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Aerial Application of Evaporation-Reducing Chemicals, Development and Evaluation of Equipment and Techniques

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EVAPORATION-REDUCING CHEMICALS

Development & Evaluation of Equipment & Techniques

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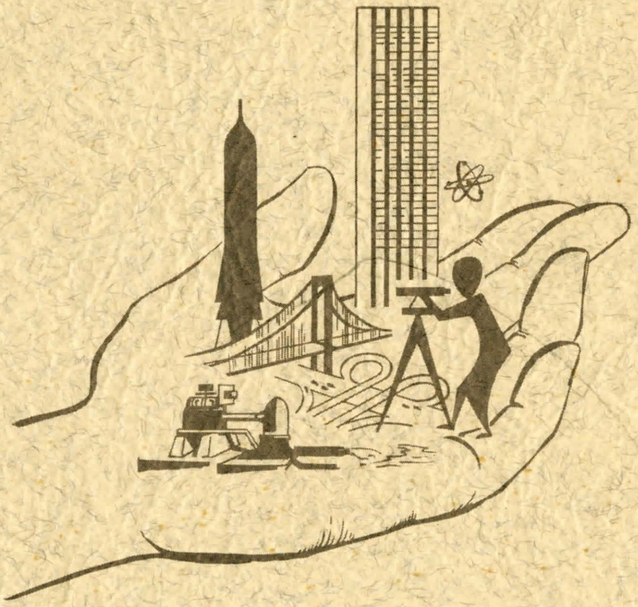

USBR Contract No. 14-06-D-4387

Final Report
to
United States Bureau of Reclamation
Department of the Interior

Prepared by
Engineering Experiment Station
Utah State University
Logan, Utah

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PR-EC47-3

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SUMMARY AND CONCLUSIONS

1. Aerial applications of both liquid and powder evaporation retardants have been made in parallel strips on large lakes for purposes of comparison. Films formed from powder spread more rapidly than did those from liquid, but usually both films ultimately spread to approximately equal widths and had the same degree of compression as determined with indicator oils.

2. Evaporation-retarding materials with large numbers of particles having diameters smaller than 75 microns are greatly affected by the wind. As the chemical is dispensed from the airplane, the fine particles drift with the wind and in some instances are carried onto the land areas surrounding the lakes. Materials with extra large particles are less affected by wind but are not as effective for film formation. Powders and sprays having mean particle-diameters between 75 and 200 microns appear to be desirable for aerial applications.

3. Initial testing with the spray applicator indicated that monolayer film covers could be obtained by applying material at rates between 0.05 and 0.3 lb/acre. The first model of the dust applicator was designed for application rates up to approximately 0.2 lb/acre, calculated for a 500-foot-wide swath. Rates very far below this amount did not consistently produce fully compressed films. Rates slightly in excess of 0.2 lb/acre seemed to produce wider swath widths, but not enough information is available at the present time to recommend an optimum rate of application. An "upper limit" for application rate will be determined in the next series of tests.

4. The detection and repair of breaks in the monolayer film are greatly simplified when aerial means are used. When the chemical is applied from a boat, extra help is usually required to locate the breaks from a high vantage point and to direct the boat to the desired location. Often it is extremely difficult to determine film location from a boat. When aerial applications are made, the pilot is able to do his own observing.

5. As with agricultural crop dusting, application of chemical to water surfaces is best done in the morning and late evening hours. During the hottest part of the day, the air becomes very turbulent, increasing the danger to the pilot when flying low over water, and also increasing the amount of chemical lost by thermal air movements. Aerial applications are best made under the same wind conditions as have been found to be desirable for other methods of application.

6. Flying at low altitudes over large bodies of water is often extremely dangerous. Conventional pressure-type altimeters are not satisfactory for this type of flying, and pilots rely largely on their judgment to maintain safe altitudes. A light weight radio altimeter that may be adaptable for use on light aircraft is currently being investigated.

7. For aerial application of monolayer-forming materials, powder applicators are more desirable than liquid applicators for the following reasons:

a. The powder applicator is quickly and easily attached and removed. This feature permits use of the plane for purposes other than evaporation control. Several hours time are required for installation of the liquid dispensing unit and assembly of necessary ground-support equipment.

b. A lower capital investment is required, since no heating, pumping, or insulation is necessary for the powder dispenser.

c. Extra equipment and labor are required for melting the chemical before it can be used in the spray dispenser.

d. When powder is used the plane can be readied for flight in a few minutes time. Such is not the case when liquid is used. The tank, booms, and nozzles must be preheated to prevent their clogging when the chemical is loaded.

e. Experience has shown that a fire hazard exists while the chemical is being melted prior to loading for spray application. On one occasion a sudden flashback of flames from the melting tank very nearly engulfed one of the workmen. On another occasion the high pressure required for liquid applications caused a gage to fail and filled the cockpit with vaporized chemical. A serious fire could have resulted and destroyed both the plane and the pilot.

f. When spraying, hot water must be kept available to rinse out the equipment after each application. Any molten chemical remaining in the tank will normally be wasted when the equipment is flushed out. The powder dispenser requires no such special care. Using powder will reduce operational costs and will reduce the amount of material wasted after an application.

In the light of experimental work accomplished to date, it is reasonable to assume that monolayer films formed from powder are at least as effective as those formed from liquid. The problem associated with the use of powder is its tendency to lump and to bridge across the outlet from the hopper. Substantial progress has been made in solving this problem, but further refinement in the equipment is needed. From an economic and also from a practical standpoint, the advantages of using a powder instead of a liquid dispenser for aerial applications of hexadecanol outweigh the disadvantages. Further research and testing can surely solve the few remaining problems.

INTRODUCTION

Prior to 1961 evaporation retardants had been applied to water surfaces by various means, including boats, rafts, and automatic dispensers. Generally the cost per pound of applying chemicals by these methods greatly exceeded the cost of the chemical itself.

It became apparent that if evaporation retardants were to be successfully and economically used on larger bodies of water, aerial application equipment would be required. In 1961, under the sponsorship of the U. S. Bureau of Reclamation, Utah State University undertook the task of determining the feasibility of applying evaporation retardants by aerial means. The first year was spent primarily in developing a dispenser that would handle the retardants in a liquid state. The dispenser worked well and decreased application costs sufficiently so that the cost per pound of applying the chemical was approximately equal to the cost of the chemical itself.

It was apparent that flying expenses could not be altered significantly and that any further reduction in cost would have to come in the dispensing unit and in the chemical itself.

Consequently, a decision was made to further refine and test the liquid dispenser and also to develop a unit through which chemicals could be dispensed in powder form.

The following presentation first describes briefly the development of equipment for the aerial dispensing of evaporation-retarding chemicals. A second section describes some of the test applications made to reservoirs and the behavior of the film on the water. The reader should keep in mind that much tedious detail of work has been omitted and that considerable time and effort have been expended in developing and testing various units. Aerial applications were made from time to time throughout the development period for the purpose of checking equipment as modifications were made. Some of these were made over airport runways and some over lakes and reservoirs in the vicinity of the University Laboratories.

EQUIPMENT DEVELOPMENT

Spray Dispenser

Research on improving techniques and equipment for aerial application of agricultural dusts and sprays has been in progress for several years at the University of California at Davis under the direction of Norman B. Akessen and Wesley E. Yates. Similar work, consisting of aerial application of insecticides to forests, has been conducted at the Agricultural Research Center at Beltsville, Maryland, under the supervision of D. A. Isler and Bohden Maksymink. Information gleaned from these two projects through correspondence and a personal visit to Davis, California, decreased considerably the amount of time and the number of tests which were initially thought to be necessary for optimizing aerial spraying equipment to be used with evaporation-retarding chemicals.

