ARGONNE NATIONAL LABORATORY
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ADVANCED DESIGNS OF MAGNETIC JACK-TYPE
CONTROL ROD DRIVE

by

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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.


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

<table>
<thead>
<tr>
<th>AEC No.</th>
<th>Price</th>
<th>ANL No.</th>
<th>Description</th>
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<tbody>
<tr>
<td>CAPE-34-21</td>
<td>$2.48</td>
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<td>control rod</td>
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<tr>
<td>CAPE-34-22</td>
<td>0.32</td>
<td>RE-1-17892-B</td>
<td>connection</td>
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<tr>
<td>CAPE-34-23</td>
<td>0.32</td>
<td>RE-1-17893-B</td>
<td>(round rod, small diameter type)</td>
</tr>
<tr>
<td>CAPE-34-25</td>
<td>0.16</td>
<td>RE-1-17895-A</td>
<td>March, 1956</td>
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<tr>
<td>CAPE-34-26</td>
<td>0.16</td>
<td>RE-1-17897-A</td>
<td></td>
</tr>
<tr>
<td>CAPE-34-28</td>
<td>0.16</td>
<td>RE-6-19155-A</td>
<td></td>
</tr>
<tr>
<td>CAPE-34-30</td>
<td>0.32</td>
<td>RE-1-19093-B</td>
<td>control and power supply,</td>
</tr>
<tr>
<td>CAPE-34-31</td>
<td>0.32</td>
<td>RE-1-19096-B</td>
<td>(relay type)</td>
</tr>
<tr>
<td>CAPE-34-32</td>
<td>0.16</td>
<td>RE-6-19125-A</td>
<td>Oct. 1956</td>
</tr>
<tr>
<td>CAPE-34-33</td>
<td>0.16</td>
<td>RE-1-19126-A</td>
<td></td>
</tr>
<tr>
<td>CAPE-34-34</td>
<td>0.16</td>
<td>RE-6-19127-A</td>
<td></td>
</tr>
<tr>
<td>CAPE-34-35</td>
<td>0.16</td>
<td>RE-7-17995-A</td>
<td></td>
</tr>
</tbody>
</table>
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 scrambling 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):

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coils (unpotted)</td>
<td>$180</td>
</tr>
<tr>
<td>Coil shells</td>
<td>1000</td>
</tr>
<tr>
<td>Coil assembly and potting</td>
<td>320</td>
</tr>
<tr>
<td>Coils</td>
<td>$1500</td>
</tr>
<tr>
<td>Parts from Rock Island</td>
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<tr>
<td>Miscellaneous parts and assembly</td>
<td>460</td>
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<td>Mechanical parts</td>
<td>3000</td>
</tr>
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<td>Jack</td>
<td>$4500</td>
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<tr>
<td>Commutator switch</td>
<td>129</td>
</tr>
<tr>
<td>Switch motor</td>
<td>21</td>
</tr>
<tr>
<td>Rectifiers</td>
<td>74</td>
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<tr>
<td>Assembly and miscellaneous parts</td>
<td>276</td>
</tr>
<tr>
<td>Power supply</td>
<td>500</td>
</tr>
<tr>
<td>Total</td>
<td>$5000</td>
</tr>
<tr>
<td>Design Pressure (P.S.I.)</td>
<td>100°F</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Maximum Capacity (f=45), LBS.</td>
<td>1120</td>
</tr>
<tr>
<td>Rated Capacity, LBS.</td>
<td>580</td>
</tr>
<tr>
<td>Power for Holding, WATTS</td>
<td>190</td>
</tr>
<tr>
<td>Power for Moving, WATTS</td>
<td>200</td>
</tr>
</tbody>
</table>

Low Pressure
Bottom Drive
Magnetic Jack
(EBWR) (29L)

High Pressure
Top Drive
Magnetic Jack
(29H)
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 180°F.

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...
CONTROL AND POWER SUPPLY
TO JACK

FROM SWITCH

| R1, R3, R4 | SILICON RECTIFIER, 5A., 125 VDC, BRIDGE |
| R2       | SILICON RECTIFIER, 15A., 125 VDC, BRIDGE |

RECTIFIER (SILICON)
BACK AND TOP VIEW
HOURS OF OPERATION

TEST OF EBWR MAGNETIC JACK (29L)
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 $\frac{1}{2}$ 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.

<table>
<thead>
<tr>
<th>Flange</th>
<th>Cooling</th>
<th>Boiling</th>
<th>Pressurized</th>
</tr>
</thead>
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<td></td>
<td></td>
<td>Temperatures, °F</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bottom</td>
<td>Hold Coils (Bottom)</td>
</tr>
<tr>
<td>Thin Flange</td>
<td>Natural</td>
<td>395</td>
<td>380</td>
</tr>
<tr>
<td></td>
<td>Fan</td>
<td>365</td>
<td>305</td>
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<tr>
<td></td>
<td>Water</td>
<td>350</td>
<td>370</td>
</tr>
<tr>
<td></td>
<td>Both</td>
<td>305</td>
<td>290</td>
</tr>
<tr>
<td>Insulating Flange</td>
<td>Natural</td>
<td>390</td>
<td>370</td>
</tr>
<tr>
<td></td>
<td>Fan</td>
<td>330</td>
<td>295</td>
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<tr>
<td></td>
<td>Water</td>
<td>310</td>
<td>360</td>
</tr>
<tr>
<td></td>
<td>Both</td>
<td>245</td>
<td>275</td>
</tr>
</tbody>
</table>

\[2\frac{1}{4}" TAP\]
\[8 HOLES\]
\[EQ, SP. ON\]
\[5\frac{1}{2}" D.B.C.\]
\[\frac{1}{4}" PIPE TAP\]

\[1\frac{1}{2}" DRILL\]
\[8 HOLES\]
\[EQ, SP. ON\]
\[9\frac{1}{4}" D.B.C.\]

\[GASKET SURFACE\]

\[\text{INSULATING FLANGE}\]

\[304 S/S\]

\[\text{JUNE 30, 1959}\]

\[J.N. YOUNG\]
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.
Life

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.

Reliability

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

<table>
<thead>
<tr>
<th>Importance Factor, A</th>
<th>Grooved Rod Type</th>
<th>Smooth Rod Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rating Factor, B</td>
<td>Score, A x B</td>
</tr>
<tr>
<td>Small diameter</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Short length</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Low cost</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Good position indication</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Precise step length</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>More than one step length</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>No slippage</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>No damage from overload</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Wear resistance</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Dirt resistance</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Corrosion resistance</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Score, A x B

Grooved Rod Type: 
4
8
6
12
4
0
12
60

Smooth Rod Type: 
2
4
6
12
4
0
16
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

<table>
<thead>
<tr>
<th></th>
<th>M_{12}</th>
<th>B_{12}</th>
<th>Assn.</th>
<th>I_{12}</th>
<th>H_{12}</th>
<th>E_{12}</th>
<th>I_{12} x L_{12}</th>
<th>J_{12} x L_{12}</th>
<th>B_{12} x A_{12}</th>
<th>A_{12} x L_{12}</th>
<th>J_{12} x A_{12}</th>
<th>B_{12} x A_{12}</th>
<th>L_{12} x A_{12}</th>
<th>E_{12} x A_{12}</th>
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<tbody>
<tr>
<td>L_{55}</td>
<td>A_{55}</td>
<td>E_{55}</td>
<td>A_{55}</td>
<td>I_{55}</td>
<td>H_{55}</td>
<td>E_{55}</td>
<td>J_{55} x A_{55}</td>
<td>J_{55} x L_{55}</td>
<td>A_{55} x L_{55}</td>
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<td>J_{55} x L_{55}</td>
<td>A_{55} x L_{55}</td>
<td>J_{55} x A_{55}</td>
<td></td>
</tr>
</tbody>
</table>

| COIL POWER     |
|----------------|------------|------------|------------|
| n turns        | 1240       | 5.33       |
| i amps         | 180        | 18.8       |
| r ohms         | 100        | 100        |
| e volts        | 533        | 533        |
| x watts        | 954        | 954        |

| PULL CAPACITY  |
|----------------|------------|
| F lbs.         | 72.7       |

MOVE MAGNET
Jack #29H
### Magnet Calculations

<table>
<thead>
<tr>
<th>MJ1</th>
<th>Bj1</th>
<th>Hj1</th>
<th>Lj1</th>
<th>Ej1</th>
<th>Aj1</th>
<th>Ij1</th>
<th>Ls1</th>
<th>As1</th>
<th>Is1</th>
<th>Es1</th>
<th>Mj2</th>
<th>Is2</th>
<th>Es2</th>
<th>As2</th>
<th>Ls2</th>
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### Coil Power

