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# EVALUATION OF THE NITROGEN-INJECTION SYSTEM FOR MIXING GELGARD FIRE RETARDANT IN THE PBY CANSO WATER-BOMBER

by

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## INTRODUCTION

The numerous lakes and rivers in many parts of Canada's forested regions favor the use of float-equipped and amphibious water-bombers for aerial suppression of wildfires. Water is the primary fire retardant used in these operations. The effectiveness of water can be improved by the addition of a thickening agent which increases 1) the amount of load reaching the ground, 2) the thickness of the retardant film retained by the fuels, and 3) the time and fire energy required to vaporize the retardant. Since the aircraft fills its water tank(s) or floats while skimming the water surface, an agent is required which, when added in small amounts with brief agitation, forms a viscous solution in a short period of time.

To date, GELGARD is the only water-thickening agent suitable for use with skimmer-type water-bombers. Utilization of GELGARD in this capacity became feasible with the development of the nitrogen-injection system, which permits introduction and mixing of the material in the water tank during water pickup.

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The PBY Canso operating in the northern part of Alberta is equipped with such a system. Reports from field personnel and observation of airdrops on wildfire operations indicated that GELGARD retardant mixtures were very inconsistent; at times the mixtures were little more than water. As a result, a study to evaluate the nitrogen-injection system and determine the causes of the mixture inconsistency was conducted in co-operation with the Alberta Forest Service in August, 1968.

## GELGARD FIRE RETARDANT

GELGARD is a synthetic organic polymer in insoluble powder form that can absorb water in amounts 100 to 1,000 times its own weight. At low concentrations, the polymer forms a two-phased system by distributing gelled particles throughout the liquid phase. Mixture viscosity remains low until the particles reach a concentration of about 0.05 per cent, then quickly rises. GELGARD mixtures develop 80 per cent of their final viscosity within two minutes, and reach final viscosity within 5 minutes (Anon., 1967).

Viscosity is greatly influenced by water hardness or impurities. Very hard water may require as much as 3 times the amount of powder as very soft water to achieve a given viscosity. Temperature of water also affects the amount of GELGARD powder required. As water (or air) temperature becomes lower, mixtures thicken more slowly but eventually reach a higher viscosity. One to 3 pounds of GELGARD powder is needed per 100 U.S. gallons of water (0.01 - 0.03 lb/gal) depending on hardness and temperature of water (Anon., 1967). The addition of GELGARD has no effect on freezing or boiling points of water.

GELGARD, a short-term retardant, relies entirely on the water it contains to prevent combustion. Once the water is evaporated the retardant action ends. The product comes in two forms: GELGARD M is colorless and recommended for use in ground tankers and other equipment where color is not necessary; GELGARD F IMPROVED, designed primarily for drops from aircraft, has Carmine 2B dye added for visibility.

## PBY CANSO WATER-BOMBER

The PBY Canso is a twin-engined, high-winged amphibious aircraft. Its load capacity is 800 imperial gallons, held in two 400-gallon internal tanks. The tanks are filled through a probe which is lowered while the aircraft is skimming the water at 85 to 90 knots. Loading time varies between 12 and 17 seconds, and depends on speed and weight of the aircraft and wind conditions. Loading distance is about 1,600 feet. Cruising speed of the aircraft loaded is 120 knots and drop speed is approximately 95 knots. Figure 1 shows a PBY Canso releasing an 800-gallon load of GELGARD M retardant mixture.

## NITROGEN-INJECTION SYSTEM

GELGARD is stored in two upright cylinders, each of which contains up to 150 pounds of powder. Nitrogen pressure in the cylinders is maintained at 30 psi. A flexible rubber hose runs from each cylinder

