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Trip Report #7-74
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3/8/74

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TRANSPORTATION SYSTEMS DIVISION

REPORT OF VISIT BY C.A. Burkhard DATE OF REPORT 3/8/74 NO. 7-74
 OBJECT OF VISIT To review the Pyranol usage problem in Company.

VISIT TO	ACCOMPANIED BY	DATE
Pittsfield, Mass.	—	2/25-27
Hudson Falls		
Schenectady		

SUMMARY AND RECOMMENDATIONS

The Pyranol problems facing the Capacitor and Transformer businesses of the General Electric Co. were reviewed with personnel at Hudson Falls, Pittsfield, and Schenectady. Company effort is being expended in securing proper definitions of the intent of the Environmental Protection Agency's proposed regulations and recommendations are being formulated with regards to revision of the proposed revisions which would permit the Company to continue its transformer and capacitor manufacturing and use operations. As long as there exists an industrial and commercial requirement that a non-flammable liquid insulating material will be required for transformers and capacitors in certain applications, it is doubtful that anything other than Pyranol will truly satisfy this requirement.

I first met with Drs. Robert Osthoff and Robert Anderson at the Pittsfield Transformer Laboratory. We very briefly discussed the day's activities. Dr. Osthoff stated that Dr. George Moore of the Research & Development Center has a flammability program which should be a real interest to us and to the Transformer people as regards the definition of parameters which will make it possible to predict the flammability of liquids without actually going through experimental activity. He further stated that Pittsfield is working with Mr. Torkelson of Waterford on silicones for use on railroad transformers. He further pointed out that the report which Mr. Lustenader obtained from Rudy Koehler which stated that the Japanese are using silicones on their vehicles is not correct. Hitachi, the Japanese firm, is using only 10-C oil in their transportation transformers. Silicone oil may be in use in no more than one or two substations of the Japanese national railroads, but as far as Pittsfield can determine, silicones are not being used on any of the vehicles. Dr. Osthoff made one other very interesting comment; he stated that the polychlorobiphenyls are not toxic as far as humans are concerned. It may cause a dermatitis problem on certain people. He further pointed out that oftentimes in their factory when Pyranol is splashed into a person's eye the man grabs a handful of 10-C oil and places it on his eye to wash out the Pyranol.

I met with Mr. Jenney who gave me two reports; one on Pyranol formulations and the other was a memo report on the evaluation of new Pyranol blends. He pointed out

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that by definition, an Askarel material (Pyranol is an Askarel) is one in which the arc formed gases are not explosive. In other words, if flame develops it does not travel to the fluid. This definition is often used. As I continued my conversations with others in the Power Transformer Department during the day I find that this definition is causing a hangup when they are dealing with the problem in Washington. I will discuss this later. The trade names which are used for polychlorinated biphenyls are:

- a) Asbestol
- b) Chloraxtol
- c) Elemex
- d) Inerteen (Westinghouse Electric trade name)
- e) No-flamol
- f) Saf-T-Kuhl
- g) Pyranol (General Electric trade name)

Pyranols as used in Pittsfield have been a mixture of polychlorinated biphenyls which generally have been mixtures of the isomers of hexa- or pentachlorobiphenyl and polychlorinated benzene which were a mixture of tri- and tetrachlorobenzenes. Recently trichlorobenzene was established as the only benzene derivative that would be available for use.

General Electric first used Pyranol commercially in 1932. Pittsfield stated that there have been no known cases of toxicity of humans, other than a temporary skin acne.

