Factory Mutual Labeled Transformers

And methods of protecting transformers

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Bio

- From Columbus, GA
- Georgia Institute of Technology
  - BSEE in 2002
  - Co-op
    - Georgia Tech Research Institute
    - Powell Electrical Manufacturing Company
- Eaton Cutler-Hammer
  - Sales Leadership Training
    - Asheville, NC
    - Houston, TX
  - Haddon-McClellan, Associates, Inc.
  - McClellan Sales
  - L-3 Levine Lectronics and Lectric

Transformer trivia

Why do transformers hum?

A Word on Ethics

At the end of the day, all we have is our integrity.

Agenda

Who is FM? When did they start labeling transformers?

Minimum requirements for FM label

Why specify the FM label?

Why NOT specify the FM label?

Alternate classifications

Resources

Questions

Who is FM?

- ➔ Factory Mutual Insurance and Loss Prevention
  - ◆ www.fmglobal.com
- ➔ Mutual Insurance Company
  - ◆ Owned wholly by its policyholders
  - ◆ Different from Stock Insurance Company, profits are:
    - Retained by the company
    - Distributed back to policyholders via
      - Dividend
      - Reduced Future Premium

Fun Facts of FM

Named “Best property insurer in the world” by Euromoney Magazine.

Non-traditional business model based on engineering analysis rather than actuarial calculations.

History of FM

1835

Zachariah Allen, Textile Mill Owner

Availability of FM Label

As far as transformers go, liquid filled transformers only

Reasons to specify FM

1. In an indoor application, some installation costs may be ***potentially*** offset.
    a. Sprinkler system
    b. Oil containment
2. Reduce required clearances from buildings, equipment.
3. If your plant is insured by FM, you ***may*** be eligible for a reduced premium.

Reasons NOT to specify FM

1. Cost
2. Limited competition

How close can I put a transformer to a building?

TABLE 8. FM Required Separation Distance Between Outdoor Liquid Insulated Transformers and Building.*

Liquid	FM Approved Transformer or Equivalent	Liquid Volume gal/(m^3)	Horizontal Distance			Vertical Distance ft/(m)
			Fire Resistant ft/(m)	Non-Combustible ft/(m)	Conbustible ft/(m)	
Less-Flammable (Approved)	Yes	N/A	3(0.9)	3(0.9)	3(0.9)	5(1.5)
	No	≤1000(3.8)	5(1.5)	5(1.5)	25(7.6)	25(7.6)
		>1000(3.8)	15(4.6)	15(4.6)	50(15.2)	50(15.2)
Mineral Oil	N/A	<500(1.9)	5(1.5)	15(4.6)	25(7.6)	25(7.6)
		500-5000(1.9-19)	15(4.6)	25(7.6)	50(15.2)	50(15.2)
		>5000(19)	25(7.6)	50(15.2)	100(30.5)	100(30.5)

How close can I put a transformer to other equipment?

TABLE 9. FM Outdoor Fluid Insulated Transformers Equipment Separation Distance.*

Liquid	FM Approved Transformer or Equivalent	Fluid Volume gal/(m^3)	Distance ft/(m)
Less-Flammable (Approved)	Yes	N/A	3(0.9)
	No	≤1000(3.8)	5(1.5)
		>1000(3.8)	25(7.6)
Mineral Oil	N/A	<500(1.9)	5(1.5)
		500-5000(1.9-19)	25(7.6)
		>5000(19)	50(15.2)

