PLAINTIFF'S EXHIBIT
MET-888

Volatile Solvents as a Problem in Industrial Medicine*

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The increasing prominence of volatile solvents in modern industrial processes emphasizes the need of early recognition of any toxic action on exposed workers which, if recognised, may lead to corrective measures being adopted. Within the past few years, the number of newly perfected solvents has steadily mounted, until today, well in excess of three hundred are in common use, contrasted with a bare half dozen used twenty years ago. One or more of the solvents are used in ever-increasing quantity and variety in very nearly every manufacturing industry today either as a solvent or diluent. They are employed as cleaning or degreasing agents, in lacquer coatings, in dyes and cement, as plasticizers, and as solvents of cellulose and gums of various kinds in a myriad of synthetic finishing materials.

The volatile solvent vapors enter the body chiefly through the respiratory passages, but appreciable quantities may either be ingested or absorbed through the intact skin.

When toxic substances are inhaled, they pass into the general circulation and are distributed to the heart and to the central nervous system with a rapidity second only to that seen when they are injected directly into the veins. They can produce either a general toxic action without harm to the

*Presented at the 88th Annual Session of the American Medical Association, Atlantic City, N.J., June 9, 1937.

respiratory tract or a mixed effect, being generally toxic and locally irritant. A few irrespirable vapors act so violently in the upper respiratory tract and lungs that their general toxic effects are secondary considerations.

The absorption of vapors through the alveolar wall is accomplished by the process of diffusion which depends on a difference in the partial pressures of the gases contained in the blood and in the inhaled air - a physiological fact of great importance when it comes to the consideration of first aid treatment. As long as the partial pressure of the vapor in the lungs is greater than that in the blood, absorption will continue. Hence, the first and most essential step in acute poisoning is the removal of the victim from the polluted atmosphere. Equally important and essential, taking precedence over any and all other measures or drugs, when natural respiration has been affected, is the application of manual artificial respiration.

Substances ingested, if they do not set up sufficient irritation to cause vomiting, may be absorbed by the intestines in varying amounts, depending on their properties and their reaction with the material of the digestive tract. A large portion of the absorbed substance passes into the portal circulation and may be satisfactorily handled by the liver.

Some of the more toxic fat soluble vapors are absorbed through the intact skin. Dermatitis may be set up by the continual handling of almost any of them, either because of their fat solvent properties or because of sensitivity, natural or acquired. Many of them may also affect the eyes and any optic neuritis or paralysis in workers exposed should give rise to investigation.

It is characteristic of the quick drying lacquers that the solvent which is their vehicle evaporates with great rapidity, and hence may produce a high concentration of the vapors in a confined space.

The increasing use of a spray gun in applying finishes to large surfaces has greatly increased the hazard of toxic vapors in many processes. Dip and flow methods also involve the use of large quantities of solvents.

With few exceptions, all volatile solvents, if inhaled in sufficient concentration for a sufficient length of time, are detrimental to health, although their early effects on the body frequently go unrecognized, or are regarded as minor ailments of no consequence, because of inadequate knowledge of their physiological properties. The concentration of vapor solvents in the air breathed depends upon their volatility, which, in turn, is often dependent on their temperature, and the effectiveness of ventilating equipment.

While the responsibility of finding satisfactory solutions of these new problems created by the use of solvents lies primarily in the field of industrial medicine, more knowledge of these poisons is desirable among general practitioners who see the slighter forms of poisoning. The failure to diagnose industrial poisoning is well illustrated by Lejeune,(1) a general practitioner himself, who discusses twenty-nine cases of poisoning by tetrachlorethane, benzol, benzin, and trichlorethylene, which he has treated in his practice during the last few years. Thirteen of these had previously consulted other doctors and in twelve of them, no diagnosis of poisoning had been made.