Results of tests from these two research centers indicated that the two factors most greatly affecting particle size of aerially applied sprays are aircraft speed and the angle of the nozzles in relation to the direction of flight. The effects of pressure and the size of nozzle opening on droplet size are much less pronounced for aerial spraying than for ground spraying. The tests also indicate that a wide spread of particle sizes is obtained with the use of any particular pressure and nozzle. A change of pressure or nozzle or both will shift the entire range of sizes slightly one way or the other but will not greatly change the spread of sizes.

Figure 1 shows results of a particle analysis performed at Utah State University. The graphs substantiate the results of work performed at the two previously mentioned research centers. The mean-diameter particle size on this test varied from 170 microns to 250 microns, depending on the nozzle-pressure combination and on the method of sampling.

The hot-spray applicator developed during 1961[1] was modified in accordance with the aforementioned test results to improve its performance. The ends of the spray booms were lowered so as to be parallel to the airplane wings. The nozzle placement was left unchanged, but the nozzles were directed forward and down at an angle of approximately 40° from horizontal in the direction of flight. These modifications were made in an attempt to decrease the average particle size and also to minimize drift and loss of material caused by wing-tip vortices. The storage tank, heaters, and pressurizing equipment were modified only slightly.

Material for use in the tests was melted in a large, open, steel drum, using a propane burner as a heat source. When the material had melted, it was transferred to buckets through a spigot and poured into the hot tank in the spray plane. As

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[1] Stringham, Glen E. and Vaughn E. Hansen. **Aerial Spraying Equipment.** Utah State University, Sept. 1961 (Multi)

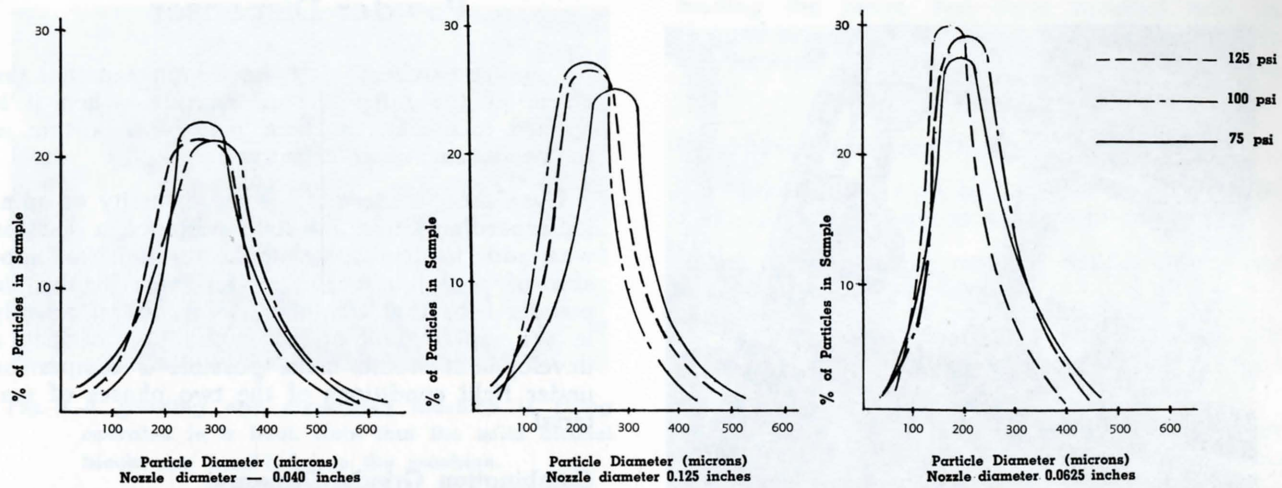

Fig. 1. Size distribution of sprayed particles collected from three different sets of nozzles during flight. Note that varying the pressure and nozzle sizes has very little effect on the size of the particles. The two factors most greatly affecting particle size are aircraft speed and the angle of the nozzles in relation to the direction of flight.

was done during 1961 tests, the material was kept hot in the plane by means of a 20,000 BTU gas heater.

Test runs, using the modified spraying equipment, were made over the airport runways. Early in the tests the shrouds directing hot air around the nozzles were found to require modification to prevent the nozzles from freezing. Several changes were made without securing satisfactory results. Finally the nozzles were directed downward instead of forward and in this position received sufficient hot air to prevent their freezing. The tests were completed with the nozzles in the downward position.

Plastic strips two feet square were placed on the runway at 15-foot intervals normal to the direction of flight, as shown in Figure 2. Nine test-strip applications were made and for each flight, ten samples were collected from the plastic strips in order to make the particle-size analyses (Shown in Figure 1.) Nozzles with 0.040-, 0.625-, and 0.125-inch openings were used, and each was operated at pressures of 75, 100, and 125 pounds per square inch. All applications were made from an altitude of approximately 25 feet.

At the conclusion of the tests, it was necessary to flush the remaining chemical from the tank, booms, and nozzles with hot water to prevent the chemical from freezing in the system.

The spray equipment has been developed for a light aircraft that travelled at a speed of approximately 90 miles per hour during applications. The spray equipment was removed from the small plane and installed in a larger one whose flying speed was approximately 125 miles per hour. Instead of using a single-walled tank and supplying heat from an inside air duct, as was done during 1961, a 90-gallon tank with double walls through which hot air could be circulated was installed. Figures 3 and 4 show the heater, insulated tank, and aluminum shrouding in place.

Fig. 2. Material was sprayed on the plastic strips at the airport and was then collected for making particle-size analyses.

A hydraulic pump which was capable of producing pressures up to 150 psi was installed. On this model, tank pressures of 125 psi, and four 0.125-inch diameter nozzles produced mean diameter particle sizes of 175 microns and an application rate of approximately 0.2 lb/acre for a 500-foot swath.

When nozzles with small openings were used with high pressures, or when clogging occurred, considerable back-pressure was built up in the system. On one occasion the back-pressure became so great that a pump drive-shaft sheared off. Testing was completed using a pressure of 125 psi and four nozzles with 0.125-inch-diameter openings. No further trouble with back-pressure was encountered.

Fig. 3. **A gasoline heater supplies hot air to the shrouded boom and nozzles to prevent their freezing.**

Fig. 4. **Aluminum shrouding directs hot air around the booms and nozzles.**

Powder Dispenser

Some researchers[2, 3, 4] have indicated that the phase of the fatty alcohol mixture, when it is applied to a water surface, may be important in the production of an effective film.

Even though there was some diversity of opinion regarding phase and its importance, a decision was made to develop an applicator that was capable of applying monolayer-forming chemical in powder form that was presumably almost entirely in the rapid-spreading sub-alpha phase. Such a development would make possible a comparison under field conditions of the two phases of material.

Combination Grinder-Dispenser

Considerable success has been achieved by scientists in Australia in applying monolayer-forming materials to small reservoirs from boats with a grinding machine and blower. This machine, developed and patented in Australia, utilizes solid blocks of chemical, and thus eliminates many problems incurred by using either liquids or powders. These small, solid blocks are hand-fed into the machine. A rotating wire brush reduces the blocks to powder and blows the powder through a conduit over the water surface. It was felt that the operating principle of the machine might be incorporated into an aerial dispenser and should be considered.

An equipment inspection trip was made to Pactola Reservoir, Rapid City, South Dakota, where the South Dakota State College was conducting evaporation studies in collaboration with the U. S. Bureau of Reclamation. Their tests involved the use of the aforementioned grinding machine as one of several methods used for applying hexadecanol to the lake surface. Figure 5 shows the unit in operation.

