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# Fire Retardant Standard Mixing System

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## INTRODUCTION

The current Government fire retardant program requires that retardant suppliers develop complete systems, consisting of fire retardant chemicals and compatible mixing and handling equipment developed and sized specifically for their chemical. As a result, these proprietary systems and hardware are often incompatible between suppliers, and require costly and time consuming changeover of equipment each time a supplier changes at a base. Prior to the fire chemical companies developing proprietary mixers, the Forest Service used, without modification, mixers that were commercially available and commonly used by the fertilizer, chemical, and petroleum industries. The goal of this project was to define a properly sized, low energy mixing system that could be used to mix any dry powder-based product, as well as recondition fluid or liquid concentrate products.

After an extensive survey of commercially available mixer types, requirements for a standard system were defined jointly by the USDA Forest Service, Technology and Development Center, San Dimas, California (SDTDC), and the National Wildfire Suppression Technology Group, Missoula, Montana (NWST). A performance specification was prepared by SDTDC and proposals were solicited from mixer manufacturers in the United States and Canada.

Shar Systems, Inc., Fort Wayne, Indiana, was the successful bidder and a contract was awarded in September 1997. The contract required Shar to provide a prototype mixing system to SDTDC for testing and evaluation. The procurement specifications required that the system furnished be capable of efficiently mixing all Forest Service currently approved powder based products, with the additional capability of being able to vary retardant viscosity and color should that become desirable in the future. Consideration was also given to the conditioning and mixing of liquid fertilizer-based retardants. The overall objective was to determine if the Shar mixing system met the Forest Service's current need for a standard, low energy mixer. To be acceptable, the mixer must have the capability to rapidly mix all currently approved retardants, and have the potential to satisfy future mixing needs.

Shar delivered their mixing system to SDTDC in February 1998. Acceptance testing of the system was conducted during March 1998 at Hemet-Ryan Airtanker Base in southern California. Further tests were conducted during June 1998 at Redding Airtanker Base in northern California. Upon completion of the Redding tests, the mixer was installed as the base mixer at West Yellowstone Airtanker Base in Montana. It was used exclusively to support retardant mixing operations at West Yellowstone during the 1998 fire season. To date, the mixer has successfully met the requirements of the procurement specification. The following sections of this report discuss mixing issues, systems requirements, acceptance testing, test results, and SDTDC recommendations. Mixing system final specifications and procurement information are provided in Appendix A.

## MIXING ISSUES AND BACKGROUND INFORMATION

Fire retardants are basically fertilizer, furnished to airtanker bases either as a dry powder mixture stored in 1-ton bulk containers (see figure 1) or as a liquid supplied by tanker truck. The fire retardants currently approved for Government use, are defined in the *Lot Acceptance, Quality Assurance, and Field Quality Control for Fire Retardant Chemicals, April 1995*.

*Figure 1—Typical retardant 1-ton dry powder bulk (sack).*

Both Solutia, Inc. and Fire-Trol offer products that are delivered to the Government as liquids. Prior to their final use, during aircraft loading, the products are proportioned into the loading pipeline and blended with an additional amount of water to achieve their final as-used properties. To maintain the proper mixture of these products when stored in base storage tanks, frequent recirculation within the storage tanks is required. To define the proper configuration of storage tank internal piping and fluid devices to achieve effective recirculation in base storage tanks has become a major problem for the Forest Service. This is due to the as-stored properties of the liquid mixtures, variation between bases of tank configurations, and base pump capabilities. It may be more economical, and simpler, to cycle the stored mixes back and forth between a standard batch mixer and each storage tank to maintain mix quality, than to try to standardize base storage tanks, plumbing and pumps.

The Forest Service requires all formulations, when stored as a liquid in base tanks or final-mixed for aircraft use, inhibit corrosion. The maximum corrosion allowed for various metals is given in table 1 of *USDA Forest Service Specification 5100-304a, Long Term Retardant, Forest Fire Aircraft Or Ground Application*. All fire retardant formulations are tested for compliance with *Specification 5100-304a* prior to their acceptance for use by the Government. Although the Government makes every effort to assure that metals will be protected from corrosion caused by fire retardant ingredients, there is a potential for fretting and crevice corrosion of mixer mechanical components such as shaft seals and bearings. Also, mechanical components may experience abrasion depending on the amount of clay used in each formulation. These issues were addressed by the Forest Service during the selection of suitable components and materials used for the fabrication of the test mixer system.

### Properties of Dry Powder Fire Retardants

The primary ingredient of the dry powder products, depending on the manufacturer, is ammonium sulfate or ammonium phosphate salt. Additional ingredients are corrosion inhibiting chemicals, colorant, thickeners (primarily guar gum), clay and other miscellaneous chemicals in small quantities. The exact formulations are proprietary to each manufacturer.

#### *Solutia, Inc. Powder Products*

These products are based on mixtures of monoammonium phosphate and ammonium sulfate or diammonium phosphate salts. They contain a gum thickener. One ton of powder yields between 1,768 and 1,869 gallons of mixed retardant. They are mixed by adding between 1.12 and 1.2 pounds of powder to each gallon of water in the mixer. During the mixing process the mixture of powder and water can thicken to an end viscosity of 1,800 centipoise depending on which product is being mixed. The specific weight of these products, after mixing, is between 8.9 and 9.0 pounds per gallon.

#### *Fire-Trol Powder Products*

These products are mixtures of ammonium sulfate and ammonium phosphate salts. They also contain a gum thickener. One ton of powder can yield up to 1,375 gallons of mixed retardant, depending on the product used. They are mixed by adding 1.7 to 1.8 pounds of powder to each gallon of water in the mixer. During the mixing process the mixture of powder and water can thicken to an end viscosity of 1,800 centipoise. The specific weight of these products, after mixing, is 9.1 pounds per gallon.

## Properties of Liquid Fire Retardants

### *Solutia, Inc. Liquid Products*

These products are based on mixtures of monoammonium phosphate and ammonium sulfate. They contain varying concentrations of gum thickener, depending on the product. As delivered, it has a specific weight of 10.6 pounds per gallon. The viscosity of the stored mixture is relatively low (usually less than 100 centipoise). When stored for more than one hour component settling occurs; consequently there is a need to recirculate the mixture for at least five minutes every hour to properly maintain the mix. Because of the relatively low viscosity of the mixture, recirculation is not difficult. However, there is a tendency for a layer of clabber or scum to accumulate on the surface of the stored fluid. This layer is very low density and cannot be easily reincorporated into the mixture by recirculation. Because of this problem, it may be beneficial to run the stored fluid through a batch mixer once each week to reincorporate this surface buildup back into the mixture. For final use, these products are blended with water at a ratio of between three and four parts of water to one part of fluid concentrate. The water blending causes a net change in the final viscosity of these products. Depending on the product, final viscosities are between 75 and 1,800 centipoise and the specific weight is reduced to around nine pounds per gallon.

### *Fire-Trol Liquid Products*

These products are delivered as a liquid mixture composed primarily of liquid ammonium polyphosphate, colorant and a small amount of attapulgite clay. As delivered it has specific weight of between 12 and 12.25 pounds per gallon. The viscosity of the stored mixture is temperature dependent and can vary between 1,000 to greater than 4,000 centipoise. When stored for more than 24-hours some component settling may occur, daily recirculation is recommended by the Forest Service to assure a proper mix is maintained. Because of the variation in storage viscosity and the non-Newtonian fluid properties of the mixtures, they can be difficult to recirculate. For final use they are blended with water at ratios of four to five parts of water to one part of liquid concentrate. The water blending reduces the final viscosity to less than 50 centipoise and specific weight to around nine pounds per gallon.

## TEST MIXER SYSTEM REQUIREMENTS

This section contains the requirements SDTDC imposed on Shar for the design and fabrication of the prototype mixer system. Some of the requirements were necessary to facilitate the movement and rapid setup of the mixer at multiple test locations. Others were required features to demonstrate system capability to meet potential future needs. These special requirements and options are not required to meet current airtanker base needs.

### General Requirements

During fire activity the mixer is required to operate continuously for 8 to 12 hours per day. Currently dry powder products are batch-mixed at bases. A typical batch operation takes a total of 15 minutes. Four minutes to fill the mixer tank with water; one minute or less to load the tank (one-ton of powder); three minutes to mix the powder and water to the required specifications; and seven minutes to draw test samples and to transfer the mixed retardant to a storage tank. During the mixing process the bulk container for the next batch is positioned for loading. The mixer system shall, as a minimum, be able provide mixed retardant at this current batch rate.

Currently, fire fighting aircraft can require up to 3,000 gallons of retardant to fill their tanks. In the near future, aircraft with 5,000 gallon tanks may be used. On many bases a single 3,000 gallon tanker can be loaded and dispatched every 15 minutes. Some bases have the capability of loading two aircraft simultaneously which currently equates to 6,000 gallons every 15 minutes. Most bases have a minimum retardant storage capability of 20,000 gallons. The mixer system shall be designed, to be scaled to the volume necessary, to support the loading of 6,000 gallons of powder or liquid retardant every 15 minutes into an aircraft. A facility to store 20,000 gallons of mixed retardant must be available at the base.

The mixer system and all its ancillary equipment shall be designed to operate in an ambient temperature range of 30 °F to 120 °F. The system and all of its components shall be installed outside without the benefit of any protective building or cover. System components shall withstand winter storage temperatures of -40 °F, coverage by snow and ice, and exposure to heavy rain and hail.

Because of the critical role the mixer plays in the successful operation of the base it must be an extremely reliable, easily serviceable and rugged piece of equipment. During fire season, the contractor shall be able to provide field service and/or spare parts to the user base on a seven days per week basis and within 24 hours of notification of a problem. The mixer system manufacturer shall consider the possibility of providing the mixing system with redundant critical components or assemblies, or spare components and/or assemblies to assure that mixer operation can be rapidly restored (in one hour or less) in the event of a component failure.

## Special Requirements

The system shall have provisions for the future addition of solid (see figure 2) and liquid metering equipment (see figure 3) to precisely meter in colorant (dye pigments, dry powder or liquid), thickeners (such as, gums and clay) and fertilizer salt mixtures (both liquid and dry powder). Dye powders, thickeners and other dry chemicals normally are provided to the base in 60 or 90 pound sacks. Dry powder salt in one ton bulk bags, and liquid salt mixtures would be delivered by tanker truck to a suitably sized base storage tank. Dye pigment liquids would be furnished in 5 gallon or 55 gallon drums.

*Figure 2—Dry powder feed hopper and conveyor assembly.*

*Figure 3—Liquid storage tank and metering pump assembly.*

The estimated amounts and metering accuracy required for each type of ingredient are given in table 1. Powder ingredients shall be metered into a common blender and thoroughly blended prior to their mixing with any liquid component. Liquid ingredients can be metered into a common feed tank or pipe, or directly into the mixer.

*Table 1. Estimated amounts and metering accuracy required for each ingredient.*

| Dry Powder Feed Hopper Number | Capacity | Ingredient | Amt of ingredient required per 1500-2000 gallons of mixed retardant | Measurement Accuracy Required |
|---|---|---|---|---|
| 1 | 1 ton | Thickener | 150-200 lb | +/- 1.5 lb |
| 2 | 1000 lbs | Colorant | 20-50 lb | +/- 0.2 lb |
| 3 | 1000 lbs | Colorant | 20-50 lb | +/- 0.2 lb |
| **Liquid Tank Number** | | | | |
| 1 | 300 gal | Liquid Colorant | 20-50 lb | +/- 0.2 lb |

The mixer system shall be a modular design that facilitates final assembly of one hour or less at the use site. The system shall be designed such that, all system components can be transported on a single 40- foot flatbed semi trailer. All mixer system modules shall be skid mounted in a manner suitable for loading on and off a 40-foot flatbed semi trailer with a fork lift (see figure 4).