Before November of 1944, Pyranols contained no hydrogen chloride scavenger. As a result, corrosion could take place. In November 1944, they found that the addition of tin tetraphenyl as a hydrogen chloride scavenger was advantageous from a standpoint of preventing corrosion. In April of 1952, they substituted a mixture of tri- and tetrachlorobenzene for the trichlorobenzene previously used and changed the ratio of the chlorinated biphenyls to chlorinated benzenes for economic as well as viscosity reasons. In March of 1963, they replaced the tin compound by a diepoxide scavenger. I presume that this was done in part because of the high price of tin. The compound that they are now using is less expensive than is tin. In April of 1972 they changed from the 60% chlorinated biphenyls to a 54% chlorinated biphenyl because of pressures put on their Department. The lower chlorine content compounds are generally more easily degraded biologically. In November of 1973, they replaced the tri- and tetrachlorobenzene blend with trichlorobenzene. This substitution took place because of the ban which EPA placed on the production of hexachlorophene which gave the tetrachlorobenzene. The reason they use a mixture of these materials rather than a pure compound is to obtain a proper viscosity for good impregnation, and to maintain a low pour point temperature. This makes the transformer workable in a start-up condition in a low temperature ambient. Many of these compounds become very waxy or even crystalline solids at fairly moderate temperatures even as low as -15C which, while it is below the freezing point of water, is still relatively warm when you consider some of the areas of the United States where our equipment operates. Any new liquid dielectric must not affect the materials used in the construction of the transformer. They must also be compatible with the environment so as to satisfy EPA requirements. This is not an easy problem to do. The Pyranols have been excellent in this regard. Pittsfield has changed from a B2 spec to a B3 spec. This change was made at the first of 1974.

I met with Dr. W.A. Fessler who is an organic chemist. He stated that Factory Mutual considers that a difference actually exists, depending on whether the transformer oil is located on a transit car or a locomotive. He also said that GE and Factory Mutual may want to check this out at a later date to determine whether this is actually important, but no plans have been made now. This could become important, at least from a locomotive standpoint since the smoke part of the problem is moved away from the car containing people up to a vehicle which has only railroad employees on it. Dr. Fessler has looked at a number of new materials, and he is trying to find something that is in between Pyranol and 10-C oil in all its properties. Examples of materials which he has evaluated are as follows:

- a) **Silicone oils.** These oils are not as flammable as is 10-C oil but they will burn. They tend not to burn. The silica which is formed dampens or deadens the flame. Could be used as a replacement for 10-C oil, but it must have a 50 centistoke viscosity, in order to work properly. This requires that a large pump and larger cooling pipes, larger than that used today. Arc generated gases are easily formed and are explosive. The Japanese have written specs for silicone oil, but are not using it as yet.
- b) **The Dow Chemical Co.** has formed a new brominated compound. This is one in which the chlorines we are used to are replaced by bromine, the next heavier halogen. It is superior to Pyranol as regards liquid flammability, but under arcing conditions it is poorer than Pyranol. It has not passed the GE corrosion specifications! It is also a good solvent for the solid phase insulation systems that they are using, a better solvent than are the Pyranols. This is a serious drawback to its use.
- c) **They have considered the use of fluoro-organic liquids.** These are polymeric fluid materials formed from chlorotrifluoroethylene. The cost is extremely high; the decomposition products formed under arcing conditions are too toxic and much more persistent as regards environmental considerations than are those formed from the decomposition of Pyranol.

Dr. Fessler stated that it will be necessary for somebody to check what is really meant by persistence. Pittsfield is not doing this.

I asked him whether they have looked at Freons, since these too are fluoro-organic compounds. They have not done so in Dr. Fessler's laboratory.

- d) **Hexachlorobutadiene** is an inert organic compound which oxidizes at 180 C. It gives corrosive decomposition products under arcing conditions and will not pass the GE corrosion spec. The decomposition is felt to be an oxidation initiated reaction rather than a thermal reaction. This material is less compatible with the insulation system than is Pyranol, in other words it tends to dissolve the solid phase insulation.

Pittsfield wants to lower the viscosity of any new transformer fluid without increasing the flame tendencies and solubility characteristics. This means that possibly silicone types may have to be used, but unfortunately, the flame characteristics of the silicones are not that good. The solubility characteristics of silicones are excellent.

Pittsfield is really in a quandry because if the environmental air requirements are not as important as has been thought, then they may want to very seriously reconsider the entire scope of their endeavors. They will not have a reading on this until later.