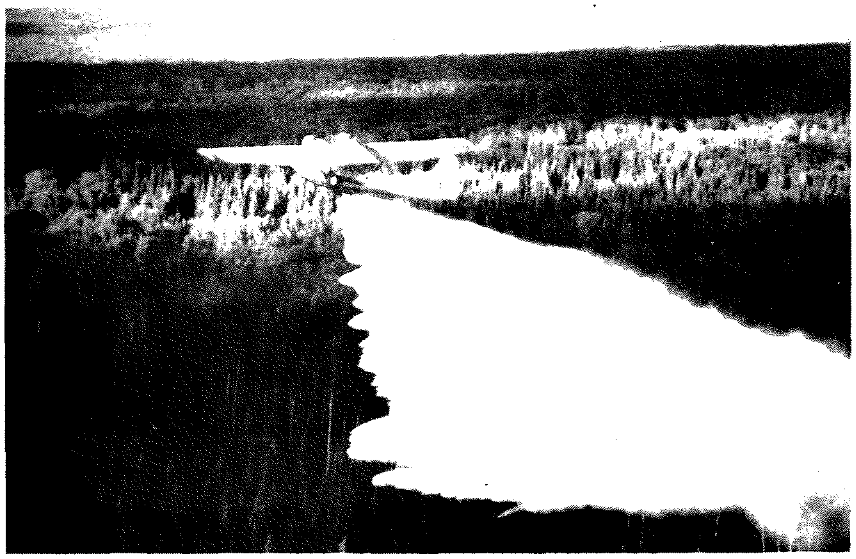

Figure 1. PBY Canso water-bomber releasing an 800-gallon load of GELGARD retardant mixture.

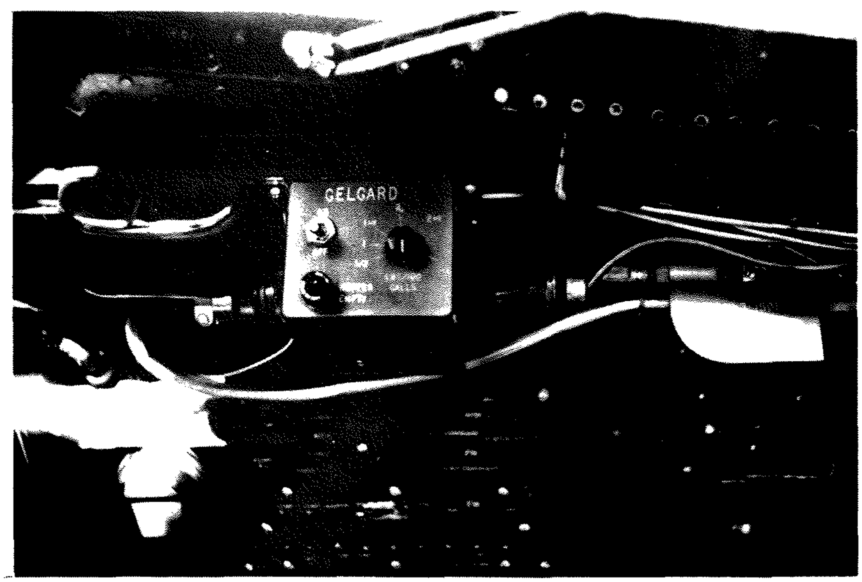


Figure 2. Dial for selecting quantity (pounds) of GELGARD powder per 100 gallons of water. Dial is set on 3½ lb/100 gal. water.

to a 400-gallon water tank. The GELGARD is introduced through a pencil-sized orifice located at the mid-rear of each tank. The amount of powder desired per 100 gallons of water is selected by the co-pilot (Fig. 2) before loading, which commences when the water pickup probe is lowered. Pressure from the water activates a switch and the desired amount of GELGARD is injected into each tank. Another switch which maintains the nitrogen pressure in the cylinders is also activated. Approximately 2 seconds are required to inject ½ to 1 pound GELGARD per 100 gallons water (lb/100 gal); about 12 seconds are required for 3½ lbs/100 gal water. The co-pilot retracts the probe when the mixture becomes visible in the two windows located at the top-front of the water tanks.

## PROCEDURES

Mixing tests were carried out at Slave Lake, Alberta. Water was picked up from two sites, one a deep channel with water temperature less that 50°F and the other a shallow bay with water temperature 60° to 70°F. Mixtures were prepared by injecting 1,2,3 and 3½ lb GELGARD M/100 gal water[2]. Viscosity of the GELGARD mixtures was to be measured with the Marsh funnel five minutes after mixing. However, the inconsistency of the mixtures and presence of impurities, i.e., weeds, grass, etc. prevented meaningful measurements from being obtained. References to viscosity, which follow, are from visual assessment.

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[2] The use of GELGARD F was discontinued in water-based operations during 1967 after it was discovered that balls and/or flakes of dye and opaque filler used to color the powder were plugging the injection hoses and orifices.