*Figure 4—Mixer modules loaded on flat bed trailer for transport from SDTDC to Hemet for testing.*

Wherever necessary, to facilitate safe operation, the mixer system modules shall be fitted with platforms, catwalks, ladders and handrails that are in accordance with current federal and state safety codes. These devices shall be readily removable or hinged to facilitate highway dimensional codes for truck transport (see figure 5).


*Figure 5—Mixer loading platform with nonskid surface, safety chains and portable stairs with handrails.*

The mixer shall be able to demonstrate the ability to automatically recondition the retardant stored in base tanks. This shall be accomplished by the mixer having a self loading, automatic batch mix time and unloading capability (see figure 6).

*Figure 6—Mixer setup for storage tank reconditioning at Redding Airtanker Base.*

## Primary Requirements

The mixing system and all its ancillary devices, where appropriate, shall have suitable dust control or collection equipment (air or water curtain assembly, cyclone separator or other means to contain or collect dust generated during loading operations - see figure 7).


*Figure 7—Torit self cleaning dust collector mounted on the top of the mixer.*

Consideration shall be given to provide the mixing system with material handling devices that will readily support the use of a fork lift to load the system without lifting bulk material containers more than four feet off the ground. Devices such as a simple swing boom or loading frame with an electric chain hoist or a loading hopper with a conveyor are examples of potential material handling devices (see figure 8).

The system shall be a batch mixer fitted with a mixer tank with a geometry suitable for top loading.

### *Tank features*

A minimum capacity of 2,500 gallons.

Top opening with a cover, suitable for loading from bulk powder containers (refer back to figure 8).


*Step 1—Offloading bag from forklift and initial hookup to hoist.*

*Step 2—Commence bag lifting with the hoist.*


*Step 3—Moving bag to mixer with the hoist trolly.*

*Figure 8—Mixer loading operation. (Series of 8 photographs illustrating loading operation.)*

*Step 4—Positioning bag over loading hatch safety ring with hoist.*

*Step 5—Bag positioned on safety ring and bag dumping started.*

*Step 6—Mixer loading.*

*Step 7—Moving empty bag away from mixer.*


*Step 8—Removing empty bag from loading area to ready mixer for next batch. The entire loading process takes less than 5 minutes.*

Appropriately sized Schedule 40 pipe with 150 psi flanged fittings at top and bottom. The top fitting shall provide a water break for tank filling. The bottom fitting shall be a flanged fitting for off loading mixed retardant (see figure 9).

*Figure 9a—Mixer water inlet line with 3-inch motor operated ball valve. Connection to base water is with 4-inch camlock fitting.*

*Figure 10—Mixer tank access port. Allows cleaning of tank and maintenance without tank entry.*

*Figure 9b—Mixer outlet connection to transfer pump. Connection is made with 4-inch camlock fitting.*

The tank shall be fabricated from a suitable thickness of corrosion resistant steel alloy or 1/4-inch thick carbon steel plate. If fabricated from carbon steel, all internal surfaces subject to long term contact with mixed retardant shall be sand blasted to white metal and coated with a suitable epoxy (or coal tar).

The tank shall be fitted with suitable flanged access ports that shall facilitate all routine maintenance and cleaning operations on mixer components and tank interior surfaces to be conducted without entering the tank (see figure 10).

The tank shall be fitted with an external fluid level indicator (sight gauge), that can be readily seen by the operator while operating or loading the mixer (see figure 11).

*Figure 11—Mixer tank fluid level indicator (sight gage).*

The tank plumbing shall incorporate an adjustable liquid level sensor that shall actuate a shutoff valve and/or shut-off the water supply pump when the tank is filled to the proper level. Shutoff levels will depend on the product being mixed and will be determined by use of a contractor provided sensing system (see figure 12).

*Figure 12—Mixer tank load cell.*

## Mixer system plumbing

Provisions shall be made for all plumbing and valves to interface with the base water supply and retardant transfer lines (mixer off-load plumbing) with four-inch camlock fittings (refer back to figure 9).

The mixer system shall have appropriately sized outlet and inlet lines fitted with shutoff (isolation) valves that can be manually operated if necessary.

Mixer system inlet and outlet lines shall be provided with backflow prevention valves (anti-siphon and/or check valves) wherever the potential for backflow into base interface piping exists.

The Forest Service shall provide flexible four-inch hard rubber suction hose with camlock fittings to connect the mixer system plumbing to the base retardant storage tanks, water supply and peripheral liquid handling pumps.

## Electrical system

The mixer system shall have a switching (system control) panel with switches to operate mixer motor(s) and two 25-horsepower pumps. The switching control panel shall be provided in a suitable weather proof enclosure for outdoor mounting on the mixer system. All switching will be done with either low voltage (12 to 24 volts dc) or 120 volt ac single-phase switches and circuits. A 120 volt ac single-phase weather resistant external duplex plug to operate ancillary devices (such as a chain hoist) will be provided if needed on the panel (see figure 13).

*Figure 13—Mixer electrical control console (weather proof enclosure).*

The mixer system shall have motor controls enclosed in a suitable weather proof box mounted adjacent to or incorporated in the switching control panel box. It shall include either 480 or 240 volts ac 3-phase motor controls and starters with individual circuit protection for each mixer system motor. The motor controls shall be operated by relays energized by the control panel switches (see figure 14).


*Figure 14—Mixer control panel.*

Suitable grounding and ground-fault interrupt circuitry shall be provided for all mixer system circuits.

## MIXER SYSTEM ACCEPTANCE TESTING

### Test Cooperators

The California Department of Forestry and Fire Protection allowed SDTDC to conduct initial acceptance testing at Hemet-Ryan Airtanker Base. The Forest Service Airtanker Base Manager and Fire-Trol, Inc., the base contractor, agreed to allow SDTDC to conduct the final acceptance testing at the Redding Airtanker Base in Redding, California. The principal test cooperators are listed below.

*San Dimas Technology and Development Center*
Sig Palm, Fire Program Leader
Fred Cammack, Project Leader

*National Wildfire Suppression Technology Group (NWST)*
Charles George, Program Leader
Cecilia Johnson, Chemist

*Solutia, Inc.*
John Moore, Technical Representative

*Fire-Trol*
Rob Crouch, Manager of Research & Development
Mitch Glatfelder, Technical Representative

*Shar Systems, Inc.*
Greg DeLong, President

*Hemet-Ryan Airtanker Base*
Don Cockrum, Base Manager,
California Department of Forestry and Fire Protection

*Redding Airtanker Base*
Cecil Stinson, Base Manager, USDA Forest Service
California Department of Forestry and Fire Protection

### General Information

Initial acceptance tests were conducted during March 1998 at Hemet-Ryan Airtanker Base in southern California (see figure 15) using Solutia, D75-F. Further tests were conducted during June 1998 at the Redding Airtanker Base in northern California (see figure 16) using Fire-Trol GTS-R. Upon completion of the Redding tests, the mixer was installed as the base mixer at West Yellowstone Airtanker Base in Montana (see figure 17). It was used exclusively to support retardant mixing operations at West Yellowstone during the 1998 fire season. During testing the uniformity of the mixed retardant was determined by measuring the density, salt content and viscosity. The measurements taken determined if the mixed retardant was in conformance with *Specification 5100-304a* and lot acceptance, quality assurance and quality control requirements.

User response to the mixing system was recorded. Any deficiencies and exceptional or extraordinary performance was noted. In particular, ease of use and time to mix successfully was noted.

Each acceptance test was conducted until a minimum of five batches of each type of mixed retardant had passed through the mixer. The mixers ability to accurately portion in dry powder and liquid ingredients during mixing was also demonstrated during the testing at Redding. Also demonstrated was the potential use of the mixer for reconditioning mixed retardant stored over winter in base storage tanks. Test duration and quantity mixed depended on the amount of available mixed retardant storage at each test base at the time the testing was conducted.

### Test Responsibilities

#### *SDTDC*

1. Transporting mixing system to test base and performing the initial installation.

2. Providing a 150 kW portable generator to provide power to the mixing system.

3. Providing for appropriately trained personnel to install the mixer and operate the base.

4. Providing appropriately trained personnel to conduct the testing.

5. Coordinating testing with all cooperators.

6. Preparing work plan and the final report.

7. Collecting, analyzing and shipping retardant samples.

*Figure 15—Views of mixer system setup for testing at Hemet-Ryan Airtanker Base.*

*Figure 16—View of mixer system test setup at Redding Airtanker Base.*

*Figure 17—View of mixer system installation at West Yellowstone Airtanker Base.*

### Shar Systems, Inc.

1. Loading the mixing system on SDTDC's truck in Indiana.

2. Providing 2-25-foot-sections of 4-inch rubber hose with camlock fittings for interface with base plumbing.

3. Providing 75 feet of appropriately sized 4 conductor wire to interface with the SDTDC provided generator.

4. Training SDTDC personnel to properly install and operate the mixing system.

5. Performing any onsite mixing system modifications or repairs required.

6. Providing for the transportation of the mixing system to their plant or other offsite location for the performance of modifications or repairs identified during, or resulting from, the testing.

7. Delivering all contractually required equipment and documents at the conclusion of the testing to SDTDC for acceptance.

## Test Procedure

1. Before testing, the mixer tank was sterilized using approximately 2,500 gallons of water and 13 gallons of liquid bleach. The tank remained filled with the bleach treated water for a minimum of 24 hours.

2. Mix batch water volume was set in accordance with the retardant manufacturers specifications. It was determined prior to the testing by use of the mixer system load cells and verified by use of a Micro Motion Flowmeter. Once the proper volume had been verified by weight, it was programmed into the mixer system computer which then controlled the filling of the tank between batches. The Micro Motion Flowmeter and sight glass on the mix tank were used during testing as additional verification that the water volume was correct for each batch mixed (see figure 18).

*Figure 18—Micro Motion Flowmeter installed in water fill line at Redding Airtanker Base.*

3. To determine the optimum mixing time required for each batch, the first batch was mixed using the following procedure:

(a) Three sampling valves are installed on the mix tank. The primary sampling valve is located at about the mid-level of the fluid (800-1000 gallons) when the mixer is full. Another valve is located near the bottom of the tank at the intersection of the cone bottom and the main tank cylinder. A third valve is located about four inches below the fluid surface (see figure 19). The three valves were designated as follows:

top, valve A; middle, valve B; bottom, valve C

*Figure 19—Sampling valves installed on mix tank.*

(b) The appropriate amount of water was added to the mixer. The time to complete the water transfer was noted. The first bag was positioned over the mixer. The mixer was then turned on and the mixer timer started. The powder was added to the water and the time required to complete the powder addition was noted.

(c) Immediately upon completion of the powder transfer, a one-quart sample of retardant was drawn from each valve. The sample set for one minute prior to measuring and recording the viscosity. Additional samples were drawn from each valve at one minute intervals for ten minutes and their viscosities measured and recorded. Two more samples were drawn from each valve, one at 15 minutes and the final at 30 minutes. The viscosities of these samples were measured and recorded. The mixer was turned off after 30 minutes of operation. All samples were then checked for density and salt (see figure 20).

*Figure 20—Sample collection.*

(d) Optimum mix time was determined when two consecutive samples from all three sampling valves agreed within 100 centipoise and +/- 0.25 refractive index units. When this occurred the sample was considered to be homogeneous. The mix time required to attain homogeneity was then used for mixing the balance of the batches.

4. The balance of the testing was conducted using the optimum mix time determined. That time had been set in the system computer. The mixer was loaded again and operated for the preprogrammed time and shut down. Samples were then drawn and their properties measured as before. If the sample properties met requirements, the retardant was transferred to the base storage tank. This process was continued until all batches had been mixed. In all cases, the first batch mixed identified the proper mix time.

