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St. Louis Department

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Final Report on Transformer Insulating Fluids

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note! two versions of INTRO. SUM. & CONCL. have been added to choose from [illegible]

INTRODUCTION

This report describes the laboratory work which was done to identify and determine the explosive characteristics of the aroclor decomposition gases resulting from subsurface electrical arcs. This information was needed on aroclors related to their use a transformer insulating fluids.

SUMMARY

The decomposition gases evolved from Arolors 1242, made in W.G.K & Anniston Plants, Pyranol, Rome Ga., and Inerteen PPO, were determined at 240 and 15,000 volts. The gases were identified by means of gas chromatographic analysis. The explosive ranges of the simulated synthetic mixtures of the gases in air were established.

CONCLUSIONS

The explosive range of decomposition gases from arochlors mixed with air broadens as the amount of hydrogen in the decomposition increases. Arochlor 1242 decomposition gases had the broadest range when mixed with 45-47.5% to 77.5-80.0% air (240 V) and 45-47.5% to 82.5 to 85.0% air (15,000 V) Pyranol arochlor, Rome Ga. had a narrower explosive range, 50-52.5 to 72.5-75.0%, air (240 V) and 40-42.5 to 57.5-60.0%, air. Inerteen PPO arochlor, was not explosive when mixed with air.

Apparently, the portions of the elements hydrogen and chlorine in the molecular mixtures of compounds which are used to make up different types of arochlors are the governing factors involved in designing arochlor transformer fluids which are non explosive in air.

INTRDUCTION

This report describes the laboratory work done to identify the aroclor decomposition gases and determine their explosive characteristics resulting from subsurface electrical arcs. This information was needed on aroclors as applied to their use as transformer insulating fluids.

SUMMARY

Aroclors 1242 (W.G.K & Amniston), Pyranol Rome Da., and Inerteen PPO, were tested at 240 and 15,000 V. The decomposition gases were identified by means of gas chromatographic analysis and the explosive ranges of simulated decomposition gas were established.

Conclusions

The data indicates that when only a very small amount of free hydrogen is present in the decomposition gases such as in Inerteen, PPO-5H201-KA, (0.25% at 240 V and 0.6% at 15,000 Volts) the gases are not explosive.

Optional submitted to approval

References.

Coward, H.F and G.W. Jones, Limits of Flammability of Gases and Vapors, U.S. Bureau of Mines Bulletin 503. U.S. Government Printing Offices Washington, 1952. A treatise on limitations accuracy and variables involved in laboratory flammability tests.

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← EXPERIMENTAL WORK

A. Decomposition Tests

Several types of arochlors were subjected to submerged electrical sparking at 240 and 15,000 volts for the purpose of determining the amount and kinds of decomposition gases evolved. The apparatus ~~used~~ is shown in Figure 2, Spark Decomposition Apparatus. The power supply for the 240 volt series was a General electric Autotransformer, 400 Watts, Type H-1, Cat.# 58-H-2. Ammeter, Weston Electric Co, model 433. For the 15,000 Volt experiments, Hypotronics Inc.; AC, DC, Dielectric Tester, Model No. 750-2-870.

The experiments were were performed in the following manner:

1. Cooling water flow was started through the electrodes to maintain their temperature about 20-30°C.
2. Arochlor was then charged into the reservoir.
3. The sparking chamber was ~~then~~ filled by means a 50 or 100 ml syringe fitted with a #25 needle. The needle was ~~pressed~~ thru the septum and the air sucked out, thus

