

THE PROBLEM OF POSSIBLE SYSTEMIC EFFECTS FROM CERTAIN CHLORINATED HYDROCARBONS*

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THE use of chlorinated naphthalenes and compounds of allied pharmacological possibilities is extremely wide, and with the steady growth of the use of electricity is certain to expand much farther. For years it has been known that many of these compounds cause a troublesome acne, and there is a large literature upon this phase of the subject. Our investigations have not been concerned with chloracne but with the possibility of systemic effects following ingestion or inhalation of such products. In the spring of 1936, the Halowax Corporation, a division of the Bakelite Corporation, called our attention to three fatal cases of jaundice in workmen using chlorinated naphthalenes and chlorinated diphenyl, and requested that the subject be investigated as

rapidly and thoroughly as possible.† In brief these cases were as follows:

Patient 1. Male, age 21. The previous medical history of this man was in no way significant except for the fact that he had an attack of jaundice about 6 weeks prior to his fatal illness. Late in December, 1936, he became badly constipated and had much abdominal pain and distention. When admitted to the hospital he was slightly jaundiced and was evidently very ill. He was somewhat anemic and his skin, particularly upon the arms, face, chest and back, showed many pustules. He died after a brief period in the hospital, and at autopsy was found to

† The Halowax Company makes many products besides chlorinated naphthalenes, and it has come to our knowledge that all of these products are indiscriminately called "halowaxes" by purchasers and users, and are lumped together as possible causes of acne and even of systemic disease. Since "halowax" is merely a trade designation, care should be taken to describe compounds by their chemical names and thus avoid condemnations which are both troublesome and misleading.

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have a cirrhosis of the liver with acute yellow atrophy superimposed upon it. This man had been exposed to low concentrations of vapors arising from a mixture of tetra and pentachloronaphthalenes, together with approximately 10 per cent of a refined chlorinated diphenyl. While both he and others engaged in the same work had chloracne, there were no other disturbances of health in fellow workmen, nor was there any precipitating cause for the acute yellow atrophy such as treatment with arsenamine or exposure to dangerous concentrations of carbon tetrachloride.

Patient 2. This was a young man who died in February, 1936, after an acute illness characterized by jaundice. He had been exposed to fumes arising from a mixture of penta, and hexachloronaphthalenes. There is no record of chloracne. The patient worked with a large number of other people of whom but one (Patient 3), a close friend, had significant illness.

Patient 3. Another young man employed with Patient 2. He became jaundiced in March, 1936, and died after an illness of 2 weeks. A careful autopsy resulted in a diagnosis of acute yellow atrophy of the liver. Here again no history could be obtained as to a precipitating cause, and there was no record of preceding attacks of jaundice.

In addition to these three very recent fatalities, we have learned of four other possible cases, none of them fatal. All of these have had jaundice and the entire group consists of isolated individuals who have been picked out of large groups having the same exposure. In but one instance, Patient 1, is there record of antecedent disturbance of health, and the general health of fellow workers has been good.

Such cases have not been reported in the medical literature and only occasionally can one find reference to systemic effects of any sort. For example, Courtois-Suffit (1934) reports on work done by Touraine and his associates (1934) who examined 60 workers

who had been exposed to trichloronaphthalene. Of these 13 were found to have mild digestive complaints, anorexia, nausea and vertigo, but Courtois-Suffit remarks finally, "Absorption is certainly possible and we have for proof of it some of the digestive and general complaints which have been due to it. But they appear to be of little consequence considering the mildness of the digestive troubles and the absence of respiratory phenomena."

In Touraine's cases the exposure was to a trichloronaphthalene, whereas the American cases of acute yellow atrophy were exposed to compounds of higher chlorination. Our own experiments indicate that trichloronaphthalenes require enormous dosage, far beyond anything encountered in industry, in order to produce liver damage. Telcky (1927) reported a number of cases of chloracne in persons exposed to chlorinated naphthalenes with a chlorine content ranging from 14 to 53 per cent. He found that the lower the chlorine content the less the acne. Mittelstädt (1935) examined a number of cases of chloracne due to trichloronaphthalene and reported a number of vague general complaints but nothing in the nature of serious disease. Regarding his animal experimentation, Lehmann (1919) reported that animals fed chlorinated naphthalenes refused to eat after a time and that, whether poisoned by inhalation or by feeding, at death showed "peculiar" lesions in the liver. Flinn and Jarvik (1936) gave subcutaneous injections of enormous doses of chlorinated naphthalenes dissolved in paraffin oil to rabbits. The compounds used were as follows:

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1. A mixture of tri and tetrachlor-naphthalene.
2. A mixture of tetra and penta-chloronaphthalene.
3. A mixture of penta and hexa-chloronaphthalene.

In addition, sublimate from (2) and (3) were collected in oil and injected subcutaneously.

None of the animals receiving (1) or the sublimate from (2) died, and even after 2 months were quite normal when autopsied. The first death in the animals receiving (3) occurred on the 12th day and the last died on the 26th day. Those receiving the sublimate from (3) were even more severely affected. Autopsy in these animals revealed striking changes in the liver, not, as described, entirely characteristic of acute yellow atrophy but sufficiently suggestive to cause the authors to conclude that "certain chlorinated naphthalenes or impurities contained in them are capable of producing yellow atrophy of the liver in the rabbit."

At the beginning of their paper, Flinn and Jarvik (1936) mention the fact that there have been three cases of acute yellow atrophy of the liver in men working with chlorinated naphthalenes but give no details in regard to them. These cases are undoubtedly the same as those described in the beginning of this paper.

One may summarize the meagre literature upon systemic effects from these substances as follows:

1. With the exception of the mention of acute yellow atrophy by Flinn and Jarvik (1936) there are no reports or even suggestions of serious effects upon human beings.

2. There is evidence (Teleky, 1927) that the degree of chlorination is sig-

nificant in relation to the production of acene. In the work of Flinn and Jarvik (1936) the compounds producing serious liver injury were the most highly chlorinated of those tested, though the chlorine contents as given by analysis vary surprisingly little.

3. There are no published figures upon the amounts of various chlorinated naphthalenes in the air which will produce injury of any sort, and while the work of Lehmann (1919) and of Flinn and Jarvik (1936) point to the liver as a possible site of injury this indication rests upon such extreme dosage as to fail to apply directly to human exposure.

EXPERIMENTAL WORK

In appraising the possible toxicity of any substance met in industry it is first necessary to determine the principal route of absorption. In the case of the compounds under consideration there can be no doubt that inhalation is their chief means of entering the body. They are used hot in a great variety of operations and volatilize in varied degree. They are often applied in solution in such volatile solvents as carbon tetrachloride and toluene. The amounts reaching the air under such circumstances are hardly detectable. It will however be shown that carbon tetrachloride adds to the toxicity of the chlorinated naphthalenes and allied compounds, and if there is possibility of inhaling these compounds in other parts of the factory then inhalation of carbon tetrachloride adds a decided hazard. Under such circumstances solvents such as toluene should be used.

Observation in a number of plants causes us to feel that even though

workmen may be extremely dirty and careless, comparatively little of these waxes is eaten. They are tenacious substances, insoluble in water, and if they get on the hands they stick there and are not transferred to the food.

Skin absorption is the third possible means of entering the body. It may occur but at best must be slight when compared to the steady inhalation of finely divided or gaseous material in the air.

They thrive upon a diet very similar to man, and in the case of these chlorinated compounds it is possible that diet may be very significant. Finally, their normal characteristics have been described so well as to make the detection of abnormalities both easy and certain.

Method of exposure.—The inhalation experiments were carried out in four large air-tight wooden boxes, each capable of holding ten rat cages, size

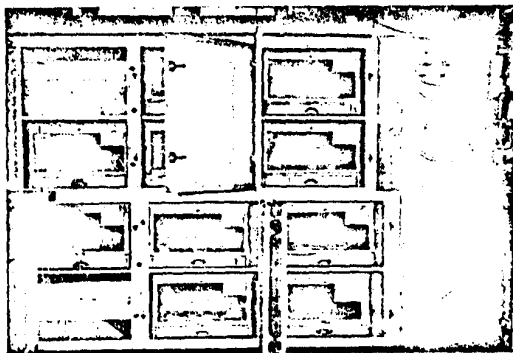


FIG. 1. Front view and inflow end of two boxes with rat cages in place and doors open.

Inhalation experiments are then the most important sources of information, but to them we have added a certain number of observations upon ingestion and subcutaneous injection of various compounds.

Inhalation Experiments

Animals.—White rats have been employed throughout. They permit the use of a large number of animals in a relatively small inhalation installa-

tion. They thrive upon a diet very similar to man, and in the case of these chlorinated compounds it is possible that diet may be very significant. Finally, their normal characteristics have been described so well as to make the detection of abnormalities both easy and certain.

At the center of one end of each box—the inflow end—air was introduced through a pipe 7 inches in diameter (figure 2). Each box was equipped with an individual variable-speed electric blower which blew the air through several feet of 7-inch pipe before enter-

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ing the end of the box. An orifice meter was placed in the pipe line, and the flow of air in cubic feet per minute could be adjusted and read off directly from a calibration curve. A vane deflector placed at the entrance of the pipe into the box was adjusted to assure a uniform distribution of the stream of air to the two tiers of cages.

At the opposite end of the box—the outflow end—the air from each box was exhausted through a 7-inch pipe fitted with a damper and connected to a large central exhaust fan (figure 3).