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<tr>
<th>n</th>
<th>iEC/n</th>
<th>r</th>
<th>eixr</th>
<th>Watts</th>
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<tbody>
<tr>
<td>416</td>
<td>.005</td>
<td>6.28</td>
<td>22.5</td>
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<table>
<thead>
<tr>
<th>bsi</th>
<th>N</th>
<th>Nf</th>
<th>Mag. circuits</th>
<th>Coefficient of friction</th>
<th>F</th>
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<tbody>
<tr>
<td>40.0</td>
<td>8</td>
<td>.45</td>
<td>36.05</td>
<td>lbs.</td>
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### Grip Capacity

<table>
<thead>
<tr>
<th>BS1</th>
<th>Is1/As1</th>
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</tr>
</thead>
</table>

### Grip Magnet

Jack # 29 H
### Magnet Calculations

<table>
<thead>
<tr>
<th>Mj1</th>
<th>Bxj1</th>
<th>Hj1</th>
<th>Assume</th>
<th>B-H curve</th>
<th>416 SST</th>
<th>100</th>
<th>320</th>
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<tbody>
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<td>Lj1</td>
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### Hold Capacity

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### Hold Magnet

Jack #29L
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<th>ES8</th>
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### GRIP AND HOLD MAGNETIC CALCULATIONS

**Jack #27**

- **B-H curve**
- **H-J curve**
- **L-J curve**
- **A-J curve**
### COIL POWER

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<th>r</th>
<th>e x i x 8</th>
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<th>HOLD</th>
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### GRIP OR HOLD CAPACITY

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<td>( \frac{B_s^2A_sN_xf}{36.05} )</td>
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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:**

\[ Q = 0.0873 \, K \, C \, D \, (P/B)^{1/2} \text{ for any fluid} \]
\[ Q = 0.4 \, C \, D \, P^{1/2} \text{ for } 100^\circ F \text{ water and } K = 0.87 \]

**leakage formula for small clearances:**

\[ Q = 0.0018 \, C^3 \, D \, P / M \, L \text{ for any fluid} \]
\[ Q = 0.00265 \, C^3 \, D \, P / L \text{ for } 100^\circ F \text{ water} \]

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:

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

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:

\[ J = \text{pipe inside diameter, in.} = 3.826 \]
\[ P_1 = \text{pressure, psi} = F_1 / A = 210 / 10.0 = 21.0 \]
\[ C_1 = \text{radial clearance, mils} = 1000 \times (J - D) = 1000 \times (3.826 - 3.568) = 129 \]
\[ D_1 = \text{clearance mean diameter, in.} = D + (C_1 / 1000) = 3.568 + (129 / 1000) = 3.697 \]
\[ \text{water temperature, } ^\circ F = 100 \]
Q flow, in. \(3/\text{sec} = 0.4 C_1 D_1 (P_1)^{1/2}\)
\[= (0.4)(129)(3.697)(21.0)^{1/2} = 874.4\]
V piston velocity, in./sec = \(Q/A = 874.4/10.0 = 87.4\)
E\(_1\) kinetic energy, in. lb \(= W V^2/2g\)
\[= (234)(87.42)/(2)(12)(32.2) = 2310\]
E\(_2\) potential energy, in. lb = \(F_1 S = (210)(3) = 630\)
E total energy, in. lb = \(E_1 + E_2 = 2310 + 630 = 2940\)

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. = \(F_1 S_1 = (210)(18.75) = 2940\)

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

\(F_2\) average force, lb = \(E/S = 2940/3 = 980\)
R maximum over average force ratio = 1.3
\(F_3\) maximum force, lb = \(R F_2 = (1.3)(980) = 1270\)
\(F_4\) initial force, lb = \(F_2 = 980\)

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

\(P_2\) pressure, psi = \(F_4/A = 980/10.0 = 98\)
\(D_2\) clearance mean diameter (estimated), in. = 3.6
\(C_2\) radial clearance (first try), mils
\[= Q/0.4 D_2 (P_2)^{1/2} = 874.4/(0.4)(3.6)(98)^{1/2} = 61.3\]
\(D_3\) clearance mean diameter, in.
\[= D + (C_2/1000) = 3.568 + (61.3/1000) = 3.629\]
\(C_3\) initial radial clearance, mils
\[= Q/0.4 D_3 (P_2)^{1/2} = 874.4/(0.4)(3.629)(98)^{1/2} = 60.8\]

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. = \(D + (C_4/1000)\)
\[= 3.568 + (10/1000) = 3.578\]
\(Q_2\) flow, in. \(3/\text{sec}\) (orifice formula)
\[= 0.4 C_4 D_4 (P_1)^{1/2} = (0.4)(10)(3.578)(21.0)^{1/2} = 65.5\]
\(L\) effective length of clearance, in.
\[= S - 0.75 L_1 \text{ (approx.)} = 3 - (0.75)(2.75) = 0.94\]
Q₃ flow, in.³/sec (leakage formula) = 0.00265 C₄ D₄ P₁/L = (0.00265)(10³)(3.578)(21.0)/0.94 = 212

Q₄ flow, in.³/sec = smaller of Q₃ and Q₂ = 65.5
V₄ piston velocity, in./sec = Q₄/A = 65.5/10.0 = 6.55

E₄ kinetic energy, in. lb = W V₄²/2 g = (234)(6.55²)/(2)(12)(32.2) = 13.0

amount of compression of the parts to give a striking force equal to F₃, in. = 2 E₄/F₃ = (2)(13.0)/1270 = 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. = E₄/W = 13.0/234 = 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.

<table>
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<th>try</th>
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<th>1st increment end</th>
<th>2nd increment end</th>
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<td>E_G</td>
<td>energy gained, in lb = F₁ S - 210 S</td>
<td>52.5</td>
<td>52.5</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>total energy, in lb = E₁ + E_G</td>
<td>2362.5</td>
<td>2160</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>initial flow, in.²/sec = (Q_f from previous column)</td>
<td>874.4</td>
<td>834</td>
<td></td>
</tr>
<tr>
<td>F_A</td>
<td>estimated average force, lb</td>
<td>1000</td>
<td>1020</td>
<td>1070</td>
</tr>
<tr>
<td>E_L</td>
<td>energy lost, in lb = F_A S</td>
<td>250</td>
<td>255</td>
<td>267.5</td>
</tr>
<tr>
<td>E_f</td>
<td>final energy, in lb = E - E_L</td>
<td>2112.5</td>
<td>2107.5</td>
<td>1892.5</td>
</tr>
<tr>
<td>V_f</td>
<td>final velocity in./sec = (2 g E_f/W)²</td>
<td>83.5</td>
<td>83.4</td>
<td>79.1</td>
</tr>
<tr>
<td>Q_f</td>
<td>final flow, in.²/sec = A V_f = (10.0) V_f</td>
<td>835</td>
<td>834</td>
<td>791</td>
</tr>
<tr>
<td>Q_A</td>
<td>average flow, in.²/sec = (Q + Q_f) / 2</td>
<td>854.7</td>
<td>854.2</td>
<td>812.5</td>
</tr>
<tr>
<td>P_A</td>
<td>average pressure, ps = (Q A/0.4 K C_A D_A)² = (Q_A 0.4 C_A D_A)²</td>
<td>102</td>
<td>102</td>
<td>108.8</td>
</tr>
<tr>
<td>F_A</td>
<td>average force, lb = A P_A + 10.0 F_A</td>
<td>1020</td>
<td>1020</td>
<td>1088</td>
</tr>
</tbody>
</table>
SAMPLE FORCE CURVE