5. The last batch of retardant mixed during the Redding test was mixed using only one of the two mixers to demonstrate the ability to mix should one mixer motor fail. The single mixer was run for the time defined initially for a batch and shut down. Samples were drawn from the mix tank and their properties measured. If the sample properties did not meet retardant specifications, the mixer was started and allowed to run for another two minutes and samples drawn and measured again. This process was repeated until the samples showed that the mixed retardant met specifications. The time required to accomplish this was recorded in the test data.

6. The proportioning of powder and liquid into the mix tank during mixing was checked after the general testing at the Redding base (see figure 21). It was accomplished as follows:

(a) Liquid metering accuracy was checked by using the load cells on the liquid chemical storage tank and comparing their weight measurements with the load cell readings from the main mix tank whose calibration had been verified earlier with measurements made with the Micro Motion Flowmeter during tank filling operations. The mixer tank was prefilled with enough water to mix a full batch of retardant. The mixer was then turned on and the water in the liquid supply tank incrementally metered another 100 gallons of water into the mixer tank. During the metering the change in the water weight in both tanks was displayed on the mixer system control panel and noted.

(b) Powder proportioning accuracy was checked by loading the powder hopper with 100 pounds of dry ammonium sulfate powder. The powder was then proportioned into the mix tank which had been prefilled with water. The weight of powder conveyed into the mix tank from the powder hopper, was measured by the load cells on the powder hopper. That weight was compared with the change in weight sensed by the load cells on main mix tank. Both weighing system measurements were displayed on the mixer control console. Weight measurements from each tank were compared and noted.

## Data Collection

Quality and consistency of the mixed retardant was determined by analysis of one quart samples taken from the mix tank sampling valves defined in the previous section and located on the mix tank. Samples were drawn from the top middle and bottom of the batch being mixed. Samples were drawn initially to determine the mixing time required for each retardant type. Subsequent samples were drawn at the end of each batch cycle. Salt content (by refractometer), viscosity (by Brookfield viscometer) and density (by density meter) of each sample was measured and the results recorded (see figure 22).

*Figure 21a—View of powder conveyor and hopper platform load cells.*

*Figure 21b—Positioning powder hopper with fork lift. Notice liquid feed tank in the foreground.*

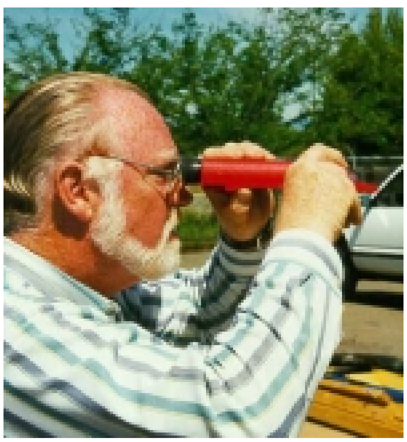

*Figure 22—Measurement of retardant salt content using the refractometer.*

All samples were evaluated in accordance with applicable Forest Service specifications, and as prescribed in the *Lot Acceptance, Quality Assurance, and Field Quality Control for Fire Retardant Chemicals*.

## Physical Inspection

SDTDC observed and documented the mixer installation at each airtanker base. Mixer operation during the testing was observed, any concerns or problems regarding its use were documented and discussed with Shar (the contractor).

At the conclusion of each test a meeting was held with the contractor and a plan to correct any observed problems was defined.

## TEST RESULTS

## Hemet-Ryan Test

Initial testing was conducted March 23 and 24, 1998 at Hemet-Ryan Airtanker Base, Hemet, CA to determine if the contractor met the requirements of the procurement specifications. At the conclusion of this testing, March 24th, a meeting was held between Fred Cammack representing the USDA Forest Service Technology and Development Center San Dimas, CA (SDTDC) and Greg DeLong representing the contractor, Shar Systems, Inc.. The purpose of the meeting was to address modifications required to the mixer to fully meet Forest Service needs and contract requirements. The following was discussed:

The testing demonstrated that the mixer can successfully mix Solutia, Inc. D75-F fire retardant. Batch mix time was not totally defined because the water loading valve operator malfunctioned. Approximately 9,000 gallons of retardant was successfully mixed during the testing. The specified 15 minute batch rate was achieved with this product in spite of the loading valve problem.

*Figure 23—Mixer loading valve assembly.*

The malfunction of the loading valve operator (see figure 23) did not allow all the features of the mixer to be fully demonstrated. Nor did it allow the contractor to fully train SDTDC personnel to operate the mixer. The automation of mixer loading and off loading, and powder and liquid metering was postponed until the testing at Redding. The contractor agreed to provide a higher torque operator for the loading valve.

During the testing the retardant manufacturers informed SDTDC that the one-ton hoist furnished with the mixer was undersized for the products currently planned and offered by Fire Trol. This information was not known when the contract was awarded. Also, the addition of a powered hoist trolley would make mixer loading operations much easier and safer. The mixer was retrofitted with a two-ton hoist with a powered trolley for the Redding test (see figure 24).

*Figure 24—Two-ton hoist and powered trolly assembly.*

The installation of a safety ring above the mixer loading hatch (see figure 25) was needed to protect the operator during loading operations. This issue concerned the retardant manufacturers as well as Forest Service observers. The contractor agreed to provide the required ring.

The mixer control panel needed wiring plugs to accommodate easy installation

*Figure 25—Safety ring.*

and removal for winter storage. The contractor agreed to provide SDTDC with the plugs and instructions for their installation (see figure 26).

*Figure 26—Control console mounting bracket assembly. Notice wiring plug connections at the bottom of the console.*

The contract specified only one sample extraction valve was required. More sampling valves were required on the mix tank to lower extraction time. During testing provisions were made to extract samples from the top, middle and bottom of the mix tank. However, the method used proved to be slower than desired and difficult to use. SDTDC agreed to install the additional valves prior to the Redding test.

The control console needed to be moved off of the mixer work platform to allow more space for the operator to safely manipulate retardant sacks while loading the mixer. SDTDC agreed to modify the control console mounting bracket to allow it to be mounted on the side of the platform and to facilitate easy removal for winter storage (refer again to figure 26).

The sack lifting fixtures required redesign to allow the retardant sacks to be lifted higher above the mixer during dumping. The height of the hoist frame may also need to be adjusted upward to accommodate the addition of a safety ring to the mix tank and a larger hoist and trolley. SDTDC agreed to accomplish this modification (see figure 27).

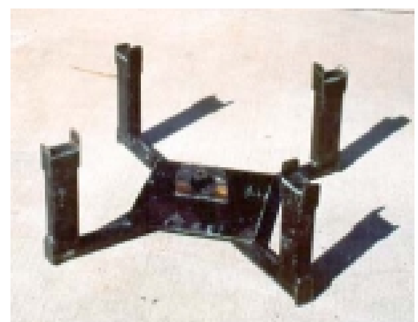

*Figure 27—Redesigned sack lifting fixture.*

The problems defined during the testing were considered to be minor by SDTDC and the mixer was transported to SDTDC for modifications to correct the problems discussed above. The needed modifications were completed prior to conducting the testing at Redding Airtanker Base.

## Redding Test

The testing at Redding Airtanker Base began on June 9th and ended on June 11th. All planned testing was completed without problems. The testing demonstrated that the mixer can successfully mix Fire-Trol GTS-R fire retardant. Approximately 14,000 gallons of retardant was mixed without incident during testing. Batch mix time was totally defined and the 15 minute batch rate was more than achieved. Testing successfully demonstrated the accurate metering of liquid and powder additives into the mix tank. The capability of the system to mix using only one mixer motor and to automatically recondition stored retardant was successfully demonstrated.

At the conclusion of the testing the following issues were discussed with the contractor:

During mix tank filling there was a noticeable flexing of the water inlet line and valve assembly at the weldment located on the top of the mix tank. This concerned observers that a potential failure of the weldment could occur if the flexing continued. It was agreed that the contractor would provide reinforcement gussets to alleviate the perceived problem. SDTDC agreed to arrange for their installation at West Yellowstone.

Due to the location of the tank loading hatch, the powder being dumped from the sacks was not directed to the center of the mix tank. This caused small amounts of powder to form lumps at the bottom of the tank. The lumps were usually incorporated into the next batch (see figure 28). No noticeable change in batch properties was indicated in the data collected. However, this caused some concern to test observers. The contractor agreed to design a deflector chute for the loading hatch that would direct the powder to the center of the tank during bag dumping. The chute would be installed and tested at West Yellowstone.

*Figure 28—Lumps at the bottom of the mix tank. (View of mixer shafts and turbines.)*

The data collected from the Hemet-Ryan and Redding tests is summarized in Appendix B.

## MIXER OPERATIONAL TESTING AT WEST YELLOWSTONE

The mixer was installed by SDTDC at West Yellowstone Airtanker base in mid July 1998 and served as the primary mixer for that base during the 1998 fire season. When the mixer arrived at the base, reinforcement gussets were installed on the water inlet line to reduce flexing during tank filling. The loading hatch deflector chute provided by the contractor was also installed (see figure 29). After the mixer modifications had been completed SDTDC instructed base personnel in the use of the mixer. Joe Fleming a SDTDC technician, provided the base support during mixer set up, modifications and personnel training.

*Figure 29—Loading chute.*

After training, the mixer was used to top off the base retardant storage tank. Approximately 8,000 gallons of Solutia D-75 retardant was mixed during this operation. The retardant used had been stored at the base for more than one year and was extremely lumpy due to moisture exposure during the storage period. This provided an excellent opportunity to check the effectiveness of the newly installed deflector chute and the mixers general effectiveness. The bags could not be poured into the mixer due to the large lumps inside. Instead the bags were opened on the loading platform and the lumps broken up with a shovel to a size that could pass through the loading hatch. Once inside the mixer the lumps were readily incorporated into the mixture. This initial mixing operation proved that the chute worked well and the mixer should not have any significant problems handling older inventory powder. However, this type of operation requires much more then the allotted 15-minutes per batch to accomplish. Powder in poor condition should only be mixed during topping-off operations; it is not recommended for use during a fire activity because of the excessive time required to handle and mix it.

During the initial use of the mixer at West Yellowstone, problems were experienced with the water loading valve operator. The valve did not power open and an attempt was made to assist it manually by twisting the operator valve stem with a wrench while the operator was powered on. With the assistance of the wrench the valve opened but the valve stem was sheared off in the process. The cause of this problem is not yet fully understood. The loading valve was left open and a manually operated valve placed upstream of it for tank filling until the problem is corrected.

Because of the problem with the loading valve, the mixer could not be filled automatically. The mixer tank weighing system was used in conjunction with a Micro Motion Flowmeter to define the desired water level in the mix tank and that level was marked on the mix tank sight gage. SDTDC notified the contractor of the problem and they ordered a higher torque operator for the valve. The combination of the mix tank sight gauge and the manually operated loading valve was used through the 1998 fire season and will be used until a new valve operator is received from the contractor. The base reported that the mixer worked well through the season in spite of the loading valve problem. The base mixed in excess of 56,000 gallons during the 1998 season. Further operational use with the repaired loading valve will be reported to SDTDC during the 1999 season.

Base personnel also reported to SDTDC that the redesigned bag (sack) lifting fixture (as previously shown in figure 25) was not efficient to use. Time could be saved during mixer loading operations by using a less awkward lifting fixture. The reason for the current fixture design is to allow the retardant bulk bag to be lifted high enough to easily position the bag over the loading hatch safety ring. The loading hoist cannot lift the bag high enough without the current fixture due to limits imposed by the height of the hoist frame. Base personnel would like to move the hoist frame up another four feet to allow the use of a less awkward and lighter weight lifting fixture. If the Forest Service decides to leave the mixer at West Yellowstone this modification can be easily accomplished. However, extending the frame upward would make it too high for transport on a flatbed trailer. This would make it difficult to move the mixer to another base for further testing. Until the final disposition of the mixer has been defined, the current lifting fixture will continue to be used. The outside edge metal pieces (ears) on the fixture could be replaced with slightly larger ones to make the fixture/ bag hookup less awkward. Use of the fixture does not slow the mixing operation enough to be significant. The mixer can easily be loaded, mixed and off-loaded in less than 15 minutes with the use of the current fixture.