About 4 inches from the entrance of the 7-inch pipe into the box, the fumes of the substances listed were introduced into the inflowing air. Specially designed pyrex glass flasks (figure 4), 7½ inches long and with a diameter of 1½ inches, were used to hold the heated waxes. These flasks were made with a side arm and tube that extended to the bottom. The top of the flask was ground, and into this fitted a short tube 1½ inches in length. This short tube was inserted into a large rubber stopper that fitted tightly into a hole cut out of the 7-inch pipe on the under side (figure 2). The flask in turn was placed in an electric heater made to cover it completely below the side arm and ground glass top. Rubber tubing connected the side arm with a compressed air reservoir and a gentle stream of air blown through the melted wax kept it in motion and assured uniform heating. Into each flask was inserted a long stem centigrade thermometer which was kept in place and could be read at any time above the 7-inch pipe through which it passed (figure 2).

Approximately 30 gm. of pulverized chlorinated naphthalenes or 20 gm. of

chlorinated diphenyl were placed in the bottom of each flask and melted in the electric heater. Fresh samples were used every other day, but it was often found necessary to add 20 gm. of new material even after one run since so much had sublimed. Whatever the case, the collected sublimate was



FIG. 2. Electric heater for maintaining chlorinated compounds at a constant temperature in place at inflow end of box.

always removed from the upper part of the flask and a clean top used each day. No sample was ever used for more than two runs.

The flask plus the contents was carefully weighed at the beginning of the run and at the end, and the loss in weight used to calculate the average

amount in a cubic meter of air per minute as determined by a series of

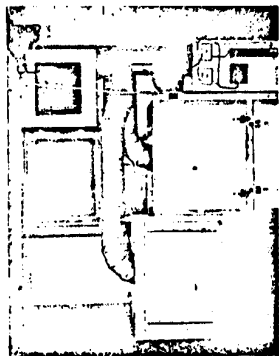


FIG. 3. Outflow end of two boxes showing connections to exhaust system.

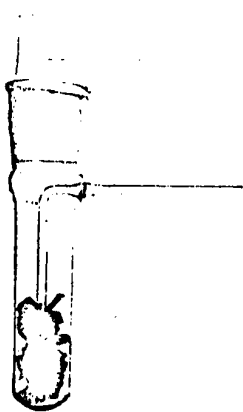


FIG. 4. Pyrex glass flask

flowmeter readings. The figures obtained were not absolute because of slight variations in the air flowing through the boxes and because of deposition of material on the thermometers and on the inside surfaces of the box, but they checked well with direct determinations through air samples.

Approximately 1 hour was allowed for the wax in the flasks to melt and come to a constant temperature. At that time the box doors were tightly closed, air bubbled through the flasks, and the blowers turned on. This was the beginning of the exposure period. By means of rheostats on the fans and dampers in the outflow pipes, the amount of air flowing through the boxes was adjusted and an attempt was made to keep the four boxes as uniform as possible—usually between 165 and 175 c.f.m.

In the first group of experiments the following substances were tested:

1. A mixture of trichloronaphthalenes plus a trace of tetrachloronaphthalene. Chlorine content 49.9 per cent.
2. A mixture of penta and hexachloronaphthalenes. Chlorine content 62.6 per cent.
3. A mixture of 90 per cent penta and hexachloronaphthalenes plus 10 per cent refined chlorinated diphenyl. Chlorine content 63.0 per cent.
4. Chlorinated diphenyl. Chlorine content 65.0 per cent.

The compounds were selected as representing a certain range in chlorination and also because of their industrial importance. In each instance 80 animals were exposed, 10 rats being placed in each cage. They were fed Purina

Dog Chow supplemented by lettuce, eggs, milk and cod liver oil.

This first group of experiments was begun on July 1, 1936 and the last exposure to number 2 (penta and hexachloronaphthalenes) was on November 16th. The exposure to the other three compounds ceased upon November 18th. On October 15th representative animals were taken out of exposure from groups 1, 2, and 4 and were killed after 2 months on December 15th, in order to see whether this clear

wax concentrations were somewhat higher at the inflow end of the boxes. Preliminary runs showed that once properly adjusted, wax concentrations in the air remained very uniform from day to day, but to insure absolute safety readings of temperature, air-flow, etc. were made every night between 10:00 and 12:00 p.m. as well as on starting and stopping. At different times during the course of the experiment tests for free chloride were made but were uniformly negative and

TABLE I
CONDITIONS MAINTAINED IN INHALATION EXPERIMENT FROM JULY 1 TO NOVEMBER 16 AND 18

MATERIAL	CHLORINE CONTENT	TEMP.	AV. CONCENTRATION OF AIR IN BOX		TOTAL EXPOSURE	AV. DAILY EXPOSURE
			mg./cu. m.	range	hours	hours
Trichloronaphthalenes plus traces of tetrachloronaphthalene	49.9	150-160	1.31	High 2.60 Low 0.10	1896	16
Penta and hexachloronaphthalenes....	62.6	160-170	1.16	High 2.19 Low 0.51	1861	16
90% penta and hexachloronaphthalenes plus 10% chlorinated diphenyl.	63.0	165-175	1.37	High 3.17 Low 0.64	1896	16
Chlorinated diphenyl	65.0	165-175	0.57	High 1.19 Low 0.23	1896	16

period would bring about recovery in the affected livers. Animals from group 3 were similarly removed from exposure on October 4th and killed for examination on December 4th.

The average length of exposure was 16 hours daily for 6 days a week. Each morning at about 9:00 exposure ceased, and between this time and 4:00 p.m. the rats were cleaned, fed, weighed, etc. In order to secure uniformity of exposure the cages were shifted on a regular schedule, since

showed that under the temperatures used no decomposition occurred.

Table 1 shows the temperatures at which the various substances were held, the average concentrations per cubic meter of air, and the average exposures from July 1 to November 16 and 18.

The concentration of chlorinated naphthalenes and chlorinated diphenyl in the air of workrooms.—Table 1 shows that animals have been exposed to varied concentrations of the substances under

test. The concentrations employed may be regarded as fairly representative of industrial experience. Prior to the initiation of inhalation experiments a number of estimates of chlorinated hydrocarbons in the air of different factories were made and the

in question is passed over heated platinum in an electrically heated quartz tube and the effluent gas scrubbed in a column of glass beads moistened with sodium carbonate containing a trace of sodium sulfite. The beads are then washed down and the chloride deter-

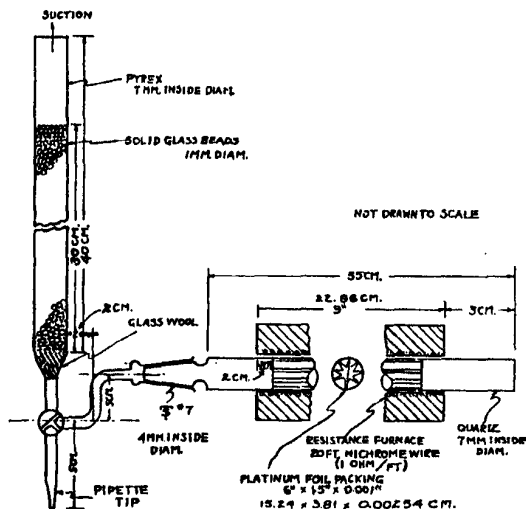


FIG. 5. Dimensioned sketch of combustion tube and absorption apparatus.

concentrations chosen for inhalation experiments depended on these examinations. The technique of analysis and the apparatus employed were the work of Frederick R. Millhiser and William F. Homperly.

The method and apparatus used for determining concentrations of chlorinated hydrocarbons in air were adapted from well-known procedures. The air

mined nephelometrically as silver chloride.

Tebbens (1937) has recently described a method and apparatus which should be equally satisfactory for this work. In figure 5 we show a dimensioned sketch of the combustion tube and absorption apparatus as used by us in both our laboratory and field problems. The absorption tube is

somewhat like Tebbens's but devices are th

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somewhat easier to wash down than is Tebbens's but the essentials of the two devices are the same.*

In both cases conversion of the chlorinated hydrocarbons to hydrochloric acid and subsequent absorption as sodium carbonate should be complete. In our case concentrations in air are apt to be very low—the objective is less than 1 mgm. per cu. m. Consequently the amount of silver chloride actually formed in the final reaction is so small that it can not be determined either gravimetrically or by titration. For this reason we have been forced to use the nephelometric procedure which is sensitive to concentrations as low as 0.1 mgm. per cu. m. of air.

It is doubtful if the sampling rate should exceed 1 liter per minute as conversion of the chlorinated compound to hydrochloric acid and its subsequent absorption are not efficient unless the velocity of the gas stream is low. Another precaution to be noted is that the method is not selective—any chlorinated substance will be determined. Furthermore it does not distinguish between solid particles and gases but determines them all alike and the results must, of course, be computed in terms of total chlorine.

At the present time we possess information as to the amounts of chlorinated naphthalenes in the air of 30 different plants, and in a number of instances the measurements have been repeated several times. Frequently the amounts have been greater than those used in our experiments, but it must be remembered that the rats

have been exposed for 16 hours to an atmosphere constantly impregnated with the substance under test, whereas human exposure is usually a variable quantity, intense for a short time and then negligible. It is our opinion at the present time that the concentrations of chlorinated hydrocarbons used in our experiments would be dangerous for workers in the case of compounds above trichloronaphthalene in chlorination. Fortunately it is easy to ventilate processes of manufacture which require these substances and to reduce air contamination practically to the vanishing point. Such treatment of the problem at once removes both the possibility of systemic poisoning and the annoyances that arise from cases of acne.

Results of Inhalation Experiments.

1. Animals exposed to a mixture of trichloronaphthalenes plus small amounts of tetrachloronaphthalene. Living animals were apparently entirely normal. Autopsies performed near the end of exposure seemed to show slight swelling of the liver, and microscopic examination occasionally showed swollen and hypergranular liver cells. The changes were, however, never more than slight.

