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Determining Fire Retardant Quality in the Field

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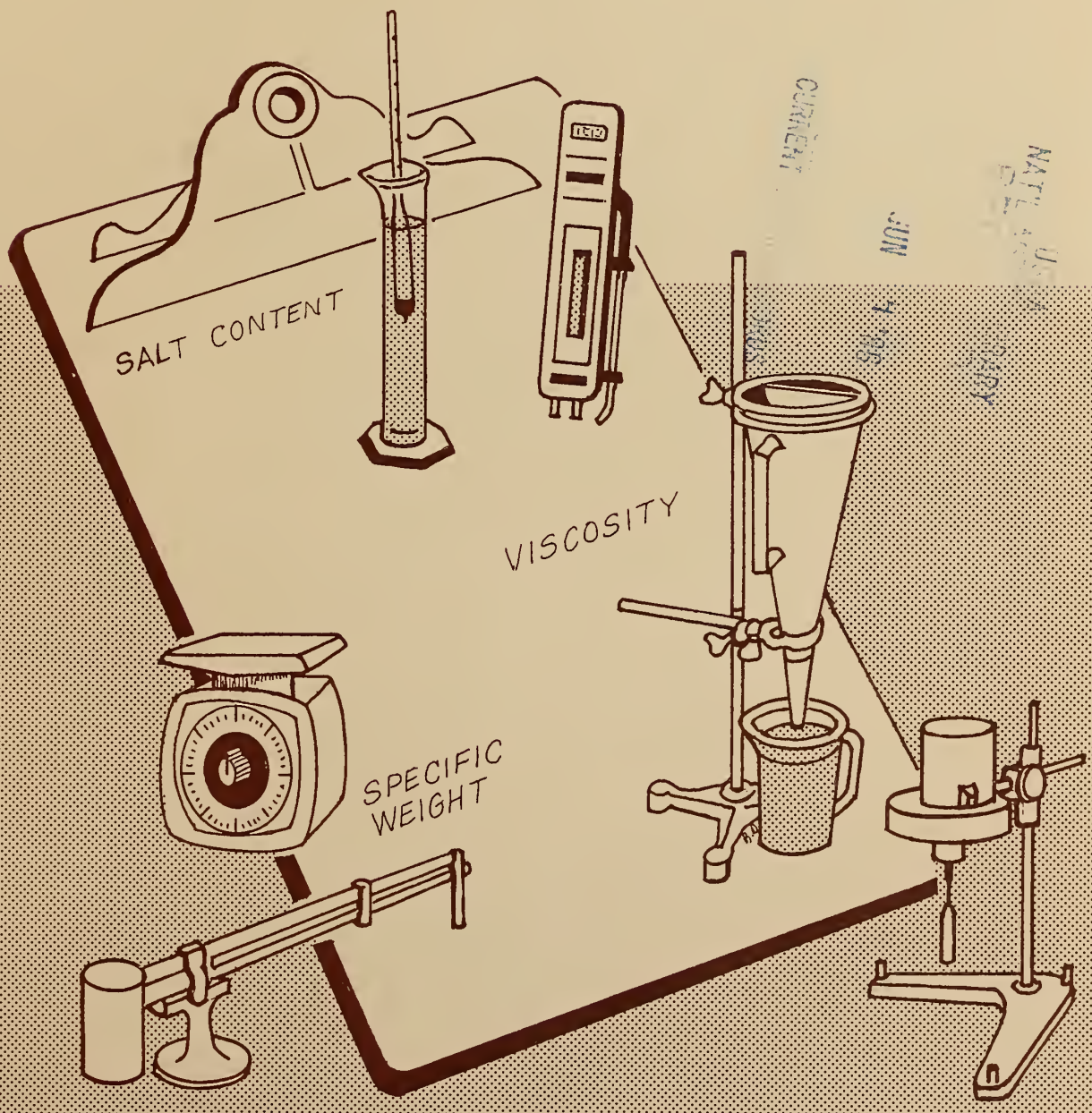

THE AUTHORS

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RESEARCH SUMMARY

Wildland fire retardants are evaluated in the laboratory and the field prior to agency approval for operational use. Proper performance requires that the dry or liquid retardant concentrate is mixed with water in the proper proportions and that the properties of the mixed solution remain within prescribed limits until used. To assure this condition, field personnel must have simple and reliable means of measuring the critical parameters. Quality of retardants in current use can be ascertained by measuring just two parameters: viscosity and active salt content.

Viscosity can be determined by measuring the time required for a specified volume of retardant slurry to flow through the narrow opening (orifice) of a Marsh funnel. Salt content can be determined from the specific gravity (measured by hydrometer) of a thinned retardant. This paper describes the procedures used to measure these properties. Alternate methods using a hand-held density meter, mud balance, and hand-held refractometer are also described. Calibration tables have been developed for most short-term and long-term fire retardants. Some of those included may not be approved for a specific agency's use as a result of varying policies. Also, several retardants used extensively in the past but no longer commercially available have been included for baseline references as have several improved formulations that are in final stages of development. In addition to the calibration tables, descriptive information is given on each retardant formulation, sampling techniques, and corrective actions for situations where viscosity and/or salt content are not within acceptable limits.

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INTRODUCTION

Millions of gallons of forest fire retardants are dropped on wildland fires every year. For both tactical effectiveness and cost effectiveness the retardant must be properly formulated and prepared. Retardants in use have been subjected to laboratory testing wherein the performance of properly mixed retardant is measured and evaluated (USDA Forest Service 1982b,c). Retardant should also be tested in the field to assure that certain critical characteristics are being maintained.

Two specific retardant characteristics that have a major effect on fire control effectiveness and accuracy of delivery are the amount of active retardant chemical (often referred to as salt) and the viscosity (and elasticity) of the prepared slurry. The amount of active salt present is directly related to the retardant's ability to slow a fire. Viscosity (and elasticity) affects the behavior (breakup) of the retardant as it is dropped from an air-tanker or sprayed from a ground tanker, and the way it clings together (or breaks apart) and penetrates the fuel complex. Viscosity (and elasticity) is also important in determining the amount of retardant chemical retained on the fuel.

There are a number of methods for determining these important retardant characteristics, but most are not suitable for use under field conditions; that is, they may require elaborate equipment, long time periods, highly trained personnel, or a combination of these and/or other factors.

The retardant-mixing operation at many bases is performed by employees who may have limited knowledge of chemistry and who are often detailed or hired for the job part time. Thus, the field test should not require special skills, should be simple and quick to perform, and should use a minimum of equipment. The tests must give relatively accurate and repeatable results when used by field personnel following detailed procedures.

Previous studies have led to field procedures for determining retardant solution viscosity (George and Hardy 1966, 1967, 1969; George and Johnson 1976) and salt content (George 1971), and have been combined in a guide for field quality control by the Fire Chemical Working Team of the National Wildfire Coordinating Group (1981). The procedures selected for field analysis of salt content were based on correlations of direct salt content measurements made in the laboratory with measurements of specific gravity of the retardant slurry using a hydrometer. Reducing solution viscosity is required with some formulations. The elasticity of fire retardant solutions cannot be readily measured in the field; however, a method of measuring viscosity using a Marsh funnel has proven to be adequate for field characterization of retardants with known rheology.

Since the original procedures and reports incorporating calibration data were published, a number of the retardant formulations have been modified, several are no longer commercially available as originally formulated, and new products have and are being developed. This report describes many short-term and long-term fire retardant products, their physical-chemical properties, and step-by-step procedures and instructions for measuring retardant properties in the field. *Some of the retardants included in the report may not be approved for a specific agency's use as a result of varying policies. Several retardants used extensively in the past but no longer commercially available are included for baseline reference as are several improved formulations that are in final stages of development.* Calibration and conversion tables for each product are included in this paper.

Table 1 summarizes the physical-chemical characteristics and mix ratios of the products discussed in this paper. These are the characteristics of a *properly formulated and mixed* retardant, and although minor deviation can be expected for a number of reasons, major deviation from the values given for either salt content or viscosity for a *properly mixed* retardant suggests a formulation and/or product stability problem. Such variations in operational field mixtures can adversely influence retardant effectiveness and efficiency in fire control operations.

Table 1.—Fire retardant mix factors and characteristics (80 °F)[1]

Retardant	Type of salt[2]	Normal use[3]	Recommended use level lb (gal)/ gal H_2O	Increase in volume	Quantity of powder or concentrate per gal of mixed retardant	Gallons of mixed retardant per ton of powder or concentrate	Specific weight of mixed retardant	Viscosity of mixed retardant	Specific gravity of treated retardant	Percent salt in mixed retardant
			Lb (gal)	*Percent*	*Lb (gal)*	*Gal*	*Lb/gal*	*Centipoise*		
LONG-TERM RETARDANTS										
Unthickened or low-viscosity gum-thickened										
Phos-Chek G-WX	MAP	G	0.96	5.7	0.908	2,203	8.78	< 10	1.057	9.6% $NH_4H_2PO_4$
Fire-Trol 934, 936[4]	APP	G	2.95 (0.25)	23.9	2.38 (0.20)	840	9.11	< 50	1.100	8.5% P_2O_5
Phos-Chek G-W,G-F,G-R	MAP	G	.96	5.7	.908	2,203	8.78	50-150	1.057	9.4% $NH_4H_2PO_4$
Fire-Trol 931[5]	APP	A	2.99 (.25)	23.6	2.42 (.20)	826	9.15	< 50	1.088	8.4% P_2O_5
Phos-Chek 259-F,259-R, 259-W	DAP	A/G	1.14	6.3	1.07	1,869	8.90	50-150	1.068	10.9% $(NH_4)_2HPO_4$
Phos-Chek 259-F,259-R, 259-W	DAP	G	1.60	9.4	1.46	1,370	9.07	50-150	1.089	14.5% $(NH_4)_2HPO_4$
Gum-thickened										
Phos-Chek A-F,A-R,A-W	MAP	A	.96	5.7	.908	2,203	8.78	1,200-1,800	1.057	9.0% $NH_4H_2PO_4$
Fire-Trol GTS-F,GTS-R	AS	A	1.76	10.4	1.59	1,258	9.13	1,200-1,800	1.098	14.8% $(NH_4)_2SO_4$
Phos-Chek D75-F,D75-R, D75-W	AS/MAP	A	1.20	6.9	1.12	1,786	8.91	1,200-1,800	1.071	11.3% $(NH_4)_2SO_4$/ $NH_4H_2PO_4$
Phos-Chek XB	MAP	A	1.14	7.4	1.06	1,885	8.81	1,200-1,800	1.056	10.7% $NH_4H_2PO_4$
Megatard 2700-A										
Liquid sulfate	AS		3.60	22.9	2.93	682	9.71	< 10	1.166	28.2% $(NH_4)_2SO_4$
Mixed retardant	AS	A								
Liquid sulfate + color/thickener			9.71 (1.00) +.244	101	4.83 (.50) +.116	414 17,241	9.07	1,200-1,800	1.096	15.0% $(NH_4)_2SO_4$
Clay-thickened										
Fire-Trol 100	AS	A	2.78	18.2	2.35	851	9.40	1,500-2,500	1.100	15.6% $(NH_4)_2SO_4$
SHORT-TERM RETARDANTS										
Fire-Kill IIP[6]		A/G	.048 (.005)	.4	.048 (.005)	41,667	8.34	150-250	1,000	—
Fire-Trol ST-Poly[7] (Poly-Trol)		A/G	.059 (.006)	.5	.059 (.006)	33,898	8.34	150-250	1,000	—

[1]Consult your agency manuals and guidelines for specific product availability.
[2]Monoammonium phosphate (MAP), diammonium phosphate (DAP), ammonium sulfate (AS), ammonium polyphosphate (APP).
[3]A = aircraft, G = ground.
[4]Specific weight of concentrate is 11.78 lb/gal.
[5]Specific weight of concentrate is 11.96 lb/gal.
[6]Specific weight of concentrate is 9.67 lb/gal.
[7]Specific weight of concentrate is 9.54 lb/gal.

RETARDANT SAMPLING FOR QUALITY CONTROL TESTING

Although the reason for sampling (lot acceptance, routine quality control, or suspected problem) will affect the manner in which a sample is taken, certain general guidelines (see procedures 1 and 2) will usually apply.

1. *Is the sample representative of the product being tested?* Using a sampling valve, a valve at the pump, or sampling from the end of a loading hose may be acceptable in many circumstances. If attempting to sample the retardant in a tank, be sure the contents are circulated adequately to resuspend any settled material and that the sampling point will provide representative tank material. For example, a sampling outlet may contain product from the last sample taken, or a loading hose may contain aged material or material affected by temperature or contamination and therefore no longer representative of the tank contents. A seldom-used outlet low on the tank may sample only the dregs of a prior season's use. If possible, allow the product to flow through or circulate through the sampling outlet for a short time prior to sampling to obtain a representative sample. Discarding 1 gal of retardant that has flowed through a small valve prior to sampling is usually sufficient to obtain a representative sample. A sample taken immediately after recirculation or after filling an aircraft (if a loading valve is used) is usually adequate.

2. *How often should sampling be done?* Samples for lot acceptance testing should be taken from each new truckload (or lot) of retardant as soon as it is received. Testing should also be done during mixing operations. The type of retardant and mix setup will determine the frequency of sampling. For a product that does not require storage, samples should be taken often enough to assure proper adjustment of equipment and maintain product quality. During slow times and early in the year, each airtanker load should be tested. Once equipment is adjusted and personnel are familiar with the operation or when large quantities of retardant are being pumped, samples should be taken periodically (every few hours or no less than daily) during the operations.

Samples can be marked to identify when they were taken (or aircraft loaded) and held for analysis at the end of the day, depending on the purpose of the sampling; however, this does not allow adjustments in retardant quality or equipment settings to be made when needed. In a continuous-mix operation, such as an eductor and silo of retardant, testing should be frequent enough to assure proper concentration (ratio of water to dry retardant). Recirculation is necessary to get a uniform sample. A batch mixer needs less frequent checking (assuming proper formulation of each batch container by the manufacturer and accurate water level indicator). During initial mixing at the beginning of the season every batch should be sampled to assure correct adjustment of the equipment, then periodically during the fire season and several times a day when large quantities are being mixed. Samples are most easily taken from a batch mixer by installing a small valve in the mix tank at about the midpoint of the retardant solution.

Additionally, retardant in storage at a base should be sampled approximately once a week during the fire season. If problems are noticed, such as a change in salt content or loss of viscosity, samples may need to be taken more often. When a base is first opened for the season any material stored over the winter should be tested prior to use. In general, testing should be performed after thorough recirculation; however, if a visual check (or spot sampling) reveals significant stratification in the tanks the supplier should be consulted for specific instructions. (These may include pumping the water layer and about an inch of retardant out of the tank prior to recirculation. The nearly clear layer on top may be condensation or water that has entered the tanks over winter and may be contaminated with bacteria that could cause significant viscosity loss if the water layer were mixed with the remaining retardant.)

3. *Is the sample liquid or dry?* Liquids may be recirculated to resuspend any settled or crystalized material and assure a homogeneous mixture prior to sampling. This is not true of dry products. It is extremely difficult to assure a uniform sample from a complete container of dry materials; however, in many cases, a sample of properly mixed liquid made from dry product provides a good sample if it is properly mixed into a relatively clean, empty tank. This is also true of samples taken for lot acceptance and quality assurance. If a dry sample is required, special care must be taken to obtain a homogeneous sample; it is probably best to request assistance from agency specialists or the manufacturer since there are special techniques and sampling equipment that must be used to obtain a representative sample from a lot of dry material.

4. *Why is this test being performed?* If the sample is to be taken for lot acceptance tests, it is necessary to obtain a uniform sample that is representative of the lot. This will necessitate a relatively clean, empty storage or mix tank to prepare the sample. (See USDA Forest Service 1982a, Lot Acceptance and Quality Assurance Procedures . . .) If the sample is for routine quality control, a sample should be taken after thorough recirculation of the retardant solution to assure a uniform solution. If recirculation between tanks is not possible, then a sample of the contents of each tank should be taken. If the sample is being obtained to troubleshoot a problem (separation, loss of viscosity, etc.), it may be more meaningful to obtain individual samples from throughout the system (top of tank, bottom of tank, loading hose) prior to recirculation in order to identify the source of the problem.

ACTIVE SALT CONTENT

Long-term, combustion-retarding effectiveness of a retardant is related to the type and amount of active chemical, usually referred to as "active salt," that it contains. All salts are not equally effective when applied to fuels in the same concentration. By adjusting the amount of salt in the concentrate or dry product, and the mix ratio or use level, the retardant manufacturers have produced fire retardant formulations with similar combustion-retarding effectiveness. The effectiveness of

the mixed retardant solution is thus directly related to its concentration of the active salt. It is therefore important to maintain the salt content within prescribed limits.

The specific gravity of a retardant solution is directly related to the concentration of retardant salt in the solution. Corrosion inhibitors, coloring agents, flow conditioners, and other ingredients have a minor effect on specific gravity because they are present in relatively low concentrations. Because proportions and quantities of all ingredients in a properly formulated retardant concentrate are relatively constant, the specific gravity of its solutions can be related to the amount of active salt present (George 1971), using conversion tables. But use of specific gravity to determine salt content has limitations. One cannot tell what salt is used, only its quantity. Similarly, when a retardant contains a combination of salts (the relative weights of each must be specified by the manufacturer) the specific gravity method will not indicate whether the proportions of the salts are changed or if one of the salts is missing entirely, merely the total weight of salt. Quantitative laboratory analysis may be necessary to resolve problems of this type.