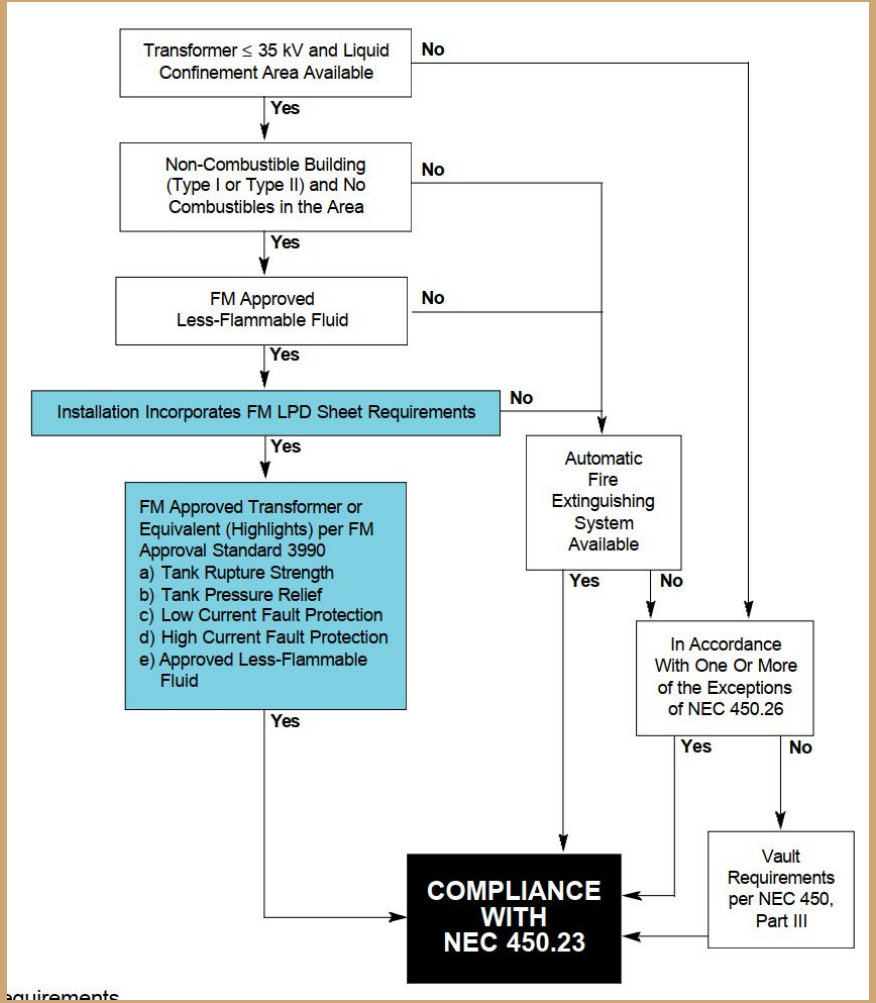
* Tables 8 and 9 are reproductions of Separation Distance Table 2a and 2b from the FM LPD.

