tates a costly mechanical agitation mechanism and use of a substantial amount of power. The action of the agitator sometimes causes a problem of excessive foaming of the material. This has been attributed to the effect of the wetting agents which are compounded with the chemicals in amounts satisfactory for normal dilute usage. When these compounds are mixed for concentrate use of four, six or even 10 times the dilute strength, the amount of wetting agent present is reported to cause the mixture to foam when agitated and during refilling operations.

Clogging of filling screens, line filters, and nozzles is another problem which has been amplified by the change to higher chemical concentrations used in air sprayers. Since discharge volume is reduced when using concentrates, the nozzle orifice sizes must be reduced to ensure proper break-up and spray patterns. To prevent excessive clogging of these smaller orifices, finer mesh filters and screen must be employed which, consequently, have greater tendency to clog, especially with materials difficult to keep in suspension in the quantities used in concentrate spraying.

While these examples of difficulties in handling chemical concentrates have been referred to as equipment manufacturers' problems, they are, of course, also limitations which the chemical manufacturers must recognize in practical use of their products. However effective the chemicals may be as toxicants, their value to the user is determined by his ability to place them at the proper location, in the proper quantity, and at the proper time to take advantage of their toxic effect.

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PROBLEMS AND MATERIALS OF SPRAYER CONSTRUCTION

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New types of pesticides and fertilizers have intensified the problems of the designer and manufacturer of sprayers. Chemical accumulation, corrosion, and abrasion are the trouble areas

SPRAY APPLICATION OF AGRICULTURAL pesticides has become a widely diversified practice involving several types of equipment. Some types of sprayers are produced for a specific purpose while others are used for numerous pest control requirements and many of the recent or present problems in sprayer design are a result of the diversified requirements and the complex situations occurring in spraying practices.

The versatility required in the modern sprayer can be best illustrated by a brief review of the history of agricultural pest control practices.

Prior to 1946 we had a long period of stabilization in the types of chemicals and equipment used. Inorganic chemicals, such as the arsenicals, coppers, and sulfur, were very generally used and the high pressure plunger pump was the accepted standard for a power sprayer. The basic sprayer unit was supplied with hand operated spray guns for orchard or grove spraying and with booms for field spraying. The operating pressure was generally 600 pounds per square inch to apply what is now termed a "dilute" spray.

Construction materials to withstand corrosion and abrasion have been under continuous study since pesticides were first applied by mechanical means. During this period of stabilization the high pressure sprayer was refined to handle effectively the dilute sprays commonly used. This was accomplished by the selective use of corrosion and abrasion resistant materials for the critical components. In addition, these components were designed for easy replacement at nominal cost.

Recent Changes in Pesticide Application

Four significant developments have occurred in agricultural sprayer use since 1946. These are: new chemical groups for insecticidal and fungicidal use; new chemicals for new purposes, such as herbicides, defoliants, soil conditioners, and liquid or water-soluble fertilizers; new spraying methods, such as the air blast sprayer and the tractor-mounted sprayer; and use of concentrated spray mixtures.

A demand for greater versatility in spraying equipment has resulted from these developments. The types and characteristics of the pesticides available have broadened. Many pesticides can be applied very effectively at low pressure while others may require high pressure and the quantity required per unit of area is quite variable. The same type of sprayer may be required to apply a dilute spray in addition to mixtures concentrated 5 to 10 times the dilute ratio.

The introduction of the air blast spraying method was a transition from manually operated spray guns or booms to an automatic operation in distributing the pesticide on the plants. Air is used as a carrier to replace some of the water formerly used, thus providing a means of safely applying concentrated spray mixtures.

In recent sprayer development the objective has been to obtain the required versatility at the lowest possible cost. However, the use of new pesticides and new application practices have brought forth some new problems and intensified the old ones. For purpose of discussion, the numerous factors which influence the serviceability, life, and usefulness of a sprayer can be broadly classified as: the effects of chemical accumulation, the effects of solvents, abrasion, and corrosion.

Each factor enumerated can be troublesome alone or in combination with one or more of the other factors. To avoid the details required to present the innumerable variations possible, only the typical problems are discussed.

Effect of Chemical Accumulation

The air blast spraying method furnishes several excellent examples of the effects of chemical accumulation on spraying equipment. The air blast and the spray issuing from one or both sides of the sprayer does not have the close manual control formerly obtained with the use of spray guns. After the initial air velocity is expended, wind conditions, indifferent operation, or improper adjustment can cause the spray drift to accumulate on the sprayer. The drive components, the engine, pump, and especially the bearings, must be properly protected or sealed against corrosive and abrasive spray chemicals.

Another example of this problem is the corrosion caused by the accumulation of spray material on engine radiators, particularly some forms of sulfur and liquid lime-sulfur. In this instance, the problem cannot be solved by a protective coating or sealing the radiator to prevent contact of the chemical without interfering with the thermal conductivity. In some cases brass has been reported to be superior to copper for radiator cores. In changing from copper to any other material the radiator must be carefully designed to maintain proper engine cooling. Usually oversize radiator cores are required with larger cooling fans and efficient fan shrouding.

