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# AN ALTERNATIVE TO 1,1,1, TRICHLOROETHANE

## FOR

## ELECTRIC POWER UTILITIES



INLAND TECHNOLOGY INCORPORATED 2612 Pacific Hwy. East, Tacoma, WA 98424 206-922-8932 • 800-552-3100

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## CITRA SAFE®

CITRA SAFE is an ultra safe industrial solvent produced from all natural, nonpetroleum distillates. CITRA SAFE is far safer to work with than chlorinated petroleum solvents.

CITRA SAFE exhibits no toxic properties, has no threshold limit value or Permissible Exposure Limits imposed upon its usage in the work place and has no carcinogenic properties.

CITRA SAFE is literally a biodegradable solvent replacement for mineral spirits, thinners, and chlorinated solvents. The use of CITRA SAFE reduces risks of hazardous chemical spills, eliminates most hazardous waste disposal costs, and reduces the health hazards associated with petroleum solvents.

CITRA SAFE removes tough greases, oils, tars, and other contaminates from metals, painted surfaces, ceramic, fiberglass, and many plastics. It is also effective in removing some glues, and resins, and can be used to remove oil based stains from carpets and upholstery. Its ability to evaporate totally after use makes CITRA SAFE an ideal replacement for hazardous chlorinated solvents in cleaning electrical parts and apparatus. Its ability to safely clean polyethylene grease and "Icky Pik" from flooded telephone cables and semiconductors has made CITRA SAFE the solvent of choice for many telephone and power utilities. Inland Technology Incorporated has initiated a thorough search of the available scientific literature regarding our product CITRA SAFE. Our product CITRA SAFE is technically identified as 95% D-Limonene and is a 100% citrus derivative. All health data and test results pertaining to D-Limonene will also quite equally pertain to our product CITRA SAFE.

\* F.E.M.A. (Flavoring Extract Manufacturer's Association) has assigned G.R.A.S. (Generally Recognized as Safe) status to D-Limonene.

\* D-Limonene is approved by the F.D.A. (regulation 21 CFR section 182.60) for food use.

\* N.F.P.A. rating of health hazards associated with products of combustion is "0", the safest rating assigned.

\* O.S.H.A. does not limit exposure and has established no permissible exposure limits on the materials.

\* A.C.G.I.H. has not established a threshold limit value on the product.

This material is not listed in N.T.P., I.A.R.C., or O.S.H.A. directories of carcinogenic materials.

In addition, our product, CITRA SAFE does not contain any hazardous components as defined in 29 CFR 1910.

A systematic review of the literature indicates that acute over exposure may cause temporary irritation of the eyes and mucous membranes. Chronic over exposure may produce localized dermatitis in some sensitive individuals. Prolonged over exposure has caused mild photosensitivity in some individuals.

This research of the available literature has reinforced our belief that CITRA SAFE is an ideal safe substitute for toxic petroleum distillates in most applications.



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San Diego Gas and Electric has, like many utilities, been engaged in a carefully structured search for a suitable alternative for 1,1,1 Trichloroethane.

During their search they examined and tested over 24 different proposed substitutes. Only six materials made it through initial screening to be subjected to the full batter of tests.

Of the six materials, only one was deemed satisfactory in terms of volatility, lack of residue, lack of damage to components, and in terms of environmental and human safety. The clear winner, according to these tests, was the product CITRA SAFE, by Inland Technology Incorporated of Tacoma, Washington.

The results of this testing were shared with the members of the Western Underground Committee at their January 1991 meeting in Pleasanton, California.

San Diego Gas and Electric's test results are included in the following pages. San Diego Gas & Electric

A. M. Archer

CATE October 17, 1990

FROM

TO

S. W. Hale

FILE NO.

GAA 020

SUBJECT

#### 1,1,1 TRICHLOROETHANE ALTERNATIVE SOLVENT STUDY

As part of the Company's ongoing effort to minimize the use of 1,1,1 trichloroethane, the Materials Analysis Laboratory received six samples of materials for evaluation as electrical cleaning solvents. The samples were identified as "Tekusolv", "Voltz", "Citra-Safe", "EPA 2000", "Attack" and "PF 32". The six samples, along with 1,1,1 trichloroethane (TCA), were subjected to several tests and the results compared with the trichloroethane's performance. The test regimen is described below.

