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# Standard Test Procedures For the Evaluation of Wildland Fire Chemical Products

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USDA Forest Service
Wildland Fire Chemicals Systems at
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These test procedures provide detailed test methods used by the Forest Service Technology and Development Centers at Missoula, Montana and San Dimas, California in the evaluation of wildland fire chemical products. The tests described are required by one or more Forest Service specifications for the qualification of wildland fire chemical products.

This information will assist the manufacturers of wildland fire chemical products in developing and evaluating a product in the laboratory, using procedures required by applicable Forest Service specifications. Specific product information is required prior to submission of product test samples to the Forest Service under the Wildland Fire Chemical Products Evaluation and Qualification Program.

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## Test Method 1 – Health, Safety and Environment



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## General Description

Fire suppression chemicals are used in a variety of emergencies by people with different levels of awareness and training in their use. The Forest Service specifications require disclosure and testing to minimize risks.

Manufacturers of wildland fire fighting chemicals are required to disclose in full, the types and amounts of each chemical in all products. These are reviewed for known hazards. Products are also subjected to laboratory testing to determine toxicity.

## Chapter 1. Review of Disclosure Information

The manufacturer of each product is required to provide a completed confidential formulation disclosure sheet for each product submitted to the Forest Service. Full disclosure of the types and amount of each chemical in the product will be provided, to include the Chemical Abstract Services (CAS) number, quality or grade, manufacturer, and manufacturing process for each ingredient. A designated Forest Service representative will review the confidential formulation disclosure sheet, technical data sheet, Material Safety Data Sheet (MSDS) for each product, and the MSDS for each ingredient. This review will determine whether or not the product complies with Forest Service policy regarding use of chemicals that may be on any of the regulatory lists below:

- 40 CFR 302.4; Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Hazardous Substances.
- 40 CFR 261.33; Resources Conservation and Recovery Act (RCRA) Acutely Hazardous and Toxic Products.
- 40 CFR 372; Superfund Amendment and Reauthorization Act (SARA) Title III, sec. 313.
- 40 CFR 355, Appendix A; CERCLA Extremely Hazardous Substances (EHS).
- National Toxicology Program's (NTP) Annual Report on Carcinogens (U.S. Department of Health and Human Services).
- International Agency for Research on Cancer (IARC) monographs for potential carcinogens.

The status of each chemical with regard to the first three items is informational, to assure proper handling and storage. The status of each chemical with regard to the last three items 6 carries more importance.

The Forest Service takes a conservative view toward the use of any material of questionable safety in Forest Service operations. As a general rule, the Forest Service will not use any product that contains an ingredient appearing in the last three items.

If a listed ingredient is used in small amounts, the manufacturer may request a risk assessment be performed by an approved process and at manufacturer expense. This risk assessment will be used to determine the additional risk to Forest Service employees, the general public, and the environment associated with the use of a product containing the listed chemical. If the risk assessment findings support the manufacturer's claim of insignificant risk or impact, the product may be considered for use in fire suppression activities.

## Chapter 2. Acute Mammalian Toxicity and Irritation Tests

Standard mammalian toxicity tests are performed in accordance with the United States Environmental Protection Agency (EPA) Health Effects Guidelines (OPPTS), series 870 acute Toxicity and Irritation Studies. Laboratories conducting the toxicity tests shall be in compliance with 40 CFR 160 and 792 - Good Laboratory Practice Standards.

Acute oral and dermal toxicity tests are conducted as well as skin irritation tests and eye irritation tests on washed and unwashed eyes. This mammalian toxicity and irritation testing on all wet and dry components, and mixed retardant, shall be conducted by an independent biological testing laboratory approved by the Government. All testing shall be conducted in accordance with EPA/OPPTS guidelines, Series 870, and to include:

a. 870-1100 Acute Oral Toxicity Study

b. 870-1200 Acute Dermal Toxicity Study

c. 870-1300 Acute Inhalation Toxicity Study

d. 870-2400 Primary Eye Irritation Study

e. 870-2500 Primary Dermal Irritation Study

The results of the toxicity tests performed on the wet or dry components will fall into one of the following categories:

1. When the toxicity test results are as good or better than the lowest, least toxic, level as required by the specification, the product is acceptable and no further action is required.
2. When the toxicity test results are at or above the upper, most toxic, level in the specification, the product is determined to be unacceptable and no further action is required.
3. If the toxicity test results fall in between the two extremes, the product may be used if additional requirements are met. The manufacturer must recommend personal protective equipment and safe handling procedures that minimize the hazardous exposure to the product. The Safety and Health Branch of the Forest Service National Headquarters shall review the recommendations. If a determination is made that the recommendations will adequately protect the worker, the product is acceptable. If the recommendations are not judged adequate, the manufacturer may try again or the product will be unacceptable.

The mixed product, at the dilution qualified for field use, is also tested to determine acute oral and dermal toxicity and skin and eye irritation. In this case, there is no intermediate level of performance. Each product is determined to be acceptable or not acceptable.

## Chapter 3. Biodegradability

## Chapter 4. Fish Toxicity

## General Description

The combustion retarding effectiveness of a mixed retardant is determined by burning treated aspen excelsior and ponderosa pine needle fuel beds. Each fuel bed is loaded in the prescribed manner with either Ponderosa pine needles or aspen excelsior to obtain even distribution of fuel. The beds, 8 feet long by 18 inches wide by 3 inches high (2.4 meters by 46.7 centimeters [cm] by 7.6 centimeters [cm]), are sprayed uniformly with the mixed retardant or a specified standard chemical.

Coverage levels of one gallon-per-hundred-square feet (GPC) and two GPC are used. Each treated bed is dried to remove the water contained in the applied retardant or the standard. The weight loss of each bed is monitored until 95 to 100 percent of the added water is lost. Then the bed is burned under controlled conditions (90 ºF [32 °C] ±5 ºF, 20 percent ±2 percent relative humidity, and 5 miles per hour [mph] ±0.25 mph wind velocity) while monitoring the fire behavior. Each day that burn tests are performed, an untreated fuel bed (control) and a fuel bed treated with 10.6 percent technical grade diammonium phosphate (DAP; standard) are burned, in the same manner as the beds treated with test product.

The rate of spread and rate of weight loss for each bed is determined. These results are compared to those rates for untreated fuel beds and for beds treated with DAP. Reductions in the rates of fire spread and weight loss calculated from these comparisons provide the basis for evaluation.

## Fuels

All fuels for a test series must come from the same source; i.e., the same season's needle cast and the same site for the needle collection or the same purchase of aspen excelsior. Ponderosa pine needles are collected from natural sources in the immediate area, shortly after needle cast. Commercially available, standard grade aspen excelsior is obtained in 70-pound bales from a single source.

Both pine needles and split bales of excelsior are stored inside to equilibrate with ambient indoor conditions. The excelsior is then manually separated into individual fibers. Care is taken to remove knots, bundles, and any other collected fibers that may create non-uniformity in the fuel texture.

## Fuel-Bed Building

A fuel bed is used to contain the test fuel and ensure the proper fuel structure during each test. The fuel bed, 8 feet long by 18 inches wide by 3 inches high (2.4 meters by 46.7 cm by 7.6 cm), is built on an aluminum frame. Hardware cloth with half-inch openings is used for the floor and sides of the bed to form an open-ended box. Heavy aluminum foil covers the hardware cloth. The foil floor and hardware cloth sides are covered, in turn, by ceramic paper, which serves as the test bed surface. Finally the ceramic paper is painted with a hardener to extend the life of the paper. Experience has shown that ceramic paper with three coats of ceramic hardener will remain intact, to contain fuel and limit airflow, through a 4-week burn-test period.

Fuels used for a test series are stored inside for at least 2 days to allow the fuels to equilibrate with ambient indoor conditions prior to use. After the beds are built they are taken into the combustion chamber and allowed to come to constant weight at 90 ºF (32 °C) and 20 percent humidity before the retardant is applied. The fuel for each test is spread in a uniform manner on the fuel bed.

## Aspen Excelsior

Aspen excelsior is separated into individual fiber (fluffed) and weighed into tared paper bags, each containing approximately 1 pound (455 to 465 grams). This fuel is spread onto half of the 8-foot length of the fuel bed. The content of a second bag is spread on the other 4 feet of the bed. This excelsior is pulled apart and spread evenly, ensuring that no tight bundles of fibers or knots remain. At this point, the fuel is roughly 15 to 18 inches high (38 cm to 46 cm). The evenly distributed fuel is then

gently compressed and kneaded to fill the width and length of the frame completely and the resulting layer is no higher than 4 or 5 inches. Two more bags, for a total of 4 pounds of excelsior fuel are spread, fluffed, and gently compressed as before. During this process, raking through the fuel with fingers penetrates through the fibers to make one bed of uniform thickness from two layers. The resulting homogeneous fuel layer is no thicker than the height of the bed walls. All loose fibers that extend from the surface are trimmed. Aspen excelsior beds can be made the day before they are used for burn tests.

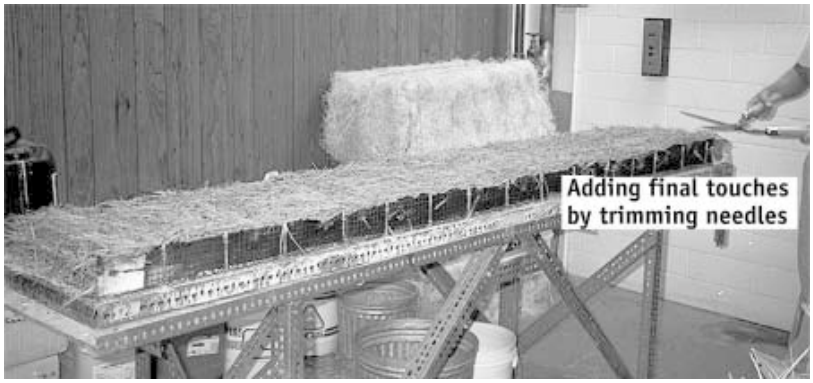



*Figure 2.1—Adding final touches by trimming needles.*

## Ponderosa Pine Needles

Pine needles are cleaned before storing by removing any twigs, moss, cones, or other debris. As the needles are weighed for bed building, twigs or cones that were missed during the earlier cleaning are removed. The needles are weighed into paper bags, each containing approximately 1 pound (455 to 465 grams) of needles. Three bags of needles are spread evenly along the 8-foot length of the bed. Another 3 bags of weighed needles are distributed and spread evenly on top of the previous layer for a total of 6 pounds of needles on each test bed. Light trimming removes needles that extend from the ends or the top surface. See figure 2.1.

Pine needle beds are made on the morning of burning. Needles can settle and slide within the fuel layers overnight, even with no disturbance.

## Starter Beds

Starter beds, 3 feet (0.9 meters) in length, are built in the same manner, with the same fuels and fuel loading, to provide an ignition source for the fuel test beds. The starter beds contain 1-1/2 pounds (0.7 Kilograms [Kg]) of excelsior, or 2-1/4 pounds (1.02 Kg) of pine needles. These 3-foot (0.9 meters) starter beds provide a developed fire across the width of the fuel bed as an ignition source for the test bed.

## Mixed Retardant

Fire retardant to be tested is prepared according to the manufacturer's directions. Sufficient retardant is made (10 to 15 gallons or 38 to 57 liters) to complete the planned series of test burns. Measurements are made to determine the density, viscosity, and percent solids. These values are used to assure the retardant was mixed properly and to calculate the volumes of liquid to be applied for each coverage level.

The percent solids is determined by drying samples, 4 to 7 milliliters, of the mixed retardant to constant weight in a drying oven set to 100 °F (38 °C).