A procedure has been developed for determining the salt content in the field using a hydrometer and specific gravity/salt content correlation tables. (A hydrometer is a weighted and sealed glass bulb calibrated to be read in specific gravity units.) After the hydrometer is allowed to settle into a solution for several minutes, the specific gravity scale can be read at the liquid meniscus (the lowest point of the curved upper level of the liquid). If the solution has a viscosity appreciably greater than that of water, however, the buoyancy of the hydrometer may give a false reading. In some instances, it is necessary to correct for, minimize, or eliminate this effect by reducing viscosity to less than 200 centipoise. This can be accomplished in several ways, depending on the nature of the thickening agent. For retardants containing clay, such as Fire-Trol 100 or undiluted Fire-Trol 931, the mixed retardant must be filtered to remove the clay before the specific gravity of the clear filtrate is determined. A different procedure for gum-thickened retardants has been developed. Gum-thickened retardants are chemically thinned by adding a "viscosity-reducing agent" (usually an enzyme that when added to the retardant sample causes the thickener to "break" or thin) prior to determining the specific gravity. Special care must be taken to ensure that the viscosity reducing agent and any retardant containing it are properly disposed of because a small amount may thin the contents of an entire storage tank. The equipment necessary to determine salt content in the field is shown in figure 1.

Two other factors must be considered when determining salt content from specific gravity—hydrometer accuracy and solution temperature. The accuracy of the hydrometer in general use varies and occasionally has been found to cause significant errors in retardant quality determinations. Hydrometers with unspecified accuracy should be checked using a known solution. Consistency in handling the hydrometer and the solution each time a reading is taken will minimize inaccuracies. It is recommended that the hydrometer be slowly immersed until the buoyancy supports it in the solution; then the hydrometer should be allowed to settle for 3 to 5 minutes before reading.

All data presented in this paper were gathered at 80 °F (26.7 °C). A correction should be made if the temperature varies from the standard. The rule for temperature correction is:

> For every 5 °F (2.8 °C) that the temperature is lower than 80 °F (26.7 °C), subtract 0.001 from the hydrometer reading; for every 5 °F (2.8 °C) that the temperature is greater than 80 °F (26.7 °C), add 0.001 to the hydrometer reading. The corrected hydrometer reading is the value to use to determine salt content.

A table of values to correct for temperatures deviating from 80 °F using the above rule is given in appendix 3, table 26.

The tables for specific retardants are arranged by type of thickener or characteristics:

(a) unthickened or low viscosity gum-thickened (not requiring viscosity-thinning treatment)
(b) gum-thickened
(c) clay-thickened.

The right-hand portion of each retardant/salt table lists "corrections per 100 gal of retardant solution." These values will enable field personnel to adjust the salt content of the retardant if it varies significantly (indicated by the boxed area) from the proper value.

Specific procedures for sampling and determining retardant salt content for each type of product are given in the back of this publication. An alternative to using a hydrometer to determine specific weight of a retardant is to use a hand-held density meter. Although density meters are relatively expensive ($1,000 to $1,500) and are fairly delicate, with care it is possible to use them in the field for quality control measurements. The density meter measures the actual density of the solution including incorporated air. To obtain densities suitable for use with salt content tables the sample must be allowed to sit until the entrapped air has escaped. A hand-held density meter (Mettler DMA-35) is shown in figure 2. Directions for using a hand-held density meter to determine specific weight and salt content are described in procedures 11 and 12 of this paper.

Another alternative to the hydrometer/specific gravity method to determine salt content is the hand-held refractometer. The refractometer is moderately priced (about $150) and has several advantages. Pretreatment of the retardant sample is required only for undiluted liquid concentrates. Temperature corrections are not needed if solution temperatures are between 45 and 100 °F. However, the refractometer may give inaccurate results if it is subjected to extremes of temperature. Low temperatures cause greater changes than do high temperatures. Keep the refractometer between 60 °F and 85 °F for best results. Because the refractometer used for this work incorporates an arbitrary scale, calibration tables developed for this specific instrument are required.

Figure 1.—Equipment for determining salt content: (A) unthickened or low-viscosity retardants; (B) gum-thickened retardants; (C) clay-thickened retardants.

Figure 2.—Hand-held density meter (Metler DMA-35).

Procedure 13 describes the use of the refractometer and provides tables for determining retardant salt content with the refractometer, American Optical Scientific Instruments, Model 1440, shown in figure 3.

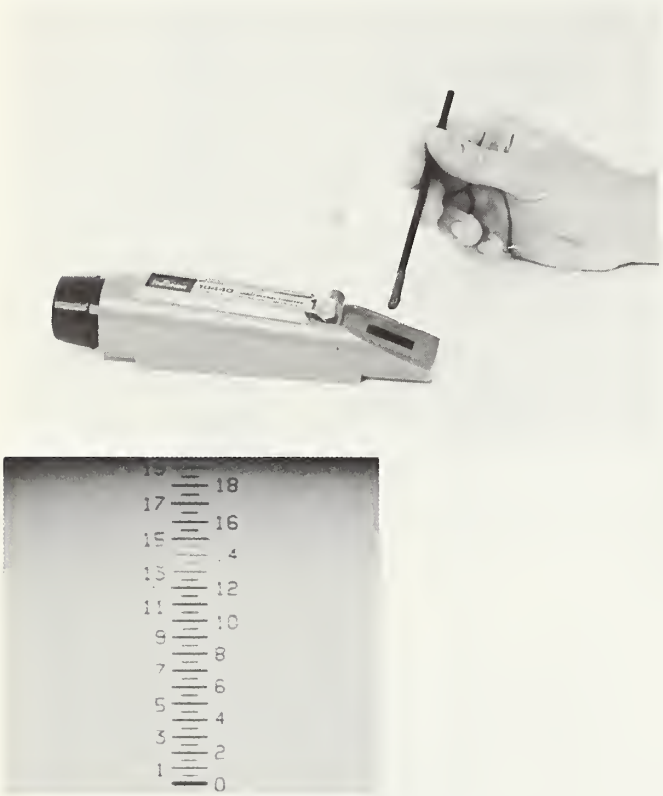

Figure 3.—Refractometer (American Optical Scientific Instruments, Model 1440).

VISCOSITY

The physical-chemical or rheological properties of a retardant slurry have a major impact on the delivery, distribution, accuracy, and effectiveness of a retardant drop (George 1981). The viscosity of the retardant solution is the most common rheological property used to characterize retardant performance because it is easily measured. The performance of a particular retardant, however, is dependent on several rheological properties rather than just viscosity; that is, the retardant with the highest viscosity does not necessarily have the best drop characteristics and performance.

As the retardant leaves the aircraft, droplets are stripped from the falling mass of retardant by the air velocity acting on it. This stripping action, often referred to as breakup, is affected by the cohesiveness of the retardant (resistance to breakup). The cohesiveness is determined by the rheological properties, including viscosity. It is known, however, that the elasticity (another rheological property) of the solution is the most important property affecting breakup (Andersen and others 1974a, 1974b). Too little elasticity of the retardant solution, such as in the case of water or unthickened retardants, results in little resistance to breakup and causes a mistlike condition where most of the retardant occurs as very small retardant droplets. Small droplets evaporate faster, are influenced more by wind, and result in less retardant being spread over a larger area. Accuracy is more difficult because crosswinds may blow clouds of small drops beyond targeted areas.

Rheological properties (including viscosity and elasticity) also affect the ability of the fire retardant to remain on the fuel and spread over the fuel surface (combustion-retarding effectiveness is related to the amount of fuel surface covered with retardant). That is, how much of the retardant coming in contact with the fuel will adhere to it to build up a retardant coating, and how much will run or drip off, either to come into contact with lower aerial fuel or the ground? The extent to which differences in retardant thickening systems may affect retention of retardant by aerial fuels and the fuel coating characteristics has not been well defined. Previous studies have indicated that the overstory can intercept a significant portion of the retardant dropped. Actually, the difference between amounts of thickened and unthickened retardant reaching the ground below the overstory was small (less than 6 percent) (Johansen and Shimmel 1967). Recent studies conducted in Australia (George 1984) indicated that in eucalyptus fuels, gum- and polymer-thickened retardants performed better than unthickened when both the ability to penetrate the overstory and to coat aerial fuels are considered. Retention by the aerial fuels was somewhat greater with thickened retardant, as expected; however, contrary to common belief, so was the amount reaching the ground. (Less retardant was lost to evaporation and drift and there was less dispersion, especially before the retardant cloud entered the overstory.) There were larger areas of the higher coverage levels that more than made up for differences in canopy interception. Thus, the impact of differences in the rheology of different thickening agents in terms of retardant penetrating an overstory is only a fraction of the retardant losses due to evaporation and drift occurring during a retardant drop.

The use of standard and consistent products will allow experienced fire personnel to accurately predict the behavior of specific retardants and adjust for retardant type when planning a fire control strategy. If the retardant being used fails to act in the expected manner, that strategy may fail.

Measurement of the rheological properties necessary to specify a retardant's performance is difficult because of the relative importance of the specific properties (viscosity, elasticity, etc.) and the interactions that occur between them in the case of each general type of retardant. Although elasticity might be a better measure of retardant performance than viscosity, it is difficult to measure, both in the laboratory and field. Viscosity, on the other hand, can be easily measured in the laboratory or field. To achieve acceptable results, only a few conditions of the measurements need to be held constant or monitored. Each retardant formulation has specific rheological properties that vary with thickener concentration (mix ratio). Thus retardant viscosity can serve as an indicator of performance for a given retardant formulation with known rheological properties.

The viscosity of fire retardants has generally been measured using a Brookfield viscometer (model LVF) (fig. 4). The Brookfield viscometer rotates a cylindrical spindle that is immersed in the fluid for which the viscosity is to be determined. The spindle is rotated at a selected speed and the viscous drag exerted by the fluid on the motor is measured. For a reference or standard, a spindle speed of 60 r/min is used with either spindle 2 or 4, depending on the viscosity of the solution (spindle 2 for viscosities below 500 cP or spindle 4 for viscosities above 500 cP). Use of a different speed setting will result in a different viscosity reading, because the relationship of shear rate (r/min) and viscosity are nonlinear for such products. Procedure 7 contains directions for measuring viscosity using the Brookfield viscometer.

The most accurate retardant viscosities will be obtained if samples are not tested until hydration of the thickener is complete and most entrapped air is released. Hydration and release of air bubbles can take from 15 minutes up to 1 hour, depending on mixing and recirculation time, and depending on the specific hardware and situation. The Brookfield viscometer has not been incorporated in field operations, probably because of the cost of the instrument (about $800) and its delicacy.

As an alternative to the Brookfield viscometer, the viscosity of a retardant slurry can be related to the time required for a fixed quantity of slurry to flow through a small hole of known diameter and length. The Marsh funnel (designed for determining the viscosity of drilling muds) has been adapted for this purpose (George and Hardy 1966) and is shown in figure 5. (Instructions for converting a Marsh funnel and commercial sources are available from Intermountain Fire Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807.) The Marsh funnel is filled with retardant and the time for 1 quart to flow through determined. (See procedure 8 for details.)

Figure 4.—Brookfield viscometer used to determine retardant viscosity.

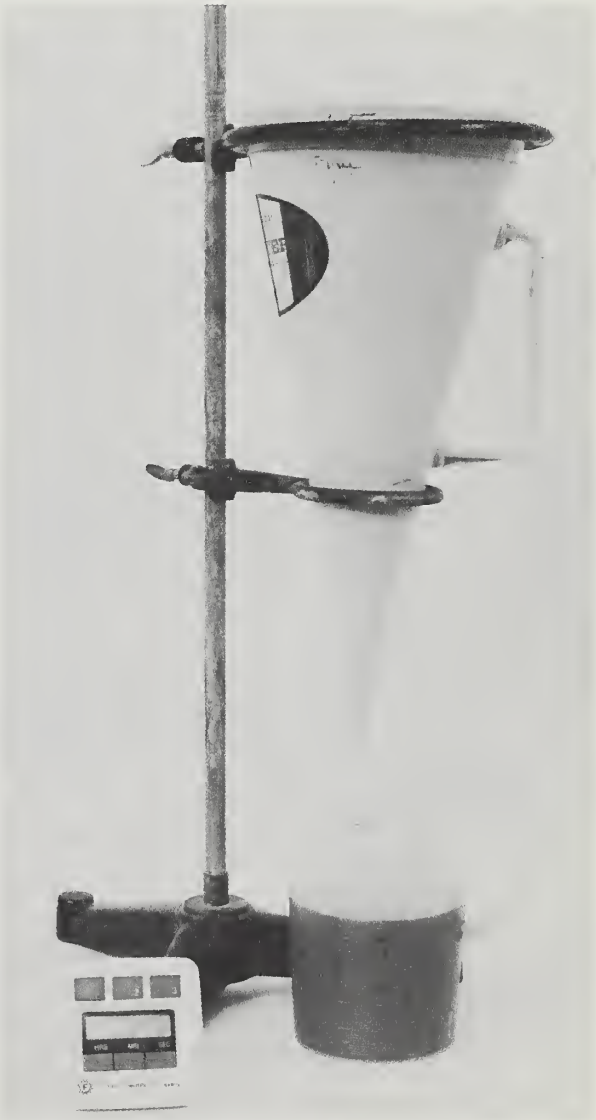

Figure 5.—Marsh funnel used for determining retardant viscosity.

Table 22 (see procedure 8) relates Marsh funnel time to retardant solution viscosity as measured with the Brookfield viscometer. The Marsh funnel time read to the nearest second and compared to table 22 will give viscosities accurate to ±200 centipoise (±10 percent). Such accuracy is adequate for field use. Because thickened retardants are suspensions rather than true solutions measurements of both Marsh funnel time and Brookfield viscosity vary considerably. The retardant concentration, temperature of the solution, time since agitation or recirculation, and age of retardant can affect the viscosity. The tabulated values apply only to the viscosity at the time and temperature of measurement. As the temperature of a retardant solution increases, the viscosity decreases. Conversely, as the temperature of a retardant solution decreases, the viscosity increases. For this reason temperature should be noted as well as the Marsh funnel flow-through time. A material that is too thin at 90 °F may be adequate at 80 °F.

The diameter of the orifice of the Marsh funnel should be 0.269 ± 0.002 inch for the large tip and 0.187 ± 0.002 inch for the small tip. Variations between Marsh funnels in the orifice diameter and length, and volume will cause variations in flow-through time. These variations may result in different viscosity determinations when different funnels are used. Nevertheless, this variation is not usually a problem if it is remembered that Marsh funnel viscosities are accurate to about ±200 centipoise (±10 percent) for most thickened products.

Specific tables were developed using freshly mixed retardant that was fully hydrated and contained a minimum of entrapped air. The length of storage time and degree of agitation prior to sampling may affect the results.

The viscosities of unthickened, diluted Fire-Trol 931-L, 934-L, 936-L, and Megatard 2700 (liquified sulfate) are very low and limit the usefulness of the Marsh funnel. The Brookfield viscosity for Fire-Trol 931-L is approximately 70 centipoise, while the viscosities of Fire-Trol 934-L and 936-L and Megatard liquified sulfate are approximately 10 centipoise.

Because adjusting the viscosity is not as straightforward as adjusting the salt content, changes are not often undertaken unless deviations are excessive. General methods are discussed under the section "Taking Corrective Action." Severe or continued problems in achieving a proper mix should be reported to the agency specialist or other authority and the manufacturer.

SPECIFIC WEIGHT

The specific weight of a retardant is the weight of 1 gal of the mixed retardant, typically expressed in pounds. Although specific weight is usually less accurate an indication of salt content than the other measurements, the specific weight of a sample can be an indicator of whether or not the retardant is properly mixed. It is imperative that entrapped air has been removed. Variations from the acceptable levels should be verified by performing the salt content test before corrective action is taken. Determining the specific weight of a highly aerated retardant can, however, be useful for applications such as determining the actual weight loaded onto an airtanker. Procedures 9, 10, and 11 give detailed instructions for determining the specific weight of a retardant using conventional weight/volume measurements, a mud balance, and a hand-held density meter (fig. 2). A mud balance is shown in figure 6.

