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IEEE Guide for Containment and Control of Oil Spills in Substations

Sponsor

**Substations Committee
of the
IEEE Power Engineering Society**

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Abstract: *The significance of oil-spillage regulations and their applicability to electric supply substations are discussed; the sources of oil spills are identified; typical designs and methods for dealing with oil containment and control of oil spills are discussed; and guidelines for preparation of a typical Spill Prevention Control and Countermeasures (SPCC) plan are provided. This guide excludes polychlorinated biphenyl (PCB) handling and disposal considerations.*

Keywords: *collecting pit, oil-containment methods, oil-containment system, oil discharge, oil spill, primary oil containment, retention pit, secondary oil containment, spill prevention control and countermeasures (SPCC) plan*

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Introduction

(This introduction is not a part of IEEE Std 980-1994, IEEE Guide for Containment and Control of Oil Spills in Substations.)

On December 31, 1973, the United States government published in its Code of Federal Regulations, under Title 40 Protection of the Environment, the federal requirements for the preparation and implementation of Spill Prevention Control and Countermeasure (SPCC) plans applicable to the discharge of oil at electrical facilities. While these regulations, in the strictest sense, relate to oil spills into navigable waters from shore facilities, it should be realized that these regulations could very easily be, and in some states are, extended to cover onshore areas. Onshore areas could be a distance away from navigable waters and could include those areas where substations are installed.

It is prudent, therefore, to recognize that there exists a potential for oil spills in almost every substation throughout the utility industry. It is consequently reasonable to identify the extent of the problem, if any, and to recommend plausible measures to control oil spills by means of an IEEE guide.

This guide was revised by members of Working Group G2—Design and Location of Substations for Community Acceptance—and is under the sponsorship of the Substations Environmental Subcommittee of the IEEE Power Engineering Society (PES) Substations Committee.

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IEEE Guide for Containment and Control of Oil Spills in Substations

1. Overview

1.1 Scope

This guide discusses the significance of oil-spillage regulations and their applicability to electric supply substations; identifies the sources of oil spills; discusses typical designs and methods for dealing with oil containment and control of oil spills; and provides guidelines for preparation of a typical Spill Prevention Control and Countermeasure (SPCC) plan. This guide excludes polychlorinated biphenyl (PCB) handling and disposal considerations.

It is not the intent of this guide to interpret the applicability of the governmental regulations or the oil-containment systems presented. Such interpretation is left to each individual user. The guide is intended to identify concerns, offer solutions, and let users make their own evaluations.

This guide applies only to insulating oil containing less than 50 ppm of PCB, which is considered to be non-PCB oil. Non-PCB oils have a PCB content that has been designated by the U.S. Environmental Protection Agency (EPA) as nonhazardous to the public, and they are not deemed to be toxic substances. While the effectiveness of the containment methods described in this guide is generally not affected by the PCB content of the oil, the regulations governing cleanup and handling of oil spills containing PCB are much more restrictive.

1.2 Purpose

Containment and control of oil spills at electric supply substations is a concern for most electric utilities. The environmental impact of oil spills and their cleanup is governed by several federal, state, and local regulations, necessitating increased attention in substations to the need for secondary oil containment, and an SPCC plan. Beyond the threat to the environment, cleanup costs associated with oil spills continue to escalate, and the adverse community response to any spill is becoming increasingly unacceptable.

This guide identifies the applicable governmental regulations, the sources of oil spills, and the typical methods used to contain and control them. It discusses the need for an SPCC plan and provides the typical plan requirements. It documents survey-reported considerations for oil-spill containment, control, and cleanup; the methods used; and their effectiveness. In June 1992 an IEEE questionnaire was sent to 190 utilities in the U.S. and Canada, surveying their experiences. Of these utilities, 59 responded. Where relevant, the survey results are referenced in the body of this guide.

2. References

This guide shall be used in conjunction with the following publications:

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).¹

IEEE Std 979-1984 (Reaff 1988), IEEE Guide for Substation Fire Protection (ANSI).