I talked with Mr. Don Johnston, Manager of Engineering for Transportation Transformers. Dana Anderson of the Marketing Group, and Dr. Fessler. We discussed the problems associated with the dry type transformers. They are larger than Pyranol devices and they are flammable. Dry type transformers were estimated to be 50% larger than Pyranol transformers. They require a source of clean, dry air at a rate 10 to 15 thousand cfm. They have poorer heat transfer characteristics, and can have hot spot temperatures as high as a 100 C. On the SEPTA cars it is estimated that

temperatures can be 130 C, while the Metroliner car can see 175 C. The maximum temperature in a liquid cooled transformer approximates 100 C.

The sealed high pressure gas-filled transformers are larger than is the Pyranol transformer, about 30% larger. These can develop leaks. A leak in a sealed high pressure gas-filled transformer can be electrically disastrous in a very short period of time because the gas pressure reduces to the point where it no longer serves as a dielectric or as a coolant. Furthermore, these gases when subjected to discharge conditions lead to extremely toxic materials. Pittsfield is seriously concerned should anyone ask them to build a sealed high pressure gas-filled transformer. They don't feel they could handle this in the immediate future because it would require that they change their Manufacturing Processes drastically so as to handle boiler-type construction.

The use of Freon as a refrigerant in a transformer has not been refuted. Mr. Johnston stated that he does not have any information. He felt that much engineering would be required. In fact he told his General Manager that it would take at least 15 months to design and develop an engineering model. His Manager, being a little more cautious, said it would take 2-1/2 years to do this, therefore the official figure is 2-1/2 years to design and bring out a Freon-cooled transformer. If one tilted such a transformer there would be real problems associated with cooling of this transformer. Furthermore, it was estimated that they would require at least 30% more space than that currently occupied by the Pyranol filled transformers.

The use of 10-C oils to replace Pyranol will require the same size for the transformer or could even require a little less space. Unfortunately, 10-C oil may possibly not be used to replace Pyranol in the Pyranol-filled transformers we are currently using. The reason for this is that unless one gets all of the Pyranol out and Pittsfield said all of it, the 10-C oil and Pyranol in a mixture tend to degrade one another in unknown chemical reactions giving hydrochloric acid and other decomposition products which can be corrosive and provide for poor electrical performance. In a later conversation it was learned that this may not be the problem it once was thought to be.

I inquired of these people about the use of fluorobiphenyls which indeed would be far more stable than the chlorobiphenyls. This was confirmed by Dr. Fessler but he was very quick to point out that the environmental problems which the EPA wants to solve would be made more difficult to handle. EPA does not specify the chlorination level that they are attempting to attack in their proposed regulations. They have included all chlorinated biphenyls in their definition and Pittsfield and others are not in agreement with this broad general approach.

I asked Dr. Fessler and the others in attendance what they felt was the weakest point of their transformer. They stated that under thermal conditions the paper was the weakest component. Under arcing conditions the liquid insulation is perhaps the weakest component, be it Pyranol or anything else. This is because the liquid fills in a void and can continue to be decomposed as the arc continues, whereas in a dry type transformer, when the paper has decomposed, if it has not burned, it is not necessarily a fact that decomposition will continue at the same point.

We returned to Dr. Fessler's office and discussed some of their chemical problems in greater detail. In their current studies they are looking at other oils. They are actually looking at some oils which will form waxes. The paraffin hydrocarbons for example, would fall in this category. If they use compounds like this they will