The chemical to be used in the machine was melted and cast into rectangular blocks. After a short curing period, the blocks were ready for use. The blocks were hand-fed into the grinder, the feed rate being controlled by varying the pressure of the blocks on the rotating wire brush. The powder thus produced contained no large lumps; and, when blown onto the water surface, very quickly produced a monolayer film.

The feasibility of using such a machine on an airplane was carefully considered, and the following conclusions were made:

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[2] Kolp, D. G. and E. S. Lutton. "The polymorphism of n-hexadecanol and n-octadecanol" Jour. Amer. Chem. Soc. 73, 5593, 1951.

[3] Stewart, F. H. C. "Phase relationship and spreading behavior of cetyl alcohol mixtures" Austral. Jour. Appl. Sci. 11 (1) 157-168. 1960.

[4] Vines, R. G. and R. J. Meakins "Phase transformation in commercial cetyl alcohols for water conservation" Austral. Jour. Appl. Sci. 10: 190, 1959.

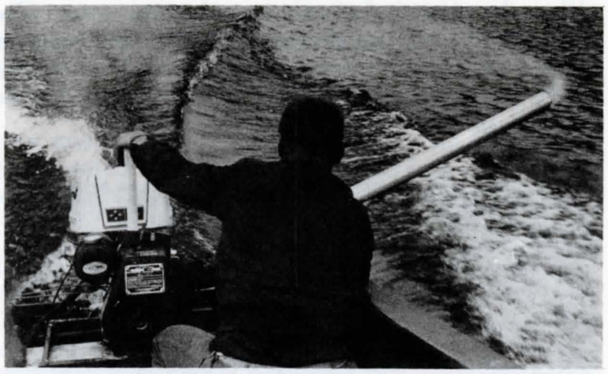


Fig. 5. A grinding and dispensing machine is being operated in a boat. Note that the solid alcohol blocks are hand-fed into the machine.

1. A much larger unit would be required for aerial use. The weight and powder demands of such a unit would be excessive.
2. Conventional crop-dusting aircraft would require considerable modification in order to permit the use of large, solid blocks of hexadecanol.
3. A constant rate of feed would be difficult to obtain with such a unit.
4. The feed rate would be difficult to adjust in flight.

In light of the aforementioned conclusions, no attempt was made to adapt a grinding machine for aerial use.

Agricultural Dust Spreaders

Attempts were made to dispense evaporation-retarding powder through a crop-dusting chemical dispenser. It consisted of a simple venturi section, called a spreader, which was mounted on the underside of an aircraft and was attached to the dust-hoppers. The rate of application was controlled by a sliding gate which was operated from the cockpit by the pilot. However, in agricultural dusting the application rate is normally 20-30 pounds per acre, and a carrier (normally talc) is used with the insecticide. A suitable inert carrier for use with the monolayer-forming chemicals has not yet been found, but, even if one were, its use would add considerable extra weight and decrease the amount of chemical that could be carried.

Agricultural dust-spreaders proved inadequate for dispensing monolayer-forming chemicals, because, when the gates were adjusted for extremely low application rates in the range of 0.05 to 0.40 pounds per acre, the chemical bridged across the gate opening and caused erratic feeding. Also the dust spreaders provided no means for pulverizing lumps that normally existed in the powder. Attempts were made to screen out the lumps before loading the plane, but these resulted only in clogged screens. New lumps were also formed in the material due to vibration of the plane during flight.

Controlled Feed-Rate Dispenser

If powder were to be successfully used, two major difficulties would have to be overcome.

1. Lumps in the material would have to be pulverized or removed.
2. An accurate method of dispensing the powder at low rates would have to be devised.

Experience soon indicated the desirability of developing a positive-feed mechanism for metering the material from the plane. Specifications and prices for a commercial feed control mechanism used on a wheel-mounted crop-duster were obtained and studied. Costs were high, and extensive modifications would be required to adapt the unit to an aircraft. Its use was deemed inadvisable.

An attempt was made to use small-diameter augers installed vertically in the dust hopper for metering the material in controlled amounts. However, the augers were not satisfactory because vibration caused the powder to slide down the flighting and into the airstream even when the augers were not turning.

An auger-type unit seemed most likely to provide the desired control of discharge rate. A five-inch-diameter auger was constructed for horizontal mounting on the underside of the plane's hopper. This unit was tested in the laboratory, using a compressor to supply a high-velocity airstream Powder flowed from the hopper into the auger and was carried to a central opening in the rear of the auger shroud. The powder discharged into an 8-inch diameter steel tube, the exit end of which was screened. A high-velocity airstream flowing through the tube carried the material against the screen where many of the lumps were pulverized. It was apparent, however, that some of the lumps were being retained behind the screen. The round tube was replaced by a rectangular venturi section, shown in Figure 6 to provide a larger area for screening.

The auger was driven by a constant speed 12-vdc motor through a gear reducer by means of a V-belt. Figure 7 shows the unit with the screen in place installed on an aircraft.

During aerial testing, the auger seemed to work well in metering the material from the hopper, but lumpy powder still continued to pile up ahead of the screen during each run. Each time the auger was stopped several seconds elapsed before the last lumps filtered through the screen, resulting in a loss of material between runs, and also in a

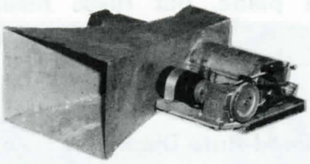


Fig. 6. A motor-driven auger dispenser was developed for use with powdered evaporation retardants.

Fig. 7. The discharge end of the venturi tube was screened in an attempt to pulverize lumps in the chemical.

loss of control of application rate per unit area. The constant-speed motor was undesirable because it prevented variation in the application rate.

Larger percentages of lumps were pulverized in the screened venturi than in the smaller round tube. Indications were that if more screened-area were provided, all of the lumps would be pulverized. Therefore, another dispenser was constructed which had two venturi sections and twice the screened area. The 4-inch diameter auger moved the material in opposing horizontal directions and discharged it from openings in each end of the auger shroud. (See Figure 8)

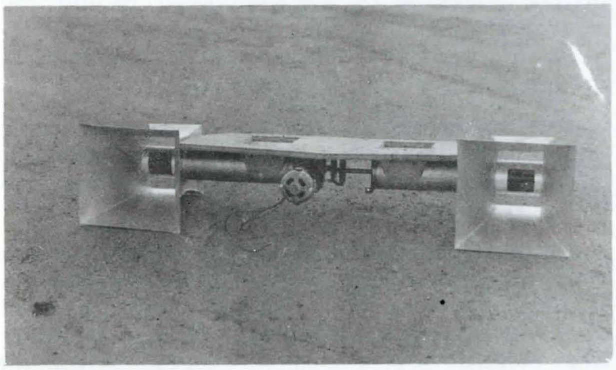


Fig. 8. A double-venturi powder dispenser was equipped with a variable-speed motor for controlling discharge rate.

A variable-speed 115-vdc motor was used to drive the auger through a reduction gear. The pilot could vary the discharge rate of the material from zero to maximum by adjusting a control knob in the cockpit. Fig. 9 shows the double-venturi unit on a dusting plane.

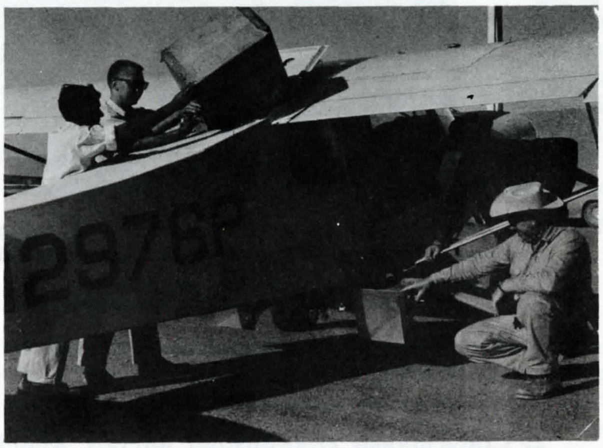


Fig. 9. A dusting plane equipped with the double-venturi dispenser is being loaded.

