Even the pooled expertise of cleaning system specialists can be challenged by the multitude of variables inherent in each installation.

Design Criteria and Equipment Specifications for Metals Spray-Washing

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Selecting a safe, productive, economical, and environmentally-compliant approach for present and future cleaning needs is no simple task — made even more difficult by the wide variety of cleaning systems available. Informed decisions require a thorough understanding of the various principles of industrial cleaning processes.

Just as a chain is no stronger than its weakest link, a cleaning system's efficiency will be no better than its weakest element. Therefore, great care must be exercised to anticipate and eliminate every conceivable problem during the all-important design stage.

Input should be solicited from a variety of specialists including the product designer, manufacturing manager, finishing engineer, quality control manager, as well as chemical and equipment supplier(s). System design must be a team effort, as each individual's expertise will directly impact the system's overall viability.

In order to properly develop complete design criteria and equipment specifications, an in-house audit must be undertaken to ascertain crucial information, the most fundamental being characteristics of both the workload and soil to be cleaned, and degree of cleanliness required.

Workload Characteristics

Characterizing the type of material to be cleaned — cold-rolled steel, aluminum, stainless steel, brass, castings, etc. — should be among the first steps in establishing equipment design parameters.

It is important to recognize that the differences in metal alloys and surfaces profoundly affect the material's ability to be cleaned. The cause-and-effect relationship is most dramatically demonstrated with regard to steel. Generally, that of higher carbon composition tends to be easier to phosphate, but it can also cause cleaning problems due to a greater amount of carbon being leached out onto the metal's surface.[1]

The reaction between the phosphate solution and the steel actually converts a layer of steel into a layer of chemically-bound phosphate crystals. Physically, paint takes a stronger grip on the rugged layer of crystals than on the comparatively smooth layer of untreated steel.[2]

The part's dimensions, including hanging height and width across conveyor, must be applied to properly size the cleaning machine's upper housing height and width as well as system work openings. The part's shape might prompt concern for cleaner/water entrapment as well as rinsability and dragout potentials.

Part weight and gauge of metal, in conjunction with desired pounds processed per hour and productivity per shift, determine the BTUs required for each heated stage of the washer, plus any hot air blow-off requirements. Total hourly load is derived by multiplying the weight of each piece by the number of pieces processed per hour.

Contaminant Characteristics

Soil can be broadly defined as any substance on the surface that will hinder any cleaning/finishing process being performed. Generally speaking, types to be removed can be divided into two categories:

Organic

a. Saponifiable — animal and vegetable oils.
b. Unsaponifiable — mineral oils and waxes.
c. Miscellaneous — contaminants either formed in situ (metallic soaps formed in the buffing operation), or inhibitors from certain acid pickles redepositing on the metal.

Inorganic

a. Scale and smut oxide, and metallic residues.
b. Polishing compounds — abrasive, grinding, and polishing residues or grits.
c. Miscellaneous — shop dust and soldering flux.

Other soils encountered include paints, cleaning residues such as water-in-oil emulsions, fingerprints, inorganic coatings such as phosphates and chromates, and rust preventatives.[3]

The type and quality of various soils, and length of time that they remain (age) in contact with the substrate, all contribute to difficulty of thorough removal.

Degree of Cleanliness

The common denominator in all surface preparation is thorough surface cleaning. Pretreatment may be applied to the clean surface to enhance adhesion and, in the case of metals, provide a barrier against the spread of corrosion. Whereas, the purpose of basic surface preparation is to achieve a physically clean surface.[4]

The value of chemical pretreatment, particularly for metals, lies in the thin, tightly adherent, ideally roughened, paint-receptive film formed on the metal surface. Not only does such a film provide an excellent base for coatings adhesion, it also resists the spread of corrosion beneath it, so that damage to the substrate from a break in the film is not likely to progress beyond the immediate area of that break.[5]

Among the most common failures attributable to improper cleaning are poor adhesion of various chemical coatings, poor corrosion resistance, blistering and pitting, failure to pass specifications/standards tests, and stained and/or irregular coatings.[6]

The degree of cleanliness required — as considered practical or necessary — depends on the metal-finishing process and established standards and specifications for a given product. What type of coating system is to be applied? What is the nature of the service environment? What is the cost factor to be expected in relation to the improved durability from more thorough surface preparation?[7]

Incomplete removal of oils and smuts will provide "carrying agents" on the metal surface, causing excessive dragout when a cleaner begins to clean. The cleaner becomes absorbed in the soil so thoroughly that it will not rinse off.