Hydrocarbons

Of the various groups of solvents encountered, perhaps the most important to the physician are the chlorinated compounds, because of their anesthetic and poisonous action. The member of this group with which we are all familiar is chloroform. Although chloroform possesses high solvent powers,

(1)Lejeune, E., The Frequency of Industrial Poisonings Seen in General Medical Practice, Schweizerische medizinische Woch., 66, 914-917; 940-941,1936. Abstract in Bulletin of Hygiene, 12, 16, 1937.

it does not find wide application in industry because of its well-known anesthetic properties. Carbon tetrachloride is perhaps the most widely used solvent of this group. It is very much like chloroform, but is more toxic and is used extensively as a cleaning fluid and in fire extinguishers. It has been used medically as a vermifuge in hookworm disease. Its narcotic effects are less marked than those of chloroform, but its effects on the liver, heart, and kidneys are much more rapid. Carbon tetrachloride, together with other members of the group, also has a marked effect on the nervous system, probably because these are lipoid solvents. There are changes in the blood in the direction of a leucocytosis, but these do not dominate the picture as they do in hydrocarbons of the benzene ring group. The effects on the heart are very important in cases of acute poisoning, because, in addition to acting as a heart depressant, there is a tendency to cause fibrillation. This means that stimulants, such as adrenalin, are a dangerous first aid measure in resuscitating persons overcome by these vapors.

Trichlorethylene is the least inflammable of the group and, because of its solvent action in fats and oils, it is used as a thinner for coatings and varnishes, and as a solvent for rubber, replacing carbon tetrachloride in many instances. It is also claimed to be a less poisonous substance, but increasing evidence shows it to be far from innocuous. Two hundred and eighty-four cases of poisoning with 24 deaths have been collected by Stüber.[2] While not so damaging to the body organs, it is a profound nerve poison. It has been suggested, however, that the impurities present are responsible for its poisonous properties.

Dichlorethylene is severely toxic. Severe cases of poisoning have

(2) Stüber, K., Archiv für Gewerbepathologie und Gewergehygiene, 2, 398, 1931.

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been reported in men who were coating the interior of beer vats, using a lacquer containing this solvent. Autopsies on men overcome by its vapors showed an excess of fat in the blood suggesting death from embolism rather than asphyxiation. Perchlorethylene causes a severe and rapid narcosis.

Tetrachlorethylene is a relatively new solvent and is less narcotic than the majority, although symptoms of drowsiness, headache, giddiness, and a narrowing of the visual field have been reported from repeated daily inhalations.

Tetrachlorethane is the most poisonous of the chlorinated hydrocarbons. In acute poisoning, the symptoms develop rapidly. The condition is characterised by acute yellow atrophy of the liver, jaundice, fatty changes in other viscera, especially the heart, and death frequently results. In chronic cases, the blood changes are marked, leading to secondary anemia, hemoglobinuria, and hemolysis. Emaciation and even jaundice may follow.

A toxic amblyopia, or an optic neuritis, has been noted by several observers in the case of exposure to chlorinated hydrocarbons. Some of this group decompose when heated and undergo chemical changes. Chloroform, dichlorethylene, ethyl-dichloride, and carbon tetrachloride are oxidised to carbon oxychloride or phosgene.

Chlorinated naphthalene products used, among other ways, as a form of wax in insulating, have been clearly shown to cause severe skin troubles, and have been suspected of causing fatal cases of yellow atrophy of the liver. It is interesting that these substances appear relatively harmless when cold, but when heated, despite the fact that they do not decompose or liberate chlorine and hydrochloric acid, the vapors cause acne more or less characteristic of chlorine acne.

Of the other groups of coal tar hydrocarbons, those of the aromatic series are the most important from the viewpoint of toxicity. The principal effect of this group of narcotics is on the hemapoietic system.

Benzol, one of the most volatile of the group, is a solvent for cellulose, gums, resins, fats, and oils. Its use as a diluent in paints and lacquers, and in paint removers is disappearing because of its dangerous toxic effects.