Since the start of testing, the mixer has satisfactorily mixed more than 78,000 gallons of retardant. The only unresolved issues are the mixer loading valve problem and the hoist frame height.

## CONCLUSIONS AND RECOMMENDATIONS

Based on the testing and the limited operational use at West Yellowstone, the mixer system as currently configured has met the requirements of the Forest Service performance specification.

The optimum mix time per batch was determined to be three minutes for both Solutia D75-F and Fire-Trol GTS-R. The two retardants used for the testing are believed to represent the mixing characteristics of all other currently approved powder products used by the Forest Service. Based on the data collected, all currently approved powder products can be mixed with the mixer tested in the following batch turnaround time:

1. Mixer loading: 7.5 minutes:

    Four minutes to deliver bulk bag to mixer. Mixer was being filled with water during this period, assumes a supply water flow rate of 400 gallons per minute.

    Three and one-half minutes to position bag and empty it into mixer. Bag positioning two minutes. Bag emptying one and one-half minutes. Mixer is turned on when bag emptying starts.

2. Batch mixing time: 3 minutes

3. Mixer off-loading to base storage tank: 4.5 minutes:

    Assumes a transfer pump flow rate of 400 gallons per minute.

Total batch turnaround time: 15 minutes

The above estimate assumes the powder being mixed is in good condition and is stored on the base in a location that is near the mixer with adequate forklift accessibility. Each base may experience slightly different turnaround times. During testing, even with the loading valve problems experienced, a 15 minute turnaround was achieved.

As currently configured, the mixer can be readily scaled to a larger size to accommodate the batch mixing of three bags or more, if desirable and economical. Drawings of Shar Systems, Inc. model FSSM-2 are included in Appendix A. This ability to be scaled upward in batch volume meets the future need to accommodate larger volume airtankers at bases with limited space for additional mixers and storage tanks. There is an economic trade off between finding more space, buying more mixers and tanks, and purchasing a larger mixer. These trade-offs should be analyzed and considered prior to finalizing plans for improved base capacity.

The mixer, if equipped with the automation furnished for testing, is an alternative for the reconditioning of over winter stored retardant or concentrate to some of the tank recirculation systems currently in use. To manage the reconditioning of stored retardants the base storage tanks would need to be re-plumbed so that the mixer would remove retardant from the bottom of the tank and return it to the top of the tank.

The mixer configuration tested can meet all Forest Service needs now, and in the foreseeable future. It can be furnished from the manufacturer with the options tested or with less features depending on the needs of a base at the time of order. The reliability of the mixer components could not be fully evaluated due to the limited duration of the tests. Another fire season of use at West Yellowstone should give more insight into that issue. The testing did demonstrate that the current design can be readily operated manually, if necessary, without a significant increase in mix cycle time. Also, undefined at this time is what spare parts a base should have on hand for emergency repairs. The manufacturer has in stock most of the primary components for the mixer. Special components such as the valve operators, hoist, weigh system, and dust collector must be ordered from the manufacturers of those items. Factory support for the testing was excellent. Longterm product support hopefully will be the same.

The loading valve problem and the hoist height issue should be resolved prior to the 1999 fire season. It is recommended that the mixer be used for one more fire season prior to making a final determination of its suitability for general use at all bases. Assuming the additional testing is successful, at that time, the mixer should be considered to be the only system fully qualified for use with all Forest Service currently approved fire retardant products. If other manufacturers, including the current retardant suppliers, wish to offer competitive systems, it is recommended that they be required to qualify, at their expense, the systems in accordance with the specifications given in this report. If bases have a future plan to buy mixers, it is recommended that they assure the mixer selected is qualified in accordance with the requirements provided in this report.

# APPENDIX A

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## MIXING SYSTEM FINAL SPECIFICATIONS AND PROCUREMENT INFORMATION

### A.1 Mixer System Specifications

The following is a listing of the Governments minimum requirements for the procurement of a "standard mixer system."

### GENERAL REQUIREMENTS

(a) During a fire activity the mixer is required to operate continuously for 8 to 12 hours per day. Currently dry powder products are batch mixed at bases. A typical batch operation takes a total of 15 minutes. Four minutes to fill the mixer tank with water. One minute or less to load the tank (one-ton of powder). Three minutes to mix the powder and water to the required specifications, and seven minutes to draw test samples and to transfer the mixed retardant to a storage tank. During the mixing process the bulk container for the next batch is positioned for loading. The mixer system shall, as a minimum, be able provide mixed retardant at this current batch rate.

(b) Currently, fire fighting aircraft can require up to 3,000 gallons to fill their tanks. In the near future, aircraft with 5,000 gallon tanks may be used. Aircraft are loaded and dispatched continuously during fire operations. In many bases a single 3,000 gallon tanker can be loaded and dispatched every 15 minutes. Some bases have the capability of loading two aircraft simultaneously which currently equates to 6,000 gallons every 15 minutes. Most bases have a minimum of 20,000 gallons of retardant storage capability. The mixer system shall be designed, to be scaled to the volume necessary, to support the loading of 6,000 gallons of powder or liquid retardant every 15 minutes into an aircraft, with a maximum of 20,000 gallons of base pre-installed mixed retardant storage available.

(c) The mixer system and all its ancillary equipment shall be designed to operate in an ambient temperature range of 30 °F to 120 °F. The system and all of its components shall be installed outside without the benefit of any protective building or cover. During the selection of system components, the contractor shall select them to withstand winter storage temperatures of - 40 °F, coverage by snow and ice, and exposure to heavy rain and hail .

(d) Because of the critical role the mixer plays in the successful operation of the base it must be an extremely reliable, easily serviceable and rugged piece of equipment. During fire season, the contractor shall be able to provide field service and/or spare parts to the user base on a 7-days per week basis and within 24-hours of notification of a problem. The mixer system manufacturer shall consider the possibility of providing the mixing system with redundant critical components or assemblies, or spare components and/or assemblies to assure that mixer operation can be rapidly restored (in one-hour or less) in the event of a component failure.

### SPECIFIC DESIGN REQUIREMENTS

(a) The system shall have provisions for the future addition of solid and liquid metering equipment to precisely meter in colorant (dye pigments, dry powder or liquid), thickeners (such as, gums and clay) and fertilizer salt mixtures (both liquid and dry powder). Dye powders, thickeners and other dry chemicals normally are provided to the base in 60 or 90 pound sacks. Dry powder salt in 1-ton bulk bags, and liquid salt mixtures would be delivered by tanker truck to a suitably sized base storage tank. Dye pigment liquids would be furnished in 5 gallon or 55 gallon drums.

The estimated amounts and metering accuracy required for each type of ingredient are given in table 1. Powder ingredients shall be metered into a common blender and thoroughly blended prior to their mixing with any liquid component. Liquid ingredients can be metered into a common feed tank or pipe, or directly into the mixer.

(b) The mixing system and all its ancillary devices, where appropriate, shall have suitable dust control or collection equipment (air or water curtain assembly, cyclone separator or other means to contain or collect dust generated during loading operations).

(c) Consideration shall be given to provide the mixing system with material handling devices that will readily support the use of a fork lift to load the system without lifting bulk material containers more than 4-ft. off the ground. Devices such as, a simple swing boom with an electric chain hoist or a loading hopper with a conveyor are examples of potential material handling devices.

(d) Wherever necessary, to facilitate safe operation, the mixer system shall be fitted with platforms, catwalks, ladders and handrails that are in accordance with current Federal and State Safety Codes.

(e) The system shall be a batch mixer fitted with a mixer tank with a geometry suitable for top loading. The tank shall have the following features:

1. A minimum of 2,500 gallon capacity.

2. Top opening with a cover, safety ring and loading chute, suitable for loading from bulk powder containers currently available from Solutia and Fire-Trol.

3. Appropriately sized Schedule 40 with 150 psi pipe fittings at top and bottom. The top fitting shall provide a water break for tank filling. The bottom fitting shall be a flanged fitting for off loading mixed retardant.

4. The tank shall be fabricated from a suitable thickness of 304 series corrosion resistant steel alloy or 1/4-inch thick carbon steel plate. If fabricated from carbon steel, all internal surfaces subject to long term contact with mixed retardant shall be sand blasted to white metal and coated with a suitable epoxy (or coal tar).

5. The tank shall be fitted with a suitable flanged access port that shall facilitate all routine maintenance and cleaning operations on mixer components and tank interior surfaces to be conducted without entering the tank.

6. The tank shall be fitted with an external fluid level indicator (sight gage), that can be readily seen by the operator while operating or loading the mixer.

7. The tank plumbing shall incorporate an adjustable liquid level sensor that shall actuate a shutoff valve and/or shut-off the water supply pump when the tank is filled to the proper level. Shutoff levels will depend on the product being mixed and will be determined by use of a contractor provided sensing system.

*Table 1. Estimated amounts and metering accuracy required for each ingredient.*

| **Dry Powder Feed Hopper Number** | **Capacity** | **Ingredient** | **Amt of ingredient required per 1500-2000 gallons of mixed retardant** | **Measurement Accuracy Required** |
|---|---|---|---|---|
| 1 | 1 ton | Thickener | 150-200 lb | +/- 1.5 lb |
| 2 | 1000 lbs | Colorant | 20-50 lb | +/- 0.2 lb |
| 3 | 1000 lbs | Colorant | 20-50 lb | +/- 0.2 lb |
| **Liquid Tank Number** | | | | |
| 1 | 300 gal | Liquid Colorant | 20-50 lb | +/- 0.2 lb |

(f) Mixer system plumbing:

1. Provisions shall be made for all plumbing and valves to interface with the base water supply and retardant transfer lines (mixer off-load plumbing) with 4-inch camlock fittings.

2. The mixer system outlet and inlet line valves shall be fitted with shutoff (isolation) valves. The valves shall be lever operated rubber seated wafer butterfly valves.

3. Mixer system inlet and outlet lines shall be provided with backflow prevention valves (anti-siphon and/or check valves) wherever the potential for backflow into base interface piping exists.

4. The Forest Service shall provide flexible 4-inch hard rubber suction hose with camlock fittings to connect the mixer system plumbing to the base retardant storage tanks, water supply and peripheral liquid handling pumps.

(g) Electrical system:

1. The mixer system shall have a switching (system control) panel with switches to operate mixer motor(s) and two-30-horsepower pumps. The switching control panel shall be provided in a suitable weather proof enclosure for outdoor mounting on the mixer system. All switching will be done with either low voltage (12 to 24 volts dc) or 120 volts ac single-phase switches and circuits. A 120 volt ac single-phase weather resistant external duplex plug to operate ancillary devices (such as a chain hoist) will be provided if requested on the panel.

2. The mixer system shall have motor controls enclosed in a suitable weather proof box mounted adjacent to the switching control panel box. It shall include 480/240 volt ac 3-phase motor controls and starters with individual circuit protection for each mixer system motor. The

motor controls shall be operated by relays energized by the control panel switches.

