TRANSFORMERS - ARRANGEMENT AND FIXED FIRE PROTECTION

INTRODUCTION

A transformer can be destroyed by being exposed to a nearby fire. Also, high winds, heavy rain, snow accumulation, and severe icing can lead to major transformer damage. Such events can result in costly interruptions to business. One approach to loss prevention is to locate a transformer where it neither exposes nor is exposed by other hazards or perils.

Where exposures cannot be eliminated, fixed fire protection can be an effective means of limiting losses. The selection of protection equipment depends on property values, separation, construction, and the degree of combustibility of contents.

Another form of fixed protection, electrical protection, is described in PRC.5.9.3, PRC.5.2.1 and PRC.5.2.2. Electrical protection prevents and controls electrical faults.

Transformer manufacturers do not usually provide guidelines for fire or exposure protection. The *National Electrical Code*® (NEC) provides some guidance on the arrangement and protection of transformers, but it delineates a minimum level of protection.

This guide provides a detailed approach to fixed fire protection for transformers rated over 75 kVA or considered to be highly important. Additional transformer loss control measures are described in PRC.5.9.1 and PRC.5.9.4.

POSITION

Protect oil insulated transformers and their exposures as described in the NEC and follow additional guidance in Table 1.

Protect walls and roofs of important buildings and structures exposed by outdoor, oil insulated transformers as described in the NEC and follow additional guidance in Table 2.

Protect less-flammable liquid-insulated (LFLI) transformers and their exposures as described in the NEC and follow additional guidance in Table 3.

Arrange outdoor oil insulated transformers as follows:

- Over a curbed basin filled with clean, coarse, crushed stone approximately 1 in. (25 mm) to 1.5 in. (38 mm) in size. This curbed basin should be deep enough to retain all of the oil from the units located it.
- On substantial supports, such as a concrete pad or foundation.

- In an area having overflow drainage to a safe location so that water from fire-fighting systems and burning oil will not endanger nearby property. When topography will not satisfy this condition, an overflow drain and conduit may be used to divert liquids to remote areas.
- In an area readily accessible to qualified personnel for maintenance and firefighting, but fenced to prevent unauthorized entry.
- In a yard kept free of weeds, debris, and ice which could obstruct drainage and spread fire.
- Curb, grade, or ditch the immediate area around outdoor LFLI transformers to conduct or divert liquid spillage away from buildings and essential equipment.

Maintain a 6 ft (1.8 m) space between combustible storage and any transformer.

TABLE 1

Fire Protection For Oil Insulated Transformer Installations

LOCATION/EXPOSURE	OIL TANK CAPACITY (gal)		
	≤500	>500 to 5000	>5000
INDOORS WITHOUT A VAULT			
All	5	5	5
IN A VAULT			
No exposures within vault	0	2	2
Other transformers in same vault	2	2	2
Highly important or special use unit, such as Arc Furnace or Rectifier Transformer	0	2	2
Important equipment is also located in vault	2	2	2
OUTDOORS			
On roof without vault	5	5	5
No exposures	0	0	2
Highly important or special use unit,, such as Arc Furnace or Rectifier Transformer	0	0	2
Auxiliary equipment or another transformer is exposed or exposes the unit with a separation of:			
Less than 50 to 25 ft (15 to 7.6 m)	0	1	3
Less than 25 to 10 ft (7.6 to 3.1 m)	0	3	3
Less than 10 ft (3.1m)	1	5	5

SI Units: gal = 3.785 L

LEGEND:

0 = No Additional Protection Needed
1 = Barrier Wall
2 = Water Spray
3 = Water Spray and Barrier Wall
4 = Transformer Vault with interior protection (such as Water Spray or double shot Carbon Dioxide)
5 = Beyond the scope of this guide; or not advisable

NOTE: This table presumes good public or private protection and good drainage. A transformer bank may be treated as a single unit if the units are used together in parallel or to form a three phase branch.

HOW TO USE THIS TABLE:

- Find the column applicable to the oil tank capacity of the single unit requiring evaluation. Read down to find the applicable protection number from each row matching the location criteria.
- Using the highest of the applicable numbers, and referring to the Legend, design protection as described for that, or any higher number.

