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METAL SURFACE TREATMENTS, CLEANING

Cleaning, the removal of unwanted matter, is the beginning of the treatment cycle for metal. The unwanted matter may be carbon smut, welding flux, ink, oxidation products, oil, fingerprints, or other material. Cleaners may be classified as solvent-based or aqueous. Within the aqueous class there are many subclasses, the most important of which are the alkaline cleaners. There are also a variety of ways to apply cleaners. As of the mid-1990s, solvent-based cleaner usage is declining.

1. Alkaline Cleaners

Alkaline cleaners are the most commonly used for metal surfaces. These are typically composed of a blend of alkaline salt builders, such as sodium phosphates, sodium silicates, sodium hydroxide, or sodium carbonate. In addition, they almost always contain detergents, ie, surfactants (qv), and, optionally, wetting agents, coupling agents, chelating agents (qv), and solubilizers. Alkaline cleaners are usually applied in the range of 38–93°C.

The composition of the builders in an alkaline cleaner is dependent on the metal substrate from which the soil is to be removed. For steel (qv) or stainless steel aggressive, ie, high pH, alkaline salts such as sodium or potassium hydroxide can be used as the main alkaline builder. For aluminum, zinc, brass, or tin plate, less aggressive (lower pH) builders such as sodium or potassium silicates, mono- and diphosphates, borates, and bicarbonates are used.

The mechanisms by which an alkaline cleaner removes the soil are saponification, emulsification, and dispersion. These mechanisms can operate independently or in combination. Saponification occurs when alkaline salts react with fatty components of the soil, forming a soluble soap compound.

Emulsification involves the joining of two mutually insoluble materials, such as petroleum oil and water. The surfactant, which usually has a hydrophilic or water-soluble end and a hydrophobic or oil-soluble end, holds the oil and water together in much the same manner that a fastener holds two pieces of material. Often, the emulsion which forms is unstable, subsequently breaking up and releasing the oil from the water. Break-up is actually preferred, because the oil then floats to the surface, whereas the surfactant is free to emulsify more oil.

Dispersion is the process of wetting the surface of the metal, thereby penetrating the oil film. Surfactants can reduce the surface tension and interfacial tension of the cleaning solution at the metal–liquid interface. As the cleaner undercuts and penetrates the oil, the cleaner breaks the oil into small droplets which then float to the surface.

2. Applications

Cleaners are typically applied either by immersion or by spray. Immersion or soak cleaning involves simply immersing a part or panel into a tank containing the cleaner and letting the metal sit for a period of 1–10 min. A

simple variation of immersion cleaning is to recirculate the cleaner so that fresh cleaner is continuously passing by the object to be cleaned. Other variations include electrocleaning, ultrasonic cleaning, and barrel cleaning. Variations of spray cleaning include steam cleaning and power washing. Additionally, solvent cleaners can be applied by vapor degreasing, and both solvent and aqueous cleaners can be applied by mechanical methods such as hand wiping or hand brushing the cleaner onto the soiled area. Because of high evaporation rates and toxic fumes, solvent cleaners are not usually applied by spray.

2.0.1. Immersion Cleaning

The simplest method for using an alkaline cleaner is by immersion. A part is placed on a hook or rack and immersed in the cleaner solution so that all of the part is below the liquid level. A typical concentration, temperature, and process time for an immersion cleaner would be ca 75 g/L at 77°C for 5 min. In addition to being the simplest method, immersion is also among the least expensive in terms of equipment. Only a vessel to contain the cleaning solution and a means of heating the solution are needed.

2.0.1.1. Electrocleaning. Electrocleaning is a specialized variation of immersion cleaning. Electrocleaners are very similar in composition to immersion cleaners, except that the surfactant levels are usually lower and less foaming. The cleaning action of the cleaner is assisted through the use of direct-current electricity. Electrodes are placed on two sides on the inside of the tank, and in most cases they carry a negative charge (making them the cathode). The part to be cleaned carries a positive charge (anode). The oxygen evolving at the part acts as a mechanical scrubber assisting in removal of the soil. The concentration and temperature are usually a little higher than for a straight immersion cleaner: 75–120 g/L at 77–99°C. The d-c current is supplied by a large rectifier, and the current density on the part varies from 27–160 mA/cm^2 (25–150 A/ft^2). Electrocleaning is usually preceded by an immersion or a spray cleaner to remove the bulk of the soil. The part is typically left in the electrocleaner for 1–3 min to produce an exceptionally clean surface.