FORCE

CLEARANCE

DECELERATION FORCE, Pounds

RADIAL CLEARANCE, Mils

BEGINNING

DASH POT TRAVEL, Inches

END
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

<table>
<thead>
<tr>
<th>Device</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counterweight</td>
<td>Complicated mechanism; large space.</td>
</tr>
<tr>
<td>Negator Spring</td>
<td>One break would cause complete failure; large space.</td>
</tr>
<tr>
<td>Hydraulic Cylinder</td>
<td>Depends on unfailing supply of water under pressure.</td>
</tr>
<tr>
<td>Compression Spring</td>
<td>Force varies with position; large space.</td>
</tr>
<tr>
<td>Tension Spring</td>
<td>One break would cause complete failure; large space; force varies with position.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Advantages of Drive at the Bottom of the Reactor</th>
<th>Advantages of Drive at the Top of the Reactor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. lower temperatures</td>
<td>1. less dirt</td>
</tr>
<tr>
<td>2. lower building height</td>
<td>2. less basement depth</td>
</tr>
<tr>
<td>3. control rod parts are in compression and therefore cannot fall apart, thus increasing reactivity</td>
<td>3. if the end of the drive blows off, the control rod will not be forced down by pressure, thus increasing reactivity</td>
</tr>
<tr>
<td>4. drive rods are in tension and therefore are less likely to buckle</td>
<td>4. control rod is pulled thru the reactor during scram and therefore is less likely to jam</td>
</tr>
<tr>
<td>5. water dash pot may be used</td>
<td></td>
</tr>
<tr>
<td>6. no special provisions are needed to keep the reactor heat from the drive</td>
<td></td>
</tr>
<tr>
<td>7. no interference at top of reactor</td>
<td></td>
</tr>
</tbody>
</table>
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 scrambling 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 3\(\frac{3}{4}\) in.
- magnetic jack travel = 81 in.
- blow down valve length = 4\(\frac{4}{3}\) in.

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

Control rod assembly net weight (lb):

- fuel and absorber rod = 360
- seven 4\(\frac{1}{2}\) 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 = 25 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 = **1/16** in.
- number of springs = 7

<table>
<thead>
<tr>
<th>mean dia.</th>
<th>wire dia.</th>
<th>max. load</th>
<th>active coils</th>
<th>lb defl., inch</th>
<th>load at 81 in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.562</td>
<td>0.375</td>
<td>135</td>
<td>187</td>
<td>0.34</td>
<td>397</td>
</tr>
<tr>
<td>6.781</td>
<td>0.344</td>
<td>118</td>
<td>203</td>
<td>0.31</td>
<td>380</td>
</tr>
<tr>
<td>6.062</td>
<td>0.312</td>
<td>97</td>
<td>224</td>
<td>0.27</td>
<td>359</td>
</tr>
<tr>
<td>5.406</td>
<td>0.281</td>
<td>81</td>
<td>250</td>
<td>0.22</td>
<td>368</td>
</tr>
<tr>
<td>4.812</td>
<td>0.250</td>
<td>64</td>
<td>280</td>
<td>0.17</td>
<td>376</td>
</tr>
<tr>
<td>4.281</td>
<td>0.219</td>
<td>47</td>
<td>319</td>
<td>0.125</td>
<td>376</td>
</tr>
<tr>
<td>3.812</td>
<td>0.187</td>
<td>34</td>
<td>374</td>
<td>0.082</td>
<td>415</td>
</tr>
</tbody>
</table>

| total force | 576 | 453 |

Net scram force:

- spring force at bottom position = 576
- net weight = -390
- **F** scram force at bottom position = 186 pounds
- spring force at top position = 453
- net weight = -390
- scram force at top position = 63 pounds

Time to scram rod:

- \(a_0\) initial acceleration = \(Fg/W = (186)(32.2)/450\) = 13.3 ft/sec²
- \(s_{0-2}\) 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/sec²
- \(v_2\) terminal velocity = \((2a_{0-2}s_{0-2})^{1/2} = [(2)(6.65)(2)]^{1/2}\) = 5.16 ft/sec
- \(t_{0-2}\) time to reach terminal velocity = \((2s_{0-2}/a_{0-2})^{1/2}\) = \([2](2)/6.65\)¹/² = 0.77 sec
- \(F_2\) scram force at the 2-ft point = 147 lb
- distance to the beginning of slowing down by dash pot = 6 ft
- \(F_6\) scram force at the 6-ft point = 77 lb
\[ v_b \text{ velocity at the 6-ft point} = v_2 \left( \frac{F_b}{F_2} \right)^{1/2} \]
\[ = 5.16 \left( \frac{77}{147} \right)^{1/2} = 3.74 \text{ ft/sec} \]
\[ v_{2-6} \text{ average velocity between 2-ft and 6-ft points} \]
\[ = \frac{(v_2 + v_6)}{2} \text{ (approx.)} = \frac{(5.16 + 3.74)}{2} = 4.45 \text{ ft/sec} \]
\[ t_{2-6} \text{ time to travel from 2-ft point to 6-ft point} \]
\[ = \frac{s_{2-6}}{v_{2-6}} = \frac{4}{4.45} = 0.90 \text{ sec} \]
\[ s_{6-7} \text{ dash pot length} \]
\[ = 0.75 \text{ ft} \]
\[ v_{6-7} \text{ average velocity in dash pot} = \frac{v_6}{2} \text{ (approx.)} \]
\[ = \frac{3.74}{2} = 1.87 \text{ ft/sec} \]
\[ t_{6-7} \text{ time of dash pot travel} = \frac{s_{6-7}}{v_{6-7}} = \frac{0.75}{1.87} = 0.40 \text{ sec} \]
\[ \text{total time} = t_{o-2} + t_{2-6} + t_{6-7} = 0.77 + 0.90 + 0.40 = 2.07 \text{ sec} \]

**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 \( \frac{1}{2} \)-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

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
DERIVED FROM MACHINERY'S HANDBOOK, 11th ED., P. 1660

TYPICAL HEAT DISSIPATION CURVE

HEAT DISSIPATION; WATTS PER SQ.INCH OF SURFACE (AVERAGE FINISH)

TEMPERATURE DIFFERENCE, °F BETWEEN SURFACE AND SURROUNDING AIR (STILL)
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.
<table>
<thead>
<tr>
<th>Specification</th>
<th>100°F</th>
<th>350°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Pressure, P.S.I.</td>
<td>505</td>
<td>490</td>
</tr>
<tr>
<td>Maximum Capacity (f= .45), Lbs.</td>
<td>450</td>
<td>340</td>
</tr>
<tr>
<td>Rated Capacity, Lbs.</td>
<td>150</td>
<td>110</td>
</tr>
<tr>
<td>Power for Holding, Watts</td>
<td>400</td>
<td>270</td>
</tr>
<tr>
<td>Power for Moving, Watts</td>
<td>1720</td>
<td>1150</td>
</tr>
</tbody>
</table>

**SHORT-LENGTH MAGNETIC JACK(#27)**
MAGNETIC JACK #27

SEE DRAWING
RE-1-20471-D

111-7508
NO. REQUIRED: 2
MOVE COIL ASSEMBLY
RE-1-21538-A
**COIL ASSEMBLY NOTES - JACK #27**

A Slip glass cloth sleeving over the long lead wire.