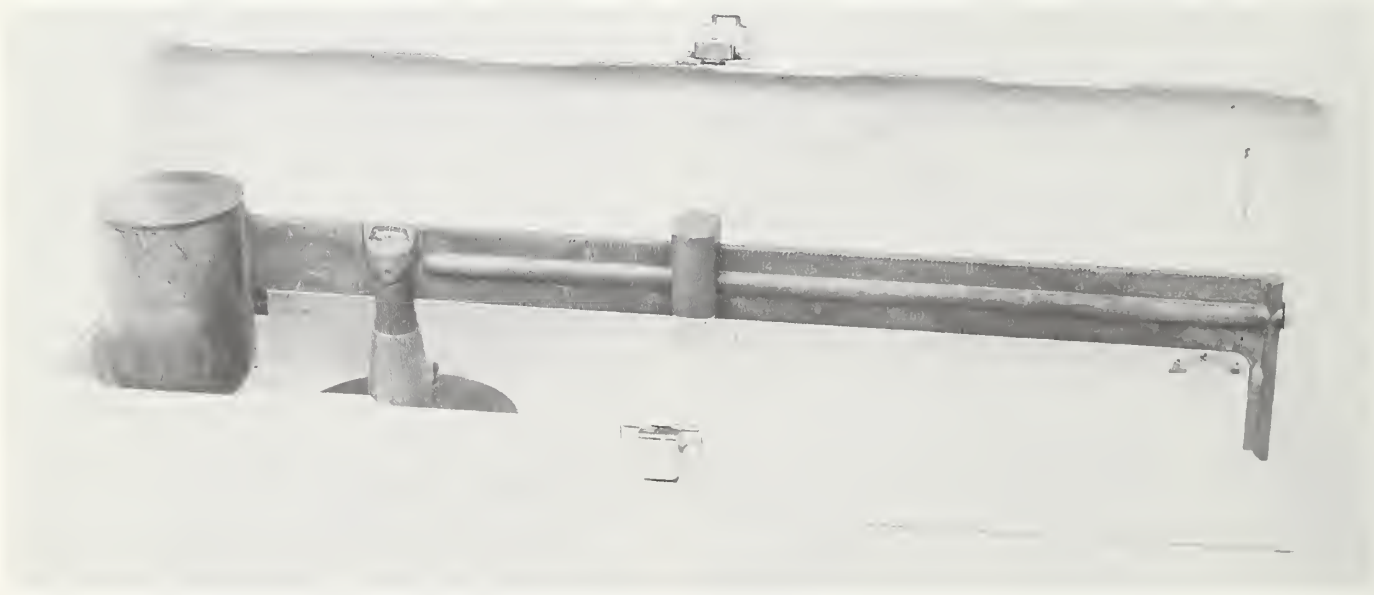

Figure 6.—Mud balance used to determine the specific weight of a retardant.

TAKING CORRECTIVE ACTION

When should corrective action be taken? During the fire season retardant solutions not meeting acceptable characteristics should be corrected as soon as detected. All the tables indicate ranges that will yield acceptable performance and allow some leeway for normal variation in manufacturing and mixing.

If a problem has occurred during the off season, consult the manufacturer and agency experts. Some corrective procedures recommended for use during the fire season may aggravate a problem during winter storage of retardant solution.

An improperly mixed product can cause many problems. If the values are above those specified, the retardant may:

1. Contain excessive salt and cost more per gallon than necessary.
2. Be too viscous to flow readily in loading operation.
3. Salt-out or precipitate in storage, especially as temperatures fluctuate.
4. Exhibit abnormal drop characteristics.
5. Cause excessive corrosion.

If the test values are lower than those specified, the retardant may:

1. Not effectively retard the fire because of inadequate salt content.
2. Experience greater losses due to evaporation and wind drift when dropped from an airtanker.
3. Separate easily in storage.
4. Be more susceptible to viscosity loss and more corrosive due to inadequate levels of bactericide and corrosion inhibitors.

What corrective action should be taken? The corrective action to be taken depends on the characteristics of the particular retardant. The following guidelines are generally appropriate for correcting deficiencies found during the fire season and are based on the type of retardant.

The most common quality control problem is improper mixing ratio leading to other than recommended salt content and viscosity and possibly inadequate short-term stability. The basic corrective action is to adjust the amounts of water and/or retardant concentrate in the mixed retardant.

If both salt content and viscosity are high, water can be added to the slurry using the salt content tables as a guide and thoroughly recirculating the stored retardant. The salt content tables show the amount of water or retardant concentrate per 100 gal of slurry necessary to achieve the proper salt content.

If both salt content and viscosity are low, it is necessary to add retardant concentrate (dry or liquid) to the mixed retardant to obtain the proper level of salt and viscosity. This can be accomplished in several ways, depending on the retardant and particular mixing and storage facilities (each base should develop procedures suitable to the retardant and equipment used). The total amount of additional dry retardant or liquid concentrate required should first be calculated using the correction factors provided. For liquid concentrate formulations, the concentrate can simply be added and the entire mix thoroughly recirculated. This, however, is an infrequent situation, because retardant mixed from liquid concentrates is seldom stored (for aerially applied retardants), but instead it is pumped directly into the aircraft. Suitable adjustments to the proportioning equipment should be made and verified. In the case of dry retardant formulations where quantities of mixed retardant are stored, the corrective action depends on the amount of dry product to be added. In some cases, it will be possible to mix a particularly rich (more powder or less water than usual) batch of retardant and add it to the product in storage, and then recirculate. In other cases, especially with the lower viscosity products or when only a slight correction is needed, the additional dry powder may be added to the stored retardant directly in a batch mix or by passing retardant slurry rather than water through an eductor mixer, while drawing additional powder. In all cases, the stored retardant should be recirculated very thoroughly and then retested. The time required for recirculation depends on the specific storage and handling system. To estimate the time to turn the stored retardant once, divide the total stored retardant by the pumping rate. For example, a 10,000-gal tank of mixed retardant should be recirculated for at least 25 minutes if the pumping capacity is 400 gal per minute (10,000 gal $\div$ 400 gal/min = 25 min). Adequate recirculation should be achieved if pumping is continued for about four times this duration. Although this is not possible in all situations, the longer the recirculation time, the more uniform the solution throughout the tank, and the more accurately the test results will reflect the true situation.

If the salt content is low and the viscosity is high, the problem is more difficult to correct. This is a rare situation and usually occurs with clay-thickened retardants or gum-thickened retardant mixed with unusually cold water. (The viscosity of clay-thickened retardants will increase with increased shear or mixing time; thus relatively high viscosities can be produced at nearly any salt content.) In the case of clay-thickened retardant, the salt content should be corrected first. Usually adding a batch or two of retardant mixed on the rich side and recirculating will correct the salt deficiency. For clay-thickened retardants, the additional batch should be mixed with the minimum shear that will yield a stable slurry. This will aid in lowering the viscosity. With a gum-thickened product (normal mixing-water temperatures), the viscosity cannot be adjusted easily and will likely remain high. Recirculate the tank thoroughly (a very high viscosity solution tends to form a separate layer rather than mix with other solutions), or if possible, circulate to mix several tanks together. This will improve mixing and allow greatest possible lowering of viscosity. The viscosity of gum-thickened retardants usually peaks at some period (12 to 36 hours) after mixing, depending on the specific mixing procedure and equipment. If operations allow, it is recommended that a further sample or samples be taken after this time has elapsed. Prior to any adjustment be sure to consider the temperature of the retardant and whether it is likely to change in storage. It is recommended that adjustments be made to obtain the proper salt content and the resulting viscosity be accepted unless extremes exist. If this occurs, assistance from the agency technical staff and the manufacturer should be sought.

If the salt content is high and the viscosity is low, the addition of a "lean" mix or water (depending on the situation and equipment available) will correct the salt content. It is recommended that a slightly high salt content (10 to 15 percent above the normal acceptable range) be used if additional corrections mean lowering further a substandard viscosity. For a clay-thickened retardant, such as Fire-Trol 100, additional shearing (longer mix time) will raise the viscosity, as previously discussed. On the other hand, the viscosity of gum-thickened retardants cannot be controlled independently of the salt content and there are a limited number of things that can be done to adjust the viscosity. An additional viscosity test may be appropriate for a freshly mixed batch, as other factors such as water temperature will affect the rate of hydration (viscosity development). Although a low viscosity may alter the drop characteristics, separation of the mixed product is also possible. This may lead to compounding problems and result in an increased loss of the viscosity. If possible, storage of such retardant in a separate tank and/or prompt use are recommended. Remember that a properly mixed retardant that loses its viscosity may still be an effective retardant and perform similarly to unthickened or waterlike retardants.

A gum-thickened retardant held in storage for long periods of time can be expected to show some loss of viscosity due to deterioration. Loss of viscosity of freshly mixed retardant or retardant stored for only a short time is also possible and may be a result of contamination. Examples of contamination are:

1. Enzyme - either the viscosity-thinning agent (breaker) used for the salt content test or enzymes from natural bacteria. A very dilute solution of retardant such as would occur after incomplete rinsing and emptying of a mix tank (or if the mix tank is routinely filled with water for the next batch immediately after emptying and without cleaning) is an excellent growth medium for bacteria, and if allowed to sit for several days or weeks, bacterial growth could be sufficient to overwhelm the bactericides in the retardant formulation. There are also many natural sources of bacterial contamination occurring in the air and water used for preparing the retardant. Bacteria from all these sources produce enzymes that may degrade the retardant.
2. Excessive amount of chlorine. Bleach used for disinfection is a potential source of chlorine contamination. Tanks treated with chlorine must be thoroughly rinsed prior to use with retardant.
3. Oil, gas, brighteners, or other chemicals found around bases and aircraft.
4. Other types of retardant.

Viscosity is not generally a concern for unthickened or slightly thickened materials. In most cases, it is not necessary to develop correlations between Marsh funnel times and viscosity. In those instances where correlations can be used (Phos-Chek 259 and G series of retardants), however, they have been included. Adjusting salt content to the proper level by addition of water or additional retardant powder or concentrate on the low-viscosity products is sufficient in most cases.

In all cases, the effect of temperature should not be overlooked. In general, the higher the temperature of the solution, the faster the viscosity of the retardant will deteriorate if any of the above factors are present.

RECORDKEEPING

It is recommended that each retardant-mixing base maintain permanent quality control records that include data on each lot of retardant received, retardant sent to other locations for testing, and tests performed at the base. Appendix 5 offers examples of recordkeeping forms that include information for assessing retardant quality.

When a lot (usually a truckload) of retardant is received, enough information should be recorded to assure future identification. This would include date and time of receipt, quantity of product received, manufacturer's lot number, and invoice or freight bill number.

When a sample is sent to another location for testing (for lot acceptance or to manufacturer for troubleshooting), a record should be made of date and location shipped, manner of sampling, date and time mixed, results of tests performed at the base, lot identification, and reason for sending the sample.

Results of all base tests should also be kept, including mixing and sampling dates and times, solution temperatures, Marsh funnel times and corresponding viscosities, specific gravity and corrections to the specific gravity, and the corresponding salt content. Product identification to the extent known should be included as well as the reason for testing (routine quality control, troubleshooting, etc.). Additional information, such as sampling location (top, tank 1; loading hose pumping from tank 2; etc.) and when tank was last recirculated or new product added, is often helpful as well.

These records are useful when monitoring product quality trends and provide essential background when documenting incidents involving retardant performance and application.

LONG-TERM RETARDANT FORMULATIONS

Unthickened or Low-Viscosity Gum-Thickened Retardants

Phos-Chek® G-WX.—Phos-Chek G-WX is a monoammonium phosphate-based retardant formulation containing no color or thickener (G-ground, W-white, X-no thickener), and designed for ground application. Phos-Chek G-WX contains corrosion inhibitors and can be mixed by an eductor system, batch-mixed, or put in solution by recirculation with water. In other respects, the formulation is like Phos-Chek A and G.

Application : Ground tanker and helicopter bucket.

Use level : 0.96 lb of dry retardant mixed with 1 gal of water will produce 1.057 gal of mixed retardant. Each gallon of mixed retardant contain the equivalent of 0.908 lb of powder.

Viscosity : <10 centipoise (cP).

: Field measurement for viscosity is not meaningful; therefore, no data are provided.

Salt content : 9.6% by weight MAP ($NH_4H_2PO_4$).

: Field measurement (hydrometer): a reading of 1.057 at 75 °F (procedure 3 and table 2 for conversion to salt content and acceptable range).

Specific weight: 8.78 lb/gal slurry (procedure 9, 10, or 11).

Phos-Chek® G-W, G-R, and G-F.—Phos-Chek G-W, G-R, and G-F are monoammonium phosphate-based retardant formulations designed for application from the ground or helicopter bucket. Phos-Chek G-W is uncolored (W-white), while G-R contains iron oxide coloring (R-red), and G-F contains a fugitive coloring agent (F-fugitive). (Fugitive coloring agents fade to a neutral shade several weeks after application.) Phos-Chek G-W, G-R, and G-F contain a low concentration of gum-thickener to provide viscosity in order to improve retardant drop characteristics and adherence to the fuel. The products also contain bactericide and corrosion inhibitors.

Application : Ground tanker and helicopter bucket.

Use level : 0.96 lb of dry retardant mixed with 1 gal of water will produce 1.057 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 0.908 lb of powder.

Viscosity : 50-150 centipoise (cP).

: Field measurement (Marsh funnel): 35-50 sec through the small tip (procedure 8 and table 22 show conversions to viscosity and acceptable range).

Salt content : 9.4% by weight MAP ($NH_4H_2PO_4$).

: Field measurement (hydrometer): a reading of 1.057 at 80 °F (procedure 3 and table 2 for conversion to salt content and acceptable range).

Specific weight: 8.78 lb/gal slurry (procedure 9, 10, or 11).

Table 2.—Salt content of Phos-Chek G-WX, G-W, G-R, and G-F related to specific gravity at 80 °F (use with procedure 3)

Measured specific gravity of the retardant	Percent by weight $NH_4H_2PO_4$	Percent by weight P_2O_5 equivalent	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			Lb	*Gal*
1.000	0.5	0.3	91	
1.005	1.3	0.8	84	
1.010	2.1	1.3	76	
1.015	2.9	1.8	68	
1.020	3.7	2.3	60	
1.025	4.5	2.6	52	
1.030	5.3	3.2	45	
1.035	6.0	3.7	36	
1.040	6.8	4.2	28	
1.045	7.6	4.7	20	
1.050	8.4	5.2	12	
1.051	8.6	5.3	10	
1.052	8.8	5.4	9	
1.053	8.9	5.5	7	
1.054	9.1	5.6	5	
1.055	9.2	5.7	4	
1.056	9.4	5.8	2	
1.057	9.6	5.9	0	0
1.058	9.7	6.0		2
1.059	9.9	6.1		3
1.060	10.0	6.2		5
1.061	10.2	6.3		7
1.062	10.3	6.4		9
1.063	10.5	6.5		10
1.065	10.9	6.7		14
1.070	11.6	7.2		23
1.075	12.4	7.7		32
1.080	13.2	8.2		41
1.085	14.0	8.7		50
1.090	14.8	9.1		60
1.095	15.6	9.6		69
1.100	16.4	10.1		79
1.105	17.2	10.6		88
1.110	18.0	11.1		98
1.115	18.8	11.6		108
1.120	19.6	12.1		117
1.125	20.4	12.6		127
1.130	21.2	13.1		137
1.135	22.0	13.6		147
1.140	22.8	14.1		157
1.145	23.6	14.6		168
1.150	24.4	15.0		178

The boxed area represents a variation in salt content such that no corrective action is needed.

Fire-Trol® 934-L and 936-L.—Fire-Trol 934-L and 936-L are formulations comprised of liquid ammonium polyphosphate (Arcadian Poly-N® 11-37-0 diluted to 10-34-0), and designed for ground application only. (Poly-N was previously a product of Allied Chemical Co.) Fire-Trol 934-L has no coloring added, and Fire-Trol 936-L contains red dye. These products do not contain a thickener, and the solutions are light in color. A corrosion inhibitor contained in the formulation imparts a bluish tint to the uncolored Fire-Trol 934-L. Both products contain a wetting agent for improved penetration of organic fuels. Fire-Trol 934-L and 936-L can be batch-mixed by dilution and agitation during circulation, or they can be mixed using simple proportioners, eductors, or other devices controlling the flow of the concentrate and water, and relying on flow-induced turbulence or pump-mixing.

Application : Ground tanker and helicopter bucket.

Use level : 1 gal of liquid concentrate mixed with 4 gal of water will produce 4.96 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 0.20 gal of liquid concentrate.

Viscosity : <50 centipoise (cP).

: Field measurement for viscosity is not meaningful; therefore, no data provided.

Salt content : 8.5% by weight P_2O_5 equivalent.

: Field measurement (hydrometer): a reading of 1.100 at 80 °F (procedure 3 and table 3 for conversion to salt content and acceptable range).
Field measurement (refractometer): a reading of 16.9 (procedure 13 and table 4 for conversion to salt content and acceptable range).

Specific weight: 9.11 lb/gal slurry (procedure 9, 10, or 11).

Table 3.—Salt content of Fire-Trol 934-L and 936-L related to specific gravity at 80 °F (use with procedure 3)

Dilution ratio	Measured specific gravity of the retardant	Percent by weight P_2O_5	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			------ Gallons ------	
20:1	1.020	2.1	19.3	
15:1	1.029	2.8	17.3	
10:1	1.045	4.1	13.6	
9:1	1.049	4.4	12.6	
8:1	1.055	4.9	11.2	
7:1	1.062	5.5	9.5	
	1.065	5.7	8.8	
	1.070	6.1	7.5	
6:1	1.071	6.2	7.3	
	1.075	6.5	6.3	
	1.080	6.9	5.1	
5:1	1.084	7.2	4.0	
	1.085	7.3	3.8	
	1.090	7.7	2.5	
	1.095	8.1	1.2	
	1.096	8.2	1.0	
	1.097	8.3	0.7	
	1.098	8.4	0.5	
	1.099	8.4	0.2	
4:1	1.100	8.5	0	0
	1.101	8.6		1
	1.102	8.7		2
	1.103	8.8		3
	1.104	8.8		4
	1.105	8.9		5
	1.110	9.3		11
	1.115	9.7		16
	1.120	10.1		21
3:1	1.123	10.4		25
	1.125	10.5		27
	1.130	10.9		32
	1.135	11.3		38
	1.140	11.7		43
	1.145	12.1		49
	1.150	12.5		55
	1.155	13.0		60
	1.160	13.4		66
2:1	1.162	13.5		69
	1.165	13.8		72
	1.170	14.2		78
	1.175	14.6		84
	1.180	15.0		90
	1.185	15.4		96
	1.190	15.8		102
	1.195	16.2		108
	1.200	16.6		114
	1.205	17.0		120
	1.210	17.4		126
	1.215	17.8		133
	1.220	18.2		139
	1.225	18.6		145
1:1	1.229	18.9		151
	1.230	19.0		152
	1.235	19.4		158
	1.240	19.8		165
	1.245	20.2		171
	1.250	20.6		178
	1.275	22.6		212
	1.300	24.6		247
	1.325	26.7		283
	1.350	28.7		320
	1.375	30.7		359
Conc	1.398	32.5		395
	1.400	32.7		399

(con.)

