A REVIEW OF RETARDANT DELIVERY SYSTEMS USED IN FIXED-WING AIRTANKERS

BY

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ABSTRACT

The fixed-wing airtanker has emerged as the primary tool for applying long-term fire retardant onto wildfires in Canada. Most retardant delivery systems used are of the rigid door type. Efficiency of retardant application with this type of system varies widely depending on tank design, drop system, and venting. Several delivery systems now in use require improvements to increase their effectiveness. Specifications for retardant delivery systems in airtankers are also required.

RESUME

L'avion citerne à aile fixe est devenu l'outil pour l'arrosage de produits ignifuges sur les incendies au Canada. La plupart des dispositifs de décharge sont du type à porte rigide. L'efficacité de l'arrosage avec ce dispositif peut varier considérablement, tout dépendant du modèle de citerne, du système de décharge et d'évents. Plusieurs des dispositifs de décharge utilisés actuellement nécessitent des améliorations pour augmenter leur efficacité. Sont également nécessaires des spécifications concernant ces dispositifs.

CONTENTS

INTRODUCTION

The fixed-wing airtanker has emerged as the primary tool for applying long-term fire retardant onto wildfires. In 1973, over 90% of the 18 million litres (4 million gal) used in Canada was applied by the airtanker (Grigel 1974). The cost of delivering this retardant to the fires was 25-50¢ per litre ($1-$2 per gal), or between $4 and $8 million (Grigel 1974).

The effectiveness of the airtanker in applying retardant depends upon many factors:

1. design of the delivery system
2. aircraft height and speed at the time of drop
3. aircraft maneuverability
4. volume of retardant released
5. type of retardant applied
6. pilot accuracy
7. bird-dog direction
8. terrain, visibility and other drop conditions
9. the fire itself.

The factor of paramount importance is the design of the delivery system. An efficient system is essential for an effective retardant ground distribution pattern.

The lack of specific design criteria for retardant delivery systems and the availability of numerous types of aircraft for conversion into airtankers have led to the construction of a variety of systems. Many of these systems are inefficient. Most of the improvements to delivery systems to date have been made through the initiative of the individual airtanker operators in cooperation with interested government agencies. However, the latter have not made a serious effort to identify performance standards and to establish and implement specifications.

This paper reviews current retardant delivery systems in land-based airtankers used in Western Canada, discusses the problems associated with their use, and makes recommendations for improving the systems.

HISTORY OF AIRTANKER DEVELOPMENT

The concept of free-dropping water onto wildfires from aircraft gained impetus in 1954 following a series of drop tests in California using a converted TBM Avenger torpedo bomber. From this study it was concluded that it was feasible to apply water or non-corrosive fire retardants without the use of containers, but that this type of attack would not replace ground forces (Anon. 1955). The following year, a Stearman sprayer was equipped with a 473-litre (125-US gal) tank and specially designed drop gate. The mechanically operated 17.8 x 20.3 cm (7 x 8 in.) gate was hinged at the front and fitted with rubber gaskets to ensure a water-tight seal (Ely and Jensen 1956). The resultant drop pattern was a great improvement over those previously obtained with spray apparatus, bags, and valves.[1]

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[1] Reviews of earlier attempts to utilize aircraft for dropping water or fire retardants are presented by Linkewich (1972) and Fraser (1964).

Following additional use of the Stearman, criteria for adequate tanking were established:

> Minimum tank capacity should be about 50 US gallons. The tank should be accurately calibrated and properly vented. One square inch of vent for each five square inches of gate area allows unrestricted flow. The gate should have a minimum gate opening of 175 square inches for plane speeds up to 110 mph and tanks up to 200 US gallons. The gate size should be larger for higher drop speeds. A free swinging (hinges at leading edge), quick release door which can be closed in flight seems to be most satisfactory. (Ely *et al.* 1957).

Operational use of the Stearman airtanker soon confirmed the need for larger loads. As a result, larger multi-engine aircraft, primarily of military origin, were converted into airtankers with multi-compartmented tanks. These included the TBM Avenger, PBY5A Canso, B-25, B-26, F7F, PB4Y2, and B-17.

USE IN CANADA

The abundance of water in many parts of Canada encouraged the use of float-equipped and amphibious aircraft (e.g., DHC-2 Beaver, DHC-3 Otter, PBY5A Canso) for aerial fire suppression. However, in water-deficient areas in Western Canada, the use of land-based air-tankers was initiated. Small single-engine airtankers were introduced in the late 1950's and became the mainstay of land-based airtanker fleets. In British Columbia, the 2273-litre (500 gal) TBM Avenger emerged as the primary airtanker; in Alberta, the 455-litre (100-gal) Stearman and 955-litre (210-gal) Snow Commander became popular (Figures 1-3).[2] The 3637-litre (800-gal) PBY5A Canso

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[2] All volumes are in Imperial gallons unless otherwise stated.

Figure 1. The single-engine TBM Avenger; 2273-litre (500-gal) two-compartmented tank.

Figure 2. The single-engine Stearman; 455-litre (100-gal) single-compartmented tank.

amphibian doubled as a land-based and water-based airtanker in both regions (Figure 4).

In the late 1960's the 4091-litre (900-gal) twin-engine B25 was operationally introduced in Canada; the 3637-litre (800-gal) twin-engine A-26 and the 4091-litre (900-gal) twin-engine B-26 followed shortly thereafter (Figures 5 and 6).[3] In 1972, the 3637-litre (800-gal) twin-engine S2F Tracker and the 11 365-litre (2500-gal) four-engine DC-6B were operationally introduced (Figures 7 and 8). A summary of the airtankers available to deliver long-term retardants in Canada is presented in Table 1.

Unlike in the United States, medium and large-capacity twin and multi-engine airtankers were not introduced into Canada on a fully operational basis until the late 1960's.[4] There were several reasons for this delay:

1. The demand for airtankers was limited and was satisfied by small airtankers.
2. Land-based airtankers, especially the medium and large-capacity models, were not widely accepted until the use of long-term retardants became established in the late 1960's.

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[3] The A-26 and the B-26 aircraft as used in the airtanker role are essentially the same aircraft. In this report, the A-26 is referred to as having a two-compartmented tank with a 3637-litre (800-gal) retardant capacity while the B-26 is referred to as having a four-compartmented tank with a 4091-litre (900-gal) or greater retardant capacity, in areas where they are used at present.

[4] Size categories for airtankers in this report are: small - <2273 litres (500 gal), medium - 2273 to 9092 litres (500 to 2000 gal), and large - >9092 litres (2000 gal). Medium land-based airtankers (e.g., B-17) were used on a limited basis in British Columbia in the early 1960's.

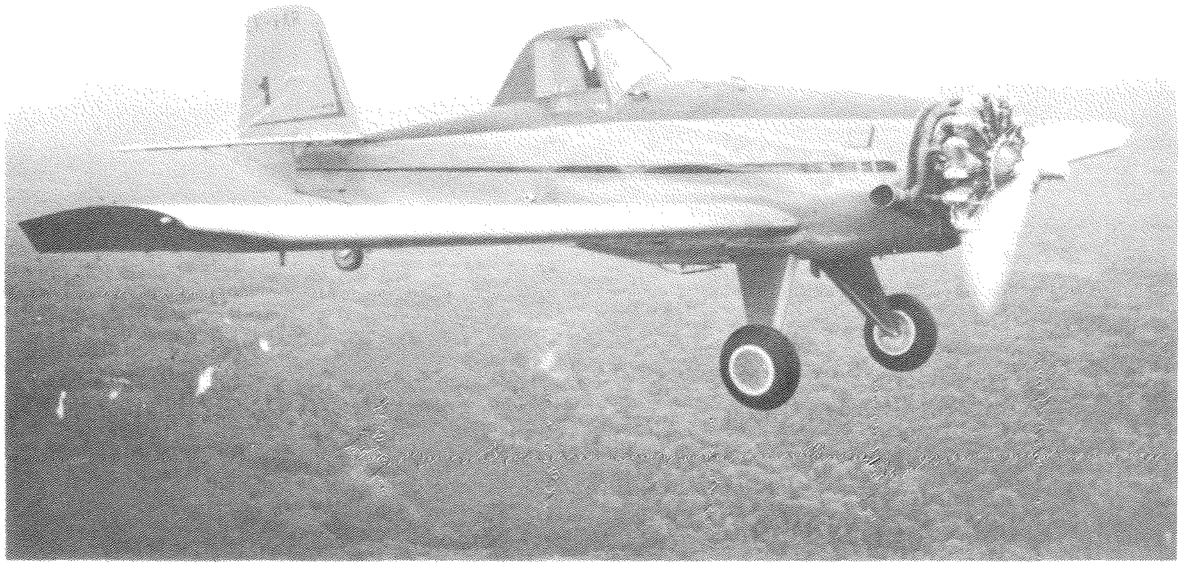

Figure 3. The single-engine Snow Commander; 955-litre (210-gal) single-compartmented tank.

Figure 4. The twin-engine PBY5A Canso amphibian; 3637-litre (800-gal) two-compartmented tank.