2. Animals exposed to a mixture of penta- and hexachloronaphthalenes. No abnormalities were observed in the living animals. Rats were killed and autopsied every 6 weeks. In the first animals sacrificed liver changes were observed. These were swelling of cells, slight granulation and hyalinization. In September and October these conditions were somewhat more advanced, and in November the process became stationary. There were highly

* The combustion and absorption apparatus suited to field sampling is now made by Wilson Products, Inc., Reading, Pa. The equipment includes flowmeter and suction pump with a carrying case.

granular cells, hyaline inclusions and mitotic figures, but no more than 2 months previously.

3. Animals exposed to a mixture of 90 per cent penta and hexachloronaphthalenes plus 10 per cent refined chlorinated diphenyl. No abnormalities were seen in the living animals. After 6 weeks the livers showed changes similar to those in the animals exposed to penta and hexachloronaphthalenes. These advanced in grade during August and September and then became stationary.

4. Animals exposed to chlorinated diphenyl. No abnormalities were seen in the living rats. After 6 weeks' exposure there was slight liver damage which advanced during the next 2 months. The changes consisted in slight to moderate swelling of the liver cells, an increased granularity and many mitotic figures. Hyalinization was always present as a result of inhalation of chlorinated diphenyl.

Summary of the first inhalation experiment.—In these experiments careful observation of appearance, body weight, activity, blood, and urine showed no abnormalities of any sort. Yet after 6 weeks' exposure all the compounds with chlorination above trichloronaphthalene caused minor degrees of liver damage, and no changes whatsoever in other organs. There was no acute yellow atrophy or anything suggesting it except that a slight degree of liver damage was always present and was quite clear in the liver sections examined microscopically. This damage had no detectable effect on the health of the animals. They held their weight, ate and behaved normally, being in every respect similar to the many people who have been

exposed to these compounds without illness of any sort.

The functional appraisal of the liver damage caused by certain chlorinated naphthalenes and by chlorinated diphenyl.—There are no tests of liver function useful in such minor degrees of liver damage as were produced in these experiments. Indeed the animals resisted the injury so perfectly as to display no abnormalities except upon histological examination of the liver. The situation was perhaps similar to that met in industry, where, barring acne, the health of workers in these compounds has been good with the exception of the fact that in isolated instances jaundice has occurred which upon at least three occasions has gone on to acute yellow atrophy.

During recent years this disease has been seen following administration of carbon tetrachloride, arsphenamine and cincofen. In the case of carbon tetrachloride it is known that a low calcium diet and alcohol favor the production of liver damage. For the acute yellow atrophy that occasionally complicates use of the other two drugs no cause can be assigned. One cannot produce acute yellow atrophy with arsphenamine, but somehow or other this now and then does happen to patients under antisyphilitic treatment.

It occurred to us that something of the same sort might be involved in this problem. The human cases have been scattered and few. They have been isolated instances out of large groups of healthy employees who have had equal degrees of exposure. It was our idea that perhaps many of these people got liver changes such as existed in our rats, changes not recognizable through

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any means other than autopsy examination. If, upon the substratum of such changes, they got an acute liver disturbance, acute catarrhal jaundice, not a very common disease but one which any of us may experience, would this relatively innocuous disease go over to acute yellow atrophy?

Knowing that our inhalation rats had liver changes, but changes too slight to cause recognizable symptoms, we decided to test their resistance to substances known to cause liver destruction. Carbon tetrachloride and alcohol were selected. Having information that 1.0 cc. of carbon tetrachloride plus 1.0 cc. of ethyl alcohol per kilogram would kill 14 per cent of normal white rats, we reduced the dose to 0.75 cc. carbon tetrachloride and 0.75 cc. of ethyl alcohol.

This mixture was given by stomach tube to the following groups of animals and with the results found in the following tabulation.

Rats fed 0.75 cc. per kgm. each of carbon tetrachloride and ethyl alcohol by stomach tube

1. *Trichloronaphthalene plus trace of tetrachloronaphthalene.* Fed at 9:00 a.m., Nov. 10, 1930. 10 rats. No deaths.

2. *Penta and hexachloronaphthalenes.* Fed at 9:30 a.m., Nov. 10, 1936. 10 rats.

8 died Nov. 11th between 4:30 and 10:30 p.m.

1 died Nov. 12th at 3:20 p.m.

1 died Nov. 12th at 4:30 p.m.

1 died Nov. 13th between 9:30 and 11:30 a.m.

1 died Nov. 15th between night of Nov. 14th and 12:30 p.m. Nov. 15th. 2 died Nov. 16th between 10:15 p.m. Nov. 15th and 9:00 a.m. Nov. 16th (still).

3. *90 per cent penta and hexachloronaphthalenes and 10 per cent chlorinated diphenyl.* Fed at 10:00 a.m., Nov. 10, 1936. 10 rats.

1 died Nov. 10th between 5:00 and 10:30 p.m.

5 died Nov. 11th between 4:30 and 10:30 p.m.

1 died Nov. 11th between 4:30 p.m. and 9:00 a.m. Nov. 12th.

2 died Nov. 12th about 1:00 a.m.

1 died Nov. 13th between 5:00 and 10:00 p.m.

4. *Chlorinated diphenyl.* Fed at 10:00 a.m., Nov. 10, 1936. 10 rats.

1 killed Nov. 10th at 10:30 p.m. (almost dead).

2 died Nov. 11th between 4:30 and 10:30 p.m.

1 died Nov. 12th before 8:30 a.m. (still).

1 died Nov. 13th between 9:30 and 11:00 a.m.

1 died Nov. 16th between 10:15 p.m. Nov. 15th and 9:00 a.m. Nov. 16th (still).

Controls: Fed at 9:30 a.m., Nov. 12, 1936. 10 rats. 1 killed Nov. 13th for normal liver.

This tabulation summarizes into the facts that:

1. No normal rats were killed by carbon tetrachloride and ethyl alcohol.

2. No trichloronaphthalene exposed rats were killed, and this finding agrees with our inability to find lesions of moment in the livers of the animals that inhaled this substance.

3. The penta and hexachlorinated naphthalene, the mixture of these with 10 per cent chlorinated diphenyl, and finally the latter substance alone seem to have produced conditions lowering the resistance to an agent capable of producing serious liver disease.

4. The sole lesion produced by this test of liver function was acute yellow atrophy usually accompanied by jaundice.

This test of liver function was accomplished with a substance which itself is an organic chloride and curiously enough it is the only substance we were able to find that was effective.

In animals with the minor degree of liver injury which has been described we were unable to produce acute yellow atrophy or any variety of liver effect with arsenphenamine, cincofen, butyl chloride, ethylene chloride and tetrachlorethylene, but carbon tetrachloride was uniformly effective in disclosing the existence of liver damage.

Recovery from liver damage following removal from exposure.—Animals exposed to trichloronaphthalenes plus traces of tetrachloronaphthalene being practically normal on removal from exposure need no consideration. In the case of the penta and hexachlor-

signs of liver injury will be many months in returning to normal.

The effect of high concentrations of trichloronaphthalenes with traces of tetrachloronaphthalene.—The first group of inhalation experiments showed that this material in concentrations averaging 1.31 mgm. per cu. m. of air was relatively innocuous, judged both by direct observation and by the carbon tetrachloride test. This is an interesting fact since such compounds cause acne, though less potently than substances of higher chlorination. In order to explore the matter further one of the inhalation boxes was arranged

TABLE 2
CONDITIONS MAINTAINED DURING INHALATION OF HIGH CONCENTRATIONS OF
TRICHLORONAPHTHALENES PLUS TETRACHLORONAPHTHALENE

MATERIAL	TEMP.	AV. CONCENTRATION OF AIR IN BOX		TOTAL EXPOSURE	
		mg./cu. m.	range	hours	hours
Trichloronaphthalenes plus traces of tetrachloronaphthalene	137-200	10.97	High 16.49	1232	16
			Low 5.78		

naphthalene, rats after 2 months' removal from exposure still showed swollen liver cells, increased granularity, hyalinization and mitotic figures. The condition was not advanced as compared with rats killed at the time of removal from exposure but on the other hand 2 months were insufficient for recovery.

The same findings were true of the mixture of penta and hexachlorinated naphthalenes and chlorinated diphenyl and for chlorinated diphenyl alone.

Apparently the changes induced in the liver cells by these substances are exceedingly persistent and one must expect that an individual showing any

so that fumes from four glass containers were delivered to the air line instead of one. This resulted in the conditions shown in table 2. The animals subjected to these conditions showed no clinical effects of any sort. After 1 month the liver cells were slightly swollen and over-granular and there were occasional mitotic figures. These changes were similar to the early effects of more highly chlorinated compounds, and progressed only slightly during the third and fourth months. When rats in this condition were given carbon tetrachloride and alcohol, in some instances their livers showed massive central necrosis and

in others this did not develop. Fifty rats were used in this experiment and one may conclude that while the trichloronaphthalenes are in no degree as toxic as those of higher chlorination they are not entirely free from effects upon the liver if high enough concentrations are inhaled over long periods.

The effects of high concentrations of penta and hexachloronaphthalenes.—There can be no doubt as to the damage done the liver by these compounds but in the concentrations so far reported no symptoms were caused that could be recognized clinically and nothing approaching acute yellow

the liver after 35 days of freedom from inhalation. It is thus evident that penta and hexachloronaphthalenes are markedly toxic compounds and that recovery from their effects is extremely slow.

