PDR

Dr. Richard E. Webb
Research Associate
Department of Environmental Sciences
University of Massachusetts
Amherst, Massachusetts 01002

50-268

Dear Dr. Webb:

Thank you for your letter of November 18. I'm sorry I was out of town and only now have gotten to answer it. The foreign power reactor which was found to have its scram system totally inoperative was the Kahl reactor in Germany. This was a GE design. I do not know who manufactured the actual relays, initially installed, that were removed in the incident, nor do I know who manufactured the replacement relays whose manufacturing deficiency caused the incident.

It is worth noting that we had a problem of similar nature during the commissioning of one of the GE reactors (Monticello). In this case I believe the relays were GE-type HFA. This makes one wonder whether the earlier incident might have been the same batch. I don't know whether it is worth asking the Germans or not. Enclosed you will find copies of GE and AEC reports and an AEC "ROE" evaluation on the Monticello failures.

It seems to me that the lesson to be learned from such incidents is not that GE relays are bad, because they're not; they are an acceptable product made by a reliable manufacturer. Like all human products and most natural ones, they fall short of perfection. Errors in design, manufacture, installation, and operation of safety-related components are possible, have happened, and will continue to happen. The objective is to achieve an acceptable level of safety in the presence of the known impossibility of perfection. We do this through defense in depth, redundancy, diversity, design reviews, and vigilance during operation.

Sincerely,

DR 7897

Original Signed by
Stephen H. Hanauer

Stephen H. Hanauer, Director
Office of Technical Advisor -
Regulation

EGCase
12/7/74

Enclosures:
1. Memo dtd 6/2/70 to J.P. O'Reilly
2. Ltr dtd 7/29/70 to R.Boyd
3. ROE 71 16

OFFICE ▶		L	L	L	L
SURNAME ▶	SHHanauer:cgk	TAIppolito	VAMoore	FSchroeder	AGiambusso
DATE ▶	12/4/74	12/5/74	12/6/74	12/6/74	12/6/74

Form AEC-318 (Rev. 9-53) AECM 0240

9212080386 741209
PDR ADOCK 05000263
P PDR

UNITED STATES
ATOMIC ENERGY COMMISSION
DIVISION OF COMPLIANCE
REGION III
799 ROOSEVELT ROAD
GLEN ELLYN, ILLINOIS 60137

June 2, 1970

J. P. O'Reilly, Chief, Reactor Inspection and Enforcement Branch
Division of Compliance, Headquarters

COMPLIANCE INQUIRY MEMORANDUM
NORTHERN STATES POWER COMPANY (MONTICELLO)
DOCKET NO. 50-263
UNSAFE FAILURE OF PLANT PROTECTION SYSTEM RELAYS

During a routine inspection on May 25, 1970, the assigned inspector was informed that several [illegible] had failed to operate during [illegible]tional and preoperational [illegible]ing. The relays were all General [illegible] (GE) Type HFA51 [illegible] auxiliary relays installed [illegible] the reactor protection system (RPS) and primary containment [illegible] system (PCIS). [illegible] RPS and PCIS [illegible] normally energized "Failsafe" systems. [illegible] of a relay to drop out on loss of power in these systems [illegible] unsafe failure.

A brief description of the events is given below:

March 2, 1970: During the functional checkout of the RPS, Relay 5A-K9D (Control Valve Fast Closure Scram Bypass) failed to drop out when pressure switch 5-14D was actuated. It was found that when the movable contact block was given a tug, the relay dropped out. From then on the relay operated properly and the condition would not repeat itself. A wiring problem such as an intermittent ground was suspected to have caused the failure.

March [illegible]: During the RPS Preop Test, Relay 5A-K2A (Low Condenser Vacuum Scram) failed to drop out when pressure switch 5-11A was actuated. Again it was found that the relay released when tugged by hand. Once the relay released, everything worked normally and the condition would not repeat itself.