3. Suitable grounding and ground-fault interrupt circuitry shall be provided for all mixer system circuits.

## SYSTEM ASSEMBLY, ACCEPTANCE TESTING AND DELIVERY

The contractor is required to deliver to the Government a completed mixer system no later than 240 calendar days from the contractors receipt of notification to proceed from the Government. The mixer system shall be in accordance with the Governments instructions, approved plans and bill of materials. The Forest Service shall witness acceptance testing and perform final inspection at the contractors facility, or a mutually pre-agreed location. The testing shall be to demonstrate that all aspects of the system are functioning properly and in accordance with the system procurement contract. At the conclusion of the acceptance testing the Forest Service shall report any problems with the mixer system to the contractor. The contractor shall correct any problems identified during acceptance testing or final inspection prior to delivery of the system to the Forest Service. During the testing, final inspection of the mixing system shall be performed by the Government. Upon acceptance by the Government representative, the contractor shall provide mixing system operational training at the test site to Forest Service personnel. Upon satisfactory completion of the inspection and testing the contractor shall then deliver, at the test site, to the Forest Service the completed mixing system, and an as-built set of drawings, materials list and operation manual.

## A.2. Mixer System Procurement Information

The drawings contained in this appendix were supplied by the manufacturer, Shar Systems, Inc. The prices quoted were in effect December 3, 1998 and are subject to change without notice by the manufacturer.

*View of Shar Model FSSM-1 with optional powder feed hopper & rack assembly and liquid feed tank.*


*View of Shar Model FSSM-1 with optional loading platform and hoist rack, electric loading hoist & trolly assembly and control panel.*

SHAR SYSTEMS, INC.
P.O. BOX 9196 • 3210 FREEMAN STREET
FORT WAYNE, IN 46899
PHONE (219) 432-5312
FAX-(219) 432-8933

**USDA FOREST SERVICE** **PRICE LIST** **December 3, 1998**

**STANDARD 2500 GALLON (1) BAG UNIT**

| MODEL | DESCRIPTION | PRICE |
|---|---|---|
| FSSM-1 | 2-25 HP MIXERS WITH 2500 GALLON TANK | $39,400.00 |
| FSSM-1A | DUST COLLECTOR | $5,500.00 |
| FSSM-1B | MANUAL MOTOR CONTROL PANEL MIXER AND DUST COLLECTOR ONLY | $6,200.00 |
| FSSM-1C | SMALL WORK PLATFORM | $2,500.00 |
| FSSM-1D | FREIGHT | $3,000.00 |
| FSSM-1E | OPERATION & MAINTENANCE MANUAL | INCL |
| FSSM-1F | 1 YEAR CONDITIONAL WARRANTY | INCL |
| | TOTAL | $56,600.00 |

OPTIONAL EQUIPMENT

| | | |
|---|---|---|
| FSSM-1G | AUTOMATED HIGH LIQUID LEVEL CONTROL | $500.00 |
| FSSM-1H | LOADING AND UNLOAD PUMP STARTERS AND CONTROLS | $1,700.00 |
| FSSM-1I | AUTOMATED LIQUID LOADING CONTROL PANEL | $9,100.00 |
| FSSM-1J | LARGE LOADING PLATFORM | $8,950.00 |
| FSSM-1K | MANUAL 2 TON HOIST AND TROLLEY WITH BAG LIFT | $1,450.00 |
| FSSM-1L | ELECTRIC 2 TON HOIST AND TROLLEY WITH BAG LIFT | $5,700.00 |
| FSSM-1M | 300 GALLON AUTOMATED LIQUID FEED TANK | $9,800.00 |
| FSSM-1N | 1000 # POWDER FEED HOPPER WITH AUGER AND AUTOMATIC CONTROLS | $7,450.00 |
| FSSM-1O | 2000 # POWDER FEED HOPPER WITH AUGER AND AUTOMATIC CONTROLS | $7,650.00 |
| FSSM-1P | ONE (1) HOPPER STAND | $6,700.00 |
| FSSM-1Q | TWO (2) HOPPER STAND | $12,900.00 |
| FSSM-1R | THREE (3) HOPPER STAND | $18,750.00 |
| FSSM-1S | ONSITE INSTALLATION AND TRAINING | $60.00/HR + EXPENSES |
| FSSM-1T | ONSITE SERVICE AGREEMENT | $60.00/HR + EXPENCES |

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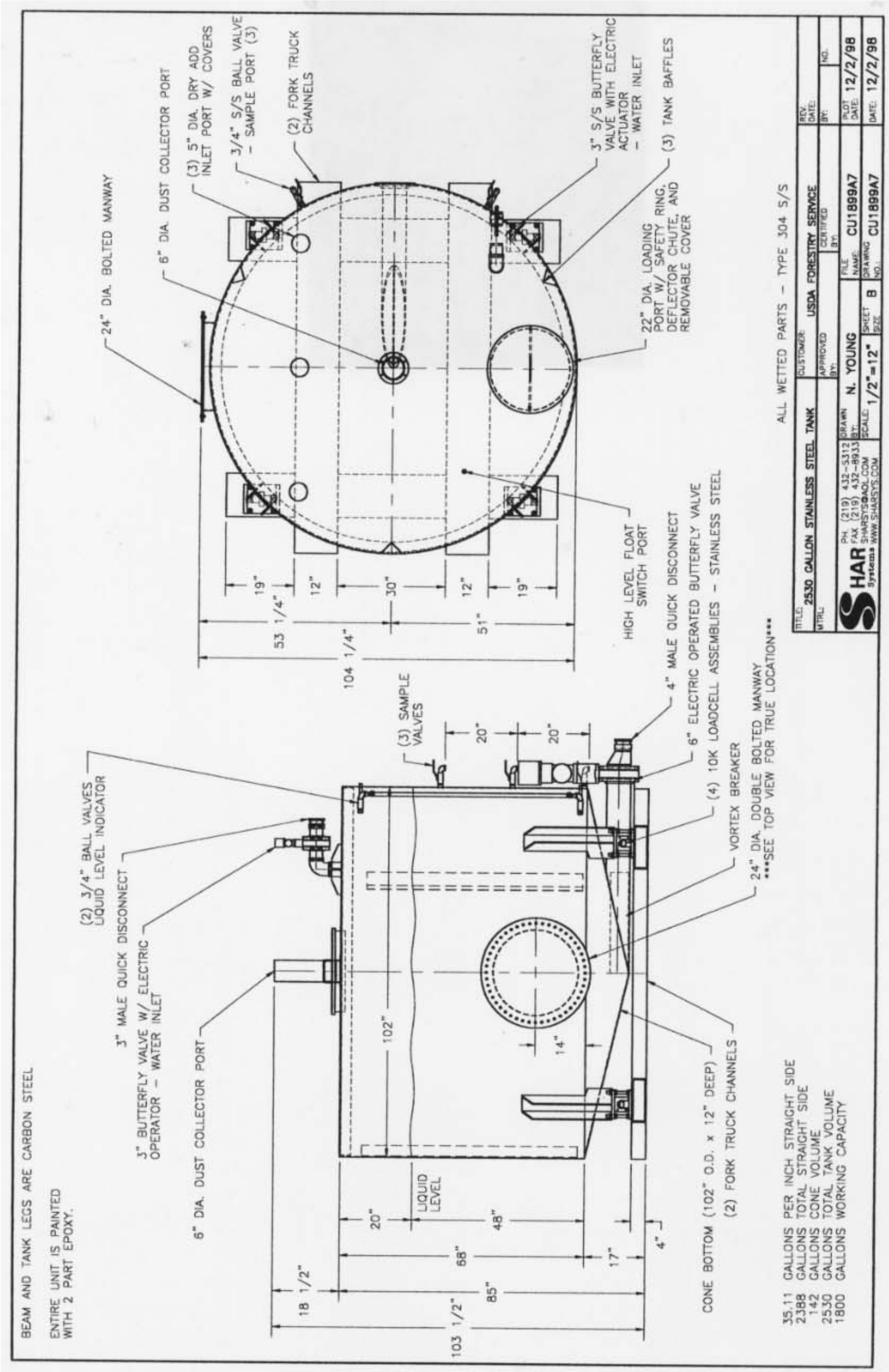
BEAM AND TANK LEGS ARE CARBON STEEL
ENTIRE UNIT IS PAINTED WITH 2 PART EPOXY.
(2) 3/4" BALL VALVES LIQUID LEVEL INDICATOR
3" MALE QUICK DISCONNECT
3" BUTTERFLY VALVE W/ ELECTRIC OPERATOR – WATER INLET
6" DIA. DUST COLLECTOR PORT
18 1/2"
20"
102"
LIQUID LEVEL
103 1/2"
68"
85"
48"
14"
17"
4"
(3) SAMPLE VALVES
20"
20"
4" MALE QUICK DISCONNECT
6" ELECTRIC OPERATED BUTTERFLY VALVE
(4) 10K LOADCELL ASSEMBLIES – STAINLESS STEEL
VORTEX BREAKER
24" DIA. DOUBLE BOLTED MANWAY
***SEE TOP VIEW FOR TRUE LOCATION***
CONE BOTTOM (102" O.D. x 12" DEEP)
(2) FORK TRUCK CHANNELS
35.11 GALLONS PER INCH STRAIGHT SIDE
2388 GALLONS TOTAL STRAIGHT SIDE
142 GALLONS CONE VOLUME
2530 GALLONS TOTAL TANK VOLUME
1800 GALLONS WORKING CAPACITY
24" DIA. BOLTED MANWAY
6" DIA. DUST COLLECTOR PORT
(3) 5" DIA. DRY ADD INLET PORT W/ COVERS
3/4" S/S BALL VALVE – SAMPLE PORT (3)
(2) FORK TRUCK CHANNELS
19"
53 1/4"
12"
104 1/4"
30"
12"
51"
19"
HIGH LEVEL FLOAT SWITCH PORT
22" DIA. LOADING PORT W/ SAFETY RING, DEFLECTOR CHUTE, AND REMOVABLE COVER
3" S/S BUTTERFLY VALVE WITH ELECTRIC ACTUATOR – WATER INLET
(3) TANK BAFFLES
ALL WETTED PARTS – TYPE 304 S/S
TITLE: 2530 GALLON STAINLESS STEEL TANK
MTRL:
CUSTOMER: USDA FORESTRY SERVICE
APPROVED BY:
CERTIFIED BY:
REV. DATE:
BY:
NO.
SHAR Systems
PH. (219) 432-5312
FAX (219) 432-8933
SHARSYS@AOL.COM
WWW.SHARSYS.COM
DRAWN BY: N. YOUNG
FILE NAME: CU1899A7
PLOT DATE: 12/2/98
SCALE: 1/2"=12"
SHEET SIZE B
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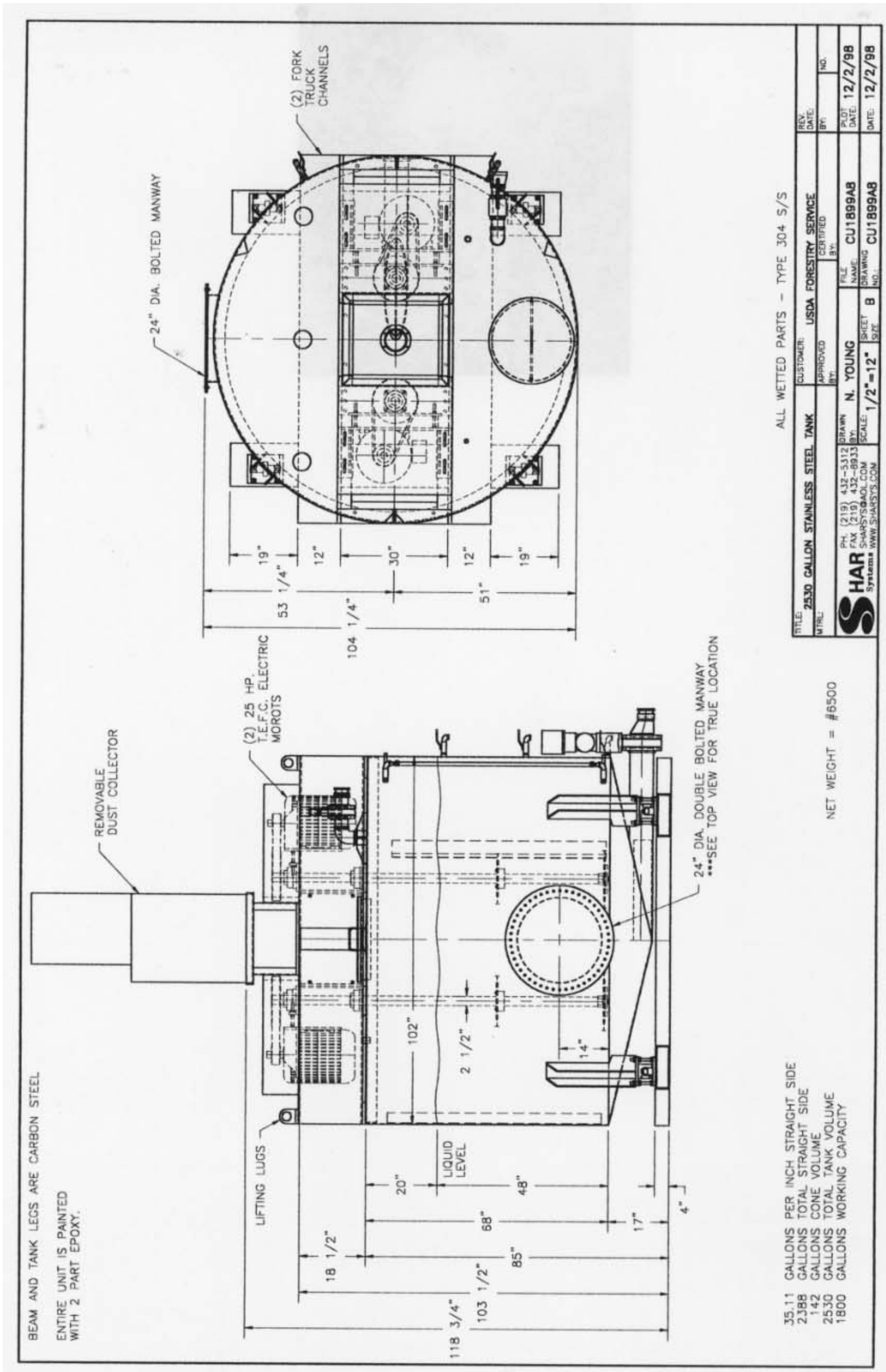
DATE: 12/2/98