The effects of penta and hexachloronaphthalenes, the mixture of these with 10 per cent chlorinated diphenyl, and of chlorinated diphenyl alone, when inhaled in low concentrations through an 8-hour day instead of a 16-hour day as in the first experiment.—Since steady human exposure to any of the compounds tested would invariably be for 8 hours rather than 16-hour periods, a further

TABLE 3
CONDITIONS MAINTAINED DURING INHALATION OF HIGH CONCENTRATIONS OF PENTA AND HEXACHLORONAPHTHALENES

MATERIAL	TEMP.	AV. CONCENTRATION OF AIR IN BOX		TOTAL EXPOSURE	AT. DAILY EXPOSURE
		mg./cu. m.	range	hours	hours
Penta and hexachloronaphthalenes.....	137-195	8.88	High 14.0 Low 5.75	608	16

atrophy occurred except through the use of the carbon tetrachloride test. On December 1, 1936, 80 rats were subjected to the conditions summarized in table 3. This experiment was terminated on January 21. All of the animals lost weight and appetite and deaths began after 8 days of exposure. Fifty-five rats died, most of them heavily jaundiced, 8 were killed for microscopic examination, 9 were killed by the carbon tetrachloride test and 8 lived through the period of exposure. The livers of the animals killed for examination showed marked fatty degeneration, central in type with necrosis of liver cells. Surviving animals showed pronounced changes in

inhalation experiment was arranged under the conditions shown in table 4 which are quite comparable to those in table 1 except for the shorter inhalation periods. Eighty rats were used for each of the three compounds tested. None at any time showed the slightest evidence of illness. Microscopic examination beginning after 6 weeks' exposure showed swollen liver cells, excess granulation, hyaline inclusions and occasional mitotic figures. These changes did not progress and were very similar to those in the animals exposed for 16 hours under the conditions set forth in table 1. The carbon tetrachloride test was uniformly fatal to them and one must conclude that con-

centrations of these compounds such as were employed cause a certain degree of liver damage even if inhaled for but 8 hours daily. This injury is resisted successfully by the rats just as was the 16-hour injury but it is none the less there and destroys the ability of the animal to resist the carbon tetrachloride test.

Summary of inhalation experiments.

The findings that have been described briefly will be amplified upon the pathological side in a further paper by Dr. G. A. Bennett. What has been given is, however, sufficient to indi-

men never inhale enough of any of these substances to get acute yellow atrophy. They may, however, acquire a substratum of liver damage upon which acute yellow atrophy may develop. Experience in a number of plants has shown how easy it is to reduce concentrations of these compounds practically to the vanishing point, and every effort should be made to attain such conditions.

Gross Feeding Experiments

The various compounds used were ground as finely as possible and mixed with a standard balanced ration for

TABLE 4
CONDITIONS MAINTAINED DURING INHALATION OF LOW CONCENTRATIONS OF THREE COMPOUNDS DURING 8-HOUR INSTEAD OF 16-HOUR PERIODS

MATERIAL	TEMP. °C.	AV. CONCENTRATION OF AIR IN BOX		TOTAL EXPOSURE hours	AV. DAILY EXPOSURE hours
		mg./cu. m.	range		
Penta and hexachloronaphthalenes.....	140-103	1.44	High 2.58 Low 0.42	920	8
90% penta and hexachloronaphthalenes plus 10% chlorinated diphenyl.....	150-107	1.66	High 3.30 Low 0.56	912	8
Chlorinated diphenyl.....	153-174	0.93	High 3.23 Low 0.03	920	8

cate that compounds more highly chlorinated than trichloronaphthalene are capable of causing liver injury when inhaled steadily in quite low concentrations. It is an extraordinary thing that even the most searching examination fails to show injury in any other region. It is not easy to grade the toxicity of the different compounds tested, but the chlorinated diphenyl is certainly capable of doing harm in very low concentrations and is probably the most dangerous. Industrial experience combined with these experiments make it appear probable that work-

the white rat. The food was placed in a single container, at which the 10 animals in a cage had an equal chance, the amount of the compounds added being reduced as the number of rats lessened during the feeding period. The experiments were designed to give an idea as to the possible toxicity of the compounds selected and, if toxicity was observed, some idea as to the site or sites of damage.

The experiments were successful in both respects, and indeed one may anticipate that future appraisals of the possible toxicity of chlorinated hydro-

carbons may often be made by simple feeding and do not require the elaborate apparatus and the expense necessary for inhalation experiments. The essential reason for this opinion resides in the identity of the lesions produced by both methods, and the fact that the different compounds so far studied seem to arrange themselves identically so far as toxicity is concerned whichever way they are administered.

Trichloronaphthalene plus traces of tetrachloronaphthalene.—Feeding began on May 4, 1936 and continued until November 2, 1936. In the beginning 3 gm. of this mixture were added to the food for 10 rats each day, and this concentration was maintained throughout the experiment. All the animals were killed except the last which died on Nov. 2. There was no loss of weight and no appearance of wasting illness of any sort. The single death was due to some variety of respiratory infection which had no relation to the material inhaled.

Histological examination showed slight changes in the liver but nothing of great significance.

Tetra and pentachloronaphthalenes.—Feeding began on June 29, 1936. A dosage of 0.5 gm. daily was employed. All the animals sickened gradually and were either killed or died by August 29, 1936.

At autopsy both grossly and histologically the liver was the single organ affected. The liver cells showed swelling, hypergranulation, hyaline inclusions and vacuolation. Here and there necrotic cells were found. There was a tremendous accumulation of fat.

Penta and hexachloronaphthalenes.—Feeding began May 4, 1936, a 3 gm. dosage being used. By June 6, nine

rats had died. The last one was obviously ill and was killed for autopsy examination. All animals lost weight from the beginning and were ill. At autopsy the liver alone was affected, the lesions observed being similar to those that have been described for tetra and pentachloronaphthalenes but worse.

90 per cent penta and hexachloronaphthalenes and 10 per cent chlorinated diphenyl.—Feeding began May 4, 1936 on a 3 gm. dosage. On May 16th feeding was stopped but all the animals went on to death, the last dying on June 8th. An autopsy the liver lesions were extremely severe and of the usual type.

On account of the high toxicity of the 3 gm. dosage, four rats were given a 0.5 gm. dose every other day. Feeding began June 24, 1936 and the last animal was killed Sept. 11th. There were no deaths but all the animals lost weight. At autopsy the liver as usual was the single organ affected, the lesions being characteristic and extensive.

Chlorinated diphenyl.—Feeding began May 4, 1936 on a 3 gm. dosage and was discontinued on May 10th. Seven of the 10 rats were dead by May 12th. The three remaining rats gained in weight but were sacrificed for autopsy purposes on July 8th. The liver changes began at once. There were no changes in other organs.

A second group of 10 rats was fed a much smaller dose—0.5 gm. every other day. Feeding began May 20, 1936. The first rat died on May 29th and four more before June 24th. The remaining were sacrificed. Those rats that died showed losses in weight, while those sacrificed had recovered

their initial loss in weight and were gaining. The liver lesions were similar to those found in rats fed penta and hexachloronaphthalenes plus 10 per cent chlorinated diphenyl but not so marked.

Summary of gross feeding experiments.—Of the various materials fed rats in large doses trichloronaphthalene plus traces of tetrachloronaphthalene was quite innocuous. Tetra and pentachloronaphthalene showed definite liver damage. Penta and hexachloronaphthalenes caused a similar grade of injury. The addition of chlorinated diphenyl to penta and hexachloronaphthalenes increased the toxicity. Chlorinated diphenyl alone produced liver lesions but in the dosage used was less effective than when mixed with highly chlorinated naphthalenes. In no case did the compounds used produce acute yellow atrophy but the lesions observed indicate this might be possible if one found a dosage which could act for the proper period of time.

Feeding Precise Doses by Stomach Tube

The compounds employed were suspended in gum acacia. In figuring the dosage the total amount a man of 50 kg. would inhale in an 8-hour day assuming an air concentration of 20 mgm. per cu. m. was first calculated and reduced to milligrams per kilogram. The rats and rabbits received this dose each day. The compounds used were those employed in the gross feeding experiments and the results were essentially similar though the lesions were less severe.

Subcutaneous Injections

The same gum acacia suspensions were injected subcutaneously into rats

and rabbits, the dosage being calculated on the basis of 4 mgm. per cu. m. of air. Again similar results were obtained. In all such experiments there must of necessity be differences in the degree of effect but invariably the liver was the sole organ affected and the lesions were those already described many times.

DISCUSSION

These experiments leave no doubt as to the possibility of systemic effects from the chlorinated naphthalenes and chlorinated diphenyl. As in the case of the effects upon the skin, the degree of chlorination seems to determine the systemic toxicity, and it is a striking thing that when trichloronaphthalene is reached systemic effects are never marked and are produced with the greatest difficulty. It is most remarkable, too, that all the compounds tested attack the liver and the liver alone. During the past few months we have determined the organically combined chloride in the livers of animals very severely poisoned by penta and hexachloronaphthalenes but have found no increase over normal figures, though the livers, as determined histologically, were very severely affected. At the present time we are conducting inhalation experiments on a chlorinated diphenyl containing 55 per cent of chlorine instead of 64 per cent as in the case of the experiments reported in this paper and on a compound with a chlorine content between tri and tetrachloronaphthalene. We are also determining the degree to which the diet may increase or decrease toxicity, this being suggested by similar work upon carbon tetrachloride.

In the basis of these experiments

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and on many field determinations of different compounds in the air of work-rooms, it appears safe and it is certainly easily attained, to ventilate so that the air breathed does not contain more than 0.5 mgm. per cu. m. of any of these compounds above trichloronaphthalene. In the case of the latter compound concentrations of 10.0 mgm. are permissible. We know from many examinations in many different plants that such concentrations have been greatly exceeded during the past 20 years, and we are conscious of the fact that our rat exposures have been inexorably constant whereas human exposure is never so ordered. Time and careful observation may change these opinions as to standards, but today we are convinced they are safe. Impregnating tanks and other arrangements utilizing the chlorinated hydrocarbons are easy to hood and to safeguard. Compared with benzene, lead tetraethyl and many other com-

pounds, these substances are very little toxic and operations employing them can easily be safeguarded. It may be argued that where possible trichloronaphthalene should be used, but this compound will cause acne and if employed very carelessly might do more. Furthermore, higher chlorination is often essential for highly practical reasons. The solution consists in thoroughly adequate ventilation plus good housekeeping around all wax containers.