When tested over the airport the same difficulty was experienced as with the previous models. Smaller amounts of powder were being retained on the screens, but even so, it prevented accurate control of application rate. The venturi sections were replaced with propeller-driven wire flails, shown in Figure 10. The flails were so mounted that the material being discharged passed through the rapidly spinning flails. Most lumps were finely pulverized by the flails.

Sliding doors, to prevent loss of powder from the auger between applications, were also installed on the auger shroud outlets. They were so positioned as to be closed when the auger was not moving, and to open when the auger was turning. The doors were opened by solenoids and were spring-loaded to close at the completion of each run. The solenoids were later replaced by a small reversible electric motor.

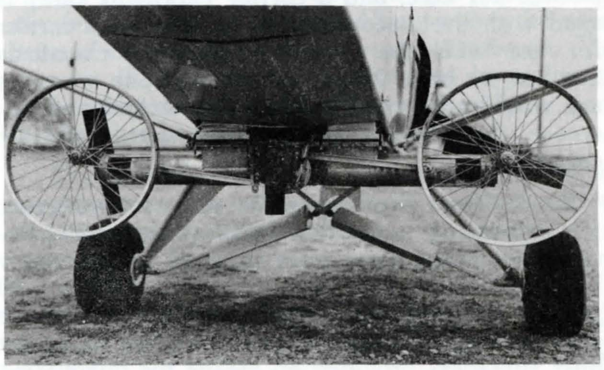


Fig. 10. Propeller-driven heavy-duty wire-spoked wheels serve as flails for pulverizing lumpy powder.

The control switch for the doors and auger was mounted in the cockpit so that the pilot could, with a single movement, open the doors and start the auger or close the doors and stop it.

The dispensing unit was tested in the laboratory and over the airport runway. (See Figure 11) It operated very well during application of test-strips to a large reservoir.

However, some difficulty was experienced with the material bridging in the hopper. An air scoop was installed in the lid of the hopper and was directed forward in the direction of flight. This air scoop served to partially pressurize the hopper and minimized the problem of bridging. Experience indicated the need for intercommunication between the application plane and the ground observers. Consequently a 2-way citizens'-band radio was installed in the dusting plane, and three portable units were obtained for use at observation stations and in boats.

Fig. 11. The improved flail-type dust dispenser was tested over an airport runway.

Observations Regarding Equipment

Spray Dispenser

1. Installation of the spraying equipment on a plane requires several hours time, thus eliminating the possibility of using the plane for other dusting or spraying projects during the evaporation season.
2. Presence of a gas heater in the cockpit of the plane presents a definite fire hazard.
3. The tank, booms, and nozzles must be heated before the chemical is loaded or it freezes in the system.
4. The molten chemical must be filtered before it is loaded into the plane to remove foreign particles that may clog the nozzles.
5. Hot water should be flushed through the spraying equipment at the completion of each application thus preventing excess material from freezing in the system.
6. As far as dispensing is concerned, the previous history of the chemical material is unimportant because it is all melted to the same consistency before it is used.
7. Extra labor and equipment are required to keep a supply of molten chemical and hot water available for the spraying operation.
8. A fire hazard exists when the chemical is being melted. On one occasion a sudden flashback from the melting tank nearly engulfed one of the workmen as he was adding more chemical.

The spraying equipment herein described has been used efficiently for several large-scale applications. Equipment refinements can still be made but no major modifications are anticipated. At a flying speed of 125 miles per hour using four 0.125-inch-diameter nozzles with 125-psi tank pressure, the application rate calculated for a 500-foot-wide swath is 0.2 lb/acre.

Powder Dispenser

1. The powder dispenser is quickly and easily attached to conventional crop-dusting aircraft, which permits use of the plane for purposes other than evaporation control.
2. When the powder dispenser is used the plane can be made ready for flight in a few minutes time.
3. The pilot can also load his own plane, thus eliminating the need for extra labor and equipment.
4. The use of powder is relatively safe because no pressurizing or heating equipment is required on the plane.
5. Powder remaining in the hopper can normally be left there for the next application without adverse effect.

Powder dispensing equipment designed and used thus far has been quite satisfactory. However, the following program of testing and equipment modification is recommended for the successful completion of the development program.

1. To eliminate bridging of powdered materials in the hopper the following possibilities should be considered.
    a. Use of a different diameter auger.
    b. Installation of a hopper in the plane that has a single wide-feed opening instead of a conventional double opening.
    c. Installation of an agitator in the hopper directly above the auger.
2. Install a more powerful motor or a hand-operated mechanism for opening and closing the doors.
3. Provide equipment that will cover a wider range of application rates to facilitate the determination of an optimum rate.
4. When an optimum rate has been determined by making test-strip applications, eliminate the inverter and motor control and use aircraft power directly to operate the mechanism. Eliminating the variable feed-rate dispenser will decrease weight and cost, making the unit more efficient.
5. Field-test the modified dispensing unit by using it for a sustained application of at least two weeks duration.

MONOLAYER APPLICATIONS

Many of the applications made to reservoirs during 1962 were made for the sole purpose of testing dispensing equipment, and therefore, only nominal data were collected regarding film behavior or effectiveness. The following presentation will describe briefly the equipment tests that were made on which film-strip behavior data were collected.

Liquid Applications

Many of the behavior studies of films formed from liquid are outlined in the report of the 1961 tests. Some modifications were made in the earlier equipment to improve its performance, and it was then transferred to a larger aircraft. It was deemed necessary to conduct further tests using the modified equipment on a larger aircraft before it was used for a sustained application.

Several different brands of evaporation-retarding chemicals were used in testing the liquid dispenser. All were melted in steel drums by applying a flame underneath, and no difference was noted in their behavior.

Utah Lake

Test strips were applied in a north-south direction and were approximately three miles long. Applications were made parallel to one another from an altitude of approximately 50 feet above the water surface. A boat equipped with a 2-way radio was on the lake to obtain temperature and wind measurements.

The first test strip was applied using four 0.125-inch diameter nozzles with a tank pressure of 125 psi. The water temperature was 65°F, and the temperature of the air above the water was 89°F. Wind velocity was less than 3 miles per hour. One minute after the chemical was applied the film strip was visible from the air. Eight minutes later the strip had spread to a width of 250 feet, and after 24 minutes to a 500-foot width. The film strip was very distinct.

A second strip was applied using four 0.0625-inch diameter nozzles and 125 psi pressure. Approximately six minutes elapsed before the strip was visible from the air. One hour later it had spread to a width of approximately 400 feet but its edges were very ragged, as can be seen in Figure 12.

Fig. 12. The film strips shown are approximately three miles long. The strip on the left was applied at a rate of 0.14 lb/acre and the right strip at a rate of 0.20 lb/acre.

Four 0.040-inch diameter nozzles were installed; and, using 125 psi pressure as before, an attempt was made to apply a third test strip. The small nozzles and high pressure resulted in so much back-pressure that it broke the pump drive shaft, and the application was discontinued.

The tests on Utah Lake indicated that, if small nozzles were to be used, they would either have to be increased in number or another liquid bypass valve would have to be installed in the system to prevent failure of the pump drive shaft. However, because the 0.125-inch diameter nozzles worked well and produced good film strips, it was decided to test them further by using them for a large-scale coverage operation at Elephant Butte Reservoir, New Mexico.