B Silver solder the wire connections with "Easy-Flo."

C Wrap the terminals \( \frac{3}{4} \)" thick with \( \frac{1}{8} \)" 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 follows: 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 immediately. Place filled mold in 200°F furnace for two (2) hours.

**NO. REQUIRED:** 16

**GRIP COIL ASSEMBLY RE-1-21541-B**
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

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

<table>
<thead>
<tr>
<th>1/16 * 45° CHAMFER</th>
</tr>
</thead>
</table>

**NOTES:**
- This side must be flat.
- 3/16 DR Holes

**WRAP COIL:**
1300 turns of #18 double glass-silicone magnet wire. (If single glass-silicone magnet wire is used, put .003" .003" thickness of untreated glass cloth tape between layers of wire.)

**SECTION 2-A**

NO. REQUIRED: 2 MOVE COIL RE-1-24236-B
NO. REQUIRED: 32
TOLERANCES:
  FRACTIONAL ±1/32
  DECIMAL ±.005
MATERIAL: LOW CARBON HOT ROLLED STEEL
COIL SHELL
RE-I-21542-B

NO. REQUIRED: 36
TOLERANCES: ±1/32
MATERIAL: COM. PURE NICKEL TERMINAL POST
RE-I-21540-A

NO. REQUIRED: 16
GRIP COIL
RE-I-24237-B
NO. REQUIRED: 2
TOLERANCES: ±1/32
MATERIAL: LOW CARBON STEEL
FLANGED TUBE
RE-1-20386-B

NO. REQUIRED: 2
TOLERANCES: ±1/32
MATERIAL: LOW CARBON STEEL
FLANGED PLATE
RE-1-23430-B

NO. REQUIRED: 1
TOLERANCES: ±1/32
MATERIAL: LOW CARBON STEEL
COIL CLAMP
RE-1-20387-A
51

**No. Required:** 26  
**Tolerances:** ±1/32  
**Material:** COM.  
**Pure Nickel**  
"S" Connector  
RE-1-22432-A

---

**No. Required:** 2  
**Tolerances:** ±1/32  
**Material:** COM.  
**Pure Nickel**  
"C" Connector  
RE-1-22430-A

---

**No. Required:** 2  
**Tolerances:** ±1/32  
**Material:** COM.  
**Pure Nickel**  
"L" Connector  
RE-1-22431-A
NOTE: MACH ALL SURFACES AFTER WELDING

231/8

RE-1-20391-B

NOTE: MACH ALL SURFACES AFTER WELDING

RE-1-20396-B

NOTE: MACH ALL SURFACES AFTER WELDING

RE-1-20397-B

NOTE: MACH ALL SURFACES AFTER WELDING

RE-1-20398-A
5. REQUIRED 1
TOLERANCES: ± 1/32
SMALL END PLUG
RE-1-20392-B

NO. REQUIRED: 1
TOLERANCES: ± 1/32
MATERIAL: 304 SST
SMALL END PIPE
RE-1-20394-A

NO. REQUIRED: 1
TOLERANCES: ± 1/32
MATERIAL: 405 SST
SMALL END FLANGE
RE-1-20395-B
NO. REQUIRED: 1
HOLDER
RE-1-20399-B

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

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>&quot;L&quot; DIM.</th>
<th>NO. REQ'D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 3/16</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>2 5/16</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1 5/16</td>
<td>1</td>
</tr>
</tbody>
</table>

TOLERANCES: ±1/32
MATERIAL: 405 SST
END
RE-1-20377-B
NO. REQUIRED: 1
ARMATURE
RE-1-20400-B

NO. REQUIRED: 1
WELDMENT
RE-1-20401-B

NO. REQUIRED: 14
TOLERANCES: ± 1/32
MATERIAL: 405 SST
DISC
RE-1-20376-A
NO. REQUIRED: 3
MATERIAL: 304 SST
NON-MAG. SLEEVE
RE-1-20381-A

NO. REQUIRED: 2
MATERIAL: 304 SST
NON-MAG. WASHER
RE-1-20380-A

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

NO. REQUIRED: 2
TOLERANCES: ±1/64
MATERIAL: 405 SST
CUSHION WASHER
RE-1-20378-A
NO. REQUIRED: 1
TOLERANCES:
FRACTIONAL ± 1/64
DECIMAL ± .005
MATERIAL: SST
ARMCO 17-4-PH
DRIVE ROD
RE-1-20177-B

NO. REQUIRED: 1
TOLERANCES:
FRACTIONAL ± 1/64
DECIMAL ± .005
MATERIAL: SST
ARMCO 17-4-PH
P.I. ROD
RE-1-20383-A

NO. REQUIRED: 1
TOLERANCES: ± 1/32
MATERIAL:
MILD STEEL
FLANGE RING
RE-1-20382-B

NO. REQUIRED: 16
TOLERANCES: ± 1/32
MATERIAL:
MILD STEEL
COIL SPACER
RE-1-20388-A
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\(\frac{1}{2}\) 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\(\frac{3}{4}\) 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\(\frac{1}{2}\) 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\(\frac{1}{4}\) 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 \(\frac{1}{2}\) 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\(\frac{3}{4}\) in. OD Belleville springs concave side up on the spacer retainer.

15. Place two 5\(\frac{3}{4}\) 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 \(\frac{1}{6}\) 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 \(\frac{3}{4}\) 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 \( 5\frac{3}{8} \) 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

<table>
<thead>
<tr>
<th>Number Required</th>
<th>Page</th>
<th>Part Name</th>
<th>Drawing Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62</td>
<td>Adapter Flange</td>
<td>RE-1-22615-B</td>
</tr>
<tr>
<td>1</td>
<td>62</td>
<td>Spring Seat Tube</td>
<td>6-B</td>
</tr>
<tr>
<td>1</td>
<td>63</td>
<td>Filler Tube</td>
<td>7-B</td>
</tr>
<tr>
<td>1</td>
<td>63</td>
<td>Lock Tube</td>
<td>8-B</td>
</tr>
<tr>
<td>14</td>
<td>63</td>
<td>5 in. dia Belleville Spring</td>
<td>9-A-Part #1</td>
</tr>
<tr>
<td>102</td>
<td>63</td>
<td>5( \frac{3}{8} ) in. dia Belleville Spring</td>
<td>9-A-Part #2</td>
</tr>
<tr>
<td>1</td>
<td>64</td>
<td>Support Washer</td>
<td>20-A</td>
</tr>
<tr>
<td>2</td>
<td>64</td>
<td>Spacer</td>
<td>1-A</td>
</tr>
<tr>
<td>1</td>
<td>64</td>
<td>Spacer Retainer</td>
<td>2-A</td>
</tr>
<tr>
<td>1</td>
<td>64</td>
<td>Back-up Ring</td>
<td>3-A</td>
</tr>
<tr>
<td>1</td>
<td>65</td>
<td>Outer Tube Assembly</td>
<td>4-B</td>
</tr>
<tr>
<td>1</td>
<td>65</td>
<td>Body</td>
<td>5-B</td>
</tr>
<tr>
<td>1</td>
<td>65</td>
<td>End</td>
<td>6-A</td>
</tr>
<tr>
<td>1</td>
<td>66</td>
<td>Extension Rod Assembly</td>
<td>7-B</td>
</tr>
<tr>
<td>1</td>
<td>66</td>
<td>Drive End</td>
<td>8-A</td>
</tr>
<tr>
<td>1</td>
<td>66</td>
<td>Tube</td>
<td>9-A</td>
</tr>
<tr>
<td>1</td>
<td>66</td>
<td>Rod End</td>
<td>30-B</td>
</tr>
<tr>
<td>1</td>
<td>66</td>
<td>Upper End</td>
<td>RE-1-22769-A</td>
</tr>
<tr>
<td>1</td>
<td>62</td>
<td>Lift Tool</td>
<td>RE-1-24181-B</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Gasket, Flexitallic #R4-4N</td>
<td></td>
</tr>
</tbody>
</table>
MATERIAL:
11 GA. (.049)
MILD STEEL
LIFT TOOL
RE-1-24181-8
(SEE ASSEMBLY
PROCEDURE)