Flow Charts

NEC 450.23 Compliance

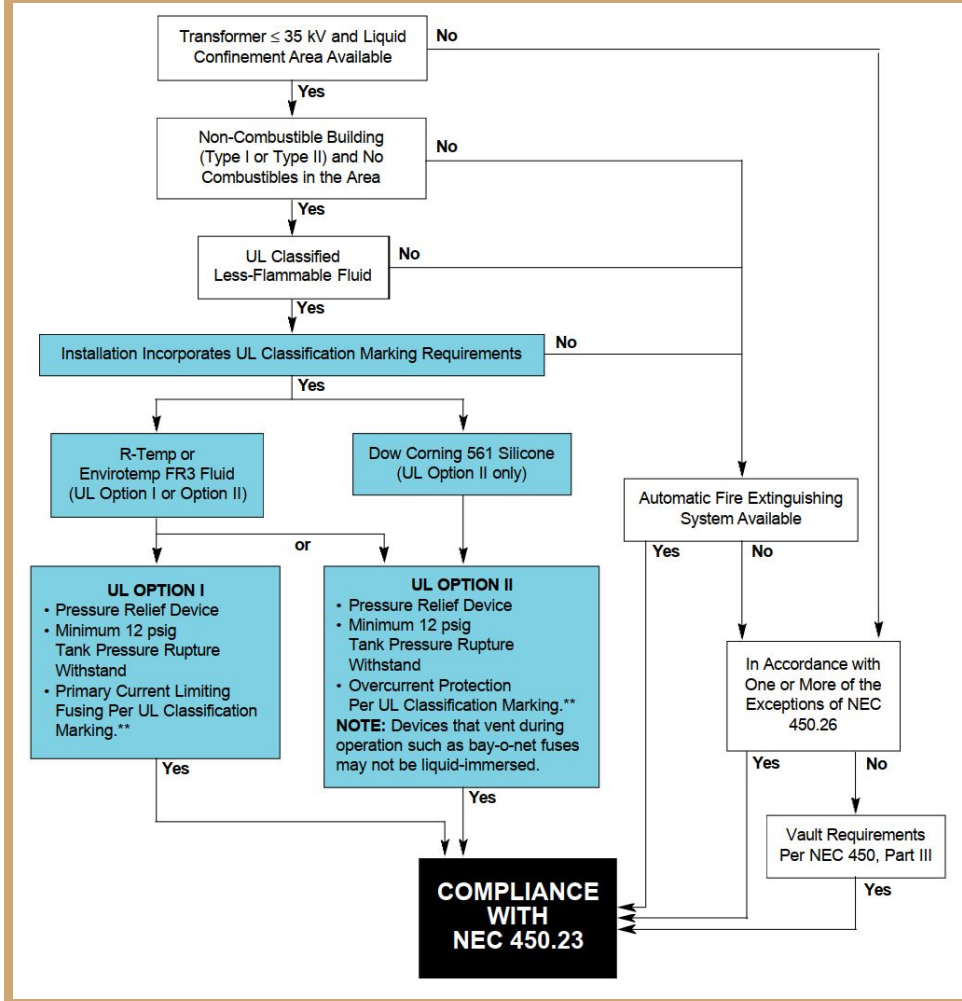
NEC 450.23 Compliance Flow Chart

Per FM
Indoor Applications



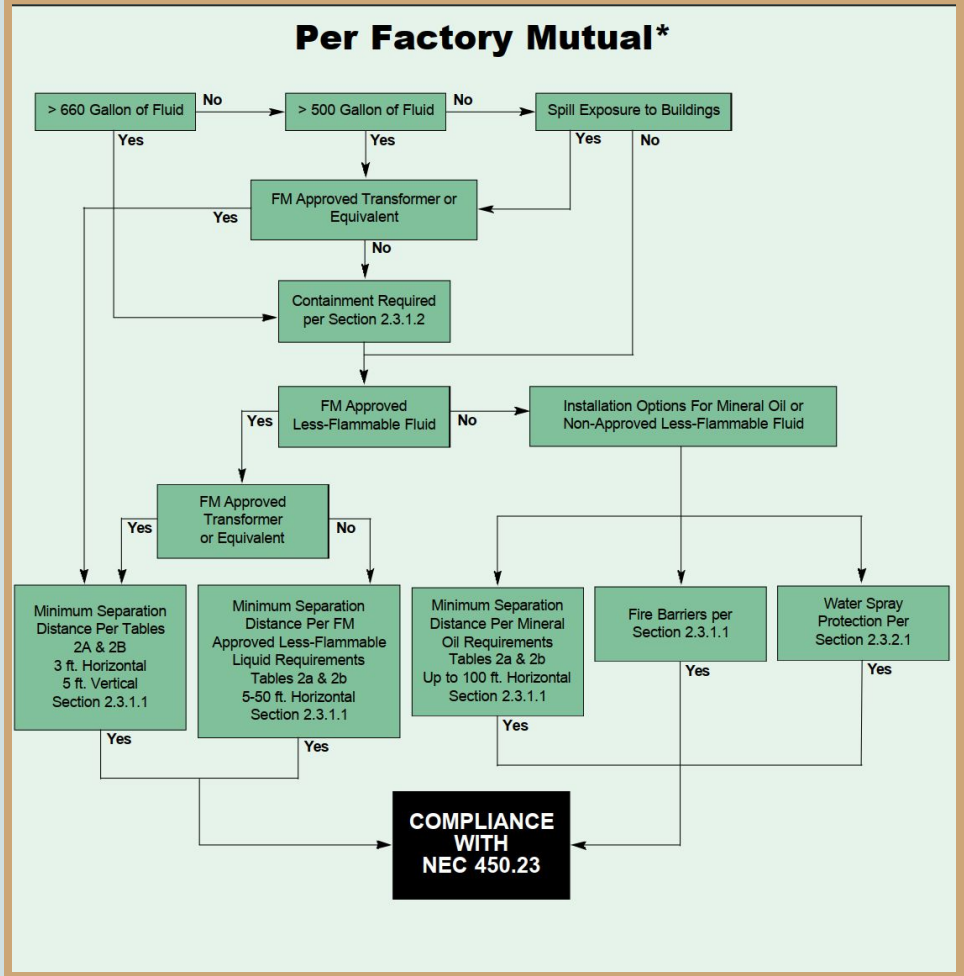
NEC 450.23 Compliance Flow Chart

Per UL
Indoor Installations



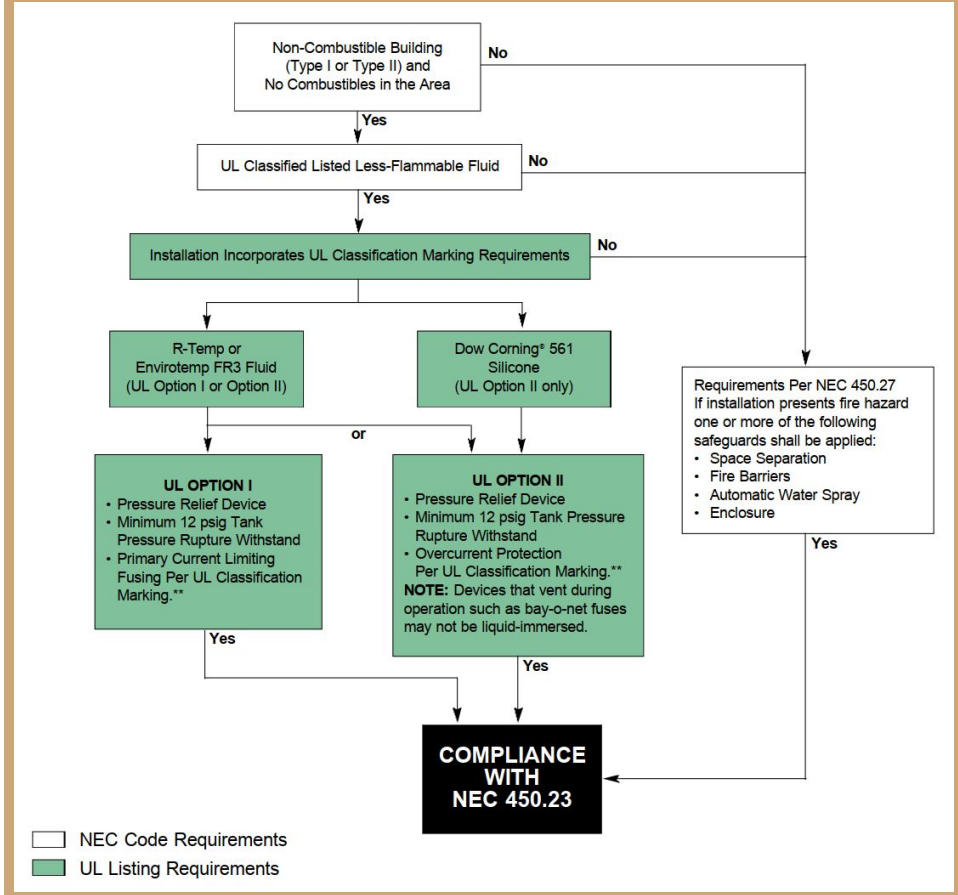
NEC 450.23 Compliance Flow Chart

Per FM
Outdoor Installations



NEC 450.23 Compliance Flow Chart

Per UL
Outdoor Applications



Marketing Material from one manufacturer

Envirotran™ FM Approved special protection transformer

Eaton's Cooper Power series Envirotran™ transformer is FM Approved and suitable for indoor locations. Factory Mutual Research Corporation's (FMRC) approval of the Envirotran transformer line makes it easy to comply with and verify compliance with Section 450.23, 2008 NEC, Less-Flammable Liquid-Filled Transformer Requirements for both indoor and outdoor locations.

Envirotran FM Approved transformers offer the user the benefit of a transformer that can be easily specified to comply with NEC, and makes FM Safety Data Sheet compliance simpler, while also providing maximum safety and flexibility for both indoor and outdoor installations.

Because the "FM Approved" logo is readily visible on the transformer and its nameplate, NEC compliance is now easily verifiable by the inspector.