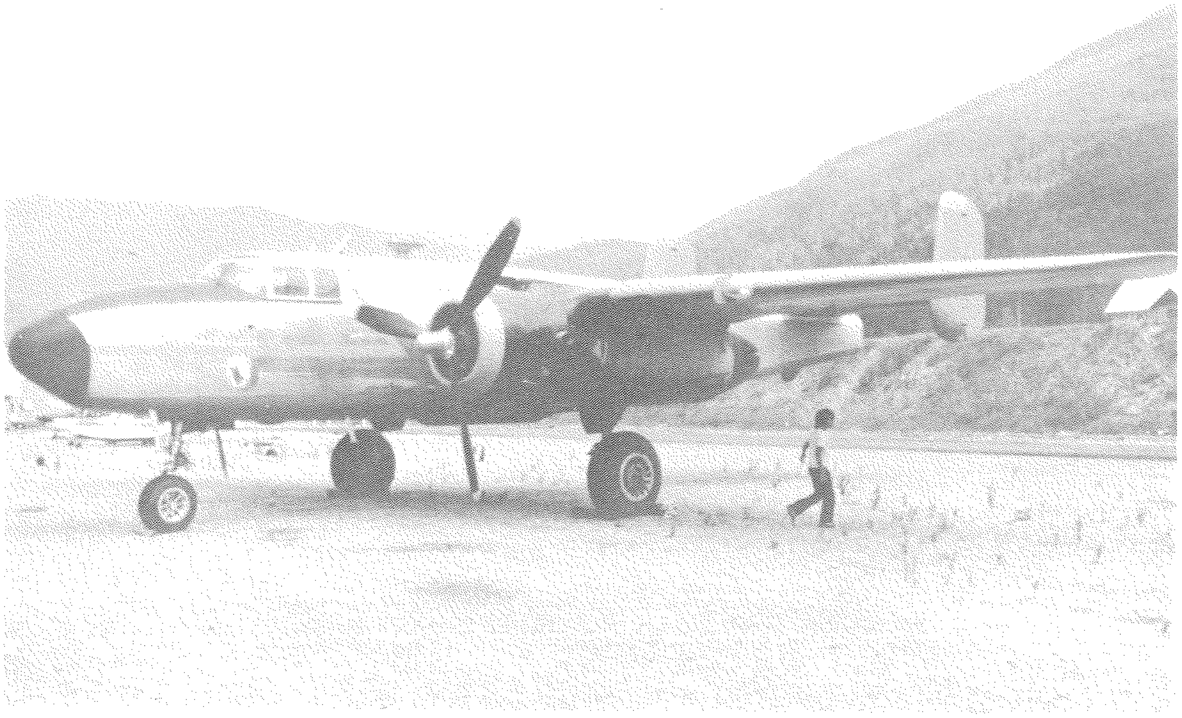

Figure 5. The twin-engine B-25 Mitchell; 4091-litre (900-gal) two-compartmented tank.

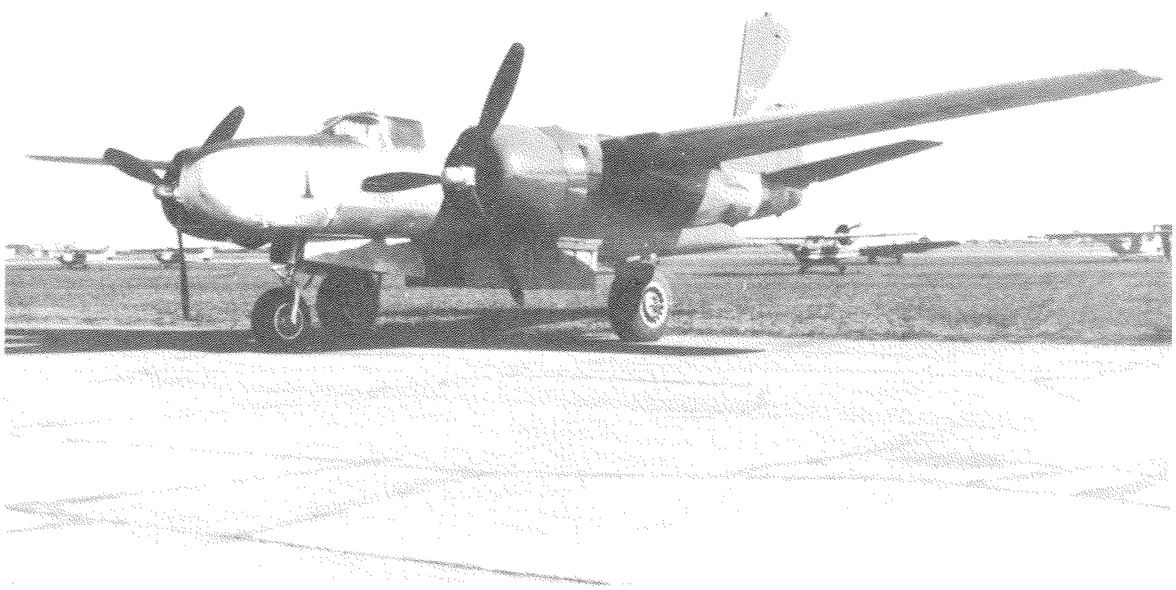

Figure 6. The twin-engine B-26; 4091-litre (900-gal) four-compartmented tank.

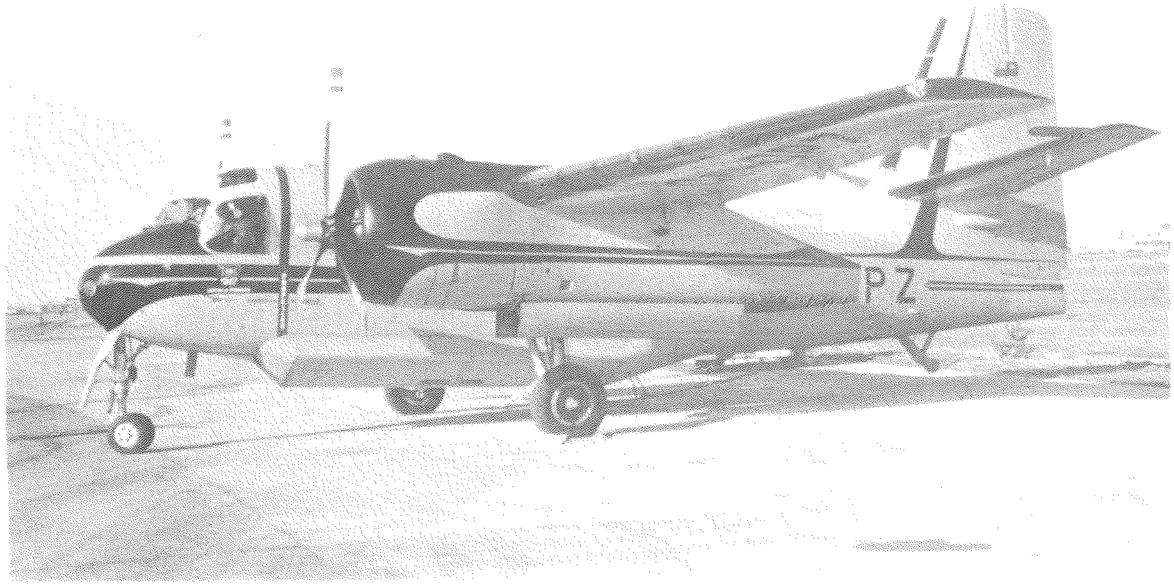

Figure 7. The twin-engine S2F Tracker; 3637-litre (800-gal) four-compartmented tank.

Figure 8. The four-engine DC-6B; 11 365-litre (2500-gal) eight-compartmented tank.

TABLE 1. Airtankers Available to Deliver Long-term Retardant in Canada in 1974

Base Province	Type of Aircraft	No.	Retardant Capacity (gal)[1]	No. of Compartments	Compartment Size (gal)	Owner
British Columbia	TBM Avenger	10	500-500	2	250-275	Conair Aviation Ltd.
	A-26	12	800	2	400	" " "
	DC-6B	4	2500	8	312	" " "
	PBY5A Canso	5	800	2	400	Flying Fireman Ltd.
Alberta	B-26	5	870-915	4	200-250	Airspray '67 Ltd.
	B-25	2	900	2	450	Northwestern Air Lease Ltd.
	PBY5A Canso	2	800	2	400	Avalon Aviation Ltd.
Saskatchewan	PBY5A Canso	2	800	2	400	Norcanair Ltd.
Manitoba	PBY5A Canso	2	800	2	400	Midwest Airways Ltd.
Ontario	S2F Tracker	5	800	4	200	Province of Ontario
Quebec	PBY5A Canso	6	800	2	400	Province of Quebec
	CL-215	15	1200	2	600	" "
Newfoundland	PBY5A Canso	5	800	2	400	Province of Newfoundland
New Brunswick	Snow Commander	4	210	1	210	Maritime Air Services

[1] Metric equivalent 1 gal = 4.546 liters

3. The availability of medium and large airtankers was limited in Canada.
4. Regulations by the federal aviation agency (MOT) restricted the use of many types of airtankers used commonly in the United States.
5. Strategic airports capable of handling the medium and large airtankers were limited in some regions.

