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VOLATILE COMPOUNDS AS FUNGICIDES

by

Walter L. Clark, Lt., USNR and John M. Leonard

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Approved by:

Dr. P. Borgstrom	Commodore H. A. Schade, USN
Superintendent	Director
Chemistry Division	Naval Research Laboratory

NAVAL RESEARCH LABORATORY
Washington, D.C.

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ABSTRACT

The vapors of approximately 250 organic compounds have been examined for fungus inhibitive properties. The procedure was a petri-dish assay, which, though scarcely comparable to actual tests under service conditions, does afford a rapid and convenient method of screening. Some of the more promising compounds have been scrutinized for secondary degradative effects, vis., corrosion of metals and impairment of plastics. A number of promising compounds were disclosed, among them tricresyl phosphite and trioxy-methylene.

AUTHORIZATION

The study of tropical deterioration was initiated by the Bureau of Ships Project Order No. 152/46 and ONR Project Order No. 46/46. The NRL designation is Problem 32C03-06.

PROBLEM STATUS

The exploration of new compounds will continue. The more promising compounds already uncovered will be examined by techniques which are more nearly representative of conditions of use.

VOLATILE COMPOUNDS AS FUNGICIDES

BACKGROUND

The deteriorating action of tropical environments has been described many times. It is, therefore, unnecessary to present here a dissertation on the losses in textiles, cordage, electronic equipment, and service materiel of almost every sort. In a tropical environment, one factor which has been exceedingly troublesome is the molds, bacteria, and other biological agents. To stem the losses, various remedial measures have been undertaken, each appropriate to the type of equipment involved. For example, the direct incorporation of toxic chemicals has yielded gratifying results with textiles. Several of these agents have been found to be sufficiently persistent to assure an inhibition comparable in duration to the normal service life of the item concerned. In some instances it is found helpful to replace the mold susceptible material by a substance which has a very low nutritional availability.

With certain electrical and electronic equipments, the application of an overall varnish or lacquer coating to the assembly has proved beneficial. The organic film has been regarded as serving a dual purpose, first as a retardant barrier against the ingress of moisture, and second as a convenient vehicle or matrix for the retention of a toxic agent.

This second aspect, that of preparing coatings of persistent fungus-inhibitive powers, has occupied the attention of this Laboratory for some time, and has been the subject of numerous reports. The problem of conferring a lasting toxicity upon a varnish or lacquer film is exceedingly difficult. Coatings containing as much as 10 percent of some compounds which are very toxic per se, will support luxuriant growth of fungi after a few weeks of exposure. The problem is not regarded as insoluble, but its difficulties must not be minimized.

An alternative method of fungus control has been considered worthy of exploration. A previous report of the Naval Research Laboratory [1] enumerates the work of other laboratories in the development of means of fungal control by means of toxic vapors, and describes an examination of about fifty compounds for their fungicidity in the vapor state.

Scheffer and Duncan [2] describe experiments on forty-seven organic compounds of possible utility in the packaging field. This method of fungal control, rather widely a adopted in the field of optics, is regarded as having potentialities in the protection of

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[1] Whaley, Wilson M., W. L. Clark, W. E. Weaver, K. L. Englund, and J. M. Leonard, "Volatile Compounds as Fungicides for Electronic Equipment - Part I" NRL Report No. P-2653, 6 November 1945, p. 1

[2] Scheffer, Theodore C., and Catherine G. Duncan, "Fungistatic Vapors for Control of Mold in Packages and Equipment," Ind. Eng. Chem., 38, 619-621, June 1946

electrical and electronic equipment. The varnish film may still serve, where needed, as a barrier for the exclusion of moisture while fungus inhibition would be obtained from the toxic vapor.

The applicability of a mold-inhibiting vapor is considerably wider, however, than the protection of optical and electronic equipment. It should find use with any fungus-susceptible device or material which is not open to a free circulation of air. It is most applicable under the conditions where the hazard of fungal growth is greatest; namely, in a stagnant atmosphere. The characteristics of a desirable fungicide are:

"(a) It must be non-volatile enough to have a practicable service life, even at the operating temperatures of the equipment.
(b) It must be toxic enough to prevent mold growth at the vapor concentration obtained with low temperatures.
(c) It must not induce corrosion of metallic surfaces.
(d) It must not dissolve or react with rubber or with commonly used plastics.
(e) It must not, in the vapor state or by condensation, markedly reduce the surface resistance of insulating materials.
(f) It must not sublime upon the equipment and form possible short circuits or mechanical hazards.
(g) It must be non-toxic to the persons handling the apparatus, and must not have an unbearable odor.
(h) It must be available, or potentially available, in significant quantity." [3]

The Naval Research Laboratory report cited gives the results of the examination of more than 50 different organic compounds. These included most of those materials which other laboratories have regarded as having fungicidal potentialities. It was found, however, that none was completely satisfactory. Where fungicidity was sufficiently high, persistency was low or there was an adverse effect, either upon metallic surfaces or upon the plastic materials which are likely to be present in ordinary applications.

The study reported herein is an extension of the work previously reported and describes the examination of approximately 250 additional compounds.

EXPERIMENTATION

METHOD

The technique employed for the evaluation of the volatile fungicides is the same as that previously described.[4] In brief, it consists in placing a small cylindrical cup, 1 cm in internal diameter and 0.25 ml capacity, in the center of a 100 mm petri dish. A nutrient malt agar surrounds the cup. A small quantity of the material under test is placed in this central vessel and the agar is inoculated with a suspension of mixed fungal spores. The only opportunity for contact between fungicide and mold is by evaporation of the material from the central well. As a result, a concentration gradient is set up across the dish, as evidenced by a suppression of fungus growth in the vicinity of the cup. The

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[3] Whaley, W. M., et al, op. cit., p.4

[4] Ibid.

mycelial growth is annular, commencing at the periphery of the plate and growing toward the center. The dishes are inspected after 40 and 120 hours of incubation at 30°C and the observations recorded. The method of rating is the same as that used previously, namely that of an arbitrary scale, of extent of growth, viz:

0 = No growth.
1 = Slight annular growth, 1 centimeter wide or less
2 = Growth 1 to 2 centimeters in width
3 = Little or no evidence of fungal inhibition

For studying possible degradative effects of the toxic agent on plastics and other similar materials, a quantity of the fungistatic agent in a small open vessel was placed inside a laboratory desiccator together with various specimens of metal and plastic. Means for making insulation resistance measurements upon a sample of bakelite terminal block were afforded by wires through the cover. Where indicated, water in the bottom of the desiccator served to maintain a humid atmosphere. This test was performed only upon materials which showed promise in the fungistatic assay.