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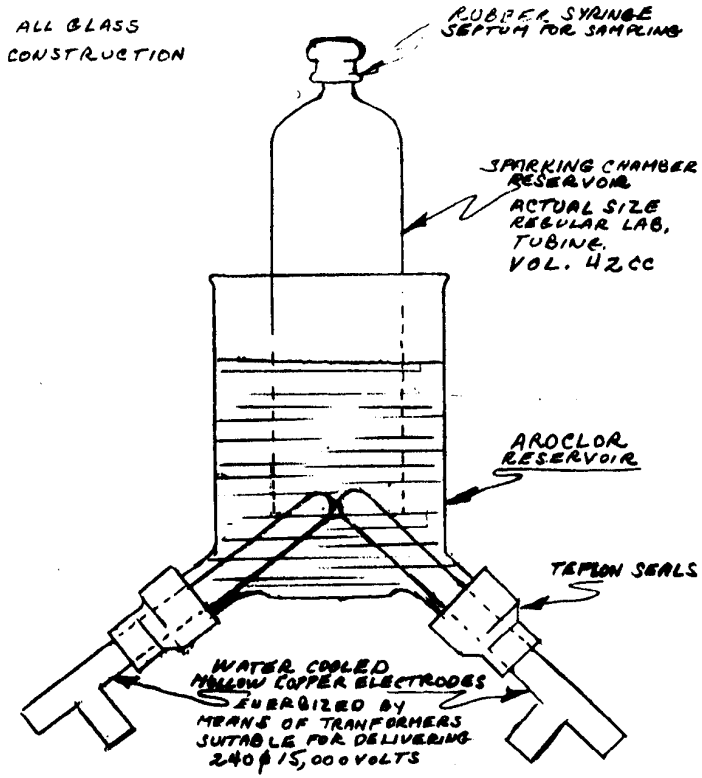

FIGURE 1

SPARK DECOMPOSITION APPARATUS

4a. For those experiments made at 15,000 V the electrodes were set at about 1/8" apart to permit arcing.

filling the Chamber full without leaving any residual air space. A five minute time test was made to determine if the chamber septum was gas tight.

4. For the experiments made at 240 volts, 10 amperes, the current was applied and sparking was achieved by manually manipulating the insulated electrodes.

5. The decomposition was continued until about 20 cc of gases were evolved, displacing the liquid downward.

6. Two 1.00 cc samples of the gas were then obtained thru the septum. They were analyzed by means of Gas Chromatography Ref. to the analytical section of this report.

The equipment was cleaned after each decomposition. A new septum was installed for each experiment.

The results of the decomposition experiments are summarized in Table 1. The nitrogen, oxygen carbon monoxide and dioxide shown in the analyses are apparently due to dissolved air in the aroclors or accidental entry into the system. ~~during sampling~~.

The residual gases from the foregoing experiments were mixed with air and flame tests to determine the qualitative explosive characteristics. These tests indicated that Aroclor 1242, and the Pyranol type aroclor went thru an explosive range. The Inerteen type aroclor was not explosive.

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TABLE I

TRANSFORMER FLUIDS DECOMPOSITION GASES INITIATED BY MEANS OF AN ELECTRICAL ARC

EXPERIMENT No. OR NOTE BOOK PG	TRANSFORMER FLUID IDENTIFICATION	DECOMPOSITION SPARK GAP VOLTAGE	DECOMP. SPARK-GAP AMPERAGE	GAS CHROM. ANALYSES (AVERAGES) HYDROGEN	NITROGEN	OXYGEN	CARBON MON-OXIDE	CARBON DIOXIDE	ACETYLENE	HYDROGEN CHLORIDE	UNKNOWNS	
122803 122804 122006	AROCLOR 1242-KN456 ANNISTON, SPLE. 2 ¢3	240	10	19.7	1.77	0.75	0.10	0.21	12.7	65.1	0.54	*1
11	DITTO	15,000	45 MILLI-	27.0	3.7	1.27	1.09	0.75	12.27	54.53	0.75	*2
122837	80% ARCLOR 1242(KN-456 20% TTCB MIX. *3	240	10	14.86	3.75	1.75	-	-	9.16	70.9		
	DITTO	15,000	45 MILLI-	11.4		10.3			3.76	74.45		*2
122805	INERTEEN PPO	240	10	0.25	2.53	0.73	0.33	0.53	0.3	95.8		
	DITTO	15,000	45 MILLI-	0.6	1.9	0.8	1.7	-	1.2	93.8		