#### Test Description

Nine analyses were selected to evaluate the solvents as candidates for electrical components cleaning materials. Those tests were: Liquid Dielectric Value; Tracking, or Residue Dielectric Value; Flash Point; Volatile Evaporation Rate; Volatile/Non-Volatile Content; Solvent Absorption by PVC Cable Jacket; Effect on Semiconductor Adhesion to Insulation; Effect on Semiconductor Mechanical Strength and Effect on Semiconductor Volume Resistivity. The personnel safety aspect and the environmental/disposal implications were previously evaluated by the Safety Department and the Environmental Department, respectively. Individual tests are described below with test results summarized in Attachment 1.

The Liquid Dielectric Value test measured the dielectric value of the solvent prior to any significant evaporation of volatiles (dielectric value is a measure of a material's ability to withstand electrical stress). Two electrodes, separated by a space of approximately 1/4", were immersed in approximately 100ml of solvent. Increasing voltage was applied to one electrode until the circuit was completed by current crossing to the opposite electrode.

The Tracking, or Residue Dielectric Value test was performed on the non-volatile portion of the solvent (for this evaluation, non-volatiles were defined as the material remaining after 24 hours of open dish evaporation in a fume hood). Electrodes,

approximately 2" apart, were placed in the residue. As in the previous test, voltage was applied until the circuit was completed. The dielectric value of the residue was compared to the dielectric value of the dish before solvent addition and subsequent volatile evaporation. Figure 1 is a graph of the test results, with the dielectric value of the dish before solvent addition normalized to 100%.

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The Flash Point of a solvent is a measure of the material's tendency to form a flammable mixture with air. It can indicate the possible presence of highly volatile and flammable materials in a relatively nonvolatile or nonflammable mixture. The test was performed by placing a measured amount of solvent in a Pensky-Martens Closed Cup tester. As the sample was heated, a small flame was. periodically directed into the cup. The flash point was measured as the lowest temperature at which the vapor was ignited by the flame. Figure 2 is a graph of the flash point test results.

The Volatile Evaporation Rate test was performed by placing 4ml of solvent in a culture dish, then placing the dish in a fume hood to aid evaporation. The dish was periodically weighed during a 24 hour period. Figure 3 illustrates the evaporation rate curves (to make the graph more easily readable, only the first 20 hours of evaporation are plotted). For comparison, the evaporation curve of water is also illustrated. In the

Residue Dielectric (Tracking) Dielectric change before solvent added and after 24 hour evaporation period



Solvent Flash Point









A. M. Archer

table in Attachment 1, the volatile evaporation rate is expressed in grams/hour.

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The Volatile/Non-Volatile Content was measured by comparing the sample weight at the start of the above Evaporation Rate test with the weight of the sample at the end of the 24 hour Evaporation Rate test. (As previously mentioned, for this evaluation the non-volatile content was defined as the material remaining after 24 hours of open-dish evaporation). The weight-percent of the volatiles and non-volatiles was then calculated. Figure 4 is a graph illustrating the test results.

The Solvent Absorption by Cable Jacket was measured by placing a pre-weighed 1" by 1" coupon of PVC cable jacket in a solvent for 24 hours. Upon removal, the coupon's exterior was dried before reweighing. The two weights were then compared. Figure 5 illustrates the test results.

The Effect on Semiconductor Adhesion was determined by first measuring the adhesion strength to the insulation on a sample of #2 cable. The cable sample was then immersed in a solvent for 1 hour. Following a 24 hour drying time at 90°C and a cool down period, the adhesion strength was again measured and the value compared to the beforeimmersion value. Figure 6 illustrates the test results.