NOTE
INTERNAL DIA.
INTERIOR NOTCH

NOTE:
ADAPTER FLANGE
RE-1-22616-B

NOTE:
SPRING SEAT TUBE
RE-1-22616-B

MATERIAL:
405 SST
ADAPTER FLANGE
RE-1-22616-B

MATERIAL:
304 SST
SPRING SEAT TUBE
RE-1-22616-8

NOTE:
ADAPTER FLANGE
RE-1-22616-B

NOTE:
SPRING SEAT TUBE
RE-1-22616-8

NOTE:
ADAPTER FLANGE
RE-1-22616-B

NOTE:
SPRING SEAT TUBE
RE-1-22616-8

NOTE:
ADAPTER FLANGE
RE-1-22616-B

NOTE:
SPRING SEAT TUBE
RE-1-22616-8
TOL FOR DIAMETERS: ± 1/64
TOL FOR LENGTHS: ± 1/32
TOL DECIMAL: ± .005

NO. REQ'D.: 1
MATERIAL: .304 SST
FILLER TUBE
RE-1-22617-B

TOLERANCES:
FRACTIONAL ± 1/64
DECIMAL ± .005
MATERIAL: 304 SST
LOCK TUBE
RE-1-22618-B

NOTE:
RENAM TO 1/8 Dia
F NECESSARY AFTER
WELDING

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

FRACTIONAL TOL = \( \frac{1}{32} \)

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

FRACTIONAL TOL = \( \frac{1}{32} \)

NO. REQ'D.: 1
TOLERANCES: ± \( \frac{1}{64} \)
MATERIAL: 304 SST
SPACER RETAINER
RE-1-22622-A

TOLERANCES:
FRACTIONAL ± \( \frac{1}{32} \)
DECIMAL ± .005
MATERIAL: 304 SST
BACK-UP RING
RE-1-22623-A
NO. REQ'D.: 1
TOLERANCES: ±1/64
MATERIAL: 304 SST
OUTER TUBE
RE-1-22624-B

RE-1-22625-B

5 5/16 DIA
5 7/8 DIA
2 7/8 DIA
1/16 X 45°
NO. REQ'D.: 1
MATERIAL: 304 SST
EXTENSION ROD
RE-1-22627-B

TOLERANCES: ±\frac{1}{64}
RE-1-22628-A

TOLERANCES: ±\frac{1}{64}
RE-1-22629-A

TOL OF LENGTHS = ±\frac{1}{32}
RE-1-22769-A
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 milli-amps 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.
LINEAR SCALE-TYPE POSITION INDICATOR COIL ASSEMBLY

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.

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

*As required for spacing coils
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F1, F2</strong></td>
<td><strong>Fuse, 5A</strong></td>
</tr>
<tr>
<td><strong>S1</strong></td>
<td><strong>Switch, DPST, 5A</strong></td>
</tr>
<tr>
<td><strong>T1</strong></td>
<td><strong>Adjustable transformer, 120 V. input, 0-132 V. output, 1.25 A.</strong></td>
</tr>
<tr>
<td><strong>T2</strong></td>
<td><strong>Power transformer, 115 V. input, 460 V. output, 0.1 KVA</strong></td>
</tr>
<tr>
<td><strong>T3</strong></td>
<td><strong>Filament transformer, 117 V. input, 6.3 V. output, 3 A</strong></td>
</tr>
<tr>
<td><strong>R1, R2, R3</strong></td>
<td><strong>Resistor, 1000Ω 100 W</strong></td>
</tr>
<tr>
<td><strong>M3</strong></td>
<td><strong>Voltmeter, 0-130 AC, 4½ in. expanded long scale, GE #AB-18</strong></td>
</tr>
</tbody>
</table>

**ALPR P.I. Power Supply (One Drive)**
Ali PR P.I. Selector (one drive)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S2</th>
<th>Selector switch, 2 sec, 7 pos., N-S</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2</td>
<td>Milliammeter, 0-1, 4½&quot; long-scale, GE #DB-18</td>
</tr>
<tr>
<td>D2</td>
<td>Silicon diode, PSI Type IN628</td>
</tr>
<tr>
<td>K1, K2</td>
<td>Sensitive relay, sigma #5RS-12AS-SIL</td>
</tr>
<tr>
<td>P1, P2</td>
<td>Potentiometer, 1000 Ω, 1 W.</td>
</tr>
<tr>
<td>R4</td>
<td>Res., 300 Ω, 1 W</td>
</tr>
<tr>
<td>R5</td>
<td>Res., 2200 Ω, 1 W</td>
</tr>
<tr>
<td>R6</td>
<td>Res., 1500 Ω, 1 W</td>
</tr>
<tr>
<td>R7</td>
<td>Res., 2000 Ω, 1 W</td>
</tr>
</tbody>
</table>

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

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>M1</th>
<th>Microammeter, 0-300, 8½&quot; long-scale, GE #DB-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Silicon diode, PSI Type IN628</td>
</tr>
<tr>
<td>R8</td>
<td>Resistor, 74400 Ω, 1 W</td>
</tr>
<tr>
<td>L1</td>
<td>Light, red, 115 V</td>
</tr>
<tr>
<td>L2</td>
<td>Light, amber, 115 V</td>
</tr>
<tr>
<td>L3</td>
<td>Light, green, 115 V</td>
</tr>
</tbody>
</table>
**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
CONTROL (for one rod)

Back View

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Switch, DPST, 15 A</td>
</tr>
<tr>
<td>S2</td>
<td>Switch, DP3T, spring return to center off, 5A</td>
</tr>
<tr>
<td>S3</td>
<td>Switch, SPST, 10 A</td>
</tr>
<tr>
<td>F1, F2</td>
<td>Fuse, 30 A</td>
</tr>
<tr>
<td>L</td>
<td>Indicating light, 115 V.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>S4</strong></td>
<td>Commutator switch, RE-1-23472-D, 3-D, 4-D</td>
</tr>
<tr>
<td><strong>M</strong></td>
<td>Gear motor, Merkle-Korff #SG-15, 30 rpm, 9 lb. in. torque, tandem reversible, $\frac{1}{4}$&quot; diam x $\frac{7}{8}$&quot; long horizontal shaft, no base, 115 VAC</td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>Relay, 3PDT, 115 VAC coil, 15 A contacts</td>
</tr>
</tbody>
</table>