Subtracting the dry weight from the wet weight of the product and dividing the result by the dry weight calculate the percent solids. Average the results for all samples.

Thickened products must have the viscosity reduced to approximate the condition of the retardant following breakup from an aerial drop and to permit consistent spraying from the application system's nozzle onto the test bed's fuel surface. An enzyme additive obtained from the product's supplier is most commonly used to reduce the retardant viscosity.

## Spray Apparatus

The spraying system, shown in figure 2.2, applies a constant and even coating of mixed retardant from a TeeJet™ Spray Systems nozzle, model number TP8030-SS

with a nominal opening of 2.5 millimeters. With an applied head pressure of 12 pounds per square inch in the 4-gallon (15 liter) stainless steel tank, the nozzle produces a flat, fan-shaped spray pattern, perpendicular to the bed length, from a height of 37 inches (94 cm) above the fuel bed surface. This spray pattern, assures even coverage across the bed surface.

The volume delivered from the nozzle is determined by spraying the test product for 10 seconds onto a tared tray. The weight of retardant sprayed is measured and the volume calculated. Several trials are made and the results averaged to calibrate the sprayer.

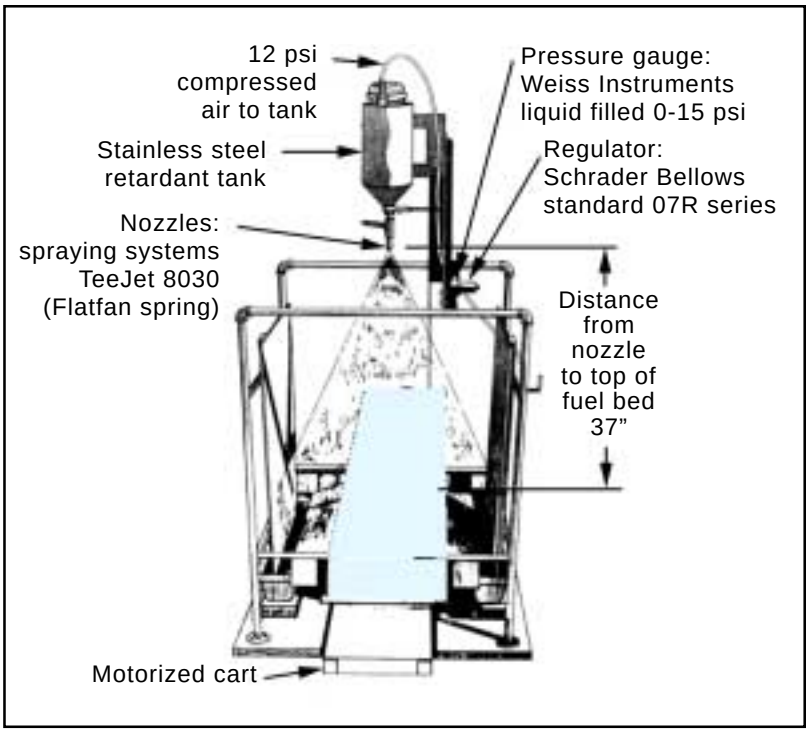



*Figure 2.2—Spraying system.*

The volume delivered per second is used to calculate the spray time necessary to deliver retardant equivalent to coverage of 1 GPC or 2 GPC to the test bed. In turn this value is used to set the travel time for the bed.

An electronically driven transport system is adjusted with the test bed in place to move the entire test bed under the spray apparatus in the calculated travel time.

## Retardant Application

Once a fuel bed has reached a constant weight in the combustion chamber, it is sprayed with either 1 GPC or 2 GPC of mixed retardant. The bed is immediately weighed again and the difference in the treated and untreated weights used to calculate the actual retardant coverage for that bed.

The fuel beds are then dried under the standard conditions of 90 °F (32 °C) and 20 percent relative humidity until the applied moisture evaporates. Air-drying is accomplished under circulating air in these controlled environmental conditions similar to those in the wind tunnel.

The weight of each bed is checked periodically. When the treated beds have dried sufficiently that 95 to 100 percent of the water applied with the retardant had been removed, the beds are burned.

## Data Collection System

The data collection system consists of a weighing system for the fuel bed; a computer that records the weighing system outputs and the flame spread data, and then calculates the rate of weight loss and rate of spread.

The weighing system, shown in figure 2.3, is located in the wind tunnel. The framework is an 11-foot-long steel structure anchored in sand to ensure a level surface. A 30 kilogram capacity balance is

positioned approximately 4 feet from the downwind end of the framework. A 4-foot-long (1.2 meter) aluminum frame sits on the balance and supports the 8-foot (2.4 meter) test bed.

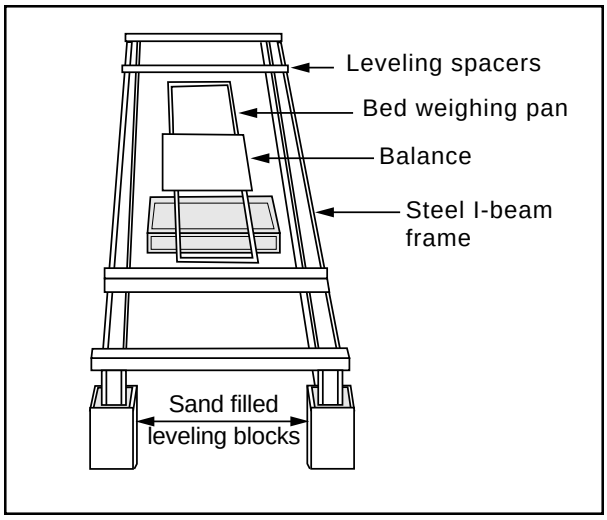



*Figure 2.3—Weighing system.*

Communication is established between the balance and the computer used to record data and compile results. A Tbasic computer program is used to collect the burn test data and calculate rates of spread and weight loss. The program is available from the Technology and Development Center/Wildland Fire Chemicals Systems Program in Missoula, Montana.

A video recording system of tripod, camera, and monitor is used to record each test for reference to clarify fire behavior or in case of questions.

## Burning

Once the fuel bed has reached the proper weight, the bed is removed from the combustion chamber and placed in the wind tunnel where burning conditions 90 °F (32 °C), 20 percent relative humidity, and 5 mph wind) have been established. The bed is balanced on the weighing system, a final weight is recorded, and a sample of fuel, roughly 2 inches by 4 inches (5 cm by 10 cm) through the fuel depth, is cut from the downwind end of the fuel bed for a fuel moisture determination. See figure 2.4. The sample weighs approximately 15 to 25 grams.

At this point final trimming is done to remove pine needles or excelsior fibers extending over the surface. These stray fibers may spread the flame front unevenly or cause flame spotting or uneven advancement of the observed flame front. Refer back to figure 2.1.

Tables, covered with nonflammable material, are arranged on all 4 sides of the test apparatus to minimize edge effects and air whorls and their influence on the fire behavior.

The computer program is started and the starter bed is ignited by an electronically heated wire. This starter bed provides an established flame front for ignition across the entire fuel bed rather than from a single point.

As the flame front reaches each 0.5-foot point (15.2 cm), measured against a reference bar, along the test bed, the operator presses a switch connected to the computer. The computer program records the time that the switch was pressed. The weight of the test bed is recorded every 10 seconds throughout the test burn.

At the conclusion of the combustion, the rates of spread and weight loss are calculated. As a rule, the 3-foot point and the 7-foot point are chosen as the basis for calculation. This allows space for the fire to become established on the bed and eliminates end effects from the starter bed or the downwind direction. Other points can be chosen by the operator to accommodate uneven burning or unique fire behavior.

All beds burned on the same day are made from the same fuel. At least one untreated bed and one test bed treated with technical grade diammonium phosphate (21-53-0 DAP) will be burned each day along with one or more test beds treated with the product being tested.

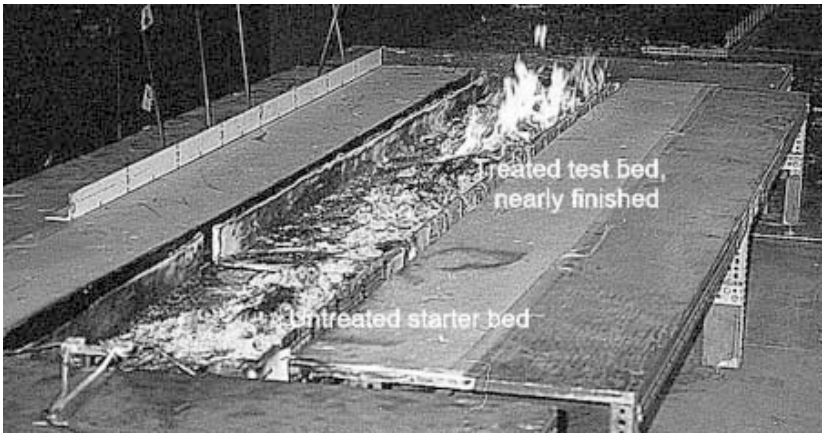



*Figure 2.4. Burning bed.*

## Fuel Moisture Analysis

The sample cut from the end of the test bed is placed into a 500 milliliter Florence flask that has been cleaned, dried, and weighed empty. It is sealed with a rubber stopper and set-aside until the end of the day when it will be run through a xylene-distillation process to determine the fuel moisture content.

The rubber stopper is removed, the flask and fuel are weighed, and then the flask and contained fuel is placed in an electrically heated mantle. Sufficient histological grade xylene is poured into the flask to reach the middle of the flask and be visible above the edge of the heating mantle. A condensing tube with collecting column attached is connected to the flask and all seals are secured. The heated mantle applies heat for 1 hour. Water and xylene boil off and the vapor is trapped and condensed over the graduated collecting column. The water (heavier than xylene) collects at the bottom of the graduated column and the volume measured to the nearest 0.025 milliliter.

The weight of the collected water is subtracted from the weight of the fuel sample contained in the flask to give the dry fuel weight. The weight of the water collected from the distillation is divided by the dry fuel weight. This calculation will yield the percentage of fuel moisture.

## Repeating Tests and Discharging Data

More than the required number of tests may be run. Additions may be used to replace other burns, to confirm results, or to reduce variations in the results. Each additional burn test will be subject to the same requirements as the original tests.

The results of individual burns can be discarded completely if the fuel and treatment fall outside of standard conditions and:

The coverage level for a 1 GPC test must be between 0.95 and 1.05 GPC.

The coverage level for a 2 GPC test must be between 1.95 and 2.05 GPC.

The test bed must be between 95 and 100 percent dry.

On occasion there will be results that do not fall outside the required parameters, but also do not agree with the remaining test results. These are not discarded. Additional tests may be run to confirm that the result is an oddity. These tests may also fill in the gap so that the non-agreement no longer exists.

## Calculations

Each test series consists of five fuel beds of each coverage level of the test product (1GPC and 2GPC) on each type of fuel bed (aspen excelsior and ponderosa pine needles).

The numerical data from the fuel bed tests is entered into an Excel™ spreadsheet and the rate of spread and rate of weight loss for each bed (test product, standard, and control) is calculated.

At the end of the burn test series, of the rates of spread for all untreated beds of the same fuel are averaged. Similarly, the rates of weight loss for all untreated beds of the same fuel are averaged. These four average values are used to determine reductions.

The reduction in rate of spread and rate of weight loss is calculated for each bed treated with the test product or standard chemical using the general formula:

$$\text{Reduction} = \frac{\text{Rate}_{\text{Untreated}} - \text{Rate}_{\text{Treated}}}{\text{Rate}_{\text{Untreated}}}$$

All reductions in rate of spread for the same coverage level on the same fuel with the same product are averaged. Similarly all reductions in rate of weight loss for the same coverage level on the same fuel with the same product are averaged.