Table 3.—(Con.)

The boxed area represents a variation in salt content such that no corrective action is needed.

Table 4.—Salt content of Fire-Trol 934 and 936 related to scale reading on the refractometer (use with procedure 13)

Dilution ratio	Refractometer scale reading for the retardant	Percent by weight P_2O_5	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			-------- Gallons --------	
20:1	4.4	2.1	19.1	
15:1	5.6	2.7	17.4	
10:1	8.1	4.0	13.7	
9:1	8.9	4.4	12.5	
8:1	9.7	4.8	11.3	
7:1	11.0	5.5	9.4	
	11.5	5.8	8.6	
	12.0	6.0	7.8	
6:1	12.4	6.2	7.2	
	12.5	6.3	7.0	
	13.0	6.5	6.2	
	13.5	6.8	5.4	
	14.0	7.0	4.7	
5:1	14.3	7.2	4.2	
	14.5	7.3	3.9	
	15.0	7.5	3.1	
	15.5	7.8	2.2	
	16.0	8.1	1.4	
	16.5	8.3	0.6	
4:1	16.9	8.5	0	0
	17.0	8.6		1
	17.5	8.8		4
	18.0	9.1		7
	18.5	9.3		11
	19.0	9.6		14
	19.5	9.8		18
	20.0	10.1		21
	20.5	10.3		24
3:1	20.6	10.4		25
	21.0	10.6		28
	21.5	10.9		31
	22.0	11.1		35
	22.5	11.4		38
	23.0	11.6		42
	23.5	11.9		45
	24.0	12.1		49
	24.5	12.4		52
	25.0	12.6		56
	25.5	12.9		60
	26.0	13.2		63
	26.5	13.4		67
2:1	26.7	13.5		68
	27.0	13.7		71
	27.5	13.9		74
	28.0	14.2		78
	28.5	14.4		82
	29.0	14.7		83
	29.5	14.9		89
	30.0	15.2		93

The boxed area represents a variation in salt content such that no corrective action is needed.

Fire-Trol® 931-L.—Fire-Trol 931-L is a formulation composed primarily of liquid ammonium polyphosphate (Arcadian Poly-N 11-37-0 diluted to 10-34-0), and designed for fixed-wing and helicopter bucket air application. (Poly-N was previously a product of Allied Chemical Co.) Although attapulgite clay is added to the concentrate to suspend the color and enhance visibility, when diluted for use it is essentially an unthickened product. Fire-Trol 931-L contains a corrosion inhibitor, and iron oxide and a dye provide the color. Mixing is accomplished through simple proportioning of the retardant concentrate and water. The resulting mixed retardant is usually pumped directly into aircraft without intermediate storage.

Application : Demand-mixed air tanker and helicopter bucket. Can be used for ground application, but less suitable than Fire-Trol 934-L or 936-L.

Use level : 1 gal of liquid concentrate mixed with 4 gal of water will produce 4.94 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 0.20 gal of liquid concentrate.

Viscosity : <50 centipoise (cP).

: Field measurement for the viscosity of the retardant mixed 4:1 is not meaningful; therefore, no data provided for the mixed retardant. Viscosities can be determined on the concentrate (procedure 8 and table 22).

Salt content : 8.4% by weight P_2O_5 equivalent.

: Field measurement (hydrometer): a reading of 1.224 at 80 °F for the liquid concentrate (procedure 6 and table 5 for conversion to salt content). A reading of 1.108 at 80 °F for the mixed retardant (procedure 3 and table 6 for conversion to salt content and acceptable range). For more precision, a sample may be filtered prior to reading. A reading of 1.088 at 80 °F for a filtered sample (procedure 5 and table 7 for conversion to salt content and acceptable range).
Field measurement (refractometer): a reading of 15.6 (procedure 13 and table 8 for conversion to salt content and acceptable range).

Specific weight: 9.15 and 11.96 lb/gal, respectively, for mixed retardant and liquid concentrate (procedures 9, 10, or 11).

Table 5.—Salt content of Fire-Trol 931-L concentrate related to specific gravity at 80 °F (use with procedure 6)

Measured specific gravity of the diluted retardant filtrate	Percent by weight P_2O_5
1.150	22.9
1.155	23.5
1.160	24.1
1.165	24.7
1.170	25.3
1.175	25.9
1.180	26.6
1.185	27.2
1.190	27.8
1.195	28.4
1.200	29.0
1.205	29.6
1.210	30.2
1.215	30.8
1.220	31.4
1.224	**31.9**
1.225	32.0
1.230	32.6
1.235	33.3
1.240	33.9
1.245	34.5
1.250	35.1
1.255	35.7
1.260	36.3
1.265	36.9
1.270	37.5
1.275	38.1
1.280	38.7
1.285	39.4
1.290	40.0
1.295	40.6

The boxed area represents a variation in salt content such that no corrective action is needed.

Table 6.—Salt content of Fire-Trol 931-L related to specific gravity at 80 °F (use with procedure 3)

Dilution ratio	Measured specific gravity of the retardant	Percent by weight P_2O_5	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			------ *Gallons* ------	
20:1	1.013	2.1	18.9	
15:1	1.023	2.7	17.1	
10:1	1.042	4.0	13.4	
9:1	1.048	4.4	12.4	
8:1	1.055	4.9	11.1	
	1.060	5.2	10.0	
7:1	1.064	5.5	9.2	
	1.065	5.5	9.0	
	1.070	5.9	8.0	
6:1	1.075	6.2	7.0	
	1.080	6.5	6.0	
	1.085	6.9	5.0	
5:1	1.089	7.1	4.2	
	1.090	7.2	3.9	
	1.095	7.5	2.9	
	1.100	7.9	1.8	
	1.101	7.9	1.6	
	1.102	8.0	1.4	
	1.103	8.0	1.2	
	1.104	8.1	1.0	
	1.105	8.2	0.7	
	1.106	8.2	0.5	
	1.107	8.3	0.3	
4:1	**1.108**	**8.4**	**0**	**0**
	1.109	8.4		0
	1.110	8.5		1
	1.111	8.6		2
	1.112	8.6		3
	1.113	8.7		4
	1.114	8.8		5
	1.115	8.8		6
	1.116	8.9		7
	1.120	9.2		10
	1.125	9.5		15
	1.130	9.8		19
	1.135	10.2		24
3:1	1.137	10.3		26
	1.140	10.5		28
	1.145	10.8		33
	1.150	11.2		38
	1.155	11.5		42
	1.160	11.8		47
	1.165	12.2		52
	1.170	12.5		57
	1.175	12.8		62

The boxed area represents a variation in salt content such that no corrective action is needed.

Table 7.—Salt content of Fire-Trol 931-L related to specific gravity of the retardant at 80 °F (filtered for improved accuracy and readability) (use with procedure 5)

Dilution ratio	Measured specific gravity of the retardant filtrate	Percent by weight P_2O_5	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			----- *Gallons* -----	
20:1	1.018	2.1	19.2	
15:1	1.025	2.7	17.1	
10:1	1.039	4.0	13.6	
9:1	1.043	4.4	12.5	
8:1	1.048	4.9	11.6	
	1.050	5.0	11.1	
7:1	1.055	5.5	9.3	
	1.060	5.9	9.0	
6:1	1.063	6.2	7.1	
	1.065	6.4	6.3	
	1.070	6.8	5.2	
5:1	1.073	7.1	4.4	
	1.075	7.3	3.7	
	1.080	7.7	2.3	
	1.081	7.8	2.0	
	1.082	7.9	1.7	
	1.083	8.0	1.5	
	1.084	8.1	1.2	
	1.085	8.1	0.9	
	1.086	8.2	0.6	
	1.087	8.3	0.3	
4:1	1.088	8.4	0	0
	1.089	8.5		1
	1.090	8.6		2
	1.091	8.7		3
	1.092	8.8		4
	1.093	8.8		5
	1.095	9.0		8
	1.100	9.4		13
	1.105	9.9		19
3:1	1.110	10.3		25
	1.115	10.7		31
	1.120	11.2		36
	1.125	11.6		42
	1.130	12.0		48
	1.135	12.4		54
	1.140	12.8		60
	1.145	13.3		66

(con.)

Table 7.—(Con)

Dilution ratio	Measured specific gravity of the retardant filtrate	Percent by weight P_2O_5	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			----- *Gallons* -----	
2:1	1.146	13.3		67
	1.150	13.7		72
	1.155	14.1		77
	1.160	14.5		84
	1.165	14.9		90
	1.170	15.3		96
	1.175	15.7		102
	1.180	16.1		108
	1.185	16.5		114
	1.190	16.9		120
	1.195	17.3		126
	1.200	17.7		132
	1.205	18.1		138
	1.210	18.5		145
1:1	1.214	18.8		150
	1.215	18.9		151
	1.220	19.3		157
	1.225	19.7		163
	1.230	20.0		170
	1.235	20.4		176
	1.240	20.8		182
	1.245	21.1		189
	1.250	21.6		195
	1.275	23.5		228
	1.300	25.3		260
	1.325	27.1		294
	1.350	28.9		328
	1.375	30.6		362
Conc	1.394	31.9		389
	1.400	32.3		397
	1.425	34.0		433
	1.450	35.7		469
	1.475	37.3		505
	1.500	38.9		542

The boxed area represents a variation in salt content such that no corrective action is needed.

Table 8.—Salt content of Fire-Trol 931-L related to refractometer scale reading (use with procedure 13)

Dilution ratio	Refractometer scale reading for the retardant	Percent by weight P_2O_5	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			----- Gallons -----	
20:1	4.1	2.1	19.1	
15:1	5.3	2.8	17.2	
10:1	7.6	4.0	13.6	
9:1	8.3	4.4	12.5	
8:1	9.1	4.9	11.2	
	9.5	5.1	10.5	
	10.0	5.3	9.7	
	10.3	5.5	9.2	
7:1	10.5	5.6	8.9	
	11.0	5.9	8.0	
	11.5	6.2	7.2	
6:1	11.6	6.2	7.0	
	12.0	6.4	6.3	
	12.5	6.7	5.5	
	13.0	7.0	4.6	
5:1	13.2	7.1	4.3	
	13.5	7.3	3.7	
	14.0	7.5	2.9	
	14.5	7.8	2.0	
	15.0	8.1	1.1	
	15.5	8.3	0.2	
4:1	15.6	8.4	0	0
	16.0	8.6		3
	16.5	8.9		6
	17.0	9.2		10
	17.5	9.5		14
	18.0	9.7		17
	18.5	10.0		21
	19.0	10.3		25
3:1	19.1	10.3		26
	19.5	10.5		29
	20.0	10.8		32
	20.5	11.1		36
	21.0	11.4		40
	21.5	11.6		44
	22.0	11.9		48
	22.5	12.2		52
	23.0	12.5		56
	23.5	12.7		60
	24.0	13.0		64
	24.5	13.3		68
2:1	24.6	13.3		69
	25.0	13.6		72
	25.5	13.8		76
	26.0	14.1		80
	26.5	14.4		85
	27.0	14.6		89
	27.5	14.9		93
	28.0	15.2		97
	28.5	15.5		102
	29.0	15.7		106
	29.5	16.0		111
	30.0	16.3		115

The boxed area represents a variation in salt content such that no corrective action is needed.

Phos-Chek® 259-W, 259-R, and 259-F.—Phos-Chek 259-W, 259-R, and 259-F are diammonium phosphate-based (DAP) retardants designed for all types of air or ground application. Phos-Chek 259-W is uncolored (W-white), while 259-R contains iron oxide coloring (R-red), and 259-F contains a fugitive coloring agent (F-fugitive). (Fugitive coloring agents fade to a neutral shade several weeks after application.) Phos-Chek 259-W, 259-R, and 259-F contain a low concentration of gum thickener to improve drop characteristics. The products also contain bactericide and corrosion inhibitors. They are the only products relatively noncorrosive to magnesium, thus enhancing their application by helicopter. The three formulations are suitable for ground, helicopter (fixed tank or bucket), or airtanker application at either a mixing rate of 1.14 lb/gal (10.9% DAP) or 1.60 lb/gal (14.5% DAP). Although the higher concentrations at high-use level provided greater line-building capability, the limited flexibility of application systems (air or ground) as well as increased cost has generally precluded their use at other than the lower (1.14 lb/gal) use level.

Application : Ground tanker, fixed-tank helicopter or bucket, or airtanker.

Use level : 1.14 lb of dry retardant mixed with 1 gal of water will produce 1.063 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 1.07 lb of powder.
1.60 lb of dry retardant mixed with 1 gal of water will produce 1.094 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 1.46 lb of powder in each gallon of slurry.

Viscosity : 50-150 centipoise (cP).

: Field measurement (Marsh funnel): 42-62 sec through the small tip (procedure 8 and table 22 for conversions to viscosity and acceptable range).

Salt content : 10.9% by weight DAP ($(NH_4)_2HPO_4$) at 1.14 lb/gal use level.
14.5% by weight DAP ($(NH_4)_2HPO_4$) at 1.60 lb/gal use level.

: Field measurement (hydrometer): a reading of 1.068 at 80 °F (procedure 3 and table 9) for Phos-Chek 259 mixed at 1.14 lb/gal or 1.089 at 80 °F (procedure 3 and table 10 for Phos-Chek 259 mixed at 1.60 lb/gal).

Specific weight: 8.90 lb/gal slurry at the 1.14 lb/gal use level and 9.07 lb/gal slurry at the 1.60 lb/gal use level (procedure 9, 10, or 11).

Table 9.—Salt content of Phos-Chek 259-R, 259-F, and 259-W mixed at 1.14 lb/gal related to specific gravity at 80 °F (use with procedure 3)

Measured specific gravity of the retardant	Percent by weight $(NH_4)_2HPO_4$	Percent by weight P_2O_5 equivalent	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			Lb	*Gal*
1.015	1.6	0.9	98	
1.020	2.5	1.4	89	
1.025	3.4	1.8	81	
1.030	4.3	2.3	71	
1.035	5.1	2.8	62	
1.040	6.0	3.2	53	
1.045	6.9	3.7	44	
1.050	7.7	4.2	35	
1.055	8.6	4.6	25	
1.060	9.5	5.1	16	
1.063	10.0	5.4	10	
1.064	10.2	5.5	8	
1.065	10.3	5.6	6	
1.066	10.5	5.7	4	
1.067	10.7	5.8	2	
1.068	10.9	5.8	0	0
1.069	11.1	5.9		2
1.070	11.2	6.0		3
1.071	11.4	6.1		5
1.072	11.6	6.2		7
1.073	11.7	6.3		9
1.074	11.9	6.4		10
1.075	12.1	6.5		12
1.080	13.0	7.0		21
1.085	13.8	7.4		29
1.090	14.7	7.9		38
1.095	15.6	8.4		47
1.100	16.4	8.8		56
1.105	17.3	9.3		65
1.110	18.2	9.8		75
1.115	19.1	10.2		84
1.120	19.9	10.7		93
1.125	20.8	11.2		103
1.130	21.7	11.7		112
1.135	22.5	12.1		122
1.140	23.4	12.6		131
1.145	24.3	13.1		141
1.150	25.2	13.5		151

The boxed area represents a variation in salt content such that no corrective action is needed.

Table 10.—Salt content of Phos-Chek 259-R, 259-F, and 259-W mixed at 1.60 lb/gal related to specific gravity at 80 °F (use with procedure 3)

Measured specific gravity of the retardant	Percent by weight $(NH_4)_2HPO_4$	Percent by weight P_2O_5 equivalent	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			Lb	*Gal*
1.035	5.1	2.8	107	
1.040	6.0	3.2	98	
1.045	6.9	3.7	88	
1.050	7.7	4.2	79	
1.055	8.6	4.6	69	
1.060	9.5	5.1	59	
1.065	10.3	5.6	49	
1.070	11.2	6.0	39	
1.075	12.1	6.5	29	
1.080	13.0	7.0	19	
1.084	13.7	7.3	11	
1.085	13.8	7.4	9	
1.086	14.0	7.5	7	
1.087	14.2	7.6	5	
1.088	14.4	7.7	3	
1.089	14.6	7.8	0	0
1.090	14.7	7.9		1
1.091	14.9	8.0		2
1.092	15.1	8.1		4
1.093	15.2	8.2		5
1.094	15.4	8.3		6
1.095	15.6	8.4		8
1.100	16.4	8.8		14
1.105	17.3	9.3		21
1.110	18.2	9.8		28
1.115	19.1	10.2		34
1.120	19.9	10.7		41
1.125	20.8	11.2		48
1.130	21.7	11.7		55
1.135	22.5	12.1		62
1.140	23.4	12.6		69
1.145	24.3	13.1		76
1.150	25.2	13.5		84
1.155	26.0	14.0		91
1.160	26.9	14.5		98
1.165	26.8	14.9		106
1.170	28.6	15.4		113
1.175	29.5	15.9		120

The boxed area represents a variation in salt content such that no corrective action is needed.

