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Safety Measures for Prevention of PCB Accidents

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This paper attempts to clarify the most common measures available for the fire and electrical engineer in the prevention of polychlorinated biphenyl (PCB) hazards. It points out the risks and the potential for making large risks involved in the use of transformers and capacitors more manageable. The focus in solving the PCB problem is on priority. This should be reflected in the agenda of the workshop: it should discuss not only transformers and capacitors as such, but deal more with questions concerning waste disposal, getting correct information to people on substances containing PCBs and on the proper and nonpanicky handling of such substances.

The PCB issue does not lend itself to any black and white solution. Instead, a number of different aspects have to be taken into account. Any solutions arrived at are therefore always compromises between risk evaluation and cost effectiveness. Reduction of PCB risks does not have to result, for example, in an increase in fire risks. It is preferable to move step by step and avoid making irretractable decisions.

Alternatives available for replacing PCB-filled devices or the widely used method of refilling PCB-filled transformers with silicone oils are not discussed. Refilling is not dealt with because its capacity to reduce the fire risk sufficiently in locations where these transformers are usually found in northern Europe is not known with certainty.

Introduction

Use of PCBs in Transformers

The main reasons for the use of PCB liquids in transformers and capacitors (*1*) are: their excellent electrical properties, their high chemical stability and their noninflammability. In the case of capacitors, the first two factors are of importance because of the limited space available for insulation. The last property makes it possible to place transformers in the center of the electrical network inside a building without considering fire precautions. This saves cables and reduces power losses in the network.

Placement of Transformers

There is no specific location for transformers or capacitors. In most cases they have been placed in separate switchgear rooms for better electrical safety, or for the avoidance of dust, or for other environmental reasons. Especially in industry, the prevailing notion of flexible building design has led to the development of equipment which no longer requires placement in separate rooms. As a result, noninflammable transformers with switchgear and compensating capacitors can be placed in the middle of a production area. This location is not suitable for transformers using mineral oil because of the high fire load.

In Finland and in northern Europe in general, the use of PCB liquids in transformers is not as extensive as elsewhere because of the high price of such transformers compared with transformers filled with mineral oil. The price ratio is roughly 1.7:1, while elsewhere it is about 1.3:1 (*2,3*). As a result, the number of askarel-filled transformers in Finland (and in Sweden) has been only about 200 to 300, while in the Federal Republic of Germany there are some 50,000 and even more in the U.S.

Types of PCB Accidents

Cold Leakage

Cold leakage from transformers and capacitors, where PCB liquid has not been exposed to heat, (Fig. 1) is usually harmless. Such leakage can endanger health only if PCB liquid finds its way into a river, or lake, or if it contaminates food or animal feed. As noted above, askarel transformers in northern Europe are normally located inside buildings, which facilitates the stopping of leaks. Capacitor batteries, which can also be found for example at waterworks and near rivers, constitute a

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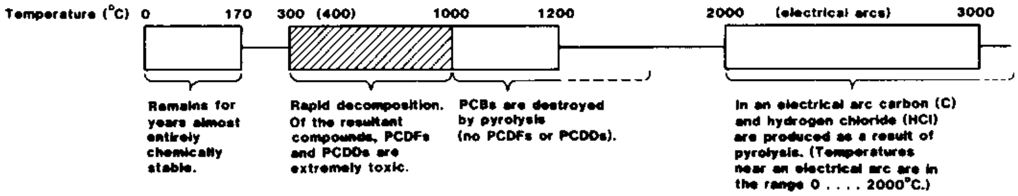

FIGURE 1. Thermal stability of PCB-liquids (6).

minor risk, as the content of free PCB liquid in a capacitor unit is about 5 L, whereas in an askarel transformer it can be 1000 L.

Arc Explosions and Fires

Extremely toxic polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-*p*-dioxins (PCDDs) have been found in connection with transformer and capacitor fires (e.g., in Binghamton 1982, Skövde 1982, Surahammar 1983) and electrical arc explosions (e.g., Danviken 1981, Kaukopää 1982). Arc explosions have resulted from a voltage imbalance or resonance in the high-voltage circuit due to harmonic currents. High-voltage capacitor banks are normally protected by unbalance relays, but in Danviken the relay was timedelayed, and in Kaukopää it was defective. Harmonic currents increase, for example, if new thyristor devices or DC-loads are connected to the network.

Both capacitor bank explosions referred to (Danviken, Kaukopää) involved high-voltage capacitors, where capacitor units are connected both in series and in parallel. When a malfunction occurs in one of the units, voltage imbalance increases, and if the protection relay does not work, the voltage increases even further and the capacitor units suffer additional damage. The ultimate result can be an arc explosion in the capacitor bank.