U.S. Code of Federal Regulations, Title 40 (40CFR), Protection of the Environment, Parts 109–112.²

3. Definitions

This clause contains key terms as they are used in this guide. For additional definitions, see IEEE Std 100-1992.³

3.1 collecting pit: A pit built under oil-filled equipment to collect any accidental discharge of oil from that piece of equipment.

3.2 fire quenching: Shock cooling by immersion of liquid or molten material in a cooling medium (crushed stones in collecting pits).

3.3 gallon: One U.S. gallon equals 3.785 liters.

3.4 harmful quantity of oil: A discharge of oil that 1) violates applicable water quality standards, 2) causes a film or sheen upon or discoloration of the surface of the water or adjoining shorelines, or 3) causes a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines.

3.5 oil-containment system: A system designed to collect and retain oil in order to prevent 1) its migration beyond the boundaries of the system and 2) the contamination of navigable waters.

3.6 oil discharge: Any leak or spillage of oil, regardless of volume and including those that do not reach navigable waters. A discharge includes but is not limited to any spilling, leaking, pumping, pouring, emitting, emptying, or dumping of oil.

3.7 oil spill (spill event): A discharge of oil into or upon navigable waters or shorelines in harmful quantities.

3.8 permeability: The drainage characteristic of soil that denotes its capacity to conduct or discharge fluids under a given hydraulic gradient.

3.9 primary oil containment: A tank or enclosure designed for continuous containment of oil for operating or storage purposes.

3.10 retention pit: A pit designed to retain (hold) oil-contaminated liquids.

3.11 secondary oil containment: A system designed to contain the oil discharged from an oil-filled piece of equipment in situations of primary oil-containment failure.

3.12 void volume ratio: The volume of the void spaces between stones divided by the total volume occupied by the stones in a stone-filled collecting pit.

4. Statutory requirements

In general, the U.S. Code of Federal Regulations, Title 40 (40CFR), Parts 110 and 112, requires that appropriate oil containment and diversionary structures be provided to prevent discharged oil from reaching navigable waters, if a

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²This document is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

³Information on references can be found in clause 2.

facility could reasonably be expected to discharge oil in harmful quantities into or upon said navigable waters. Further, where necessary a written SPCC contingency plan (see 8.1) shall be prepared that commits manpower, equipment, and materials to control and remove any quantity of discharged oil.

On October 22, 1991, the EPA issued proposed changes to 40CFR, Part 112. The changes were prompted by the spill that resulted from the collapse of a four million gallon aboveground storage tank near the Monongahela River as well as other major oil spills, but not by any substation event. The proposed regulations prompted a barrage of protests and lobbying efforts for less stringent requirements on smaller oil tanks. The issue has not yet been entirely resolved, and further EPA clarifications and changes can be expected for several years.

The regulations are very dynamic, and may have changed since the publication of this guide. The user is cautioned to check the latest regulations for revisions.

The application of these federal regulations to oil-spill containment and control in substations is further complicated by several key points that are currently subject to revision or interpretation. These include:

- a) The minimum storage capacity in a single container or the entire substation before an SPCC plan and appropriate containment is required. Any change from the current limits may significantly impact the number of transformers, circuit breakers, and other oil-filled substation equipment where secondary containment is required.
- b) What constitutes a bulk storage tank for which 40CFR, Part 112 regulations currently require secondary oil containment. The proposed rules currently indicate that transformers (and other electrical equipment) containing oil for operational rather than storage purposes will not be considered “bulk storage tanks.”
- c) The term “navigable waters,” which as currently written in 40CFR, Part 110, is broad and encompassing. As defined by the EPA, it can include, in addition to the major lakes and waterways, tributaries of rivers, lakes, and streams, as well as mud flats and wetlands. The results of the 1992 IEEE survey found user interpretations of navigable waters as extreme as “any water conveyance, whether wet or normally dry.”
- d) The amount of discharged oil that constitutes “harmful quantities.”

As stated earlier, interpretation of the specific regulations is left to each individual user. However, it should be noted that in test case applications of the law, the EPA has tended to be very conservative in its interpretations.