The late introduction of the medium and large-capacity airtankers into Canada was perhaps beneficial. The design of many of these aircraft (i.e., size and shape of the bomb or torpedo bays, structural members and auxilliary systems) frequently prevented the construction of efficient retardant delivery systems. During conversion the basic criteria established for an efficient drop system and adequate venting in the Stearman airtanker were often neglected through necessity or expediency. In many cases, the massive size of the available load permitted the criteria to be ignored. For example, if a 2273-litre (500-gal) drop did not prove effective, 4546 litres or more (1000 gal) were salvo dropped. Even though efficient delivery systems were developed, their additional cost and maintenance standards made competition with the low-priced but inefficient systems difficult.

The delivery systems in the small airtankers, particularly the TBM Avenger, were successively modified through trial and error to permit the greatest efficiency with the small load (i.e., 1136 or 2273 litres; 250 or 500 gal) available. Consequently, when the medium and large-capacity airtankers became acceptable in Canada, many were modified or refitted with retardant delivery systems incorporating the improvements made in these small airtankers. In addition, the latest developments made elsewhere with tanking systems were utilized. Unfortunately, numerous airtankers equipped with inefficient delivery systems were also imported and utilized with little or no improvements being made. These airtankers are still in use.

A summary of the retardant delivery systems installed in airtankers commonly used in Canada is presented in Appendix I. Appendix II contains a summary of performance criteria for these airtankers.

RETARDANT DELIVERY SYSTEMS

Four types of delivery systems are used to apply retardant from fixed-wing airtankers:

1. rigid door
2. modified rigid door
3. progressive release
4. aft (tail) release.

Only the rigid door delivery system is fully operational in Canada. The other systems are either experimental or are being operationally tested at present. The latter are reviewed under Alternative Systems.

THE RIGID DOOR SYSTEM[5]

The rigid door system is compatible with the majority of aircraft used in the airtanker role. These include small agricultural

[5] The rigid door system is often referred to as the bomb bay system. However, with the introduction of the belly pod system, the use of the term "bomb bay" is no longer totally applicable. The rigid door system is described in detail by Linkewich (1972).

spray planes; medium and large military aircraft, in which the bomb or torpedo bays are usually used; and large passenger/cargo aircraft, in which a belly-pod is used (Figures 9 and 10). The system is relatively simple and inexpensive to construct, operate, and maintain.

The rigid door delivery system is comprised of a tank, drop system, and air vents. The characteristics of each of these components affect the efficiency of the delivery system. These charteristics include:

1. Tank:
   - (i) size and shape of tank and compartments
   - (ii) baffle structures between and within compartments
   - (iii) internal mechanisms, including door support structures and release apparatus.
2. Drop System:
   - (i) shape and area of doors
   - (ii) rate of door opening
   - (iii) extent and direction of door opening
3. Air Vents:
   - (i) type
   - (ii) size.

Operational Problems

The efficiency of the rigid door systems used in Canada at present varies considerably. For example, it is not uncommon to observe:

1. a 4091-litre (900-gal) capacity airtanker carrying only 3182 litres (700 gal)

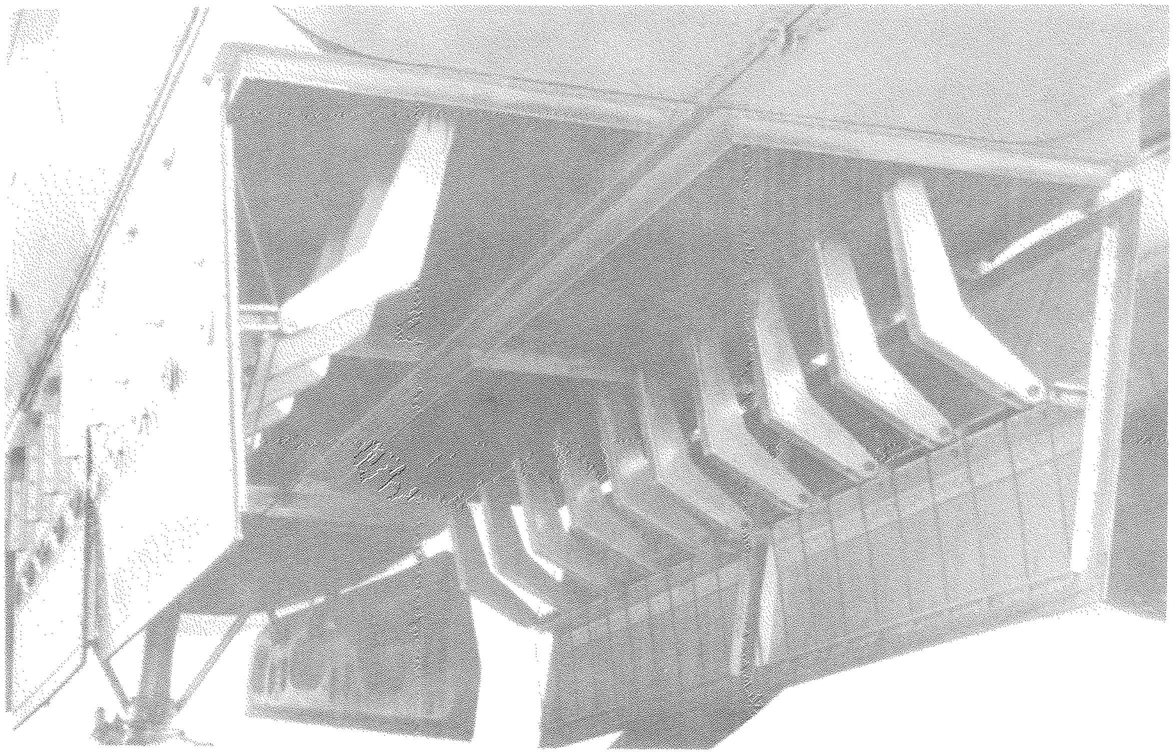

Figure 9. A rigid door delivery system mounted in the fuselage of a B-26 aircraft; four-compartmented tank with four drop doors.

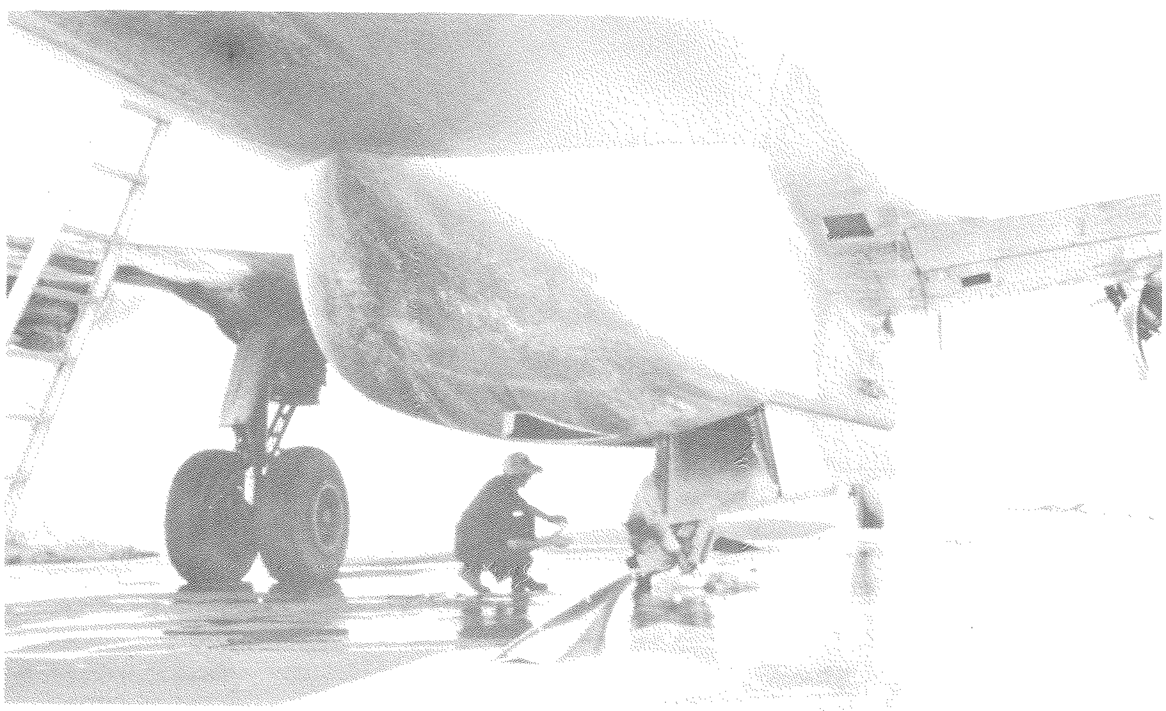

Figure 10. A rigid door delivery system mounted as a belly pod on a DC-6B aircraft; eight-compartmented tank with eight drop doors.