The eight average reductions for the test product are added. The eight average reductions for the standard product are added. The totals of the reductions are compared. The performance of the test product is considered to be acceptable if the total of the reductions for the test product is at least as great as the total of the reductions for the standard product.

**General Description**

**Sample Preparation**

**Measure the Viscosity**

**Selection of Optimum Mixing**

## General Description

Wet and dry components are added to water and agitated to prepare mixed retardant. Each product must be mixed by an appropriate method, in order to give each mixed retardant the best chance to perform acceptably during qualification testing. An appropriate optimum mixing method must be determined for each product prior to performing other laboratory tests.

## Sample Preparation

All samples will be prepared in 1-quart, glass jars with straight sides. Measure the amount of dry or wet components required for addition to 800 milliliters of water. Pour 800 milliliters of 70 °F (21 °C) water, into a clean jar.

Attach a double bladed, 2-tier agitator (Indco Jiffy Model LM105) to an adjustable mixer motor. This agitator was selected due to the ability to mix quickly without splashing or entraining air into the mixture. Insert the agitator into the jar of water. Adjust the mixer so that the bottom of the agitator is about one-half inch above the bottom of the jar.

Adjust the mixer speed as shown in table 3.1. With the mixer running, quickly add the premeasured dry or wet components to the water. Mix for the time shown in the table.

Record the time that mixing started. Remove the agitator from the solution and clean with tap water.

Repeat the mixing process using all conditions shown in the table.

## Measure the Viscosity

Measure the viscosity of each sample at 10 minutes, 60 minutes, 24 hours and 7 days after mixing, following the procedure below. A single viscosity measurement is sufficient at 10 minutes. However, take 3 measurements and determine the average, at 60 minutes, 24 hours, and 7 days.

Attach spindle number 2 for viscosities 1 to 500 centipoise (cP) and spindle number 4 for viscosities above 500 cP to a Brookfield Model LVF viscometer while holding the shaft with the other hand to prevent movement.

**Caution - This is a left-hand thread.**

Ensure that the speed setting is on 60 rpm. 60 will be in the uppermost position. Lower the viscometer head and spindle into the test solution, using the threaded knob, until the surface of the solution is even with the indicator ring on the spindle.

While firmly holding the brake down, start the viscometer, release the brake and let the viscometer run for 60 seconds. Depress the brake firmly and stop the viscometer.

Keeping the brake depressed, turn the viscometer on and off until the red indicator needle over the scale can be seen.

Record the location of the needle on the scale and then release the brake. Multiply the scale reading by the appropriate multiplier (multiply by 5 for spindle 2, multiple by 100 for spindle 4) to obtain the viscosity. Record all viscosities and the average on the data sheet. See table 3.1. Transfer the average values to table 3.2.

## Selection of Optimum Mixing

The optimum mixing procedure is selected by choosing the mixing condition that gives a combination of fast viscosity development (measured at 60 minutes and 24 hours) and viscosity stability (measured at 7 days).

This mixing procedure will be used throughout the remainder of the laboratory evaluation.

Table 3.1—Data Sheet

| Mixer Speed | Mixing Time | 10-minute Viscosity | Average 10-minute Viscosity | 60-minute Viscosity | Average 60-minute Viscosity | 24-hour Viscosity | Average 24-hour Viscosity | 7-day Viscosity | Average 7-day Viscosity |
|---|---|---|---|---|---|---|---|---|---|
| 600 rpm | 1 minute | | | | | | | | |
| 600 rpm | 1 minute | | | | | | | | |
| 600 rpm | 1 minute | | | | | | | | |
| | | | | | | | | | |
| 600 rpm | 2 minutes | | | | | | | | |
| 600 rpm | 2 minutes | | | | | | | | |
| 600 rpm | 2 minutes | | | | | | | | |
| | | | | | | | | | |
| 600 rpm | 5 minutes | | | | | | | | |
| 600 rpm | 5 minutes | | | | | | | | |
| 600 rpm | 5 minutes | | | | | | | | |
| | | | | | | | | | |
| 1200 rpm | 1 minute | | | | | | | | |
| 1200 rpm | 1 minute | | | | | | | | |
| 1200 rpm | 1 minute | | | | | | | | |
| | | | | | | | | | |
| 1200 rpm | 2 minutes | | | | | | | | |
| 1200 rpm | 2 minutes | | | | | | | | |
| 1200 rpm | 2 minutes | | | | | | | | |
| | | | | | | | | | |
| 1200 rpm | 5 minutes | | | | | | | | |
| 1200 rpm | 5 minutes | | | | | | | | |
| 1200 rpm | 5 minutes | | | | | | | | |
| | | | | | | | | | |
| 1800 rpm | 1 minute | | | | | | | | |
| 1800 rpm | 1 minute | | | | | | | | |
| 1800 rpm | 1 minute | | | | | | | | |
| | | | | | | | | | |
| 1800 rpm | 2 minutes | | | | | | | | |
| 1800 rpm | 2 minutes | | | | | | | | |
| 1800 rpm | 2 minutes | | | | | | | | |
| | | | | | | | | | |
| 1800 rpm | 5 minutes | | | | | | | | |
| 1800 rpm | 5 minutes | | | | | | | | |
| 1800 rpm | 5 minutes | | | | | | | | |

Table 3.2—Mixing Text Summary

| Mixer Speed | Mixing Time | 10-minute Viscosity | 60-minute Viscosity | 24-hour Viscosity | 7-day Viscosity |
|---|---|---|---|---|---|
| 600 rpm | 1 minute | | | | |
| 600 rpm | 2 minutes | | | | |
| 600 rpm | 5 minutes | | | | |
| | | | | | |
| 1200 rpm | 1 minute | | | | |
| 1200 rpm | 2 minutes | | | | |
| 1200 rpm | 5 minutes | | | | |
| | | | | | |
| 1800 rpm | 1 minute | | | | |
| 1800 rpm | 2 minutes | | | | |
| 1800 rpm | 5 minutes | | | | |

## General Description

Fire suppression chemicals are used in a variety of situations that seldom start or end according to human plan or prediction. It is typical for a fire season to very quickly become serious and just as quickly end with a change in the weather, bringing rain or snow. All too often the sudden end of the fire season also means that airtanker bases are at full inventory of retardant on hand, both concentrate and mixed for use. In order to avoid waste and make the best use of the retardant, it must be effective over a long period of time despite storage in adverse conditions. Product stability tests ensure a minimum level of stability and effectiveness following storage.

## Chapter 1. Outdoor Storage

All components and mixed retardant prepared from fresh or stored components will be stored outdoors as described below. The results of the specified laboratory tests performed on the stored components, mixed retardant prepared from the stored components, and on stored mixed retardant will be compared to the results of tests performed on fresh components and freshly mixed retardant prepared from the fresh components.

The test duration and specific conditions depend on the type of product being tested, although the basic design is similar in all cases.

## Dry Components

Dry components will be stored in the plastic buckets that were used to ship the product to the Forest Service. Unopened containers will be stored outdoors at Missoula, Montana, and at San Dimas, California, for 1 year. Storage racks are located so that the product is exposed to natural light and temperature fluctuations. The racks may be covered to protect the containers from rain and snow. Following the test period the plastic buckets will be shipped to the Wildland Fire Chemicals Systems Program (WFCS) in Missoula.

The components will be mixed according to manufacturer directions and established laboratory procedures. The salt content, viscosity, density, and pH values will be measured and compared to the corresponding values for retardant prepared from the fresh component.

## Wet Components

Wet components will be stored in 5-gallon polyethylene carboys (Nalgene 2210-0050). Three buckets of the wet component will be mixed to ensure homogeneity and poured into 2 carboys to a depth of 16 inches. A mild steel coupon, 2 inch by 12 inch by 0.13 inch (5 cm by 30 cm by 0.3 cm), previously cleaned with a solution of 50 grams of $SnCl_2$ and 20 grams of $SbCl_3$ in one liter of concentrated HCl will be suspended in the retardant, by a length of 90 to 100 pound-test braided dacron fishing line, in such a way that the bottom edge of the coupon does not touch the bottom of the carboy. A rubber stopper is used to close the top of the carboy. The carboy lid is screwed in place over the stopper.

Carboys will be stored outdoors at Missoula, Montana, and at San Dimas, California for 1 year. Storage racks are located so that the product is exposed to natural light and temperature fluctuations. The racks may be covered to protect the containers from rain and snow. Following the test period, the carboys will be shipped to the Wildland Fire Chemicals Systems Program in Missoula. Each carboy will be mixed at low shear, 1800 rpm with a 3-bladed agitator, for 1 minute.

The components will be poured through a 0.25-inch (0.64 cm) sieve. Samples of these components will be used to prepare mixed retardant according to manufacturer directions and established laboratory procedures. The salt content, viscosity, density, and pH values will be measured and compared to the corresponding values for retardant prepared from the fresh component. Uniform corrosion tests will be performed on the mixed retardant prepared from the stored component.

If the mixed retardant prepared from the wet components is a gum-thickened retardant, the mixed retardant prepared from the stored components must then be tested for outdoor stability for 30 days as described below.

## Storable, Mixed Retardant

Storable, mixed retardant will be stored in 5-gallon polyethylene carboys (Nalgene 2210-0050). The freshly prepared mixed retardant will be poured into two carboys to a depth of 16 inches (41 cm). A mild steel coupon 2 inch by 12 inch by 0.13 inch (5 cm by 30 cm by 0.3 cm) previously cleaned with a solution of 50 grams of $SnCl_2$ and 20 grams of $SbCl_3$ in one liter of concentrated HCl will be suspended in the retardant, by a length of 90 to 100 pound test braided dacron fishing line, in such a way that the bottom edge of the coupon does not touch the bottom of the carboy. A rubber stopper is used to close the top of the carboy. The carboy lid is screwed in place over the stopper.

Carboys will be stored outdoors at Missoula, Montana, and at San Dimas, California for 1 year. Storage racks are located so that the product is exposed to natural light and temperature fluctuations. The racks may be covered to protect the containers from rain and snow. Following the test period, the carboys will be shipped to the Wildland Fire Chemicals Systems Program (WFCS) in Missoula. Each carboy will be mixed at low shear, 1800 rpm with a 3-bladed agitator, for 1 minute.

The mixed retardant will be poured through a 0.25-inch (0.64 cm) sieve and tested to determine the standard physical properties. The salt content, viscosity, density, and pH will be measured and compared to the corresponding values for retardant prepared from the fresh component. Uniform corrosion tests will be performed on the stored, mixed retardant.

## Not Storable, Mixed Retardant

Not storable, mixed retardant will be stored in 5-gallon polyethylene carboys (Nalgene 2210-0050). The freshly prepared mixed retardant will be poured into two carboys to a depth of 16 inches (40 cm). An aluminum coupon 2 inch by 12 inch by 0.13 inch (5 cm by 30 cm by 0.3 cm) previously cleaned with a solution of concentrated nitric acid will be suspended in the retardant, by a length of 90 to 100 pound test braided dacron fishing line, in such a way that the bottom edge of the coupon does not touch the bottom of the carboy. A rubber stopper is used to close the top of the carboy. The carboy lid is screwed in place over the stopper.

Carboys will be stored outdoors at Missoula, Montana, and at San Dimas, California, for 30 days. Storage racks are located so that the product is exposed to natural light and temperature fluctuations. The racks may be covered to protect the containers from rain and snow.

