LICENSEE EVENT REPORT (LER)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
DIABLO CANYON UNIT 1	0 5 0 0 0 2 7 5	1 OF 14

TITLE (4) MEDIUM VOLTAGE CABLE FAILURES

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MON	DAY	YR	YR	SEQUENTIAL NUMBER	REVISION NUMBER	MON	DAY	YR	FACILITY NAMES	DOCKET NUMBER (8)
10	29	89	93	- 0 0 5 -	0 0	04	23	93	DIABLO CANYON UNIT 2	0 5 0 0 0 3 2 3
										0 5 0 0 0

OPERATING MODE (9)	1
POWER LEVEL (10)	1 0 0

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR: (11)

__X__ 10 CFR __VOLUNTARY__
____ OTHER - _____
(Specify in Abstract below and in text, NRC Form 366A)

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER AREA CODE	TELEPHONE NUMBER
DAVID P. SISK, SENIOR REGULATORY COMPLIANCE ENGINEER	805	545-4420

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS		CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	
B	E A	C B L	0 0 4 0	N		X	E B	C B L	0 0 4 0	N	

SUPPLEMENTAL REPORT EXPECTED (14)		EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
|X| YES (if yes, complete EXPECTED SUBMISSION DATE)	| | NO		08	01	93

ABSTRACT (16)

This voluntary LER is being submitted for information only purposes as described in Item 19 of Supplement 1 to NUREG-1022.

Diablo Canyon has experienced three 4kV and two 12kV circuit underground cable failures. The cables were manufactured by Okonite and were installed in 1973 and 1974.

Laboratory analyses have established that the 12kV cable failure mechanism is chemical attack. The cause of the 4kV cable failures is still under investigation; however, laboratory analysis has also established that the contaminants found in the 12kV cable jacket and shield are not present in the 4kV cables. PG&E believes that the 4kV and 12kV cable failures were caused by different mechanisms.

Final corrective actions will be identified following completion of the root cause investigation.

I. Plant Conditions

Units 1 and 2 have been in various modes and at various power levels.

II. Description of Event

A. Summary:

Diablo Canyon Power Plant (DCPP) has experienced three 4kV and two 12kV circuit cable (EA)(CBL) failures. These failures have occurred only in underground duct bank conduits (FA)(DUCT)(CND) between the turbine building (NM) and the intake structure (NN) (see Figure 1). Both 12kV cable failures occurred on Unit 1 between the first pull box outside the turbine building and the next pull box toward the discharge structure elevation.

The subject cables were manufactured by Okonite in 1972, and are insulated with black ethylene-propylene-rubber (EPR) and jacketed with neoprene. The cables were installed at DCPP in 1973 and 1974. The cable circuits were then energized intermittently until 1984, when the circuits were then placed into service.

Laboratory analyses have established that the 12kV cable failure mechanism was chemical attack. The cause of the 4kV cable failures is still under investigation; however, laboratory analysis has also established that the contaminants found in the 12kV cable jacket and shield are not present in the 4kV cables.

B. Background:

Cable Construction

The 4kV cables are rated for up to 5kV applications and the 12kV cables are rated for up to 15kV applications.

The cable construction is similar for both the 4kV and 12kV cables. The cables are a shielded single-conductor cable design and are constructed in concentric layers (see Figure 2). There are four cable layers of interest for this LER: (1) the insulation (EA)(CBL)(INS) layer, which is approximately 115 mils of black EPR for the 4kV cables and approximately 220 mils of black EPR for the 12kV cables; (2) the tinned copper shield tape, which acts to equalize the electrical stress; (3) the wax coated synthetic binder tape, which holds the copper shield against the cable, thereby allowing the outer jacket to be extruded over the cable during manufacture; and (4) the outside layer, which is a neoprene jacket. The function of the outer neoprene jacket is to protect the cable during installation (impact and abrasion resistance) and to act as a physical barrier between the

outside environment and the shield once the cable is installed. The cable jackets are not bonded to the cable shield or insulation layers.

Duct Bank Construction

The 4kV feeders consist of three separate single-conductor cables (one for each phase), routed in a single conduit (one circuit). The 12kV motor-driven circulating water pump (CWP) (KE)(MO)(P) feeders consist of six separate single-conductor cables (two for each phase), routed as two separate three phase circuits in two single side-by-side conduits (two circuits).

