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Safety and Environmental Aspects in the Use of Impregnating Materials

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Introduction:

The secondary insulation of electrical devices, such as motors and transformers, is important for several reasons, for example, the mechanical stability, the electrical insulation and protection of coil winding against dust, moisture and chemicals. Thereby, leakage currents or short circuits can be avoided so that safe and reliable electrical products can be produced. Therefore, the manufacturer of such devices gets these materials for secondary insulation (SI) and has to apply and transform them by means of a chemical curing process, in the course of which liquid materials become solid thermoset. The varnish or resin, which is provided for this purpose, is a more or less highly reactive material. It is unstable and tends to transform into a stable state. This transformation can happen spontaneously and violently. Such impregnating materials may be solvents containing varnishes or resins containing less solvents.

Besides the risks resulting from the spontaneous reaction, the materials themselves have a certain risk potential. These are to be found in the material safety data sheets (MSDS). The purpose of this paper is to show where the risks are and how can they be minimized.

Risks:

There are two conventional classes of SI materials curable to form thermosets.

Varnishes: They contain polymers which are usually free of danger materials that are dissolved in a solvent. Solvents are usually the dangerous components of varnishes.

Resins: They are 100% systems by definition, despite containing some solvents. Resins are very often used for SI made of unsaturated polyester. They consist of a solution of polymeric unsaturated polyester and a co-monomer, which is the component that determines the hazardous potential. Other resins are epoxy resins and polyurethane resins and the corresponding curing compounds which frequently have to be declared as dangerous materials.

In addition, inert fillers resins may contain further substances like catalysts, hardeners, accelerators, inhibitors, stabilizers and additives for different effects. All these materials may also be classified as dangerous materials. Relevant information can usually be found in the MSDS.

Depending on current condition of SI materials, there may be different kinds of risks.

Manufacturing:

Risks during the manufacturing of such materials are not subject of this paper because they are to be avoided in the chemical plant and the respective manufacturer is responsible for the elimination of these risks. Also, the chemicals manufacturer is obliged to provide information on any known and expected risks related to the materials and how can they be avoided.

As mentioned above, risks and hazards can differ according to the conditions under which the materials are and the way they are stored and applied.

Transportation:

After the manufacturing process, the product has to be transported to the customer. This is mostly be done by train and lorry. In this case, the main danger arises from collision produced from traffic accidents in which the liquid insulating materials are set free as a result of container damages.

As most liquid insulating materials have a flash point, there is a great risk for a fire and even explosion. In addition, there is a health risk to people trying to aid, for instance, members of the fire brigades. And there are great risks to the environment, especially to surface water and its inhabitants (micro organisms and fish), and to ground water, especially when used as water supply for people.

There are lots of governmental rules, regulations and laws dealing with the transportation of dangerous goods. They start with the type of containers; the accompanying documents and the labelling of containers and the lorry; the construction and supervision of the technical state of the lorry and its special equipment; the special training of drivers and the supervision of driving times by means of special registered equipment; and they reach as far as to rules guiding the route and traffic hours, such as the avoidance of tunnels, which are not allowed to be passed during peak traffic hours. During bad weather conditions, the transportation of dangerous goods may even be forbidden. There are also regulatory rules on which substances are not allowed to be transported in the same lorry, because they may react in case of an accident. All these regulations serve to avoid accidents and to minimize the consequences if an accident happens in spite of all precautions.

But potential accidents happen not only on the road. There is another source of danger: This is the untimely start of the gelling and curing of the transported material. Under warm weather conditions and in warm regions in general, the tem-

perature in the loading space of a lorry may easily reach 50 to 60°C. The storage time at such a temperature may be quite short, and if the transport takes too long, the curing reaction may start spontaneously even without the addition of a hardener. This is very dangerous because such reactions are producing large amounts of heat. They result in a rise of pressure and then a bursting of the containers. The fumes set free due to a high temperature may be toxic and may be ignited. In addition, other containers would be heated by this fire and may burst. Therefore, some products have to be transported in refrigerated lorries, or alternatively, transportation has to be arranged during the night.