TABLE 2

Fire Protection For Walls And Roofs Of Important Buildings And Structures Exposed To Outdoor, Oil Insulated Transformers

Transformer Oil Capacity (gal)	Horizontal Clearance (ft)	Distance Above The Transformer (ft)	PROTECTION CODE	
			Light Wall Construction	Heavy Wall Construction
Less than 500	10	5	2	1
500 – 5,000	20	10	4	3
More than 5,000	30	15	5	3

SI Units: gal = 3.785 L; ft = 0.305 m

NOTE: This table assumes good drainage, yard arrangement and public or private protection. Fixed protection for the transformer(s) is not assumed. Unusual situations are beyond the scope of this guide. Transformers located under an elevated building structure should be treated as "indoors."

LIGHT WALL CONSTRUCTION - Noncombustible construction including sheathed combustible construction. Exposed combustible construction is prohibited.

HEAVY WALL CONSTRUCTION - Exposed construction consisting of 12 in. (300 mm) hollow tile, 4 in. (100 mm) reinforced concrete, 8 in. (200 mm) concrete block coated with cement plaster, or 8 in. (200 mm) brick.

PROTECTION CODES:

1 = Walls must be blank or windows must be wired glass in fixed metal sash; doors must be fire rated
2 = Walls must be blank and have water curtain or heat resistant barrier
3 = Walls must be blank or openings must be protected with a water curtain
4 = Barrier wall or transformer vault must be provided
5 = This is beyond the scope of this guideline

HOW TO USE THIS TABLE:

- STEP 1 - DETERMINE PARAMETERS FROM THE TABLE - Use transformer nameplate information to identify oil capacity. For a bank of transformers, combined capacities should be used. The quantity of oil identified in the first column, determines the row of the table to be used in the following steps.
- STEP 2 - IDENTIFY THE SEVERELY EXPOSED PORTIONS OF STRUCTURES - Use table dimensions to identify severely exposed segments of walls, roofs and structures. Identified segments contain **ALL POINTS** on the structure having less than the required "Horizontal Clearance" from the transformer(s), and located at or below the elevation described by the column "Distance Above The Transformer." Additionally, any eaves above an exposed wall segment are included.
- STEP 3 - DETERMINE PROTECTION REQUIREMENTS – The protection code describes the appropriate protection for the type of wall construction. This protection is required only for the identified wall segments.
  - Identified roofing segments should be protected from oil spray, exposure to heat and fire spread. A parapet or barrier wall should be constructed if there is a direct line path between the unit and the roof. Exposed roof area should be noncombustible. Heavy noncombustible roof construction is preferred. Combustible roof coverings should be avoided.
  - Other important structures identified as severely exposed generally require heavy structural components and thermal protection. Fixed water spray systems, barrier walls, and spray-on coatings may be acceptable.

TABLE 3

Fire Protection For Less-Flammable Liquid-Insulated (LFLI) Transformers And Their Exposures

Protection Code	EXPOSURE
3	**INDOORS WITHOUT A VAULT**: Building Area of Combustible Construction or Occupancy
6	Warehouse Area having any combustible storage
6 4 3	Production Area, ≤ moderate combustible loading with: - combustibles < 8 ft (2.5 m) away - combustibles ≥ 8 ft (2.5 m) and < 15 ft (4.5 m) away - combustibles ≥ 15 ft (4.5 m) and ≤ 30 ft (9 m) away
3 6	Production Area,, heavy combustible loading maintained: - ≥ 30 ft (9 m) away - < 30 ft (9 m) away
0 1 4	Noncombustible construction and occupancy with: - No additional transformers within 30 ft (9 m) - Another LFLI transformer within 30 ft (9 m) - Another LFLI transformer within 15 ft (4.5 m)
5	Transformer liquid capacity > 500 gal (1.9 m^3)
0	**IN A VAULT**: No other transformers or other essential equipment in vault
2	Transformer liquid capacity > 500 gal (1.9 m^3)
2	All other cases
6	**OUTDOORS**: ≤ 10,000 gal. (37.9 m^3) Tank Capacity Less than 25 ft (7.6 m) to wall openings, combustible buildings, combustible storage, or important structures
1	Less than 10 ft (3.1 m) to auxiliary or essential equipment exposure
0 1	Exposing another LFLI transformer or non-combustible buildings with a separation of: - 5 ft. (1.5) or greater - Less than 5 ft (1.5 m)
6 1	**OUTDOORS**: > 10,000 gal. (37.9 m^3) Tank Capacity Less than 50 ft (15.2 m) to wall openings, combustible buildings, combustible storage, or important structures Less than 25 ft (7.6 m) to auxiliary or essential equipment exposure, and to other LFLI transformers

