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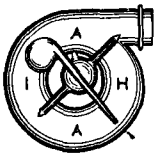

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Cutting and Grinding Fluids and Their Effects on the Skin

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Although improvements in formulations of cutting and grinding fluids have been made, occupational dermatitis can still be a problem. Oil acne and folliculitis are the most common cutaneous problems of those who work with insoluble oils. Bacteria in lubricating coolants may contribute to breakdown of the coolant but are unrelated to outbreaks of folliculitis. The chief problem which results from exposure to soluble oils and synthetic coolants is eczematous contact dermatitis, a disease of multiple causation. These two important skin diseases as well as several minor ones associated with exposure to lubricating coolants can be prevented by measures designed to minimize contact and to improve personal hygiene.

History

CUTTING FLUIDS have run full cycle in their development—from water, to oil, and back to water-base coolants. An American engineer, Frederick W. Taylor, the father of cutting fluid research, discovered in 1883 that a heavy stream of water directed at the cutting edge of the tool would permit an increase in cutting speed.[1] Carbonate of soda was added to prevent the obvious problem of rusting. The next development was the use of fatty oils, such as lard, which lubricated well and prevented rust but did not cool well and had a tendency to become rancid. The precursor of emulsifiable cutting oils—a cutting paste—was made by mixing soap with mineral or coal tar oils and required hot water for dilution. The oil-in-water emulsions combined the cooling action of water and the lubricating and rust-preventing properties of oil. These early cutting and screwing compounds,[2] as the British called them, were crude preparations when compared with today's transparent cutting oils, the perfumed and pastel tinted emulsifiable oils, and the new water-base synthetic or chemical coolants. But even with the sophistication of modern formulations and efforts by manufacturers to reduce the dermatitis potential, dermatitis from cutting and grinding fluids can still be a problem.

Scope of the Problem and Future Trends

During the heightened industrial activity of World War II, cutting oils were blamed for much of the industrial skin disease in the United States, and acquired a bad reputation. Actually, they caused only 3.1% of the cases of industrial skin diseases reported by seven states to the U. S. Public Health Service between 1938 and 1943.[3]

Direct comparisons cannot be made among the occupational disease reports of the various states, because of variations in workmen's compensation laws, reliability of reporting, classification systems, and influences of climate and occupational exposures, but the compilation in Table I does indicate that dermatitis from cutting fluids is still a problem.

A prospective study in 1956 by the Industrial Hygiene Foundation showed that 27% of cases of industrial dermatitis seen in dispensaries of a variety of manufacturing in-

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TABLE I
Reported Cases of Occupational Skin Disease

State	Year	Reported Cases of Cutting Fluid Dermatitis	Total Reported Cases of Occupational Skin Diseases	Percentage
California[4]	1964	139	14,234*	1%
Connecticut[5]	1965	54**	262	20%
Illinois[6]	1964	38**	184	20%

*Includes 4,166 cases of poison oak dermatitis.
**Includes greases.

TABLE II
Composition of Insoluble Oil
(Straight Cutting Oil)

1. Mineral oil base (paraffinic or naphthenic), 60-100%. If 100%—straight mineral oil; otherwise a blend with fatty oils such as lard oil and sperm oil.
2. Bactericides, sometimes added to prevent rancidity.*
3. Extreme pressure (EP) additives.*
   a. Sulfur, free or combined with base oil or fats, 1-3%.*
   b. Chlorinated fats and paraffin oils, 1-3%.
   c. Sulfochlorinated fats, 1-3%.

*Additives, not present in all formulations.

TABLE III
"Soluble" Oil (Emulsifiable Oil, "Soup," "Suds")

Depending on intended use, concentrate is diluted 1:5 to 1:50 by adding to water, pH 8-9.
1. Mineral oil, 60-85% of concentrate.
2. Emulsifiers, e.g., petroleum sulfonates, soaps.
3. Bactericide (germicide, antiseptic, disinfectant), e.g. cresylic acid, orthophenylphenol, tris (hydroxymethyl) nitromethane. 0.1-2% of use concentration. Recharged as needed.*
4. Corrosion (rust) inhibitors, e.g., hydroxyl amines.*
5. Extreme pressure additives.*
6. Anti-foaming agents, e.g., silicones.*
7. Dyes, e.g., fluorescein.*
8. Water-used in pre-formed emulsions and also for dissolving water soluble ingredients.
9. Water conditioners, e.g., polyphosphates, trisodium phosphate, borax, sodium carbonate (soda ash). Added to water before formation of emulsion.*

*Additives, not present in all formulations.