When this happens, the chemicals in the cleaner can be carried all the way into the phosphate tank, where they will not only cause a loose and coarse coating, but also lower the free acidity (phosphate solution) to the point where it does not attack the metal sufficiently to initiate the necessary phosphate conversion reaction.[8]

Seeking Solutions

Once the workload and applicable contaminants have been adequately analyzed, "the team" can begin to explore the potentials of various cleaning and rinsing agents, as well as process stages and other system specifics.

Selecting the proper cleaning/phosphating system depends on the soil(s) and workload to be processed. While alkalinity is necessary for effective cleaning, the amount required depends on the type and amount of soils to be removed. The amount of wetting or emulsifying agents also depends upon the soil load.

It is of the utmost importance to maintain the proper balance of alkalinity, water conditioning, and wetting agents which are to remove soils under conditions of dwell time, solution temperature, and spray pressure and impingement.

Alkaline cleaners owe their cleaning ability to the displacement of soil by surface-active materials (surfactants/wetting agents) and alkaline builders to create emulsions that are easily rinsed away. The correct blend of builders, surfactants, and water-conditioning agents provides the aqueous cleaner you need.[9]

Water In the Mix

Water is a most critical component in an aqueous cleaning system. Its degree of hardness or softness controls the ultimate performance level of the cleaning chemicals used. Water samples should be sent to an independent testing laboratory for analysis prior to establishing any particular cleaning chemicals and/or schedules.

The efficiency of any cleaner is directly proportional to how it performs when mixed with water; the cleaner must do three important things: (1) "tie up" or inactivate hard water ions for better rinsing and cleaning; (2) lower the water's surface tension, making it wetter; and (3) ionize or dissociate when added to water.[10]

After a part has been cleaned, partially contaminated cleaner still covering it must be removed. Where quality standards are high, the residue must be removed by a plain and/or deionized (DI) water rinse. The detrimental effect of this residue varies with the application. Salts present in the water remain in the residue unless special water is used. Thus, rinsing and water quality are closely related.[11]

Process Stages

The number of process stages required depends upon the established cleaning schedule, which in turn depends on the type and quantity of soil involved and degree of cleanliness required. A simple cleaning system processing fairly clean steel might only require a two-stage machine: Stage 1 — clean; Stage 2 — fresh water rinse.

On the other hand, with heavy or difficult-to-remove soil conditions, or when chemical coatings are to be applied, additional stages may be of paramount importance. A clean/phosphate machine processing mildly to heavily soil-laden steel to which a powder coating is to be applied might require a five- to seven-stage washer:

Stage 1 — clean
Stage 2 — fresh water rinse
Stage 3 — phosphate
Stage 4 — fresh water rinse
Stage 5 — non-chrome or DI water rinse

Stage 1 — pre-clean
Stage 2 — clean
Stage 3 — fresh water rinse
Stage 4 — fresh water rinse
Stage 5 — phosphate
Stage 6 — fresh water rinse
Stage 7 — DI water rinse

The length of each stage must be sufficient to provide the proper dwell time per stage. If it is determined that proper cleaning of a metal surface requires a cleaning solution to be in contact (spray impingement) with the part(s) for a minimum of 90 seconds, stage length at a line speed of 10 feet per minute (FPM) would have to be at least 15 feet.

Drain stages should be kept as short as possible while minimizing solution dragout, which can cause dilution and/or contamination of the next stage. Longer drain stages often allow drying of the ware in process, which can cause degradation of cleaning quality and/or flash rusting. When long drain stages are unavoidable, wetting or misting nozzles should be incorporated.

Qualified chemical suppliers can assist in establishing the ideal cleaning schedule, including dwell time and temperature of each stage, based on chemicals recommended.

Equipment Construction, Dimensions

Material of construction is a most important design consideration, as the system's viability and life are directly dependent upon chemicals used, solution concentration, water condition, and chemical reactions with various materials to be used for solution tanks, upper housing, piping, heater, nozzles, and baffles. These include mild steel, stainless steel (304, 316, 321, or 347), composite materials, high-temp polyvinylchloride (HPVC), polypropylene, and polyvinyldichloride (PVDC).

