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Underground Medium Voltage Cable Failures and Status of Testing

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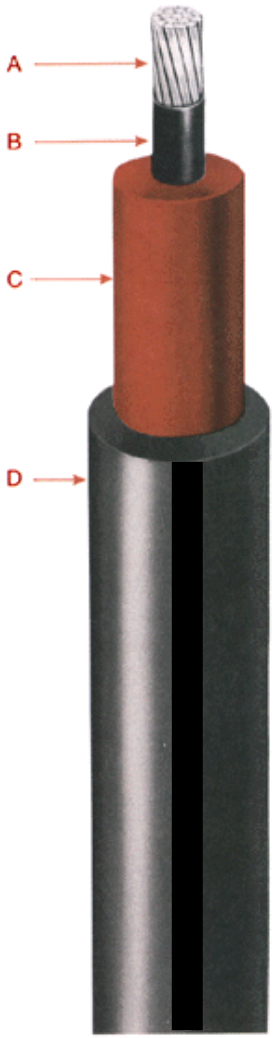
Nuclear Plant MV Cable Configurations

Multiple types of cable have been used:

- Single conductor, triplexed, and 3 conductor cable
- All have conductor shields; most shields are extruded semi-conducting polymer
- Insulation is XLPE or EPR
  - Three types of EPR in use: black, brown, red

    Each has different electrical deterioration characteristics
- Insulation shield always used on XLPE
- Insulation shield sometimes used on 4-5kV EPR; generally used on 8 kV; 15-kV construction has shield
- Insulation shield is important to provide uniform ground plane for electrical testing

Unshielded Cable



A. Conductor

B. Conductor Shield

C. Insulation (red EPR)

D. Jacket

Cable with Insulation Shields of Semi-conducting Polymer and Copper Tape

A. Conductor

B. Conductor Shield

C. Insulation (red EPR)

D. Insulation Shield

E. Copper tape shield

F. Jacket

NEI Underground MV Cable Survey Results

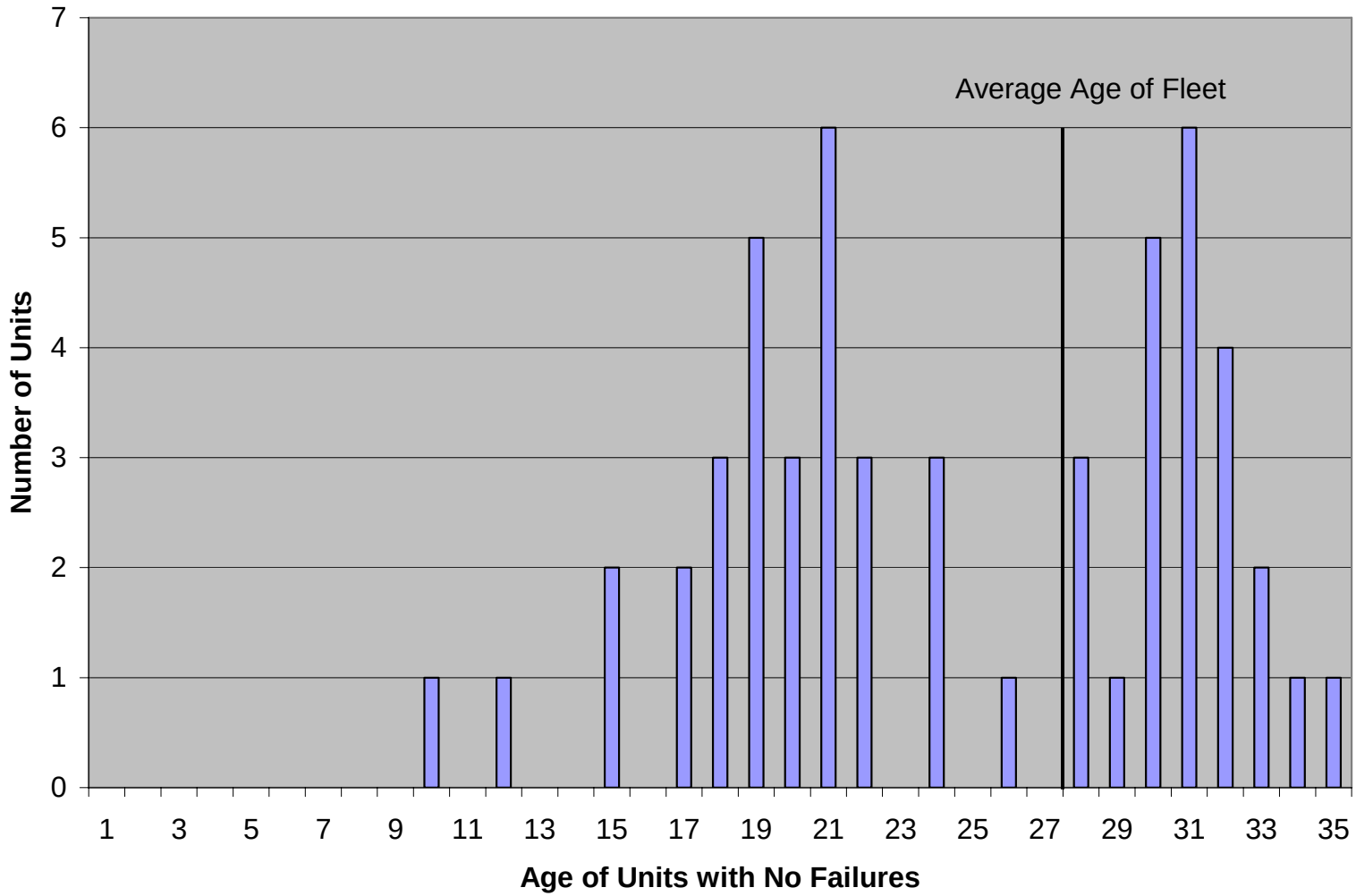
- All 81 responding units reported some underground cable.
- 75 units (80%) reported use of underground conduits
- 76 units (94%) reported underground ducts
- 23 units (28%) reported some direct buried circuits
- 21 units (28%) reported having enclosed trenches with cables supported within the trench
- Of the plants reporting underground circuits, 31 percent indicated the circuits were dry and 69 percent indicated that the circuits were wet