**SWITCH (Commutator)**

Back and Top View
TO DRIVE SELECTOR OR TO MAGNETIC JACK

FROM SWITCH

R1, R2, R3, R4, R5, R6, SELENIUM RECTIFIER, 5A, 100VDC, BRIDGE

RECTIFIER (SELENIUM) BACK AND TOP VIEW
COMMUTATOR SWITCH — B/M

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>PART NAME</th>
<th>MATERIAL</th>
<th>NUM. REQ.</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>DISC</td>
<td>PHENOLIC</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>CONDUCTOR</td>
<td>COPPER</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>END BAR</td>
<td>COPPER</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>MIDDLE BAR</td>
<td>COPPER</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>BRUSH HOLDER</td>
<td>PHENOLIC</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>PLAIN PLATE</td>
<td>BRASS</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>MOTOR BASE</td>
<td>MILD STEEL</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>CARBON BRUSH*EB-27</td>
<td>STANDARD</td>
<td>16</td>
</tr>
<tr>
<td>10</td>
<td>ROLL PIN*3/8 X 1/2 LG</td>
<td>STEEL</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>RD. HD. SCR*10-32 X 2 3/4 LONG</td>
<td>BRASS</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>RD. HD. SCR*10-32 X 3/4 LONG</td>
<td>BRASS</td>
<td>20</td>
</tr>
<tr>
<td>13</td>
<td>RD. HD. SCR*6-32 X 1/2 LONG</td>
<td>BRASS</td>
<td>16</td>
</tr>
<tr>
<td>14</td>
<td>HEX. NUT*3/8-32</td>
<td>BRASS</td>
<td>12</td>
</tr>
<tr>
<td>15</td>
<td>LOCK WASHER*10</td>
<td>STEEL</td>
<td>28</td>
</tr>
<tr>
<td>16</td>
<td>FLAT WASHER*10</td>
<td>BRASS</td>
<td>10</td>
</tr>
<tr>
<td>17</td>
<td>INSULATOR*1/8 THK X 3/8 DIA</td>
<td>MICA SHEET</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>RD. HD. SCR. 6-32 X 1/2 LONG</td>
<td>BRASS</td>
<td>4</td>
</tr>
<tr>
<td>19</td>
<td>HEX. NUT*6-32</td>
<td>BRASS</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>LOCK WASHER*8</td>
<td>STEEL</td>
<td>8</td>
</tr>
</tbody>
</table>

COMMUTATOR SWITCH ASSEMBLY

RE-1-23474 - D
**PART No 1**

1\(\frac{1}{4}\)" REAM SQUARE WITH FACE

1\(\frac{1}{8}\)" THK CLOTH BASE

PHENOL FIBER TOL = +\(\frac{1}{64}\)

**PART No 2**

1\(\frac{1}{8}\)" THK COPPER PLATE

TOL = +\(\frac{1}{64}\)

1\(\frac{1}{8}\)" DRILL

10-32 TAP

\(\frac{1}{4}\)" X 45° CHAMP (APPROX)

**PART No 3**

\(\frac{1}{2}\)" THK COPPER PLATE

TOL = +\(\frac{1}{64}\)

**PART No 4**

\(\frac{1}{2}\)" THK COPPER PLATE

TOL = +\(\frac{1}{64}\)

**COMMUTATOR SWITCH ROTOR PARTS**

RE-1-23472-D
PART No. 5
1/8 THK. CLOTH BASE
PHENOL FIBER - TOL. = 1/64

PART No. 7
5/32 THK. BRASS SHEET
TOL. = 1/64

PART No. 8
1/8 THK. MILD STEEL
SHEET - TOL. = 1/64

COMMUTATOR SWITCH MOUNTING PARTS
RE-1-23473-D
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
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, SP3T, 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

CONTROL
For 4 Outer Rods and 1 Center Rod
**DRIVE SELECTOR**

Back View

<table>
<thead>
<tr>
<th>Relay Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>K1, K2, K3, K4</td>
<td>Relay, 3PST, 115 V. 60 ~ coil, 15 A contact</td>
</tr>
<tr>
<td>K5, K6, K7, K8</td>
<td>Relay, DPDT, 115 V. 60 ~ coil, 15 A contact</td>
</tr>
<tr>
<td>R</td>
<td>Silicon rectifier, 15 A, 125 VDC, bridge</td>
</tr>
</tbody>
</table>
ALPR PI.
Voltage Adjustment
(Five Drives)

115 V AC
Input

F1

S1

F2

T1

M7

10

20

R1 Thru R15

To Selector

20

917

717

517

317

117

10

9

ALPR PI. Power Supply
(Five Drives)
ALPR P. I. SELECTOR (Five drives)
Back and top view
ALPR P.I. METERS AND LIGHTS
(FIVE DRIVES)
BACK VIEW
**ALPR POSITION INDICATOR (FIVE DRIVES) PARTS LIST**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1, F2</td>
<td>Fuse, 15 A</td>
</tr>
<tr>
<td>T1</td>
<td>Adjustable transformer, 115 V. input, 0-135 V. output, 7.5 A</td>
</tr>
<tr>
<td>T2</td>
<td>Power transformer, 115 V. input, 460 V. output, 500 W</td>
</tr>
<tr>
<td>T3</td>
<td>Filament transformer, 117 V. input, 6.3 V. output, 10 A</td>
</tr>
<tr>
<td>R1 through R15</td>
<td>Resistor, 1000 Ω , 100 W</td>
</tr>
<tr>
<td>R16</td>
<td>Resistor, 2200 Ω , 1 W</td>
</tr>
<tr>
<td>R17</td>
<td>Resistor, 300 Ω , 1 W</td>
</tr>
<tr>
<td>R18</td>
<td>Resistor, 2000 Ω , 1 W</td>
</tr>
<tr>
<td>R19</td>
<td>Resistor, 1500 Ω , 1 W</td>
</tr>
<tr>
<td>R20 through R24</td>
<td>Resistor, 74400 Ω , 1 W</td>
</tr>
<tr>
<td>M1 through M5</td>
<td>Microammeter, 0-300, 8 3/4&quot; long-scale, GE #DB-16</td>
</tr>
<tr>
<td>M6</td>
<td>Milliammeter, 0-1, 4 3/4&quot; long-scale, GE #DB-18</td>
</tr>
<tr>
<td>M7</td>
<td>Voltmeter, 0-130, 4 3/4&quot; exp., long-scale, GE #AB-18</td>
</tr>
<tr>
<td>D1 through D6</td>
<td>Silicon diode, PSI type IN628</td>
</tr>
<tr>
<td>L1, L4, L7, L10, L13</td>
<td>Light, red, 115 V</td>
</tr>
<tr>
<td>L2, L5, L8, L11, L14</td>
<td>Light, amber, 115 V</td>
</tr>
<tr>
<td>L3, L6, L9, L12, L15</td>
<td>Light, green, 115 V</td>
</tr>
<tr>
<td>S1</td>
<td>Switch, DPST, 15 A</td>
</tr>
<tr>
<td>S2</td>
<td>Selector switch, 7 sec, 5 pos, N-S</td>
</tr>
<tr>
<td>S3</td>
<td>Selector switch, 2 sec, 7 pos, N-S</td>
</tr>
<tr>
<td>K1 through K10</td>
<td>Sensitive relay, sigma #5RS-12AS-S1L</td>
</tr>
<tr>
<td>P1 through P10</td>
<td>Potentiometer, 1000 Ω , 1 W</td>
</tr>
</tbody>
</table>
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 \( \frac{5}{32} \) 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 (420°F). The flange at the bottom of the jack was 390°F in still air. It was 340°F 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 100°F the position indicator input was set at 110.0 volts and at 230°F it was set at 105.0 volts. The following table shows the position indicator error.
<table>
<thead>
<tr>
<th>Actual Position</th>
<th>Coarse Meter</th>
<th>Fine Meter at 230F</th>
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<tr>
<td></td>
<td>100F</td>
<td>230F</td>
</tr>
<tr>
<td>0</td>
<td>0.1</td>
<td>-0.1</td>
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<tr>
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<td>4.8</td>
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<td>24.9</td>
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<td>30</td>
<td>29.9</td>
<td>30.5</td>
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APPENDIX C
DETAILS OF THE HIGH PRESSURE AND THE EBWR MAGNETIC JACKS