Toluene and xylene, the higher homologues of benzene, are perhaps just as toxic, but are less dangerous under ordinary circumstances because they are less volatile. These, too, are gradually being replaced by the apparently less toxic hydrogenated naphthas.

High concentrations of benzol are rapidly fatal. Exposures to moderate concentrations cause symptoms similar to alcoholic intoxication at first, but are followed by symptoms of progressive depression with possible Parkinsonian syndrome. Repeated exposures to small concentrations of benzene cause gastro-intestinal disturbances, headaches, vertigo, gingivitis, and frequently nose bleeds, and small hemorrhages of the gums and conjunctiva. Purpura may be noticed and sometimes uncontrollable hemorrhages occur, particularly if there is any surgery done.

The blood undergoes important changes as a result of destruction of the blood-forming organs. Anemia, and later, leucopenia with special reference to the granular polynuclears, is seen. Fatty degeneration of the blood vessels, heart, liver, and kidneys frequently follow.

It may be of interest to recall that recently considerable evidence has been produced to the effect that therapeutic drugs derived from the

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benzene ring - such as amidopyrene - may be the cause of an agranulocytosis in susceptible individuals. Once these blood changes have taken place, they are, in the present state of our knowledge, very apt to be irreversible.

The findings of a red blood count of under 4,000,000 or a white blood count of under 5,000 on repeated observation, accompanied by the symptoms indicated and a history of sufficient exposure, should be considered diagnostic of chronic benzol poisoning.

Yant and Schrenk's [3] method for determining increased organic sulfate in the urine is probably the best indication of benzol exposure and absorption.

Naphthalene is somewhat similar to benzene. It has a less pungent odor and probably is less toxic. Naphthalene has been suspected by a number of observers as a cause of cataract.

Among the derivatives of the hydrocarbons, carbon disulfide deserves special mention because of its varied effects on the body following repeated exposure to small concentrations. Concentrations of from 300 to 400 parts per million in the air for several hours are thought to be possibly toxic. Carbon disulfide is used chiefly in the rubber and artificial silk industry.

Chronic poisoning is characterized by persistent headache, somnolence during the day, and weakness of the limbs. Carbon disulfide is extremely damaging to the nervous system, causing polyneuritis, visual disturbances, tremors, mental confusion, severe psychosis, and ataxia. An important characteristic of this poison is its effect on the higher nerve centers. Anemia is not uncommon, with occasional changes in the red blood cells and, rarely, a leucocytosis. Not only is it damaging to the eyes, but the disappearance of the corneal reflexes is said to be an early sign of poisoning. However, Wiley,

(3) Yant, W.P., Schrenk, H.H., Sayers, R.R., Horvath, A.A., Reinhart, W.H. Urine Sulfate Determinations as a Measure of Benzene Exposure, Jour. Ind. Hyg. and Toxicology, 18, 69, (January) 1936.

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Hueper, and von Oettingen (A) quote Rodemacher as recommending the carbon disulfide level in the blood to be the best indication of incipient carbon disulfide poisoning.

Petroleum hydrocarbons, which are very often confused with the coal tar derivatives because of the similarity in names (benzine, naphtha, etc.), are all familiar solvents which have a mildly anesthetic action. The higher concentrations cause headache, dizziness, blurred vision, and even loss of consciousness.

Any chronic blood damage from this group is controversial and, if found, probably points to the advisability of looking for some other exposure or cause, particularly the admixture of one of the more dangerous types of solvents in the substance handled. Like all the other solvents, these can readily cause a dermatitis.

Turpentine vapors have a direct action on the skin, causing reddening, and not infrequently an obstinate eczema. The inhalation of heavy fumes of turpentine induce symptoms of a mild narcotic poisoning. Nephritis has been reported from prolonged exposure.