A final word of caution bears upon the use of carbon tetrachloride as a wax solvent. Obviously this compound adds readily to the toxicity of the highly chlorinated waxes. If carbon tetrachloride is used, ventilation should be excellent, but in our opinion it would be better to dispense with carbon tetrachloride and depend on other solvents, especially upon those containing no chlorine.

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DISCUSSION

Dr. CECIL K. DRINKER: We have had quite a long morning, but since Dr. von Osttingen has to leave, I am going to ask him to say a word.

Dr. W. F. VON OSTTINGEN (Director, Haskell Laboratory of Industrial Toxicology, Wilmington, Delaware): I wish to congratulate Dr. Drinker and his group on the very interesting and excellent work on the subject. I also wish to congratulate the Halowax Corporation on the fact that they didn't spare any effort to elucidate the problem so that the dangers which apparently are connected with the use of this material can be controlled.

I personally believe that there is no toxic material which cannot be used safely if it is handled properly. In order to handle such materials properly during the different operations it is absolutely essential to be familiar with the toxicity and especially with the mechanism of the action. Since there is no animal which corresponds in all its physiological characteristics to the human being it is important that such compounds be studied with different species of animals so that one can get a cross-section of the potential dangers.

In addition, this fact illustrates the importance of the pre-employment and periodical examination of workers in such work. As was pointed out by Dr. Drinker, there are individuals who are apparently more susceptible to certain toxic agents than others. On the other hand, we have to try to detect the very first signs of incipient poisoning in order to prevent more serious damage. In the present instance it is very difficult to find these very first symptoms because there are no adequate methods, but I trust that in time the scientific profession will supply the medical profession with adequate methods which will allow the physician to determine incipient damage of the organ before serious clinical symptoms become manifest.

Thank you.

Afternoon Session

Dr. CECIL K. DRINKER: In this discussion I will call on one or two individuals and I shall expect others to speak as their notes

incline them to. First of all I shall ask Dr. Sayers if he will open the discussion for us.

Dr. R. R. SAYERS (Chief, Division of Industrial Hygiene, National Institute of Health, U. S. Public Health Service, Washington, D. C.): Dr. Drinker, Ladies and Gentlemen: It gave me a great deal of pleasure to have the opportunity to listen to the excellent and interesting discussion and presentations made this morning. Dr. Drinker, and I might add, the members of the Halowax Corporation, have discussed this matter with us, as well as the manufacturers of the diphenyls.

We have been doing some work but not nearly as extensive as that carried on here. The work that we have been doing seems to confirm the work that Dr. Drinker has carried on. I think there are certain parts of it that we can very well keep in mind.

We are dealing with toxic substances, but we are dealing with toxic substances each and every day in industry—harmful substances, hazardous substances. That these can be controlled is well known, no matter what they are, and that we can use them and use them in a safe manner. Dr. Drinker has called your attention to the fact that this apparently has been done and can be done in any of the plants where halowax is used. I have information from one or two of the other men who are in the audience that in plants where damage has been done—skin damage and apparently liver damage to some of the workers—the manufacturers have since corrected the conditions and apparently have adequate engineering control supplemented with adequate medical control.

After all, the proof of the pudding is in the eating. If the man does not get the disease your engineering control is successful. If he does get the disease, no matter what you have done in the way of engineering, you haven't been successful. We must go hand in hand. Neither profession alone can be successful. We have got to work together whether we like it or not. I happen to like it.

There is one other thing. As far as materials are concerned I think we ought to be

smart and carefully adapted to it. Another view to it was flaming approximations never just might have happened with this electric car armor on the and was brought proximately to a steel bottom of the inspecting it bid cap-lane the fire killer mine. Many here we have. Now we have due to the I evaluate them. I am informed not just our flammability chlorination is also increases creases, never think that they have these has control them. we can. Perhaps we are better even present time I better. I am submerises, it is non-flammable of their electrical.

Dr. CECIL K. I you care to say a

Dr. ALBERT H. of Occupational Injuries and Diseases. Cont.: Dr. Drinker anything that this material is

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smart enough to use every one of them suc-
cessfully. If this material is particularly
adapted for a certain purpose we should use
it. Another material that was used pre-
viously to this for insulation purposes, which
was flammable, caused a disaster in which
approximately 167 men lost their lives. I
say approximately 167 because they were
never just sure whether it was 167 or 168.
It might have been one or two more but they
were quite sure that 167 lost their lives. It
happened when they had insulated a cable
with this material. They had an armored
electric cable. It was covered with lead
armor on the outside. It was 1200 feet long
and was being lowered into a mine shaft ap-
proximately 3000 feet deep. It was lashed
to a steel rope. It slipped and fell to the
bottom of the shaft. When the foreman was
inspecting it he set it on fire with his car-
bide cap-lamp. The carbon monoxide from the
fire killed those men that were in that
mine. Many of course escaped.

Here we have one hazard, a fire hazard.
Now we have another one, a health hazard
due to the toxic materials. We have to
evaluate them. Certain of these materials,
I am informed, are also flammable. I am
not just sure how flammable they are but
flammability probably decreases as your
chlorination increases. But your toxicity
also increases as your chlorination in-
creases, according to Dr. Drinker, and I
think that checks with other findings. We
have these hazards to balance but we can
control them. I feel quite confident that
we can.

Perhaps we can find other substances that
are better even than this material. At the
present time I am advised that we have no
better. I am advised that in ships, such as
submarines, it is quite important to have a
non-flammable substance for the insulation
of their electrical wire.

DR. CECIL K. DRINKER: Dr. Gray, would
you care to say a word?

DR. ALBERT S. GRAY (Director, Bureau
of Occupational Diseases, State of Con-
necticut Department of Health, Hartford,
Conn.): Dr. Drinker, I don't think there is
anything that I can say except that we used
this material in Connecticut and we had a

number of so-called cases. All I can say is
a confession of ignorance on our part at that
time and I was very glad to see that your
digging into the literature as thoroughly as
you have hasn't elicited any further infor-
mation than we were able to get, basically.
About all we could find was about the two
cats that our friend, Lehmann, experi-
mented with. We got in touch with him and
he confessed that the amount that he had
given the cats and his method of determin-
ing it were probably subject to very serious
scientific criticism, and we agreed with him
on that point.

We felt, and I am very glad that it is what
you feel as a result of your experiments,
that if we put in an efficient ventilation sys-
tem sufficient to prevent the dermatitis, we
probably wouldn't have liver damage.
That is what we did entirely empirically.

I think that is about all I have to say. I
have been delighted to be here and to have
as many members of my staff here as I could
jack out of the office. We have been de-
lighted to listen to the discussion.

DR. CECIL K. DRINKER: May we now
make the discussion general and those who
have questions please volunteer.

MR. MANFRED BOWDITCH (Director,
Division of Occupational Hygiene, Massa-
chusetts Department of Labor and Indus-
tries, Boston, Mass.): I would like to second
very strongly what Dr. Sayers has said with
regard to the approach to this problem in
proper control rather than by prohibition,
which seems to me wholly unnecessary not
only in this case but in the case of other
toxic substances with which we have to deal.
The problem of proper ventilation seems to
me relatively simple from what I have heard
of the situation thus far. The problem of
maintaining that ventilation properly does
not seem to me quite so simple. I think it
is going to be quite necessary that there
should be a very adequate inspection of
the plants using the materials and I can
assure you that that will be the case here in
Massachusetts.

When this trouble first broke in this state
a little over a year ago we issued a quite
strongly worded warning letter to all plants
using these substances and it has all along

been my plan to follow that up with a further letter bringing the situation as we now know it, as a result of Dr. Drinker's work, to the attention of users in this state. In that letter we shall unquestionably advocate the concentrations that Dr. Drinker has suggested this morning.

One point that I think is worth commenting on in that connection is the question of identification of the substances. It is extremely important from the state administrative point of view that employers using these substances should know what they are using. They are identified at present only by numbers. If we list those numbers in a warning letter which we send out there are likely to be changes in those numbers. The Halowax Corporation is a progressive concern and it is going to be putting out bigger and better halowaxes all the time. The company's cooperation in this present investigation has been such that I feel assured that they will take the proper steps to see that we in the state offices and also the users of the products will know what we are using.

I wonder whether Mr. Brown would care to say anything about that.

Mr. RANDFORD BROWN (President, Halowax Corporation, New York, N. Y.): There are some aspects of this situation on which I think I can enlighten the medical and state and civic authorities, with respect to the commercial and practical aspects. If you go into the research laboratories of any large chemical manufacturing company today you will find anything from one to a thousand different new chemical products which have not yet been put on the market. Some of those may or may not be toxic. The problem so far as the chemical manufacturer is concerned is a question of timing. You have heard this excellent presentation given this morning by the Drinker brothers as to the work that they have done here. Should you take a product of which you have developed, say, 5 or 10 gm. and spend \$50,000 on research to determine whether or not it is toxic or should you wait until you have determined whether you have a market for it?

If you are producing only one hundred substances a year you can see that that would run into boxcar numbers in the way

of dollars and cents before you ever sold any. That is the problem we have had in this case. It has been on the market for 25 years. Until within the past 4 or 5 years there has never been any intimation that it would cause any systemic effects. Thousands and thousands of workmen have dealt with millions and millions of pounds of certain of these materials, particularly the trichloronaphthalenes. Then we come to the higher stages, combined with chlorinated diphenyl and other products, and suddenly this problem is presented to us.