The subject cables are routed in two separate sets of duct bank conduits, one for each unit, between the turbine building and the intake structure. Concrete vaults are located at various intervals to serve as pull boxes for the circuits. These duct bank conduits are directly buried in sand and are covered for their entire length by a six-inch thick concrete cap. The duct bank conduits include 12kV, 4kV, and 480V (CBL4) power cables, 120V ac control cables (EF)(CBL3), 125V dc control cables (EJ)(CBL3), and instrument cables (EF)(CBL1).

The pull boxes immediately outside of the turbine building have drains (DRN), which are routed to common sump vaults (manholes) (FA)(PBX) for Units 1 and 2. These manholes are equipped with automatic submersible Class II sump pumps (PBX)(P).

The Unit 1 and Unit 2 trenches are similar, except that the Unit 1 duct bank rises to cross over the circulating water discharge tunnel and then slopes downhill towards the intake structure. This design makes the Unit 1 section of cable conduits near the turbine building susceptible to submergence if the pull box sump pumps are not functional and if the water within the pull boxes rises above the conduit openings.

Cable Testing

In accordance with applicable industry standards, DCPP performs direct-current, high-potential testing (hi-pot testing) as a maintenance activity each refueling outage. Normal practice for hi-pot testing of DCPP 4kV motors (MO) is to hi-pot the motors from the switchgear (SWGR) end of the circuit, through associated cables and motor terminations. The normal hi-pot test voltage level used at DCPP for 4kV motors is 10.5 kV dc.

The 12kV motors, due to hi-pot test equipment limitations, are hi-pot tested locally at the motor with the cables disconnected. The cables are hi-pot tested separately from the motor. The maximum voltage level used for the in-service 12kV cables is 30 kV dc.

C. Event Description:

4kV Cable Failures

On October 29, 1989, ground current alarms (EA)(GI)(IA) associated with the Unit 2 Auxiliary Saltwater (ASW) Pump (BA)(MO)(P) 2-2 annunciated twice and immediately cleared both times. The pump was removed from service. A ground was found on one cable that runs between the turbine building pull box and the first pull box at the discharge structure. Cables in this pull box were found submerged in water. The faulted portion and a similar length of the other two cables for this circuit were removed, the water was pumped out of the pull box, a mandrel was passed through the conduit several times to remove standing water, and new cables were installed. Visual examination found no obvious physical defects in the removed cables. Cable samples were sent to Okonite and to the PG&E Technical and Ecological Services (TES) laboratory for examination and testing. The cable testing determined that the cable met or exceeded the original mechanical and electrical stress limits set forth in the original purchase specification, except for some minor loss of mechanical strength of the jacket material. The testing laboratories determined the failure to be an isolated event.

On May 3, 1992, intermittent ground current alarms were received associated with Unit 1 nonsafety-related 4kV Bus D (EA)(BU). The 4kV Bus D was removed from service. The ground was determined to be located on one cable between the pull box located immediately outside of the intake structure and the Bus 14D transformer (EA)(XFMR) in the intake structure. The pull box located outside of the intake structure was found to have water inside, which was pumped out to facilitate cable replacement. Approximately 40 feet of the single faulted cable was replaced. Visual examination found no obvious physical defects in the removed cable. Cable samples were sent to Okonite and to the PG&E TES laboratory for examination and testing. The examination and testing determined that the physical properties of the insulation were normal and that the jacket properties displayed some loss of elongation which was considered normal for neoprene installed for almost 18 years. The electrical properties were normal for 18-year old cable. The testing laboratories could identify no definitive reason for the failure.

On October 31, 1992, ASW Pump 1-2 on Unit 1 was removed from service for refueling outage maintenance. As part of the procedure to return the pump to service, a motor hi-pot test was conducted. During the hi-pot test, the cable insulation developed a ground fault at approximately 6kV. Investigation determined that the fault was located on one cable between the first pull box outside the turbine building and the next pull box at the discharge structure elevation. Cables in this pull box were also found submerged in water. The

faulted portion and a similar length of the other two cables for this circuit were removed, the water was pumped out of the pull box, a mandrel was passed through the conduit several times to remove standing water, and new cables were installed. Other than at the fault point, visual examination revealed no obvious physical defects in the removed cables. Cable samples were sent to Okonite, the PG&E TES laboratory, and Cable Technologies Laboratory (CTL) for examination and testing. In February 1993, an additional sample was sent to Altran Materials for chemical analysis. Interim progress reports indicate that the electrical properties of the cable are acceptable, no firm evidence of manufacturing defects has been identified, and no indication of installation problems or abnormal operating conditions can be found. The root cause investigation for this event is in progress.