*1 AVERAGE OF THREE SPARK TESTS OF EACH OF THE THREE AROCLOR LOTS

*2 AVE OF 2 ANAL. FROM EACH OF THE THREE AROCLORS

*3 PYRANOL TYPE AROCLOR, ROME, GA. PLANT

B. Thermal Decomposition Experiments.

The apparatus shown in Figure 2 was used to determine the effect of heated surfaces on the stability of aroclor 1242. (Exp. 122 817)

The liquid aroclor was sucked up into the heating chamber by means of a 100 cc syringe. Then 2 cc of nitrogen was injected to keep the aroclor from contacting the liquid aroclor. When heat was applied to the heating element, the volume of the gas expanded to a point just below the heating element (gas volume about 15 cc). During the heating period of about 2 hrs. 45 min. only about 2 - 3 ml of gas was evolved. The temperature of the heating element in the gaseous space was about 770 °C.
When cooled to room temperature the total gas volume was only 5 cc.

Samples of the gas were analyzed by means of gas chromatographic methods. The present components found were:

Hydrogen	0.3
Nitrogen	71.7
Oxygen & carbon monoxide	9.2
Carbon dioxide	2.1
Acetylene	0.0
Hydrogen chloride	9.2
Water	7.3

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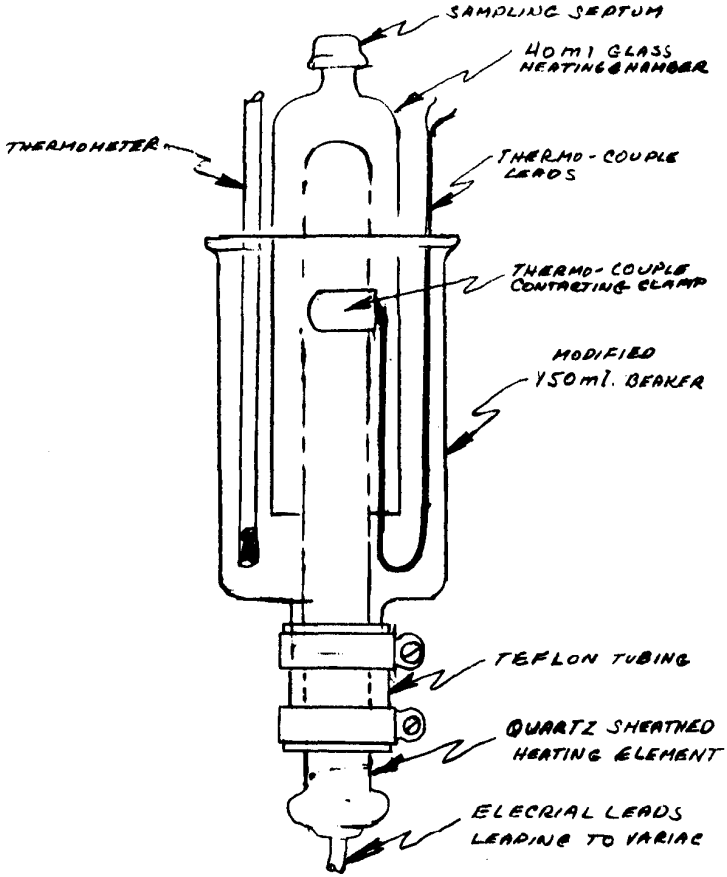

FIG. 2
THERMAL DECOMPOSTION APPARATUS

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Apparently very little decomposition occurred.

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C.. Explosive Range Determination

1.. Apparatus

The apparatus used to determine the explosive limits of the synthetic decomposition gases is shown in Fig. 3 - Apparatus for Flammability Tests.

a. Explosion tube, 150 cm X 5 cm, diameter, standard laboratory glass tubing. The bottom was carefully ground flat.

b. The bottom seal was a circular piece of plate glass held against the bottom by means of a reservoir of mercury as shown. The the mercury container was held at the desired height by means of a block of wood so that the level of mercury was about 1/4 " above the ground glass seal.

c. Electrodes used for ignition power supply, High Frequency Generator, Tesla type. Matheson Scientific Co. (Cat. 56532-40) One electrode was grounded to the laboratory water line.