March 23, 1970: Relay 16A-K6D (Group Three valve isolation) failed to drop out during the Reactor Water Cleanup System Preop. The relay was dropped out by hand so that the Cleanup Preop could be continued. As in the previous failures, the condition would not repeat itself. It was decided that if another suspected failure should occur the circumstance surrounding the incident would be studied in detail before touching the relay.

01910

G102140439

April 21, 1970: Relay 5A-K3A (Main Steam Isolation Valve Closure Scram) failed to drop out when MSIV 2-86A was operated. All the field wires were lifted one by one and finally, the relay was removed from the panel still in the picked up condition. The relay was then dropped out, using the tension adjusting screw, disassembled, and examined for abnormal conditions, but none were found.

GE was contacted at San Jose (NID) and Philadelphia (Relay Product Department) and informed of the situation. It was decided that the GE leadman for the RPS Preop would fly to Philadelphia with two of the failed relays. A third relay was sent to San Jose.

In Philadelphia various electrical and mechanical tests were performed on the failed relays. It was found that the self-aligning tabs were chipped on one of the relays, and the contact block was cracked on the other. When the self-aligning tabs were cut off it was discovered that with a good deal of hand force, the relays could be made to stick because of misalignment. It was thought that misalignment may have been the problem, but this was not conclusive because the failed relay that was at the site did not have any chipped tabs.

GE notified field personnel of the problem via Field Engineering Memo on April 2[illegible], 1970, requesting that all relays be inspected for alignment and chipped or broken carrier guides.

May 1, 1970: The replaced Relay 5A-K2A failed to drop out when it's coil was deenergized. (The original failed 5A-K2A relay had been replaced so that the RPS preop could be continued.) It was evident that the relay was not misaligned, so the relay was left in the panel with the coil wires removed until a factory representative arrived from Philadelphia to study the exact field conditions. The factory representative returned to Philadelphia with the relay for more extensive tests after finding no obvious reason for the failure.

In a subsequent Field Engineering Memo, dated May 18, GE notified field personnel that the first memo had incorrectly ascribed the cause to be chipped or broken contact carrier guides, but that extensive testing at Power Systems Management Department, Philadelphia, and at NID had demonstrated that the relay hangup was due to heat bonding the armature to the upper (contact end) pole piece. The bonding agent is a black chromate primer which is applied to the pole pieces as a corrosion inhibiter. During some relay production cycles, the primer used did not fully cure at room temperatures. In some few relays, this lack of

curing plus primer buildup between laminations permitted bonding due to internal heat generated during initial extended (12 hours or less) energization.

The memo stated that heat generated also cures the primer and that if no bonding occurs following the above initial energization, it will not occur, and that if bonding does occur, it will not recur once the armature is freed from the upper pole piece, and that this was verified by repeated testing of new relays on overnight cycles.

GE instructed that curing must be accomplished in the field by energizing all HFA relays (whether AC or DC or normally energized or deenergized) for 48 hours (providing at least a 36-hour extra curing time) requiring that this be done at sites except where it can be positively established that a particular relay has been energized for that period or longer and has subsequently dropped out upon test deenergization. The memo also stated that it is likely that all sites past fuel loading can establish this on normally energized relays, and that normally de-energized relays are in a safe mode when picked up, so curing their pole pieces can await the earliest shutdown. The memo instructed that each nonoperational site perform or verify the above 48-hour energization and perform additional site testing following curing in accordance with the memo.

It was noted that the GE memoranda were addressed to sixteen persons, with four of them being identified with specific facilities. These were Tsuruga, NMP, OYC, and Tarapur.

A preliminary count of the relays in the Monticello plant identified 18[illegible] HFA relays installed. The inspector was informed that some additional relays of the same type may have been provided in Bechtel supplied panels.

The curing and test program had not been initiated at the time of the inspection, however, detailed inspection and tests will be performed on each Type HFA relay in the plant.

NSP personnel indicated that the matter would be reported to DRL.