12kV Cable Failures

On February 5, 1993, Unit 1 was ramped down from 100 to 46 percent power due to a ground current alarm for CWP 1-1. While the ground alarm annunciated, smoke was reported in the 12kV switchgear room (NM)(EA)(SWGR) due to ground resistor bank heating of accumulated dust, as is expected during ground fault conditions. An Unusual Event was declared at 2156 PST due to a precautionary assistance request to an offsite agency. An immediate emergency report was made to report the declaration of an Unusual Event in accordance with 10 CFR 50.72(a)(1)(i).

Investigation determined that the ground was located on one cable between the first pull box outside the turbine building and the next pull box at the discharge structure elevation. When the cables were removed, the neoprene jacket was found to be separating from all three cables of the circuit for a distance of approximately 200 feet.

The faulted portion and a similar length of the other two cables for this circuit were removed, the water was pumped out of the pull box, a mandrel was passed through the conduit several times to remove standing water, and new cables were installed. When the new cable sections were spliced in, no visual degradation was found at the splice locations. Cable samples were sent to Okonite, the PG&E TES laboratory, and Altran Materials for comprehensive examination and testing. Interim progress reports indicate that the outer neoprene jacket had been chemically degraded and the copper shield shows evidence of corrosion. However, electrical properties of the cable are acceptable, no evidence of manufacturing defects has been identified, and no indication of an installation problem or abnormal operating conditions can be found. The root cause investigation for this event is in progress.

While removing the failed CWP 1-1 cable from the conduit, water was introduced into the conduit from the discharge structure elevation pull box in order to lubricate the cables for removal. No water came out the pull box at the turbine building end of the conduit run. Investigation determined that the six-inch acrylonitrile-butadiene styrene (ABS) conduit was broken, and that this damage had resulted from the initial attempts to remove the cable.

On March 12, 1993, intermittent ground current alarms annunciated for Unit 1 CWP 1-2. The Unit was ramped to less than 50 percent power and the pump was secured. Investigations determined that one cable was shorted to ground between the first pull box outside the turbine building and the next pull box at the discharge structure elevation. When the cables were removed, the neoprene jacket was found to be separating from all three cables of the circuit for a distance of approximately 200 feet. There was evidence (pull box water marks) that the cables had previously been submerged in water.

The faulted portion and a similar length of the other two cables for this circuit were removed, the water was pumped out of the pull box, a mandrel was passed through the conduit several times to remove standing water, and new cables were installed. When the new cable sections were spliced in, no visual degradation was found at the splice locations. Cable samples were sent to Okonite, the PG&E TES laboratory, and Altran Materials for examination and testing. Interim progress reports indicate that the outer neoprene jacket has been chemically degraded and the copper shield shows evidence of corrosion. However, electrical properties of the cable are acceptable, no evidence of manufacturing defects has been identified, and no indication of installation or abnormal operating conditions can be found. The root cause investigation for this event is in progress.

Following the March 12 event, PG&E conservatively replaced all Unit 1 non-failed medium voltage circuits between the pull boxes outside the turbine building and the next pull box at the discharge structure elevation (ASW Pump 1-1 4kV cables and the second 3-phase 12kV circuits for CWPs 1-1 and 1-2). Also, one complete circuit, between the turbine building switchgear and the motor terminations at the intake structure, of the Unit 2 12kV CWP 2-1 motor feeder circuits was replaced. The neoprene jacket on the Unit 1 12kV CWP cables showed evidence of chemical degradation, similar to that on the previously replaced Unit 1 12kV CWP circuits. Visual examination of the ASW 1-1 4kV cables and the CWP 2-1 12kV cables revealed no defects.

D. Inoperable Structures, Components, or Systems that Contributed to the Event:

SM-1 and SM-2 are the pull box drain systems and associated sump pumps for Units 1 and 2, respectively, for the pull boxes immediately

outside of the turbine building. Investigation determined that water had accumulated in the pull boxes as a result of the pull box drain systems and associated sump pumps not being functional for a period of time preceding the cable failure events.

E. Dates and Approximate Times for Major Occurrences:

1. October 29, 1989: A Unit 2 ASW Pump 2-2 4kV cable ground alarm was received.

2. May 3, 1992: A Unit 1 nonsafety-related Bus 14D 4kV cable ground alarm was received.

3. October 31, 1992: Unit 1 ASW Pump 1-2 4kV cable degradation was detected during maintenance hi-pot testing.

4. February 5, 1993: A Unit 1 nonsafety-related CWP 1-1 12kV cable ground alarm was received.

5. March 12, 1993: A Unit 1 nonsafety-related CWP 1-2 12kV cable ground alarm was received.

F. Other Systems or Secondary Functions Affected:

None.