be forced to heat their radiators to soften the wax before they can place the transformer in operation. This is required so that the cooling system will be actually working when they want to use the transformer. They feel that toxicity is not their real problem with materials. He stated that trichlorobenzene is possibly more toxic than is chlorinated biphenyls, yet it is decomposed more readily than the chlorinated biphenyls by biological mechanisms. Organisms other than humans may be affected more seriously than are humans by these materials. Such organisms could be plant life, water life, and birds. Little is really known about this. Pittsfield has a paper which was published in Sweden in which it is stated that the polychlorinated biphenyls cause the problem. However, on checking this out Pittsfield finds that the chlorinated biphenyls from Sweden are not made in the same way as are those which we obtain in this country. The chlorinated biphenyls in Sweden are actually a mixture of chlorinated coal-tar products and can include in addition to biphenyl chlorination products, biphenyl ether chlorination products, as well as the chlorination products of naphthalenes, benzenes, anthracenes, and a host of other aromatic materials, which are in some cases toxic and some may also be carcinogenic. Monsanto's biphenyl raw material is a pure compound and is not a mixture of coal tar derivatives. This could be what has touched off this problem with the Environmental Protection Agency. Much more needs to be done before it is really known whether or not these materials are as serious as they are projected to be at this time.

It is my opinion as a result of my discussions at Pittsfield that the Environmental Protection Agency will need to redefine the proposed regulations much more clearly than they had done in order to get regulations that will stand up in court. I feel much better after my discussions with these people today in what the Company is doing.

On Tuesday morning, February 26th, in Hudson Falls, I visited with Dr. Al Pozefsky. He stated that they feel that Pyranol is not dangerous and that it should be taken off the toxic materials substances list. Hudson Falls is concerned with the solid waste disposal program which would involve the use of incineration to dispose of capacitors containing Pyranol. They do this now by use of a clean landfill, but this may not be acceptable in the very near future. They are earnestly trying to get polychlorobiphenyls taken off the Federal list of dangerous materials. I discussed at length his feeling with regard to the biodegradation studies being conducted by Monsanto. He feels that these studies have not been well done. The biodegradation rate depends on the polychlorobiphenyl isomer used. Those having more chlorine are much more persistent in nature and therefore should be eliminated from use. Hudson Falls uses the trichlorobiphenyl isomers containing less than 1% of the higher chlorinated materials. He says that this isomer biodegrades slowly, but it does degrade. Nature does not have much of the lower chlorine content isomers in it which confirms that they do biodegrade with relative ease.

Hudson Falls has now proposed as a replacement material for Pyranol di-2-ethylphenyl phthalate, an ester plasticizer, which is 99+% biodegradable. It contains an epoxy stabilizer, the diglycidal ether of bisphenol A. The GE trade name for this mixture is ECONOL. ECONOL is a flammable material. Hudson Falls state that there is zero probability at this time of obtaining the capacitor that has a liquid fillant other than Pyranol which is non-flammable. Dr. Pozefsky clearly stated that the Japanese National Railroad will not be using any Pyranol-type derivatives starting March 1974. This is by a legal edict from their government.

It was reported that Japan's problem with Pyranol-type derivatives was generated in a rice mill where they were using this material as a heat transfer agent. It got into the rice and the people who ate the rice developed the usual liver type

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symptoms that come from the injection of organic chlorinated compounds. The Japanese law gives them 12 years to change out Pyranol and get rid of all present Pyranol installations. There is no data on how this changeout is to be conducted. In fact, there was a question as to whether they could wait until the last day of the 12-year period before doing anything. It has been reported that the Japanese will have to incinerate these materials in order to decompose them. The Japanese do not know how or what they are going to do as yet.

Hudson Falls does not recommend the mixing of ECONOL or 10-C oil with Pyranol. They have no data as to the life expectancy of these mixtures. However, Dr. Pozefsky was not too concerned with this point. They do not use silicone oil because it is too costly and the dielectric constant is much too low for capacitor usage. They are interested in corona extinction and corona start characteristics of any materials they use. Corona extinction is their biggest hurdle. They are proposing to use a blended system of fluids in the future.

Mr. Richard J. Hopkins, Mgr.-Power Capacitor Production Engineering joined us and we discussed this matter further. He stated that all new materials will be flammable. Capacitors using ECONOL will be approximately 40% larger than those using Pyranol. As work progresses, and there is very little work being done at Hudson Falls, the final material which they will be using will be similar to Pyranol, at least as close as is possible regarding its electrical properties, but flammability and flashpoint may be the limiting factor and the final choice of a new fluid may be actually much poorer than is Pyranol in this regard. They feel that overall the performance of their devices will be somewhat poorer as a result of such a change of materials. He indicated that they will need alkyl-aromatic type materials with a higher aromatic content in order to get the electrical characteristics that they are interested in.