Storage:

When the material has reached its destination, it usually has to be stored. Also, the untimely start of the gelling and curing process in the containers is a major problem at this stage. This is for the same reasons as the reaction that may occur in the course of transportation. Therefore, storage should take place in a cool place, away from other inflammable substances. The storage time that is guaranteed by the manufacturer can be extended by cool storage. Reducing the environment temperature of the SI materials during the storage by 10°C, can double their specified defensibility time.

Attention should always be paid to the guaranteed storage time, because the probability for an untimely curing is growing from day to day after its expiry. Therefore, materials with expired guaranteed storage time should be removed from the storing place and discarded. Otherwise, there is a danger that the scenario described above for transportation is growing, with much heavier consequences for the whole factory. Therefore, the rule "first in – first out" should be followed consequently.

As most SI materials are more or less flammable in liquid state, the dangers of an external fire are increased when these materials are involved. Therefore, they should be stored in a place that is out of reach of an accidental fire in the area. This also helps avoid the spread of a fire that is started in the resins store.

Application:

The untimely curing reaction is also a risk in the application stage, though for different reasons. One reason is that the turnover of the impregnating bath is too low so that the gel-time may have become so short that the pot life at ambient temperature is so short that the whole resin will start to gel.

The reasons for the lowering of gel-time may be that the content of inhibitors and stabilizers are greatly reduced due to the fact that the content of the bath is too old. Another reason for untimely curing may be catalytic effects of substances brought into the bath unwillingly, for instance, bare copper and copper alloys like bronze and brass, especially in the form of fine chips with fresh surfaces. Also, iron oxide in the form of rust is able to accelerate gelling of an activated unsaturated polyester resin.

The risk of gelling of an impregnation bath can be overcome by regularly testing the gel-time of resin. There should be a plan on how to stabilize the bath content by the addition of an inhibitor, without making the resin unusable. The manufacturers of the resins can establish such plans and supply the user with the necessary inhibitor.

In the application stage, the fire risk comes from possible external ignition sources. As the impregnating materials mostly have a flash point, it is necessary to draw off the vapours of solvents or co-monomers so that the lower explosion limit is not reached in the surrounding of the impregnating equipment. Also, all electrical devices of the impregnating equipment itself and in the surrounding should be selected to meet the requirements of the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations.

Another source for sparks, which could ignite the fumes of an impregnating material, is static electricity. The source for such sparks can be unexpected, for instance, insulating rubber soles of shoes, but also static electricity generated when refilling the bath with the resin.

Special attention has to be paid to the curing oven. The solvent of the impregnating varnish or parts of the co-monomers of unsaturated polyester resins are driven off. Also, here it is important to keep the concentration of the fumes under the lower explosion limit to prevent an explosion of the oven. This can be achieved by continuous exchange of the heated air so that the critical concentration of flammable substances cannot be reached.

During the application of SI materials the customer has to handle the resin and also the auxiliary products, such as hardeners and accelerators. Therefore, there are also the hazards connected with these materials. When activating an unsaturated polyester resin with hardener – in most cases a peroxide – and an accelerator – in most cases a heavy metal salt – it is important never to bring these two components in contact in the concentrated form. The activation has to be done in the

right sequence: firstly by thoroughly mixing in the accelerator and then by adding the hardener. If any of these materials is spilled, it is absolutely essential to follow the instructions given in the MSDS for the uptake and disposal of the spilled materials.

There is also a risk of fire when an air-drying varnish is used for impregnation. If a cloth is contaminated with such a material, this may auto-ignite by the oxidative drying of the varnish which is an exothermic reaction setting free enough energy to ignite the rag. Until final disposal, it has to be kept away from air either in a well-closed container or even under water.