We had asked various authorities interested in public health, going back over a period of 15 to 20 years, to investigate it but there wasn't much enthusiasm for it. Mr. Bowditch suggested that we take it up with the Drinker brothers at this institution, which we did. You know the results of that work.

Now so far as these changes are concerned, they are beyond our control to a certain extent. We will manufacture a product—let's call it 1234. It has certain chemical and physical characteristics. It is supplied to a cable manufacturer. It is composed of certain constituents. These may be some tetrachloronaphthalene, trichloronaphthalene, paraffin, a little pitch or bitumen, and possibly some chlorinated diphenyl. It does a certain job but he wants it to a little more plastic or he wants its viscosity or the specific gravity changed. Possibly by a change in those constituents of only 1 per cent we can get that particular property. We can't sell it to him as the same product so we put a new number on it. Basically, however, if the variation in the chlorinated naphthalene or the chlorinated diphenyl constituent hasn't changed, the toxic property of that will not change.

When it comes to a question of cooperating with the state authorities in that connection, if there were some major change made in a product we would have no hesitation in advising them and we would also advise our customers. Virtually every consumer of these materials at some time or another has been given their technical or chemical designation along with their various properties, whether they be physical or chemical.

Those are some of the practical problems

with which all manufacturers of chemicals are confronted today, particularly in the synthetic organic field where the development is so rapid that our sales departments can't even keep up with the research departments sometimes, in knowing what they are doing.

MR. F. R. KAIMER (Assistant to Manager, York Wireworks, General Electric Co., York, Pa.): I am certainly pleased to have this opportunity to say a few words with reference to the experience we have had at our York plant. I perhaps should say that again in this case experience alone has been the best teacher. I have lived with the problem at York with the men who went through the experience from its beginning.

It is only 1½ years ago that we had in the neighborhood of 50 to 60 men afflicted with various degrees of this acne about which you all know. Eight or ten of them were very severely afflicted—horrible specimens as far as their skin condition was concerned. One man died and the diagnosis may have attributed his death to exposure to halowax vapors but we are not sure of that. There was an atrophied condition found as a result of the autopsy but we are not definitely sure that it was or was not connected with his work. Knowing the man as I did when he was employed, with the superficial examination that he had, he appeared to me very thin, pallid in his appearance, and I would not say from my poor knowledge of the physical make-up of the human being that he presented a healthy appearance. However, it was only for a 6 months' period from the time of his employment that he complained of this constipated condition and we advised that he see his home physician. It rapidly developed to the point where he was in the hospital and in a very short time he died.

More serious than that perhaps is the fact that we had 50 other men in very bad condition as far as the acne was concerned. The first reaction that several of our executives had was to throw it out—get it out of our plant. They didn't want anything like that for treating wire. But that was easily said but not so easily done. We might just as well have thrown our business to the four winds and said, "We'll close up," because

there was no substitute and there is none today in spite of all the efforts we have made through our own research laboratories to find one.

But we did develop—and I was most closely associated with it—and set up a routine for bringing these men back to normal health conditions. A number of them were sent to Dr. John H. Stokes and to Dr. O. H. Perry Pepper of the University of Pennsylvania Hospital, and the others to Dr. Isaac R. Pele at Johns Hopkins. Through their recommendations and studies we employed a trained nurse and two local physicians and you might say established a small hospital and its facilities at the plant. Through the application of quartz light, x-ray, mechanical removal of comedones and the treatment of pustules that developed in later stages, an utterly strict routine where the worst cases were administered to each day for a period of 15 to 20 minutes, another group who were less serious three times a week, and still another group once a week, we have in this year and a half brought each and every man back to a normal skin condition. Those who were very seriously afflicted do show scars, but otherwise their skin is as healthy in appearance as my own. I tell you we are very proud of the fact that they are still all employed and the amount of halowax that we are using today is even greater in quantity and in types than we were using a year and a half ago.

With the adequate ventilation system we have installed, with the routine for change of clothing from street clothing to work clothing when they come to work and the reverse of that process, with the assurance that a shower will be taken before the street clothing is again put on, we have found no recurrence of this skin trouble. Each and every man working with halowax products, either from solution, from solid compounds or handling the wire insulated and treated with it, is examined twice yearly with a complete physical examination, including blood analysis and efforts to determine any liver damage.

However, there is the point which was very definitely brought out this morning. We do not know as yet when this thing starts. I believe it would be of great help

to us all in industry if some very fundamental work was done on humans, as Dr. Jones mentioned before we came into this meeting, some control in fundamental work to determine some method whereby we may determine the inception of any liver disorder.

We have had our men examined in groups three times since the trouble developed and nothing has shown up in any one man. We have learned and appreciate the fact that we must handle hazardous materials, but we have learned how to handle them. It has been a very great experience for us and for myself, and again the best teacher.

DR. CECIL K. DRINKER: Can you recollect the air concentration that you are maintaining now with your present ventilating equipment?

MR. F. R. KAIMER: We have had two examinations made of the air by Mr. William F. Hemperly and they average from 0.2 to 0.6 mgm. per cu. m. We recently discovered one condition which was found as the cause of a high reading in one of the examinations. The compound is one that is not manufactured by the Halowax Corporation that is used rather infrequently, perhaps not more than 50 gallons of it in a 6 month period. It is in the form of a paste, reduced with solvent to a paste form, and it was not known that it contained a chlorinated solvent in certain percentage. We discovered it only recently through the analysis of a sample and we found that that was the cause of throwing the results off to a high value. It was then about 8 mgm. per cu. m., I believe. That is going to be eliminated now. That is a combination of toluene and carbon tetrachloride solvent. When that compound is exposed to the air the chlorinated solvent odor is completely masked by the toluene. It is lost. I was able to detect it only by removing the head of the drum and immediately smelling the odor of carbon tetrachloride. As soon as that head was removed for a period of 10 seconds the toluene predominated and we had no knowledge of the other being in there.

MR. ARTHUR G. BAYER (Research Engineer, United American Bosch Corporation,

Springfield, Mass.): Do I understand you to say that those men who were afflicted are back on the same job?

MR. F. R. KAIMER: They all returned to normal skin health, as I say, and are working on the same job.

DR. CECIL K. DRINKER: Dr. Schwartz, you have seen a good deal of this general subject.

DR. LOUIS SCHWARTZ (Medical Director, Dermatoses Investigations, United States Public Health Service, New York, N. Y.): I am primarily interested in dermatitis and it was only because of my researches in that field that I happened to come across information given to me by Dr. Gray that there were some cases of yellow atrophy of the liver attributed to halowax. I can only talk from personal experience about the skin cases. I know from what I have seen and from what I have heard from doctors who have been treating these cases that if they are treated like an ordinary acne vulgaris and kept away from further large exposure they all get well, with the same results as acne vulgaris. Those who have large pustules may have scars resulting and those who have superficial pustules or only comedones won't have any scars.

As far as prevention goes, I felt even before this investigation was undertaken that this substance, like any other poisonous substance, can be handled and used in industry provided proper safety precautions are taken, and I so advocated at the meeting in Pennsylvania when this was discussed.

About ventilation and safety precautions, I think that while we cannot, with our present knowledge, detect by any chemical tests the early symptoms of intoxication from this substance, the skin offers an easy way of proving whether your method of ventilation is efficient or not. If there are any cases of acne or of this dermatitis occurring in a plant where halowax or the chlorinated naphthalene or chlorinated diphenyls are used, then that shows that there is sufficient concentration of these substances in the air to cause plugging of the follicles and to cause a skin condition. If there is sufficient concentration to do that there may be

sufficient concentration to cause systemic poisoning in the few people who are hypersensitive to the action of these hydrocarbons. Everybody is not hypersensitive to them. If they were, of the thousands of people who have been handling these substances, more would have contracted this disease and it would have been reported very much earlier. This material was used in Germany as early as 1914 or 1915.

While I cannot add anything to the methods outlined here for safety in the way of ventilation and so forth, I can say that if you go into a plant and find that there is any acne present among the workers with this material you will know that there is sufficient of the substance in the air to cause acne and consequently sufficient perhaps to be dangerous to the few people who are hypersensitive to its action.

DR. CECIL K. DRINKER: There is a practical point in regard to the question of determining these substances in air. My brother pointed out this morning that there are several pieces of apparatus for doing this. It has seemed desirable to a number of the men who are here that during the next couple of years, while we are in a position of learning, that we endeavor, if we can, to confine our analyses to one piece of apparatus, so that at least our results will be as comparable as we can make them from place to place.

I don't know much about this phase of the subject; perhaps, Mr. Cook, you have an idea or two about that.

MR. WARREN A. COOK (Chief Industrial Hygienist, Bureau of Occupational Diseases, State of Connecticut Department of Health, Hartford, Conn.): On the determination of the halowax I wonder if it wouldn't be preferable to have Mr. Hemperly discuss the method he has been using throughout the country for the determination of chlorinated naphthalenes.

DR. CECIL K. DRINKER: I think so far as that is concerned it is best to leave that to discussions with Mr. Hemperly and Dr. Brandt afterward. But the question of determining some uniformity of technic for a while at least is, I think, a matter of general interest to us.

MR. WARREN A. COOK: I am not quite sure that I have in mind exactly what you want in that regard. In connection with sampling?

DR. CECIL K. DRINKER: Yes, in connection with the whole technic of determining the material in air, length of sampling, type of apparatus, and so forth. It has been suggested that we endeavor to agree upon some uniform procedure for that and as figures begin to come in, as they will in the course of the next couple of years, we will at least have them on a comparable basis.