Phenol Compounds

Cyclohexanol, (hexalin, adronol, anol, or sexol), is a hydrogenated phenol used in pyroxylin lacquers. It is not very volatile, and evaporates much more slowly than other solvents. It is narcotic and may cause poisoning if inhaled. From animal experiments, it is thought to paralyze the central nervous system, and to be more toxic than benzene, though not as dangerous on account of its low volatility. No cases of poisoning in man are on record.

(A) Wiley, F.H., Hueper, W.C., and von Oettingen, W.F., On the Toxic Effects of Low Concentrations of Carbon Disulfide, Journal of Industrial Hygiene and Toxicology, 18, 733, (December) 1936.

A very dangerous substance which may be used in plasticizers is ortho-tricresyl phosphate. This is the poison which was identified some years ago as the cause of an epidemic of "Jake paralysis" from drinking bootleg Jamaica ginger. These men have never completely recovered. Usually, in solvents the para and meta tricresyl phosphates are used, and these do not appear to have the peculiar action of the ortho compounds, according to Hamilton.(5)

Alcohols and Their Ethers

The alcohols are perhaps the most widely used of the various classes of solvents. As a group, they are narcotic and injurious to the nervous system. Ethyl alcohol is used for research and analytical work in educational and industrial laboratories, and is employed for many scientific and medical needs. It is a solvent for gums, resins, and many organic and inorganic compounds. Methanol is used largely in the manufacture of pyroxylin plastics, varnishes, textile soaps, wood stains, as well as in extraction processes. One of its most important uses is in the manufacture of formaldehyde. Isopropyl alcohol is used as a substitute for ethyl alcohol, mainly in perfumes and high grade toilet preparations. It is claimed to be an effective germicide and is used in lotions, liniments, liquid soaps, and antiseptic solutions. Normal butyl alcohol is the most popular and widely used of the higher alcohol group. Large quantities enter into the manufacture of nitrocellulose lacquer.

Generally speaking, the toxicity of the alcohols increases with the molecular weight, but the decreased solubility and volatility of the higher alcohols partially offset the danger of exposure to concentrated vapors.

(5) Hamilton, A., Recent Changes in the Painter's Trade, Bulletin No. 7, Division of Labor Standards, U.S. Department of Labor, Washington, D.C. p.59, 1936.

The exception to this rule is methyl alcohol, which may be produced synthetically or by distillation of wood. It is a powerful nerve poison which specifically affects the optic nerves and may result in blindness and death. Due to its slow oxidizing action in the body, its effects are cumulative, and severe poisoning may result from continued exposure to even small concentrations, without any early warning symptoms. Experimentally, it has been shown to cause poisoning through skin absorption.

Although amyl alcohol and fusel oil are more toxic then taken by mouth than any other way, they play a minor role in industrial poisonings. Butyl alcohol produces liver and kidney damage in animals exposed to its vapors.

Tertiary alcohols are more toxic than secondary alcohols, and primary alcohols are the least toxic. Iso-alcohols are usually less narcotic than the corresponding normal alcohols.

A most interesting case of toxic encephalopathy has been reported, however, in a woman who used a mixture of solvents containing 3% dimethyl phthalate, 3% cellosolve, and 74% isopropyl alcohol in "fusing" collars with a hot iron.[6]

A larger group of newer solvents which is rapidly coming into greater prominence is the alcohol-ethers, or oxides, and the furfurals. Often these may be compounded with phthalic acid, oxalic acid, or formic acid, thereby introducing the possibility of a second toxic agent.

Our knowledge of this group is largely based on animal experimentation, though a number of cases of industrial poisoning have been reported. As a group, they are narcotic or anaesthetic, and some of them are known to be toxic

(6) Donley, Dorothy E., Toxic Encephalopathy and Volatile Solvents in Industry, Journal of Industrial Hygiene and Toxicology, 18, 571, (October) 1936.

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in the higher concentrations, but there is little data concerning their chronic effects or the maximum permissible concentrations.