MATERIALS

The materials studied are given in Tables I to XIII, and in Appendix A. Each compound was tested as received, without further purification. Data on the physical constants presented in this Appendix are from information given by the supplier or obtained from standard reference works. To avoid overlooking good materials, the criteria previously set forth were interpreted rather liberally in selecting the samples for study. In addition to disclosing a number of interesting compounds, the large mass of data serves as a basis for some generalizations which will guide future work.

OBSERVATIONS

The data of the fungus inhibitive experiments are presented in Tables I to XIII. The effects upon insulation resistances of the selected compounds are shown in Table XV, corrosion data and related observations are given in Table XVI. Trioxymethylene, a material of excellent fungus-inhibitive properties, has been omitted from the last two tables. It was tested previously by a technique similar but not precisely comparable to the method here employed. At a somewhat elevated temperature (and therefore at a higher vapor pressure of both water and compound), the insulation resistance of bakelite dropped from 10,000 megohms to 850 megohms in a week. On a percentage basis, this is fairly close to the controls of the present experiment (Table XIV). It is notable that there were no marked degradations of metal and plastic exposed to the vapors of trioxymethylene.

In the present study, under dry conditions most of the compounds did not degrade the insulation resistance below the upper limit of the measuring instrument, namely 50,000 megohms. Two compounds did induce measurably lower readings within the experimental period as follows:

Methylene iodide	850 megohms
Furfural diacetate	400 megohms

The presentation of findings on insulation resistance (Tables XIV and XV) has been adopted for simplicity and to facilitate comparisons. The compounds were tested in three successive groups, each with a control. The data on these controls are given in Table XIV.

to show the magnitudes of the quantities involved. The behavior of the bakelite in the presence of the fungicidal vapor is reported as a ratio of the simultaneous readings of sample and control (Table XV).

DISCUSSION

It must be emphasized that the observed fungal inhibition is resultant of a number of factors. One of these is the actual toxicity of the material itself, another is its vapor pressure, or the concentration obtained at the temperature of the experiment. Unfortunately there is a serious lack of vapor pressure data at normal temperatures for most of the compounds studied. Stull[5] gives a lengthy compilation of vapor pressure data, but unfortunately only a small fraction of the compounds here studied are contained in his tabulations. Reliable vapor data would enhance greatly the value of these findings. They would, for example, be of great assistance in interpreting the biological assays and would permit more nearly absolute indices of toxicity to be established. If the vapor pressure measurements were made at several temperatures, the persistence of a compound might be predicted with a fair degree of accuracy and more fundamental properties of the material determined.

HYDROCARBONS

None of the hydrocarbons (Table I) showed evidence of fungus inhibition. Two of the compounds, styrene and p-cymene were completely evaporated after 40 hours. This would indicate an exceptionally low toxicity inasmuch as the vapor concentration in the dish must have been very high during the greater portion of the brief incubation period. The toxicity of the first two compounds of the table is also low. In no case can their inocuous behavior be ascribed to either the fungitiveness of very high volatility or to the low vapor concentration identified with low volatility. It is concluded that the molecules d-limonene and camphene are simply nontoxic. The lack of inhibition on the part of the last four compounds is probably the result of low volatility combined with low intrinsic toxicity. In any event, the hydrocarbon classes studied here do not show promise for future study.

HALOGENATED HYDROCARBONS

Table II discloses several items of interest. The first compound, methylene iodide, seems to be very nearly ideal, inasmuch as it completely suppressed fungus growth for the entire incubation period with no perceptible evaporation loss. Introduction of an additional halogen atom to give iodoform, the second compound, probably decreases the vapor pressure below the toxic threshold, though a more fundamental mechanism cannot be excluded. Though most of the halogenated aliphatics of short chain length (3 carbon atoms or less) show a definite fungus inhibition, it is usually associated with such a high evaporative loss as to exclude the compounds from immediate consideration as a practical means of fungus control.

Bromine substitution is considered as enhancing toxicity more than chlorine[6]

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[5] Stull, Daniel R., "Vapor Pressure of Pure Substances - Organic Compounds," Ind. Eng. Chem. 39, 517-550, April 1947

[6] Weaver, W. E. and W. M. Whaley, Chemical Studies on Fungicides - Part I, Correlation of Structure with Fungicidity, NRL Report No. P-2877, 19 July 1946.

Brominated C_2 - and C_3 - compounds are worthy of attention because such treatment would simultaneously augment the absolute toxicity of the compound and decrease the volatility. A nice balance of the two factors might ultimately be achieved. The longer chain aliphatics show a low order of toxicity which, even as high as C_8 cannot be charged to low vapor concentration, because 2-bromo-n-octane shows no inhibition even though a significant amount of evaporation occurs. Though the halogened aromatic compounds may be more toxic than their aliphatic counterparts, halogenation to the point of reasonable persistence results in loss of fungicidity.

ALDEHYDES AND KETONES

The data of Tables III and IV sustain, in general, the earlier contention[7] that the carbonyl group has a definite, though limited, toxicity. Those compounds having the carbonyl as the only toxic group are usually inhibitive only when the vapor concentration has been very high, as evidenced by considerable evaporation losses. Several of these, however, displayed sufficient promise from the standpoints of fungus inhibition and persistence to warrant studying their effects on metals and plastics. These are 2-ethyl hexaldehyde, o-chlorobenzaldehyde, 2-ethyl-3-propyl acrolein, 1, 3-dichloroacetone, furfural diacetate, and acetyl acetone.

OTHER COMPOUNDS

The alcohols and other hydroxy compounds (Table V) show, in the main, very little fungus inhibition except when the vapor concentration is so great as to make the evaporation prohibitively high. However, trioxymethylene is regarded as promising.

The samples of Table VI, halogenated hydroxy compounds, are notable for their generally low evaporative rates. When this phenomenon is associated with good fungus inhibition, an especially high degree of intrinsic toxicity is indicated. The most promising compound from this standpoint is trichlorophenol. The higher members of the series, tetrachlorophenol and pentachlorophenol, are probably of higher actual toxicity[8] but their intrinsic toxicities are offset by the decreased volatility. Though tetrabromo-o-cresol is inactive under the conditions of the experiment, it is planned to examine other phenols of lower bromine content.

