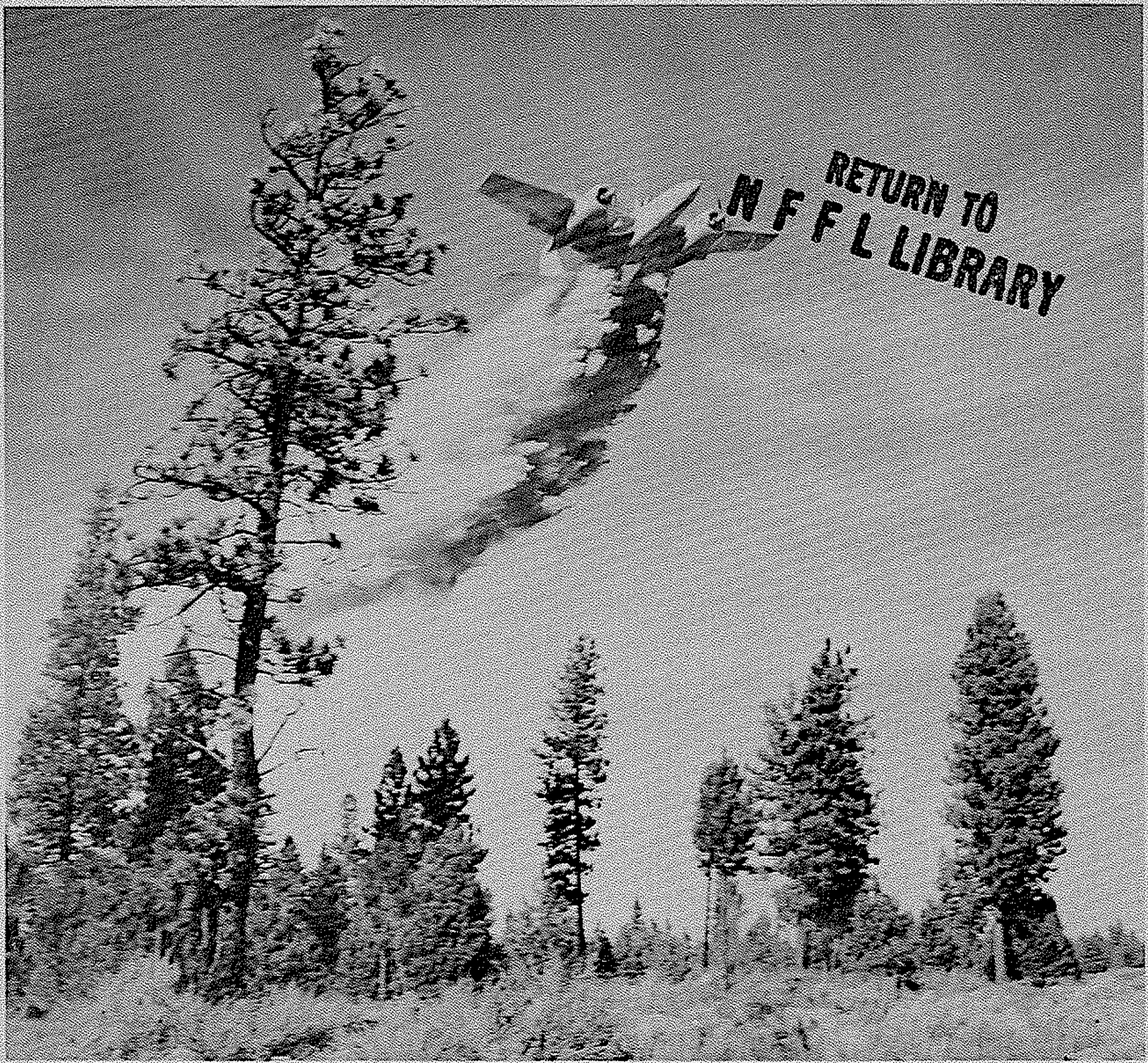

CHEMICALS
for
FOREST FIRE FIGHTING

A report of the NFPA Forest Committee

NATIONAL FIRE PROTECTION ASSOCIATION
International
60 Batterymarch Street, Boston 10, Mass.

NATIONAL FIRE PROTECTION ASSOCIATION

International

Executive Office: 60 Batterymarch St., Boston 10, Mass.

The National Fire Protection Association was organized in 1896 to promote the science and improve the methods of fire protection and prevention, to obtain and circulate information on these subjects and to secure the cooperation of its members in establishing proper safeguards against loss of life and property by fire. Its membership includes two hundred national and regional societies and associations and more than twenty thousand individuals, corporations, and organizations. Membership information is available on request to the NFPA Executive Office.

This book is one of a large number of publications on fire safety issued by the Association. A complete list of periodicals, books, posters and other publications is available without charge on request. Technical standards adopted by the Association are published in seven volumes of the National Fire Codes which are re-issued annually. The standards, prepared by committees of the Association and adopted in the annual meetings of NFPA prescribe reasonable measures for minimizing losses of life and property by fire. All interests concerned have opportunity through the Association to participate in the development of the standards and to secure impartial consideration of matters affecting them.

NFPA standards are purely advisory as far as the Association is concerned, but are widely used by law enforcing authorities in addition to their general use as guides to fire safety.

Definitions

Units of measurements used in this book are U. S. standard. 1 U. S. gallon = 0.83 Imperial gallons = 3.785 liters.

A glossary of the terms commonly used in this special field is included in the text.

Approved Equipment

The National Fire Protection Association does not "approve" individual items of fire protection equipment, materials or services. Its standards are prepared, as far as practicable, in terms of required performance, avoiding specifications of materials, devices or methods so phrased as to preclude obtaining the desired results by other means. The suitability of devices and materials for installation under these standards is indicated by the listings of nationally recognized testing laboratories, whose findings are customarily used as a guide to approval by agencies applying these standards. Underwriters' Laboratories, Inc., Underwriters' Laboratories of Canada and the Factory Mutual Laboratories test devices and materials for use in accordance with the appropriate standards, and publish lists which are available on request.

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October 1964

Supplement to:

CHEMICALS *for* FOREST FIRE FIGHTING

A report of the NFPA Forest Committee
(Published May 1963)

Price 50 cents

NATIONAL FIRE PROTECTION ASSOCIATION
International
60 Batterymarch Street, Boston, Mass. 02110

Supplement to Chapter II (page 9, paragraph preceding Other Viscous Agents)

Compositions and Description. *Gelgard** is a mixture of synthetic dry powder (polymer) which can be made into viscous water or gel depending on the amount of powder used. The powder absorbs water but does not dissolve. Only small amounts of powder are needed for satisfactory retardant mixes of jelly-like consistency.

Gelgard is non-toxic, non-abrasive and is very slippery. It does not appear to be corrosive to metals commonly used in forest fire fighting equipment. Corrosion tests must yet be completed before final information regarding this characteristic can be given. *Gelgard* comes in two forms: *Gelgard M* is colorless and is recommended for use in ground tankers and other equipment where coloring is not necessary. *Gelgard F* has Rhodamine B Aniline dye added for visibility. It is designed primarily for drops from aircraft. *Gelgard* is still in a state of development, and its final characteristics may possibly be changed slightly from those described here.

Mixing Ratio. From one to three pounds of *Gelgard* powder is needed per 100 gallons of water. Hardness and temperature of the water affect viscosity, so trial or sample mixes are recommended to get desired viscosity. Solutions develop viscosity very rapidly. Within two minutes, 80 per cent of viscosity is reached with maximum reached in about four minutes.

Mixing is performed by eductor systems, batch mixers and with special "demand" ground tankers designed by the USFS. These are described in the Supplement to Chapter VI and in Figure 1-S, page 5.

Mode of Action. *Gelgard* is not a chemical retardant but serves only to hold water in a viscous mixture. Once the water is evap-

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*Gelgard — polymer — product of Dow Chemical Company.

orated the retardant action ends. The addition of *Gelgard* has no effect on freezing or the boiling point of water.

Cost. *Gelgard* is supplied in 50-pound bags for about $1.50 per pound, in ton lots, exclusive of transportation costs.

Desirable Characteristics. *Gelgard* is non-toxic, non-abrasive and may be stored indefinitely without spoilage. Small quantities of powder are needed which is favorable for blending in aircraft use and in transportation and storage. The gel sticks effectively to fuels and flat surfaces. Mixing is comparatively simple.

Undesirable Characteristics. The mixture is very slippery. Care must be exercised to prevent over-mixing or shear effect which destroys viscosity of the mix. Gear pumps or powered agitator-type mixers may cause shear effect and should be used only if alternate mixing equipment is not available. In pumps, the tapioca-like globules will not pass a fine screen, but most forest fire pumps should pass the *Gelgard* mix. Salts affect the gelling capacity of the polymer.

Supplement to Chapter III (page 15, paragraph preceding Viscous DAP Combinations)

Liquid Phosphate Concentrate, "*Pyro*" (11–37–0)

Chemical Composition. Concentrated liquid fertilizer, 49 per cent ammonium phosphate, 28 per cent orthophosphates (about half and half DAP and MAP), 17 per cent tripoly-phosphates, and 6 per cent other (mainly tetrapolyphosphates).

Description. A liquid concentrate that readily disperses in water. May be stored indefinitely in mild steel drums which do not have welded seams or tanks without corrosion problems. In storage it will not settle, and will not freeze until subjected to very low temperatures. The green concentrate does NOT impart color to the final solution of concentrate in water.

Mode of Action. The exact chemical reactions which occur when heat is applied to a phosphate coated cellulose fuel are not known. The phosphate appears, however, to hinder the formation of volatile tars when cellulose is exposed to high heat, and to increase the charcoal fraction. It is an effective retardant on small volume fuels. It is not fully effective on large volume fuels such as large timber slash and large brush (roughly 10 feet or more in height). Thickened chemical solutions are needed for these larger fuel types.

Cost. Sixty-three dollars and fifty cents per ton (TVA price) or $.37 per gallon. One gallon of solution would contain 6.2 cents worth of concentrate. This price range applies within economic distance from TVA. However, the formula for this concentrate is available for use by commercial fertilizer manufacturers to meet demand outside reasonable shipping distance from TVA.

Mixing. No mixing tank needed. One gallon of concentrate in 5 gallons of water will give an 8.1 per cent phosphate equivalent solution. Pump action is enough to get complete dissolution.

Desirable Characteristics:

a. No physical handling necessary for unthickened solutions.

b. No need to store pre-mixed solution.

c. Stable solution, does not "settle out."

Undesirable Characteristics:

a. Not easily colored.

b. Corrosive under some operating conditions.

c. High expense if mobile storage tankers need be purchased.

d. Not effective on larger fuel types.

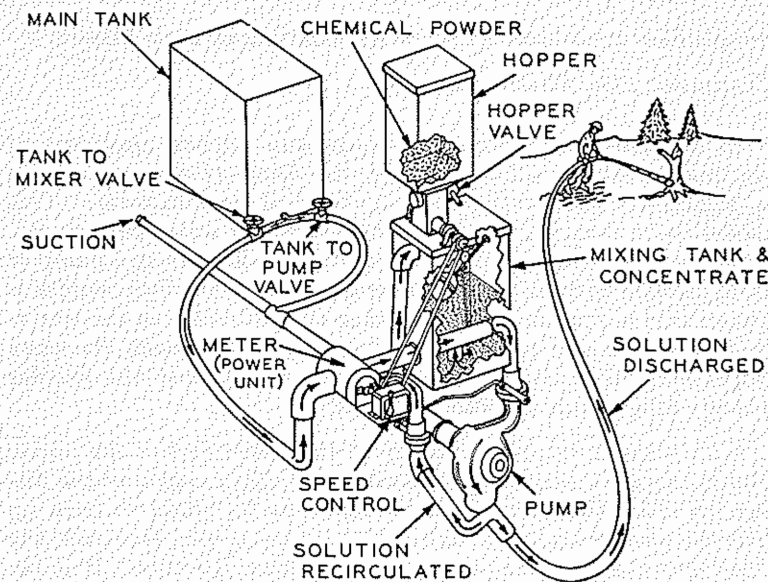

Figure 1-S. Typical arrangement of mixing system for ground application. *(U.S. Forest Service sketch.)*

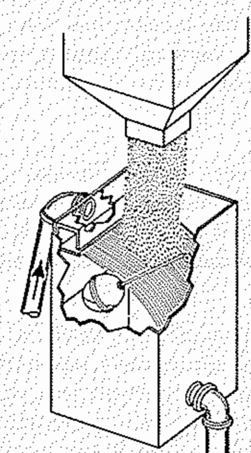

Figure 2-S. DETAIL OF MIXING SYSTEM

Supplement to Chapter VI (page 43, Continuous Flow Mixers)

Continuous Flow Mixer (Aardvark)

In an effort to overcome stoppage and prevent problems of wetting the hopper inlet or shutoff, the *Aardvark* disperser shown in Figure 4-S was developed by a chemical manufacturer. This model has a capacity of 100 to 300 gallons of water per minute. Water is supplied to the unit under pressure either from a pump or from a water hydrant. The proper amount of chemical powder is placed in a hopper at the top. When the ball-valve in the waterline is opened and water flows, air is sucked through the open upper end. The hopper valve is then opened and the powder quickly falls by gravity into the water.

Since there is no back pressure at the outlet end of the nozzle and no negative pressure produced in the upper region of the dispersing head, there should be no tendency for water to back up into the powder hopper unless sudden surges occur. However, the open end enables the operator to look down the tube. If it becomes plugged, it is easily cleaned by inserting a brush or rod into the tube. Little testing has been performed to date on this mixer to delineate operating limitations, but it should produce a continuous mix of measured amounts of water and chemical, and discharge into a tank.

Demand Mixer. A system was developed during 1963–64 at the Arcadia Equipment Development and Testing Center with the full descriptive title "Continuous or Intermittent Flow, Water or Chemical Demand Tanker-Mixer" for use on a 300-gallon DT Tanker.

The mixing tank and chemical hopper is an independent circuit which can be alternately selected when a chemical mix is desired or closed when only water is needed. This provides the advantage of mixing on demand in proportion to the amount of flow desired. The main water tank is not used for storage of the mix which is often an advantage.

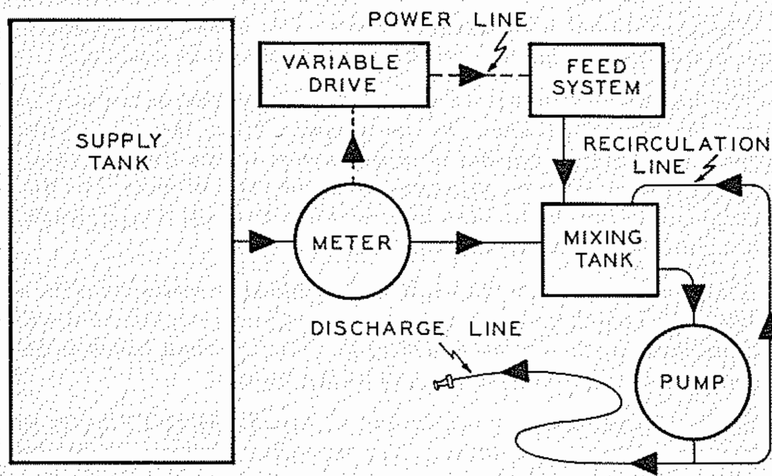

Figure 3-S. Typical layout of supply and mixing system.

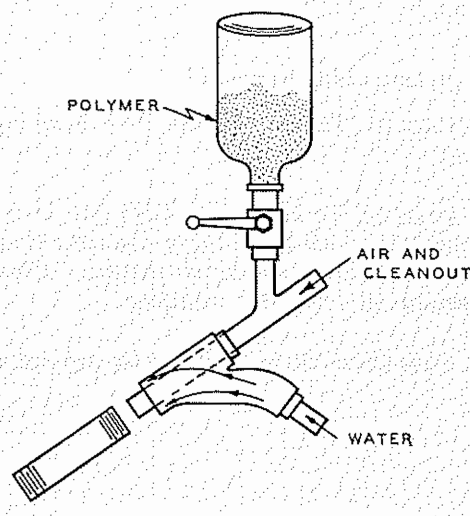

Figure 4-S. CONTINUOUS FLOW SYSTEM (NON-RECIRCULATING) AARDVARK DISPERSER

The operational line drawing, Figure 1-S, shows the circuitry, and Figure 2-S depicts the mixing activity shown in cutaway.

The heart of the unit is a flow meter actually used as a motor to drive the dispensing screw on the hopper. Thus, the rate of dispensing of chemical powder is proportioned to the flow of water. A speed control permits adjustments to the ratio of mix. The discharge is directly to the hose line, or when shut off at the nozzle, recirculated through the mixing tank.

The tanker on which this unit was installed is equipped with a single stage centrifugal high volume booster pump capable of working pressures up to 400 psi at 175 gpm. The Demand Mixer is designed to deliver from 3 to 90 gpm at the nozzle.

Study of this design is continuing at Arcadia ED&T Center to select new fittings and develop less expensive systems for slip-on tankers.

Supplements to Appendix

Page 81, Table 1, *Pectate-DAP* is no longer commercially available.

Page 82, Table 3, *Phos-Chek 201* is being replaced with *Phos-Chek 202* which has a lower viscosity than *201*, found to be desirable through operational testing. *Phos-Chek 202* also has an "improved" corrosion inhibitor.

Phos-Chek 258 is available for ground application use.

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Chemicals

for

Forest Fire Fighting

CHEMICALS

for

FOREST FIRE FIGHTING

A report of the NFPA Forest Committee

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Preface

This text is the result of two years of study and compilation of research reports and field experience concerning the use of chemicals in forest fire fighting. It was prepared under the direction of the NFPA Forest Committee and has been approved by that committee as a report of progress in this specialized field. Although it cannot be considered as a technical standard of the National Fire Protection Association, it should provide valuable guidance to all persons and agencies interested in forest fire control, including those industries whose production and properties can be seriously affected by forest, brush and other outdoor fires.

Particular acknowledgment is given to the following individuals who devoted considerable time and their specialized knowledge to preparation of this text:

Committee member Merle S. Lowden, Director, Division of Fire Control, Forest Service, U. S. Department of Agriculture, chairman of the sub-committee responsible for preparing the text; W. M. Carter, Test Engineer, C. W. Howard, Supervising Engineer, and A. V. Shoemaker, Fire Equipment Specialist, all of the U. S. Forest Service Arcadia Equipment Development Center, Arcadia, California; C. B. Phillips, Forester, Division of Forestry, California Department of Conservation, Sacramento, California; Floyd W. Waklee, California Division of Forestry; Robert S. McBride, Division of Fire Control, California Region, U. S. Forest Service, Department of Agriculture; Battalion Chief Frank Hamp, Los Angeles County Fire Department; Horace G. Cooper, Pacific Northwest Region, U. S. Forest Service, Department of Agriculture; Carl C. Wilson and Deal L. Dibble, Division of Forest Fire Research and J. B. Davis, Forester, California Division of Forestry, all at the Pacific Southwest Forest and Range Experiment Station; and Andrew G. Brenneis, Division of Fire Control, Southwest Region, U. S. Forest Service, Department of Agriculture.

Acknowledgment is also made to the many other individuals and agencies of the U. S. Forest Service who reviewed the initial draft of the text before final consideration and adoption by the NFPA Forest Committee.

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SCOPE: This committee functions in a technical and educational capacity in cooperation with forest and range fire control organizations of the United States and Canada to assist in forest, grass, brush and tundra fire control, including coordination between all fire protection agencies regardless of federal, state and provincial, county and municipal boundaries.

†Non-voting member.

Revisions

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GLOSSARY OF TERMS

ABRASION. The grinding or wearing away of a solid surface by another surface in the presence of abrasive materials, slurries, and dirty water. Silica found in sodium calcium borate is very abrasive to pump seals and similar parts.

ADHESION. The act or state of sticking or holding on to another object; such as a glutinous retardant sticking to forest vegetation.

AERIAL FUELS. The standing and supported forest combustibles not in direct contact with the ground and consisting of leaves, needles, twigs, stems, branches, limbs, trunks, and vines.

AIR TANKER. Any aircraft equipped to bulk-drop retardants (or suppressants) on fires (*Ref. 10*).

CASCADING. Free-fall dropping of uncontained liquid retardant or suppressant materials, not in spray form (*Ref. 7*). The term "bombing" implies contained liquids, slurries, or gels.

CENTIPOISE. A unit of measure of the viscosity or thickness of liquids, equal to one hundredth of a poise. See "Poise."

COHESION. Sticking together by molecular attraction, or when the particles of a body are united throughout the mass or batch.

CONTAMINATION. A foreign material, or chemical, introduced into a fire chemical which renders it unfit for normal use. It can result from a chemical's reacting with another incompatible chemical or material, or in bacteria or enzymes attacking the material. A scum or precipitate may be formed, or the whole mass solidified. Certain proportions of algin and borate will form a tough, rubbery gel. Algin in contact with zinc may form a scum which in time turns to a granular precipitate that can plug screens or spray nozzles. Bacteria or enzymes reduce viscosity.

DEGRADATION. A deterioration of viscosity or gel strength.

EROSION. The act of eroding or wearing away surfaces from the impingement of chemical slurries and solutions which contain abrasive materials.

FOAM. Compounds introduced into a stream of water by special nozzles or proportioning devices to develop a stream of tenacious form capable of smothering fires . . . and also the foam produced by such equipment (*Ref. 10*).

GEL. A jelly-like material, formed from a colloidal solution, or slurry, when allowed to come to rest. Some gels may contain 90 percent water, yet in their properties are more like solids than liquids. Before fracture or breaking occurs a gel has the characteristic of being flexible and recovering its original form or shape after stress is removed.

GEL STRENGTH. A measure of the power of a gel to resist a force which would cause deformation or fracture. A force exceeding the gel strength will cause shear planes through the gel along which, if the force is continued, energy is expended, reducing the fire chemical to a fluid mass.

IMPINGE. To project one stream into another or a high velocity stream against a metal wall, or lining of a pipe, or fitting. Much of the erosive wear found when soft brass fittings are used in high pressure retardant lines is due to impingement against gates, sharp turns, and protruding surfaces.

INHIBITOR. Any agent which retards a chemical reaction and, in this text, generally refers to corrosion.

INJECTOR. A device which uses the vacuum produced by discharging a fluid through a nozzle within a pipe, or chamber and venturi tube connected to a pipe, to entrain or suck in dry chemical or fluid concentrate. In practice, a dry chemical hopper is connected to a chamber surrounding a nozzle. A high pressure stream of water mixes and carries the material into an outlet pipe. Sometimes the configuration is reversed. The water enters around the outside through an annular orifice while the chemical is drawn in through the center. Occasionally an injector is used to proportion mixes. It is better practice to use the device for introducing chemicals to a batch lot and depend on measured quantities for good ratio control. This kind of equipment is also frequently known as an "ejector" or "eductor."

INTUMESCENCE. Expansion or swelling of a fire-retardant coating when heat is applied. Intumescent fire-retardant paints develop a puffy coating resulting in one of the following effects: insulation of fuel from heat, exclusion of oxygen from fuel, production of diluent gases, and reduction of flammable gases (*Ref. 11*).

POISE. "The unit of absolute viscosity of a fluid, signifying that a force of one gram will maintain unit rate of shear of a film of unit thickness between surfaces of unit area. Otherwise one dyne-second per square centimeter." (Chamber's Technical Dictionary)

PRECIPITATE. A substance separated from a solution or slurry that usually settles to the bottom of the mixture. It may be caused by improper mixing or by contamination resulting in some physical or chemical change.

RETARDANT. A fire retardant is any substance that by chemical or physical action reduces flammability of combustibles. The rate of spread of the flame front is thereby slowed or retarded (*Ref. 11*).

SHEAR. An action or stress which causes the fluid particles to slide relative to a hard surface in a direction parallel to their plane of contact. It is of interest here because shearing may alter some chemical agent's physical characteristics. Borate slurries may be damaged and excessive settling caused. Excessive shear may cause damage to viscous water. In some types, viscosity may be reduced while, in others, a rope-like consistency may develop.

SLIP-ON TANKER. Consists primarily of a tank, a live hose reel or tray, an auxiliary pump, and an engine, combined into a single, one-piece assembly which can be rolled onto a truck bed or trailer (*Ref. 12*).

SLURRY. A watery mixture of clay, or other largely undissolved chemical agent used to suppress or retard grass, brush, or forest fires. Examples are borate slurry or bentonite slurry.

SOLUTION. A homogeneous mixture formed by a substance (solid, liquid, or gas) dissolving in a liquid.

SUPPRESSANT. An agent used to extinguish the flaming and glowing phases of combustion by direct application to the burning fuel.

SUSPENSION. A finely divided solid, evenly dispersed, but not dissolved, in a liquid. Clay slurries are "suspensions" while diammonium phosphate dissolved in water forms a "solution."

THIXOTROPIC. A thixotropic suspension (or solution) is one that tends, when held without appreciable stirring, to become relatively thick (*Ref. 13*) and that becomes more fluid upon agitation. It has the ability to go from one stage to the other an indefinite number of times.

VISCOUS. A relative term connoting that a fluid has a thicker consistency than water. Bentonite slurry is more viscous than plain water.

VISCOSITY. The thickness of a solution or suspension. A measure of the relative ability of a fluid to resist flow. Heavy syrup has a high viscosity; gasoline has a low viscosity. Viscosity is usually measured in centipoises.

WETTING AGENT. A chemical additive used to modify the characteristics of water used for fire fighting. It reduces surface tension permitting better dispersal and greater penetration. In some respects the action is similar to familiar detergents which make water wetter (*Ref. 18*).

WET WATER. Water to which a wetting agent has been introduced.

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Introduction

Water has been used for years in forest fire fighting. In rural or mountainous areas, however, water is frequently hard to find. The forest fireman is often limited to the water he carries in his truck or on his back. The big question, then, is how to make water last longer and do a better job. Adding chemicals to water helps to accomplish these purposes.

Work with fire chemical coatings and impregnation is not new. The ancient Egyptians steeped wood in a solution of vinegar and alum (*Ref. 1*)*. The Romans used these same agents but also added such noncombustibles as clay or lime. Fire-resistant coatings of clay or gypsum were suggested for Italian theaters as early as 1638. Combinations of ammonium phosphate and ammonium chloride with borax were suggested by Gay-Lussac for fireproofing wood and wood-fiber materials in 1821.

Forest firemen have wondered about the possibility of applying water and chemical solutions to forest fires from the air. Early experiments (*Refs. 1, 2, 3 and 4*) by the U. S. Forest Service during the 1930's and the 1940's dealt with the problems and advantages of this means of attacking fires.

Interest in, and the use of, chemical fire retardants and suppressants for range and forest fire fighting have accelerated greatly in recent years, especially since Operation Firestop field tests of chemicals for forest fire control conducted in 1954 (*Ref. 5*). Studies by the U. S. Forest Service in its Forest Products Laboratory maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin, added diammonium phosphate, monoammonium phosphate, zinc chloride, ammonium sulphate, and other chemicals, to the list for wood impregnation and use in fire-retardant paints. Additional studies by this laboratory from 1929 to 1954 were significant as related to melting and boiling points of chemicals, concentrations required, and effects on the rate of combustion.

Another significant study is one conducted for the U. S. Navy by the Syracuse Research Institute from 1957 to 1961 (*Ref. 6*). The objective of this study was to determine if the effectiveness of water for fire fighting could be increased by making it viscous (having a thicker consistency than water [see *Glossary of Terms*, page viii]). The results are now to be seen in the use of viscous water by ground fire fighting equipment and by the use of gel and viscous chemical solutions in air tankers and helitankers. All these studies have aided the search for an effective, practical, and inexpensive chemical agent for forest and range fire fighting.

The purpose of this report is to provide information and principles learned in the use of forest fire fighting chemicals since 1954, and to denote the differences in the descriptions of the various chemicals and in their use as suppressants and retardants. Other reports are available which describe more fully the guidelines for using chemicals (*Refs. 7, 8 and 9*).

*All italicized references in this text refer to the numbers of texts and research information sources which will be found under the heading *LIST OF REFERENCES*, beginning on page 83.

CHAPTER I

MAXIMUM DESIRABLE CHARACTERISTICS

Fire retardants and suppressants have many characteristics in common. However, since they are used differently in fire fighting, they also have their own unique characteristics. One of the main differences is that retardants must remain effective, minutes or hours, after application. A suppressant should be most effective at the time of application.

A list of *Performance Standards and Test Procedures for New Chemical Fire Retardants* was prepared by the California Air Attack Coordinating Committee. The committee included representatives of the California Division of Forestry, the Los Angeles County Fire Department, California Region of the U. S. Forest Service, the Arcadia Equipment Development Center, and the Pacific Southwest Forest and Range Experiment Station of the U. S. Forest Service. Based on the committee's list, the following are maximum desirable characteristics to look for in a good fire retardant or suppressant (*Ref. 14*).

Characteristics Common to Retardants and Suppressants

1. Low cost. The cost-benefit ratio must support and justify the use of the chemical agent for fire use. Reasonable account must be made for all direct charges to chemical handling and application. To qualify for operational uses, the agent must be comparatively inexpensive.

2. Readily available in adequate quantities in areas of primary use.

3. Nontoxic to plant and animal life. Must not be irritating or troublesome to personnel involved with mixing and handling, or to firemen on the line. It should not be a soil sterilant.

4. Adheres well to forest fuels. Must hold to, and cover, bark, stems, grass, and deciduous and coniferous foliage.

5. Prevents, or sharply reduces, rekindling. Slows down reignition.

6. Should not act as a desiccant to vegetation.

7. Requires a small amount of chemical material per gallon of water to produce an effective gel, slurry, or solution, thereby reducing handling and transportation costs.

8. Mixes easily and readily into a stable suspension or complete solution. Should disperse and hydrate easily, and remain suitable for immediate use without agitation or recirculation. A minimum of inspection should be necessary.

9. Tolerates changes of temperature in storage tanks or fire equipment. Chemical should not change its viscosity or characteristics greatly during cold nights or hot days.

10. Nonabrasive, noncorrosive, and nonerosive to the metals used in mixing equipment, or to air tanker and ground application unit parts.

11. Stores well before mixing operation. Furnished in convenient containers. Should not pack, lump, or deteriorate in dry warehouse storage, even over winter.

12. Not oversensitive to either the pH or mineral content of water.

13. Not subject to deterioration from bacteria, fungi, enzymes, or by action with metals. Some organic combinations may act as cultures and could be detrimental to personnel if insufficient attention is given this health factor.

14. Not altered appreciably by minute contamination.

15. Final characteristic reached shortly after mixing, and does not change with further standing or agitation.

16. Mixing and handling requirements should not be beyond the capabilities of trained fire crew personnel.

17. Flows through fire hoses and nozzles without serious friction loss, yet sets up and holds once it is applied.

18. Slipperiness should not be a serious problem. Material should not be so slippery that crews have a safety problem with their footing, or difficulty with nozzles and couplings.

Characteristics Desirable for Suppressants

A good fire suppressant permits acceptable straight stream and spray patterns. If the spray does not produce a true aerosol, it should at least be a fine spray which will absorb heat and protect the nozzle man from radiation.

Characteristics Desirable for Retardants

1. Retains water for at least several daylight hours, insuring wet fuels and retardant characteristics for a reasonable period during control time.

2. Effective after drying. Should inhibit combustion, or modify the combustion process by chemical action, in order that the material is not entirely dependent on its moisture-holding ability.

3. Adheres well to forest fuels when dry. It should remain effective when dry or when exposed to heat without cracking, crumbling, or turning to flakes or powder.