Diethylene dioxide (dioxan), also used as a lacquer solvent, is irritating and unpleasant, and these effects were thought to constitute a sufficient warning that concentrations were approaching the danger point. In England, however, five deaths were recorded due to the fumes of dioxan, with severe inflammation of the liver and kidneys.

Esters, Ketones, Glycols and Their Ethers, and Furfurals

These constitute probably the most important group of solvents for nitrocellulose and cellulose acetate. All are narcotic in sufficiently heavy concentrations and in proportion to their volatilities. Although fatal accidents are very rare, evidence is beginning to appear pointing to their physiological effects as being more dangerous than they were formerly considered. Reference to a reported death in one man from the inhalation of amyl acetate and another from the inhalation of ethyl acetate is made by A.V. St.George.[7] In the former, edema of the glottis and diffuse irritation of the respiratory and gastrointestinal tract were the chief findings, and in the latter there was a marked congestion of the viscera and the eyes, almost entirely liquid blood in the vessels, petechial-like hemorrhages throughout the serous cavities and mucous membranes, and a pungent odor on opening the body.

Amyl acetate is readily recognized by its sweet, sickening odor, and it is generally known as "banana oil". Its vapors cause irritation of the throat, burning of the eyes, vertigo, drowsiness, and gastric irritation. In experimental animals, the inhalation of amyl acetate produces chronic inflammatory changes in the respiratory system, parenchymatous degeneration of the

(7) St. George, A.V., The Pathology of the Newer Commercial Solvents, American Journal of Clinical Pathology, 7, 69, (January), 1937.

kidneys, and fatty livers. The blood shows a moderate leucocytosis with a secondary anemia.

Methyl, ethyl, propyl, and butyl acetate are other members of the ester group of solvents. Methyl acetate is sometimes used as a substitute for acetone, but it is not widely used due to its acid reaction with water. Ethyl and butyl acetates are the most widely used of all the solvents of nitrocellulose.

Of the ketone group of solvents, acetone is probably the most widely used, and it is one of the most powerful solvents known. The impurities present depend upon the method of manufacture and are no doubt responsible for some of the toxic symptoms which are encountered. Its narcotic action in animals is more pronounced than that of chloroform. The examination of the blood after continued inhalation shows a destruction of the red cells and hemoglobin. It does not appear to produce chronic tissue damage as long as the vapor concentrations are low, even though exposure is prolonged.

Several ketones of higher molecular weight have been recommended as good solvents for nitrocellulose, but they have little or no effect on cellulose acetate. The more important members of this group are methyl-propyl ketone, or pentanone, and methyl-butyl ketone, or hexanone. Their acute effects on guinea pigs were studied by Yant[8] and his colleagues, who report that death results from a state of narcosis rather than from the irritation of the lungs. All fatalities occurred during the exposure. Men momentarily exposed to approximately 1.3% and 5.0% pentanone vapor, and to 1.23% and 2.0% hexanone vapor complained of irritation of the eyes and nasal passages, and of a characteristic strong odor.

(8) Schrenk, H.H., Yant, W.P. and Patty, F.A., Acute Response of Guinea Pigs to Vapors of Some New Commercial Organic Compounds. X. Hexanone (Methyl Butyl Ketone) Public Health Reports, 51, 624, (May 15, 1936).
Ibid, Acute Response of Guinea Pigs to Vapors of Some New Commercial Organic Compounds. IX Pentanone (Methyl Propyl Ketone), Public Health Reports, 51, 392, (April 3, 1936).