Of the acids examined (Table VII) only iodoacetic acid completely suppressed fungal growth. Its hygroscopicity introduces a serious difficulty to its practical application.

The behaviors of several compounds of Table VIII deserve special mention. Cresatin (m-cresyl acetate) has been shown by other workers to be of merit in suppressing fungal growth in optical equipment. In the test here reported, however, it performed poorly. Two halogenated esters, ethyl α-chloroacetoacetate and ethyl α-bromo-n-butyrate esters, are very nearly ideal in suppressing growth with little or no evaporative loss. The toxicity of the last compound of the table, tri-m-cresyl phosphite, is surprising in view of the very low vapor pressure of the material (b.p. 235°C at 7 mm).

The nitro compounds (Table IX) tested show no promise. Nithromethane and nitroethane probably have some toxicity, inasmuch as fungus growth is retarded at first,

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[7] Ibid.

[8] Ibid.

presumably until the samples evaporated. The third item, 1-chloro-1-nitropropane, is probably somewhat less volatile and more effective.

None of the aromatic amines in Table X showed enough fungus inhibition to warrant consideration. Three of the aliphatic compounds showed inhibitions fairly consonant with their rather rapid evaporation rates. Further studies of this class of compounds should inclu the straight chain compounds in the vicinity of C_6 and additional substituted cyclohexyl compounds.

In the previous report[9] butyl thiocyanate was shown to be moderately toxic. The compound is also volatile. Table XI of this report gives data on the higher homologs. In the amyl compound good toxic properties are maintained and the evaporative loss decreases markedly. In the next member, the impaired fungicidity becomes apparent and the evaporation loss is practically nil. Above C_6 there is no evidence of inhibition.

The data on the aliphatic mercaptans of Table XII gives no promise of good volatile fungicidity from this class of compounds. The octyl compound shows a marked volatility without perceptible retardation of mold. The lower members display little mold retardant properties, even though their volatilities are higher. Benzyl mercaptan, however, combines good toxicity with fairly low volatility. As previously pointed out[10] the mercaptans are alcohol analogs. The relatively high toxicity of benzyl alcohol and low toxicity of the aliphatic alcohols are duplicated in the mercaptans. Unfortunately the offensive odor of this class of compounds eliminates it from practical consideration.

However noxious the mercaptans are, they are far exceeded by the three selenium compounds studied. The excellent fungistatic characteristics of the latter group makes their noisome properties all the more regrettable

The reaction of ethyl thiocyanoacetate is especially gratifying, showing complete suppression of fungus growth with no observable evaporative loss. This action of the ethyl compound contrasts strongly with the indifferent behavior of the cyclohexyl and the isobornyl esters previously reported.[11]

Pyridine (Table XIII) is obviously fugitive (20 mm. at 24.8°C),[12] consequently, the initially good fungus inhibition was only temporary. The next two compounds, vinyl and methyl substituted pyridines, respectively, are less volatile. As a result fungus inhibition persisted for the duration of the experiment. The last compound of the table, a substituted piperidine, probably owes its toxicity to the presence of halogen.

SECONDARY EFFECTS

With regard to the insulation-resistance studies, the degrading influence of moisture is indeed marked; it quite obscures any deleterious effects of the fungistatic vapors. It

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[9] Whaley, W. M., et al., op. cit.

[10] Weaver, W. E., et al., op. cit.

[11] Whaley, W. M., et al., op. cit.

[12] Stull, D. R., op. cit.

may be noted, however, that in each case except two (iodobenzene and furfural disacetate) the vapor might be construed as effecting a protective action. It appears more conservative, however, to point out that the initial values of the ratio (resistance of sample/ resistance of control) is maintained fairly well throughout the course of each exposure. Under the experimental conditions no seriously deleterious effect could be observed. At a lower relative humidity, for example, the effect of moisture might be sufficiently reduced to permit better evaluation of the effects of the vapors.

The humid atmosphere does not obscure the corrosion data (Table XVI) so much. Most of the compounds do show a tendency to accelerate the corrosion of metals under wet conditions. Tri-m-cresyl phosphite does not follow this general trend. Altogether it appears, along with trioxymethylene, to be the most promising of the materials examined. Except for its exceedingly low vapor pressure, it might be expected to be as corrosive as the majority of the other materials. These generally are acidic, either actually (as iodoacetic acid), or potentially, through hydrolysis or oxidation.

As already indicated, the conditions of these tests were quite extreme. In a practical application it would be most undesirable to have a saturated atmosphere of toxic vapor. Even a compound showing satisfactory persistence in the pure state should be diluted or otherwise prepared so that its vapor concentration is kept well below a saturation value. Otherwise condensation is inevitable. It seems desirable, therefore, to ascertain a lower limit at which each vapor is fungistatically effective, and then re-examine the degradative tendencies of the diluted vapor under somewhat less drastic conditions.

It should also be stated that a compound having good toxic properties is not necessarily excluded because it is excessively volatile. It may still possess adequate inhibitive properties when its evaporation is impeded. Such retardation may be achieved by diluting the material so as to reduce its equilibrium pressure. It may also be attained by restricting the exposed surface of fungicide so that its evaporation is approximately balanced by the leakage of vapor from the enclosed space. An Army technique, in which the diluted fungicide is enclosed in a perforated metal capsule, combines both these principles.

For the immediate future, it is planned to continue the examination of the more fungistatic compounds of this report for corrosion and other degradative tendencies. Some of those already examined will be more exhaustively tested under closer approximations of actual use. It is planned, of course, to continue the examination of new materials especially along the avenues which the present study indicates as offering special promise.

SUMMARY AND CONCLUSIONS

As part of a continuing study, approximately 250 substances have been examined for fungicidity in the vapor state. The procedure was a rather simple petri dish assay readily adapted to the screening of large numbers of samples.

Fourteen of the fungistatic compounds were subjected to further study to ascertain possible corrosive tendencies and adverse effects upon insulating materials. Two of this number, tricresyl phosphite and trioxymethylene, even under the drastic test conditions, appear very promising.

Certain generalizations have been made regarding the chemistry of volatile fungicides. On the basis of these, the work will be continued.

A number of the agents warrant further study by techniques which more nearly simulate conditions of use.