LEGEND:

0 = No Additional Protection Needed
1 = Water Spray or Barrier Wall
2 = Water Spray or Automatic Sprinklers
3 = Automatic Sprinklers
4 = Water Spray and Barrier Wall; or Automatic Sprinklers and Barrier Wall
5 = Transformer Vault with interior protection, such as Water Spray or double shot Carbon Dioxide
6 = Not Advisable

NOTE: Use of this table presumes good public or private protection and a good arrangement with appropriate curbing, drainage, or liquid confinement. A transformer bank may be treated as a single transformer if the units are used together (in parallel or to form a three phase branch.)

HOW TO USE THIS TABLE:

- Note the protection code in the column at the left for each row meeting the described location criteria.
- Find the largest applicable protection code in the LEGEND. Protection should be as shown for that code, or for any higher number.

Relocate transformers from sites that are likely to encounter:

- Severe snow drifts.
- Flooding, soil erosion, and surface water runoff.
- Airborne dust particles that can readily accumulate on bushings and insulators and cause a ground fault.
- Damage from the rupture of buried water or gas mains, pressurized vessels or piping.

- Damage from being struck, unless screens or guards can be installed for protection. Analyze exposures from moving vehicles; objects falling or being thrown from open windows or viaducts; and snow and ice falling from sloped roofs, towers, bridges, and conveyors.

Develop a thorough loss control program that integrates with electrical system designing and planning. Include the following goals when selecting the site and designing the equipment layout:

- Allow for future growth and changes without compromising good loss control principles.
- Locate components to provide system reliability and safety, particularly if these components serve a loss control function such as a fire pump power supply or a heat and smoke venting power supply.
- Make transformers accessible for inspection, overhaul, repair, and replacement.
- Locate transformers and associated electrical equipment so they do not cause a severe exposure. As examples:
    - A transformer should not be located indoors if other equipment or occupancies in the area are highly susceptible to smoke damage.
    - High voltage overhead lines should not be routed between buildings and the fire hydrants protecting those buildings.
    - Oil-insulated transformers and oil-filled circuit breakers should not be located indoors unless placed in a vault.
    - Sulfur hexafluoride gas-filled circuit breakers should not be located where the construction or occupancy is highly susceptible to corrosion.

Protect transformers from damaging environments. Verify the suitability of proposed transformer use if the site is subject to harsh conditions. The types of transformers and their potentially damaging environments that should be investigated with the manufacturer include:

- Dry type and high voltage units proposed for areas subject to salt water spray, mist, fog, or high humidity.
- Dry type units proposed for areas subject to direct sunlight, high temperatures, or abrasive dust.
- Liquid insulated units proposed for areas likely to experience earth movement, e.g., earthquake, or areas likely to require cold start-ups when the ambient temperature drops below -4°F (-20°C).

Take corrective action if the loss of a transformer will cause a severe and lengthy interruption to production. Actions may include obtaining spare transformers or redesigning the electrical system with additional on-line or backup units.

DISCUSSION

The NEC sets minimum requirements for protection. It does not totally address the importance, value, and exposure presented by a transformer. Importance of a transformer is described in PRC.5.9.0.1 and is one of the key factors in evaluating protection.

Protection can be provided to protect a transformer from exposures, protect exposures from a transformer, control or limit loss to a portion of a transformer, or provide any combination of these. Even a large, single, outdoor, oil insulated unit located far from buildings and other structures can benefit from protection. For instance, automatic water spray might limit damage to the initial winding fault and tank rupture; the protection can save the transformer core, other windings, and associated equipment from an ensuing fire. A unit remote from buildings that exposes another transformer might require water spray and a barrier wall; the barrier wall protects against exposure fires (or fire spread to exposures) and the water spray limits fire damage to the unit.

Tables

The information in Tables 1, 2, and 3 has provided successful approaches to loss control. Good judgement may suggest a protection item is not practical, or that more stringent protection requirements are necessary, based on an evaluation of the importance of the unit.