G. Method of Discovery:

1. The four "in-service" cable failures were immediately apparent to plant operators due to ground fault alarms and indications received in the control room (NA).

2. The ASW Pump 1-2 4kV cable degradation was found during maintenance when Electrical Maintenance personnel observed that the cable failed to pass its hi-pot test.

H. Operator Actions:

For the four "in-service" events, the associated equipment was removed from service and troubleshooting activities were initiated.

I. Safety System Responses:

None.

III. Cause of the Event

A. Immediate Cause:

1. For the four "in-service" cable failures, the immediate cause was a conduction path to ground, which resulted in sufficient current to flow through the ground detection circuitry.

2. For the ASW Pump 1-2 4kV cable degradation, the immediate cause was failure of the cable to withstand the hi-pot test voltage during post-maintenance activities.

B. Root Cause:

Extensive root cause investigation has been conducted since the first cable failure in 1989. Three potential root cause hypotheses and/or contributory causes are being investigated:

1. Manufacturing

Extensive cable dissection, wafer slicing and staining, and examination have not found any evidence of insulation breakdown due to moisture in any of the failed 4kV or 12kV cables.

Based on evidence evaluated to date, PG&E believes that the failures in the 4kV and 12kV cables are not caused by manufacturing defects.

2. Installation

Cable pulling tensions for the 4kV and 12kV cables routed between the turbine building and the intake structure were evaluated. The evaluation concluded that the vendor specified pulling tension and sidewall pressure limits were not exceeded.

Based on video probe inspections and the ease of cable replacement, the duct bank is intact, except for the conduit section damaged during CWP 1-1 cable removal, which is no longer used.

3. Operating Environment

Moisture Intrusion: The cable design basis is for wet and/or dry conditions. The cable can be submerged for prolonged periods. Inquiries to other nuclear power plants did not identify any trends for medium voltage EPR insulated cable failures in similar applications. The Okonite black EPR cable is widely used in electric utility distribution systems, including PG&E (five million feet has been installed in the PG&E

distribution system for a longer period of time than the DCPP cables), and has been highly reliable in similar applications.

Chemical Attack: Laboratory chemical analysis results have established that the 12kV neoprene jacket was attacked by a chloride and/or fatty acid. High ambient temperatures accelerate the chemical related jacket degradation. PG&E has evaluated the cable operating temperature and estimated that, in the worst case, the 12kV CWP cables are operating with insulation temperatures in the range of 80 to 85°C. The 4kV cables operate at a significantly lower temperature (60 to 70°C, based on self-heating) due to loading requirements. The hypothesized method of chemical migration and degradation is by way of water that intruded into the conduits through the cable pull boxes that are located immediately outside of the turbine building; the water intrusion resulted from the inoperable sump pumps and associated pull box drainage system.

Maintenance Testing: The routine maintenance hi-pot testing of the 4kV and 12kV cables is within vendor recommended values and does not electrically overstress the cable.

Summary

PG&E has concluded that the most probable failure mechanism for the 12kV cable insulation failures is long-term chemical degradation of the neoprene jacket, probably due to chloride and/or a fatty acid, followed by corrosion of the copper shield. When the shield deteriorates, uneven electrical stresses occur, ultimately resulting in a cable ground.

PG&E believes that the 12kV cable failures occurred over an extended period of time (greater than a year). This conclusion is based on the relatively mild pH (approximately 8.5) of the liquid found beneath the neoprene jacket and the copper shield binding tape showing no evidence of high cable operating temperatures (the binding tape melts at approximately 85°C).

PG&E concludes that the failure mechanism of the 4kV cables was not chemical degradation. This conclusion is based on chemical analysis indicating: (1) lack of excess chlorine or fatty acids for the 4kV cables; and (2) much lower levels of "self-heating." Laboratory testing has determined that the 4kV cables meet or exceed the electrical stress requirements set forth in the original purchase specification. However, the root cause investigation is continuing.

Cables rated 600 volts or less experience lower electrical stress and, therefore, do not require a shield to equalize the electrical equipotential between the conductor and ground. Visual examination of

cables rated 600 volts and lower show no obvious signs of physical degradation.

