UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

January 6, 1992

NRC INFORMATION NOTICE 92-04: POTTER & BRUMFIELD MODEL MDR ROTARY RELAY FAILURES

Addressees

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees of failures experienced with MDR series Potter & Brumfield (P&B) rotary relays installed in safety-related systems at certain nuclear power plants. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

On January 14, 1986, September 17, 1987, and December 8, 1987, an emergency diesel generator (EDG) failed an operability surveillance test at the LaSalle County Station, Units 1 and 2. In each case, while the Commonwealth Edison Company (CECO) attempted to synchronize the EDG to its bus, the EDG output breaker would not close. CECO replaced all P&B MDR relays in the output breaker closing circuits with General Electric HFA relays. The NRC staff has received no reports of relay failures at LaSalle affecting EDGs since these were replaced.

On October 10, 1988, the Arizona Public Service Company (APSC), the licensee for the Palo Verde Nuclear Generating Station, submitted a report in accordance with Title 10 of the Code of Federal Regulations, Part 21 (10 CFR Part 21). This report documented 18 instances over a 2-year period in which P&B MDR relays failed to change position.

APSC detected these failures during either routine surveillance testing or actuation of the engineered safety features (ESF) actuation system or the reactor trip switchgear. After replacing all P&B MDR series relays, APSC experienced only two failures; improperly sized coils or contamination in the insulating material of the switch caused these two failures.

On July 19, 1991, during a monthly surveillance test, the River Bend Station experienced ESF actuation of containment isolation valves, control room filter trains, the standby gas treatment system, and the fuel building filter trains because of an MDR relay failure.

On July 23, 1991, during a monthly surveillance test at the River Bend Station, the failure of an MDR-5111-1 relay caused an ESF isolation of a reactor water sample valve. The Gulf States Utilities Company (GSU), the licensee, committed to replace all P&B MDR relays.

Discussion

P&B MDR relays are used in various safety-related applications in commercial nuclear power plants with reactors manufactured by the Babcock and Wilcox Company; Combustion Engineering, Incorporated; the General Electric Company; and the Westinghouse Electric Corporation. Industry records identify over 60 instances of P&B MDR rotary relays failing to operate properly since 1984.

An MDR relay failure may cause the loss of a train of the ESF actuation system, the emergency core cooling system, or the reactor protection system. A common-mode failure may result in the loss of one or more of these systems. GSU performed a probabilistic risk assessment (PRA) of the reactor protection system at River Bend, based on plant-specific, P&B MDR relay failure rates that were greater than the generic failure rates by a factor of 5.1. This PRA showed that the reactor protection system failure rate increased by a factor of 25 to 3.3E-4.

The principal failure mechanism of P&B MDR rotary relays appears to be mechanical binding of the rotor caused by deposits from coil varnish outgassing and chlorine corrosion products. A secondary failure mechanism appears to be the intermittent continuity of electrical contacts. A number of variables contribute to these failure mechanisms and cause the relays to fail at random mostly within 2 to 5 years of the in-service date. Failures may occur regardless of current or wattage, the use of ac or dc power, or whether normally energized or de-energized. It is also important to note that a relay rotor can bind immediately after a surveillance test.

Attachment 1 provides a detailed description of the failure mechanisms, contributing causes, and failure investigations. Attachment 1 also discusses modifications made to P&B MDR series relays by the manufacturer to reduce susceptibility to the failure mechanisms discussed above.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Attachments:
1. Potter & Brumfield Model MDR Rotary Relays
2. Figure 1, Potter-Brumfield Model MDR Rotary Relay
3. Figure 2, MDR Non-Latching Relay
4. List of Recently Issued NRC Information Notices

Computer Printouts: see Jacket

Potter & Brumfield Model MDR Rotary Relays

Description of the MDR Rotary Relay

Potter & Brumfield (P&B) manufactures two types of MDR rotary relays: latching and non-latching. Various series of these relays are provided for service at 28 and 125 volts (V) dc and 115 and 440 Vac, with from 4 to 24 pole double throw (PDT) contacts. While each series has a different number of contact stacks and has a different coil, power, and current capacity, each of the series is similarly constructed and exhibits similar failure mechanisms.

Non-Latching Relays

The non-latching MDR relay has two coils connected in series inside the relay which, when energized, rotate the relay rotor shaft, which operates the contacts through a shaft extension. The stator faces and stop ring limit the rotor movement to a 30-degree arc. Two springs return the rotor to the stop ring and the contacts to their normal positions when the coils are de-energized. The non-latching MDR relays have two positions: "energized" and "de-energized." (See figures 1 and 2).