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Of the glycols and their ethers, the mono-ethyl ether of ethylene glycol, or "cellosolve", is the most important solvent of this class. It is a stable liquid and it is used as a solvent for nitrocellulose and resins, and offers the advantage over most other solvents of similar boiling point in being nearly odorless. The acute physiological response of guinea pigs to air containing its vapor was determined by Waite, Patty, and Yant,[9] who found the cause of death, in the animals who died 24 hours following exposure, to be congestion and edema of the lungs, and in animals dying three days following exposure, to be broncho-pneumonia. Two of the investigators who breathed 0.6% cellosolve vapors for a few seconds reported the atmosphere to be irritating to the eyes and to have a very disagreeable odor. They thought that the odor and the irritation were sufficiently disagreeable to make one desire to avoid a like exposure. Furfurals are excellent solvents and are used considerably in industry. The vapors are irritating and are very damaging to the eyesight of some people.

Summary

An estimation of the extent of any health hazard resulting from solvents and mixtures of solvents can be reached only after careful analysis of individual circumstances.

The mere knowledge that volatile solvents are used in certain industrial processes does not justify the conclusion that all illnesses among the working personnel may be attributed to exposure to these substances. Solvent vapors can be, and frequently are, confined within a closed system, or are prevented, by proper exhaust equipment, from escaping into the plant atmos-

(9) Waite, C.P., Patty, F.A., and Yant, W.P., Acute Response of Guinea Pigs to Vapors of Some New Commercial Organic Compounds. III. "Cellosolve" (Mono-ethyl Ether of Ethylene Glycol), Public Health Reports, 45, 1459, (June 27,1930).

phere. In doubtful instances, the diagnosis of industrial intoxications through inhalation should be further confirmed by chemical analyses of the air breathed. Such analyses are also essential in determining the efficiency of measures instituted to prevent the diffusion of these vapors into the breathing zone of the workers.

The difficulties encountered in determining the concentration of vapors in the plant atmosphere are many. In the first place, distinction must be made between vapor concentrations associated with plant operations and those resulting from accidents and irregularities in operation. Under normal operations, they may be present in the air in very low concentrations, which may require special technics in collecting air samples and selective methods of analysis. Where two or more solvents are present in the air in combinations at the same time, it is frequently impossible, by existing methods of chemical analysis, to identify and estimate individual components, although they can be differentiated and estimated as groups. Benzol and its homologues may be detected by a rather intricate colorimetric method, while carbon disulphide must be estimated by microtitration after absorption in an alcoholic potash solution. The chlorinated hydrocarbons may be determined by a combustion method, in which the liberated hydrogen chloride is absorbed. Other groups, such as the alcohols, esters, ethers, ketones, etc., may be determined or estimated by various analytical methods. When two or more members of a group are present, it is usually impossible to separate them and the results of the analysis must be recorded on the basis of the more toxic material. When a mixture, such as a lacquer thinner which may contain methyl and ethyl alcohol, acetone, benzene, ethyl and amyl acetate and butyl cellosolve, is under consideration, the problem becomes involved. It then becomes necessary to use a method which will determine the total amount of solvent vapor present. This may be done quantitatively by freezing out the vapors with liquid air; by absorption with activated charcoal or silica gel; by a carefully calibrated interferometer; or by a combustible gas indicator which will indicate the presence of all inflammable solvents present. Many of these methods of analyses, however, are far from satisfactory and considerable research work must be conducted before the analyst and industrial hygienist will feel confident of the results.

The recognition of industrial poisoning from the inhalation of volatile solvents is generally quite difficult. Acute and fatal poisonings do occur, but usually under circumstances that disclose the responsible agent.

The detection of volatile solvents in the body after death from an acute poisoning is possible for all substances having a boiling point below that of water by the micro methods of Gettler[(10)] and others. This method depends on condensation of the material in tubes immersed in freezing mixtures. In the living, or in those who have lived a few days before death from poisoning, these small amounts cannot be detected. Examination of the urine is revealing in some cases, and in others, examination of the blood tells the story of cumulative exposures. Nothing much is known regarding the detection of halogenated hydrocarbons, but with brominated compounds, there will be some bromine in the urine, and it is possible with chlorinated hydrocarbons, that organic chlorides may prove to be indicative of absorption.