2.0.1.2. Ultrasonic Cleaning. Ultrasonic cleaning is another variation of immersion cleaning. Waves of bubbles are generated in the cleaning solution through the use of sound waves. The sound waves are generated by electrically powered devices called transducers, which vibrate rapidly causing the sound waves and bubbles. This is called cavitation. The ultrasonic cleaning action literally vibrates or shakes dirt loose from narrow cracks and crevices. This is aided by the cleaning action of the detergents in solution.

The transducers are typically mounted on an outside wall of the cleaning tank, but may also be mounted on the inside of the tank below the solution level in a sealed container. Alkaline cleaning solutions are typically at the same concentration and temperature as for a normal immersion cleaner, but the time required to clean may be less because of the ultrasonic effect. Like electrocleaning, ultrasonic cleaning produces an extremely clean surface. The main drawback is the relatively high cost.

2.0.1.3. Barrel Cleaning. Barrel cleaning is a minor variation of immersion cleaning in which parts are placed in a six- or eight-sided barrel the sides of which are perforated, allowing the cleaning solution to enter the barrel. The barrel is immersed in the cleaner and rotated around the long axis by an electric motor. The parts inside tumble and rub against each other, thus aiding in the removal of the soil. Electrodes can also be inserted and hooked up to a rectifier to add electrocleaning assistance. The restriction of barrel cleaning is that it is generally used only for small parts such as fasteners, cabinet handles, and screwdriver shafts.

2.0.2. Spray Cleaning

The other principal method of application of cleaners is by spray. In spray cleaning, the cleaning solution is pumped out of a holding tank into a series of pipes (risers) which have other pipes called headers coming out from the risers. These headers have holes drilled into them and nozzles screwed into the holes. The pipes are configured in such a way that a part going by on a conveyor would be sprayed with cleaner from every conceivable angle. This configuration of pipes is housed in a steel hood which keeps the spray mist confined. The hood is generally over the holding tank so that the excess cleaner drains back into the holding tank. The

hood has a narrow slit at the top to permit conveyor parts racks to pass through and at least one exhaust stack to remove the steam. Spray pressures for commercial spray cleaner systems are usually in the range of 70–275 kPa (10–40 psi), concentrations are typically 4–30 g/L, and temperatures vary between 21–88°C. The main difference in composition from immersion cleaners is that spray cleaners contain low foaming surfactants.

2.0.2.1. Steam Cleaning. In steam cleaning, a machine generates high pressure steam and injects a cleaning solution at the nozzle where the steam is exiting. Cleaner concentration is varied by changing the concentration of the cleaner in the reservoir or the rate at which the cleaner feeds into the exiting steam.

2.0.2.2. Power Washing. Power washing is similar to steam cleaning, except that the cleaner is injected into a high pressure (6.9–35 MPa (1000–5000 psi)) water blast in power washing. The water can be cold, warm, or hot, because the power washer is fed from a water tap.

2.0.3. Solvent Cleaning

Solvent cleaning employs the natural solubilizing properties of various nonaqueous solvents or blends of solvents. Either 100% solvents or aqueous emulsions of solvents can be used. Application is typically by immersion, hand application, or via a vapor degreaser machine, where the solvents are continuously vaporized and condensed. Solvent cleaners are rarely applied by spray because of excessive loss by evaporation and the subsequent environmental considerations. Solvent cleaning also requires a lot of ventilation and an adequate exhaust system. Whereas solvent cleaning is effective, its cost is usually higher than other cleaning methods.

3. Economic Aspects

In 1990 the value of the metal cleaner industry was $\$390 \times 10^6$ (1). An estimated figure for 1994 was on the order of $\$450 \times 10^6$. Usage of solvent-based cleaners is decreasing; usage of aqueous-based alkaline, acid, or neutral cleaners is increasing. There are over 60 suppliers of metal cleaners in the United States. One of the leading suppliers of aqueous-based cleaners is the Parker Amchem Division of Henkel Corp. Aqueous cleaners, aqueous slurry cleaners, and dry blend cleaners are available worldwide in acid, alkaline, and neutral media. Common cleaners found have the trademarks Parco, P3, Alumiprep, Ridoline, Metalprep, and Prep-N-Cote, to name just a few.

Most cleaners are available for $<\$2.20$/kg either as a dry blend or as a liquid. Liquid cleaners are usually less expensive than the dry blend type. A trend toward liquid cleaners is evident as of this writing (ca 1994) because of convenience features such as automatic additions of the cleaner by chemical feed pump. Safety features such as minimized heat generation upon blending with water to make the desired concentration are also important.

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