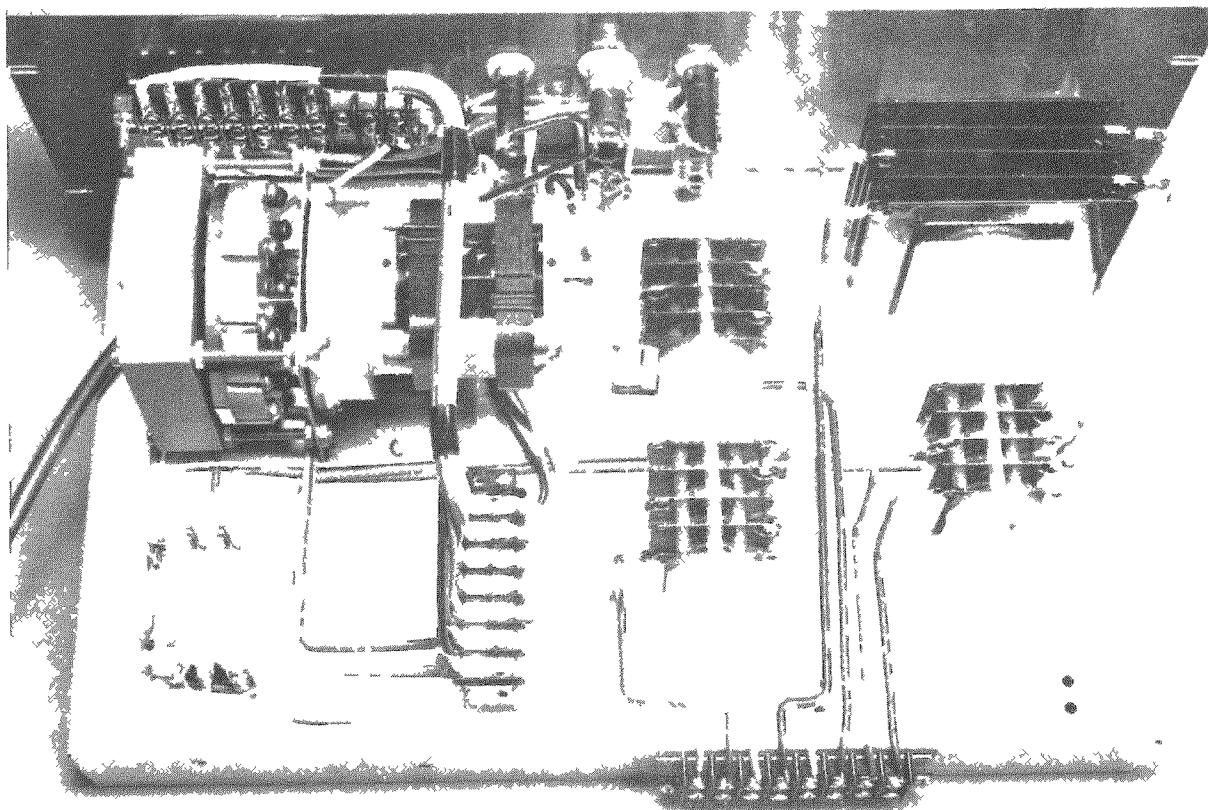
BACK VIEW

CONTROL AND POWER SUPPLY
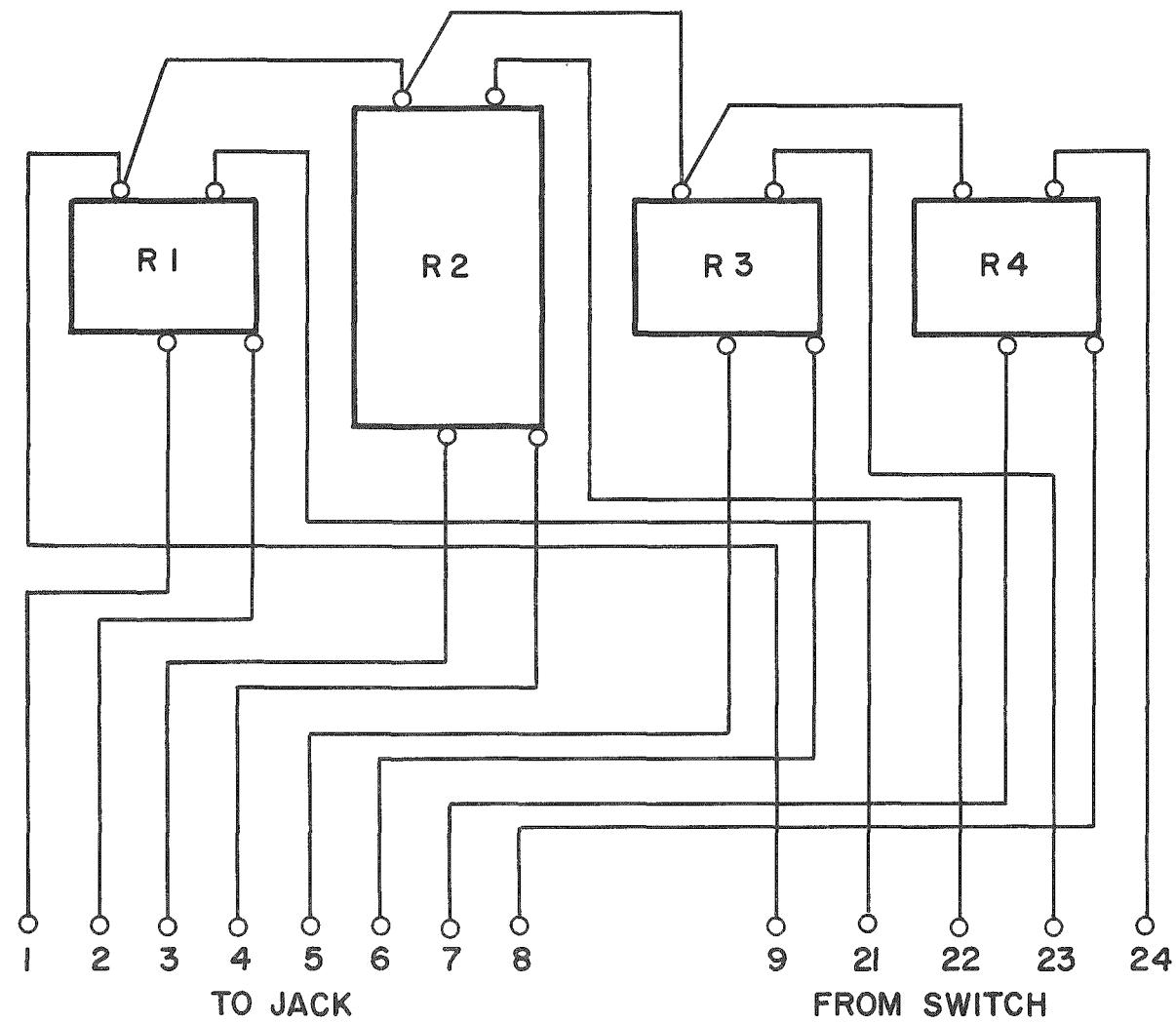
R1, R3, R4	SILICON RECTIFIER, 5A., 125 VDC, BRIDGE
R2	SILICON RECTIFIER, 15 A., 125 VDC, BRIDGE

RECTIFIER (SILICON)
BACK AND TOP VIEW
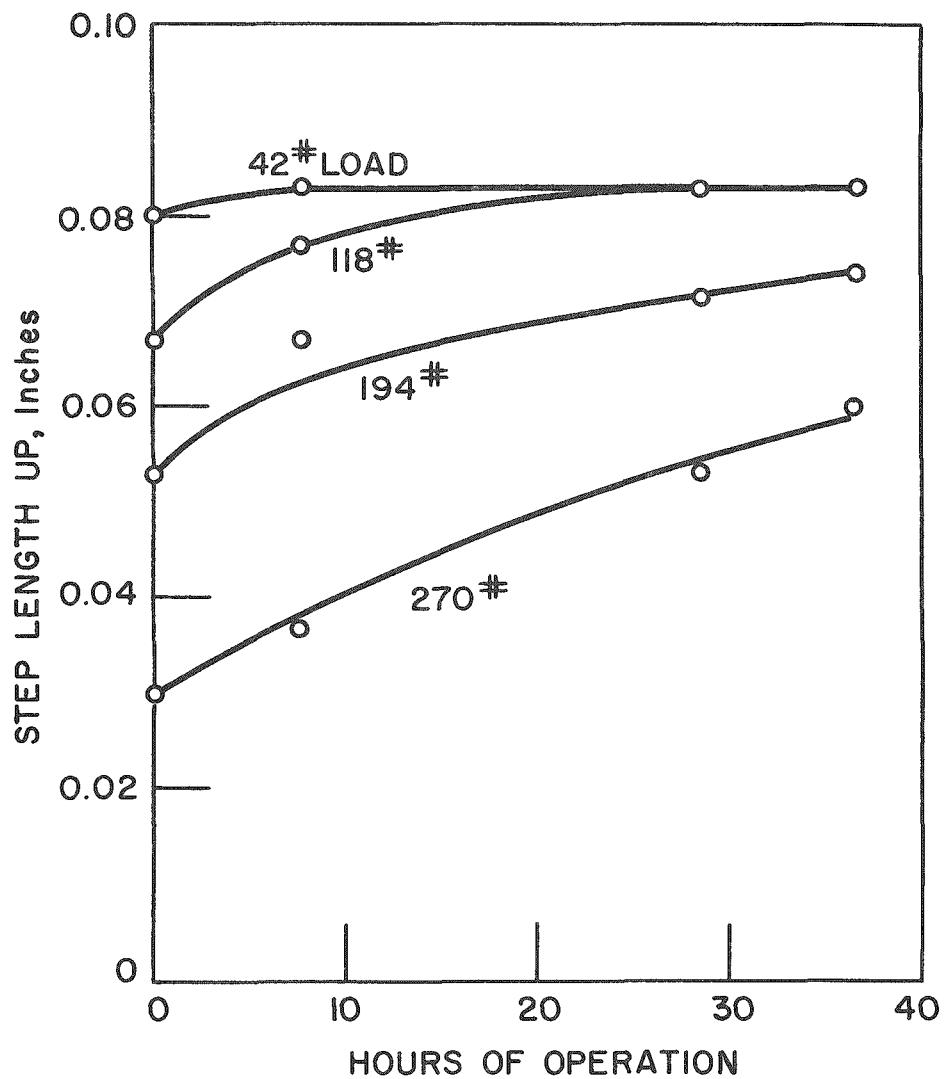
TEST OF EBWR MAGNETIC JACK (29L)

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on during the test. The thin flange consisted of the flange shown on page 62 with a water inlet hole added and with a sleeve which reduced the $1\frac{3}{4}$ in. bore to a $1\frac{1}{2}$ in. bore. This sleeve gave a smaller clearance for the drive rod and thus kept water in and steam out of the jack with a moderate amount of cooling. The insulating flange is shown below.

| | | Temperatures, °F | | | | | | | |
| | Cooling | Boiling | | | | Pressurized | | | |
		Bottom of Jack	Hold Coils (Bottom)	Top of Jack	Position Indicator (Pipe)	Bottom of Jack	Hold Coils (Bottom)	Top of Jack	Position Indicator (Pipe)
Thin Flange	Natural	395	380	345	365				
	Fan	365	305	295	330				
	Water	350	370	345	370	240	235	110	90
	Both	305	290	150	130	200	170	90	80
Insulating Flange	Natural	390	370	360	355	280	280	150	125
	Fan	330	295	305	270	175	175	90	80
	Water	310	360	360	355				
	Both	245	275	120	90				
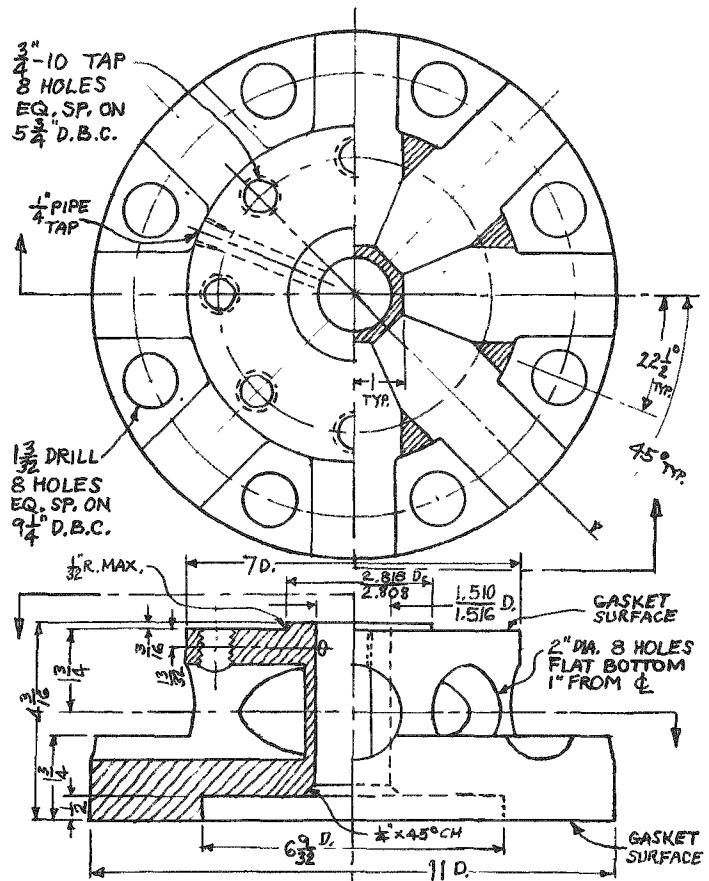
304 SST INSULATING FLANGE

DISCUSSION

The Grooved Rod Type Magnetic Jack vs the Smooth Rod Type

Size

Both types would be of the same diameter since the load capacity is limited by the diameter of the lift magnet. Although the grooved rod could be a little smaller than the smooth rod cluster, this would make very little difference in the outside diameter of the jack. The smooth rod type is about twice as long as the grooved rod type and, if the gripping strength must be stronger than the lifting strength, the difference is somewhat greater.

Cost

The cost of the grooved rod type is probably a little more since it has two precision gripper mechanisms that must not wear and a long rod with many grooves, while the coils and the pressure shell are less costly.

Position Indication

The grooved rod type has the advantage in this respect since the precise position may be obtained by counting steps, assuming that it does not miss a step.

Movement

The grooved rod type gives a precise step length while the smooth rod type step length is about 3% larger in the down direction than in the up direction and varies about 2% from other causes. The smooth rod has the advantage of being able to go down in large steps by the drop and catch method and being able to go up or down with an extra fine step of about 0.006 in., as well as the standard step.

Slippage

The grooved rod type will not slip under any conditions; however, overloading will cause serious damage. This is not likely in a stationary application except if the rod is gripped while it is dropping. The smooth rod type will slip only if the load capacity is exceeded and this does no damage.

<u>Life</u>

In the grooved rod type wear is slight because the gripper parts do not carry a load when they are moving, but the allowable wear is quite low. The smooth rod type has a longer life since a great deal of wear may be tolerated.

<u>Reliability</u>

The smooth rod type has only one moving part and is not affected by dirt, corrosion and wear. The grooved rod type is not recommended for a below the reactor application where dirt is likely to be present.

MAGNETIC JACK COMPARISON CHART

	Impor-tance Factor, A	Grooved Rod Type		Smooth Rod Type	
		Rating Factor, B	Score, A x B	Rating Factor, B	Score, A x B
Small diameter	2	2	4	2	4
Short length	2	4	8	2	4
Low cost	2	3	6	4	8
Good position indication	3	4	12	0	0
Precise step length	1	4	4	0	0
More than one step length	1	0	0	4	4
No slippage	3	4	12	0	0
No damage from overload	4	0	0	4	16
Wear resistance	4	2	8	4	16
Dirt resistance	3	0	0	4	12
Corrosion resistance	3	2	6	4	12
			60		76

Thick vs Thin Pressure Shells for a Magnetic Jack

The idea of using a thin pressure shell for a magnetic jack is a carryover from the canned rotor motors the only real advantage being that it avoids the use of nonmagnetic sections, which require quite a few welds. The welding problem has been minimized by a new weld material (see Appendix E) and by the fact that a thick pressure shell has low stresses due to pressure.

Actually, a thick pressure shell is an advantage for the magnetic jack if it is provided with magnetic and nonmagnetic sections along its length. These magnetic sections, if they are thick enough, spread out the magnetic flux which is transmitted from the shell to the armature. It is important to spread out this magnetic flux since the radial forces on the armature are thereby reduced.

Another way of reducing the unbalanced radial force is by reducing the radial clearance of the armature, but this makes the device more sensitive to wear, dirt, corrosion and manufacturing errors. Use of a moderately thick pressure shell does not increase the overall diameter of the jack since spreading out the flux reduces the ampere turns required to transmit the flux, thus reducing the size of the coil.

Cooling vs High-temperature Operation

There is no cooling problem in the case of a control rod drive located below the reactor vessel since there is no heat transfer by convection, and the heat brought down by conduction is removed by the surrounding air in less than a foot of thimble length   The heat produced by the magnet coils is also removed simply by the surrounding air with a temperature rise of 135°F for the hold coils (#29).

In the case of a drive located above a boiling reactor, special provisions are necessary in order to keep the drive cooler than the reactor. This may be done with a device for reducing the heat transfer by conduction and convection, with about 0.1 gpm of cooling water and with some fan cooling (see page 18). The cooling water is fed in just below the drive, thus it does not interfere with the removal of the coils. Cooling of a drive on a pressurized reactor is less of a problem.

The system is simplified if no special cooling is required and there is less danger of failure if the drive does not depend on a flow of cooling water and a fan.

On the other hand, coils that are designed to operate at high temperatures are expensive and they must be larger because their resistance is higher at high temperatures.

In any case, the surrounding air must be cool enough to remove the electrical heat or the coils will become even hotter than the reactor.

Future Development

Although Argonne is not expecting to continue development work on the magnetic jack, there are several parts of the system that could be developed further. These are listed below:

1. mild steel or Armco iron magnet parts with Neo-chrome plating or other protective coating;

2. conforming-type drive rods with re-entry flux path using long coils such as those used on jack #29;

3. conforming-type drive rods made from extruded-to-size stainless steel;

4. better coil-sequencing switch;

5. metal mounting brackets on the position-indicator coils;

6. digital position indicator.

High-speed Operation

Using the simple circuit, switching and magnets shown in this report, three inches per minute is about as fast as the jack will lift a rod. This is adequate for most applications, especially if more than one rod is moved at a time. Other laboratories have obtained substantially higher speeds. Atomics International mentions 14 inches per minute with a 300-pound load and 25 inches per minute with a 50-pound load in their report NAA-SR-3350, page IV-6.

The magnet action limits the speed more than the mechanical action. This is indicated by the results of speed calculations which consider only the inertia effects on the moving parts. The maximum theoretical speed for lifting a 200-pound rod assembly is 285 inches per minute, assuming a 30-pound armature, a 600-pound grip and lift force, and a 0.1-inch step length

APPENDIX A

CALCULATIONS
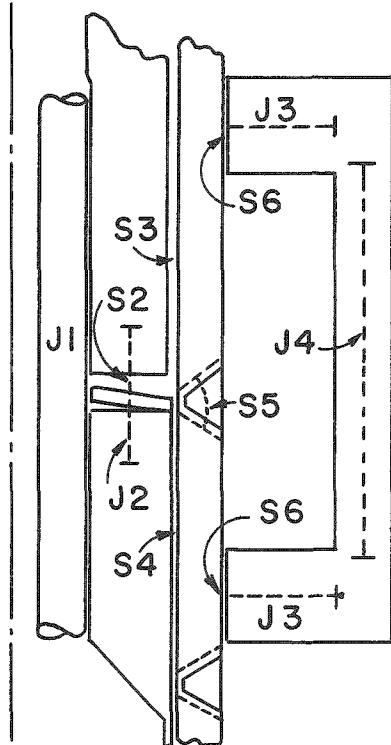
M = Material

B = Flux density, kilolines per in.^{2}

H = Field intensity, amp turns per in.

E = Magnetomotive force, amp turns

I = Flux, kilolines

A = Area, in.^{2}

L = Length, in.

Subscript "J" is used for magnetic material

Subscript "S" is used for air gaps or other nonmagnetic material

MAGNET CALCULATIONS

MAGNET CALCULATIONS						
M_{J2}		430 SST	L_{S5}		.4	
			A_{S5}		8.1	
B_{J2}	Assume	100	I_{S5}	$\dfrac{E_{S5} \times A_{S5}}{313 \times L_{S5}}$	398	
H_{J2}	B-H curve	620				
L_{J2}		1.25	L_{S6}		.005	
E_{J2}	$H_{J2} \times L_{J2}$	775	A_{S6}		13.4	
			I_{S6}	$I_{S5} + I_{S5}$	1248	
A_{J2}		6.87				
I_{J2}	$B_{J2} \times A_{J2}$	687	E_{S6}	$\dfrac{313 \times L_{S6} \times I_{S6}}{A_{S6}}$	146	
M_{J1}		416 SST				
			A_{J3}		16	
B_{J1}	Max. B	138	L_{J3}		1.2	
A_{J1}		1.18				
I_{J1}	$B_{J1} \times A_{J1}$	163	B_{J3}	I_{S6} A_{J3}	78	
			M_{J3}		Mild Steel	
L_{S2}	.003+.150	.153				
E_{S2}	$\dfrac{313 \times L_{S2} \times I_{J2}}{A_{J2}}$	4790	H_{J3}	B-H curve	29	
I_{S3}	$I_{J2} - I_{J1}$	850	E_{J3}	$H_{J3} \times L_{J3}$	35	
			A_{J4}		12.5	
L_{S3}		.0625	L_{J4}		4.2	
A_{S3}		34.4				
E_{S3}	$\dfrac{313 \times L_{S3} \times I_{S3}}{A_{S3}}$	483	B_{J4}	I_{S6} A_{J4}	100	
			M_{J4}		Mild Steel	
L_{S4}		.0125	H_{J4}	B-H curve	86	
A_{S4}		30.0				
E_{S4}	$\dfrac{313 \times L_{S4} \times I_{S3}}{A_{S4}}$	111	E_{J4}	$H_{J4} \times L_{J4}$	361	
E_{S5}	$E_{J2} + E_{S2} + E_{S3} + E_{S4}$	6159	E_c	$E_{S5} + 2(E_{S6} + E_{J3}) + E_{J4}$	6882	

COIL POWER			
n		turns	1290
i	E_c n	amps	5.33
	temp.	°C	180
r	res.	ohms	18.6
e	i x r	volts	100
	e x i	watts	533

PULL CAPACITY		
F	$\dfrac{B_{J2}^2 \times A_{J2}}{72.1}$	954 lbs.

MOVE MAGNET

Jack #29H

MAGNET CALCULATIONS					
M_{J1}		416 SST	A_{S5}		4.57
B_{J1}	Assume	100	L_{S5}		.005
H_{J1}	B-H curve	320	E_{S5}	$\dfrac{313 \times L_{S5} \times I_{S5}}{A_{S5}}$	102
L_{J1}		.688	I_{J3}	I_{S5}	298
E_{J1}	$H_{J1} \times L_{J1}$	220	A_{J3}		4.90
A_{J1}		1.18	B_{J3}	I_{J3}/A_{J3}	61
I_{J1}	$B_{J1} \times A_{J1}$	118	M_{J3}		Mild Steel
L_{S1}	.002+.00375	.00575	H_{J3}	B-H curve	16
A_{S1}	$A_{J1} \times 2.5$	2.95	L_{J3}		.28
I_{S1}	I_{J1}	118	E_{J3}	$H_{J3} \times L_{J3}$	4.5
E_{S1}	$\dfrac{313 \times L_{S1} \times I_{S1}}{A_{S1}}$	72.0	E_{S6}	$E_{S4}+2E_{S5}+2E_{J3}$	1485
M_{J2}		430 SST	L_{S6}		1.344
B_{J2}	Max. B	138	A_{S6}		9.12
A_{J2}		.488	I_{S6}	$\dfrac{E_{S6} \times A_{S6}}{313 \times L_{S6}}$	32
I_{J2}	$B_{J2} \times A_{J2}$	67.3	M_{J4}		Mild Steel
E_{S2}	$E_{J1}+2E_{S1}$	364	I_{J4}	$I_{J3}+I_{S6}$	330
A_{S2}		6.54	L_{J4}		.875
L_{S2}		.25	A_{J4}		5.49
I_{S2}	$\dfrac{E_{S2} \times A_{S2}}{313 \times L_{S2}}$	30.4	B_{J4}	I_{J4}/A_{J4}	60
I_{S3}	$I_{J1}+I_{J2}+I_{S2}$	215.7	H_{J4}	B-H curve	16
L_{S3}		.0625	E_{J4}	$H_{J4} \times L_{J4}$	14
A_{S3}		9.29	I_{J5}	I_{J4}	330
E_{S3}	$\dfrac{313 \times L_{S3} \times I_{S3}}{A_{S3}}$	454	L_{J5}		1.64
E_{S4}	$E_{S2}+2E_{S3}$	1272	A_{J5}		5.5
L_{S4}		.4	B_{J5}	I_{J5}/A_{J5}	60
A_{S4}		8.1	M_{J5}		Mild Steel
I_{S4}	$\dfrac{E_{S4} \times A_{S4}}{313 \times .4}$	82	H_{J5}		16
I_{S5}	$I_{S3}+I_{S4}$	298	E_{J5}	$H_{J5} \times L_{J5}$	26
			E_c	$E_{S6}+2E_{J4}+E_{J5}$	1539

COIL POWER			
n		Turns	430
i	E_c/n	amps	3.58
		Temp. °C	180
r		Res. ohms	6.28
e	i x r	volts	22.5
	e x i x 8	watts (8 coils)	644

GRIP CAPACITY		
B_{S1}	I_{S1}/A_{S1}	40.0
N	Mag. circuits	8
f	Coefficient of Friction	.45
F	$\dfrac{B_{S1}^{2} A_{S1} N\, f}{36.05}$	470 lbs.

GRIP MAGNET

Jack # 29 H

MAGNET CALCULATIONS

M_{J1}		416 SST
B_{J1}	Assume	100
H_{J1}	B-H curve	320
L_{J1}		.625
E_{J1}	$H_{J1} \times L_{J1}$	200
A_{J1}		1.18
I_{J1}	$B_{J1} \times A_{J1}$	118
L_{S1}	.002+.00375	.00575
A_{S1}	$A_{J1} \times 2.5$	2.95
E_{S1}	$\dfrac{313 \times L_{S1} \times I_{J1}}{A_{S1}}$	72.0
E_{S2}	$E_{J1} + 2 \times E_{S1}$	344
A_{S2}		1.13
L_{S2}		.25
I_{S2}	$\dfrac{E_{S2} \times A_{S2}}{313 \times L_{S2}}$	5.0
I_{S3}	$I_{J1} + I_{S2}$	123
A_{S3}		4.22
L_{S3}		.0075
E_{S3}	$\dfrac{313 \times L_{S3} \times I_{S3}}{A_{S3}}$	68
M_{J2}		Mild Steel
B_{J2}	Max. B	138
A_{J2}		.29
I_{J2}	$B_{J2} \times A_{J2}$	40
E_{S4}	$E_{S2} + 2E_{S3}$	480
L_{S4}		.6
A_{S4}		2.5
I_{S4}	$\dfrac{E_{S4} \times A_{S4}}{313 \times L_{S4}}$	6.4

I_{S5}	$I_{S3} + I_{J2} + I_{S4}$	169
A_{S5}		2.3
L_{S5}		.005
E_{S5}	$\dfrac{313 \times L_{S5} \times I_{S5}}{A_{S5}}$	115
A_{J3}		2.6
B_{J3}	I_{S5}/A_{J3}	65
M_{J3}		Mild Steel
H_{J3}	B-H curve	19
L_{J3}		.37
E_{J3}	$H_{J3} \times L_{J3}$	7
E_{S6}	$E_{S4} + 2(E_{S5} + E_{J3})$	724
L_{S6}		1.094
A_{S6}		7.07
I_{S6}	$\dfrac{E_{S6} \times A_{S6}}{313 \times L_{S6}}$	15.0
M_{J4}		Mild Steel
I_{J4}	$I_{S5} + I_{S6}$	184
L_{J4}		1.10
A_{J4}		3.5
B_{J4}	I_{J4}/A_{J4}	53
H_{J4}	B-H curve	12.3
E_{J4}	$H_{J4} \times L_{J4}$	13.5
M_{J5}		Mild Steel
L_{J5}		1.39
A_{J5}		4.0
B_{J5}	I_{J4}/A_{J5}	46
H_{J5}	B-H curve	10
E_{J5}	$H_{J5} \times L_{J5}$	14
E_c	$E_{S6} + 2E_{J4} + E_{J5}$	765

COIL POWER

n		Turns	600
i	E_c/n	amps	1.28
		temp. °C	180
r	res.	ohms	9.18
e	i x r	volts	11.75
	e x i x 8	watts (8 coils)	120

HOLD CAPACITY

B_{S1} N	I_{J1}/A_{S1} Mag. circuits	40.0
		8
f	Coefficient of Friction	.45
F	$\dfrac{B_{S1}^2 A_{S1}\, N\, f}{36.05}$	470 lbs.

HOLD MAGNET
Jack #29L

B_S	Assume	55
A_S		1.33
I_S	$B_S \times A_S$	73.1
L_S		.006
E_S	$313 \times L_S \times B_S$	103
L_{J2}		.0547
A_{J2}		1.37
B_{J2}	I_{J2}/A_{J2}	53.4
M_{J2}		405 SST
H_{J2}	B-H curve	38
E_{J2}	$H_{J2} \times L_{J2}$	2.1
L_{J1}		.195
A_{J1}		1.334
B_{J1}	I_S/A_{J1}	54.8
M_{J1}		17-4 PH SST
H_{J1}	B-H curve	280
E_{J1}	$H_{J1} \times L_{J1}$	54.5
E_{S1}	$E_S + E_{J2} + E_{J1}$	159.6
A_{S1}		1.03
L_{S1}		.086
I_{S1}	$\dfrac{E_{S1} \times A_{S1}}{313 \times L_{S1}}$	6.1
I_J	$I_S + I_{S1}$	79.1
B_J	I_J/A_{J1}	59.3
M_J		17-4 PH SST
H_J	B-H curve	350
L_J		.328
E_J	$H_J \times L_J$	115
L_{J3}		.414
A_{J3}		1.80
B_{J3}	I_J/A_{J3}	44.0
M_{J3}		405 SST
H_{J3}	B-H curve	32
E_{J3}	$H_{J3} \times L_{J3}$	13.2

E_{S2}	$E_J + 2E_{S1} + 2E_{J3}$		460
L_{S2}			.437
A_{S2}			7.18
I_{S2}	$\dfrac{E_{S2} \times A_{S2}}{313 \times L_{S2}}$		24.1
I_{J4}	$I_J + I_{S2}$		103.2
L_{J4}			.469
A_{J4}			2.59
B_{J4}	I_{J4}/A_{J4}		40.3
M_{J4}			405 SST
H_{J4}	B-H curve		30
E_{J4}	$H_{J4} \times L_{J4}$		14.1
E_{S3}	$E_{S2} + 2E_{J4}$		488
L_{S3}			.25
A_{S3}			1.84
I_{S3}	$\dfrac{E_{S3} \times A_{S3}}{313 \times L_{S3}}$		11.5
L_{S4}			.125
A_{S4}			1.38
I_{S4}	$\dfrac{E_{S3} \times A_{S4}}{313 \times L_{S4}}$		17.2
I_{S5}	$I_{J4} + I_{S3} + I_{S4}$		131.9

		GRIP	HOLD
L_{S5}		.045	.0075
A_{S5}		4.87	5.10
E_{S5}	$\dfrac{313 \times L_{S5} \times I_{S5}}{A_{S5}}$	381	60.7
E_{S6}	$E_{S3} + 2E_{S5}$	1250	609
L_{S6}		.25	.25
A_{S6}		1.16	1.16
I_{S6}	$\dfrac{E_{S6} \times A_{S6}}{313 \times L_{S6}}$	18.5	9.0
I_{S7}	$I_{S5} + I_{S6}$	150.4	140.9
L_{S7}		.008	.008
A_{S7}		3.7	3.7
E_{S7}	$\dfrac{313 \times L_{S7} \times I_{S7}}{A_{S7}}$	102	95.2

		GRIP	HOLD
E_{S8}	$E_{S6} + 2E_{S7}$	1454	799
L_{S8}		.37	.37
A_{S8}		3.1	3.1
I_{S8}	$\dfrac{E_{S8} \times A_{S8}}{313 \times L_{S8}}$	39.0	21.4
I_{J5}	$I_{S7} + I_{S8}$	189.4	162.4
L_{J5}		.25	.25
A_{J5}		2.01	2.01
B_{J5}	I_{J5}/A_{J5}	94.3	80.7
M_{J5}		Mild Steel	Mild Steel
H_{J5}	B-H curve	60	32
E_{J5}	$H_{J5} \times L_{J5}$	15	8
E_{S9}	$E_{S8} + 2E_{J5}$	1484	815
L_{S9}		.669	.669
A_{S9}		11.8	11.8
I_{S9}	$\dfrac{E_{S9} \times A_{S9}}{313 \times L_{S9}}$	83.5	45.9
I_{J6}	$I_{J5} + I_{S9}$	273	208
L_{J6}		1.1	1.1
A_{J6}		2.59	2.59
B_{J6}	I_{J6}/A_{J6}	105	80.5
M_{J6}		Mild Steel	Mild Steel
H_{J6}	B-H curve	130	32
E_{J6}	$H_{J6} \times L_{J6}$	143	35
L_{J7}		.70	.70
A_{J7}		3.1	3.1
B_{J7}	I_{J6}/A_{J7}	88	67
M_{J7}		Mild Steel	Mild Steel
H_{J7}	B-H curve	44	20
E_{J7}	$H_{J7} \times L_{J7}$	30.8	14
E_c	$E_{S9} + 2E_{J6} + E_{J7}$	1775	899

GRIP AND HOLD MAGNETIC CALCULATIONS
Jack #27
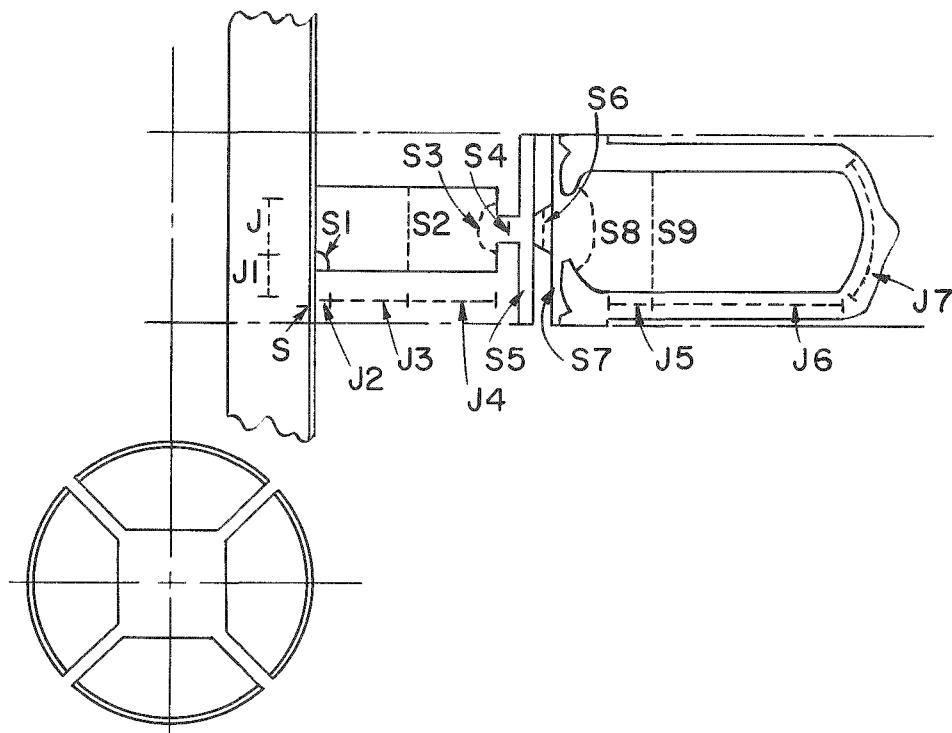
COIL POWER

			GRIP	HOLD
n		Turns	300	300
i	E_c/n	amps	5.91	3.00
	Temp	°C	180	180
r	Res.	ohms	4.73	4.73
e	i x r	volts	28.0	14.2
	e x i x 8	watts		
		(8 coils)	1330	340

GRIP OR HOLD
CAPACITY

N	Mag. circuits	8
f	Coefficient of Friction	.45
F	$\dfrac{B_S^2 x A_S x N x f}{36.05}$	401

Water Dash Pot Design

One of the functions of a control rod in a nuclear reactor is to shut the reactor off quickly in case of an emergency. This is done by a fast insertion of the control rod into the reactor core, usually by gravity. A dash pot is one means of stopping the rod at the end of its travel. The design of such a dash pot is the subject of this paper.

The dash pot piston is a part of the control rod assembly and the dash pot cylinder is stationary. A self-contained dash pot using a return spring is not used because of the possibility of the rod operating while the dash pot is stuck closed.

The piston, as it travels down through the pipe before entering the dash pot cylinder, limits the speed of insertion without delaying the initial movement of the rod to any measurable extent.

The clearance between the piston and the cylinder is used as the orifice and is made to decrease toward the end of the travel by tapering the piston or the cylinder or both. A taper with a certain contour will provide a constant deceleration. This would give the ideal action; however, a straight taper is more economical and is sufficient for most applications. The clearance at the beginning of the travel is calculated to give an initial force equal to the average force. This gives the smallest peak force, which occurs near the center of the travel, and is equal to 1.3 times the average force.

The minimum clearance (at the end of the travel) is a compromise between a clearance that is large enough to prevent trouble from dirt and corrosion and a clearance that is small enough to slow the rod down to a point where the final impact is small. This compromise is no problem if the diameter of the piston is large enough. To minimize the final velocity for a given minimum clearance, the last 10% of length is not tapered.

The following example of calculations is similar to that used to calculate the internal dash pot that has been in operation on EBWR with the linear seal drive.

The following method is a convenient way of calculating fluid flow The orifice formula was derived from the general law of flow: $V = (2gh)^{1/2}$. The leakage formula was derived from the stuffing box leakage formula given in Marks' Mechanical Engineers' Handbook.

Flow through annular clearances

orifice formula for large clearances:

$$Q = 0.0873 \; K \; C \; D \; (P/B)^{1/2} \text{ for any fluid}$$
$$Q = 0.4 \; C \; D \; P^{1/2} \text{ for } 100°F \text{ water and } K = 0.87$$

leakage formula for small clearances:

$$Q = 0.0018 \; C^3 \; D \; P/M \; L \text{ for any fluid}$$
$$Q = 0.00265 \; C^3 \; D \; P/L \text{ for } 100°F \text{ water}$$

Use the formula which gives the smaller Q.

Q = flow in cubic inches per second
C = radial clearance in mils (inch/1000)
D = mean diameter of clearance in inches
P = pressure in pounds per square inch
L = length of clearance in inches
M = absolute viscosity of fluid in centipoises
B = density of fluid in pounds per cubic inch
K = discharge coefficient

For this example the following parameters are assumed:

W	weight in air, lb	= 234
W_1	buoyancy (half submerged), lb	= 14
W_2	friction (estimated), lb	= 10
F_1	load, lb = $W - W_1 - W_2$ = 234 - 14 - 10	= 210
D	piston diameter, in.	= 3.568
A	piston area, in.	= 10.0
S	dash pot length (total), in.	= 3
L_1	dash pot length (tapered portion), in.	= 2.75
C_4	final dash pot radial clearance (minimum), mils	= 10

If the velocity at which the piston enters the dash pot is governed by the retarding effect of the piston displacing water in a pipe, the energy to be absorbed by the dash pot may be calculated as follows:

J	pipe inside diameter, in.	= 3.826
P_1	pressure, psi = F_1/A = 210/10.0	= 21.0
C_1	radial clearance, mils = 1000 (J-D) = 1000 (3.826-3.568)	= 129
D_1	clearance mean diameter, in. = $D + (C_1/1000)$ = 3.568 + (129/1000)	= 3.697
	water temperature, °F	= 100

Q flow, in.^{3}/sec $= 0.4\ C_1\ D_1\ (P_1)^{1/2}$

$\quad = (0.4)(129)(3.697)(21.0)^{1/2}$ $\qquad\qquad = 874.4$

V piston velocity, in./sec $= Q/A = 874.4/10.0 \quad = 87.4$

E_1 kinetic energy, in. lb $= W\ V^2/2g$

$\quad = (234)(87.42)/(2)(12)(32.2)$ $\qquad\qquad = 2310$

E_2 potential energy, in. lb $= F_1\ S = (210)(3) \qquad = 630$

E total energy, in. lb $= E_1 + E_2 = 2310 + 630 \quad = 2940$

If the rod is not retarded by hydraulic effects, the energy to be absorbed by the dash pot may be calculated as follows:

S_1 length of rod travel including dash pot, in. (for this example a length is assumed which gives the same energy arrived at by the previous calculation) $= 18.75$

E total energy, in. $= F_1 S_1 = (210)(18.75) \qquad = 2940$

Knowing the energy to be absorbed, the stopping forces may be calculated as follows:

F_2 average force, lb $= E/S = 2940/3 \qquad\qquad = 980$

R maximum over average force ratio $\qquad\qquad = 1.3$

F_3 maximum force, lb $= R\ F_2 = (1.3)(980) \qquad = 1270$

F_4 initial force, lb $= F_2 \qquad\qquad\qquad\qquad = 980$

Using the initial force, the initial dash pot clearance is calculated as follows:

P_2 pressure, psi $= F_4/A = 980/10.0 \qquad\qquad = 98$

D_2 clearance mean diameter (estimated), in. $\qquad = 3.6$

C_2 radial clearance (first try), mils

$\quad = Q/0.4\ D_2(P_2)^{1/2} = 874.4/(0.4)(3.6)(98)^{1/2} \quad = 61.3$

D_3 clearance mean diameter, in.

$\quad = D + (C_2/1000) = 3.568 + (61.3/1000) \qquad = 3.629$

C_3 initial radial clearance, mils

$\quad = Q/0.4\ D_3\ (P_2)^{1/2} = 874.4/(0.4)(3.629)(98)^{1/2} = 60.8$

The impact at the end of the dash pot travel is determined by the final radial clearance and by the spring constant of the parts. The energy which must be dissipated by deflection of the mechanical parts is calculated as follows:

D_4 clearance mean diameter, in. $= D + (C_4/1000)$

$\quad = 3.568 + (10/1000) \qquad\qquad\qquad = 3.578$

Q_2 flow, in.^{3}/sec (orifice formula)

$\quad = 0.4\ C_4 D_4\ (P_1)^{1/2} = (0.4)(10)(3.578)(21.0)^{1/2} \quad = 65.5$

L effective length of clearance, in.

$\quad = S - 0.75\ L_1 \text{ (approx.)} = 3 - (0.75)(2.75) \qquad = 0.94$

Q_3 flow, in.^{3}/sec (leakage formula)

$\quad = 0.00265\ C_4^3\ D_4\ P_1/L$

$\quad = (0.00265)(10^3)(3.578)(21.0)/0.94 \qquad = 212$

Q_4 flow, in.^{3}/sec = smaller of Q_2 and Q_3 = 65.5

V_4 piston velocity, in./sec = Q_4/A

$\quad = 65.5/10.0 \qquad\qquad\qquad\qquad = 6.55$

E_4 kinetic energy, in. lb = $W\ V_4^2/2\ g$

$\quad = (234)(6.552)/(2)(12)(32.2) \qquad = 13.0$

amount of compression of the parts to
give a striking force equal to F_3, in.

$\quad = 2\ E_4/F_3 = (2)(13.0)/1270 \qquad\qquad = 0.0205$

height from which the rod could be
dropped freely to give a striking force
equal to the impact at the end of the
dash pot travel, in. $= E_4/W = 13.0/234 = \quad 0.0555$

The following calculations are not necessary for designing the dash pot but may be used if a force curve is desired. The maximum over average force ratio, R, is obtained from this curve; however, R is close to 1.3 in most cases. The dash pot length is divided into increments the average force of which is estimated and then checked. The correct force is usually obtained after a few tries. The use of about ten increments gives a close enough approximation; thus the only uncertainty in these calculations is the discharge coefficient, K.

The following example shows the calculating of the second and third points of the curve. The first point was calculated on page 30.

	try	1st	2nd	1st	2nd
	increment beginning	0		0.25	
	increment end	0 25		0 50	
S	increment length, in.	0 25		0 25	
C_A	average radial clearance, mils	58 4		53 8	
D_A	average clearance mean diameter, in. $= D + (C_A/1000) = 3\,568 + (C_A\ 1000)$	3.626		3 622	
E_I	initial kinetic energy, in lb $= (E_F$ from previous column)	2310		2107 5	
E_G	energy gained, in. lb $= F_1\ S - 210\ S$	52.5		52.5	
E	total energy, in. lb = $E_I + E_G$	2362 5		2160	
Q	initial flow, in.^{3}/sec = $(Q_F$ from previous column)	874.4		834	
F_A	estimated average force, lb	1000	1020	1070	1085
E_L	energy lost, in lb = $F_A\ S$	250	255	267.5	271
E_F	final energy, in. lb = $E - E_L$	2112.5	2107.5	1892 5	1889
V_F	final velocity in./sec = $(2\ g\ E_F/W)^{1\ 2}$ $= (3\ 3\ E_F)^{1\ 2}$	83 5	83.4	79 1	79 0
Q_F	final flow, in.^{3}/sec = $A\ V_F$ = (10.0) V_F	835	834	791	790
Q_A	average flow, in.^{3}/sec = $(Q + Q_F)\ 2$	854 7	854 2	812.5	812 0
P_A	average pressure, psi = $(Q_A/0.46\ K\ C_A\ D_A)^2 = (Q_A\ 0\ 4\ C_A\ D_A)^2$	102	102	108.8	108.7
F_A	average force, lb = $A\ P_A$ = 10.0 P_A	1020	1020	1088	1087

SAMPLE FORCE CURVE

CONTROL
ROD

PIPE

PISTON

C_1

J

DASH
POT

ROD
DRIVE

F_1

D

C_3

L_1

S

C_4

DASH POT
SCHEMATIC DRAWING
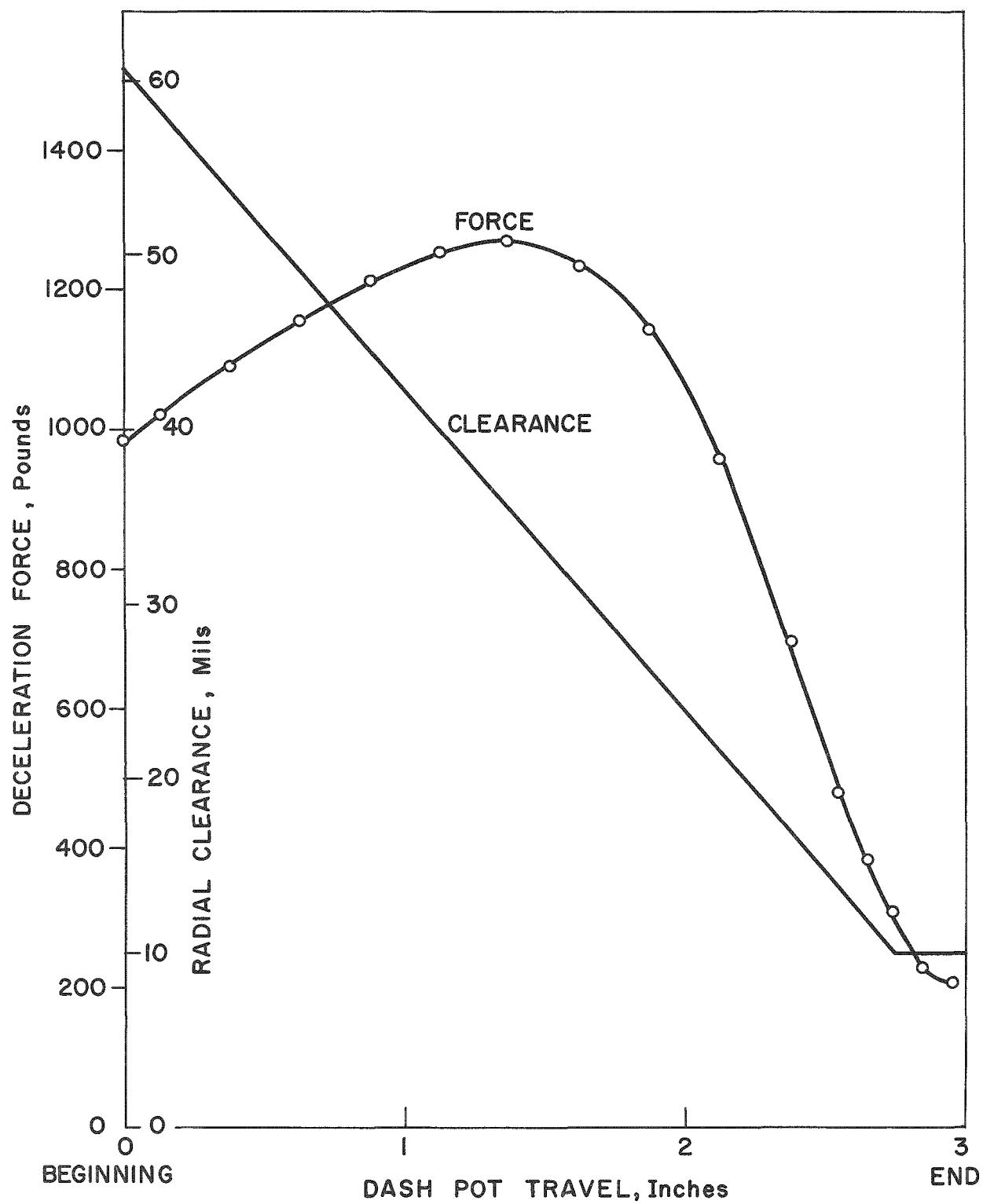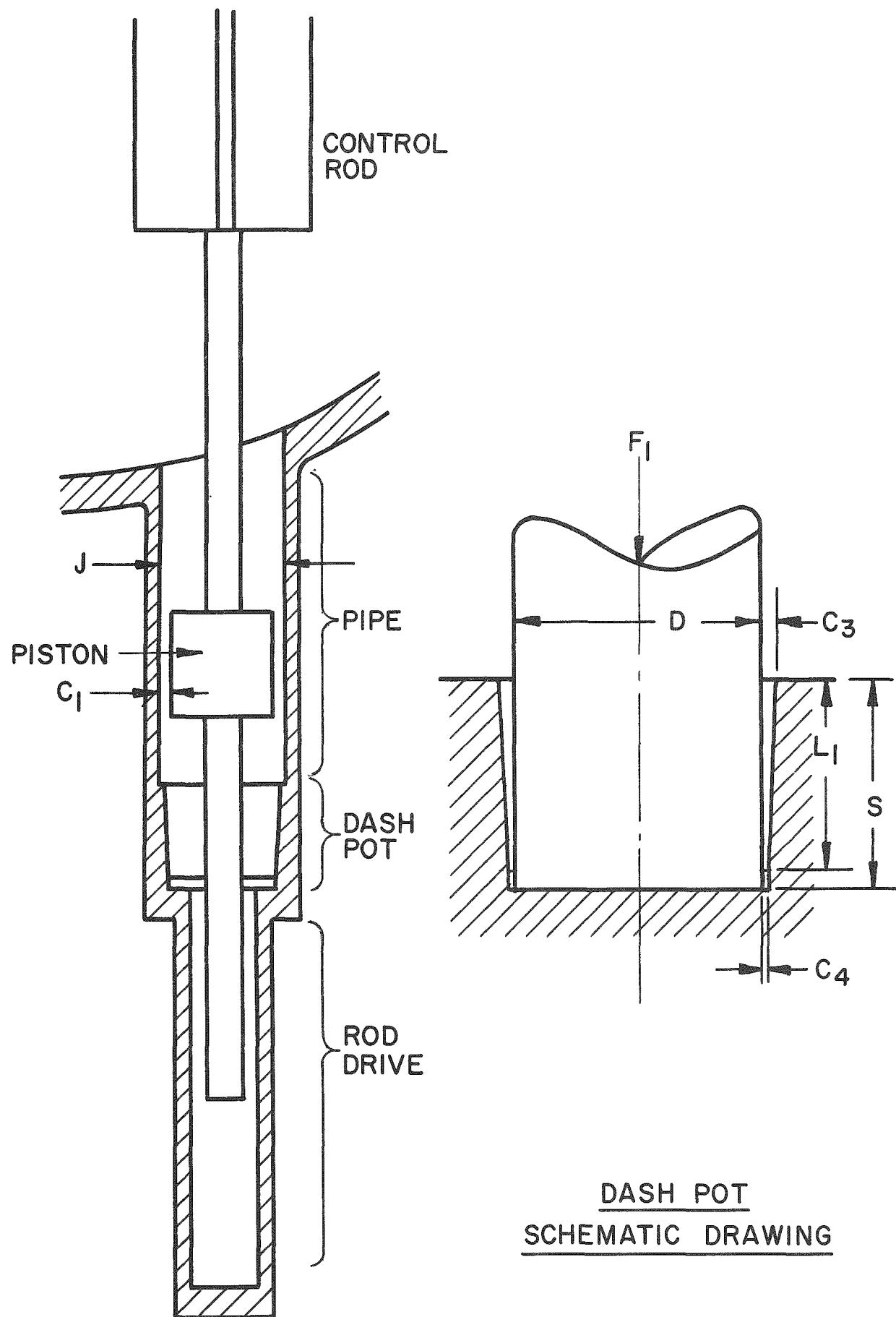
Antigravity-scram Control Rod Drive using the Magnetic Jack

For emergency shutdown of a nuclear reactor by control rods, a force to move the rods must be available under any condition; in the case discussed here, the force must work against gravity. To retain the principal advantage of the magnetic jack the scram device should not use shaft seals or other openings through the reactor vessel. This means that the device must operate in the reactor coolant; therefore, there should be no close-fitting or load-bearing moving parts. Although being required to use an antigravity-scram device complicates the drive somewhat, it has the advantage of balancing the weight of the control rod, thus requiring less load capacity of the drive. This reduces the acceleration and speed of the rod during shutdown, but in most cases this does not matter.