The probability of an oil spill occurring in a substation is very low (see 6.2). However, certain substations, due to their proximity to navigable waters or designated wetlands, the quantity of oil on site, surrounding topography, soil characteristics, etc., have or will have a higher potential for discharging harmful quantities of oil into or upon navigable waters or wetlands. At minimum, an SPCC plan will probably be required at these locations, and installation of secondary oil-containment facilities should be considered.

4.1 Federal

The federal requirements of the United States for discharge, control, and countermeasure plans for oil spills are contained in the Code of Federal Regulations, Title 40 (40CFR), Parts 110 and 112. The purpose of these regulations is to prevent the discharge of oil in harmful quantities into navigable waters, which also includes shorelines, wetlands, or areas that would adversely affect the natural resources of the United States, and to provide for containment systems in lieu of only providing cleanup measures after a spill has occurred. Definitions and specifics regarding navigable waters and other terms that are covered by these regulations are contained in the publication.

These regulations prohibit the discharge of oil in harmful quantities into navigable waters of the United States. Through the implementation of an SPCC plan, which may include secondary containment, the regulations require that effective containment plans be made to prevent the discharge of oil, and specify that a cleanup procedure or contingency plan be established to be implemented in the event of an oil spill. An SPCC plan alone can be utilized only where containment is shown to be impractical. Oil containment may be deemed impractical in situations where

constraints prevent the installation of oil-containment systems and/or it is highly unlikely that oil would reach and contaminate navigable waters in the event of a discharge. Financial considerations alone are no longer a valid argument for not providing oil containment, as any contamination of navigable waters is unacceptable. Also, the cost associated with the expeditious cleanup of a spill will most likely exceed the cost of providing secondary oil containment.

These regulations apply to installations where the storage capacity of a single container aboveground exceeds 2500 L (660 gal), the aggregate capacity stored aboveground exceeds 5000 L (1320 gal), or where the capacity to contain oil stored underground exceeds 159 000 L (42 000 gal). The SPCC plan and appropriate containment can include the use of dikes, berms, curbing, culverts, weirs, absorbent materials, sumps, and collecting systems designed for the purpose of containing the discharge of harmful quantities of oil. In short, this requirement specifies that a properly engineered plan shall be developed and documented to contain the surface discharge of oil from a storage container at a facility that, due to its location, could reasonably be expected to discharge oil into or upon navigable waters in sufficient quantity to cause an oil sheen, or to clean up the spilled oil if containment can be shown to be not practicable. This plan shall be reviewed and certified by a registered professional engineer that has become familiar with these regulations, visited and examined the facility, concurs that good engineering practices have been used, and verifies that the appropriate testing has been performed and the plan is adequate for the facility.

In addition to the requirements prohibiting the discharge of harmful quantities of oil, 40CFR, Part 112 specifies that a report shall be made to the EPA Regional Administrator within 60112 days from the date of the spill in the event of a discharge of more than 3786 L (1000 gal) in a single spill or two spills of harmful quantities from the same facility in any 12-month period. Such a report (see annex A) shall contain the identification of the facility and information relating to the date and description of the spill, copy of the SPCC plan, cause, corrective action, and additional preventive measures that have been taken. Regulations require that any report of an oil spill be sent to the appropriate state agency as well.

In as much as the regulations make reference to an SPCC plan for a facility, it is the interpretation by the EPA that each facility (installation) shall have its own plan. While an overall plan for substations could be generic in nature, there is a requirement to site-specify the plan uniquely for each installation. Sufficient detail shall be included in the overall plan to identify location of equipment, contour of the site and surrounding area, and the drainage patterns.

In summary, federal regulations require that each installation exceeding the specified storage capacity limitations be assessed for the possibility of contaminating navigable waters. If the potential for contamination exists, then an SPCC plan (see 8.1) shall be developed. Such a plan shall contain all requirements of 40CFR, Part 112.7, including appropriate containment provisions and a contingency cleanup plan.

4.2 State and local

State and local requirements regarding oil spills are contained in 40CFR, Part 109.