ACKNOWLEDGMENTS

The writers are indebted to Drs. Wilson M. Whaley and Warren E. Weaver for their syntheses of a considerable number of the compounds studied. Thanks are due also to Miss Constance M. Patouillet and Mrs.Ruth M. Little for their technical assistance.

TABLE I

FUNGISTATIC ACTIVITY OF HYDROCARBONS

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
d-Limonene	3		++
Camphene	3		++
Styrene	3		+++
p-Cymene	3		+++
Fluorene	3		0
o-Terphenyl	3		0
m-Terphenyl	3		0
Phenanthrene	3		0

* Estimated on the basis of the amount of fungicide remaining at the conclusion of the incubation period (40 or 120 hours)

KEY:

+++	Sample completely evaporated
++	More than half of sample evaporated
+	Perceptible loss, half of sample or less
0	Negligible loss

TABLE II

FUNGISTATIC ACTIVITY OF HALOGENATED HYDROCARBONS

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
Methylene iodide	0	0	0(a)
Iodoform	3		0
Carbon tetrabromide	0	0	++
Tetrachloroethylene	3		+++
s-Tetrachloroethane	0	1	+++
Hexachloroethane	3		0
Trichlorotrifluoropropane	0	0	+++
1-chloro-3-iodopropane	2	2	+++
1,1,2-Trichloropropane	0	1	+++
1,1,1,2-Tetrachloropropane	0	1	+++
1,2,2,3-Tetrachloropropane	1	1	+++
1,1,1,2,3-Pentachloropropane	2	3	++
1,1,2,3,3-Pentachloropropane	0	0	+++
alpha-Heptachloropropane	1	1	0
alpha-Butylene bromide	2	3	+++
1,4-Dichlorobutane	2	3	+++
Dichloropentanes	2	3	+++
n-Hexyl bromide	2	3	+++
n-Heptyl bromide	3		0
2-Bromo-n-octane	3		+
Undecyl bromide	3		0
Lauryl bromide	3		0
Bromocyclohexane	3		+
Benzenehexachloride	3		0
Bromobenzene	2	3	+++
Iodobenzene	0	0	+
o-Chlorotoluene	0	3	+++
m-Chlorotoluene	0	3	+++
o-Dichlorobenzene	0	3	+++
p-Dichlorobenzene	3		+++
p-Dibromobenzene	3		0
1,2,4,5-Tetrachlorobenzene	3		0
Hexachlorobenzene	3		0
alpha-Chloronaphthalene	3		0
alpha-Bromonaphthalene	1	3	0

* See footnote, Table I

(a) Some decomposition

TABLE III

FUNGISTATIC ACTIVITY OF ALDEHYDE COMPOUNDS

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs	
Chloral hydrate	2	2	0(a)
Butyl chloral	1	1	0(a)
Hexaldehyde	0	0	+++
2-Ethyl butyraldehyde	0	0	+++
Heptaldehyde	1	2	+
2-Ethyl hexaldehyde	0	1	+
2-Ethyl-3-propyl acrolein	0	0	+
Pelargonic aldehyde	3		0(b)
Benzaldehyde	0	0	(b)
o-Methoxybenzaldehyde	3		0
Piperonal	3		0
Vanillin	3		0
o-Chlorobenzaldehyde	0	1	+
m-Nitrobenzaldehyde	3		+
Furfural	0	0	++
Furyl acrolein	2	2+	0
Furfural diacetate	0	0	0(a)

* See footnote, Table I
(a) Hygroscopic
(b) Oxidized

TABLE IV

FUNGISTATIC ACTIVITY OF KETONES

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
Pinacolone	2	3	+++
Methyl-n-amyl ketone	0	2	+++
Methyl-n-hexyl ketone	1	3	+++
Methyl n-nonyl ketone	3		0
Methyl n-undecyl ketone	3		0
Methyl n-heptadecenyl ketone	3		0
Octadecyl ketone	2^{+}	3	0
Acetyl acetone	0	0	+
Acetonyl acetone	3		0
Propionyl acetone	0	1	+++
Acetyl propyl chloride	0	0	+++
1,3-Dichloracetone	0	0	+
Methylcyclopropyl ketone	3		+++
Diethylaminopentanone-2	2		++
Cyclohexanone	0	1	+++
4-Methyl cyclohexanone	0	0	+++
Isophorone	3		0
Carvone	2^{+}	3	0
Bromocamphor	3		0
Hexachlorophenol	2	3	0
Acetophenone	2^{+}	3	0
4-Chlorobenzophenone	3		0
p-Bromophenacyl bromide	2^{+}	2^{+}	0
Benzil	3		0
Benzoin	3		0
o-Benzoylbenzoic acid	3		0
Furoin	3		0
alpha-Acetylbutyrolactone	3		0

* See footnote, Table 1

TABLE V

FUNGISTATIC ACTIVITY OF HYDROXY COMPOUNDS AND DERIVATIVES

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
n-Amyl alcohol	2^+	3	0+
n-Octyl alcohol	3		0
Linaloöl	2	2+	0
Diacetone alcohol	3		0
Butyroin	2+	3	0
alpha-Terpineol	2+	3	0(a)
Borneol	3		0
o-Cresol	1	1	0
m-Cresol	2	2	0
p-Cresol	2	2	0
Benzyl alcohol	3		0
1,2,4-Xylenol	2	2	0
1,3,5-Xylenol	2	2	0
p-t-Amylphenol	2	2+	0
Thymol	1	2	0
Carvacrol	2	2	0
o-Phenylphenol	3		0
p-Phenylphenol	3		0
Anisole	0	3	+++
Phenylmethyl carbinol	3		0
Phenyl ether	3		0
Benzylethyl ether	1	2	+
Catechol	3		0(a)
Resorcinol	3		0(a)
2,5-Dimethylfurane	0	0	+++
Styrene oxide	3		0
Diphenylene oxide	3		0+
Trioxane	3		0
Trioxymethylene	0	0	0
Paraldehyde	3		+++
Phenothioxine	3		0

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* See footnote, Table I

TABLE VI

FUNGISTATIC ACTIVITY OF HALOGENATED HYDROXY COMPOUNDS

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
Glycerol alpha-monochlorohydrin	3		0
Glycerol alpha, gamma-chlorohydrin	2+	2+	0
2, 2 -Dichloroethyl ether	3		0
1,3-Diiodopropanol-2	3		0
Trichloro-t-butanol	2	2	0
p-Chlorophenol	1	1	0(a)
2-Chloro-5-hydroxytoluene	2	2	0
2,4-Dichlorophenol	0	0	+
2,4,6-Trichlorophenol	0	0	0
2,3,4,6-Tetrachlorophenol	2	2+	0
Pentachlorophenol	2	2	0
Tetrabromo-o-cresol	3		0
2-Chloro-6-phenylphenol	3		0
Epibromohydrin	0	0	+