Five Possible Antigravity-scram Methods

Device	Disadvantages
Counterweight	Complicated mechanism; large space.
Negator Spring	One break would cause complete failure; large space.
Hydraulic Cylinder	Depends on unfailing supply of water under pressure.
Compression Spring	Force varies with position; large space.
Tension Spring	One break would cause complete failure; large space; force varies with position.

The force variation of the compression spring device can be reduced by using a larger spring; however, some variation is all right, since the force is least when the rod is being stopped at the end of its travel. The space requirement of the compression spring device can be reduced by using several springs, one inside of another and alternately wound left hand and right hand.

Bottom vs Top Drive using the Magnetic Jack with a
Compression Spring Antigravity-scram

Advantages of Drive at the Bottom of the Reactor	Advantages of Drive at the Top of the Reactor
1. lower temperatures 2. lower building height 3. control rod parts are in compression and therefore cannot fall apart, thus increasing reactivity 4. drive rods are in tension and therefore are less likely to buckle 5. water dash pot may be used 6. no special provisions are needed to keep the reactor heat from the drive 7. no interference at top of reactor	1. less dirt 2. less basement depth 3. if the end of the drive blows off, the control rod will not be forced down by pressure, thus increasing reactivity 4. control rod is pulled thru the reactor during scram and therefore is less likely to jam

Conclusions

An antigravity-scram control rod drive using the magnetic jack is practical. The scram device recommended in this report requires the length of the drive to be increased by two travel lengths. In the case of a reactor having a control rod travel of 81 in., the drive would be 25 ft 2 in. long. The device would fit in a standard 8 in. pipe. The time required to travel the 81 in. during scram would be 2.07 sec.

Helical compression springs, because of their reliability, would be the best type of device for scramming a control rod against gravity.

The scram device should be located between the magnetic jack drive and the control rod so that the scram device does not interfere with the removal of the magnet coils.

In most cases, the drive should be located below the reactor.

Calculations

Control rod drive length:

spring travel	= 81 in.
spring, etc. length	= 81 in.
magnetic jack length	= $54\frac{3}{4}$ in.
magnetic jack travel	= 81 in.
blow down valve length	= $4\frac{1}{4}$ in.

Total length = 302 in. = 25 ft 2 in.

Control rod assembly net weight (lb):

fuel and absorber rod	= 360
seven $\frac{1}{2}$ in. dia. drive rods, 11 ft long	= 51.5
extension rod, $1\frac{1}{2}$ in. pipe 10 ft long	= 27.2
connectors, etc. (estimated)	= 11.3
W	450 lb in air
buoyancy (half submerged)	= -30
	420 lb in boiling water

pressure drop across core	=	2 5 psi
cross-sectional area of rod	=	18.5 in.^{2}
pressure drop force = (2.5)(18.5)	=	-46.2 lb
outlet jet reaction (estimated)	=	+16.2 lb
		-30
		390 lb net weight

Compression spring forces:

coil housing I.D. $= 7.98$ in.
solid length of active coils $= 70$ in.
maximum stress in wire $= 50{,}000$ psi
diametral clearances $= \frac{1}{16}$ in.
number of springs $= 7$

mean dia.	wire dia.	max. load	active coils	lb inch	defl., in.	load at 81 in.
7.562	0.375	135	187	0.34	397	107
6.781	0.344	118	203	0.31	380	93
6.062	0.312	97	224	0.27	359	75
5.406	0.281	81	250	0.22	368	63
4.812	0.250	64	280	0.17	376	50
4.281	0.219	47	319	0.125	376	37
3.812	0.187	34	374	0.082	415	28
total force		576				453

Net scram force:

spring force at bottom position $= 576$
net weight $= -390$
F scram force at bottom position $= \boxed{186 \text{ pounds}}$
spring force at top position $= 453$
net weight $= -390$
scram force at top position $= \boxed{63 \text{ pounds}}$

Time to scram rod:

a_0 initial acceleration $= Fg/W = (186)(32.2)/450$ $= 13.3$ ft/sec^2

s_{0-2} with a certain dash pot piston orificing (before entering the dash pot), the distance to reach terminal velocity would $= 2$ ft

a_{0-2} average acceleration $= (a_0 + a_2)/2 = (13.3 + 0)/2$ $= 6.65$ ft/sec^2

v_2 terminal velocity $= (2 a_{0-2} s_{0-2})^{1/2} = [(2)(6.65)(2)]^{1/2}$ $= 5.16$ ft/sec

t_{0-2} time to reach terminal velocity $= (2 s_{0-2}/a_{0-2})^{1/2}$
$= [(2)(2)/6.65]^{1/2}$ $= 0.77$ sec

F_2 scram force at the 2-ft point $= 147$ lb

distance to the beginning of slowing down by by dash pot $= 6$ ft

F_6 scram force at the 6-ft point $= 77$ lb

v_6 velocity at the 6-ft point $= v_2(F_6/F_2)^{1/2}$
$$= 5.16\,(77/147)^{1/2} \qquad\qquad = 3.74\text{ ft}/\text{sec}$$

v_{2-6} average velocity between 2-ft and 6-ft points
$$= (v_2 + v_6)/2 \text{ (approx.)} = (5.16+3.74)/2 \qquad = 4.45\text{ ft}/\text{sec}$$

t_{2-6} time to travel from 2-ft point to 6-ft point
$$= 4/v_{2-6} = 4/4.45 \qquad\qquad = 0.90\text{ sec}$$

s_{6-7} dash pot length $\qquad\qquad = 0.75\text{ ft}$

v_{6-7} average velocity in dash pot $= v_6/2$ (approx.)
$$= 3.74/2 \qquad\qquad = 1.87\text{ ft}/\text{sec}$$

t_{6-7} time of dash pot travel $= s_{6-7}/v_{6-7}= 0.75/1.87 \quad = 0.40\text{ sec}$

total time $= t_{0-2}+t_{2-6}+t_{6-7} = 0.77 + 0.90 + 0.40 \boxed{= 2.07\text{ sec}}$

Heating Test of Hold Coil #29

A coil (see page 105) was supplied with an increasing amount of DC voltage until it burned out. The coil operated for 68 hours at 300 F and for 168 hours at 450 F with no sign of failure Then, after a short time at 500 F, the epoxy resin began to give off fumes After 116 hours at 550 F and a few hours at 680 F, the epoxy resin became charred, thus reducing its thermal conductivity and causing the wire temperature to rise to 720 F. After 16 hours at 720 F, 24 hours at 780 F and about 48 hours at 800 F, the coil failed by short circuiting The short circuit was probably caused by the carbon which was formed as the epoxy resin charred.

The coil was tested under conditions which simulated those of a coil in a drive operating in 68 F still air To simulate the effect of adjacent coils, the test coil had each end covered with a $\frac{1}{4}$ in. thick disc of asbestos board. The temperature of the coil was measured by measuring the resistance of the coil with a voltmeter and an ammeter This gave the average wire temperature which was close to the temperature of the center windings (maximum temperature) and close to the temperature of the iron shell (minimum temperature), since the coil is thoroughly impregnated.

The heating curves were calculated from coefficients given in Machinery Handbook, eleventh edition page 1660. The surface area of the coil was assumed to be 32.9 square inches, which is the area of the periphery plus 8.2% of the exposed area of the ends   This 8.2% represents the effect of the small space between the coils in the jack assembly.

AMPERES

COIL TEMPERATURE, °F

POWER INPUT, Watts

AMPERES

WATTS

LINES ARE CALCULATED
POINTS ARE EXPERIMENTAL

AMBIENT: 68°F STILL AIR

HEATING TEST OF HOLD COIL #29
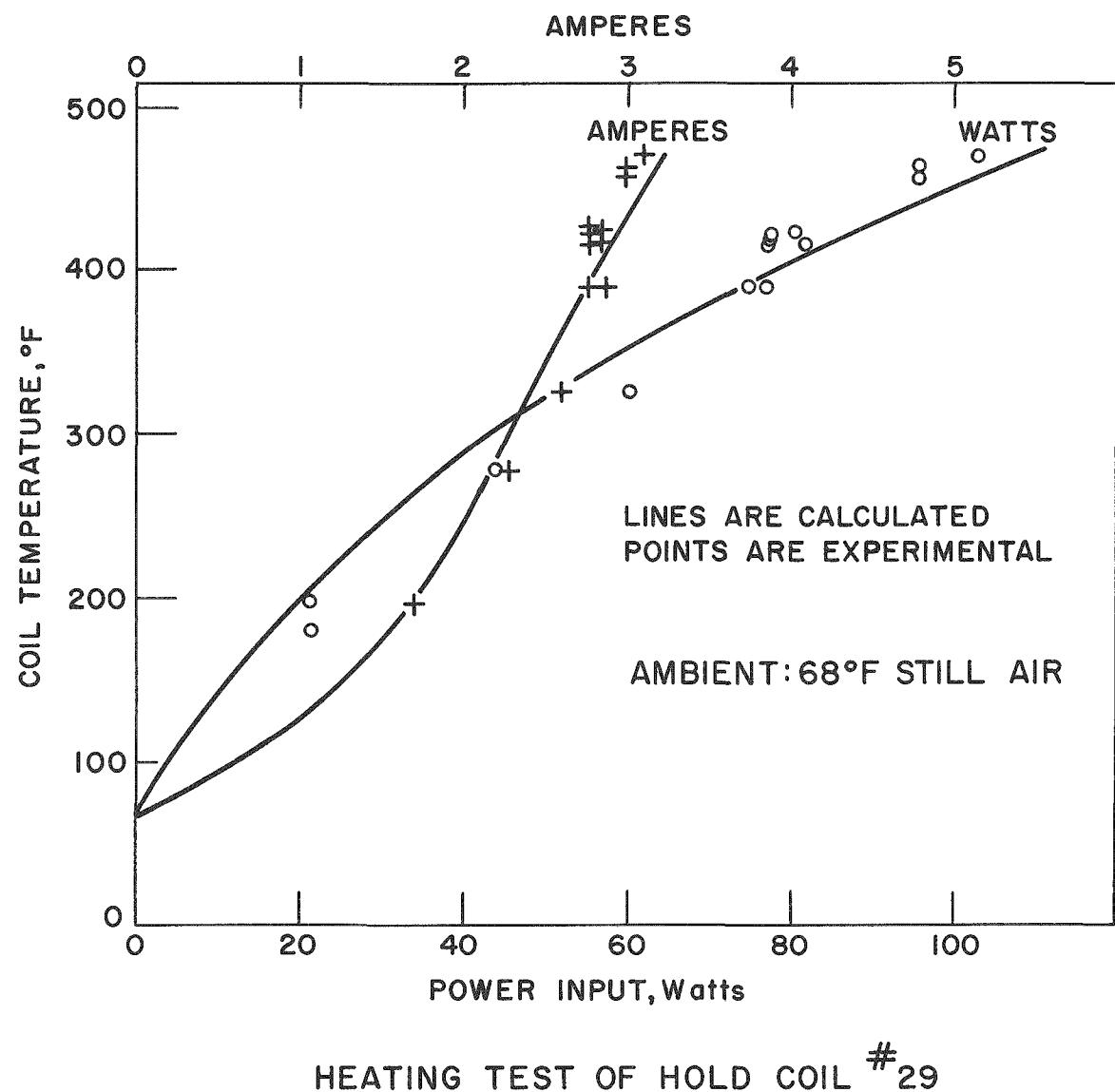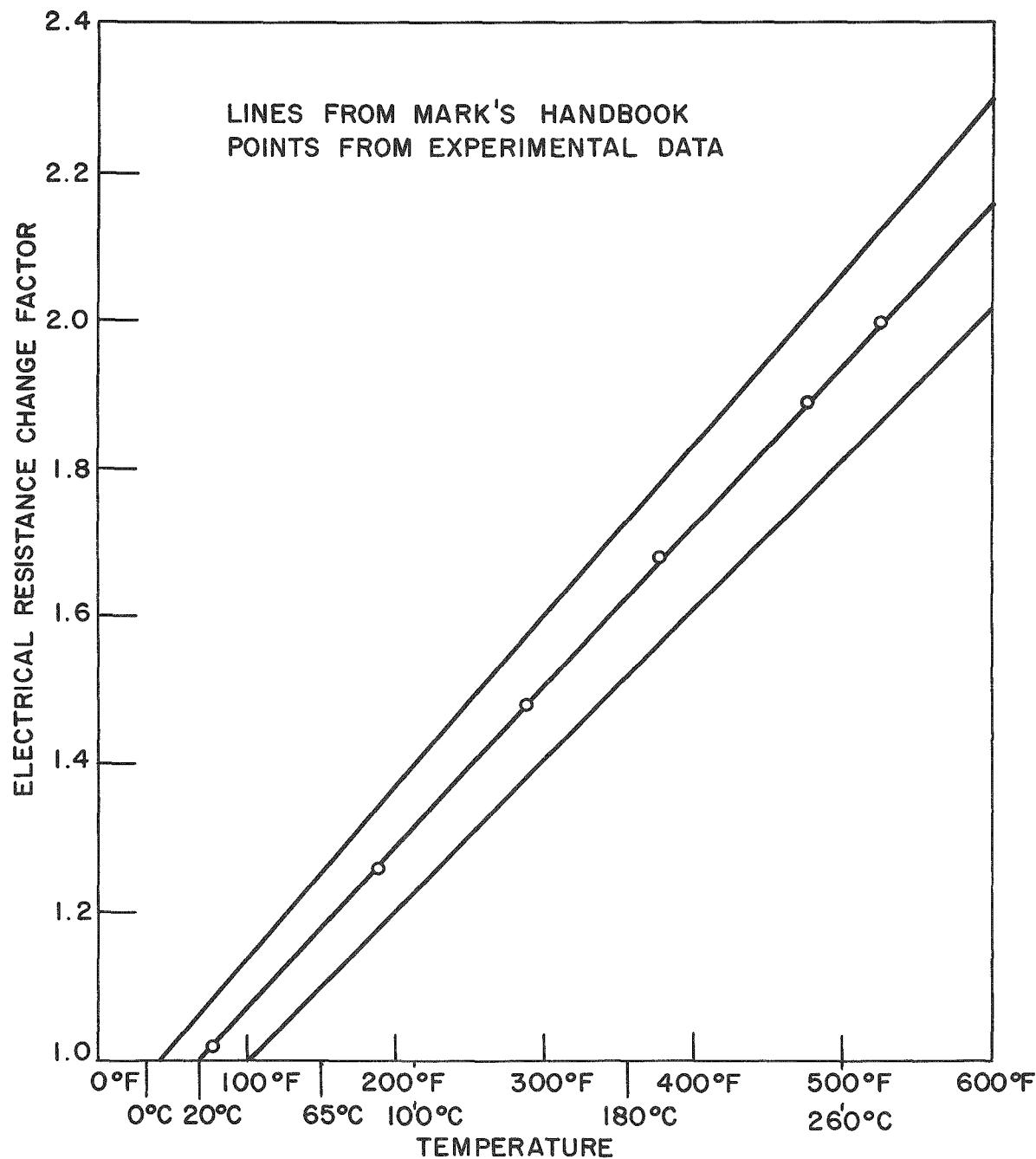
THERMAL COEFFICIENT OF ELECTRICAL RESISTANCE
FOR COPPER MAGNET WIRE
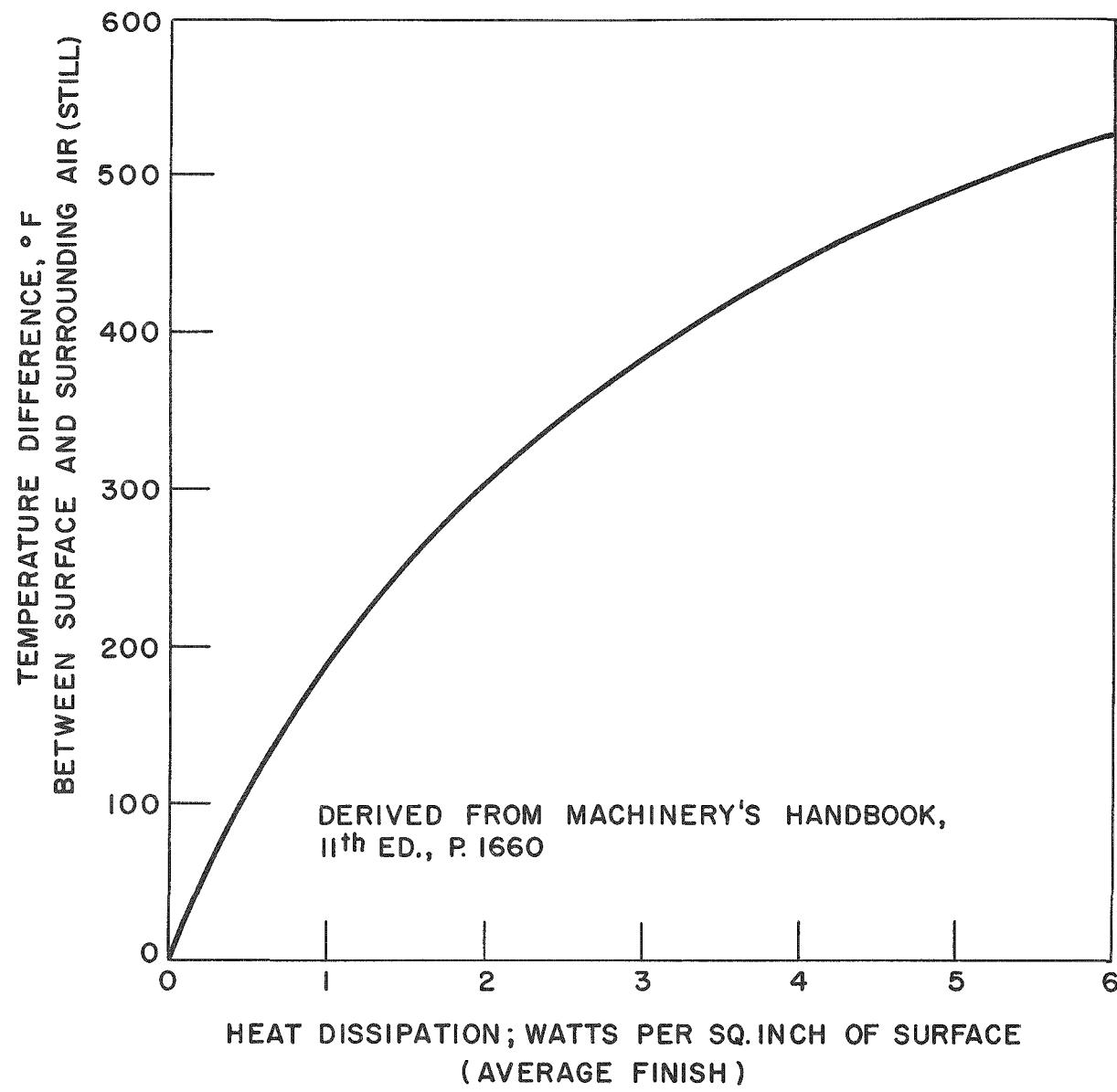
TYPICAL HEAT DISSIPATION CURVE

APPENDIX B

JACK DRIVE FOR ALPR (SL-1)

Introduction

The SL-1 (ALPR) magnetic jack (#27) is designed for low pressure and minimum length. This report describes the installation and operation of one magnetic jack control rod drive and gives detailed information on the construction of the magnetic jack, the control rod connection, the position indicator, the control and the power supply. A description of the electrical circuit for five jack drives is given at the end of Appendix B.

The magnetic jack control rod drive system consists of the following assemblies:

A. The jack is pre-assembled for shipping and installation. It consists of:

1. the parts listed on page 44 (drawing RE-1-20471-D) except the drive rod (part #8) and the position indicator rod (part #9);
2. the adapter flange (drawing RE-1-22615-B) on page 62;
3. the position indicator coil assembly on page 68;
4. a high-temperature, flexible cable assembly.

B. The rod connection device is shipped and installed unassembled. It consists of:

1. the parts listed on page 60;
2. the drive rod and the position indicator rod shown on page 57.

C. The position indicator components are mounted on the instrument panel. They are:

1. the power supply shown on page 69;
2. the selector shown on page 70;
3. the meter shown on page 70.

D. The jack power supply components may be mounted away from the instrument panel. They are

1. the coil sequence switch shown on page 74;
2. the rectifier assembly shown on page 75.

		100°F	350°F
Design Pressure,	P.S.I.	505	490
Maximum Capacity (f=.45),	Lbs.	450	340
Rated Capacity,	Lbs.	150	110
Power for Holding,	Watts	400	270
Power for Moving,	Watts	1720	1150

31" TRAVEL

61"

1.90" D.

$4\frac{7}{16}$"

$24\frac{13}{16}$"

$9\frac{1}{2}$" D.

$7\frac{1}{2}$" D.

SHORT - LENGTH
MAGNETIC JACK (#27)

POSITION
INDICATOR
COILS

LIFT
COIL

GRIP
COILS

PULL
DOWN
COIL

HOLD
COILS
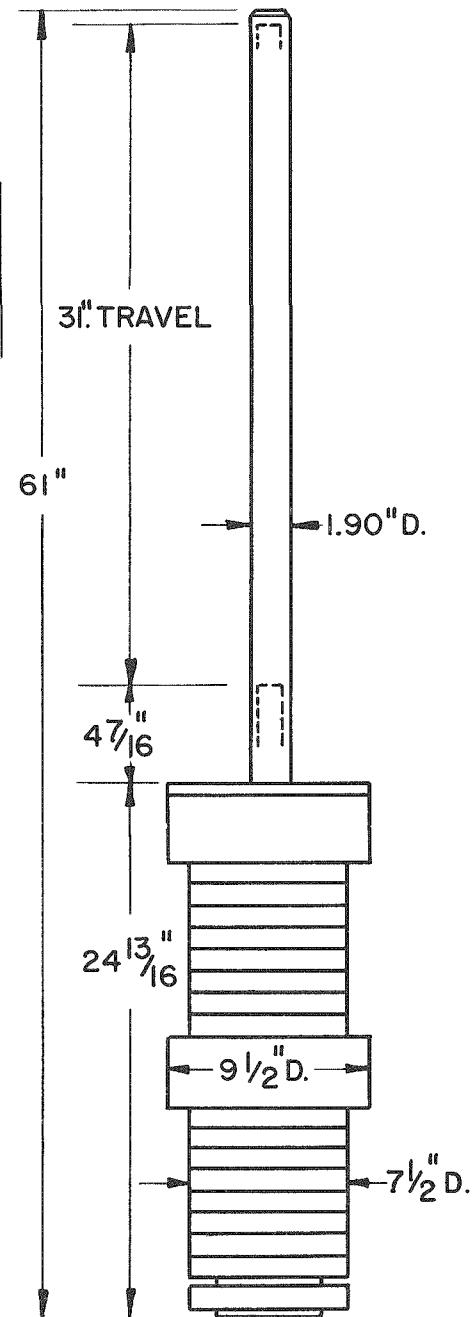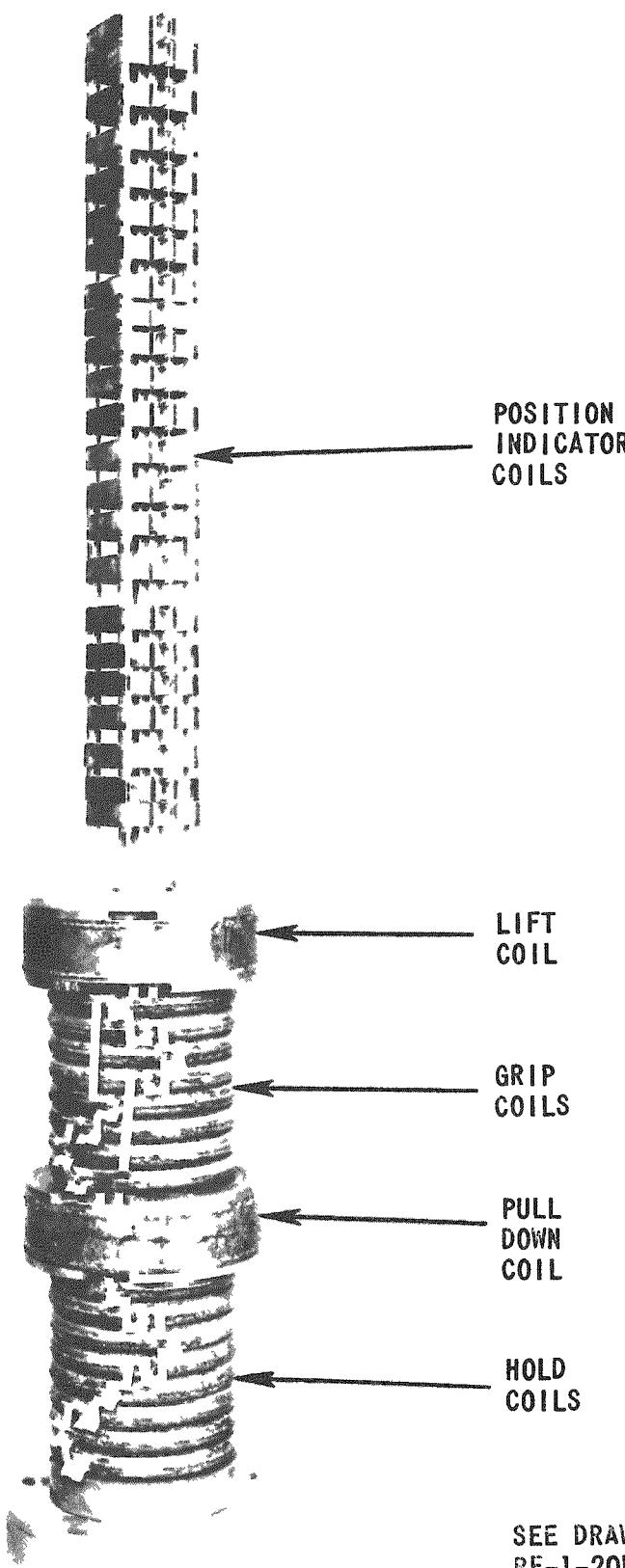
SEE DRAWING
RE-1-20471-D

111-7508

MAGNETIC JACK #27

44
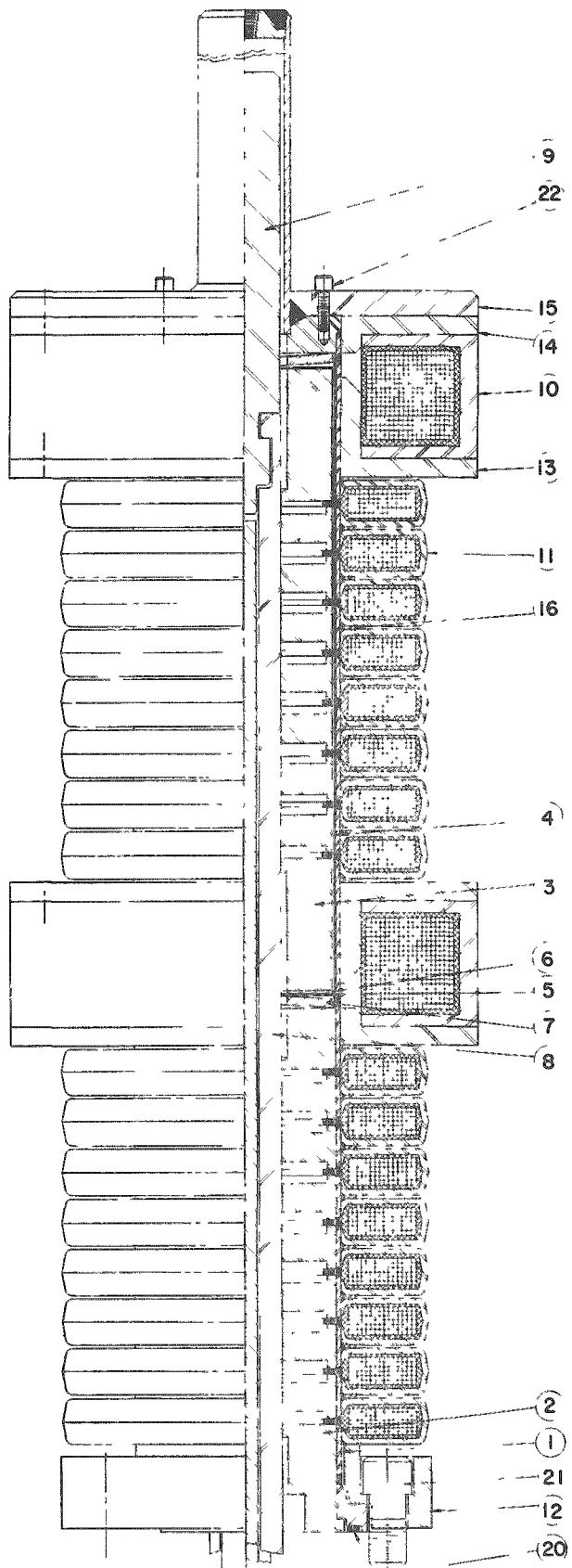
DRAWING LIST - JACK 27

Part No.	No. Req'd.	Part	Drawing No	Page No.
1	1	Pressure Shell	RE-1-20592-B	52
		Body	RE-1-20346-B	
		Flange	RE-1-20498-A	
		Tube	RE-1-20447-F	
		Extension	RE-1-20392-B	53
		Flange	RE-1-20395-B	
		Pipe	RE-1-20394-A	
		Plug	RE-1-20548-A	
2	1	Holder	RE-1-20399-B	54
		Weldment	RE-1-20402-B	
		End	RE-1-20377-B	
		Disc	PE-1-20476-A	
3	1	Armature	PE-1-20403-B	55
		Weldment	PE-1-20401-B	
4	2	Nonmagnetic Sleeve	RE-1-20581-A	
5	2	Nonmagnetic Washer	RF-1-20390-A	56
6	1	Shim	RE-1-20379-A	
7	2	Cushion Washer	PE-1-20378-A	
8	1	Drive Rod	PE-1-20177-B	57
9	1	Pull Rod	PE-1-20198-A	
10	2	Move Coil Assembly	RE-1-21598-A	48
		End Plate	RE-1-21599-B	
		Ring	PE-1-24246-A	
		Coil	PE-1-24276-B	
11	16	Grab Coil Assembly	RE-1-21541-A	49
		Shell	PE-1-21542-A	
		Coil	RE-1-24247-B	
		Terminal Post	RE-1-21540-A	
12	1	Flange Ring	RE-1-20585-B	57
13	2	Flanged Tube	PE-1-20586-B	
14	2	Flanged Plate	PE-1-20430-B	60
15	1	Coil Clamp Plate	RE-1-20357-A	
16	16	Coil Spacer Ring	RE-1-20398-A	57
17 *	20	S Connector	RE-1-22432-A	
18 *	2	C Connector	PE-1-22430-A	61
19 *	2	I Connector	PE-1-22431-A	
20	2	Gasket - Flexitallic R4-6J		
21	8	Socket Hd. Sc.-3/4 - 10 x 1½ lg. Steel		
22	4	Socket Hd. Sc.-1/4 - 20 x 7/8 lg. SST		
23 *	60	Round Hd. Screw - 24 x 5/16 lg. SST		
24 *	50	Hex Nut - 6 - 32 SST		
25 *	50	Lock Washer - 6 SST		

*These parts are shown on the Terminal Assembly Drawing on page 45

MAGNETIC JACK #27
RE-1-20471-D

LIFT
COIL

$\frac{3}{4}''$ $\frac{3}{4}''$ $\frac{9''}{16}$

3
2
1

18

45°
TYP.

$1\frac{1}{4}''$

$1\frac{1}{4}''$

GPIP
COILS

$4''$

17

23

$1\frac{1}{4}''$

4

19

25

24

5 6

$\frac{3''}{4}$ $\frac{3''}{4}$ $\frac{9''}{16}$

PULL
DOWN
COIL

PART NUMBERS
SEE PAGE 44

$\frac{13''}{16}$ $\frac{1''}{4}$

7

HOLD
COILS

$1\frac{1}{4}''$

$1\frac{1}{4}''$

$1\frac{1}{4}''$

$1\frac{1}{4}''$

8

TERMINAL NUMBERS
SEE PAGES 72 & 75
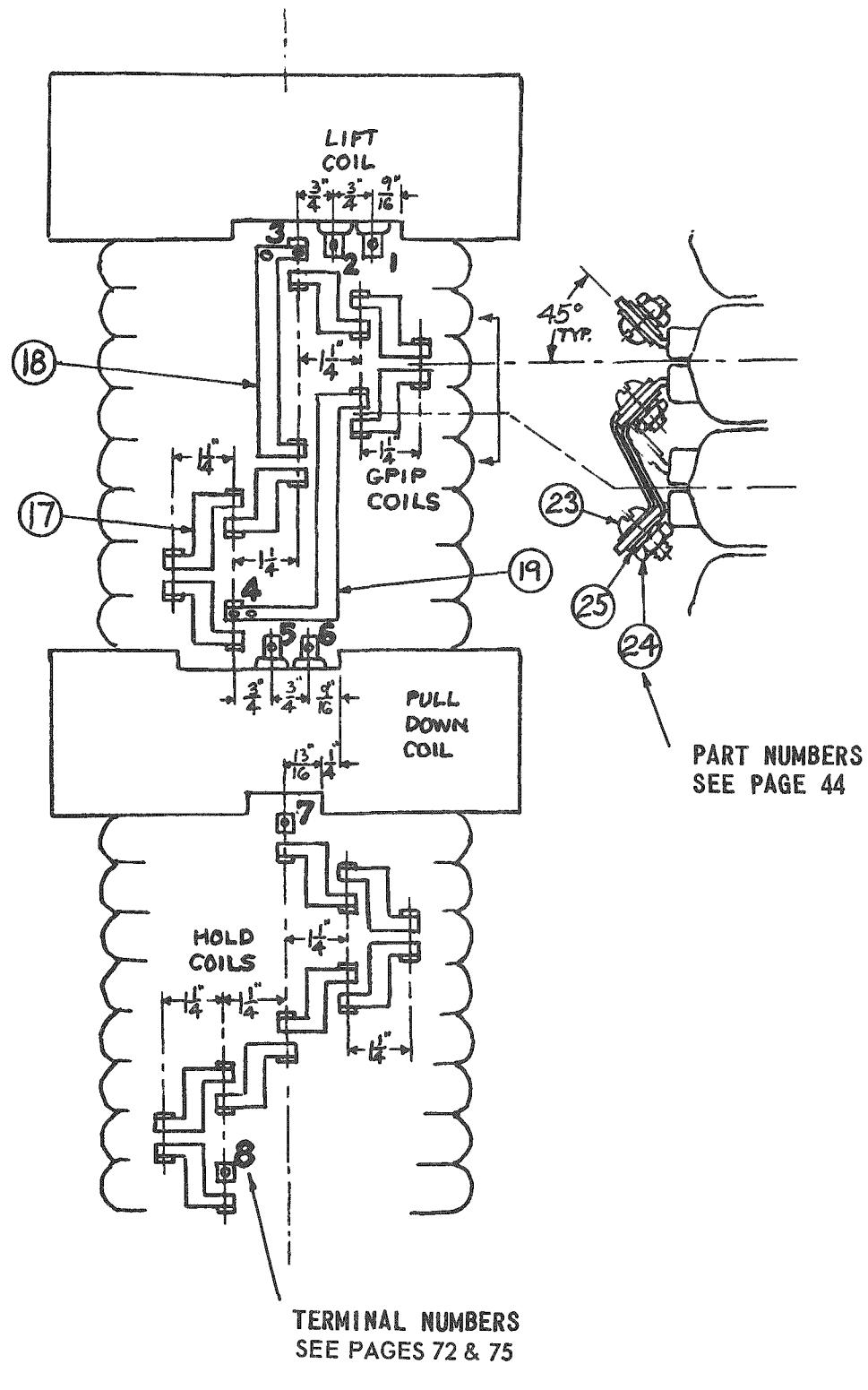
COIL TERMINAL CONNECTIONS

$2\frac{1}{2}$

$\frac{11}{16}$

$9\frac{1}{2}$ D.

4.770 D.

$\frac{3}{16}$ 90°

RE-1 21539 B PT#1

RE-1 24235 A

RE-1 21539 B PT#2

RE-1 21540 A

$\frac{9}{16} \pm \frac{1}{32}$

B-B

A-A

RE-1 24236 B

A E

C

D-D   C-C
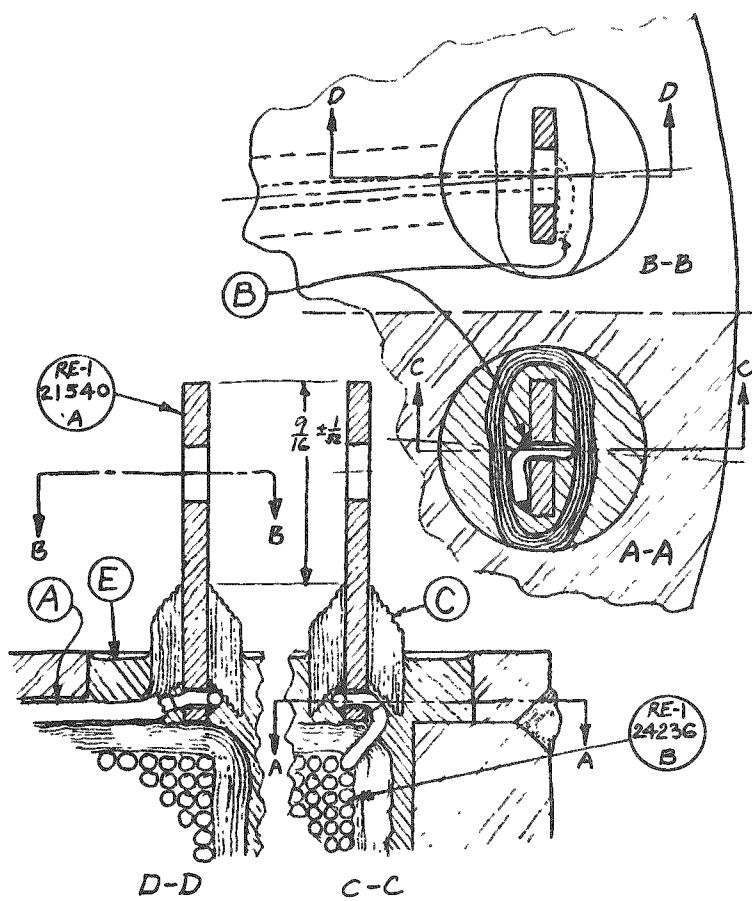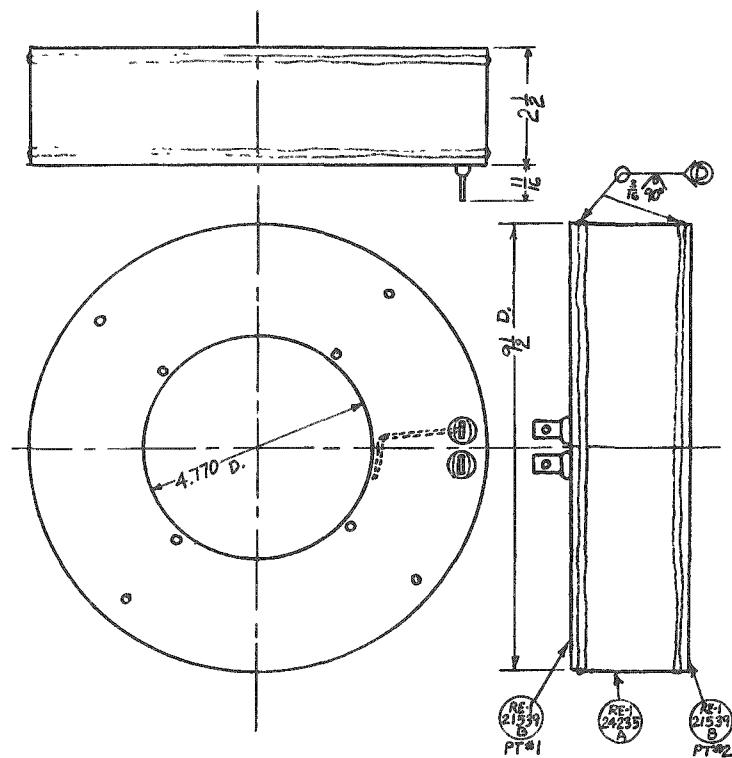
NO. REQUIRED: 2
MOVE COIL ASSEMBLY
RE-1-21538-A

10

COIL ASSEMBLY NOTES - JACK #27

(A) Slip glass cloth sleeving over
the long lead wire.

(B) Silver solder the wire connec-
tions with "Easy-Flo."

(C) Wrap the terminals $\frac{3}{32}$" thick with
$\frac{3}{8}$" wide untreated glass cloth tape.

(D) Clean the steel parts to provide a
good bond with the potting material.
Clamp the steel parts and the coil
in the welding jig and weld as
shown using mild steel weld rod.

(E) Clamp the welded assembly in the
teflon mold and vacuum impregnate
with epoxy resin prepared as fol-
lows: to Shell Epon Resin 815 add
7.5% by weight of MMM Cardelite
N.C. 513; heat mixture to 140°F;
to mixture add 14% by weight of
Shell Epon Curing Agent CL (heated
until melted); stir well; use imme-
diately. Place filled mold in 200°F
furnace for two (2) hours.
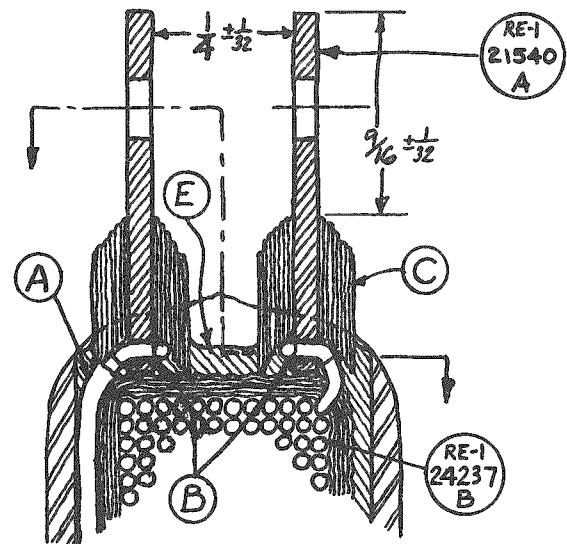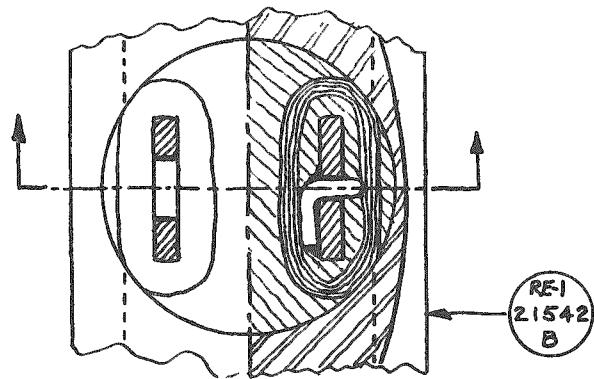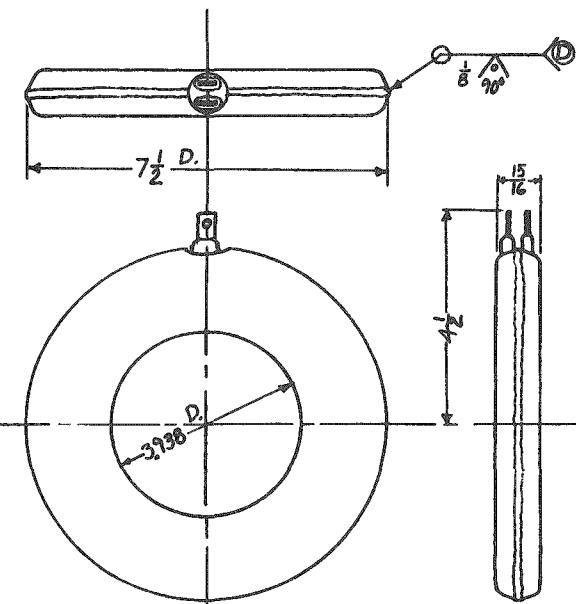
NO. REQUIRED: 16

GRIP COIL ASSEMBLY   RE-1-21541-B

(11)

48

$\frac{3}{32} \times 45°$ CHAMFER

$9\frac{1}{2}$ D

$\frac{1}{4}$

THIS SIDE MUST —
BE FLAT

$\frac{3}{16}$ DR HOLES

$\frac{1}{16}$ DR
8 HOLES

$\frac{1}{32}$ TYP

$\frac{1}{16}$ TYP

$4\frac{1}{4}$ R

45° $\frac{3}{4}$ 45°

$\frac{1}{16}$ L
$\times \frac{1}{8}$ L GROOVE

$-.4770$
$\pm.005$ D
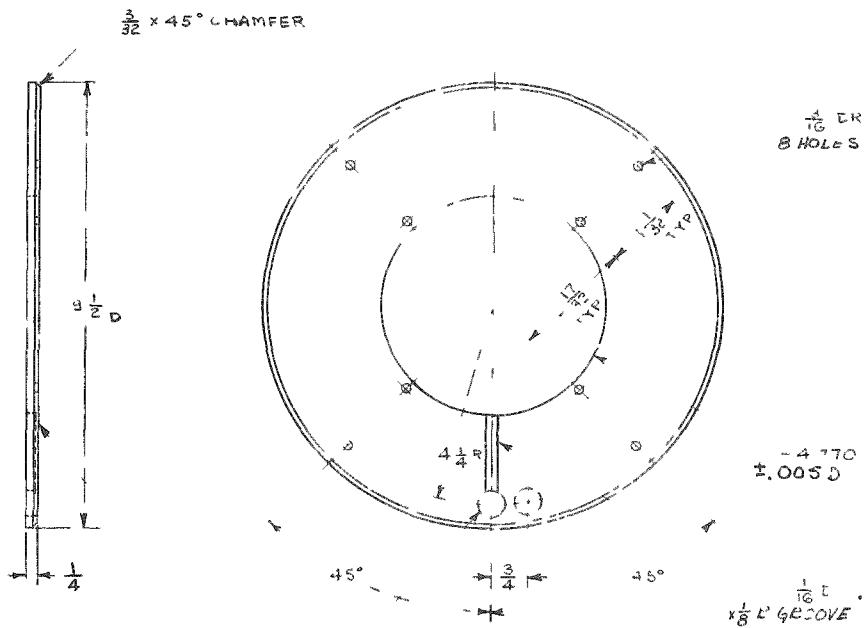
PART #1
AS SHOWN
NO. REQUIRED: 2

PART #2
WITHOUT DRILLED
HOLES & GROOVE
NO. REQUIRED: 2
TOLERANCES: ±1/32
MATERIAL: LOW
**   CARBON STEEL**
END PLATE
RE-1-21539-B

$\frac{3}{32} \times 45°$ CHAMFER

$8\frac{3}{4}$ DIA.

$9\frac{1}{2}$ Dia.

2
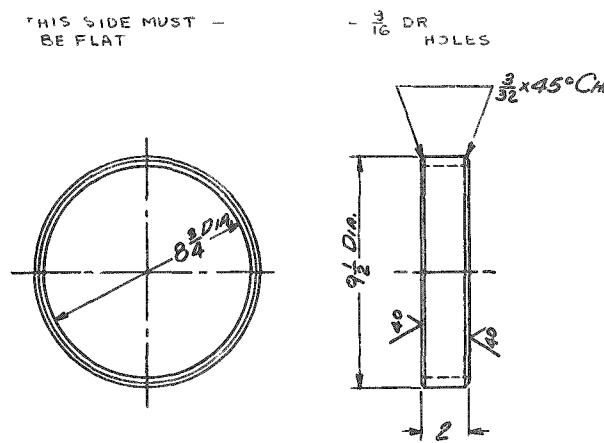
NO. REQUIRED: 2
TOLERANCES: ±1/32
MATERIAL: LOW
**   CARBON STEEL**
MOVE COIL RING
RE-1-24235-A

WRAP COIL $\frac{3}{32}$" THICK WITH UNTREATED
GLASS CLOTH TAPE. A FEW $\frac{1}{2}$" WIDE STRIPS
OF GLASS CLOTH ADHESIVE TAPE MAY BE
USED TO BIND THE COIL.

$4\frac{13}{16}$ DIA $\pm\frac{1}{16}$

5 DIA $\pm\frac{1}{32}$

$8\frac{7}{16}$ DIA $\pm\frac{1}{8}$

$1\frac{1}{16} \pm\frac{1}{32}$ $\frac{3}{4} \pm\frac{1}{8}$

$2 \pm\frac{1}{32}$ $2\frac{1}{2} \pm\frac{1}{8}$

A

A

WIND FIRST LAYER
RIGHT HAND

1300 TURNS OF #18 DOUBLE GLASS-
SILICONE MAGNET WIRE. (IF SINGLE GLASS-
SILICONE MAGNET WIRE IS USED, PUT .005
TO .010 THICKNESS OF UNTREATED GLASS
CLOTH TAPE BETWEEN LAYERS OF WIRE.)