MR. WARREN A. COOK: In that regard there is no question but what the determinations and results of analyses of the concentration of injurious materials in air, correlated with pathological findings or freedom from pathological findings, are real factors in further substantiating toxic limits which are originally given us from animal experimentation. In order to obtain data which are of value along that line it is desirable to know to what extent, in terms of milligrams per cubic meter, workers are exposed to in breathing any potentially injurious material.

It seems to me that one of the things that should be done, which many of the plants and many of the organizations equipped to make determinations of injurious materials in air should do, is to make an effort to develop one group and series of results which will represent average exposures of workers to chlorinated naphthalenes. In getting that figure I think that it is of great importance that we should consider average daily exposure. There is a tendency very often in taking samples of air to determine maximum exposures, to get the exposure over a 15 or 20 minute period when the worker may be actually tending a pot where the material is being used, whereas during the subsequent half hour he may be 40 or 50 feet away from that particular location. Therefore, for one thing, it seems to me it would be extremely desirable to obtain information in as many plants and as many locations as possible of the average exposure, taking into consideration not only the worker's maximum exposure while actually

at work with these materials but also his much smaller exposure and possibly even lack of exposure as he may go to other parts of the room or even to other departments during the course of the day.

Another type of determination which seems to be extremely desirable to have is concentrations of the chlorinated naphthalenes at certain reference points. I believe that Mr. Hemperly very carefully duplicated these reference points in each of the plants where he took his determinations. He took the samples, I believe, at breathing level and a certain measured distance from the pots where the chlorinated naphthalenes were being handled, so that next year he could go back to those same locations or others could take determinations at those same locations, which are definitely fixed and recorded, and learn whether, due perhaps to clogged pipe lines or to fans which might become loaded with the condensed chlorinated naphthalene, there might be poorer ventilation than originally designed and higher concentrations of the chlorinated naphthalene than originally determined.

It seems to me that it would be an extremely desirable thing to have made available for all of us who are making these determinations these reference points so that in Massachusetts and in Connecticut, at one plant or at another, a considerable group of workers could be taking samples at this one particular point with reference to the source of generation of the vapor. Such results would permit a comparison of knowledge between plants.

In that regard it happens that there is a committee of the American Public Health Association which is charged with the development of chemical methods for determination of atmospheric contamination such as that now under consideration. It seems to me that it might be a very desirable project for that committee to consult with the investigator of the Halowax Corporation and suggest to all of those who are doing work of this type, after some discussion, what reference points could be adopted and also what should be done in connection with getting these average exposures. As a matter of fact our committee will discuss that very feature and possibly include it in our report

before the A. P. H. A. in October as one of the projects which we shall carry out at that time.

As I have not given this consideration, I am afraid my discussion is not as connected as I might wish it to be. We have a real problem here and one that deserves some study.

DR. CECIL K. DRINKER: Would it be of service to the American Public Health Association Committee if a sub-committee from this meeting, collected perhaps by my brother and those of you involved with these problems, were to make a recommendation to the A. P. H. A. as to the things you have brought up and as to suitable apparatus, and let the final statement come from the Association after they have considered that material?

MR. WARREN A. COOK: I think that would be a splendid idea because we have a bulk of information on this particular material. A number of individuals have given much thought to the development of apparatus, both the combustion method which we have here and also the continuous record type of apparatus which Professor Drinker mentioned this morning. I think that it is a sufficiently important project that a sub-committee made up from this group could give that committee a very definite steer.

[Personnel of the Sub-committee: W. A. Cook, chairman, A. L. Coleman, H. B. Elkins, W. B. Fulton, S. W. Gurney, E. R. Hayburat, W. F. Hemperly, F. W. Sehl, and A. N. Setterlind.]

MR. HERVEY B. ELKINS (Chemist, Division of Occupational Hygiene, Massachusetts State Department of Labor and Industries, Boston, Mass.): In connection with what Dr. Schwartz has said, I am not sure that I am in complete agreement as regards the use of skin lesions as warning agents. It is my understanding that in insulated wire plants the chlorinated diphenyls are very commonly compounded with the chlorinated naphthalenes. It is also my understanding that these are more likely to cause a severe skin irritation than the straight chlorinated naphthalenes. On the other

hand, from Dr. Drinker's work one would judge that the straight chlorinated naphthalene was nearly as toxic at least as the mixture of it with a small amount of chlorinated diphenyl.

In the condenser factory where we had our cases there is no chlorinated diphenyl used and no acene of the type described in the reports on the insulated wire factories.

DR. R. EMMETT KELLY (Monsanto Chemical Co., St. Louis, Mo.): I can't contribute anything to the laboratory studies but there has been quite a little human experimentation in the last several years, especially at our plants where we have been manufacturing this chlorinated diphenyl. It has been our observation that although on one occasion we did have a more or less extensive series of skin eruptions which we were never able to attribute as to cause, whether it was impurity in the benzene we were using or to the chlorinated diphenyl, we have never had any systemic reactions at all in our men. We have examined them very closely both from what laboratory tests we thought might help us and from the clinical viewpoint. Also from chlorinated diphenyl alone there have been no cases of systemic poisoning reported.

I don't believe that we can transpose the laboratory results into the actual humans without paying considerable attention to the volatility of different substances and the way they are being used.

DR. JOHN A. HOOKEY (Consulting Dermatologist, Halowax Corporation, Detroit, Mich.): I have had considerable experience with the dermatological angle of this problem. The experience at the Halowax plant at Wyandotte definitely was that the dermatosis did increase when compounds were used rather than the straight chlorinated naphthalenes.

From the discussion we have heard today I think the observation Dr. Drinker made that the chances are that dermatological problems will disappear along with the other is probably true. However, I think that certain precautions, certain insurance measures, you might say, should be taken in hiring men who are going to work with these products, even though we are going

to attempt to get the concentrations low. We saw this morning that the effect of these products was on the liver and that if some one working in these products developed liver damage from some other source the chances of his having serious trouble was increased. Therefore, inasmuch as there is no test to tell whether a person has had liver disease, certainly in the preliminary medical examination of applicants for work the history at least should be gone into very carefully for a history of previous liver diseases.

There are other things that should be taken into consideration also. One is the history of syphilis, because syphilis does have an effect on the liver. If there is any history of syphilis I don't think that that man should be hired. A Kahn test should be taken and I think that it would be a good plan to take Kahn tests on men at stated intervals, because they might develop syphilis after they are hired.

I think those things should be done even though we feel that if the concentration of these vapors in the air is kept as low as was recommended this morning, the chances of having toxic effects are very small.

MR. F. R. KAIMER: I would like to clarify a point of Dr. Hookey's.

You mentioned at the beginning of your talk that your experience in acene condition was more pronounced from the compounds of various materials with chloronaphthalene than with the straight chloronaphthalenes. Did you mean by that, that the acene condition actually was more pronounced with the compounds than with the straight chloronaphthalene or was that due to the fact that you were in a plant operated in a different fashion? In other words, you handled your numerous wire compounds in more of a batch operation. That is my understanding from Mr. Brown.

Is it a fact that the straight chloronaphthalenes are less harmful in so far as acene is concerned or is it because of the handling of batch compounds?

DR. JOHN A. HOOKEY: That is a question that would be difficult to answer. I based my statement on the fact that in taking a general survey of these cases after I started working with them the men in the plant said

that they developed acne more often and more severely after they started making compounds. It may be that it was in the method of the handling.

MR. F. R. KAIMER: You say that the condition increases with the increased chlorine content and we are attributing the acne primarily to the chlorine radical. If that is true, what are we to associate insofar as these various other constituents are concerned, such as various plasticizing agents? How much do we know about those insofar as development of acne is concerned? Some of these compounds have a half dozen constituents in them other than chlorodiphenyl and chloronaphthalene. We are at the present time considering the chloronaphthalene as the basic element responsible for the acne condition which we have. We know very little about what the other materials may or may not do.

DR. JOHN A. HOOKEY: I don't know about these other materials. Perhaps Dr. Schwartz would know something more about them.

DR. LOUIS SCHWARTZ: It is well known in industry that there are many compounds that cause acne. For instance, paraffin acnes and oil acnes have been known for a long time. Paraffin acnes, wax acnes, are simply a mechanical plugging of the follicles of the skin by the minute particles of wax that fall on the skin. I think that the acne caused by these chlorinated naphthalenes and diphenyls, because it is caused by both—I was down at the Swan Chemical Company where they make chlorinated diphenyls and they have acne there just the same as over at Wyandotte where they make the chlorinated naphthalenes—I believe that that is caused by the same thing, a blocking up of the follicles of the skin, the formation of the comedone and then the comedone becomes infected and forms a pustule. They don't all pustulate because they don't all become infected. Many of these men never have any pustules. They just have little white elevations on their skin.

In those people who are in the acne age, the youngsters of 18, 20, 22 and 23, acne

vulgaris is most apt to occur. The sebaceous glands are most active and they seem to have it much more than the older people in whom the sebaceous glands are not so active.

We keep a clipping of all articles relating to industrial dermatitis in my office and I recently read an article in a German magazine in which they report in Germany a similar acne condition from chlorinated phenols and chlorinated benzenes and solid waxes. It seems that this acne-like condition is not peculiar to halowax or chlorinated naphthalenes or diphenyls but can occur with any condition that blocks up the sebaceous follicles of the skin.

DR. ROYAL MEEKER (Special Agent, State of Connecticut Department of Labor, Hartford, Conn.): I am full of questions. As a statistician I am a little bit suspicious of averages, so I should think that we should take maxima as well as averages in getting at the threshold dose or the dangerous impregnation of the atmosphere with these poisonous compounds. I just wanted to drop that as a hint for this committee to consider in its work.