The Effect on Semiconductor Mechanical Strength was measured using the pull strips derived from the above

#### Non-Volatiles Content 24 Hour Evaporation Time



Solvent Absorption by Cable Jacket Change in Jacket Weight after Immersion

% Increase in Jacket Weight









semiconductor adhesion test. The semiconductor samples, a strip before solvent immersion and another strip after drying, were tested on a tensile tester at a crosshead speed of 20 inches/minute.

A solvent's Effect on Semiconductor Volume Resistivity was measured to determine if the conductance/resistance properties of the semiconductor were changed by solvent exposure. This was determined by measuring the volume resistivity both before and after solvent immersion and a 24 hour drying period at





90°C. Figure 7 is a graph of the test results, with the volume resistivity of the semiconductor before solvent addition normalized to 100%.

#### Summary

It should first be mentioned that none of the alternative solvents tested is a direct substitute for 1,1,1 trichloroethane (TCA). These solvents are chemically different from TCA and thus often exhibit different properties. This study attempted to evaluate those different properties in their relation to electrical components cleaning.

With one exception, no significant differences exist between TCA and the tested solvents from a liquid dielectric and residue dielectric standpoint. That exception is the "Attack" solvent (see Attachment 1 and Figure 1). As can be seen the Attachment, the liquid dielectric value was 6KV (approximately 84% less than TCA) and the tracking test also exhibited a significant reduction in dielectric value. Because of these low values, it is recommended that this solvent not be considered for electrical components cleaning.

None of the solvents exhibited significant effects on semiconductor adhesion and semiconductor mechanical strength. See Figure 6 and the Attachment.

compared to TCA, which has no flash point, all the alternative solvents exhibited a significant reduction in flash point temperatures (see the Attachment and Figure 2). These comparatively low flash point temperatures, i.e., approximately 120°F-140°F, will probably not present a safety problem, however. (The Safety Department should be consulted for their final A. M. Archer

approval in this area.)

None of the tested solvents caused significant change in the semiconductor volume resistivity (see Attachment 1 and Figure 7).

There were significant differences displayed in the volatile evaporation rate and the volatile/non-volatile content tests. TCA evaporated relatively quickly and left no measurable residue in this evaluation. The other solvents evaporated much more slowly and left measurable residues. Using water as a reference, all the alternative solvents but one (Citra-Safe) evaporated more slowly than water would when applied to a surface using the test conditions in this evaluation (see Attachment 1, Figures 3 and 4 and the applicable test discussions).

The Disposal Costs comments and Personnel Safety Considerations comments in Attachment 1 were derived from evaluations by the Environmental Department and Safety Department, respectively.

Due to its relatively rapid evaporation rate as compared with the other alternative solvents, its low non-volatile content, minimal disposal costs and favorable dielectric quality, it is recommended that Citra-Safe be submitted to the Kearny Electric Shop for their evaluation. The Safety Department, however, should be specifically consulted about the relatively low flash point of this product (125°F in the SDG&E evaluation, 113°F according to the product's Material Safety Data Sheet).

Store

S. W. Hale Extension 4995

Attachment

cc: B. I. Heramb G. E. Lehmann T. M. Reguly

	TCA	Tekusolv	Voltz	Citra-Safe	EPA 2000	Attack	PF 32
Liquid Dielectric Value (XV)	>35	>35	31	35	>35	6	>35
% Change in Dielectric on a Surface Due to Residue (Tracking)	-3≍	-13X	-2%	-12	-2X	-38x	+10X
Flash Point (degrees F)	None	135	140	125	140	124	124
Volatile Evaporation Rate (grams/hour)	20.61	0.03	0.08	0.14	0.09	0.10	0.11
Kon-Volatile Content	0≍	65×	50×	0.12	40X	172	112
Solvent Absorption by Jacket	8.2%	1.7%	1.9%	6.5X	1.7%	5.6×	3.2%
Effect on Semiconductor Adhesion		No sign	ificant e	ffect display	red by any	solvent	
Effect on Semiconductor Kechanical Strength		No sign	ificant e	ffect display	ved by any	solvent	
Effect on Semiconductor Volume Resistivity	-5X	-72	-10%	+11%	-42	-4%	-sx
Disposal Costs as Determined by the Environmental Department (S/drum)	\$\$25	2300	\$300	\$0.00*	2300	\$0.00'	\$300
Personnel Safety Considerations as determined by the Safety Department	note *	note *	note 1	note *	note <sup>1</sup>	note '	note *

<sup>1</sup> Since material purports itself not to contain petroleum products, disposal in local landfill via regular trash cans should suffice for disposal.