Envirotran FM Approved transformers are manufactured under strict compliance with FMRC Standard 3990 and are filled with FM Approved Envirotemp™ FR3™ fluid, a fire-resistant dielectric coolant.

FM
APPROVED

Transformer Requirements

To achieve FM approval

Minimum Requirements for FM Label (FMRC3990)

1) Transformer Tank Strength
2) Pressure Relief Device
3) Filled with FM Approved less flammable fluid
4) Overcurrent protection limits let-thru current to pre-defined maximum
5) FM nameplate

Transformer Tank Strength

Per FM3990

“The transformer tank rupture strength shall be at least 15 PSI for rectangular tanks and 20 PSI for cylindrical tanks.”

Pressure Relief Device

“The transformer shall be provided with a pressure relief device to vent internal over pressures. The device must be capable of venting a specified flow rate based on the kVA as shown in Table 5 in Section 2.3.3.”

One example….

Definitely not....

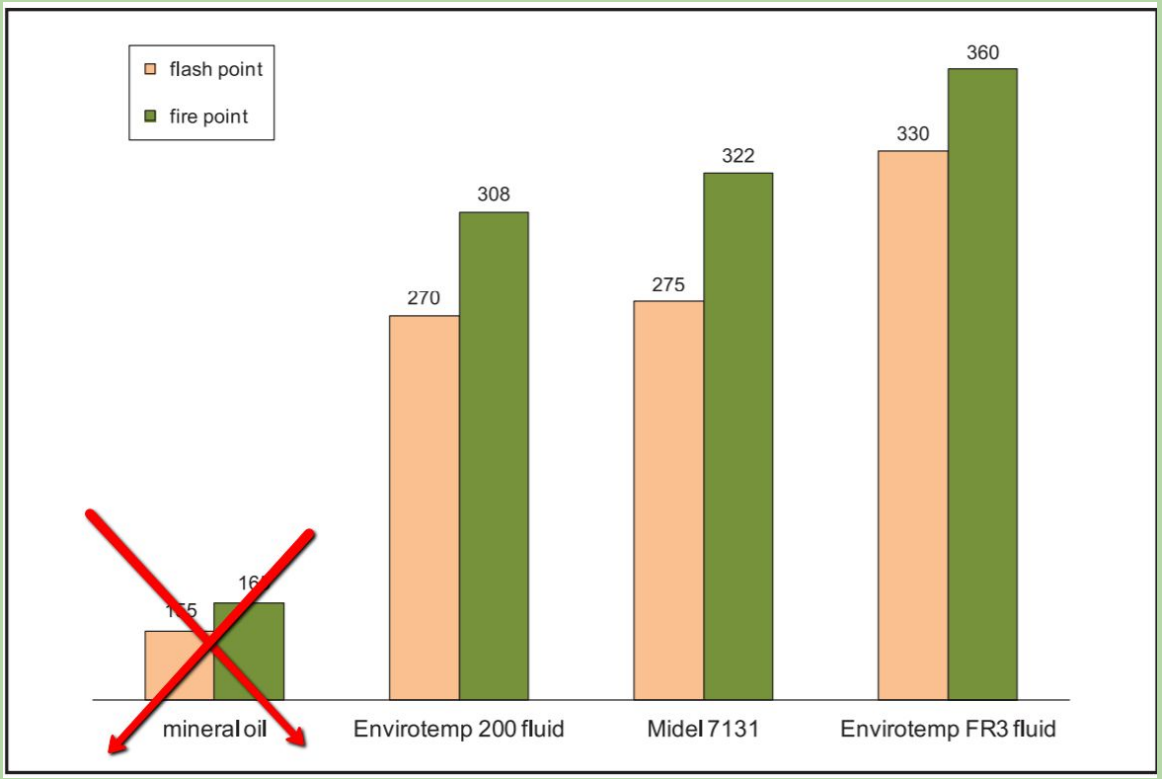
Required CFM Ratings of PRD

Table 5: FM Pressure Relief Device Required Ratings

kVA Rating 3-Phase (1-Phase)	Flow Rate SCFM @ 15psi (103 kPa)
112.5 (37.5)	35
150 (50)	50
300 (100)	100
1,000 (333)	350
2,000 (667)	700
10,000 (3,333)	5,000

Note: For kVA ratings not listed use next ***highest*** rating in table.