Gum-Thickened Retardants

Phos-Chek® A-W, A-R, and A-F.—Phos-Chek A-W, A-R, and A-F are gum-thickened monoammonium phosphate-based retardant formulations approved for airtanker application. Phos-Chek A-W is uncolored (W-white) while A-R contains iron oxide coloring (R-red) and A-F contains a fugitive coloring agent (F-fugitive). (Fugitive coloring agents fade to a neutral shade several weeks after application.) Because they contain a relatively high concentration of gum-thickener to provide a high viscosity (approximately 1,500 centipoise) for improved drop characteristics from fixed-wing airtankers, these formulations are not recommended for ground or helicopter use. The products also contain viscosity stabilizers and corrosion inhibitors.

Application : Airtanker.

Use level : 0.96 lb of dry retardant mixed with 1 gal of water will produce 1.057 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 0.908 lb of powder.

Viscosity : 1,200-1,800 centipoise (cP).

: Field measurement (Marsh funnel): 28-38 sec through the large tip (procedure 8 and table 22 show conversion to viscosity and acceptable range).

Salt content : 9.0% by weight MAP ($NH_4H_2PO_4$).

: Field measurement (hydrometer): a reading of 1.057 at 80 °F (procedure 4 and table 11 for conversion to salt content and acceptable range).

: Field measurement (refractometer): a reading of 7.9 (procedure 13 and table 12 for conversion to salt content and acceptable range).

Specific weight: 8.78 lb/gal slurry (procedure 9, 10, or 11).

Table 11.—Salt content of Phos-Chek A-R, A-F, and A-W related to specific gravity at 80 °F (use with procedure 4)

Measured specific gravity of the thinned retardant	Percent by weight $NH_4H_2PO_4$	Percent by weight P_2O_5 equivalent	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			Lb	*Gal*
1.025	3.6	2.2	59	
1.030	4.5	2.8	50	
1.035	5.3	3.3	41	
1.040	6.2	3.8	31	
1.045	7.0	4.3	22	
1.050	7.9	4.9	13	
1.051	8.1	5.0	11	
1.052	8.2	5.1	9	
1.053	8.4	5.2	7	
1.054	8.6	5.3	5	
1.055	8.7	5.4	3	
1.056	8.9	5.5	1	
1.057	**9.0**	**5.6**	**0**	**0**
1.058	9.2	5.7		3
1.059	9.4	5.8		5
1.060	9.6	5.9		7
1.061	9.7	6.0		9
1.062	9.9	6.1		11
1.065	10.4	6.4		17
1.070	11.3	7.0		27
1.075	12.1	7.5		37
1.080	13.0	8.0		48
1.085	13.8	8.5		58
1.090	14.7	9.1		69
1.095	15.5	9.6		79
1.100	16.4	10.1		90
1.105	17.2	10.6		101
1.110	18.1	11.2		112
1.115	18.9	11.7		123
1.120	19.8	12.2		134
1.125	20.6	12.7		145

The boxed area represents a variation in salt content such that no corrective action is needed.

Table 12.—Salt content of Phos-Chek A-R, A-F, and A-W related to refractometer scale reading (use with procedure 4)

Refractometer scale reading for the retardant	Percent by weight $NH_4H_2PO_4$	Percent by weight P_2O_5 equivalent	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			Lb	*Gal*
3.5	3.7	2.3	57	
4.0	4.3	2.7	51	
4.5	4.9	3.0	45	
5.0	5.5	3.4	39	
5.5	6.0	3.7	33	
6.0	6.6	4.1	26	
6.5	7.2	4.5	20	
7.0	7.9	4.8	13	
7.5	8.5	5.2	6	
7.9	**9.0**	**5.6**	**0**	**0**
8.0	9.1	5.6		1
8.5	9.7	6.0		9
9.0	10.4	6.4		16
9.5	11.1	6.8		24
10.0	11.7	7.2		32
10.5	12.4	7.7		41
11.0	13.1	8.1		49
11.5	13.8	8.5		58
12.0	14.5	9.0		66
12.5	15.2	9.4		75
13.0	16.0	9.8		85
13.5	16.7	10.3		94
14.0	17.5	10.8		104
14.5	18.2	11.2		114
15.0	19.0	11.7		124
15.5	19.8	12.2		134
16.0	20.6	12.7		145
16.5	21.4	13.2		156
17.0	22.3	13.7		167
17.5	23.1	14.3		178

The boxed area represents a variation in salt content such that no corrective action is needed.

Phos-Chek® D75-R and D75-F.—Phos-Chek D75-R and D75-F are formulations comprised of a mixture of monoammonium phosphate and ammonium sulfate as the active fire retardant salts. The formulations are approved for airtanker application. Due to their high viscosity, they are not recommended for application by ground tanker or helicopter. D75-R contains iron oxide coloring (R-red) and D75-F contains a fugitive coloring agent (F-fugitive). (Fugitive coloring agents fade to a neutral shade several weeks after application.) Both formulations contain a relatively high concentration of gum thickener to provide a high viscosity (approximately 1,500 centipoise) for improved drop characteristics from airtankers. The products also contain viscosity stabilizers and corrosion inhibitors.

Application : Airtanker.

Use level : 1.20 lb of dry retardant mixed with 1 gal of water will produce 1.069 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 1.12 lb of powder.

Viscosity : 1,200-1,800 centipoise (cP).

: Field measurement (Marsh funnel): 28-56 sec through the large tip (procedure 8 and table 22 show conversion to viscosity and acceptable range).

Salt content : 11.20% by weight active salt: 8.43% by weight AS ($(NH_4)_2SO_4$) and 2.77% MAP ($NH_4H_2PO_4$).

: Field measurement (hydrometer): a reading of 1.071 at 80 °F (procedure 4 and table 13 for conversion to salt content and acceptable range).

: Field measurement (refractometer): a reading of 12.1 (procedure 13 and table 14 for conversion to salt content and acceptable range).

Specific weight: 8.91 lb/gal slurry (procedure 9, 10, or 11).

Table 13.—Salt content of Phos-Chek D75-R and D75-F related to specific gravity at 80 °F (use with procedure 4)

Measured specific gravity of the thinned retardant	Percent by weight active salt $(NH_4)_2SO_4/NH_4H_2PO_4$	Correction required per 100 gallons of retardant solution	
		Retardant	Water
		Lb	*Gal*
1.020	3.2	87.9	
1.025	4.0	79.5	
1.030	4.8	71.1	
1.035	5.6	62.6	
1.040	6.4	54.0	
1.045	7.2	45.5	
1.050	8.0	36.9	
1.055	8.8	28.2	
1.060	9.6	19.6	
1.065	10.3	10.8	
1.066	10.5	9.1	
1.067	10.6	7.3	
1.068	10.8	5.6	
1.069	11.0	3.8	
1.070	11.1	2.1	
1.071	**11.3**	**0**	**0**
1.072	11.4		1
1.073	11.6		3
1.074	11.7		4
1.075	11.9		6
1.076	12.0		7
1.077	12.2		9
1.078	12.3		10
1.080	12.6		13
1.085	13.4		20
1.090	14.2		28
1.095	14.9		35
1.100	15.7		43
1.105	16.4		50
1.110	17.2		58
1.115	17.9		65
1.120	18.6		73
1.125	19.4		81

The boxed area represents a variation in salt content such that no corrective action is needed.

Table 14.—Salt content of Phos-Chek D75-R and D75-F related to refractometer scale reading (use with procedure 13)

Refractometer scale reading for the retardant	Percent by weight active salt $(NH_4)_2SO_4/NH_4H_2PO_4$	Correction required per 100 gallons of retardant solution	
		Retardant	Water
		Lb	*Gal*
3.5	3.2	88.4	
4.0	3.6	83.5	
4.5	4.1	78.6	
5.0	4.6	73.6	
5.5	5.1	68.7	
6.0	5.5	63.7	
6.5	6.0	58.6	
7.0	6.5	53.6	
7.5	6.9	48.5	
8.0	7.4	43.4	
8.5	7.9	38.2	
9.0	8.3	33.1	
9.5	8.8	27.9	
10.0	9.3	22.6	
10.5	9.8	17.4	
11.0	10.2	12.1	
11.5	10.7	6.7	
12.0	11.2	1.4	
12.1	**11.3**	**0**	**0**
12.5	11.6		3
13.0	12.1		8
13.5	12.6		12
14.0	13.0		17
14.5	13.5		21
15.0	14.0		26
15.5	14.5		31
16.0	14.9		35
16.5	15.4		40
17.0	15.9		45
17.5	16.3		49
18.0	16.8		54
18.5	17.3		59
19.0	17.7		64
19.5	18.2		69
20.0	18.7		73

The boxed area represents a variation in salt content such that no corrective action is needed.

Fire-Trol® GTS-R and GTS-F.—Fire-Trol GTS-R and GTS-F formulations contain ammonium sulfate as the primary active fire retardant salt. They also contain a small amount of ammonium phosphate that acts as both a corrosion inhibitor and a retardant salt. The formulations are designed for airtanker application; Fire-Trol GTS-R is iron oxide colored (R-red) while GTS-F contains a fugitive coloring agent (F-fugitive). (Fugitive coloring agents fade to a neutral shade several weeks after application.) Both formulations contain a relatively high concentration of gum thickener to provide a high viscosity (approximately 1,500 centipoise) for improved drop characteristics from airtankers. Due to the high viscosity these formulations are not normally used for ground or helicopter use. The products also contain spoilage and additional corrosion inhibitors.

Application : Airtanker.

Use level : 1.76 lb of dry retardant mixed with 1 gal of water will produce 1.10 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 1.59 lb of powder.

Viscosity : 1,200-1,800 centipoise (cP).

: Field measurement (Marsh funnel): 36-52 sec through the large tip (procedure 8 and table 22 for conversions to viscosity and acceptable range).

Salt content : 14.81% by weight AS ($(NH_4)_2SO_4$) and 1.26% DAP ($(NH_4)_2HPO_4$).

: Field measurement (hydrometer): a reading of 1.098 at 80 °F (procedure 4 and table 15 for conversion to salt content and acceptable range).

: Field measurement (refractometer): a reading of 16.4 on the unthinned retardant, (procedure 13 and table 16 for conversion to salt content and acceptable range).

Specific weight: 9.13 lb/gal slurry (procedure 9, 10, or 11).

Table 15.—Salt content of Fire-Trol GTS-R and GTS-F related to specific gravity at 80 °F (use with procedure 4)

Measured specific gravity of the thinned retardant	Percent by weight $(NH_4)_2SO_4$	Correction required per 100 gallons of retardant solution	
		Retardant	Water
		Lb	*Gal*
1.050	5.9	111	
1.055	6.8	100	
1.060	7.8	89	
1.065	8.7	78	
1.070	9.6	66	
1.075	10.5	55	
1.080	11.5	43	
1.085	12.4	31	
1.090	13.3	19	
1.091	13.5	17	
1.092	13.7	15	
1.093	13.9	12	
1.094	14.1	10	
1.095	14.3	7	
1.096	14.4	5	
1.097	14.6	3	
1.098	**14.8**	**0**	**0**
1.099	15.0		1
1.100	15.2		3
1.101	15.4		4
1.102	15.5		5
1.103	15.7		7
1.104	15.9		8
1.105	16.1		10
1.106	16.3		11
1.110	17.0		17
1.115	17.9		24
1.120	18.9		31
1.125	19.8		38
1.130	20.7		45
1.135	21.7		52
1.140	22.6		60
1.145	23.5		67
1.150	24.4		75

The boxed area represents a variation in salt content such that no corrective action is needed.

Table 16.—Salt content of Fire-Trol GTS-R and GTS-F related to refractometer scale reading at 80 °F (use with procedure 13)

Refractometer scale reading for the retardant	Percent by weight active salt $(NH_4)_2SO_4$	Correction required per 100 gallons of retardant solution	
		Retardant	Water
		Lb	*Gal*
7.0	5.9	111	
7.5	6.4	105	
8.0	6.9	99	
8.5	7.4	94	
9.0	7.8	88	
9.5	8.3	82	
10.0	8.8	77	
10.5	9.2	71	
11.0	9.7	65	
11.5	10.2	59	
12.0	10.6	53	
12.5	11.1	47	
13.0	11.6	42	
13.5	12.0	36	
14.0	12.5	30	
14.5	13.0	24	
15.0	13.5	18	
15.5	13.9	12	
16.0	14.4	6	
16.4	**14.8**	**0**	**0**
16.5	14.9		1
17.0	15.3		4
17.5	15.8		7
18.0	16.3		11
18.5	16.7		14
19.0	17.2		18
19.5	17.7		21
20.0	18.1		25
20.5	18.6		29
21.0	19.1		32
21.5	19.5		36
22.0	20.0		40
22.5	20.5		43
23.0	21.0		47
23.5	21.4		51
24.0	21.9		54
24.5	22.4		58
25.0	22.8		62
25.5	23.3		66
26.0	23.8		69
26.5	24.2		73
27.0	24.7		77
27.5	25.2		81

The boxed area represents a variation in salt content such that no corrective action is needed.

Phos-Chek® XB.—Phos-Chek XB is a monoammonium phosphate-based product containing a gum thickener. It is produced and sold for use in Canada and some overseas markets. Minor ingredients include corrosion inhibitors, viscosity stabilizers, and coloring agents.

Application : Airtanker.

Use level : 1.14 lb of dry retardant mixed with 1 gal (U.S.) of water will produce 1.074 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 1.06 lb of dry retardant.

Viscosity : 1,200-1,800 centipoise (cP).
: Field measurement (Marsh funnel): 34-50 sec through the large tip (procedure 8 and table 22 for conversions to viscosity and acceptable range).

Salt content : 10.65% by weight MAP ($NH_4H_2PO_4$).
: Field measurement (hydrometer): a reading of 1.056 at 80 °F (procedure 4 and table 17 for conversion to salt content and acceptable range).

Specific weight: 8.81 lb/gal slurry (procedure 9, 10, or 11).

Table 17.—Salt content of Phos-Chek XB related to specific gravity at 80 °F (use with procedure 4)

Measured specific gravity of the thinned retardant	Percent by weight $NH_4H_2HPO_4$	Percent by weight P_2O_5 equivalent	Correction required per 100 gallons of retardant solution	
			Retardant	Water
			Lb	*Gal*
1.015	3.5	2.2	77	
1.020	4.4	2.7	68	
1.025	5.3	3.2	59	
1.030	6.1	3.8	50	
1.035	7.0	4.3	41	
1.040	7.8	4.8	31	
1.045	8.7	5.4	22	
1.050	9.6	5.9	12	
1.052	9.9	6.1	8	
1.053	10.1	6.2	6	
1.054	10.3	6.3	5	
1.055	10.5	6.4	3	
1.056	**10.7**	**6.6**	**0**	**0**
1.057	10.8	6.7		1
1.058	10.9	6.8		3
1.059	11.1	6.9		5
1.060	11.3	7.0		6
1.061	11.5	7.1		8
1.065	12.1	7.5		15
1.070	13.0	8.0		24
1.075	13.9	8.6		32
1.080	14.7	9.1		41
1.085	15.6	9.6		50
1.090	16.4	10.2		59
1.095	17.3	10.7		68
1.100	18.2	11.2		78
1.105	19.0	11.7		87
1.110	19.9	12.3		96
1.115	20.7	12.8		106
1.120	21.6	13.3		115
1.125	22.5	13.9		125
1.130	23.3	14.4		135
1.135	24.2	14.9		144
1.140	25.0	15.5		154

The boxed area represents a variation in salt content such that no corrective action is needed.

Megatard® 2700-R and 2700-F.—Megatard 2700-R and 2700-F are two-component systems. One component contains a water solution of ammonium sulfate and corrosion inhibitor, liquified at the time of delivery at the base. The other component contains a gum thickener, coloring agent, and spoilage inhibitor. Megatard 2700 is colored with either iron-oxide (R-red) or a fugitive coloring (F-fugitive). (Fugitive coloring agents fade to a neutral shade several weeks after application.) The two components are pumped together with additional water to produce the mixed retardant with a relatively high viscosity suitable for fixed-wing air application. Megatard 2700 is designed to be pumped directly into an aircraft as the final product is not storable.

Application : Airtanker.

Use level : 1.00 gal liquified ammonium sulfate (LS) + 0.244 lb of thickener/color package added to 1.00 gal of water will produce 2.01 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 0.50 gal of LS and 0.116 lb of thickener/color package.

Viscosity : Mixed retardant: 1,200-1,800 centipoise (cP).

: Field measurement (Marsh funnel) of mixed retardant: 30-44 sec through the large tip (procedure 8 and table 22 for conversions to viscosity and acceptable range).

Salt content : 28.2% and 15.0% by weight AS ($(NH_4)_2SO_4$), respectively, of liquified sulfate and mixed retardant.

: Field measurement (hydrometer): Liquified sulfate: a reading of 1.166 at 80 °F (procedure 3 and table 18 for conversion to salt content and acceptable range).
Mixed retardant: a reading of 1.096 at 80 °F (procedure 4 and table 19 for conversion to salt content and acceptable range).

Specific weight: 9.71 and 9.07 lb/gal slurry, respectively, for liquified sulfate and mixed retardant (procedure 9, 10, or 11).