TABLE VII

FUNGISTATIC ACTIVITY OF CARBOXYLIC DERIVATIVES

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
Chloroacetic acid	2	2+	0(a)
Iodoacetic acid	0	0	0(a)
Trichloroacetic acid	3		0(a)
alpha-Chloropropionic acid	1	1	0(a)
alpha-Bromopropionic acid	2+	2+	0(a)
d-Camphoric acid	3		0
Cyclohexylacetic acid	3		0
Cyclohexylpropionic acid	3		0
Cyclohexylbutyric acid	3		0
Cyclohexylcaproic acid	3		0
o-Chlorobenzoic acid	3		0
p-Chlorobenzoic acid	3		0
2,4-Dichlorobenzoic acid	3		0
3,4-Dichlorobenzoic acid	3		0
Benzonitrile	0	1	+
Benzyl cyanide	1	3	0

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*See footnote, Table I

(a) Hygroscopic

TABLE VIII

FUNGISTATIC ACTIVITY OF ESTERS

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
Acetylmethyl acetate	3		0
Ethyl bromoacetate	0	0	+++
Ethyl trichloroacetate	1	1	+
Ethyl cyanoacetate	3		+ (a)
Ethyl acetoacetate	2+	2+	++
Ethyl alpha-chloroacetoacetate	0	0	0
Ethylidene diacetate	2	2+	+++
Amyl acetate	3		+++
m-Cresyl acetate (cresatin)	2+	3	0
Dodecylammonium acetate	3		0
Ethyl alpha-oxalpropionate	3		0
Ethyl alpha-bromo-n-butyrate	0	0	+
Isoamyl-n-butyrate	3		0
Ethyl glycolate	3		0
Tetrahydrofurfuryl salicylate	3		0
Ethyl-o-formate	3		+++
tri-m-Cresyl thiophosphate	3		0
tri-m-Cresyl phosphite	1	1	0

* See footnote, Table I
(a) Hygroscopic

TABLE IX

FUNGISTATIC ACTIVITY OF NITRO COMPOUNDS

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
Nitromethane	1	3	+++
Nitroethane	0	3	+++
1-Chloro-1-nitropropane	0	0	+++
2-Nitro-p-cymene	3		0
alpha-Nitronaphthalene	3		0
p-Nitrophenol	3		0
2,4-Dinitrophenol	3		0
o-Nitroanisole	3		0
o-Nitrophenetole	3		0
m-Nitroacetophenone	3		0
2-Nitrobenzonitrile	3		0
o-Nitroaniline	3		0
m-Nitroaniline	3		0
p-Nitroaniline	3		0
2,4-Dinitroaniline	3		0
p-Nitrosodimethylaniline	3		0

* See footnote, Table I

TABLE X

FUNGISTATIC ACTIVITIES OF AMINES

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
Dimethylamine hydrochloride	3		0(a)
mono-n-Butylamine	0	0	+++
mono-n-Amylamine	0	0	+++
Diamulamine	2	3	+++
Diethylene triamine	3		0(a)
tri-n-Butylamine	2	3	+++
Salicylal mono-sec-butylamine	1	3	0
Ethanolamine	3		0(a)
n-Butylethanolamine	3		0(a)
Diethylaminoethanol	2	2	+
Salicylal monoethanolamine	3		0
n-Ethylcyclohexylamine	0	0	+++
Aniline	2	2+	0
o-Toluidine	3		0
m-Toluidine	3		0
p-Toluidine	2+	3	0
N-methylaniline	3		0
Dimethylaniline	3		0
o-Phenylene diamine	3		0
p-Phenylene diamine	3		0
o-Xenylamine	3		0
Diphenylamine	3		0
Benzidine	3		0
o-Anisidine	3		0
p-Anisidine	3		0
o-Aminophenol	3		0
p-Aminoacetophenone	3		0
p-Aminobenzophenone	3		0
4,4'-Diaminodiphenyl ether	3		0

* See footnote, Table I

(a) Hygroscopic

TABLE XI

FUNGISTATIC ACTIVITY OF THIOCYANATE COMPOUNDS

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
Amyl thiocyanate	0	0	+
Hexyl thiocyanate	0	1	0
Heptyl thiocyanate	3		0
Octyl thiocyanate	3		0
Ethylene thiocyanate	3		0
Cyclohexylthiocyanate	3		0
Phenacyl thiocyanate	2+	3	0

* See footnote, Table I

TABLE XII

FUNGISTATIC ACTIVITY OF SULFUR AND SELENIUM COMPOUNDS

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
t-Hexyl mercaptan	0	3	+++
t-Heptyl mercaptan	2+	3	+++
t-Octyl mercaptan	3		++
Decyl mercaptan-1	3		0
t-Dodecyl mercaptan	3		0
Ethyl disulfide	1	3	+++
Propyl disulfide	3		0
Diamyl sulfide	3		0
Ethyl diselenide	0	-	0(a)
Butyl selenocyanate	0	0	0(a)
Hexyl selenocyanate	0	0	0(a)
Thiophenol	0	0	+++
Benzyl mercaptan	0	0	+
Ethyl thiocyanoacetate	0	0	0
alpha-Naphthyl isocyanate	3		0
beta-Naphthyl isocyanate	3		0

* See footnote, Table I
(a) Stench

TABLE XIII

FUNGISTATIC ACTIVITY OF COMPOUNDS RELATED TO PYRIDINE

Chemical Name	Extent of Growth		Evaporation Loss*
	40 hrs.	120 hrs.	
Pyridine	0	3	+++
2-Vinylpyridine	0	0	+++
alpha-Picoline	0	0	+++
2-Aminopyridine	3		0
2-Ethanol pyridine	3		0
2-Propanol pyridine	3		0
4-Propanol pyridine	3		0
Piperidine	0	0	+++
2-Hexyl piperidine	3		0
N-(alpha-bromoacetyl)-piperidine	0	0	0