2. a 3637-litre (800-gal) capacity airtanker being credited with carrying 4091 litres (900 gal)
3. more than one retardant intake port on a medium-sized airtanker, resulting in an increased loading time
4. undersized retardant cross-flow ports between tank compartments, resulting in slow loading and possible under-loading
5. the absence or malfunction of a retardant level indicator, resulting in tank overflow
6. retardant dripping or flowing from an inadequately sealed drop door
7. a retardant load spilled onto a runway or taxiway due to a malfunctioning drop system
8. retardant trailing from the leaking doors or vents of an airborne airtanker
9. a drop door opening to less than 90° from the horizontal, resulting in restricted exit of retardant
10. a malfunction or delayed opening of the drop doors, resulting in overshooting of the target or "trailing" of the retardant
11. an airtanker consistently returning to base with a partial load because of a non-operating drop door
12. a multi-headed retardant mass developing shortly after load release, indicating inadequate venting

13. a prominent "rooster-tail" following the airtanker because of an inefficient drop system and venting
14. a patchy retardant distribution pattern resulting from load breakup.

Several of these problems can be corrected through effective maintenance and supervision, but many are a result of inefficiency in the tank design, drop system, venting, or a combination of these.

Tank Design

Size and shape. The size and shape of the retardant tank are related to the design characteristics and load capability of the aircraft. With the use of multi-compartmented tanks, the size of the individual compartments varies from 1136 to 2046 litres (250 to 450 gal) (see Table 1). Although the volume requirements for slowing or stopping wildfire vary greatly, the minimum effective drop increment is generally believed to be in the order of 1364-1818 litres (300-400 gal).

The shape of the tank is critical to load discharge. To minimize the effect of load erosion due to the tank design, it is advisable to make the tank long, increasing door length and reducing width and height, and to keep the width and height equal (Hawkshaw 1970). Evidence indicates that the length of the tank determines the initial value of acceleration of the liquid drop. A tank can be too long, resulting in stringing out of the material. A length-to-width ratio of 3:1 and a similar head (height) ratio are considered acceptable (Swanson and Helvig 1973). The angle of the bottom to the horizontal and the angle of the sides affect retardant flow rate. A tank that is tapered towards the top will exhibit different discharge characteristics than one which is rectangular (i.e., 90° to the horizontal) (Hawkshaw 1970).

Many of the airtankers used at present are of military origin. As a result, the design of the retardant tank in these aircraft is largely determined by the size and shape of the bomb or torpedo bay. In addition, structural members, tubes, and fittings within the aircraft fuselage dictate the geometry of the tank. Any structural modifications necessary for conversion into an airtanker and the center-of-gravity restrictions must be considered in determining the final design of the tank. As a result, many tanks cannot be designed with optimum discharge characteristics in mind. Aircraft such as the DC-6B which utilize belly-pod tanks are exceptions.

Most tanks used at present are rectangular. They are, however, generally irregular and are not conducive to favorable load exit (Figure 11). The bulkheads, corners, and internal obstructions in the tank create a reduction in the flow rate of retardant during discharge and affect the trajectory of the retardant mass (Figure 12).

Cross-flow ports. The use of multi-compartmented tanks necessitates installation of cross-flow ports to permit simultaneous filling of the compartments. A port is usually covered by a water-tight one-way baffle. Since most airtankers have a 7.6-cm (3-in.) male Kamlock adapter mounted on the right side of the tank for loading, the baffle

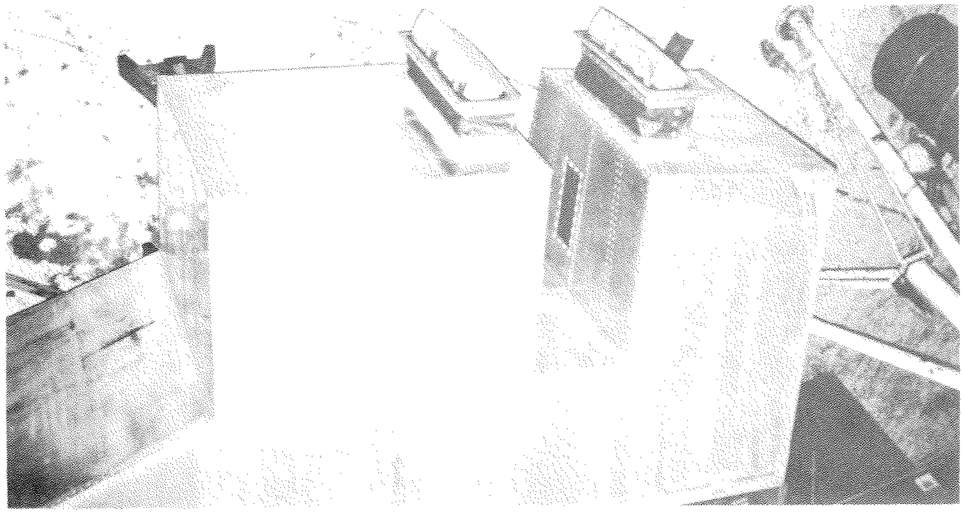

Figure 11. The irregularity in the design of the tank is a result of aircraft limitations, as with the A-26.

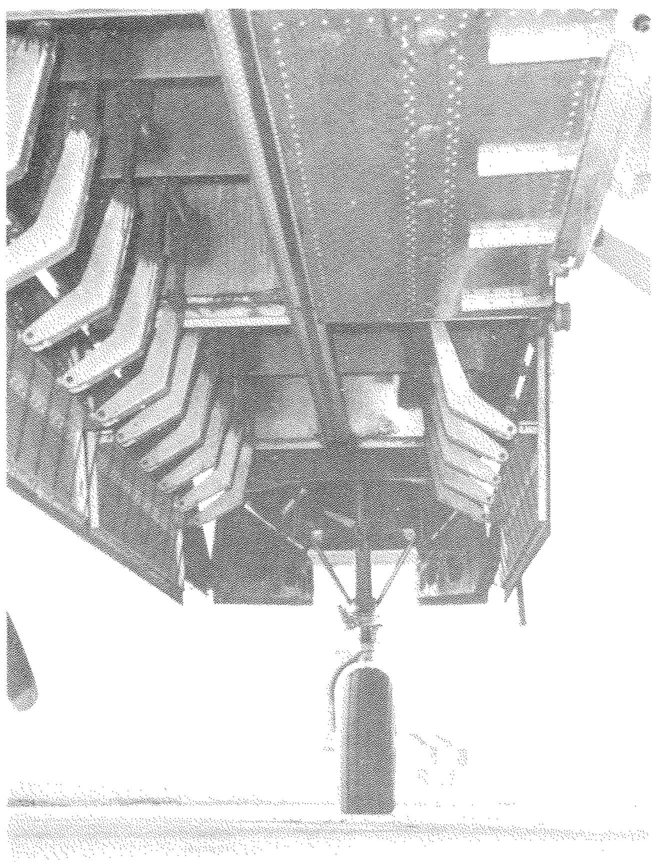

Figure 12. Internal obstructions, including door support and release apparatus, produce a reduction in the flow of retardant and introduce instabilities and turbulences to the retardant mass. A four-compartmented B-26 tank is shown with three doors open.

on the cross-flow port opens to the left (Figure 13). When a partial drop is made, the right tank is released first and the pressure of the retardant in the full tank keeps the one-way baffle tightly closed. This allows discharge of retardant by individual compartments on a selected basis.

Prior to the introduction of the large airtanker, the size of the cross-flow ports was not critical since loading pumps were generally of the low-volume type (15-19 litres per sec or 200-250 gal per min). However, to accommodate the larger aircraft, high-volume loading pumps (26 + litres per sec or 350 + gal per min) were installed. The tanks in the small two-compartmented airtankers (e.g., TBM Avenger) and the two- and four-compartmented medium airtankers (e.g., A-26 and B-26) may have insufficient cross-flow systems for the present high-volume pumps. The cross-flow ports in the multi-compartmented tanks in the large airtankers such as the eight-compartmented 11 365-litre (2500-gal) DC-6B may even be inadequate when high volume loading pumps are used. Even though the latter airtanker is loaded through two 7.6-cm (3-in) intakes, the retardant from one intake must flow into four compartments.

The high-volume output necessitates an increase in the size of cross-flow port(s) to accommodate the additional volume of retardant. Since the compartments are usually filled from right to left, and since many of the retardant level indicators are mounted on the right side (near the loading port), the right tank indicates "full" first. If the cross-flow ports are undersized, the remaining compartment(s) will not be full when loading is stopped. The load in the tank will subsequently stabilize at a level less than that which was indicated. Inadequate cross-flow can result in as much as a 909-litre (200-gal) underloading in a 11 365-litre (2500-gal) indicated load, particularly where the high-volume pumps are used.

Not all delivery systems are fitted with the baffled cross-flow ports. With some medium-sized airtankers, one tank must be filled before the retardant flows into the other compartment over a tank divider or through holes at the top (e.g. B-25). With others, two individual loading intakes are used, requiring recoupling of the loading hose during the filling operation (e.g. B-26, Figure 14).