SECTION "A-A"

NO. REQUIRED: 2   MOVE COIL   RE-1-24236-B

#10GA (.1345)

$\frac{1}{32}$R MAX

10°

20°

$\frac{5}{16}$

4 D

3.998 D

$\frac{25}{32}$ DR
(2 FIN SHED
SHELLS
CLAMPED
TOGETHER)
$1\frac{1}{8}$ DEEP

$\frac{1}{16}$ × 45° CH

.469

$4\frac{3}{8}$ D REF

$7\frac{1}{2}$ D
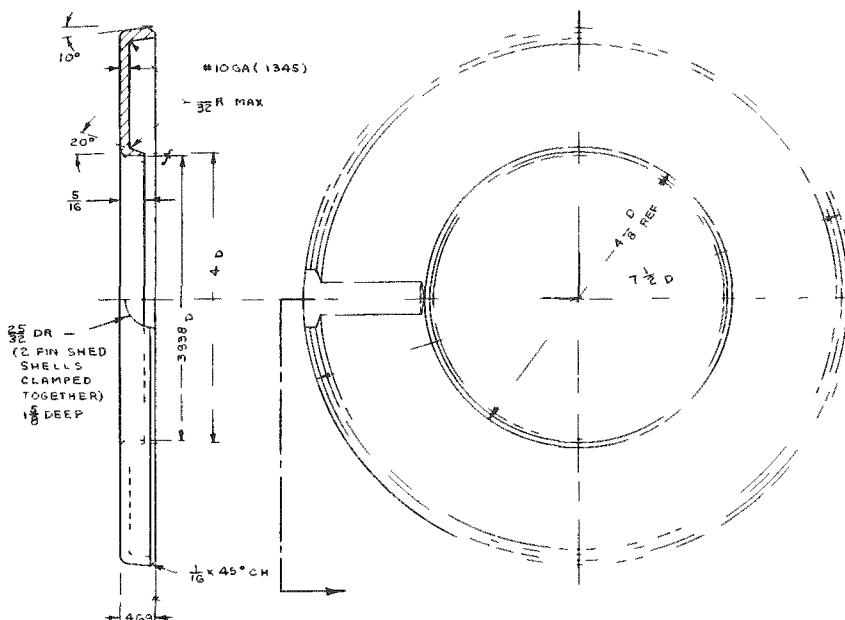
NO. REQUIRED: 32
TOLERANCES:
    FRACTIONAL ±1/32
    DECIMAL ±.005
MATERIAL: LOW
    CARBON HOT
    ROLLED STEEL
COIL SHELL
RE-1-21542-B

$\frac{3}{8}$

$\frac{3}{16}$

$\frac{1}{4}$

$\frac{15}{16}$

$\frac{1}{16}$

$-\frac{5}{32}$ PUNCH

$\frac{1}{16}$ PUNCH

#16 GA (.062) TH'K
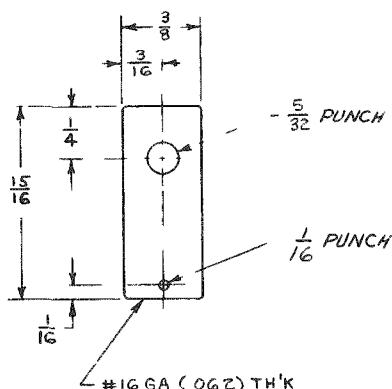
NO. REQUIRED: 36
TOLERANCES: ±1/32
MATERIAL: COM.
    PURE NICKEL
TERMINAL POST
RE-1-21540-A

WRAP COIL TO $\frac{1}{8}$" THICK WITH UNTREATED
GLASS CLOTH TAPE. A FEW $\frac{1}{4}$" WIDE
STRIPS OF GLASS CLOTH ADHESIVE
TAPE MAY BE USED TO BIND THE COIL.

$4\frac{5}{8}$ DIA ±$\frac{1}{16}$

$4\frac{1}{4}$ DIA ±$\frac{1}{16}$

$2\frac{1}{8}$

$6\frac{7}{8}$ DIA ±$\frac{1}{16}$

300 TURNS OF #18 DOUBLE GLASS-
SILICONE MAGNET WIRE. (IF SINGLE
GLASS-SILICONE MAGNET WIRE IS
USED, PUT .005 TO .010 THICKNESS OF
UNTREATED GLASS CLOTH TAPE BETWEEN
LAYERS OF WIRE.)

WIND FIRST LAYER
RIGHT HAND

"A"

SECTION "A-A"
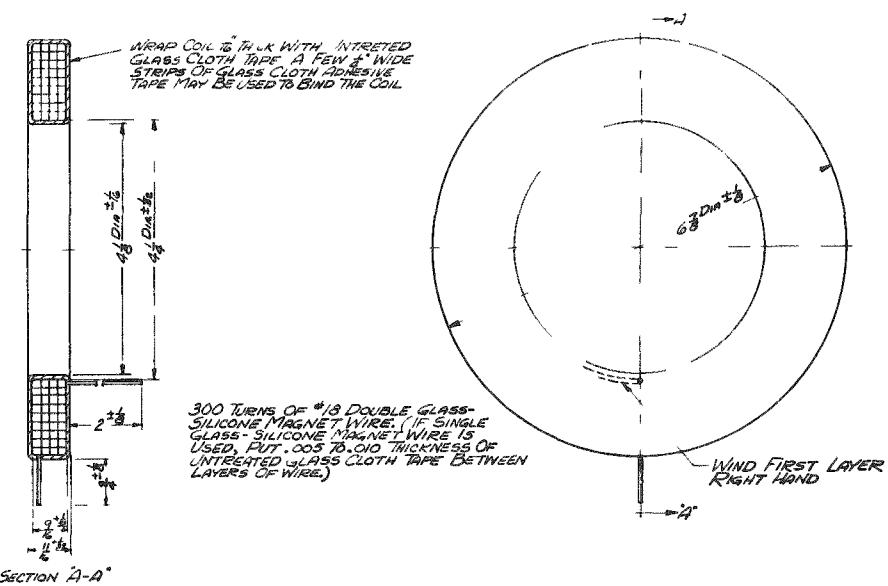
NO. REQUIRED: 16
GRIP COIL
RE-1-24237-B

BAND SAW CUT

45°

$3\frac{3}{4}$ R

$9\frac{1}{2}$ D

4.750 D ± .005

3.938 D ± .005

$\frac{5}{16}$

$\frac{3}{8}$

2
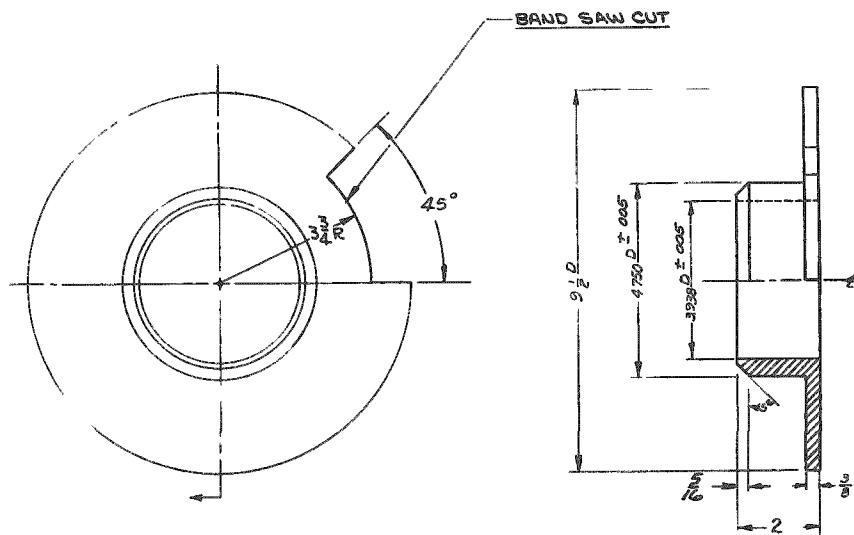
NO. REQUIRED: 2
TOLERANCES: ±1/32
MATERIAL: LOW
  CARBON STEEL
FLANGED TUBE
RE-1-20386-B

⑬

$22\frac{1}{2}°$

$3\frac{3}{4}$ R

BAND SAW CUT

$9\frac{1}{2}$ D

4.750 D ±.005

3.938 D ±.005

45°

$\frac{1}{8}$

$\frac{3}{16}$

$\frac{3}{4}$
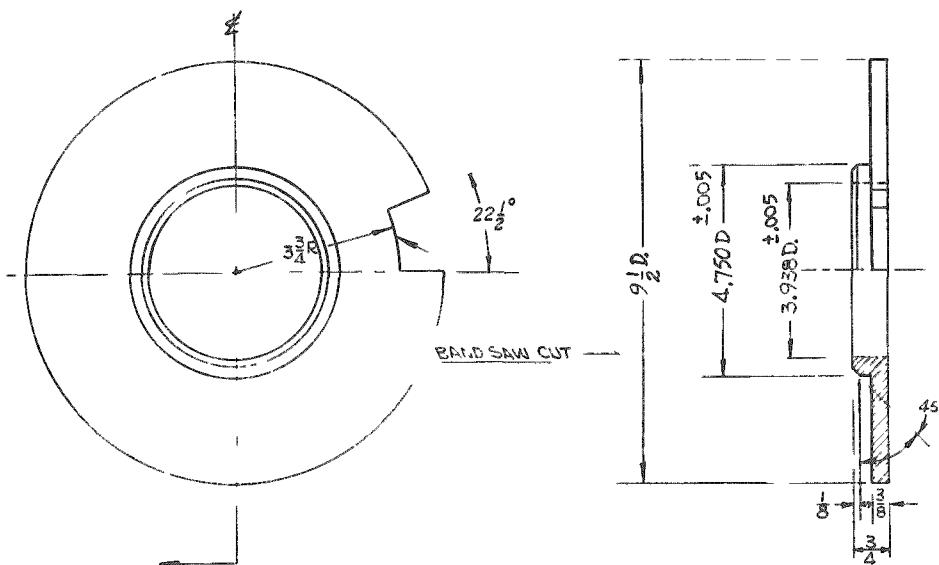
NO. REQUIRED: 2
TOLERANCES: ±1/32
MATERIAL: LOW
  CARBON STEEL
FLANGED PLATE
RE-1-23430-B

⑭

$2\frac{5}{8}$ D THRU HOLE

$\frac{1}{8}$" x 45° CHAMFER

45°

$9\frac{1}{2}$" D

$\frac{1}{2}$

#7 (.2010) TAP DRILL
4 HOLES
$\frac{1}{4}$ 20 TAP THRU
EQ SP ON $4\frac{1}{16}$ D B C

$\frac{9}{32}$ DRILL THRU
4 HOLES
EQ SP ON $3\frac{1}{4}$ D. B C
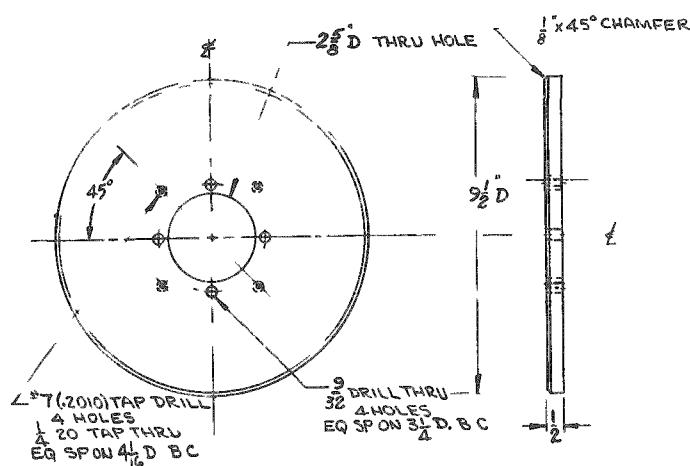
NO. REQUIRED: 1
TOLERANCES: ±1/32
MATERIAL: LOW
  CARBON STEEL
COIL CLAMP
RE-1-20387-A

⑮

$\frac{1}{32}$ THICK

$\frac{5}{32}$ DIA. 2 HOLES

$\frac{5}{8}$

$\frac{3}{16}$ TYP.

$1\frac{5}{8}$

$\frac{5}{8}$

$\frac{3}{16}$ TYP.

$\frac{3}{8}$ TYP.

$1\frac{17}{32}$
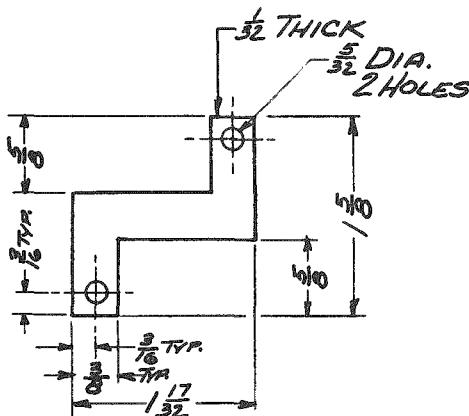
NO. REQUIRED: 26
TOLERANCES: ±1/32
MATERIAL: COM.
PURE NICKEL
"S" CONNECTOR
RE-1-22432-A

⑰

$4\frac{1}{2}$

$\frac{1}{32}$ THICK

$\frac{3}{16}$ TYP.

$\frac{3}{16}$ TYP.

$\frac{3}{8}$ TYP.

$\frac{5}{8}$

$\frac{5}{8}$

$1"$

$\frac{5}{32}$ DIA. 3 HOLES
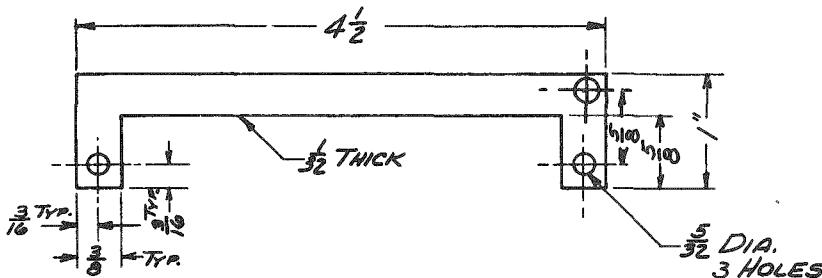
NO. REQUIRED: 2
TOLERANCES: ±1/32
MATERIAL: COM.
PURE NICKEL
"C" CONNECTOR
RE-1-22430-A

⑱

$4\frac{1}{2}$

$\frac{1}{32}$ THICK

$\frac{3}{16}$ TYP.

$\frac{5}{8}$

$2\frac{7}{8}$

$\frac{3}{8}$

$\frac{5}{8}$

$\frac{3}{16}$ TYP.

$\frac{3}{8}$ TYP.

$\frac{5}{32}$ DIA. 3 HOLES
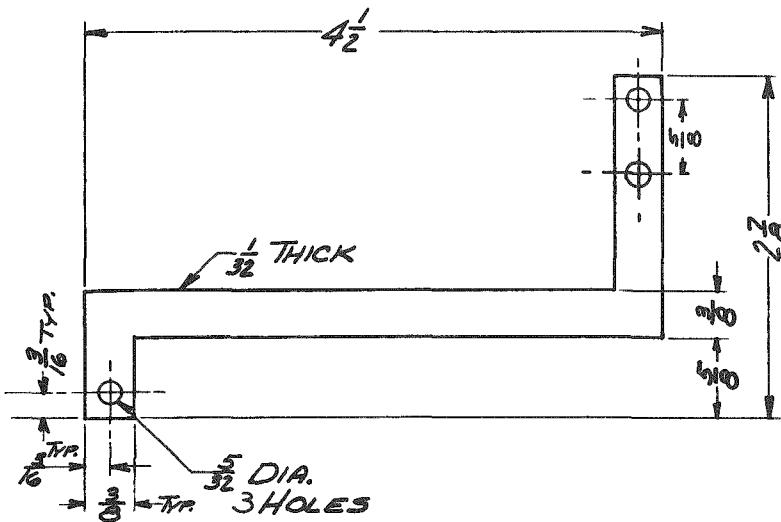
NO. REQUIRED: 2
TOLERANCES: ±1/32
MATERIAL: COM.
PURE NICKEL
"L" CONNECTOR
RE-1-22431-A

⑲

NOTE:
① WELD ROD 308 SST LIME COATED
DESIGN PRESSURE   600 PSI
DESIGN METAL TEMP 300 °F
WELD JOINT EFFICIENCY 80 %
COLD HYD PRESS TEST 800 PSI

FINISH TO O D OF TUBE
AFTER WELDING
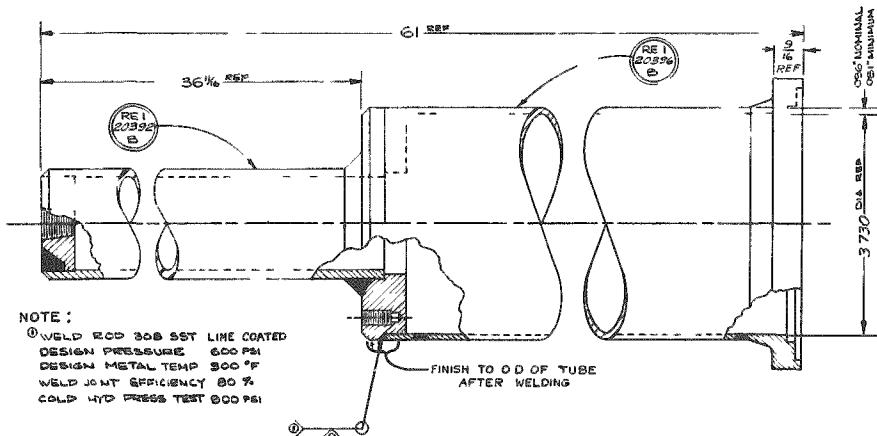
NO. REQUIRED: 1
PRESSURE SHELL
RE-1-20391-B
①

FILL 18 GROOVES SEE-
WITH WELD   RE-1-20391 B
                 NOTE 1

20°

1/16 x45° CHAM

SEE RE-1-20391 B NOTE-1

REMOVE AN EQUAL AMT
FROM EACH END

NOTE -
MACHINE ALL SURFACES
AFTER WELDING
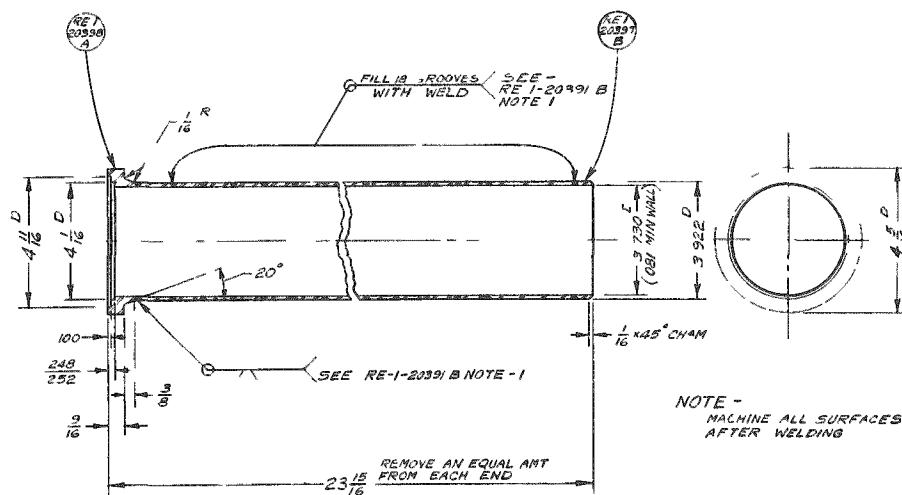
NO. REQUIRED: 1
TOLERANCES:
   FRACTIONAL ±$\frac{1}{64}$

   DECIMAL   ± .005
LARGE END
RE-1-20396-B

3½ SCH 40 PIPE
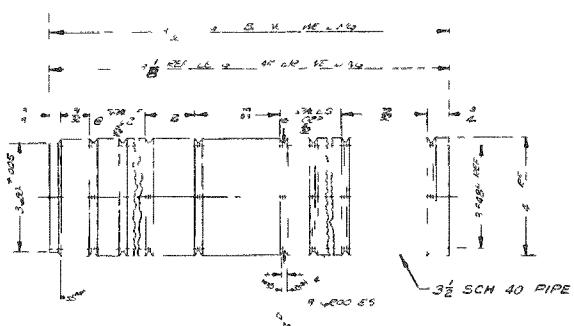
NO. REQUIRED: 1
TOLERANCES:
   FRACTIONAL ±$\frac{1}{64}$

   DECIMAL   ± .005
   ANGLE   ± 2°
MATERIAL: 405 SST
LARGE END PIPE
RE-1-20397-B
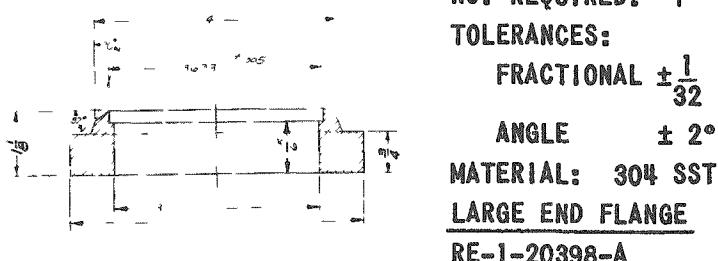
NO. REQUIRED: 1
TOLERANCES:
   FRACTIONAL ±$\frac{1}{32}$

   ANGLE   ± 2°
MATERIAL: 304 SST
LARGE END FLANGE
RE-1-20398-A
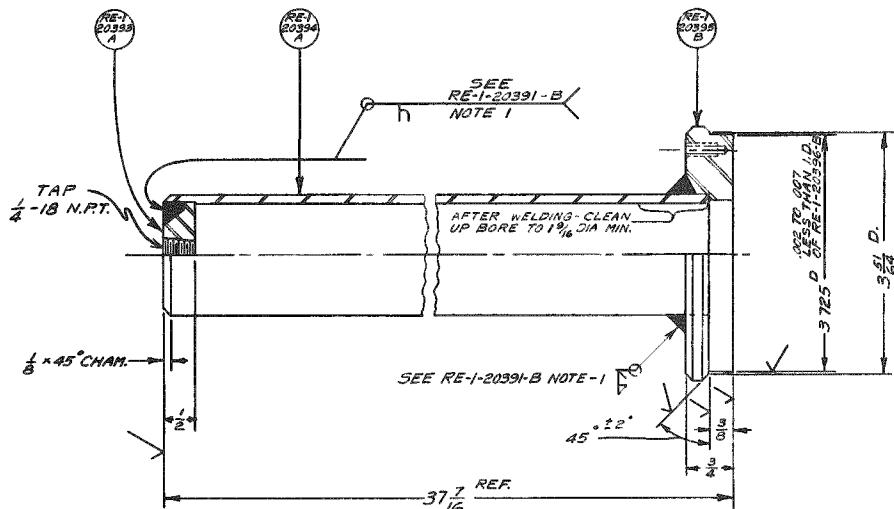
NO. REQUIRED 1
TOLERANCES: $\frac{1}{64}$

SMALL END
RE-1-20392-B
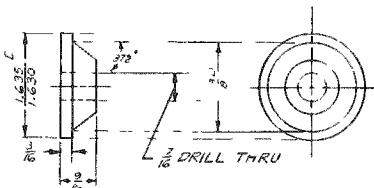
NO. REQUIRED: 1
TOLERANCES:
  FRACTIONAL ± $\frac{1}{32}$
  ANGLE ± 2°
MATERIAL: 304 SST
SMALL END PLUG
RE-1-20393-A
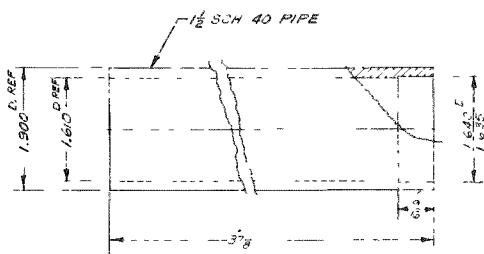
NO. REQUIRED: 1
TOLERANCES: ± $\frac{1}{32}$
MATERIAL: 304 SST
SMALL END PIPE
RE-1-20394-A
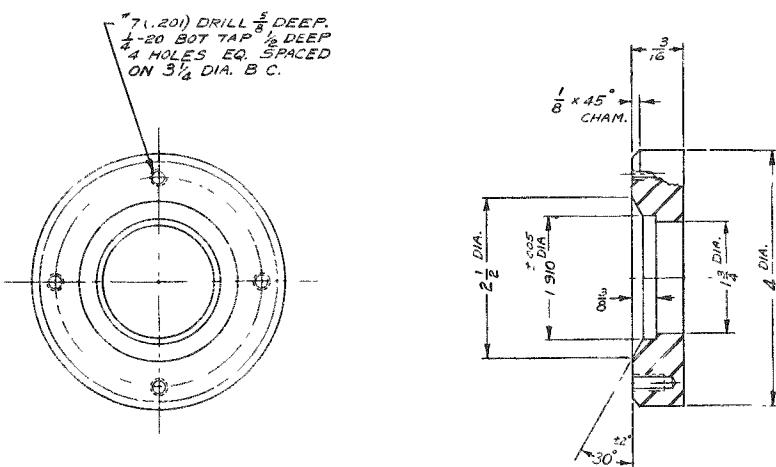
NO. REQUIRED: 1
TOLERANCES: ± $\frac{1}{32}$
MATERIAL: 405 SST
SMALL END FLANGE
RE-1-20395-B

54

SECTION A-A

REMOVE AN EQUAL AMOUNT FROM EACH END
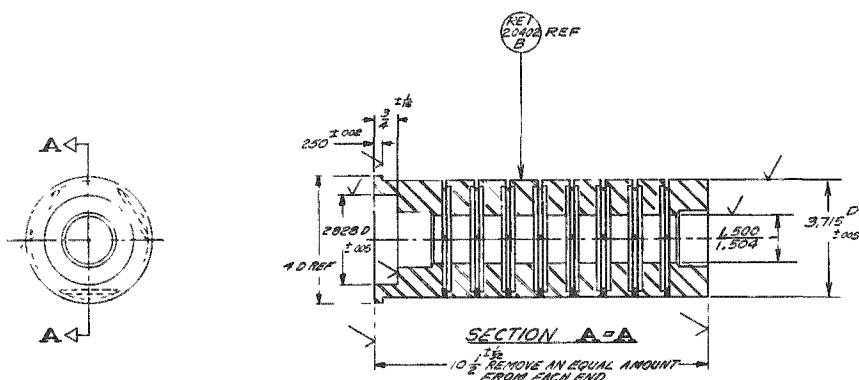
NO. REQUIRED: 1
HOLDER
RE-1-20399-B
②

RE-1-20377 PART #2
RE-1-20376 A
RE-1-20377 PART #3

24 WELDS 1"LG 308 SST
LIME COATED WELD ROD

TWO CORNERS OF
SPACER BAR IN LINE
WITH O.D. OF DISCS

120° ±5°

APPROX SEE NEXT ASSEM

WELDING JIG
(1) 1"-8×16 THD'D ROD
(2) 1"-8 HEX. NUT
(3) 1 LOCKWASHER
(4) 1" FLATWASHER

SPACER BAR
18"SQ×1¾ LG
304 SST
24 REQ'D

SECTION B-B

SECTION A-A

120° ±5°

NO. REQUIRED: 1
WELDMENT
RE-1-20402-B

3/16 ×45° CHAM.

STD DRILL POINT ANGLE

"L"
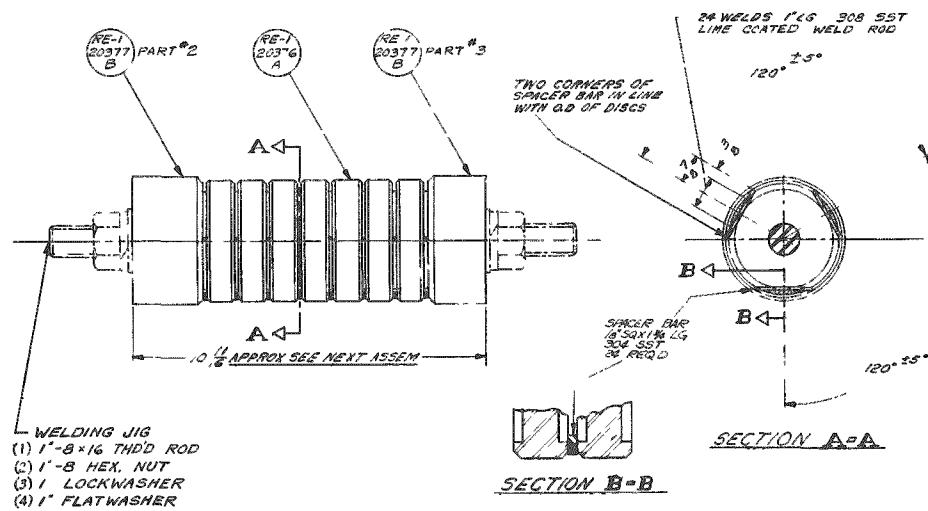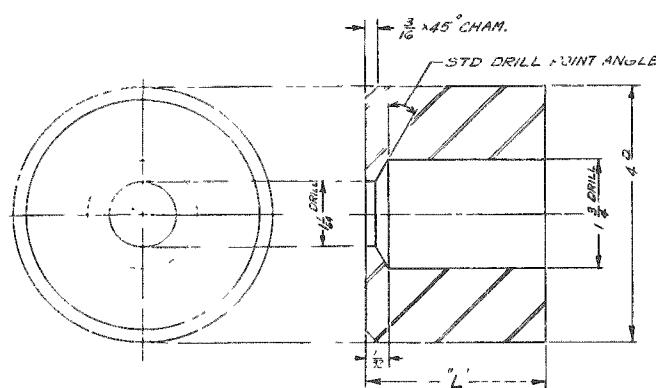
PART. NO.	"L" DIM.	NO. REQ'D.
1	$2\frac{13}{16}$	2
2	$2\frac{1}{4}$	1
3	$1\frac{5}{16}$	1

TOLERANCES: $\pm\frac{1}{32}$

MATERIAL: 405 SST
END
RE-1-20377-B

REMOVE AN EQUAL AMT
FROM EACH END

$12\frac{9}{16} \pm \frac{1}{32}$

1.500
1.504
DD

$\pm .005$ DIA
$.3640$
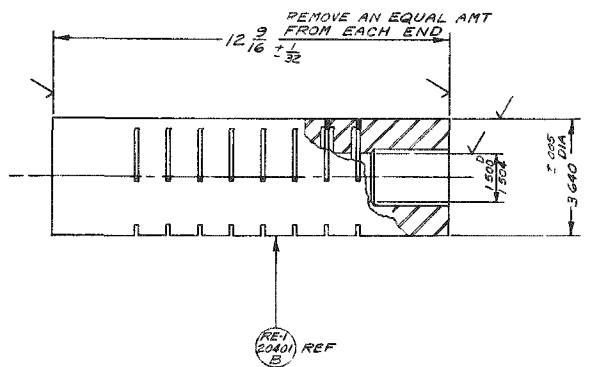
$\overset{RE-1}{\underset{20401}{\;B\;}}$ REF

NO. REQUIRED: 1

ARMATURE

RE-1-20400-B

③

PART #1 $\overset{RE-1}{\underset{20377}{\;B\;}}$ $\overset{RE-1}{\underset{20376}{\;A\;}}$

TWO CORNERS
OF SPACER BAR
IN LINE WITH
O.D. OF DISCS

A

A

$12\frac{3}{4}$ (APPROX SEE
NEXT ASSY.)

WELDING JIG
(SAME AS ON RE-1-20402-B)

SECTION-B-B

$\frac{7}{8}$

24 WELDS / LG
308 SST LIME COATED
WELD ROD

$120° \pm 5°$

$\frac{3}{64}$

SPACER BAR
$\frac{1}{4}$ SQ. $\times$ $\frac{3}{4}$ LG
304 SST
24 REQ'D

B

B

$120° \pm 5°$

SECTION-A-A

NO. REQUIRED: 1

WELDMENT

RE-1-20401-B

$\frac{3}{32} \times 45°$ CHAM

$1\frac{1}{64}$ DRILL

$3\frac{1}{8}$ D

$3\frac{1}{16}$ D

$\frac{9}{16}$

$\frac{5}{32}$

$\frac{1}{16}$ R MAX

$.875$
$\pm .015$
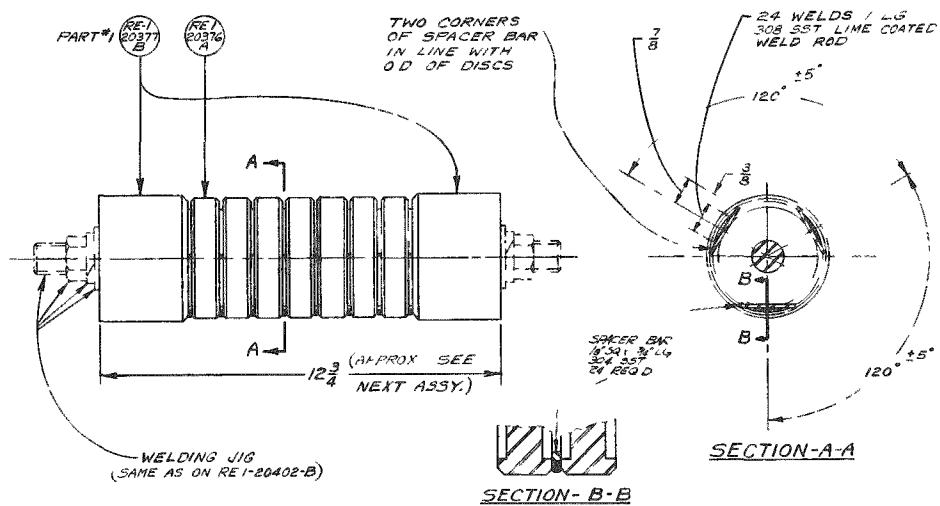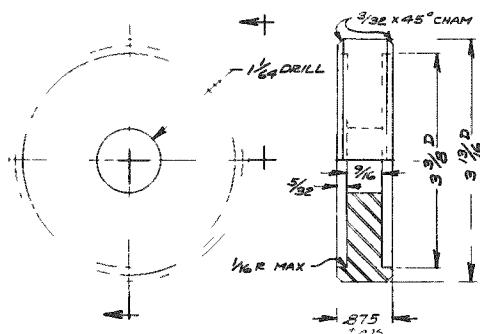
NO. REQUIRED: 14

TOLERANCES: $\pm\frac{1}{32}$

MATERIAL: 405 SST

DISC

RE-1-20376-A

$13 \pm \frac{1}{32}$

22 GA.
(.031")

$1.834 \pm .030$ R.

$3\frac{13}{16} \pm \frac{1}{32}$
FLAT WIDTH
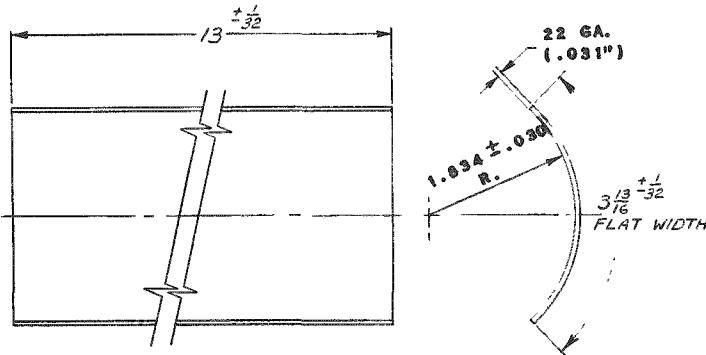
NO. REQUIRED: 3
MATERIAL: 304 SST
NON-MAG. SLEEVE
RE-1-20381-A
④

$1\frac{3}{4} \pm \frac{3}{64}$ DIA.

$3\frac{5}{8} \pm \frac{5}{64}$ DIA.

#26 GA.(.018)
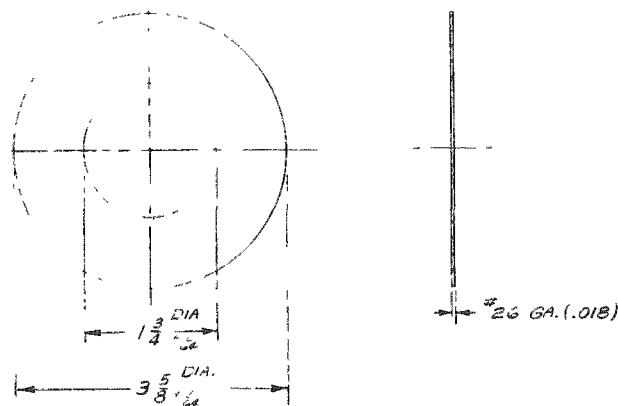
NO. REQUIRED: 2
MATERIAL: 304 SST
NON-MAG. WASHER
RE-1-20380-A
⑤

NOTE
THE THICKNESS OF THIS SHIM IS DETERMINED
BY TEST TO GIVE THE STEP LENGTH SPECIFIED.
IF NECESSARY, UP TO A MAXIMUM OF .075"
MAY BE REMOVED FROM EACH END OF THE ARMATURE
RE-1-20400-B   TO GIVE THE NECESSARY
CLEARANCE.

$1\frac{3}{4} \pm \frac{3}{64}$ DIA.

$3\frac{5}{8} \pm \frac{5}{64}$ DIA.

SEE NOTE
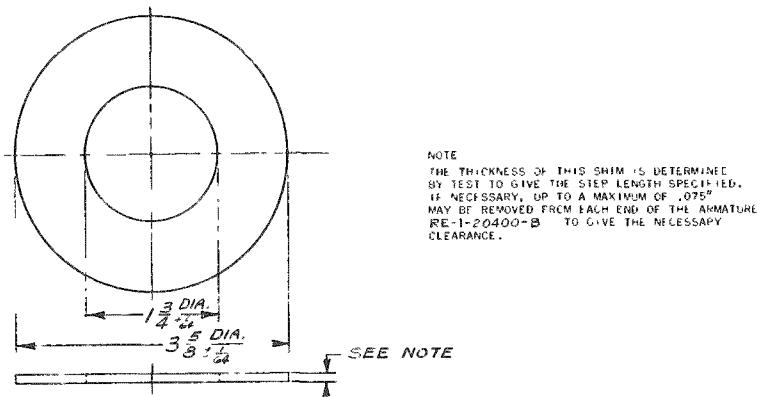
NO. REQUIRED: 1
MATERIAL: 405 SST
SHIM
RE-1-20379-A
⑥

$3\frac{5}{8}$ DIA.

$1\frac{3}{4}$ DIA.

$\frac{3}{16}$
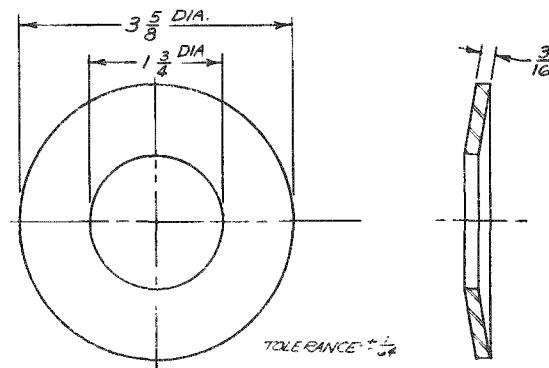
TOLERANCE $\pm \frac{1}{64}$

NO. REQUIRED: 2
TOLERANCES: $\pm \frac{1}{64}$
MATERIAL: 405 SST
CUSHION WASHER
RE-1-20378-A
⑦

SEQUENCE
1   FACE AND BORE ENDS
2   STAMP ONE END AS SHOWN USE DIFFERENT
    NUMBERS FOR EACH SET OF RODS
3   "NEO-CHROME" PLATE 0.6 ** C..T CR
    FOR WEAR RESISTANCE (E FACE (INCL ING
    1 1/2" OF ENGTH) NEED NOT BE PLATED
4   SAW ROD INTO FOUR QUARTERS AND CUT FLAT
    REMOVE SHARP EDGES
5   STRAIGHTEN ROD SO THAT LESS THAN A 10 PO ID
    FORCE IS REQUIRED T MAKE THE ROD STRAIGHT
    WITHIN 1 64"

END VIEW "STAMPED"
SEE SEQUENCE #2
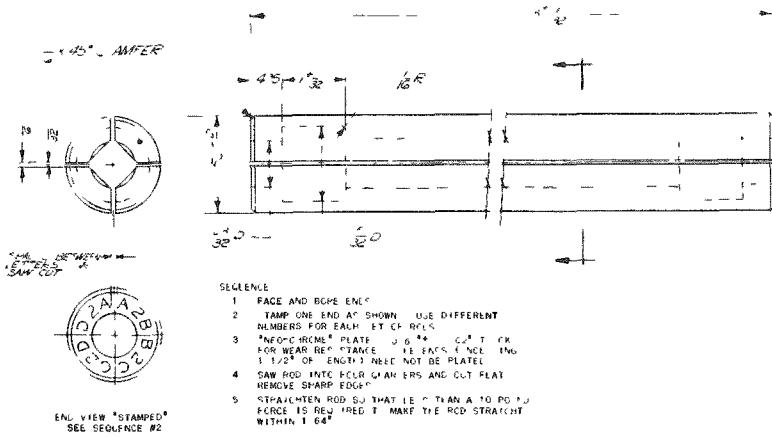
NO. REQUIRED: 1

TOLERANCES:

FRACTIONAL $\pm\frac{1}{64}$

DECIMAL $\pm$ .005

MATERIAL: SST

ARMCO 17-4-PH

DRIVE ROD

RE-1-20177-B

(8)
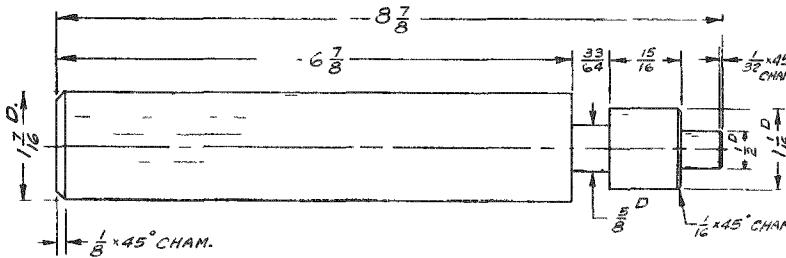
NO. REQUIRED: 1

TOLERANCES:

FRACTIONAL $\pm\frac{1}{64}$

DECIMAL $\pm$ .005

MATERIAL: SST

ARMCO 17-4 PH

P.I. ROD

RE-1-20383-A

(9)
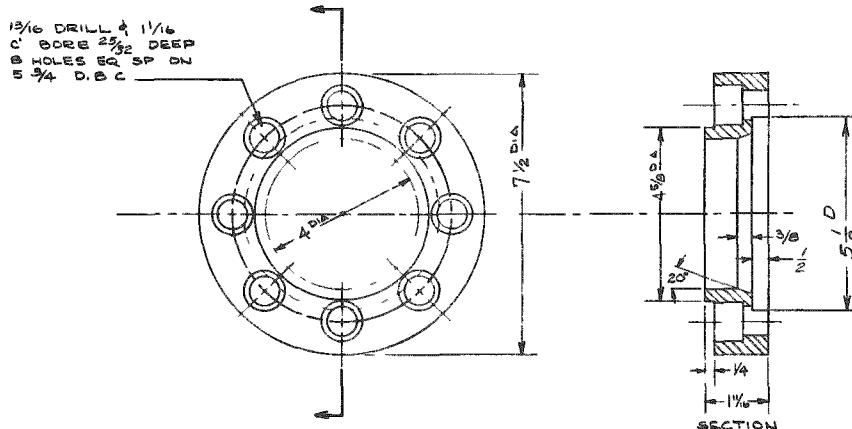
NO. REQUIRED: 1

TOLERANCES: $\pm\frac{1}{32}$

MATERIAL:

MILD STEEL

FLANGE RING

RE-1-20382-B

(12)
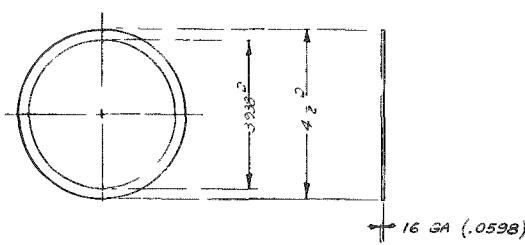
NO. REQUIRED: 16

TOLERANCES: $\pm\frac{1}{32}$

MATERIAL:

MILD STEEL

COIL SPACER

RE-1-20388-A

(16)

Rod Connection

The assembly and detail drawings of the device which connects the control rod to the drive rod of the magnetic jack are listed on page 60 In addition to the connection parts, this device has a stack of Belleville washers which cushion the rod assembly after it is dropped for scramming. The washers also serve as a heat barrier and radiation shield.

The procedure for installing and removing the drive without removing the control rod or the vessel cover is shown on pages 59 and 60 There are no close fitting parts and no screw threads.

Since the crane hook rises only 7 ft above the floor, a lift beam is used with the crane to lift the jack high enough to go over the drive rod. The end of the beam is clamped on the pipe just below the position indicator coils. The crane hook lifts the beam close to the load. The free end of the beam is held down by hand to make the jack hang vertically.

ASSEMBLY PROCEDURE FOR JACK #27 CONNECTION

1. Lower the extension rod ($1\frac{1}{4}$ in. dia by 112 in. long) into the vessel and onto the control rod ball tip. Push the extension rod down lightly to engage the rod. The connection should snap together when the top end of the extension rod is 4 in. above the flange face.

2. Insert the outer tube (6 in. dia. by 34 in. long) in the vessel thimble.

3. Drop the $5\frac{3}{16}$ in. OD Belleville springs into the outer tube, making sure that each spring faces in the opposite direction from the one next to it. Stack them to within $9\frac{1}{4}$ in. and $9\frac{1}{2}$ in. below the top of the outer tube (about 97 springs).

4. Drop the 5 in. OD Belleville springs on top of the larger springs in the same manner. Stack them to within $6\frac{1}{4}$ in. and $6\frac{1}{2}$ in. below the top of the outer tube (about 12 springs).

5. Insert the lock tube ($1\frac{1}{2}$ in. dia by 75 in. long), small bore end up, in the spring seat tube (2 in. dia by 65 in. long), flanged end up, and hook the lift tool into the groove.

6. Lower the spring seat tube into the stack of springs until the flange rests on the springs.

7. Raise the extension rod about $\frac{1}{8}$ in. to allow the connector to close and the lock tube to seat.

8. Raise the extension rod 3 to 6 in. to see that the control rod is connected, then lower it gently to the bottom again.

9. Lower the drive rods (1 x $\frac{1}{2}$ x 53 in.) into the space around the extension rod. Have the stamped end of the rods at the top and arrange the rods so that the letters correspond and each rod has the same number.

10. Lower the filler tube (2 in. dia by 34 in. long) over the drive rods until the flange rests on the spring seat tube.

11. Raise the spring seat tube 6 to 7 in. with the lift tool.

12. Place the two spacers ($2\frac{1}{2}$ x 1 x 6 in.) under the flange of the spring seat tube and lower the tube onto the spacers. Remove the lift tool.

13. Place the spacer retainer (3 in. dia by $6\frac{1}{2}$ in. long) over the flange and spacers.

14. Place two $5\frac{3}{16}$ in. OD Belleville springs concave side up on the spacer retainer.

15. Place two $5\frac{3}{16}$ in. OD Belleville springs concave side down on the other two springs.

16. Raise the filler tube about 2 in. and slip the support washer (6 in. dia by $\frac{1}{16}$ in. thick) into the slots near the top of the filler tube. Then drop the tube.

17. Place the back-up ring ($2\frac{1}{2}$" dia by $\frac{1}{4}$ in. long) on the support washer.

18. Insert the position indicator rod ($1\frac{1}{2}$ in. dia by 9 in. long) in the top end of the drive rod.

19. Place the gasket in the groove of the thimble flange.

20. Lower the magnetic jack over the rod. See that the support washer fits up into the adapter flange of the jack and the four springs fit down into the outer tube.

21. Bolt the adapter flange down to the thimble flange. There should be no gap between the flanges.

REMOVAL PROCEDURE FOR JACK #27 CONNECTION

1. Remove the bolts that fasten the adapter flange to the thimble flange.

2. Hoist the magnetic jack at least 33 in. straight up; then remove.

3. Remove the position indicator rod, the gasket and the back-up ring.

4. Remove the support washer and let the filler tube drop onto the spring seat tube.

5. Remove the four $5\frac{3}{16}$ in. OD Belleville springs.

6. Remove the spacer retainer.

7. Raise the spring seat tube $\frac{1}{2}$ to 1 in. with the lift tool. Then remove the two spacers and lower the spring seat tube slowly onto the stack of Belleville springs. Remove the lift tool.

8. Remove the filler tube.

9. Remove the four drive rod quarters by moving the lower ends outward, then lifting. Use drive rod tool if necessary (48" aluminum bar).

10. Use the lift tool to lift the spring seat tube out with the lock tube in it.

11. Remove most of the Belleville springs to reduce the weight; then remove the outer tube.

12. Lift the extension rod 3 to 6 in. to see that the control rod is disconnected. If the control does not remain at the bottom, hold it there with an 8-ft rod or tube while lifting the extension rod.