d. Sampling port. A close fitting ground glass joined nipple for attaching rubber syringe septums.

e. Three way cocks for the addition of the desired gases.

f. A three way cock for a source of a water fed vacuum jet to remove and flush out spent gases. (polyethylene construction)

g. Gas mixing pump, 8 cm long × 7.5 cm diameter. All glass construction, equipped with a glass ball check in the exhaust tubing leading to the bottom of the ion exchange column and a mercury pump which was manually operated to actuate the pump. A pinch clamp was provided on the tubing at the bottom outlet of the pump to shut off the mercury flow when vacuum was applied to the system.

The drying tower was filled with, Indicator Grade, Soda lime (4-8 mesh) from Fischer Scientific Co.

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2. Experimental Procedure

The desired amount of each gas to the apparatus on the basis of Daltons law which states that the total pressure of a mixture of gases is the sum of the partial pressure of the components The amounts were calculated, thus;

$$\left[\left(\frac{P_a \cdot G}{100}\right)\frac{P_1}{100} + \left(\frac{P_a \cdot G}{100}\right)\frac{P_2}{100} + \left(\frac{P_a \cdot G}{100}\right)\frac{P_3}{100} \cdot S\right] + \left(P_a - \frac{P_a \cdot G}{100} \cdot A\right)$$

where:

P_a is the barometric atmospheric pressure in mm hg. abs.

G is the percent of the total synthetic gases to be added in m m

P_1 P_2 P_3 etc are the percent of each component in the total synthetic gas in m m

S is the total synthetic gases required in m m

A is the total amount of air in m m to be added by difference to atmospheric pressure.

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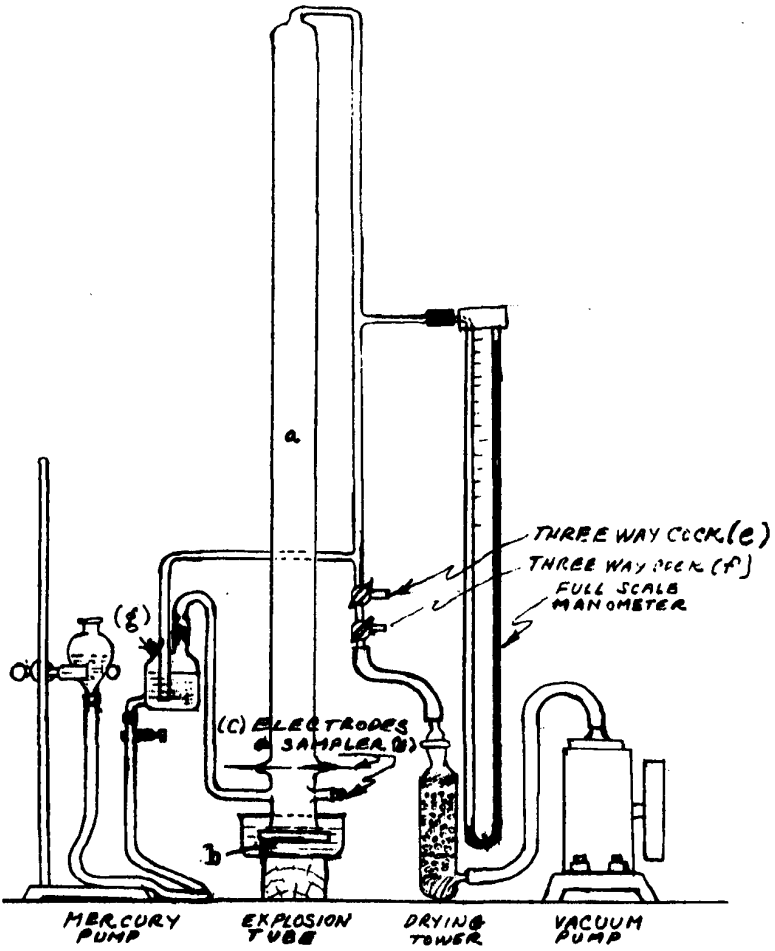

FIG. 3. APPARATUS FOR FLAMMABILITY TESTS

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The entire apparatus was first evacuated to the lowest pressure possible with the mechanical vacuum pump (about 0.5 mm). The cock (2) was then closed to determine if the system was gas tight. When it has been determined that the system was gas tight, the first component was added in the desired amount, controlled by the same stop-cock as indicated by the manometer reading. After all the component gases were added, air was admitted into the system until atmospheric pressure was indicated. The cock was immediately closed.