<sup>2</sup> Personnel safety considerations for the tested solvents include the following:

A. For minimum exposure, all personnel required to wear goggles/safety glasses and nitrile gloves.

B. For moderate exposure, all personnel required to use a respirator with organic vapor cartridges, goggles/safety glasses, nitrile gloves, boots and a suit/apron.

C. Due to the relatively rapid evaporation rate of 1,1,1 trichloroethane, moderate to severe exposure levels could occur more quickly than the alternative solvents in the event of a large spill.

D. Other controls required are moving air (natural or mechanical), no ignition sources and no contact with oxidizers. Additionally, Voltz and Tekusolv require a storage area with a temperature range of  $0^{\circ} - 100^{\circ}$  F.

<sup>3</sup> No personnel safety information given due to absence of completed Product Approval Request.

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The Elastimold Division of Eagle Industries is a manufacturer of conductive connectors and components for the Electrical Power Transmission Industry.

Elastimold conducted an extremely careful series of tests on nearly twelve serious solvent substitution contenders for 1,1,1 Trichloroethane as it is used for component cleaning in their industry.

In all of these rigorous tests, the product identified as product "B" performed better than any of the non-halogenated materials tested. The accompanying letter from Elastimold identifies product "B" as CITRA SAFE by Inland Technology Incorporated, Tacoma, Washington. The actual test results are included following the letter from Elastimold.



(908) 852-1122 FAX: (908) 852 6158

December 18, 1990

Mr. Joe Lucas Inland 2612 Pacific Highway East Tacoma, WA 98424

Dear Joe:

As you requested, I am sending you with this letter a copy of the paper I delivered at the 1989 T&D Meeting, in New Orleans, on the effects of various solvents on connector and cable shield materials. For your information, Citra-Safe is solvent "B" in Table I on the second page of the paper.

As I mentioned to you, we have since tested additional solvents and are now in the process of testing molded parts with a number of solvents. This occasioned my request for an additional gallon of Citra-Safe.

I will be presenting our most recent results at the Western Underground Meeting, on January 24 or 25, in Pleasanton, California.

Thanks for your help in providing the sample for our tests.

Sincerely yours,

Donald D. Perry A Manager Material Sciences

Attachment

/peh

#### EFFECT OF DEGREASING SOLVENTS ON CONDUCTIVE AND SEMICONDUCTIVE SHIELD COMPOUNDS, AND ON THE ELECTRICAL PERFORMANCE OF MOLDED CONNECTORS

Presented to the Western Underground Committee January 23-24, 1991 San Ramon, CA

> D.D. Perry and J.P. Bolcar Elastimold Division, Eagle Industries Hackettstown, N.J.

Most solvents that are effective in cleaning and degreasing cable and molded connectors also tend to swell the EPDM and EPR rubber used in conductive jackets and shields. (They have little effect on polyethylene). This swelling action tends to disrupt the carbon chains that are responsible for the conductivity of these materials. The degree to which the conductivity is reduced depends on several factors: (1) the time of exposure to the solvent, (2) the volatility of the solvent, and the time elapsing after the solvent is removed.