Tables 1, 2, and 3 target the dielectric fluid capacity of a transformer to guide fire loss control measures. Some guidelines base protection needs on kVA ratings. However, because a unit is likely to pose the same fluid fire threat to its exposures when a transformer is derated or uprated, the fluid capacity is more likely to be the major determinant of the severity of a transformer fire.

The quantity of fluid applicable to Tables 1, 2, and 3 can typically be obtained from the manufacturer or the transformer nameplate. But if this information is unavailable, tank measurements can be used to estimate the fluid capacity.

Many variables preclude defining fluid volumes based on volt-ampere ratings. Table 4 may serve as a guide; however, approximate ranges are all that can be presented. These ranges apply to typical 3-phase units.

The terms “Less-Flammable Liquid” and “Nonflammable Fluid” mean the transformer fluids are listed or approved by some recognized testing lab. Otherwise the protection requirements should be as specified for oil insulated units. PRC.5.4.5 and PRC.5.4.5.1 contain additional information about dielectric fluids and transformer placement.

TABLE 4
Representation Of 3-Phase Transformer Fluid Capacities

Transformer Rating	Estimated Capacity Range (Gallons)
300 kVA	100-250
2 MVA	200-350
5 MVA	800-2,000
30 MVA	7,000-9,000
50 MVA	10,000-11,000
100 MVA	12,000 OR MORE

SI Units: gal=3.785 L

Barrier Walls

An outside barrier wall is located outdoors between a liquid insulated transformer and a protected exposure to reduce the likelihood of fire spread. The wall is masonry, 2 hour fire-rated, wind resistant and its surrounding topography and the drainage in the area are such that oil and firefighting water will flow away from this barrier and not around it. A minimum 12 in. (300 mm) clearance is maintained on both sides of the wall. The minimum wall size may be determined as follows:

- Between two transformers, the height of the wall is at least 2 ft (0.6 m) above the highest unit, including the bushings. Lengthwise, the wall extends at least 3 ft (0.9 m) beyond all possible intersecting points made by lines connecting any two points on the two units.
- Between a transformer and a wall of a structure, the height of the outside barrier wall is at least 2 ft (0.6 m) above the point found by the intersection of the plane of the barrier wall with a line connecting two points: the highest point on the transformer, including the bushings; and the highest point on the building or structure wall, or, a point in the plane of the building wall or structure that is 15 ft (4.6 m) above the elevation of the top of the transformer, whichever is less. The minimum length of the barrier is twice the length of the transformer, including radiators. The barrier wall is set parallel to the building wall in order to pose similar exposures around either end.
- Any two or more connected barrier walls that provide exposure protection equal to that previously described.

An inside barrier wall is a masonry, 2 hour fire-rated wall installed between the fire hazard and its exposure to reduce the likelihood of fire spread. Surrounding curbing and drainage are such that oil and firefighting water will be safely contained. Wall height is from floor to ceiling, and length is at least twice the length of the transformer, including radiators, or longer as needed to prevent direct fire exposures. A minimum 12 in. (300 mm) clearance is maintained on both sides of a barrier wall to maintain its integrity.

Electrical System Design

The design of an electrical system greatly influences loss control. A good system design can reduce property loss, avoid costly interruptions, and reliably power critical and protective equipment, such as fire pumps and powered smoke and heat vents.

System design considerations affecting loss control include:

- **Equipment placement** - The physical placement of equipment and components determines their exposures. Further, because the routing of a power line is dictated by the placement of electrical equipment, transformer placement should not be decided without evaluating the power line route.
- Equipment arrangement - The electrical sequence of system components affects system coordination and reliability.
- Flexibility - If the design of a system does not plan for future growth and changes, necessary expansion might diminish the level of loss control. For example, if space is not provided for future transformers and adequate separation, congestion and high loss potentials can result.
- Backup units - Large or unusual transformers that are vital to production and have lengthy replacement times can cause major production outages. Duplicate or backup units can reduce this potential.

When it becomes necessary to build an addition or change the use of a building, it may also be necessary to modify existing protection and the power system design. Similarly, changes that affect the importance and use of individual components in a power system may also bring about the need for changes in protection and design. The extent of changes often depends on the foresight of those involved with the original design and the loss control concepts that were followed.