Many chemicals tested to date do not meet a significant number of the characteristics outlined in this text. Others were disqualified after a few test samples, especially if they were prohibitive in cost, toxic to animals or plants, or corrosive or highly abrasive to equipment.

Testing New Chemicals

To insure use of only the best available chemicals, the following systematic testing procedure for new forest fire fighting chemicals has been suggested (*Ref. 15*) by several fire control agencies:

1. INITIAL SCREENING. The supplier submits only those samples that show promise when checked against the list of desirable characteristics.
2. PRELIMINARY LABORATORY TESTS. Determines whether or not the chemical offers promise (*Ref. 16*).
3. MIXING AND HANDLING TESTS. Chemicals that have passed the above tests are tested to determine whether they can be mixed and applied with conventional equipment or if they require special handling.
4. LABORATORY FIRE TESTS. Performance evaluation on controlled fires burning in forest fuels under controlled laboratory conditions (*Ref. 15*).
5. FIELD TESTS. Drop patterns and application requirements under varying conditions are evaluated jointly by fire control agencies and fire research and development groups (*Ref. 17*).
6. OPERATIONAL TESTS. Evaluation of operational performance by fire control personnel to study handling characteristics, costs, and overall effectiveness.

General. Equipment is adapted and operational guidelines are prepared for using chemicals found to be suitable for operational use.

CHAPTER II

SHORT-TERM RETARDANTS

All chemicals described in this text can be used as suppressants or retardants or for both purposes. Some, however, are more suited for suppressing fires, while others have characteristics which make them preferable for retarding fire spread. Transportation is an important element of cost especially for the heavier chemicals. The following chemicals are noted for their fire-retardant qualities.

Water and its Modifications

Water has been used for years as the most practical fire fighting agent because it is available in hydrants, streams and ponds (*Ref. 18*). Fortunately, the physical characteristics of water can now be modified and improved by the addition of chemicals. It can be changed so that it will penetrate smaller openings and will flow through more restricted channels to get at the source of heat, or, so that it will cover a fuel with a thicker layer of water capable of absorbing much more heat. By the addition of other combinations of chemicals, water can be made into a gel which will cling to fuel surfaces in layers up to ¾ inch thick, capable of absorbing tremendous amounts of heat energy before being driven off as water vapor. The various modifications of water are described in the following sections.

Wet Water

Description. "Wet water" (*Ref. 18*) is the commonly accepted term which describes water whose surface tension has been reduced by the addition of a "wetting agent." This physical change imparts several characteristics to water important to suppressing and retarding forest fires in certain situations. One report (*Ref. 19*) which compared wet water to plain water showed that with wet water:

1. Penetration into wood is about eight times greater.
2. Penetration into charcoal is about ⅔ as much as wood.
3. Surface spreading on wood is increased two to eight times, depending on species of wood.
4. All wetting agents tested readily formed foam.

Retardant use. As a retardant, wet water is superior to plain water only where penetration and surface spreading would be beneficial. Such fires might include those spreading through a bed of pine needles, or leaves, or a pile of sawdust. Since plain water is unable to penetrate as well as wet water, it remains near the surface of the layer of fuel and evaporates quicker. When applied to aerial fuels, wet water spreads over the fuel surface in a much thinner layer. Its heat-absorbing capacity per unit area of fuel surface is considerably reduced over that of plain water.

Suppressant use. For suppression situations, one study indicated that wet water could be superior to plain water because of its surface-spreading characteristics and its ability to break up into finer particles. Nozzle men seemed to have the ability to advance on a fire more easily and suppress the fire in less time and with less water. Good techniques were needed. Sprays were found to be superior to straight streams, thus limiting the advantage of wet water to certain fire situations. It appears to have an advantage if matted grass is present.

Mop-up use. Wet water is particularly desirable in mopping up certain types of forest fires. After the flaming stage of combustion has been controlled, glowing combustion remains in deep beds of coal, in deeply charred logs and stumps, and smoldering layers of duff and leaves. The penetrating and spreading ability of wet water can be used to good advantage in suppressing glowing combustion and in reducing rekindling in these situations. Again, technique of application is important. Rapid spraying of the fuel bed with a fine fog at a distance which gives minimum air entrainment and effective spray distribution with maximum coverage is necessary. Low rates of discharge are most effective.

Foaming of wet water seems to be a desirable property in the mop-up stage of controlling forest fires because it prevents water from channeling. The films formed by the foam between the particles hold the excess water until it is taken up by penetration.

Wet water agents are available at most fire supply houses. They all have different mixing rates for different fire situations but instructions are usually included with the agent.

Most wet water agents are corrosive, particularly to iron and galvanized iron, unless they contain a rust inhibitor, such as potassium dichromate. This chemical is a poison, and water treated with it should not be used for human consumption. Care should also be taken to avoid skin irritation.

Viscous Water Group

Description. Viscous water is water which has been thickened by one of several viscosity agents. It can be made so thick that it will not pour. Like wet water, it does not depend on a chemical reaction to retard or suppress forest fires, but the viscous mixture will absorb more heat than plain water. (For gels see page 9.)

Advantages. At the viscosity which seems to be most practical for application from fire truck pumps (about 150 centipoises, measured with a Brookfield Viscometer, No. 2 spindle; 60 rpm), viscous water seems to have the following advantages over plain water:

1. Sticks and clings more readily to forest fuels.
2. Spreads itself out in a continuous coating over all fuel surfaces, including waxy leaves.
3. Sets up in a layer about three times the thickness of plain water.
4. Absorbs a little more than three times as much heat.
5. Projects somewhat further and higher from straight-stream nozzles.

These advantages indicate the superior suppressing and retarding qualities that viscous water can have over plain water. Most evident is the increased protective layer of water laid over the fuel surface. The physical properties of this layer are such that its particles resist the creation of convective heat cells. Mixing of the water molecules is delayed until the viscosity has been reduced by heat to that of plain water. Heating by convection then begins to take place, and boiling occurs at the normal 100 degrees centigrade. This delay in evaporation and boiling is quite significant in the amount of extra heat that can be absorbed by viscous water, perhaps 20 percent more than that absorbed by plain water.

Some viscosity agents leave a tough, dry film after the water has evaporated. Although combustible, this film can seal the fuel from the oxygen of the air, thus reducing rekindling. Other desirable characteristics of viscous water common to the two viscosity agents in present use (algin and CMC) are:

1. Less run-off and waste.
2. Very little dry chemical is needed to mix the viscous water.
3. The weight per gallon of mixed chemical is low (8.4 pounds per gallon or less) which gives lighter, and safer, loads for air tankers when compared to other fire retardants currently in use.

4. Mixes easily and quickly.
5. Abrasion and erosion to pumping equipment is almost negligible.
6. Nontoxic to plants or animals.
7. Compatible as a carrier for good fire-retardant chemical salts.
8. Considerably reduced wind drift in air drops when compared to water and other presently used fire retardants.

Disadvantages. Viscous water has several disadvantages. Thick viscous water does not penetrate like plain water. Therefore, viscous water is not recommended where penetration is necessary to reach the source of heat to extinguish the glowing phase of combustion. Often this may be a matter of technique. If charred logs, stumps, fence posts, and wood chunks can be completely coated and sealed with viscous water, suppression and mop-up time and effort can be reduced, as can the volume of water. Friction loss can be considerable with viscous water. (See Table 2 in *Distribution Systems for Chemical Handling*, Chapter VIII.)

Flow characteristics. The flow characteristics of viscous water which affect friction loss also cause it to "hold together" in the air. There is much less dispersion of water particles off to the side of the water stream as it goes through the air.

Fog characteristics. The use of fog nozzles with viscous water does produce an effective pattern for the protection of nozzle men. However, with viscous water the droplet sizes are larger and aerosols are not produced.

Slipperiness. The slipperiness of viscous water is a serious personnel hazard. Men walking in areas where viscous water has been applied must be extremely careful about their footing. Slipperiness can be a nuisance to the nozzle men, especially to the man operating a nozzle which he must occasionally alternate from straight to spray stream. Rags are essential for drying the nozzle.

Viscosity variations. Loss of viscosity of viscous water kept in storage for several days can occur several ways. Viscosity varies inversely with the water temperature. Water mixed to the desired viscosity early in the morning when the water temperature is low will thin out to a certain extent as the water warms up during the day. Viscosity will then rise again during the night as the water cools.

Bacterial action. Those viscosity agents which are derived from organic materials are subject to bacterial action after they have been used to mix viscous water. The particular bacteria which cause this action are not always present. When they are, viscosity loss and spoilage of the mix may take place in a matter of a few days. Their presence is denoted by strong, offensive, waste odors. Once the particular bacteria have invaded a tank, they are extremely difficult to remove. Complete loss of viscosity of subsequent loads may also occur in a matter of a few days, or even hours. The bacterial action can be prevented by the introduction of bacteriacides, such as paraformaldehyde. Most bacteriacides, however, are toxic to humans if taken internally in sufficient quantities. In dry form, they irritate the eyes, nose, and throat. The presence of considerable rust in a storage tank can also cause loss of viscosity. The practical remedy is a tank treated with a rust preventative.

Contamination. Viscous water made from several viscosity agents may form insoluble precipitates in the presence of certain chemicals. Small quantities of borate added to certain viscous waters can form a rubbery, thick gel that can be extremely troublesome. (See *Inspection of Chemicals*, under *Storage*, Chapter IX.)

Zinc alginate. Viscous water with algin reacts with the zinc of galvanized metal to form a hard insoluble gel (*Ref. 20*). Other chemicals will also form precipitates with viscous water. Some can be controlled to advantage, such as in the production of algin gel, discussed later.

Mixing and handling. All the factors causing loss of viscosity can be overcome by one simple expedient: Do not store viscous water; mix only as needed. This technique is especially applicable for use in ground tanker equipment. At air tanker or helitanker bases viscous water can be stored by taking proper precautions to prevent viscosity loss. Perhaps the most important disadvantage of viscous water to the man who uses it is the added effort required to mix, handle, and use the material. This factor is most important in respect to the use of viscous water in ground tankers. Carefully designed and engineered equipment is needed to mix the material. Bags of dry viscosity agent must be carried on the truck. Time must be taken to mix the solution prior to use, and care must be taken to avoid spillage. Once the fire crew has used viscous water on an extremely hot fire and the men realize how much more quickly and easily they have controlled the fire, they will readily accept the added effort involved in the use of viscous water.

Use of viscous water on actual fires. Experience on 212 fires in California (*Refs. 8 and 21*) showed that viscous water should not be used on all fires. Plain water was often capable of handling the ordinary fire situation, but on other occasions, wet water was preferred. In some instances, viscous water, or gel, was all that was available to the ground crews who would perform the necessary fire control. These experiences indicated that viscous water should not be kept in storage in the fire truck, but should be mixed only when needed. An important adjunct was the development of viscosity agents which would mix 500 gallons of viscous water within several minutes.

The difference between the fire suppressing and retarding abilities of viscous water and plain water is most evident on fires with high rates of heat energy output. Viscous water can be used to good advantage to suppress brush and slash fires. Repeatedly, structural fires, particularly those which are well involved with flame, have been suppressed more quickly and easily with viscous water. Water damage to furniture and clothing was usually less with viscous water. Plain water failed to knock down hot flames consuming a pile of new telephone poles treated with pentachlorophenol. Viscous water stuck to the poles, spread out, and extinguished the flames quickly. Similar experiences were encountered with a fire involving a stockpile of oil barrels, and several fires involving burning tires.

For the general run of small, roadside or back yard debris fires the advantages of viscous water are not required. Most grass fires can also be easily handled with plain water. Fires that are running hot and fast in tall, heavy grass on a day of high-burning index, however, can possibly be attacked to advantage with viscous water. Once the flames have been knocked down, follow-up action may employ plain water or wet water, especially if there is a matted layer of old grass near the ground. Viscous water will not readily penetrate this matted layer and rekindling may occur. If the grass is just one season's growth with no matted layer, viscous water has been found to reduce rekindling.

Where penetration is needed to suppress a fire, plain water or wet water should be used. Occasionally, the burning object or area may be small enough to be completely coated and sealed with a layer of viscous water. Fires in small sawdust piles, baled hay, cotton, or shredded paper, have been extinguished by viscous water in this manner with an overall saving in time, effort, water and damage.

Penetration is often a requisite in mop-up operations, calling for the use of plain water or wet water. This is especially true where the fuel type is matted grass, deep duff, and closely piled debris. Where a majority of the mop-up job involved large chunks, logs, stumps, fence posts, and parts of a structure, viscous water shortened the total time needed to perform the job. The objects must be completely coated and sealed on all sides with viscous water, which is then left to steam, sizzle, and eventually, to dry to a film which will seal the fuel from the air and prevent reignition. Backpack pumps filled with viscous water have been used in such mop-up operations to good advantage. Beds of hot coals can be similarly treated. Apply a heavy layer of viscous water, mixing and stirring at the same time. If a thorough and careful job is done, one operation is all that is necessary. Repeated applications, so often necessary with plain water or wet water, can be eliminated.

Viscous water, when used as a retardant, is far superior to plain water. It has been used successfully to retard, and even suppress, fires burning in grass or light brush as much as two hours after application (*Ref. 17*). The following applications can be used:

1. Pre-treat exposures prior to the arrival of an advancing fire front.
2. Pre-treat snags and low-hanging branches of trees just ahead of a back-firing operation.
3. Treat fuels along a back-fire line on the side opposite the fuels to be ignited, thereby effectively widening the back-fire line and possibly reducing time needed to physically remove fuel from what otherwise would have to be a wider line. Viscous water has been used successfully to treat structures, piles of hay, and other objects for protection from ignition by radiant heat from an adjacent burning building. In several cases, the crews were satisfied that they could not have achieved such success with plain water.

Viscosity agents used. Currently, two viscosity agents are being used to make viscous water. These two, algin and CMC (sodium carboxymethylcellulose), most closely meet the following desired requirements for use in ground tankers:

1. Small quantity of dry powder necessary for batch mix.
2. Adequate batch mix in a few minutes.
3. Near maximum viscosity reached in the batch mix period.
4. Viscosity retained indefinitely, assuming no contamination or spoilage.
5. Reasonable cost.
6. Nontoxic.
7. Noncorrosive.
8. Easily pumped.
9. Good stream pattern from the nozzle.
10. Good coverage on fuels.

Algin (Sodium Alginate)

Description. Algin (*Ref. 8*) is a product of the giant kelp beds of warm ocean waters. It resembles finely ground corn meal in color and texture. Algin is commercially available. (See Table 3, Appendix, for commercial sources.)

Mixing ratio. Five to seven pounds of one commercial powder are required for 100 gallons. Manufacturers' recommendations should be followed in mixing. Temperature is known to be a factor in the amount of material used. Day and night temperature variations will also cause rather abrupt changes in viscosity readings. In test work, the water is thickened to the consistency of light motor oil with a range of 40 to 200 centipoise (measured with a Brookfield Viscometer, No. 2 spindle; 60 rpm, 38 to 81 Marsh funnel seconds). Below this range this viscous water does not build up well on vegetation, and above this point handling difficulties may occur.

The carrier dissolves quite readily in cold water when added to a batch under maximum agitation. This viscous water can be mixed easily in side-entry batch mixers. (See *Equipment for Mixing Chemicals*, Chapter VI.) When algin-thickened water is used in a fire tanker for ground application, the dry chemical is introduced by a simple injector (eductor) system (*Ref. 8*).

Costs. At $1.00 per pound, alginate-water costs from 5 to 7 cents per gallon. This product is packaged for ground tanker and helicopter use.

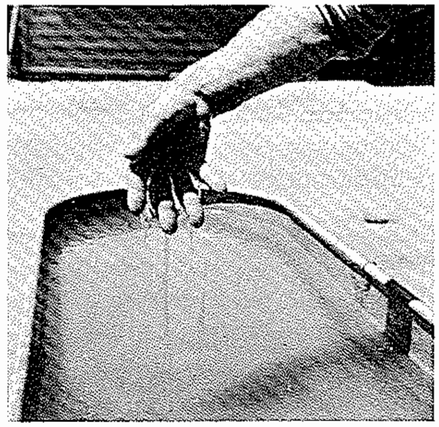

Figure 1. Viscous algin water flows off a crewman's hand as a thin-flowing gel.

Desirable characteristics.

1. Reduces rekindling
2. Adheres to forest cover well
3. Sticks to vertical surfaces well
4. Inexpensive
5. Small amount required per gallon of solution
6. Weight increase negligible
7. Mixes readily
8. Abrasion and erosion negligible
9. Nontoxic
10. Less runoff and waste
11. Compatible with some other good chemical salts
12. Converts to a gel by the addition of calcium chloride.

Undesirable characteristics.

1. Tendency to spoil easily
2. Slight tendency to plug and gum equipment and plumbing
3. Corrosive, especially to galvanizing
4. Contamination likely with other chemicals such as borate
5. Not efficient for mop-up work where penetration is needed
6. Very slick and slippery.

CMC (Sodium Carboxymethylcellulose)

Description. CMC is used as a 100-mesh granular powder, light cream to white in color (*Ref. 22*). Like algin, CMC is an efficient water thickener with film-forming characteristics. This product is physiologically inert, both externally and internally. It is commonly used in the food, pharmaceutical, textile, and cosmetics industries.

Mixing ratio. For a 500-gallon tanker load, 20 pounds of the thickening powder are used. A 0.5 percent solution of CMC-7HP is most commonly used. (See Table 3, Appendix, for commercial sources.) This results in a viscosity range of 200 to 400 centipoise (measured with a Brookfield Viscometer, No. 2 spindle; 60 rpm), which has been about right for most temperatures. Viscosity is higher at low temperatures and lower in warm to hotter locations. These gum solutions are not altered permanently by freezing. The pH range will also influence mixing requirements somewhat with maximum viscosities about pH7 to 9. Changes are not too drastic between pH5 to 11.

The powder is most commonly introduced into water by the injector (eductor) system which provides an even flow and proper separation as the particles come in contact with the water. Mixing by mechanical agitation should take place under high shear to avoid "clumping and fish eyes."

Costs. CMC is available in 50-pound bags for about 63 cents a pound and, as mixed, costs about 3 cents per gallon exclusive of transportation costs.

Spoilage. One hundred parts per million of formaldehyde have been recommended to prevent spoilage. This treatment has not been entirely satisfactory. First evidence of spoilage has been a noticeable loss in viscosity. This has led to the use of the Marsh funnel for daily viscosity checks. Some synthetic inorganic formulas may not be as subject to this spoilage problem.

One brand of CMC has been mixed with DAP crystals for greater effectiveness. Generally, this results in a lowering of viscosity, and in principle, the mix ratio can be raised to about 8 pounds of thickener to 100 gallons of water to compensate for the change. (See *Viscous DAP Combinations*, page 15.)

The lower cost, and weight factor, make CMC thickened water attractive.

Desirable characteristics.

1. Reduces rekindling
2. Adheres to forest cover well.
3. Sticks to vertical surfaces well
4. Inexpensive
5. Small amount required per gallon of solution
6. Weight increase negligible
7. Mixes readily
8. Abrasion and erosion are minor factors.
9. Nontoxic
10. Goes farther than many slurries or solutions
11. Forms a cellophane-like film
12. Little water damage on structural fires.

Undesirable characteristics.

1. Tendency to spoil easily
2. Not efficient for mop-up work where penetration is needed
3. Very slick and slippery, especially on highway surfaces.

Other Viscous Water Agents

Pectate, a synthetic viscosity agent, is another water thickener presently used. To date, its use has been confined to that of a viscosity agent for diammonium phosphate solution (discussed in section *Viscous DAP Combinations*, page 15).

Another manufacturer has produced a synthetic viscosity agent especially for use in fire trucks. It produces good viscosity at a mix ratio of only 0.8 pounds of powder per 100 gallons of water. The powder mixes quite readily. The mixture lacks gel strength, however, and although it clings to fuels readily, it does not set up in a thick protective layer of water. The manufacturer is presently aiming to add gel strength to the formula. The possible advantages are:

1. Very small quantities of dry powder needed
2. No viscosity loss due to bacterial action
3. Low cost.

Unfortunately no dry film forms with this agent. The possibilities are intriguing, however, and future results may make the use of viscous water even more desirable than at present. A large number of other viscosity agents exist for various industrial purposes. Many of these agents have already been screened or tested. Many are lacking in one or more important respects. Only algin and CMC have passed all screening and testing procedures with merit to date (*Ref. 16*).

Gels

Description. Gels are apparently solid, often jelly-like, coagulations formed by adding certain chemicals to water. For forest fire fighting purposes, a "thinner," more fluid state of gel is produced and used which can be pumped and moved more readily through hose. Using a gel permits fire fighters to apply a heavy layer of water on forest fuels, a layer that sticks, clings, and can be built up to as much as 10 to 20 times the thickness of a layer of plain water. This thicker layer of gelled water has an outstanding capability for absorbing heat.

The advantages and disadvantages of gel are virtually the same as those of viscous water, except that they are emphasized. A layer of gel, being thicker, will absorb more heat energy. It sticks and clings more readily, leaves a tougher, dry film, and produces either a straight or spray stream from the nozzle similar to that of viscous water with even less dispersion of water droplets on the straight stream. On the other hand, it penetrates even less than viscous water, is more hazardous to walk on and requires more specialized mixing equipment.

Use on fires. Although the use of gel on forest fires has been limited, there is strong evidence that it can be used equally well as a suppressant or a retardant, in a variety of fire situations. As a suppressant, it has been used from ground tankers on structures, to extinguish the flames and prevent reignition.

As a retardant, gel has been used successfully after 3 hours of drying, to stop an advancing fire front (*Ref. 17*). It has been used to treat snags and slash ahead of a fire (*Refs. 23 and 24*). In protecting exposures, such as a structure, from radiant heat, gel can coat vertical surfaces of all kinds, including window panes. Because of its viscosity, around 2000 centipoises (measured with a Brookfield Viscometer, No. 4 spindle; 60 rpm) and gel strength, it can be built up to fill in openings in lattice work or open mesh up to one inch in width.

Calcium Alginate Gel

Chemical used. At present, only one gel (calcium alginate gel), is used operationally in forest fire fighting. This gel is produced by adding a little calcium chloride solution to algin-thickened water. Variations in the concentrations of either solution will change the gel viscosity and strength. The amount of calcium chloride used is so small and inexpensive that the cost per gallon of the algin gel remains virtually the same as that of the algin-thickened water. Gel for fire trucks is presently mixed in one of two methods, both using an injector system of introducing the calcium chloride solution to the algin-thickened water.

Mixing at the nozzle. One method (*Ref. 8*) uses a back pump arrangement which can be used at the end of any length of hose through which algin-thickened water can be pumped. The calcium chloride solution, contained in a canister on the backpack unit, is introduced to the algin-thickened water in a special mixing chamber which is an integral part of the nozzle. Gel is formed immediately and leaves the nozzle with no additional friction loss or appreciable change in stream pattern. (Refer to *Application of Chemicals from the Ground*, Chapter V.)

Mixing at the pump. Another method of mixing gel for use with fire trucks is to introduce the calcium chloride solution to the algin-thickened water through an injector, just ahead of the suction side of the pump. Experience is limited with this type of equipment on actual fires. (Refer to *Application of Chemicals from the Ground*, Chapter V.)

Batch mixing for air tankers. Gel can be mixed for air tankers in most of the batch mixers described in *Equipment for Mixing Chemicals*, page 37. An exception might be the continuous-flow type. Algin-thickened water is first mixed at the rate of 4.17 pounds per 100 gallons of water. Calcium chloride solution, mixed at the rate of 8 pounds of calcium chloride per 100 gallons of water, is then sprayed slowly into the viscous water at the rate of 5.45 gallons per 100 gallons of viscous water. The gel is then pumped directly into the air tanker or into a temporary storage container. Gel begins to lose its viscosity and gel strength after a day or two in storage and should not be stored beyond that time.

Other Water Carriers

Bentonite Clay (Montmorillonite)

Description. Bentonite clay slurry is another short-term fire retardant in which the effectiveness depends almost wholly upon the amount of water it holds.

The swelling clay acts as a carrier for the water. As such, it could be considered as another method of producing a heavy coat of water. It is effective as a retardant for 1 to 2 hours under normal summer drying conditions.

Many grades of bentonite are mined in several states. The grade required for fighting forest fires is a high sodium swelling-type bentonite (90 barrel yield of mud used in oil well drilling). Both powdered and granular grades are used and are included in the current forest service specification (*Ref. 26*). (See Table 3, Appendix, for commercial sources.) When shipped, bentonite looks like fine flour, with an off-white to a very light brown-to-green cast.

Mixing. Bentonite is added to water at the ratio of about 0.75 pounds per gallon of water. This results in a viscosity range of 1000 to 1200 centipoises (measured with a Brookfield Viscometer, No. 4 spindle; 60 rpm). Mix ratios will vary somewhat depending primarily upon the water used. Hard water reduces the water-holding capacity of the clay. A very thick "pudding-like" consistency is desirable and can be reached by adding additional quantities of bentonite. As much as a pound of bentonite per gallon of water has been used. The pH of water also affects viscosity but can be controlled by the use of dispersants such as SAPP (sodium acid pyrophosphate) and mineral lignin (*Ref. 27*). When properly mixed, bentonite slurry becomes a thick gel which remains in suspension indefinitely. A gallon of the slurry weighs about 8.8 pounds. The mixture will not spoil when stored for long periods of time; however, a thin layer of water should be maintained over the surface of the slurry to prevent drying out, hardening, and cracking. Bentonite can be mixed in most of the batch mixers described in *Equipment for Mixing Chemicals*, page 37.

Dye. Plain bentonite slurry is difficult to see on vegetation after it has been dropped from an air tanker. In order that air tanker pilots can judge subsequent drops, a dye is added. Specifications (*see page 24*) require that Rhodamine B dye, which appears pink on vegetation, be added to the dry bentonite powder (*Ref. 26*).

Cost. Two hundred mesh swelling bentonite with dye at $28.50 per ton, results in a cost of a little over one cent per gallon of slurry.

Desirable characteristics.

1. Holds a high percentage of water for suppressing action
2. Forms a stable gel
3. Comparatively inexpensive
4. Readily available
5. Noncorrosive
6. Nontoxic.

Undesirable characteristics.

1. Effective for only 1 or 2 hours under summer conditions
2. Is not compatible with true fire-retardant salts, such as DAP
3. Water factor is quite a consideration, i.e., if hard or alkaline
4. Slickness presents unusual safety problems on the fireline
5. Abrasive and erosive.

CHAPTER III

FLAME-INHIBITING CHEMICALS
(LONG-TERM RETARDANTS)

Another way of breaking the chain of combustion is by the use of flame-inhibiting chemicals. These chemicals can be applied in either dry form or solution. In this publication we consider only chemicals in water presently used as forest fire retardants or suppressants. These chemicals are depended upon, primarily, for their chemical action in stopping or slowing combustion. There may also be important side effects such as cooling, and smothering, by the formation of a glazed layer over the surface of the fuel.

Borate (Sodium Calcium Borate)

Description. Boric acid and some sodium borate salts have long been used in the paper, paint, and textile industries for their retardant properties. Borate was tested extensively in ground and air tankers in 1955 and 1956 (*Ref. 28*). When processed, borate is a finely ground, pinkish-white powder that can be readily mixed into a stable slurry by any of several mixers. Corrosion to metals is not a problem.

At present, borate and bentonite are the two most widely used forest fire retardants from air tankers, bentonite being the only fully operational short-term retardant, and borate the only fully operational long-term retardant. (See Table 3, Appendix, for commercial sources.)

Abrasion and erosion. Borate is highly abrasive and erosive to pumps and is not recommended for use in ground tankers. At air tanker installations, abrasive resistant parts should be used, where possible, in lieu of brass or other soft materials (Figure 2).

Figure 2. Erosive wear to a brass gate valve. (Arcadia Equipment Development Center Tests)

U.S. Forest Service Photo

Soil sterilization. Borate can be a soil sterilant if applied in heavy enough concentrations. There are many documented cases of soil being sterilized for grass growth for 2 to 3 years. Brush and timber have been killed by heavy concentrations where little or no rain has fallen. In soils having a boron deficiency, plant growth may actually be accelerated by small additions of borate. Slight quantities of boron beyond the optimum, however, cause the opposite reaction. Agricultural crops which are most adversely affected by small quantities of boron beyond the optimum, include: citrus trees, grapes, walnuts, and avocados.

Contamination. Borate can be contaminated by algin, possibly CMC, and other viscosity agents. (See *Inspection of Chemical Batches*, page 58.)

Mixing. Borate is only slightly soluble in water. It can be mixed into a relatively stable slurry with mild thixotropic properties. It is usually mixed at the rate of 4 pounds per gallon of water. This results in a viscosity range of 800 to 1000 centipoises (measured with a Brookfield Viscometer, No. 3 spindle; 60 rpm). This rate means high transportation costs, considerable handling from factory to mixer, and a large amount of warehouse space. The mixed slurry weighs about 10.1 pounds per gallon, highest for any retardant in use operationally or experimentally. It means a much greater weight for a given gallonage of retardant, an important factor in the ability of air tankers to lift a maximum load from an airport, and in their maneuverability while flying low over forest fires. The volume of loads of air tankers operating from high altitude bases is often reduced below the plane's actual tank capacity because of the weight of borate slurry.

Care must be taken not to get too thin a mix as the batch has a critical point around 2.8 pounds per gallon of water, below which the suspended agent will precipitate out. Either a jet injector or a mechanical agitator-type mixer will do a satisfactory job with this material. Avoid overmixing. Properly mixed borate slurry does not require further mixing or recirculation when stored. Good mixtures of borate slurry have been held through winter and used a second season. The freezing point for a 4-pound-per-gallon mix is 0°C, the same as for plain water.

Cost. Borate @ $94 per ton results in a cost of about 15 cents per gallon of slurry, based on pounds of chemical used per gallon of mix. (See Table 2, Appendix.)

Use on forest fires. Borate is used primarily as a fire retardant, although it can also be used satisfactorily as a suppressant. Application is almost exclusively by aircraft. Borate does not need additional coloring since it quickly dries to an easily discernible white color. It adheres, and covers vegetation well (Figure 2). Since borate reacts chemically to break the chain of combustion, its effectiveness as a retardant lasts until it is washed off the fuel by rain. Because of its long-term retardant qualities, borate is most commonly used to treat fuels ahead of, or around, forest fires which must be held for 2 hours or more. This length of time is beyond the ability of single applications of bentonite. It is also used to pre-treat ridges or other planned fire lines far in advance of a fire front so that a continuous line can be established before the arrival of the fire. Borate is quite effective on all but the very hottest fires, but its use has been declining because of the following factors:

1. Initial cost of the material
2. High transportation and handling costs
3. Manpower requirements
4. High weight per gallon of slurry
5. Sterilization of soil.

DAP (Diammonium Phosphate)

Description. Diammonium phosphate (DAP) and monoammonium phosphate (MAP) are chemicals most commonly used as commercial grade agricultural fertilizers. The primary difference lies in the materials and methods of manu-

Figure A. Yellow pine well covered with borate. Angeles N.F.

U.S. Forest Service Photo

facture. What is said here about DAP is largely true of MAP. The grade of DAP presently used is 21–53–0: 21 percent nitrogen, 53 percent phosphorus, and 0 percent potassium. (See Table 3, Appendix, for commercial sources.) The ammonia in the chemical is noticeable when mixing and when applied to a fire. The fumes may be slightly irritating to the eyes and nasal passages of crewmen, but is not toxic or dangerous. DAP treated fuels usually char when exposed to heat, but seldom support flaming combustion (*Ref. 29*). Paper-match stock and building materials are often treated with DAP to conform to the fire-retarding regulations.