The solvents employed in this study are listed in Table

Ι,

Solvent	Specific <u>Gravity</u>	<sup>8</sup> .p. ( <sup>0</sup> <u>C</u> )	Flash <u>Pt.(<sup>0</sup>F)</u>	Appearance, etc.	Description
A	1,385	74-122	Kone	Water White	1.1.1-trichlorethane/ perchloroethylene (75/25)
8	.860	171	150*	Yellow-amber	>901 limonene
С	.841	178	122**	Water White	Essentially pure limonene
D	.760	193-221	144**	Water White	Citrus-petroleum solvent blend
E	.801	186	205**	Orange	Citrus-petroleum distillate
F	H/A	H/A	K/A	Pale Yellow	Citrus-petroleum solvent blend
G	.77	185-216	146**	Water White	Hydrocarbon-terpene blend
H	.82	127	100-105	Water White	Alcohol-terpene blend
I	1.33	43	Xone	Water White	Fluorocarbon 1,1,3
J	0.784	188-193	147**	Water White	Citrus-petroleum solvent blend
Limonene	.840	176	122**	Clear, Water White	Hatural terpene

#### TABLE [ PROPERTIES OF SOLVENTS

\* Cleveland Open Cup

Closed cup (TAG)

Closed cup (Pennsky-Martens) along with their key properties and some descriptive information. Solvents A-F were included in the original study, while G-J were evaluated later. Items of interest are the boiling points, which reflect relative volatilities, and flash points. All the hydrocarbons are rated as "combustible" materials (flash points, 100-200°F) as is solvent H. Thus, the low toxicity and environmental benefits of these solvents are paid for to a certain extent by the fact that they are all combustible materials.

0f solvents tested, G are the newer and J citrus-petroleum blends, H is a blend of an alcohol and terpene derivative, and I is а Freon type а (chlorofluorocarbon). Although I is non-flammable, relatively non-toxic, and a good cleaning solvent, it belongs to that class of materials, the chlorofluorocarbons, that are being heavily taxed and whose manufacture and use is being phased out world-wide due to their damaging effects on the ozone layer.

#### B. Conductive Shield Materials

The conductive jacket compound used in the slab tests was a peroxide-cured EPDM. In addition, two semiconductive cable shield materials were tested, an EPR jacket from a 15kV 1/0 175 mil stranded aluminum cable, and an XLPE jacket from a similar type of cable. These materials had rated maximum volume resistivities of 5,000 ohm-cm under ambient conditions.

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#### C. Test Procedure

Volume resistivity measurements were made by the voltage/current method using the arrangement shown in Figures 1 and 2. Samples of conductive materials were cut into one-inch wide strips. The EPDM material was 40 mils thick, while the EPR and XLPE cable shields were between 28 and 34 mils. As shown in Figure 2, a current of 100 microamperes was passed between two electrodes clipped to the sample strip three inches apart. Voltage drop across the sample was measured between two fine wire electrodes attached to the underside of the sample one inch apart. Volume resistivity was calculated from the voltage drop, the known current, and the sample dimensions. A one square-inch area of the conductive rubber strip was enclosed by a liquid-tight Teflon dam. Solvent (2.5ml) was placed inside the dam cavity and allowed to remain in contact with the rubber for 15 minutes. Resistance measurements were made prior to addition of the solvent, then after addition of the solvents, about every five minutes for the first 15 minutes, after which measurement intervals were increased.





FIGURE 2

~ 4

#### D. Results of Tests on Slab Samples

The effects of the various solvents on the connector jacket samples and two cable shield materials are shown in Tables II - IV and in graphical form in Figures 3 - 13. The curves obtained on the EPDH and EPR samples all show the same general features: (1) an initial rise in volume resistivity as the solvent penetrates into the rubber. This rise continues even after removal of the solvent; (2) a decrease in volume resistivity as the solvent evaporates, and (3) a leveling off at some value which varies with each type of solvent tested. In many cases the final value is at or below the initial level of resistivity. The only exception to this behavior was solvent I (Freon type) which does not swell the rubber and therefore has little effect on its volume resistivity.

In the case of cross-linked polyethylene, the solvents generally had little effect on the volume resistivity (Figures 11 - 13). This is because polyethylene, which is a semi-crystalline polymer, is not attacked by most solvents. Solvent J had somewhat more of an effect on the XLPE samples than did the other solvents, but did not approach the changes occurring with EPDM and EPR.