Elephant Butte Reservoir

Details of film behavior will be presented in a report to be published by the Bureau of Reclamation.

The first three applications made to the approximately 8000-acre reservoir were of liquid evaporation retardant. A pressurized kerosene burner provided the heat which circulated through a 250-gallon drum to melt the material. (See Figure 13)

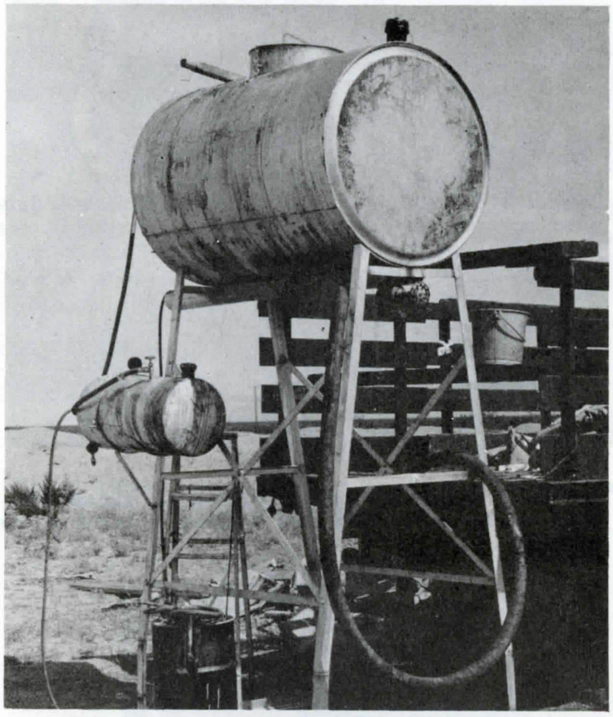


Fig. 13. Flaked evaporation-retarding chemical was melted in a large steel drum using kerosene-fueled burner for heat.

A separate compartment was provided at one end of the tank wherein water was heated for flushing out the spray equipment after each day's application. Because the heating conduit was located a few inches above the floor of the tank, some difficulty was experienced with material solidifying and adhering to the floor. An auxiliary propane burner was placed in a shroud with its flame directed at the underside of the tank and no further "freezing" occurred. When the material was completely liquified, it was transferred to the tank in the spray plane by means of a long flexible hose as shown in Figure 14. Figure 15 shows a propane torch being used to heat the booms and nozzles prior to each day's application, thus decreasing the waiting time for loading the liquid onto the plane.

While applying the last load of the first day's application, a shaft vibrated loose in the plane's hydraulic system. A replacement part was not available locally and had to be ordered from Los Angeles. This resulted in a one-day delay in the schedule, but no further shaft difficulties were encountered throughout the tests.

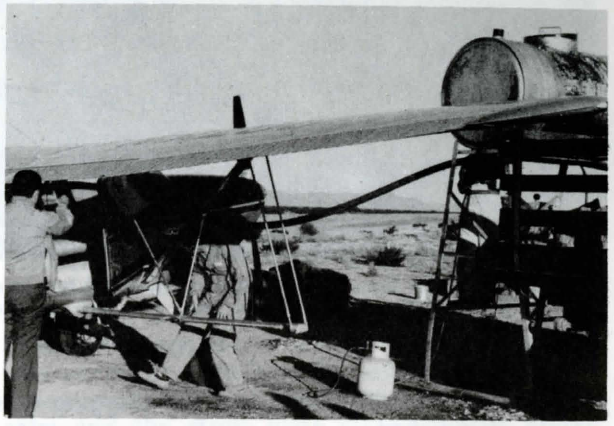


Fig. 14. Molten evaporation-retarding chemical was transferred from the melting tank to the airplane through a flexible conduit.

Fig. 15. Time required for pre-heating the booms and nozzles was decreased by supplementing the aircraft heat with heat from a propane torch.

Considerable difficulty was experienced with plugging of the nozzles. An aerial view, Figure 16, shows the spray plane operating with one nozzle plugged.

Investigation showed the responsible particles to be slag from the welded melting tank, and also pieces of solder from the storage tank in the airplane.

Henceforth, the hot liquid was filtered through a sieve of wire-mesh and cheesecloth before it

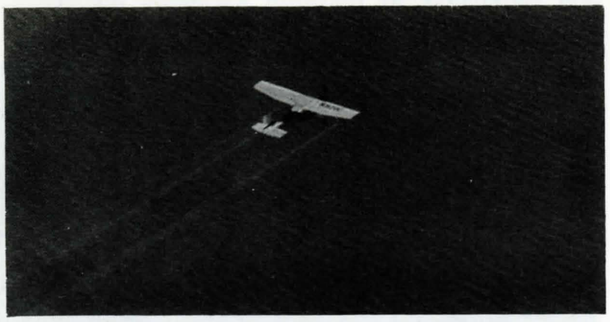


Fig. 16. Slag from the melting tank occasionally got into the system and plugged one or more of the nozzles.

was loaded into the plane, and the clogging was greatly diminished.

No major problems were encountered in applying the liquid retardant to the reservoir. Flying conditions were generally favorable during the morning hours and became less favorable during the heat of the day. All applications were made from an altitude of approximately 50 feet above the water surface. (See Figure 17)

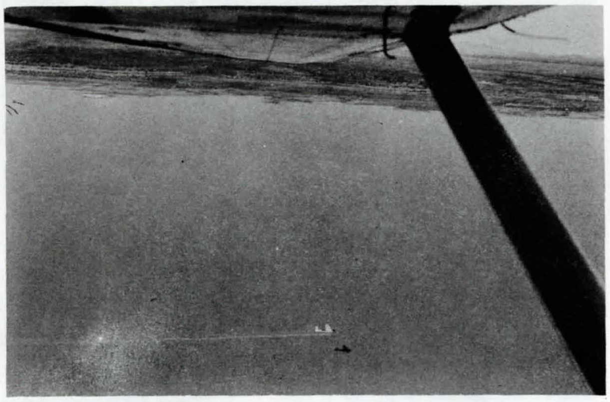
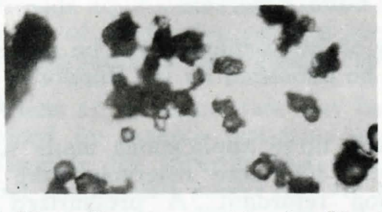


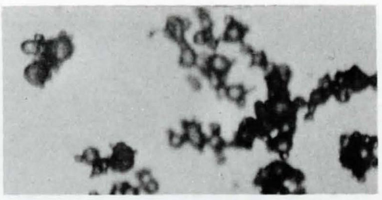
Fig. 17. Chemical applications were made to the water surface from an altitude of approximately 50 feet.

Four 0.125-inch diameter nozzles were used throughout the test at a pressure of 125 psi. The nozzles were directed downward, and all other configurations were as described for earlier tests. Applications were made at a speed of 125 mph, which resulted in a coverage rate of approximately 125 acres per minute at 0.2 lb/acre for a 500-foot swath.

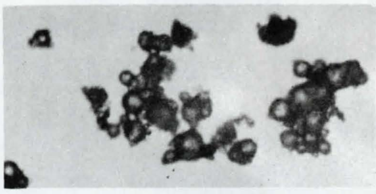
During the last day's applications, the pressure-indicator gage blew off, and immediately the cockpit was filled with vaporized spray material. The pilot was fearful of fire or of an explosion but fortunately neither occurred. He returned immediately to the airport and the gage-hole was plugged to complete the application.