Dielectric Fluid



Latest Edible, Seed Based FM Fluid

PROLEC GE

VG-100® Fluid
Natural Ester-based Fluid for Transformers

Technical Data Sheet

Description

VG-100® is a dielectric fluid derived from natural esters of edible seeds, formulated using a proprietary process for use in electrical transformers – both new and retrofill. It was developed by **Prolec GE** in 2009 as an environmentally-friendly alternative to existing dielectric fluids. It is 100% natural and biodegradable, and does not contain any synthetic antioxidant, petroleum, or toxic compounds.

Table 1. Electrical, physical and chemical properties of **VG-100®** fluid

Properties	Test Method		Requirement		VG-100 fluid[3]
	ASTM	ISO/IEC	ASTM D6871[1]	IEC 62770[2]	
ELECTRICAL					
Dielectric breakdown, kV 2mm	D1816		≥ 35		>60
2.5mm		IEC 60156		≥ 35	80-98
Dissipation factor,% 25°C	D924		≤ 0.2		0.08
90°C		IEC 60247		≤ 0.05	0.011
100°C	D924		≤ 4.0		0.29
PHYSICAL					
Color	D1500	ISO 2211	L1.0		L0.5
Appearance	visual	visual	bright & clear	bright & clear	bright & clear
Relative density, g/cm³ 15°C	D1298		≤ 0.96		0.916
Density, g/cm³ 20°C		ISO 3675		1.00	0.919

Overcurrent Protection

"The primary circuit shall have overcurrent protection that limits the let-through current to a specified maximum value as shown in Table 6…"

Table 6: FM Maximum I^2t Let Through Required Ratings

kVA Rating 3-Phase(1-Phase)	Current Limiting Fusing	Other Protection
45 (15)	500,000	700,000
75 (25)	500,000	800,000
112.5 (37.5)	550,000	900,000
150 (50)	600,000	1,000,000
225 (75)	650,000	1,200,000
300 (100)	750,000	1,400,000
500 (167)	900,000	1,900,000
750 (250)	1,100,000	2,200,000
1,000 (333)	1,250,000	3,400,000
1,500 (500)	1,500,000	4,500,000
2,000 (667)	1,750,000	6,000,000
2,500 (833)	2,000,000	7,500,000
3,000 (1,000)	2,250,000	9,000,000
3,750 (1,250)	2,500,000	11,000,000
5,000 (1,667)	3,000,000	14,000,000
7,500 (2,500)	3,000,000	14,000,000
10,000 (3,333)	3,000,000	14,000,000

Note: For kVA ratings not listed use next ***lowest*** rating in table.

Lots of overcurrent protection options

- ➔ Internal transformer fusing
  - Must include ELSP current limiting fuse
- ➔ External fusing
  - Primary fused disconnect switch
  - Elbow fuses
  - Fuse part number must be sent to xfmr manufacturer
- ➔ Circuit breaker
  - Metal-clad
  - SF6
  - Relay settings and breaker catalog number must be sent to xfmr manufacturer

Internal Fusing Limitations

What is the largest kVA transformer that can be fused internally?

@ 15kV

Eaton Cooper ELSP Fuse

ABB Cartridge Fuse

Around 2500/2750 kVA, fusing is not available at 15kV.

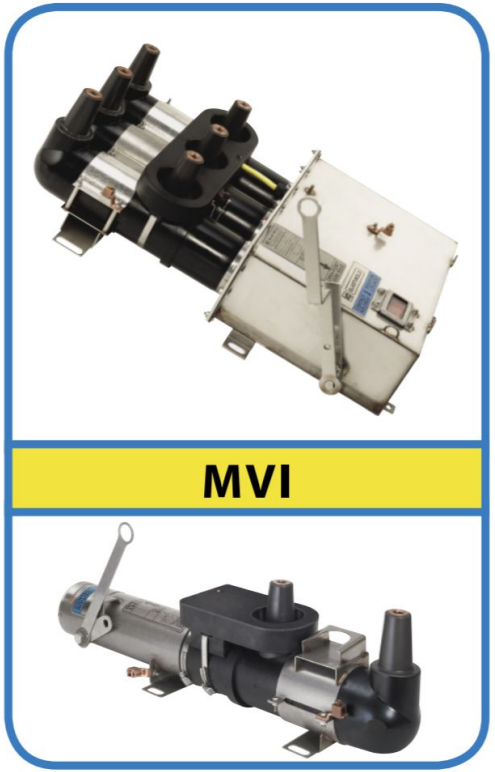
Other Innovative Overcurrent Protection Methods