PARTS LIST FOR JACK #27 CONNECTION

Number Required Per Unit		Page	Part Name	Drawing Number
1		62	Adapter Flange	RE-1-22615-B
1		62	Spring Seat Tube	6-B
1		63	Filler Tube	7-B
1		63	Lock Tube	8-B
14		63	5 in. dia Belleville Spring	9-A-Part #1
102		63	$5\frac{3}{16}$ in. dia Belleville Spring	9-A-Part #2
1		64	Support Washer	20-A
2		64	Spacer	1-A
1		64	Spacer Retainer	2-A
1		64	Back-up Ring	3-A
1		65	Outer Tube Assembly	4-B
	1	65	Body	5-B
	1	65	End	6-A
1		66	Extension Rod Assembly	7-B
	1	66	Drive End	8-A
	1	66	Tube	9-A
	1	66	Rod End	30-B
	1	66	Upper End	RE-1-22769-A
		62	Lift Tool	RE-1-24181-B
1			Gasket, Flexitallic #R4-4N	
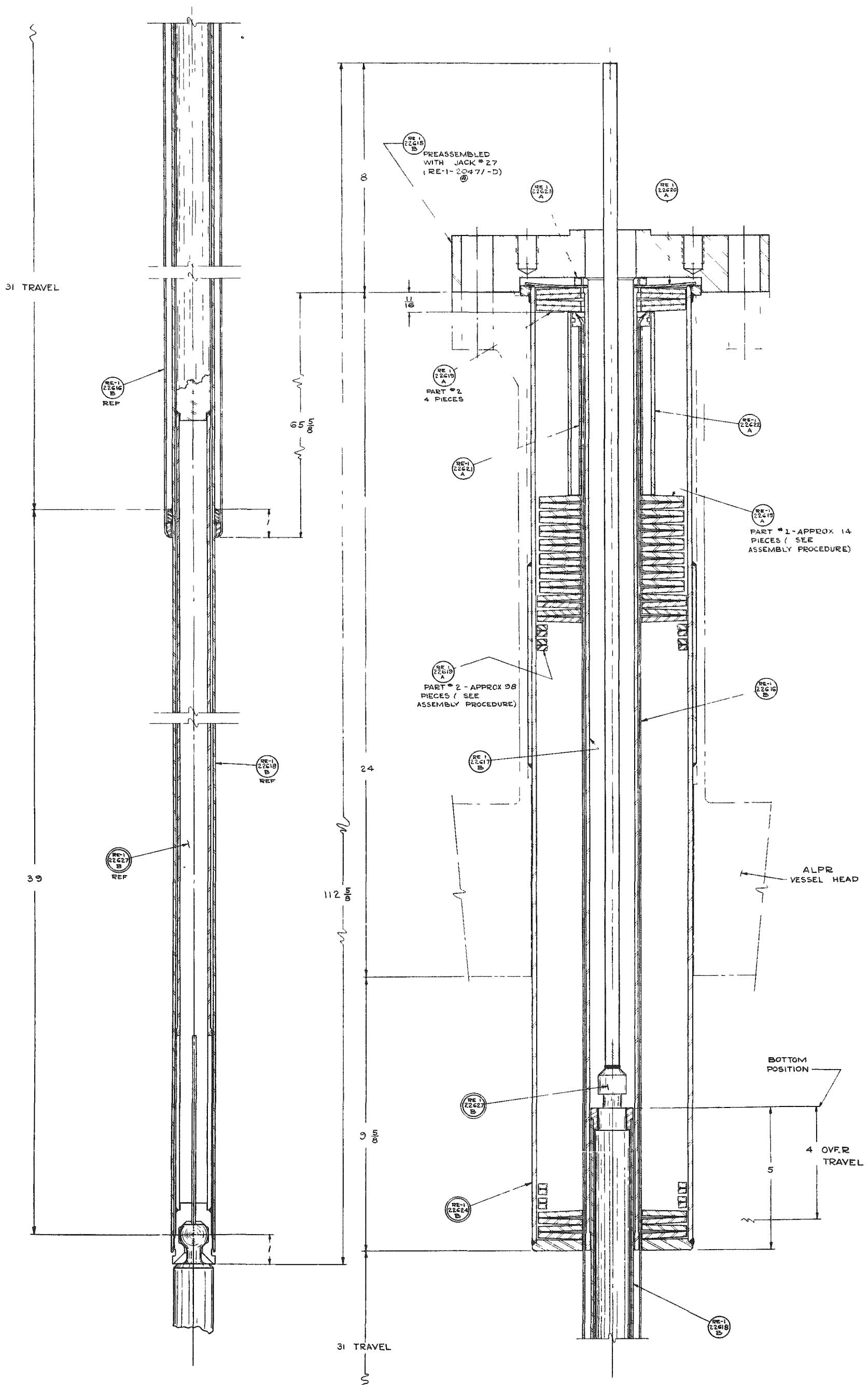
ROD CONNECTION ASSEMBLY

RE-1-22614-F

3/8" X 4"LG. PIPE NIPPLE
2 REQ'D

3
2 1/2 ±1/64

1 1/2
10
1/2
1 1/4

3/8" PIPE TAPE
2-HOLES

NOTE FRACTIONAL DIMS
ARE ±1/64 UNLESS
OTHERWISE NOTED

MATERIAL:
11 GA. (.119)
MILD STEEL
LIFT TOOL
RE-1-24181-B
(SEE ASSEMBLY
PROCEDURE)

FRAC TOL ± 1/32

1 3/4 D HOLE

21/32 DIA DRILL- 1 3/8 DEEP
3/4-10 BOTTOM TAP
1" DEEP, 8 HOLES
EQ SP ON 5 3/4 DBC

45°

1 3/32 DR, 8 HOLES
EQ SP ON
9 1/4 DBC

1"D

2 25/32 DIA ± 1/64

NOTE
1/16 X 45° CHAMF
ON ALL EDGES

2 3/16
2

1/2

6 9/32 DIA ± 1/64   SECTION A-A

NO. REQ'D.: 1
MATERIAL: 405 SST
ADAPTER FLANGE
RE-1-22615-B

FRAC. TOL ± 1/32

3/16
1/16

3/16 ± 1/16
3/8

1 21/32 DIA ± 1/64
1/32 X 45°
60° ± 5°

2" O D X 1/16 WALL
TUBE

± 5°
60°

2 11/16 DIA
1 1/2 DIA

1/8

NOTE:
FINISH ONLY 1 11/16 D BORE
AFTER WELDING
DO NOT REMOVE METAL
FROM THE 1/16" WALL TUBE

1/2
1/2
7/32

64 15/16 ± 1/16

NO. REQ'D. 1
MATERIAL: 304 SST
SPRING SEAT TUBE
RE-1-22616-B

TOL FOR DIAMETERS - ± /64
TOL FOR LENGTHS = ± / 6
TOL DECIMAL = ±.005

NO. REQ'D.: 1
MATERIAL: 304 SST
FILLER TUBE
RE-1-22617-B
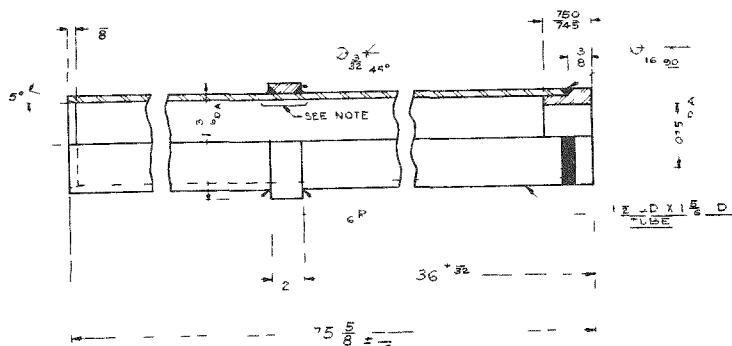
NOTE
REAM TO 1 3/32 DIA
F NECESSARY AFTER
WELDING

NO. REQ'D.: 1
TOLERANCES:
    FRACTIONAL ± $\frac{1}{64}$
    DECIMAL   ± .005
MATERIAL: 304 SST
LOCK TUBE
RE-1-22618-B
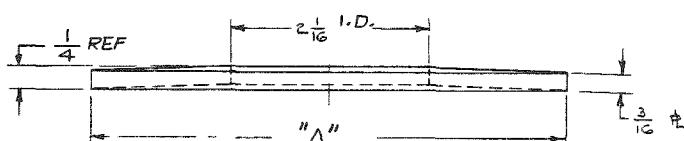
TO GIVE DESIRED SPRING
BACK, PRESS WITH 10° DIE,
THEN PRESS WITH FLAT DIE

PART #1, "A"=5", NO.REQ'D.: 14
PART #2, "A"=5 $\frac{3}{16}$ ", NO.REQ'D.:102
TOLERANCES: ± $\frac{1}{64}$
MATERIAL: 17-4 PH SST
BELLEVILLE SPRING
RE-1-22619-A
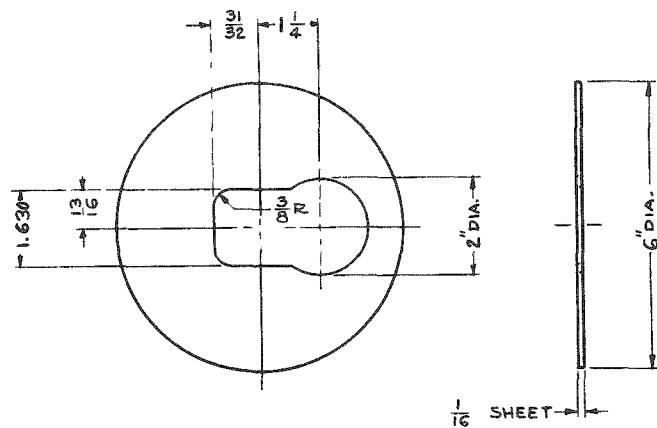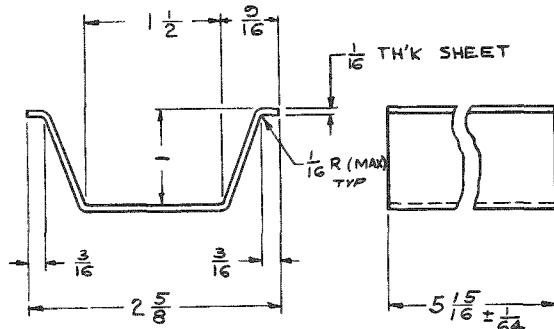
FRACTIONAL TOL ± 1/32
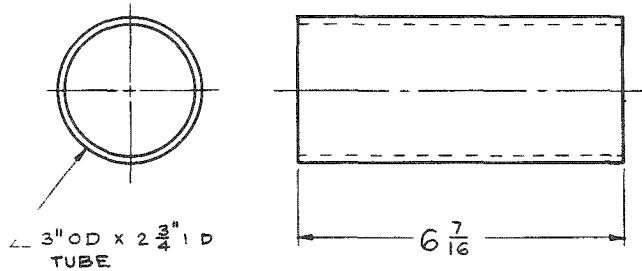
NO. REQ'D.: 1
MATERIAL: 304 SST
SUPPORT WASHER
RE-1-22620-A

FRAC TOL ± 1/32

NO. REQ'D.: 2
MATERIAL: 304 SST
SPACER
RE-1-22621-A

3" OD X 2 3/4" I D
TUBE

NO. REQ'D.: 1
TOLERANCES: ± $\frac{1}{64}$
MATERIAL: 304 SST
SPACER RETAINER
RE-1-22622-A
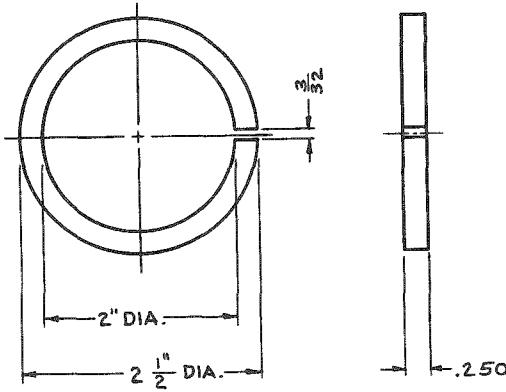
NO. REQ'D.: 1
TOLERANCES:
    FRACTIONAL ± $\frac{1}{32}$
    DECIMAL   ± .005
MATERIAL: 304 SST

BACK-UP RING
RE-1-22623-A
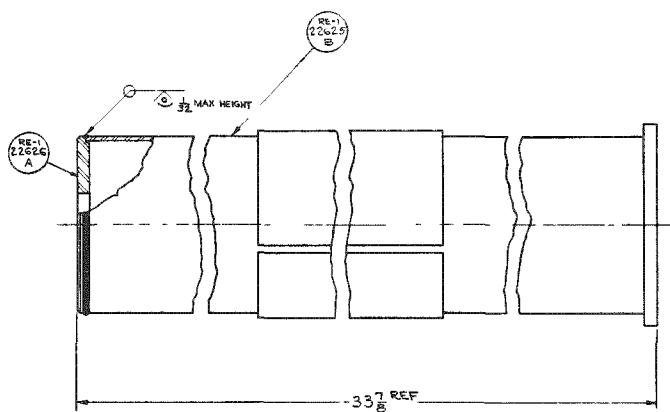
NO. REQ'D.: 1
TOLERANCES: $\pm \frac{1}{64}$
MATERIAL: 304 SST
OUTER TUBE
RE-1-22624-B

RE-1-22625-B

66
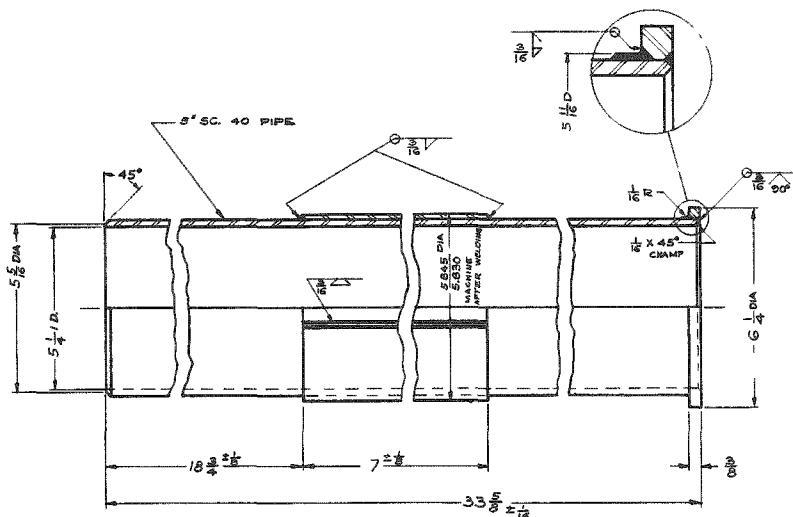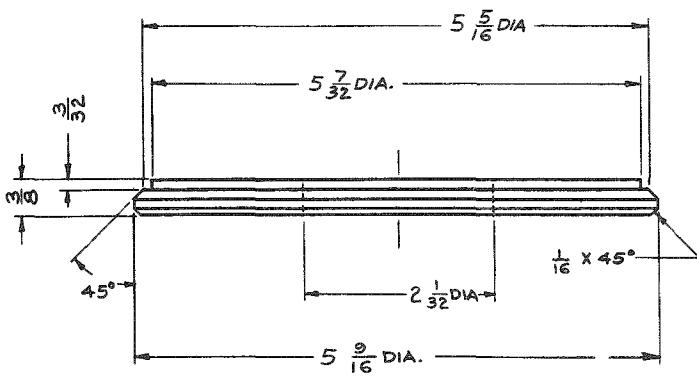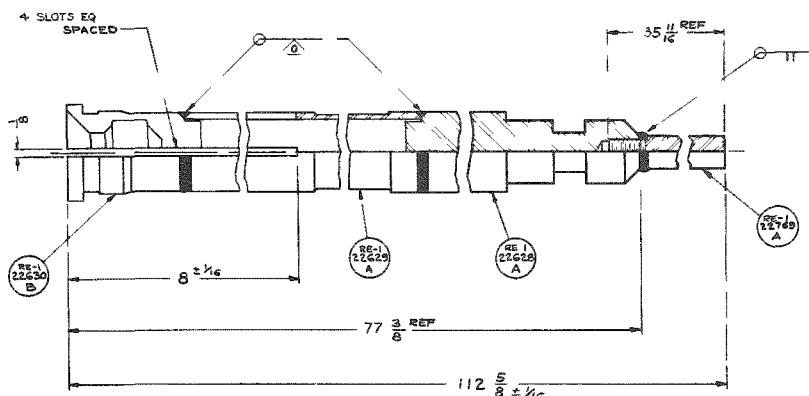
NO. REQ'D.: 1
MATERIAL: 304 SST
EXTENSION ROD
RE-1-22627-B
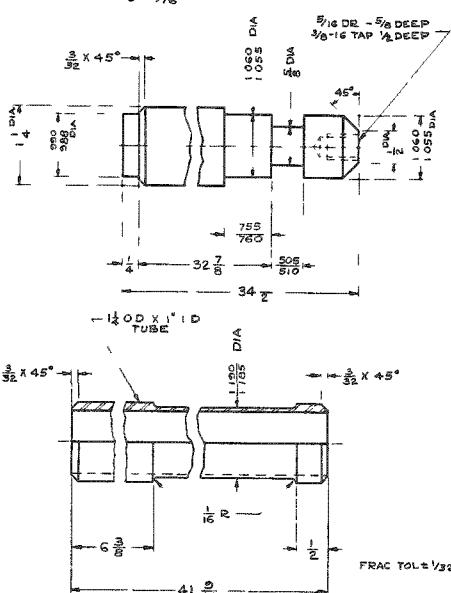
TOLERANCES: $\pm \frac{1}{64}$
RE-1-22628-A

RE-1-22629-A
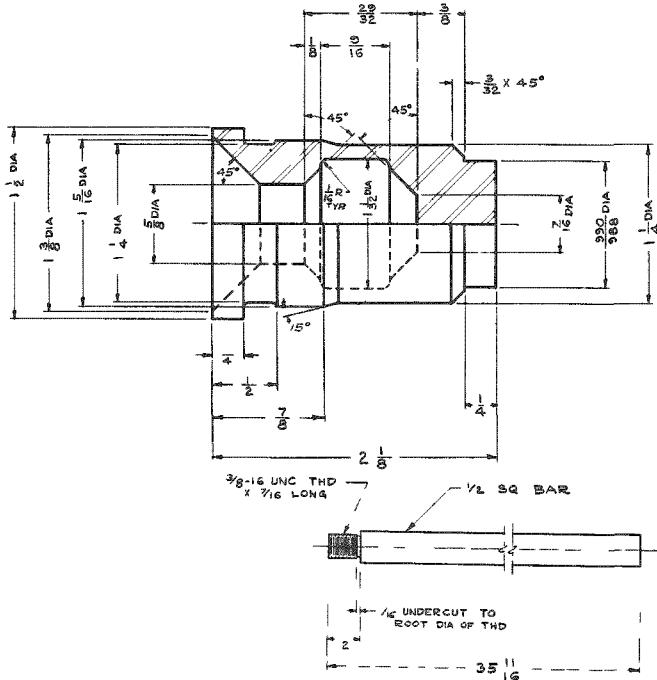
TOLERANCES: $\pm \frac{1}{64}$
RE-1-22630-B

RE-1-22769-A

TOL OF LENGTHS = $\pm \frac{1}{32}$

Position Indicator

       Approximate position is shown on a long-scale meter which has equally spaced inch marks. Close position is measured by switching a milliammeter to the group of coils in which the end of the drive is located. The position is then read on a corresponding curve which converts milliamps to inches.

       To adjust for any variation in line voltage and also to compensate for changes in temperature of the drive, the voltage is adjusted manually so that a meter indicates the voltage which should be used at that temperature.

       The center light (amber) located under the position meter indicates that this drive is selected to be operated. This is the same as that used with the rack and pinion drive. The right light (red) indicates that the rod is all the way out and the left light (green) indicates that the rod is all the way in. This function is similar to that used with the rack and pinion drive, but the actuation is by coil and relay instead of by limit switch.

       Although the position indicator meter is mounted in a standard cabinet for testing and shipping, the meter may be mounted on the ALPR panel in place of one of the existing position indicators.

       The position indicator coil assembly is shown on page 68. The spaces between the coils are adjusted to make the meter read correctly.

       In addition to the coils, the position indicator system consists of the following components: Power Supply, page 69; Selector, page 70; Meters and Lights, page 70.

68

COIL NO.

TERMINAL NUMBER
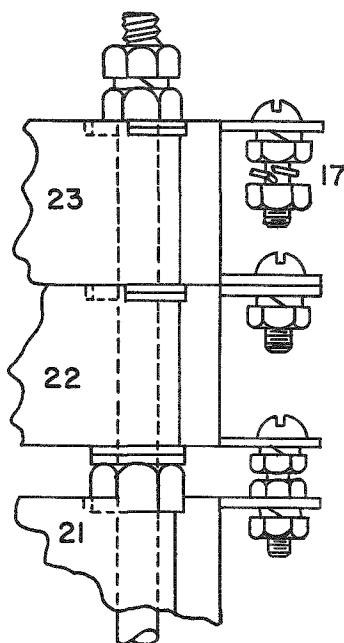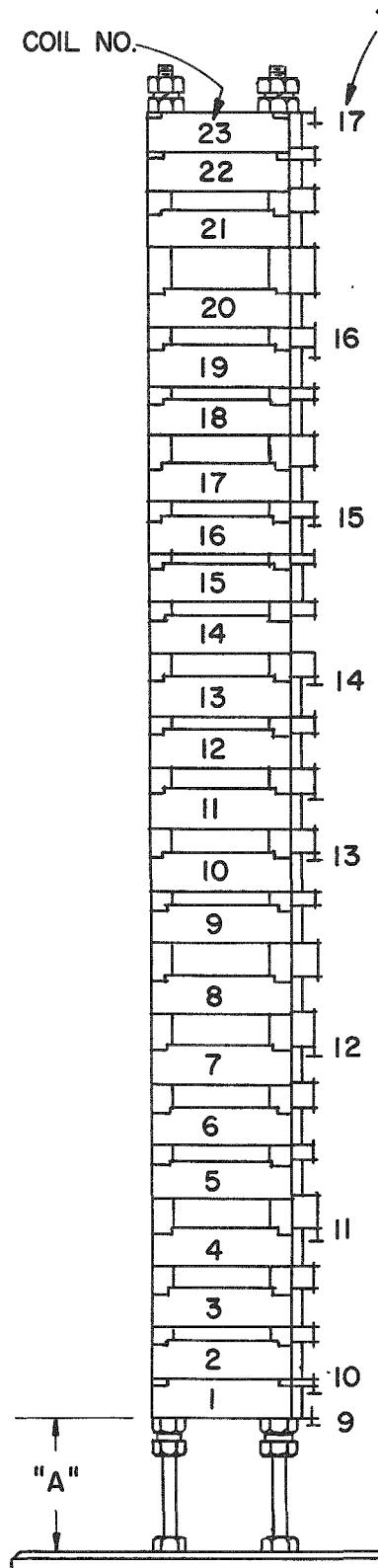
Coil No.	Distance from Top of Plate to Bottom of Coil
23	34-5/8
22	33-5/8
21	32-5/16
20	30-9/32
19	28-13/16
18	27-9/16
17	25-15/16
16	24-21/32
15	23-7/16
14	22-5/32
13	20-5/8
12	19-3/8
11	17-7/8
10	16-3/16
9	15-1/16
8	13-5/16
7	11-17/32
6	9-31/32
5	8-21/32
4	7-1/16
3	5-1/2
2	4-1/4
1	3-1/4

NOTE: Coil spacing is slightly different for different meters.

"A"

No. Req'd.	Part
23	Coil, see page 113
1	Plate, RE-1-20387-A, (15) , see page 50
4	Tie rod, 1/4" dia x 37" long 1/4" - 20 thd. 4" long, 304 SST
20	Hex. nut, 1/4" - 20, brass
8	Lock washer, 1/4", steel
*	Hex. nut, 5/16"-24, 1/2" across flats, SST
*	Flat washer, #14, 9/16" OD x 260" ID x .040" th., brass
24	Round head screw, #6-32, lengths to suit, brass
71	Hex. nut, #6-32, brass
52	Lock washer, #6, plated steel
*	Flat washer, #6, brass

*As required for spacing coils

LINEAR SCALE-TYPE POSITION INDICATOR COIL ASSEMBLY
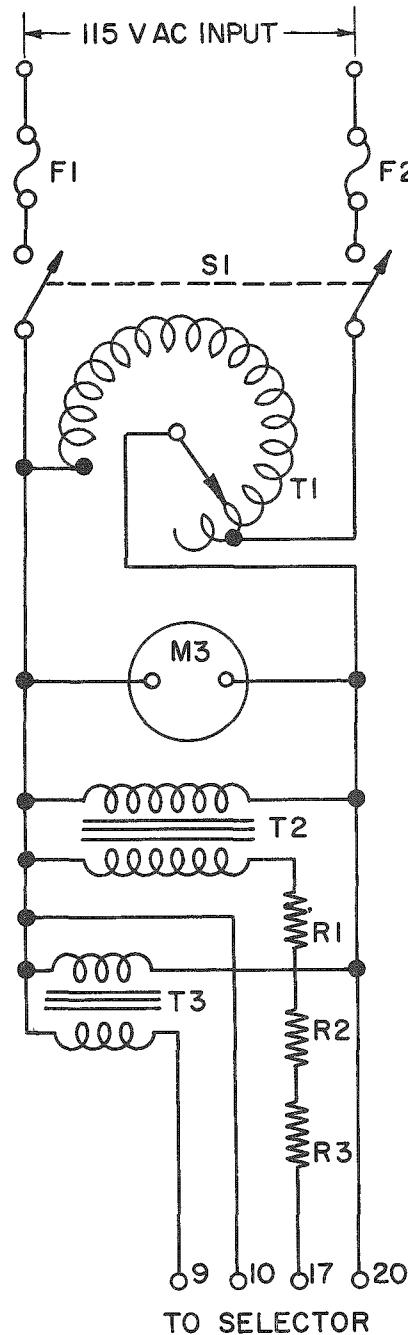
F1, F2	Fuse, 5A
S1	Switch, DPST, 5A
T1	Adjustable transformer, 120 V. input, 0-132 V. output, 1.25 A.
T2	Power transformer, 115 V. input, 460 V. output, 0.1 KVA
T3	Filament transformer, 117 V. input, 6.3 V. output, 3 A
R1, R2, R3	Resistor, 1000Ω 100 W
M3	Voltmeter, 0-130 AC, $4\frac{1}{4}$ in. expanded long scale, GE #AB-18

ALPR P.I. Power Supply (One Drive)
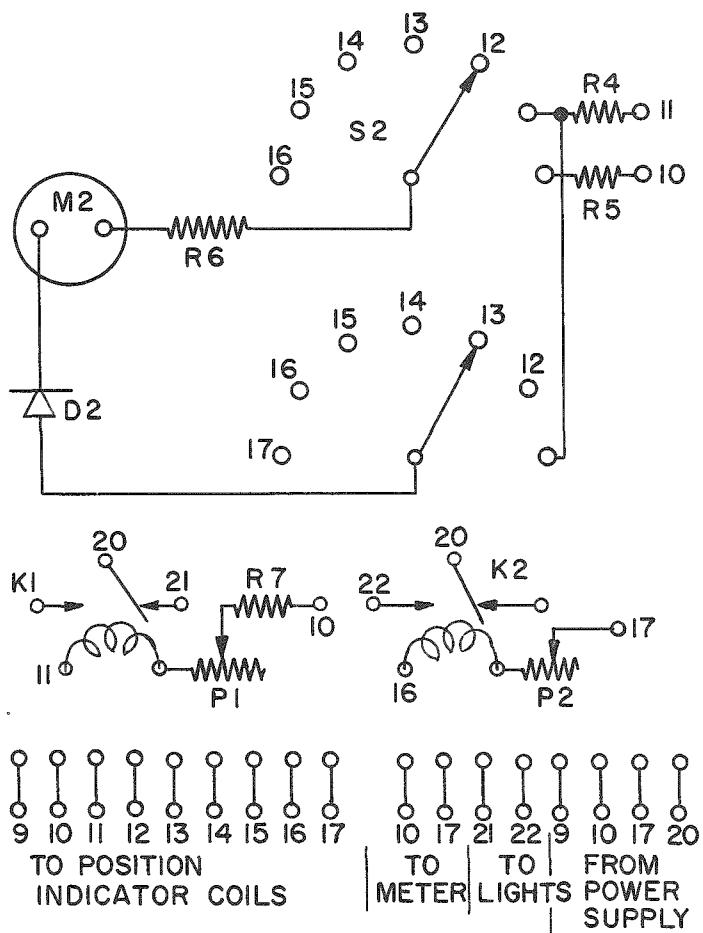
S2	Selector switch, 2 sec, 7 pos., N-S
M2	Milliammeter, 0-1, $4\frac{1}{4}''$ long - scale, GE #DB-18
D2	Silicon diode, PSI Type IN628
K1, K2	Sensitive relay, sigma #5RS-12AS-SIL
P1, P2	Potentiometer, 1000 Ω , 1 W.
R4	Res., 300 Ω , 1 W
R5	Res., 2200 Ω , 1 W
R6	Res., 1500 Ω , 1 W.
R7	Res., 2000 Ω , 1 W.

ALPR P.I. Selector (one drive)
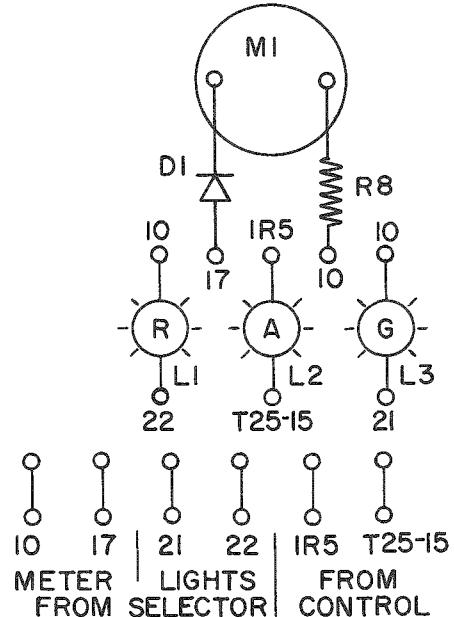
M1	Microammeter, 0-300, $8\frac{3}{4}$ " long-scale, GE #DB-16.
D1	Silicon diode, PSI Type IN628
R8	Resistor, 74400 Ω , 1 W.
L1	Light, red, 115 V
L2	Light, amber, 115 V.
L3	Light, green, 115 V.

ALPR P.I. METER AND LIGHTS (One drive)

Control

The control shown on page 73 is used for preliminary test operation of the magnetic jack. For actual reactor operation the jack power supply is connected to the reactor control panel.

The jack makes 30 steps per minute. The step length is adjusted to 0.10 inch at assembly to give a speed of 3 inches per minute (see shim drawing RE-1-20379-A, page 56). A switch may be provided on the control panel for switching from the coarse step to a fine step of about 0.006 inch.

Power Supply

The power supply consists of a commutator switch (page 74) and a rectifier assembly (page 75). The commutator switch should be replaced after about 300 hours of operation (1 year, assuming the control rod is moving 3.4% of the time).

The magnet coils and the position indicator coils are powered by a high-temperature flexible cable which goes through the rack and pinion drive shaft hole in the shield. The cable has a plug which plugs into the socket that powered the rack and pinion drive.
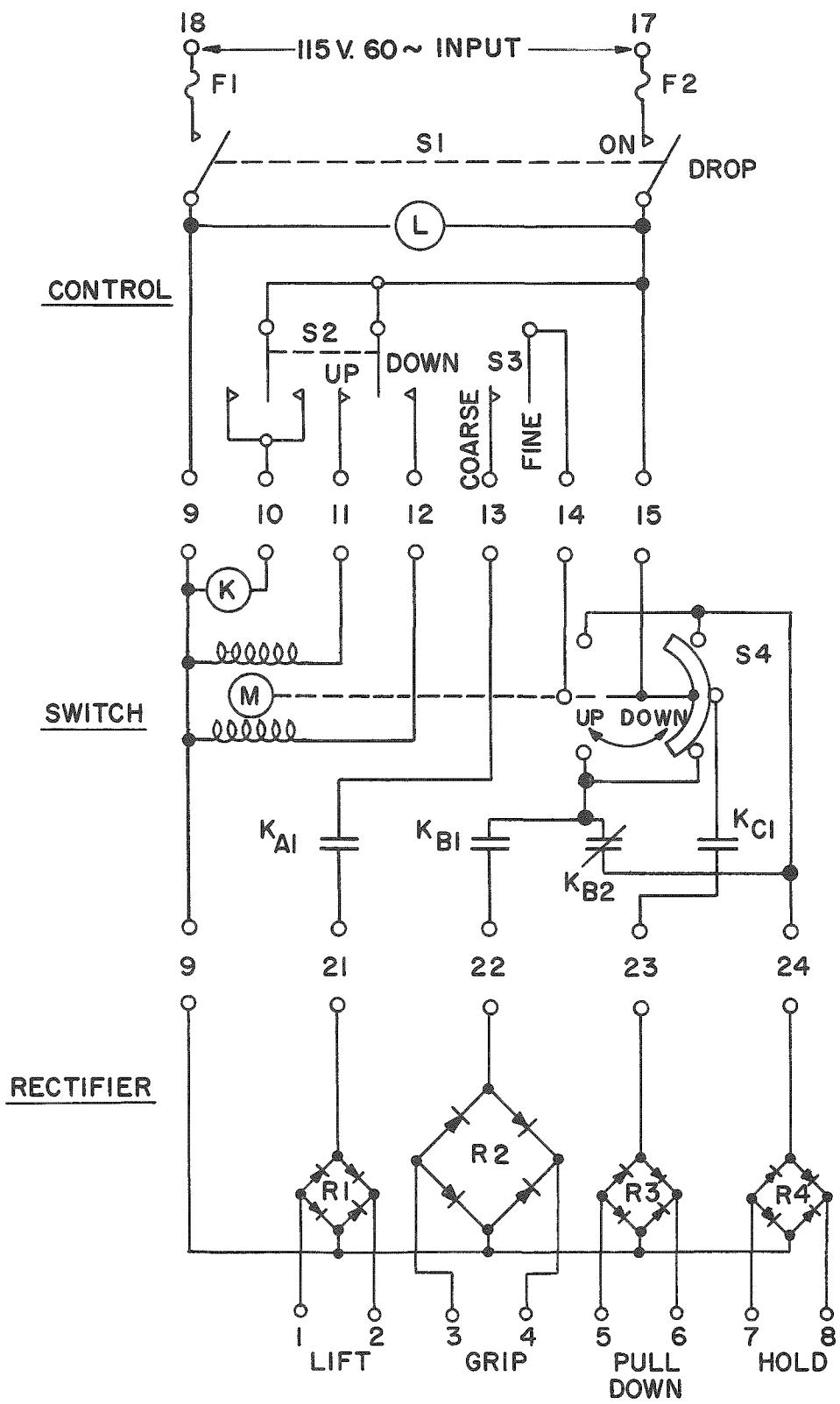
POWER SUPPLY FOR ONE MAGNETIC JACK
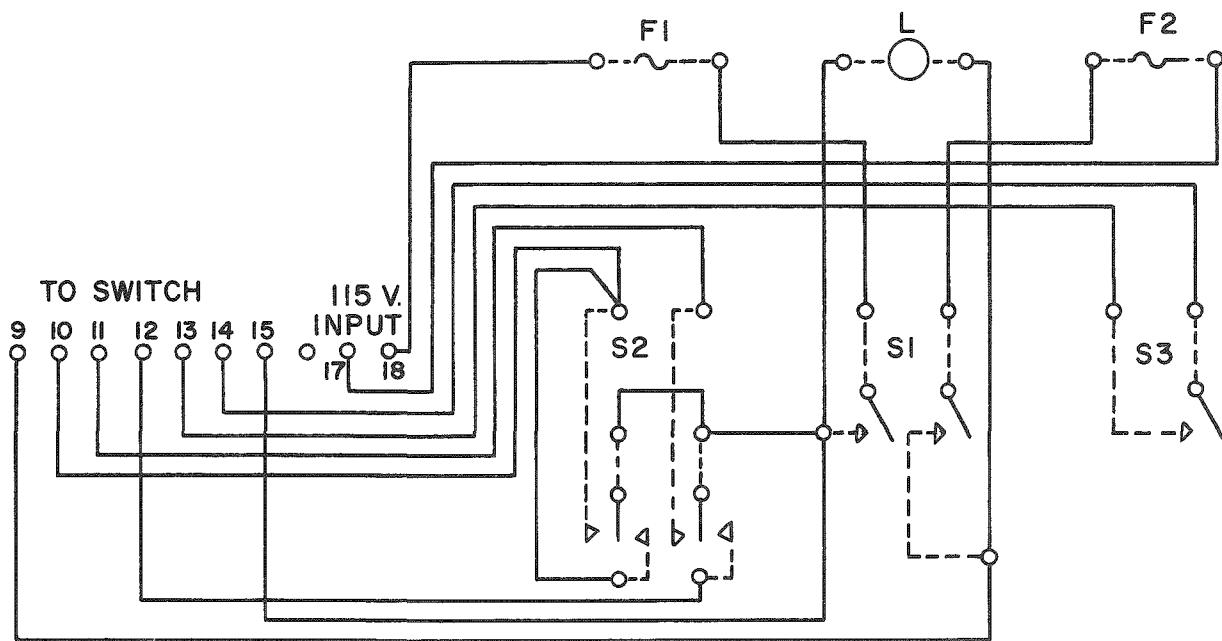
S1	Switch, DPST, 15 A
S2	Switch, DP3T, spring return to center off, 5A
S3	Switch, SPST, 10 A
F1, F2	Fuse, 30 A
L	Indicating light, 115 V.

CONTROL (for one rod)
Back View
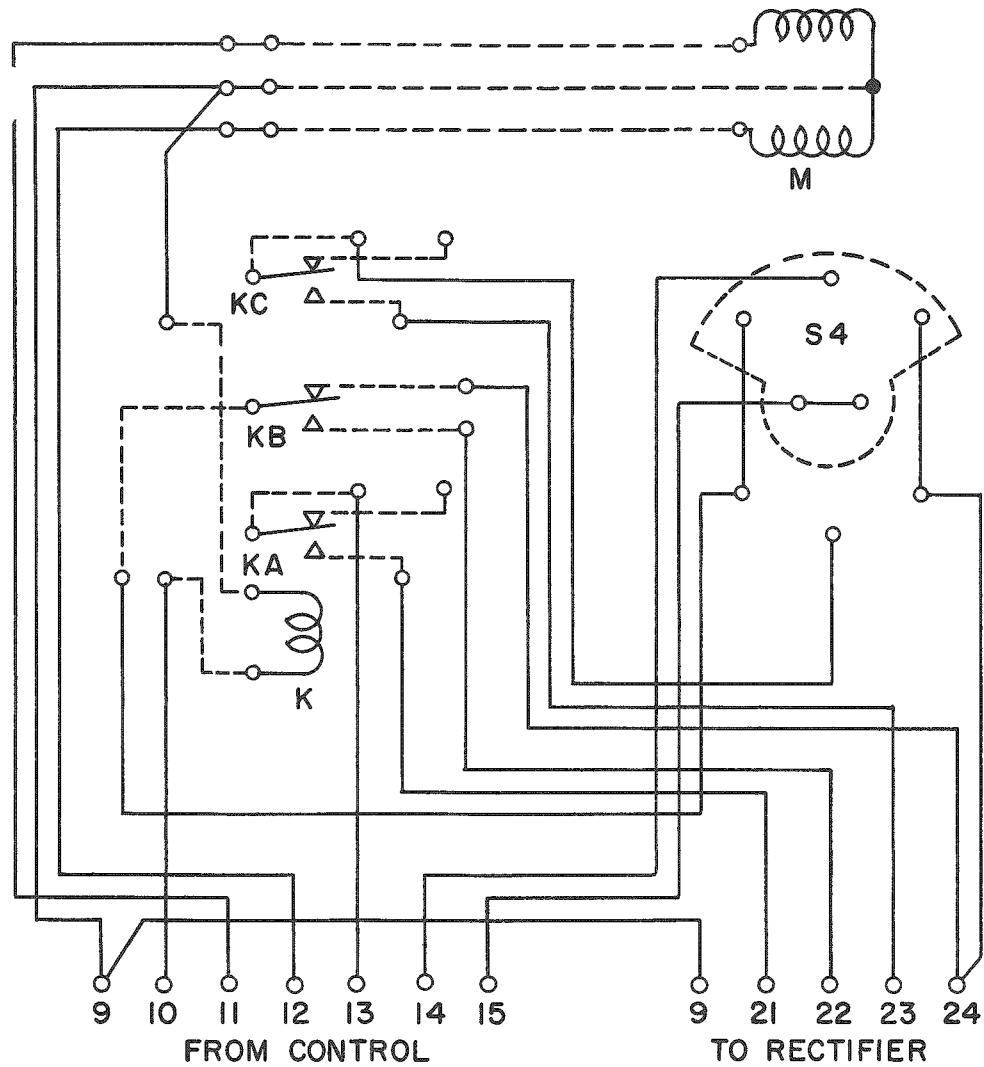
S4	Commutator switch, RE-1-23472-D, 3-D, 4-D
M	Gear motor, Merkle-Korff #SG-15, 30 rpm, 9 lb. in. torque, tandem reversible, $\frac{1}{4}$" diam x $\frac{7}{8}$" long horizontal shaft, no base, 115 VAC
K	Relay, 3PDT, 115 VAC coil, 15 A contacts

SWITCH (Commutator)
Back and Top View

R2 R5 R6

R1 R3 R4

1 2 3 4 5 6 7 8   9 21 22 23 24

TO DRIVE SELECTOR OR TO   FROM SWITCH
MAGNETIC JACK

R1, R2, R3, R4, R5, R6, SELENIUM RECTIFIER, 5 A., 100 VDC, BRIDGE
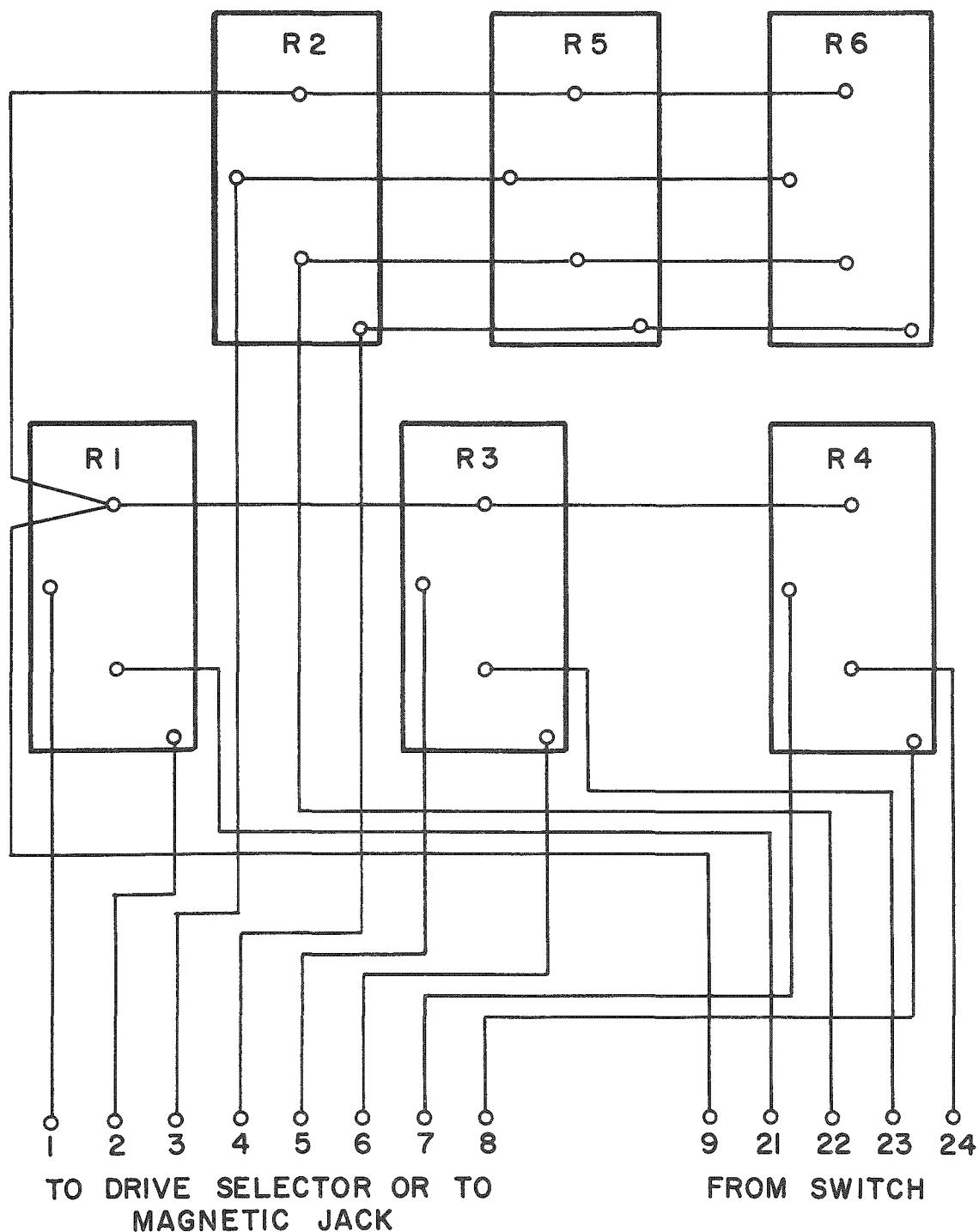
RECTIFIER (SELENIUM) BACK AND TOP VIEW

MOTOR SHAFT

⑩

⑮ ⑫ ⑯ ⑨

$\frac{3}{32}$ DRILL

$\frac{7}{16}$

$\frac{1}{8}$

⑲

⑳

MOTOR
(SEE CIRCUIT DIAGRAM)

⑱

⑦

⑰

⑧ ⑭ ⑪ ① ⑤

⑬

② ③ ④
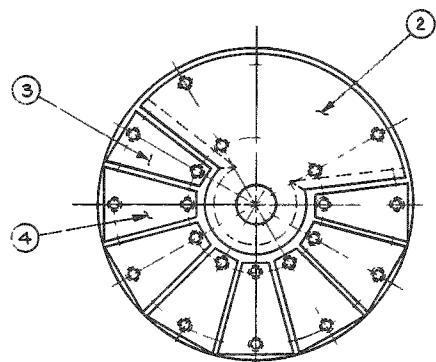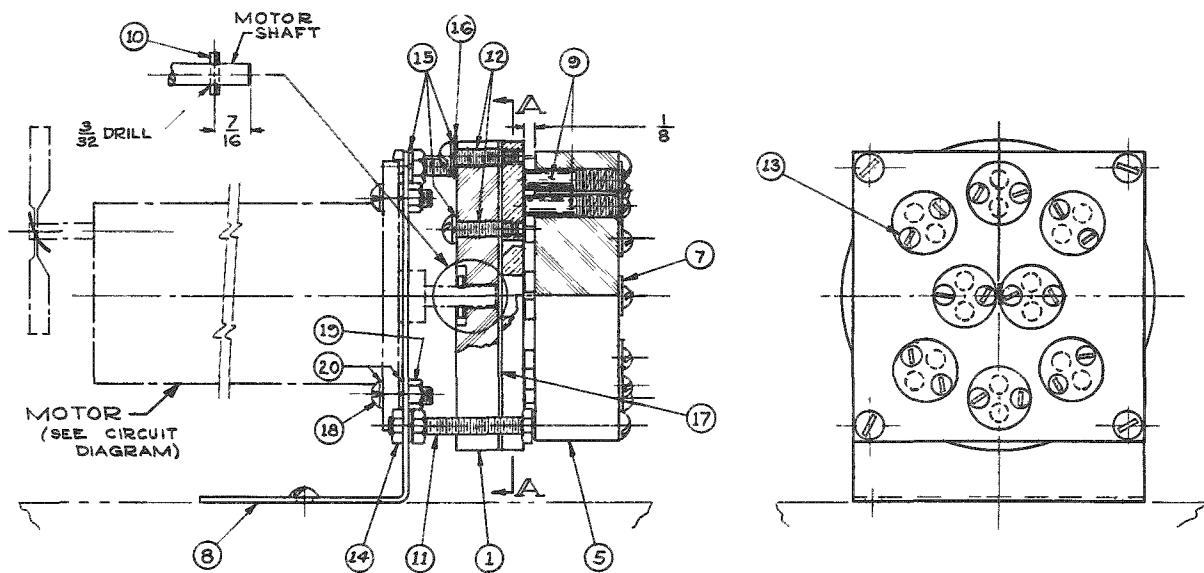
SECTION A~A

COMMUTATOR SWITCH — B/M			
PART No.	PART NAME	MATERIAL	No. REQ.
1	DISC	PHENOLIC	1
2	CONDUCTOR	COPPER	1
3	END BAR	COPPER	2
4	MIDDLE BAR	COPPER	6
5	BRUSH HOLDER	PHENOLIC	1
6			
7	PLAIN PLATE	BRASS	8
8	MOTOR BASE	MILD STEEL	1
9	CARBON BRUSH *YB-27	STANDARD	16
10	ROLL PIN~$\frac{3}{32}$D X $\frac{1}{2}$ LG.	STEEL	1
11	RD. HD. SCR. #10-32 X 2$\frac{3}{4}$ LONG	BRASS	4
12	RD. HD. SCR. #10-32 X $\frac{3}{4}$ LONG	BRASS	20
13	RD HD. SCR. #6-32 X $\frac{1}{2}$ LONG	BRASS	16
14	HEX. NUT #10-32	BRASS	12
15	LOCK WASHER~#10	STEEL	28
16	FLAT WASHER~#10	BRASS	10
17	INSULATOR $\frac{1}{32}$ THK. X 3$\frac{3}{4}$ DIA	MICA SHEET	1
18	RD. HD. SCR. #8-32 X $\frac{1}{2}$ LONG	BRASS	4
19	HEX. NUT #8-32	BRASS	4
20	LOCK WASHER #8	STEEL	8

COMMUTATOR SWITCH ASSEMBLY

RE-1-23474-D

PART No 1
½" THK CLOTH BASE
PHENOL FIBER- TOL.= ± ¹⁄₆₄

3/16 WIDE X 5/16 DEEP
12 SLOTS IN LINE
WITH HOLES

3/16 DRILL
12 HOLES EQ. SPACED
ON 1⅝ DIA B C

¼" REAM
SQUARE WITH FACE

3 ¾ DIA

7/64

PART No 2
¼" THK COPPER PLATE
TOL = ± ¹⁄₆₄

½ DRILL
19/32 R
13/16 R
1 13/16 R
1 11/16 R
3/32
45°
3/32
22½°
90°
#21(159) DRILL
#10 32 TAP
4 HOLES

⅛ X 45° CHAMF
(APPROX)

¼

PART No 3
¼" THK COPPER PLATE
TOL = ± ¹⁄₆₄

15°
7½°
23/32
17/64
#10-32 TAP

PART No. 4
¼" THK COPPER PLATE
TOL = ± ¹⁄₆₄

15° 15°
29/32
29/64
#10-32 TAP
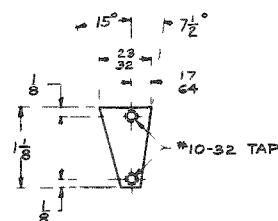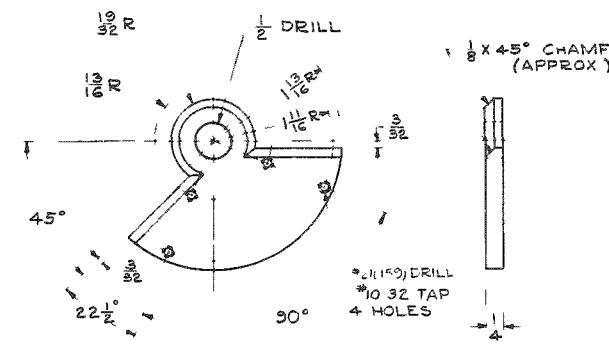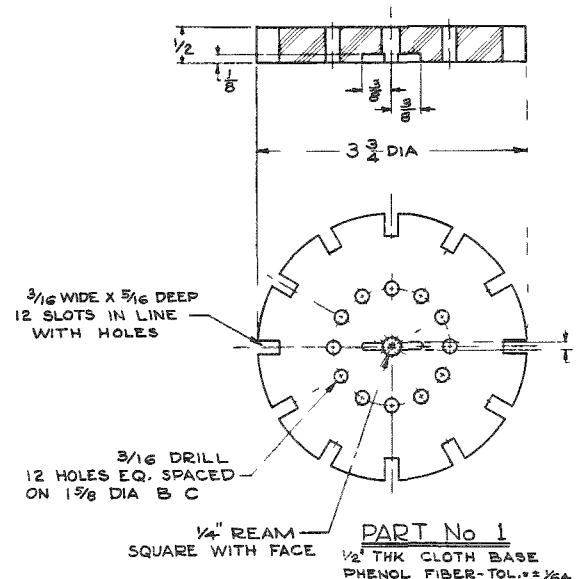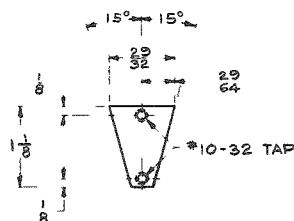
COMMUTATOR SWITCH ROTOR PARTS
RE-1-23472-D

78

#36(.1065) DR. THRU
#6-32 TAP-½ DEEP
16 HOLES

3½

1 9/16 (TYP)

1 13/32 13/32

1 ¼ (TYP)

1 3/4

#F (.257) DRILL
16 HOLES

13/64 DRILL
4 HOLES

1/4 (TYP)

½ (TYP)

45°   45°

1 3/4

3½
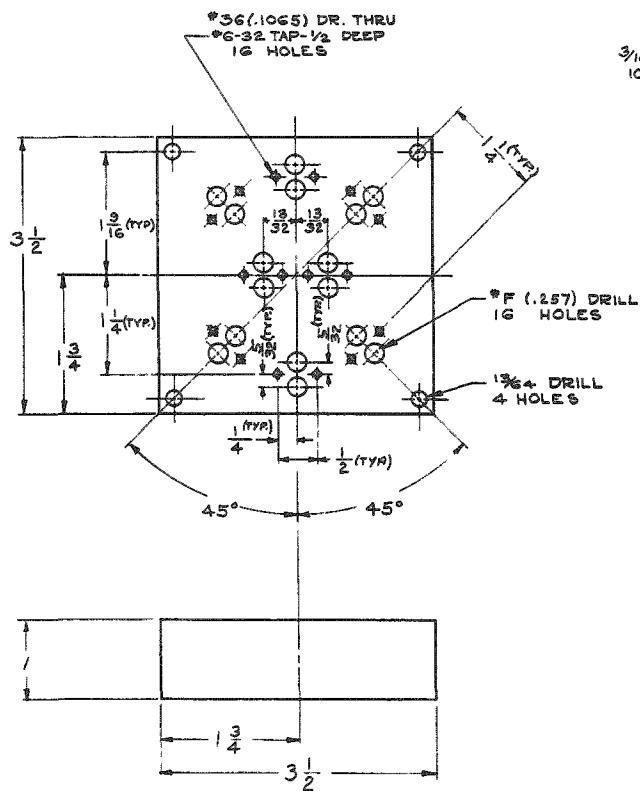
PART No. 5
1" THK. CLOTH BASE
PHENOL FIBER ~ TOL.= ± 1/64

3½

1 3/4

3/16 PUNCH
10 HOLES

3/4 PUNCH

2½

1 9/16

1 3/16

1 3/16

4 ¼

1 9/16

1 3/16   1 3/16

1 9/16   1 9/16

1 ½   1 ½

1/16 SHEET

1 ¼

2½
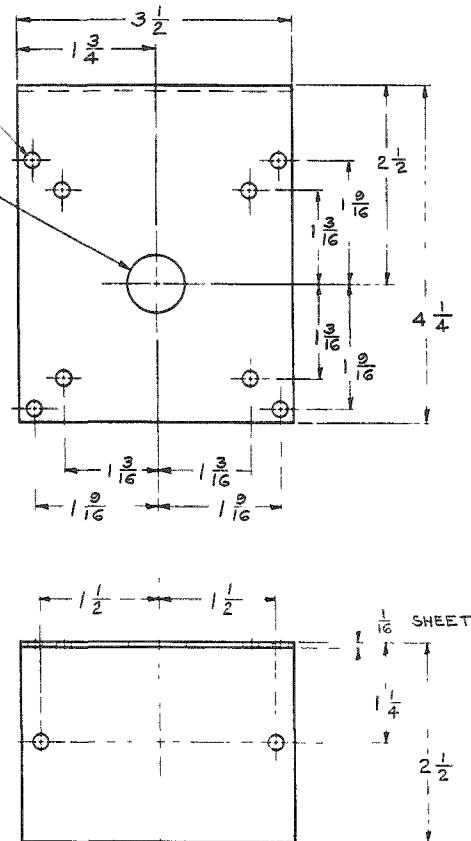
PART No. 8
1/16" THK. MILD STEEL
SHEET – TOL.= ± 1/32

5/32 PUNCH
2 HOLES

1/4   ½

1/32 SHEET

3/4 DIA.
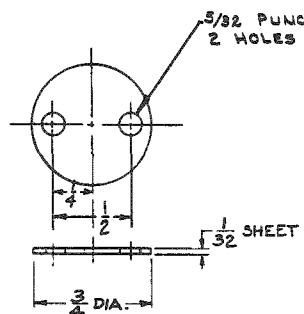
PART No. 7
1/32 THK. BRASS SHEET
TOL. = ± 1/64

COMMUTATOR SWITCH MOUNTING PARTS
RE-1-23473-D
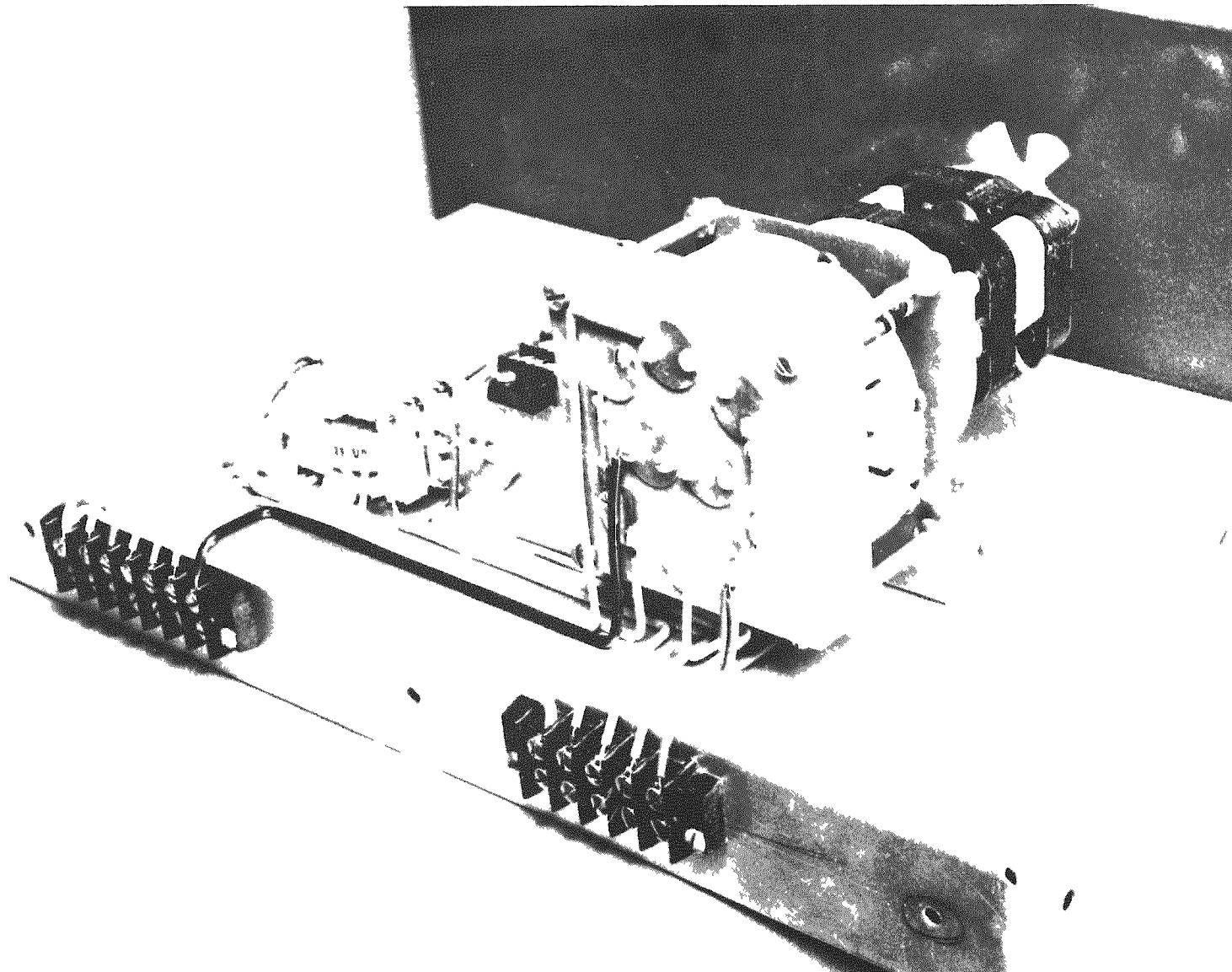
111-7509   COMMUTATOR SWITCH   SEE DIAGRAM ON PAGE 35

Electrical Components for Five Jack Drives

Although the components are shown on page 81 as mounted in two standard cabinets the position indicator meters may be mounted on the ALPR panel in place of the existing position indicators and the ALPR control panel may be used by rewiring it for the magnetic jack drive.