Use on fires. DAP has long been recognized for its fire-proofing characteristics (*Ref. 23*). DAP has been tested quite extensively on a variety of forest fuel types since the early 1930's (*Refs. 29, 30 and 31*). It has consistently been placed near the top of lists of good fire retardants. Straight water solutions of DAP are effective on grass and other fine fuels (*Ref. 33 and 34*), but are not adequate on larger fuels.

Effectiveness in stopping or slowing forest fires seems to be related to the amount of DAP that can be placed on the surface of the fuel. If the fuel volume-to-surface area ratio is small (as with grass), a straight water solution of DAP apparently places sufficient amounts of the chemical on the fuel to break the flaming and glowing chains of combustion. If, however, the fuel volume-to-surface area ratio is large, as with the heavier brush species and slash, then a straight water solution of DAP is insufficient. The obvious objective is to place a thicker layer of DAP solution on the fuel so that there is more of the chemical per unit area of the fuel's surface.

Viscous DAP Combinations

Tests. Tests of viscous DAP, both in the laboratory and on natural fuels, support the use of viscous DAP on larger fuels (*Refs. 15, 17, 35, 36 and 37*). Viscosity agents that have been used include algin, CMC, and two kinds of pectate. The results of these preliminary tests indicate that viscous DAP is superior to borate in its ability to stop or retard fires. Because of the bulk of the material that must be handled, it is anticipated that the greatest use of viscous DAP would be from air tankers, although some use could also be made from ground units.

Air drops. Drop patterns from air tankers are excellent, with less side drift than is normally experienced with borate or bentonite. The decrease in drift makes it possible for air tankers to drop from a higher, safer altitude. Viscous DAP solutions are not easily seen on vegetation, especially from the air. To aid air tanker pilots on subsequent drops, the solution should be colored. A dye has not been used that is entirely satisfactory.

Mixing. DAP test solutions have varied from 10 to 40 percent (by weight of water); however, most of the work with viscous DAP has been at 10 to 18 percent (one pound of DAP per gallon of water is 12 percent). The crystals are buff in color and vary in size up to ⅛-inch diameter. They are quite soluble in water but require some agitation to get them into solution. Batch mixers are adequate to perform the job. DAP crystals can usually be pre-mixed with the viscosity agents presently used. This aids in the mixing of the viscous solution in batch mixers. Viscosities are usually in the range of 1000 to 2000 centipoises (measured with a Brookfield Viscometer, No. 4 spindle; 60 rpm).

The DAP-viscosity agent mixtures must be used at the rate of about 0.9 to 1.6 pounds per gallon of water, depending on the viscosity agent used. The most commonly used mixing ratios for algin-DAP and CMC-DAP are 1.5 percent algin and 15 percent DAP, and 1 percent CMC and 10 percent DAP. Percentages are by weight of water. Higher rates of DAP may be desirable to stop or slow down the very hottest fires, increasing the weight of the dry mix needed. The viscous solutions weigh around 9 pounds per gallon, more than bentonite, but considerably less than borate.

Costs. Costs per gallon of viscous DAP mixtures vary from about 12 cents for CMC-DAP, to 16 cents for Pectate-DAP, to 22 cents for algin-DAP. These figures do not include charges for transportation.

Corrosion. The basic problem remaining with DAP is corrosion. Of primary concern are aluminum and copper alloys which are used extensively on air tankers. The extent of the problem, particularly as related to metal strength, is not quite known at present, but research is being conducted. Air tanker operators who use DAP solutions in their aircraft must recognize the corrosion problem by making regular washdowns, thorough inspections, and necessary parts replacements. The use of DAP must be limited to aircraft operations where this highly supervised type of maintenance will be made without fail.

Pectate-DAP

Description. Pectate-DAP is a combination of ammonium pectate, versene — a dispersing agent, diammonium phosphate, and a corrosion inhibitor. (See Table 3, Appendix, for commercial sources.) The pectate creates a viscous water carrier for the DAP in a manner similar to algin-DAP. This pectate gives the mixture a dark olive color.

Mixing. Pectate-DAP is mixed at the ratio of 1.6 pounds per gallon of water. The mixture weighs about 9 pounds per gallon. The viscosity for application should be about 1200 centipoises (measured with a Brookfield Viscometer, No. 4 spindle; 60 rpm). Viscosity is affected both by the temperature of the water source and the mixing time. A water temperature of 83°F will yield the maximum viscosity of about 1200 centipoises. Viscosity decreases when the water temperature varies either above or below 83°F. Mixing to date has been done by mechanical agitation. Rapid dispersion is the basic requirement of this product but best results have been obtained using a high shear impeller similar to Figure 25. Limited tests indicate maximum viscosity is obtained in less than one minute of mixing with a good batch mixer and decreases as mixing is continued. The proper mixture has a consistency similar to catchup.

Costs. Pectate-DAP at a cost of $220 per ton or 11 cents per pound, results in a cost per gallon of chemical mixture of about 16 cents (based on pounds of chemical required per gallon mix [See Table 2, Appendix]), not including transportation costs.

Corrosion. DAP is normally corrosive to aluminum and copper alloys. One chemical company has indicated that the ammonium pectate appears to act as a natural inhibitor for DAP with copper alloys. Aluminum alloys still require an inhibitor to be added to the mixture such that the inhibiting characteristics of the pectate with copper alloys is not affected. These corrosion problems are under investigation and have not been resolved, particularly as related to stress corrosion in structural members of aircraft.

General. DAP is an excellent long-term fire retardant and the pectate as a viscous water carrier increases its ability to coat fuels. Testing has been mostly on laboratory, brush, and slash plots and results have shown it to rank very high in fire-retardant effectiveness (*Refs. 15 and 37*). Limited operational testing has been done with air tankers. The requirement of 960 pounds of mix to mix 600 gallons of chemical will limit the use of this product to air tankers. Mixing has not been tried in an eductor-type mixer as commonly used on fire trucks. If this proves successful, ground application might be extended to fire trucks.

Attapulgite Clay — Ammonium Sulphate

Description. Ammonium sulphate is another chemical long recognized for its fire-retarding ability (*Ref. 29*). One commercially formulated fire retardant includes ammonium sulphate as its fire-retarding chemical and uses attapulgite clay as the carrier, or viscosity agent. Iron oxide is added to provide a brick-red coloring on vegetation. (See Table 3, Appendix, for commercial sources.) The ammonium sulphate is corrosive to copper, brass, and mild steel, without inhibitors. It should not give difficulty with aluminum or its alloys.

Mixing. This commercial product is mixed at the rate of about 2.8 pounds per gallon of water. The viscosity usually varies between 1000 and 1500 centipoises (measured with a Brookfield Viscometer, No. 4 spindle; 60 rpm). The mixed slurry weighs 9.5 pounds per gallon. These figures begin to approach those of borate and affect transportation costs and the amount of handling and warehousing needed in all operations. Logistics will probably limit its main use to air tankers and helitankers. High-shear impellers are required to mix attapulgite clay-ammonium sulphate in batch mixers. Once mixed, it remains in a stable slurry.

Cost. At $100 per ton, this material costs 12 cents per gallon of slurry, based on pounds of chemical required per gallon of mix. (See Table 2, Appendix.)

Use on fires. This mixture drops in a pattern similar to other viscous materials with somewhat less side drift than bentonite or borate. It coats fuels well, and its red color makes it readily seen from the air. Testing has been mostly on laboratory, brush, and slash plots. All these tests have shown this mixture to rank with viscous DAP, and above borate, in its fire-retarding effectiveness (*Refs. 15 and 37*).

Other Flame-Inhibiting Chemicals

The U. S. Forest Service established a rather lengthy list of satisfactory chemical fire retardants during its tests of the 1930's (*Ref. 29*). Similar work was done in Canada (*Ref. 41*). The Forest Products Laboratory and various Experiment Stations continue to investigate the characteristics of these and other chemicals, often in close cooperation with other forest fire control agencies (*Ref. 37*). The National Research Council of Canada also conducts research on fire chemicals. The National Academy of Sciences sponsors many studies of all kinds (*Ref. 38*). Universities and other institutions, world-wide, continue to pursue the study of fire and its control (*Refs. 11 and 40*).

Most studies of fire are related to the chemical reaction of combustion and seek ways to break the chain reaction of the process by inhibiting the propagation of flames or the glowing phase. The widespread use of chemicals in forest fire fighting is relatively new, and as more is known about their use new and more effective chemicals will undoubtedly be found.

CHAPTER IV

EFFECTS OF FOREST FIRE FIGHTING CHEMICALS

Effects of Chemicals on Fires

Application rates. Studies of the effect of chemicals on forest, brush and grass fires have not progressed to where it is possible to prescribe a specific quantity of any particular chemical on fuels by type. Measured concentrations of retardants dropped from air tankers have been reported varying from 0.3 (*Ref. 39*) to 25 (*Ref. 23*) gallons per 100 square feet of ground surface. The 0.3-gallon concentration was effective on a particular light fuel type while the 25-gallon concentration was not excessive on a heavier fuel.

A rule of thumb drop has been 2 to 4 gallons per hundred square feet, for most chemicals and fuel types. The majority of aircraft drops fall in this range, although some larger craft may produce much heavier concentrations in the center of the drop pattern. A 2-gallon rate would produce a uniform coverage 1/32-inch in depth. In light fuel it appears that this is entirely adequate, but where good penetration of tree or large brush canopies is necessary, dispersion may reduce aerial fuel coverage to coatings much less than 1/32-inch.

Research objective. Much research remains to be done in order to answer the following questions:

1. What chemical?
2. Where?
3. In what concentration?
4. In what physical form?

These questions apply to the various fire situations and fuel types. The objective is to reach a state of knowledge where the fire manager can prescribe the chemical tool needed to perform a specific job of fire control.

Select the right chemical. To a certain degree this prescription procedure is followed in some locations today. Air tankers are loaded with bentonite slurry for initial attack. After the first drops, the fire boss will decide whether or not to continue subsequent drops with the short-term retardant (bentonite), or to switch to the long-term retardant (borate). Addition of viscous DAP to his arsenal of fire fighting tools would provide an even wider latitude of choice for the fire boss. He could prescribe the concentration of DAP most likely to control the fire: 10 percent, 15 percent, or 20 percent. With the present level of knowledge, the following generalizations can probably be stated.

Use of water and chemicals in fire apparatus.

1. The ordinary day-to-day fire: plain water will usually perform the required job of fire control.
2. Where penetration is needed: wet water is probably superior to any other form of water.
3. For the hottest brush and slash fires: the use of viscous water or gel seems to be indicated.
4. Fires involving oil-covered or impregnated fuels: viscous water or gel seems to be best.
5. Grass fires: plain water, or in some cases where there is much matted material, wet water would be best.
6. Structures: if the fire is confined to one room, plain water in the form of fog may do the job. If the building is quite fully involved, or if there are many outside openings which would prevent the confinement of water vapor, then viscous water or gel could produce the best effect in controlling the fire.

Use of water and chemicals in air tankers and helitankers.

1. Ordinary grass, brush, or timber fire of low heat-intensity: bentonite or gel will usually perform the needed job of fire control.

2. High heat-intensity fires, low fuel volume: borate or perhaps one of the newer chemicals such as diammonium phosphate in straight water solution may be needed.

3. High heat-intensity fires, high fuel volume: borate or viscous diammonium phosphate or ammonium sulphate should have the best effects in these situations.

4. Where penetration is needed: the problem of penetration through dense canopies of tall brush or timber remains a problem. There presently seems to be a variance of opinion as to what chemical or material will do the best job. Studies are needed on this problem to determine which fire retardants will have the best effect on fires when penetration of air drops is needed.

Effects of Some Chemicals on Vegetation

Soil sterility. There are reports of soil sterility from borate use in grass, brush, and timber types. Such damage is usually limited to the center of a single drop pattern or to those areas where repeated drops have overlapped each other, resulting in heavy borate concentrations. The time of year and the concentrations of boron ions already in the soil undoubtedly affect the degree of soil sterility caused by borate. The sterility effect may last several years before plant growth resumes in extremely low rainfall areas. To counter these cases, technicians have noted new grass growth pushing up through heavy accumulations of borate slurry around some mixing areas. Application rates under 3 gallons per 100 square feet ordinarily is not harmful under average rainfall conditions (*Ref. 13*). Application of borate on croplands or near valuable landscaping plants should be avoided.

Soil fertility. The nitrogen available in the ammonia compounds, such as monoammonium phosphate, diammonium phosphate, and ammonium sulphate, comprises an ideal chemical fertilizer. The primary use of these chemicals is specifically for this purpose. DAP has been suggested as a pre-treatment solution around fence posts and utility poles. If such treatment were used year after year, heavier annual growth might be expected which possibly could complicate prescribed burning techniques over a period of several years. If applied in too heavy concentrations these chemicals can temporarily desiccate vegetation. This phenomenon is observed when DAP is applied too heavily on green lawns. The grass is temporarily "burned." To date, there are no reports of this problem with brush or timber species.

Effects of Some Chemicals on Humans and Animals

Dermal toxicity. Dermal toxicity does not appear to be a problem with borate or the bentonites. Ammonia fumes are noticeable when handling MAP and DAP and might be somewhat irritating to a nozzle man in ground tanker application. One experimental technician commented about the "burning sensation" which resulted when the phosphate solution got into cuts on hands and arms. Any discomfort experienced was only temporary and none of these characteristics experienced should be physically harmful.

Domestic water supplies. Boron in drinking water is not regarded as a hazard to human beings. Goudy and others have reported that boron concentrations up to 30 parts per million are not harmful in drinking water. While traces of boron are necessary for good plant growth, concentrations of free boron in water above 2 to 5 parts per million may be injurious to most plants, and concentrations above 0.5 ppm may be injurious to many (*Ref. 13*).

Organic gels. As a safety precaution crews working with retardants in the viscous water class should be conscious of the handling aspects of this assignment. Actually, some thickened with organic compounds or products become ideal cultures for bacteria and as such could be harmful. While organic contaminators might be usable on the fireline they could cause illness. Formaldehydes have been used as inhibitors in this general class of agents. Some crewmen handling

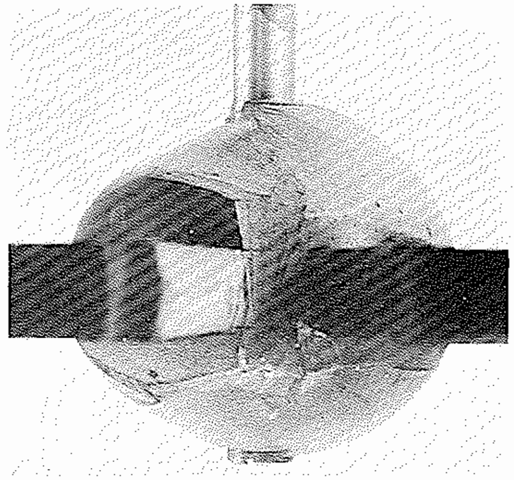

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Figure 3. Abrasive 200-mesh bentonite wear to a round, disc-type meter part. Inspection was made after pumping 300,000 gallons at 200 gpm. (Arcadia Equipment Development Center tests — 1960.)

these thickened gels have been allergic to paraformaldehydes and have been subject to symptoms quite similar to a common cold, including congestion in the nasal passages, plugged ears, and watery eyes.

If plumbing and valving systems are carefully laid out around mixing areas there should be no possibility of contamination back into domestic water supply lines. However, since more and different chemicals are being used in ground tanker systems, crews should be cautioned against the personal use of water in tankers, even though they may consider it safe for drinking.

Effects of Some Chemicals on Equipment

Abrasion. In the normal operation of pumps, meters, and other fluid handling equipment, water provides lubrication. When a slurry, such as bentonite, borate, or attapulgite clay-ammonium sulphate is substituted, the fluid becomes a grind-

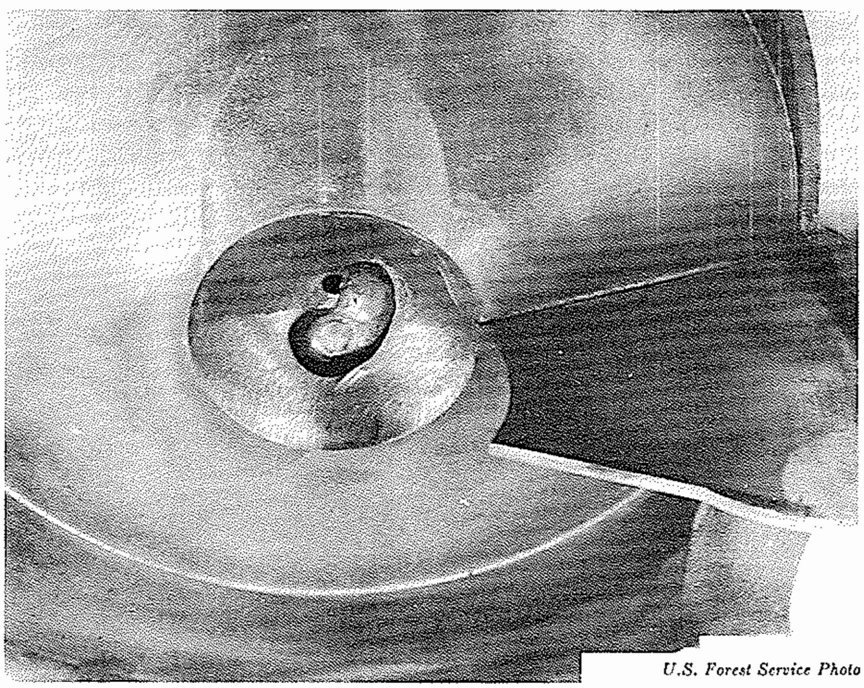

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Figure 4. Abrasive retardant damage to a pivot point in a disc-type meter assembly. Note extreme off-center wear. (Arcadia Equipment Development Center tests — 1960.)

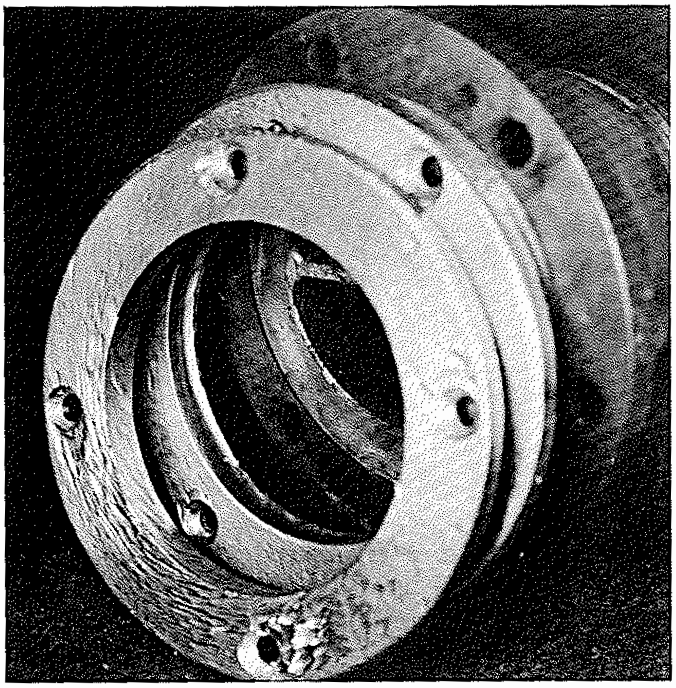

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Figure 5. Borate erosion to parts of a pump. (Arcadia Equipment Development Center tests — 1957.)

ing compound. It can quickly damage rubbing parts — cylinders, gears, and seals. Brass and aluminum are highly susceptible to rapid wear — stellite, or aluminum oxide in ceramic form, are not. Centrifugal transfer pumps are most abrasive resistant because of few rubbing parts. Mechanical shaft seals must have abrasive-resistant materials on the wearing faces. Where shaft packing is used the rubbing surface should be hard chrome plated.

Erosion. Erosion is the wearing away of solid material by impingement of a fluid, as water washes away a hillside. In plumbing and pumping equipment, at fire hose pressures, this action normally goes unnoticed until suspended particles, such as sand, borate or bentonite are carried by the fluid. Then as each particle strikes a metal surface it tends to gouge out a small piece. At high velocities it becomes serious and is most pronounced around abrupt turns, through valves, or across areas of high differential pressure in pumps. Soft metals — brass or aluminum — are very susceptible to erosion. Ceramic aluminum oxide or hard

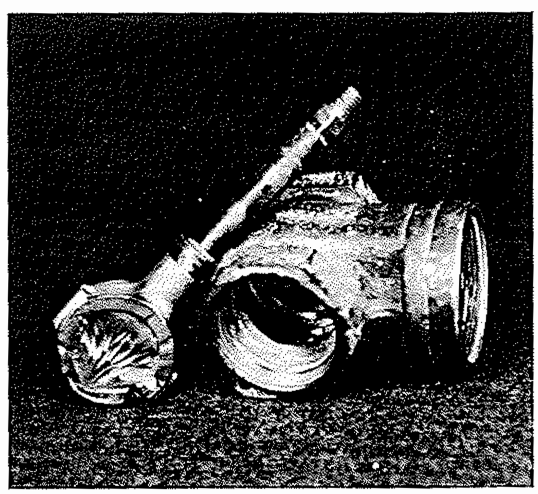

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Figure 6. Erosion by impingement to the gate of an ordinary brass valve. (Arcadia Equipment Development Center borate tests.)

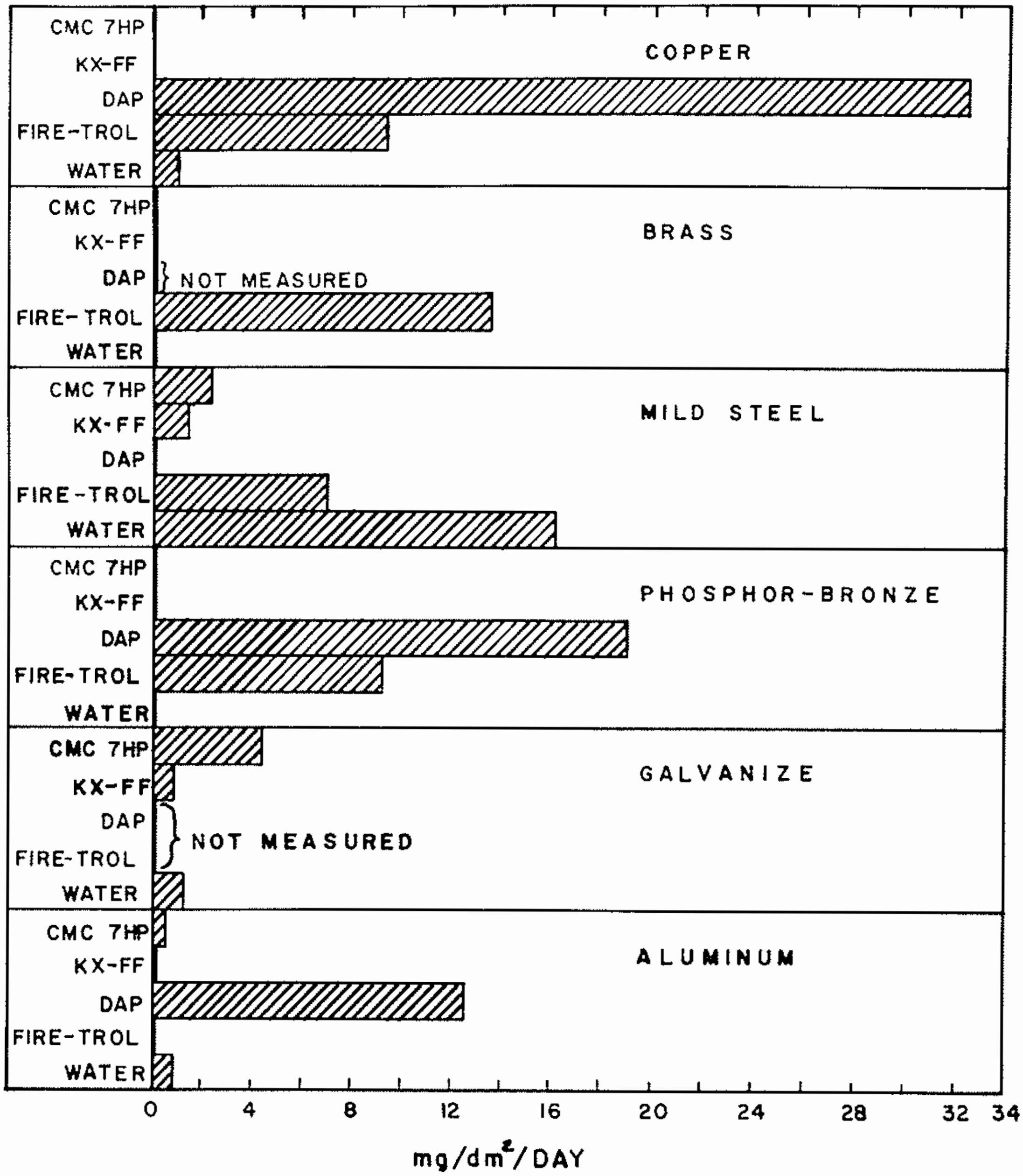

Figure 7. Weight loss due to corrosion during a 48-hour test using the total immersion procedures described in the Chemical Engineer's Handbook (Perry, 1950). (Information supplied by Pacific Southwest Forest and Range Experiment Station, Berkeley, California.)

chrome over hard steel (to prevent peening) drastically reduces this action. At transfer pressures of less than 100 psi, cast iron or steel will give satisfactory life but brass or aluminum parts should be avoided.

Corrosion. The chemical attack of a fire chemical on metal can lead to serious consequences. It can weaken structural members and cause failure or it can corrode moving parts, fouling their action.

The localized attack on structural members, introducing high stress points and possible failure, is recognized, but data is not available. Weight loss measurements have been made and do show some areas where trouble may develop. Figure 7 indicates some chemicals tested. Borate and bentonite are not included but neither has shown a tendency to attack the metals listed. In fact, in some cases they act as a preservative.

Some trouble has developed not predicted by the weight loss studies. Algin-thickened water showed a rather low weight loss, in fact less than water, but in practice it removes the coating from a galvanized tank or pipe. In the process it forms zinc alginate, which may cling to the surface or be precipitated. The viscosity of the remaining fluid is reduced to a useless level. Tank coating can reduce this problem — the most suitable type is uncertain.

Effects of Some Dyes

Dyes are a proven necessity in aerial retardant application. This is especially true of the clear viscous water combinations and of the soil-like clays which blend in with dark forest-cover types and the ground.

Borate has a characteristic light-rose hue as it cascades through the air. It is light enough that it forms a good contrast on dark vegetation. The drop pattern becomes even more visible and conspicuous as the application dries out.

Bentonite drops have been very difficult for pilots to see on forest backgrounds. Since bentonite holds great quantities of water and remains wet for several hours the problem is further complicated. To solve this problem a Rhodamine B aniline dye is included in dry crystal form in each bag furnished under Forest Service specifications. (Current bentonite specification calls for "21 grams of the aniline dye Rhodamine B in regular concentration or a proportionate lesser amount of a concentrate [i.e., 4.2 grams of Rhodamine B 500 percent concentrate]" in each 50-pound bag. The dye crystals and clay need not be intermixed.) Much of the bentonite furnished to various agencies comes from oil well stock and does not have dye in it. Problems resulting from the use of this and similar dyes have been of a very minor nature as related to any contact with the skin, or with clothing, or on painted surfaces. The dyes are the same as those used

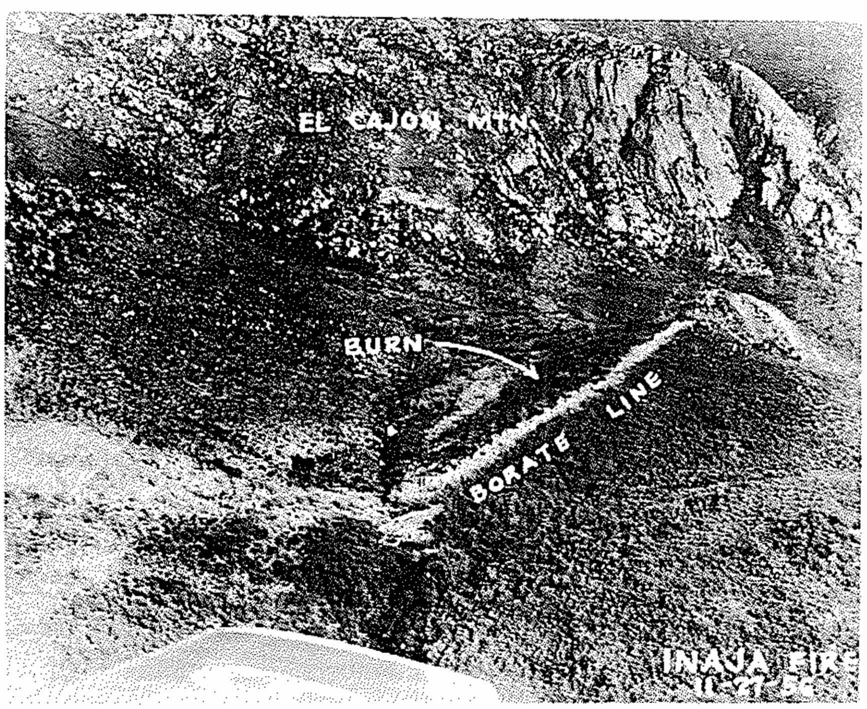

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Figure 8. Borate line laid by Air Tankers on El Cajon Mt., Inaja fire, November 27, 1956, Cleveland N. F., San Diego, California.

in the textile industries and are set in garments by heat. It has been found that if the hands or spots on clothing are first washed in cold tap water no permanent stain results.

Dyes in viscous water combinations have caused minor problems in ground tanker equipment. This has been noted under dripping live hose reel nozzles where some discoloration and lacquer deterioration has resulted. Dyes in such combination also shortens the life and usefulness of waxed finishes on carefully maintained fire equipment.

Ordinary household blueing has been used on a limited basis for an algin dye. It seems reasonable that as other chemicals prove themselves and are added to the operational list that a further need may arise for additional color coding. Further study and selection should dictate the types of dyes used, the most effective colors, and the direction of the code pattern. The fireman on the line should be able to determine by color just what suppressant or retardant is being applied, or has been laid down, independent of any other means of message communication.

CHAPTER V

APPLICATION OF CHEMICALS FROM THE GROUND

It should be noted that ground application of viscous water and gels is currently in a period of very rapid development. Three years of development work has produced the three generations of equipment outlined below.

Requirements. Ground application equipment should be capable of quickly mixing any chemical or combinations of chemicals normally intended for use and to apply them so that they will either cling to aerial foliage or penetrate to the ground as required. When applying chemicals with backpack units accessory equipment may be necessary for mixing.

The equipment should be convenient and easy to use and require a minimum of skill. It should be easy to move to point of application by conventional methods. It must be safe — excessive high lifting of chemicals avoided. Design should consider spills and their effect on safety.

Tanker equipment. Most ground application of retardants to date has been done by using conventional fire tankers with some modification to the unit to provide for introduction of chemicals. Figure 9 below shows an installation on a demonstration truck. An injector recirculation system is used here and gives good results with either algin or CMC.