* See footnote, Table I

TABLE XIV

EFFECTS OF HUMID ATMOSPHERE ON BAKELITE TERMINAL BLOCKS

Exposure Time, Days	Insulation Resistance in Megohms		
	BLOCK A	BLOCK B	BLOCK C
.10	5500		10,000
.16			
.20	4250	6800	7,000
1.0	2100	3250	3,200
2	1100	2500	1,600
3		1300	
4	500	1000	1,100
5	500		1,350
6	320		
7	320	700	850
8		700	900
9		380	
10	340	340	800
11	300	280	750
12	260		

TABLE XV

EFFECTS OF FUNGICIDAL VAPORS ON INSULATION RESISTANCE OF BAKELITE UNDER HUMID CONDITIONS

Exposure Time, Days	Ratio $\left(\frac{\text{Resistance, sample}}{\text{Resistance, control}}\right)$												
	MI	AT	ET	IB	CP	BP	EH	CA	EC	TC	1A	EB	F.A.
0.10	1.8	2.0	(a)	.47	1.5								
0.16											3.0	2.0	1.2
0.20	1.7	1.9	(a)	.47	1.4	2.4	2.7	7.4	1.8	5.9			
1	1.6	1.8	2.1	.45	1.5	1.9	1.7	4.0	1.9	4.6	1.7	1.1	1.0
2	1.5	1.8	2.0	.55	1.5	1.8	1.6	4.5	2.0	3.2	1.5	1.1	.81
3						2.0	1.9	5.8	2.3	3.5	1.5	1.1	1.1
4	1.4	1.8	3.0	.66	1.6	1.9	1.7	5.0	2.3	3.0			
5	1.4	1.8	2.8	.64	1.6						1.4	1.1	.86
6	1.7	2.5	3.4	.94	2.0						1.3	1.1	.78
7	1.6	2.4	3.4	.94	1.9	1.7	1.4	5.7	2.4	2.6			
8						1.7	1.3	5.7	2.3	2.4	1.1	1.2	.77
9						1.8	1.6	5.8	2.6	2.8	1.1	1.2	.72
10	1.5	2.2	3.1	.82	1.6	2.1	1.6	6.2	2.8	3.2			
11	1.6	2.5	3.5	.93	1.9	2.0	1.6	6.1	2.9	3.0	1.3	1.4	.88
12	1.8	2.7	3.8	1.0	2.0						1.2	1.3	.80

Key:

MI	Methylene iodide	CA	1,3-dichloroacetone
AT	Amyl Thiocyanate	EC	Ethyl alpha-chloroacetoacetate
ET	Ethyl Thiocyanoacetate	TC	Tricresyl phosphite
IB	Iodobenzene	IA	Iodoacetic acid
CP	Trichlorophenol	EB	Ethyl alpha-bromo-n-butyrate
BP	N-alpha-bromoacetyl piperidine	FA	Furfural diacetate
EH	2-ethyl Hexaldehyde		

(a) Sample resistance > 50,000 megohms

TABLE XVI

EFFECTS OF FUNGICIDAL VAPORS ON VARIOUS MATERIALS

Fungicide	Extent of Degradation after 12 Days									
	Aluminum		Copper		Steel		Vinylite		Rubber	
	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet
GROUP A										
None (Controls)	0	+	0	+	0	+	0	0	0	0
Methylene iodide	++	+	+	+	+++	++	0	0	0	0
Amyl Thiocyanate	0	+	0	+	+	++	+	++	0	0
Ethyl thiocyanoacetate	+	++	++	++	0	++++	0	0	0	0
Iodobenzene	0	+	0	±	0	+	+	++	0	0
Trichlorophenol	+	+	+	+	+	+++	0	0	0	0
GROUP B										
None (Controls)	0	0	0	0	0	±	0	0	0	0
N-alpha bromo acetyl piperidine	+	++	0	±	0	++	0	0	0	0
2-ethyl hexaldehyde	0	+	(a)	(a)	(b)	(b)	0	0	0	0
1,3-dichloroacetone	0	++++	0	±	0	++++	0	0	0	0
Ethyl alphachloroacetoacetate	0	±	±	±	0	++++	0	0	0	0
Tri-m-cresyl phosphite	0 0	+	0	±	0	0	0	0	0	0
GROUP C										
None (Controls)	0	0	0	+	0	+	0	0	0	0
Iodoacetic acid	0	++	+	++(c)	0	++++	0	0	0	0
Ethyl alpha bromo-n-butyrate	0	0	0	+	0	++++	+++	+++	0	0
Furfural diacetate	0	+	++(c)	++(c)	++	++++	++	±	0	0

KEY:

±	Barely perceptible degradation	(a)	Formation of soluble copper salt on the metallic surface
+	Slight, but definite degradation	(b)	Resinous deposit
++	Moderate degradation	(c)	Also corrosion of nickel-plated-brass screws of terminal board
+++	Strong degradation		
++++	Very severe degradation		

APPENDIX

IDENTIFICATION OF MATERIALS

Chemical Name	M.P.°C	B.P.°C	Source
(1) Hydrocarbons			
d-Limonene		178	Eastman Kodak Co., Rochester, N.Y.
Camphene	50	160	Eastman
Styrene		146	Eastman
p-Cymene		177	Eastman
Fluorene	116	295	Reilly Tar & Chem. Corp., Indianapolis, Indiana
o-Terphenyl	57	332	Eastman
m-Terphenyl	87	363	Eastman
Phenanthrene	212	405	Eastman
(2) Halogenated Hydrocarbons			
Methylene iodide	5-6	180d	Eastman
Iodoform	119		NRL synthesis
Carbon tetrabromide	90	189	Eastman
Tetrachloroethylene	-22	121	Eastman
s-Tetrachloroethane	0.1	146	
Hexachloroethane		187(subl.)	Eastman
Trichlorotrifluoropropane			Columbia Organic Chemicals Co., Columbia, S.C.
1-Chloro-3-iodopropane		140	Eastman
1,1,2-Trichloropropane		140	Columbia
1,1,1,2-Tetrachloropropane			Columbia
1,2,2,3-Tetrachloropropane			Columbia
1,1,1,2,3-Pentachloropropane			Columbia
alpha-Heptachloropropane	30	248	Columbia
alpha-Butylene bromide		166	Eastman
1,4-Dichlorobutane		163	E. I. duPont, Wilmington, Del.
Dichloropentanes		130-200	Sharples Chemicals Inc., Phila., Pa.
n-Hexyl bromide	-85	156	Columbia
n-Heptyl bromide		179	Columbia
2-Bromo-n-octane		189	Eastman
Undecyl bromide			Columbia
Lauryl bromide		175/45 mm	Eastman
Bromocyclohexane		165/714mm	Eastman
Benzenehexachloride	157		Eastman
Bromobenzene	-31	156	Eastman
Iodobenzene	-31	189	Eastman
o-chlorotoluene	-34	159	Eastman
m-chlorotoluene	-48	162	Eastman
p-chlorotoluene	7.5	162	Eastman
o-Dichlorobenzene	-18	179	Eastman
p-Dichlorobenzene	53	174	Eastman
p-Dibromobenzene	87	218	Eastman
1,2,4,5-Tetrachlorobenzene	135	246	Eastman
Hexachlorobenzene	231	309	Eastman

APPENDIX (Cont.)