If we were to rate these solvents in order of their increasing effects on the conductivity of the EPDM and EPR materials, they would be ranked as follows:

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- <u>Solvent A</u> <u>Chlorinated solvent</u>.
   This solvent exhibited the lowest maximum volume resistivity and more rapid and complete recovery of conductivity.
- (2) <u>Solvents B and C</u> <u>Essentially pure limonene</u>. These solvents showed a higher maximum volume resistivity and slower recovery, but eventually returned to levels of conductivity approximating the initial values.
- (3) <u>Solvents D, E, F, G and J Citrus (or other terpene)</u> <u>- petroleum blends.</u>

These solvents showed considerable variation in behavior, which probably reflects differences in their composition. Solvents E, F and J took longer to reach their maximum resistivity values and leveled off at considerably above their initial values of volume resistivity. It is believed that these solvents contain higher proportions of high boiling hydrocarbons than do B, C, D and G, so that even after a considerable period of time, some solvent is still retained in the rubber. This phase of the investigation showed the following:

All the solvents tested affected the conductivity of the rubber samples to some degree, but had little effect on polyethylene.

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The solvents varied in the degree to which they decreased the conductivity of the rubber, as shown by the relative peak values of volume resistivity, the recovery times, and the degree of recovery they exhibited. It should be noted, however, that at no time did any sample become insulating.

Finally, based on the tests on slab samples of shield materials, it can be concluded that all of these solvents are acceptable for use as cleaners/degreasers, if properly used. This means that the following general procedure should be followed:

- Parts should not be immersed in solvent, and solvent should not be poured inside a connector.
- (2) Cable and connector interfaces should be cleaned by wiping with a solvent-soaked cloth, then wiped with a clean cloth.

#### E. Tests on Molded Parts

The next phase of the investigation involved exposing molded connectors to solvents and evaluating the resultant effects on the electrical performance of the connectors. It was decided to look at three principal areas:

. The effect on the conductivity of the shield,

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- . The effect on connector interfaces (e.g. elbow-bushing),
- . The effect on the loadbreak mechanism.

#### (1) Effect on Shield Conductivity

This was investigated using a small Elastimold splice. Splices were immersed for 15 minutes in the five representative solvents. The splice ends were plugged up to prevent solvent from getting inside the splice. They were then tested in accordance with IEEE Standard Most of the resistance measurements were made 592. using a direct resistance measurement, rather than the current-voltage measurement specified in IEEE 592. This was done because of the complications envisioned in clamping four contacts on the cylindrical splice. However, as a check, in one case (Solvent B - limonene type) the measurements were made by both methods. These results are shown in Table X. Although the results obtained by the four wire (voltage-current) method were lower, the behavior in both cases was similar, and the 5,000 ohm limit was not even approached in either instance. The results for the various solvents are shown in Tables V - X. Although these solvents did cause a reduction in conductivity, in no case did the resistance approach the maximum value of 5,000 ohms permitted by the Standard.

Some points of interest regarding these results are as follows:

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In general, there was much less of an effect on the splice shield than on the 30-40 mil slab samples tested in the first part of the This is attributed to the much greater study. thickness of the splice shield (approximately 125 mils). To confirm this, an experiment was run in which the splice was immersed in 1,1,1-trichloroethane for an hour instead of 15 minutes. In this case, the resistance rose to 2,210 ohms, compared to 1,800 ohms, and it took much longer to return to the initial level of 1,210 ohms. (1400 vs. 382 minutes - Tables V and VI).

Trichloroethane, due to its high volatility, showed the most rapid recovery of conductivity. While the other solvents (D, G and H) did not increase the resistance any more than did trichloroethane, the effect tended to last much longer: 7202 minutes for Solvent G, for example, vs. 382 minutes for trichloroethane. This reflects the presence of higher boiling components in these solvents.

#### (2) Fault Current Initiation Test

The second part of the test of solvent effects on splices involved measuring the ability of the parts to initiate a fault current. The results obtained are quite preliminary, but may be indicative of trends that are worthy of further investigation.