Latching Relays

Each relay in the MDR latching series has two sets of series coils, which provide a latching two-position operation. When one set of coils is energized, the rotor shaft rotates through a 30-degree arc, changing the state of the contacts. The other set of coils must be energized to return the relay to its original position.

Failure Investigations

The Commonwealth Edison Company (CECO) determined that the three events at the LaSalle County Station resulted from the failure of P&B MDR-137-8 or MDR-138-8, 125 Vdc normally energized relay contacts to close. CECO performed diagnostic testing after the earlier events but could not repeat the failure. This lack of repeatability is typical of MDR intermittent failures.

The Arizona Public Service Company (APSC) found that three of the P&B MDR relay rotors at Palo Verde Nuclear Generating Station (PVNGS) would not move more than 12 degrees of the complete 30-degree arc. The failed relays, located in cabinets without forced ventilation, were in an ambient temperature of 95 to 104°F (the design limit is 149°F) and had an external surface temperature of 157°F.

APSC detected no relay failures in cabinets with forced ventilation which provided an ambient temperature of 81°F or less. Such relays had a temperature of 112°F on their external surfaces. APSC determined that it had applied up to 39.8 Vdc to the 28 Vdc coils. APSC tested 7 of the 18 failed relays on an 18-month frequency and 10 on a 62-day frequency. APSC had the relay failures analyzed and determined that varnish on the relay coils outgassed, condensed, and accumulated between the rotor shaft and the end-bell bearings, binding the rotor and the bearings together. The outgassing was due to excessive coil temperatures that occurred when the coils were continuously energized at voltages above their nominal ratings. The heat also may have caused the release of chlorine from (1) the PVC coating on the fiberglass tubing covering the solder joint between the magnet wire and the Teflon coated lead wire, and (2) the Neoprene rubber grommet through which the coil lead wires penetrate the base of the relay. The chlorine corroded brass parts inside the relay. P&B and APSC concluded that long intervals between de-energizing of the relays may have also contributed to the failures.

In May 1989, APSC installed replacement P&B relays at PVNGS that were manufactured with coils coated with epoxy instead of varnish. APSC conducted tests and found that 5 of the 42 relays tested would not rotate to their de-energized position and that 5 other relays operated slowly. Two independent laboratories observed that; (1) the relays' epoxy was not properly cured, (2) uncured epoxy contaminated the rotor and (3) P&B did not de-aerate the epoxy prior to use, contrary to the manufacturer's recommendations. This caused the rotor and stator surfaces to bond together, preventing the rotor from rotating freely. P&B informed the NRC that APSC returned the 42 relays and that P&B rebuilt them.

On September 10, 1990, the General Electric Nuclear Energy Division (GENE) issued Rapid Information Communication Services Information Letter 053 to address P&B MDR relay failures reported at two GE boiling water reactors. P&B believed that chlorine released from rubber grommets and polyvinyl chloride sleeves caused corrosion and that varnish on the coils outgassed while the relays were continuously energized. Both chlorine-corrosion products and varnish accumulated in the bottom end-bell bearing and caused the rotor shaft to bond to the bearing. P&B suspected that the failed relays were exposed to high ambient temperatures and could have been exposed to high coil voltages or could have been rarely cycled.

On November 2, 1990, GENE issued Potentially Reportable Condition 90-11 in which it stated that both 24 Vdc and 120 Vdc coils had lower coil powers than the 125 Vdc relays and were therefore not vulnerable to this failure mode. GENE concluded that no substantial safety hazard existed. However, upon investigating the failed MDR relays at River Bend as discussed below, the NRC obtained results that may contradict these conclusions.

On July 19, 1991, a high resistance on one set of contacts on a P&B 24 Vdc, MDR-5111-1 rotary relay, which should have been closed, caused a voltage drop to the downstream relays which opened their contacts and resulted in an ESF actuation at the River Bend Station. The Gulf States Utilities Company (GSU), the licensee, later performed bench testing of this failed relay and verified that the relay actuated properly and all contacts changed state properly, and exhibited proper continuity. The coil was meggered and found to be acceptable. The contacts all appeared to be clean and shiny, with no evidence of pitting or residue. GSU found no foreign material in the relay or on the rotor shaft and found nothing that may have contributed to the high resistance across the contacts.