The position indicator components for five drives are:

Five coil assemblies, page 68

One voltage adjustment, page 84

One power supply, page 84

One selector, page 85

Five meter and lights assemblies, page 86

The power supply components for five drives are:

One drive selector, page 83

Two commutator switches, page 74

Two rectifier assemblies page 75
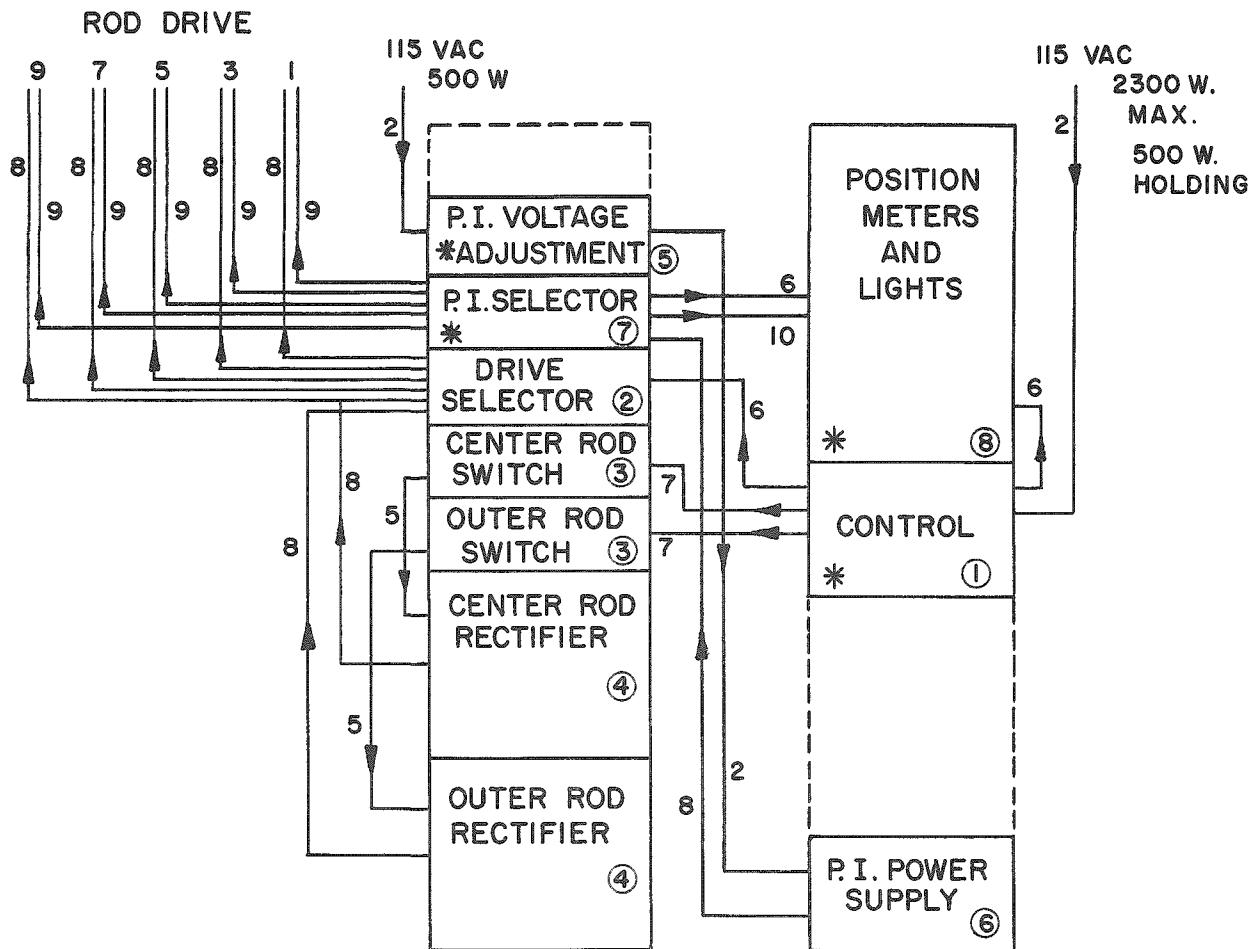
NUMBERS ON CABLES
INDICATE CONDUCTORS

* PANELS WHICH HAVE
COMPONENTS MOUNTED
ON THE FRONT

ALPR MAGNETIC JACK CONTROL ROD DRIVE ELECTRICAL
PANEL (FIVE DRIVES)
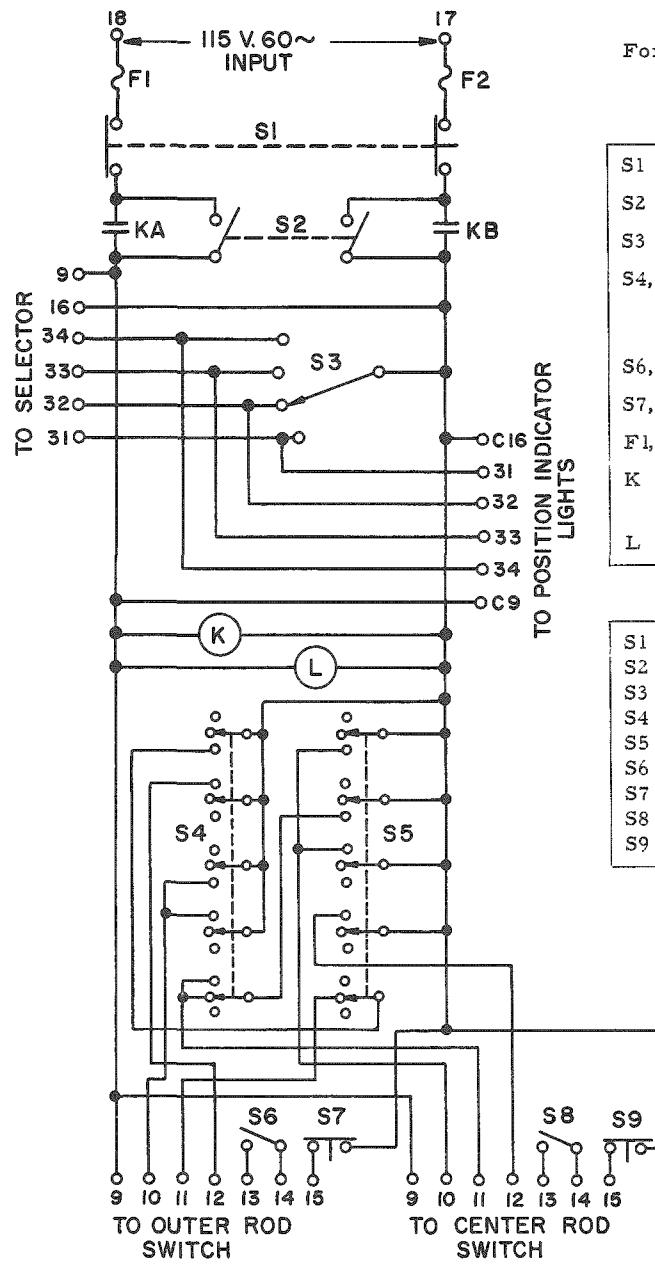
For: CONTROL for 4 outer rods and 1 center rod

S1	Pushbutton, DP, N.C., 30 A
S2	Key switch, DP, N.O., 30 A
S3	Selector switch, SP4T, 5 A
S4, S5	Pistol grip control switch, 5P3T, spring return to center, 15 A
S6, S8	Switch, SPST, 10 A
S7, S9	Pushbutton, SP, N.C., 15 A
F1, F2	Fuse, 30 A
K	Relay, DPST, 115 V. 60~ coil, 30 A. con.
L	Indicating light, 115 V

S1	Drop all rods
S2	Reset after dropping all rods
S3	Select one of outer rods
S4	Control selected outer rod
S5	Control center rod
S6	Fine or coarse movement of outer rod
S7	Drop selected outer rod
S8	Fine or coarse movement of center rod
S9	Drop center rod

115 V. 60~ INPUT

TO SELECTOR

TO POSITION INDICATOR LIGHTS

S4 S5

S6 S7 S8 S9

9 10 11 12 13 14 15
TO OUTER ROD SWITCH

9 10 11 12 13 14 15
TO CENTER ROD SWITCH

CONTROL
For 4 Outer Rods and 1 Center Rod

K1, K2, K3, K4	Relay, 3PST, 115 V. 60 ~ coil, 15 A contact
K5, K6, K7, K8	Relay, DPDT, 115 V. 60 ~ coil, 15 A contact
R	Silicon rectifier, 15 A, 125 VDC, bridge

DRIVE SELECTOR
Back View

84

ALPR P.I.
VOLTAGE ADJUSTMENT
(FIVE DRIVES)

ALPR P.I. POWER SUPPLY
(FIVE DRIVES)
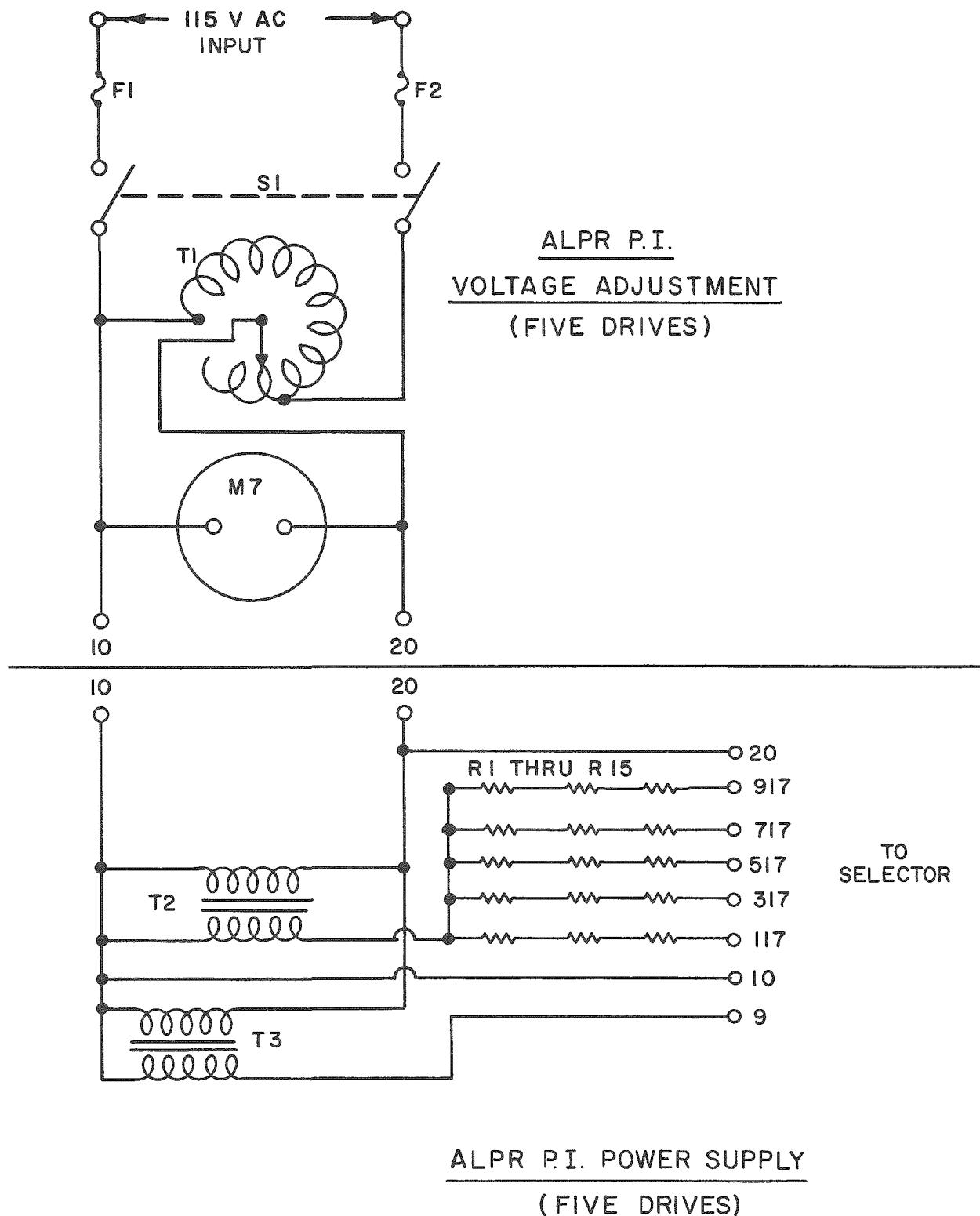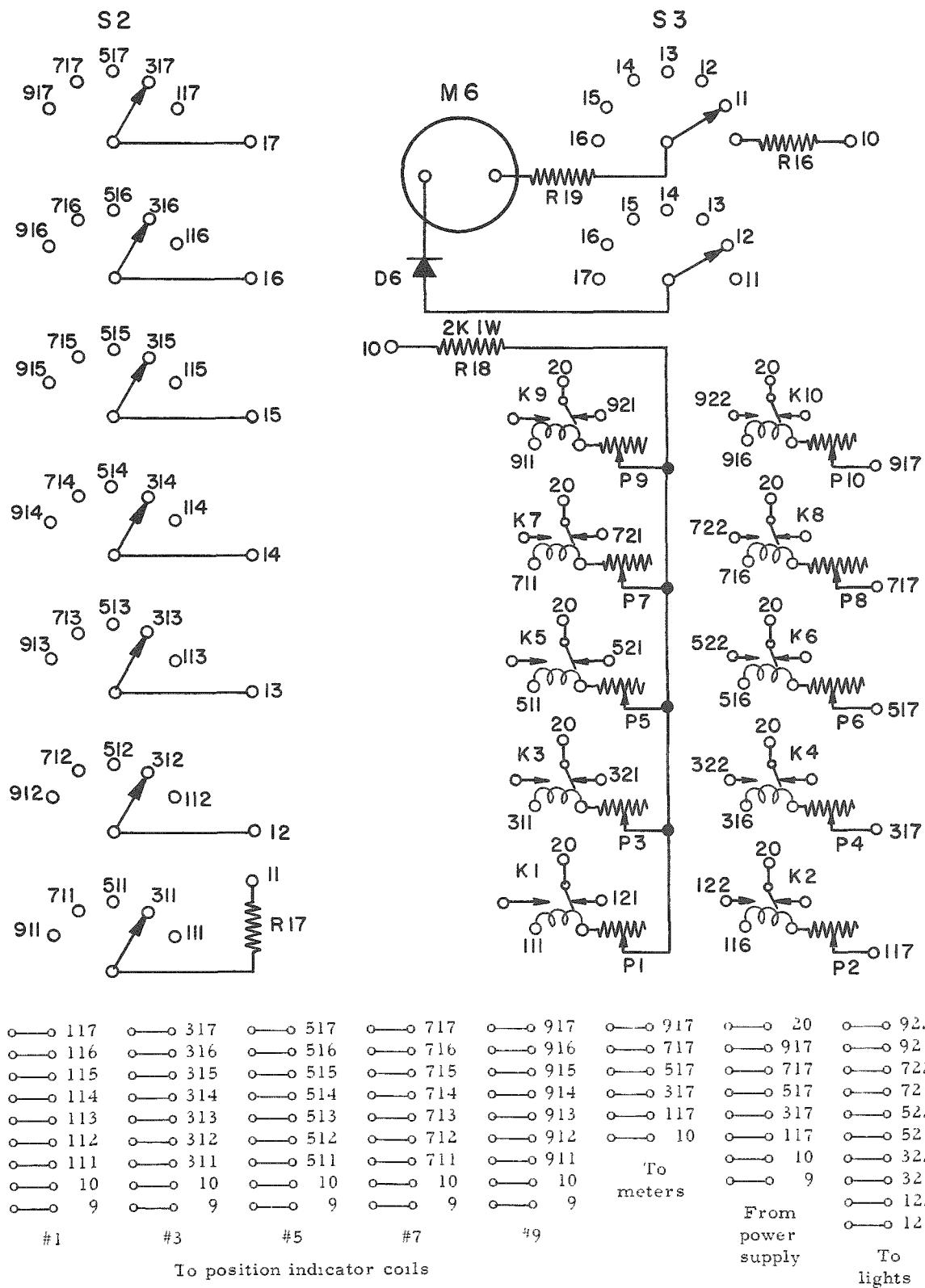
ALPR P. I. SELECTOR (Five drives)
Back and top view
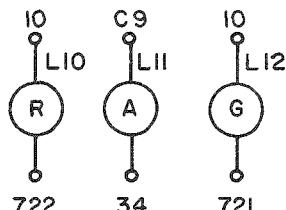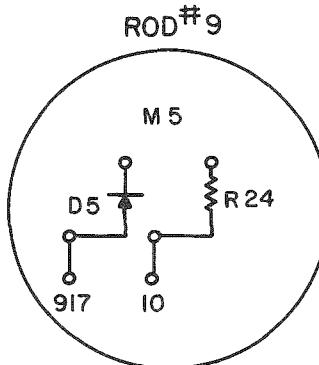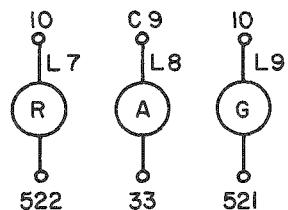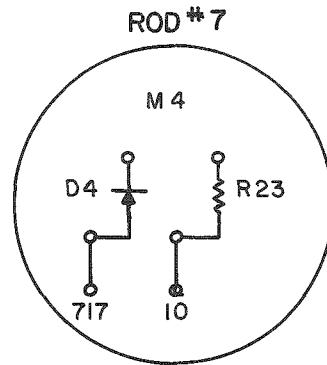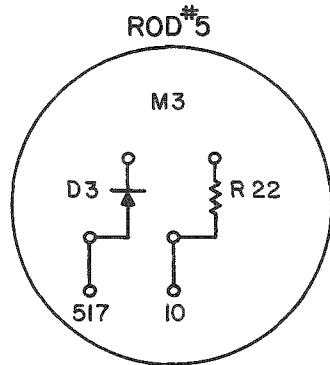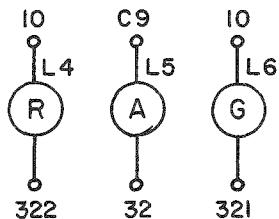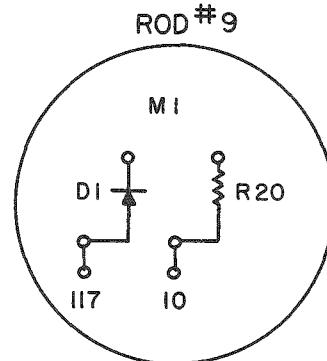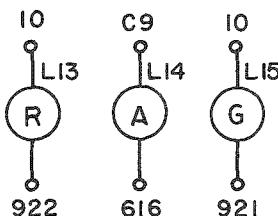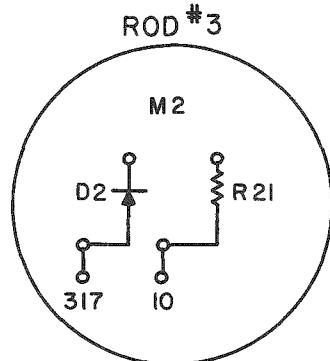
ROD #5

M3

D3   R22

517   10

ROD #7

M4

D4   R23

717   10

o—o 917
o—o 717
o—o 517
o—o 317
o—o 117
o—o 10

FROM
SELECTOR
(METERS)

10   C9   10
L7   L8   L9

(R)   (A)   (G)

522   33   521

10   C9   10
L10   L11   L12

(R)   (A)   (G)

722   34   721

ROD #9

M5

D5   R24

917   10

10   C9   10
L13   L14   L15

(R)   (A)   (G)

922   616   921

ROD #3

M2

D2   R21

317   10

ROD #9

M1

D1   R20

117   10

o—o 922   o—o C16
o—o 921   o—o 31
o—o 722   o—o 32
o—o 721   o—o 33
o—o 522   o—o 34
o—o 521   o—o C9
o—o 322   FROM
o—o 321   CONTROL
o—o 122
o—o 121

FROM
SELECTOR
(LIGHTS)

10   C9   10
L4   L5   L6

(R)   (A)   (G)

322   32   321

10   C9   10
L1   L2   L3

(R)   (A)   (G)

122   31   121
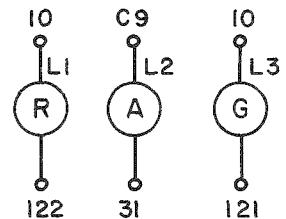
ALPR P.I. METERS AND LIGHTS
(FIVE DRIVES)
BACK VIEW

ALPR POSITION INDICATOR (FIVE DRIVES) PARTS LIST

F1, F2	Fuse, 15 A
T1	Adjustable transformer, 115 V. input, 0-135 V. output, 7.5 A
T2	Power transformer, 115 V. input, 460 V. output, 500 W
T3	Filament transformer, 117 V. input, 6.3 V. output, 10 A
R1 through R15	Resistor, 1000 Ω , 100 W
R16	Resistor, 2200 Ω , 1 W
R17	Resistor, 300 Ω , 1 W
R18	Resistor, 2000 Ω , 1 W
R19	Resistor, 1500 Ω , 1 W
R20 through R24	Resistor, 74400 Ω , 1 W
M1 through M5	Microammeter, 0-300, $8\frac{3}{4}$" long-scale, GE #DB-16
M6	Milliammeter, 0-1, $4\frac{1}{4}$" long-scale, GE #DB-18
M7	Voltmeter, 0-130, $4\frac{1}{4}$" exp., long-scale, GE #AB-18
D1 through D6	Silicon diode, PSI type IN628
L1, L4, L7, L10, L13	Light, red, 115 V
L2, L5, L8, L11, L14	Light, amber, 115 V
L3, L6, L9, L12, L15	Light, green, 115 V
S1	Switch, DPST, 15 A
S2	Selector switch, 7 sec, 5 pos, N-S
S3	Selector switch, 2 sec, 7 pos, N-S
K1 through K10	Sensitive relay, sigma #5RS-12AS-S1L
P1 through P10	Potentiometer, 1000 Ω , 1 W
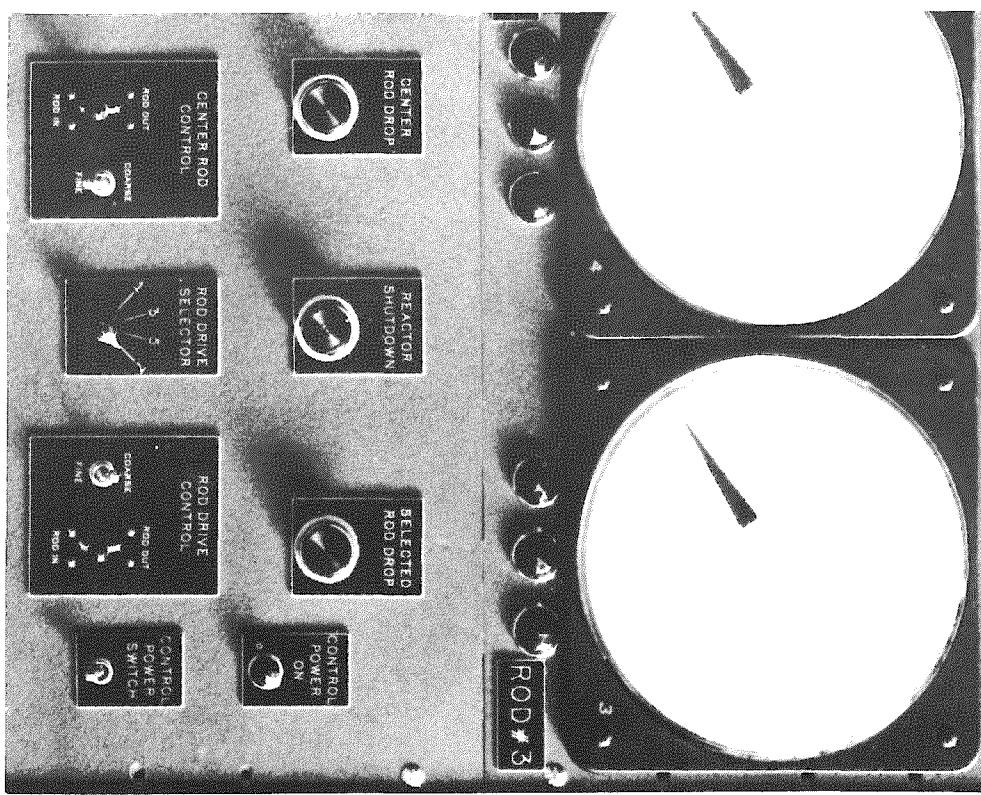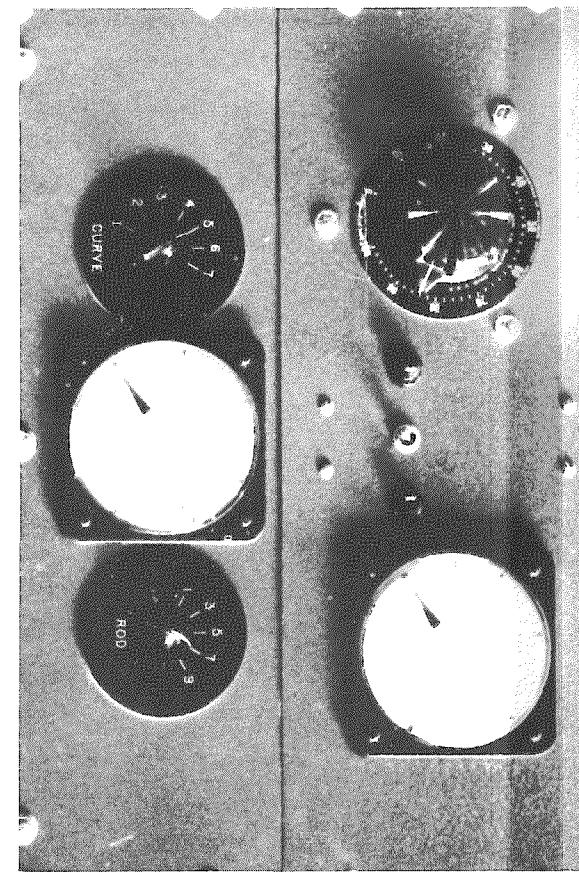
111-7916

ELECTRICAL PANEL FOR FIVE JACK DRIVES

Front View

CENTER ROD
DROP

CENTER ROD
CONTROL

ROD OUT

ROD IN

COARSE

REACTOR
SHUTDOWN

ROD DRIVE
SELECTOR

ROD DRIVE
CONTROL

COARSE

FINE

ROD OUT

ROD IN

SELECTED
ROD DROP

CONTROL
POWER
SWITCH

CONTROL
POWER
ON

ROD #3

CURVE

ROD
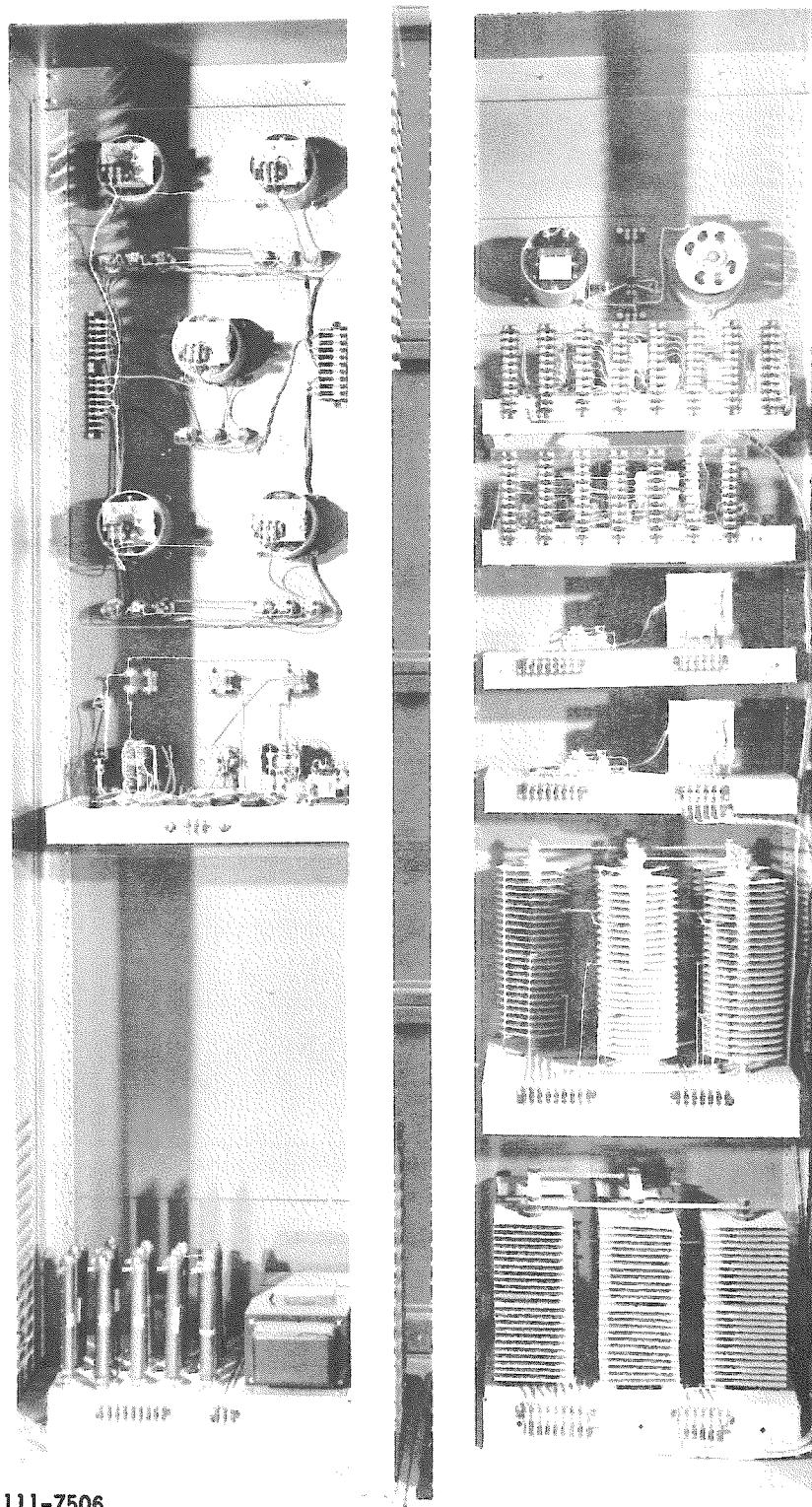
111-7506

BACK VIEW

ELECTRICAL PANEL FOR FIVE JACK DRIVES

Test Results

The components of the six #27 magnetic jack drives are numbered from 1 through 6. The first drive to be installed on ALPR, the test data for which are given here, is numbered as follows: jack #2, drive rod #5, rod connection #2, position indicator coils #3, position indicator meter #2.

The jack was tested for 15 days under simulated reactor conditions of 300-psig steam on the test facility which was used to test the rack-and-pinion drives. The jack was in operation 77% of the time.

Rod connection #1 was used in this test and in the tests of the other jacks. Rod connection #2 will be given a test before shipping.

The extension rod has a diametral clearance of $\frac{1}{32}$ in. where it goes into the steam space. This clearance is small enough to keep water up in the drive, thus allowing the jack to be cooler than the reactor (420F). The flange at the bottom of the jack was 390F in still air. It was 340F with a 12 in. fan blowing on it.

The step length, especially in the down direction, is effected by the temperature of the coils, the presence of water in the jack, and the coefficient of friction. The step length in the up direction was 0.087 to 0.098 in., and in the down direction was 0.122 to 0.142 in. The switch made 29 rpm, thus giving a rod speed of 2.5 to 2.8 in. per minute up and 3.5 to 4.1 in. per minute down.

The minimum amount of current to hold the rod was 0.40 to 0.60 ampere. The operating current was 2.6 to 4.1 amperes. The control rod assembly weighed 110 pounds.

A commutator switch, which was used on this and other tests, failed after 980,000 revolutions (2 years assuming the control rod is moving 3.2% of the time) due to burning of the copper, which caused one of the carbon brushes to lock the rotor. The switch was repaired by refacing the commutator. This may be done several times without reducing the thickness of the copper too much.

The position indicator was tested with a magnetic jack on a test facility that showed the position of the rod through a sight glass while the drive contained water at 300 psig and at various temperatures. At 100F the position indicator input was set at 110.0 volts and at 230F it was set at 105.0 volts. The following table shows the position indicator error.

Actual Position	Coarse Meter		Fine Meter at 230F
	100F	230F	
0	0.1	-0.1	-0.10
5	4.8	4.7	4.88
10	9.8	9.7	10.00
15	15.0	15.0	14.98
20	20.0	20.2	20.02
25	24.9	25.2	25.02
30	29.9	30.5	30.05

APPENDIX C

DETAILS OF THE HIGH PRESSURE AND THE EBWR MAGNETIC JACKS
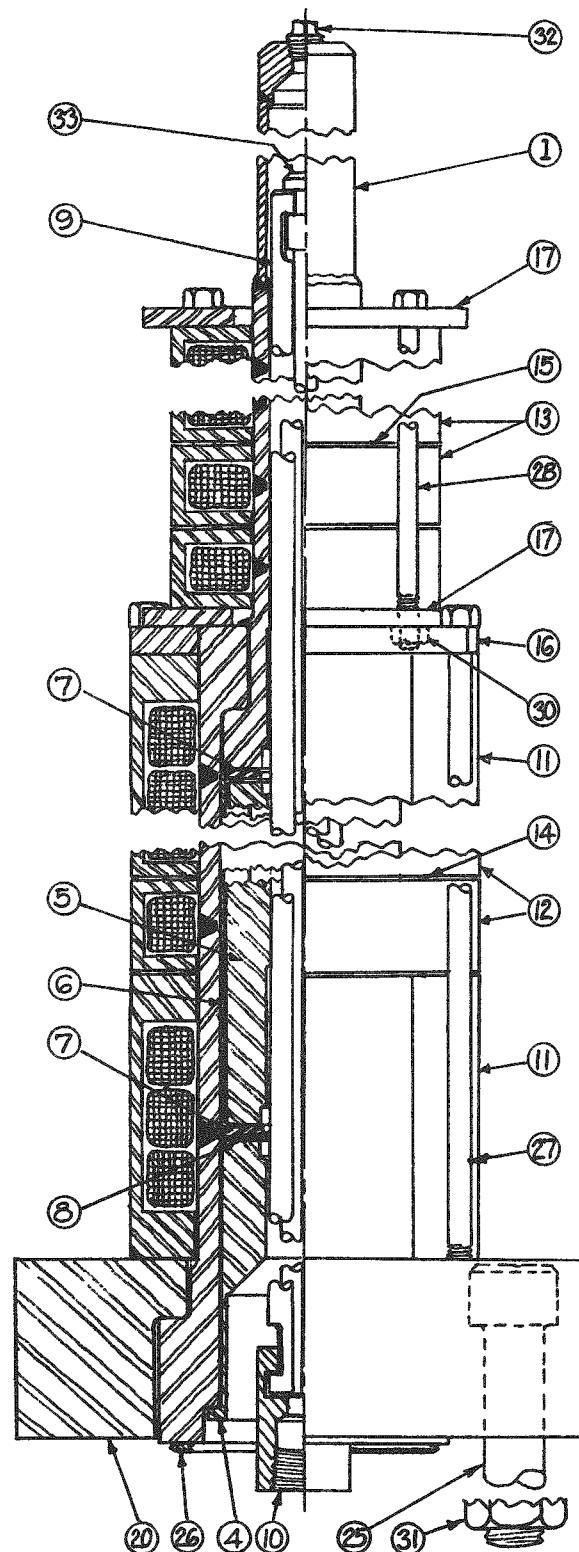
HIGH-PRESSURE MAGNETIC JACK (29 H) ASSEMBLY
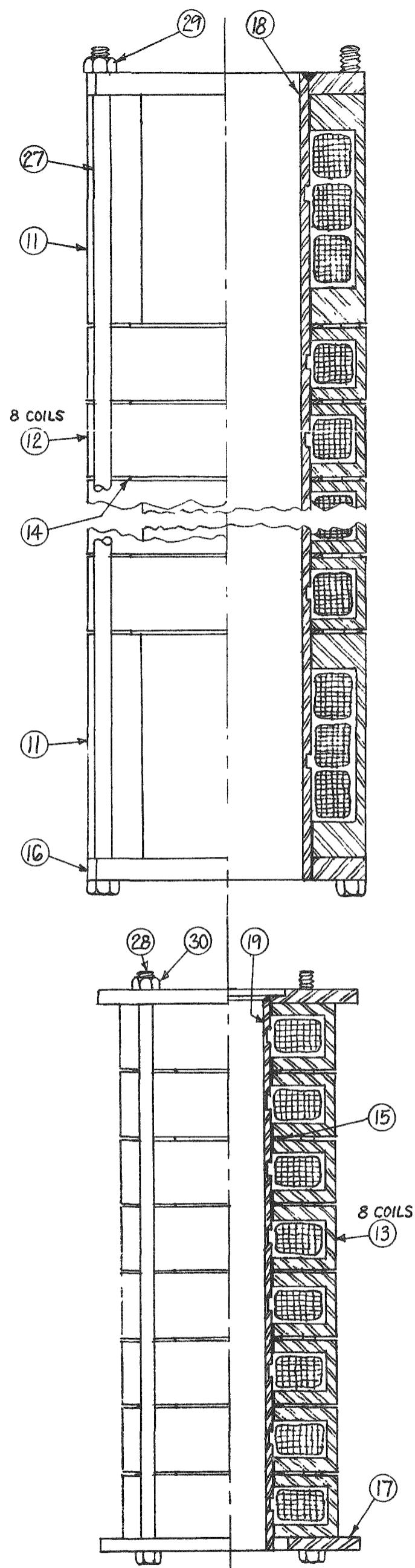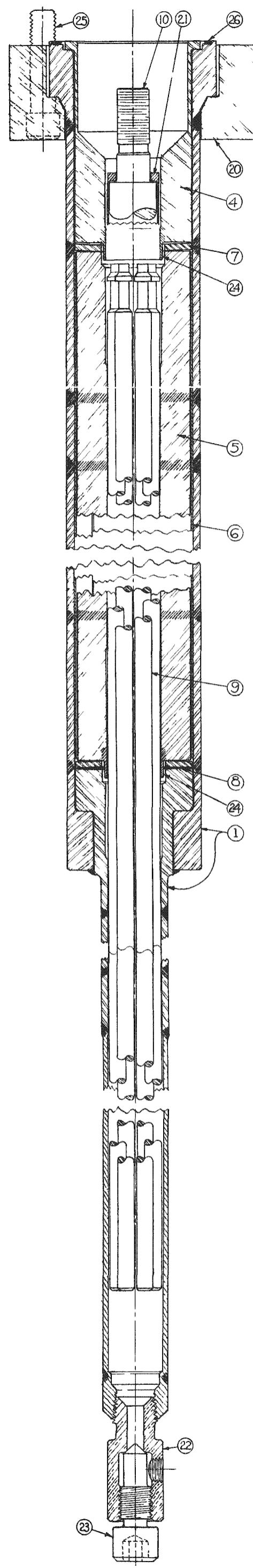
LOW-PRESSURE BOTTOM DRIVE MAGNETIC JACK
(EBWR) (29L) ASSEMBLY WITH COILS REMOVED

COIL WIRING DIAGRAM

COM. PURE NICKEL
CONNECTOR

PART NO.	NO. REQ'D	PART
1	12	LONG CONNECTOR, 60° BENDS
2	14	SHORT CONNECTOR, 70° BENDS
3	36	RD. HD. SC., #6-32 x 5/16", SST
4	36	HEX. NUT, #6-32, SST
5	36	LOCK WASHER, #6, SST
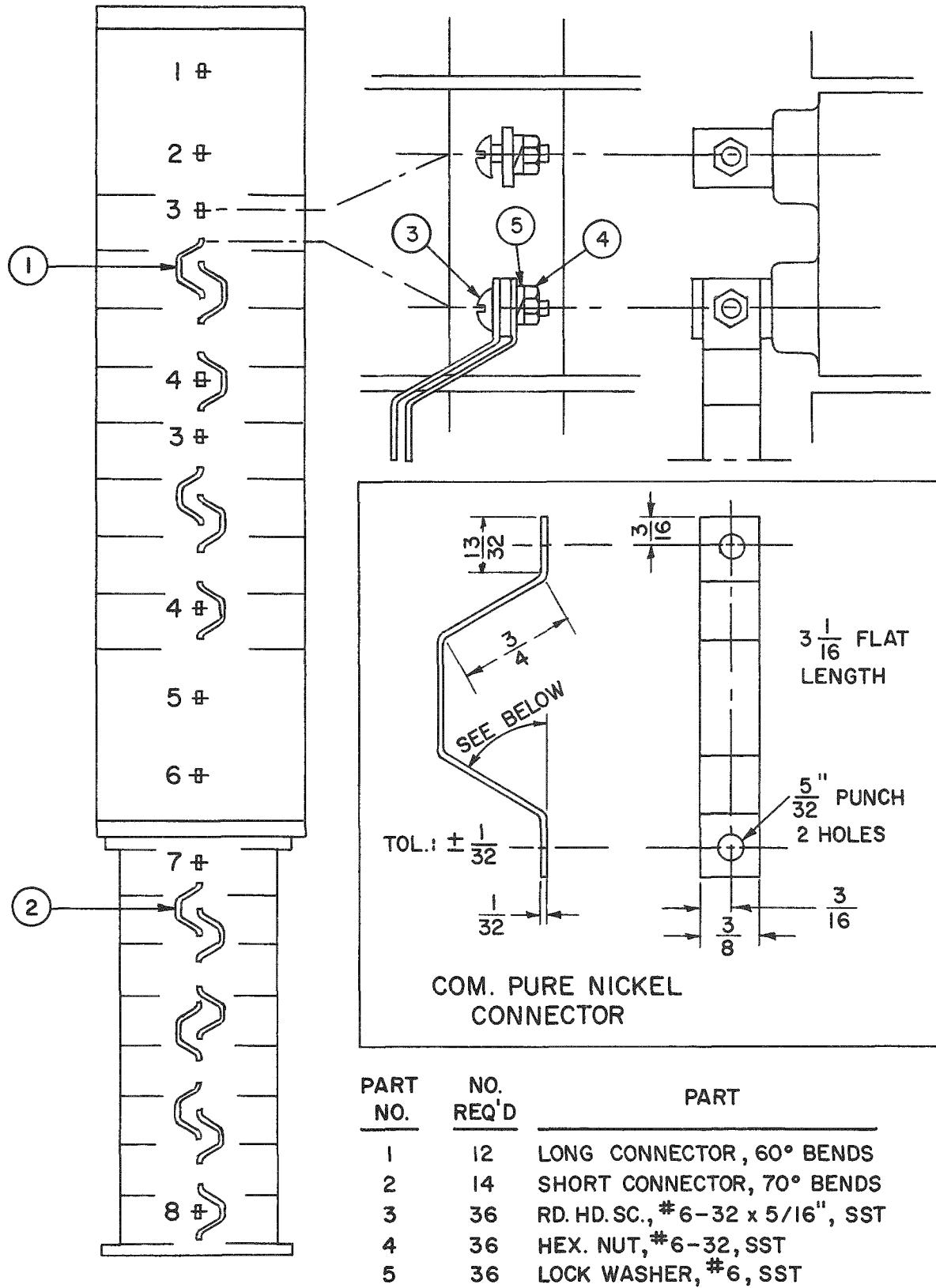
DRAWING LIST FOR THE HIGH-PRESSURE MAGNETIC JACK (29H)

Part No.	Number Required					Part	Drawing Number	Page No.
1	1					Pressure shell	RE-1-31081-A	98
		1				Body	RE-1-31085-A	99
			1			Flange	RE-1-31086-A	99
			1			Tube	RE-1-31087-A	99
			1			Head	RE-1-31088-A	99
		1				Extension	RE-1-31089-A	100
			1			Flange	RE-1-31090-A	100
			1			Tube	RE-1-31091-A	100
			1			Pipe	RE-1-31092-A-1	100
			1			Cap	RE-1-31092-A-2	100
4	1					Plug	RE-1-31082-A	98
5	1					Armature	RE-1-31083-A	98
6	3					Non-magnetic sleeve	RE-1-31093-A-1	102
7	2					Cushion washer	RE-1-31093-A-2	102
8	1					Shim ⎧149" long⎫	RE-1-31093-A-3	102
9	6					Drive rod ⎨for six -⎬	RE-1-18795-B	101
10	1					Rod connector ⎩ft. travel⎭	RE-1-17894-A	101
33	1					Filler rod	RE-1-18799-A	101
11	2					Move coil	RE-1-31095-A	103
		4				End plate	RE-1-31096-A	103
		2				Ring	RE-1-31097-A	103
12	8					Grip coil	RE-1-31098-A	104
		16				End plate	RE-1-31099-A-1	104
		8				Ring	RE-1-31099-A-2	103
		14				Coil	RE-1-31100-A	104
13	8					Hold coil	RE-1-31101-A	105
		16				End plate	RE-1-31102-A-1	105
		8				Ring	RE-1-31102-A-2	105
		8				Coil	RE-1-31103-A	105
		--				Coil assembly notes	RE-1-31104-A	105
		44				Terminal	RE-1-21540-A	49
14	9					Large coil spacer	RE-1-31094-A-1	102
15	7					Small coil spacer	RE-1-31094-A-2	102
16	1					Large coil clamp	RE-1-31094-A-3	102
17	2					Small coil clamp	RE-1-31094-A-4	102
20	1					Flange ring	RE-1-31084-A	98
25	8					Flange bolt, Soc. hd. sc, $1\frac{1}{4}$-7x$6\frac{1}{2}$, st.		
26	1					Flange gasket, Flexitallic #R3-25K		
27	4					Large tie bolt, Hex hd., $\frac{1}{2}$-13x$29\frac{1}{4}$, st.		
28	4					Small tie bolt, Hex hd., $\frac{3}{8}$-16x$15\frac{1}{8}$, st.		
30	2					Small nut, Hex, $\frac{3}{8}$-16, st.		
31	8					Flange nut, Hex, $1\frac{1}{4}$-7, st.		
32	1					Pipe plug, $\frac{3}{8}$, sst.		