HIGH-PRESSURE MAGNETIC JACK (29 H) ASSEMBLY
COIL WIRING DIAGRAM

<table>
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<th>PART</th>
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<tr>
<td>1</td>
<td>12</td>
<td>LONG CONNECTOR, 60° BENDS</td>
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<td>2</td>
<td>14</td>
<td>SHORT CONNECTOR, 70° BENDS</td>
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<tr>
<td>3</td>
<td>36</td>
<td>RD. HD. SC., *6-32 x 5/16&quot;, SST</td>
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<tr>
<td>4</td>
<td>36</td>
<td>HEX. NUT, *6-32, SST</td>
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<tr>
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<td>36</td>
<td>LOCK WASHER, *6, SST</td>
</tr>
<tr>
<td>Part No.</td>
<td>Number Required</td>
<td>Part</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
<td>-----------------------</td>
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<td>Extension</td>
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<td>Flange bolt, Soc. hd. sc, 1/4-7x64, st.</td>
</tr>
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</table>
# Drawing List for the EBWR Magnetic Jack (29L)

<table>
<thead>
<tr>
<th>Part No.</th>
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<th>Drawing Number</th>
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</table>

*Changes in drawing for:

- L five-foot travel
- P low pressure
- D bottom drive

- One required P

Socket head screw, 10x3 lg., steel
Flexitallic #R4-6J
Hex head bolt, 1-23 x 29 lg., steel
Hex head bolt, 1-16x15 lg., steel
Hex nut, 1-13, steel
Hex nut, 1-16, steel

RE-1-31080-A
NO. REQ.: 1
PRESSURE SHELL, HIGH PR.
RE-1-31081-A

1 1/2" DRILL THRU
SEAL WELD

1/8" HOLE
1/8" SP.

C CLAMP
PARTS TIGHTLY.
HELIDARC
WELD WITH
INCO-WELD "A".

RE-1
31085
A

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

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

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

NOTE: 1/16" X 45° CH. ALL EDGES
NO. REQ.: 1
TOL.: ± 1/32
MATERIAL: 430 SST
BODY HEAD RE-1-31086-A

NO. REQ.: 1
TOL.: ± 1/16
MATERIAL: 430 SST
BODY FLANGE, HIGH PR.
RE-1-31086-A

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

**PRESSURE SHELL**

**EXTENSION, HIGH PR.**

**RE-1-31092-A**

**EXTENSION PIPE RE-1-31092-A-1**

**EXTENSION CAP RE-1-31092-A-2**

**MATERIAL:** 430 SST ± 1/32

**EXTENSION TUBE, HIGH PR.**

**MATERIAL:** 430 SST ± 1/16
LENGTH MUST BE THE SAME FOR G RODS WITHIN .004

2 SLOTS 180° ± 5° APART. TURN SLOTS OF G RODS TOGETHER USING 7TH 3/16 D. ROD IN CENTER OF BUNDLE

CENTERLESS GROUND BAR ARMCO 17-4 PH SST HEAT TREATMENT OPTIONAL

FILE KNOB FOR LENGTH "L" TO MATCH 3/16 R. OR SLIGHTLY BELOW ON ONE END OF ONE ROD ONLY.

DRIVE ROD, NOTCHED RE-1-18795-B

NO. REQ.: 1
FR. TOL.: ± 1/64
DE. TOL.: ± .005
MATERIAL: 304 SST
ROD CONNECTOR RE-1-17894-A

NO. REQ.: 1
TOL.: ± 1/64
MATERIAL: 304 SST
FILLER ROD RE-1-18799-A

10
33
10 REQ.: 3  TOL.: ± 1/16
MATERIAL: 304 SST
NON MAGNETIC SLEEVE
RE-1-31093-A-1

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

THICKNESS IS DETERMINED BY TEST TO GIVE DESIRED STEP LENGTH

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

NO. REQ.: 1  TOL.: ± 1/32
MATERIAL: LOW CARBON STEEL
LARGE COIL CLAMP
RE-1-31094-A-3

NOTE:
Cadmium Plate
.0005" ± .003"
Low Carbon Steel Parts
SPEC.:
1290 TURNS
12.0 OHMS AT 77°F
NO. REQ.: 2, TOL.: ± 1/32.
MOVE COIL, POTTED RE-1-31095-A

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

WIND FIRST LAYER
RIGHT HAND

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

450 TURNS OF
#6 DOUBLE GLASS-
sILICONE MAGNET WIRE

WRAP COIL 1/8 THICK
WITH UNPREPARED
GLASS CLOTH TAPE.
A FEW EIGHT STRIPS
OF GLASS CLOTH
ADHESIVE TAPE
MAY BE USED TO
BIND THE COIL.

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

NO. REQ.: 14
GRIP COIL
RE-1-31100-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 Cardellite N.C. 513; heat mixture to 140°F; to mixture add 14% by weight of Shell Epon Curing Agent GL (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.
WE THE WELDER FIRST PASS WITH 92" DIAM. ING-WELD."  
ARC WELD OTHER PASS'S WITH 96" DIAM. ING-WELD."  

RE-1 31088 A

RE-1 31107 A

RE-1 31106 A

1-13 TAP 1 DEEP 2 HOLES  
1/2 - 45 CH.

1/2 DRILL & 1/2 C'BORE  
1/2 DEEP 8 HOLES  
EQ SPON 5/8 D.B.C.

1.0008" ± 0.0003"  
Cadmium Plate

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

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

NO. REQ.: 1  
TOL.: ± 1/16  
MATERIAL: 430 SST  
BODY FLANGE, LOW PRESSURE  
RE-1-31113-A
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.

6. Before welding, ref.

9. Welds

* 1.562 I.D.
* 1.565 before plating

1.960 O.D.

* Neo-Chrome® plate
* I.D. surface .004-.001" thick for wear resistance.

No. Req.: 1
Pressure Shell Extension,
Low Pressure RE-1-31108-A

No. Req.: 1
Tol.: ± 1/16
Material: 430 SST
Extension Tube,
Low Pressure RE-1-31109-A
"NEO-CHROME FLAT
ALL SURFACES
.004" .001 THICK
FOR CORROSION AND
WEAR RESISTANCE.
CADMIUM PLATE
.0008" ± .0003"