TABLE IV
Synthetic (Chemical) Coolant

An aqueous solution—contains little or no emulsified oil. Concentrate is diluted 1:10 to 1:200 depending on intended use. pH 8-10.
1. Corrosion inhibitors, e.g., hydroxyl amines, inorganic and organic nitrites, nitrates for nitrite stabilization.
2. Soaps and wetting agents.*
3. Blending agents, e.g., glycols.*
4. Bactericides.*
5. Water conditioners, e.g., phosphates and borates.*
6. Anti-foaming agents, e.g., silicones.*
7. Dyes.*

*Additives, not present in all formulations.

dustries were due to cutting oils.[7] However, a distinction should be made between skin diseases seen in a plant dispensary and those that cause lost time and are compensated.

Soluble oils and synthetics now comprise about two-thirds of the market, but there has been renewed interest in insoluble oils since the development of transparent and multipurpose oils. In 1961, over 14 million gallons of insoluble and soluble oils were used in the U. S. About two-thirds of this oil was used by the metal working industry; chemical processing, textile manufacturing, and other industries accounted for the remainder.[8] The number of machine tool operators, machinists, layout men, instrument makers, tool and die makers, and setup men in the U. S. in 1965 was estimated at slightly over one million.[9]

The effect of automation on employment in the machine tool and metalworking industries in the next few years is expected to be offset by industrial expansion, so that the total number of machinists and workers in allied trades is not expected to decrease. Automation may influence formulation of cutting fluids by permitting a more irritating cutting fluid with better lubricating or cooling qualities to be used. Changes in metal cutting and forming, such as chipless machining, machining of very tough metals which are temporarily softened by induction heating, and ultra-high speed machining, will undoubtedly require different formulations.[10]

Types

Consideration of the composition of cutting and grinding fluids is helpful in understanding the kinds of skin disease produced. The three principal types are oils, oil-in-water emulsions, and aqueous solutions.[11] Their ingredients are listed in Tables II, III and IV.

Action on Metal

In metal cutting, a hardened tool edge removes chips by different mechanical means such as planing, turning, drill and milling. The chip is for deformation of the metal imm of the tool edge. A large am generated in this shearing pro and tool may weld together sipated. The friction of the c the tool and of the tool slidi surface also contributes to Grinding may be thought of a of cutting in which the meta a grinding wheel, containing sive grains which act as mini

Thus, cutting fluids hav functions: (1) to cool, whic tortion of the workpiece an life, and (2) to lubricate, w frictional heat formation. S tions are to prevent rust an metal chips and swarf.

Action on Skin

Oil Acne and Folliculitis. the most common cutaneo those who work with insolub ment of as many as 80% o has been reported,[17] but fort dition is seldom disabling. hygiene (infrequent skin cle longed wearing of soiled clot licular openings in hairy con come blocked by oil, produ (blackheads) and papular l with varying degrees of infl licular occlusion is believed mechanical, similar to bloc carbon black, and various sites are the backs of the har surfaces of the forearms and and back of the neck. Infla the blocked follicles may be by the oil, rupture into the ti sebum, or secondary infecti teria (staphylococci). The terial folliculitis occasionall furunculosis (oil boils).

Chloracne.[14] In the pas were chlorinated naphthale nated diphenyl oxides, whic extreme pressure additives. acne-like lesions on exposed

such as planing, turning, drilling, broaching, and milling. The chip is formed by plastic deformation of the metal immediately ahead of the tool edge. A large amount of heat is generated in this shearing process, and metal and tool may weld together if it is not dissipated. The friction of the chip sliding past the tool and of the tool sliding over the cut surface also contributes to the heat load. Grinding may be thought of as a special form of cutting in which the metal is removed by a grinding wheel, containing countless abrasive grains which act as miniature cutters.[12]

Thus, cutting fluids have two primary functions: (1) to cool, which prevents distortion of the workpiece and prolongs tool life, and (2) to lubricate, which minimizes frictional heat formation. Secondary functions are to prevent rust and to flush away metal chips and swarf.