RE-31079-A

DRAWING LIST FOR THE EBWR MAGNETIC JACK (29L)

Part No.	Number Required	Part	Drawing Number	Page No.	Changes in drawing for: L five-foot travel / P low pressure / D bottom drive
1	1	Pressure shell	RE-1-31081-A	98	114¾ overall length (L)
	1	Body	RE-1-31105-A	106	
	1	Flange	RE-1-31106-A	106	
	1	Tube	RE-1-31107-A	106	
	1	Head	RE-1-31088-A	99	4 1/16 outside diameter (P)
	1	Extension	RE-1-31108-A	107	
	1	Flange	RE-1-31090-A	100	
	1	Tube	RE-1-31109-A	107	
	1	Pipe	RE-1-31092-A-1	100	{ 66⅜ long (L) / 304 SST material (P)
	1	Cap	RE-1-31092-A-2	100	{ 1" pipe tap (P)(D) / 304 SST material (P)
4	1	Plug	RE-1-31082-A	98	Add dirt shield, (see 24) (D)
5	1	Armature	RE-1-31110-A	108	Add dirt shield, (see 24) (D)
6	3	Non-mag. sleeve	RE-1-31093-A-1	102	
7	2	Cushion washer	RE-1-31093-A-2	102	
8	1	Shim	RE-1-31093-A-3	102	
9	6	Drive rod	RE-1-31111-A-1	109	
10	1	Rod connection	RE-1-31111-A-2	109	
11	2	Move coil	RE-1-31095-A	103	
	4	End plate	RE-1-31096-A	103	
	2	Ring	RE-1-31097-A	103	
12	8	Grip coil	RE-1-31098-A	104	
	16	End plate	RE-1-31099-A-1	104	
	8	Ring	RE-1-31099-A-2	104	
	14	Coil	RE-1-31100-A	104	
13	8	Hold coil	RE-1-31101-A	105	
	16	End plate	RE-1-31102-A-1	105	
	8	Ring	RE-1-31102-A2	105	
	8	Coil	RE-1-31103-A	105	
	--	Assembly notes	RE-1-31104-A	105	
	44	Terminal	RE-1-21540-A	49	
14	9	Large coil spacer	RE-1-31094-A-1	102	
15	7	Small coil spacer	RE-1-31094-A-2	102	
16	1	Large coil clamp	RE-1-31094-A-3	102	One required (P)
17	1	Small coil clamp	RE-1-31094-A-4	102	
18	1	Large coil sleeve	RE-1-31116-A	110	
19	1	Small coil sleeve	RE-1-31114-A	110	
20	1	Flange ring	RE-1-31113-A	106	
21	1	Rod retainer	RE-1-31111-A-3	109	
22	1	Valve body	RE-1-31115-A-1	109	
23	1	Valve stem	RE-1-31115-A-2	109	
24	2	Dirt shield	RE-1-31117-A	108	
25	8	Flange bolt	Socket head screw, ¾-10x3 lg., steel		
26	1	Flange gasket	Flexitallic #R4-6J		
27	4	Large tie bolt	Hex head bolt, ½-13x29¾ lg., steel		
28	4	Small tie bolt	Hex head bolt, ⅜-16x15⅛ lg., steel		
29	2	Large nut	Hex nut, ½-13, steel		
30	2	Small nut	Hex nut, ⅜-16, steel		

RE-1-31080-A

98

RE-1
31089
A

SEAL WELD Ⓒ

Ⓒ CLAMP
PARTS TIGHTLY.

HELIARC
WELD WITH
INCO-WELD "A".

RE-1
31085
A

127¼ REF.
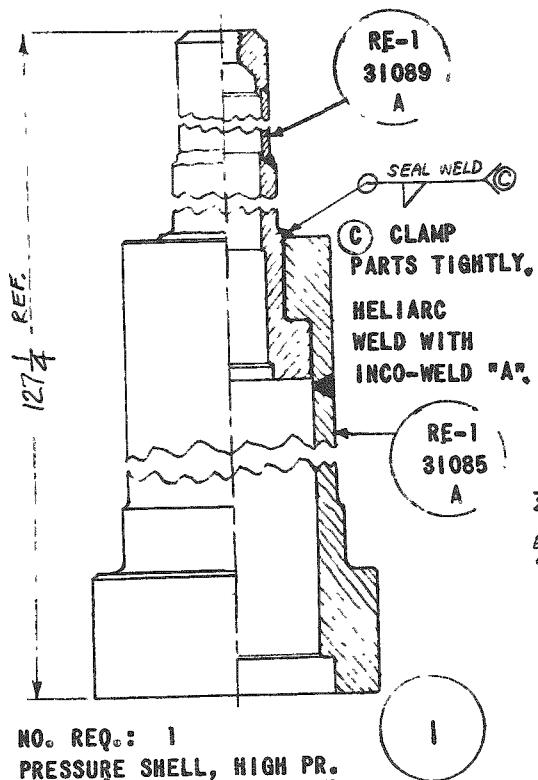
NO. REQ.: 1
PRESSURE SHELL, HIGH PR.
RE-1-31081-A

①

1 5/16" DRILL THRU
2" DIA. C'BORE 1 3/8"
DEEP 8 HOLES
EQ. SP. ON
9½" D.B.C.

22½° ± 1°

12 D.

½"-13 TAP
1" DEEP 4 HOLES
EQ. SP. ON
9 3/16" D.B.C.

13 D.
4 16

5 13/16

2½

1/8 R.

6 1/8 D.
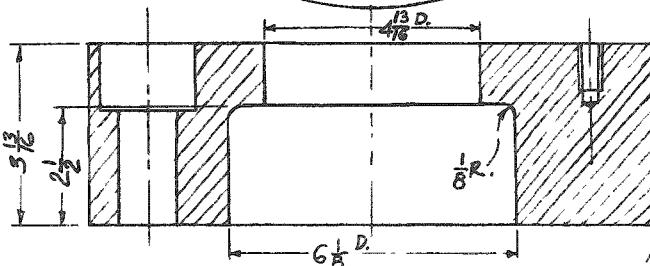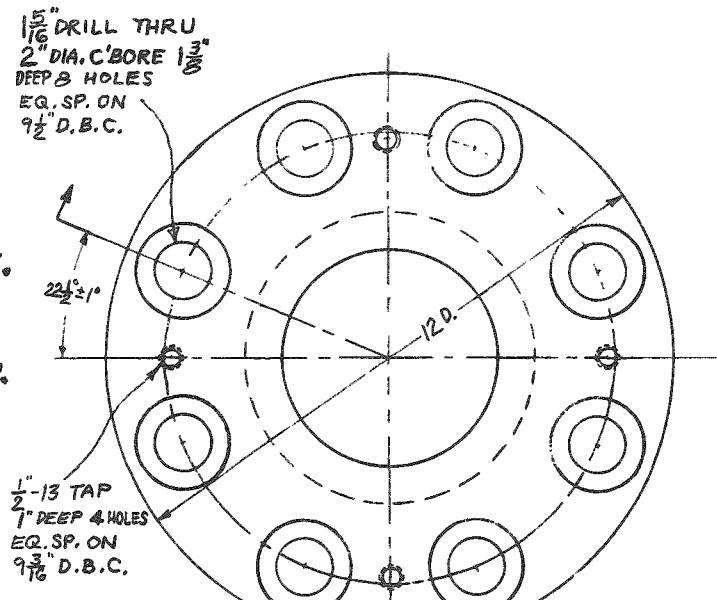
NOTE: 1/16" x 45° CH. ALL EDGES
NO. REQ.: 1   TOL.: ± 1/32
MATERIAL: LOW CARBON STEEL
FLANGE RING, HIGH PR.
RE-1-31084-A

⑳

1 7/8 DRILL
3/100
3 3/32
1/4 TYP.

1 5/8 DRILL

1 3/4 ± 1/64 D.
TYP.

1.560 D.
1.565

2" TYP.

ALL FILLETS
1/16" R.

7 SPACES @ 2" = 14"

22 9/16

1 5/8 DRILL
3 9/32
4 5/32

1 7/8 DRILL
3/100

3 3/8 ± 1/64 D.

⑤
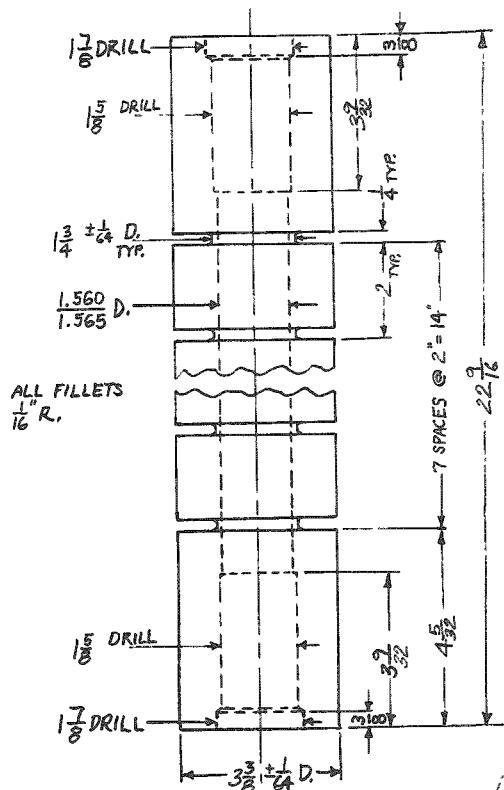
NO. REQ.: 1   TOL.: ± 1/32
MATERIAL: 430 SST
ARMATURE, GROOVED   RE-1-31083-A

3.480 D.
3.470

1 21/32 D.

1 7/8 DRILL

3/100

5 7/8

45° ± 1°

.252
.250

5/100

3 1/4 D.

4 D.

1/16 R.

④
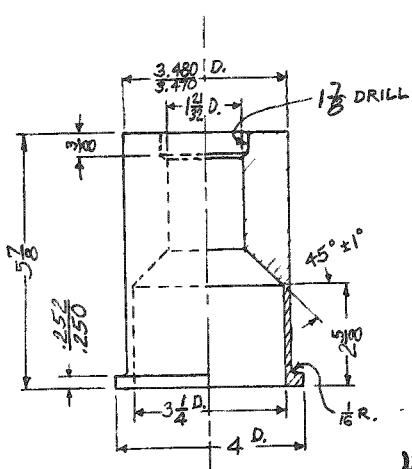
NO. REQ.: 1   TOL.: ± 1/32
MATERIAL: 430 SST
CHAMBER PLUG
RE-1-31082-A

4.391 / 4.385 D.

RE-1
31088
A

$\frac{1}{16}"\times 45°$ CH.

2.375 / 2.380 D.

$\frac{1}{8}$ R.

$\frac{3}{4}$

10 WELDS
1. PRE-HEAT TO 300-350F
2. HELIARC WELD FIRST PASS WITH 3/32" DIA. INCO-WELD "A".
3. ARC WELD OTHER PASSES WITH 1/8" DIA. INCO-WELD "A".

3.495 / 3.505 D. CONCENTRIC WITHIN .020"

RE-1
31087
A

RE-1
31086
A

REMOVE AN EQUAL AMOUNT FROM EACH END

$32\frac{7}{16}$

$\frac{3}{16}$ R.

$\frac{1}{8}$

$2\frac{5}{8}$

.745 / .755

$\frac{1}{16}$ R.

$1"\times 45°$ CH.

$4\frac{1}{8}$ D.

$4\frac{11}{16}$ D.

6 D.

NO. REQ.: 1
TOL.: ± 1/32
PRESSURE
SHELL BODY
HIGH PR.
RE-1-31085-A

$4\frac{9}{16}$ D.

$2\frac{1}{4}$ D.

$37\frac{1}{2}°$ ±2°

$\frac{1}{8}$ R.

$\frac{3}{16}$

$1\frac{5}{16}$

$3\frac{5}{16}$ D.

3.470 / 3.465 D.

$3\frac{5}{8}$ D.

NO. REQ.: 1   TOL.: ± 1/16
MATERIAL: 430 SST
BODY HEAD   RE-1-31088-A

$3\frac{5}{8}$ D.

3.475 / 3.480 D.

$3\frac{5}{8}$ D. TYP.

$37\frac{1}{2}°$ ±2°

$\frac{1}{8}$ TYP.

7 SPACES @ $2\frac{1}{16}$ = $14\frac{7}{16}$

$23\frac{1}{16}$

$4\frac{1}{2}$

3.475 / 3.480 D.

$3\frac{3}{8}$ R.

$3\frac{5}{8}$ D.

$4\frac{9}{16}$ D.

NO. REQ.: 1   TOL.: ± 1/16
MATERIAL: 430 SST
BODY TUBE, HIGH PR.
RE-1-31087-A

$4\frac{9}{16}$ D.

3.470 / 3.465 D.

$3\frac{5}{8}$ D.

$37\frac{1}{2}°$ ±2°

$\frac{1}{8}$

$4\frac{15}{16}$ D.

$\frac{3}{16}$ R.

$6\frac{11}{16}$

$2\frac{7}{00}$

$3\frac{5}{16}$ D.

$6\frac{1}{16}$ D.
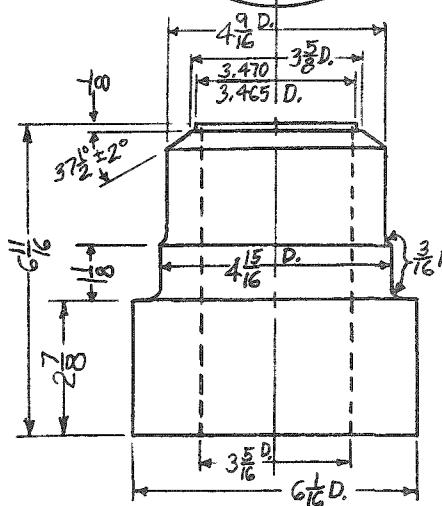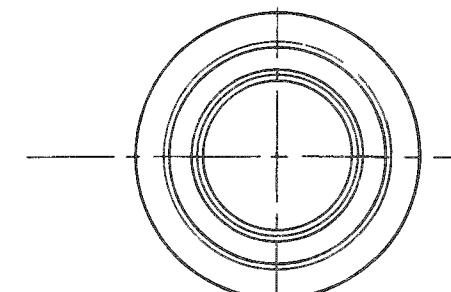
NO. REQ.: 1
TOL.: ± 1/16
MATERIAL:
430 SST
BODY FLANGE,
HIGH PR.
RE-1-31086-A

RE-1-31092 A-2

RE-1-31092 A-1

RE-1-31091 A

RE-1-31090 A

TURN

B 1. PRE-HEAT TO 300-350F.
2. HELIARC WELD FIRST PASS WITH 3/32" DIA. INCO-WELD "A".
3. ARC WELD OTHER PASSES WITH 1/8" DIA. INCO-WELD "A".

REMOVE SHARP EDGE

9 WELDS B

$\frac{1.560}{1.565}$ I.D. } CONCENTRIC WITHIN .020"

$\frac{2.212}{2.207}$ O.D.

$\frac{1}{8}$ R.

REMOVE SHARP EDGE

$3\frac{21}{32}$

$98\frac{1}{4}$ BEFORE WELDING, REF.
$97\frac{13}{16}$ AFTER WELDING, REF.

NO. REQ.: 1
PRESSURE SHELL
EXTENSION, HIGH PR.
RE-1-31089-A

$1\frac{21}{32}$ D.

$1\frac{1}{2}$" SC. 40 PIPE

$37\frac{1}{2}°±2°$

$18\frac{5}{8}$

$37\frac{1}{2}°±2°$

1.90 D. REF.

1.61 D. REF.

$1\frac{21}{32}$ D.

NO. REQ.: 1
TOL.: ±1/32
MATERIAL: INCONEL

EXTENSION PIPE RE-1-31092-A-1

$\frac{1}{4}$"×45° CH.

$1\frac{29}{32}$ D.

$\frac{3}{8}$" PIPE TAP

$3\frac{1}{100}$

$37\frac{1}{2}°$

$\frac{1}{8}$ R.

45°

$\frac{1}{16}$×45° CH.

$\frac{1.600}{1.590}$ D.

$1\frac{7}{16}$ D.

$1\frac{21}{32}$ D.
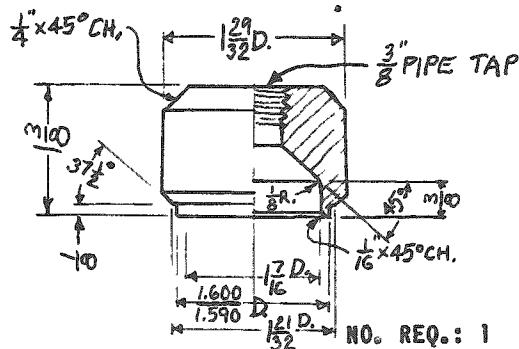
NO. REQ.: 1
TOL.: ± 1/32
± 2°

MATERIAL: 430 SST
EXTENSION CAP   RE-1-31092-A-2

$1\frac{21}{32}$ D.

$\frac{1.600}{1.590}$ D.

$1\frac{47}{64}$ REF.

$37\frac{1}{2}°±2°$ TYP.

$\frac{1}{8}$ TYP.

$1\frac{5}{8}$ D. TYP.

7 GROOVES EQ. SP.

6 SPACES @ $1\frac{51}{64}$ = $10\frac{25}{32}$

$14\frac{7}{16}$

$1\frac{51}{64}$

$1\frac{7}{16}$ D.

$\frac{1.535}{1.540}$ D.

$1\frac{5}{8}$ D.

$2\frac{5}{16}$ D.

NO. REQ.: 1
TOL.: ± 1/16
MATERIAL: 430 SST
EXTENSION TUBE, HIGH PR.

RE-1-31091-A

$\frac{2.360}{2.355}$ D.

$1\frac{5}{8}$ D.

$\frac{1.534}{1.529}$ D.

$1\frac{7}{16}$ D.

$37\frac{1}{2}°±2°$

$\frac{1}{8}$ R.

$\frac{1}{16}$ R.

$2\frac{1}{2}$

$1\frac{3}{4}$

$4\frac{7}{16}$

$\frac{1}{8}$"×45° CH.

$\frac{11}{16}$ D.

$1\frac{7}{8}$" DRILL

$\frac{3.485}{3.480}$ D.
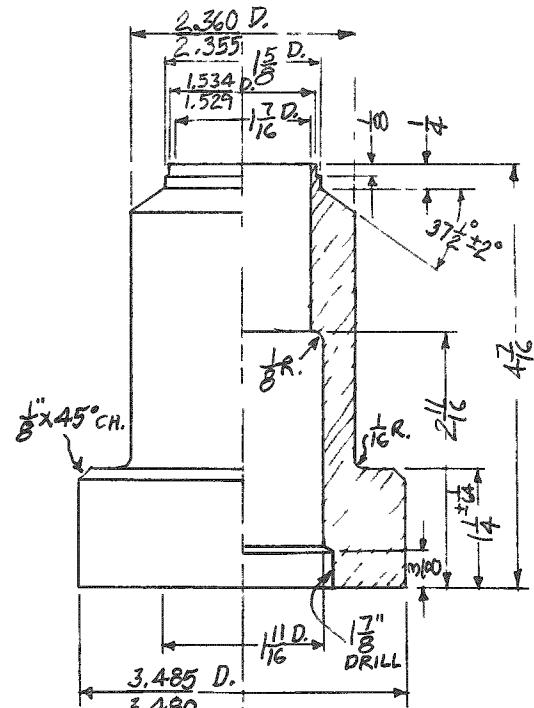
NO. REQ.: 1   TOL.: ± 1/32
MATERIAL: 430 SST
EXTENSION FLANGE   RE-1-31090-A

$105\frac{1}{4} {}^{+1}_{-32}$ LENGTH MUST BE THE SAME FOR 6 RODS WITHIN .004

$\frac{9}{16} {}^{+1}_{-64}$ R.

$\frac{.310}{.313}$

A' $\frac{1}{2}$

$1'' {}^{\pm\frac{1}{32}}$ $\frac{.486}{.482}$

$\frac{1}{16}$ R

$\frac{.310}{.313}$

$\frac{9}{16} {}^{+1}_{-64}$ R.

$\frac{1}{16}$ × 45° CHAMFER BOTH ENDS

'L'

$\frac{1}{16}$ R.

$1\frac{1}{2} {}^{+\frac{1}{32}}$

2 SLOTS 180°±5° APART. TURN SLOTS OF 6 RODS TOGETHER USING 7TH $\frac{1}{2}''$ D. ROD IN CENTER OF BUNDLE

CENTERLESS GROUND BAR ARMCO 17-4 PH SST HEAT TREATMENT OPTIONAL
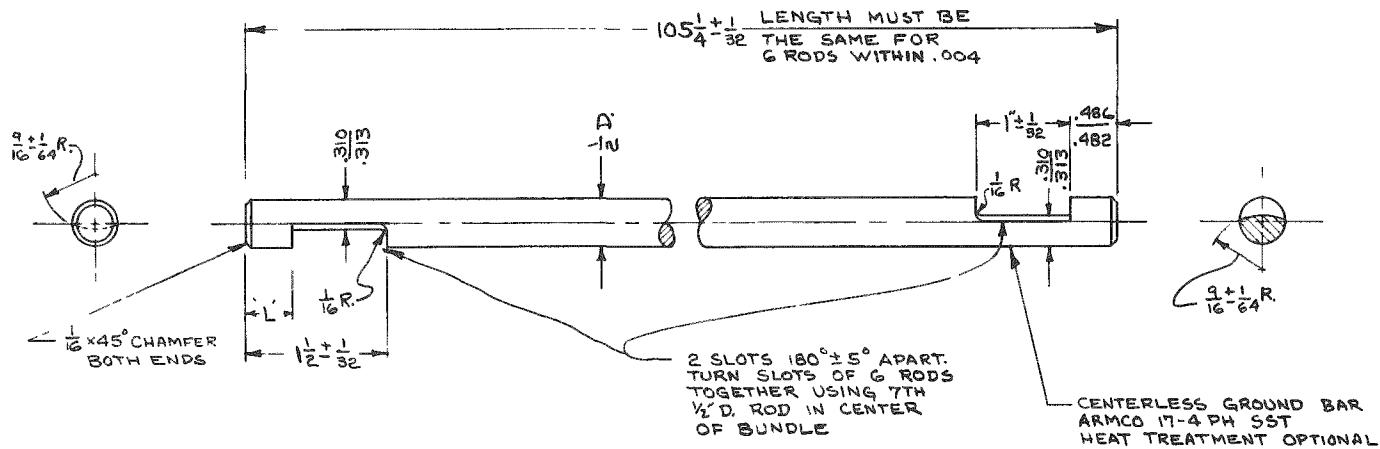
PART	"L"	NO. REQ'D
1	$\frac{.486}{.482}''$	5
2	* "0"	1

* FILE KNOB FOR LENGTH "L" TO MATCH $\frac{9}{16}$ R. OR SLIGHTLY BELOW ON ONE END OF ONE ROD ONLY.

9

DRIVE ROD, NOTCHED   RE-1-18795-B

3

1"

$1\frac{1}{2}$ REF.

.500

$1\frac{9}{64}$ D.

$1\frac{5}{8}$ D.

$\frac{11}{16}$ DRILL THRU

$\frac{1}{4}$ × 45° CHAMFER

$1\frac{15}{16}$
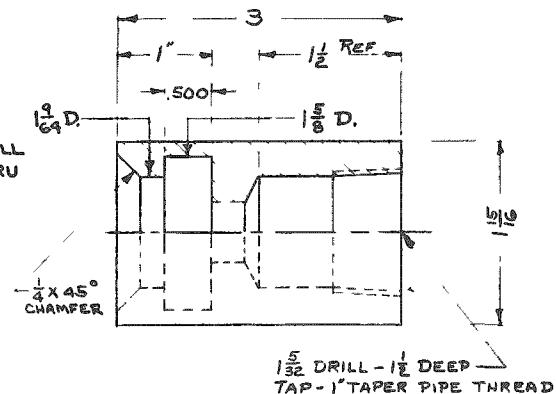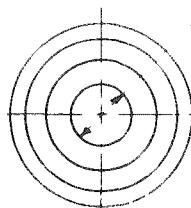
$1\frac{5}{32}$ DRILL - $1\frac{1}{2}$ DEEP TAP - 1" TAPER PIPE THREAD

NO. REQ.: 1

FR. TOL.: ± 1/64
DE. TOL.: ± .005

MATERIAL: 304 SST
ROD CONNECTOR   RE-1-17894-A

10

$48 \pm \frac{1}{16}$

$1\frac{5}{16} \pm \frac{1}{16}$

$\frac{1}{2}$ DRILL × $\frac{9}{16}$ DP

$\frac{33}{64}$

$\frac{3}{8}$

D' $\frac{1}{2}$

D' $\frac{5}{8}$

D' $\frac{1}{2}$

$\frac{1}{16}$ × 45° CHAMFER

$\frac{1}{8}$

$\frac{1}{8}$ × 45° CHAMFER

1" D.

NO. REQ.: 1

TOL.: ± 1/64

MATERIAL: 304 SST
FILLER ROD   RE-1-18799-A

33

101

20 GA. (.038")

$\frac{13}{14}$ R.

$\frac{3}{32}$ FLAT WIDTH

$22\frac{1}{4}$
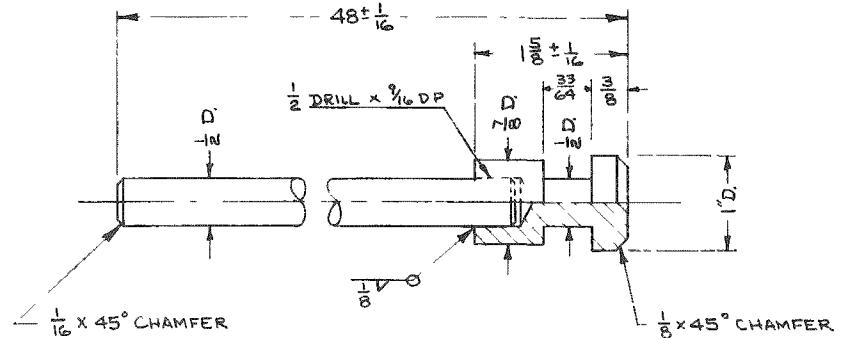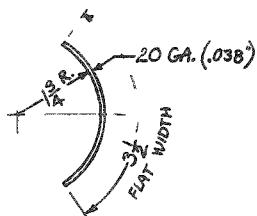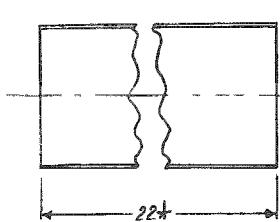
NO. REQ.: 3   TOL.: ± 1/16
MATERIAL: 304 SST
NON MAGNETIC SLEEVE
RE-1-31093-A-1

(6)

$\frac{+3}{32}$ D.

5 $\frac{+3}{32}$ D.

4.395
4.405 D.

NO. REQ.: 10
MATERIAL: #16 GA (.0598")
LOW CARBON STEEL
LARGE COIL SPACER
RE-1-31094-A-1

(14)

"NEO-CHROME" PLATE .0030"±.0005"
THICK ON CONVEX SURFACE
AFTER PRESSING.

$\frac{3}{16}$

PRESS WITH 10° DIE.
THEN PRESS WITH
FLAT DIE. THE SPRING
BACK GIVES THE
DESIRED CONE ANGLE.

$3\frac{15}{32}$ D. $1\frac{7}{8}$ D.

NO. REQ.: 2   TOL.: ± 1/64
MATERIAL: 430 SST
CUSHION WASHER
RE-1-31093-A-2

(7)

D.

$2\frac{+3}{32}$ D.

2.217
2.227 D.
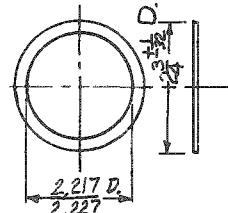
NO. REQ.: 8
MATERIAL: #16 GA (.0598")
LOW CARBON STEEL
SMALL COIL SPACER
RE-1-31094-A-2

(15)

THICKNESS IS
DETERMINED BY
TEST TO GIVE
DESIRED STEP LENGTH

$3\frac{15}{32}$ D. $1\frac{7}{8}$ D.

NO. REQ.: 1   TOL.: ± 1/64
MATERIAL: 430 SST
SHIM
RE-1-31093-A-3

(8)

$7\frac{1}{4}$

$3\frac{5}{8}$

$\frac{17}{32}$ DRILL
4 HOLES

$\frac{5}{8}$"-16 TAP
THRU
2 HOLES

$3\frac{1}{4}$ $3\frac{1}{4}$

$\frac{3}{4}$

$\frac{3}{4}$

$\frac{3}{4}$

1" DRILL
2 HOLES

$2\frac{3}{8}$ $2\frac{3}{8}$ $7\frac{1}{4}$

$\frac{3}{16}$ x45° CH.
4 CORNERS

$2\frac{1}{8}$ $2\frac{1}{8}$

$\frac{9}{16}$
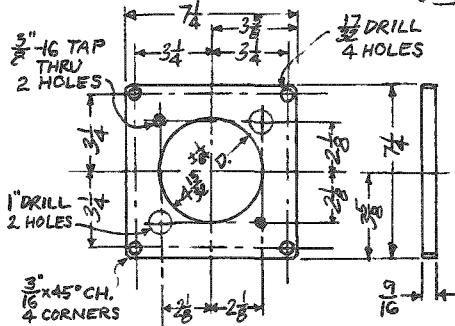
NO. REQ.: 1   TOL.: ± 1/32
MATERIAL: LOW CARBON STEEL
LARGE COIL CLAMP
RE-1-31094-A-3

(16)

$\frac{13}{32}$ DRILL
4 HOLES
EQ. SP. ON
6" D.B.C.

3 D.

D. $\frac{1}{64}$

$\frac{1}{4}$"-20 TAP
THRU 4 HOLES
EQ. SP. ON
$4\frac{1}{16}$" D.B.C.

$\frac{3}{8}$

NO. REQ.: 2
TOL.: ± 1/32
MATERIAL:
LOW CARBON
STEEL
SMALL COIL CLAMP
RE-1-31094-A-4

(17)

NOTE:
CADMIUM PLATE
.0008" ± .003"
LOW CARBON
STEEL PARTS

E
F
G
H

SEE
PAGE
105

SEE
PAGE
49

RE-1
21540
A

RE-1
31096
A

RE-1
31097
A

RE-1
31100
A
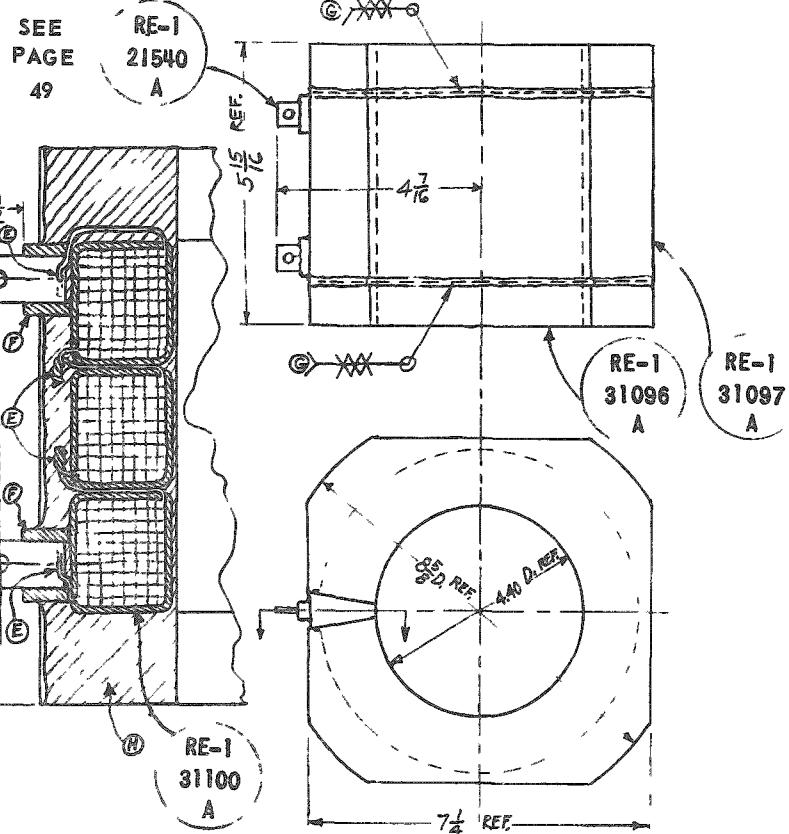
SPEC.:
1290 TURNS
12.0 OHMS AT 77°F
NO. REQ.: 2, TOL.: ± 1/32
MOVE COIL, POTTED   RE-1-31095-A

11
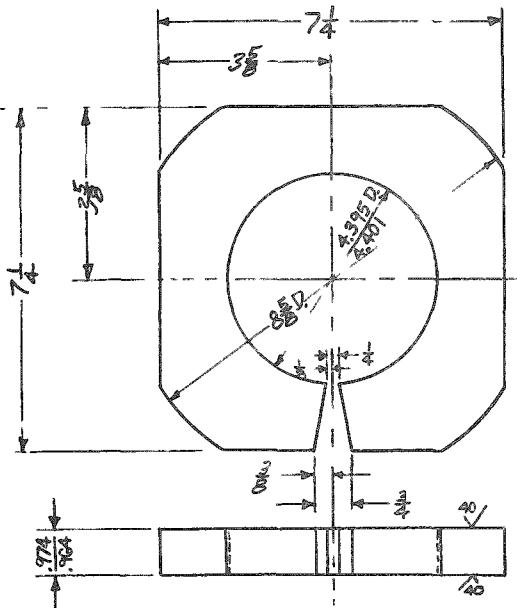
NO. REQ.: 4,   TOL.: ± 1/32
MATERIAL: LOW CARBON STEEL
MOVE COIL END PLATE   RE-1-31096-A
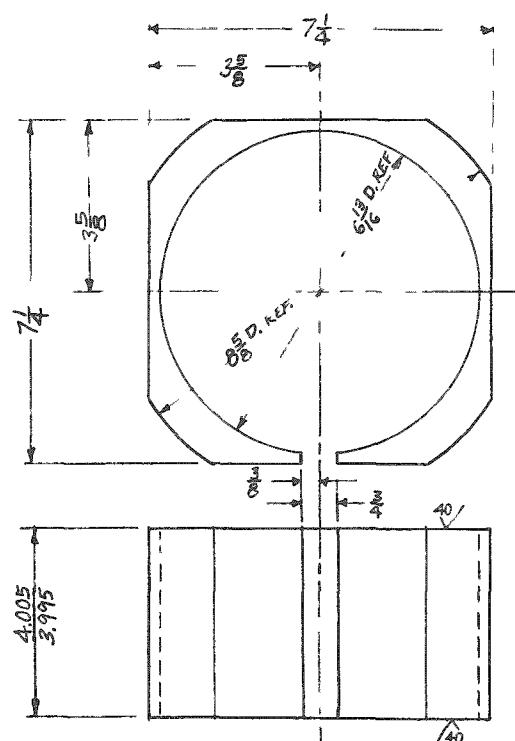
NO. REQ.: 2, TOL.: ± 1/32, MATERIAL:
LOW CARBON STEEL 8"SC.160 PIPE
MOVE COIL RING   RE-1-31097-A

104

E F G H

RE-1
21540
A

RE-1
31099
A-1

RE-1
31099
A-2

RE-1
31100
A

$4\frac{2}{16}$

SPEC.:
430 TURNS
4.0 OHMS AT 77°F
NO. REQ.: 8, TOL.: ± 1/32
GRIP COIL, POTTED   RE-1-31098-A

12

.302
.292

NO. REQ.: 16, TOL.: ± 1/32
MATERIAL: LOW CARBON STEEL
GRIP COIL END PLATE
RE-1-31099-A-1

WIND FIRST LAYER
RIGHT HAND

430 TURNS OF
#18 DOUBLE GLASS-
SILICONE MAGNET WIRE

$4\frac{1}{2} \pm \frac{1}{16}$ D.

$4\frac{5}{8} \pm \frac{1}{16}$ D.

1.349
1.339

40

40

WRAP COIL $\frac{1}{16}$" THICK
WITH UNTREATED
GLASS CLOTH TAPE.
A FEW $\frac{1}{4}$" WIDE STRIPS
OF GLASS CLOTH
ADHESIVE TAPE
MAY BE USED TO
BIND THE COIL.

$6\frac{5}{8} \pm \frac{1}{8}$ D.

NO. REQ.: 8
MATERIAL: LOW CARBON STEEL
GRIP COIL RING
RE-1-31099-A-2

NO. REQ.: 14
GRIP COIL
RE-1-31100-A

.302 / .292

2.217 D / 2.222

5/16 D.

40   40
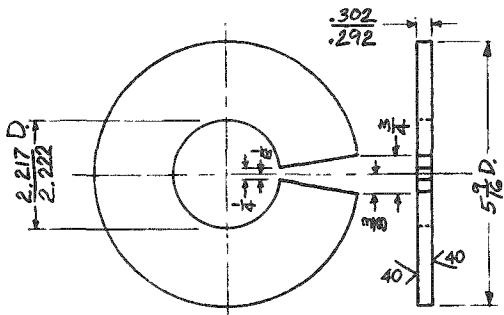
NO. REQ.: 16, TOL.: ± 1/32
MATERIAL: LOW CARBON STEEL
HOLD COIL END PLATE
RE-1-31102-A-1

SEE PAGE 49

RE-1 21540 A

RE-1 31102 A-1

RE-1 31102 A-2

RE-1 31103 A

3 5/8

1 1/16 REF.

7/8

13/32

F

E

F

R

5 9/16 D. REF.

2 7/32 D. REF.

SPEC.:
600 TURNS
5.8 OHMS AT 77°F
NO. REQ.: 8, TOL.: ± 1/32
HOLD COIL, POTTED RE-1-31101-A

13

1.099 / 1.089

5/16 REF.

3/4

5 9/16 D. REF.

40   40

NO. REQ.: 8, TOL.: ± 1/32
MATERIAL: LOW CARBON STEEL
HOLD COIL RING
RE-1-31102-A-2

WIND FIRST LAYER RIGHT HAND

4 7/8 ± 1/8 D.

600 TURNS OF #20 DOUBLE GLASS-SILICONE MAGNET WIRE.

3/4 ± 1/8

1/16 ± 1/32   5/16

1/16 ± 1/32

3/4 ± 1/8

WRAP COIL 1/16" THICK WITH UNTREATED GLASS CLOTH TAPE. A FEW 1/4" WIDE STRIPS OF GLASS CLOTH ADHESIVE TAPE MAY BE USED TO BIND THE COIL.

2 5/16 ± 1/16 D.
2 7/16 ± 1/16 D.

NO. REQ.: 8
HOLD COIL
RE-1-31103-A

Coil Assembly Notes

E. Silver solder the wire connection with "Easy-Flo."

F. Wrap the terminals and the long lead wire 1/8" thick with 3/4" wide untreated glass cloth tape. Hold the end of the tape with a 1/8" wide strip of glass cloth adhesive tape.

G. Clamp the parts in the welding jig and seam weld by fusing the base metal (no filler rod). The weld is required to be strong enough to hold the parts together during ordinary handling and to be leak-proof enough to hold the potting material while it is liquid.

H. Clamp the welded assembly in the teflon mold and vacuum impregnate with epoxy resin prepared as follows: to Shell Epon Resin 815 add 10% by weight of MMM Cardelite N.C. 513; heat mixture to 140°F; to mixture add 14% by weight of Shell Epon Curing Agent CL (heated until melted); stir well; use immediately. Keep the filled mold at room temperature for 12 hours to allow the resin to gel. Place filled mold in 180°F to 200°F furnace for two (2) hours.

106

RE-1
31088
A

3.891 D.
3.885

$\frac{1}{16}$"x45°CH.

2.375 D.
2.380

$\frac{1}{4}$

$\frac{1}{8}$ R.

11 WELDS — 1. PRE-HEAT TO 300-350F.
2. HELIARC WELD FIRST PASS
WITH 3/32" DIA. INCO-WELD "A".
3. ARC WELD OTHER PASSES
WITH 1/8" DIA. INCO-WELD "A".

REMOVE AN EQUAL
AMOUNT FROM EACH END

3.495 D, CONCENTRIC
3.505   WITHIN .020"

RE-1
31107
A

$3\frac{15}{16}$

$3\frac{1}{2}$ REF.

RE-1
31106
A

26° ±1°

$\frac{5}{8}$±.010

$\frac{1}{16}$"x45°CH.

$4\frac{1}{8}$D.

$4\frac{3}{8}$ D.

.250
.252

.095
.105

$4\frac{11}{16}$ D.

$4\frac{15}{16}$ D.

NO. REQ.: 1
TOL.: ± 1/32
PRESSURE
SHELL BODY,
LOW PRESS.
RE-1-31105-A

$4\frac{1}{16}$ D.

$3\frac{5}{8}$ D.

3.470 D.
3.465

26°

$2\frac{3}{4}$

$\frac{1}{8}$±.010

$1\frac{7}{8}$±.010

$37\frac{1}{2}$°

$3\frac{5}{16}$ D.

5 D.

NO. REQ.: 1   TOL.: ± 1/16 ± 2°
MATERIAL: 430 SST
BODY FLANGE, LOW PRESSURE
RE-1-31106-A

$7\frac{1}{4}$

$1\frac{1}{2}$

$3\frac{5}{8}$ D.

$3\frac{1}{4}$

$\frac{1}{2}$"-13 TAP 1" DEEP
2 HOLES

$\frac{3}{16}$" x45°CH.

$3\frac{1}{4}$

$22\frac{1}{2}$°

$7\frac{1}{4}$

$3\frac{5}{8}$

$3\frac{1}{4}$

$\frac{1}{2}$

4 D.

$\frac{13}{16}$" DRILL & $1\frac{1}{2}$" C'BORE
$\frac{25}{32}$" DEEP 8 HOLES
EQ SP. ON $5\frac{3}{4}$" D.B.C.

$\frac{3}{16}$"x45°CH.

$3\frac{1}{4}$

$1\frac{1}{2}$

24° ±1°

$2\frac{3}{4}$

$\frac{1}{2}$

$4\frac{3}{8}$ D.

$5\frac{1}{2}$ D.

NO. REQ.: 1
TOL.: ± 1/32
MATERIAL: LOW CARBON STEEL
FLANGE RING, LOW PR.   RE-1-31113-A

CADMIUM PLATE
.0008"±.0003"

20

3.480 D.
3.475

$\frac{1}{4}$

$\frac{1}{8}$±.010

$4\frac{15}{32}$ REF.

$37\frac{1}{2}$° ±2°
TYP.

$3\frac{5}{8}$ D.
TYP.

$\frac{1}{8}$ TYP.

7 SPACES @
$2\frac{1}{32}$=$14\frac{7}{32}$

8 GROOVES
EQ. SP.

$4\frac{1}{16}$ D.

$3\frac{12}{16}$ D.
DIA.

$26\frac{3}{4}$

$4\frac{15}{32}$

$3\frac{19}{32}$

$\frac{1}{4}$

$\frac{1}{8}$

3.480 D.
3.475

NO. REQ.: 1
TOL.: ± 1/16
MATERIAL:
430 SST
BODY TUBE,
LOW PR.
RE-1-31107-A

RE-1
31092
A-2

RE-1
31092
A-1

RE-1
31109
A

86 $\frac{1}{8}$ BEFORE WELDING, REF.

85 $\frac{13}{16}$ AFTER WELDING, REF.

TURN

(B)

(B) 1. PRE-HEAT TO 300-350 F.
2. HELIARC WELD FIRST PASS
   WITH 3/32" DIA. INCO-WELD "A".
3. ARC WELD OTHER PASSES
   WITH 1/8" DIA. INCO-WELD "A".

REMOVE
SHARP
EDGE

9 WELDS (B)

* $\frac{1.562}{1.565}$ I.D.
BEFORE PLATING   CONCENTRIC
WITHIN .020"

$\frac{1.960}{1.955}$ O.D.

$\frac{1}{8}$ R.

REMOVE
SHARP
EDGE

* "NEO-CHROME" PLATE
$\frac{1.562}{1.565}$ I.D. SURFACE
.004" ±.001" THICK FOR
WEAR RESISTANCE.

$\frac{1}{3}$ $\frac{1}{32}$ ±
3 $\frac{1}{8}$

RE-1
31090
A

NO. REQ.: 1
PRESSURE SHELL EXTENSION,
LOW PRESSURE   RE-1-31108-A

1 $\frac{5}{8}$ D.

$\frac{1.600}{1.590}$ D.

$\frac{1}{8}$

1 $\frac{5}{8}$ D.
TYP.

37 $\frac{1}{16}$ ±2° TYP.

$\frac{1}{8}$ TYP.

2 $\frac{1}{16}$ D.

1 $\frac{7}{16}$ D.

14 $\frac{5}{16}$

6 SPACES @ 1 $\frac{25}{32}$ = 10 $\frac{11}{16}$

7 GROOVES
EQ. SP.

1 $\frac{25}{32}$

$\frac{1}{4}$

$\frac{1.535}{1.540}$ D.

1 $\frac{5}{8}$ D.
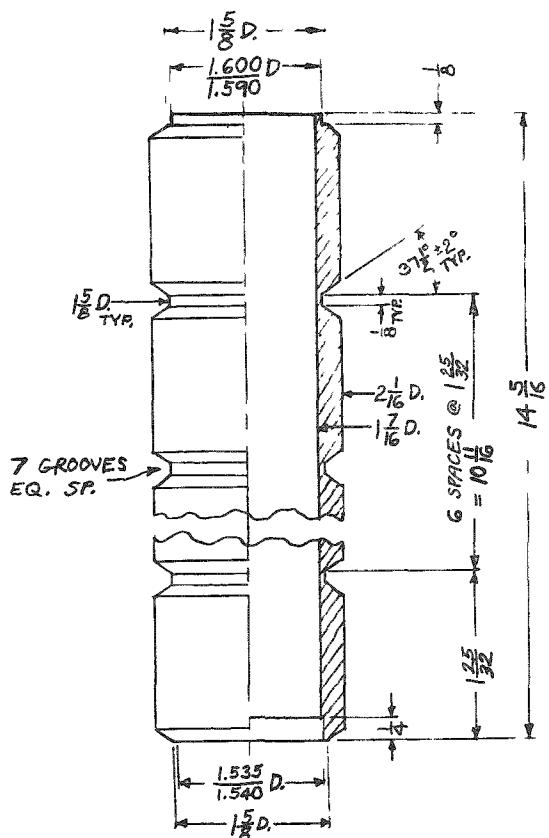
NO. REQ.: 1
TOL.: ± 1/16
MATERIAL: 430 SST
EXTENSION TUBE,
LOW PRESSURE
RE-1-31109-A

"NEO-CHROME PLATE
ALL SURFACES
.004' ± .001 THICK
FOR CORROSION AND
WEAR RESISTANCE.

$1\frac{7}{8}$ DRILL

$1\frac{5}{8}$ DRILL

INCO-WELD "A"
8 WELDS

$\frac{1.562}{1.565}$ D
BEFORE
PLATING

REMOVE AN EQUAL
AMOUNT FROM EACH END

$22\frac{9}{16}$

$3\frac{1}{4}$

$3\frac{1}{4}$

$\left\{ 3\frac{7}{16}" \text{O.D.} \times 1\frac{33}{64}" \text{I.D.} \times \frac{1.880}{1.870} \text{LONG,} \right.$
LOW CARBON STEEL, 7 REQ'D.

$\left\{ 3\frac{1}{4} \text{I.D.} \times 1\frac{33}{64} \text{I.D.} \times \frac{.130}{.120} \text{THICK,} \right.$
INCONEL , 8 REQ'D.

$1\frac{5}{8}$ DRILL

$\left\{ 3\frac{7}{16} \text{O.D.} \times 1\frac{33}{64} \text{I.D.} \times 4\frac{5}{16} \text{LONG,} \right.$
LOW CARBON STEEL, 2 REQ'D.

$1\frac{7}{8}$ DRILL

$3\frac{3}{8} \pm \frac{1}{64}$ D.

REMOVE ALL
SHARP EDGES

NO. REQ.: 1, TOL.: ± 1/32
ARMATURE   RE-1-31110-A

(5)

$1\frac{1}{2}"$ SC. 40 PIPE
INCONEL

$\frac{1}{16}$

$\frac{9}{16}$°

31°

SHRINK FIT IN
$1\frac{7}{8}"$ DRILLED HOLE

TURN AFTER SHRINK FIT ASSEMBLY

$1\frac{30}{4}$ D.

$1\frac{5}{8}$ D.

ROUND EDGES

$\frac{1}{2}$

$\frac{1}{32}$ R.

ONE END OF
THE PLUG AND
ONE END OF
THE ARMATURE

NO. REQ.: 2, TOL.: ± 1/64
DIRT SHIELD   RE-1-31117-A

(24)

$104\frac{1}{2}$

$\frac{.497}{.492}$ $\frac{13}{16}$

$\frac{1}{4}$

$\frac{.300}{.295}$ D.

$\frac{5}{16}$ D.

45° 45°

$\frac{1}{2}$" D. CENTERLESS GROUND BAR
416 SST

$\frac{1}{16}$"×45° CH.
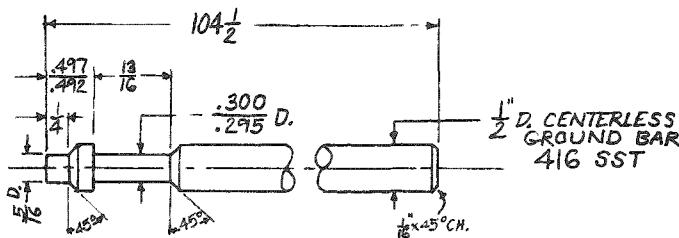
NO. REQ.: 6
TOL.: ± 1/32
DRIVE ROD
RE-1-31111-A-1

9

$6\frac{3}{8}$

$\frac{1}{4}$ $\frac{7}{8}$ $\frac{25}{8}$ $\frac{.500}{.505}$ $\frac{3}{4}$

45°

$\frac{5}{32}$ R. TYP.
6 SLOTS EQ. SP.

$\frac{1}{2}$ D.

$\frac{15}{16}$"-32 NS3 THREAD

$\frac{7}{8}$ D. $\frac{1.000}{.995}$ D.

$\frac{1}{2}$ D. $\frac{1}{32}$" R.

$1\frac{3}{8}$ D.
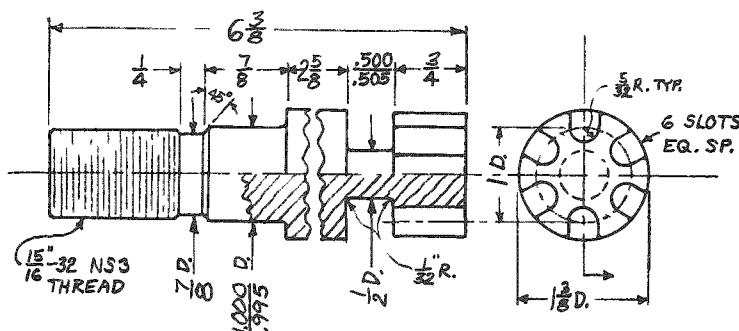
NO. REQ.: 1
TOL.: ± 1/64
MATERIAL:
ARMCO 17-4 PH SST
ROD CONNECTION
RE-1-31111-A-2

10

$3\frac{1}{16}$

$\frac{1}{4}$

$\frac{1}{2}$ D.

$\frac{1.025}{1.010}$ D.

$\frac{1.440}{1.430}$ D.

$\frac{1}{16}$"×45° CH.
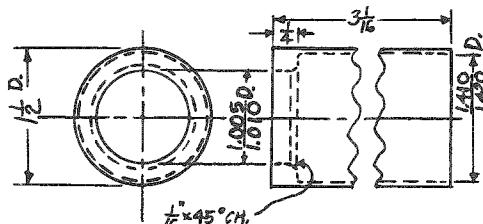
NO. REQ.: 1
TOL.: ± 1/32
MATERIAL: 304 SST
ROD RETAINER
RE-1-31111-A-3

21

1" PIPE THREAD

$1\frac{1}{2}$ D.

1 D.

$\frac{3}{8}$" PIPE TAP

1"-8 TAP

$\frac{1}{2}$ 1

45°

1 D.

$\frac{1}{2}$" DRILL

$\frac{3}{4}$

45°

$1\frac{1}{4}$ D.

$2\frac{3}{8}$

45°

$3\frac{5}{8}$

$\frac{1}{16}$" R. FILLETS

$\frac{1}{16}$"×45° CH. VALVE SEAT MUST BE SMOOTH

$1\frac{3}{16}$

$\frac{1.625}{1.615}$

$1\frac{7}{8}$ D.
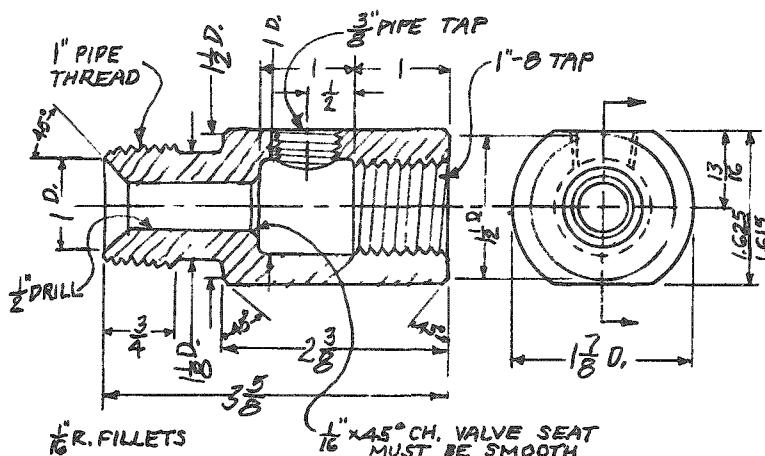
NO. REQ.: 1
TOL.: ± 1/32
MATERIAL:
ALUMINUM BRONZE
VALVE BODY
RE-1-31115-A-1

22

$2\frac{1}{2}$ REF.

$\frac{31}{32}$ $1\frac{3}{16}$ $\frac{1}{4}$

$\frac{11}{16}$ D.