IV. Analysis of the Event

The 4kV power and associated control circuits potentially affected by these cable failures are associated with the ASW pumps. The 12kV power and associated control circuits potentially affected by these cable failures are associated with the CWPs.

The ASW system has a safety-related function to remove heat from other safety-related system components during normal operation and plant shutdown via the component cooling water (CCW)(CC) system. The ASW system also provides vital cooling necessary for the engineered safeguards feature (ESF) systems to perform their functions. Each DCPP unit has two redundant ASW trains, each consisting of a full capacity ASW pump and associated piping to supply the CCW heat exchanger. The ASW pump motors are supplied by vital 4kV power. The ASW trains within a unit can be cross-tied to allow either of the ASW pumps to supply either CCW heat exchanger. In addition, both units' ASW trains can be cross-tied to add further redundancy to the system.

The motor-driven CWPs are part of the saltwater system which removes energy from the turbine exhaust steam (SG) entering the main condenser (SG)(COND) by providing cooling water to the condenser. Each unit is provided with two nonsafety-related 12kV motor-driven pumps located in the intake structure. At 100 percent unit power level, both pumps must run to support full load operation.

In all cases, DCPP has ground detection alarms that provide indication that a potential cable problem exists. Upon receipt of this alarm, troubleshooting activities will determine the location of the problem, and the situation will be remedied.

A portion of the ASW pumps control circuitry is fed from the 125V dc system, which is an ungrounded system. The occurrence of a ground in any 125V dc circuit is alarmed, but does not affect the operation of the circuit itself.

The 12kV, 4kV, and 480V systems have high-resistance grounding, which allows continued operation for a limited time in the event of a single-line-to-ground fault. Operators have received simulator training on ground fault incidents. The normal plant procedure, as demonstrated in the past failure incidents, is to declare the associated component inoperable, and then troubleshoot and repair the faulted circuit. The ground detection system, as well as additional control room indication (i.e., red/green lights associated with the motors), provide sufficient time to identify and correct a problem prior to another failure causing a portion of a mutually redundant system from becoming inoperable.

Loss of 120V ac control or low power instrument circuits does not affect the operability of any safety-related components.

The ability to operate for a limited time with a ground on the CWPs ensures that time is available to bring the plant to a stable condition where the affected pump can be removed from service and the circuit repaired without challenging any safety systems.

In summary, since both ASW trains are electrically separate and independent, a cable fault in one ASW train would not have prevented the other train from performing its safety-related function. Furthermore, since the failures have been separated in time, and diagnostic examinations of the failed cables and additional "non-failed" cables show no evidence that additional failures are imminent, the probability of a design basis accident followed by a random 4kV cable failure is considered to be very low. In addition, as discussed above, the ASW system can be cross-connected to the ASW system of the other unit. This helps maintain the ability to perform the ASW system safety function of the unit with a design basis accident. Thus, the health and safety of the public were not affected by this event.

V. Corrective Actions

A. Immediate Corrective Actions:

1. All Unit 1 ASW pump and CWP cables between the turbine building and the discharge structure elevation pull boxes have been replaced.

2. PG&E TES, Okonite, and two independent laboratories were sent 4kV and 12kV cable samples for chemical, electrical, and mechanical examination and testing.

3. After the event on March 12, 1993, one circuit of the 12kV CWP 2-1 motor feeder circuit was replaced from the switchgear to the intake structure to verify the condition of the Unit 2 12kV cables. Visual examination revealed no defects in the removed cable. Unit 2 has not experienced any 12kV CWP cable failures.

4. The pull boxes were pumped dry and the sump pumps for the first outside pull boxes have been overhauled and returned to service.

B. Corrective Actions to Prevent Recurrence:

1. Hi-pot testing will continue for the 4kV and 12kV affected circuits during each refueling outage.

2. A formal preventive maintenance program has been established for the sump pumps and drains immediately outside the turbine building.

3. Final laboratory reports on the chemical analyses and electrical testing are scheduled for completion in May 1993 and the results of these evaluations, including any further corrective actions, will be reported in a supplemental LER.

VI. Additional Information

A. Failed Components:

Component: Medium Voltage Cable
Manufacturer: Okonite
Model Number: 5kV & 15kV Rated, w/ 133 percent insulation
Type: EPR Black Insulation w/ neoprene jacket.