BEAM AND TANK LEGS ARE CARBON STEEL
ENTIRE UNIT IS PAINTED WITH 2 PART EPOXY.
35.11 GALLONS PER INCH STRAIGHT SIDE
2388 GALLONS TOTAL STRAIGHT SIDE
142 GALLONS CONE VOLUME
2530 GALLONS TOTAL TANK VOLUME
1800 GALLONS WORKING CAPACITY
REMOVABLE DUST COLLECTOR
(2) 25 HP. T.E.F.C. ELECTRIC MOROTS
LIFTING LUGS
LIQUID LEVEL
24" DIA. DOUBLE BOLTED MANWAY ***SEE TOP VIEW FOR TRUE LOCATION
NET WEIGHT = #6500
24" DIA. BOLTED MANWAY
(2) FORK TRUCK CHANNELS
ALL WETTED PARTS – TYPE 304 S/S
2530 GALLON STAINLESS STEEL TANK
USDA FORESTRY SERVICE
N. YOUNG
1/2"=12"
B
CU1899A8
12/2/98
SHAR Systems

SHAR SYSTEMS, INC.
P.O. BOX 9196 • 3210 FREEMAN STREET
FORT WAYNE, IN 46899
PHONE (219) 432-5312
FAX-(219) 432-8933

**USDA FOREST SERVICE** **PRICE LIST** **December 3, 1998**

**STANDARD 8000 GALLON (4) BAG UNIT**

| MODEL | DESCRIPTION | PRICE |
|---|---|---|
| FSSM-2 | 2-50 HP MIXERS WITH 8000 GALLON TANK | $48,200.00 |
| FSSM-2A | DUST COLLECTOR | $5,500.00 |
| FSSM-2B | MANUAL MOTOR CONTROL PANEL MIXER AND DUST COLLECTOR ONLY | $7,900.00 |
| FSSM-2C | SMALL WORK PLATFORM | $2,800.00 |
| FSSM-2D | FREIGHT | $3,000.00 |
| FSSM-2E | OPERATION & MAINTENANCE MANUAL | INCL |
| FSSM-2F | 2 YEAR CONDITIONAL WARRANTY | INCL |
| | TOTAL | $67,400.00 |

OPTIONAL EQUIPMENT

| | | |
|---|---|---|
| FSSM-2G | AUTOMATED HIGH LIQUID LEVEL CONTROL | $500.00 |
| FSSM-2H | LOADING AND UNLOAD PUMP STARTERS AND CONTROLS | $2,700.00 |
| FSSM-2I | AUTOMATED LIQUID LOADING CONTROL PANEL | $12,800.00 |
| FSSM-2J | LARGE LOADING PLATFORM | $9,500.00 |
| FSSM-2K | MANUAL 2 TON HOIST AND TROLLEY WITH BAG LIFT | $2,450.00 |
| FSSM-2L | ELECTRIC 2 TON HOIST AND TROLLEY WITH BAG LIFT | $5,700.00 |
| FSSM-2M | 300 GALLON AUTOMATED LIQUID FEED TANK | $9,800.00 |
| FSSM-2N | 2000 # POWDER FEED HOPPER WITH AUGER AND AUTOMATIC CONTROLS | $7,450.00 |
| FSSM-2O | 2000 # POWDER FEED HOPPER WITH AUGER AND AUTOMATIC CONTROLS | $7,650.00 |
| FSSM-2P | ONE (2) HOPPER STAND | $6,700.00 |
| FSSM-2Q | TWO (2) HOPPER STAND | $22,900.00 |
| FSSM-2R | THREE (3) HOPPER STAND | $28,750.00 |
| FSSM-2S | ONSITE INSTALLATION AND TRAINING | $60.00/HR + EXPENSES |
| FSSM-2T | ONSITE SERVICE AGREEMENT | $60.00/HR + EXPENCES |