45°

$\frac{1}{16}$ R.

$\frac{11}{16}$ D.

1"-8×$2\frac{1}{2}$"
SOCKET HEAD
CAP SCREW
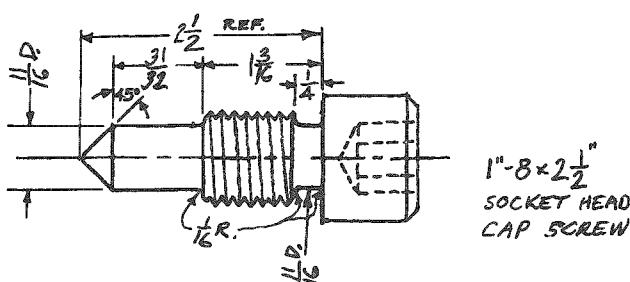
NO. REQ.: 1
TOL.: ± 1/32
MATERIAL:
303 OR 304 SST
VALVE STEM
RE-1-31115-A-2
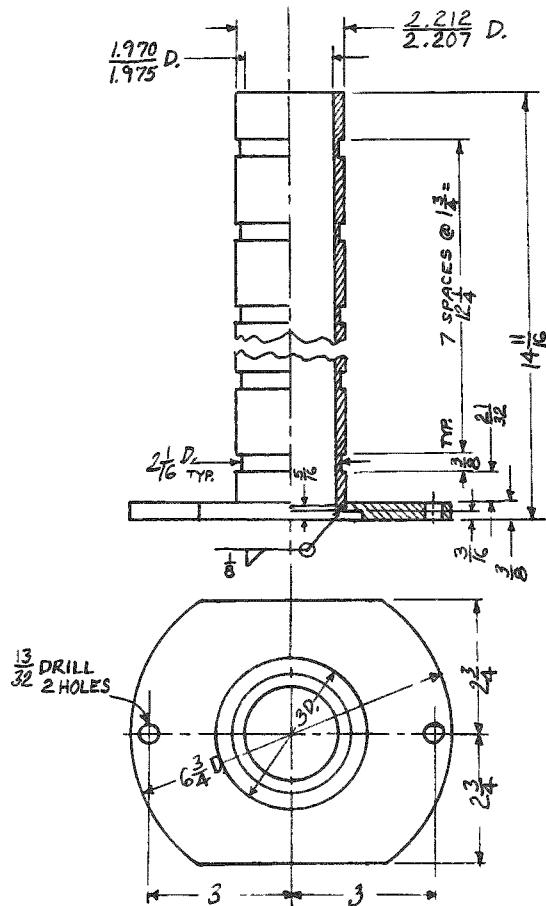
23

$\frac{1.970}{1.975}$ D.

$\frac{2.212}{2.207}$ D.

7 SPACES @ $1\frac{3}{4}$ = $12\frac{1}{4}$

$14\frac{11}{16}$

TYP.

$2\frac{1}{32}$

$2\frac{1}{16}$ D. TYP.

$5\frac{1}{16}$

$3\frac{3}{100}$

$\frac{3}{16}$

$\frac{3}{8}$

$\frac{1}{8}$

$\frac{13}{32}$ DRILL 2 HOLES

3 D.

$2\frac{3}{4}$

$2\frac{3}{4}$

$6\frac{3}{4}$ D.

3

3

CADMIUM PLATE
.0008"±.0003"

NO. REQ.: 1   TOL.: ± 1/32
MATERIAL: LOW CARBON STEEL
SMALL COIL SLEEVE
RE-1-31114-A

19

$\frac{3.901}{3.907}$ D.

$\frac{4.391}{4.385}$ D.

$4\frac{13}{32}$

7 SPACES @ 2" = 14

$29\frac{1}{16}$

$4\frac{13}{32}$

$4\frac{1}{32}$ D. TYP.

$\frac{3}{8}$ TYP.

$2\frac{3}{4}$

$0\frac{9}{16}$

$\frac{17}{32}$" DRILL 2 HOLES

$1\frac{1}{4}$" × 45° CH.

$\frac{3}{16}$" × 45° CH.

$7\frac{1}{4}$

$3\frac{1}{4}$

$3\frac{5}{8}$

$3\frac{1}{4}$

$3\frac{1}{4}$

$3\frac{1}{4}$

$3\frac{5}{8}$

$7\frac{1}{4}$

CADMIUM PLATE
.0008"±.0003"
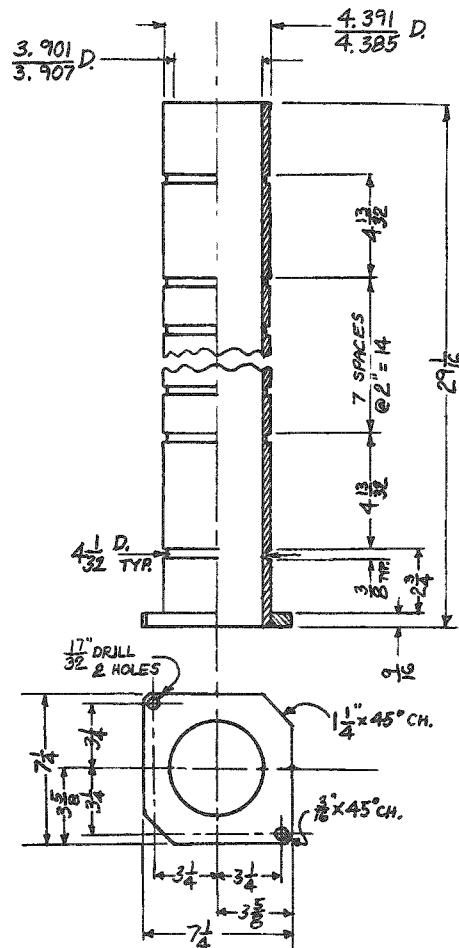
NO. REQ.: 1   TOL.: ± 1/32
MATERIAL: LOW CARBON STEEL
LARGE COIL SLEEVE
RE-1-31116-A

18

APPENDIX D

POSITION INDICATORS

Position indicators used with the magnetic jack are of the electro-magnetic, stationary-coil type. This type is used because it avoids, as does the magnetic jack, the use of shaft seals and mechanisms near the reactor which might require maintenance. Basically, these position indicators consist of a coil that fits over a nonmagnetic pipe which is the portion of the pressure shell which is used for containing the drive rod as it moves through the jack. Since the drive rod is magnetic, the length of rod in the coil effects the impedance of the coil. Measuring the impedance gives the position of the rod.

The impedance-measuring system which seems to be most attractive involves the measuring of the voltage across the coil, which is supplied with a 60-cycle constant (or nearly constant) current. This voltage increases by a factor of eleven when the rod is inserted in the coil. A bridge circuit is not used because it is more complicated and because of the possibility of loose connections overloading the meter.

For this size of device (a cluster of six $\frac{1}{2}$-in. diameter rods in a $1\frac{1}{2}$-in. standard pipe), a coil of #18 wire with 200 turns per inch of coil length has about the right amount of copper. Less copper has too much resistance and more copper has too much self-inductance.

The coil shown on page 113 is used for all of the position indicators described here. They are assembled to suit the particular application. The first coil of an assembly is supplied with a slightly higher voltage than the rest of the coils, to compensate for its being at the end. Closer readings and a smaller temperature error are obtained by using a larger number of shorter coils; however, there is little improvement below a two-inch spacing.

The table on page 112 describes six types of position indicators in the order of their simplicity.

COMPARATIVE DESCRIPTION OF SIX TYPES OF POSITION INDICATORS

TYPE	light bulb	light and meter	automatic meter	linear scale meter	decade switch	automatic digital
BUILT AND TESTED	Jan. 1955; June 1959	June 1957	March 1958	April 1958	Feb. 1959	
COARSE INDICATION	light bulbs	light bulbs	bar indicator	207° linear scale	calibrated scale	digital display
COARSE READING PROCEDURE	position is read on scale at dim light or between bright lights and dark lights	position is read on scale at dim light or between bright lights and dark lights	position is indicated by length of red line	position is read directly in inches on meter scale	position is read directly in inches on meter scale	numbers are read
COIL SWITCHING FOR CLOSE INDICATION	manual selector switch	manual selector switch	automatic selector switch	manual selector switch	two manual selector switches	two automatic selector switches
CLOSE INDICATION	meter and graph	meter with calibrated dial	meter with calibrated shifting dial	meter with graph	meter with calibrated decade dial	multi-contact meter-relay with digital display
CLOSE READING PROCEDURE	1. lights are unplugged 2. meter selector switch is plugged in 3. meter is switched to last coil that reads high 4. rheostat is adjusted to make meter read 2.5 volts 5. meter is switched to next coil (coil that reads in middle range) 6. meter is read 7. graph is read	1. coil indicated by light is selected 2. number indicated on selector switch dial is added to meter reading	1. position is read directly on meter scale	1. coil is selected 2. voltage is adjusted 3. meter is read 4. graph is read	1. coil is selected 2. numbers indicated on seclector switch dials are read as first two digits and meter is read as the third digit	1. numbers are read
REGULATION FOR CLOSE INDICATION	rheostat	voltmeter, rheostat, coil with fixed iron core	automatic constant voltage power supply	voltmeter, variable transformer	automatic constant current power supply	automatic constant current power supply
ADVANTAGES	simple, reliable	good compromise between simple construction and easy to read close indication	easy to read close indication	looks like standard position indicators, reliable	easy to read close indication, reliable, magnifies movement, accurate	digital indication, accurate
DISADVANTAGES	close reading requires seven operations	meter is inaccurate if any light bulb burns out	depends on sensitive relays	close reading requires four operations	requires a wire for each inch of indication from drive to control panel	complicated construction
REFERENCES	pages 114 thru 117	ANL-5768, pages 20 thru 24	pages 118 thru 121	appendix B	pages 122 thru 125	

17/64" DRILL THRU AND 5/8" D. C'BORE 4 HOLES

RE-1 21409 B

SPEC.:
200 TURNS
0.91 OHMS @ 77°F.

TOL.: ± 1/64"

MOLDED POSITION INDICATOR COIL
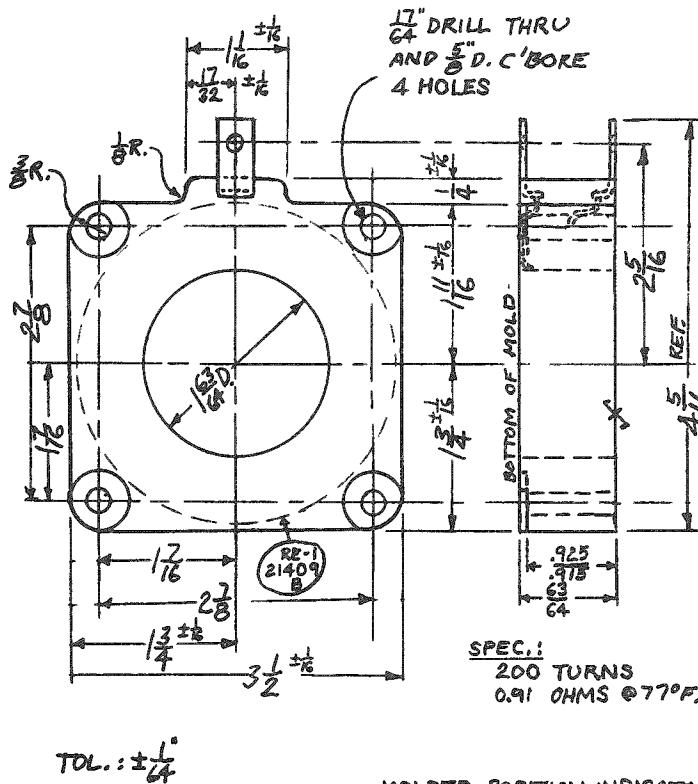
MOLDED POSITION INDICATOR COIL CONSTRUCTION NOTES

A. USE TWO TERMINAL POSTS. DRAWING RE-1-21540-A (SEE PAGE 9). MAKE 90° ± 5° BEND 3/16 ± 1/32 FROM END WITH SMALL HOLE.

B. USE ONE COIL, DRAWING RE-1-21409-B. CUT OUTER LEAD TO 1/2 LONG AND INNER LEAD TO 1 LONG. REMOVE INSULATION BACK 3/16 FROM ENDS.

C. SILVER SOLDER THE LEAD WIRES TO THE TERMINAL POSTS WITH EASY-FLO.

D. PLACE THE COIL IN THE MOLD WITH THE INNER LEAD WIRE UNDER THE COIL. PRESS THE COIL DOWN FIRMLY AGAINST THE BOTTOM OF THE MOLD.

E. VACUUM IMPREGNATE THE COIL AND FILL THE MOLD TO A DEPTH OF 1 - 1/4 WITH EPOXY RESIN PREPARED AS FOLLOWS: TO SHELL EPON RESIN 815 ADD 10% BY WEIGHT OF MMM CARDELITE N.C. 513; HEAT MIXTURE TO 140°F; TO MIXTURE ADD 14% BY WEIGHT OF SHELL EPON CURING AGENT CL (HEATED UNTIL MELTED); STIR WELL; USE IMMEDIATELY. KEEP THE FILLED MOLD AT ROOM TEMPERATURE FOR 12 HOURS TO ALLOW THE RESIN TO GEL. PLACE FILLED MOLD IN 180°F TO 200°F FURNACE FOR TWO (2) HOURS.

LEADS MUST BE IN LINE WITHIN 1/8"

WIND FIRST LAYER RIGHT HAND
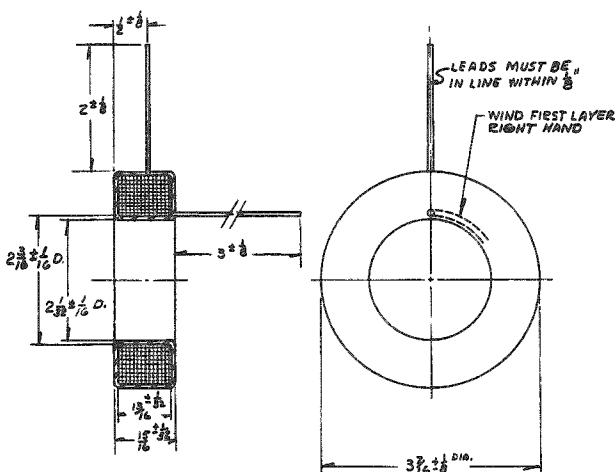
CONSTRUCTION NOTES:
1. WIND EXACTLY 200 TURNS OF #18 DOUBLE GLASS SILICONE MAGNET WIRE.
2. WRAP COIL 1/16" THICK WITH UNTREATED GLASS CLOTH TAPE. A FEW 1/8" WIDE STRIPS OF GLASS CLOTH ADHESIVE TAPE MAY BE USED TO BIND THE COIL.
3. THE COIL MUST WITHSTAND AN INSULATION BREAKDOWN TEST OF 1000 VOLTS ACROSS THE COIL.

POSITION INDICATOR COIL
RE-1-21409-B

Light Bulb Type

This type of position indicator is extremely simple and reliable. It is best suited to power reactors where the approximate position of the control rods should be easily seen and where precise measurements of position are needed only occasionally.

The diagram of a position indicator of this type for a 31-in. travel is shown on page 115. A three-inch coil spacing is close enough, since closer spacing gives an overlapping effect which cancels any benefit derived from having more lights. Using more than one 1-in. coil for each 3-in. space would give a greater change in voltage across the light; however, one coil gives sufficient contrast and is more economical.

The voltage across the coil varies from 0.92 to 2.23 v with the light bulbs in the circuit and varies, as shown on page 116, with the light bulbs removed.

The procedure for obtaining close indication, shown below, eliminates the error due to changes in input voltage and almost eliminates the error due to changes in temperature. The position may be read to within one tenth of an inch. The effect of a 150°F change in temperature is less than this one tenth of an inch.

The series of coils are held together by $\frac{1}{4}$-in. threaded rods and nuts on both sides of each coil.

TO OBTAIN CLOSE POSITION INDICATION

1. Unplug the lights and plug in the meter circuit.

2. Turn the selector switch to the highest number which gives a high meter reading.

3. Adjust the rheostats to make the meter read full scale.

4. Turn the selector switch to the next higher number.

5. Convert the meter reading to inches on the curve numbered as indicated by the selector switch.
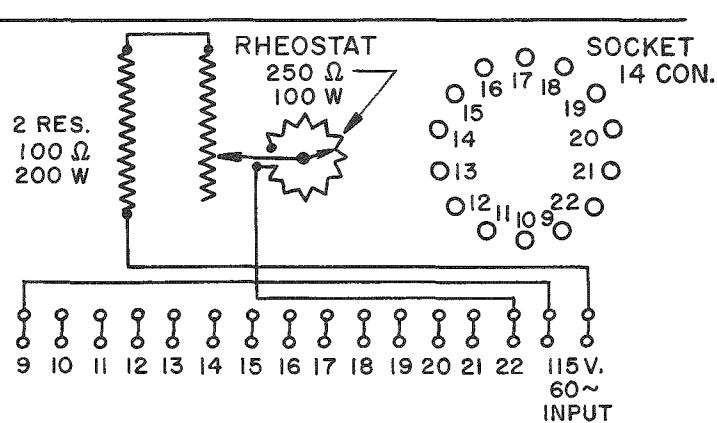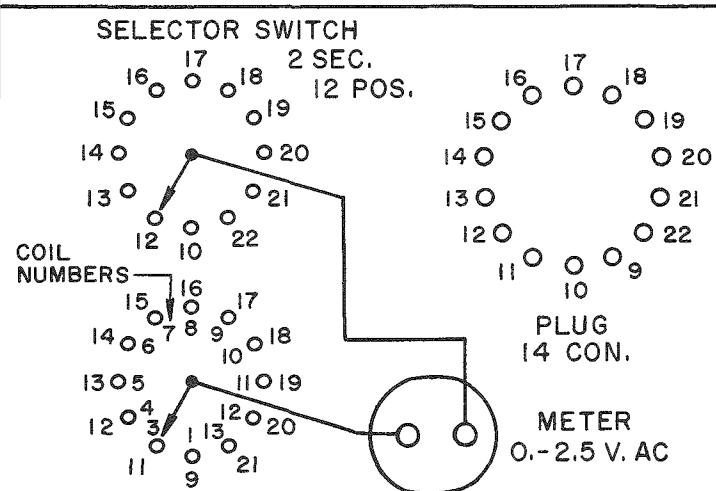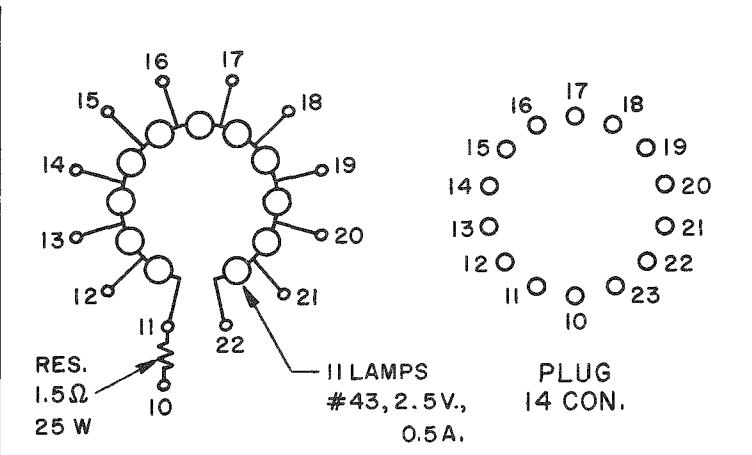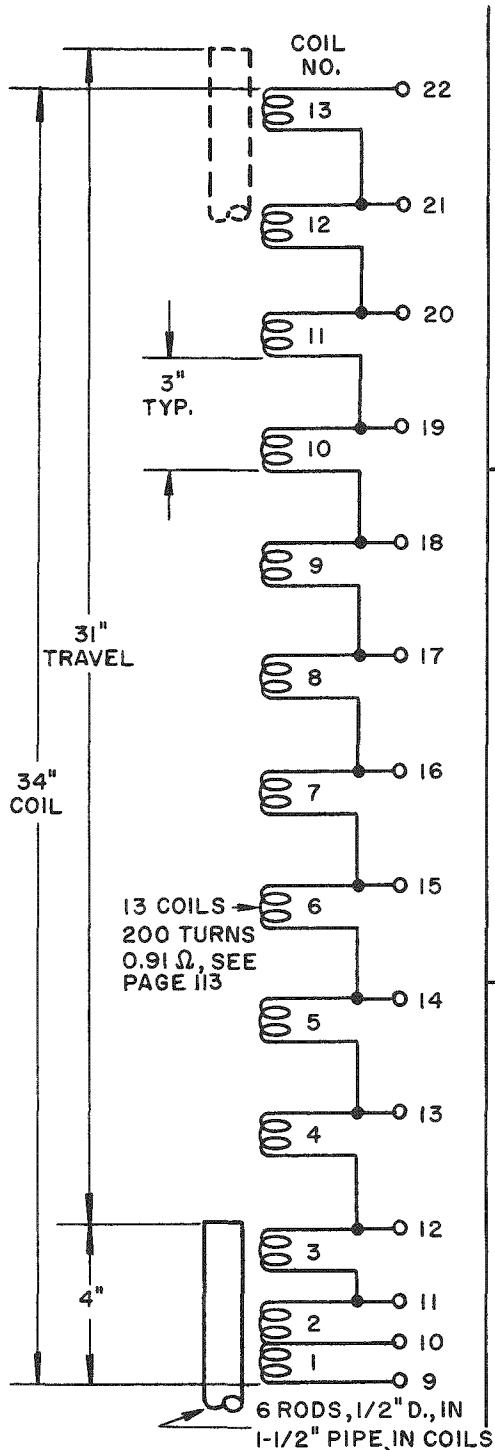
LIGHT BULB-TYPE POSITION INDICATOR (SCHEMATIC)

## VOLTAGE VARIATION ACROSS COIL
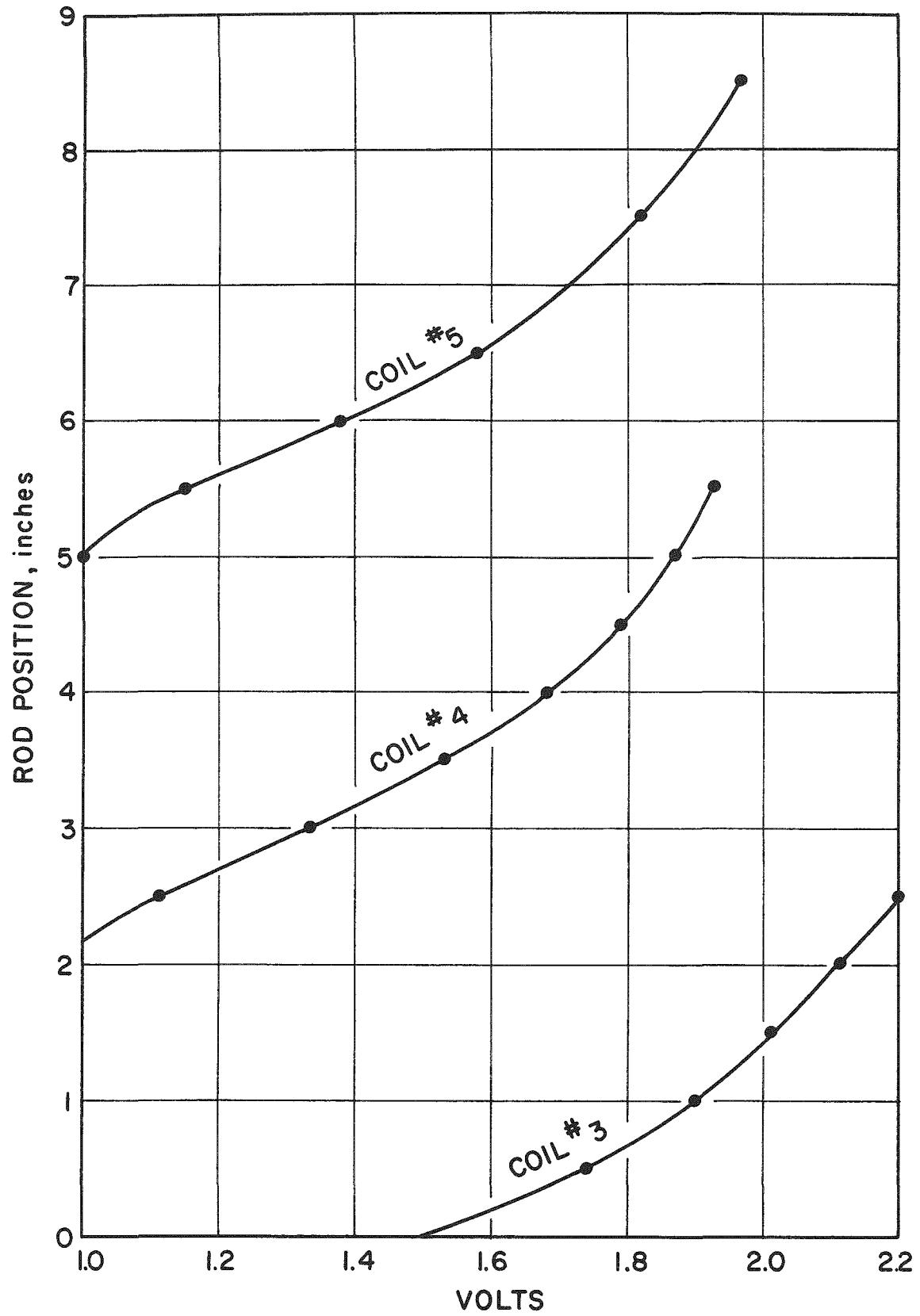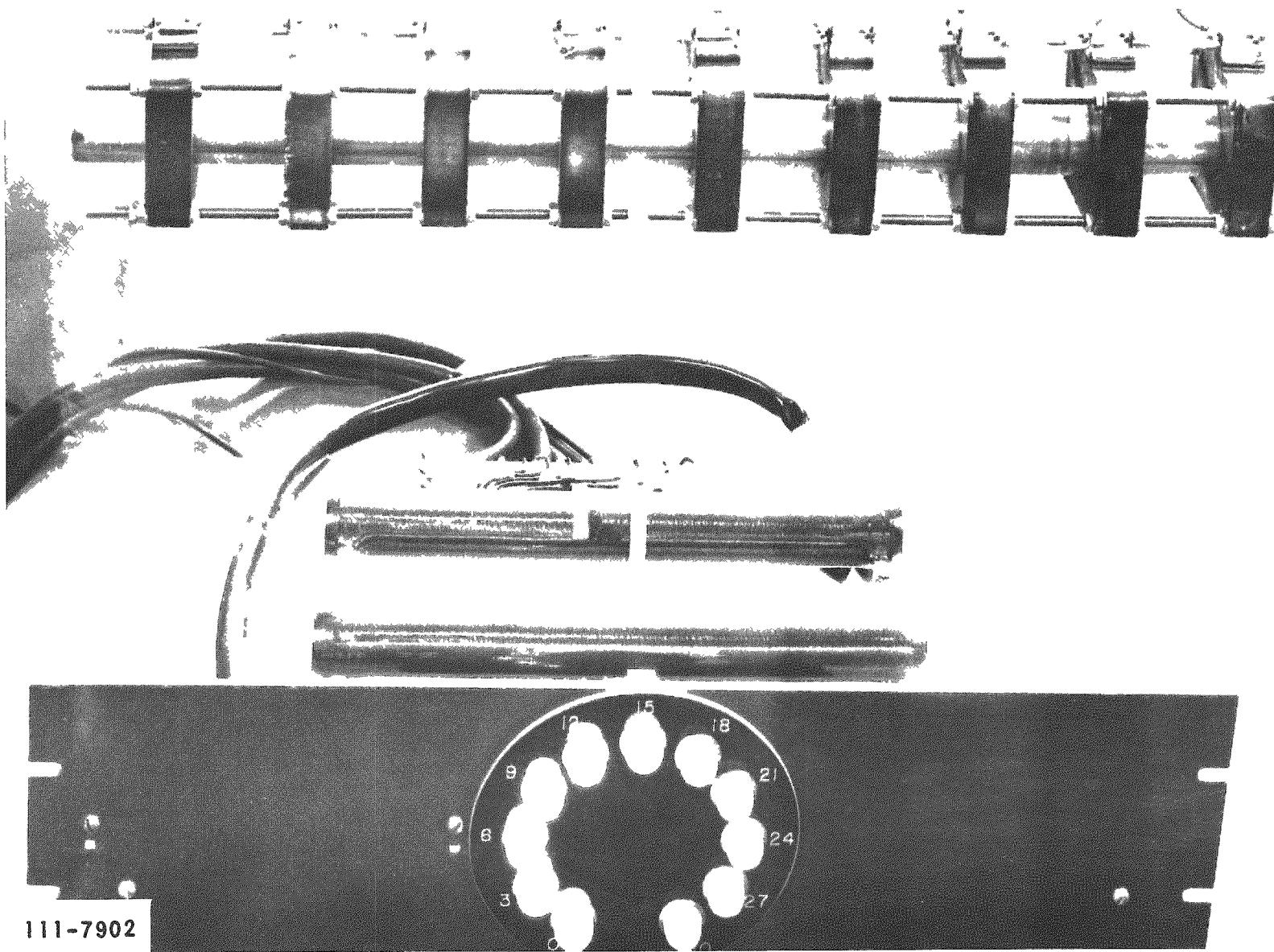
LIGHT BULB TYPE POSITION INDICATOR

111-7902
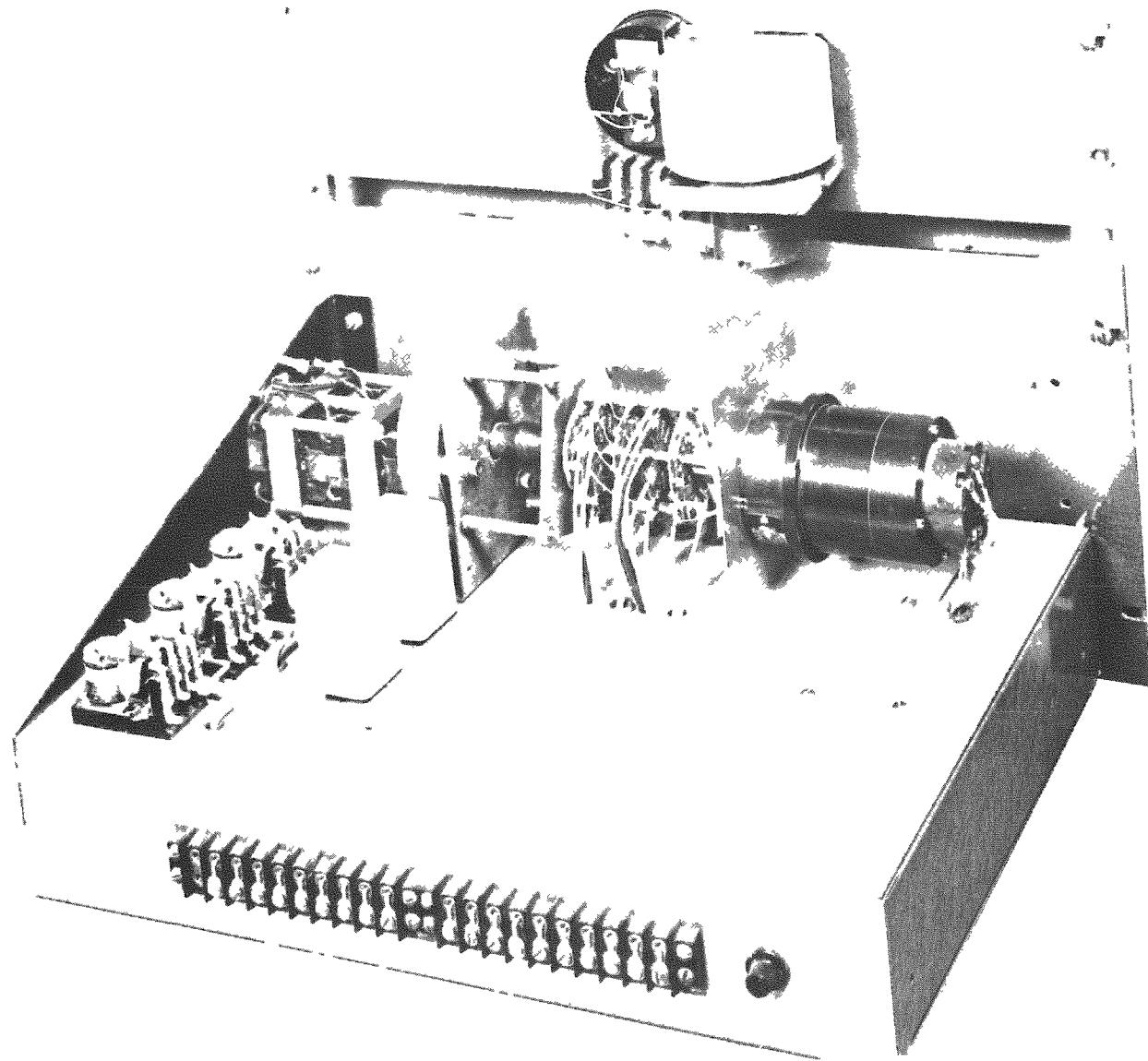
111-7906

AUTOMATIC METER TYPE POSITION INDICATOR
(BACK VIEW)

111-7905
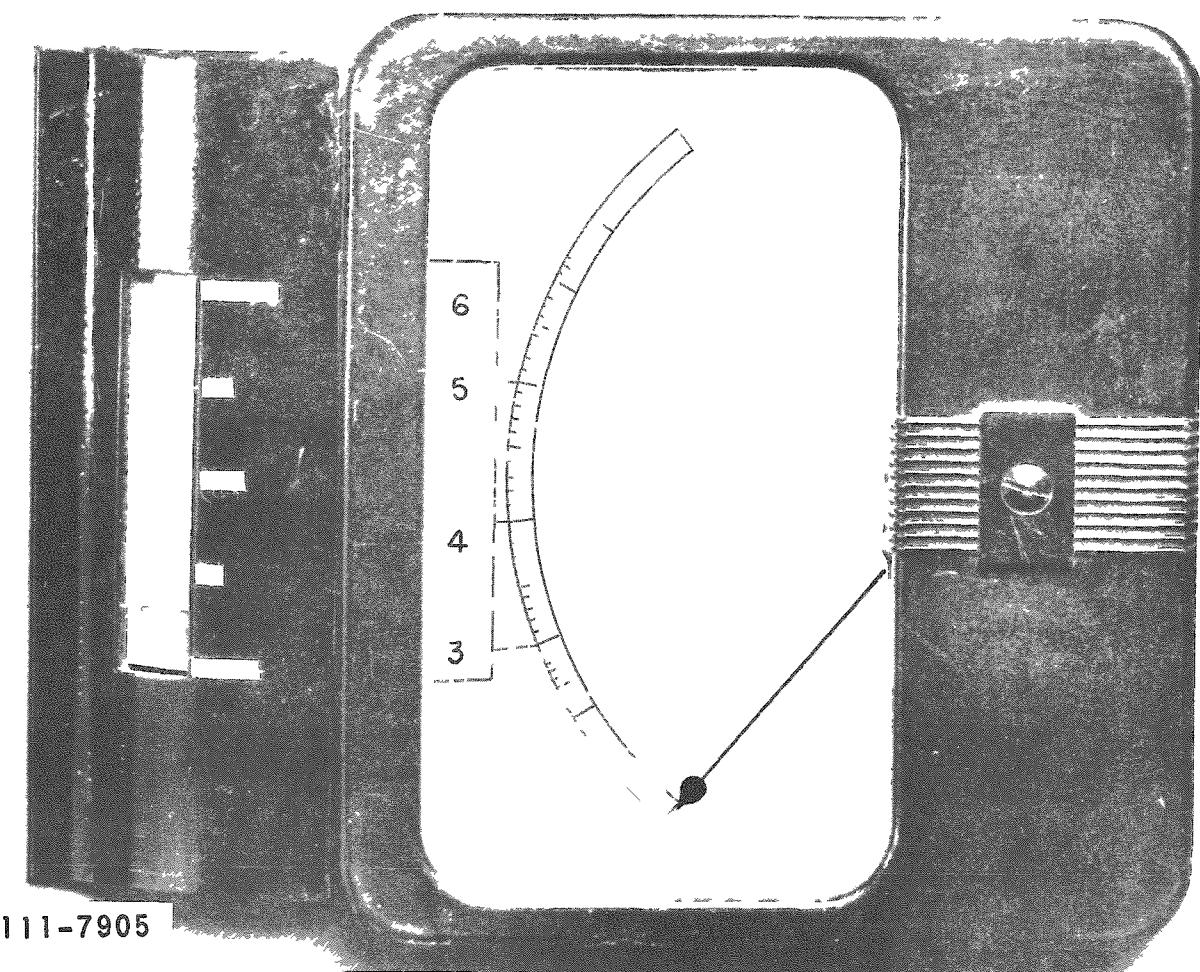
AUTOMATIC METER TYPE POSITION INDICATOR PANEL
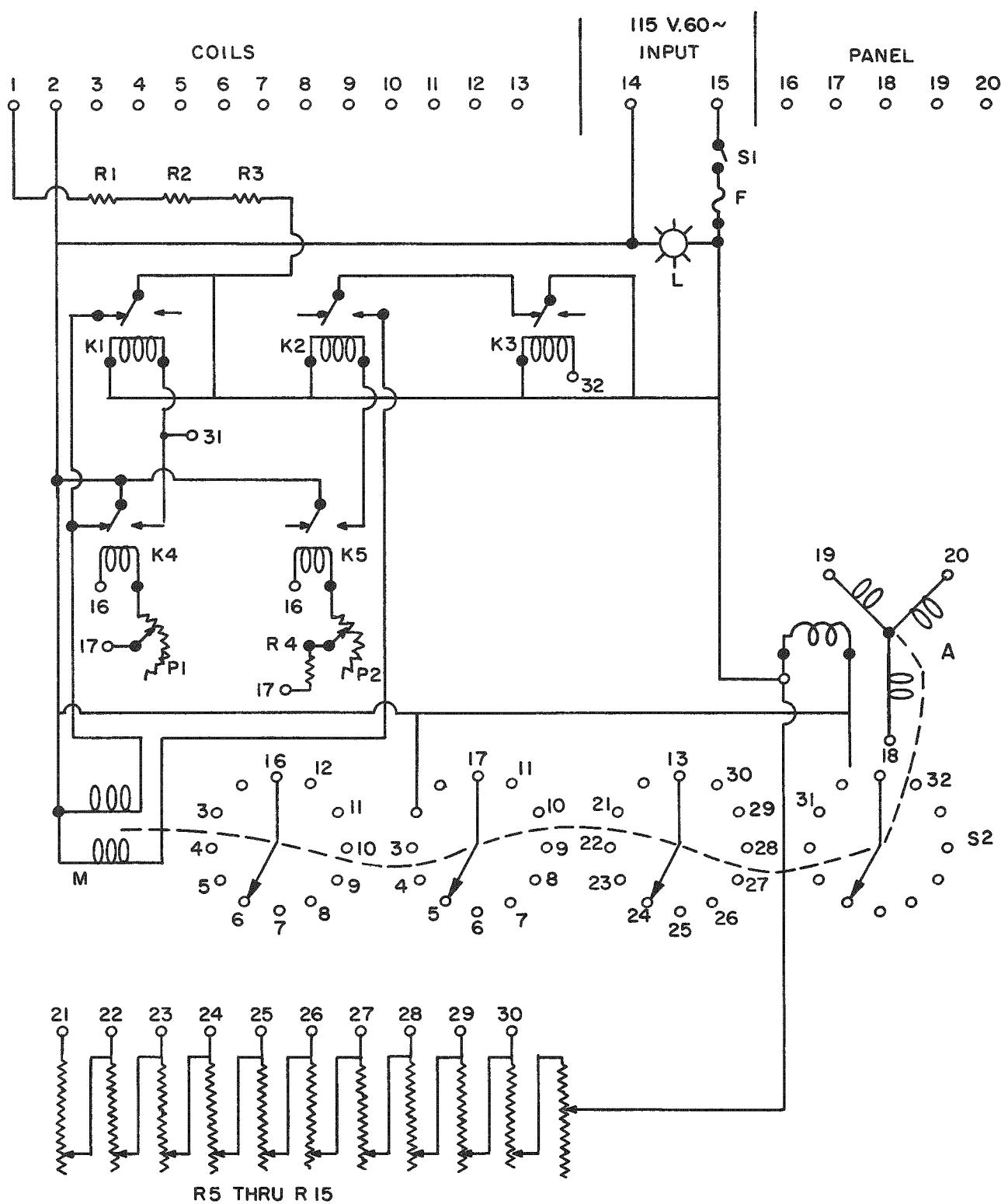
TRANSMITTER DIAGRAM

AUTOMATIC METER POSITION INDICATOR

CI THRU C 33

13
12
11
10
5
4
3
2
1

31" TRAVEL

33" COIL

ROD

COIL DIAGRAM

19   20

E

D   R16

B

16   17   115 V
18
60~
INPUT

PANEL DIAGRAM
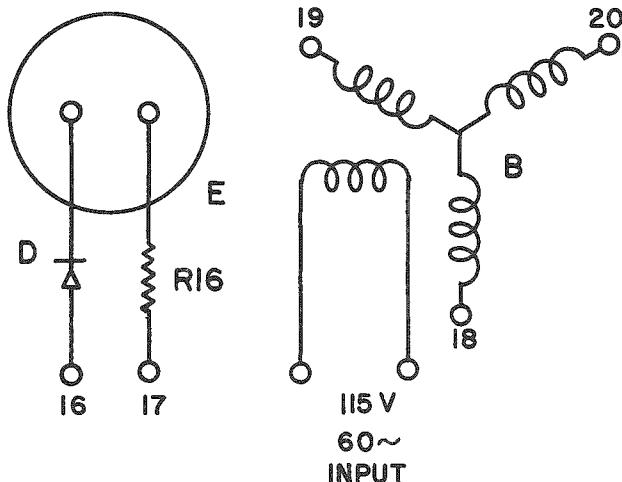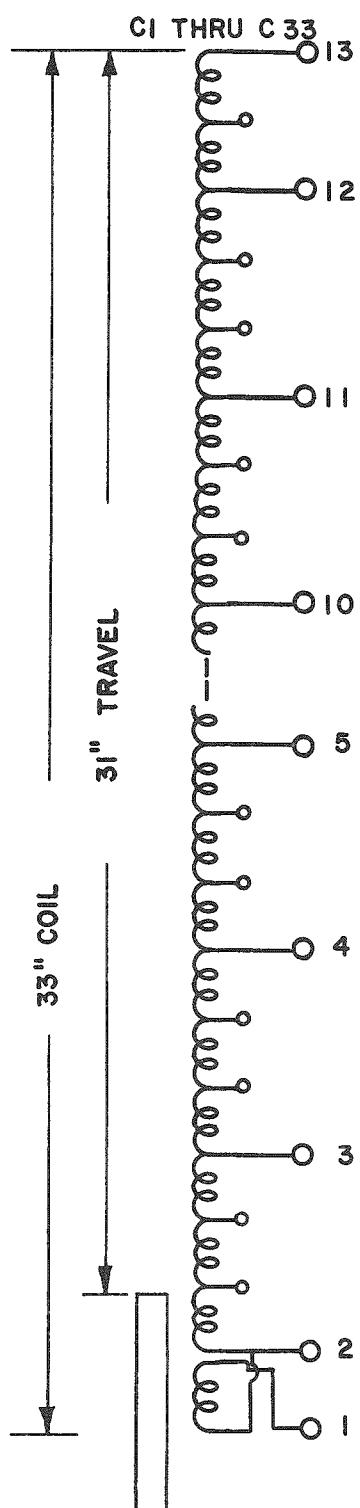
PARTS LIST

A.	Selsyn Transmitter, 115 V., 60 Cy, 2"D.
K1, K2, K3	Relay, SPDT, 115 VAC Coil, 5 Amp Con.
S1	Switch, On-Off, Toggle
F	Fuse, 10 A
P1, P2	Rheostat, 500 Ω, 1 W
R1, R2, R3	Resistor, 100 Ω, 100 W
M	Motor, Gleason-Avery #530BRA2
K4, K5	Relay, Sigma Type 5RS 12AS-SIL
R4	Resistor, 1500 Ω, 1 W, Precision
S2	Selector Switch, 4 Section, 11 Position
R5 thru R15	Resistor, 100 Ω, 10 W, Adjustable
R16	Resistor, 7000 Ω, 1 W Precision
B	Selsyn Receiver, 115 V, 60 Cy, 2"D
E	Meter, DC, 0-1 Milliamps, 50 Ohms
D	Silicon Diode, PSI Type IN628
C1 thru C33	Coil, 200 Turns, 0.91 Ohms, page 113

AUTOMATIC METER POSITION INDICATOR

Test Results of the Decade Switch-type Position Indicator

A test was made to determine the effect of changes in temperature. The part of the system which is located at the drive consists of the drive rod, the pipe and the set of coils. Any one of these will increase the meter reading if temperature increases. This would give a lower position reading, since the inch scale is reversed. The following table gives the effect of temperature on the 0 to 48-in. meter at various rod positions:

rod position	0	6	12	18	24	30	36	42	48
inches per °F	0.067	0.053	0.042	0.034	0.027	0.020	0.013	0.0078	0.0045
% due to rod	44	44	43	43	42	39	35	30	24
% due to pipe	51	50	50	50	50	50	48	42	28
% due to coil	5	6	7	7	8	11	17	28	48

The effect of temperature on the 0 to 1-in. meter is 0.0023 in. per °F at the 1-in. end of the scale, and is 0.0033 in. per °F at the 0-in. end.

SELECTOR SWITCH
2 SEC., 10 POS., N-S

66 o   65 o 64
67 o   o 63
68 o   o 62
69 o   o 61
70 o

67 o   66 o 65
68 o   o 64
69 o   o 63
70 o   o 62
71 o

SILICON
DIODE,
PS1, 1N628

33 Ω
1W

MILLIAMMETER
0-1, 4¼" WIDE
LONG-SCALE
G.E. #DB-18

29 39
19 56 30 49
68   0 5
61   59

28 38
18 82 56 48
82   150
120   58

27 62 56 47
17 56   20 57
10

36
26 91 91 46
16 68   130 56
130

3.5
25 75 47 45
15 39   20 55
10

24 34
14 62 100 100 44
30 54
130

23 33
13 24 75 47 43
30 53
15

22 32
12 39 91 91 42
120 52
130

21 31
11 68 56 41
30 51
15

20 30
10 91 75 40
120 50
130

19 29 39
9 68 56 30 49
10

SILICON
DIODE
PS1
1N628

10   60

72600 Ω
1W

MILLIAMMETER
0-1, 8¾" WIDE
LONG-SCALE
G.E. #DB-16

SELECTOR SWITCH
11 SEC., 5 POS., N-S.
RESISTORS, ½ WATTS

POWER TRANSFORMER
P9908

BK
117V.
BK

10W 23 Ω   o 9
6.3V., 3A

200W 750 Ω   o 10

320V. 150MA

R&Y   o 60
200W 1250 Ω

STABILINE VOLTAGE REGULATOR
(TYPE IE5101R) USED TO GIVE
CONSTANT CURRENT

PLUG & SOCKET

OUTPUT TERMINALS

o 9
o 10
o 60

o—o59 o—o52 o—o45 o—o38 o—o31 o—o24 o—o17
o—o58 o—o51 o—o44 o—o37 o—o30 o—o23 o—o16
o—o57 o—o50 o—o43 o—o36 o—o29 o—o22 o—o15
o—o56 o—o49 o—o42 o—o35 o—o28 o—o21 o—o14
o—o55 o—o48 o—o41 o—o34 o—o27 o—o20 o—o13
o—o54 o—o47 o—o40 o—o33 o—o26 o—o19 o—o12
o—o53 o—o46 o—o39 o—o32 o—o25 o—o18 o—o11

NOTE:
CONNECT THE 6.3 VOLT
TRANSFORMER LEADS
TO GIVE THE HIGHER
METER (#DB-16) READING.

SEE COIL DIAGRAM

DECADE SWITCH TYPE POSITION INICATOR
(48" METER DIAL, MANUAL SELECTOR SWITCHES, 1" METER DIAL)
BACK & TOP VIEW

RE-2-30138-C

PLATE

7/8

4-3/8

O 9

O 10

O 11

O 12

O 13

O 14

48
TRAVEL

O 15

O 16

54 SPACES
@ 1" = 54"

O 56

O 57

O 58

O 59

2-1/2

O 60
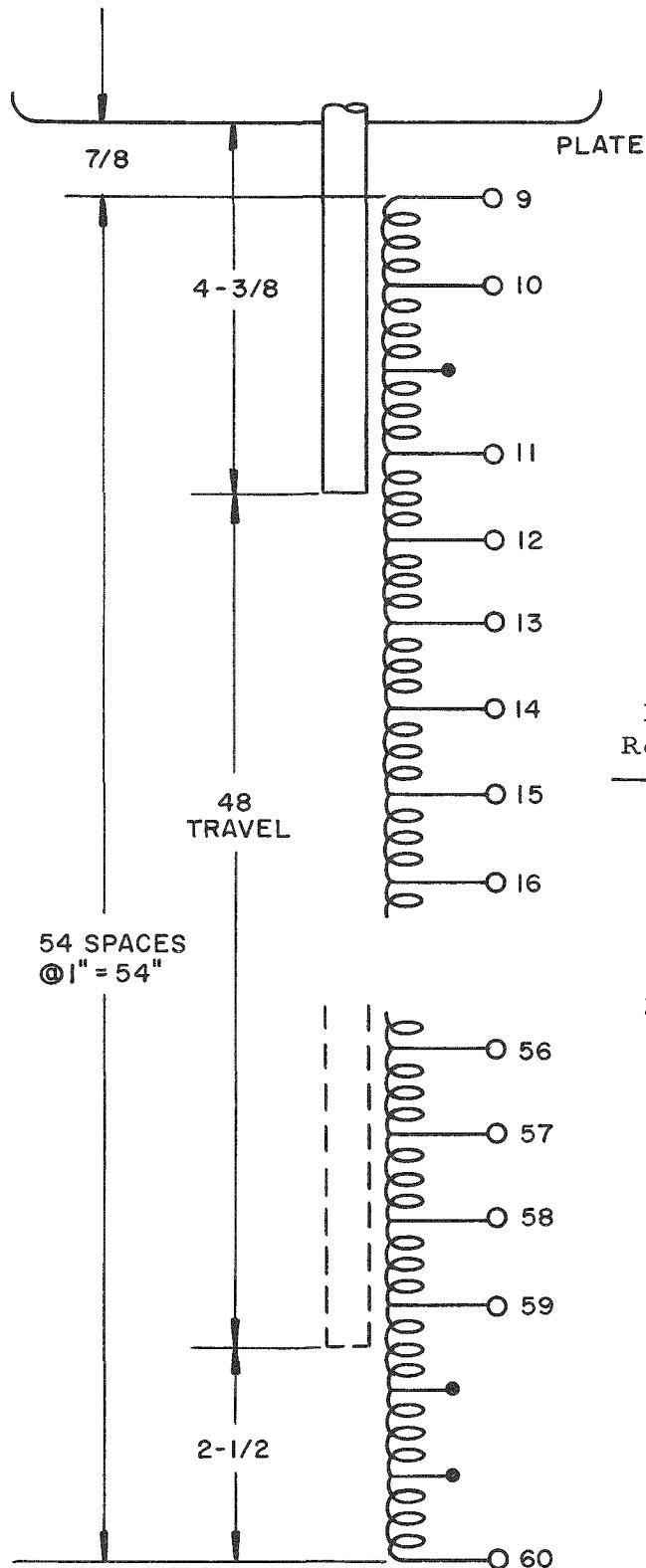
No. Req'd.	Part
54	molded position indicator coil, page 113
1	plate, drawing 29-17, page 102.
4	tie rod, $\frac{1}{4}$"D.x56"lg., $\frac{1}{4}$"-20thd. 2"LG., 304SSt.
20	hex nut, $\frac{1}{4}$"-20, brass.
12	lock washer, $\frac{1}{4}$", plated steel.
216	flat washer, #14, $\frac{9}{16}$"O.D.x.260" I.D.x.040" th., brass.
55	round head screw, #6-32x$\frac{1}{2}$", brass
110	hex nut, #6-32, brass.
110	lock washer, #6, plated steel.