Five ounces of Rhodamine 2B pink analine dye were added to each water tank before and after mixing to test the dye as a coloring agent for GELGARD M. Visibility of the drop areas was checked after each release.

## RESULTS AND DISCUSSION

Viscosity of the GELGARD M mixtures obtained during the tests was highly variable. This inconsistency was due to the water source and the nitrogen injection system.

In the channel with cold water, application rates of up to $3\frac{1}{2}$ lb/100 gal water were insufficient to obtain more than a very thin mixture. In the shallow bay with warm water, as little as 1 lb/100 gal water produced a very thick gel. At times, loads with 1 lb/100 gal were more viscous than those with $3\frac{1}{2}$ lb/100 gal; and loads with the same application rate varied greatly in consistency.

Because viscous mixtures could not be obtained in the deep channel area when even the maximum of $3\frac{1}{2}$ lb powder per 100 gal water was injected, evaluation of the nitrogen injection system was confined to the shallow bay area where water temperature was suitable. The reason for the inconsistency in GELGARD mixtures, when water source and amount of retardant powder used remain constant, follow.

1. The powder enters the tanks in a continuous stream below the jet of incoming water. The water "shoots" downward out of the water intake and hits the GELGARD stream. This usually results in the form-

ation of golf-ball size pieces of hydrated GELGARD and occasionally large masses of GELGARD hydrated on the surface and dry inside (Figs. 3 and 4). During actual bombing operations, the pieces of hydrated gel may be residue from the preceding load(s). However, during the tests, care was taken to flush the water tanks after the release of each load.

2. When GELGARD is used in small quantities, the injection time is brief and the water that enters first forces the GELGARD particles to the front of the tanks. Usually, adequate agitation occurs to mix the gelled material with the water entering the tanks during the later stages of loading. However, at times it appears that "split-loads" of GELGARD mixtures, i.e., water occuring within a retardant gel, form. This may be a result of inadequate agitation or may be explained by the next point.

3. The water probe is usually retracted when the co-pilot observes that the water level has reached the full line indicated on the tank windows. However, many operators wait until the GELGARD mixture is flowing out of the overflow ports before retracting the probe. In this case GELGARD mixture is flowing out of the ports into the lake, while at the same time water is entering the tanks through the probe. An example of overflow is shown in Figure 5. Considering the small amount of GELGARD used, inconsistent mixtures occur. For example, if the probe is not retracted for three seconds after the tanks are full and loading times is 15 seconds, possibly one-fifth of the 800 gallons, or 160 gallons, of the retardant mixture is lost. Possibly a portion of the material that overflows is foam. This

Figure 3. Hydrated balls of GELGARD powder following an air drop.

Figure 4. Large piece of dry GELGARD powder with hydrated surface.

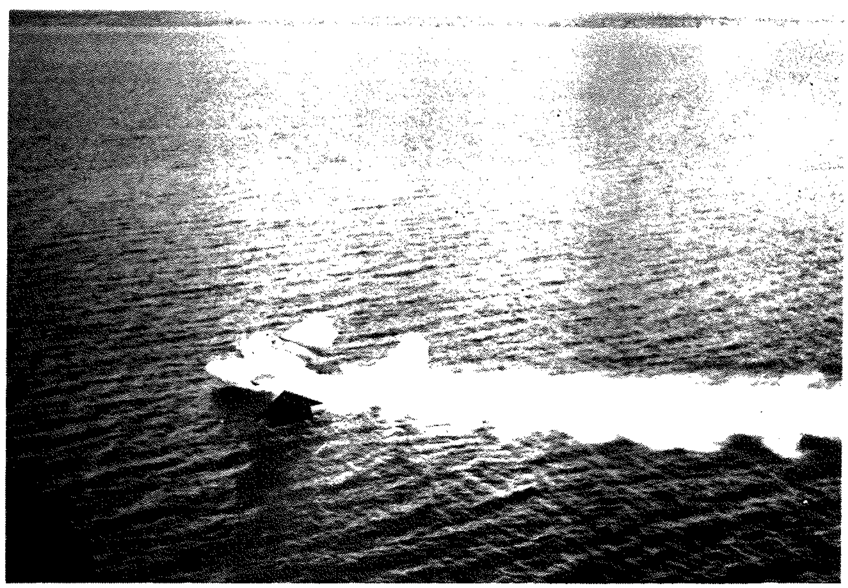

Figure 5. GELGARD mixture streaming out of overflow ports of PBY Canso water-bomber during loading.

situation occurred during the tests and was attributed largely to the addition of the dye, which produced foam and prevented the co-pilot from accurately observing the water-level in the tanks. This factor is important and contributes to the inconsistency problem.