This truck (Figure 9) was outfitted with special equipment to handle calcium chloride for producing algin gel. A small tank was installed in the truck and filled with 37 percent solution of calcium chloride. It in turn was pumped by a separate small pump through a second swivel joint on the hose reel, and then through a small hose parallel to the 1½-inch main hose to the nozzle. The two hoses were taped together at 2- or 3-foot intervals so they could be reeled or handled as one. By a special adjustable proportioner, the nozzle man could adjust the flow of calcium chloride to produce any degree of viscosity needed.

Another early method of introducing calcium chloride at the nozzle was with a pressurized backpack (Figure 10). The nozzle man carried the calcium chloride unit; therefore, no second hose was required, and it could be used at the

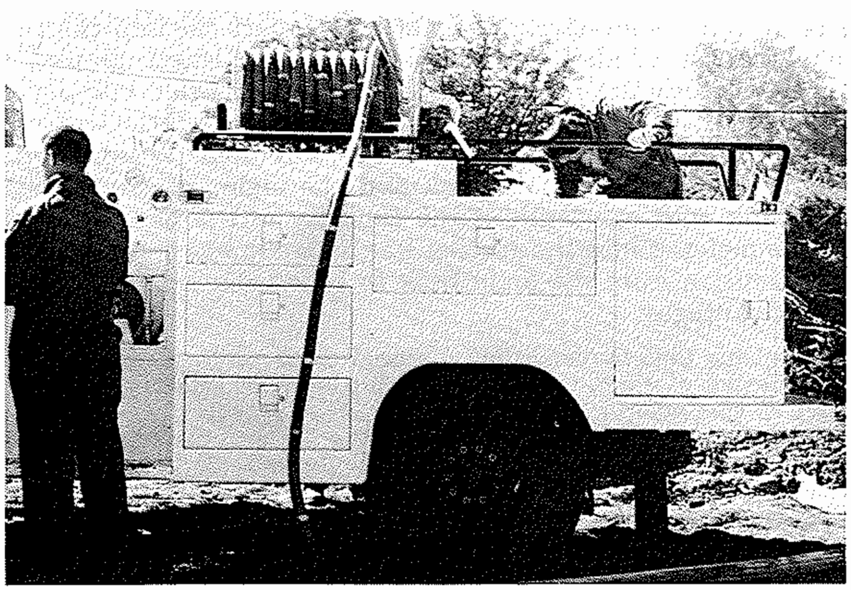

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Figure 9. Ground application demonstration tanker.

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Figure 10. Pressurized calcium chloride backpack test unit.

end of a long hose lay. However, use was restricted to 150 gallons of algin. If a greater quantity of gel was required, it was necessary for the nozzle man to return to the truck for a calcium chloride refill, and much of the advantage was lost for such refilling is time consuming.

A method developed late in 1961 for producing algin gel has proven satisfactory. The Washington State Department of Natural Resources developed an injector (Figure 11) to be used on the inlet of a 1½-inch positive displacement pump (Figure 12). A standard McDaniels tee has proven a satisfactory substitute for this shop-built unit. This method has also been adapted to 1-inch positive displacement pumps. Calcium chloride solution was aspirated into the algin-thickened water at the suction side of the pump. The ratio of chemicals was changed to improve operation. Algin was mixed at 20 pounds per 500 gallons of water in the main tank of the truck. Calcium chloride was mixed in a separate tank at the rate of 6 pounds to 50 gallons of water. (The proportion of algin to calcium chloride for producing gel is subject to change by the algin manufacturer.) By the use of a valve to meter the calcium chloride flow, the two were blended at the rate of 10 parts algin-thickened water to 1 part calcium chloride solution.

To make the use of algin gel more practical in larger ground units (500 gal. +), the above procedure for introducing calcium chloride into algin-thickened water at the pump inlet was modified by the Division of Fire Control, State Department of Natural Resources, P.O. Box 110, Olympia, Washington. Calcium chloride was dissolved in the main tank and the algin, in concentrate, was put into a second tank with one-tenth of the capacity of the main tank. This algin concentrate was metered into the suction line where it was combined with the calcium chloride solution from the main tank to produce a gel. This procedure has the following advantages:

1. Reduces mixing time by employing a special mixer which meters the proper amount of powder to each gallon of water, thereby directly producing 60 gallons of concentrate in about 2 minutes with a 30 gpm pump.
2. Eliminates the problem of spoilage by reducing the quantity of organic solution to an amount practical to preserve.
3. Eliminates problems associated with deterioration due to rusty or galvanized tanks.
4. Provides operator with complete latitude in choice of whether or not to use the retardant. He may change from water to algin gel and back to water at will.
5. Operator may vary the type of gel to suit suppression needs.
6. Simplifies preparation of solutions because algin powder does not need to be measured, this being accomplished automatically by the mixer.

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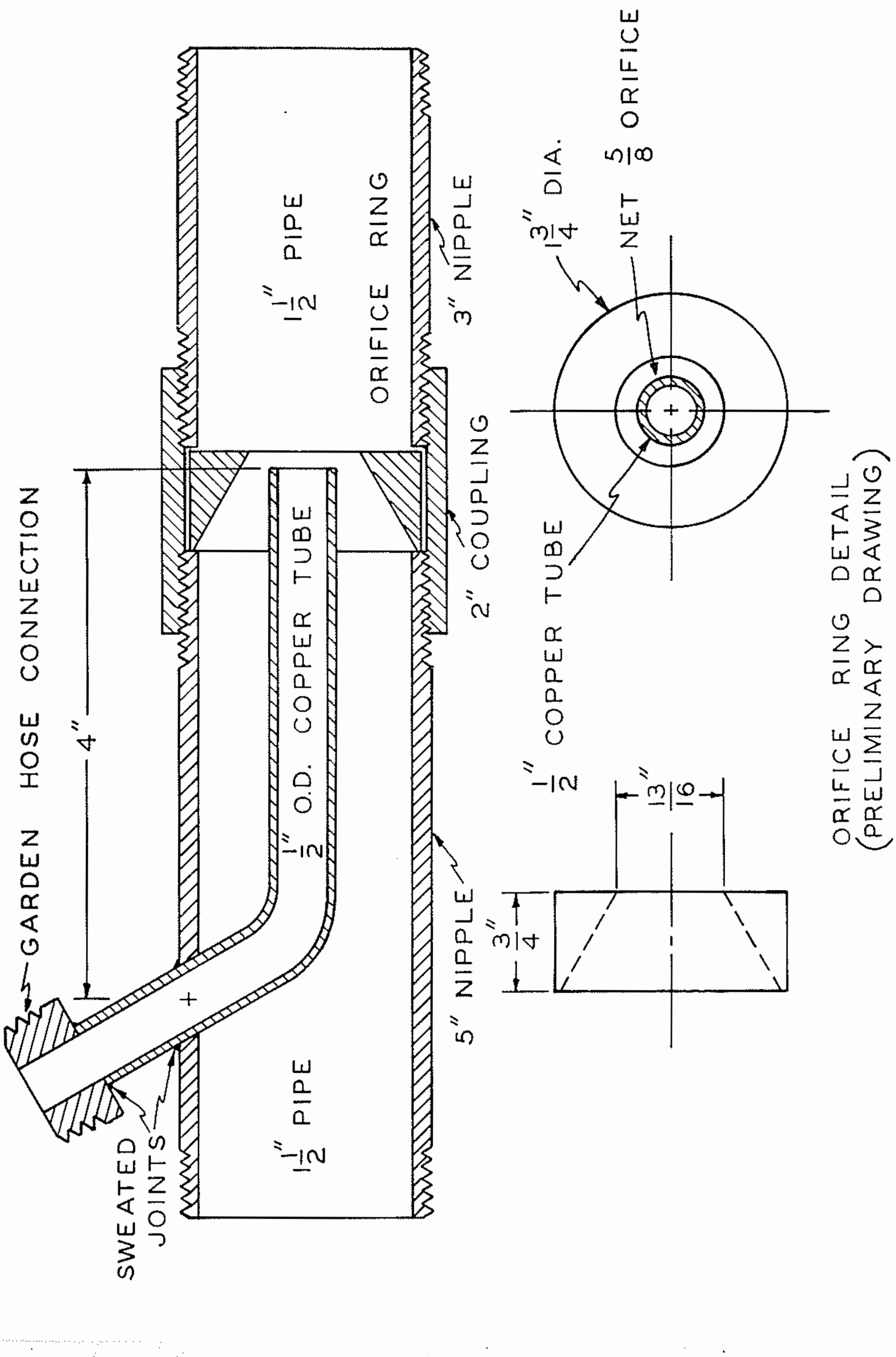
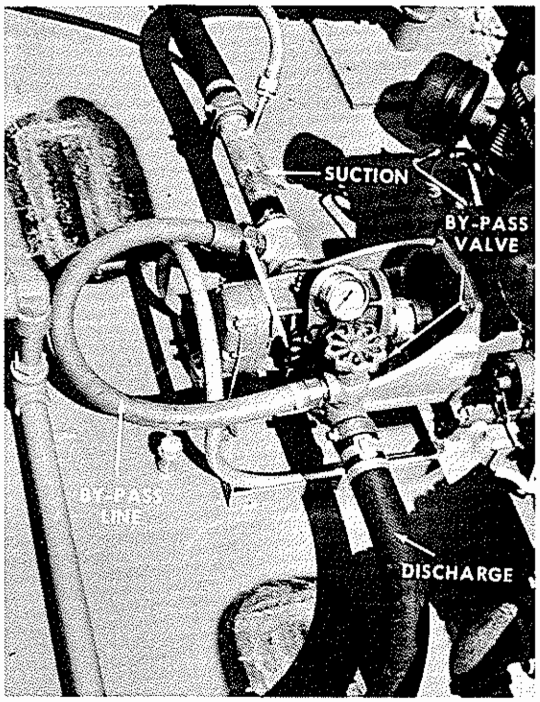


Figure 11. Calcium chloride injector.



Washington State Department of Natural Resources Photo

Figure 12. 1½-inch positive displacement pump.

Preparation and handling of the algin concentrate is the key to success with this system. When prepared at concentrations of 3 to 4 percent, algin solutions reach viscosities in excess of 30,000 centipoises. This honeylike solution cannot be pumped at high flow rates and, therefore, cannot be prepared by conventional recirculation processes, but must be blended in one pass through the mixer.

The following two controlling conditions have been adopted as design limitations:

1. The design should be such that rate of fluid flow is readily determined.
2. Dry powder should not contact a wetted metal surface.

The pressurized orifice was selected as the most suitable method of measuring flow rate. In order to isolate the dry powder the mixer (Figure 13) was designed with three concentric cylinders, the outermost carrying water, the next, air and the core, powder. The powder at the end of the center tube is thereby shielded with air until incorporated in the water stream.

With a pressure gage installed on the mixer, the flow can be determined and adjusted to any rate desired. Powder flow rate is controlled by installing an orifice at the base of the funnel.

The length of the outflow pipe below the mixer should not be less than 12 inches and should be preferably 14 inches for proper operation. The concentric tubes within the mixer must be perfectly centered for proper operation. If the rate of powder flow is to be consistent, an orifice must be used, otherwise the device becomes position sensitive due to powder friction when running the tube full.

The truck is piped in accordance with Figure 14. A 55-gallon drum is used for the algin concentrate tank. This drum should have a removable head to facilitate cleaning and servicing the container. The plumbing leading to the main suction line should not be less than 1½-inch size to permit flow of highly viscous fluids. The concentrate tank must be located so as to provide for gravity flow to the main suction line.

Some units are using 1-inch McDaniels tees on 1-inch pumps and 1¼-inch tees on 1½-inch pumps. The 1-inch tees are bored and tapped to 1¼-inch on the large side outlet to receive the concentrate line. The small side outlet is fitted with a ⅜-inch needle valve and check valve. This provides for addition of a third

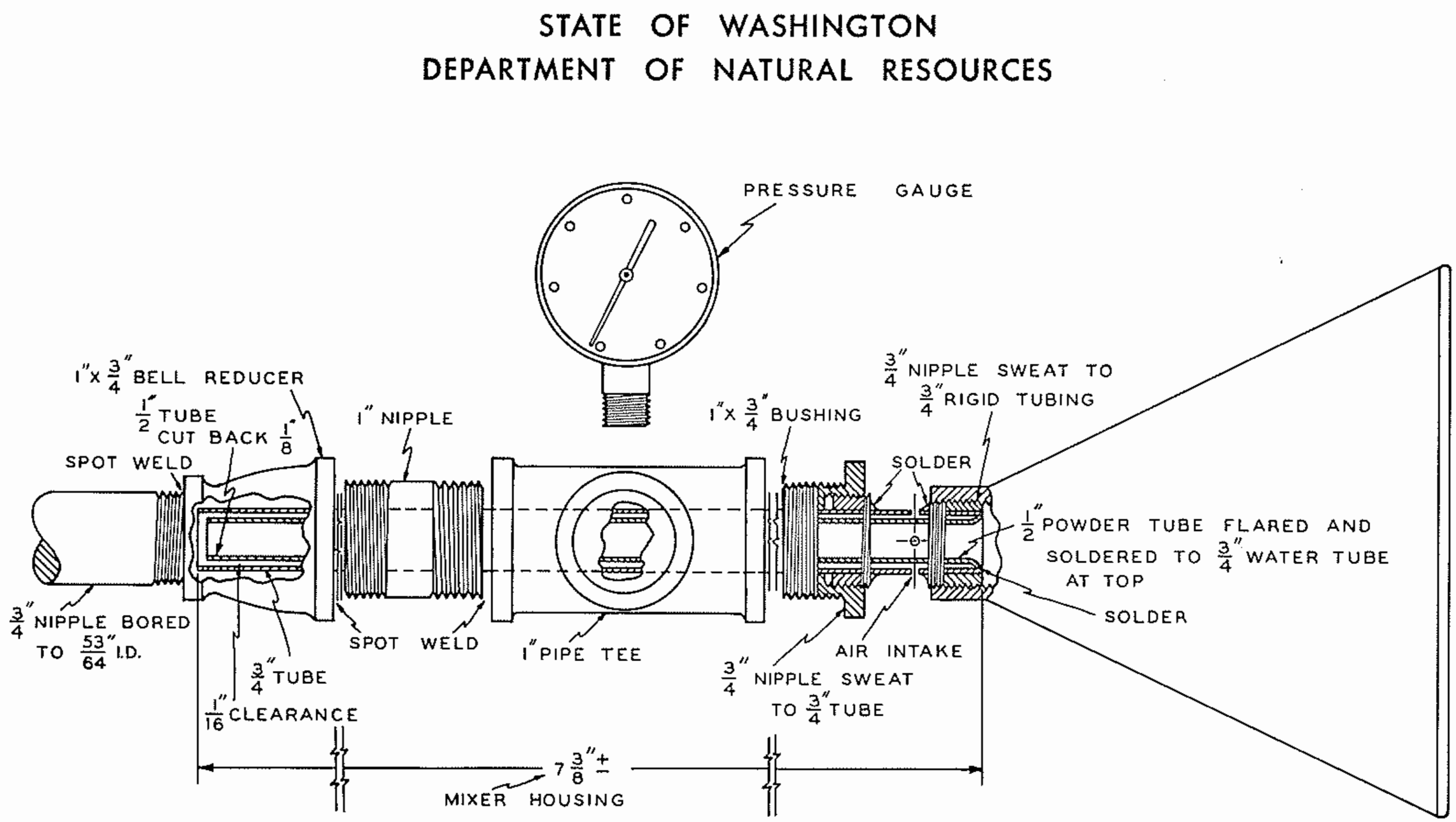
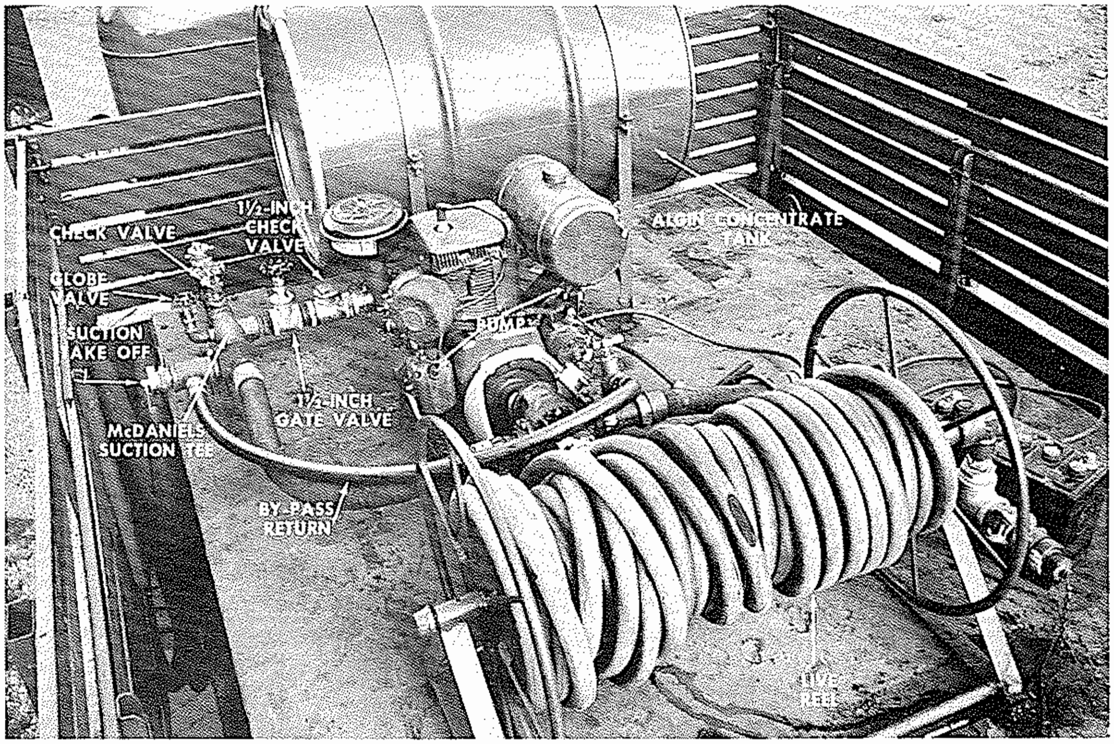


Figure 13. New type inductor mixer having 3 concentric cylinders, the outermost carrying water, the next, air and the core, powder.



Washington State Division of Natural Resources Photo

Figure 14.

chemical, if desired. For example, calcium chloride solution could be introduced here rather than being mixed in the main tank.

Although a few operational problems have been encountered, the above units have generally worked well. By using this system, algin gel has been pumped up to 1100 feet through 1½-inch fire hose.

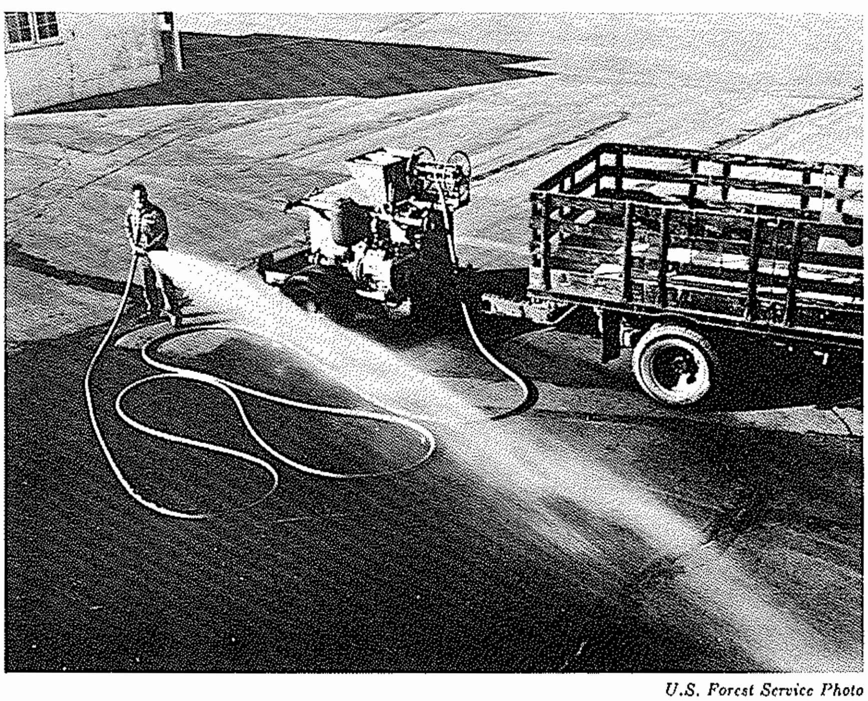


Figure 15. Slip-on tanker-mixer designed and built by Arcadia Equipment Development Center (1961).

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A 300-gallon slip-on tanker has been designed and constructed by the Arcadia Equipment Development Center (Figure 15). It can rapidly mix and apply any of the current fire chemicals with the possible exception of some types of CMC which have not been thoroughly tested. This unit can deliver up to 100 gallons per minute at 100 pounds per square inch for rapid application. Maximum pressure is 130 psi. With adequate water and chemical supplies, average application, including mix time, can be kept above 50 gpm. Normally, it would be operated on a heavy-duty trailer (see Figure 15) or as a slip-on mounted on a flatbed truck. It can also be used as a mixer for supplying helicopters or airtankers (see *Equipment for Mixing Chemicals*, page 37). Dry weight of the unit is around 2,700 pounds. Additional weight of water load is 2,500 pounds; of borate is 3,030 pounds.

Backpacks. Backpack units have been used effectively to apply viscous water in mop-up operations. The conventional metal type, the rubberized fabric type, and the new fiberglass type have all proven satisfactory. Tank vents have plugged occasionally on the rigid types, but enlarging with a loosely fitting cotter pin appears to solve the problem. Little other trouble has been reported. The viscous chemical must be premixed before filling the backpack. Normally this can be done in a properly equipped tanker. Mixing in the backpack tank has not been successful.

Blowers. Two types of blowers have been tried for applying retardants. One turbine mist blower was tested with both borate and bentonite (Figure 16). The results were not satisfactory — too little material was deposited on foliage to be effective. Pump volume was low for the speed of application but repeated passes did not solve the problem. Failure was possibly caused by the combination of the high wind velocity, possibly 140 miles per hour, and the thixotropic nature of both chemicals tested. Droplet size was reduced too far and much material was carried away by the wind. Because of the thixotropic characteristics and wind shear, the viscosity was reduced to a point where the chemical that did contact foliage only dripped off before gelation could occur. No attempt has been made to handle viscous water.

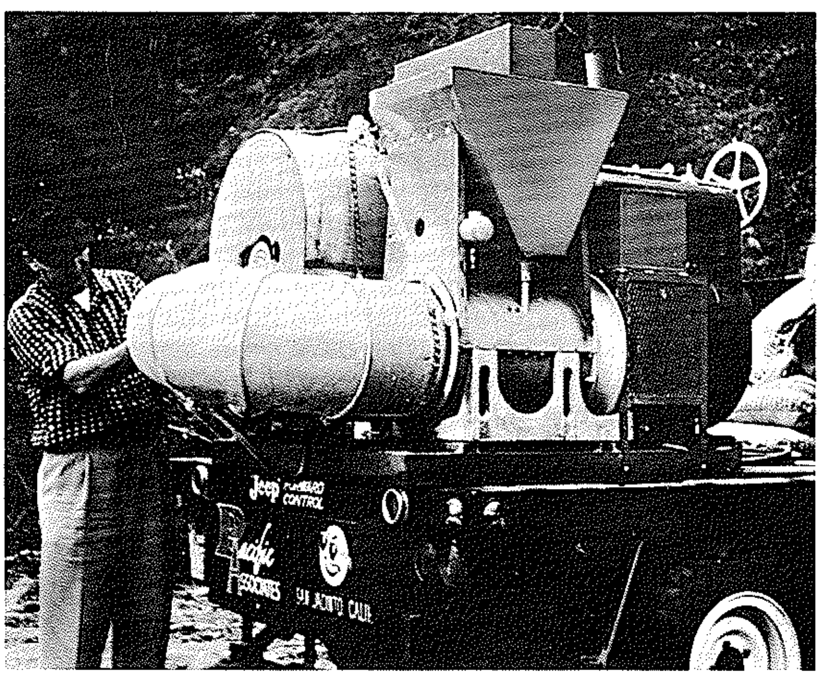

Figure 16. A truck-mounted Turbine Sprayer. (Arcadia Equipment Development Center tests.)

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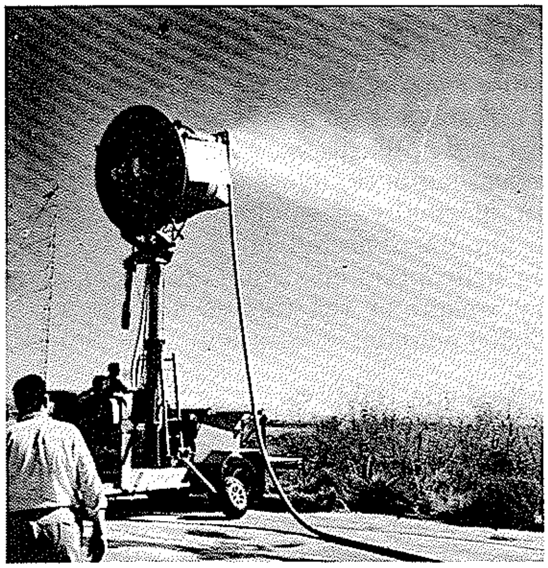

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Figure 17. Injection of bentonite slurry into a wind machine on a truck unit. (Arcadia Equipment Development Center tests — 1960.)

The second machine tried for applying retardants was a 72-inch wind machine. (See Figure 17). A transfer pump supplied bentonite to a spray bar above the air stream. The effect was to carry the slurry in large droplet form and let it fall as rain. In the area covered the results were good. A uniform strip was covered from about 50 to 125 feet from the machine. Penetration of large dense tumble weeds on the site was excellent. Unfortunately, the first 50 feet out from the machine was left untreated. No development work has been done to correct this difficulty.

Nozzles. In the application of viscous water, algin, or CMC, many of the conventional fire nozzles will give satisfactory results. Normally neither chemical will attack or erode brass or aluminum. The fine fog-type nozzle should be avoided but those giving coarse droplets should give satisfactory results. Any screens must be removed.

Nozzles for the application of slurry-type fire chemicals have been a troublesome item. The conventional brass and aluminum nozzle tips are rapidly eroded to a point of uselessness. A brass spray tip may be destroyed in only a few minutes while a brass straight stream nozzle may last for an hour if pressures are kept to a minimum. Rubber and some synthetic spray tips have been tested with disappointing results. Special nozzle tips have been made using cast alumina inserts (a ceramic aluminum oxide). They promise extremely long life (100 hours of continuous flow have caused no deterioration). These tips are not now commercially available but could be made at low cost. The inserts are produced for nozzles in oil drilling bits and in those sizes the cost is less than $1.00.

Cast iron swirl-type nozzles have been tested. Their expected "life" with slurries would be acceptable, partially because application pressures are low (30 psi). The spray is a hollow cone which may not be acceptable for direct impingement application but works well when directed upward over the target area and the chemical is allowed to fall like rain. At present they are manufactured for permanent fixed installation and are somewhat heavy and awkward to handle. Development could eliminate these latter objections.

Effective uses. Successful application depends on understanding the physical characteristics of the fire chemical. The chemical must be able to wet the surface before it can adhere. It must be cohesive to build an adequate film. Penetration or build-up needs to be controlled. Selection of a chemical can alter characteristics but once a selection is made the greatest control variable left for the tanker operator is viscosity.

Varying the application viscosity (viscosity at time of contact with the target) can afford better control. Higher viscosities will promote heavier film — important on heavy aerial fuel. Lower viscosities will improve canopy penetration and, indeed, better penetration into duff. Changing the mix ratio will alter the viscosity of all fire chemicals. With the more thixotropic chemicals, altering pump and nozzle pressure can appreciably effect application viscosity.

Most chemicals used exhibit some degree of thixotropy — the phenomenon of becoming less viscous when agitated and thickening again when quieted. Borate and bentonite exhibit this characteristic more than any other fire chemicals used — attapulgite clay to a lesser degree — algin only slightly. Borate at rest in a tank or on fuel will probably have a viscosity in excess of 5000 centipoises. When discharged through a nozzle under high pressure the viscosity may drop to 15 or 20 centipoises. Since the wind tearing at the droplet in flight continues the agitation, the fluid will still have a very low viscosity upon contact. Higher pump pressures will reduce application viscosity, lower pressures will cause less of a viscosity drop.

Nozzle design can have an appreciable effect on application of thixotropic chemicals. Wind shear appears to have less effect on large droplets than on small ones — probably because of the lower surface area to mass ratio. The larger droplets, leaving the nozzle at a lower pressure, have a greater viscosity at time of contact.

Where possible as a technique, it is helpful in building up heavier films to direct the spray upward so that the chemical falls like rain. The impact velocity and wash-off is thus reduced and with thixotropic chemicals some gelation and increase in viscosity can take place before contact.

While allowing some flexibility in application, in several respects a thixotropic chemical is easier to handle. It can be more efficiently pumped with lower cost equipment, with less power requirements and for greater distances than a constant viscosity agent of equal effectiveness. Once applied the thixotropic chemical stays in place — it will neither drip nor run.

Adding calcium chloride to algin-thickened water is another method of increasing viscosity and building heavy films. It requires little material and provides a tough, fibrous gel.

Advantages and limitations. When compared to aircraft, the most pronounced advantages of ground application are use at night, use in terrain inaccessible by aircraft, and use when wind or smoke prevent the safe utilization of aircraft. Ground application has a definite place in vehicle and structure fires where aircraft are not applicable. In many cases over-all costs are less, particularly where small quantities are needed and where fire equipment has ready access. It can be applied more accurately on the target from the ground than from the air — there would never be a complete miss as now occurs occasionally in aircraft application.

Ground application is most limited by lack of roads or trails. Vehicles can take no part in remote fires away from existing roads. For practical reasons the distance a man will carry a backpack is also limited.

Supply of chemicals and water impose a second drastic limitation. Water and chemicals can be stored at airports prior to fire needs but no such convenience exists for the roving fire tanker. Follow-up trucks must be provided to compensate for this deficiency.

The actual quantity of chemicals to be handled can be a limitation. Where fork lifts at airports can take care of much of the drudgery, in the field the chemical must normally be handled by hand. Certainly selection of chemicals can play an important part in overcoming this limitation.

Chapter VI

EQUIPMENT FOR MIXING CHEMICALS

Batch mixers. Starting with a limited quantity of water, adding the proper amount of chemical, and mixing for a specified period of time are the characteristics of "batch" mixing. The three main categories of batch mixers are recirculation, mechanical agitation, and injector recirculation.

Recirculation. Batch mixing by recirculation requires a tank and a transfer pump. The tank is filled with water and recirculation is started through the pump. The proper amount of chemical for the quantity of water used is added through an opening in the top of the tank. Recirculation through the pump is continued until the mixing is complete. The mixed chemical is then pumped out and the process repeated. Figure 18 is an illustration of a recirculation mixer. The capacity of this mixer is 300 gallons. Water enters the tank tangentially near the top. The chemical is added through the screen-like grating at the top. The cone-shaped bottom assures recirculation of all material. Care must be exercised in adding material or it will be sucked to the bottom and plug the outlet and pump, necessitating lengthy downtime for cleanout. The length of time required for adding materials and for thorough mixing is excessive for a successful mixing operation. A height of about eight feet requires a platform for the personnel adding the chemicals. The unit weighs approximately 1,000 pounds but its portability is limited by its size and shape.

Mechanical agitator. Batch mixing by mechanical agitation requires a tank and a power-driven impeller. The tank is filled with water and agitation is started. The proper amount of chemical for the quantity of water used is added through an opening in the top of the tank and agitation is continued until the mixing is complete. The mixed chemical is then pumped out and the process is repeated.