Hudson Falls is seriously considering the design of a metallized power capacitor. These would be quite different than those which we are now using. However, they clearly pointed out that the lead time for such a development will be at least two years if any major changes are required. In June they will know what they are planning to do and it will take approximately one year to get underway. Currently, they are working with Monsanto on other liquids. Monsanto does the chemical work that they need, thus the General Electric Co. is not involved chemically on new materials at this time for capacitors. They are looking at sulfones and may blend these with other materials. By so doing the good flashpoint and other flammability properties may be seriously reduced. They are not particularly happy about this.

It was very clearly pointed out that we may be placed in a position, as a locomotive and rapid transit car vendor, of providing our customers with a legal means for the disposal of capacitors that can no longer be used.

I visited with Dr. P.A. George of the Capacitor Dept. and saw the polypropylene film fabrication equipment in actual operation. This is a very sizable Plant. The product which they make is used not only in GE film capacitors, but also in those of many of their competitors' capacitors. The General Electric Company is one of only a few fabricators of polypropylene film.

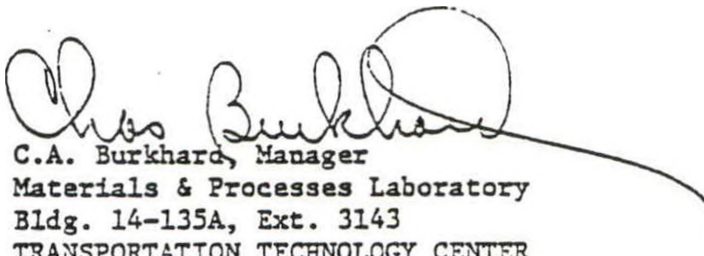
On Wednesday I visited the CR&D and discussed briefly with Dr. George Moore the work which he is conducting for Power Transformer. He is merely conducting a study of flammability properties of dielectric liquids and is trying to define the problem

that really is before the Transformer Departments. He is particularly interested in the significance of the arc formed gases. I guessed as a result of my discussions there, and have finally gotten agreement with everyone that I have talked to, that the CR&D is doing nothing with regards to the definition or development of replacement materials for Pyranol. Therefore, work in this area will be done only at the Pittsfield and Hudson Falls, with the most of it being conducted in Pittsfield.

I discussed, over the phone with John Church, the work which is going on at the CR&D, Pittsfield and elsewhere in answer to this Pyranol problem. He too confirmed that there is really nothing going on with Pyranol at CR&D and that all of the advanced work is going on in Dr. Fessler's lab in Pittsfield. He said that we should communicate with Dr. Bueche if a need develops. Church further stated that Dr. A. Hay of CR&D has not responded to them, primarily because they don't know what to do and nobody is giving him any money. He said that a letter from Tomasetti to Bueche and possibly from Vanderslice to Bueche, together with letters to Fessler and others in Pittsfield would certainly help get the show on the road.

Church stated that there is a letter from Pittsfield Sales personnel which prohibits the taking of further orders for Pyranol transformers except for transportation usage. I received a copy of this letter.

As a result of this 3-day visit and further conversations I have had around the Company with regards to Pyranol, it is my belief that we will be able to use Pyranol provided we and our customers can comply with the regulations which the Environmental Protection Agency will finally draft. If we cannot abide by the regulations as they are finally drafted, then substitute materials will be required. If the requirements for non-flammability is genuine it is my estimate, as an organic chemist, that it will be almost impossible to furnish a non-flammable liquid, and by this I mean a truly non-flammable liquid, which will be compatible with the environment in the way things are now made to fit by EPA. I know that this sounds pessimistic but, unfortunately, I feel it is true.



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