Table 18.—Salt content of Megatard 2700 liquified sulfate related to specific gravity at 80 °F (use with procedure 3)

Measured specific gravity of the retardant	Percent by weight $(NH_4)_2SO_4$	Correction required per 100 gallons of retardant solution	
		Retardant	Water
		Lb	*Gal*
1.100	16.5	164	
1.105	17.4	152	
1.110	18.3	140	
1.115	19.2	129	
1.120	20.0	117	
1.125	20.9	104	
1.130	21.8	92	
1.135	22.7	80	
1.140	23.6	67	
1.145	24.5	55	
1.150	25.3	42	
1.155	26.2	29	
1.159	26.9	19	
1.160	27.1	16	
1.161	27.3	13	
1.162	27.4	11	
1.163	27.6	8	
1.164	27.8	6	
1.165	28.0	3	
1.166	28.2	0	0
1.167	28.3		1
1.168	28.5		1
1.169	28.7		2
1.170	28.9		3
1.171	29.0		4
1.172	29.2		4
1.173	29.4		5
1.174	29.6		6
1.175	29.7		7
1.180	30.6		10
1.185	31.5		14
1.190	32.4		18
1.195	33.3		22
1.200	34.1		25
1.205	35.0		29
1.210	35.9		33
1.215	36.8		37
1.220	37.7		41
1.225	38.6		45
1.230	39.4		49
1.235	40.2		53

The boxed area represents a variation in salt content such that no corrective action is needed.

Table 19.—Salt content of Megatard 2700 related to specific gravity at 80 °F (use with procedure 4)

Measured specific gravity of the thinned retardant	Percent by weight $(NH_4)_2SO_4$	Correction required per 100 gallons of retardant solution	
		Retardant	Water
		Lb	*Gal*
1.025	3.8	75	
1.030	4.5	70	
1.035	5.3	65	
1.040	6.1	60	
1.045	6.9	55	
1.050	7.7	50	
1.055	8.5	45	
1.060	9.3	39	
1.065	10.1	34	
1.070	10.8	29	
1.075	11.6	23	
1.080	12.4	18	
1.085	13.2	13	
1.087	13.5	10	
1.088	13.7	9	
1.089	13.8	8	
1.090	14.0	7	
1.091	14.1	6	
1.092	14.3	5	
1.093	14.5	4	
1.094	14.6	3	
1.095	14.8	2	
1.096	15.0	0	0
1.097	15.1		1
1.098	15.2		2
1.099	15.4		3
1.100	15.6		4
1.101	15.7		5
1.102	15.9		7
1.103	16.0		8
1.104	16.2		9
1.105	16.3		10
1.106	16.5		11
1.110	17.1		16
1.115	17.9		22
1.120	18.7		28
1.125	19.5		34
1.130	20.3		40
1.135	21.1		46
1.140	21.9		52
1.145	22.6		59
1.150	23.4		65

The boxed area represents a variation in salt content such that no corrective action is needed.

Clay-Thickened Retardants

Fire-Trol® 100.—Fire-Trol 100 uses ammonium sulfate as its active retardant salt. It is a clay-thickened product designed for airtanker application. Its viscosity is developed by shearing (or separating) the clay during the mixing process, usually in 500- or 1,000-gal batch mixers. Iron oxide is used as a coloring agent. A corrosion inhibitor is added to protect the aircraft and mixing and storage equipment.

Application : Airtanker.

Use level : 2.78 lb of dry retardant added to 1 gal of water will produce 1.182 gal of mixed retardant. Each gallon of mixed retardant contains the equivalent of 2.35 lb of dry retardant.

Viscosity : 1,500-2,500 centipoise (cP).

: Field measurement (Marsh funnel): 20-40 sec through the large tip (procedure 8 and table 22 for conversions to viscosity and acceptable range).

Salt content : 15.6% by weight AS ($(NH_4)_2SO_4$).

: Field measurement (hydrometer): a reading of 1.100 at 80 °F (procedure 5 and table 20 for conversion to salt content and acceptable range).

: Field measurement (refractometer): a reading of 17.2 (procedure 13 and table 21 for conversion to salt content and acceptable range).

Specific weight: 9.40 lb/gal slurry (procedure 9, 10, or 11).

Table 20.—Salt content of Fire-Trol 100 related to specific gravity at 80 °F (use with procedure 5)

Measured specific gravity of the retardant filtrate	Percent by weight $(NH_4)_2SO_4$	Correction required per 100 gallons of retardant solution	
		Retardant	Water
		Lb	*Gal*
1.025	4.2	208	
1.030	5.0	194	
1.035	5.8	180	
1.040	6.6	167	
1.045	7.4	153	
1.050	8.2	139	
1.055	9.0	125	
1.060	9.7	111	
1.065	10.5	97	
1.070	11.2	83	
1.075	12.0	70	
1.080	12.7	56	
1.085	13.4	42	
1.090	14.2	28	
1.091	14.3	25	
1.092	14.5	23	
1.093	14.6	20	
1.094	14.7	17	
1.095	14.9	14	
1.096	15.0	12	
1.097	15.2	9	
1.098	15.3	6	
1.099	15.5	3	
1.100	**15.6**	**0**	**0**
1.101	15.7		1
1.102	15.9		2
1.103	16.0		3
1.104	16.2		4
1.105	16.3		5
1.106	16.4		6
1.107	16.6		7
1.108	16.7		8
1.109	16.9		9
1.110	17.0		10
1.111	17.1		11
1.115	17.7		15
1.120	18.4		20
1.125	19.1		25
1.130	19.7		30
1.135	20.4		35
1.140	21.1		40
1.145	21.7		45
1.150	22.4		50
1.155	23.0		55
1.160	23.6		60
1.165	24.3		65
1.170	24.9		70
1.175	25.5		75

The boxed area represents a variation in salt content such that no corrective action is needed.

Table 21.—Salt content of Fire-Trol 100 related to refractometer scale reading at 80 °F (use with procedure 13)

Refractometer scale reading for the retardant	Percent by weight $(NH_4)_2SO_4$	Correction required per 100 gallons of retardant solution	
		Retardant	Water
		Lb	*Gal*
7.0	6.4	171	
7.5	6.8	163	
8.0	7.3	155	
8.5	7.7	147	
9.0	8.2	139	
9.5	8.6	131	
10.0	9.1	123	
10.5	9.6	114	
11.0	10.0	106	
11.5	10.5	98	
12.0	10.9	89	
12.5	11.4	81	
13.0	11.8	72	
13.5	12.3	64	
14.0	12.7	55	
14.5	13.2	47	
15.0	13.6	38	
15.5	14.1	29	
16.0	14.6	21	
16.5	15.0	12	
17.0	15.5	3	
17.2	**15.6**	**0**	**0**
17.5	15.9		2
18.0	16.4		5
18.5	16.8		9
19.0	17.3		12
19.5	17.7		15
20.0	18.2		18
20.5	18.6		22
21.0	19.1		25
21.5	19.6		28
22.0	20.0		32
22.5	20.5		35
23.0	20.9		39
23.5	21.4		42
24.0	21.8		46
24.5	22.3		49
25.0	22.7		53

The boxed area represents a variation in salt content such that no corrective action is needed.

SHORT-TERM RETARDANT FORMULATIONS

Fire-Trol® ST-Poly.—Fire-Trol ST-Poly (formerly referred to as Poly-Trol) is a formulation developed for thickening water to improve its drop characteristics for fixed-wing aerial application. Fire-Trol ST-Poly contains both a coloring agent and corrosion inhibitor, but is primarily a synthetic acrylamide polymer which requires a low use level to achieve acceptable viscosity and/or elasticity.

Application	: Airtanker or helicopter bucket.
Use level	: 0.50% to 0.7% by weight. Use levels are dependent on water temperature and water hardness. An appropriate use level within the above range should be established using procedure 8 and table 22 as a guide. Changes in water source or quality (hardness) may necessitate a change in the appropriate use level. In general, use levels in the 0.50 to 0.75 range will provide drop performance similar to a "gum-thickened" retardant.
Viscosity	: 150-250 centipoise (cP).
	: Field measurement (Marsh funnel): 54-72 sec through the small tip (procedure 8 and table 22 show conversions to viscosity and acceptable range).
Specific weight:	8.34 lb/gal slurry (procedure 9, 10, or 11).

Fire-Kill® IIP.—Fire-Kill IIP is a short-term retardant formulation composed of xanthan gum and synthetic polymer thickener. Fire-Kill IIP also contains corrosion and spoilage inhibitors and coloring. The thickeners function to improve drop characteristics for airtanker or helicopter application.

Application	: Airtanker or helicopter bucket.
Use level	: 0.25% by weight for helicopter application; 0.50% to 0.7% by weight for fixed-wing airtanker.. Use levels are dependent on water temperature and water hardness. An appropriate use level within the above ranges should be established using procedure 8 and table 22 as a guide. Changes in water source or quality (hardness) may necessitate a change in the appropriate use level. In general, use levels in the 0.50 to 0.75 range will provide drop performance similar to a "gum-thickened" retardant.
Viscosity	: 150-250 centipoise (cP).
	: Field measurement (Marsh funnel): 46-54 sec through the small tip (procedure 8 and table 22 show conversions to viscosity and acceptable range).
Specific weight:	8.34 lb/gal slurry (procedure 9, 10, or 11).

PROCEDURES

Procedure 1: Sampling a Storable Retardant for Testing

Guidelines are given for obtaining a representative sample of the material in storage for quality control testing.

1. Recirculate the retardant in the tanks after a major mixing operation, then take a sample from a recirculation line or pump.
2. Recirculate tanks and take a sample at least every 7 days during periods when there is little activity.
3. During mixing operations, take samples often enough to ensure that the mixed product meets the requirements for the specific retardant.
4. Use fresh samples from sampling valve or line after product has been pumped or circulated. Do not use slurry that has been sitting in hoses, pumps, or valves.
5. If a sample is taken from the end of the hose, be sure that sufficient retardant has been pumped through the hose to ensure a fresh sample.
6. If significant deterioration of stored material is discovered, (a) take a sample of bad material and hold for instructions and/or additional testing, (b) notify appropriate agency personnel of the problem, and (c) notify the supplier of the material.

Procedure 2: Sampling a Nonstorable Retardant for Testing

Guidelines are given for obtaining representative samples of nonstorable retardants for quality control testing.

1. Take samples after enough retardant has been pumped to ensure complete removal of old slurry from hose (immediately after loading an airtanker).
2. Take samples often enough during mixing operations to ensure that the mixed product meets the requirements for the specific retardant.
3. If significant deterioration is discovered in stored concentrate or in mixed retardant stored in aircraft for long periods of time, (a) take a sample of bad material and hold for instructions and/or additional testing, (b) notify appropriate agency personnel of the problem, and (c) notify the supplier of the material.

Procedure 3: Field Determination of Salt Content of Unthickened or Low-Viscosity Gum-Thickened Retardants

(Phos-Chek G-WX, Fire-Trol 934-L, Fire-Trol 936-L, Phos-Chek G-W, G-R, G-F, Fire-Trol 931-L, Phos-Chek 259-W, 259-R, and 259-F, and the liquid sulfate used in producing Megatard 2700)

The salt content of unthickened or low-viscosity retardant can be determined by measuring the specific gravity of an untreated retardant sample with a hydrometer and using tables provided to convert specific gravity to percentage of salt.

1.a. Take a freshly agitated sample of the retardant solution to be analyzed. If possible, allow the sample to reach room temperature (approximately 80 °F).

1.b. For greater accuracy FT 931-L may be filtered prior to determination of the specific gravity (see procedure 5). A separate calibration table (table 7) is provided for use with a filtered solution.

2. After all entrapped air bubbles are allowed to escape, measure the specific gravity of the solution with a hydrometer readable to 0.001 divisions. Let the hydrometer settle in the solution for 3 to 5 min before reading.

3. Read and record the temperature of the retardant to the nearest °F.

4. Record the specific gravity to the nearest 0.001.

5. Using table 26 of appendix 3 or the following rule for deviation of temperature, adjust the specific gravity reading: for every 5 °F the retardant solution temperature is below 80 °F, subtract 0.001 from the hydrometer reading; or for every 5 °F the retardant solution is above 80 °F, add 0.001 to the hydrometer reading.

6. Using the appropriate table (for the retardant being tested), determine the percentage by weight of salt in the solution. The tables also show how to correct retardants with salt content outside acceptable levels.

Procedure 4: Field Determination of Salt Content of High-Viscosity Gum-Thickened Retardants

(Phos-Chek A-W, A-R, and A-F, Phos-Chek D75-R and D75-F, Fire-Trol GTS-R and GTS-F, Phos-Chek XB, and Megatard 2700-R and 2700-F)

A viscosity-reducing agent is used to lower the viscosity of gum-thickened retardants to obtain an accurate specific gravity of the solution using a hydrometer. Retardant salt content can be read directly from the conversion tables provided.

1. Take a freshly agitated sample of the mixed retardant to be analyzed. Allow the sample to reach room temperature (approximately 80 °F).

2. Fill a quart jar one-half full with the retardant sample. Add 2 level teaspoons (using a measuring-type teaspoon) of the appropriate viscosity-reducing agent to the sample.

3. Shake sample and viscosity-reducing agent together vigorously for at least 30 sec, then loosen the lid to relieve gas pressure and allow entrapped air bubbles to escape.

4. Allow the sample to sit for 10 min.

5. Pour the thinned sample into an 8-inch test tube, ease the hydrometer into the sample, and allow it to sit for an additional 10 min.

6. Read and record the temperature of the retardant to the nearest °F.

7. Measure and record the specific gravity of the solution with a hydrometer readable to 0.001 divisions.

8. Using table 26 (appendix 3) or using the following rule for deviation of temperature, adjust the specific gravity reading: for every 5 °F the retardant solution temperature is below 80 °F, subtract 0.001 from the hydrometer reading; or for every 5 °F the retardant solution is above 80 °F, add 0.001 to the hydrometer reading.

9. Use the appropriate tables to determine the percentage by weight of salt in the solution. The tables also show how to correct retardants with salt contents outside acceptable levels.

NOTE: DO NOT ALLOW ANY SOLUTION CONTAINING VISCOSITY-REDUCING AGENT TO BE RETURNED TO THE STORAGE TANK, SINCE A SMALL AMOUNT CAN CAUSE REDUCTION OF VISCOSITY OF THE CONTENTS OF THE ENTIRE TANK.

Procedure 5: Field Determination of Salt Content of Clay-Thickened Retardants

(Fire-Trol 100)

Clay-thickened fire retardants must be filtered to remove the solid particles to obtain an accurate specific gravity. The retardant salt content can be read directly from the conversion tables provided once the specific gravity has been measured with a hydrometer.

1. Take a freshly agitated sample (1 to 1.5 quarts) of the retardant solution to be analyzed.

2. Place the sample in an 8-inch funnel containing a rapid and fairly retentive filter paper. Collect sufficient filtrate to fill an 8-inch test tube (80-100 mL). This will take about 30 min depending partially on the viscosity.

3. Allow the filtrate to reach room temperature (approximately 80 °F) if possible. Read and record the temperature of the filtrate.

4. Allow the hydrometer to settle in the solution for 3 to 5 min.

5. Measure and record the specific gravity to the nearest 0.001.

6. Using table 26 (appendix 3) or the following rule for deviation of temperature, adjust the specific gravity reading: for every 5 °F the retardant solution temperature is below 80 °F, subtract 0.001 from the hydrometer reading; or for every 5 °F the retardant solution is above 80 °F, add 0.001 to the hydrometer reading.

7. Using the appropriate table, determine the percentage by weight of salt in the solution. The tables also show how to correct retardants with salt contents outside the acceptable levels.

Procedure 6: Field Determination of Salt Content of Clay-Thickened Liquid Concentrates

(Fire-Trol 931-L concentrate)

Clay-thickened liquid concentrates must be diluted quantitatively and filtered prior to measuring the specific gravity. Directions are given for making a suitable dilution container and performing the dilution and filtration steps. After the specific gravity has been determined with a hydrometer, the salt content can be read directly from the conversion tables provided.

1. Calibrate a 1-quart container (such as a disposable canteen) with a tight-fitting screw cap:

a. Pour exactly 1 cup (8 fluid oz) of water into the 1-quart container.

b. Accurately mark the water level.

c. Pour another cup of water into the container.

d. Mark the 2-cup level.

e. Empty all water from the container and allow to dry.

f. Repeat steps a through e at least two more times.

g. Mark the final 1- and 2-cup levels with a narrow-tip waterproof marker.

2. Pour a well-mixed sample of Fire-Trol 931 concentrate into the calibrated container, exactly to the 1-cup mark.

3. Add water to the 2-cup mark.

4. Shake thoroughly.

5. Place the sample in an 8-inch funnel containing a rapid and fairly retentive filter paper. Collect sufficient filtrate to fill an 8-inch test tube (80-100 mL). This will take about 30 min, depending partially on the viscosity.

6. Allow the filtrate to reach room temperature (approximately 80 °F) if possible. Read and record the temperature of the filtrate.

7. Allow the hydrometer to settle in the solution for 3 to 5 min.

8. Measure and record the specific gravity to the nearest 0.001.

9. Using table 26 (appendix 3) or the following rule for deviation of temperature, adjust the specific gravity reading: for every 5 °F the retardant solution temperature is below 80 °F, subtract 0.001 from the hydrometer reading; or for every 5 °F the retardant solution is above 80 °F, add 0.001 to the hydrometer reading.

10. Using the appropriate table, determine the percentage by weight of salt in the solution. The tables also show how to correct retardants with salt contents outside the acceptable levels.

Procedure 7: Determining Viscosity Using a Brookfield Viscometer

The viscosity of a retardant can be determined using a calibrated Brookfield viscometer (Model LVF). The standard spindles provided with a Brookfield viscometer moving at a known, constant rate for a defined time period provide the shear while the scale reading multiplied by a constant (specific to the spindle used) gives the viscosity.