Following the test period each carboy will be taken into the laboratory without disturbing the stored retardant it contains. A 250-milliliter sample will be taken from near the top, within 1 inch (2.54 cm), of the stored retardant. A second 250-milliliter sample will be taken from near the bottom, within 1 inch (2.54 cm), of the stored retardant. The remainder of the retardant in the carboy will then be mixed at low shear, 1800 rpm with a 3-bladed agitator, for 1 minute and a 250-milliliter sample of the homogeneous retardant taken. The carboys containing the remainder of the mixed retardant and the 3 samples from the retardant will be shipped to the Wildland Fire Chemicals Systems Program in Missoula. The contents of the carboy will be mixed at low shear, 1800 rpm with a 3-bladed agitator, for 1 minute and then poured through a 0.25-inch (0.63 cm) sieve. The 3 samples taken from each carboy will be tested to determine the standard physical properties. The salt content, viscosity, density, and pH of the

homogeneous, mixed samples will be measured and compared to the corresponding values for retardant prepared from the fresh component. The top and bottom samples must have a salt content within the required variation from the freshly mixed retardant.

If the retardant is gum thickened, the viscosity must also be within the required variation from the freshly mixed retardant. Any separated layers in the carboy following storage must reconstitute into the mixed retardant with no agitation beyond the specified low-shear mixing.

## Chapter 2. Laboratory Separation

All mixed retardant will be tested for laboratory separation. The duration of the test and the alloy the test coupon is made from will vary with the type of product.

### Storable, Mixed Retardant

Storable, mixed retardant will be stored on a laboratory shelf in a 1-quart, wide mouth glass jar with straight sides. The test sample, 800 milliliters of mixed retardant, will have an approximately 1 inch by 1 inch by 0.13 inch (2.5 cm by 2.5 cm by 0.3 cm) mild steel coupon previously cleaned with a solution of 50 grams of $SnCl_2$ and 20 grams of $SbCl_3$ in one liter of concentrated HCl suspended on a length of braided dacron fishing line until the coupon is totally immersed in the retardant. The jar will be closed with a Bakelite screw cap, firmly tightened by hand to control evaporation.

The retardant will be stored, undisturbed, for 1 year at room temperature, approximately 70 °F (21 °C) Once a month the sample will be examined and any changes in color, opacity, or other visual characteristics will be noted. At the same time the height of any visible layers in the retardant will be measured, to the nearest 0.1 inch (0.25 cm), including the total height of the retardant in the jar. The percent of separation will be calculated using the height of each layer and the total height.

### Not Storable, Mixed Retardant

Not storable, mixed retardant will be stored on a laboratory shelf in a 1-quart, wide mouth glass jar with straight sides. The test sample, 800 milliliters of mixed retardant, will have an approximately 1 inch by 1 inch by 0.13 inch (2.5 cm by 2.5 cm by 0.3 cm) aluminum coupon previously cleaned with a solution of concentrated nitric acid suspended on a length of braided dacron fishing line until the coupon is totally immersed in the retardant. The jar will be closed with a Bakelite screw cap, firmly tightened by hand to control evaporation.

The retardant will be stored, undisturbed, for 30 days at room temperature, approximately 70 °F (21 °C). Once a week the sample will be examined and any changes in color, opacity, or other visual characteristics noted. At the same time, the height of any visible layers in the retardant will be measured, to the nearest 0.1 inch (0.25 cm), including the total height of the retardant in the jar. The percent of separation will be calculated using the height of each layer and the total height.

### Immediate Use, Mixed Retardant

Immediate use, mixed retardant will be stored on a laboratory shelf in a 1-quart, wide-mouth glass jar with straight sides. The test sample (800 milliliters of mixed retardant) will have an approximately 1 inch by 1 inch by 0.13 inch (2.5 cm by 2.5 cm by 0.3 cm) aluminum coupon previously cleaned with a solution of concentrated nitric acid suspended on a length of braided dacron fishing line until the coupon is totally immersed in the retardant. The jar will be closed with a Bakelite screw cap, firmly tightened by hand to control evaporation.

The retardant will be stored, undisturbed, for 24 hours at room temperature, approximately 70 °F (21 °C). At 1 hour, 4 hours, 8 hours, and 24 hours following mixing, the sample will be examined and any changes in color, opacity, or other visual characteristics noted. At the same time the height of any visible layers in the retardant will be measured,

to the nearest 0.1 inch (0.25 cm), including the total height of the retardant in the jar. The percent of separation will be calculated using the height of each layer and the total height.

## Chapter 3. Viscosity Loss

All mixed retardant will be tested for viscosity loss. The duration of the test and the alloy the test coupon is made from will vary with the type of product.

### Storable, Mixed Retardant

Storable, mixed retardant will be stored on a laboratory shelf in a 1-quart, wide mouth glass jar with straight sides. The test sample, 800 milliliters of mixed retardant, will have an approximately 1 inch by 1 inch by 0.13 inch (2.5 cm by 2.5 cm by 0.3 cm) mild steel coupon previously cleaned with a solution of 50 grams of $SnCl_2$ and 20 grams of $SbCl_3$ in one liter of concentrated HCl suspended on a length of braided-dacron fishing line until the coupon is totally immersed in the retardant. The jar will be closed with a Bakelite screw cap, firmly tightened by hand to control evaporation.

The retardant will be stored, undisturbed except for the scheduled testing, for 1 year at room temperature, approximately 70 °F (21 °C). Once a month the sample will be stirred and the viscosity measured. Compare the measured viscosity with the viscosity of the freshly mixed retardant.

### Not Storable, Mixed Retardant

Not storable, mixed retardant will be stored on a laboratory shelf in a 1-quart, wide mouth glass jar with straight sides. The test sample, 800 milliliters of mixed retardant, will have an approximately 1 inch by 1 inch by 0.13 inch (2.5 cm by 2.5 cm by 0.3 cm) aluminum coupon previously cleaned with a solution of concentrated nitric acid suspended on a length of braided dacron fishing line until the coupon is totally immersed in the retardant. The jar will be closed with a Bakelite screw cap, firmly tightened by hand to control evaporation.

The retardant will be stored, undisturbed except for the scheduled testing, for 30 days at room temperature, approximately 70 °F (21 °C). Once a week the sample will be stirred and the viscosity measured. Compare the measured viscosity with the viscosity of the freshly mixed retardant.

### Immediate Use, Mixed Retardant

Immediate use, mixed retardant will be stored on a laboratory shelf in a 1-quart, wide mouth glass jar with straight sides. The test sample, 800 milliliters of mixed retardant, will have an approximately 1 inch by 1 inch by 0.13 inch (2.5 cm by 2.5 cm by 0.3 cm) aluminum coupon previously cleaned with a solution of concentrated nitric acid suspended on a length of braided dacron fishing line until the coupon is totally immersed in the retardant. The jar will be closed with a Bakelite screw cap, firmly tightened by hand to control evaporation.

The retardant will be stored, undisturbed except for the scheduled testing, for 24 hours at room temperature, approximately 70 °F (21 °C). At 1 hour, 4 hours, 8 hours, and 24 hours following mixing, the sample will be stirred and the viscosity measured. Compare the measured viscosity with the viscosity of the freshly mixed retardant.

## Chapter 1. Uniform Corrosion

### General Description

Test specimens (coupons) of each alloy to be tested, are engraved with a unique identification code, measured to determine dimensions, cleaned to remove grease and oxidation films, rinsed in distilled water and dried. Each coupon is weighed and immersed in a test solution in glass jars with screw caps and placed in an incubator at the test temperature, undisturbed for 90 days. The coupons are rinsed to remove residual test solution and loose corrosion products, cleaned with the appropriate solution and dried. Each coupon is weighed and the change in weight during immersion is used to determine the corrosion rate.

### Preparation of Fire Chemical Products

Except for tests specifically requiring aged or stored chemicals, all test solutions should be freshly prepared, usually 24 hours before use. Fire chemical products are prepared by stirring the wet components (when testing the component) or by adding the wet or dry components to water (when testing mixed retardant) according to manufacturer's directions.

The viscosity, refractometer values, density, and pH are measured and compared to the manufacturer's submission information.

If retardant quality control values are acceptable, the retardant is measured into one-quart capacity glass jars. Each jar contains 800 milliliters of test product for a total immersion test or 400 milliliters of test product for a partial immersion test. See figure 5.1.

*Figure 5.1—The retardant is measured.*

### Coupon Description and Preparation

Coupons of four alloys (2024-T3 aluminum, 4130 steel, yellow brass, and Az31B magnesium) are used for evaluation against the Forest Service wildland fire chemical specifications. See figure 5.2. Coupons are purchased from a commercial source (Corrosion Test Supply, French Settlement, Louisiana). Each coupon is nominally 1 inch by 4 inches by 1/8 inch (2.5 cm by 10.2 cm by 0.3 cm) with a hole (13/64 inch [0.5 cm] in diameter), centered, 1/2 inch (1.3 cm) from one end of the coupon. All coupons are purchased unmarked and are stored in the original wrappings.

In the laboratory, each coupon is marked, above the hole, with a unique identification code using a vibrating engraver.

Each coupon is then measured, to the nearest 0.001 cm, in each of the 3 dimensions. The width and thickness are measured about 1 inch (2.5 cm) from the end that does not have the hole.

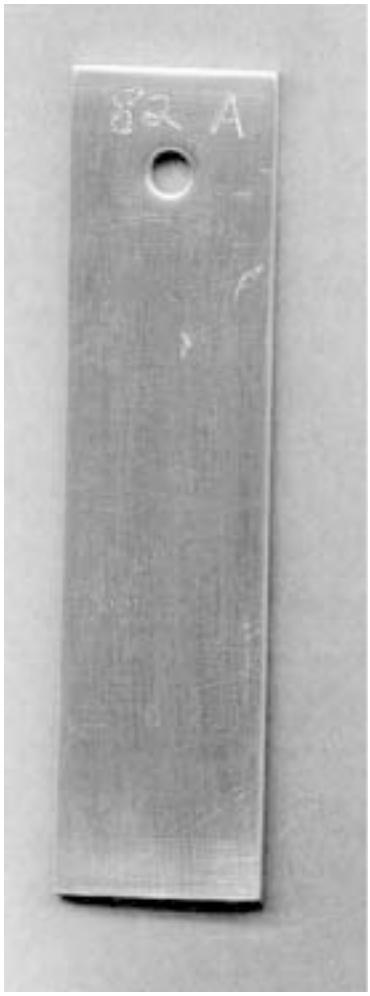


*Figure 5.2—Coupon.*

## Coupon Degreasing and Initial Cleaning

Scotch-Brite scouring pads are cut into strips about 1 inch by 3 inches (2.5 cm by 7.6 cm) and conditioned to remove excess abrasive by scrubbing a clean coupon reserved for that purpose. The conditioning coupon is the same alloy as the test coupons to be cleaned.

Coupons are degreased by scrubbing with a Scotch-Brite scouring pad and Formula 409 cleaner. They are then rinsed under cold tap water and cleaned in the appropriate solution shown in table 5.1.

Table 5.1—Cleaning Procedures Table

| ALLOY | CHEMICAL[1] | MINUTES | TEMP | REMARKS |
|---|---|---|---|---|
| Aluminum | 70% $HNO_3$ (concentrated) | 2-3 | Room | Follow with light scrub using non-metallic brush or scrubbing pad[2]. |
| Brass | 15-20% HCl (half strength) | 2-3 | Room | Follow with light scrub using non-metallic brush or scrubbing pad. |
| Steel | 50g $SnCl_2$ + 20g $SbC_3$ in 1000 mL of concentrated HCl | 3-5 | Cold ice bath | Follow with light scrub using non-metallic brush or scrubbing pad. |
| Magnesium | 15g $CrO_3$ + 1g $AgCrO_4$ in 84 mL of distilled $H_2O$ | 15 | Boiling | Follow with light scrub using non-metallic brush or scrubbing pad. |

[1] Cleaning solutions should be discarded as they become used or discolored. If in doubt, replace it. When cleaning exposed coupons, special care is needed to prevent erroneous results and in the case of the magnesium solution, fresh chemical should be used for each coupon.