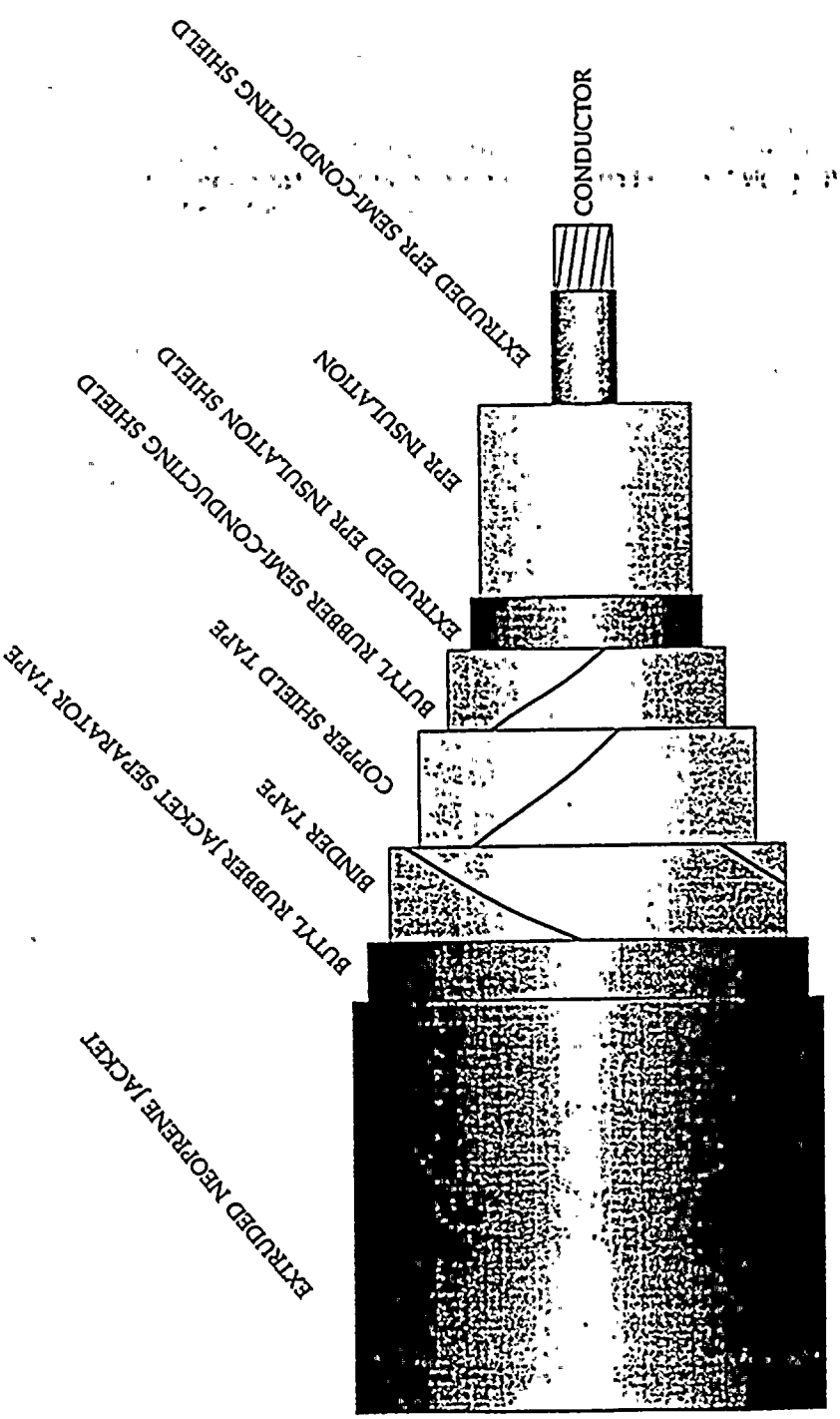
B. Previous LERs on Similar Problems:

None.

C. NRC Information Notice (IN) 92-81, "Potential Deficiency of Electrical Cables with Bonded Hypalon Jackets," dated December 11, 1992

As part of the root cause investigation, IN 92-81 was reviewed for applicability to the cable failures at DCPP. IN 92-81 was determined to not be applicable to the DCPP cable failures since neither the 4kV nor the 12kV cable jackets are bonded to the cable shield/insulation.

FIGURE 2 : DESIGN OF 4KV AND 12KV OKONITE CABLES



Construction of Okonite 5kV and 15 kV Cables Used at DCPP

from: Altran Materials Engineering
March, 1993
- NOT TO SCALE -

Figure 1: Site Overview of Conduit Trench for Units 1 & 2