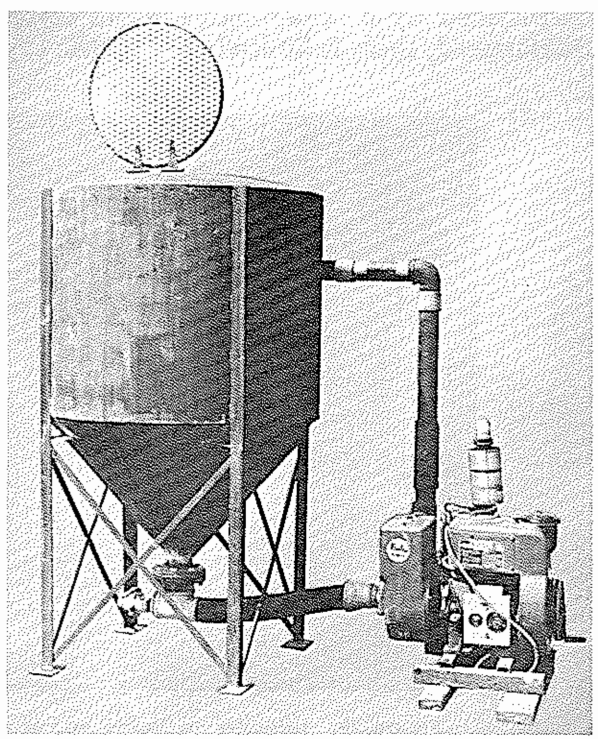

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Figure 18. A Recirculation Type Mixer.

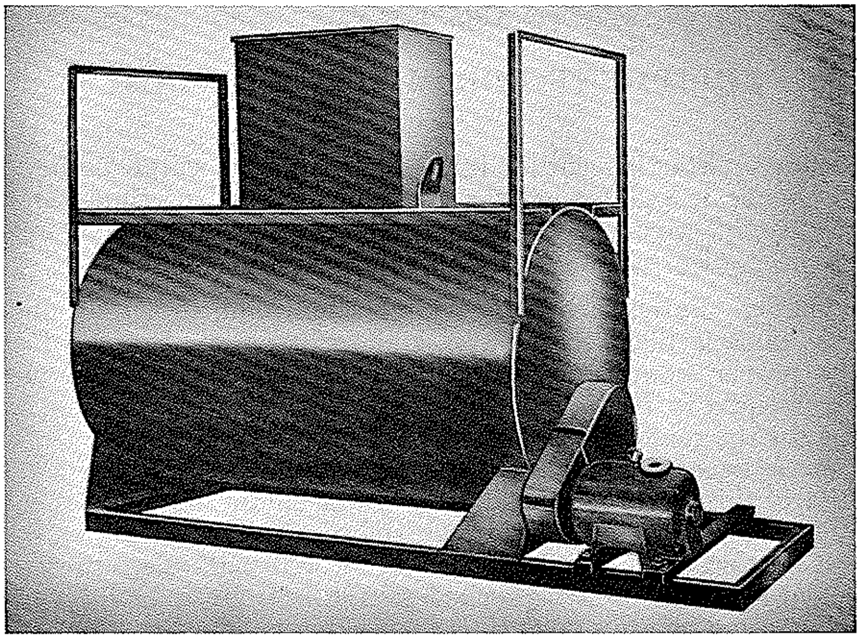

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Figure 19. A side-entering agitation-type mixer, electric motor driven.

With some chemicals, especially borate, it is possible to start adding the chemical as soon as the water covers the impeller and then start emptying the tank when the slurry reaches a predetermined level. The two main configurations of mechanical agitators are side-entering horizontal shafts and top-entering vertical shafts.

One example of side-entering agitation is shown in Figure 19. The capacity of this unit is 500 gallons. Material can be added as fast as desired without harm to the mixer as long as the water level is above the impeller. The shaft is totally enclosed with the shaft housing supported at the impeller and the impeller is surrounded by a screen-like cage to improve shearing action. (See Figure 20.) Shaft speed, then, is limited only by the type of bearings used. The shaft is usually

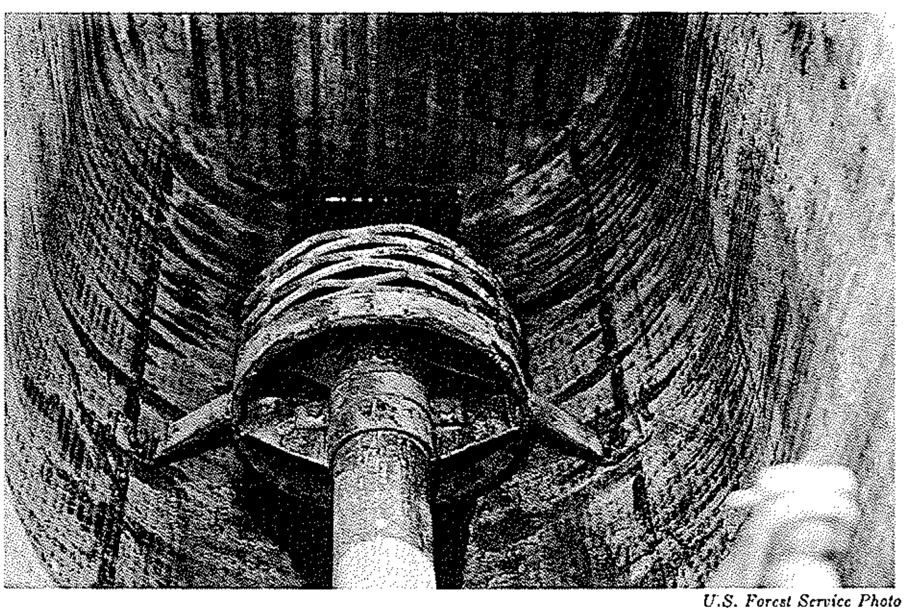

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Figure 20. Impeller enclosure and shaft support on mixer illustrated in Figure 19.

driven by a gasoline engine but for permanent installations electric motors are suitable if power is available. The dry weight of the mixer and driving unit is approximately 1,700 pounds. It is readily portable or may be mounted on a flatbed truck. With the proper impeller (see *Mixer Requirements*, page 42) this unit is capable of mixing all the commonly used chemicals except possibly some types of CMC which have not been thoroughly tested. Once filled with water the unit can mix 500 gallons of these chemicals in five minutes or less. With an adequate supply of water and chemical the mixer can produce 6,000 gallons of chemical mix per hour.

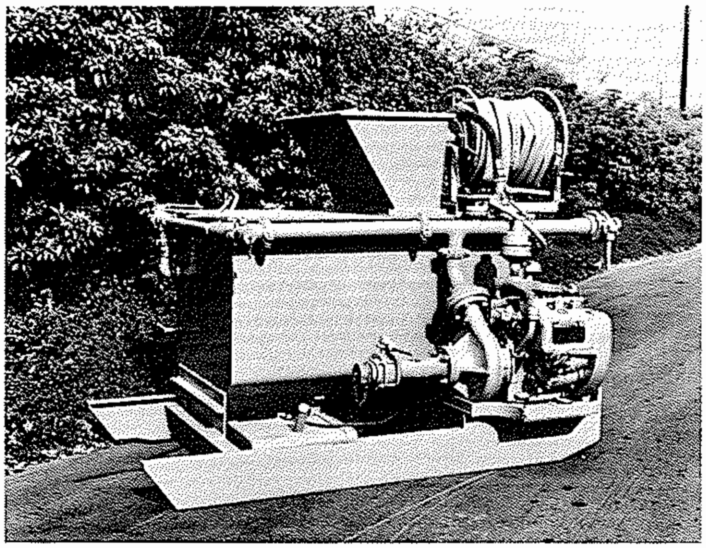

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Figure 21. AEDC slip-on chemical tanker-mixer.

Another example of this type of mixer is a slip-on chemical tanker-mixer developed by the Arcadia Equipment Development Center, shown in Figure 21. (Plans for this mixer can be obtained from the Arcadia Equipment Development Center, 701 N. Santa Anita Avenue, Arcadia, California.) The unit was designed for mounting on a heavy-duty trailer or for slip-on mounting on a flatbed truck. Dry weight of the tanker-mixer is 2,700 pounds, and its capacity is 300 gallons. Methods of adding material and agitation are similar to the mixer shown in Figure 20. A knife-edge is located on the grill over the hopper to facilitate bag opening. Rated capacity of the centrifugal pump is 300 gallons per minute at 72 pounds per square inch. Engine horsepower is 30 at 2800 revolutions per minute. The pump is connected directly to the engine with the mixing impeller belt-driven from the opposite end of the engine. The mixing impeller shaft turns at 1500 revolutions per minute and absorbs about 10 horsepower when the engine is running at full throttle. The pump should be self-priming (see dark-colored tank to left and above pump in Figure 15), to assure complete emptying of tank contents and to allow drafting from points lower than the tank. Since there is no clutch to disengage the pump, the contents of the tank must be recirculated to avoid overheating the pump and seals. The only exception to this is that recirculation is stopped at the same time addition of dry chemical begins and recirculation is started again as soon as all the material is added. Interruption of recirculation should not exceed two minutes. This interruption is to avoid the possibility of lumps clogging the pump impeller. The subsequent recirculation supplements the work of the mixing impeller and speeds the mix. The plumbing is arranged for drafting, recirculation, discharge through a 2½-inch hose, discharge through two 1½-inch lines, or discharge through the 1½-inch hose on the hose reel. The hose reel will hold 150 feet of charged 1½-inch CJRL hose. The pump can also be used as a separate transfer pump. With the proper impeller (see *Mixer Requirements* page 42) this unit can mix and apply all of the chemicals currently being used except possibly some types of CMC which have not been tested. For ground application, rapid delivery is possible up to 100 gallons per minute at 100 pounds per square inch. The maximum static pressure of the pump is about 130 pounds per square inch. Where supplies of water and chemical permit, the rate of discharge, including mixing time, can be kept above 50 gallons per minute. The portability of the unit, whether trailer- or truck-mounted, provides a ready source of chemical mix to supply helicopter operations in remote locations. The mixer can be supplied with water by a mother tanker or by fire trucks for a slower operation. The helicopters can be supplied from a collapsible storage tank or from the mixer itself. Production rates are difficult to estimate since location will determine how fast water and chemical can be supplied. Once filled with water the mixer can mix 300 gallons of any currently used chemical in five minutes or less. When installed at airport facilities with a good water and chemical supply the mixer can produce 3600 gallons of chemical mix per hour. This figure assumes some storage space. If planes are supplied directly, a TBM could be loaded in about 10 minutes.

Another example of side-entering agitation which has an efficient water handling method is a mixer used by the California Division of Forestry.

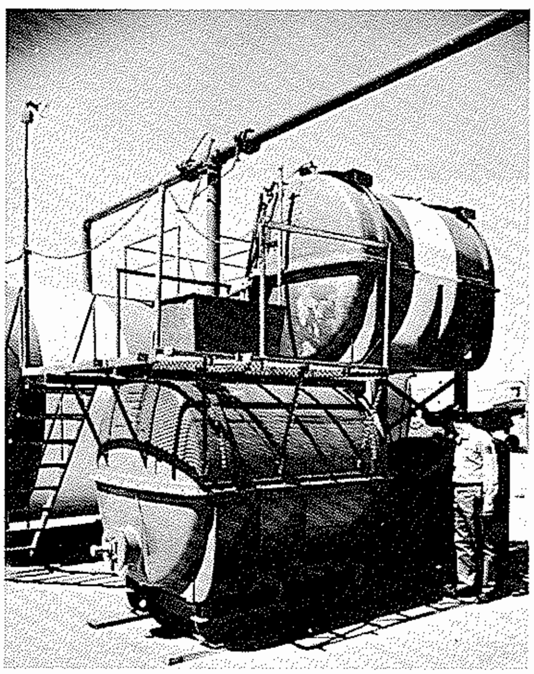

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Figure 21A. California Division of Forestry mixer, Hemet Airport.

A water tank is mounted above the mixer. The tank is provided with a calibrated sight gage so that the desired quantity of water can be placed quickly in the mixer below. The water tank is then refilled from the main while the chemicals are being mixed.

A fourth example of a side-entering agitation mixer is shown in Figure 22. The capacity of this unit is 300 gallons. Instead of a hopper, an automatic material feed is built onto the mixer. The bags are placed on the chain belt conveyor broadside. A saw blade on each side of the conveyor slices each end of the bag. The bag then travels onto a shaker bar over the opening into the tank. (See Figure 23.) The bag folds in the middle over the bar and the up and down motion empties the contents out of each end.

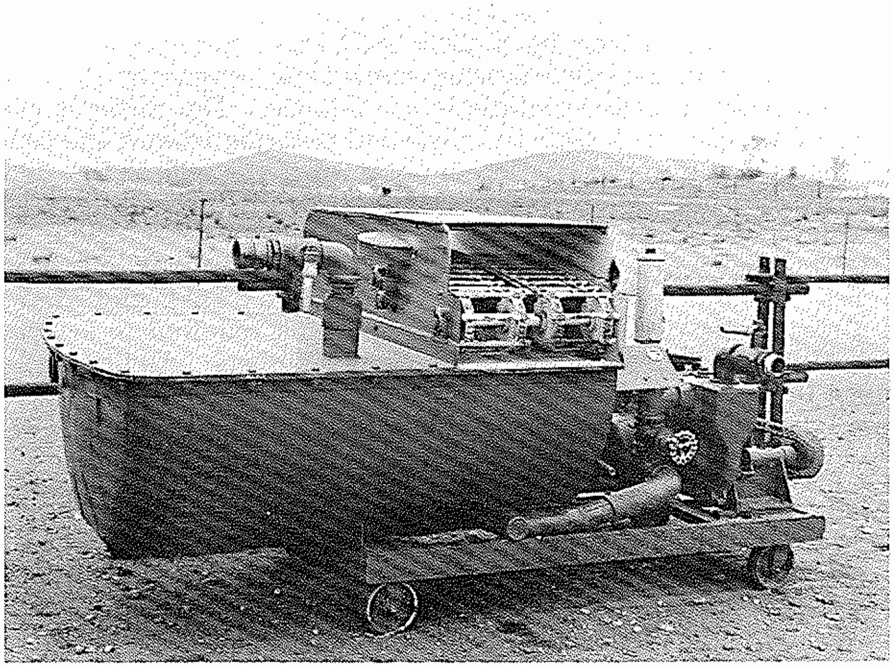

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Figure 22. Self-feeding, side-entering agitation-type mixer.

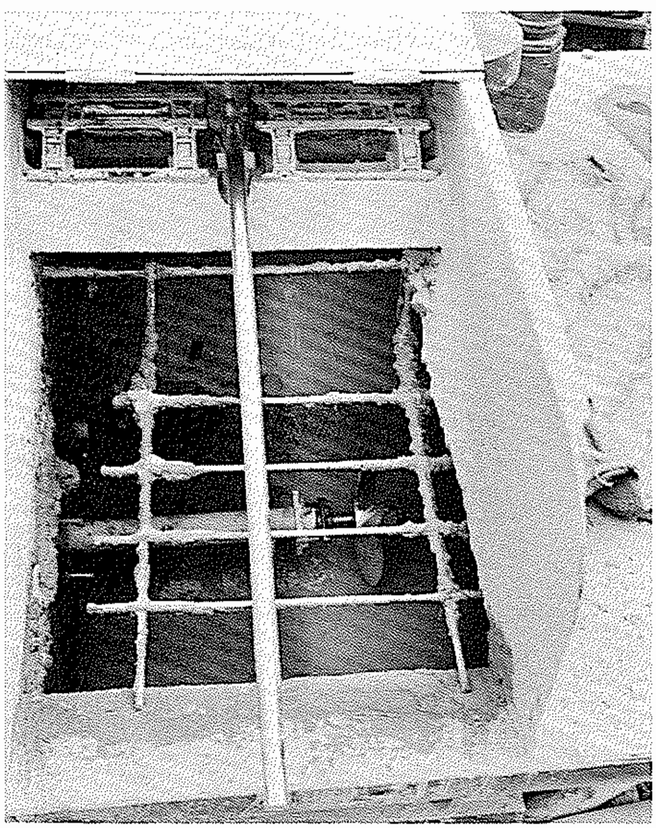

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Figure 23. Shaker bar and impeller on mixer in Figure 22.

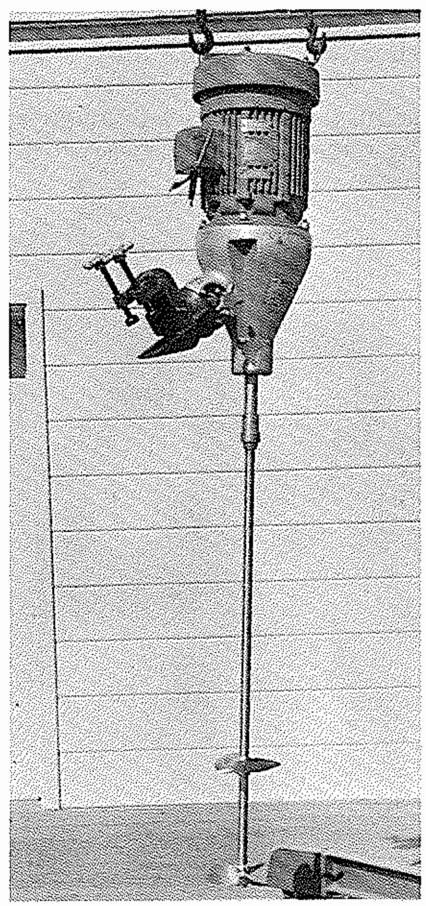

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Figure 24. Top-entering agitation-type mixer.

An example of top-entering agitation-type mixer is shown in Figure 24.

The shaft is direct-driven by a 220v A-C three horsepower motor and is 6½-feet long with two 3-bladed marine screw-type propellers 10 inches in diameter. Shaft speed is 1160 revolutions per minute. The mixer is clamped on the top edge of an open tank with the shaft end pointing toward the center of the bottom of the tank. Proper agitation is obtained if the end of the shaft is then moved slightly off center to the right. Material can be poured directly into the tank or shaken in slowly by using a vibrator. Use of the vibrator did not greatly improve the mixing times and took about three times as long to add the chemicals. Mixing times for borate and bentonite were excessive. DAP and MAP could be mixed in a reasonable time. The height of the tank required to accommodate a 6½-foot shaft would require platforms for crew members. Addition of chemicals into an open tank is excessively dusty. The mixer itself is portable but must be used where power is available and with suitable tanks.

Mixer Requirements. Size, speed, and type of impellers are important factors to be considered in using mechanical agitators. With the same horsepower input a high-speed shaft using a small impeller will produce more concentrated agitation than a slow-speed shaft using a larger impeller. The same amount of energy is distributed in both cases but over a greater area with the larger impeller.

The type of impeller used is dependent upon the mixing characteristics of the chemical. Bentonite is a fast hydrating chemical but requires an impeller which provides good dispersion. A regular marine screw-type propeller (see Figure 23) provides good dispersion of materials. Some of the newer chemicals disperse rapidly but require high shear for proper mixing. Figure 25 is an experimental impeller which provides high shear. Some chemicals, such as algin, are shear-sensitive and may require less agitation or shorter mixing times.

Using more horsepower than necessary for a reasonable mixing time of five minutes or less can damage materials. Borate is a chemical which can be harmed by over-mixing.

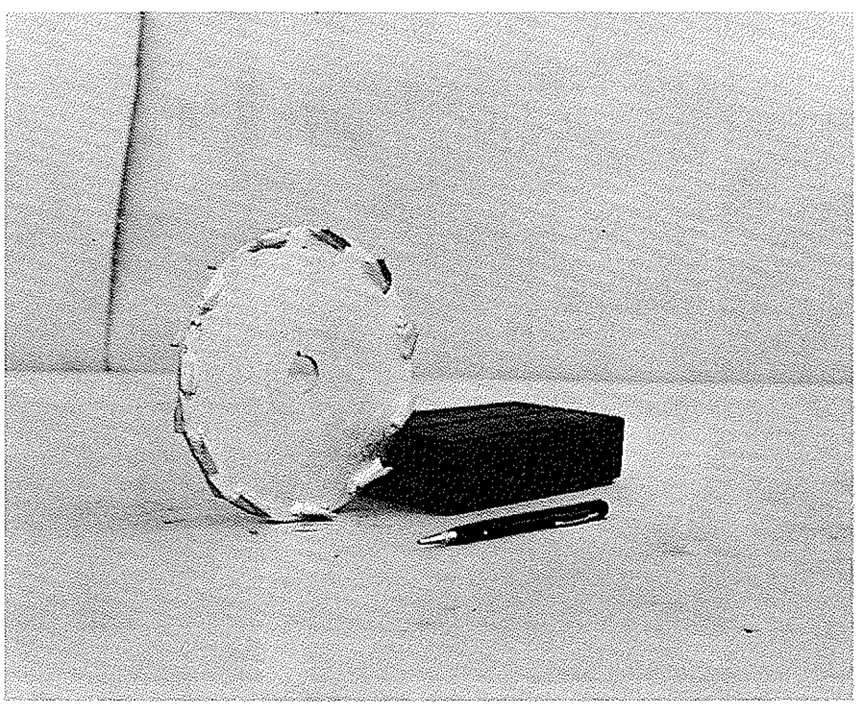

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Figure 25. High shear impeller.

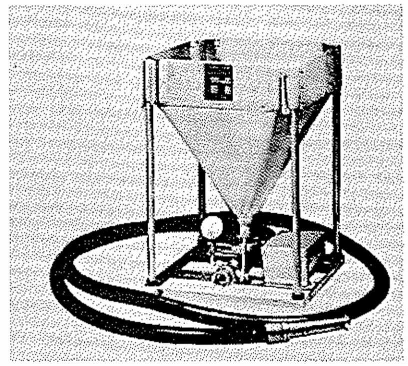


Figure 26. Continuous flow injection mixer.

Injector-Recirculation. Mixing by injector-recirculation requires a tank, a transfer pump, and an injector. The injector is mounted to discharge into the tank. Water is drawn from the tank through the pump and into the injector. The injector has a restriction to the flow of water to cause a high velocity jet discharge. This jet causes a suction at the hopper on top of the injector and draws the chemical powder into the water stream. The turbulence of the water discharge from the injector helps wet the powder. After all of the powder has been drawn from the hopper, recirculation is continued through the pump until mixing is complete.

Modification can be made on the injector-type mixer shown in Figure 26, to use it in an injector-recirculation system. The injector is removed from the base and the neoprene hopper is replaced by a suitable funnel. The injector is then plumbed into the system using the appropriate water metering orifice. This unit is originally supplied with orifices for 25, 50, or 100 gallons per minute flow. Some experimenting will be necessary to select the proper collar for metering the chemical powder. This modified mixer has been used to mix algin and CMC in one to five minutes (*Ref. 21*).

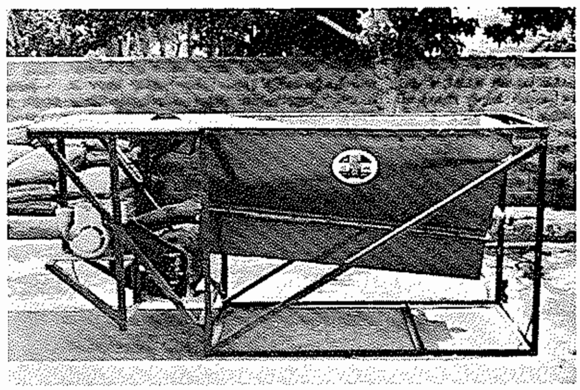
Continuous flow mixers. A continuous flow of mixed chemical can be drawn from a mixer by putting in water at a known rate and adding chemicals at the proper rate to match the water. This requires careful metering of the water and chemical and frequent checks on the mixed chemical to assure a well-mixed product. Two types which have been tried with varying degrees of success are the injector mixer and the mechanical agitator.

An example of continuous flow mixing by injection is shown in Figure 26.

This model is provided with three water orifices for 25, 50, or 100 gallons per minute at 100 pounds per square inch pressure. The hopper is neoprene impregnated nylon. Twelve chemical metering collars are provided for the bottom of the hopper to match the type of chemical used. A slide valve holds the chemical in the hopper until ready for mixing. A pressure gage is provided to monitor the water pressure. Water is supplied at 100 pounds per square inch pressure from a fire truck or other convenient source. The proper metering collar is used for the material being mixed. When the slide valve is opened, the high velocity jet of water through the injector draws the chemical from the hopper and the resultant stream of mixed chemical is directed into a storage tank. Very inconsistent results have been obtained for chemicals mixed in this manner. Densities are usually less than they should be, giving thin, weak mixtures. This is true because the unit acts as a water-activated proportioner. When the water is stopped, everything stops, but when the chemical stops the water continues diluting the mix. Once diluted, no corrective measure is possible. Any lump or piece of paper will cause a stoppage. In this type of a mixer, dispersion and most of the hydration must be done the instant the material is passing through the venturi. No further dispersion is possible after the material has left the mixer, since no agitation is present. In the comparative tests with other mixers, complete mixing was defined as a mixture which had hydrated to where no further significant rise in viscosity or gel strength was possible and where all of the material would pass a 12-mesh screen. For those materials tested, bentonite, borate, DAP and MAP, hydration was never completed to this level and it took excessive standing time before the material would pass a 12-mesh screen. Settling in storage can in part be attributed to inadequate mixing.

The unit can be packed in a case 22 by 22 by 12 inches and weighs 100 pounds. Compactness and light weight make the mixer readily portable by airplane or helicopter to remote locations. See section on *Batch Mixers*, page 37, for details of this mixer used with pump recirculation.

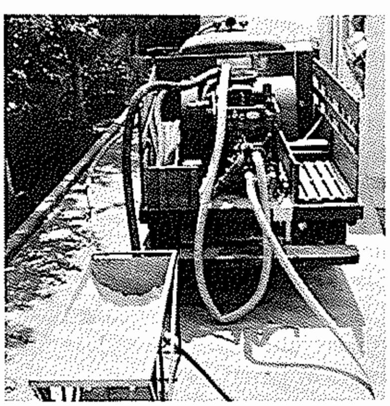
Another example of continuous flow mixing by injection utilizing a different method of adding chemicals is a mixer developed and used by the Los Angeles County Fire Department in California. This uses an air-slide and an injector mounted on top of a storage tank. The bottom section of the air-slide is charged by a rotary blower.



Los Angeles County Photo

Figure 26A. Air-slide for adding dry chemicals, used by the Los Angeles County, California, Fire Department.

This bottom section and the upper hopper are separated by a porous material, usually fabric. When chemical powder is added to the upper hopper, air passes through the porous fabric and through the powder causing it to be suspended in air or to be fluidized. The fluidized powder then flows down the sloping upper hopper toward an opening on the lower right. A hard suction line is connected from this point to the injector on top of the storage tank. The high velocity water jet through the injector causes a vacuum which draws the aerated powder from the air-slide hopper. The water and powder are mixed on discharge from the injector and the resultant mixture is directed into the storage tank. A semi-stationary arrangement uses an air-slide and a 4500-gallon tank trailer.



Los Angeles County Photo

Figure 26B. Portable truck-mounted injector-mixer used in Los Angeles County.

Chapter VII

PUMPS FOR HANDLING CHEMICALS

General capabilities. Chemical handling work involves moving slurries, gels, and solutions from the mixer to storage facilities. It also involves moving the mixed chemicals from either the mixer, or the storage point, to ground unit or air tankers. Pumps, like other handling equipment, should be able to move any chemical planned for use. They should be able to withstand the abrasive and erosive action of the slurries and the corrosive attack of several other chemicals, particularly where ammonia compounds are used.

Where viscous water solutions of algin or CMC are to be handled, most conventional fire pumps will do the job. The pump may be either centrifugal or positive displacement, with brass or iron parts. It also appears that calcium chloride may be added to algin-thickened water without damage, provided the entire pumping system is flushed out after use.

Pump seal requirements. Several types of mechanical seals have given good service with either borate or bentonite. The first successful seal used had heavy cast iron and brass mating surfaces. It has given up to 200 hours' service with either slurry but should be avoided where ammonium compounds may be used.

Later cast alumina (ceramic aluminum oxide) mated with carbon was found to work well with these same slurries. Many units have never been replaced after several hundred hours of use; however, good management still dictates annual inspection to insure trouble-free service during the fire season to follow.

Another abrasive resistant seal utilizing two mating hardened steel surfaces has been used for several years without any reported failures.

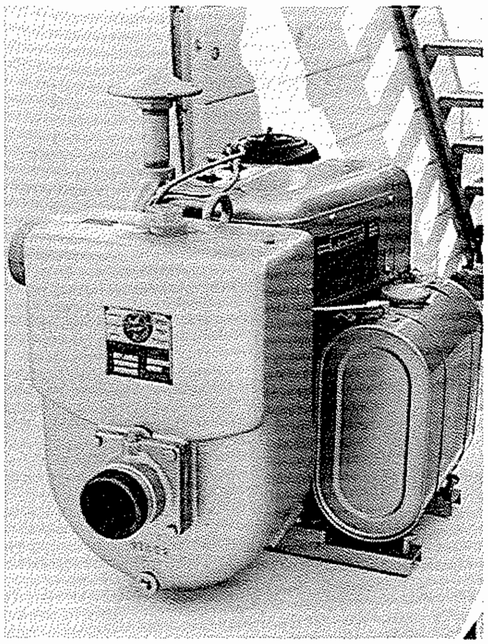
Where ammonium compounds are used, as in MAP and DAP, copper and its alloys should be avoided. If these metals are used, wearing surfaces and light intricate parts may fail in a few hours. In one instance a brass spring support was eaten away in two hours, causing a pumping system shutdown.

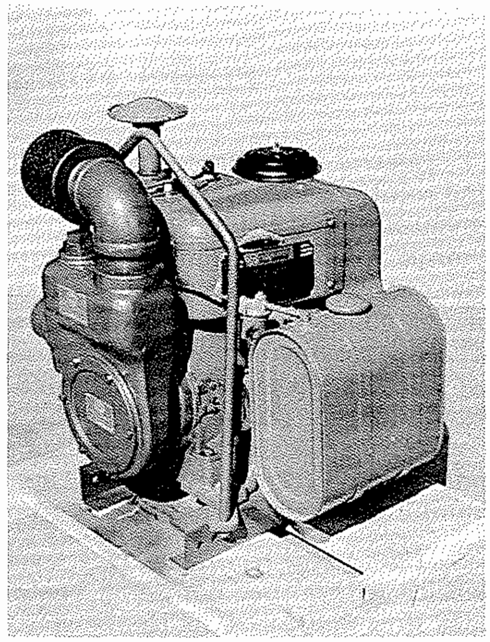
Iron or steel parts should be specified where any ammonia chemicals are to be used. Many pump manufacturers can supply these parts, as they are used widely in the fertilizer industry, and these materials will allow for pumping any fire chemical in present use.

One construction feature common to all successful seals has proved important. The spring providing the mating pressure must be exposed and wrapped around the outside of the seal. This feature insures a constant tension on the seal surfaces. Seals with enclosed springs tend to collect slurry within the enclosure. Any drying out or compaction renders the spring inoperative and failure soon follows.

If a pump with a packing-type seal is to be used for handling slurry, it should be provided with a hard, chrome-plated shaft. If this is not provided, the shaft will become grooved and leaks will result. New packing will not hold. The shaft must be either built up and refinished or replaced.