Powder A. Mean-diameter particle size 58 microns. Supplied commercially. Lumping occurred in the material, and it was quite greasy to the touch.

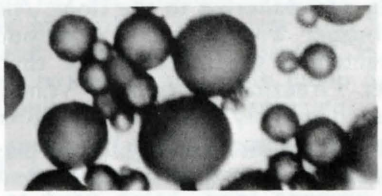


Powder B. Mean-diameter particle size 57 microns. Supplied commercially. Severe lumping occurred in the powder during storage and shipping.



Powder C. Mean-diameter particle size 45 microns. Supplied commercially. Very little lumping occurred in this material.

Powder D. Mean-diameter particle size 85 microns. This material was supplied commercially in flake form, cooled to from 25° to 35°F and then ground in a pulverizing machine as shown in Fig. 19. It emerged from the machine at a temperature of from 75° to 85°F. Some of this powder was transported in a station wagon in 50-pound bags for a distance of 800 miles and no objectionable lumping occurred.



Powder E. Mean-diameter particle size 105 microns. Flaked hexadecanol was melted and sprayed through small-diameter nozzles into the closed container shown in Fig. 20. The sprayed particles were cooled with air from an evaporative cooler and were collected as dry powder for use in the tests.

Fig. 18. Photomicrographs and descriptions of evaporation-retarding powders tested during 1962.

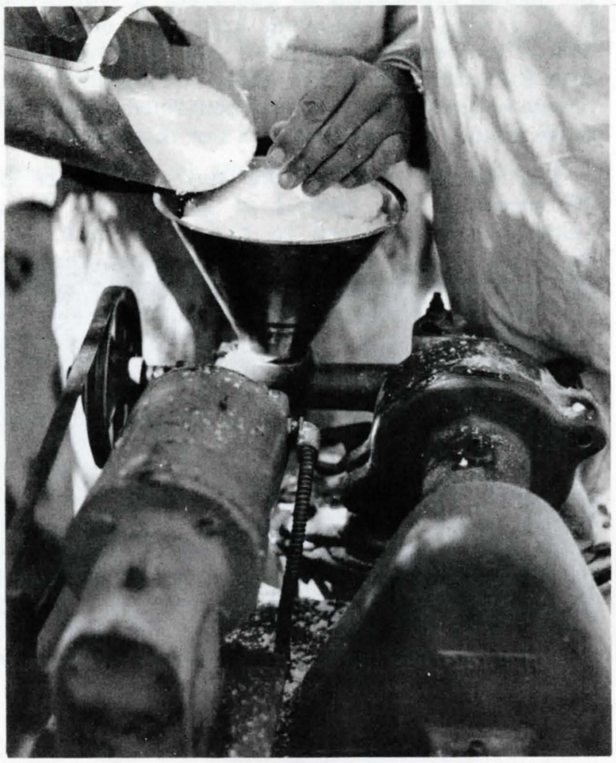


Fig. 19. **Flaked hexadecanol was ground to a fine powder in a pulverizing machine.**

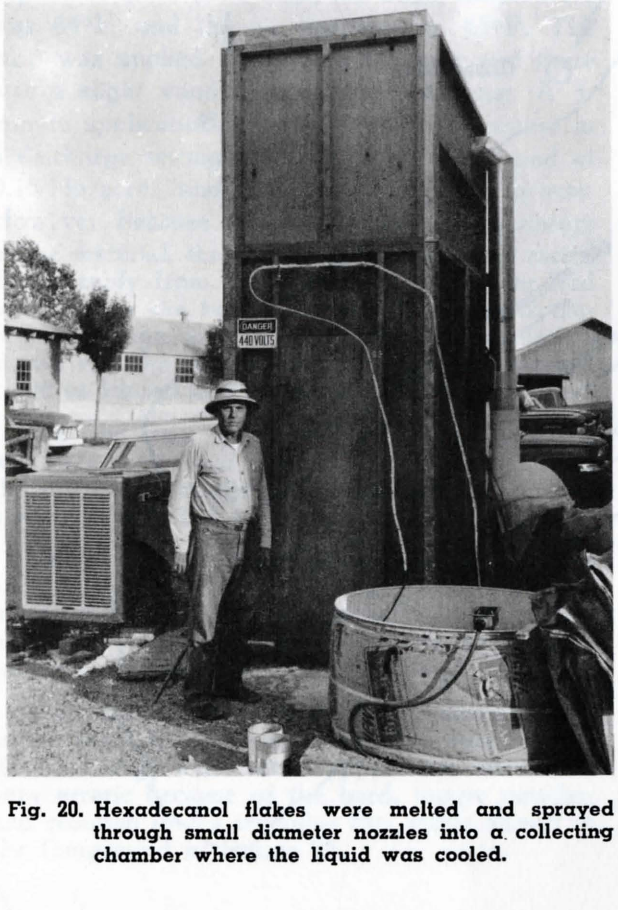


Fig. 20. **Hexadecanol flakes were melted and sprayed through small diameter nozzles into a collecting chamber where the liquid was cooled.**

Three complete lake-coverages were made with approximately 1100 gallons of the liquid retardant.

Powder Applications

Several different brands of powdered evaporation retardants were used to determine whether or not differences of behavior existed in the dispenser or on the water surface. A brief description of the five powders used is given in Figure 18.

Hyrum Reservoir

Preliminary strip-applications were made to Hyrum Reservoir, located 10 miles south of Logan, Utah. The surface area at the time of the application was approximately 300 acres. Test-strips were applied to assure that the dispenser was operating satisfactorily before any measurements were made of film behavior. The air was calm and the strips were clearly visible from a selected observation post, as can be seen in Figure 21.

Forty minutes after they were applied the film strips had drifted to the far side of the lake, as shown in Figure 22.

Fig.21. **Film test-strips applied to Hyrum Reservoir were clearly visible from the shore.**

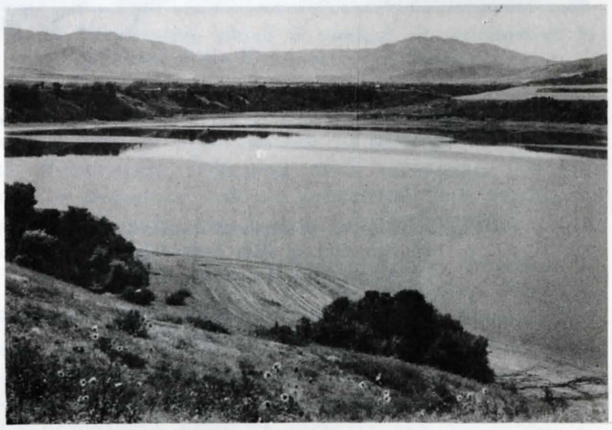


Fig. 22. **Hexadecanol strips applied to Hyrum Reservoir show as clear reflective surfaces.**

A radio base-station with a ground-plane antenna was set up at an observation post adjacent to Hyrum Reservoir. A radio-equipped boat was on the water, towing an empty oil can at the end of a 75-foot rope to serve as a scale for measurement. Excellent inter-communication existed between the plane, the observers, and the boat operators. No trace of the previous day's test applications could be visually detected.

Three strips were applied in an east-west direction the full length of the reservoir, as indicated in Figure 23. The first was Powder A (58 microns), the second was Powder B (57 microns), and the third was Powder C (45 microns). The first half of each strip was applied at a rate of approximately 0.15 lb/acre and the second half at 0.20 lb/acre. All applications were made from an altitude of approximately 50 ft. above the water surface.