[2] If corrosion film resists cleaning by this procedure alternate with a solution of 2g $CrO_3$ + 5g $_3PO_4$ n 93 mL of distilled water heated to 175-185 °F (79-85 °C) for 10 minutes.

Each batch of six coupons (aluminum, mild steel, or brass) is immersed in the specified cleaning solution shown in table 5.1 in a 600-milliliter plastic beaker. The coupons are arranged, leaning against the inside of the beaker, so that the coupons do not touch each other.

Each magnesium coupon is immersed in cleaning solution in an 8-inch (20 cm) test tube. Several test tubes are placed in a 1-liter beaker, with about 4 inches (10 cm) of water and glass beads or boiling chips, and the water heated to boiling on a hot plate.

Following required immersion in the cleaning solution, the coupons are removed from the solution and scrubbed with a fresh, conditioned scouring pad. The six coupons in a batch are scrubbed with same scouring pad. The pad is then used for degreasing new coupons of the same alloy or discarded.

**Each scouring pad is used for only one alloy.**

Clean coupons are rinsed in distilled water, surface water removed by wiping with a lint free towel, and the coupons suspended in a drying oven warmed to 125 °F (52 °C). Do not dry in the same oven (incubator) used to maintain temperature for uniform corrosion testing. The released chemical vapors may adversely affect the final corrosion rates.

**Clean coupons must be handled with tongs or gloved hands only.**

Dry coupons are removed from the oven, allowed to cool for about 15 minutes, and then weighed to the nearest tenth of a milligram. Coupons should be immersed in test solution soon after cleaning.

## Coupon Immersion

A strip of fiberglass-reinforced tape is attached across the opening of the jar and half way down each side.

A length of braided dacron fishing line, about 16 inches long, is attached to each coupon by doubling the fishing line and running the loop through the hole in the coupon and then running the cut ends through the loop. A 15- to 20-pound-test fishing line is firm enough for easy handling but not so firm as to make it difficult of tie.

The dacron line with the attached coupon is twisted over the center of the tape so that the coupon is suspended near the center of the jar. The loose ends of the fishing line are pulled over the side of the jar and held in place with tape. See figure 5.3.

One coupon is immersed in the test solution in each jar. Coupons for total immersion tests are positioned so that they are completely covered with solution but not touching the bottom of the jar. Coupons for partial immersion tests are positioned so that the lower 2 inches of the coupon are immersed in the retardant. A small grease pencil tic mark on the edge of the coupon indicates the proper immersion level. See figure 5.4.

The pulp-lined, Bakelite lid is screwed firmly (hand tight) into place on the jar. Each jar is labeled with the name and lot number of the test product, the identification of the coupon immersed in the product, and the date of the immersion.

*Figure 5.3—Coupon in retardant solution.*

*Figure 5.4—Coupons in solution.*

The jars are then placed into preheated incubators at the proper temperature, 70 °F or 120 °F (21 °C or 49 °C), and left undisturbed during the 90-day exposure period. See figure 5.5.

*Figure 5.5—Jars in the incubator.*

## End of the Test Exposure

At the end of the test period, the jars are removed from the incubators, the jars and contents inspected, and the lids removed. Notes are made of any cracked jars, evaporated test solution, or coupons that are destroyed or have pieces missing.

The test solution is poured from the jar and discarded.

## Final Coupon Cleaning

Each coupon is rinsed with a forceful stream of cold tap water to remove residual test solution and loose corrosion products. The coupons are then allowed to air dry while still suspended from the dacron fishing line. After the coupons are dry, usually overnight, the fishing line is removed. See figure 5.6.

*Figure 5.6—Test solution jars with coupons.*

After the coupons are dried, any built-up corrosion products are removed from the coupons by scraping with the flat edge of a stainless steel spatula. In some cases the corrosion inhibitor film must be gently chipped or peeled from the coupon, once more using the flat edge of a spatula. After the corrosion products and inhibitors are removed the coupons are cleaned in chemical solutions.

Each batch of coupons, no more than six, is cleaned along with a control coupon that is cleaned in the same manner as the test coupons. The aluminum, mild steel, and brass coupons are immersed in the cleaning solution, leaning against the sides of the container, a 600-milliliter plastic beaker, in such a way that the coupons do not touch each other.

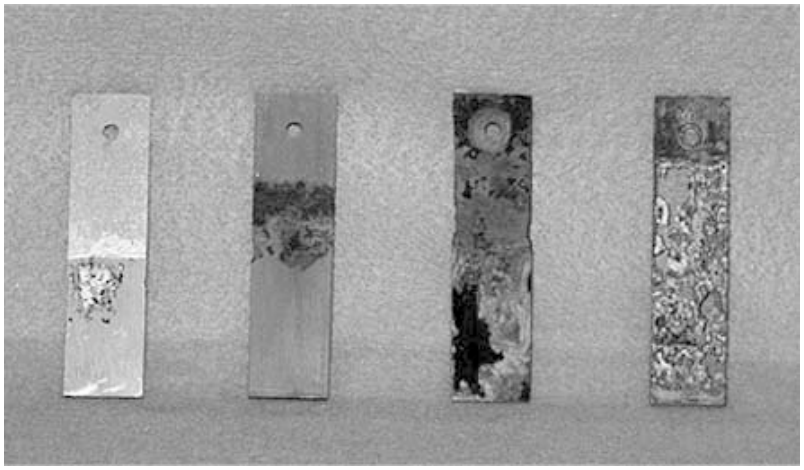


*Figure 5.7—Final coupons.*

Following soaking as specified table 5.1, each coupon is removed from the solution and scrubbed with a fresh, conditioned scouring pad. Clean coupons are rinsed in distilled water, wiped with a lint free towel, and suspended in the drying oven as previously described. See figure 5.7.

**Care must be taken to scrub and handle each coupon in the same way.** Magnesium coupons are immersed in individual, 8-inch (200 mm) test tubes containing the cleaning solution. Several test tubes are then placed in a 1-liter beaker containing water and glass beads or boiling chips. The contents of the beaker are heated on a hot plate. Coupons are scrubbed, rinsed, and dried as described previously. Since corrosion to magnesium coupons often makes the identification marks difficult to read, care must be taken to maintain the identity of each coupon during the cleaning and drying processes.

If persistent residues remain, the coupons may be cleaned a second time, again using a control coupon to determine the weight lost during cleaning. After drying the coupons are cooled and then weighed to the nearest 0.001 milligram.

## Control Coupons

Control coupons reserved for this purpose are not exposed to any of the test solutions. The control coupons are cleaned and weighed

before use; cleaned with a set of exposed coupons; and then weighed again in order to determine the weight loss of the coupon that should be attributed to the cleaning method rather than the exposure to test solution. Each control coupon must be weighed before and after cleaning.

## Calculations of Corrosion Rate

The corrosion rate is calculated for each coupon using the initial and final weights, control weight loss, coupon surface area, and density of the alloy and exposure time in the formula.

$$Cr = \frac{534\ [(Wt_I - Wt_F) - (Wt_{CI} - Wt_{CF})]}{A\ t\ d}$$

Where:

$Wt_I$ = coupon initial weight, mg
$Wt_F$ = coupon final weight, mg
$Wt_{CI}$ = control coupon initial weight, mg
$Wt_{CF}$ = control coupon final weight, mg
A = surface area of the coupon, $in^2$
t = exposure time, hr
d = density of the alloy, $g/cm^3$
2.77 $g/cm^3$ for 2024-T3 aluminum
7.86 $g/cm^3$ for 4130 steel
8.53 $g/cm^3$ for yellow brass
1.77 $g/cm^3$ for Az31B magnesium

## Replicates

Three replicates will be performed for most tests on fresh material; however, magnesium corrosion tests performed for performance information will not be replicated.

Two replicates will be performed on most test materials following one-year storage tests. Six replicates will be performed on the partial immersion tests with mild steel and high temperature aluminum.

Manufacturers may request that additional replicates be included, at their expense, for any test condition.

## Rejection of Individual Tests

After all tests are completed the results are calculated. Spurious results may be rejected if there is supporting information (based on the inspection of individual tests) or statistical basis for the action, i.e., the average without a value is more than three standard deviations from the average with the value included.

## Averaging of Results

The results of all tests (excluding those rejected as described above) with the same alloy, temperature, and immersion conditions will be averaged to determine the final corrosion rate.

At the request of the supplier, additional replicates may be performed if quantities of test material allow. The results of **all of the tests** (except those rejected as described above) for the same alloy, temperature, and immersion conditions will be included in the final average.

## Reporting of Results

The results of all tests, including those rejected, and the average will be reported in writing to the manufacturer. The reasons for including or rejecting a suspect value will be included in the report.

## Chapter 2. Intergranular Corrosion Test

Mixed retardant shall be tested for intergranular corrosion. At least one coupon for each exposure and temperature from the uniform corrosion tests on the specified alloys shall be sliced as shown in figure 5.8. The coupon will be mounted, polished to 0.3-micron alumina finish, and etched with Keller's reagent using standard metallurgical techniques.

## Coupon Examination

The coupon will then be examined microscopically with a magnification of 500. Any attack of a metal at the grain boundary in the exposed uniform corrosion alloy coupon specimens shall not be acceptable.

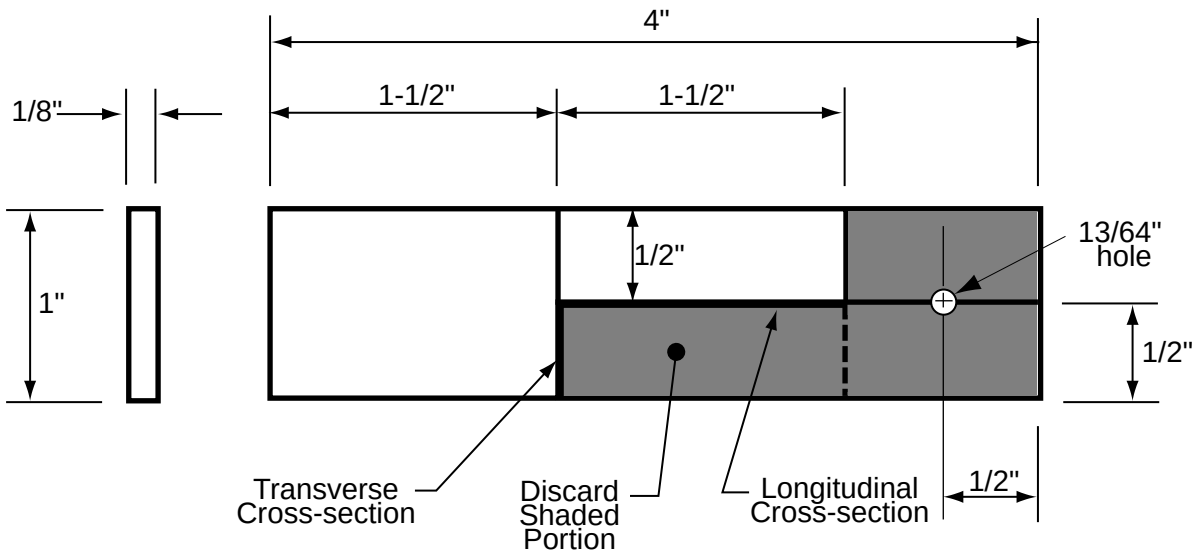



*Figure 5.8—Coupon drawing from specification.*

## General Description

Test apparatus for pumpability testing consists of a storage tank, a test pump and a scale-mounted weigh tank. Fire retardant is transferred from the storage tank to the weigh tank using a specific pump and plumbing system. The pump and associated pump performance shall be in accordance with the following specifications:

Crane Technical Bulletin 4011, dimension page 4011-1, “Dimensions of Pumps with Type A or B Steel Base, Coupling and Motor”; and figure 13, Crane Technical Bulletin 4011, Section 14, curve page 3, “End Suction Centrifugal Pumps, Semi-Open Impeller.” See figures 6.1 and 6.2.