State and local governments have generally adopted the existing federal regulations prohibiting discharges of oil. In addition, some states have issued their own oil-spill containment and control regulations. Often, the state and local requirements may be even more encompassing and restrictive than the federal requirements. Specifically, it is the responsibility of the state and local governments to enforce the cleanup portion of SPCC plans implemented by a utility within that government's jurisdiction. The procedure for the reporting of oil spills to state agencies varies from state to state, but generally, the procedure could be more stringent than that required by the federal government. The procedure usually requires a report by telephone immediately following the spill, and a follow-up written report that includes all the details of the oil spill. With respect to a cleanup plan, state agencies generally require that cleanup plans for oil spills be developed, written, and filed with the agency. Such a plan contains a written commitment of manpower, equipment, and materials that would be required to expeditiously control and remove any quantity of spilled oil.

5. Oil spill sources

Described below are various sources of oil spills within substations. Spills from any of these devices are possible. The user should evaluate the quantity of oil present, the potential impact of a spill, and the need for oil containment associated with each oil-filled device.

5.1 Large oil-filled equipment

Power transformers, oil-filled reactors, large regulators, and circuit breakers are the greatest potential source of major oil spills in substations, since they typically contain the largest quantity of oil. Spills may be caused by electrical failure, leaks, vandalism, sabotage, or accident.

Power transformers, reactors, and regulators may contain anywhere from a few hundred to 100 000 L or more of oil (500 to approximately 30,000 gal), with 7500–38,000 L (approximately 2000–10 000 gal) being typical. Substations usually contain one to four power transformers, but may have more.

The higher voltage oil circuit breakers may have three independent tanks, each containing 400–15 000 L (approximately 100–4000 gal) of oil, depending on their rating. However, most circuit breaker tanks contain less than 4500 L (approximately 1200 gal) of oil. Substations may have 10–20 or more oil circuit breakers.

5.2 Cables

Substation pumping facilities and cable terminations (potheads) that maintain oil pressure in pipe-type cable installations are another source of oil spills. Again, spills are caused by electrical failure, leaks, vandalism, sabotage, or accidents. Depending on its length and rating, a pipe-type cable system may contain anywhere from 5000 L (approximately 1500 gal) up to 38 000 L (approximately 10 000 gal) or more of oil.

5.3 Mobile equipment

Although mobile equipment and emergency facilities may be used infrequently, consideration should be given to the quantity of oil contained and associated risk of oil spill. Mobile equipment may contain up to 30 000 L (approximately 7500 gal) of oil.

5.4 Oil-handling equipment

Oil filling of transformers, circuit breakers, cables, etc., occurs when the equipment is initially installed. In addition, periodic reprocessing or replacement of the oil may be necessary to ensure that proper insulation qualities are maintained. Oil pumps, temporary storage facilities, hoses, etc., are brought in to accomplish this task. Although oil-processing and handling activities are less common, spills from these devices can still occur.

5.5 Oil storage tanks

Some consideration should be given to the presence of bulk oil storage tanks (either aboveground or belowground) in substations as these oil tanks could be responsible for an oil spill of significant magnitude. Also, the resulting applicability of the 40CFR, Part 112 rules for those storage tanks could require increased secondary oil containment for the entire substation facility. The user may want to reconsider storage of bulk oil at substation sites.

5.6 Other sources

Station service, voltage, and current transformers, as well as smaller voltage regulators, oil circuit reclosers, capacitor banks, and other pieces of electrical equipment typically found in substations, contain small amounts of insulating oil, usually less than the 2500 L (660 gal) minimum for a single container. Only under most unusual circumstances could they be responsible for an oil spill of the magnitude described in 40CFR.

6. Criteria

Based on the applicability of the latest regulatory requirements, or when an unacceptable level of oil spills has been experienced, a program should be put in place to mitigate the problems. Typical criteria for implementing oil spill containment and control programs incorporate regulatory requirements, corporate policy, frequency and duration of occurrences, cost of occurrences, safety hazards, severity of damage, equipment type, potential impact on nearby customers, substation location, and quality of service requirements.

The decision to install secondary containment at new substations (or to retrofit existing substations) is usually based on a predetermined criteria. The 1992 IEEE survey addressed the factors used to determine where oil spill containment and control programs are needed. Based on the survey, the criteria in table 1 are considered when evaluating the need for secondary oil containment.