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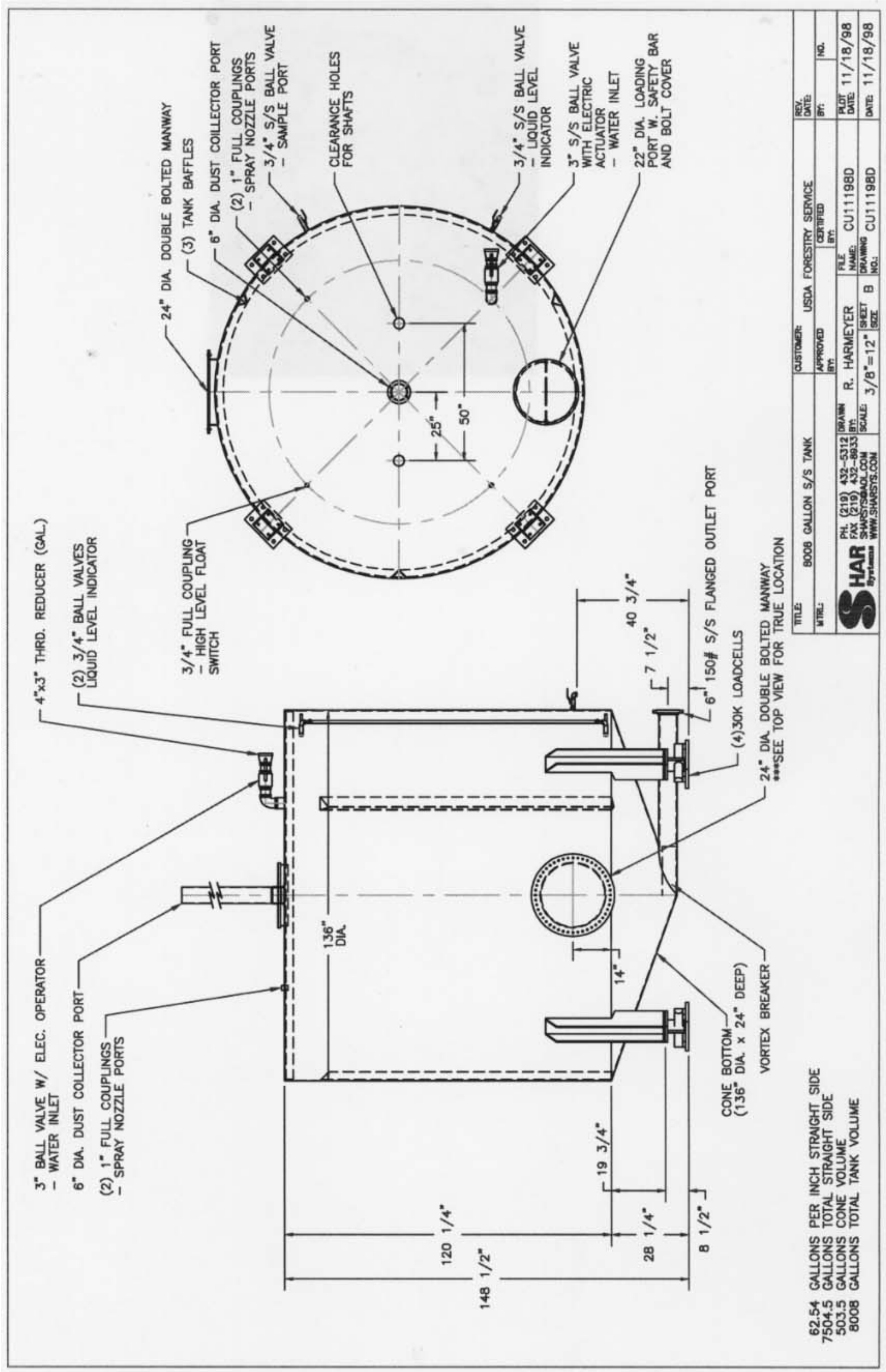
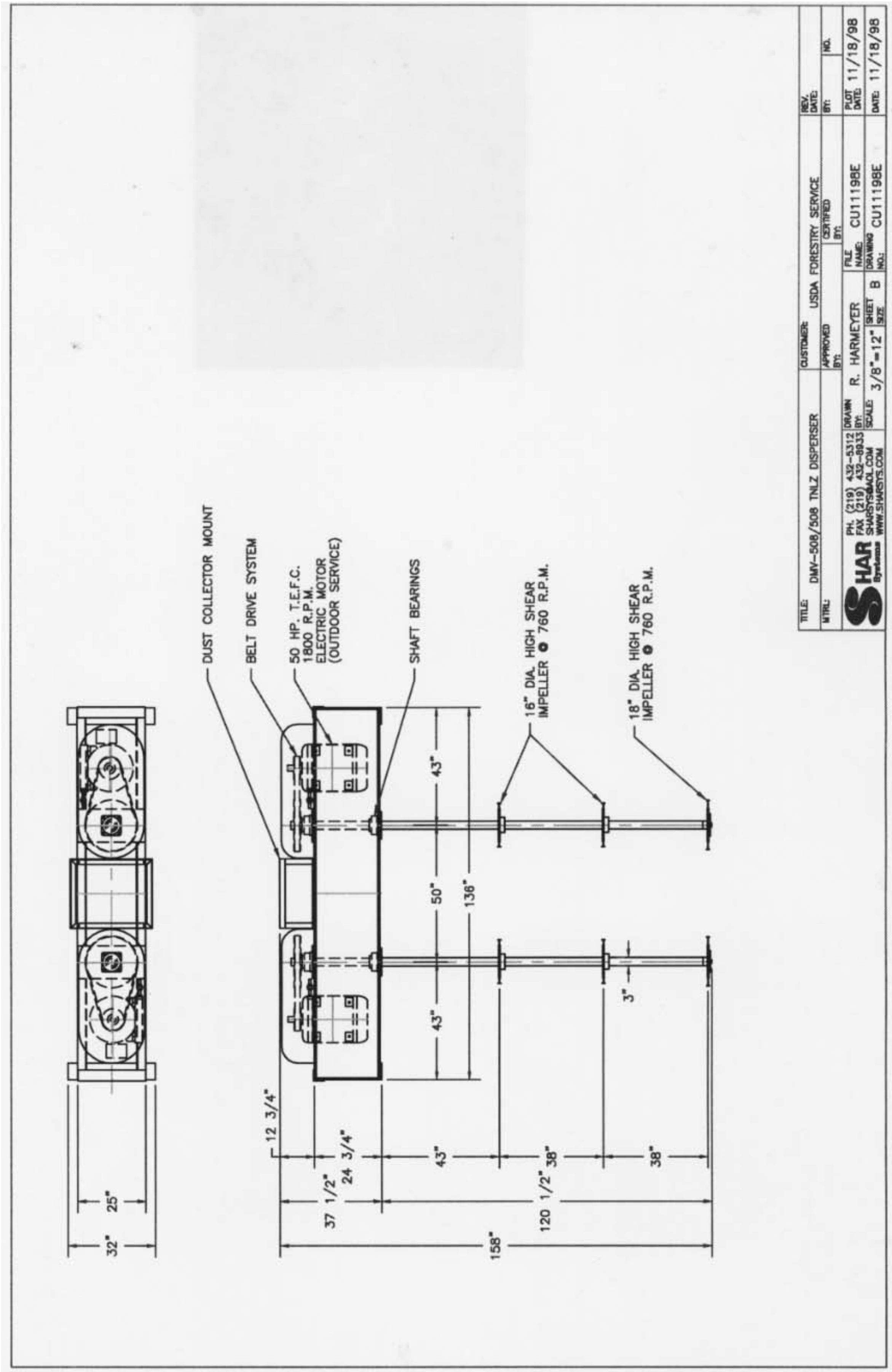
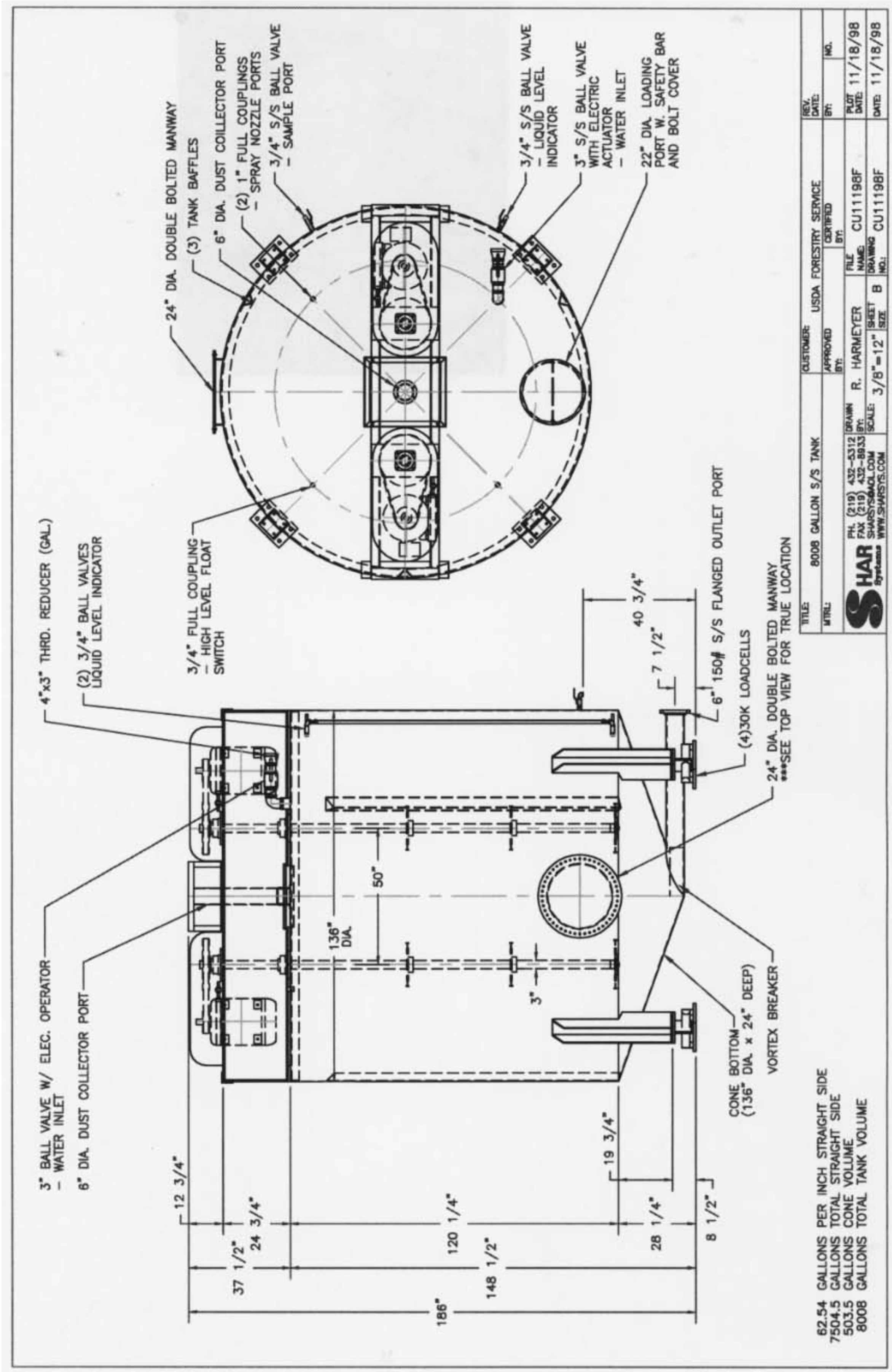


3" BALL VALVE W/ ELEC. OPERATOR – WATER INLET
6" DIA. DUST COLLECTOR PORT
(2) 1" FULL COUPLINGS – SPRAY NOZZLE PORTS
4"x3" THRD. REDUCER (GAL.)
(2) 3/4" BALL VALVES LIQUID LEVEL INDICATOR
3/4" FULL COUPLING – HIGH LEVEL FLOAT SWITCH
136" DIA.
14"
CONE BOTTOM (136" DIA. x 24" DEEP)
VORTEX BREAKER
24" DIA. DOUBLE BOLTED MANWAY ***SEE TOP VIEW FOR TRUE LOCATION
(4)30K LOADCELLS
6" 150# S/S FLANGED OUTLET PORT
7 1/2"
40 3/4"
120 1/4"
148 1/2"
28 1/4"
19 3/4"
8 1/2"
62.54 GALLONS PER INCH STRAIGHT SIDE
7504.5 GALLONS TOTAL STRAIGHT SIDE
503.5 GALLONS CONE VOLUME
8008 GALLONS TOTAL TANK VOLUME
24" DIA. DOUBLE BOLTED MANWAY
(3) TANK BAFFLES
6" DIA. DUST COILLECTOR PORT
(2) 1" FULL COUPLINGS – SPRAY NOZZLE PORTS
3/4" S/S BALL VALVE – SAMPLE PORT
CLEARANCE HOLES FOR SHAFTS
3/4" S/S BALL VALVE – LIQUID LEVEL INDICATOR
3" S/S BALL VALVE WITH ELECTRIC ACTUATOR – WATER INLET
22" DIA. LOADING PORT W. SAFETY BAR AND BOLT COVER
25"
50"
TITLE: 8008 GALLON S/S TANK
CUSTOMER: USDA FORESTRY SERVICE
PH. (219) 432-5312
FAX (219) 432-8933
SHARSYS@AOL.COM
WWW.SHARSYS.COM
DRAWN BY: R. HARMEYER
SCALE: 3/8"=12"
SHEET SIZE B
FILE NAME: CU11198D
DRAWING NO.: CU11198D
PLOT DATE: 11/18/98
DATE: 11/18/98


DUST COLLECTOR MOUNT
BELT DRIVE SYSTEM
50 HP. T.E.F.C. 1800 R.P.M. ELECTRIC MOTOR (OUTDOOR SERVICE)
SHAFT BEARINGS
16" DIA. HIGH SHEAR IMPELLER @ 760 R.P.M.
18" DIA. HIGH SHEAR IMPELLER @ 760 R.P.M.
43"
50"
43"
138"
3"
12 3/4"
37 1/2"
24 3/4"
43"
38"
38"
120 1/2"
158"
25"
32"
TITLE: DMV-508/508 TNLZ DISPERSER
CUSTOMER: USDA FORESTRY SERVICE
DRAWN BY: R. HARMEYER
SCALE: 3/8"=12"
SHEET SIZE: B
FILE NAME: CU1119BE
DRAWING NO.: CU1119BE
PLOT DATE: 11/18/98
DATE: 11/18/98
SHAR Systems


3" BALL VALVE W/ ELEC. OPERATOR – WATER INLET
6" DIA. DUST COLLECTOR PORT
4"x3" THRD. REDUCER (GAL.)
(2) 3/4" BALL VALVES LIQUID LEVEL INDICATOR
3/4" FULL COUPLING – HIGH LEVEL FLOAT SWITCH
24" DIA. DOUBLE BOLTED MANWAY
(3) TANK BAFFLES
6" DIA. DUST COILLECTOR PORT
(2) 1" FULL COUPLINGS – SPRAY NOZZLE PORTS
3/4" S/S BALL VALVE – SAMPLE PORT
3/4" S/S BALL VALVE – LIQUID LEVEL INDICATOR
3" S/S BALL VALVE WITH ELECTRIC ACTUATOR – WATER INLET
22" DIA. LOADING PORT W. SAFETY BAR AND BOLT COVER
3/4" FULL COUPLING – HIGH LEVEL FLOAT SWITCH
12 3/4"
24 3/4"
37 1/2"
120 1/4"
148 1/2"
186"
28 1/4"
8 1/2"
19 3/4"
136" DIA.
50"
3"
40 3/4"
7 1/2"
6" 150# S/S FLANGED OUTLET PORT
(4)30K LOADCELLS
24" DIA. DOUBLE BOLTED MANWAY ***SEE TOP VIEW FOR TRUE LOCATION
CONE BOTTOM (136" DIA. x 24" DEEP)
VORTEX BREAKER
62.54 GALLONS PER INCH STRAIGHT SIDE
7504.5 GALLONS TOTAL STRAIGHT SIDE
503.5 GALLONS CONE VOLUME
8008 GALLONS TOTAL TANK VOLUME
TITLE: 8008 GALLON S/S TANK
CUSTOMER: USDA FORESTRY SERVICE
REV. DATE:
BY:
NO.
MTRL:
APPROVED BY:
CERTIFIED BY:
SHAR Systems
PH. (219) 432-5312
FAX (219) 432-8933
SHARSYS@AOL.COM
WWW.SHARSYS.COM
DRAWN BY: R. HARMEYER
SCALE: 3/8"=12"
SHEET SIZE B
FILE NAME: CU1119BF
DRAWING NO.: CU1119BF
PLOT DATE: 11/18/98
DATE: 11/18/98