Explosions also occur in low-voltage (supply voltage under 1000 V) capacitor banks. While no statistics on capacitor explosions prior to the Kaukopää accident exist, the number of such explosions recorded in a one-year period following the Kaukopää accident was around 20. No PCDFs or PCDDs have been found in these cases. The reason may in part be the rapidity of the phenomena and in part the lower chlorine content in the PCB liquids used in these capacitors. Explosions in low-voltage capacitor banks are possible if electrical protection devices are not used or if these are not properly dimensioned.

Prevention of PCB Accidents

Prevention of PCB accidents—fire and explosion hazards—can be divided into three categories: reduction of fire risks and prevention of smoke spreading; prevention of arcs and explosions; and precautions in fire fighting and rescue work.

First of all, we have to know which transformers and capacitors contain PCB and where they are located. In Finland this pinpointing work, which was started in the aftermath of the Kaukopää explosion, is nearly completed. Because of the large number of capacitor banks, we in Finland have tried to establish some order of priority among them in order to eliminate major potential hazards first. These efforts have so far had little success.

The authorities are about to issue some regulations —hopefully not overly drastic ones in view of the measures taken in other countries—regarding waste disposal situation and other questions.

Particularly hazardous conditions (such as those in Surahammar and Binghamton) exist when a PCB-filled transformer or capacitor bank is located: in a facility used to produce food, feed or medicine ("small" accidents can develop into catastrophes); in some other large uncompartmentalized facility which is difficult to clean up (e.g., warehouses, large industrial production facilities); in separate electrical switchgear from which fire gases can spread to the above-mentioned facilities, or to a maze of working or living spaces for example through air-conditioning (e.g., hospitals, theaters, office buildings, hotels, and industrial workshops).

Reduction of Fire Risk and Prevention of Smoke Spread

Because of the noninflammability of PCB liquids, fire risks can be reduced only by reducing the fireload and the sources of ignition in the vicinity of PCB-filled transformers and capacitor banks. The fireload in switchgear rooms consists of cables and other insulation materials or mineral oils. Fire damage inside switchgear can be quite small if spread of fire gases to working, office, or other facilities is prevented. Short stays in the switchgear room are required only when some equipment is operated or when maintenance or repair work is carried out. (These can be done by using protective clothing and equipment.)

Consequently, air-conditioning plays a very important role in the prevention of large-scale PCB accidents. After the oil crisis, there has been a tendency to design various energy-saving air-conditioning systems without considering the spread of fire and fire gases. Replacing these systems can be costly compared, for example, with replacement of a PCB-filled transformer or capacitor bank.

The question often asked here is, "Is it not dangerous to release fire gases (PCDFs, PCDDs) into the environment?" With respect to the environment, the answer is yes. However, in PCB accidents involving transformers or capacitors the amounts of PCDFs and PCDDs are so insignificant compared to the amounts released from other sources that they are undetectable. We must keep in mind that PCB accidents such as that in Surahammar, where the amount of PCB that burned was about 3,000 kg, seldom occur. In Surahammar the surroundings were also examined, but the increase in PCDFs or PCDDs was negative (*5*). Consequently, a useful way of reducing the risk of PCB accidents in some cases is to move a PCB-filled transformer or capacitor bank outside the building, or into a room where ventilation is only to the outside. Later, when PCB-filled devices have to be replaced, for example because of their age, they can be replaced with devices filled with flammable liquids without the danger of increasing fire hazards.

One detail to be remembered when discussing the fire risks posed by capacitor banks is to keep PCB-filled units and flammable oil-filled units separate from each other, except when the bank is outside. Another important point is not to permit any openings in the walls and floors of switchgear rooms; this also applies to switchgear not containing PCB.

If a PCB-filled transformer or capacitor bank is located in the middle of a factory without any separation, the prevention of PCB hazards is as difficult as the prevention of fire hazards. Consequently, the only practical alternatives are to remove these devices from such locations or to replace them with devices that do not pose a toxic hazard or fire risk. Until this is done, all burning materials and the sources of ignition should be removed from the vicinity of the PCB-filled devices. The electrical protection system should also be inspected. In some cases, when the facility is equipped with a sprinkler system, it is possible to protect and cool these devices by water in the event of fire (*6*). Although automatic sprinkler systems are very reliable, this solution is neither very sophisticated nor foolproof.

Prevention of Electrical Arcs and Explosions

Accidents where a PCB-filled transformer breaks up as a result of an arc are extremely rare. Capacitor explosions without serious consequences seem, however, to occur frequently, mainly in low-voltage banks. The measures available to prevent arcs and explosions are, (especially if the location of the device constitutes a major potential hazard): careful checking of the dimensioning and the condition of electrical protective devices and keeping insulators clean.