On July 23, 1991, GSU investigated another MDR relay failure at River Bend and found two MDR-5111-1 relay contacts open that should have been closed when the coil was energized. GSU also found that the contacts operated intermittently with some contacts closing several minutes after the coil was energized or sometimes not at all.

Both River Bend failed relays had been in service within tightly-regulated design voltage and temperature conditions and were mounted inside stainless steel isolation cans for divisional separation. GSU measured the temperature inside the isolation can at 113°F, while the ambient cabinet temperature was 92°F. In each case, the failed relay had been recently cycled because of a short loss of power to the coil that had occurred a few days before the relay failure was discovered, and it appears that not all contacts engaged properly when power was restored.

Failure Mechanisms

The primary failure mechanism of the P&B model MDR rotary relay appears to be a mechanical binding of the rotor caused by organic outgassing and deposition of contaminants and corrosion particles on the relay rotor shaft. The contaminants are deposited in the end bell bearings and sleeves and cause the rotor shaft to bond or stick to the bearing, preventing the rotor shaft from fully rotating when the relay coils are energized or de-energized. The principal contaminant is outgassed material emitted from the brown enamel varnish used to coat the relay coils. This contamination may not be apparent to the naked eye. The corrosion results from chlorine released from the rubber grommets and the polyvinyl chloride sleeves. Gulf States and P&B disassembled six operable and two failed relays that had been in service since December 1984. The thickness and color of the deposits on the rotor, sleeve, and end-bell bearings of the relays varied widely among the eight relays, indicating varnish outgassing.

A secondary failure mechanism appears to be intermittent continuity of the electrical contacts. High resistance and intermittent continuity may result from chemical reactions on the fixed and movable silver contacts. P&B tested a MDR-5112-1, 125 Vdc relay that had been in service at River Bend and found intermittent continuity on a set of clean, unused contacts.

A number of variables contribute to these failure mechanisms and reduce the length of the operating life of the complex P&B MDR rotary relays. These variables include coil wattage, applied ac or dc voltage, normally energized or de-energized coil, manufacturing tolerances, ambient and coil temperatures, varnish thickness, mounting configurations and enclosures, cabinet ventilation, relay breathing, testing frequency, operational cycling, the number of contact decks, and the amperage and voltage of the contact load. These contributory factors cause an apparent random failure history. While each of the MDR relays failed between 1 month to 13 years after it was placed in service, most failed within 2 to 5 years.

Modifications to MDR Relays

P&B has made the following design changes to MDR series relays:

Changed the movable contacts from silver to silver-cadmium-oxide in October 1985. However, P&B recommends against using MDR relays with either silver or silver-cadmium-oxide in low current circuits.

Changed the coil coating from varnish to Dolphon CC-1090 epoxy resin in February 1986. This reduced the coil outgassing rate. However, P&B does not de-aerate Dolphon CC-1090 prior to use, contrary to Dolphon's recommendations. P&B informed the NRC that the epoxy manufacturer plans to cease production of this currently used and tested epoxy. The NRC is unaware of when P&B will change to a new epoxy. Licensees may wish to determine if P&B has examined the replacement epoxy for susceptibility to outgassing after aging. Licensees may also wish to determine if P&B applies the epoxy in accordance with the manufacturer's recommendations.

Replaced the brass switch studs in medium size MDR relays with stainless steel studs in November 1986.

Began lubricating end-bell bearings in July 1988.

Changed chloride-containing materials to chloride-free materials in June 1989.

Changed the rotor spacers from brass to stainless steel in May 1990.

Changed the brass spring retainer in small size MDR relays from brass to stainless steel in May 1990.

Changed shims from brass to phosphor bronze in May 1990.

P&B had implemented all these modifications to its MDR rotary relay design by May 1990.

When APSC reported having problems with MDR relays at Palo Verde in 1988, P&B believed that only relays normally energized with excessive voltage and operated infrequently were susceptible to the corrosion and outgassing failure mode. P&B did not notify other licensees about these problems since this condition appeared to occur only at plants with reactors manufactured by Combustion Engineering, Incorporated. P&B informed the NRC that since 1988 it has only supplied MDR relays as commercial grade components without accepting the reporting requirements of 10 CFR Part 21.