Industrial poisoning, however, is characteristically chronic in form. The worker's health is gradually impaired by repeated small inhalations of the solvent material, and evidence of toxemia may not arise for several

(10) Gettler, A.O. and Siegel, Henry, Isolation from Human Tissues of Easily Volatile Organic Liquids and Their Identification, Archives of Pathology, 19, 208, (February, 1935).

years. Although solvents do not accumulate in the body, as does lead for example, there does occur an accumulation of effects from repeated daily inhalations. Seldom do these exert their influence on a single organ. Changes usually are found in the blood, kidneys, liver, heart, nervous system, and other organs.

The clinical picture and symptomatology may be similar for many solvents and a diagnosis frequently must depend on a correlation with the chemical analysis of the air breathed and evidence revealed by the examination of the blood and the urine.

The prevention of poisoning by inhalation is dependent entirely upon the measures employed against the diffusion of vapors into the plant atmosphere. There is no single measure of control which is applicable to all operations. A combination of measures usually must be employed to insure success. These include the substitution of harmless or less harmful solvents for harmful ones; the segregation of vapor-producing operations; enclosure of processes which confines the vapors; mechanical methods including local exhausts applied either above or below the processes according as the vapors to be entrapped and removed are lighter or heavier than air and increased general ventilation to insure rapid changes of air; personal protective devices; instruction of workers regarding the hazard; and competent medical supervision.

Personal protective devices frequently offer inadequate protection. Respirators should be used only in an emergency or when the exposure is intermittent, and should be of such a type that the worker breathes air from an uncontaminated source. Skin absorption can best be prevented by cleanliness of body and clothing. The absorption of vapors through the intact skin, especially if spilled or absorbed in the clothing, must be borne in mind. This is particularly true of the fat soluble solvents.

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Classification of Industrial Solvents[11]

Chlorinated Compounds

Ethylene Dichloride
  (Dichlorethane)
Ethylene Chlorhydrine
  (Glycol chlorhydrine)
Monochlorhydrine
Dichlorhydrine
Dichlorethylene
Trichlorethylene
  ("Westrosol")
Propylene Dichloride
Epichlorhydrine
Methylene Dichloride
  (Dichlormethane)
  ("Solasthin")
Chloroform
Tetrachlorethane
  (Acetylene Tetrachloride)
  ("Westron")
Pentachlorethane
  ("Pentaline")
Perchlorethylene

Carbon Tetrachloride
  ("Asordin")
  ("Benzinoform")
  ("Phoenipine")
  ("Spectral")
  ("Tetra")
  ("Tetracol")
  ("Tetraform")
  ("Katarine")
Monochlorbenzene
Dichlorethyl ether
Amyl chloride
Amylene di-chloride
Ethylene Dichloride-Carbon Tetrachloride Mixture
  ("Chlorasol")
Tetrachlorethylene

(11) For industrial uses of solvents, see Durrans, T.H.: Solvents, VanNostrand, New York, 1933.

Hydrocarbons

Aromatic

Benzene
(Benzol)
Toluene
(Toluol)
Xylene
(Xylol)

Coal-Tar Solvent Naphtha

(Mixtures of aromatic hydrocarbons with small quantities of naphthene paraffin hydrocarbons)
Light Grade B.R. 110°-160°C.
Heavy Grade B.R. 160°-190°C.
("Solvene")
Cymene
Dipentene
Turpentine
Rosin spirit
Cyclohexene

Petroleum Hydrocarbons

Petroleum Ether
Petroleum Spirit
(Ligroin)
Varnish makers and painters naphtha
White Spirit or mineral spirit
Lacquer Petroleum

Oxidized Petroleum Hydrocarbons

(Result of passing the vapors of petroleum hydrocarbons and air over various catalysts at high temperatures)