1. Level viscometer by adjusting the tripod feet until bubble level is centered. Tighten clamp to hold in this position.

2. Adjust speed control to 60 r/min. (The 60 should be on the upper surface of the knob.)

3. Attach the guard by the screw on each side of the housing.

4. Attach the correct spindle (number 2 for viscosities less than 500 centipoise; number 4 for viscosities greater than 500 centipoise) by screwing it onto the threaded shaft.

NOTE: THIS IS A LEFT-HAND THREAD. Tighten finger-tight only, holding the shaft to prevent movement of the pointer.

5. Immerse the spindle in the liquid to be tested just to the immersion ring on the spindle.

6. Depress clutch. This procedure relieves wear and tear on the "innards" when measuring thick liquids.

7. Turn motor on, release clutch, and allow to rotate for 1 min.

8. Depress clutch to maintain pointer position and turn motor off. If pointer is not in view, turn motor on and off to bring it into view with clutch still depressed.

9. Read dial at pointer position. Clutch can now be released.

10. Calculate viscosity in centipoise by multiplying dial reading by proper factor (5 for spindle 2; 100 for spindle 4).

11. Repeat three times and report average viscosity.

Procedure 8: Determining Slurry Viscosity Using a Marsh Funnel

The time that it takes for a known volume of solution to flow through an orifice of fixed dimension is related to viscosity. Correlation tables have been provided to read viscosity directly from flow-through time.

1. Be sure the proper tip (0.269 ± 0.002-inch diameter for large tip and 0.187 ± 0.002-inch diameter for small tip) is in the Marsh funnel.

2. Use fresh samples that have completely hydrated (approximately one-half to 1 hour after mixing) without excessive air bubbles.

3. Close the funnel tip with a finger and pour retardant **through** the screen into a clean, dry, upright funnel until the fluid level exactly reaches the bottom of the screen.

4. Measure the time in minutes and seconds for exactly 1 quart (946 mL) of retardant to flow through the funnel.

5. Look up measured time in left column of table 22. Read the appropriate column for the retardant being tested.

NOTE:

1. The amount of time elapsed since agitation and the retardant temperature influence viscosity. The viscosity values in the table will apply only to retardant at the time and temperature at which the sample is tested.

2. The values in the table are for samples at 75 to 85 °F. Higher temperatures may give falsely low viscosities; lower temperatures may give falsely high viscosities.

3. Numbers included within the boxes indicate the normal use range.

4. Remember that Marsh funnel viscosities are estimates of Brookfield viscosity, good to about ±200 centipoise.

Table 22.—Marsh funnel time—Brookfield viscosity relationship for forest fire retardant solutions[1] (use with procedure 7)

Time for 1 quart to flow through funnel[2]	Large tip[3]							Small tip[4]			
	PC A	PC D75	PC XB	FT GTS	FT 100	FT 931	M 2700	FK IIP	PC 259	PC G	FT STP
Min:sec	*Centipoise*										
0:14					758						
16					1086						
18	503				1341		492				
20	676	572	457	485	1545		645				
22	832	817	596	611	1712		785				
24	975	1021	723	727	1851		912				
26	1106	1194	839	834	1969		1029				
28	1227	1342	948	932	2070		1137			20	
30	1340	1470	1048	1024	2157		1237			26	
32	1446	1583	1142	1110	2233		1332			33	
34	1545	1682	1231	1190	2301		1420		17	41	
36	1639	1770	1314	1266	2361		1504	16	26	51	
38	1727	1849	1393	1338	2415		1583	52	35	63	
40	1811	1920	1468	1407	2463		1658	84	44	76	18
42	1891	1984	1539	1471	2507		1729	113	54	91	43
44	1967	2042	1607	1533	2546		1797	139	63	109	65
46	2040	2095	1672	1592	2583		1862	163	72	128	86
48	2110	2144	1734	1649	2616		1924	186	81	150	105
50	2177	2189	1793	1703	2646		1983	206	90	175	122
52	2241	2231	1851	1755	2675		2041	225	100	203	138
54	2303	2269	1906	1806	2701		2096	242	109	233	152
56	2362	2305	1959	1854	2725		2149	258	118	267	166
58	2420	2338	2010	1901	2748		2200	273	127	305	179
1:00	2475	2369	2059	1946	2769	1900	2250	287	136	346	191
02	2529	2398	2107	1989	2789		2297	300	145	391	202
04	2581	2425	2153	2032	2807		2344	313	155	440	212
06	2632	2450	2198	2073	2824		2389	324	164	494	222
08		2474	2242	2112	2841		2432	335	173	552	231
10		2497	2284	2151	2856		2475	345	182	615	240
12		2519	2325	2188	2871		2516	355	191	683	248
14		2539	2365	2225	2885		2556	364	201		256
16		2558	2404	2260	2898		2595	373	210		263
18		2576	2442	2295	2910		2633	381	219		270
20		2593	2479	2328	2922			389	228		277
22		2610	2525	2361	2933			396	237		283
24			2550	2393	2945			403	246		289
26			2584	2425	2954			410	256		295
28			2618	2455	2964			417	265		301
30				2485	2973			423	274		306
32				2514	2982			429	283		311
34				2543	2990			434	292		316
36				2571	2998			440	302		320
38				2598	3006			445	311		325
40				2625				450	320		329
42								455	329		333
44								459	338		337
46								464	347		341
48								468	357		344
50								472	366		348
52								476	375		351
54								480	384		354
56								484	393		357
58								487	402		360
2:00						2200		491	412		363
02								494	421		366
04								497	430		369
06								500	439		372
08									448		374
10									458		377
3:00						2500					
4:00						2800					
5:00						3100					

[1]Brookfield model LVF viscometer, at 60 r/min, spindle 2 (for viscosities from 1-500 cP) or spindle 4 (for viscosities greater than 500 cP); at 70-80 °F; higher temperature may give false low readings; lower temperatures may give false high viscosities.
[2]Funnel must be full to screen before test begins.
[3]Inside diameter should be 0.269 ± 0.002 inch.
[4]Inside diameter should be 0.187 ± 0.002 inch.
[5]The boxed areas indicate the normal use ranges.

Procedure 9: Determining the Specific Weight of a Fire Retardant by Conventional Weight/Volume Measurements

The specific weight of a retardant is calculated from the weight of an accurately known volume of solution. If a container of known volume is not available, one can be calibrated by adding a known weight of water to an available container and marking the fluid level.

1. Accurately weigh an empty container (1 cup to 1 quart) that has a precisely known volume (such as a kitchen measure) on a small scale, such as a postal or kitchen scale. The capacity of the scale will determine the size container to use. (The note at the end of this procedure gives directions for determining the volume of a container.)
2. Fill the weighed container to the volume mark with the retardant to be tested. Be sure air bubbles have been allowed to escape first.
3. Weigh the filled container.
4. Subtract the weight of the empty container. This gives the weight of a known volume of retardant.
5. Convert ounces to decimal fractions of pounds by dividing the number of ounces by 16; for example:

   2 lb 4 oz = 2.25 lb (2 + 4/16)

   2 lb 8½ oz = 2.53 lb (2 + 8.5/16)

6. Determine the specific weight using table 23 (appendix 3) or calculate the specific weight of the retardant by multiplying the weight obtained in step 5 by the appropriate factor:

Volume weighed	Factor
1 cup	16
2 cups (1 pint)	8
4 cups (1 quart)	4

For example, if 1 quart (4 cups) of retardant weighs 2 lb 3 oz or 2.19 lb, the specific weight is 2.19 × 4 = 8.76 lb/gal. If 1 cup of retardant weighs 9 oz or 0.56 lb, the specific weight is 0.56 × 16 = 8.96 lb/gal.

NOTE: A narrow-mouth container is preferable to a wide-mouth container. If such a container is not available, one can be made from any appropriately sized narrow-mouth container.

1. Accurately weigh a clean, dry container.
2. Add sufficient water to the container to increase the weight as shown:

Approximate size container	Weight added *Ounces*
1 cup	8
1 pint (2 cup)	16
1 quart (4 cup)	32

3. Mark the fluid level.
4. Empty and dry container and repeat at least three times.
5. Use a fine-tipped waterproof marker to mark fluid line.

Procedure 10: Determining the Specific Weight of a Fire Retardant Using a Mud Balance

The Baroid mud balance is designed especially for measuring specific weight. (Other similar instruments may be suitable.) The special container is filled with the material being tested and then placed on the stand and the slide adjusted to balance. Specific weight can be read directly from the built-in scale.

1. Fill the cup attached to the balance with the retardant to be tested.
2. Tap cup until air bubbles are removed (see note below).
3. Seat lid firmly on cup, being sure that some retardant goes through hole. (This ensures that the cup is filled to capacity.)
4. Wipe outside of cup and lid to remove any retardant adhering to container.
5. Place balance on the base with knife edges on the fulcrum rest.
6. Move slide until balance is level.
7. Read the specific weight in pounds per gallon of retardant directly at the edge of the slide nearest the fulcrum.

NOTE: If all entrapped air is not removed the specific weight measured will be less than the specific weight of the retardant itself. Depending on the use of this value, incorrect conclusion may result. For example, the specific weight of a retardant with entrapped air included would be appropriate when the concern is the weight loaded onto an aircraft; however, that same value would not be suitable for quality control purposes such as determining retardant salt content.

Procedure 11: Determining the Specific Weight of a Fire Retardant Using a Hand-Held Density Meter

A sample of the material to be tested is injected into the instrument sample tube. During density measurements the tube oscillates and the internal electronics of the instrument uses the characteristics of the oscillation and several internal constants to automatically calculate and display density. Specific weight can be calculated from the density or it can be looked up directly, in the conversion table provided.

1. Turn density meter on. (Mettler DMA 35; other instruments may be suitable; follow manufacturer's operating instructions.)
2. Fill the sample tube by slowly injecting retardant from a hypodermic syringe into the right-hand nozzle. For unthickened retardants, the sample can be sucked into the sample tube through a tube attached to the left-hand nozzle by squeezing the long rubber bulb on the right side of the meter and then releasing.
3. If there are air bubbles in the sample tube, slowly inject more retardant until all air bubbles are gone.

4. Allow temperature (shown on the meter face) to stabilize.

5. Read density and temperature directly in windows on the meter face.

6. Use table 24 (appendix 3) to convert density (g/mL) to specific weight (lb/gal).

7. Flush sample tube with clean water.

NOTE: Freshly mixed or recirculated samples contain large numbers of small air bubbles that will cause inaccurate density readings. To obtain the true density of the retardant solution it may be necessary to wait overnight for all entrapped air to escape.

Procedure 12: Determining Retardant Salt Content Using a Hand-Held Density Meter

A sample of the material to be tested is injected into the instrument sample tube. During density measurements the tube oscillates and the internal electronics of the instrument uses the characteristics of the oscillation and several internal constants to calculate and display density and temperature automatically. If the test material was pretreated as appropriate for retardant type, the density can be looked up in the salt content tables and salt content read directly.

1. Pretreat the retardant sample as described in procedures 3, 4, or 5 as appropriate for the thickener type.

2. Turn density meter on. (Mettler DMA 35; other instruments may be suitable; follow manufacturer's operating instructions.)

3. Suck the treated sample into the sample tube by squeezing the rubber bulb on the side of the meter, inserting the inlet tube into the sample, and then releasing the rubber bulb.

4. Allow the temperature (shown on the meter face) to stabilize.

5. Read the density and temperature directly in windows on the meter face.

6. Use table 25 (appendix 3) to convert degrees Celsius to degrees Fahrenheit.

7. Correct density reading for temperatures less than 75 °F or greater than 85 °F using table 26 (appendix 3) or the following rule: For every 5 °F the retardant solution temperature is below 80 °F, subtract 0.001 from the hydrometer reading; or for every 5 °F the retardant solution is above 80 °F, add 0.001 to the hydrometer reading.

8. Look up the corrected density reading in the left-hand column of the proper salt content table (2-11) and read the salt content.

9. Flush sample tube with clean water.

NOTE: Freshly mixed retardant samples contain a large number of small air bubbles that will cause inaccurate density readings. If the retardant is to be filtered or treated with viscosity reducing agent, the entrapped air will be unlikely to cause inaccuracies. However, before making corrections to mixed retardant, the sample densities should be verified by retesting after the retardant has been allowed to sit for several hours or overnight.

Procedure 13: Determining Fire Retardant Salt Content Using a Hand-Held Refractometer

When light is focused through a drop of retardant, the light is deflected by an amount that is proportional to the amount of salt present. This deflection is measured on the arbitrary scale built into the refractometer. (American Optical Scientific Instruments model 1440, with a scale from 0 to 30 arbitrary units. Other instruments may also be used, but calibration tables for the specific instrument may be needed.) Using calibration tables provided, retardant salt content can be read directly from this scale reading.

1. Clay-thickened products should be filtered and a drop of clear filtrate used for this test. All other retardants can be used without pretreatment.

2. Lift the instrument cover plate to expose the prism.

3. Using the dipstick provided, or a plastic stirring rod, place one or two drops of the sample on the face of the prism and close the cover. The retardant should form a thin layer covering nearly the entire prism for best results. Avoid use of an excessive amount of retardant as this can give an inaccurate reading.

4. Point the instrument toward a strong light source. Natural light outdoors is best.

5. Look through the eyepiece and read the value where the light/dark line intersects the scale. Tilting the refractometer with respect to the light source may sharpen the contrast and improve readability.

6. Clean the prism and cover plate with a damp cloth or soft tissue. Dry thoroughly.

7. Refer to the appropriate table to convert the scale reading to retardant salt content.

NOTE: Although variations in solution temperature do not affect the accuracy of the refractometer, variations in the temperature of the refractometer itself may do so. To minimize this problem, store the refractometer between 60 °F and 85 °F. Low temperatures cause greater variation than do high temperatures.

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APPENDIX 1: GLOSSARY

Component - any portion of a mixed retardant that is shipped or handled separately in the mixing or delivery procedures.

Corrosion - result of reaction between a metal and its environment.

Density - the mass of substance per unit of volume, grams per milliliter.

Deterioration - the loss of viscosity over time; specifically, for evaluation purposes, any loss of more than 40 percent of the initial viscosity within 1 year after preparation of the solution.

Elasticity - the property of a material enabling it to resist deformation by stretching or pulling apart. Usually used in reference to the cohesiveness or ability of material to hold together during a drop.

Flow conditioner - chemicals that, in very small quantities, tend to prevent other powders from caking. Imparts free flowing qualities to powder.

Inhibitor - any agent that retards a chemical reaction. In retardant applications, usually refers to a viscosity loss inhibitor (bactericide) or corrosion inhibitor.

Liquid concentrate - a retardant concentrate in liquid form, which when diluted with water by simple mixing, forms a mixed retardant.

Long-term retardant - a chemical that has the ability to reduce or inhibit combustion (burning) after the water it originally contained has evaporated. The most common chemical salts used in long-term retardants are ammonium sulfate (AS), monoammonium phosphate (MAP), diammonium phosphate (DAP), and ammonium polyphosphate (APP).

pH - a measure of the acidity or alkalinity of a liquid, on a scale from 0 to 14, with 7 representing neutrality. The lowest numbers are the most acidic and the highest numbers are the most alkaline (basic).

Retardant - a substance that by chemical or physical action reduces or inhibits flammability of combustibles. Rate-of-spread of flame front is thereby slowed or retarded.

Rheologic properties - all those physical/chemical properties that influence the fluid flow characteristics of a substance. Viscosity and elasticity are principal rheological properties used to characterize retardant behavior.

Short-term retardant - a substance that relies on the moisture it contains to reduce or inhibit combustion and that is ineffective once its moisture has evaporated. Water and thickened water are short-term retardants.

Slurry - any mixed retardant as it is used operationally; normally used to refer to thickened retardants in their viscous state.

Specific weight - weight, in pounds, of 1 gal of substance.

Steady-state viscosity - the viscosity of a retardant 24 hours after initial mixing and that is expected to be maintained for an appreciable time period (week or more).

Thickener - a substance that when added to a liquid acts to increase the viscosity and/or elasticity of that liquid.

Viscosity - the internal resistance of a liquid to flow when a defined force is exerted upon it. The viscosity of retardants is normally measured with a Brookfield viscometer or a Marsh funnel.

Viscosity reducing agent - a substance (usually an enzyme) that is added to a gum-thickened retardant to eliminate enough of the viscosity that a hydrometer can be accurately floated in the product.

APPENDIX 2: TESTING EQUIPMENT AND SOURCES

For all tests, a clean container (approximately 1 gal) for transferring samples from the retardant mixing and storage area to the test area should be set aside exclusively for test purposes.

I. Viscosity - for all thickened retardants

A. Marsh Funnel Method

1. Marsh funnel (#201) - Baroid. Must be modified for use with fire retardants. Instructions for modification may be obtained from Intermountain Fire Sciences Laboratory, Missoula, MT.
2. Stand and support (S-78306-A and S-19150) - Sargent-Welch Scientific.
3. 1-quart container - local kitchen supply.
4. Thermometer, readable to 1 °F (S-80015-A) - Sargent-Welch Scientific.
5. Stopwatch, watch with second hand, or other timer readable in seconds.

B. Brookfield Viscometer Method

1. Brookfield viscometer and stand (model LVF) - Brookfield Engineering Laboratories.
2. Thermometer, readable to 1 °F (S-80015-A) - Sargent-Welch Scientific.
3. Timer or watch readable to 60 seconds.