Chemical Name	M.P.° C	B.P.° C	Source
alpha-Chloronaphthalene		260	Eastman
alpha-Bromonaphthalene		281	Eastman
		(3) Aldehydes	
Chloral hydrate	42	96d	J.T. Baker Chemical Co., Phillipsburg, N. J.
Butyl chloral	78	165	West Vaco Chlorine Products Corp., Charleston, W. Va.
Hexaldehyde		128	Carbide and Carbon Chemicals Corp., New York, N. Y.
2-Ethyl butyraldehyde		117	Eastman
Heptaldehyde	-45	155	Eastman
2-Ethyl hexaldehyde		163	Eastman
2-Ethyl-3-propyl acrolein		175	Carbide and Carbon
Pelargonic aldehyde		185	NRL
Benzaldehyde		179	Baker
o-Methoxybenzaldehyde		244	Eastman
Piperonal	37	263	Eastman
Vanillin	81	285	Eastman
o-Chlorobenzaldehyde	11	208	Eastman
m-Nitrobenzaldehyde	58	164/23 mm	Eastman
Furfural	-37	163	Quaker Oats Co., Chicago, Ill.
Furylacrolein	51	200	Eastman
Furfural diacetate	52	220	Eastman
		(4) Ketones	
Pinacolone	-53	107	Eastman
Methyl-n-amyl ketone		150	Eastman
Methyl-n-hexyl ketone	-21	173	Eastman
Methyl-n-nonyl ketone	11	223	Eastman
Methyl-n-undecyl ketone	28	260	Eastman
Methyl-n-heptadecyl ketone			Armour Laboratory, Chicago, Ill.
Octadecyl ketone			City Chemical Corp., New York, N.Y.
Acetylacetone	-23	135	Eastman
Acetonyl acetone	- 9	193	Carbide and Carbon
Propionyl acetone			Edwal Laboratories, Chicago, Ill.
Acetylpropyl chloride			U.S. Industrial Chemicals, New York
1,3-Dichloroacetone		170	NRL
Methylcyclopropyl ketone		112	U. S. Ind. Chem., New York, N.Y.
Diethylamine pentanone-2		90/22 mm	U. S. Ind. Chem., New York, N.Y.
Cyclohexanone	-45	156	Eastman
4-Methylcyclohexanone		170	Eastman
Isophorone		215	Carbide and Carbon
Carvone		230	City Chem. Co.
Bromocamphor	78	274d	Eastman
Hexachlorophenol	105	210	Eastman
Acetophenone	20	202	Eastman
4-Chlorobenzophenone	78	332	Eastman

APPENDIX (Cont.)

Chemical Name	M.P.°C	B.P.°C	Source
p-Bromophenacyl bromide	110		Eastman
Benzil	95	346	Eastman
Benzoin	135	340	Eastman
o-Benzoylbenzoic Acid	127		Eastman
Furoin	138		Eastman
alpha-Acetylbutyrolactone		122/10 mm	U. S. Ind. Chem. Co.
(5) Hydroxy Compounds			
n-Amyl alcohol		138	Mallinckrodt Chemical Works, St. Louis, Mo.
n-Octyl alcohol		194	Eastman
Linaloöl		198	Eastman
Diacetone alcohol		62/13 mm	Eastman
Butyroin		183	NRL
alpha-Terpineol	35	220	Eastman
Borneol		219(sat)	City Chem.
o-Cresol	31	191	Reilly
m-Cresol	11	202	Reilly
p-Cresol	33	202	Reilly
Benzyl alcohol	-15	205	Eastman
1,2,4-Xylenol	62	227	Reilly
1,3,5-Xylenol	58	220	Reilly
p-t-Amylphenol	93	267	Eastman
Thymol	52	233	Eastman
Carvacrol	0	237	City Chemical Corp.
o-Phenylphenol	56	275	Eastman
p-Phenylphenol	165	305	Eastman
Anisole	-37	153	Eastman
Phenylmethyl carbinol		107/12 mm	Eastman
Phenyl ether	27	259	Eastman
Benzylethyl ether		190	Eastman
Catechol	105	245	Eastman
Resorcinol	110	277	Eastman
4-t-Butylcatechol	57	285	Eastman
2,5-Dimethylfurane		93	Eastman
Styrene oxide		191	Eastman
Diphenylene oxide	86	287	Reilly
Trioxane	61	114	duPont
Trioxymethylene	150		Eastman
Paraldehyde	6	125	Eastman
Phenothioxine	58	185/23 mm	Eastman
(6) Halogenated Hydroxy Compounds			
Glycerol alpha-monochlorohydrin		213	Eastman
Blycerol alpha, gamma-chlorohydrin		174	NRL
2,2'-Dichloroethyl ether		179	Eastman

APPENDIX (Cont.)