As for specific numerical limits, 57% of the respondents install secondary containment when the maximum volume of oil per individual tank exceeds the 2500 L (660 gal) 40CFR, Part 112 limit, with a range of 1900–11 400 L (approximately 500–3000 gal) reported. Over 82% also limit the total volume of oil in the substation to the 5000 L (1320 gal) specified in 40112CFR, Part 112, with a range of 2500–5700 L (approximately 660–1500 gal) reported. The 1992 IEEE survey provided no clear cut limit for the proximity to navigable waters. Relatively equal support was reported for several choices over the range of 50–500 m (approximately 150–1500 ft).

Rarely is all of the equipment within a given substation provided with secondary containment. Table 2 lists the survey results identifying the equipment for which secondary oil containment is provided.

None of the remaining equipment surveyed, which included voltage and current transformers, capacitors, and all mobile devices, received a rating higher than 15%.

Table 1 — Secondary oil-containment evaluation criteria

Criteria	Utilities responding that apply this criteria
Volume of oil in individual device	88%
Proximity to navigable waters	86%
Total volume of oil in substation	62%
Potential contamination of groundwater	61%
Soil characteristics of the station	42%
Location of substation (urban, rural, remote)	39%
Emergency response time if a spill occurs	30%
Failure probability of the equipment	21%
Age of station or equipment	10%

Table 2— Secondary oil-containment equipment criteria

Equipment	Utilities responding that provide secondary containment
Power transformers	86%
Aboveground oil storage tanks	77%
Station service transformers	44%
Oil circuit breakers	43%
Three-phase regulators	34%
Belowground oil storage tanks	28%
Shunt reactors	26%
Oil-filling equipment	22%
Oil-filled cables and terminal stations	22%
Single-phase regulators	19%
Oil circuit reclosers	15%

The focus is clearly on the equipment that contains the largest quantities of oil (see 5.1). As for specific minimum voltage and/or megavolt ampere (MVA) criteria above which a user always installs secondary containment, a wide range of figures was reported. For voltage, the minimum criteria was most often 115 kV, with a range of 69–345 kV reported. For MVA, the minimum criteria was most often 10 MVA, with a range of 5–45 MVA reported.

Whatever the criteria, each substation should be evaluated by considering the criteria to determine candidate substations for oil-containment systems (both new and retrofit). Substations with planned equipment change-outs should be considered for retrofits at the time of the change-out.

6.1 Operating history

Once the need for a program is identified, the specific causes of the problem need to be determined. Spill records, maintenance reports, and routine inspections of facilities will afford specific information as to the cause and extent of the problem.

Typical information found in these reports includes facility name, date, time, equipment affected, duration of the discharge, quantity of oil discharged, and number of customers affected.

6.2 Probability of oil spills

Both the frequency and magnitude of oil spills in substations can be considered to be very low. The probability of an oil spill at any particular location depends on the number and volume of oil containers, and other site-specific conditions.

The probability of a spill was verified by the results of two questionnaires submitted in 1977 to utility members of the IEEE Substations Committee by the Oil Spill Prevention, Control and Countermeasures Task Force of the Environmental Subcommittee. The information showed that during the ten-year period from 1965–1974, these utilities had a total of less than one discharge for each 330 pieces of equipment in service. Over the two-year period 1975–1976, these utilities had less than one discharge for each 1200 pieces of equipment in service. The figures also showed that during the ten-year period, less than one discharge reached a waterway for each 5275 pieces of equipment in service. During the two-year period 1975–1976, less than one discharge reached a waterway for each 6640 pieces of equipment.

The task force concluded that, while this empirical data was not precise, it clearly indicated that the number of spills per piece of equipment in service per year is small.

6.3 Application determination

After reviewing the operating history and determining containment and control options, the application determination process should include consideration of the solution's cost-benefit ratio, applicable governmental regulations, and community acceptance.