II. Salt Content - all retardants

A. Hydrometer Method

1. Hydrometer of suitable range - Sargent-Welch Scientific.
   1.000-1.070 sp. gr. units (S-41885-F)
   1.060-1.130 sp. gr. units (S-41885-G)
   1.120-1.190 sp. gr. units (S-41885-H)
   1.180-1.250 sp. gr. units (S-41885-I)
2. 100-mL graduated cylinder (or 32- by 200-mm test tube and stand) (S-24631-E) - Sargent-Welch Scientific.
3. Thermometer readable to 1 °F (S-80015-A) - Sargent-Welch Scientific.

4.a. Gum-thickened retardants

Viscosity reducing agent - request from C. W. George, Intermountain Fire Sciences Laboratory.

1-quart bottle with lid (S-8416-F) - Sargent-Welch Scientific.

Measuring teaspoon

Watch or other timer

b. Clay-thickened retardants

Filter paper and funnel (or drip coffee filter and holder) (S-35433-F and S-32915-L) - Sargent-Welch Scientific.

Container for filtered solution (S-8416-F) - Sargent-Welch Scientific.

c. Clay-thickened liquid concentrate

Filter paper and funnel (or drip coffee filter and holder) (S-35433-F and S-32915-L) - Sargent-Welch Scientific.

1-quart disposable canteen (8465-00-102-6381) - General Services Administration.

Container for filtered solution (S-8416-F) - Sargent-Welch Scientific.

B. Hand-Held Density Meter Method

1. Density meter (DMA35) - Mettler Instrument Co.

2.a. Gum-thickened retardants

Viscosity reducing agent - request from C. W. George, Intermountain Fire Sciences Laboratory.

1-quart bottle with lid (S-8416-F) - Sargent-Welch Scientific.

Measuring teaspoon

Watch or other timer

b. Clay-thickened retardant

Filter paper and funnel (or drip coffee filter and holder) (S-35433-F and S-32915-L) - Sargent-Welch Scientific.

Container for filtered solution (S-8416-F) - Sargent-Welch Scientific.

c. Clay-thickened liquid concentrate

Filter paper and funnel (or drip coffee filter and holder) (S-35433-F and S-32915-L) - Sargent-Welch Scientific.

1-quart disposable canteen (8465-00-102-6381) - General Services Administration.

Container for filtered solution (S-8416-F) - Sargent-Welch Scientific.

C. Refractometer Method

1. Industrial fluid tester (model 10440) - VWR Scientific.
2. Clay-thickened retardants and liquid concentrates

Filter paper and funnel (or drip coffee filter and holder) (S-35433-F and S-32915-L) - Sargent-Welch Scientific.

Container for filtered solution (S-8416-F) - Sargent-Welch Scientific.

III. Specific Weight - all retardants

A. Weight/Volume Method

1. Container (1 cup to 1 quart size)
2. Kitchen or postal scale

B. Mud Balance Method

1. Baroid mud balance (4-scale model) - Baroid Division.

C. Density Meter Method

1. Hand-held density meter (DMA 35) - Mettler Instrument Co.

Source of Supplies:

1. Baroid Division, National Lead Co., P.O. Box 1675, Houston, TX.
2. Brookfield Engineering Laboratories, 240 Cushing St., Stoughton, MA 02072.
3. General Services Administration, Building 41, Denver Federal Center, Denver, CO 80225.
4. Mettler Instrument Co., P.O. Box 71, Hightstown, NY 08520.
5. Intermountain Fire Sciences Laboratory, RWU-4402, P.O. Box 8089, Missoula, MT 59807.
6. Sargent-Welch Scientific Co., 4040 Dahlia St., P.O. Box 7196, Denver, CO 80207.
7. VWR Scientific, P.O. Box 1004, Norwalk, CA 90650.

APPENDIX 3: TABLES FOR ADJUSTMENT, CORRECTIONS, AND CONVERSIONS

Table 23.—Conversions from weight of a known volume of retardant to specific weight (use with procedure 9)

Net weight of container of retardant		
1 cup	1 quart	Specific weight
		Lb/gal
8 oz	2 lb	8.0
8 1/8 oz	2 lb ½ oz	8.13
8 1/4 oz	2 lb 1 oz	8.25
8 3/8 oz	2 lb 1½ oz	8.33
8 1/2 oz	2 lb 2 oz	8.50
8 5/8 oz	2 lb 2½ oz	8.63
8 3/4 oz	2 lb 3 oz	8.75
8 7/8 oz	2 lb 3½ oz	8.83
9 oz	2 lb 4 oz	9.0
9 1/8 oz	2 lb 4½ oz	9.13
9 1/4 oz	2 lb 5 oz	9.25
9 3/8 oz	2 lb 5½ oz	9.33
9 1/2 oz	2 lb 6 oz	9.50
9 5/8 oz	2 lb 6½ oz	9.63
9 3/4 oz	2 lb 7 oz	9.75
9 7/8 oz	2 lb 7½ oz	9.83
10 oz	2 lb 8 oz	10.0

Table 24.—Conversion from retardant density to specific weight[1] (use with procedure 11)

Density[2]	Specific weight
g/mL	*Lb/gal*
1.010	8.4
1.022	8.5
1.034	8.6
1.046	8.7
1.058	8.8
1.070	8.9
1.082	9.0
1.094	9.1
1.106	9.2
1.118	9.3
1.130	9.4
1.142	9.5
1.154	9.6
1.166	9.7
1.178	9.8
1.190	9.9
1.202	10.0

[1]At 80 °F. At lower solution temperatures, the tabulated values will be low; at higher solution temperatures, the tabulated value will be high.

[2]For densities outside the values shown or at temperatures other than 80 °F, the conversion can be made by multiplying the density × constant. The constant depends on the solution temperature:

Temperature, °F	Constant
70	8.327
75	8.322
80	8.317

Table 25.—Conversion of temperatures from degrees Celsius to degrees Fahrenheit[1] (use with procedure 6)

Degrees Celsius	Degrees Fahrenheit
4	39
6	43
8	46
10	50
12	54
14	57
16	61
18	64
20	68
22	72
24	75
26	79
28	82
30	86
32	90
34	93
36	97
38	100

[1]For values not given in the table, the temperature in °F can be calculated by: °F = 9/5 × °C + 32.

Table 26.—Adjustments to specific gravity for temperature deviations

Retardant temperature, °F	Correction to specific gravity reading
43-47	subtract 0.007
48-52	subtract .006
53-57	subtract .005
58-62	subtract .004
63-67	subtract .003
68-72	subtract .002
73-77	subtract .001
78-82	no correction needed
83-87	add .001
88-92	add .002
93-97	add .003
98-102	add .004
103-107	add .005
108-112	add .006

APPENDIX 4: SAMPLE CALCULATIONS

I. Sample Calculation to Determine Increase in Volume During Mixing of a Retardant

A. Mixed Retardant from a Dry Chemical

The density of water and two values for the specific retardant (mix ratio and specific weight) are needed for the calculation.

Using Phos-Chek A as an example:

Mix ratio = 0.96 lb of dry chemical/gal of water

Specific weight of the mixed retardant = 8.78 lb/gal of mixed retardant

Specific weight of water (75 °F) = 8.322 lb/gal

Using these values, assume that dry retardant is added to 1 gal of water:

Weight of the mixed retardant

= 0.96 lb of powder + 8.322 lb of water

= 9.282 lb of mixed retardant

From the weight and specific weight of the mixed retardant, calculate the volume of retardant made:

$$\text{Volume} = \frac{9.282 \text{ lb of mixed retardant}}{8.78 \text{ lb/gal of mixed retardant}}$$

$$= 1.0572 \text{ gal of mixed retardant}$$

The percentage increase in volume is calculated using the amount of water added as a base:

$$\text{Percentage increase} = \frac{(1.0572 - 1.00)100}{1.00} = 5.72\%$$

To calculate the amount of powder needed to make 1 gal of retardant, divide the amount of powder added to 1 gal of water by the total volume of mixed retardant:

Weight of powder/gal of retardant

$$= \frac{0.96 \text{ lb of powder/gal of water}}{1.0572 \text{ gal of retardant}}$$

= 0.908 lb of powder/gal of retardant

This figure can be used to figure retardant yield per ton of powder.

In this example:

$$\text{Yield} = \frac{2{,}000 \text{ lb/ton}}{0.908 \text{ lb of powder/gal of retardant}}$$

= 2,203 gal of retardant/ton of powder

B. Mixed Retardant from a Liquid Concentrate

The calculations are similar when using a liquid concentrate, but an additional value, the specific weight of the concentrate, is needed.

Using Fire-Trol 931 as an example:

Mix ratio = 4:1 (4 parts water to 1 part concentrate)

Specific weight of concentrate = 11.78 lb/gal

Specific weight of mixed retardant = 9.15 lb/gal

Specific weight of water (75 °F) = 8.322 lb/gal

Using these values, assume that 0.25 gal of liquid concentrate is added to 1 gal of water:

Weight of mixed retardant

$$= \frac{11.78 \text{ lb/gal of concentrate}}{4} + 8.322 \text{ lb/gal of water}$$

= 2.945 + 8.322 = 11.267 lb of mixed retardant

From the weight and specific weight of the mixed retardant, calculate the volume of retardant made:

$$\text{Volume} = \frac{11.267 \text{ lb of mixed retardant}}{9.15 \text{ lb/gal of mixed retardant}}$$

= 1.2314 gal of mixed retardant

The percentage increase in volume is calculated using the amount of water added as a base:

$$\text{Percentage increase} = \frac{(1.2314 - 1.00)100}{1.00} = 23.14\%$$

To calculate the amount of concentrate needed to make 1 gal of mixed retardant, divide the weight of concentrate added to 1 gal of water by the volume of mixed retardant made:

Weight of concentrate/gal of retardant

$$= \frac{2.945 \text{ lb of concentrate/gal of water}}{1.2314 \text{ gal of retardant}}$$

= 2.392 lb of concentrate/gal of retardant

Similarly, to calculate the volume of concentrate needed to make 1 gal of retardant, divide the volume of concentrate added to 1 gal of water by the volume of mixed retardant made:

Volume of concentrate/gal of mixed retardant

$$= \frac{0.25 \text{ gal of concentrate/gal of water}}{1.2314 \text{ gal of retardant}}$$

= 0.203 gal of concentrate/gal of retardant

These figures can be used to calculate retardant yield per ton of concentrate or per tanker load of concentrate:

$$\text{Yield} = \frac{2{,}000 \text{ lb/ton}}{2.392 \text{ lb of concentrate/gal of mixed retardant}}$$

= 836 gal of mixed retardant/ton of concentrate

$$\text{Yield} = \frac{5{,}000 \text{ gal/tanker}}{0.203 \text{ gal of concentrate/gal of mixed retardant}}$$

= 24,631 gal of mixed retardant

II. Salt Content of Mixed Retardant

A. Calculate the Salt Content of a Mixed Retardant from a Liquid Concentrate

When the mix ratio (such as 4:1) of the retardant made from a liquid concentrate is known, the salt content can be calculated provided that the density (or specific weight [sp. wt.]) and salt content of the concentrate are known.

For example: Fire-Trol 931-L concentrate has a salt content of 31.8% P_2O_5 and specific weight of 11.96 lb/gal. If the concentrate is diluted 4:1 with water (assume 4 gal of water are mixed with 1 gal of a concentrate), what is the salt content of the mixed retardant?

(con.)

APPENDIX 4: (Con.)

Weight of P_2O_5

= (sp. wt. of concentrate) × (percent of salt in concentrate)

= 11.96 × 0.318

= 3.80 lb of P_2O_5

Weight of mixed retardant

= weight of 1 gal of concentrate + weight of 4 gal of water

= 11.96 + 4 × 8.32

= 11.96 + 33.28

= 45.24 lb of mixed retardant

Salt content of mixed retardant

$$= \frac{\text{weight of } P_2O_5 \text{ in mixed retardant}}{\text{weight of mixed retardant}} \times 100$$

= (3.80/45.24) × 100

= 8.4% P_2O_5

B. To Calculate the Salt Content of a Mixed Retardant from a Dry Powder

When the mix ratio of a product made from a powder and the salt content of that powder are known, the salt content of the mix retardant can be calculated.

For example: Phos-Chek 259 is made by mixing 1.14 lb of powder with 1 gal of water. If the powder has a salt content of 90.5% diammonium phosphate (DAP), what is the salt content of the resulting mixed retardant?

Weight of DAP

= (weight of powder used) (percent salt)

= (1.14)(0.905)

= 1.03 lb of DAP

Weight of mixed retardant

= weight of powder + weight of water

= 1.14 + 8.32

= 9.46 lb of mixed retardant

Salt content of mixed retardant

$$= \frac{\text{weight of DAP}}{\text{weight of mixed retardant}} \times 100$$

$$= \frac{1.03}{9.46} \times 100$$

= 10.9% DAP

To convert percentage DAP to percentage P_2O_5 for direct comparisons of salt content divide by 1.86:

$$\text{Percent } P_2O_5 = \frac{\% \text{ DAP}}{1.86}$$

$$= \frac{10.9}{1.86}$$

= 5.9% P_2O_5 in mixed retardant

APPENDIX 5: SAMPLE RECORDKEEPING FORMS

Not all forms are suitable for all bases. Nor are these examples intended to be all inclusive. The particular situation at each base and the type of retardant used will be the primary factors in determining the forms needed.

Example 1.—Liquid concentrate (fill out for each truckload).

Date of delivery _____ Time of delivery _____

Retardant name _____

Volume of delivery _____ (Specify pounds or gallons)

Bill of lading (or other identification) number _____

Name and address of supplier:

Lot acceptance information:

Hydrometer reading: _____ at _____°F (temperature)

Additional identification _____

Quality assurance program:

Was sample sent to designated collection point? _____ (yes/no)

Additional identification _____

Comments: (If liquified at the base, volume of water used; any obvious settling or solids; appearance out of the ordinary; if this truckload was added to material already in storage, estimate volume and salt content of the material in storage, if more than one storage tank is used, specify where new material is added, etc.)

Example 2.—Liquid concentrate summary (one line for each addition of material).

Tank identification: _____

Delivery		Amount liquified or added		Specific gravity in tank		Sample identification
Date	Time	lb	gal	before mixing	after mixing	

Example 3.—Retardant mixing data (for batch mixing—fill out for each batch or eductor mix from Phos-Bin, etc.).

Date of mix _____ Time of mix _____

Volume of water used _____ (gal)

Amount of dry material or concentrate used _____ (lb/gal)

Marsh funnel time _____ min and _____ sec at _____ °F (temperature)

Viscosity: _____ centipoise
(or Brookfield viscometer spindle) _____ × _____ (factor)

Hydrometer reading: _____ at _____ °F (temperature)

Reading corrected for temperature _____

Salt content: _____ % _____ (specify salt)

Was a correction made? _____ (yes/no)

If yes: Amount of water/retardant added _____

Hydrometer reading (after correction): _____ at _____ °F

Reading corrected for temperature _____

Salt content: _____ % _____ (specify salt)

Is this batch being used for lot acceptance? _____

Was quality assurance sample sent to proper collection point? _____ (yes/no)

Additional identification _____

Comments: (how mixed, appearance other than usual, etc.)

Example 4.—Mixed retardant storage data (to track retardant in tanks, test weekly).

Tank identification _____

Test date	Test time	Specific gravity	Temper-ature, °F	Corrected sp. gr.	Salt content	Marsh funnel time minutes and seconds	Viscosity Centipoise	Comments[1]

[1]Comments as to sample history, such as material held from last season; tanks being closed until next season; sample sent to collection point for testing, etc.

Example 5.—Retardant slurry data (for retardant mixed and pumped directly to airtanker).

Sample date	Sample time	Marsh funnel time (min & sec)	Viscosity (Centipoise)	Hydrometer reading	Slurry temperature (°F)	Corrected hydrometer reading	Field salt content	Comments[1]

[1]Comments as to sample history, such as: loaded into airtanker No. 17; fire name; sample sent to RO.

Example 6.—Information for lot acceptance inspection or other tests.

FOR USE ONLY BY COLLECTION POINT

Sample No. _____

LOT ACCEPTANCE INSPECTION & TESTS

Retardant Sample

Mixing base name/location: _____ Amount received: _____

Retardant product: _____ Shipper No. _____

Date/time received: _____ Packaging damage: Yes ☐ No ☐

Container properly marked: Yes ☐ No ☐ Remarks: _____

_____

_____

Sample Information

Date/time mixed, if not LC: _____ Volume mixed: _____

Time sample drawn: _____ Sample taking procedure (how sample drawn, etc.): _____

_____

_____

Marsh funnel time: _____ Viscosity: _____

Hydrometer reading/temperature: _____ Salt content: _____

Name/title/phone (FTS; commercial) of person testing sample: _____

_____

_____

_____

Original: Collection point — Copy: Retain at base

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George, Charles W.; Johnson, Cecilia W. Determining fire retardant quality in the field. General Technical Report INT-201. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 42 p.

Onsite fire retardant effectiveness is dependent on a retardant's physical (rheological) and chemical (active fire-inhibiting salt) properties. Quality control at each retardant base is necessary to assure cost-effectiveness is achieved. Using relatively simple techniques, retardant salt content and viscosity can be monitored in the field to determine quality. This paper describes field procedures for determining retardant quality using calibration tables developed for most long-term and short-term retardants. Corrective actions to bring properties within desired ranges are included.

KEYWORDS: fire suppression, fire retardants, quality control, active chemical, salt content, physical properties, rheology, viscosity, corrective actions, procedures, specific weight

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