Chemical Name	M.P. °C	B.P.° C	Source
1,3-Diiodopropanol-2	-16	dec.	NRL
Trichloro-t-butanol	95	167	Eastman
p-Chlorophenol	43	217	Eastman
2-Chloro-5-hydroxytoluene	66	235	Eastman
2,4-Dichlorophenol	45	209	Eastman
2,4,6-Trichlorophenol	62	252	Dow Chemical Co., Midland, Mich.
2,3,4,6-Tetrachlorophenol	70	164/23 mm	Dow Chem. Co.,
Pentachlorophenol	189	309	Dow Chem. Co.
Tetrabromo-o-cresol	208	dec.	Merck and Co. Inc., Rahway, N.J.
2-Chloro-6-phenylphenol	6	323	Eastman
Epibromohydrin		72/85 mm	Eastman
(7) Carboxylic Compounds			
Chloracetic acid	60	190	Eastman
Iodoacetic acid	82		Harshaw Chemical Co. Cleveland, Ohio.
Trichloroacetic acid	58	195	Harshaw
alpha-Chloropropionic acid		186	City Chem.
alpha-Bromopropionic acid	26	206	City Chem.
d-Camphoric acid	187		Eastman
Cyclohexylacetic acid	28	129/10 mm	Dow
Cyclohexypropionic acid	15	177/10 mm	Dow
Cyclohexylbutyric acid	29	156/10 mm	Dow
Chclohexylcaproic acid	32	144/10 mm	Dow
o-Chlorobenzoic acid	141		Heyden Chem. Corp., New York, N.Y.
p-Chlorobenzoic acid	242		Heyden
2,4-Dichlorobenzoic acid	169		Heyden
3,4-Dichlorobenzoic acid	203		Heyden
Benzonitrile		191	Eastman
Benzyl cyanide		233	NRL
(8) Esters			
Acetylmethyl acetate		62/8 mm	Eastman
Ethyl bromoacetate		168	NRL
Ethyl trichloroacetate		168	Eastman
Ethyl cyanoacetate		208	Eastman
Ethyl acetoacetate		180	Eastman
Ethyl alpha-chloroacetoacetate		193	Eastman
Ethylidene diacetate		168	Eastman
Amyl acetate		149	Baker
m-Cresyl acetate (cresatin)		212	W.G. Hutchinson, U. of Pa., Phila.,(OSRD)
Dodecylammonium acetate			Armour
Ethyl alpha-oxalpropionate		109/5.5 mm	Eastman
Ethyl alpha-bromo-n-butyrate		178	Eastman
Isoamyl-n-butyrate		178	Eastman
Ethyl glycolate		160	Eastman
tetrahydrofurfurylsalicylate		131/2 mm	Eastman
Ethyl-o-formate		145	Eastman
Tri-m-cresyl thiophosphate	34	353	Eastman
Tri-m-cresylphosphite		235/7 mm	Eastman

APPENDIX (Cont.)

Chemical Name	M.P.°C	B.P.°C	Source
(9) Nitro Compounds			
Nitromethane		101	Eastman
Nitroethane		115	Eastman
1-Chloro-1-nitropropane		140	Eastman
2-Nitro-p-cymene		152/15 mm	Eastman
alpha-Nitronaphthalene	60	304	Eastman
p-Nitrophenol	114	279 dec.	Eastman
2,4-Dinitrophenol	114		Eastman
o-Nitroanisole	9	273	Eastman
o-Nitroacetophenetole	6	275	Eastman
m-Nitroacetophenone	81	202	Eastman
2-Nitrobenzonitrile	108		NRL
o-Nitroaniline	71		Eastman
m-Nitroaniline	114	285	Eastman
p-Nitroaniline	146		Eastman
2,4-Dinitroaniline	187		Eastman
p-Nitrosodimethylaniline	86		Eastman
(10) Amines			
Dimethylamine hydrochloride	170		Eastman
Mono-n-butylamine		78	Sharples
Mono-n-amylamine		104	Sharples
Diamylamine		203	Sharples
Diethylene triamine		86	Eastman
Tri-n-butylamine		216	Sharples
Salicylal mono-sec-butylamine			NRL
Ethanolamine		171	Carbide and Carbon
n-Butylethanolamine		200	Sharples
Diethylaminoethanol		162	Eastman
Salicylal monoethanolamine			NRL
n-Ethylcyclohexylamine		165	NRL
Aniline		184	Baker
o-Toluidine		200	Eastman
m-Toluidine		203	Eastman
p-Toluidine		200	Eastman
Methylaniline		196	Eastman
Dimethylaniline		193	Eastman
o-Phenylenediamine	103	256	Eastman
p-Phenylenediamine	140	267	Eastman
o-Xenylamine	47		Monsanto Chemical Co., St. Louis, Mo.
Diphenylamine	53	302	Monsanto
Benzidine	126		Eastman
o-Anisidine	5	225	Eastman
p-Anisidine	57	243	Eastman
o-Aminophenol	173	subl.	Eastman
p-Aminoacetophenone	106	295	Eastman
p-Aminobenzophenone	124		Eastman
4,4'-Diaminodiphenylether	186		Eastman

APPENDIX (Cont.)

Chemical Name	M.P. °C	B.P.° C	Source
(11) Thiocyanates			
Amyl thiocyanate			NRL
Hexyl thiocyanate		88/10 mm	NRL
Heptyl thiocyanate		103/10 mm	NRL
Octyl thiocyanate		109/5 mm	NRL
Decyl thiocyanate		122/2 mm	NRL
Ethylene thiocyanate	90	dec.	Eastman
Cyclohexyl thiocyanate		83/7 mm	NRL
Phenacyl thiocyanate	73		NRL
(12) Sulfur and Selenium Compounds			
t-Hexyl mercaptan	147	147	Phillips Petroleum Co., Bartlesville, Oklahoma
t-Heptyl mercaptan		161	Phillips
t-Octyl mercaptan		177	Phillips
Decyl mercaptan-1			Conn. Hard Rubber Co., New Haven, Conn.
Ethyl disulfide		153	Eastman
t-Dodecyl mercaptan		232	Phillips
Propyl disulfide		190	Eastman
Diamyl sulfide		103/12 mm	Sharples
Ethyl diselenide		186	Eastman
Butyl selenocyanate		100/25 mm	NRL
Hexyl selenocyanate		88/10 mm	NRL
Thiophenol		169	Eastman
Benzyl mercaptan		195	Eastman
Ethyl thiocyanoacetate		118/15 mm.	NRL
alpha-Naphthyl isocyanate		58	Eastman
beta-Naphthyl isocyanate		55	Eastman
(13) Pyridines and Related Compounds			
Pyridine		115	Baker
2-Vinylpyridine		159	Reilly
alpha-Picoline		143	Eastman
2-Aminopyridine	56	204	Eastman
2-Ethanol pyridine		235	Reilly
2-Propanol pyridine			Reilly
4-Propanol pyridine			Reilly
Piperidine		106	Eastman
2-Hexyl piperidine			NRL
N-(alpha-bromoacetyl)-piperidine		95/0.15 mm	NRL

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