Retardant level indicators. A retardant level indicator to indicate when the tank is full, or at the desired level, is essential, but not all airtankers are equipped with one. On the B-25 and several of the B-26's, the pilot must virtually stand on top of the aircraft and visually determine the retardant level through the overflow vents. Other aircraft use a light(s) activated by a pressure switch mounted on the tank. If the light is mounted in the cockpit, the pilot must signal the loading crew; if the light is also mounted on the outside of the aircraft, the ground crew can determine when the tank is full (e.g. S2F Tracker). A plexiglass plate mounted in the tank is used with other aircraft (e.g., PBY5A Canso). Another system uses an outlet through which the retardant flows when the tank is full (e.g. TBM, DC-6B).

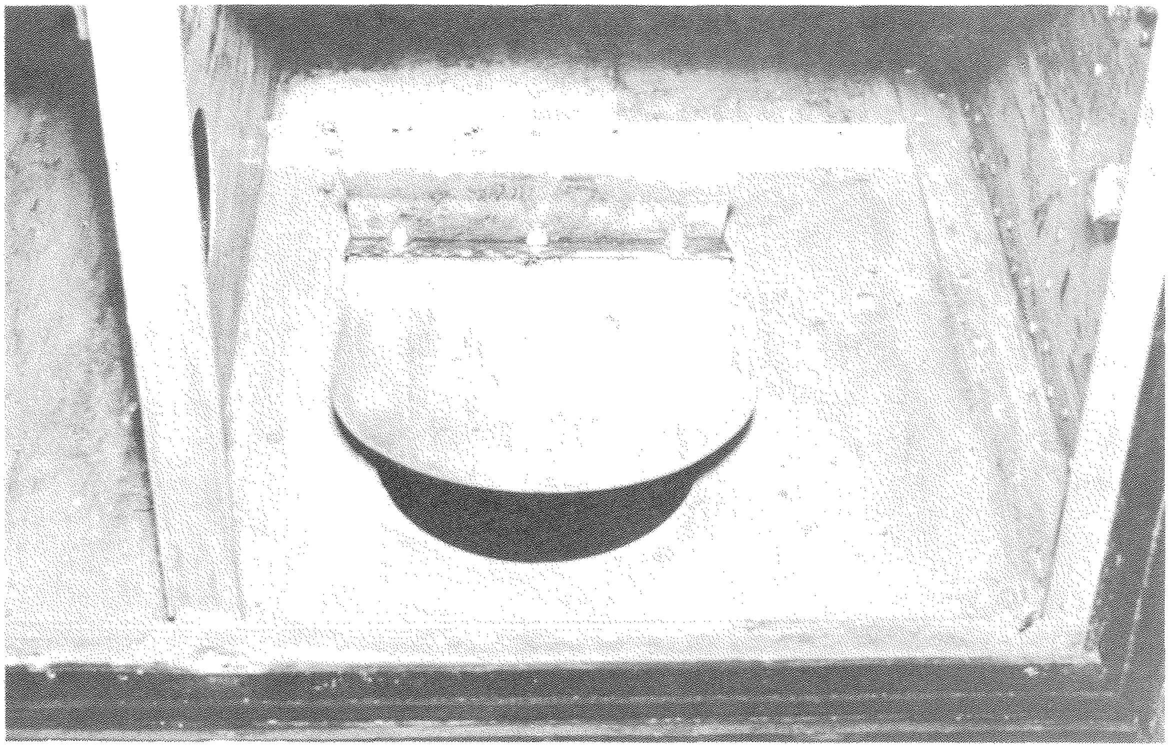

Figure 13. A cross-flow port and one-way baffle in the tank of an A-26.

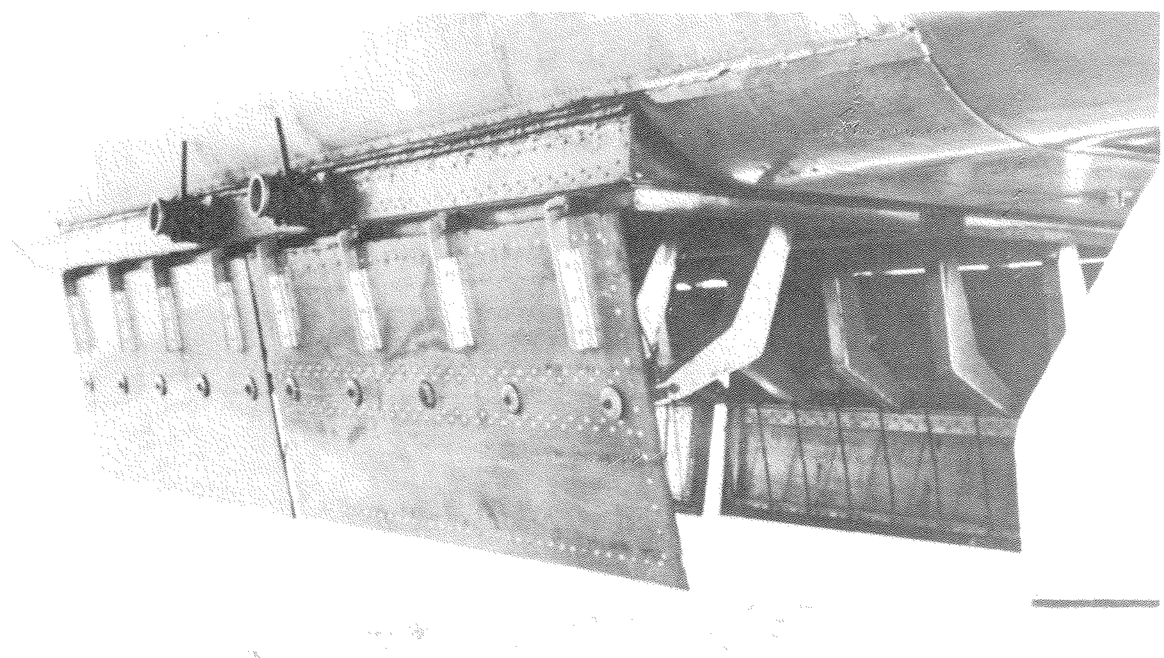

Figure 14. The lack of cross-flow ports between tank compartments requires the use of two loading intakes, as on this four-compartmented B-26. The compartment near each intake is filled first, then retardant spills over into the far compartment. Note the standard 7.6-cm (3-in.) Kamlok adapter used for loading the retardant.

Determining the retardant level visually (i.e., pilot standing on aircraft) is unsatisfactory and potentially unsafe. Without an accurate metering device, this procedure can promote underloading. A full load can be signalled at any time, particularly on a hot day with a full fuel load on board. Not only can the aircraft be under-loaded, but the user agency can be overcharged for retardant if it is purchased on an f.o.b. airtanker contract basis. For example, a 4091-litre (900-gal) aircraft can be repeatedly dispatched with a 3182-litre (700-gal) load. Thus, this aircraft is delivering only 3/4 of its designated load, while the contractor is receiving payment for a full load. Most of the systems with level indicators mounted inside the tank are also unsatisfactory because they usually malfunction after a short period due to plugging, caking,or corrosion.

The overflow-type system is the least complicated yet one of the most efficient and reliable retardant level indicators. Unfortunately it is used widely by only one aircraft operator in Canada. On the A-26 airtanker, where the top of the tank is high above the ground, a spring-loaded valve is mounted directly onto the right compartment of the tank at the 3637-litre (800-gal) level. Upon loading, the wire attached to the overflow valve is pulled and held by the loader. When the tank is full, the retardant flows down a tube and out the bottom of the aircraft (Figure 15). The wire is then released and the loading valve closed in one quick motion. (The wire can also be directly attached to the loading valve handle and be released automatically when the latter is closed). Spillage is minimal and is far less than that which occurs when the loading valve is disconnected. There are disadvantages, however. A highly viscous retardant mixture may not flow down the overflow tube rapidly enough, resulting in overloading.

A similar overflow indicator is used on both the TBM Avenger and DC-6B airtankers (Figure 16). However, since both of these aircraft have the retardant tank near the ground, spring-loaded bungs are used. The effectiveness of this system depends upon an adequate cross-flow capability which prevents buildup of retardant in the compartment adjacent to the indicator.

The capacity of each aircraft tank should be determined at the beginning of each fire season using a certified water meter. Also, tanks should be intermittently checked to determine if ballast material, such as styrofoam, has been added to reduce the tank capacity. Consideration should be given to the effect that high-volume pumps have on any level indicator system. It is possible that the turbulence created in the retardant tank by these pumps can activate the level indicator(s) prematurely. Conversely, any delay in closing the loading valve after the "full" level is indicated can result in additional retardant being pumped unless the overflow indicators are properly positioned to compensate for this factor.