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Five solvents were evaluated: A,B,D,G, and H. An untreated part was used as a control. The procedure used was as follows:

Parts were immersed in solvent for 15 minutes, as described above for the resistance measurements. The test specimen was then wiped off, assembled onto cable, and subjected to the fault current initiation test. The circuit conditions used differed from those specified in IEEE 592. Phase to ground voltage was 5.0kV vs. 7.0kV specified in the standard and the time allowed to take out the breaker was 10 cycles vs. 3 seconds permitted in the standard. Under these conditions, we obtained the following results:

- the untreated splice initiated a fault twice, as required,
- (2) the trichloroethane soaked splice failed to initiate a fault,
- (3) all the other splices (soaked in flammable solvents) caught fire in the first test.

These results cannot be considered to mean that the parts either passed or failed 592, but they do indicate that exposing connectors to solvents in the manner described can create problems by either preventing initiation of fault currents or causing parts to catch fire. We intend to investigate this matter further by studying, for example, the effect of drying time after solvent immersion and altering the circuit conditions.

#### (3) Effect on Connector Interfaces

To evaluate how representative solvents would affect connector interfaces, 15kV loadbreak elbows and bushing inserts were half submerged in solvents A,B, and D for 15 minutes. Four each of the mating parts were immersed in each of the three solvents, then assembled and tested at 15kV withstand levels. Subsequently, two parts from each solvent group were taken to breakdown. The results are summarized in Table XI. All parts passed both impulse and Hi-Pot Withstand, so it is apparent that this degree of exposure to solvent does not have a negative effect on the interfaces in terms of electrical performance.

#### III. SUMMARY AND CONCLUSIONS

- All the solvents tested, except for Solvent I (a Freon type), significantly affected the conductivity of EPDM and EPR slabs, but had very little effect on semiconductive XLPE shield materials.
- The solvents differed in the extent of conductivity loss they produced, and in the rate and degree of recovery of conductivity exhibited after solvent removal.
- The more volatile solvents permitted faster recovery of conductivity and produced the least permanent damage to conductivity of the shield materials.
- Splices immersed in solvents had resistances well below the permissible 5,000 ohm maximum of IEEE 592.

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Results of the nail test were inconclusive, but indicated that solvent soaking is potentially hazardous.

- 15kV elbow-bushing assemblies, after parts were separately exposed to three typical solvents, passed both AC Hi-Pot and Impulse Tests.
- All the solvents are considered to be acceptable when properly used.
- The following should be avoided:
- (1) immersing connectors in solvents
- (2) · pouring solvents inside connectors
- (3) failing to wipe off excess solvent.

#### IV. PLANNED FUTURE WORK

- . Investigate effect of drying time after soaking on nail test results.
- . Investigate effect of solvents on loadbreak performance (switching tests).
- Perform resistance measurements on splices immersed in solvents, then aged for 504 hours at 121°C.

DDP/ghh











Solvent	Yol. R <u>Initial</u>	esistivity, <u>Max.</u>	ohm-cm <u>Final</u>	✗ of Initial Yalue	Tîme To <u>Max.Min.</u>	Time To Final Hrs.
A	3845	18,857	1715	44.6	102	26
В	1950	53,911	3279	168.2	143	28
C	2315	41,503	4000	172.8	256	48
D	3513	16,286	4296	122.3	186	27
E .	2243	8,762	4137	184.4	414	75
F	1865	28,493	8559	458.9	394	51
G	2980	17,000	2700	90.6	300	183
Н	4520	76,000	4750	. 105.1	270	73
I	2980	8,700	2100	70.5	150	28
J	1989	19,888	2438	122.6	471	144

 TABLE
 III

 EFFECT OF SOLVENTS ON VOLUME RESISTIVITY OF

 EPR CABLE JACKETING







Figure 9



Figure 10

Volume Resistivity vs. Time - EPR Cable Shied - Solvent J



## TABLE IV EFFECT OF SOLVENTS ON VOLUME RESISTIVITY OF XLPE CABLE JACKETING

Solvent	Yolume Initial	Resistiv <u>Max.</u>	rity, ohm-cm <u>Final</u>	∡ of Initial Yalue	Time To Max.Min.	Time To Final Hrs.
А	1493	3064	1406	94.2	50	23
В	412	602	383	94.9	111	71
С	928	1415	783	84.4	92	23
D	431	522	438	101.6	20	. 4
E	422	422	400	94.8	5	7
F	693	699	670	96.7	15	6
J	774	2967	1601 ·	206.8	1451	72