In spite of what you said at luncheon, Dr. Drinker, I still think it is rather important to determine how the plugging of the pores actually does occur, whether they are plugged as Dr. Schwartz has suggested, from the particles falling on the outside of the skin or whether they are plugged, as so many doctors have informed me, from inside as it were. The fumes are breathed, the substance gets into the blood stream. It is thrown off through the pores of the skin and the pores are plugged. I think it is rather important to determine that because it seems to me, from the slight knowledge that I have of the industrial application of halowax compounds in insulating wires, that the plugging of the skin, if it is just an outside plugging, may take place either from handling a solid substance or from the coating on the wire after it becomes cold.

I haven't heard anybody say anything about those Massachusetts cases of very severe dermatitis and I am not so sure but what there was some question of liver damage there. Nobody has said anything about them at all. There is no question there

that the condition, whatever the complications might have been, came from handling cold wire, in a confined area of course.

I think this needs a great deal more study, Dr. Drinker, than you and your associates have been able to give it as yet. All I am curious about is the way we can administer the protective labor laws in order to protect both the employer and the employee.

I listened with very great interest to the expositions of suggested pots for the application of halowax, chlorinated naphthalene and diphenyl. It seemed to me that they left very much to be desired. I don't see why the application of the halowax compound, if it is necessary, as I assume it is, to use this rather dangerous substance, can't be done in a practically closed pot. If you please, Dr. Drinker, I wish you would ask Mr. Reeves of the Rockbestos Products Corporation to tell how they have handled it. If I am any judge of equipment and safety devices they have come as near to eliminating entirely from the atmosphere all contamination from fumigated or evaporated halowax as anyone. All of the application of halowax, either in the melting pots or where it is applied to the wire, is done under hooding and with ventilating apparatus, and it seems to be entirely adequate.

Mr. H. H. REEVES (Vice-president and General Manager, Rockbestos Products Corporation, New Haven, Conn.): I will be very glad to tell of our experience if it will help the picture along. Our experience has been more or less parallel with Mr. Kaimor's in as much as we manufacture the same type of wire. We have avoided the serious picture that he ran into, probably due to the fact that shortly after 1923 we were using benzene as a solvent for asphaltic materials.

We got into anemia difficulties with benzene fumes and had to install a complete ventilating system to remove all those fumes from the machines that applied the compounds to the wire. Following the installation of that equipment we were able to get a substitute for benzene, so we got it out of the picture.

We are still in the same fix as every one else is as far as finding a substitute for halowax. There is none that we know of. Consequently when we went to the use of halo-

wax we had a head start as far as the ventilating system was concerned, since ours was already installed and adaptable to a compound with a benzene solvent rather than a melted halowax compound. In order to keep the fumes of a highly volatile solvent under control we did develop a practically complete enclosure for the container in which the compound was placed and exhausted that container in order to prevent any escape of the fumes from it. When we changed to the halowax compounds we followed the same scheme of applying the compounds and used a completely enclosed pot. There is a hole in one side for the wire to go in and one on the other side for the wire to come out. There is enough exhaust suction on the enclosure to prevent any fumes from getting out of the openings where the wire enters and leaves. Of course periodically it is necessary to open the pot to replenish the compound or make adjustments. In that case we have the ventilating system interlocked with the door that the operator opens so that when he opens it he increases the amount of air travel about ten-fold.

Dr. ROYAL MEEKER: What is the velocity when the door is open?

Mr. B. H. REEVES: With the door wide open, at breathing level the velocity is 200 feet. That is the linear velocity. We check that every week on every opening at every machine with a velometer, a small instrument which is easy enough to operate and reads directly. Whenever the velocity falls below that figure the pipe connecting that machine is taken down and cleaned, because there will be condensation inside the pipe to cut down the air flow and reduce the ventilation efficiency.

Dr. ROYAL MEEKER: What do you think of that trap device shown?

Mr. B. H. REEVES: I don't know what to think of that. I don't know whether it would be practical or not. I was going to ask Dr. Drinker whether in passing the air laden with halowax fumes through the boxes of rats there was any deposit of halowax in the enclosure.

DR. CECIL K. DRINKER: Yes. It is detectable readily through the outflow pipe.

MR. B. H. REEVES: Those in the far end probably didn't get the concentration.

DR. CECIL K. DRINKER: We change the position of the boxes each day. The ones furthest away move into the nearest position, so that over a period of weeks all are exposed equally.

DR. EMERY R. HAYBURN (Consultant in Industrial Hygiene, State Department of Health, Columbus, Ohio): I would like to ask if it wouldn't be possible to put a cold water line around that trap and deposit it all before the air escapes from the trap.

MR. B. H. REEVES: We have tried cooling the surface of the exhaust pipes in order to concentrate the deposit in one place and make it unnecessary to remove long lengths of the ventilating system. While we have found a slight advantage in doing so it hasn't at all paid for the expense. It is much easier to take the piping down. Consequently I doubt the possibility of removing it all by cooling the surfaces of the trap. It might be possible, by building a labyrinth of refrigerating coils, to collect it. But then you would have the problem of removing it from the coils after you had collected it and it would involve rather complicated procedure.

DR. B. L. VOSBURGH (Medical Director, General Electric Company, Schenectady, New York): We have heard about the possibility of preventing liver damage and skin trouble among manufacturers of wires and cables and so forth, but like the old rhyme, every dog has fleas and the fleas have fleas, we also have customers who use wires and cables in tunnels, in enclosed spaces, applying them together and doing all sorts of things. I am not at all certain that we know what the concentration of these chlorinated hydrocarbons is under those conditions.

About the time we were having so much trouble at our York factory some of our customers began complaining. We thought we were having a hysteria of halowax mania throughout the country. Some of their

complaints were bona fide. We had no difficulty in handling cold wire and the men had no skin trouble. Yet when they did the same thing with possibly the application of heat in tunnels, ships and so forth, they actually did develop trouble.

We have used, of course, the icterus index in following some carbon tetrachloride cases and I wondered what you have to say about that. Is that of no value at all in the case of liver damage in this material?

DR. CECIL K. DRINKER: I don't think so until it gets so extreme that we know it any way.

DR. B. L. VOSBURGH: I did write down a few questions that came to mind. Some of them have been answered and some are foolish but I shall ask them anyhow.

It occurred to me that if trichloronaphthalene has been proved to be practically innocuous, isn't it a problem of research largely for the Halowax Corporation to use only that one material adopted with other known chlorinated compounds to meet the requirements of customers? That is one of the foolish ones probably, but I shall just ask it.

Furthermore, how long is it reasonable to expect the liver to recover after it has been pretty well damaged. I talked to you and you said you hadn't worked that out with the animals as yet.

DR. CECIL K. DRINKER: In that case we set aside a certain number of animals to recover, after knowing that a certain amount of damage had been done. Then we started to kill them but we invariably ran out of rats before they ran out of lesions. We don't know how long it lasts.

DR. B. L. VOSBURGH: Have you given them calcium and glucose as you would with carbon tetrachloride?

DR. CECIL K. DRINKER: Not yet, but we are doing an experiment now with one group on a very high calcium diet and another group on a calcium free diet. The whole question of calcium in the diet, of giving milk daily to these people may be worth while.

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Dr. B. L. VOSSBURN: I just had those questions in mind. I would like to hear what Mr. Brown would say as to the possibility of using only this one innocuous chlorinated naphthalene.

Mr. SANDFORD BROWN: That would simplify our problem exceedingly, not only from the commercial standpoint but from the toxicity standpoint. But if we did so I think that Mr. Kainer would be the first to object because he wouldn't be able to get the technical effects he desires in the cable. The same thing applies throughout all the industry where we are using these higher chlorinated products.

The problem as we see it, and it is one which we intend to study further (we have our program for this continuous work that will be done under the direction of the Drinker brothers), is to try to find a line of demarcation and whether or not within this complicated chemical structure there is some one thing that causes the trouble. If we could take hexachloronaphthalene and remove 1 per cent of some unknown constituent with which we are not now familiar and eliminate the toxicity, that would be a lovely solution. Whether we will ever be able to attain that I don't know. That is one of the things we have in mind.

As I said before, that is one of the things with which all manufacturers of these synthetic organic products are confronted at some stage, either in their laboratories or in commercial developments. It is largely a question of timing as to when you should do the work, how much you should do, and whether you know how to do it. You have to learn that first.

Dr. CECIL K. DRINKER: Unless there is some other important matter I will declare the meeting adjourned.

Dr. R. R. SAYERS: May I say a word more with regard to what Dr. Hookey stated on syphilis? If you are going to eliminate all your workers who happen to develop

syphilis during the time they are working for you, you are probably going to lose some very important employees. It would seem that it would be worth while to give serious consideration to seeing that conditions are proper and suitable for them to continue working for you and that they have proper treatment. In other words, I don't believe that is a good or sufficient reason for discharging those employees who do develop syphilis. We have not found that to be true in other places and I question whether this is one of the places. I may be in error.

Mr. SANDFORD BROWN: I want to take this occasion to express on behalf of the Halonax Corporation my thanks for the excellent cooperation we have received from various state authorities and our customers as well in this investigation. I believe you have all formed the opinion, based on what you have heard this morning, that our whole motive here is to conduct this on an ethical, scientific and constructive basis.

In collaboration with the Monsanto Chemical Company we have a much more comprehensive program in view to carry on. Therefore we want to continue that same type of cooperation.

There is one thing that I want to bring up in that connection, which will have to be observed by the state authorities, when they go out to make these inspections. That is the necessity of not creating mob hysteria on the part of the workmen in the plants where these inspections are made. Mr. Hemperly has run into some very interesting situations in the various examinations he has made. I know that he would be glad to relate them and give the benefit of his experience to the heads of any of these state departments who will have the direction of this work. Otherwise I can see where we will be unable to get the full cooperation of not only the individual workmen but the plant foremen and the management, and we must have that if we are to get the results that we are shooting for over the next several months or years. This thing may continue, probably will continue for years.