Hydrocarbon Derivative

Carbon disulphide

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Alcohols

Methyl Alcohol
(Methanol)
Etnyl Alcohol
(Ethanol)
Propyl Alcohol
(Propanol)
Isoproyl Alcohol
(Isopropanol)
("Persprit")
("Petrohol")
("Anantine")
Normal Butyl Alcohol
(Normal Butanol)
Iso-butyl Alcohol
(Isopropyl carbinol)
Secondary Butyl Alcohol
(Methyl Ethyl carbinol)

N-Hexyl Alcohol
(Normal Hexanol)
Amyl Alcohol
(Mixture of two of the eight isomeric amyl alcohols)
2 - Ethyl butyl alcohol
Octyl alcohol
(2 - ethyl hexanol)
Benzyl alcohol
Diacetone alcohol
Fusel oil (refined)
(Blend of higher alcohols of the amyl series, containing a small amount of the lower alcohols derived from genuine crude fusel oil).

Alcohol-Ethers

Ethylene Glycol Monomethyl ether
(Methyl Cellosolve
Ethylene Glycol Monoethyl Ether
(Methyl glycol)
("Cellosolve")
Ethylene Glycol Monobutyl ether
(Butyl cellosolve)
Diethylene Glycol Monomethyl ether
("Methyl Carbitol")

Diethylene Glycol Monoethyl Ether
("Carbitol")
Diethylene Glycol Monobutyl Ether
("Butyl Carbitol")
Epiethylin
Methoxy Butyl Acetate
("Butoxyl")
Ethylene Glycol Mono-ethyl Mono-acetate
("Cellosolve Acetate")

Glycols

Ethylene Glycol
(Glycol)
Methyl Ethylene Glycol
(Propylene Glycol)
Diethylene Glycol
Triethylene Glycol
Butylene Glycol
Diethylene Glycol

Ethers and Oxides

Ethyl Ether
(Ether)
Isopropyl Ether
Butyl Ether (Normal)
Propylene Oxide
Diethylene Oxide
("Dioxan")
Dichlorethyl Ether
("Chlorex")

Esters

Methyl Acetate
Ethyl Acetate
Propyl Acetate
("Technical" amyl acetate)
Isopropyl Acetate
Butyl Acetate
Methyl Amyl Acetate
Octyl Acetate
(2-Ethyl Hexyl Acetate)
Ethyl Butyrate
Benzyl Formate
Benzyl Acetate
Ethyl Lactate
Iso-propyl Lactate
Butyl Lactate
Amyl Lactate
Ethyl Butyl Acetate
Methyl Cellosolve Acetate
Amyl Acetate
Secondary Hexyl Acetate
Ethyl Formate
Carbitol Acetate
(Diethylene Glycol Mono-ethyl Ether Acetate)
Amyl Formate
Ethyl Propionate
Butyl Propionate
Amyl Propionate
Butyl Glycollate
Ethyl Benzoate
Methyl Benzoate
Di-ethyl Carbonate
Ethyl Butyl Carbonate
Dibutyl Phthalate

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Ketones

Acetone
(Dimethyl Ketone)
Methyl Acetone
Methyl N-Amyl Ketone
Methyl Isobutyl Ketone
(Hexone)
Methyl Ethyl Ketone
(Butyrone)

Di-ethyl Ketone
(Amyl Ketone)
Methyl N-propyl Ketone
(Pentanone)
Other higher ketones

Cyclohexane Derivatives

Cyclohexanol
("Hexalin")
("Anol")
Cyclohexanyl Acetate
Methylcyclohexanol
("Sextol")
("Methyl Anol")

Methylcyclohexanyl Acetate
("Sextate")
Cyclohexanone
("Sextone")
Methylcyclohexanone

Furfurals

Furfural
Furfuryl alcohol
Furfuryl acetate

Tetrahydro furfuryl alcohol
(Other furfural derivatives of less importance)

Plasticising Solvents

Diacetin
Triacetin
etc.

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