The first strip (Powder A, 58 microns) was applied at 10:06 a.m. and four minutes later had spread to a width of 100 feet. Fifteen minutes after the applications were made, the light application had spread to a width of 350 feet and the heavy application to 500 feet. A wind from 5 to 7 mph was blowing from the northwest. Water temperature was 63°F and air temperature over the water was 47°F. Forty-five minutes after it was applied, this strip still contained very small particles of material that had not dispersed.

The second strip of the series (Powder B, 57 microns) was applied at 10:41 a.m. Wind velocity had increased to nearly 10 mph, and drift of material was more pronounced than on the first strip. Four minutes after being applied the light application at the east end of the reservoir had spread to a width of 200 feet and the heavy application at the west end to 250 feet. The film spread very rapidly for about 5 minutes and reached its maximum width of 500 feet in about 10 minutes.

Strip 3 (Powder C, 45 microns) was applied at 11:15 a.m. Air temperature was 51°F, and water temperature was 64°F. The 10 mph wind caused considerable drift of this very fine powder and as a result the film was spotty and erratic. However, a continuous film strip did form and later joined with the others and lost its identity.

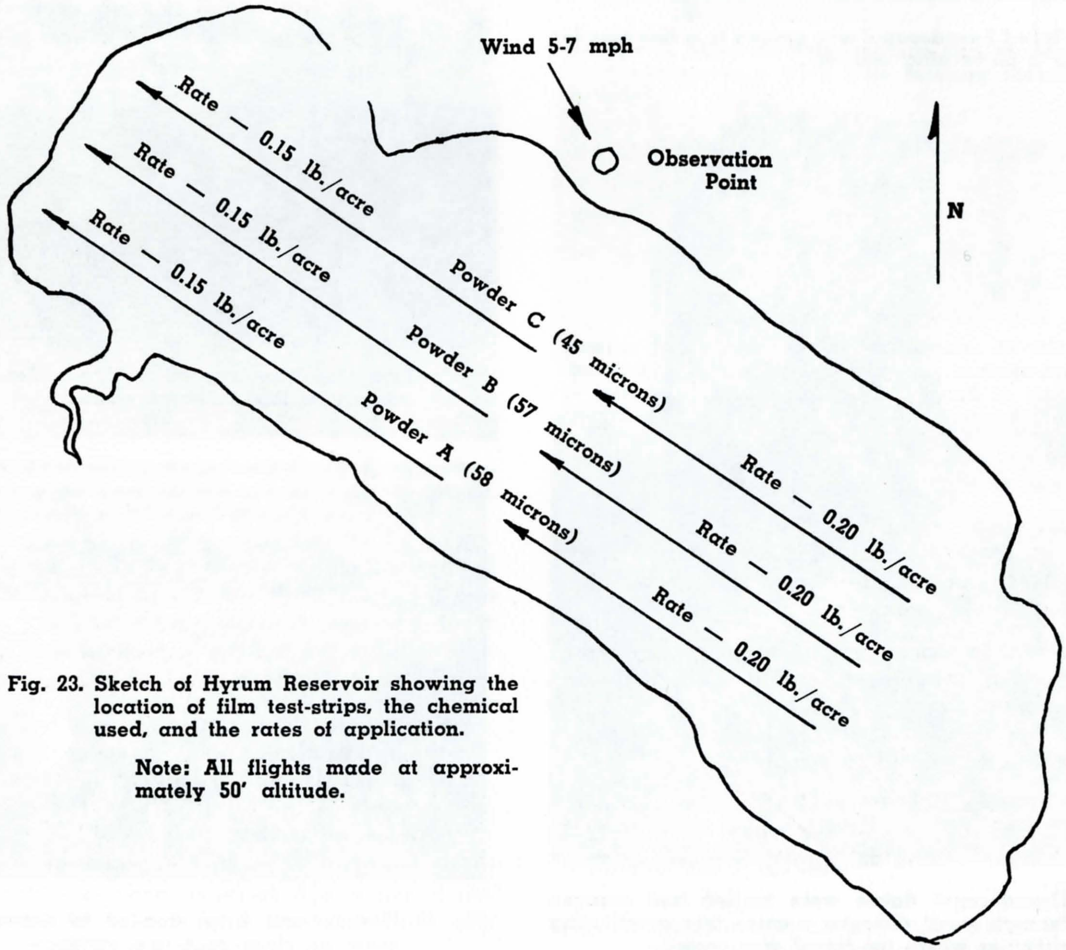


Fig. 23. Sketch of Hyrum Reservoir showing the location of film test-strips, the chemical used, and the rates of application.

Note: All flights made at approximately 50' altitude.

The wind prevented extended comparison of the results. However, because the wind changed direction a time or two during the test, an almost complete film coverage of the reservoir was obtained. It remained for several hours as a spectacular reflective surface, shown in Figure 24.

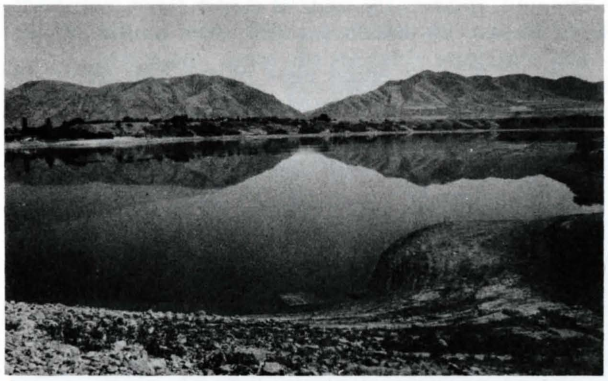


Fig. 24. With the film cover nearly complete, Hyrum Reservoir appears as a mirrored surface.

Utah Lake

A test strip of Powder B (57 microns) was applied ot Utah Lake when the water temperature was 64°F, and the air temperature, 65°F. The strip was applied from south to north and there was a slight wind blowing from the east. A 3-minute application was made, the first minute at a discharge setting of 0.2 lb/acre, the second at 0.15 lb/acre, and the third at 0.10 lb/acre. However, because of the extremely lumpy nature of the material, the actual application rates varied considerably from the settings. The powder had solidified in the barrel, apparently owing to improper storage, and had to be chipped out with a shovel and the largest lumps broken up before it could be loaded into the plane.

The film strip began to show immediately but was very spotty and erratic. Fifteen minutes after the strips were applied, the heavy application had spread to only 175 feet.

An observer in a boat reported seeing numerous small hard lumps about the size of quarters floating on the water surface 15 minutes after the application. Apparently many of these hard lumps contributed very little to film formation.

A second strip of Powder B (57 microns) was laid parallel to the first at the same rates of application. Again the actual application rates were very erratic because of the hard, lumpy powder, and resulted in the irregular film strips shown in the foreground in Figure 25.

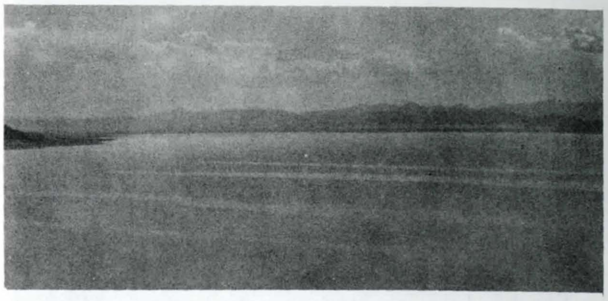


Fig. 25. Utah Lake approximately five minutes after the second strip of powder was applied. The two strips in the foreground are powder and the other two are liquid.

Film strips are approximately three miles long. The third strip in the background was applied as a liquid at a rate of 0.2 lb/acre and has spread to a width of approximately 500 feet. The farthest strip was also applied as a liquid at a rate of 0.14 lb/acre.