In the case of transformers, check the short circuit and overcurrent protection devices, and keep switching times to a minimum. It is preferable to connect all customary alarming devices to the switching circuit of the contactor or the circuit breaker (e.g., pressure or gas relay). In the case of capacitors, check the overcurrent and unbalance protection devices (the use of capacitors without overcurrent protection should be discontinued) and check the possibility for resonance also taking into account the exceptional distribution conditions in the network. Conduct a visual inspection at least once a year, and change all leaking or expanded units, check cable connections, check discharge resistances and measure, if possible, the capacitances of the units; this indicates the condition of the inside elements. All measures mentioned here are part of normal maintenance. Installations that present a greater hazard have to be inspected at shorter intervals and with greater care.

Precautions in Fire Fighting and Rescue Operations

In fire fighting and rescue work the fire fighters should be familiar with the location of PCB-filled devices. They should also be trained to contain hazards posed by PCB. They should be instructed to use proper protective clothing and equipment even in the absence of visible damage, to prevent the spreading of pollution and to administer first aid to people suffering from symptoms of toxic exposure.

Finnish authorities have issued instructions concerning measures to be taken if there are reasons to suspect that in the event of an electrical phenomenon or fire, PCB has been exposed to heat due to overheating of a transformer or a capacitor bank. The main points of these instructions are disconnect the device; leave the room immediately, close the doors, and turn off the ventilation system. Only fire fighters and rescue workers should be permitted to enter areas contaminated with PCBs. They should be equipped with protective devices and wear protective clothing (gastight, disposable protective overalls are recommended.) To prevent the spread of contamination, workers must close all openings into other parts of the building, and prevent extinguishing and cleaning water from getting into the sewage system (use absorbents). All equipment used in fire fighting and cleaning should be treated as contaminated waste. Workers should wash carefully after working in contaminated areas.

The decision to reopen a contaminated facility is made by the local labor protection district on the basis of the results of an analysis by the Institute of Occupational Health or the Chemical Instrument Centre of the University of Helsinki.

Summary

The risks to safety presented by PCB-filled transformers and capacitors at work are quite low once employees have become aware of the toxic potential of heated PCBs. The economic risk in a number of facilities (factories, warehouses, hotels, offices, etc.) may be very high because of the possibility of interrupted operations and expensive cleaning. These costs can be high when weighed against the benefits of a PCB-filled device.

With respect to the environment, the issue is safe waste disposal. The fact that the locations of transformers and compensating capacitors are now known permits greater control over them than over other PCB products or other chemical products that can form PCDFs or PCDDs when exposed to heat.

The risks presented by PCB-filled transformers and capacitors to safety at work and to property can be brought under control relatively fast. The methods of reducing the risk of PCB accidents are determining the locations of PCB-filled devices and reporting the locations to the fire fighting authorities; putting hazardous locations into an order of importance according to the size of the risk; reducing the risk of fire and the spreading of smoke; upgrading electrical maintenance work on PCB-filled devices in locations where there are major potential hazards; training of fire fighters and rescue workers and personnel in factories where the PCB-filled devices are located. In areas where there is a risk of extensive contamination, the only practical means to reduce PCB risks is to move the PCB-filled device out or to replace it while at the same time considering the fire risks.

New PCB-filled transformers or capacitors are no longer installed in northern Europe. In Finland the production of these devices was terminated in 1979. Consequently, the extent of the problem is gradually decreasing.

In my view, environmental protection will not be advanced much if the use of PCB-filled devices is prohibited in individual countries. We need an international agreement on restrictions on the use of PCB-filled devices, on safe waste disposal methods, on maximum allowable concentrations in working and maintenance areas and on the sampling methods to be used in contaminated areas. We should also keep in mind that the environmental problems posed by PCBs, PCDFs, and PCDDs do not concern merely those electrical devices discussed in this workshop.

REFERENCES

1. Plessner K. W., and Reynolds, E. H. Novel single and mixed liquids for high voltage dielectrics. Paper presented at International Conference on Large High Voltage Electric Systems. Paper 15–07, 1976 Session.
2. Douglas, H. Choosing transformers—the drier the better. Electr. Rev. 208: (19), 37–41 (May 1981).
3. Pohle, J. PCB-Ersatzprodukte fur Transformatoren. Umweltbundesamt 1979.
4. Cox, J. Environmental controls: silicone transformer fluid from Dow reduces PCB levels to EPA standards. Paper Trade J. : 36–39 (September 1982).
5. Rappe, C., Marklund, S., and Benqvist, P.-A Erfarenheten från PCB-brander. Skandia-tips, No. 4, 1982.
6. Stein, R. Askarele als Kuhlmittel in Transformatoren und als Dielektrikum in Kondensatoren. Hinweise zur Risikominderung und Schadenverhutung. Maschinenschaden No. 1, 1983.