Action on Skin

Oil Acne and Folliculitis.[13-16] These are the most common cutaneous problems of those who work with insoluble oils. Involvement of as many as 80% of those exposed has been reported,[17] but fortunately this condition is seldom disabling. Poor personal hygiene (infrequent skin cleansing and prolonged wearing of soiled clothing) causes follicular openings in hairy contact areas to become blocked by oil, producing comedones (blackheads) and papular lesions (pimples) with varying degrees of inflammation. Follicular occlusion is believed to be primarily mechanical, similar to blockage by grease, carbon black, and various dusts. Common sites are the backs of the hands, the extensor surfaces of the forearms and thighs, temples, and back of the neck. Inflammation around the blocked follicles may be due to irritation by the oil, rupture into the tissues of retained sebum, or secondary infection by skin bacteria (staphylococci). The secondary bacterial folliculitis occasionally progresses to furunculosis (oil boils).

Chloracne.[14] In the past, chloracnegens were chlorinated naphthalenes and chlorinated diphenyl oxides, which were used as extreme pressure additives. In addition to acne-like lesions on exposed skin, liver damage also occurred. Chloracne from cutting oils has not been observed in recent years.

Keratoses and Squamous Cell Skin Cancer.[17-20] These are quite rare in the United States but have occurred in Europe from contact with shale oil.

Melanosis.[21,22] Peri-follicular hyperpigmentation may result from direct irritation of oil, or may be secondary to folliculitis. Sunlight may also play a role. This rare condition is seen most often in those of Mediterranean origin.

Mechanical Injuries from Chips and Swarf.[15,23] These injuries are uncommon, except when wipe rags or waste contain sharp particles or when machined parts have sharp edges. They are sometimes complicated by secondary infection.

Irritant Contact Dermatitis.[21,23,24,25] The chief problem which results from exposure to soluble cutting oils and synthetic coolants is eczematous contact dermatitis, which is manifested in the acute stage by redness, swelling, and water blisters, and in the subacute and chronic stages by varying degrees of redness, scaling, cracking, and thickening of the skin. The subacute and chronic types are usually attributed to repeated exposures to emulsions with soap-like action and/or to alkaline aqueous solutions, both of which can act as low-grade irritants. With some of the milder products it would probably be more accurate to presuppose previous damage to the skin, such as that caused by low humidity in winter, harsh cleansers, or solvents. Often the dermatitis will subside with the onset of warm weather, without changing any of the other conditions.

The appearance of the dermatitis and response to preventive measures are similar to those of eczema of housewives and of others whose hands are in water much of the time. The common mechanism may be damage to the cutaneous barrier layer (stratum corneum), and repeated cycles of wetting and evaporative drying are probably more harmful than prolonged immersion.[26] The roles of soap and pH per se in housewives' eczema are still controversial.[27-30]

Less common causes of irritant contact dermatitis are excess bactericides, some ex-

treme pressure additives, rancid fatty oils, low boiling distillates similar to light machine oil and kerosene, acroleates from overheated oil, amines, and chlorinated solvents.

Allergic Contact Dermatitis.[14,21,31] This is difficult to distinguish clinically from irritant contact dermatitis, but is rare by comparison. Sensitizers have included bactericides and breakdown products, corrosion inhibitors, nickel salts from machined metal, and chromates. Allergic reactions to mineral oil have been reported, but are very rare.

Bacterial and Other Contaminants

The belief that bacteria present in cutting fluids is an important cause of skin disease has no basis in fact. Certain areas of skin are periodically contaminated by coagulase positive (pathogenic) staphylococci, and although they may survive for long periods in about 20% of the adult population, they do not usually multiply or cause infection on undamaged normal skin. When the skin is damaged or when drainage systems such as follicular canals are blocked, however, these areas of lowered resistance are rapidly colonized by pathogenic staphylococci.[32] The most common sources of the staphylococci that contaminate the skin are the nostrils of persistent (20% of the community) and transient (50-60%) carriers.[33]