The weight/time method is used to calculate the flow rate of the product.

## Objective

The objective of the pumpability test is to ensure that the fire retardant can be recirculated and transferred at a retardant base using the techniques, pumps and plumbing systems currently being used by Forest Service airtanker bases. This test is intended to screen out those products that, due to their unique physical properties, would require bases to change or modify their equipment in order to utilize the product. A diagram of the retardant pumpability test apparatus is shown in figure 6.3.

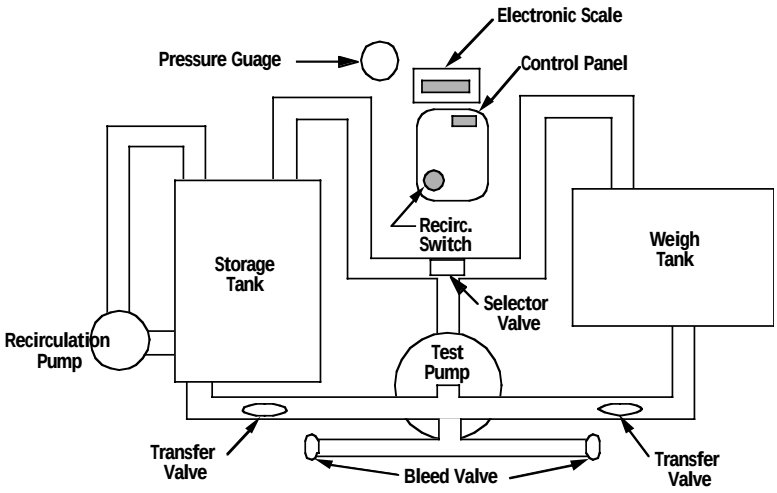



*Figure 6.3—Diagram of retardant pumpability test apparatus.*

Approximately 150 gallons (568 liters) of retardant is mixed in 30-gallon (114 liter) batches and pumped into the storage tank. The test pump is then started and the retardant flows from the storage tank to the weigh tank. The scale on this tank is linked to a computer that sends the weight data several times per second. The computer collects the weight data for precisely one minute and calculates the flow rate of the retardant in gallons per minute. This test is repeated five times and the average flow is compared to the minimum standard set at 18.0 gpm.

A calibration check using water is performed on the system both before and after the retardant tests to ensure that the system is functioning properly.

## Pumpability Test Stand Description

A photograph of the test stand is shown in figure 6.4.

*Figure 6.4—Pumpability test stand.*

A storage tank is located on the left side of the test stand and is used to maintain the mixture while serving as a supply for the test. A separate recirculation pump is shown in figure 6.5 on the left side of the storage tank

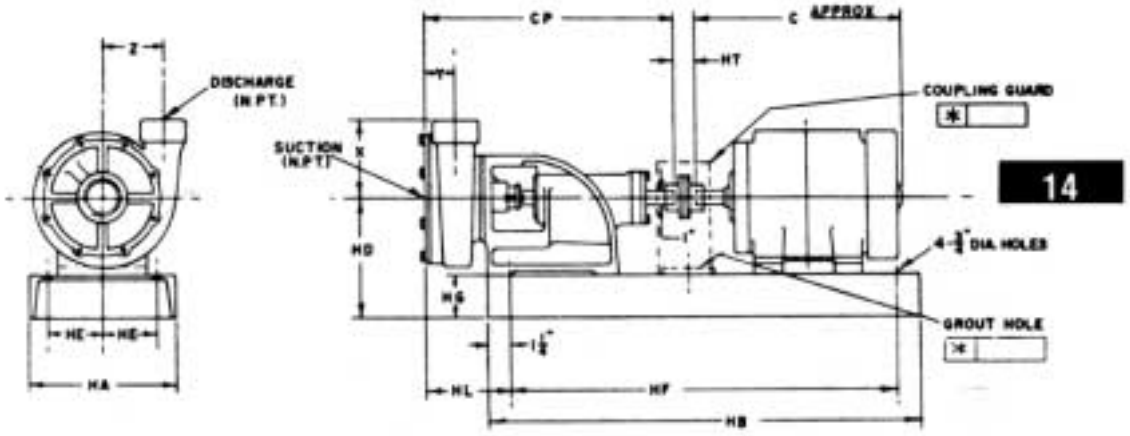
DEMING DIVISION
CRANE CO.
SALEM, OHIO, U.S.A.

SECTION 14
END SUCTION CENTRIFUGAL PUMPS
BULLETIN 4011

DIMENSION PAGE 4011-1
SUPERSEDES ALL PREVIOUS

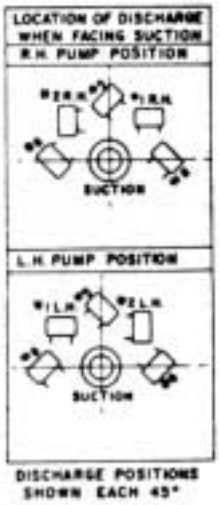
DIMENSIONS OF PUMPS WITH TYPE A OR B STEEL BASE, COUPLING AND MOTOR

FIG. 4011 – SIZES 1½S, 1½S, 1½M, 2S AND 2M




| PUMP DIMENSIONS IN INCHES | | | | | | | |
|---|---|---|---|---|---|---|---|
| SIZE | SUCT | DISCH | X | Y | Z | CP | HL |
| 1½S | 1½ | 1½ | 5½ | 2⅞ | 4½ | 19½ | 5½ |
| 1½S | 2 | 1½ | 5½ | 2⅞ | 4½ | 19⅞ | 5½ |
| 1½M | 2 | 1½ | 6½ | 2½ | 5½ | 20 | 5½ |
| 2S | 2½ | 2 | 6½ | 2½ | 4½ | 20⅛ | 5⅞ |
| 2M | 3 | 2 | 7 | 2½ | 5½ | 20⅛ | 6⅛ |

NOTE: * FURNISHED IF CHECKED




| BASE DIMENSIONS IN INCHES | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FRAME NO | 56 | 143T | 145T | 182T | 184T | 213T | 215T | 254T | 256T | 284TS | 284T | 286TS | 286T |
| BASE NO | 27501 | 27501 | 27501 | 27502 | 27502 | 27503 | 27503 | 27504 | 27504 | 27504 | 27504 | 27504 | 27505 |
| HA | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 15 | 15 | 15 | 15 | 15 | 15 |
| HB | 28 | 28 | 28 | 32 | 32 | 36 | 36 | 40 | 40 | 40 | 40 | 40 | 43 |
| C | 13 11/16 | 13⅞ | 13⅞ | 14⅜ | 15⅜ | 17⅜ | 19½ | 22⅞ | 24⅜ | 24⅛ | 25⅛ | 26 | 27⅛ |
| HD | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9⅜ | 9⅜ | 10⅜ | 10⅜ | 10⅜ | 10⅜ |
| HE | 4½ | 4½ | 4½ | 4½ | 4½ | 4½ | 4½ | 6 | 6 | 6 | 6 | 6 | 6 |
| HF | 25½ | 25½ | 25½ | 29½ | 29½ | 33½ | 33½ | 37½ | 37½ | 37½ | 37½ | 37½ | 40½ |
| HG | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3⅜ | 3⅜ | 3⅜ | 3⅜ | 3⅜ | 3⅜ |
| ½T | ½ | ½ | ½ | ½ | ½ | ½ | ½ | 1 | 1 | 1 | 1 | 1 | 1 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| CUSTOMER | | | | | | | | CO NO | |
| PROJECT NAME | | | | | CONTRACTOR ENGINEER | | | | |
| CUSTOMER IDENT NO | | | | | | | | | |
| PUMP DATA | FIG NO | SIZE | CURVE NO | G P M | HEAD | SP GR | TEMP | ROTATION | PACKING/SEAL |
| | | | | | | | | | |
| MOTOR DATA | WFGR | H P | R P M | PHASE-CYCLE-VOLTAGE | | FRAME | ENCLOSURE | INSULATION | FURNISHED BY / MOUNTED BY |
| | | | | | | | | | |
| SHOP ORDER NO | | | | CERTIFIED BY | | | | DATE | |

*Figure 6.1—Pump specification sheet.*

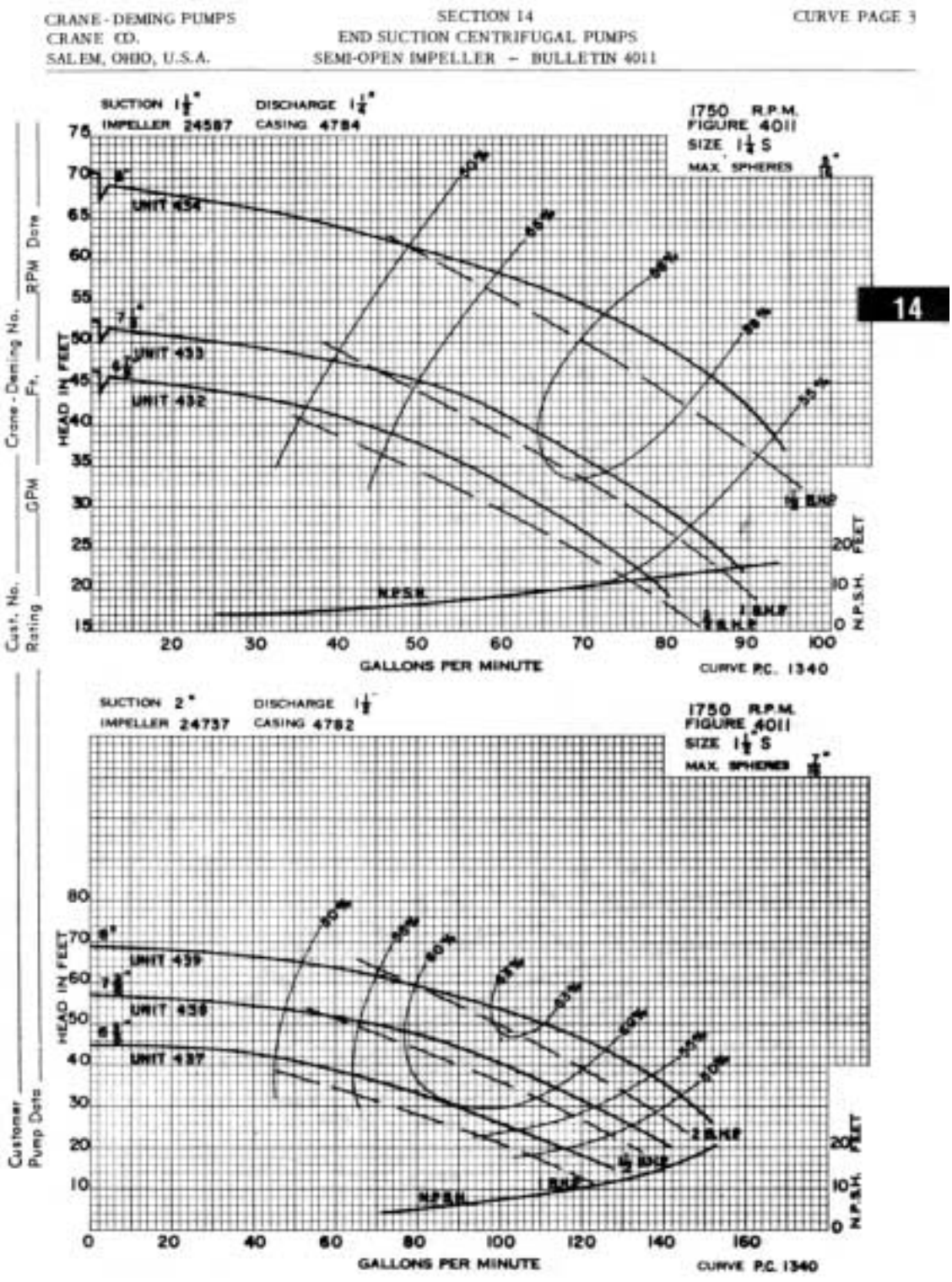



*Figure 6.2—Curve.*

pumps the retardant from one end of the tank to the other through a mixing nozzle. The pump is controlled by a switch labeled 'Recirc Pump' on the control panel, figure 6.6.