Originally Installed Cable Types

Insulation	Units	Percent of Reporting Units
Butyl Rubber	4	5
EPDM	1	1
Black EPR	48	65
Brown EPR	20	27
Red EPR	31	42
XLPE	23	31

Note: Some units reported more than one type of cable in use.

Age and Number of Units with No Wet Underground MV Cable Failures (67% of Units)



Failures of Wet MV Underground Cable

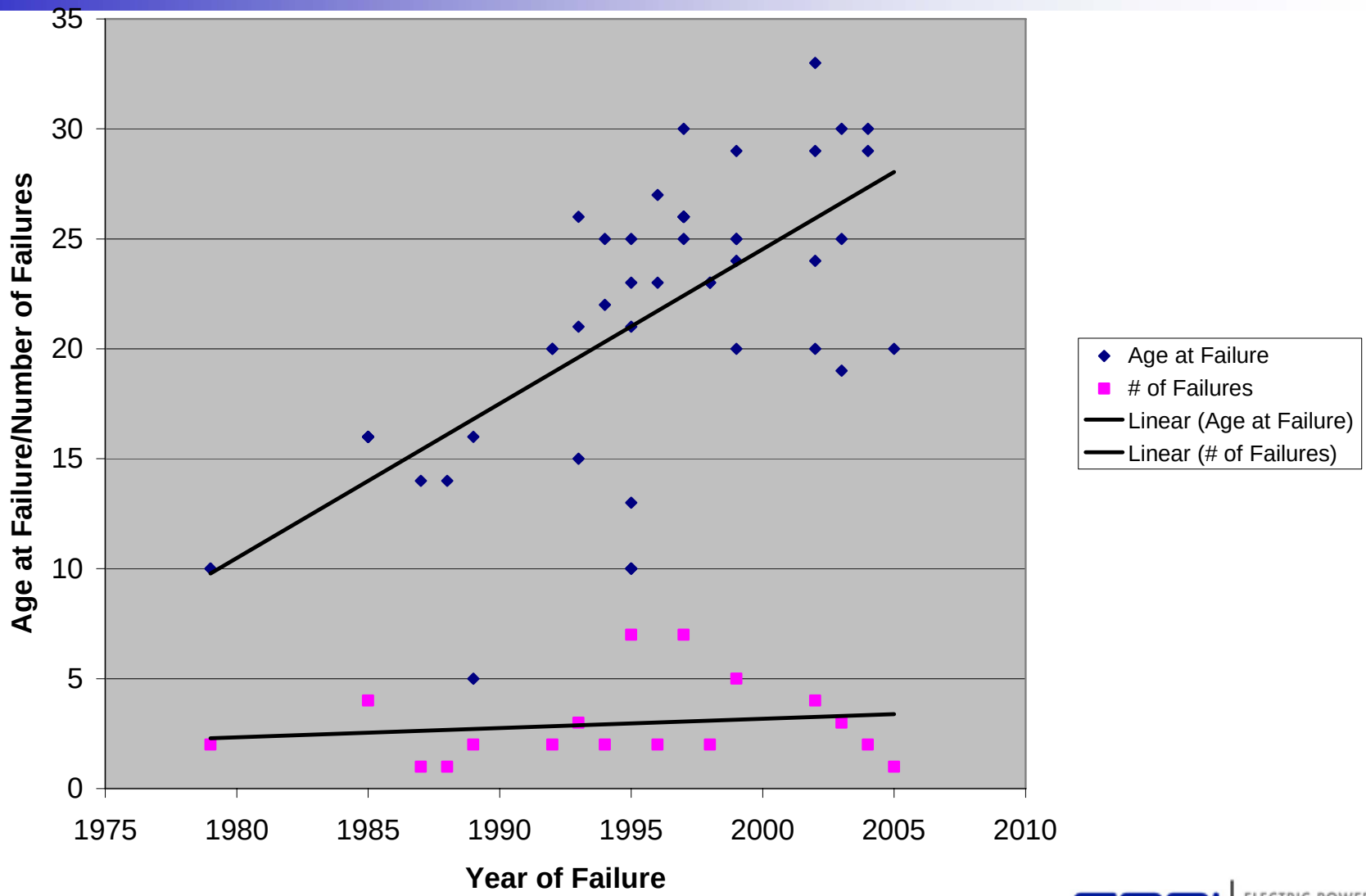
- 21 units (15 plants) experienced failures of medium-voltage, wet, or possibly wet underground cable.
- A total of 50 failures occurred that were safety-related, fire protection, off-site power, station blackout, or operationally important

Failures Per Plant Reporting Failures

Number of Failures	Number of Plants with Failures	Number of Failures
1	4	4
2	5	10
3	1	3
4	2	8
5	1	5
10	2	20

5 of 15 plants account for 66% of failures

Age at Time of Failure Vs. Number of Failures



Replacement Cable Insulation Materials

Insulation	Units
EPR (Type not indicated)	2
EPR-Black	3
EPR-Brown	5
EPR-Red	25
TR-XLPE	4

Tests

- On-line: Partial Discharge (PD) Assessment
- Off-line: Tan Delta, PD, high-potential testing

- DC high-potential testing highly discouraged for XLPE insulation (does not detect degradation and does result in somewhat earlier failure near end of life)
- DC high-potential not recommended for EPR (little information provided about overall condition of cable, may cause damage near end of life)

Test Types

- ac high potential test – A withstand test that can identify local defects (causes them to fail)

- All of these tests are potentially damaging to a deteriorated cable and could cause failure.
- If tests are to be performed:
  - They should be performed early in an outage
  - Spare cable should be available
  - Repair procedures should be prepared
  - Personnel capable of pulling and terminating cables should be available

Recommendations

1. Perform a formal failure evaluation when MV cable fails.
   - Determine if failure is from a defect or from wet aging.
   - If wet aging, identify like circuits and test or replace.
2. Verify that modern replacement cable exists (industry generally uses red EPR)
3. Verify that personnel or vendor with installation capability is available should need arise.
4. Consider testing of cables that have been subject to long-term wetting for 20 or more years.

Installed and Failure Data Sources

- NEI 06-05 *Underground Medium Voltage White Paper*, Nuclear Energy Institute, April 2006
  - Describes cables used in nuclear plants, failure data, testing information. Focuses on wet cable.
- *Life Cycle Management Planning Sourcebooks: Medium Voltage (MV) Cables and Accessories (Terminations and Splices),* EPRI, Palo Alto, CA, 1013187
  - Describes cable, terminations and splices. Provides wet and dry failure experience and alternatives for planning purposes