Health risks:

When handling varnishes or resins and their auxiliary components, there may also be a health risk from the direct contact with these substances. They are also described in the MSDS. The substances can be absorbed by the skin without harming them, whilst they may damage the skin. There may be direct toxic effects or toxic effects after accumulation by long term contact. The uptake may happen by inhalation or by direct swallowing. The first case may happen when smoking a cigarette that is held by contaminated fingers, the latter by eating or drinking in the place where these substances are handled and used. One of the most important things in this respect is never to fill such materials in bottles or containers that are normally used for beverages. And each container, cask or bottle has to be immediately labelled correctly. Interchanging such substances can have catastrophic consequences.

One health risk caused by many substances – well known for this are epoxy resins – is sensitisation and allergization. Therefore, the direct contact with such substances has to be avoided.

Risk for environment:

The risk of contaminating the environment does not only exist during transportation and storage but also during the handling process.

This could occur by means of spilling the products. This could lead to both the contamination of the soil and ground water. In this respect, the water-borne varnishes have to be handled with special care. They can easily penetrate the soil until they reach the ground water because they are soluble in water. From there, they may be transported over long distances. Rain helps to wash the material into the ground water, but also into surface water, such as rivers and lakes. It is of great importance whether they have toxic effects on the organisms

in the water or whether they are biologically degradable.

Another contamination concerns the atmosphere. Varnishes contain about 50 % of volatile organic substances (VOCs). These VOC's are usually flammable and toxic compounds. The worldwide consumption of varnishes for secondary electrical insulation is about 40 000 to/year. That means that 20 000 tonnes of VOCs are set free during the impregnating process. Unsaturated polyester resins, which have to be heated during the heating process, emit about 20 % of co-monomer by means of evaporation. By an annual use of 20 000 to worldwide for electrical insulating purposes 4000 to of VOCs are set free per year. In total, there is a potential of 24000 tonnes of VOCs worldwide per year. To avoid the contamination of the atmosphere with these VOCs, the emissions generated during the impregnating process have to be decontaminated, either by thermal or by catalytic oxidation to carbon dioxide and water.

Future possibilities to reduce risks:

There are possibilities to reduce the risks connected with the impregnation of electrical machines to form a SI. Some SI manufacturer developed successfully unsaturated polyesters, which do not need co-monomers for the formation of thermosets. These monomer-free (MF) unsaturated polyesters are low viscous polymers without any monomers or VOCs. They are declared as non-hazardous materials with extensive consequences. There are no transportation and storage problems. There is no fire hazard because they do not have a flash point lower than the decomposition temperature. Therefore, there is no explosion limit to be considered. Due to the special curing mechanism there is practically no risk of untimely gelling and curing even at temperatures up to 50 and 60°C. And there are no significant health risks in handling these resins in the right way.

Nevertheless, in the MSDS there are instructions that spilling has to be avoided. The reason is that in Europe, every spilling of any liquid chemicals necessitates the exchange of soil as a consequence. And in handling this replacement, it is necessary to use the same things like gloves and safety goggles as it is the case when handling any other chemical material.

During the curing process, between 1 % and 5 % of these resins are set free as fumes. These fumes are VOCs. They result from the fact that every organic material is decomposed to a certain extent when heated especially if it contains oxygen donor component like peroxide. The amount and composition of these fumes depends on the curing conditions

and the construction of the electrical machine. For standard conditions the composition of these fumes is well known.

Conclusion:

The listing of risks and hazards in the use of secondary insulating materials might give rise to the impression that their use is very dangerous. When safety instructions outlined in the MSDS as well as regulations and laws are disregarded, this impression may be true. Nevertheless, the manufacturers of varnishes and resins are working hard to reduce such hazards. Known risks can be avoided. To improve safety, resin manufacturers are looking for new possibilities to reduce the risk potential in materials that are used today and they are different in the capability of achieving this aim.