MDR NON-LATCHING RELAY

(SMALL)

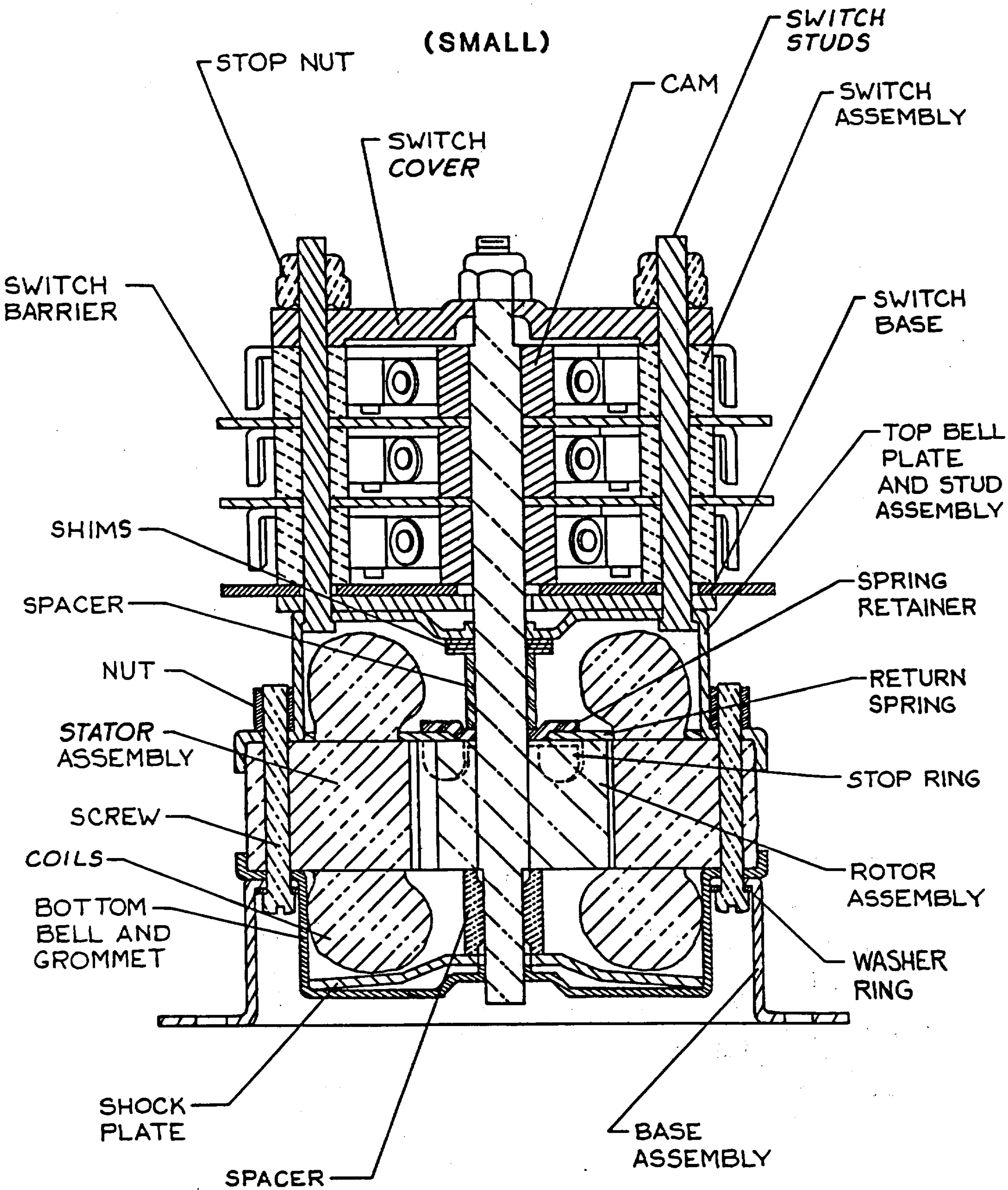

Figure 2

POTTER-BRUMFIELD MODEL MDR ROTARY RELAY

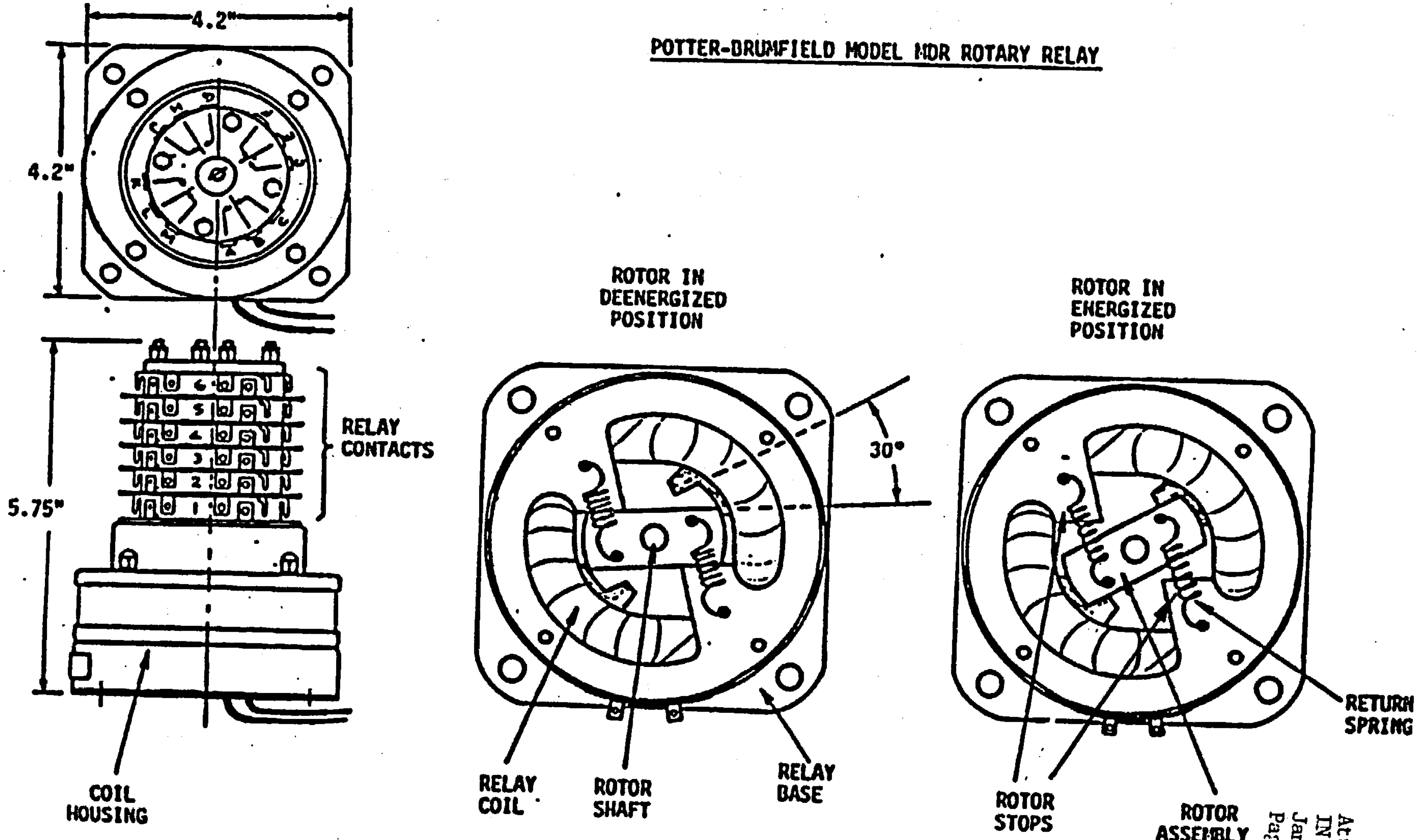

Figure 1

LIST OF RECENTLY ISSUED NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
92-03	Remote Trip Function Failures in General Electric F-Frame Molded-Case Circuit Breakers	01/06/92	All holders of OLs or CPs for nuclear power reactors.
92-02	Relap5/Mod3 Computer Code Error Associated with the Conservation of Energy Equation	01/03/92	All holders of OLs or CPs for nuclear power reactors.
92-01	Cable Damage Caused by Inadequate Cable Installation Procedures and Controls	01/03/92	All holders of OLs or CPs for nuclear power reactors.
91-87	Hydrogen Embrittlement of Raychem Cryofit Couplings	12/27/91	All holders of OLs or CPs for nuclear power reactors.
91-86	New Reporting Requirements for Contamination Events at Medical Facilities (10 CFR 30.50)	12/27/91	All licensees authorized to use byproduct materials for human use.
91-85	Potential Failures of Thermostatic Control Valves for Diesel Generator Jacket Cooling Water	12/26/91	All holders of OLs or CPs for nuclear power reactors.
91-84	Problems with Criticality Alarm Components/Systems	12/26/91	All Nuclear Regulatory Commission (NRC) fuel cycle licensees, interim spent fuel storage licensees, and critical mass licensees.
91-83	Solenoid-Operated Valve Failures Resulted in Turbine Overspeed	12/20/91	All holders of OLs or CPs for nuclear power reactors.

OL = Operating License
CP = Construction Permit