4. The two GELGARD orifices are located below the water surface even when the tanks are only partly full. Since some GELGARD remains in the flexible injection hoses, the powder at or just inside the orifices absorbs water; thus, the openings are plugged. During the air drop tests, it was necessary to clean both orifices after each drop. If the orifices are not cleaned in actual bombing, it is doubtful whether the desired amount of, or any, GELGARD is injected after the second or third loading operation.

5. The presence of solidified pieces of GELGARD in the storage cylinders restricts and at times even prevents the flow of powder into the water tanks. These pieces are either 1) present in the GELGARD bags when the powder is added to the tanks, 2) formed through a condensation process owing to hot days and cool nights, or 3) formed when water accidentally enters the cylinders during the recharging operation.

The Rhodamine 2B dye added to the mixtures did not increase aerial visibility of the drop areas in white spruce, white spruce-aspen or aspen forest cover types. Addition of the dye before loading adequately dispersed the coloring agent, but created the foam mentioned above. Addition of the dye after loading prevented its dispersion in the mixture.

General use of GELGARD fire retardant in water-based operations should be questioned. If the water source is deep or located in the northern regions, the water temperature is likely below that necessary to obtain a viscous mixture before the load is dropped. For example, in northern Saskatchewan, between 2 and 6 lb/100 gal water are needed. In areas of Slave Lake, over $3\frac{1}{2}$ lb/100 gal water are needed. Since the maximum application rate with the nitrogen injection system is $3\frac{1}{2}$ lb/100 gal water, it is both uneconomical and ineffective to use GELGARD. If the nitrogen injection system is functioning efficiently, the operator, in many cases, has no idea what the application rate should be. For a good mixture, the selector dial is set at the maximum rate of $3\frac{1}{2}$ lb/100 gal water for the duration of the operation--when in fact it is possible that 1 lb/100 gal water is sufficient.

The conditions under which GELGARD retardant can be effectively applied are critical. Both water temperature and salts affect the formation of viscous mixtures independent of the operation of the nitrogen-injection system. The use of GELGARD with the nitrogen-injection system must be brought to an acceptable level of efficiency or other possibilities must be considered.

## RECOMMENDATIONS

1. The present nitrogen-injection system should be modified to include top-injection of the retardant. Introducing the retardant into the water-intake pipe by the venturi principle should be considered. The vacuum created by the incoming water stream could likely minimize the plugging of the injection orifices. NORCANAIR is at present modifying the nitrogen-injection system to include top-injection of the

retardant and the vacuum action created by the venturi.

2. Probably a series of injectors, each of which injects a set quantity of powder throughout the loading process, would be better than one injector. Of course, the additional number of orifices may increase the plugging occurrence and maintenance. The use of one injector with a variable-size of orifice should also be considered. This modification would be essential if more than $3\frac{1}{2}$ lb retardant/100 gal water would be required.

3. Whenever GELGARD retardant is used on wildfires, the operators should attempt to retract the water probe before the mixture escapes through the overflow ports.

4. All GELGARD powder should be screened before being placed into the cylinders, and should be further screened if allowed to stand for more than two weeks. This procedure would permit the use of GELGARD F and provide easy aerial visibility of drop areas. However, use of GELGARD F requires a greater amount of retardant since 1 lb of the colored powder contains 0.85 lb GELGARD M, 0.02 lb dye and 0.13 lb opaque filler for carrying the dye.

5. If the nitrogen injection system is to function properly, it must be adequately maintained by the operator.

6. GELGARD should be used only if water conditions are favorable and the injection system is functioning properly. The aircraft operators can determine this in the first two loads.

## REFERENCE

Anon., 1967. Chemicals for Forest Fire Fighting. A report of the NFPA Forest Committee. 2nd edition (Boston National Fire Protection Association). 112 p.