A third and quite different problem of pesticide accumulation is sedimentation within the hydraulic system of the sprayer. The piping and hose conducting the spray mixture must be of proper size to prevent abnormal pressure drop while maintaining enough flow velocity to prevent sedimentation of the wettable powders. When high capacity sprayers are converted to apply highly concentrated sprays the flow rate is often reduced proportionately and the velocity of flow may not be high enough to prevent sedimentation.

Solvent Action of Emulsifiable Pesticides

The solvents commonly used in formulating organic pesticides created some problems in obtaining satisfactory materials for hose, gaskets, diaphragms, and pump packing. This problem was very disturbing after the introduction of 2,4-D because of the rapid acceptance of herbicidal sprays and it was of immediate importance due to the rapid and drastic action on rubber or synthetic rubber in prevalent use at that time. Although many of the synthetic rubbers have some degree of oil resistance and are better than natural rubber or the GRS types, they lack sufficient solvent resistance for satisfactory use.

This problem has now been substantially minimized with the synthetic rubber industry formulating new compounds and the application equipment industry testing and evaluating almost innumerable sample materials. Unless the service requirements are extremely severe, the nitrile compounds are acceptable. The polysulfide (Thiokol) materials are reported to be most suitable as they have unique solvent resistance characteristics and can be compounded to obtain various physical properties.

A similar factor of major concern is the effect of solvents on paint and organic protective coatings. The general purpose paints, enamels, and lacquers are almost worthless because the solvents soften and remove these coatings exposing unprotected metal surfaces to all the agents of corrosion. Progress in solving this problem is discussed later.

Abrasion Problems

The application of concentrated sprays has placed new emphasis on abrasion as an important factor in the serviceability and useful life of spray pumps, pressure regulating devices, and spray nozzles. Several types of pumps are being used for sprayer service. The plunger pump is the most suitable for high pressure, heavy duty service. Centrifugal pumps are used successfully where capacities of 50 gallons per minute or more are required at low or moderately low pressure, and rotary displacement pumps are popular for tractor mounted sprayers.

In designing a plunger pump the cylinders, plunger packing, valves, and valve seats are usually designed as individual parts with special attention given to easy replacement. This simplifies the replacement problem and, more important, allows the selection of the most suitable materials to minimize abrasion and corrosion. Vitreous enamel is a popular coating for cast iron or steel cylinder liners. When a coating of this type is used, it should be selected for maximum abrasion resistance.

Another possibility in reducing abrasion of pump cylinders is the selection of plunger packing. Some packing materials will score the cylinders either with or without suspended solids in the spray mixture. The phenolic resin impregnated fabric packing has this characteristic and, while undesirable from this standpoint, is the most solvent resistant.

When wettable powder sprays are applied at high pressure, the valves and valve seats in pressure regulating devices are subject to severe abrasion. With increased concentration of the spray application the seriousness of this problem has been anticipated and satisfactory service obtained by the use of chromium-cobalt-tungsten alloys where hardened stainless steel was formerly used.

Centrifugal pumps are also affected by abrasion although to a lesser extent if they are used for low pressure operation. When wettable powders are pumped, abrasion is most active at the periphery of the impeller, at the seal area of the impeller eye, and at the shaft seal or stuffing box. Extended service is obtained by using abrasion resistant metals for the impellers and by incorporating replaceable seal rings and shaft sleeves.

Rotary pumps of the gear and vane type are popular for tractor-mounted sprayers by reason of their compact size, high capacity in relation to size, nonpulsating characteristics, and economical cost. In some respects their characteristics have not been properly applied. Some types should not be recommended for pumping wettable powder spray materials and require cautious use to prevent damage from sand or other foreign material in the spray solution.

Concentrated sprays have also required renewed study of materials to reduce abrasion at the orifice of spray nozzles. The original orifice size and shape must be maintained to prevent increased flow through the nozzle and to retain the original spray characteristics. Ceramic materials, tungsten carbide and chromium carbide metals can be used in some cases. The round orifice as used for the cone shaped spray pattern is relatively easy to manufacture from the hard materials. However, the flat spray ori-

Figure 1. Abrasion at nozzle orifice measured by the flow rate. The spray mixture contained 60 pounds of sulfur, 16 pounds of lime, and 100 gallons of water. Pressure at the nozzle was 600 pounds per square inch