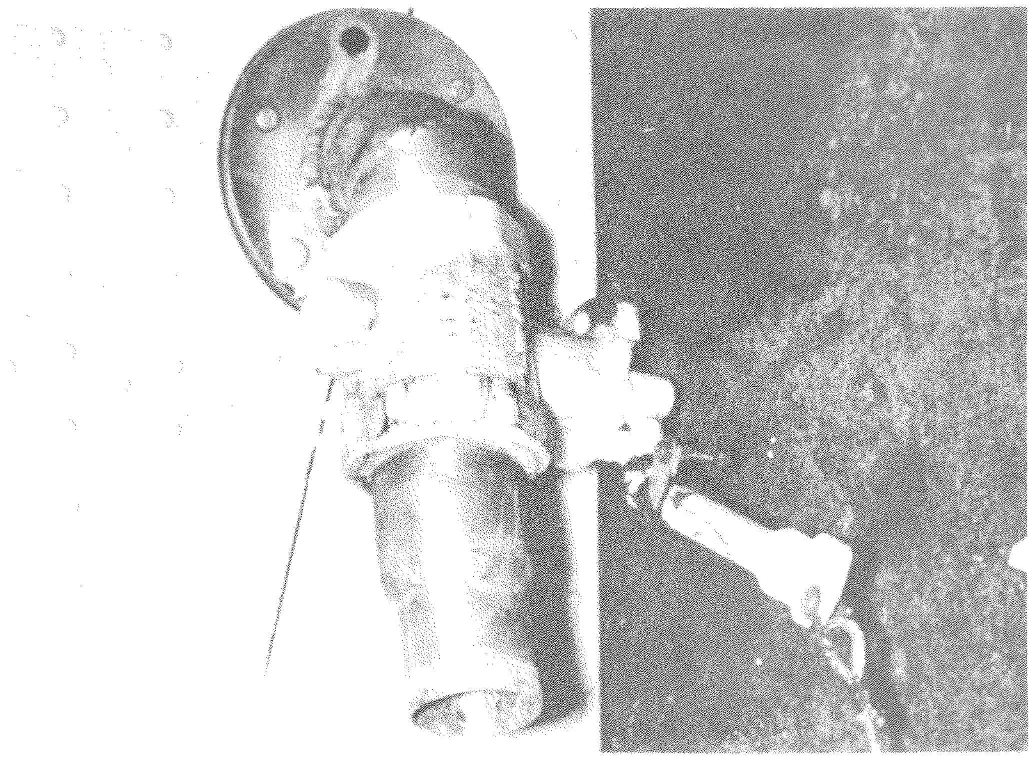

Figure 15. The overflow-type retardant level indicator is installed in the A-26 airtanker. Wire opens valve and retardant flows down tube when 3637-litre (800-gal) level is reached.

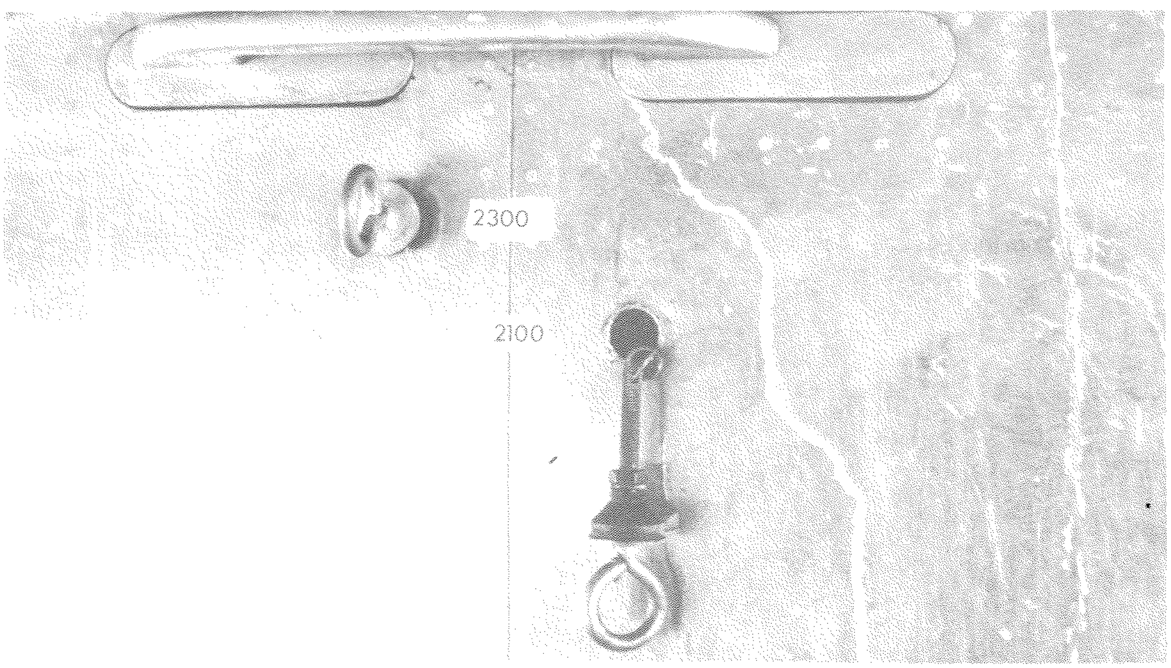

Figure 16. The retardant level indicator installed on the DC-6B airtanker.

Drop System

Doors. The doors on most drop systems are rectangular and are essentially the bottom of the tank or compartment; each compartment door can usually be opened independently from the rest of the system. The doors on the majority of drop systems are hinged at the outboard edge and open to a 90° vertical position. The angle of the open door is sometimes influenced by the angle of the bottom of the tank to the horizontal. The doors in most systems are electrically (solenoid) activated and may be mechanically, hydraulically,or pneumatically (air) opened and closed. Figure 17 show the doors on the drop system of several airtankers; other doors are shown in Figures 9, 10, 12, and 14.

Release mechanism. Two mechanisms are used for opening and closing the drop doors (Linkewich 1972). The latch and free-fall mechanical arrangement uses a latch to hold the door shut. When the latch is released, either electrically, hydraulically, or pneumatically, the door falls open by gravity with whatever assistance is given by the weight of the load above it. A short interval after the load is released, the closing jacks activate to shut the door. The solenoid or latch jacks then lock it into position. The solenoid or jacks used to open the door are independent of the ones used to close it. This mechanical arrangement is used on several TBM Avenger airtankers (see Figure 17a).

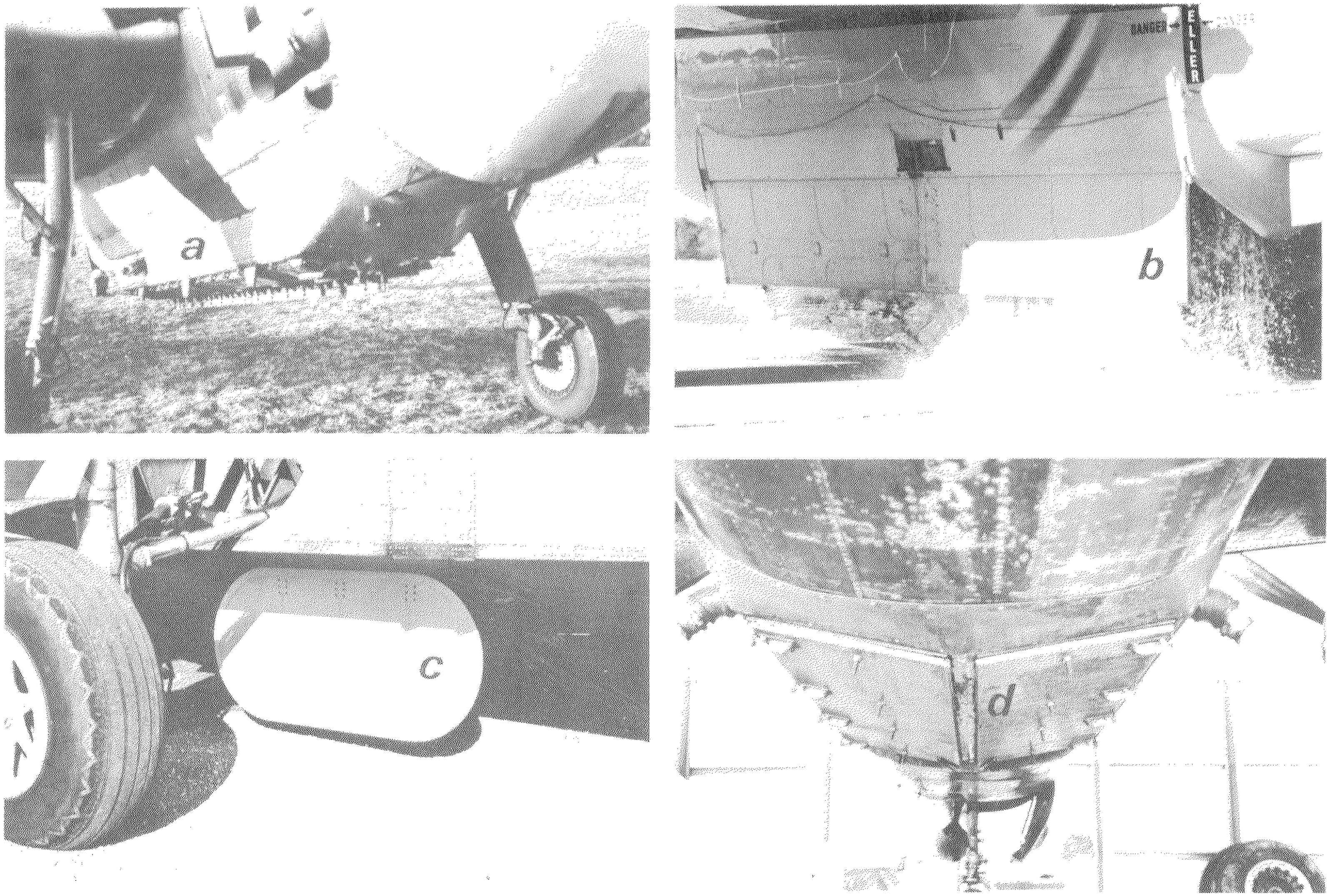

Figure 17. Drop doors on several airtankers: (a) TBM Avenger, two (b) S2F Tracker, four (c) PBY5A Canso, two, and (d) B-25 Mitchell, two

The over-center mechanism uses the same jack to open or assist the opening of the door and also to close and lock it. Locking is accomplished by moving the rod that joins the door bracket to the activating arm of the torque tube to an over-center position.