The system was now ready for mixing. The mercury reservoir was lowered well below the level of mercury in the pump (to avoid accidental suckback into the system) and the pinch clamp on the mercury tubing leading to the reservoir was opened. The gas was then mixed by manually raising and lowering the reservoir until at least 60-65 complete pumping cycles were completed. This was found to be the extent of pumping required to assure complete mixing. When the synthetic mixtures of gases were added the air was very carefully flushed out of the transfer lines leading from the cylinder.

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reducing valves. A positive pressure of about 5 psi was maintained on the transfer line tubing after flushing out the air to assure uncontaminated transfers.

When the mixing operations were complete, samples of the explosion chamber gases were removed, by means of 1 cc, gas type syringes, for analysis.

The contents of the explosion tube was now ready for spark ignition. The High Frequency Generator was turned on and adjusted to assure a spark gap of about 1/2 inch when grounded. The block supporting the plate glass seal, mercury reservoir, at the base of the column was removed while holding the mercury reservoir up until just before the current was applied to the electrode. Caution, before the ignition transformer is applied to the electrode a visual inspection should be made to be sure that the plate glass seal has dropped off. Otherwise, if an explosion occurs the tube might rupture.

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The gaseous contents of the explosion chamber were defined as being in the explosive range when a visible flame propagated to the top of the column, either audibly or inaudibly, when ignited. This was usually a crescent shaped, colored or almost colorless flame rose slowly to the top of the column in about 4-5 seconds. At times the slightly turbid flame was barely visible. A flame occurring upon ignition which was self extinguishing and non-propagating was not considered to be in the explosive range

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Table II lists the pertinent data pertaining to the [illegible] range depicted in Graph 1. The gaseous mixtures listed under the heading "Synthetic Mixtures" ~~are those~~ simulate the probable gases of decomposition of the aroclors shown under Transformer Fluid Identification. These mixtures are the synthetic mixtures taken from the spark tests listed in Table I. Only the hydrogen, acetylene and hydrochloric acid was used for the synthetic gas make-up. Nitrogen, oxygen carbon monoxide and carbon dioxide were not included because they could not have derived from the decomposition of the aroclors, because these compounds do not contain oxygen or nitrogen. The unknowns where not included because the insignificant amounts did not justify identification.

no #

Note that the components listed under the heading "G.C. Analyses Before Ignition" are in pairs. The "first" listings of each set of pairs are the results of gas chromatographic analysis. The other is a calculated value which has been included for the sake of comparison and to show an estimated accuracy of the method.

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Toxicity and Hazards.

According to Sax Hand Book on Dangerous Properties of Industrial Materials, chlorinated biphenyls are considered to be toxic and hazardous (ref. pg 596). Contact with the skin and inhalation should be carefully avoided. They can be absorbed through the skin and cause systemic reactions and skin lesions known as chloracne, comedones. Cysticules also develop.

The fire hazard is slight when exposed to heat and flame. They can be dangerous when heated to decomposition, they emit highly toxic fumes.

The dangers of working with hydrogen, acetylene and hydrogen chloride are self evident. Hydrogen and acetylene are explosive in certain portions of air and hydrogen chloride is a severe skin and respiratory irritant.

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In carrying out the experimental work on the explosive limits of the decomposition products the tests should be started near the expected parameters near the [illegible] high and low

concentrations of the explosive range. Concentrations in the center of the range should be avoided since the glass explosion tube might ruptures. For example, stoiriometric quantities of hydrogen and oxygen will shatter the explosion tube. Proper shielding and ventilation is highly recommended.

J. H. Balm

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