DECADE-TYPE POSITION INDICATOR COIL DIAGRAM

111-7903
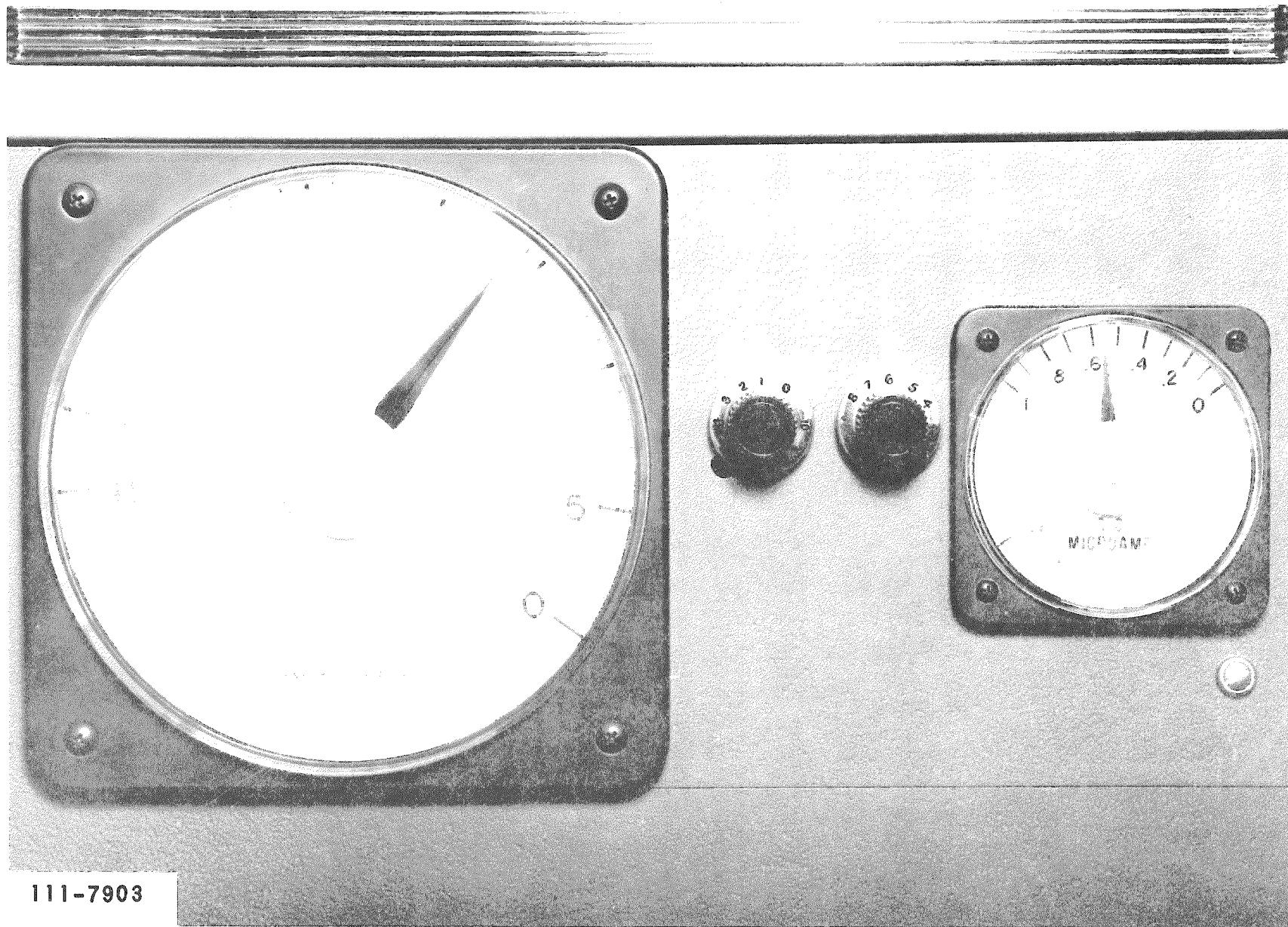
DECADE SWITCH TYPE POSITION INDICATOR PANEL

APPENDIX E

DESTRUCTION TEST OF A MODEL OF THE PRESSURE SHELL

Introduction

Driving the control rods of a nuclear reactor requires that controlled power be transmitted to the inside of the reactor pressure vessel, preferably while maintaining an hermetically sealed system. The transmission of magnetism through the wall of a pressure vessel is one way of doing this. This is the basis of the magnetic jack control rod drive, the pressure shell of which is the subject of this report. On page 12 are a drawing and specifications of this high-pressure magnetic jack. The test vessel is a short, but otherwise identical, model of the actual vessel. The drawings of these are on page 145.

This pressure vessel is unique in that it requires magnetic ring sections separated by narrow nonmagnetic sections and also one long nonmagnetic section. Moderate corrosion and heat resistance is another requirement For the $3\frac{1}{2}$ in. ID tube a wall thickness equal to about one eighth of the inside diameter is desirable from the standpoint of magnet design. This is also a good compromise between having low stresses and a coil of small diameter. A coil of small diameter is desirable for its low electrical resistance and for keeping down the size of the magnetic jack. The $1\frac{9}{16}$ in. ID tube is made extra heavy so that it will not break under pressure if the end of the long pipe happens to be bumped. The long nonmagnetic section is made of $1\frac{1}{2}$-in. schedule 40 pipe for economical reasons. In special cases the bore could be $1\frac{9}{16}$ in. in diameter to reduce the stresses.

The pressure shell is made in two pieces which are assembled after final machining. The small-diameter piece (extension) is inserted through the larger piece (body) so that the pressure load is taken on the back of extension flange and the inside of the body head. A small fillet weld seals the joint. Making the vessel in two parts is done to facilitate boring the small tube and also to help allow for axial shrinkage due to welding. Each large weld shrinks about $\frac{1}{16}$ in. axially and the small welds shrink about $\frac{3}{64}$ in.

The parts to be welded together are provided with a back-up ring integral with one of the mating parts and a small area for butting the parts together. This preparation gives a joint which is straight and concentric. The other welds, the only purpose of which is to provide the nonmagnetic sections, are made in grooves cut in the rough-machined tubes.

Inco-weld "A" was selected for the weld metal. Stainless steel, AISI type 430, was selected for the base metal (magnetic sections). Inconel was selected for the long nonmagnetic section. These materials have about the same thermal expansion.

The vessel is welded with a relatively new weld rod material in a geometry which cannot be calculated readily; however, the gasket and flange designs incorporate other experiences at ANL.[3] Therefore this test was performed to check the material and design as required by the ASME Boiler and Pressure vessel Code Par. UG101 of section VIII.

Test Apparatus

The test was made at the Steel City Testing and Engineering Laboratories, since Argonne does not have facilities for the high pressures involved. The large end of the vessel was closed off with a blind flange (see page 146). The other end of the vessel was connected to a high-pressure hose. For the first test the hose was connected to a hand pump. For the other two tests an air-driven, reciprocating water pump was used.

Test Data

The test vessel was the same for all three tests except that after the second test the flange end of the tube was cut off and a new thicker flange was welded on the tube.

The test data are described on pages 130 through 135, which are reprints of the test reports from the Steel City Test Lab.

Test Results

Test Number	1	2	3
Pressure, psi.	11,300	12,650	12,800
Result	$1\frac{1}{2}$-in. pipe section began to yield	flanged end of large tube section (as originally designed) failed	large tube section failed (flange cracked due to failure of tube section)
Page no. of photo	126	126 thru 131	132, 133
Diameters: large tube before large tube after	4.39	4.41	4.41 ruptured
middle tube before middle tube after	2.21 2.21	2.21 2.21	2.21 2.21*
$1\frac{1}{2}$-in. pipe before $1\frac{1}{2}$-in. pipe after	1.90 2.06	2.06 2.10	2.10 2.12

*2.22 near joint with pipe

[3]N. Balai, T. L. Kettles, and R. E. Bailey, Reactor Pressure Vessel Design for Nuclear Applications, Symposium on Radiation Effects on Materials, Vol. 3, Special Technical Publication, No. 233, ASTM (1958)

The test shows that the large tube section is the weakest part of the vessel. This is good, since the tube thickness is the part which is least convenient to make heavier. The middle tube showed no yielding. The pipe came with a smooth finish and an extra thick wall (0.150 in.). Perhaps a pipe of standard quality would have failed.

Apparently the 430 SST steel bar which was used for the large tube was of low quality, since the test showed an ultimate stress of 59,000 psi. The ultimate stress should be about 75,000 psi.

The flexitallic gasket (2500 psi standard) was slightly deformed where the flange split, but showed no sign of failure or leakage. This indicates that the gasket and the bolting are adequate.

None of the welds failed and the appearance of the crack in the vessel indicates that the weld is quite ductile.

Conclusions

The test indicates that the vessel has a design pressure of 3200 psi at room temperature. Calculations indicate a code design pressure of 2800 psi at 100 F (radiographed welds of 90% efficiency).

Two changes in the design resulted from the test: the flanged end of the vessel was made thicker and the pipe plug hole at the other end was changed from $\frac{1}{2}$ to $\frac{3}{8}$ in.

CALCULATED STRESSES

		$3\frac{1}{2}$ in. ID 430 SST		$1\frac{9}{16}$ in. ID 430 SST		$1\frac{1}{2}$ in. Schedule 40 pipe. inconel			
P	pressure, psi	2500	12800	2500	12800	2500	2500	11300	12800
t	minimum wall as specified, in.	0.420		0.300		0.127			
	minimum wall as measured, in.		0.440		0.325		0.150	0.150	0.123
R	inside radius, in.	1.75	1.76	0.78	0.78	0.83	0.80	0.80	0.926
S	stress = P(R+0.6t)/t, psi	11900	59000 ultimate	8000	38400	21800	14800	67000 yield	104000

		flange used for tests no. 1 and 2	flange used for test no. 3 (final design)
P	pressure, psi	2500	2500
	actual flange thickness, in.	$2\frac{1}{8}$	$2\frac{5}{8}$
t	thickness used in calculating to allow for centerbore, in.	2	$2\frac{1}{2}$
S_H	logitudinal hub stress, psi	9000	6750
S_R	radial flange stress, psi	2730	1670
S_T	tangential flange stress, psi	9520	5990

Laboratory Reports

CHEMICAL   PHYSICAL   METALLURGICAL   SPECTROGRAPHIC   PYROMETRICAL

Steel City Testing & Engineering
Laboratories

- 440616

13055 Brainard Avenue
Chicago 33, Illinois

TECHNICAL REPORT FOR. Argonne National Laboratory
Lemont, Illinois

FILE NO. 591 21 139
ORDER NO.

TEST #1

6 February 1959

SUBJECT: Pipe Assembly

INVESTIGATION Hydraulic pressure test on capped pipe assembly.

FOREWORD:

A three diameter welded pipe assembly was capped at the large end by the use of a gasket and two bolted flanges. The small end of the assembly was made with a pipe thread and thru this connection the assembly was connected to a hydraulic pump. The assembly was then pressurized until failure occurred.

TEST PROCEDURE:

The eight 1 1/4 - 8N studs and nuts were thoroughly cleaned and greased. The gasket surfaces were cleaned and the test unit assembled. The nuts were systematically torqued to 550 pound feet. The assembly was then filled with water and connected to a high pressure pumping system. The pressure was slowly increased

TECHNICAL REPORT (CONTINUED)
TEST #1

FOR: Argonne National Laboratory

and observed to determine the first point of failure.

RESULTS OF TEST:

The smallest diameter section of the pipe assembly began to yield and increase in size at 11,300 psig. The pressure was relieved and the extent of damage was examined. Mr. M. T. Burns requested that the pressure be re-applied to the test unit. With the second application of pressure the yield pressure was raised to 12,000 psig and maintained for a short period of time to increase the extent of damage. At this point the test was concluded.

EFF/ac

Respectfully submitted,
STEEL CITY TESTING & ENGINEERING LABORATORIES, INC.

Registered Professional Engineer

Steel City Testing & Engineering Laboratories

13055 Brainard Avenue
Chicago 33, Illinois

TECHNICAL REPORT FOR: Argonne National Laboratories
Lemont, Illinois

FILE NO.   593 10 484
ORDER NO. 274639

TEST #2

16 March 1959

SUBJECT: Pipe Assembly
INVESTIGATION   Hydraulic Pressure test on capped pipe assembly.

FOREWORD:

A three diameter welded pipe assembly was capped on the large end by the use of a Flexitallic gasket and two bolted flanges. The small end of the assembly was made with a half inch pipe thread and through this connection the assembly was connected to a hydraulic pump. The assembly was then pressurized until failure occurred.

This unit was previously tested on our file number 591 21 139. At this time the unit was considered to have failed by Mr. M. T. Burns of Argonne National Laboratory and the test was concluded. This same unit as assembled in this previous test was retested and the hydraulic pressure applied until an actual metal failure occurred.

TECHNICAL REPORT (CONTINUED)
TEST #2

FOR: Argonne National Laboratories

TEST PROCEDURE:

The assembly was filled with water and then connected to a high pressure pumping system. The pressure was slowly increased until failure occurred.

RESULTS OF TESTS:

The small diameter section of the pipe assembly continued to yield as pressure was applied. This yielding caused the half inch pipe connection to leak. The pressure was then relieved and the pipe joint tightened. This operation was repeated twice before the conclusion of the test.

At 12,650 psig, the heavy flanged collar on the largest of the three pipe sections cracked in several places, causing the Flexitallic gasket to blow out with the loss of all pressure and charging fluid. Figure Nos. 1, 2, 3, 4, 5 and 6 depicts the failed section after disassembly.

Mr. Joseph Young from Argonne National Laboratories, witnessed the test. Mr. Young returned the test unit to Argonne National Laboratories at the completion of the test.

MNP/jw

Respectfully submitted,
STEEL CITY TESTING & ENGINEERING LABORATORIES, IN

by _____

Registered Professional Engineer

Steel City Testing & Engineering
Laboratories

13055 Brainard Avenue
Chicago 33, Illinois

TECHNICAL REPORT FOR: Argonne National Laboratories
Lemont
Illinois

FILE NO.   594 28 871
ORDER NO.   443378

TEST #3

29 April 1959

SUBJECT: Pipe Assembly

INVESTIGATION   Hydraulic Pressure test on capped pipe assembly.

FOREWORD:

A three diameter welded pipe assembly was capped on the large end by the use of a Flexitallic gasket and two bolted flanges. The small end of the assembly was made with a half inch pipe thread and through this connection the assembly was connected to a hydraulic pump. The assembly was then pressurized until failure occurred.

TECHNICAL REPORT (CONTINUED)
TEST #3

FOR: Argonne National Laboratories

TEST PROCEDURE:

The assembly was filled with water and then connected to a high pressure pumping system. The pressure was slowly increased until failure occurred.

RESULTS OF TESTS:

copied from previous report by mistake. J.N.Y.

At 12,800 psig, the heavy flanged collar on the largest of the three pipe sections cracked in several places, causing the Flexitallic gasket to blow out with the loss of all pressure and charging fluid. Figure No. 1 depicts the failed section before disassembly. Figure No. 2 and 3 depicts the failed section after disassembly.

Mr. Joseph Young from Argonne National Laboratories, witnessed the test. The test specimen was packaged and returned to Argonne National Laboratories, Lemont, Illinois.

MNP/jw

Respectfully submitted,
STEEL CITY TESTING & ENGINEERING LABORATORIES, INC.

by _____
Registered Professional Engineer

TECHNICAL REPORT (CONTINUED)

TEST #2

FOR: Argonne National Laboratories
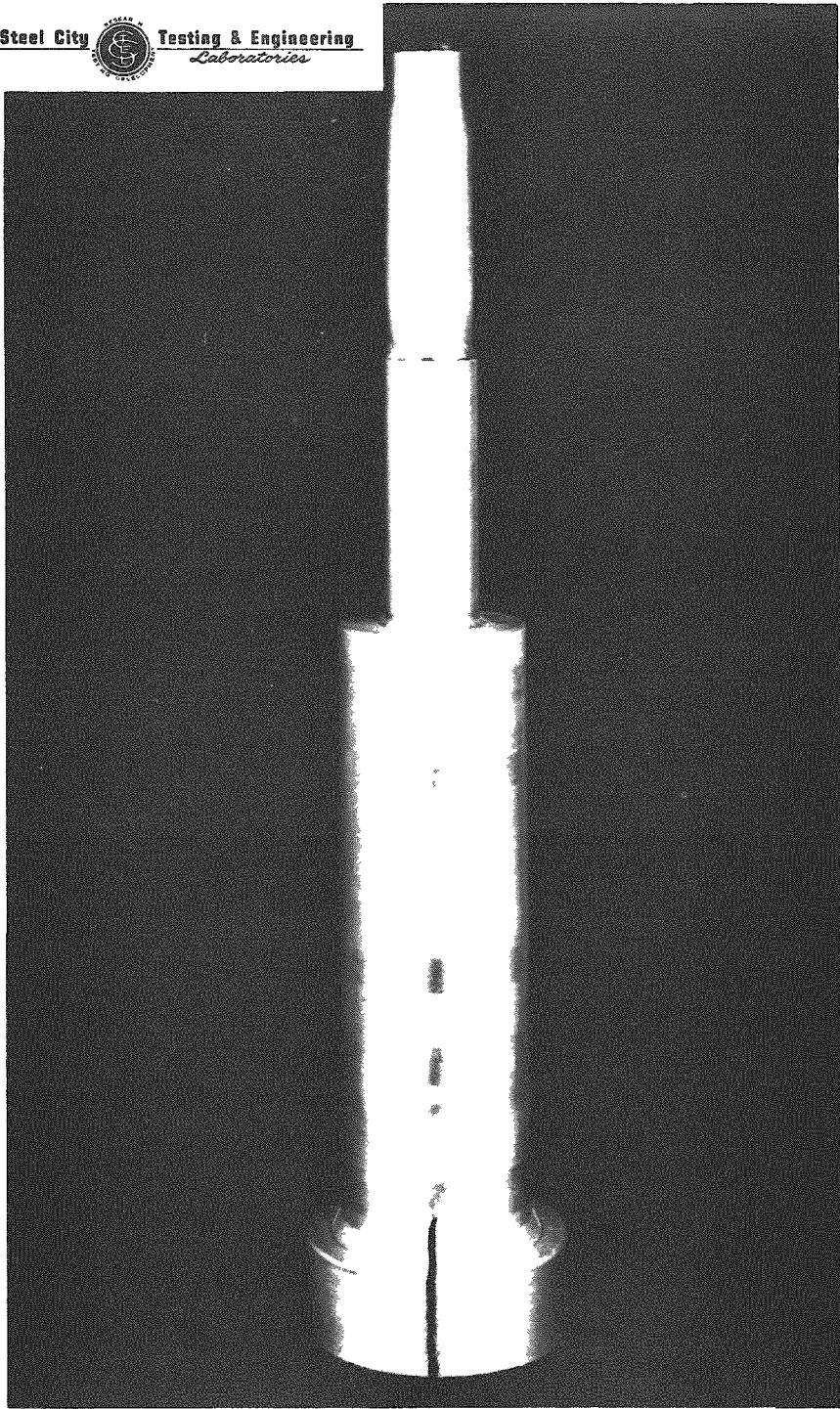
Figure No. 1

Large crack at flanged end. Note deformation of material on smallest diameter pipe section.

TEST #2

FOR: Argonne National Laboratories
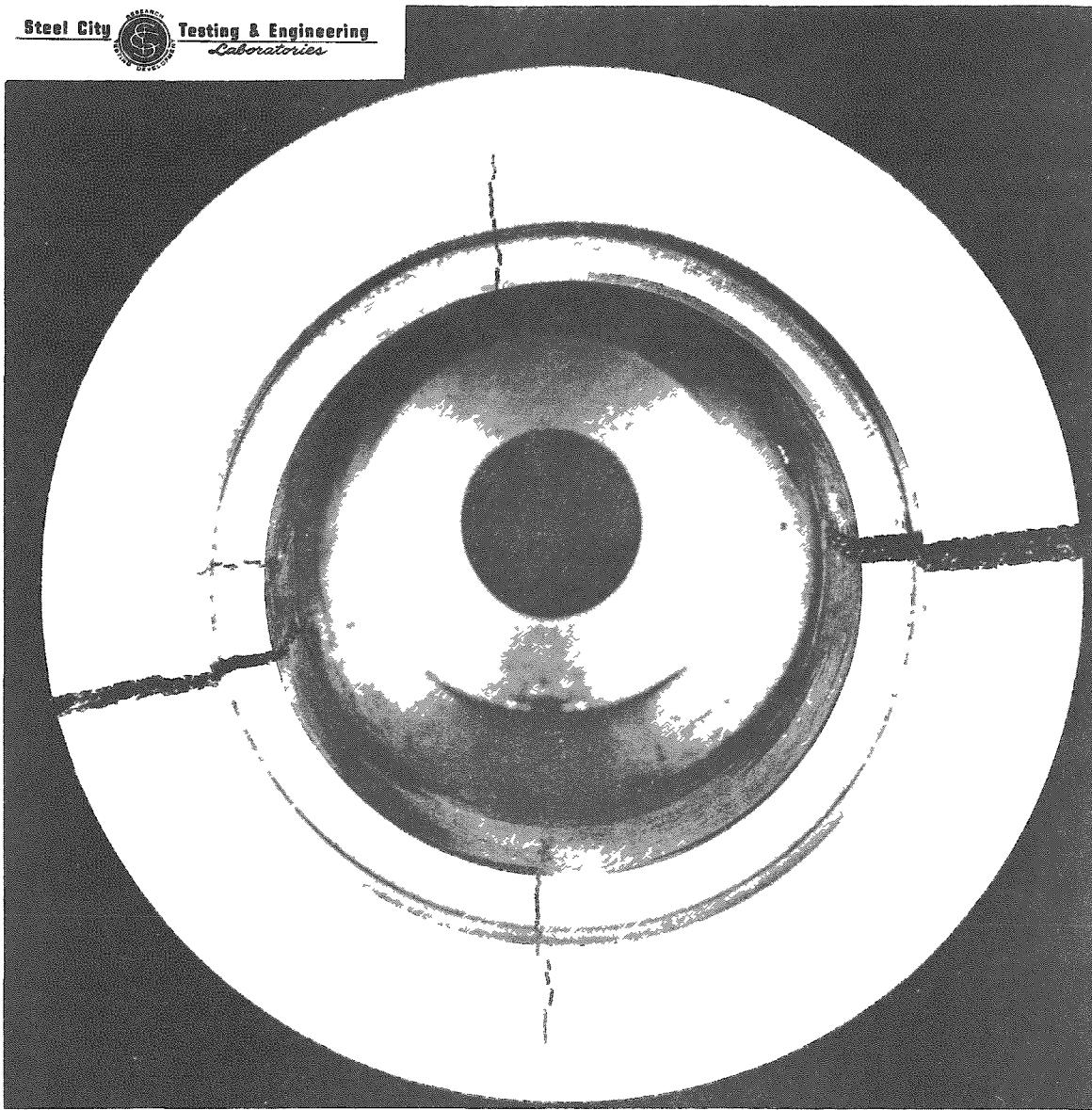
LOCATION
OF FAILURE
IN TEST #3

Figure No. 2

End view of failure

TECHNICAL REPORT (CONTINUED)

TEST #2

FOR: Argonne National Laboratories
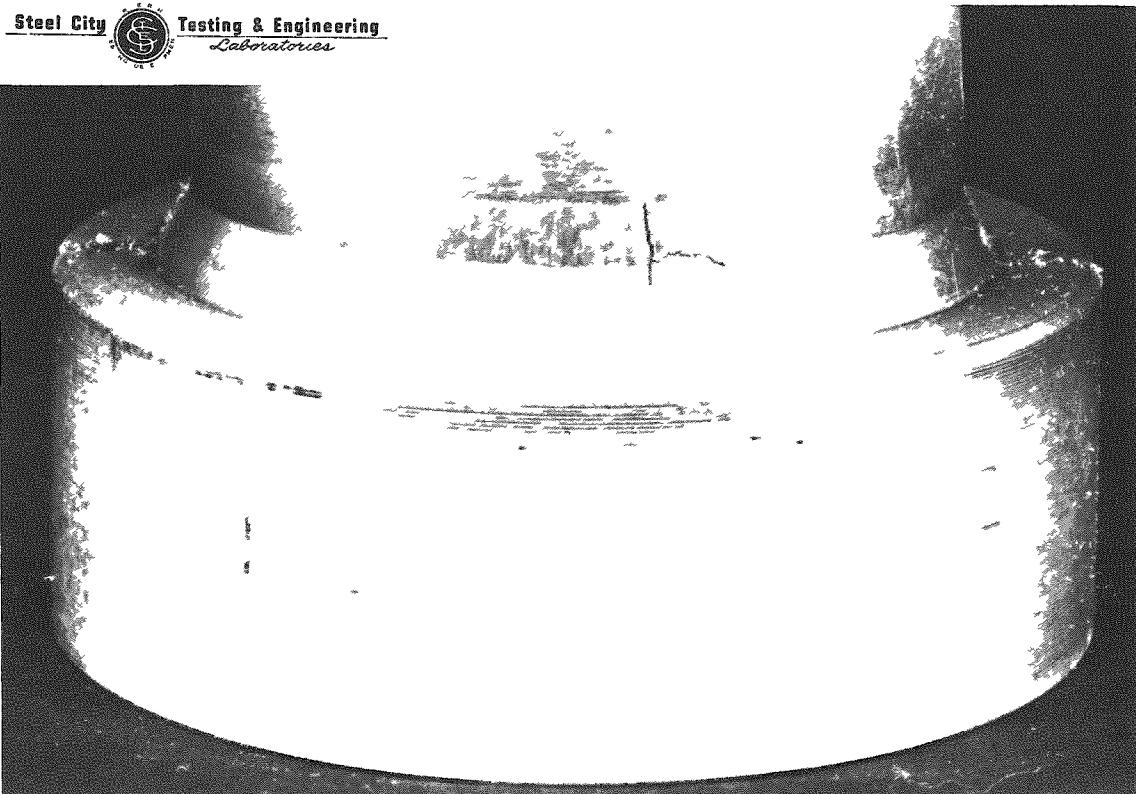
Figure No. 3

Side view of failure
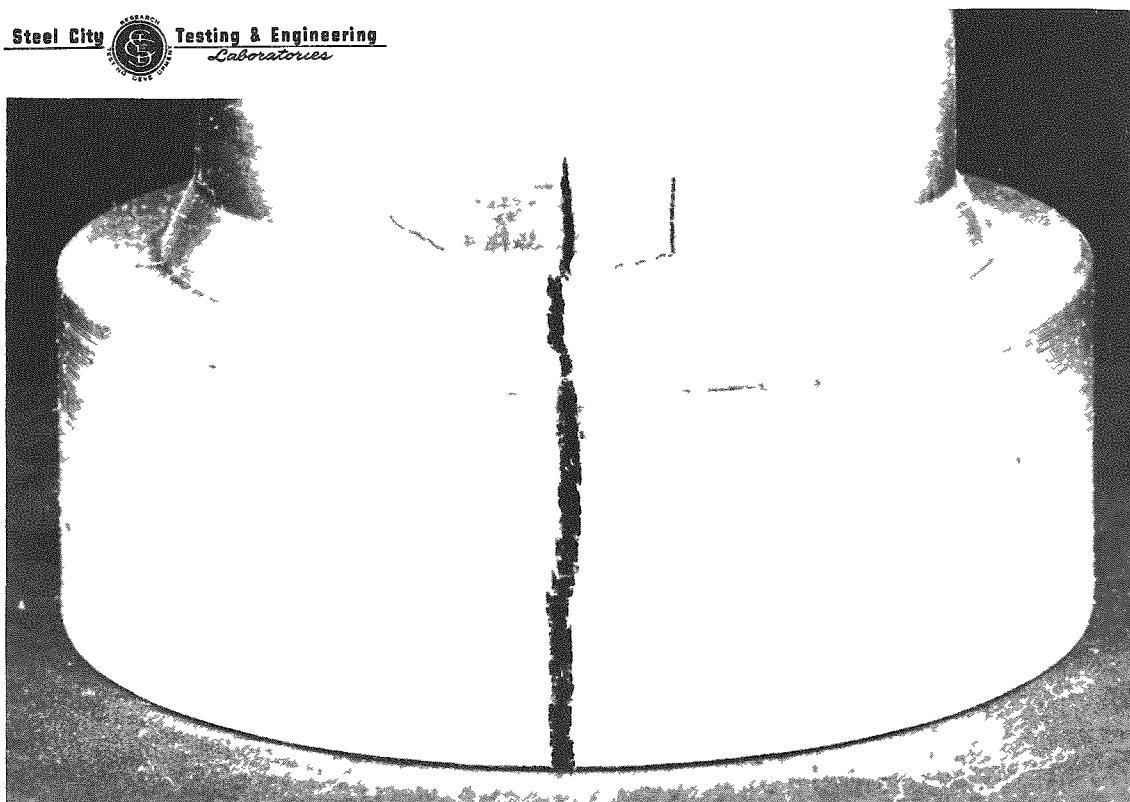
TEST #2

FOR: Argonne National Laboratories

Figure No. 4

Side veiw of failure

TECHNICAL REPORT (CONTINUED)
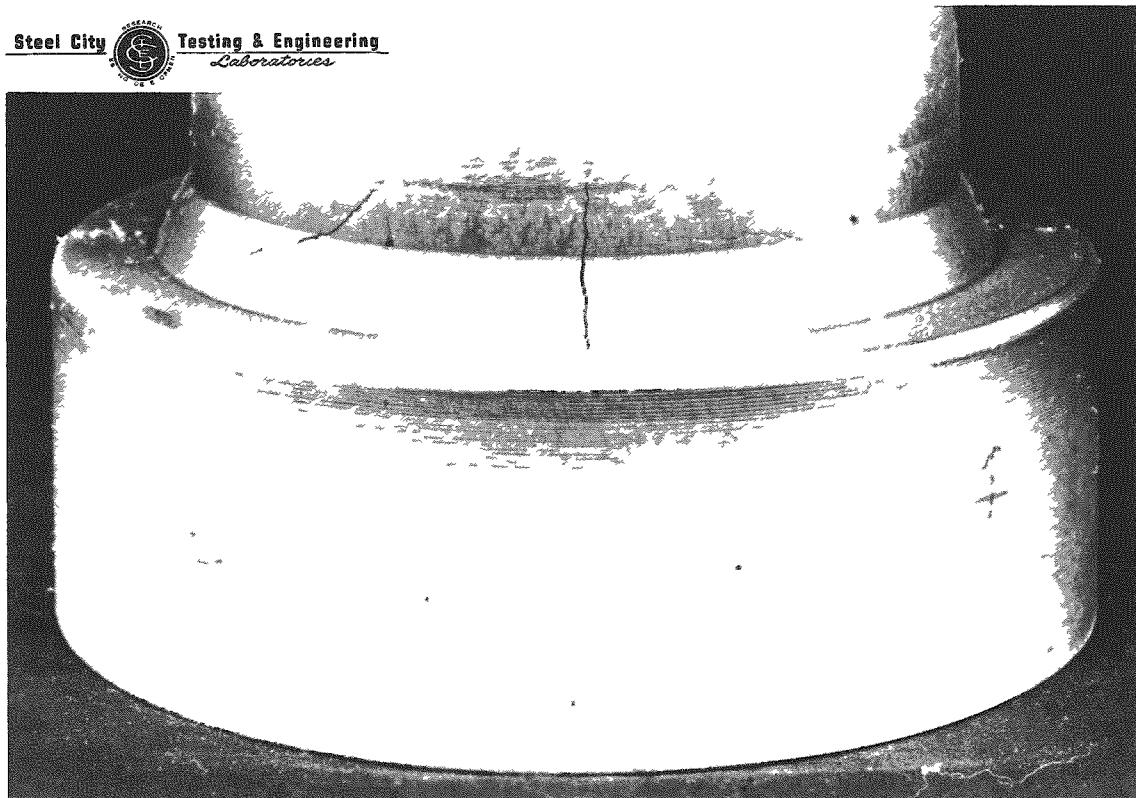
TEST #2

FOR: Argonne National Laboratories

Figure No. 5

Side view of failure

TEST #2

FOR: Argonne National Laboratories
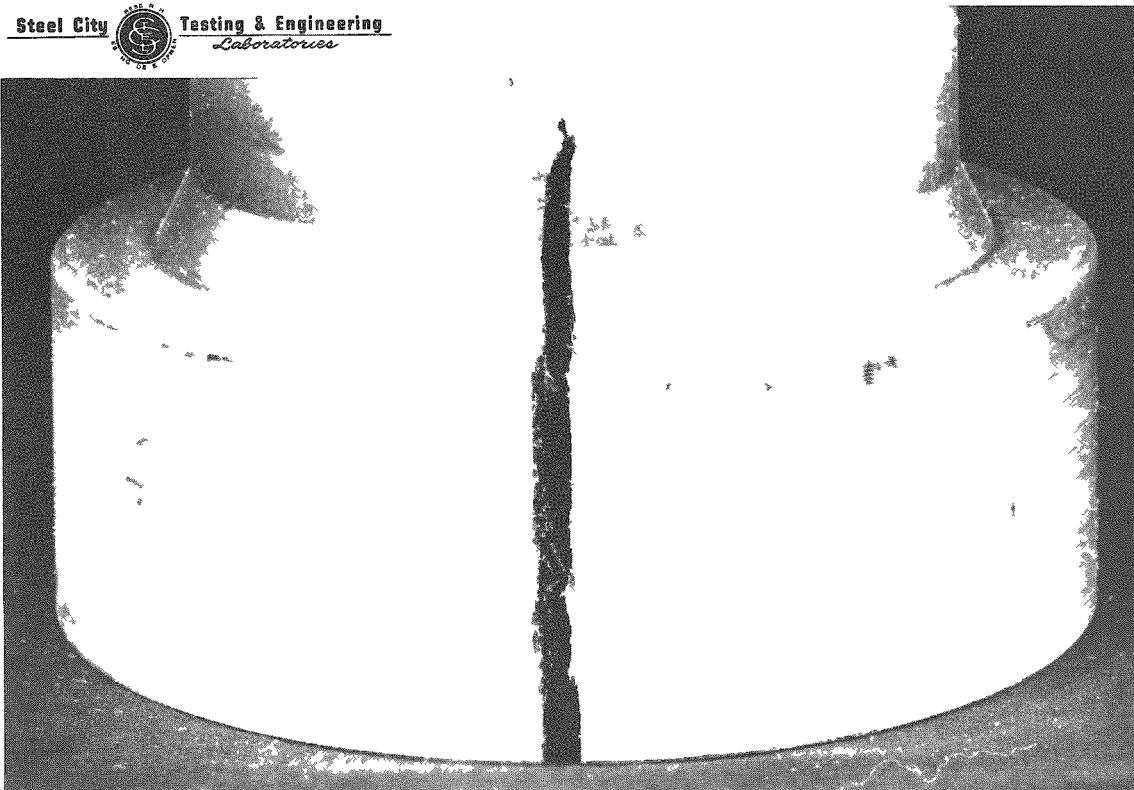
Figure No. 6

Side view of failure

TECHNICAL REPORT
TEST #3

For: Argonne National Laboratory

Steel City Testing & Engineering
Laboratories
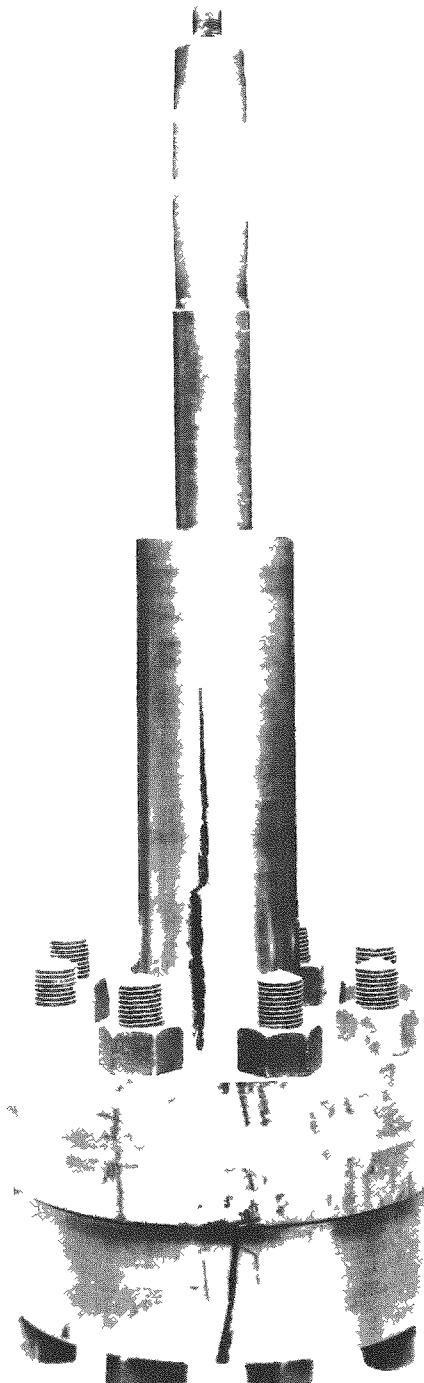
Figure No. 1

Side View

TEST #5   TECHNICAL REPORT

For: Argonne National Laboratory

Steel City (S) Testing & Engineering
Laboratories
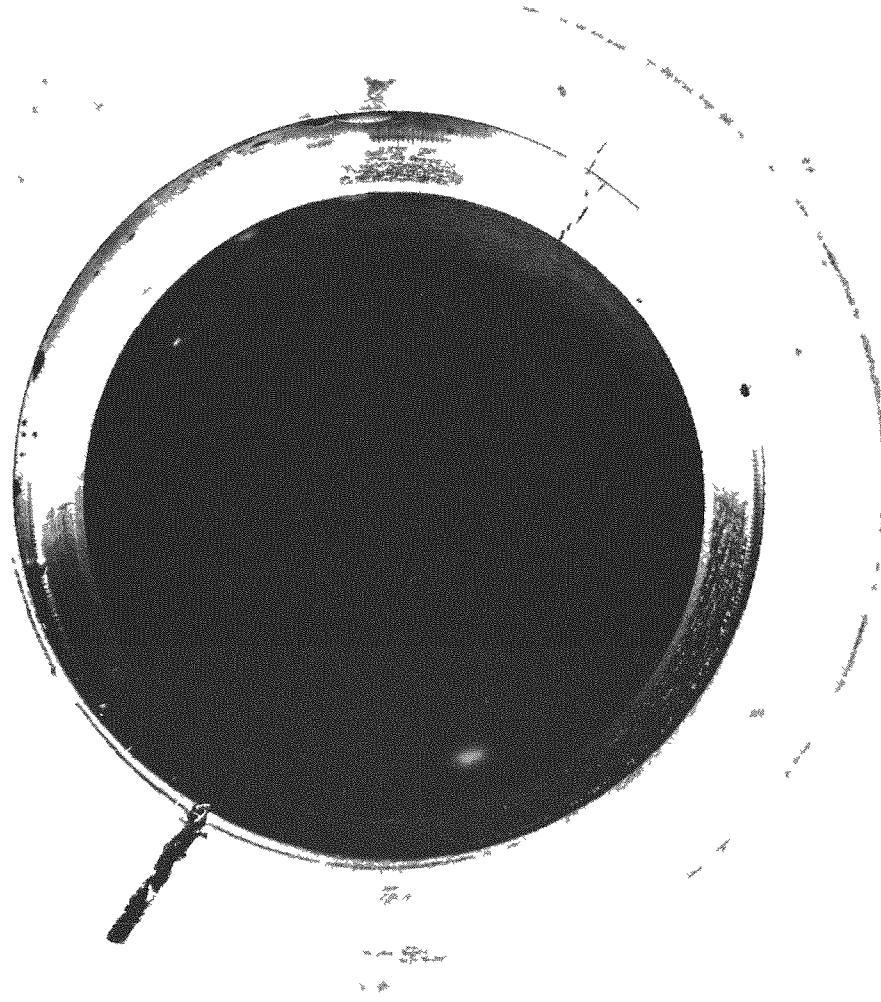
Figure No. 2

Bottom View - Disassembled

TECHNICAL REPORT
TEST #3

For: Argonne National Laboratory

Steel City Testing & Engineering Laboratories
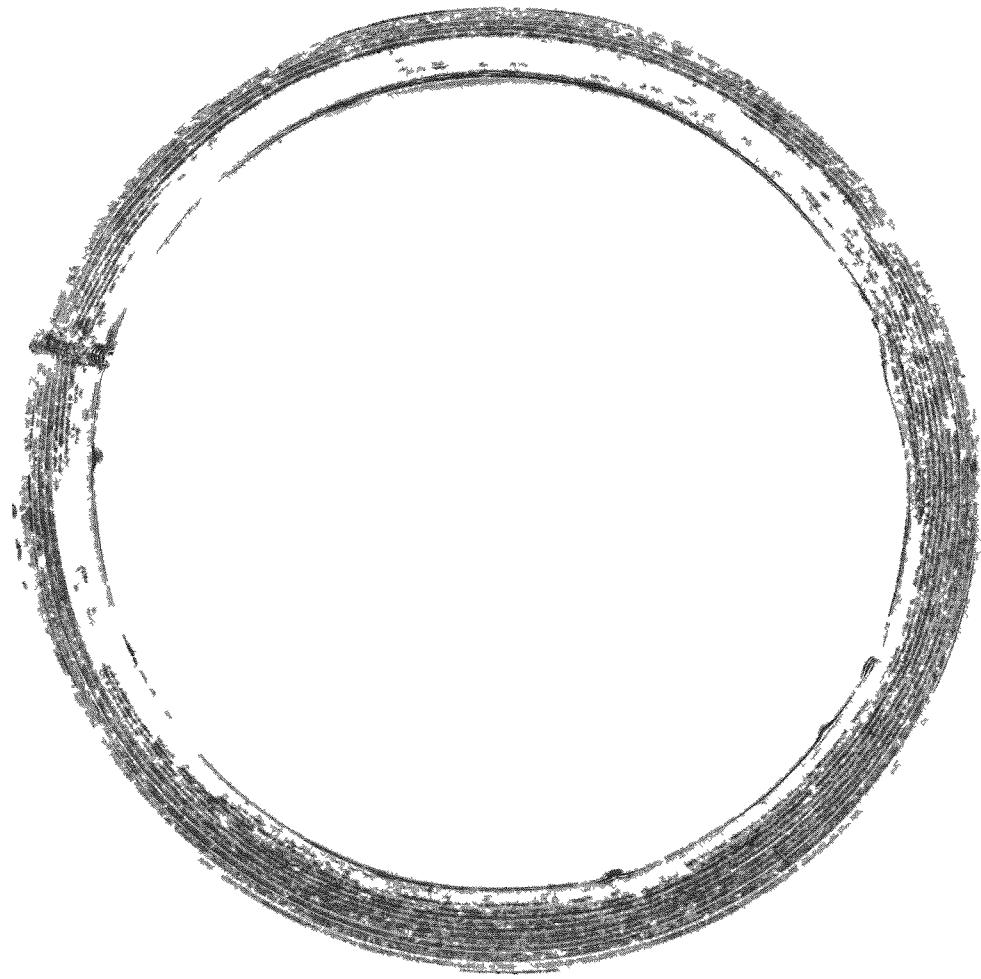
Figure No. 3

Flange and Gasket - Disassembled

Ⓐ 1. PRE-HEAT 300° TO 350°F
2. HELIARC WELD FIRST PASS 3/32 DIA INCO-WELD A
3. ARC WELD OTHER PASSES WITH 1/8 DIA INCO-WELD "A"

½" PIPE TAP

1½" PIPE TAP

⅜" PIPE TAP

1 ⅜

75°/M Ⓐ

1½" SC 40 PIPE
INCONEL
(OTHER PARTS ARE
430 SST)

78 ⅜

75° Ⓐ

1.560 / 1.565 I D

2.212 / 2.207 O D

2.375 / 2.380 D

6

6

1 ¾
1 ¼
3 ⅛

2 11/16

1 11/16 D.

3.495 / 3.505 I.D

31 ½

127 ¼

4.391 / 4.385 O D

29 7/16

16 1/16

17 7/8

32 7/16

7 WELDS

75°/M Ⓐ

7 WELDS

75°/M Ⓐ

18 WELDS

75°/M Ⓐ

3/16 R

6 11/16
1 ⅝

⅜

26°

3 ½

2 ⅛

2 ⅝

.745 / .755

4 ⅛ D.
4 1/16 D.
6" D

MODEL USED IN
TEST *1 & *2

MODEL USED IN
TEST *3

ACTUAL VESSEL
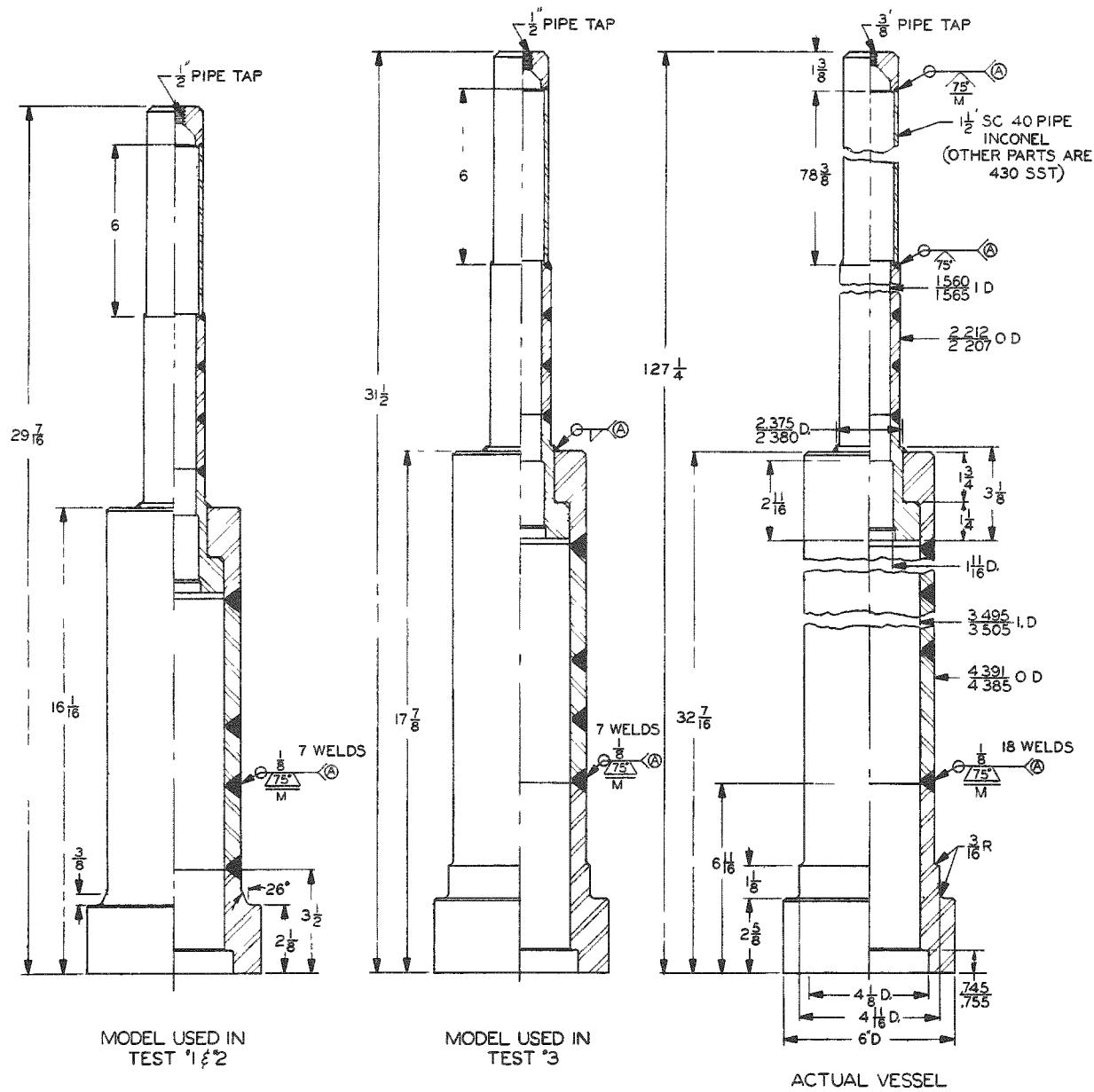
DETAIL NO	NAME	MATERIAL	NO REQ
1.	NUT	1-¼-8 STEEL	16
2	STUB	1-¼-8x11" B-14 STEEL	8
3	GASKET	FLEXITALLIC"R3-25K, 304SST AND ASBESTOS	1
4	FLANGE RING	LOW CARBON STEEL	1
5	BLIND FLANGE	LOW CARBON STEEL	1
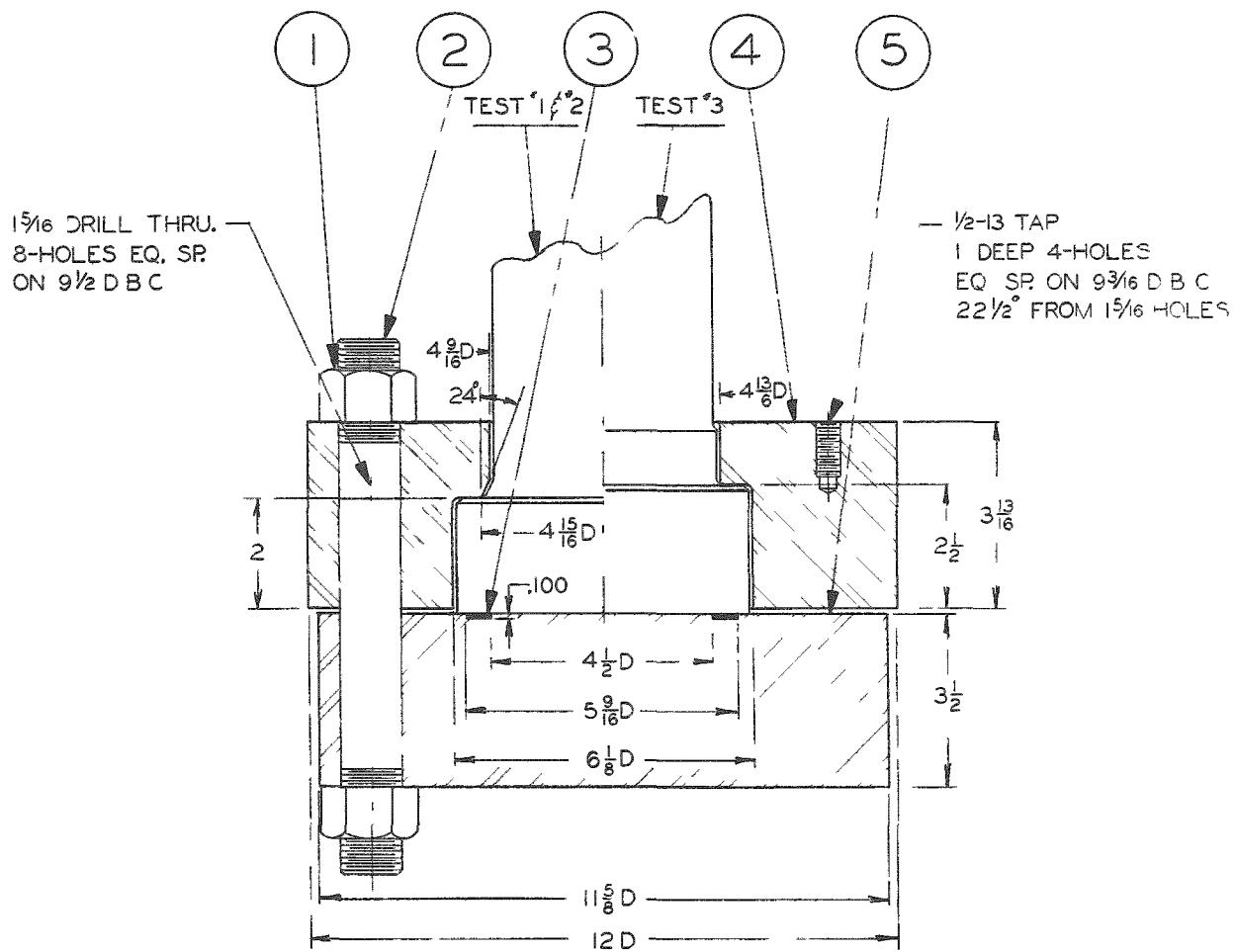
TEST MODEL FLANGE ASSEMBLY

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*ANL-5768; note that the parts list on page 35 of ANL-5768 should be on page 50, and vice versa.

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