*Figure 6.5—Recirculation pump.*

*Figure 6.6—Control panel.*

A weigh tank is located on the right side of the test stand, and is used to measure the weight of retardant pumped during the test. The tank is mounted on an electronic scale, which sends data to a computer where the flow rate is calculated.

The test pump is located between the storage tank and the weigh tank. Supply to the inlet of the pump is selected by opening one of two transfer valves, shown in figure 6.7, located at the base of each tank. Output from the pump is controlled by a 3-way selector valve located between the tanks.


*Figure 6.7—Transfer valve.*

## Pumpability Test Procedures

The following are step-by-step procedures for operating the pumpability test stand. A few things should be noted before beginning the test:

For safety: **Read MSDS sheets on the product!**
Wear facemasks, gloves, and aprons when ever appropriate.

Check the calibration dates on the pressure gages. Do not conduct the tests if the gages are out of calibration.

**DO NOT LEAN ON WEIGH TANK DURING ANY PART OF THE TESTING!**

## Water Calibration Check

### *Test Stand Preparation*

a. Turn on the power to the electronic scale and start the pumpability program on the computer.

b. Close all drain valves and transfer valves.

c. Fill the storage tank to about 3/4 full with water, enough to run the pump at least one minute.

d. Close the transfer valve on the weigh tank and open the transfer valve on the storage tank.

e. Position the output selector valve to flow to the storage tank.

f. Turn on the test pump. The water will circulate back to the storage tank.

g. Open the bleed valve for the pressure gauge momentarily while the pump is running to bleed air from the line. See figure 6.8.

h. Press the “tare” or “zero” button on the electronic scale.

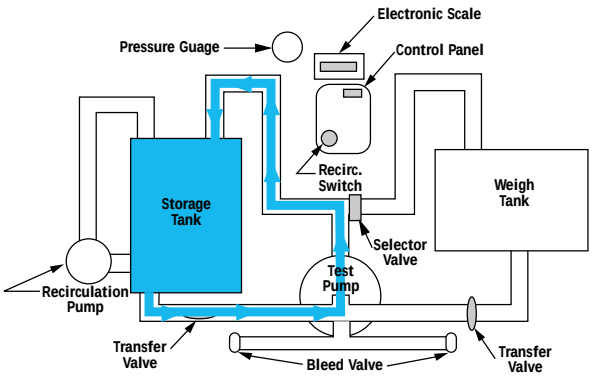



*Figure 6.8—Air is bled from the system while water is pumped back into the storage tank.*

## *Data Collection*

a. Measure and record the temperature of the water.

b. Position the output selector valve to the center (off) position to deadhead the test pump.

c. Record the zero-flow-pressure. See figure 6.9.

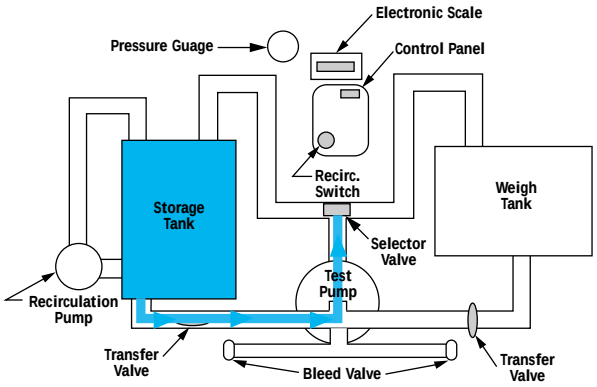



*Figure 6.9—Water flow from storage tank to closed selector valve to record pressure.*

d. Position the output selector valve to the weigh tank, (the water will flow from the storage tank to the weigh tank) and start collecting scale data with the computer program.

e. Record the pressure while the water is flowing. See figure 6.10.

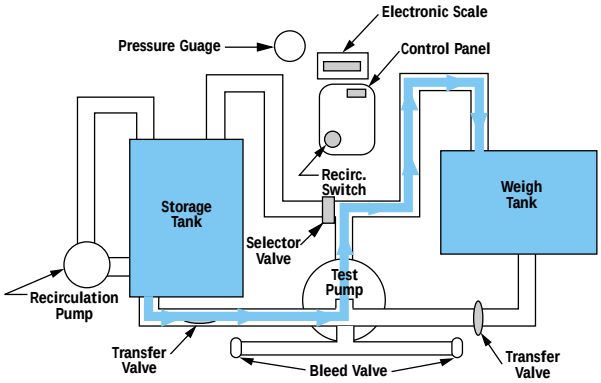



*Figure 6.10—Record the pressure while the water is flowing from the storage tank to the weigh tank.*

f. After the computer finishes collecting data (approximately one minute), turn off the test pump.

g. The flow rate calculated by the computer should be 18 gpm.

If the flow varies by more than 1.0 gpm, the calibration check must be rerun.

If the flow still varies by more than 1.0 gpm after 3 runs, there is a problem with the system, and it must be solved before testing is begun.

## Retardant Test

### *Retardant Mixing*

a. Approximately 150 gallons (568 liters) of liquid retardant is needed to run the test. Liquid Concentrates are tested as received. Follow the manufacturer’s instructions for mixing dry powder products.

b. Measure and record the temperature, viscosity, and salt content of the mixed fire retardant.

c. Do not conduct the qualification test if the viscosity and salt content are outside the tolerances provided by the manufacturer.

### *Test Stand Preparation*

a. Make sure the electronic scale is on and the pumpability test program is running on the computer.

b. Keep the retardant mixed by running the recirculation pump on the storage tank.

c. Record the preliminary information for the sample product by filling out the data form on the computer.

### *Data Collection*

a. Close the transfer valve on the weigh tank and open the transfer valve on the storage tank.

b. Position the output selector valve to the storage tank.

c. Turn on the test pump. The retardant will circulate back to the storage tank. See figure 6.11.

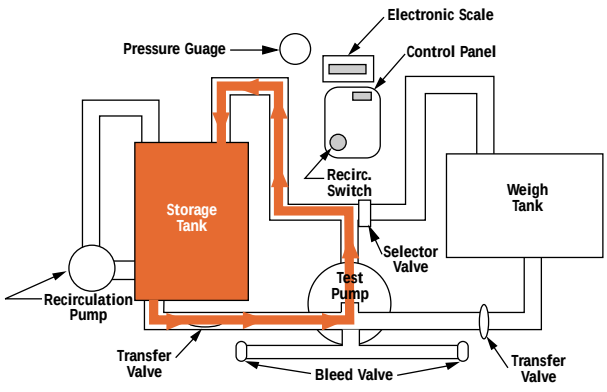



*Figure 6.11—Circulate the retardant back in the storage tank through the test pump.*

d. Position the output selector valve to the center (off) position to deadhead the pump.

e. Record the zero-flow-pressure. See figure 6.12.

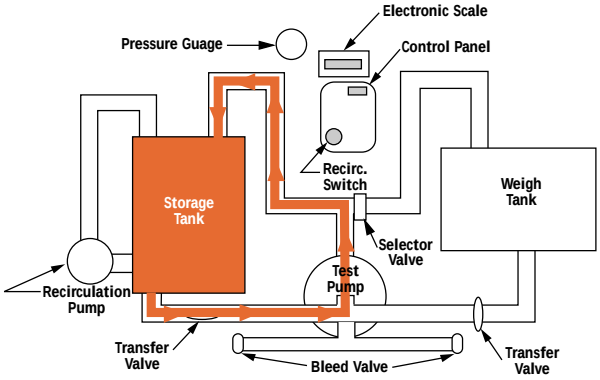



*Figure 6.12—Retardant flow from the weigh tank to the closed selector valve.*

f. Position the output selector valve to the weigh tank. The retardant will flow from the storage tank to the weigh tank. Start collecting scale data with the computer program.

g. Record the pressure while the retardant is flowing. See figure 6.13.

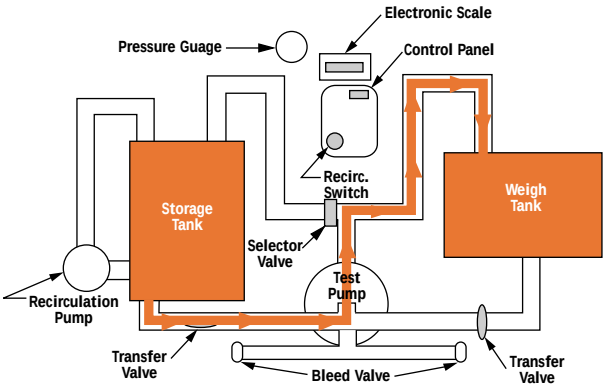



*Figure 6.13—Record the pressure while the retardant is flowing from the storage tank to the weigh tank.*

h. After the computer finishes collecting data, approximately one minute, turn off the test pump.

i. The flow rate is calculated by the computer.

j. Repeat the test until five runs have been completed.

**Repeat the water calibration check after the following clean-up procedure has been completed.**

### *Clean-Up*

a. The test pump can be used to pump most of the material from the test stand to barrels for disposal.

b. This can be accomplished with a hose connected to the auxiliary valve. See figure 6.14.

c. Position the selector valve to the off (center) position, open the transfer valve on the storage tank, and open the auxiliary valve.

d. The material will now flow through the hose when the test pump is turned on.

e. Remove as much material as possible with the pump, then dilute the remaining material with water and allow it to empty to the lab drain.

f. Flush all the test stand plumbing, the test pump and the recirculation pump with clean water.

*Figure 6.14—Valve for hose connection.*

## General Description

## Abrasion Test Method

## General Description

The objective of the abrasion test is to screen out products that might cause excessive wear to the pumps at airtanker bases due to their abrasiveness.

Two aluminum plates are set up parallel with a 0.020-inch (0.05 cm) gap and submerged in a bath of the fire retardant. The top plate is then rotated at 1800 rpm for 50 hours.

The plates are precisely measured before and after the test, to an accuracy of 0.001 inch (0.0025 cm). The maximum wear on the disk and wear plate are added together.

The combined wear on the wear plates shall not be in excess of 0.010 inches (0.025 cm) after testing.