Transfer pumps (or pumpers). In transfer work, normally at pressures of less than 100 psi, the common heavy-duty cast iron self-priming centrifugal pumps used by contractors have given good results with any of the chemicals. Many now have had several years of pumping service with little or no trouble. Self-priming centrifugal pumps come in a variety of pressure and flow ranges. For any specific engine size, as the pressure rating increases, the flow volume decreases. While in some cases more volume can be obtained from the very low head pump, it normally is advisable to select a pump with a shutoff pressure from 60 to 90 psi. This will assure flow with very viscous materials and will help to maintain higher flow if additional hose must be used.





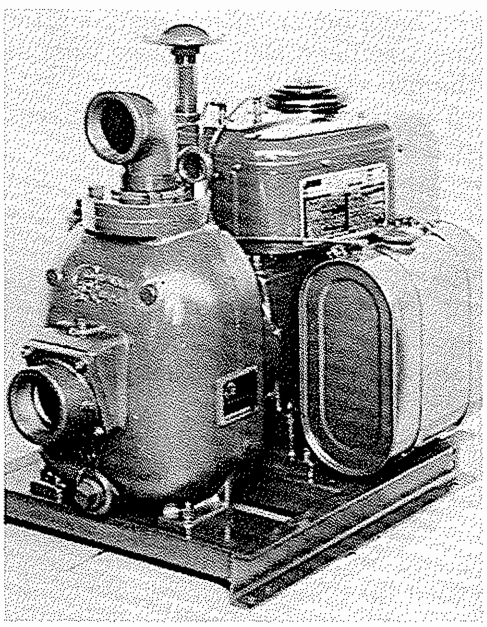


Figure 27. Typical transfer pumpers in use in the 300 gpm range.

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Transfer pumpers, 100 gpm range. (150 to 200 gpm for water.) Units of this size are usually provided with two-inch pipe connections on both suction and discharge. A minimum of 60 psi shutoff should be required to insure working pressure around 40 psi. One-cylinder, 4-cycle, air-cooled gasoline engines are commonly used to drive pumps in this general size class. About five horsepower should be adequate for this work. A stellite exhaust valve and seat, plus a positive exhaust valve rotator, are available and should be specified. Ordinarily these engines come with rope starters but electric starter modifications are available if required. The cost of a transfer pumper in the 100 gpm class is around $275, net weight about 165 pounds.

Transfer pumpers, 300 gpm range. (350 to 400 gpm for water.) Ratings of pumps in this category vary from 275 to 300 gpm at from 30 to 40 psi. For chemical use it is best to select a pump with a shutoff pressure of 60 to 90 psi. While higher shutoff pressures are available in the larger sizes, they are not needed for normal transfer work. Inlet and outlet connections are usually 3-inch pipe size. Mechanical-type seals are furnished with pumps in this class but the special parts described under *Pump Seal Requirements*, page 45, are recommended for use with chemicals.

The most satisfactory pumps in this class are driven with a two-cylinder, 4-cycle, air-cooled gasoline engine rated at 16 to 18 horsepower. Standard units are furnished with hand cranks and impulse magnetos but most air tanker bases have equipped these larger units with electric starters and generators. If there is any possibility of need for these modifications, consideration should be made in the original order since it involves the basic assembly at the home plant.

Stellite exhaust valves and positive exhaust valve rotators should be included as an engine requirement.

Costs of the standard units vary considerably in this class ranging from $475 to $725 at the factory. Net weights run from 325 to 425 pounds. Allow at least an additional $100 for the cost of a starter and generator when ordered with a pumper — $200 if modified later.

High-pressure pumps (above 200 psi) for retardant and suppressant application. At pressures above 200 psi the best centrifugal pumps have a relatively short life when pumping slurries. While much work has been done, and several new uses of abrasive-resistant materials have been made, life of the larger pumps might not exceed 50 hours. In the small 25-gallon per minute size, pump life is shorter and even somewhat unpredictable. Shaft seals and wear rings suffer more at higher pressures. None of those tested reached 50 hours. Perhaps some of the new improved seals will do better but as yet they have not been proven.

A positive displacement screw pump has been the most successful type tested in slurry application. One pump at Arcadia Equipment Development Center exceeded 200 hours of pumping bentonite and borate at an average pressure of about 250 psi. Only a small amount of wear was found on a driving toggle. No measurable wear occurred on the rotor. (See Figure 28.) Some precautions are necessary with this kind of pump. It must have a supply of fluid when running as it can be damaged if run dry, even for a short time. The steel rotor will frequently stick when left standing any length of time. Usually the pump can be

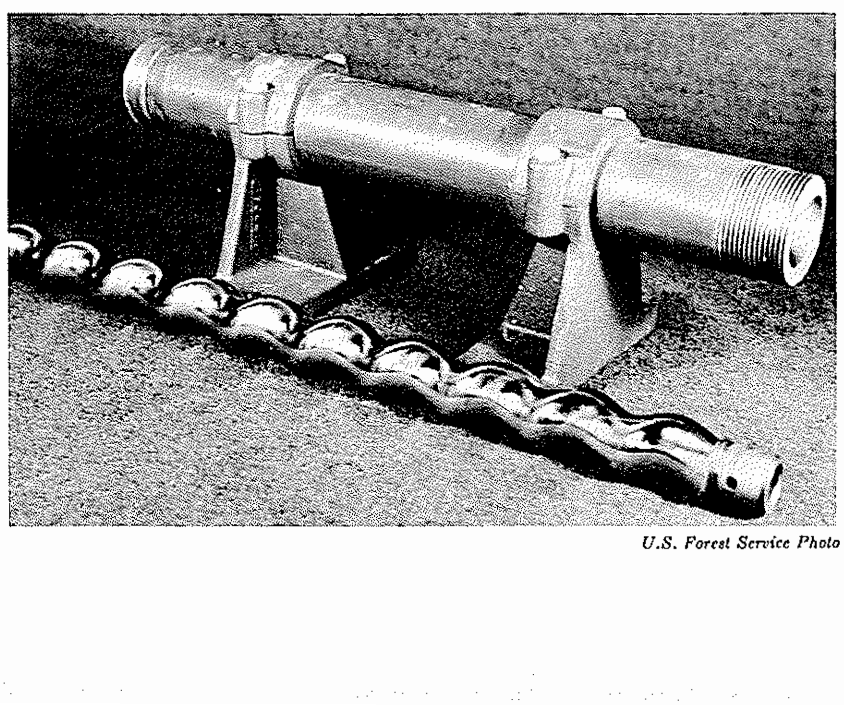

Figure 28. No measurable wear was evident on the rotor of this high-pressure pump after AEDC test.

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rotated slightly before operation. Once the pump is broken loose it can be used without further trouble.

Relief valves. Positive displacement pumps require a relief valve to handle flow whenever a nozzle is shut off. No reliable relief valve has been found to handle slurries. Consequently, positive displacement pumps have not been widely used. An experimental valve made of commercial and shop-built parts has been tried. The results appear to be adequate but it has never been fully tested. Until this problem has been fully solved, it would appear advisable, where slurries are to be applied, to use centrifugal pumps since no relief valves are necessary. The pump used on the Arcadia Equipment Development Center ground application tanker-mixer, described in the mixer section, can be relied on for distances up to 200 feet when using a 1½-inch hose. In some cases it will work up to 600 feet. The transfer pumps with a shutoff pressure above 60 psi can probably be used to apply chemicals for at least 100 feet through a 1½-inch hose.

CHAPTER VIII

DISTRIBUTION SYSTEMS FOR HANDLING CHEMICALS

Piping. While the plumbing of a fire chemical distribution system plays an important part in its success, a careful examination of several airports will show that piping is generally the most inadequate part of the operation. Often a pump has been condemned for not performing, and much time and money spent in unnecessary repairs. The effect of small pipe on a system is the same as partially closing a valve. Procuring a larger pump can be costly and may not improve performance. Unless the replacement pump has a much higher pressure rating the results will be disappointing.

For economic reasons the standard transfer pump is provided with suction and discharge fittings to match pipe which is suitable for handling water or less viscous fluids only. When more viscous liquids are handled or pipe distances become great, this pipe size will be too small for good performance. Some cases have been observed where a combination of pipe length and viscosity has reduced delivery rate to less than one-half of normal.

The number of fire-retardant chemicals now used is large, and complete flow data is not available for all of them. However, for bentonite and borate, some guide lines have worked well. Where distances from the transfer pump to the loading hose connection have been relatively short, 100 feet or less, approximately doubling the pipe capacity (cross sectional area) has been satisfactory. Where loading points are extended farther, a still larger pipe may be necessary. As an example, a 3-inch transfer pump delivering 300 gallons per minute should have a 4-inch pipe for distances up to 100 feet. For greater distances the pipe capacity should be increased.

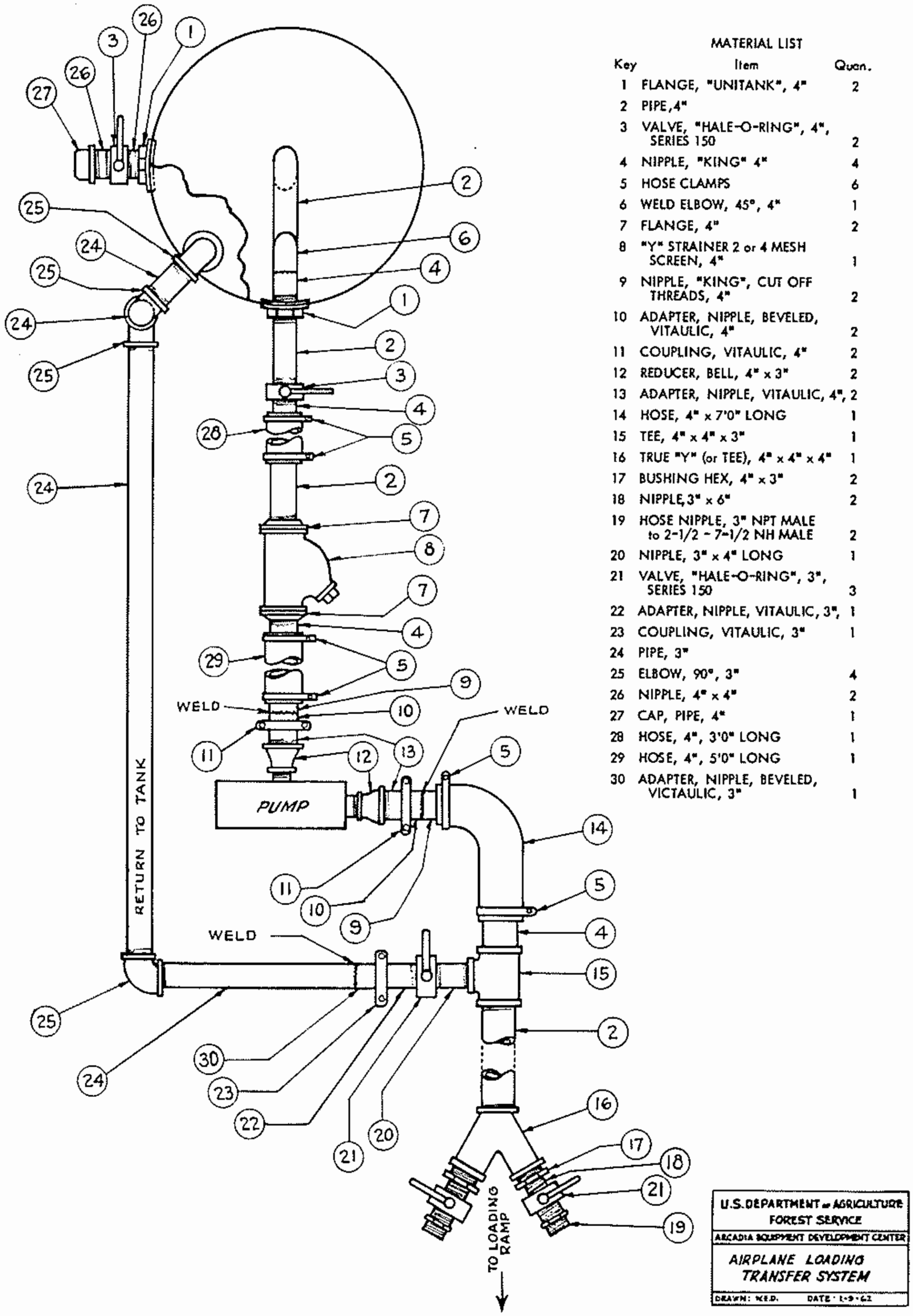
Table 1 will give a concept of the relation between pressure drop of *water* through several sizes of pipe. This table also can be used for approximate flow loss through

Table 1. Pressure Drop of Water Through Pipe

Discharge gallons per minute	Pressure Drop of *Water* per 100 Feet of Standard Pipe pounds per square inch							
	1½″	2″	2½″	3″	3½″	4″	5″	6″
50	7.5	2.1	.9	.3	.14	—	—	—
100	28	7.5	3.2	1.1	.5	.3	.1	—
150	60	18	6	2.4	1.1	.6	.2	.08
200	110	35	13	4	1.9	1.0	.3	.13
300	240	75	28	9	4.1	2.1	.7	.3

smooth hose. Losses will be much greater for viscous fluids. Thixotropic chemicals at low flow have very high friction loss. As an example, a good bentonite mix will require 30 psi to start it flowing through 100 feet of 1½-inch pipe. This, coupled with 200 feet of 1½-inch hose, would be an unsatisfactory arrangement and would require more pressure to start than is available from most transfer systems. Larger pipe and hose would be required.

A schematic airplane loading transfer system is shown in Figure 29. It was designed for use with any three-inch transfer pump having a maximum pressure of 60 psi or more. In one installation the hose connections were forty feet from the



MATERIAL LIST

Key	Item	Quan.
1	FLANGE, "UNITANK", 4"	2
2	PIPE, 4"	
3	VALVE, "HALE-O-RING", 4", SERIES 150	2
4	NIPPLE, "KING" 4"	4
5	HOSE CLAMPS	6
6	WELD ELBOW, 45°, 4"	1
7	FLANGE, 4"	2
8	"Y" STRAINER 2 or 4 MESH SCREEN, 4"	1
9	NIPPLE, "KING", CUT OFF THREADS, 4"	2
10	ADAPTER, NIPPLE, BEVELED, VITAULIC, 4"	2
11	COUPLING, VITAULIC, 4"	2
12	REDUCER, BELL, 4" x 3"	2
13	ADAPTER, NIPPLE, VITAULIC, 4"	2
14	HOSE, 4" x 7'0" LONG	1
15	TEE, 4" x 4" x 3"	1
16	TRUE "Y" (or TEE), 4" x 4" x 4"	1
17	BUSHING HEX, 4" x 3"	2
18	NIPPLE, 3" x 6"	2
19	HOSE NIPPLE, 3" NPT MALE to 2-1/2 - 7-1/2 NH MALE	2
20	NIPPLE, 3" x 4" LONG	1
21	VALVE, "HALE-O-RING", 3", SERIES 150	3
22	ADAPTER, NIPPLE, VITAULIC, 3"	1
23	COUPLING, VITAULIC, 3"	1
24	PIPE, 3"	
25	ELBOW, 90°, 3"	4
26	NIPPLE, 4" x 4"	2
27	CAP, PIPE, 4"	1
28	HOSE, 4", 3'0" LONG	1
29	HOSE, 4", 5'0" LONG	1
30	ADAPTER, NIPPLE, BEVELED, VICTAULIC, 3"	1

Figure 29.

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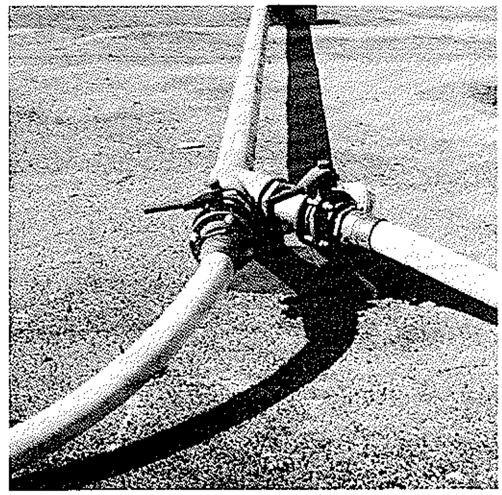
Figure 30. Underground transfer pipe lines all laid to service hose filler lines.

Figure 31. Four-inch pipe line feeding two filler hose lines.



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pump. When 100 feet of 2½-inch CJRL hose and a filler nozzle (see Figure 30) was added, it required a pressure of 53 psi to handle 300 gpm of borate through the system. Using two hoses simultaneously would have reduced pressure requirements by one-third and allowed about 400 gallons per minute total flow.

The system shown in Figure 29 has a number of features which need explanation. Short sections of heavy rubber hose are used in three places. One hose is connected between the tank and strainer to prevent the weight of the strainer from damaging the tank. In a heavy tank this could be eliminated. The other two pieces of hose isolate the pump vibration from the system, thus reducing breaks and leaks. A "Y"-type strainer is used between the tank and pump. The screen mesh should be as large as possible and still trap any object which might be caught in the pump. Two to four mesh is the normal range. If the opening size in the pump impeller is not known, specify four mesh. Victaulic couplings are used in place of unions. The cost is less and they can be readily taken apart with small wrenches. Pipe lengths are not specified but should be kept as short as possible. For economy the return line is reduced to three inches. High flow is not essential here.

Flow characteristics should be considered for every fitting in the system. A standard four-inch 90-degree elbow is equivalent to about 10 feet of pipe while a 45-degree elbow is equal to only 5. A fully open globe valve is equivalent to 100 feet of pipe while a similarly opened gate or butterfly valve is equal to about 3 feet. Figure 30 indicates good and poor examples of a distribution system. The 45-degree elbow, the Y-bend and the butterfly valves are good choices. The 3-inch pipe size has about half the capacity needed for the two 2½-inch hoses illustrated.

Figure 31 shows a better arrangement. Note the 4-inch pipe supplying the two 2½-inch hoses.

In permanent installations, or where freezing is a problem, it may be desirable to install most of the plumbing underground. It is less subject to damage and less of a hazard to personnel. It should be below the frost line. Provisions for draining may be necessary. Forty-five degree fittings can be used to an advantage in entering and leaving the ground.

Pipe and fitting may be of black iron. Galvanizing has no particular advantage for most fire chemicals and it is a definite disadvantage if algin should be used.

Table 2. Pressure Loss in PSI per 100 Feet of 1½-inch CJRL Hose

Chemical	Viscosity in cps	Flow in Gallons per Minute									
		10	15	20	25	30	35	40	45	50	55
1. Water	1	0.4	0.7	1.2	1.9	2.7	3.6	4.8	6.1	7.5	9.0
2. Algin	20	1.4	2.2	3.1	4.1	5.2	6.3	7.4	8.6	9.8	11.1
	73	3.3	4.9	6.4	7.7	9.4	10.9	12.3	13.6	14.8	15.9
	132	5.1	7.2	9.2	11.1	13.0	15.9	16.7	18.5	20.4	22.2
	183	6.4	9.2	11.9	14.3	16.5	18.5	20.5	22.3	24.1	
	291	7.9	11.2	14.4	17.5	20.4	23.3				
3. Algin-DAP	170	6.6	9.8	12.7	15.4	17.8	20.0	21.9	23.4		
	250	9.3	12.3	14.9	17.3	19.5	21.6	23.7			
	350	12.1	16.3	20.1	23.7						
4. Bentonite	200	1.0	1.4	2.0	2.8	3.7	4.8	6.1	7.7	9.3	11.1
	260	2.5	2.8	3.3	4.0	4.9	6.0	7.3	8.8	10.4	12.2
	700	6.0	6.5	7.1	7.9	8.8	9.9	11.2	12.6	14.1	15.7
	1460	13.4	14.3	15.5	16.8	18.4	20.3	22.4			
5. Attapulgite Clay-Ammonium Sulphate	250	1.0	1.4	1.9	2.6	3.5	4.5	5.7	7.1	8.6	10.2
	830	5.3	6.0	6.7	7.3	7.8	8.3	8.8	9.3	9.8	10.2
	1625	10.2	11.5	12.8	14.0	15.2	16.3	17.6	18.7	19.8	21.0
	2990	14.5	16.6	18.5	20.4	22.3	24.1				
6. Pectate-DAP	100	1.6	2.6	3.9	5.2	6.6	8.0	9.5	11.1	12.8	14.6
	400	3.5	5.1	6.6	8.2	9.7	11.1	12.6	13.9	15.2	16.5
	1680	11.0	13.0	15.0	16.9	18.7	20.4	21.9			
	2330	15.2	17.4	19.4	21.4	23.3					

Table 3. Brookfield Viscometer Spindle Number and Speed

Chemical	Viscosity in cps	Spindle number	Spindle Speed rpm
1. Algin	20	1	60
	73	1	60
	132	2	60
	183	2	60
	291	2	60
2. Algin-DAP	170	2	60
	250	2	60
	350	2	60
3. Bentonite	200	2	60
	260	2	60
	700	3	60
	1460	3	60
4. Attapulgite Clay-Ammonium Sulphate	250	2	60
	830	3	60
	1625	3	60
	2990	4	60
5. Pectate-DAP	100	2	60
	400	3	60
	1680	4	60
	2330	4	60

Hose. Flow problems in hose are similar to those in pipe — size for size, losses are about the same. Like pipe, hose used for moving chemicals should be kept large to maintain performance. Unlike pipe, hose of useful size is limited by the weight men can readily handle — normally, hose of 2½-inch or 3-inch diameter. Where flow is less than 50 gpm, 1½-inch hose will usually be satisfactory. For greater flows, 2½- or 3-inch hose is recommended.

Flow losses through hose are much greater for viscous fluids than for water. To determine the magnitude of these losses five chemicals were pumped through 500 feet of 1½-inch CJRL hose. Mix ratios were adjusted to give various viscosities. Water was also run through the system as a comparison.

The resulting flow losses are shown in Table 2, page 52. Since with most fire chemicals viscosity is a function of shear rate, the spindle size and speed for each viscosity is shown in Table 3, page 52.

Results of this test were dependent upon one type of hose common to the fire service. Another hose with different interior texture would have produced different results. Flow losses were less for water than indicated in standard flow loss tables. Consequently in a "standard" hose, flow losses for these chemicals would be somewhat greater than indicated.

In filling aircraft, two hoses used simultaneously can be an advantage. In the case of a 3-inch transfer pump, connected through a 4-inch pipe to a fill station, two large hoses can cut filling time by one-third.

Keeping the length of the hose to a minimum will also increase flow. Fifty feet of hose will cause half the flow loss of 100 and, if fill stations are properly positioned, is enough to service any aircraft now in use. In one instance airplane filling time was reduced more than two-thirds by removing excess hose.

Several types of hose have been used. One is the readily available 2½-inch cotton jacket rubber-lined fire hose. It has the advantage of being light and easily handled. It has the disadvantage of relatively short life. The cotton cover is quickly worn out by the rough texture of concrete or asphalt found around most airport aprons. To help avoid some of this wear, skates are used to support the hose. (See Figures 32 and 33.)

In loading operations at airports many lightweight covered industrial hoses give good service. Weight, flexibility and pressure rating should be considered.

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Figure 32. Chemical transfer line supported on skates.

Figure 33. Close-up of a Siamese valve and transfer line supported on a hose skate.

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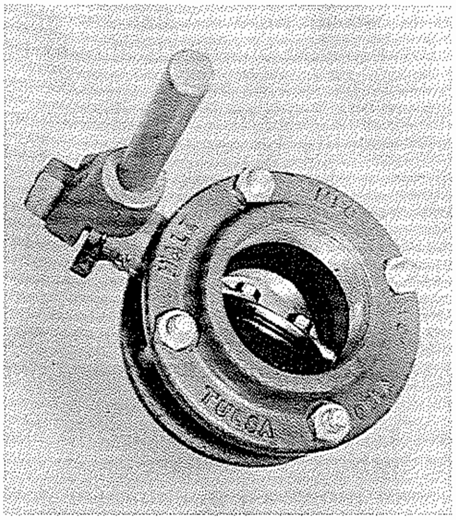

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Figure 34. A butterfly-type valve.

Valves and fittings. Valves, like the rest of the system, should be able to handle the various fire chemicals efficiently. They should be resistant to abrasion, erosion or corrosive action of the chemicals. Relief or pressure control valves must operate efficiently for long periods and maintain their set pressures. Shutoff valves should be convenient to use and have high flow efficiency when open. In transfer operations a relatively low-pressure valve has given good service, and standard fire apparatus valves have worked well for application of viscous water.

Transfer valves. A butterfly-type, quick-closing shutoff valve has proven the most reliable for handling fire chemicals. (See Figure 34.) It is rated at 150 psi pressure and has a ceramic interior coating. These valves should not be used where pressure above 150 psi are anticipated. While no damage will be done to the metal or ceramic parts by higher pressure, the rubber O-ring seal on the butterfly may be damaged causing the valve to leak.

These valves have given good service over a period of several years with little or no maintenance. They are a little heavier than a conventional gate valve — the 3-inch transfer valve weighs 18 pounds. Where used in hose, a lighter valve would be preferred.

The large conventional hose line shutoff on siamese valves should be avoided at airports. If abrasive or erosive retardants are to be turned on and off, wear is rapid. Several 2½-inch brass siamese valves have been ruined with less than a full day's use. A much better arrangement can be had by using the butterfly valve described above and at about one-third the cost. (See Figure 34.)

Application valves. The conventional fire apparatus valves have been successful in handling algin or CMC. Neither chemical is abrasive, erosive, nor corrosive.

One make of ball valve has been successful in handling bentonite and borate. This valve has a heavy brass body, chrome-plated ball and a rubber ball seal. It has handled borate for hours at 30 psi without trouble. *Important:* One note of warning in selecting and using valves. Brass is very sensitive to corrosion and erosion. Any valve purchased for handling corrosive and erosive chemicals must not have closing surfaces or seats made of brass. This is the most critical and important part of a valve and to use brass in this area with such chemicals would invite early failure.

Valves should be used in either a fully open or closed position and should not be used for throttling. Throttling is the action of partially closing a valve to

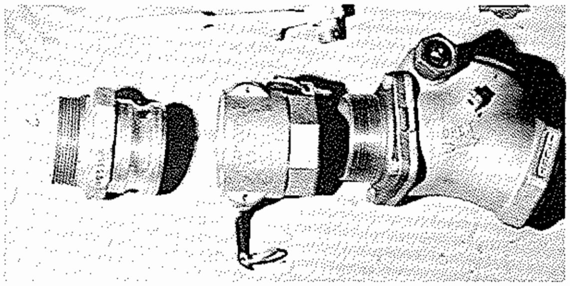

Figure 35. Parts of quick coupling used in Pacific Northwest Region for speeding bottom loading of air tankers. (Left to right) Male coupling which is attached to airplane; female coupling, which is the end of loading hose; and quick-opening, full flow, tank wagon valve.

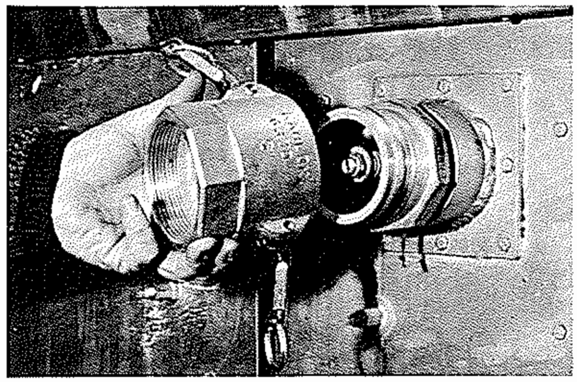

Figure 36. Male coupling is attached permanently near the bottom of the tank. Female coupling is attached easily.

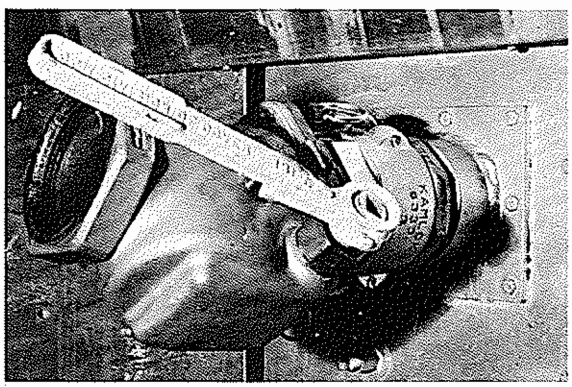

Figure 37. Complete unit attached showing quick opening valve and operating lever in position.

control flow. Throttling of erosive material is almost sure death for any valve, even those with a special hard coating on the sealing surfaces. No valve known or tested by Arcadia Equipment Development Center is recommended for throttling any erosive material.

Figures 35, 36, 37, shows a standardized quick coupling, bottom loading system that has been used. The air tank is equipped with a quick connecting male coupling in the bottom of the tank or near the bottom. The tanker opening is closed by means of a spring-loaded flapper valve or by a manually controlled gate or ball valve. The nozzle end of the hose is equipped with a valve and quick connecting female coupling.

This hookup speeds up the air tanker loading. It provides a major safety factor in that the loading crewman never has to get off the ground. It eliminates the need for changing fittings for the various individual aircraft and it protects the plane from damage which might be caused by personnel climbing around, from hose and fittings being dragged or dropped, and from chemicals which might be spilled.

CHAPTER IX

STORAGE OF MIXED AND UNMIXED CHEMICALS

Chemical supply requirements. An agency should give careful consideration to the demands on any given chemical layout. This may require the same degree of planning used to establish size and the requirements of a suppression crew, or the need for an area fire tool cache. Fire frequency, volume of business, percent of major fires, and requests from cooperative agencies would certainly be reviewed. Plans and experience can indicate the maximum demands imposed upon a base by the size and number of aircraft on call. Proximity to other bases in terms of flight time and availability of chemical stores also requires some thought. If a base is to be depended upon as a primary source it should have at least a two- to four-hour reserve of premixed material. This will allow time to call in or enlarge the mixing crew and give some time margin for short equipment repairs.

Stationary metal storage tanks. The metal tank, or tanks, should be adequate in capacity and permanently mounted on well-drained sites. The top should be covered to reduce evaporation and eliminate foreign materials from getting in the batch. The interior of the tank should be accessible through a properly installed manhole. A float-type visual gage can indicate the retardant tank level to the mixing crew from some distance.

The tank plumbing system should provide for thorough cleanout of the tank to avoid possible contamination.

Algin-thickened water reacts with the galvanizing on tanks and plumbing and results in acceleration of the corrosive action to the metal and some deterioration to the batch. Tank coating may minimize this action; however, specific recommendations are not available. The corrosive action of several retardants on mild steel and to galvanizing is indicated in Figure 7, page 23, of this report.

If there is a choice when repainting the exterior of metal tanks, a light paint or aluminum coating should help to reduce standing batch temperatures. This is an important factor with thickening agents such as algin and CMC.

Airport trailers. Airport trailers have been modified or reconstructed from surplus equipment. Capacities have ranged from 1,000 to 4,500 gallons, depending

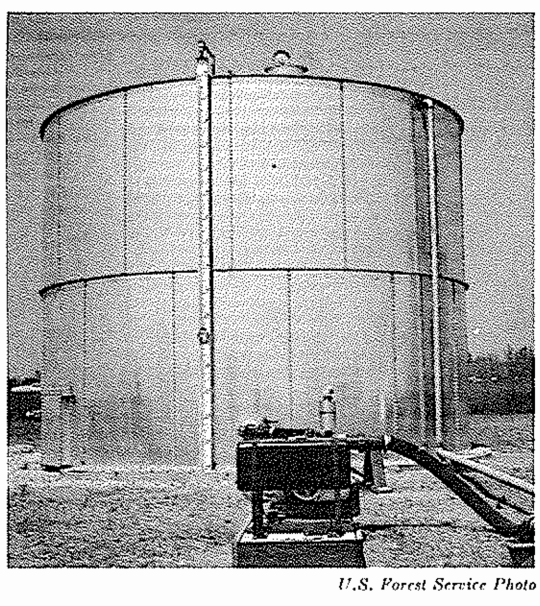

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Figure 38. A 40,000-gallon metal tank with visual gage.