The jack breaks the lock and starts opening the door within a very short travel of the cylinder. At this stage it may allow the door to free-fall; however, in many systems the jack completes the entire opening.

Newer jack systems operate fast enough to break the door away from the load to provide clean, unrestricted exit of the retardant. A short interval after the load is released, the jack closes, then locks the door in the last portion of its travel. The over-center lock system on the A-26 airtanker is shown in Figure 18. Each jack is mounted externally on the tank, and is attached to the torque tube mounted in the baffles and main bulkheads of each tank compartment.

Seals. Door seals are an important yet often neglected component of the drop system. The neoprene or rubber seals can be mounted on either the door or the tank. The tank may have a knife edge which permits the seal to fit tightly when the door is closed (see Figure 9). Use of the over-center lock mechanism permits the door to be sealed more tightly because of the tremendous pressure that can be put on the door when the jack moves to the final locking stages of its arc.

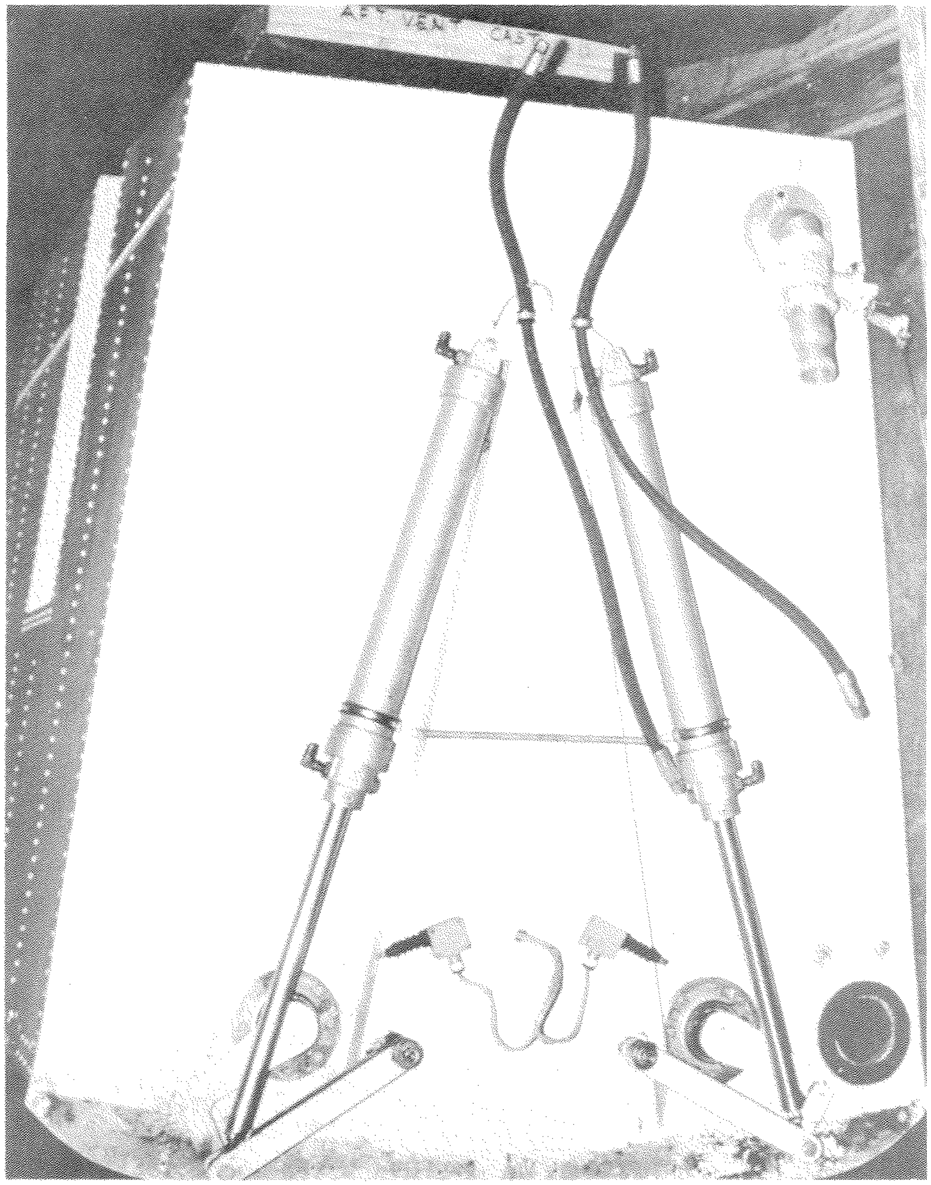

Figure 18. The over-center lock mechanism on the A-26, showing gate locking activators and pneumatic arms.

A door which is watertight usually prevents leakage of both the thickened and unthickened retardants. With unthickened liquid concentrate retardant, the doors should be opened when not in use to prevent damage to the seals in subsequent drops. The cohesive force of the dried retardant can easily cause the seal to separate from the door or tank.

Defective seals permit the retardant solution, which may be corrosive, to drip or flow onto taxiways or runways, presenting hazards to other aircraft.

Venting

Good tank venting is essential for clean retardant drops. Without adequate venting, the air that replaces the retardant must enter the tank from the bottom, through the exiting retardant. This creates a situation similar to that of water flowing out of an inverted bottle, and contributes to turbulence and instabilities in the retardant mass. As it flows from the tank, the resultant ground distribution pattern is characterized by puddles of retardant which cause discontinuous pattern contours.

Most airtankers incorporate some type of venting into their delivery system. Static vents, which are usually openings in the top of the tank or compartments, are common (Figure 19). The larger the size of the vent opening, the better the possibility of providing the air required to replace the exiting retardant. To facilitate this, atmospheric or near atmospheric pressure is required in most cases. During loading, the air in the tank escapes through these vent openings.

The "ram-air" venting system is a modification of static venting. This system incorporates scoops to "ram" the air into the tank during the drop. This permits more rapid air replacement and more adequately compensates for the vacuum created by the exiting retardant. The scoops can be permanently mounted, as on the B-26 (Figure 20), or they can be activated shortly before the drop, as with the TBM Avenger and A-26. On the TBM Avenger, the scoops are mounted on each side of the aircraft and are connected to the top of the tank. They are opened electrically when the drop system is armed on the final run; air is then forced into the top of each tank compartment (Figure 21). On the A-26, the scoops are connected by a rod to the torque tube component of the drop gate. When the drop system is fired, the fore and aft scoops are fully opened in the first inch that the door travels (Figure 22). During loading, the air in the tank escapes through the retardant level indicator (see Figure 15).

The venting system on the DC-6B is mounted on the retardant tank. Air, provided through louvres in the side of the belly pod, enters the compartments through one-way flapper valves placed along the top of the tank (Figures 23 and 24). During loading, the air escapes through the retardant level indicator(s) and through spring-loaded relief "valves" mounted on the tank (see Figures 16 and 23).

The effect that proper venting has on a drop is illustrated in Figure 25. Inadequate venting contributes to decreased retardant flow rate resulting in a multi-headed mass; a prominent rooster-rail also forms.[6]

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[6] The shape and size of the retardant mass from the B-26 can also be affected by the opening rate of the drop doors and a four-compartmented tank.