## Abrasion Test Method

A disc and a wear plate made of 2024-T3 aluminum are used to determine abrasion characteristics of the mixed retardant. The disc is 4.00 $\pm$ 0.01 inches (10.16 cm) in diameter and has a thickness of at least 5/16 inch (0.3125 inch) (0.7938 cm) at the center. See figures 7.1 and 7.2. The thickness is uniform to a tolerance of $\pm$0.001 inch (0.0025 cm). To avoid a low-pressure area near the center, the disc has two 3/8-inch (0.95 cm) holes drilled through. The holes are located on a 1.25-inch (3.18 cm) diameter circle, concentric with the disc outer diameter. The wear plate is similar to the disc (including the 3/8-inch [0.95 cm] diameter holes) except that it is rectangular and has dimensions of 4.02 inch by 5.0 inches (10.21 cm by 12.7 cm).

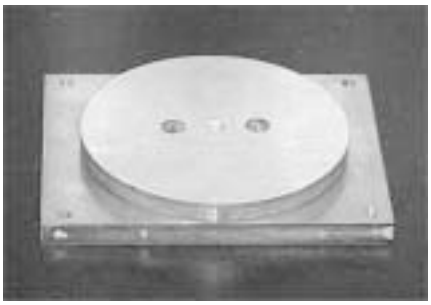


*Figure 7.1—Disc and wear plates.*

*Figure 7.2— Measuring thickness.*

a. Thickness is precisely measured in several places on the disc and plate, and recorded with reference to the location of the measurement prior to, and immediately after testing, to the nearest 0.001 inch (0.0025 cm). See figure 7.2.

b. A retardant tank and wear plate holding fixture is mounted on a milling machine which is used to rotate the disc and provides a means to precisely set the gap between the disc and wear plate. See figure 7.3.

*Figure 7.3—Abrasion test stand.*

c. The wear plate is positioned on the mountingfixture located in the center of the tank by allowing the two dowel pins attached to the mounting plate to engage two of the holes in the wear plate. Then the wear plate is fastened down through the remaining two holes in the wear plate with 10-32 allen cap screws, 1 inch long.

d. The disc is attached to a threaded shaft and the assembly is inserted into the collet of the milling machine with the disc positioned so that its lower surface is directly above and parallel to the wear plate. See figure 7.4.

*Figure 7.4—Disc and wear plates mounted onto test stand.*

e. The gap between the disc and wear plate is precisely set with the milling machine by lowering the disc until contact is made with the wear plate, then raising the disc 0.020 inch (0.05 cm) as measured with a dial indicator. The gap is also double-checked with feeler gauges.

f. The disc is then covered with mixed retardant to a depth of 2 inches (5 cm) approximately 3 gallons (11 liters). With the disc and wear plate immersed in the mixed retardant, the disc is rotated at 1,800 rpm for 50 hours.

g. At the completion of the 50-hour test, the thickness is measured to the nearest 0.001 inch (0.0025 cm), in several places on the disc and wear plate, and recorded with reference to the location of the measurement.

## General Description

## Field Visibility Test

## General Description

Mixed retardant shall be tested to determine visibility on a variety of fuel types and conditions. These conditions include slope, aspect, daylight conditions, and weather. An experienced aerial observer team shall evaluate the visibility of each product, applied by air or ground application depending on manufacturer's designated use.

## Field Visibility Test

Field visibility for uncolored retardant is determined during the operational field evaluation, where a mixed retardant shall not be noticeably visible as determined by an experienced observer team. ***Uncolored retardant contain no ingredients that impart color when applied to natural fuels.*** This team is designated by the Forest Service and may consist of an Air Tactical Group Supervisor (ATGS), lead plane pilot, airtanker pilot, and/or others.

Field visibility of colored retardant is determined during the operational field evaluation; mixed retardant visibility shall be determined to be acceptable by an experienced observer team. ***Colored retardant contains iron oxide to impart visibility from the air at time of use. The application ceases to have visual impact on a landscape level following two years of historically normal exposure to weathering elements.*** This team is designated by the Forest Service and may consist of an ATGS, lead plane pilot, airtanker pilot, and/or others.

## General Description

## Drop Pattern Test

## General Description

Retardant will be tested for airdrop characteristics when deemed necessary by the Forest Service. Retardant to be tested will be air dropped BY interagency Airtanker Board approved aircraft. The drop tests will be performed over an array of plastic bowls that are approximately one-quart containers. See Figures 1 and 2. The quantity of material in each bowl will be measured and the data used to determine drop patterns.

## Drop Pattern Test

Drops will be made at 125 knots from a height of 200 feet (60 meters). The aircraft will be capable of dropping at least 500 gallons (1900 liters) in a single drop.

Two different flow rates will be used for the test. One less than 200 gallons (750 liters) per second and the other flow rate greater than 200 gallons (750 liters) per second. Ideally the drops will be in the 150-gallon (570 liters) per second and 400 gallons (1500 liters) per second range.

The mixed retardant will demonstrate a capability of producing ground pattern lengths and total recovery equal to or greater than the values produced by using water.

A specific test plan will be developed by the Forest Service based on parameters developed and /or determined during the laboratory phase of the retardant evaluation.

Drop tests will be made following the test procedures described in the publication, An Evaluation of Drop Test Characteristics and Ground Patterns of Forest Fire Retardants, USDA Forest Service, Research Paper INT-134 (1973), 60 pages, illustrated, Intermountain Forest and Range Experiment Station, Ogden, UT, by C. W. George and A. D. Blakely.

**General Description**

**No Operational Field Evaluation**

**Monitored Operational Field Evaluation**

**Limited Operational Field Evaluation**

**Full Operational Field Evaluation**

## General Description

A long term fire retardant undergoes 16 to 18 months of laboratory evaluation after submission to the Forest Service. Following a successful completion of the laboratory evaluation, an analysis shall be undertaken to determine whether an operational field evaluation is needed.

Whether or not a product must have a field evaluation, and the complexity of the evaluation will be determined on a case-by-case basis. The operational field evaluation may vary from a slight increase in sampling, to a detailed complex evaluation. This may include outside teams to study product effectiveness and/or visibility.

There are three general categories of operational field evaluation: full, limited, and monitor. Products in the same category will be tested in similar ways. In addition to the general categories identified, the field evaluation can focus on any potential problem areas identified during the laboratory evaluation. An example might be a liquid concentrate that increases viscosity significantly during storage. Although the liquid concentrate passed the laboratory tests, additional sampling and testing would be planned to monitor the viscosity increases in the bulk storage.

Without exception, the goal is to get a full fire season of use with a minimum of 200,000 gallons (757,000 liters) mixed and loaded. Ideally, this use would include periods of steady use and periods of intense activity.

Operational field evaluations involve sampling and testing the retardant received at the base; in storage during the season and over a winter; and pumped into airtankers. The Forest Service purchases all retardant used during an operational field evaluation. The manufacturer/supplier of the retardant covers all associated costs to include travel, materials, and time expended to perform the evaluation.

## No Operational Field Evaluation

If a product contains a change in the amount or source of a minor ingredient, that product would not necessarily require a field evaluation.

There may be surveying of base personnel during the first fire season for possible problems and additional quality control type sampling to monitor for unexpected problems.

## Monitored Operational Field Evaluation

A monitor operational field evaluation will be conducted for products similar to existing, fully or conditionally qualified and approved product. Formulations that contain alternate source of ingredient(s) but do not change the type or amount of the ingredient are considered to be similar.

The National Director, Fire and Aviation Management, USDA Forest Service, will identify products requiring a monitor field evaluation.

Products requiring a monitor field evaluation may be placed on the Qualified Products List as “conditionally qualified.” The product will be included in the normal contracting process and the location for the field evaluation selected from the force account or full service contract bases where the test product is the low bid. It will be purchased at the contract price.

The operational field evaluation will be conducted in accordance with a brief written test plan. This typically involves use for one season with monitoring of the overall retardant characteristics and especially differences from the original formula. These might include variations in viscosity, foaming, or flowing of dry powders.

a. There will be a slight increase in frequency of sampling and routine observation of use by field personnel. Results of all lot

acceptance and quality assurance testing will be monitored. Sampling of retardant in base storage and during loading operations will be done.

b. Sampling on a schedule similar to that done for full-scale tests, that is either the batch-by-batch sampling or weekly storage samples should be analyzed.

c. Over-winter storage may or may not be required. When over-winter storage tests are required, the remaining product may be flown off once spring sampling has been completed.

A simple letter report will be prepared.

At the successful conclusion of the operational evaluation the status of the product will be upgraded to "fully qualified" and listed on the Qualified Products List or Backup List as appropriate.

## Limited Operational Field Evaluation

A limited operational evaluation will be conducted when there is a change in the color-enhancing system of a formulation.

The National Director, Fire and Aviation Management, USDA Forest Service, will identify products requiring a limited operational evaluation.

The test product will be substituted for a similar qualified product, from the same manufacturer, at the contract price at a force account location designated/selected by the Forest Service.

The Forest Service will prepare a written operational evaluation plan for review by the retardant supplier and other participants. In accordance with the evaluation plan, base and other support personnel will take increased sampling and special observations such as those required for color evaluation.

a. Samples will be taken and tested from each shipment to the base. Samples will also be taken and tested as retardant is pumped into the airtankers. Laboratory tests may be performed on retained samples.

b. Over-winter storage may or may not be required. When over-winter storage tests are required, the remaining product may be flown off, at Forest Service discretion, after spring sampling has been completed.

c. Products containing a new colorant system require additional testing. For one season at one base, the color and visibility will be evaluated. This evaluation will include airtanker pilots, lead plane pilots, air observers, etc. to assure that the product has acceptable visibility, allowing all involved to do their jobs properly and safely. The product must be monitored for changes in characteristics that have been brought about by the color change.

The product will be listed as "conditionally approved" after the first fire season of successful use provided that results of the initial and end-of-season corrosion testing is acceptable.

At the conclusion of the evaluation, an informal written report will be prepared containing all significant observations and conclusion.

Following successful completion of the field evaluation, the status of the product will be upgraded to "fully qualified" and listed on the Qualified Products List or Backup List as appropriate.

## Full Operational Field Evaluation

Full operational evaluations will be conducted for formulations that are determined by the Forest Service to be a completely new concept, a substantially new product, or a significant change of product type for the supplier. Formulations contain

new types and amounts of ingredient(s) and may include new mixing, handling, and storage requirements.

The National Director, Fire and Aviation Management, USDA Forest Service, will identify products requiring a full operational field evaluation following successful completion of the laboratory evaluation.

The evaluation site will be a force account base, blacked out on the National Long-term Bulk and Full Service Retardant Contract. Product will be purchased at a price negotiated by the Contracting Officer. In accordance with a formal operational evaluation plan, written by the Forest Service and reviewed by the supplier and other participants, intensive sampling will be required as well as observations and recording of mixing, handling, and storage operations.

a. Logistics from plant to field will be examined, including plant quality control, ability to sustain operations and supply material as needed.
b. Time and equipment needed for mixing and handling operations will be determined.
c. Sampling and testing will be performed during all phases of base operations to assess consistency of the mixed retardant, frequency and duration of recirculation during the season and following over-winter storage. Corrosion and other laboratory tests may be performed on retained samples.
d. Operational effectiveness of the retardant may require the implementation of a special team to gather on-site data and present findings.
e. Other product characteristics such as abnormal wear on pumps or other equipment, dustiness, irritation to mixing and loading personnel will be evaluated.
f. Over-winter storage will be required. At the discretion of the Government, over-winter storage product may be used once spring sampling has been completed.

Status **may** be listed as “conditional” when first fire season of use, including initial and end-of-season corrosion, is completed satisfactorily.

The written evaluation report will contain a complete, detailed summary of findings. In the event of an extended evaluation, progress reports may be made.

At the successful conclusion of the operational field evaluation the status of the product will be upgraded to “fully qualified” and listed on the Qualified Products List or Backup List as appropriate.

United States Department of Agriculture, Forest Service
Standardization Document Improvement Proposal

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