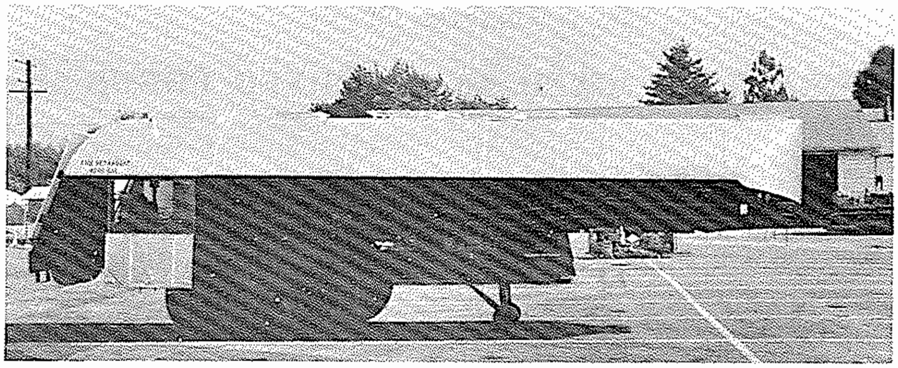

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Figure 39. A 4000-gallon fire-retardant trailer equipped with a 300 gpm transfer pump.

upon requirements. Such units are usually equipped with transfer pumps to make their loads immediately available. They can be designed simply so an air tanker crew can man the unit and refill their own aircraft if necessary. In some instances airports have permitted temporary retardant trailer space where permission could not be obtained for a permanent layout.

Collapsible and folding tanks. Often canvas stake tanks and several folding tanks have been used to establish temporary storage facilities on a limited basis. Sumps could even be dug and shaped up by tractor and then lined with wide sheet polyethylene, if such storage is required for short periods.

Inspection of chemical batches. The inspection of mixed chemicals should be on a plan-wise basis and varied with the type of material. The viscosity of algin- and CMC-thickened water should be checked daily with the Marsh Funnel. Batches involving organic agents need special attention since degradation may set in and the gel deteriorate over a few hours' time. Without preservatives, these mixtures may spoil when stored. (See Figure 41.)

All batches should be checked methodically for proper mix ratios and thorough mixing even though they are prepared for immediate fireline delivery. It is imperative that gel strength remain consistent if effective application rates are to be maintained.

Borate slurry should be checked for shear damage, a result of over-mixing. Improperly mixed batches may settle out with an excessive layer of water on top of the batch. It is desirable, however, to have a 2- or 3-inch water layer to prevent dehydration. Mix ratios in the neighborhood of 2.8 pounds of borate per gallon, or thinner, will likely precipitate out in a few hours. This precipitated layer is quite difficult to clean out of mixing facilities.

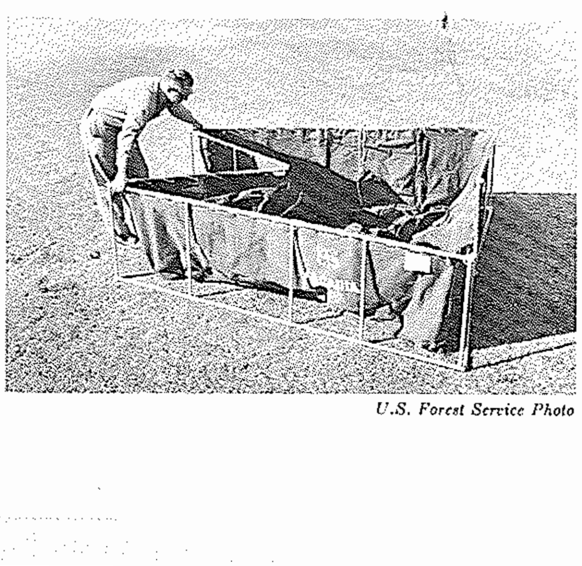

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Figure 40. A 1000-gallon canvas-lined collapsible tank is being opened for use. When completely folded the dimensions are reduced to 8 feet 3 inches x 30 inches x 10 inches and can be transported easily. Weight 119 pounds.

Figure 41. Spoiled algin water 1961 tests; Arcadia Equipment Development Center.

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While every possible precaution will be taken when a total switch is made from one chemical to another in any mixer, storage facility, or ground or air tanker, careful inspections should be stepped up to prevent or identify contamination. (See Figure 42.)

Inspections are especially critical for algin-borate combinations. Documented cases of algin-borate contamination are on file. Experience and tests have shown that almost any combination of algin and borate will form heavy gels and spongy masses that can foul equipment operation. (See Figure 43.)

Storage of unmixed chemicals. Most of the chemicals used can be stored for comparatively long periods of time if they are kept absolutely dry. An exception might be MAP and DAP which should not be purchased and held for indefinite periods. Weatherproof sheds and hangars make ideal storage areas, and if these are not available reasonable shipments can be held on pallets on the ground and covered.

Methods for efficient handling. Agencies can afford to give careful consideration to the methods of handling large quantities of dry chemical materials. Deliveries should be requested on pallets on open flatbed trucks or trailers (see Figure 45) so that fork lifts and other time-saving equipment can be employed. Borate and bentonite shipments in enclosed truck vans are very troublesome

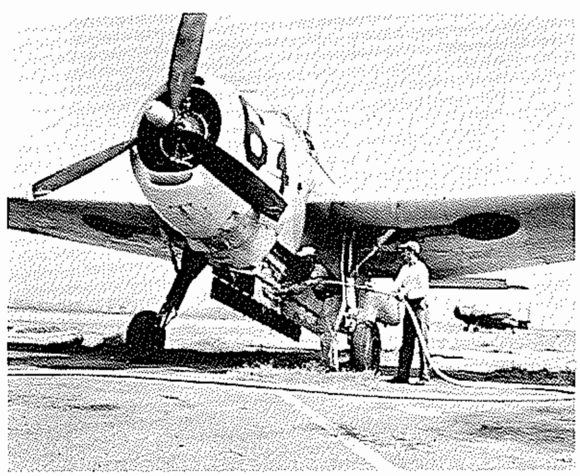

Figure 42. Thorough wash downs and flushing will reduce contamination.

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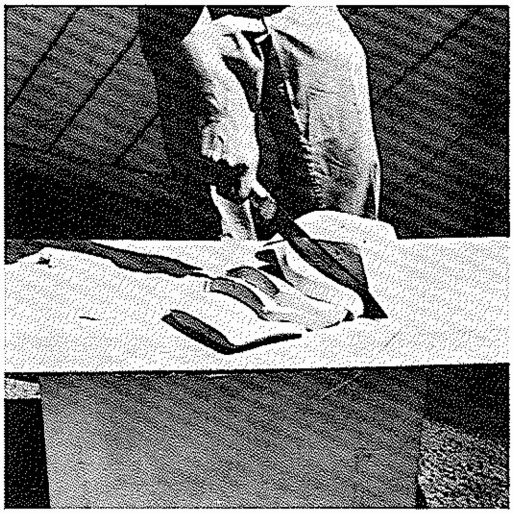

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Figure 43. Slicing a loaf of algin-borate. (Arcadia Equipment Development Center tests — 1961.)

and costly to handle. Stock piles located conveniently to the mixing area will also save time and funds.

Pallets can be moved up close to the mixer (see Figure 46) and work can be arranged off the top of the pile to reduce hand lifting to a minimum. One operator holds each pallet in place on a fork lift and as the height of the pile is lowered the fork lift is raised accordingly. This means that all sack lifting is done at waist level with a half-turn movement of the crewman.

A commercial operator has designed and built a conveyor system to reduce handling costs from a two-man feeding operation to one. (See Figures 22 and 47.) The sack is placed on three rollers at the entrance of the unit. As the bag is fed towards the unit a belt picks up the sacked material and carries it to an opening at the top of the mixer. The sack is cut and dumped automatically and is then carried out of the machine by a vibrating bar.

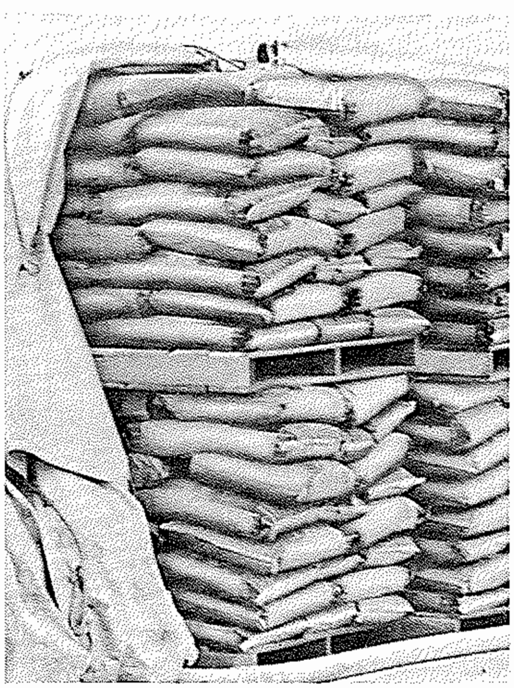

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Figure 44. Chemicals can be stored during dry summer months on pallets outside if covered.

Figure 45. Deliveries on pallets on open bed trucks or trailers cut unloading time appreciably.

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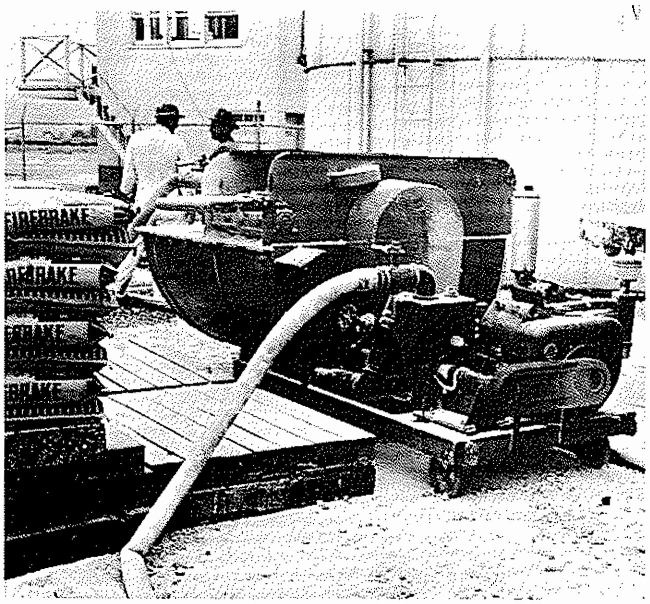

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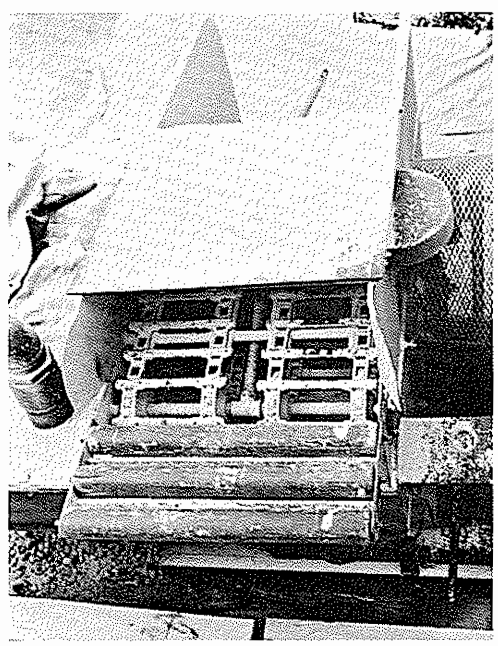
Figure 46. Loaded pallets should be moved close to the mixer entrance so that lifting and walking is reduced to a minimum.

Figure 47. This 300-gallon portable mixer employs a self-feeding and dumping device. This labor-saving device and mixer is commercially available.



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Chapter X

MEASURING INSTRUMENTS

General. The most frequently measured quantities in mixing chemicals are temperature, density of mix, gel strength, and viscosity. Measurements of viscosity are the most troublesome and the least understood. Two commonly used viscometers have rotating members which can be turned at two or more speeds. These rotating members impart a shear to the material being measured. This shear increases as the speed of the rotating member is increased. Water and light oils do not change in viscosity as the rate of shear is changed but the majority of the chemicals used in fire fighting do change. Thixotropic materials decrease in viscosity as rate of shear increases, so measurement at one speed is not enough to specify viscosity. Figure 48 shows the viscosity measurements made on a sample of borate taken after four minutes of mixing in a 20-gallon, Lely-type mixer turning at 1700 rpm with a horsepower input of 0.163. The viscosity values are 5700 centipoises at 6 rpm and 730 centipoises at 60 rpm. Had measurements been made at 12 rpm and 30 rpm the values would have been below the line to produce a concave downward curve. Because of this the rate of shear imparted while viscosity is measured must be stated or the measurement is meaningless. Most liquids become thinner as their temperature increases and thicker as they cool. Thus the temperature of the material being measured must also be stated with the vis-

TYPICAL VISCOSITY RANGE OF A THIXOTROPIC FIRE CHEMICAL

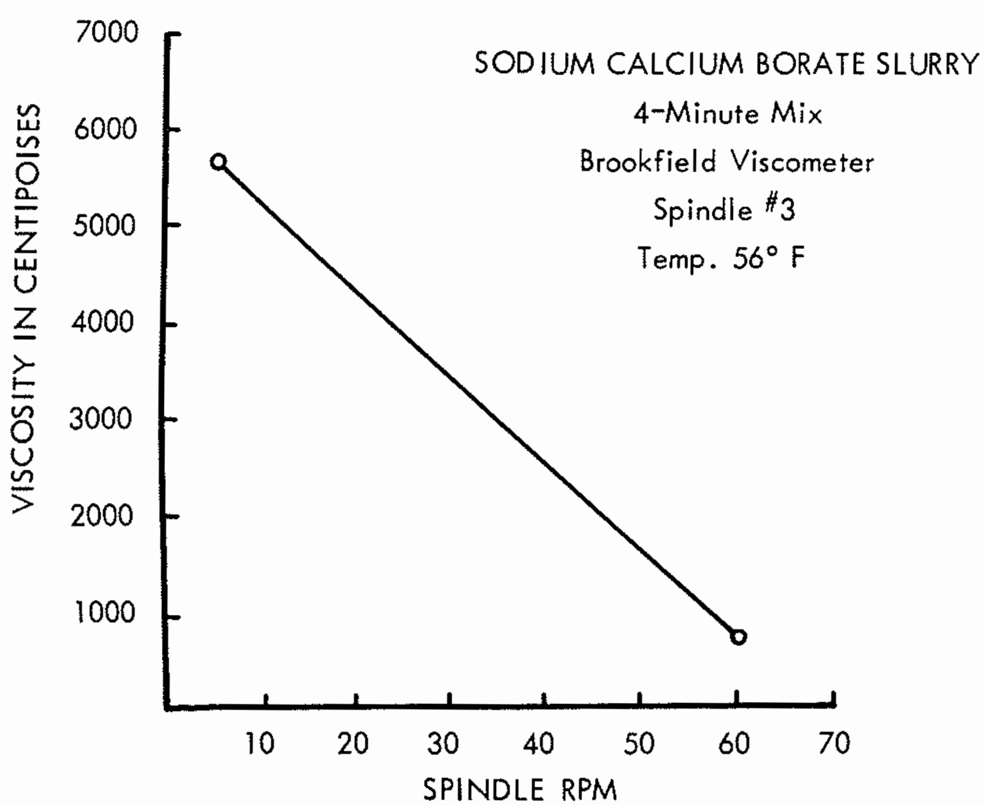

Figure 48. Rate of shears versus viscosity.

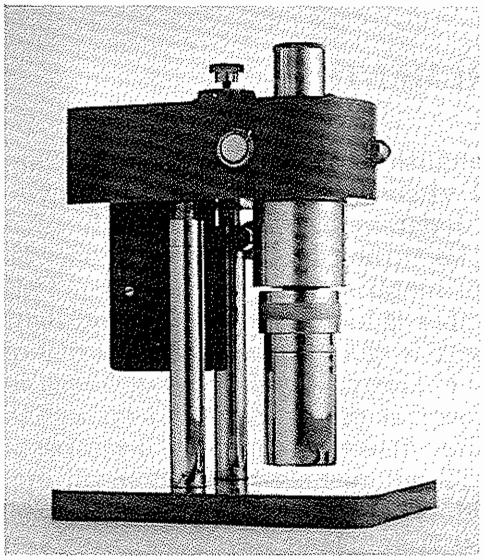

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Figure 49. Fann V-G Meter Model 34.

cosity. Other factors affecting the measurement of viscosity are the duration of agitation by the instrument and the time interval between taking the sample and taking the reading. Measurements should be standardized or no comparison of data is possible. To further increase the difficulty there is no easy, direct method for correlating the readings of various viscometers.

Bob-type viscometer. Figure 49 illustrates a two-speed bob-type viscometer with readings being measured at 600 and 300 rpm of the rotor. These two readings are used to calculate plastic viscosity in centipoises, yield point in pounds per 100 sq. ft., and apparent viscosity in centipoises.

Plastic viscosity is that part of flow resistance which represents mechanical friction (1) between the solids in the slurry, (2) between the solids and the liquid which surrounds them, and (3) the shearing of the liquid itself.

Yield point is a measure of the interparticle forces in a slurry. If the slurry is at rest, these forces tend to arrange the solid particles so that attractive and repulsive forces are satisfied. Gel strength is an indication of these forces under conditions of rest. Yield point is a measurement under flowing conditions of these forces which cause gel strength under rest conditions.

Apparent viscosity is defined as the viscosity a fluid appears to have — were it a fluid independent of rate of shear — on a given instrument at a stated rate of shear. (*Definitions from a memorandum on viscosity published by Magnet Cove Barium Corporation, P.O. Box 6504, Houston 5, Texas.* — Ed.)

This rotational viscometer has an outer sleeve which is electrically driven at 600 and 300 rpm. An inner bob is attached to a dial. As the bob is carried along by the material between the sleeve and the bob a reading is obtained on the dial. A measurement of gel strength is obtained by allowing the material to sit for periods of 10 seconds or 10 minutes with motor off and then recording the maximum dial reading as the sleeve is turned by hand. Gel strength is expressed in pounds per 100 sq. ft. Measurements are limited to viscosities of 3000 to 5000 centipoises for thixotropic materials.

Spindle type. A spindle-type viscometer rotates a cylinder or disc in a fluid and measures the torque necessary to overcome the viscous resistance to the induced movement. The immersed element, called a "spindle," is driven through a beryllium copper spring. The degree to which the spring is wound, indicated by a pointer on the viscometer's dial, is proportional to the viscosity of the fluid for any given speed and spindle. This model has speeds of 60, 30, 12, 6, 3, 1.5, 0.6, and 0.3 rpm and four spindles, as shown in Figure 50. Each spindle imparts a different shear and for a particular spindle each speed changes the rate of shear imparted to the fluid. For this reason spindle number and speed must be stated when measuring viscosities of thixotropic materials. Water and light oils will have the same viscosity for any combination of speed and spindle but thixotropic materials will show a different viscosity for each combination. At least two readings and preferably three or four are required to give the viscosity characteristics of these materials.

Gel strength measurements cannot be made directly with the Brookfield. It may be possible to obtain an indication of gel strength with Brookfield data but this has not been verified.

Marsh Funnel. The Marsh Funnel (Figure 51) is used for routine viscosity determinations in the field. It is 6 inches in diameter at the top and 12 inches long. A 10-mesh screen fitted across one-half of the top removes foreign matter from the material being tested. To make a measurement, fill the funnel to the underside of the screen and then record the number of seconds required for one quart of the sample to run out. The viscosity is recorded as Marsh Funnel seconds. As a point of reference the time for a quart of water at 70 degrees F to run out of the funnel is 26 seconds. The viscosity of water at 68.4 degrees F is 1.0 centipoise. The measurement obtained with a Marsh Funnel is influenced considerably by the rate

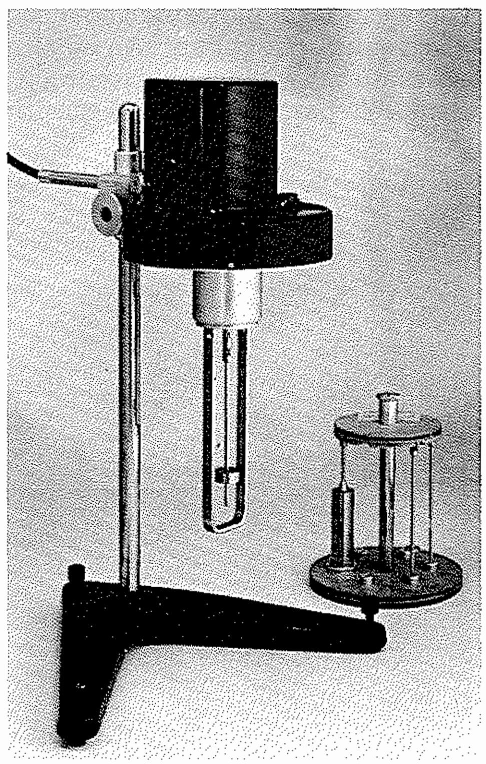

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Figure 50. Brookfield Viscometer Model LVT.

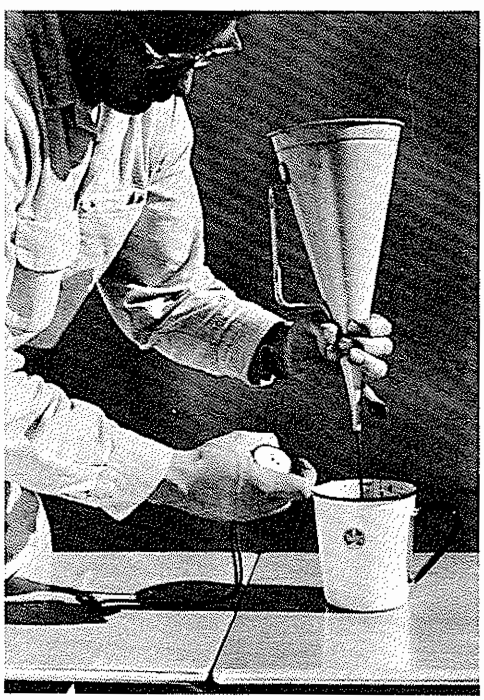

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Figure 51. Marsh Funnel.

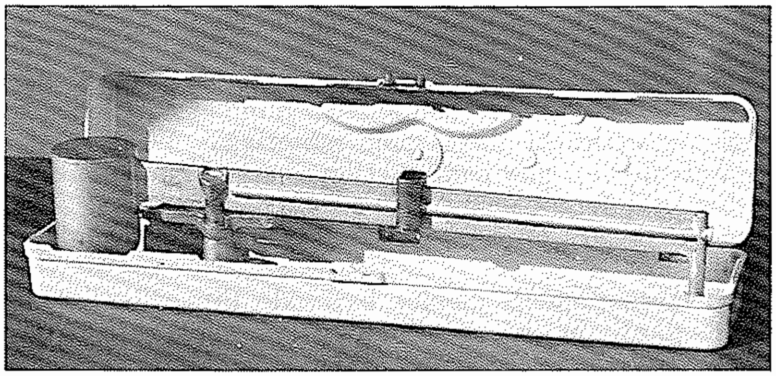

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Figure 52. A Mud Balance.

of gelation and by the density of the material. These variations account for the lack of direct correlation between the Marsh Funnel and the rotational viscometers. Use of the Marsh Funnel is not reliable with some thixotropic materials of high gel strength and is used most often on materials with characteristics like those of viscous water.

Mud balance. An easy measurement of the density of mixed chemicals in pounds per gallon can be obtained by using a Mud Balance (Figure 52). The cup is filled with the sample and the weight moved until the balance arm is level. There is a level indicator above the knife edge and fulcrum. The reading obtained is in pounds per gallon. An advantage of this instrument is that temperature does not materially affect the accuracy of the readings. The balance contains no easily breakable parts, despite its sensitivity.

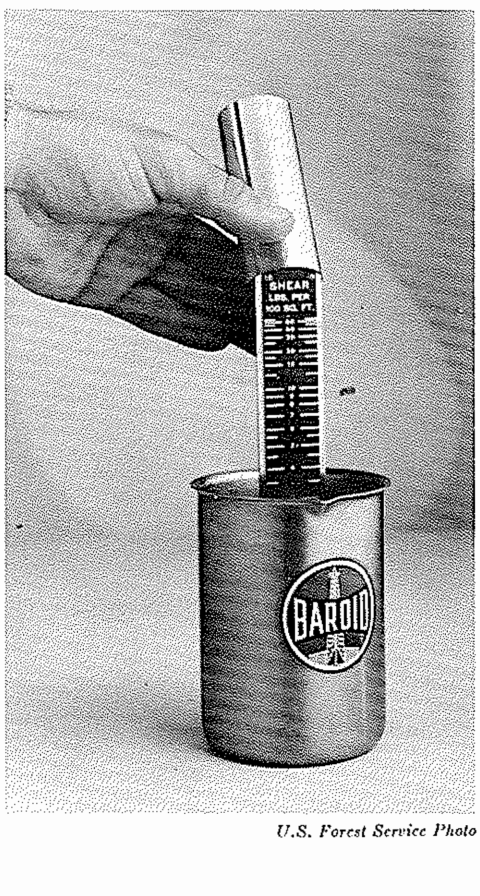

Figure 53. Shearometer.

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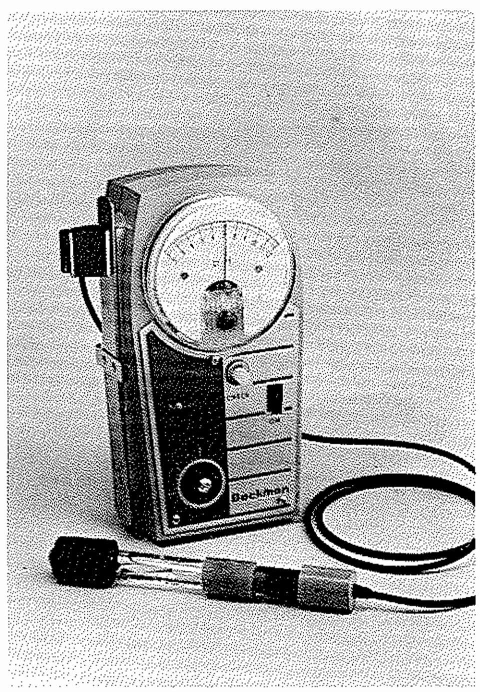

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Figure 54. Pocket pH Meter.

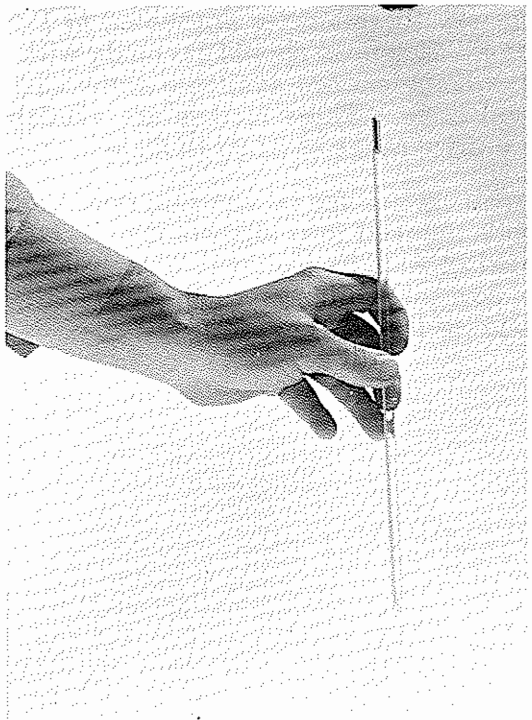

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Figure 55. Standard Laboratory Thermometer.

Shearometer. The Shearometer (Figure 53) is an instrument used in determining gel strength. The readings are obtained directly from a calibrated scale and give gel strength in pounds per 100 square feet. The Shearometer consists of a duraluminum tube 3.5 inches long, 1.4 inches inside diameter and weighing 5.0 grams. A special scale graduated in pounds per 100 square feet is secured within a sample cup. Measurements are made by agitating the sample, placing the tube over the scale, and allowing it to sink for one minute. Initial gel strength is then read on the scale opposite the top of the tube. The sample is agitated again and allowed to sit for 10 minutes and the above procedure repeated for the 10 minute gel strength. The Shearometer's only significance is in the determination of gel strength. It is not recommended for use with very low or very high gel strength materials. No exact correlation can be made with values obtained with this instrument and the rotational viscometers.

Pocket pH Meter. The pocket pH meter (Figure 54) can provide an easy field measurement of the acidity or alkalinity of water or chemical mixes. Seven on the meter scale is neutral. As numbers decrease below seven, acidity increases. As numbers increase above seven, alkalinity increases. The pH is measured by a single combination electrode which includes a measuring electrode and a reference electrode. The meter is standardized by placing the electrode in a special solution of pH 7 and the needle is adjusted to seven. Measurement is then made by placing the electrode in the sample and reading the pH value from the meter. There has been trouble in various geographical locations in obtaining consistent results in mixing some chemicals. It is possible that the pH of the water used, which varies with locality, may be responsible. This has not been verified, but warrants investigation.

Thermometers. It is important that temperatures of samples are taken when recording viscosity measurements. These temperature readings should be made with degrees Fahrenheit thermometers for easy comparison of data. Figure 55 shows a standard laboratory thermometer graduated in 1 degree increments from 0 degree to 220 degrees F. Readings should be made with a thermometer of this type. For field use thermometers are available embedded in metal armour and also in pocket-clip metal cases. These models are available at scientific instrument supply houses in a price range of $2.00 to $3.50.

Flow meters. An investigation for an accurate flow meter to precisely measure the quantity of chemicals pumped into aircraft has produced no usable product. Three models were tested at Arcadia Equipment Development Center to measure the accuracy of slurry flow and to check their ability to withstand the abrasive and gelling characteristics of the slurry.

Chapter XI

PERMANENT CHEMICAL MIXING PLANTS

Site selection. In selecting a site, space must be provided for parking and loading airplanes, taxiways, access roads, storage for raw and mixed chemicals, mixing and handling equipment, offices and parking for employee and work vehicles. A refuse or collecting area should also be provided to receive washdown residue, paper bags, and trash. To avoid long taxi distances with heavily loaded planes, the loading stations should be near the normal take-off point.

Water. Up to 100,000 gallons of water per day should be available for large airport installations; in the future, even more may be required. Some stations have been mixing in excess of 60,000 gallons of chemical a day, not including washdown and cleanup water. On an average this amount will service 10 to 12 planes. Where a different number of planes are to be serviced, water requirements can be altered.

At many sites, water mains and pumps are incapable of supplying these quantities. Where this problem occurs, tanks can be used for storing water. Large amounts can thus be collected from rather meager sources. Where water supplies are critical, covering tanks to reduce evaporation will be helpful (*Ref. 42*). Where temporary emergency storage is needed, portable canvas or rubber tanks, as well as plastic swimming pools within fences, have worked well.