Harold D. Thornburg
Senior Reactor Inspector

CO:III:CDF

cc: E. G. Case, DRS
R. S. Boyd, DRL (2)
S. Levine, DRL
D. [illegible] Skovholt, DRL (2)
L. K[illegible], Jr., CO:HQ
RLO [illegible]

DIVISION

ATOMIC POWER EQUIPMENT DEPARTMENT

July 29, 1970

Mr. R. Boyd
Assistant Director, Licensing
USAEC
Washington, D. C. 20545

SUBJECT: SAFETY SYSTEM RELAY FAILURES

At a recent meeting with some of your technical staff a request was made to provide information on reported relay failures. Following is a description of the failures, evaluation of the cause and corrective action taken. I trust this will fulfill the request.

I. Description of Failure

In April of this year our Nuclear Instrumentation Department (NID) was informed that three [illegible] safety system logic AC relays had failed to open when de-energized. It was further reported that one relay operated normally after the [illegible] was operated manually. The relay was removed from the panel and examined. Spring tension appeared normal and all parts appeared clean upon disassembly. Residual magnetism caused by a DC fault was suspected as a possible failure mechanism, but no such fault could be found.

II. Evaluation of Cause

One of the relays was returned to the vendor for further examination. The vendor discovered that portions of the molded plastic contact carrier were chipped and the conclusion was reached that the failure mechanism was due to misalignment resulting from the carrier (armature) not being properly guided. All sites were instructed to inspect and replace any chipped carrier guides. At the same time, the vendor initiated a design improvement program to find a stronger guide material and to reduce the shipping damage by improved packaging.

Continued testing at NID and the vendor revealed that the cause of sticking was not the carrier guides, but rather the paint on the pole piece which adhered to the steel armature plate of the energized relay! To prove this mechanism, 29 AC relays and 32 DC relays had the paint removed from the pole piece and replaced with a thin teflon coating. Twenty-nine (29) additional AC relays and 32 DC relays were used as received from the vendor. All 122 relays were mounted in panels similar to those in which the reported failures occurred and were energized at rated voltage for a period of 48 hours, de-energized and observed for proper operation. Meanwhile, the vendor was performing a similar test using clamps to provide [illegible] pressure between the armatures and the pole pieces. Five relays were [illegible] and 10 had teflon applied to the armature.

8306230406 2431

The results of the tests are shown in Table 1 (vendor results in parenthesis) and support the conclusion that the mechanism of failure is adherence of the paint on the pole piece to the armature plate while the relay is energized. The fact that the DC relays did not stick was thought to be due to their having a lower operating temperature (no eddy current losses).

TABLE I

Relay Type	Quantity	Number Stuck
DC	32	0
DC-Treated	32	0
AC	29 (5)	7 (4)
AC-Treated	29 (10)	0 (0)

The seven inoperative relays were manually opened and re-energized 12 hours to determine if heat curing the paint might be a possible curb against recurrance of the failure. All seven operated correctly, at the end of 12 hours (as did the other 112). On the basis of these results and the recommendation of the vendor all reactor sites with MID-supplied relays of the same type and vendor were instructed to energize the relays for 48 hours unless it could be positively established that a particular relay had been energized for that period or longer. In the latter case, the relay was exempt from the 48 hour run if it could further be proven to have operated properly upon being de-energized. In addition, all MID-equipped sites were instructed to de-energize the normally energized relays once every 24 hours for a week following the 48 hour run. A similar instruction was issued to MID Manufacturing for relays in the shop.

In June, word was received from one of the overseas sites that relays were still sticking after five cycles of operation.

III. Corrective Action

Discussions between MID and the vendor resulted in the conclusion that the paint was most likely thermoplastic and the only solutions to the problem were to either remove the paint from the pole piece or to coat the armature with a material to which the paint would not adhere. The vendor recommended a teflon paint which had been tested and proved satisfactory. When requested to provide proof that the teflon paint would last for the life of the relay, the vendor demurred. The material was too new to have real time life data and the relay life was too long to allow Arrhenius curves to be generated since the necessary extrapolation would not be defensible.