#### TABLE Y

#### EFFECT OF 1,1,1 TRICHLOROETHANE ON RESISTANCE OF SPLICE SHIELD -15 MINUTE IMMERSION

Description	Resistance, ohms	Time, min.
Initial value	1,170	0
After immersion	1,800	15
Max. value	1,800	15
Final value	1,060	382

#### TABLE VI

.

#### EFFECT OF 1,1,1 TRICHLOROETHANE ON RESISTANCE OF SPLICE SHIELD -1 HOUR IMMERSION

0 60 50 1 400

#### TABLE VII

#### EFFECT OF SOLVENT D ON RESISTANCE OF SPLICE SHIELD - 15 MINUTE IMMERSION

Description	Resistance, ohms	Time, min.
Initial value	890	0
After immersion	1,470	15
Max. value	1,880	22
Final value	950	9,800

#### TABLE VIII

#### EFFECT OF SOLVENT G ON RESISTANCE OF SPLICE SHIELD - 15 MINUTE IMMERSION

Description	Resistance, ohms	Time, min.
Initial value	970	0
After immersion	1,530	15
Max. value	1,610	285
Final value	1,070	7,202

#### TABLE IX

#### EFFECT OF SOLVENT H ON RESISTANCE OF SPLICE SHIELD - 15 MINUTE. IMMERSION

Description	Resistance, ohms	Time, min.
Initial value	1,450	0
After immersion	1,790	15
Max. value	1,790	15
Final value	1,080	7,150

#### TABLE X

## EFFECT OF SOLVENT B ON RESISTANCE OF SPLICE SHIELD - 15 MINUTE IMMERSION

Description	Resista	nce, ohms	Ťi	me, min.
	( <u>a</u> )	(b)	(a)	(b)
Initial value	830	620	0	0
After immersion	1,585	985	15	15
Max. value	1,605	1,110	56	330
Final value	990	875	2,837	2,730

(a) Direct measurement technique(b) Voltage-current technique

#### TABLE XI

#### EFFECT OF SOLVENTS ON BUSHING/ELBOW

IMPULSE AND AC HI-POT

	•	Impulse w/stand 95kV +/- 3 shots ea	AC Hi-Pot w/stand 34kV for 1 min.	d Impulse A( Breakdown B) 3 shots ea	C Hi-Pot reakdown
Solvent	Part #	Polarity	Pass/Fail	Level	Level
		Pass	Pass	+125, 1st shot	N/A
_	) 2	Pass	Pass	-110, 1st shot	N/A
А	3	Pass	Pass	N/A	70kV 1 sec.
	( 4	Pass	Pass	N/A	70kV 5 sec.
	5	Pass	Pass	N/A	70kV 5 sec.
•	) 6	Pass	Pass	N/A	70kV 26 sec.
В	5 7	Pass	Pass	+150, 1st shot	N/A
	( 8	Pass	Pass	-125, 1st shot	N/A
	9	Pass	Pass	+130, 2nd shot	N/A
	10	Pass	Pass	+130, 1st shot	N/A
D <	11	Pass	Pass	N/A	60kV 15 sec.
(	12	Pass	Pass	N/A	60kV 20 sec.

#### Failure Mode Impulse

1	puncture	bushing	interface
2	puncture	bushing	interface
7	puncture	bushing	interface
8	puncture	in test	cable
9	puncture	bushing	interface
10	puncture	bushing	interface

#### Failure Mode AC Hi Pot

3	puncture	bushing	interface
4	puncture	bushing	interface
5	puncture	bushing	interface
6	puncture	bushing	interface
11	puncture	bushing	interface
12	puncture	bushing	interface