Elephant Butte Reservoir

Powder applications were made at a speed of approximately 100 miles per hour from an altitude of approximately 50 feet above the water surface. The coverage rate calculated for a 500-foot-wide swath and an application rate of 0.2 lb/acre was 100 acres per minute. Figure 26 shows the dusting plane in operation over the lake.

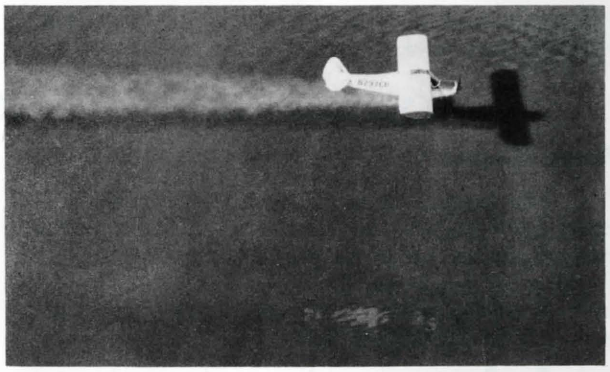


Fig. 26. The dusting plane is making an application to Elephant Butte Reservoir, New Mexico.

Two complete coverages of the lake were made with a total of 3500 pounds of powder. Two days of observation followed each coverage. Details of film behavior will be presented in a report to be published by the Bureau of Reclamation.

An attempt was made to apply Powder C (45 microns), Powder D (85 microns), Powder E (105 microns), and the liquid (220 microns) in four parallel strips on Elephant Butte Reservoir for purposes of comparison. Figure 27 is an aerial photo taken during this application. Note that the downwind edge of each of the two strips is very ragged because of a cross-wind that was blowing.

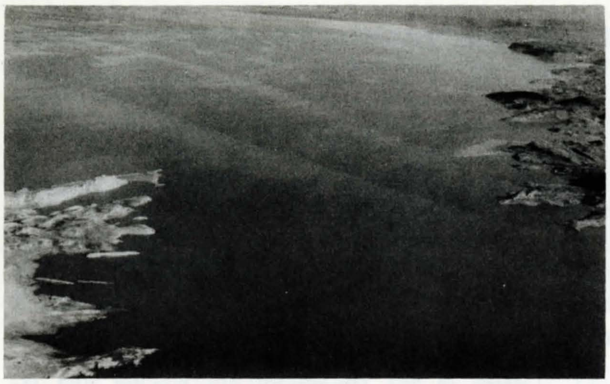


Fig. 27. A cross-wind made the two film strips appear ragged.

The other patches of film that can be seen in the picture remained from an application made two days earlier.

The film strips formed from the three powders spread faster than did the film strip from the liquid. However, further comparative tests on a clean lake surface should be conducted because numerous patches of film existed on the water surface from previous applications and made the results hazy.

A repeat application was made on Caballo Reservoir, a reservoir about 30 miles south of Elephant Butte. The test was excellent. Conditions for application were ideal, radio contact was good. Pictures and observations will be reported by the U. S. Bureau of Reclamation. A motor boat towing a marker, which assisted materially in determining film strip widths, was on the reservoir.

Little difference was noted in the rate of spread of the three powders. The films from the powders spread at a more rapid rate than that from the liquid, but ultimately all films spread to approximately equal widths. Some film patches were present on the reservoir when the tests were made. They had apparently drifted down from Elephant Butte Reservoir, which was 30 miles to the north.

Figure 28 is an aerial view of the film strips on Caballo Reservoir, New Mexico.

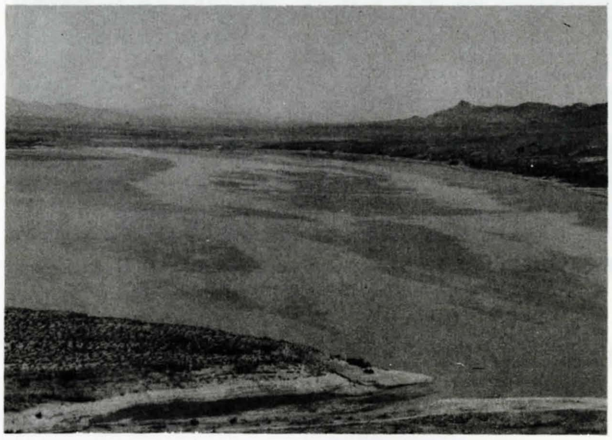


Fig. 28. Parallel strip-applications of powders and liquid were made to Caballo Reservoir for purposes of comparison.

OBSERVATIONS OF MONOLAYER APPLICATION

Spray Dispenser

1. The heated, pressurized spray dispenser has been used successfully for applying evaporation retardants to large reservoirs. Operational difficulties are minimized by using nozzles with 0.125-inch-diameter openings to prevent excessive back-pressure in the spray tank.

2. Smaller size particles can be produced by angling the nozzles forward into the direction of flight. However, angling the nozzles forward makes shielding them from cold air more difficult.

3. The shrouds should be relocated to supply equal amounts of hot air to both booms.

4. A drain should be installed in the bottom of the liquid tank so that excess material can be collected without having to pump it out through the nozzles.

5. An adequate bypass valve in the hydraulic system would prevent shearing of the pump drive.

6. Because of the extra expense of operation and the fire hazards involved, no further development of the spray dispenser is anticipated at this time.

Powder Dispenser

1. The electric motor used for controlling the sliding doors on the powder dispenser was inadequate and should be replaced with a larger motor or hand-operated mechanism.

2. Occasional bridging of the powder in the hopper occurred in spite of a pressurizing air vent in the lid. Powder E (105 microns) was especially susceptible to bridging because it had apparently taken on some moisture from the evaporative cooler during its preparation. The bridging sometimes resulted in erratic feeding of the chemical. On two or three occasions, the trouble could not be corrected by the pilot during flight, and he had to return to the airport to clean the hopper.

3. A flexible rubber drive shaft, which turns the auger, was twisted off during an application. Within a few minutes time, a replacement was made at the airport, and no further difficulties were encountered.

4. Very little difference existed in the ease of handling of the three powders. They were dispensed separately and also as a mixture, and all seemed to produce good film covers.

SUGGESTED FUTURE ACTIVITY

Flaked hexadecanol supplied by the U. S. Bureau of Reclamation to Utah State University under Contract No. 14-06-D-4387 has been ground to powder for use in further tests. It is recommended that the following development work be completed prior to making any large-scale sustained applications.

1. Make test-strip applications on a large reservoir, using the variable feed-rate powder dispenser developed under Contract No. 14-06-D-4387, with modification as deemed necessary. The purpose would be to determine the optimum combination of mean particle size, dispensing rate, aircraft speed, and altitude for the efficient and effective use of powdered evaporation retardants. Measurments would also be made of the effects of water and air temperatures on the film-spreading rate. The strip-testing should begin early to determine the effect on film behavior of extremely cold water.

2. Develop or procure a reliable, low-cost altitude control device for use on small aircraft, and field-test it. An existing commercial unit is being investigated and appears to be adaptable.

3. When optimum dispensing rates have been determined for various flying speeds, assemble a powder dispenser for use on sustained applications that employs only the optimum rates. Such a unit will weigh less and will be much less expensive than the variable-rate unit needed for the test-strip application.

4. Make a sustained application on a suitable small reservoir for a period of 2 to 3 weeks, using the modified powder dispenser, for the following purposes:

   a. To extensively field test the modified dispenser and to make necessary changes in preparation for its commercial use.

   b. To obtain field data on the cost of application under conditions of sustained application.

   c. To estimate actual evaporation savings resulting from the sustained application.