Electric power. Where available, electricity is the most convenient method for powering a mix plant. For estimating power requirements, allow 25 hp for a 500-gallon mixer, 15 hp for each 3-inch pump and about 25 hp for accessories, such as lights, air conditioners, heating appliances, fans, and radios. Some stand-by generating equipment may be advisable if the electrical power is subject to interruption. Reliability of power lines during fires should be considered.

Handling equipment. Mechanical handling equipment is essential to establish and maintain a satisfactory mix rate. A 3,000- to 6,000-pound capacity fork lift is the best method for handling dry chemicals. It is equally versatile in unloading trucks or moving materials from storage to mixer. Trucks and conveyors have been used but do not compare in usefulness.

Storage. An adequate supply of mixed chemical is essential. Usually a minimum of two hours' supply should be available without mixing — four hour supply is better. Such a reserve will eliminate stand-by of a mix crew and allow time to move men in. The storage can be adjusted somewhat, depending on the availability of a crew.

Storage of dry chemical will vary greatly, depending upon the locality. Where the unmixed chemical is stocked nearby, only a small amount may be necessary. On the other hand, large quantities must be stored where re-supply is low.

Dry powders should be stored in a dry place, under cover, and off concrete floors. Palletizing the chemical will help keep moisture from entering from the floor. It has the further advantage of convenience in handling. Frequently, the chemical can be palletized in batch lots, thus eliminating bag counting while mixing.

For additional details, see Chapter IX, *Storage of Mixed and Unmixed Chemicals*, page 57.

Mixers. Batch mixers have given the most satisfactory results. The Lely-type mixer shown in Figure 19 is a typical good mixer. All currently accepted

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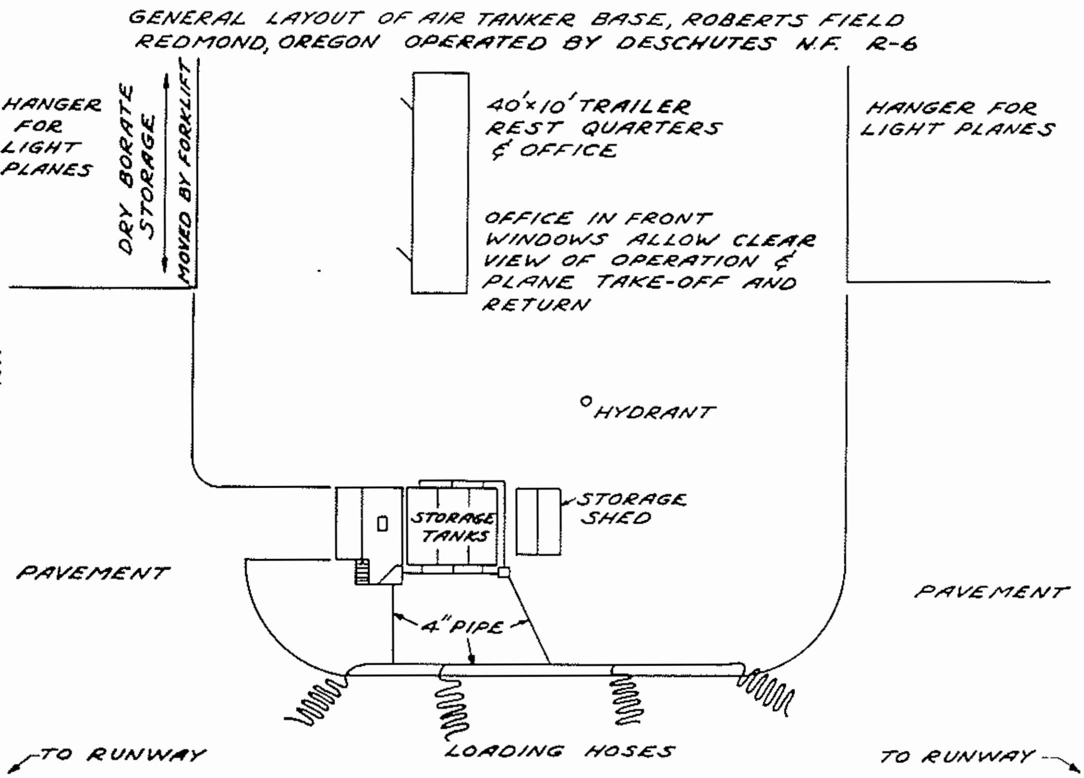

Figure 56. General layout of Air Tanker Base, Roberts Field, Redmond, Oregon.

chemicals can be handled by this unit, usually without any precautions. However, when mixing viscous water solutions, the chemicals should be added rapidly. All the chemical should be in the water within 30 seconds or viscosity may start to rise before the later chemical is dispersed. If this happens, little balls of unmixed chemical will be found. Once formed, they are difficult to disperse by mixing but will disappear overnight in storage.

Injector-type mixers have worked well in mixing viscous water. They should be used in a batch recirculation system for dispersing the chemical rapidly. They cannot be depended upon for adequate results where used as proportioners; nor can they be used for adding granular materials such as DAP, unless supplemented by tank agitation.

Injector-type mixers have been used as proportioners for mixing borate. This system works better with borate than any other chemical but results do not compare with batch mixing. Frequent stoppages, or near stoppages, inherent with this principle, cause thin and somewhat unsatisfactory slurries.

Airport mixing stations. Various airport mixing stations have been constructed. Some had serious faults but newer installations have corrected most difficulties. A few examples of good efficient features are shown. Each has the benefit of much study and planning.

A model air tanker base is shown in Figure 56. To achieve maximum utilization of existing facilities, the mixer and storage tanks were placed between the hangars and close to the paved ramp. This provided dry chemical storage in one of the hangars, a short distance from the mixer. Short 4-inch mains adequately supply the filling stations at the ramp's edge.

Figure 57 shows in detail the arrangement of the mixer and storage tanks. Most of the hand labor is done on the deck over the mixer and at mixer feed height.

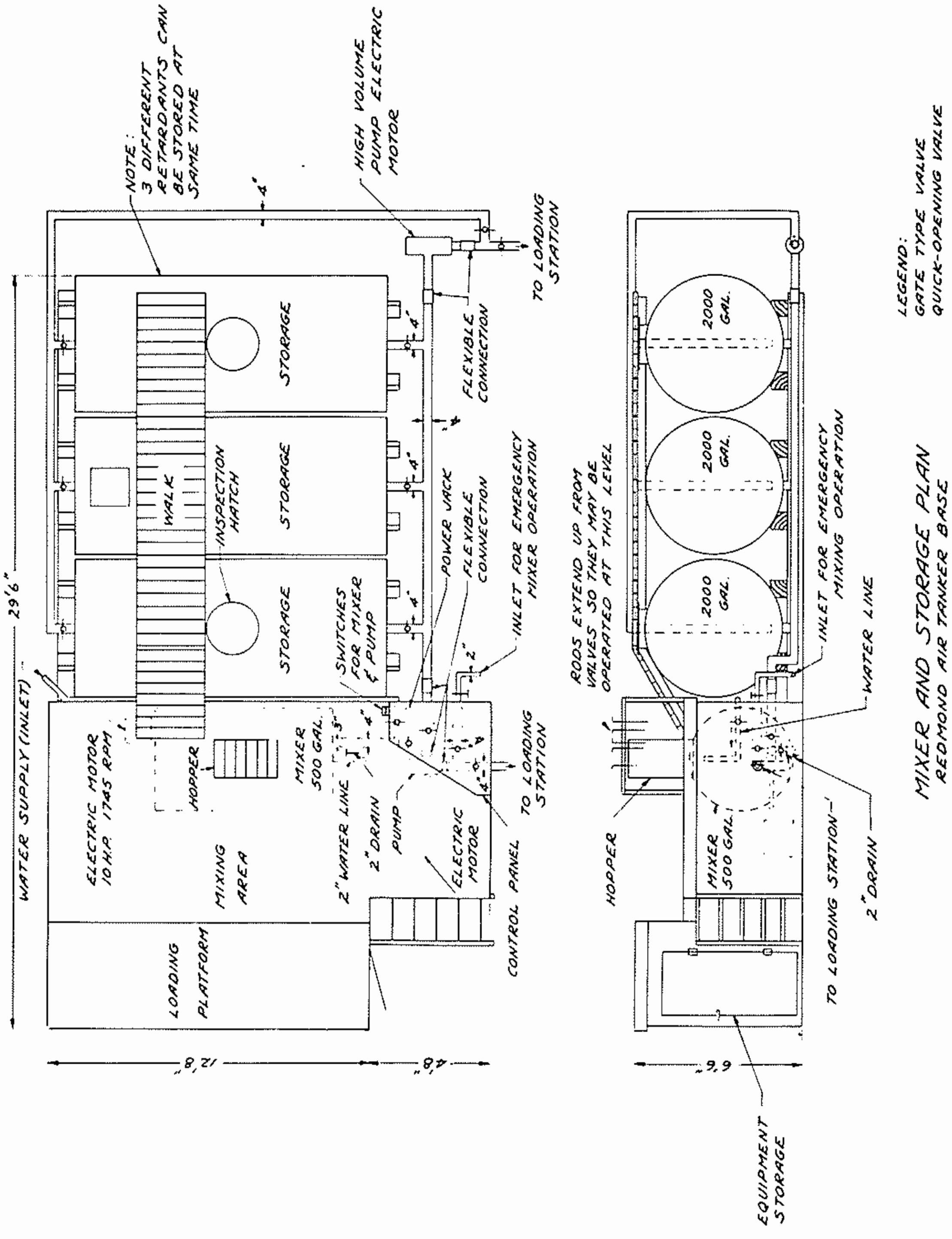

Figure 57.

A fork lift places the sacked chemical on a raised portion of the platform at a convenient height for lifting.

The mix master, or superintendent, has a clear view of the entire operation from the mix deck, including plane movement and loading. A special feature of this plant is the single central station shown in Figure 58. From this location, the more important valves and the electrically driven mixer and pumps are controlled.

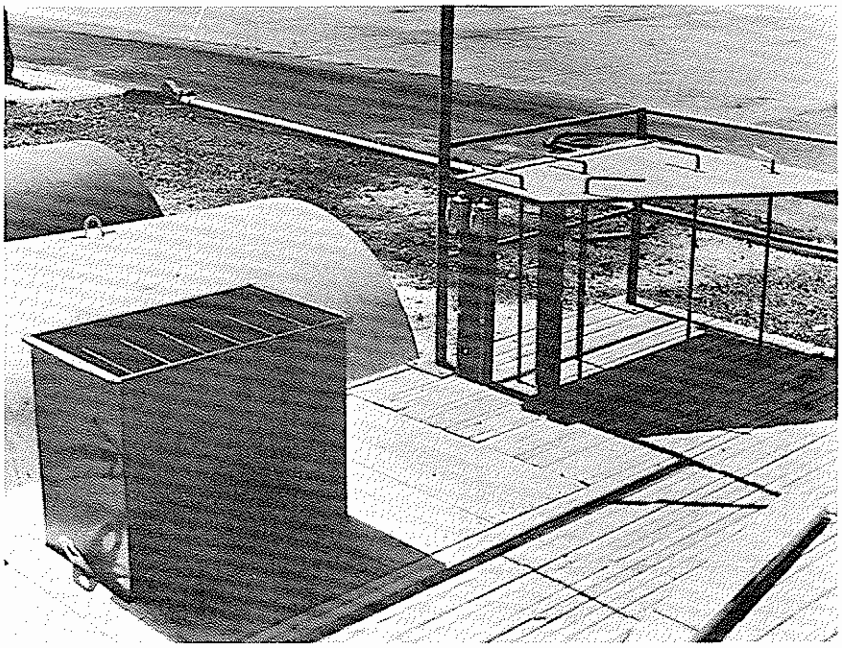

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Figure 58. The entire operation can be seen and directed from the mix deck.

The storage tanks are compactly positioned next to the mixer. (See Figure 59.) Ample pipe sizes are provided for filling, emptying, or recirculation.

Another good example of storage is shown in Figures 60 and 61. Large excess jet engine shipping tanks were adapted for storage. The arrangement is neat and compact. The tanks are mounted low in the ground which allows convenient inspection of the contents. A separate electrically powered pumping system is contained in a concrete pit, centrally located to the tanks. Piping from the mixer and to the filling station is underground.

Of interest is a ground plan resulting from a recent engineering study. It was made to determine the best layout for an airport mixing plant and loading system. (See Figure 62.) This design can handle the largest planes now being considered. It is readily expandable to mix and load 200,000 gallons per day. The study indicated such a volume as about maximum for any one station. For greater volumes, higher efficiency could be obtained with additional stations.

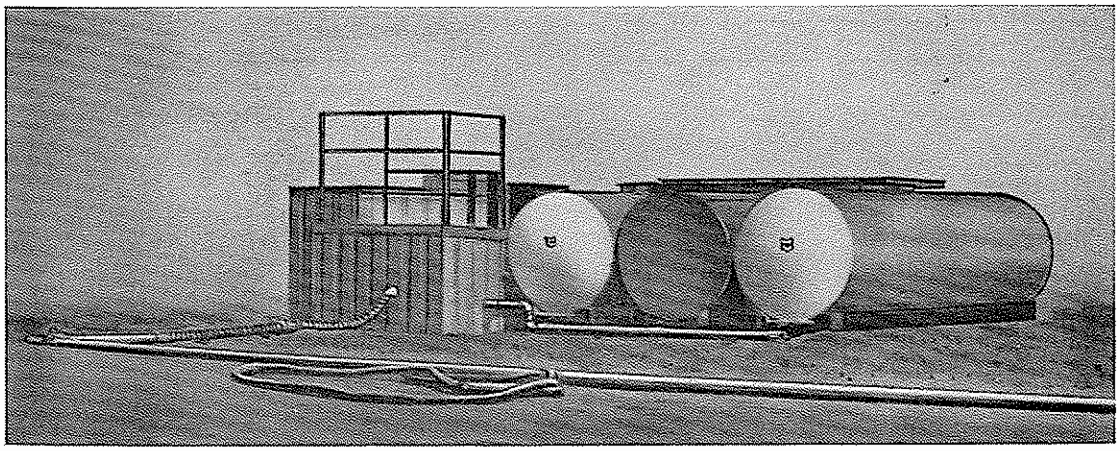

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Figure 59. Storage tanks and mixer arranged close to each other. (See Figure 57.)

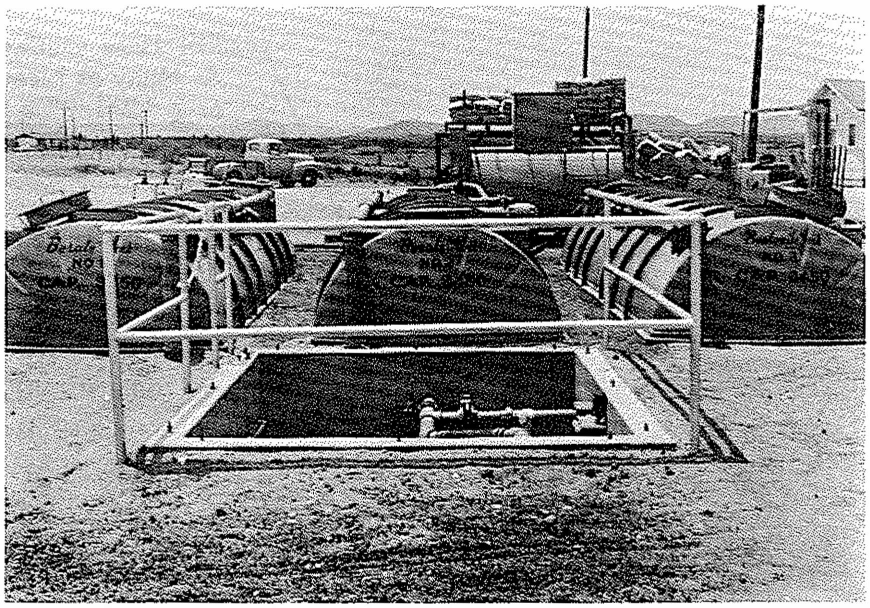

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Figure 60. Large jet engine shipping tanks used for storage.

In the plan shown, a single taxiway leads to the two loading stations. Thus, maximum utilization is obtained as the first waiting plane can move into either fill station as it becomes vacant. The plan could be cut to one circle with one loading station or expanded to four circles with four stations.

Placing the mixing plant in the area between the taxiways is another innovation. Waste space is used, propeller blast is away from the mixers and, with large radius turns, blowing is reduced. Interruptions are less from flying dirt and

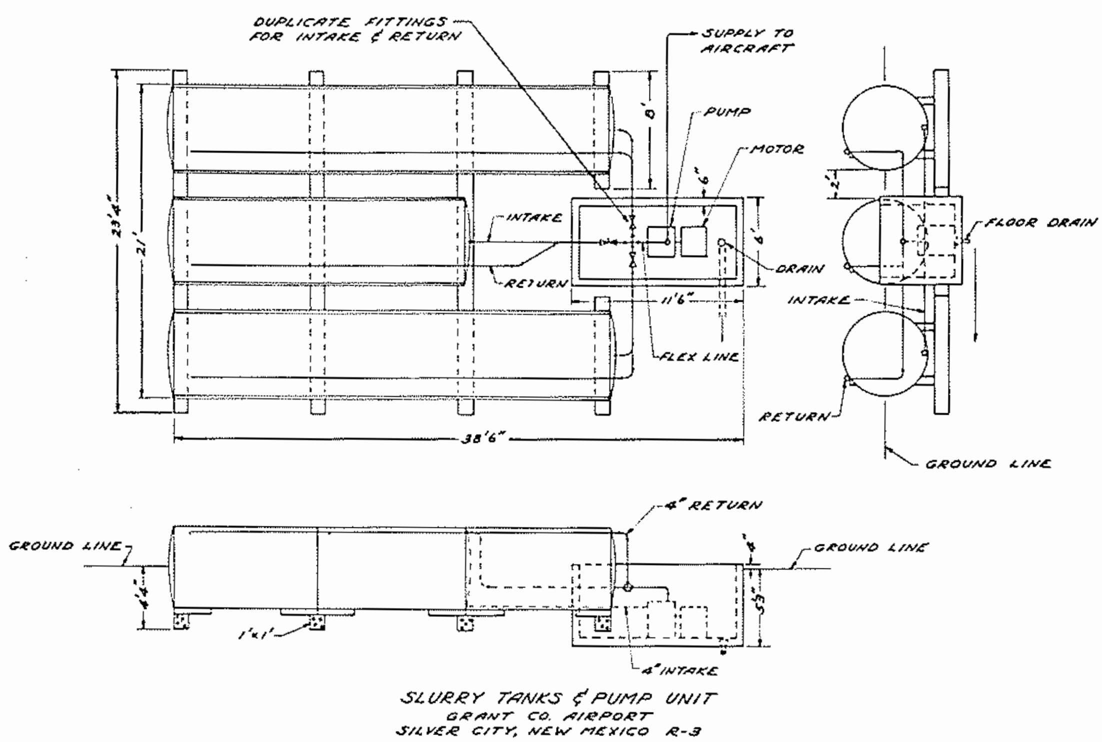

Figure 61. Slurry Tanks and Pump Unit. Grant Co. Airport, Silver City, New Mexico.

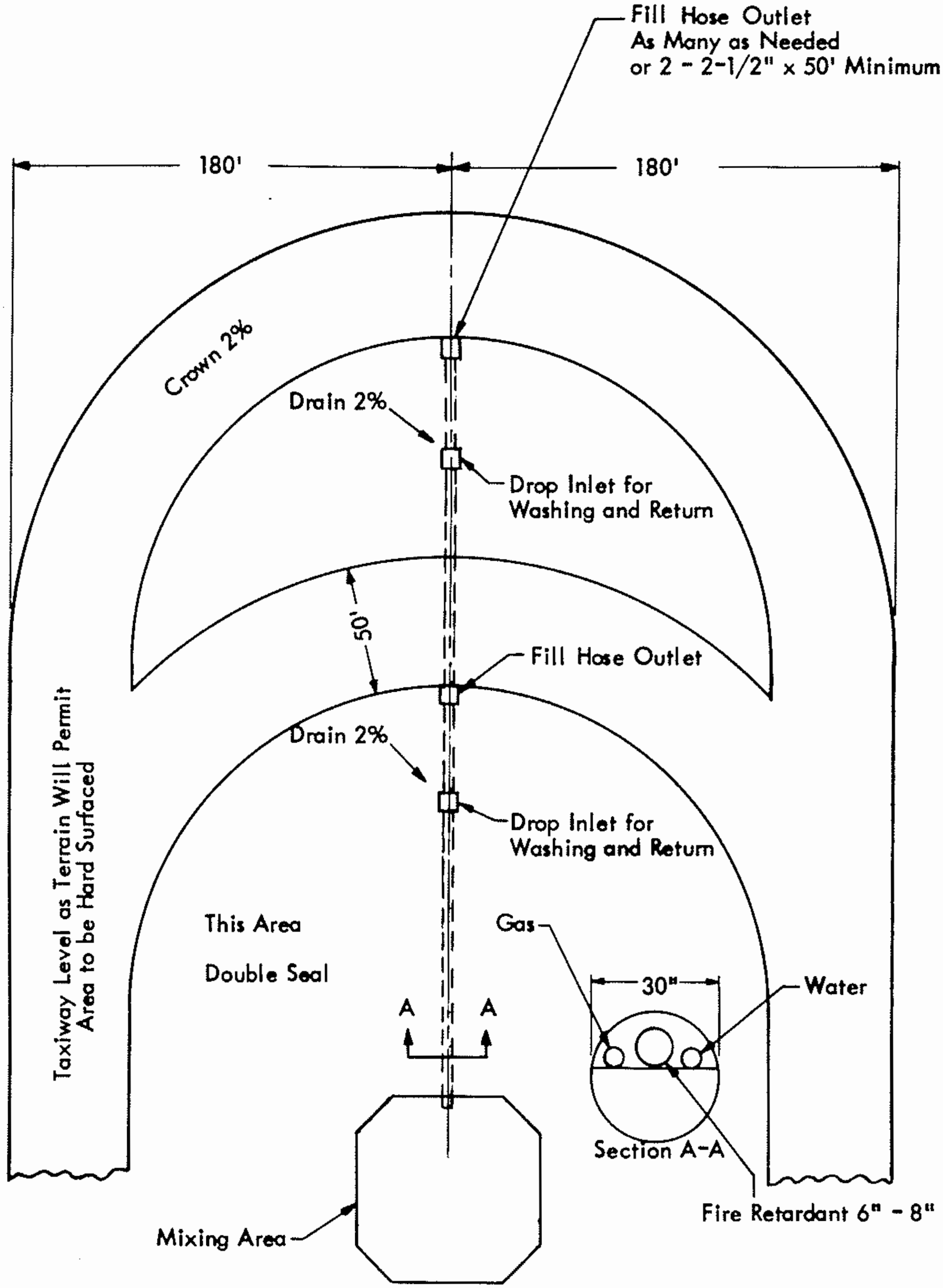

Figure 62. A suggested air tanker base for layout.

dust, and when handling dry powdered chemicals, it is an important improvement in health and safety practice. Where taxiways are long enough, additional space between taxiways can be used for plane parking. A 30-inch concrete pipe leads to each filling station. It will carry chemicals, fuel and water mains and will provide a drain for the possible recovery of dumped chemicals and washdown operations. Additional pipes can be easily added as needed Taxiways are surfaced to support the heaviest ships proposed; about 120 pounds per square inch or up to 160,000 pounds gross. Areas between loading ramps and adjacent to loading stations are seal-coated for convenient wash-down. Fifty thousand (50,000) gallons of underground chemical storage is provided along with 20,000 gallons of aviation gasoline.

Chapter XII

PORTABLE (TEMPORARY) CHEMICAL MIXING STATIONS

Site. In selecting a temporary site, the equipment to be supplied should be considered first. If the job is to supply aircraft at an airport, the appropriate guideline under Chapter XI, *Permanent Mixing Plants* will apply. If the mix plant is to supply helicopters or ground equipment, the area of their operation will influence the mix site location.

For supplying helicopters or tankers, the mix plant probably should be at an elevation equal to, or higher than, the application point. Either vehicle will be more efficient when carrying the load down and returning empty than with the reverse condition — round trips can be completed in less time. Also, it is usually less costly for cargo trucks to haul supplies to a mixer on high ground than to carry them with a fire tanker or lift them with a helicopter.

The site should have access for cargo trucks. Space must be available for mixing and handling equipment, for work vehicles and for trash and refuse. Some washdown of equipment is essential and drainage should be considered. Working efficiency and safety will be impaired if water and chemicals are allowed to accumulate around, or on, equipment.

Water. Water must be available. Quantities for mixing should be anticipated and extra included for washdown and cleanup. Water may be available at some sites; at others, tanker trucks must supply it.

Storage. In most cases, some mixed chemical storage will be desirable. Where water supply is critical, collection and storage may be required. Canvas tanks usually will be most suitable.

Dry chemicals should be stored off the ground where possible. Pallets, or even empty bags, will help prevent ground moisture from penetrating the bags. With nighttime dampness, the bagged chemical should be protected. Tarps or plastic covers are suitable.

For further details refer to Chapter IX, *Storage of Mixed and Unmixed Chemicals*, page 57.

Mixers. Batch mixers have given the most consistent results. AEDC has developed one portable unit shown in Figure 21, page 39.

The AEDC mixer is suitable for all chemicals currently accepted. It mixes all chemicals rapidly and without difficulty. Usually, chemicals will be added rapidly but this is important with the viscous water agents. The viscous agents must all be added within 30 seconds or viscosity build-up will slow dispersions of the last material and cause lumps. These lumps are difficult to disperse by agitation but will disappear overnight in storage.

Injector-type mixers, used for dispersing viscous water chemicals in batch lots, have worked well. Many fire tankers now have this equipment. (See Figure 9.) They should not be used for proportioning viscous chemicals and cannot be employed for adding granular materials such as DAP unless supplemented by tank agitation.

Injector mixers have been used for proportioning borate. In proportioning, they work best with borate but the results are inferior to batch methods.

For additional information refer to Chapter XI, *Permanent Chemical Mixing Plants*, page 69 and Chapter VI, *Equipment for Mixing Chemicals*, page 37.

CHAPTER XIII

SAFETY

The handling, mixing, and application of chemicals is a relatively new activity for forest fire fighters. Safe work practices should be followed.

Cleanliness. Most of the fire fighting chemicals discussed are extremely slippery when applied to forest floors, dropped on highways, or spilled on equipment surfaces. Extra care must be used when walking through, or working in, treated areas. Highways and equipment should be washed down carefully.

Empty bags and trash should not be allowed to accumulate in work areas.

Goggles and dust respirators. When handling dusty chemicals, workers should wear goggles and dust respirators.

Aircraft propellers. Aircraft engines will be stopped before and during any servicing of aircraft.

Hose lines. Hose lays will be kept to a minimum, consistent with efficient chemical handling operations. A jumble of crossing hose lines should not be permitted under any circumstances. Hose lines filled with retardant gels and slurries are unusually heavy. When not in use, sections should be cleaned, coiled, and racked.

Lifting. Since most of the sacked chemicals must be hand-lifted at some stage in mixing, it is important to keep this part of the job to a minimum and at convenient heights. Workers will be instructed in proper lifting techniques.

APPENDIX

Table 1. Approximate Mixing Time in Minutes

Chemical	AEDC Slip-on Tanker-Mixer	American Colloid Mixer	Forester Injector Mixer	Modified Forester Injector	Kelco Eductor	Lely Mixer	Lightnin Mixer	Westborn Mixer
1. Algin	under 2	—	—	1 to 5 (21)	3	under 2	—	—
2. Algin-DAP 1.5%–15%	2 to 4	—	—	—	—	2 to 4	—	—
3. Algin-gel	2 to 4	—	—	—	—	2 to 4	—	—
4. Bentonite	4 to 8	4 to 8	over 15	—	—	4 to 8	over 15	—
5. Borate	2 to 4	over 15	over 15	—	—	2 to 4	over 15	2 to 4
6. CMC	under 2	—	—	1 to 5 (21)	3	under 2	—	—
7. CMC-DAP 1%–10%	2 to 4	—	—	—	—	2 to 4	—	—
8. DAP	under 2	under 2	over 15	—	—	under 2	under 2	—
9. Fire-trol	2 to 4	—	—	—	—	2 to 4	—	—
10. Pectate-DAP	under 2	—	—	—	—	under 2	—	—

Data does not include times for adding chemicals.

Time values include mixing to where further increase in viscosity is negligible and all chemical mix will pass a 12-mesh screen.

No data is available for those mixers and chemicals where the dash appears.

Some difficulty has been experienced in mixing the earlier Fire-trol and Pectate-DAP but processing procedures have corrected this trouble.

Table 2. Chemical Mix Data[1]

Chemical	Pounds of Chemical per Gallon of Water	Pounds per Gallon of Mixed Chemical	Gallons of Mix per Gallon of Water	Pounds of Chemical per Gallon of Mix
1. Algin	0.0667	8.4	1.00	0.0667
2. Algin-DAP 1.5%–15%	1.375	9.0	1.08	1.27
3. Algin-gel	0.0451	8.4	1.00	0.0451
4. Bentonite	0.75	8.8	1.03	0.73
5. Borate	4.00	10.1	1.22	3.28
6. CMC	0.042	8.4	1.00	0.042
7. CMC-DAP 1%–10%	0.917	8.8	1.05	0.873
8. DAP	1.50	9.1	1.08	1.39
9. Fire-trol	2.78	9.5	1.17	2.38
10. Pectate-DAP	1.60	9.0	1.11	1.44

The density of water in pounds per gallon varies from 8.344 at 35°F to 8.286 at 100°F.

The above data was calculated, where necessary, using the density of water at 65.5°F = 8.333.

[1]Manufacturers' recommendations should be followed.

Table 3. Commercial Sources of Chemicals

Chemical	*Brand or Description*	*Sources Used*
Algin	"KeltexFF"	*East:* Kelco Company, 75 Terminal Avenue, Clark, N. J. *Midwest:* Kelco Company, 20 No. Wacker Drive, Chicago, Ill. *West:* Kelco Company, 530 W. Sixth St., Los Angeles 14, Calif.
Attapulgite clay — ammonium sulphate (formulated)	"Fire-Trol"	Arizona Agrochemical Corporation 734 East S. P. Drive Phoenix, Arizona
Bentonite	High sodium, swelling type bentonite clay; 90 bbl. yield; F. S. Spec. No. 5100-30a, 2/11/60.	Federal Supply Service, GSA.
Borate	"Firebrake"	Federal Supply Service, GSA; or, Agricultural Sales Dept., U. S. Borax & Chemical Corp., Pacific Coast Borax Co. Div., P.O. Box 7512F Sanford Sta., (630 Shatto Pl.), Los Angeles 5, Calif.
Calcium Chloride	$CaCl_2$, technical, flake 77 percent variety.	Local chemical companies.
CMC	7HP	*East:* Hercules Powder Company, Virginia Cellulose Dept., Wilmington 99, Delaware. *West:* Or other Hercules dealers including 3460 Wilshire Blvd., Los Angeles, Calif.
CMC-DAP	"Phos-Chek 201"	Monsanto Chemical Company 6670 E. Flotilla, Los Angeles, Calif.
DAP	21-53-0; commercial grade agricultural fertilizer.	Local dealers.
Pectate-DAP	"Phos-Check 100"	Monsanto Chemical Company 6670 E. Flotilla, Los Angeles, Calif.

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