Further investigation by the vendor revealed that relays made by others used the same pole piece material, uncoated, met MIL-C-2212, and had not experienced any corrosion difficulties. Also, another relay type made by the vendor of the problem relay was using the same pole piece material uncoated.

On the basis of this information, NID and the vendor decided to remove the paint from the face of the pole pieces for relays in the field, in NID's shop and in the vendor's shop. The vendor will leave the pole face unpainted for future production. A Field Memo was issued by NID to all NID-supplied sites instructing in the paint removal process, precautions to be observed and tests to be run following reassembly.

The vendor reported on July 1, 1970 on the results of a corrosion test on a relay in which a pole piece with an uncoated face was submerged in salt water for a period long enough to build up a corrosion layer. The pole piece was reassembled into its relay and tests were run which gave no indication of degradation of performance. The vendor was requested to devise and run a test which would prove that unremoved paint from surfaces other than the face of the pole piece would not migrate to the face and cause sticking. It is felt that since only a small percentage of relays with paint on the pole face stuck in the field and in the tests described above then it most likely required an optimum thickness to provide sufficient adherence. The small amount which might migrate to the face is highly unlikely to be such an amount and, further, if the paint has sufficient strength to bond it most likely is too viscous to run. Results of these tests will be made available to you as soon as they are available.

IV. Conclusions

The relay in question has been manufactured and used for 30 years without problems and with a record of high reliability. For this reason, it was chosen for this critical application. Discussions with the vendor indicate that prior to NID's purchase of the relays which failed, the vendor moved his manufacturing plant and was in the process of training new personnel. This change in personnel and lack of control of paint thickness resulted in the failures.

I feel the steps taken as described above in paragraph III, plus increased testing and surveillance by NID Quality Control adequately preclude recurrance of this failure. If I can be of further assistance in this matter, please let me know.

Sincerely,

I. F. STUART, Manager
Licensing Unit
M/C 632

IFS:jb

cc: S. Levy
A. P. Bray
J. Barnard
H. Hendon

ROE 71 16

INSTANCES OF RELAY FAILURES IN REACTOR PROTECTIVE SYSTEMS

Summary

Nine instances of RELAY FAILURES IN THE MONITORING AND REACTOR PROTECTIVE SYSTEMS OF REACTORS are described in this report. Although the significance of any individual relay failure depends on the particular circumstances, the proper operation of most of the control, protective, and engineered safety feature systems for nuclear power plants depends on the successful functioning of relays. Relay failures of the types illustrated by the occurrences reported here could, under different circumstances, have significant adverse effects on plant safety. None of these occurrences resulted in damage to the reactor nor in radiation exposure of any individual.

Circumstances

A. During a period of about two months during preoperational testing of a power reactor, there were four failures of relays in the Reactor Protection System or the Containment Isolation System. In each instance, the relays that had been designed to open when de-energized failed to drop out on loss of power. These relays were all of the same general type, and supplied by the same manufacturer. There are approximately 400 of them in this plant. After investigation, the manufacturer directed that all relays be inspected for misalignment and chipped or broken self-aligning tabs, which were thought to be the cause of the malfunctions.

A few days after the memorandum calling for this inspection was issued, a new relay, which had been installed to replace one of those mentioned in the previous paragraph, failed to drop out when its coil was de-energized. It was evident that this relay was not misaligned, and since there was no obvious reason for the failure, it was returned to the factory for more extensive tests.

Further investigation disclosed that the relay malfunction was due to heat bonding of the armature to the upper (contact end) pole piece. The bonding agent was a black chromate primer which had been applied to the pole pieces as a corrosion inhibitor. Evidently, during production of some of these relays, the primer had not been fully cured. As a result of this lack of curing and the buildup of primer between laminations, the internal heat generation during initial extended energizing of the relays in the field for periods of approximately 12 hours caused the armature to bond to the pole piece.