# APPENDIX B

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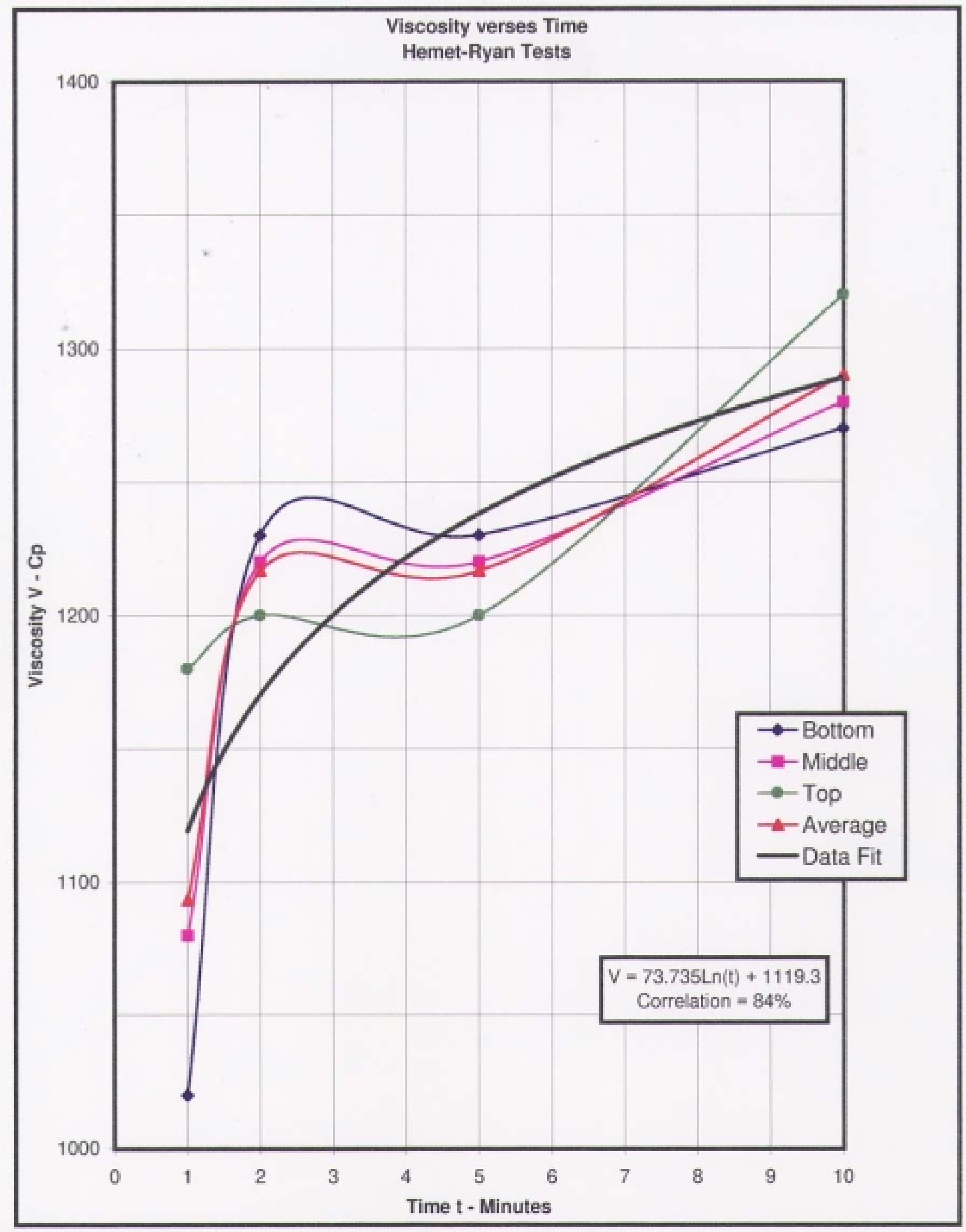
## Mixer System Test Data and Analysis

**Hemet-Ryan Test Data 22 March 1998 First Batch**

General (applies to all batches): .............. Product:D75-F
Specified Specific Gravity Range: ..... 1.065 - 1.078 g/cc
Specified Refractometer Range: ..................... 10.3 - 12.3
Specified Viscosity Range: ....................... 1200 - 1800 cp
Volume per Batch Mixed: ........................... 1782 gallons
Data taken at: ............................................................ 75 °F

| Sample Location | Time Minutes | Density g/cc | Refractometer Salt | Viscosity cp |
|---|---|---|---|---|
| **Bottom** | 1 | 1.07 | 11.25 | 1020 |
| | 5 | 1.07 | 11.75 | 1230 |
| | 10 | 1.07 | 11.75 | 1270 |
| | 15 | 1.07 | 11.75 | 1270 |
| | 20 | 1.07 | 11.75 | 1360 |
| **Middle** | 2 | 1.07 | 11.75 | 1080 |
| | 5 | 1.07 | 11.75 | 1220 |
| | 10 | 1.07 | 11.75 | 1280 |
| | 13 | 1.07 | 11.75 | 1260 |
| **Top** | 1 | 1.07 | 11.75 | 1180 |
| | 3 | 1.07 | 11.75 | 1200 |
| | 5 | 1.07 | 11.75 | 1320 |

**Total Batches Mixed:5** **Total Gallons Mixed:8908**


Viscosity verses Time
Hemet-Ryan Tests
Viscosity V - Cp
1400
1300
1200
1100
1000
0
1
2
3
4
5
6
7
8
9
10
Time t - Minutes
Bottom
Middle
Top
Average
Data Fit
V = 73.735Ln(t) + 1119.3
Correlation = 84%

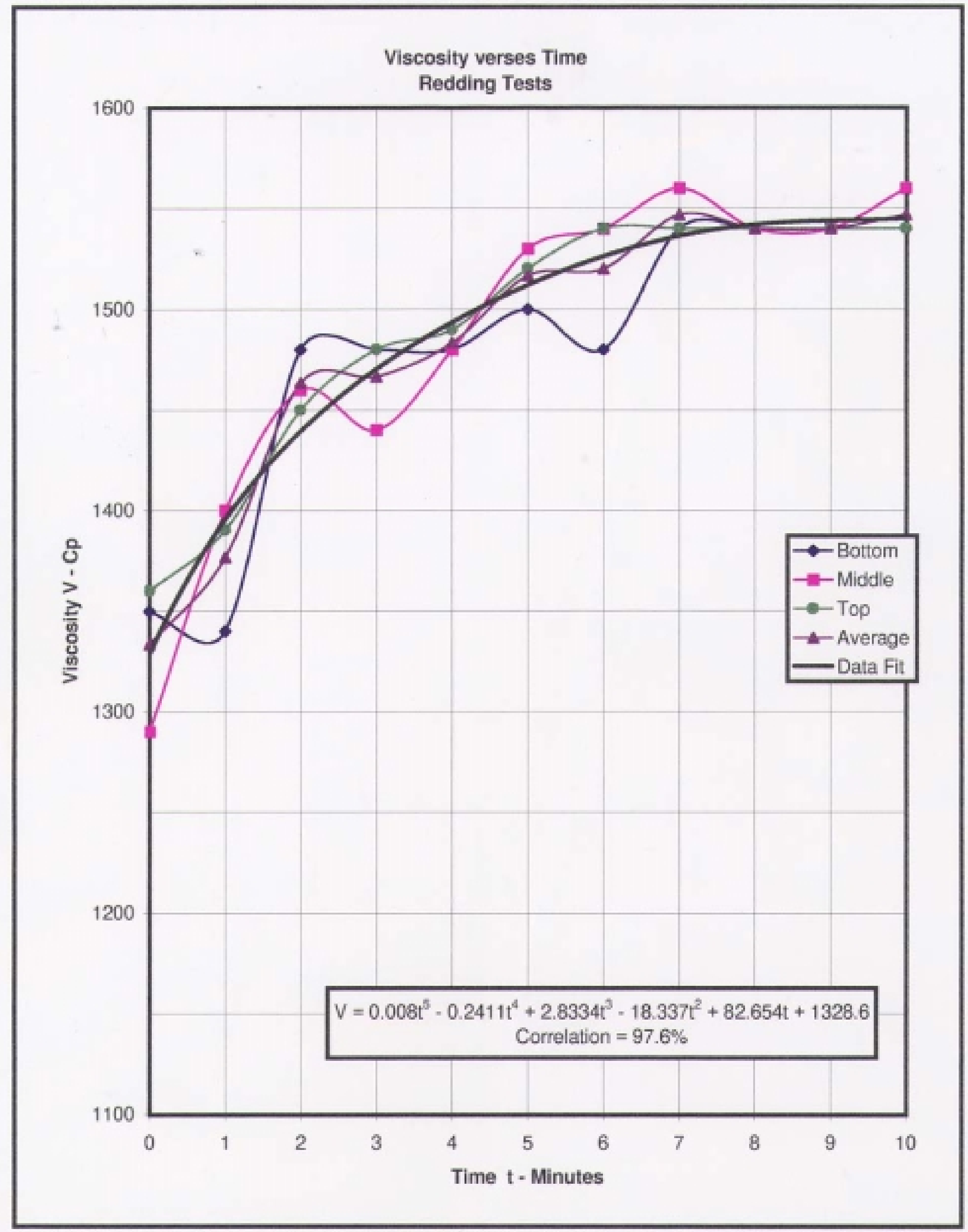
## Mixer System Test Data and Analysis

**Redding Test Data** **9 June 1998** **First Batch**

General (applies to all batches):Product: .............. GTS-R
Specified Specific Gravity Range: ...... 1.087 - 1.107 g/cc
Specified Refractometer Range: ...................... 12.8 - 15.8
Specified Viscosity Range: ....................... 1200 - 1800 cp
Volume per Batch Mixed: ............................ 1325 gallons
Data taken at: .............................................................. 75 °F

| Sample Location | Time Minutes | Density g/cc | Refractometer Salt | Viscosity cp |
|---|---|---|---|---|
| **Top** | 0 | 1.09 | 15.00 | 1360 |
| | 1 | | | 1390 |
| | 2 | 1.089 | 15.00 | 1450 |
| | 3 | 1.088 | 15.00 | 1480 |
| | 4 | | | |
| | 5 | 1.091 | 15.00 | 1520 |
| | 6 | | | 1540 |
| | 7 | 1.093 | 15.00 | 1540 |
| | 8 | | | |
| | 9 | | | |
| | 10 | | | 1540 |
| | 15 | | | |
| | 30 | | | |
| **Middle** | 0 | 1.091 | 15.00 | 1290 |
| | 1 | 1.092 | 15.00 | 1400 |
| | 2 | 1.090 | 15.00 | 1460 |
| | 3 | 1.093 | 15.00 | 1440 |
| | 4 | 1.090 | 15.00 | 1480 |
| | 5 | 1.091 | 15.00 | 1530 |
| | 6 | 1.090 | 15.00 | 1540 |
| | 7 | 1.091 | 15.00 | 1560 |
| | 8 | 1.091 | 15.00 | 1540 |
| | 9 | 1.091 | 15.00 | 1540 |
| | 10 | 1.091 | 15.00 | 1560 |
| | 15 | 1.090 | 15.25 | 1560 |
| | 30 | 1.090 | 15.00 | 1570 |
| **Bottom** | 0 | 1.091 | 15.00 | 1350 |
| | 1 | | | 1340 |
| | 2 | 1.085 | 15.00 | 1480 |
| | 3 | 1.089 | 15.00 | 1480 |
| | 4 | | | |
| | 5 | | | 1500 |
| | 6 | 1.091 | 15.00 | 1480 |
| | 7 | 1.091 | 15.00 | 1540 |
| | 8 | | | |
| | 9 | | | |
| | 10 | | | |
| | 15 | | | 1540 |
| | 30 | | | |

**Total Batches Mixed:10** **Total Gallons Mixed:13,253**


Viscosity verses Time
Redding Tests
Viscosity V - Cp
1600
1500
1400
1300
1200
1100
0
1
2
3
4
5
6
7
8
9
10
Time t - Minutes
Bottom
Middle
Top
Average
Data Fit
V = 0.008t^5 - 0.2411t^4 + 2.8334t^3 - 18.337t^2 + 82.654t + 1328.6
Correlation = 97.6%