Chemical suppliers typically offer guidance to ensure that the materials of construction selected for various equipment components will be compatible with solutions used.

Width of the upper housing as a rule is determined by allowing 12 inches from the work to the center line of the vertical risers holding nozzles, and an additional 6 inches from center line of risers to side of housing (3 feet plus width of product).[12]

For the overhead monorail conveyor, distance from top of work to top of housing varies depending on the conveyor's construction and the means by which work attaches to it; however, 24 inches should generally be considered the optimum distance for housing height.

Allow approximately 12 inches from bottom of work to center line of the bottom horizontal risers, if any, and 6 inches from center line of bottom risers to tank top (3 feet, 6 inches plus product height).[13]

Conveyor elevation (e.g., 30°, 45°, or 60°) along with part hanging height and length of travel dimensions dictate conveyor hanging centers — the consistent spacing between loads, measured from each part's bottom centerpoint. Hanging centers and production requirements dictate conveyor line speed — minimum or maximum FPM.

Risers, Spray, Pumps, Heat

Piping risers should be of sufficient size to deliver the required volume of solution to spray risers at required nozzle pressure.[14]

In general, it's necessary to have a minimum of 3 gallons of solution sprayed per minute for each square foot of spray zone area, as determined by multiplying the perimeter of the interior silhouette (baffle) opening by the length of the spray zone (distance from first to last riser).

For riser spacing, conveyor speed and the shape of work being processed are to be considered; however, where no unusual conditions exist, spacing should be uniform, using 9-inch spacing at 3 FPM and 20-inch spacing at 30 FPM. Intermediate spacing may be determined by interpolation.[15]

No hard, fast rule can be made as to how close together spray nozzles should be spaced on risers to ensure complete and continuous coverage.[16] In most cases, 9 to 12 inches is satisfactory. Influential variables include spray pattern, angle, and impingement (psi).

Vertical submersible pumps are typically recommended, as they are the most maintenance-free. Pump capacity must be at least equal to, if not 10 to 15 percent greater than, the flow rate of the total number of nozzles per stage, times the nozzle pressure required at the most remote nozzle.

Requirements for solution heating, which reduces viscosity of various surface oils, may be calculated as: BTU per hour = gallons per minute x 60 (minutes per hour) x 8.3 pounds per gallon x 1 BTU per pound x ΔT°F, where ΔT is the temperature difference between solution pumped from and solution returning to the tank after spraying.

Solutions may be heated with steam plate type coils, steam pipe coils, steam shell and tube heat exchanger, steam plate and frame heat exchanger, gas- or oil-fired tubes, electric and direct gas fired.[17]

Tanks, Filters, Blow-Off, Valves and Gauges

Tank capacity should be two-and-a-half to three times the gallons per minute (gpm) of the pump at each stage. Tanks of less than 500 gallons are not recommended, except in small machines where special circumstances dictate tank size.

Keeping each tank stage especially clean of floating oils and soils is partially achieved by skimming troughs and overflows. These must be located ahead of the removable tank screens.

Each solution tank should have double-removal filter screens located near the pump inlet. A properly designed screen system with a removable dam located at tank bottom keeps solids in the tanks from plugging spray nozzles.

Ancillary support equipment includes various valves: pressure-regulating, fill, drain, and shut-off. Also to be incorporated in the design criteria — and most important to the washer's overall operation — are liquid-filled pressure gauges and thermometers to monitor solution temperature.

Hot air blow-off is desirable to remove all moisture and entrapped water as soon as possible after ware exits the last stage of a parts washer. A properly designed blow-off station allows for substantial energy savings, as the dry-off oven can be operated at greatly reduced temperatures once this high-volume air blow-off has dislodged excess moisture and entrapped water.

All Things Considered

Design criteria and equipment specifications for precision cleaning systems in today's environmentally-sensitive society and increasingly quality-conscious industries demand a greater level of attention to the multitude of variables unique to each installation.

As stated earlier, efficiency and viability will be no better than a cleaning system's weakest component. While the intent of this article has been to highlight some of the more important considerations, it must be understood that a whole host of others must be taken into account to derive the very best cleaning system for your particular needs.

The bottom line? Leave no stone unturned and take nothing for granted. Assemble your best cleaning system team, and with due diligence assess all options, costs, and concerns associated with each proposal. PC

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