6.3.1 Economic aspects

The anticipated cost of implementing the containment measures should be compared to the anticipated benefit. However, cost alone can no longer be considered a valid reason for not implementing containment and/or control measures, because any contamination of navigable waters may be prohibited by governmental regulations. Application determination cannot rely on the low probabilistic risk of an oil spill to avoid implementation of containment and control measures.

Economic aspects can be considered when determining which containment system or control method to employ. Factors such as proximity to waterways, volume of oil, response time following a spill, etc., can allow for the use of less effective methods at some locations.

6.3.2 Governmental regulations

Due to the dynamic nature of environmental regulations, some methods described in this guide could become in conflict with governmental regulations or overlapping jurisdictions. Therefore, determination of which containment system or control method to use should include research into applicable laws and regulations.

6.3.3 Community acceptance

Community acceptance of the oil spill containment and control methods should also be considered. Certain levels of unacceptability are intangible and may be dictated by company policies, community acceptance, customer relations, etc. The impact on adjacent property owners should be addressed and, if needed, a demonstration of performance experiences could be made available.

6.4 Performance monitoring

Some means should be put in place for evaluating the effectiveness of any containment and control measures that have been applied. Records should be kept for each substation to record the method used, date of application, and the history of oil spills. A record is necessary to monitor the performance of the applied method to evaluate the feasibility of future applications.

7. Containment

It is beyond the scope of this guide to make specific recommendations as to which type of oil-containment system is best suited for specific incidents due to the wide range of site variables that can exist. However, as an aid to those engaged in the design of oil-containment systems, several examples of various types that have been utilized are provided for reference and described below.

From the 1992 IEEE survey results, it became clear that no single containment system or discharge control method is preferable. All of the methods have been utilized successfully, and are ranked in table 3 in order of survey preference. There appears to be some correlation to the cost and complexity of the system, with the less expensive, simpler systems being employed most often. As to effectiveness, it was common for each individual user to favor their own method while reporting that the other methods were ineffective. As a result, the reported effectiveness results were

inconclusive. Very few utilities reported a measured effectiveness. The effectiveness ratings appeared to be somewhat subjective, and based as much on the inconveniences associated with the application of the method as any other criteria, due in some part to the lack of testing and very few actual spills.

7.1 Containment systems

Figure 1 illustrates a typical oil-retention pit into which a pipe drainage system empties. The drainage system network connects numerous collecting pits located under oil-filled pieces of equipment, and directs surface water runoff and any potential oil discharge to the retention pit.

Figure 2 illustrates a typical cross-section of the containment system and the design principle upon which this system is based. Oil, being less dense than water, will float on top of the water and is effectively contained on site by proper sizing of the pit and the design of the gravity separator. Generally, the pit is sized such that it will contain the entire quantity of discharged oil from the largest piece of equipment plus an assumed amount of retained water (see 7.5 for a discussion of volume requirements). Substation sites located in areas of porous soil, where the permeability is greater than 10^{-3} cm/s (see 7.3), should have their oil-collecting and retention pits lined (with a layer of clay, concrete, plastic, a rubber pit liner, etc.) to prevent migration of oil into the ground.

Figure 3 is basically the same as figure 1, except the oil-retention pit has been replaced with one of several possible discharge control systems (see 7.2) that requires less land area. Therefore, this type of installation may be more practical at substations where the available land area is limited. Unlike the oil-retention pit, which is designed to contain the entire quantity of discharged oil plus an assumed amount of retained water (rainwater, melted snow, water spray system discharge, etc.), this system is constructed such that any discharged oil is backed up through the drainage system and contained in the various collecting pits beneath oil-filled equipment.

Table 3— Containment method utilization

Containment system or discharge control method	Figure no.	Utilities responding that employ method	
		For new substations	For retrofits
Perimeter or equipment berm	6, 7	67%	58%
Fire quenching and oil-retention pit	4, 5, 10	60%	42%
Oil-retention pit	1, 2	48%	43%
Oil-water separator	11	41%	27%
Oil-detection-triggered sump pump	16	31%	39%
Gravity separator	9	24%	15%
Oil-water stop valve	15	22%	35%
Gravity separator	8	15%	10%
Oil trap	12	8%	14%
Oil-absorbing polymer bead bed	13, 14	8%	17%