Field instructions were issued stating that the chromate primer was to be mechanically removed from the pole piece faces. The field memorandum

also specified additional testing of the relays in their finally installed condition, following removal of the primer. The memorandum was sent not only to the operator of the reactor involved in this instance, but also to operators of three other reactors that might have received similar relays from the manufacturer.

B. During preventive maintenance on the plant protective system at a research reactor, one of the scram relays was replaced because its contacts appeared to be dirty and pitted. During subsequent tests before reactor operation, when the manual scram button on the console was depressed, the control rods did not drop.

The trouble was traced to the newly installed relay. An internal short circuit was found that shunted the console scram buttons, thus nullifying the manual scram action. All relays at this facility had been tested on a relay checker prior to being placed into service, but the checking instrument did not include provision for testing for internal short-circuits. All new relays are now checked for this defect when they are received from a supplier.

C. While manually withdrawing a control rod at a power reactor, the operator observed that the rod continued to move out for several seconds after the selector switch was moved to another rod. The same occurrence was observed several times during tests of rod insertion and withdrawal. Current is supplied to the rod drive through the contacts of a relay in the rod control circuit.

The armature spring that opens the relay contacts was found to be weak. Tightening of the spring resolved the problem.

D. During a routine shutdown of a research reactor, all the rods were being driven in by operation of a gang switch. When the rods were about six inches from full insertion, shim rod #1 suddenly stopped moving. The operator, thinking that the rod had possibly jammed, turned the gang switch to the neutral position, and the stopped rod started moving out. The operator then returned the gang switch to the insert position and shim rod #1 stopped moving outward but still did not insert. By rapidly turning the gang switch from neutral to insert, the operator was able to accomplish full insertion of all the rods, including shim rod #1. Subsequent investigation showed that a loose armature spring on a relay was the cause of this situation.

At this facility, the direction of rotation of each of the rod drive motors depends upon which of two relays in the rod drive circuit is energized.

The armature spring of the withdraw relay of shim rod #1 drive circuit had come loose, thus permitting the relay contacts to remain closed. With the gang switch in the insert position the rod drive motor stopped

because it had two simultaneous signals, one to insert and the other to withdraw. When the gang switch was turned to its neutral position, removing the insert signal, the rod was free to withdraw. Evidently, when the operator rapidly turned the gang switch from neutral to insert, he energized the insert relay and the vibration of its contacts closing caused the loose armature spring of the withdraw relay to realign itself to open the withdraw relay contacts and permit the rod drive motor to energize in the insert direction. Replacement of the faulty withdraw relay corrected the problem.

In order to increase reliability, additional relays were inserted in series with the existing control relays. The springs on both relays in series would have to fail at the same time in order to cause the same situation to recur. Maintenance procedures were changed so that relays will be replaced, checked and visually inspected for proper operation every six months.

E. During the daily checkout of a pulsed research reactor, it was observed that the transient rod did not drop consistently upon a scram signal. A relay in the control power circuit to the air solenoid for the transient rod was found to stick in the energized position intermittently. With the relay stuck, the solenoid is energized, and air pressure is applied to the transient rod piston preventing dropping of the transient rod until the power supply is shut off. It could not be determined whether the cause of the intermittent failure was residual magnetism in the relay armature or sticking contacts. The relay was replaced, and the scram circuitry for the transient rod performed normally.

F. A pulsed research reactor had been operated for about 8 hours at a constant power level, with the pulse rod withdrawn and the pulse rod "UP" button depressed by hold-in power on its relay coil. The pulse rod had performed properly on scram tests prior to this run. At the conclusion of the run, when the manual scram bar was depressed, the "UP" button on the pulse rod failed to release. As a result the pulse rod did not drop, although the other two rods scrammed properly and shut the reactor down. The pulse rod dropped when the "DOWN" button was depressed but since the "UP" button was still depressed, the rod immediately withdrew upon release of the "DOWN" button. Repeated action of the "DOWN" button produced the same results. Finally, when the "DOWN" button was depressed for an estimated 15 to 20 seconds the "UP" button was released and the rod dropped.