Insoluble cutting oils are relatively free of bacteria.[34] Fresh insoluble oil is sterile, but the presence of water will allow survival and limited growth of certain bacteria, usually gram-negative.[35] During use, oil may become mixed with condensation water, as well as with emulsion-type cutting fluids and synthetic coolants. The U. S. Public Health Service has analyzed samples of insoluble cutting oils used by workers who had oil folliculitis and found no significant number of pyogenic organisms.[14]

Emulsifiable oil and synthetic coolants are sterile when manufactured. After being mixed with water and used, a variety of bacterial and mycotic organisms can be isolated —some coming from human contamination, and some from water and air. The predominating bacteria are Pseudomonads, frequently in association with *Achromobacter* and *Vibrio* species, *Bacillus subtilis,* and *Proteus vulgaris.* Coliform bacteria and enterococci, indicative of fecal pollution, are occasionally found, and rarely pathogenic *Staphylococcus, Salmonella,* and *Shigella* species.[36,37] Thus, soluble oil emulsions, which frequently contain bacteria, are not associated with bacterial infections of the skin. Ironically, the insoluble oils, which are relatively free of bacteria, are the cutting fluids associated with folliculitis.

The presence of certain bacterial species in emulsion-type lubricating coolants has been associated with deterioration of the emulsion, with rusting, and with odor production. Bactericides are added primarily to prevent these changes and not for prevention of infections. Emulsions can deteriorate for other reasons, *e.g.,* hard water, and an excess of bactericide may be needlessly added. Bacteriologic examination of a cutting fluid may be of value in ascertaining the cause for lubricating coolant breakdown,[38] but it is unlikely to be helpful in finding the cause of an outbreak of skin disease.

It is not surprising that a variety of contaminants may get into lubricating coolants and sumps; these include spit, urine, feces, garbage, floor sweepings, floor cleaning detergents, cigarette butts, dead rats, live frogs, lubricating and hydraulic oils and their additives, and nickel salts from machined nickel. Of these only nickel salts and floor cleaning detergents have been implicated as causes of dermatitis. The cleanliness of the lubricating coolant system is a good index of environmental hygiene.

Prevention and Management

There are several categories of preventive measures. Environmental methods, such as splash guards on automatic screw machines and good housekeeping, are designed to prevent or reduce contamination of the machinist or his clothes. Protective clothing, such as aprons and sleeves, and protective ointments of both oil and water-repellent types are used when contact cannot be avoided. The last line of defense is to effectively remove the offending agent from the skin. Personal cleanliness is always feasible, even in the smalles hand cleaner stations can b machines, if handwashing mote. Waterless hand clean useful for removal of oil, b care must be taken to avoi The use of raw solvent for should be forbidden.

In managing an outbreak a cutting or grinding operat should be establishing the break. With irritants, this i ing a compatible clinical ap reputation of the suspected difficult to distinguish irrita by clinical appearance, patc ly necessary.

In oil folliculitis the wo more often, preferably wit soap. In primary irritant c from water-base lubricati worker should wash only wh use a mild white soap or so lukewarm water. With expo or drying agents, it is advisa emollient cream for applic washing. Regardless of the break of dermatitis from lub contact should be minimized giene should be improved.[15]

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feasible, even in the smallest shop. Waterless hand cleaner stations can be set up near the machines, if handwashing facilities are remote. Waterless hand cleaners are especially useful for removal of oil, but as with soap, care must be taken to avoid harsh cleansers. The use of raw solvent for cleaning the skin should be forbidden.

In managing an outbreak of skin disease in a cutting or grinding operation, the first step should be establishing the cause of the outbreak. With irritants, this is done by matching a compatible clinical appearance with the reputation of the suspected agent. Since it is difficult to distinguish irritation from allergy by clinical appearance, patch testing is usually necessary.

In oil folliculitis the worker should wash more often, preferably with a bacteriostatic soap. In primary irritant contact dermatitis from water-base lubricating coolants, the worker should wash only when necessary and use a mild white soap or soap substitute and lukewarm water. With exposures to defatting or drying agents, it is advisable to provide an emollient cream for application after hand washing. Regardless of the cause of an outbreak of dermatitis from lubricating coolants, contact should be minimized and personal hygiene should be improved.[15,39,40,41]

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