Elastimold MVI

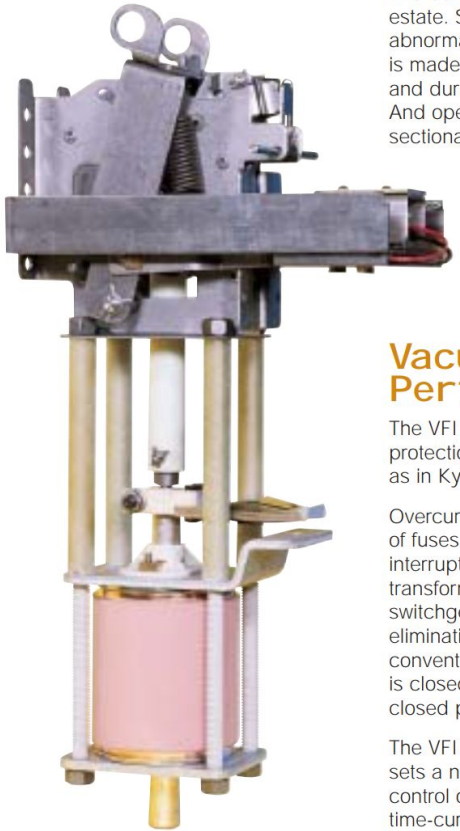
Elastimold MVI Molded Vacuum Fault Interrupters are devices capable of making, carrying and automatically interrupting currents through 12,500 amperes symmetrical on 5-35kV distribution systems. The MVI combines vacuum interrupters, programmable electronic self powered controls and high dielectric strength EPDM rubber insulation, to provide compact, light-weight submersible over-current protection. Units include molded-in elbow connection interfaces, trip free mechanism, and are available in single phase and three phase models.

Units are self powered and include current sensing and electronic control. The control is field programmable with a wide range of Time-Current Characteristic (TCC) curves and trip settings. The TCC curve provide predictable tripping for ease of coordination with up-stream and/or down-stream protective devices. The control monitors the circuit condition and sends a signal to the tripping mechanism if the programmed parameters are exceeded.

Motor operators and controls are available, and allow reconfiguration of radial feeders or loops, manually or via SCADA.



Cooper VFI



The benefits of the VFI Transformer are not limited to just saving money and real estate. System reliability is also improved with superior protection against faults or abnormal currents. Flexibility to accommodate changes in load and fault conditions is made easier with trip settings that are simple to modify in the field. Outage area and duration are minimized by better coordination with other protective devices. And operator safety is enhanced with the trip-free VFI breaker that can be used for sectionalizing or as an On/Off switch.

The VFI Transformer can be used for outdoor or indoor installations (R-Temp® or Envirotemp® FR3™ less-flammable fluid-filled) and is available as a:

- Single-phase, dead-front, pad-mounted transformer
- Three-phase, live- or dead-front, pad-mounted transformer
- Primary open and secondary unit substation transformer

Vacuum Fault Interrupter – Proven Performance & Safety

The VFI Transformer incorporates the latest technology in transformer and loop protection. The VFI (Vacuum Fault Interrupter) uses the same proven technology as in Kyle® VFI Pad-Mounted Switchgear.

Overcurrent protection is accomplished with Kyle vacuum interrupters instead of fuses. The VFI breaker has a continuous current carrying capability and an interrupting rating that far exceeds standard fuses. This expands the scope of transformers that can be protected internally instead of with a separate piece of switchgear. The resettable breaker mechanism allows immediate service restoration, eliminating the added downtime and expense associated with changing out conventional fuses. However, if a fault condition is present when the VFI breaker is closed, the trip-free feature will prevent the mechanism from being held in the closed position.