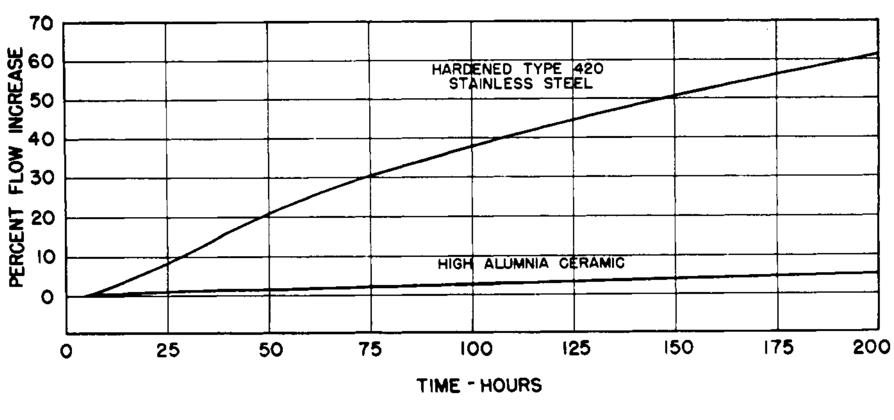

Figure 2. Sprayer tank failure due to corrosion

fice is quite difficult to produce from the hard materials due to the limitations in the manufacturing methods that can be used to shape the orifice. Figure 1 illustrates the relative wear resistance of hardened stainless steel compared with one of the ceramic materials.

In studying materials for maximum abrasion resistance it has been determined that hardness alone may not be a true indication of abrasion resistance. This is especially true of the carbides where a hardness test may indicate the relative hardness of the carbide without indicating the true nature of the alloying elements surrounding the carbide particles. If the surrounding elements are soft the abrasive may cause loosening and loss of the carbides and unexpected abrasion will occur.

The Corrosion Problem

Corrosion is partially a natural problem in power sprayers because water is the primary diluent in the spray mixture and being an agricultural implement, a sprayer is exposed to outdoor conditions while in use and in many cases when not in use. In some cases, it has been quite evident that corrosion has been accelerated more by the type water used or atmospheric conditions than by direct action of the pesticide involved. This problem is illustrated in Figure 2. However, we must recognize that many pesticides are quite corrosive to the common metals and that formulating solvents are required which adversely affect the general purpose paints, enamels, and lacquers.

The corrosion of steel sprayer tanks has been a particularly acute problem. In fact, a survey of the application equipment industry has definitely established this to be the most serious of all the problems. The reasons for this importance are:

(1) The early appearance of rust in a new unit is very disturbing to the owner even before it becomes a nuisance or damaging factor.

(2) Scale accumulation inside the tank will cause improper function of the pump and clog nozzles and strainers.

(3) The tank is of relatively thin material, therefore, subject to failure much sooner than the other more rugged components.

(4) Cleaning and recoating the inside of a tank by the owner is time consuming and difficult. In fact, it's impossible to satisfactorily clean the surface for repainting unless sand blasting equipment is available.

Wood sprayer tanks have been widely used in the past. However, from a manufacturing standpoint, steel is preferred because it is easy to fabricate, more compact, and lower in cost. Stainless steel tanks have been considered, but due to the high material and fabricating costs of corrosion resistant steel, a good corrosion and chemical resistant coating for steel tanks is a more logical answer to this problem.

Evaluating Protective Coatings

When evaluating paints or protective coatings for steel tanks the first requirement is a good adhesion to the base metal. Next, the coating must remain substantially unaffected by the pesticides and the solvents commonly used in their formulation. If the tank is to be subjected to severe stresses during use, the coating should be as flexible and elastic as possible. Abrasion resistance is desirable in tanks containing heavy, highly agitated suspensions, and, finally, the cost must be considered.

Good adhesion has a two-fold purpose. It prevents loosening or peeling and it minimizes corrosion creepage under the paint adjacent to a damaged or unpainted area.

To obtain good adhesion, laboratory testing will quickly illustrate the relative values of pre-paint treatment. Various types of phosphate coatings are available for different metals and paints. Usually the paint manufacturers are in position to recommend the preferred pre-paint treatment for their product and this should include proper cleaning and degreasing of the base metal.

Many types of coatings have been suggested and tested for sprayer tank protection. With solvent resistance being one of the primary requirements, many paints that are excellent for ordinary outdoor or industrial service are decidedly unsatisfactory for general purpose sprayer use. Laboratory testing and field testing have been necessary to determine the types of coatings most promising.

From the data available on the pesticide resistance of the various types of coatings, the following generalized statements can be made.

The bituminous, chlorinated rubber, neoprene, and vinyl coatings have low solvent resistance and should not be used where the service requires the application of emulsion formulations.

The air-drying epoxy and phenolic resin coatings have moderate to good solvent resistance depending upon the coating formulation and the type of solvent in the spray mixture.

The heat curing epoxy and phenolic resin coatings have the highest solvent resistance of all the organic coatings tested. Some coating formulations are quite brittle and subject to cracking or chipping. The brittleness can be reduced to some extent by modifying the coating or reducing the time and temperature of the heat cure.

Porcelain enamel coatings offer very good chemical resistance but are expensive and inconvenient to apply.

Tanks made of fiberglass-reinforced polyester resin have been reported as being satisfactory. However, their cost and design limitations may be a serious handicap to commercial use.

When selecting materials of construction to minimize one specific problem a compromise is sometimes necessary to fulfill the general service requirements. Thus, all the problem factors must be considered including the cost and manufacturing processes involved. Industry is continually offering new and better materials for special purposes. It is reasonable to assume that new materials will be developed which will further reduce or eliminate some of the problems of sprayer design.

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