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

19

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 ½-in. diameter rods in a 1½-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.
<table>
<thead>
<tr>
<th>TYPE</th>
<th>light bulb</th>
<th>light and meter</th>
<th>automatic meter</th>
<th>linear scale meter</th>
<th>decade switch</th>
<th>automatic digital</th>
</tr>
</thead>
<tbody>
<tr>
<td>COARSE INDICATION</td>
<td>light bulbs</td>
<td>light bulbs</td>
<td>bar indicator</td>
<td>20° linear scale</td>
<td>calibrated scale</td>
<td>digital display</td>
</tr>
<tr>
<td>COARSE READING PROCEDURE</td>
<td>position is read on scale at dim light or between bright lights and dark lights</td>
<td>position is read on scale at dim light or between bright lights and dark lights</td>
<td>position is read by length of red line</td>
<td>position is read directly in inches on meter scale</td>
<td>position is read directly in inches on meter scale</td>
<td>numbers are read</td>
</tr>
<tr>
<td>COIL SWITCHING FOR CLOSE INDICATION</td>
<td>manual selector switch</td>
<td>manual selector switch</td>
<td>automatic selector switch</td>
<td>manual selector switch</td>
<td>two manual selector switches</td>
<td>two automatic selector switches</td>
</tr>
<tr>
<td>CLOSE INDICATION</td>
<td>meter and graph</td>
<td>meter with calibrated dial</td>
<td>meter with calibrated shifting dial</td>
<td>meter with graph</td>
<td>meter with calibrated decade dial</td>
<td>multi-contact meter-relay with digital display</td>
</tr>
<tr>
<td>CLOSE READING PROCEDURE</td>
<td>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</td>
<td>1. coil indicated by light is selected 2. number indicated on selector switch dial is added to meter reading</td>
<td>1. position is read directly on meter scale</td>
<td>1. coil is selected 2. voltage is adjusted 3. meter is read 4. graph is read</td>
<td>1. coil is selected 2. numbers indicated on selector switch dials are read as first two digits and meter is read as the third digit</td>
<td>1. numbers are read</td>
</tr>
<tr>
<td>REGULATION FOR CLOSE INDICATION</td>
<td>rheostat</td>
<td>voltmeter, rheostat, coil with fixed iron core</td>
<td>automatic constant voltage power supply</td>
<td>voltmeter, variable transformer</td>
<td>automatic constant current power supply</td>
<td>automatic constant current power supply</td>
</tr>
<tr>
<td>ADVANTAGES</td>
<td>simple, reliable</td>
<td>good compromise between simple construction and easy to read close indication</td>
<td>easy to read close indication</td>
<td>looks like standard position indicators, reliable</td>
<td>easy to read close indication, reliable, magnifies movement, accurate</td>
<td>digital indication, accurate</td>
</tr>
<tr>
<td>DISADVANTAGES</td>
<td>close reading requires seven operations</td>
<td>meter is inaccurate if any light bulb burns out</td>
<td>depends on sensitive relays</td>
<td>close reading requires four operations</td>
<td>requires a wire for each inch of indication from drive to control panel</td>
<td>complicated construction</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>pages 114 thru 117</td>
<td>ANL-5768, pages 20 thru 24</td>
<td>pages 118 thru 121</td>
<td>appendix B</td>
<td>pages 122 thru 125</td>
<td></td>
</tr>
</tbody>
</table>
MOLDED POSITION INDICATOR
COIL CONSTRUCTION NOTES

A. USE TWO TERMINAL POSTS, DRAWING RE-1-21409-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 WIRES 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: SHELL EPOX RESIN 815
ADD 16% BY WEIGHT OF WMM CARDELITE
N.C. 513; HEAT MIXTURE TO 140°F, TO
MIXTURE ADD 14% BY WEIGHT OF SHELL
EPOX 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 200°F TO 200°F FURNACE
FOR TWO (2) HOURS.

MOLDED POSITION INDICATOR COIL

CONSTRUCTION NOTES:
1. Wind Exactly 200 Turns On 1/8
Double-Gauge Silicon Primary Wire.
2. Wind Coil In 3-4 Turns Of Glass Cloth Tape. 3-4 Turns 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.
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 1/8-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

ROD POSITION, inches

VOLTS
LIGHT BULB TYPE POSITION INDICATOR
AUTOMATIC METER TYPE POSITION INDICATOR
(BACK VIEW)
AUTOMATIC METER TYPE POSITION INDICATOR PANEL
TRANSMITTER DIAGRAM

AUTOMATIC METER POSITION INDICATOR
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
CI 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:

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

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

Silicon Diode, 2N528

Milliammeter
C-1, 4½ Wide
Long Scale
G.E. DB-18

Power Transformer
P9908

Silicon Diode, 2N528

Milliammeter
0-½ 4½ Wide
Long Scale
G.E. DB-18

Note:
Connect the 9.5 volt
Transformer leads
to give the higher
meter (DB-16) reading.
See coil diagram

Decade Switch Type Position Indicator
(4½ Meter Dial, Manual Selector Switches, 1½ Meter Dial)
Back & Top View

RE-2-30138-C
DECADE-TYPE POSITION INDICATOR COIL DIAGRAM

<table>
<thead>
<tr>
<th>No.</th>
<th>Req'd.</th>
<th>Part</th>
</tr>
</thead>
<tbody>
<tr>
<td>54</td>
<td>molded position indicator coil, page 113</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>plate, drawing 29-17, page 102.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>tie rod, ( \frac{1}{4} '' \times 56'' ), 1/2''-20thd.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2''LG., 304SSt.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>hex nut, ( \frac{1}{4} '' )-20, brass.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>lock washer, ( \frac{1}{4} '' ), plated steel.</td>
<td></td>
</tr>
<tr>
<td>216</td>
<td>flat washer, ( #14, \frac{9}{16} '' \times 0.260'' )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I.D.x.040'' th., brass.</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>round head screw, ( #6-32 \times \frac{3}{8} '' ), brass</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>hex nut, ( #6-32 ), brass.</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>lock washer, ( #6 ), plated steel.</td>
<td></td>
</tr>
</tbody>
</table>
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{3}{8} 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. 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

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

*2.22 near joint with pipe

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.

<table>
<thead>
<tr>
<th>CALCULATED STRESSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3$\frac{1}{2}$ in. ID 430 SST</td>
</tr>
<tr>
<td>( P )</td>
</tr>
<tr>
<td>pressure, psi</td>
</tr>
<tr>
<td>2500</td>
</tr>
<tr>
<td>12800</td>
</tr>
<tr>
<td>minimum wall as specified, in.</td>
</tr>
<tr>
<td>minimum wall as measured, in.</td>
</tr>
<tr>
<td>inside radius, in.</td>
</tr>
<tr>
<td>0.125</td>
</tr>
<tr>
<td>0.150</td>
</tr>
<tr>
<td>0.150</td>
</tr>
<tr>
<td>0.150</td>
</tr>
<tr>
<td>0.150</td>
</tr>
<tr>
<td>1$\frac{1}{2}$ in. Schedule 40 pipe, inconel</td>
</tr>
<tr>
<td>11300</td>
</tr>
<tr>
<td>12800</td>
</tr>
</tbody>
</table>

| 2500 | 2500 | 2500 | 2$\frac{1}{8}$ | 2$\frac{1}{8}$ |
| 9000 | 6750 | 2730 | 1670 |
| 9520 | 5990 | 2 | 2$\frac{1}{3}$ | 2$\frac{1}{3}$ |
Laboratory Reports

Steel City Testing & Engineering Laboratories
13055 Brainard Avenue
Chicago 33, Illinois

TECHNICAL REPORT FOR: Argonne National Laboratory
Lemont, Illinois

FILE NO. 591 21 139
ORDER NO. 6 February 1959

TEST #1

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...
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.

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

[Signature]
Registered Professional Engineer
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.
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 flexible 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.
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.
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:

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.
Figure No. 1

Large crack at flanged end. Note deformation of material on smallest diameter pipe section.
Figure No. 2

End view of failure

STEEL CITY TESTING & ENGINEERING LABORATORIES
Figure No. 3

Side view of failure
Figure No. 4

Side view of failure
Figure No. 5

Side view of failure
Figure No. 6

Side view of failure

STEEL CITY TESTING & ENGINEERING LABORATORIES
Figure No. 1

Side View
Figure No. 2

Bottom View - Disassembled
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 X

MODEL USED IN TEST '1' & '2'

MODEL USED IN TEST '3'

ACTUAL VESSEL
<table>
<thead>
<tr>
<th>DETAIL NO</th>
<th>NAME</th>
<th>MATERIAL</th>
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<tr>
<td>1</td>
<td>NUT</td>
<td>1-1/4-8 STEEL</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>STUB</td>
<td>1-1/4-8x11 B-14 STEEL</td>
<td>8</td>
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<tr>
<td>3</td>
<td>GASKET</td>
<td>FLEXITALIC® R3-25K, 304 SSST AND ASBESTOS</td>
<td>1</td>
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<tr>
<td>4</td>
<td>FLANGE RING</td>
<td>LOW CARBON STEEL</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>BLIND FLANGE</td>
<td>LOW CARBON STEEL</td>
<td>1</td>
</tr>
</tbody>
</table>

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