The VFI breaker is controlled by the Tri-Phase electronic breaker control. This control sets a new standard for ease of time-current-curve coordination. The Tri-Phase control offers over 100 minimum trip settings and an assortment of field replaceable time-current-characteristic curve modules. TCC curves for the Tri-Phase control can approximate either an S & C "E" fuse, a McGraw Edison® "K" or "T" link fuse, or resemble a recloser or relay curve. With standard instantaneous trip and optional ground trip curves, the Tri-Phase control will satisfy all coordination requirements.

Additional Requirements for FM

Indoor units >500 kVA OR Outdoor units > 2500 kVA	All units > 750 kVA
REQUIRE	REQUIRE
Alarm contacts on PRD	Pressure vacuum gauge
Rapid rise relay	Oil temperature gauge

Additional Requirements for FM - cont'd

If the transformer secondary is > 150V, and transformer is rated > 1000A,

A note must be placed on the neutral bushing stating that ground fault protection is required.

Transformer shall be capable of passing BIL testing at a minimum of 1.5° from vertical.

Alternate label

CLASSIFIED BY UNDERWRITERS LABORATORIES INC.* AS TO FIRE HAZARDS ONLY.

R-Temp* Fluid and Envirotemp* FR3™ Fluid Classed 4 to 5 less hazardous than paraffin oil in respect to Fire Hazard. May evolve flammable gases when decomposed by an electric arc.

CLASSIFIED BY UNDERWRITERS LABORATORIES INC.* AS TO SECTION 450.23 OF THE 2002 NATIONAL ELECTRICAL CODE.

Classified as a "less-flammable liquid" as specified in the National Electric Code when used in 3-phase transformers, 45 through 10,000 kVA with the following "use restrictions":

A. For use only in 3-phase transformers having tanks capable of withstanding an internal pressure of 12 psig without rupture.

B. Required use of pressure relief devices on transformer tank in accordance with the following tabulation to limit internal pressure buildup and prevent tank rupture due to gas generation under low current arcing faults, and

C1. Required use of current limiting fusing in the transformer primary having I^2t characteristics not exceeding the values in the following tabulation. Under-fluid expulsion fuses may be used in series with the current-limiting fuses, in accordance with the manufacturer's protection scheme,

or

C2. Required use of overcurrent protection in the transformer primary having I^2t characteristics not exceeding the values in the following tabulation. If the fuse is designed to vent during operation (such as an expulsion fuse), it shall be located external to the transformer tank.

TRANSFORMER	REQUIRED PROTECTION		REQUIRED PRC
3-Phase Transformer Rating, kVA	Required Current Limiting Fusing (+) Maximum I^2t (A^2s)	OR Required Overcurrent Protection (+) Maximum I^2t (A^2s)	Minimum Required Pressure Relief Capacity, (++) SCFM at 15 psi
45	500,000	700,000	35
75	500,000	800,000	35
112.5	550,000	900,000	35
150	600,000	1,000,000	50
225	650,000	1,200,000	100
300	750,000	1,400,000	100
500	900,000	1,900,000	350
750	1,100,000	2,200,000	350
1,000	1,250,000	3,400,000	350
1,500	1,500,000	4,500,000	700
2,000	1,750,000	6,000,000	700
2,500	2,000,000	7,500,000	5,000
3,000	2,250,000	9,000,000	5,000
3,750	2,500,000	11,000,000	5,000
5,000	3,000,000	14,000,000	5,000
7,500	3,000,000	14,000,000	5,000
10,000	3,000,000	14,000,000	5,000

(+) This is an additional requirement to the overcurrent protection required in accordance with Section 450.3 of the 2002 National Electrical Code.

(++) Opening pressure, 10 psig maximum.

To Sum

FM and UL are both designed to assist the end user, engineer, and contractor in complying with NEC 450.23.

Final Thoughts

Questions that may help the decision making process

FM and UL Classification both assist in NEC 450.23 compliance.

Is your company insured by Factory Mutual?

Do you need to place the liquid transformer close to the building?

Does the transformer need to be placed indoors?

Questions?

Additional questions?

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