The "UP" button on the pulse rod is held in by a holding coil. Current to the coil is supplied by the scram circuit and the current was apparently interrupted satisfactorily since the associated light operated correctly to indicate rod scram circuit action. The investigators concluded that the sticking of the "UP" button may have been caused either by mechanical binding of the switch or by a residual magnetic flux in the electromagnet core due to hysteresis. Since the button released some

seconds after current collapse, it was judged that the second [illegible] was the most likely. The switch and coil assembly was disassembled, cleaned and reassembled and no obvious defect was observed. Further testing, after reinstallation of the assembly, failed to reproduce [illegible] previously observed. Operating procedures were issued to instruct the operator to turn off the Reactor Key or Reactor Power immediately should this situation recur.

A few weeks later, a similar situation did occur. The assembly was again removed and tested for residual magnetism. The coil and plunger were observed to exhibit some magnetism, which was eliminated by a degaussing coil. Operation was resumed, with the concurrence of the Reactor Safety Committee, after a replacement switch was installed. [illegible] testing of the old switch on a mock-up test circuit failed to reproduce the effect following degaussing.

G. During checkout prior to startup of a research reactor, it was found that none of the automatic scram circuits could be reset. Investigation revealed that one of the six scram reset switches, all of which must be in the closed position in order to reset the scram system, was open, thus interrupting the common return from all six of the automatic scram relays to the power supply for the rod magnets. The defective switch was replaced and the scram system was reset.

During the investigation of the cause of the inability of the scram system to reset, analysis of the circuit revealed that the magnetic and automatic shutdown circuit was not protected from a single failure in the scram relay power supply for the six automatic scram relays. One or more of these six relays must be energized in order to interrupt the current to the magnets in the control rod drives (by de-energizing the normally closed master scram relay in the circuit to the magnet power supply). These individual automatic scram relays would not be energized in the event of a failure of any component in the relay power supply, if such failure caused the power supply voltage to drop significantly. The normally closed, series-wired contacts in the vital scram bus remain closed so long as the automatic shutdown relays are de-energized. To correct this condition, a new relay has been added to the circuit, which is energized by the scram relay power supply via a voltage divider network. One set of contacts on this new relay is used to interrupt the magnet power to the control rods in the event of a failure of the scram relay power supply or one of the scram reset switches. Another set of contacts is used for an indicator light which indicates that the relay is energized. A similar problem in the reactor protection-system at another research reactor was reported in ROE: 69 16, dated June 13, 1969.

H. At a sodium-cooled reactor a leak detector is provided to trip the auxiliary primary coolant system pump if sodium leakage is detected. During the performance of monthly tests of the leak detectors, the leak detector trip contacts in the safety chassis were jumpered to prevent tripping of the pump each time a detector was tested. During subsequent

removal of the jumper, one end was inadvertently grounded resulting in high current. The control circuit fuse opened, was immediately replaced and the detector was returned to service.

A month later, during the monthly leak detector testing, the pump failed to trip when a leak was simulated by shorting across the detector output. Investigation disclosed that the leak detector relay contacts in the pump control circuit had been welded together, evidently as a result of the maintenance error the previous month.

I. The signals from the stack effluent sensors, at a power reactor, feed into indicators, equipped with containment isolation trip contacts, of the type sometimes referred to as meter-relays. In meter-relays, the indicator needle moves upscale until it contacts an internal trip contact, at which point the trip is initiated. The indicator cover is sealed by a sponge rubber gasket.

In this instance, the gasket evidently had age-hardened, dried out and cracked into pieces. One small piece of gasket material dropped into one of the indicator needle mechanisms and prevented it from going upscale (the containment isolation would still have been initiated, if required, by redundant trip units). The operator discovered the problem during the daily trip test of the system. Other meters of the same design were also found to have loose pieces of gasket. The gaskets on all the meters were replaced with a more resilient material of a guaranteed longer life.