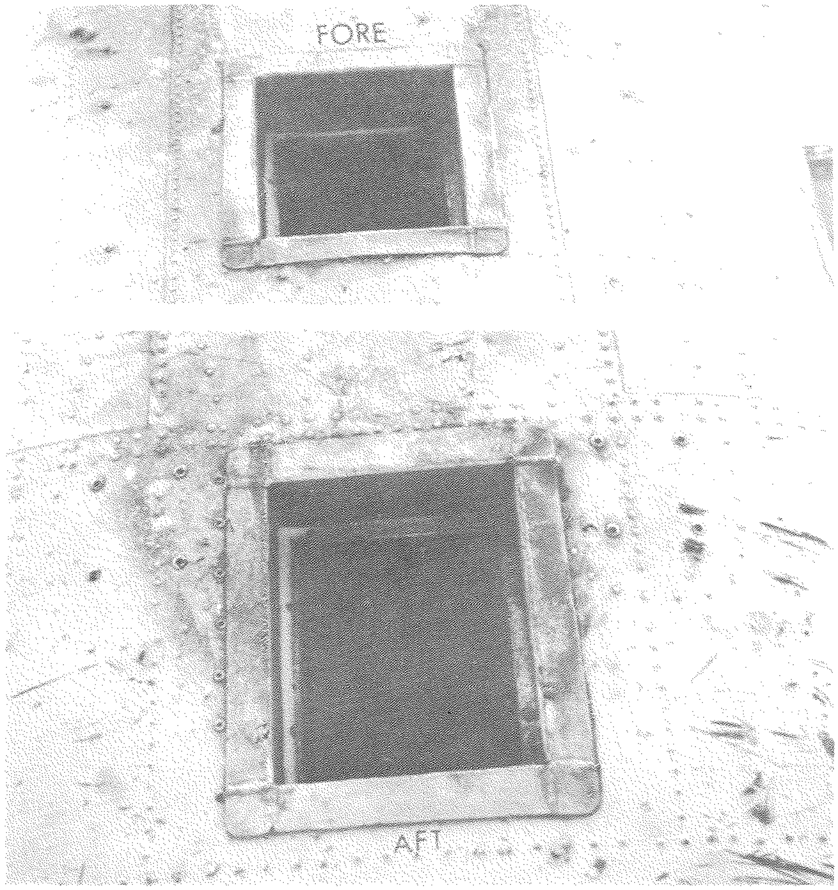

Figure 19. Two static vents 22.9 by 30.5 cm (9 by 12 in.) mounted on the top of the B-25 Mitchell tank.

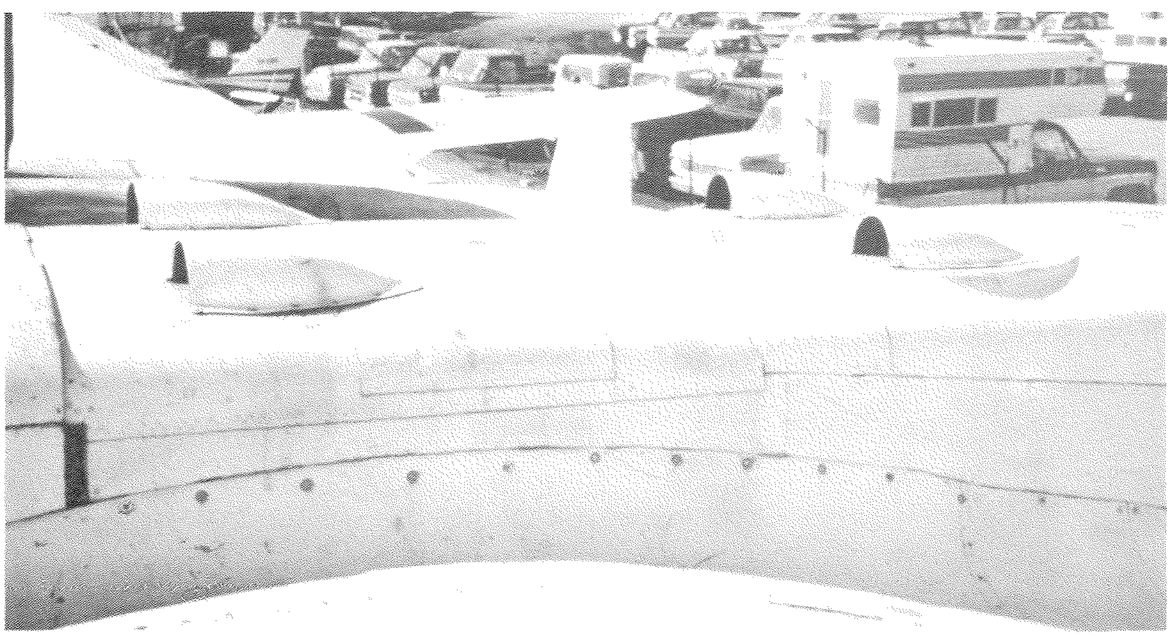

Figure 20. Four air scoops mounted on 10.2 cm (4-in.) diameter vents on a four-compartmented B-26 tank.

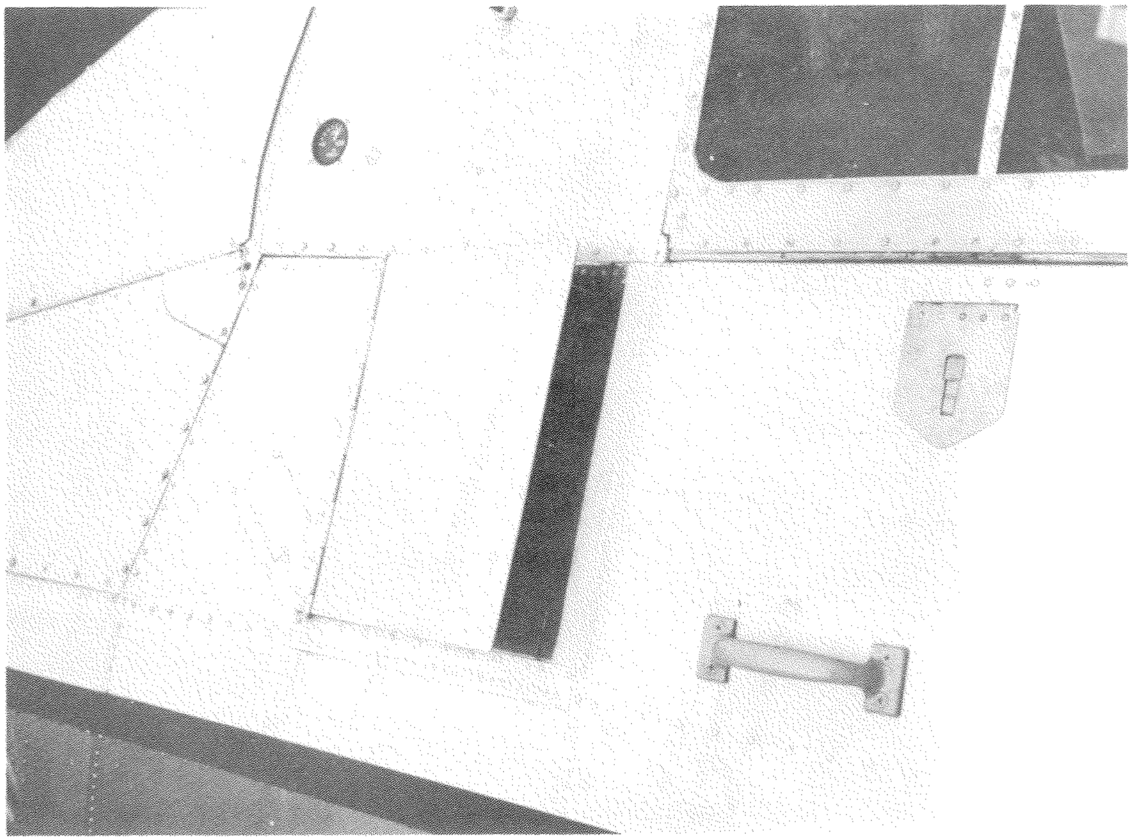

Figure 21. A "ram-air" door 30.5 by 35.6 cm (12 by 14 in.) mounted on the side of a TBM Avenger. Door is electrically operated and air flows directly to the top of the tank.

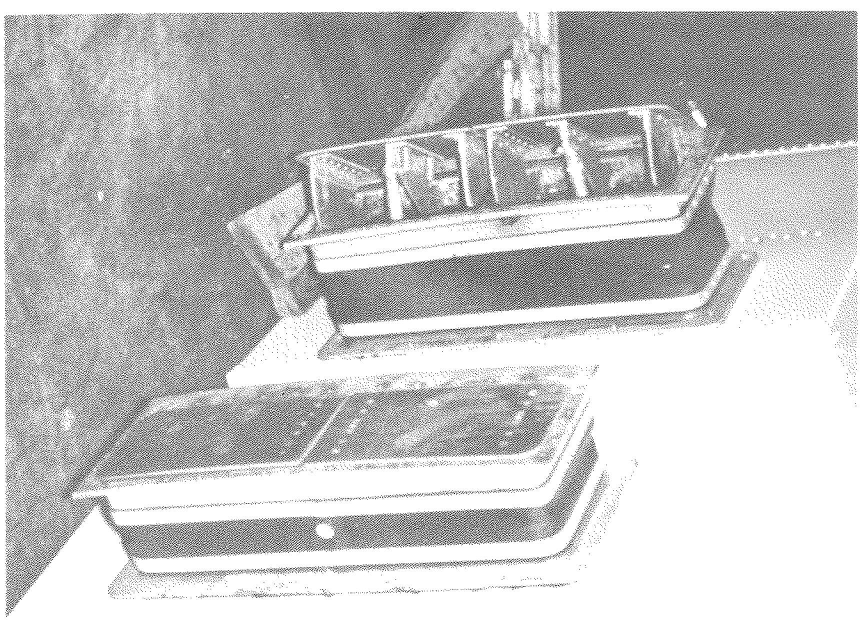

Figure 22. "Ram-air" scoops 15.2 by 61.0 cm (6 by 24 in.) on an A-26. The fore and aft scoops open in the first inch that a drop door travels when activated.

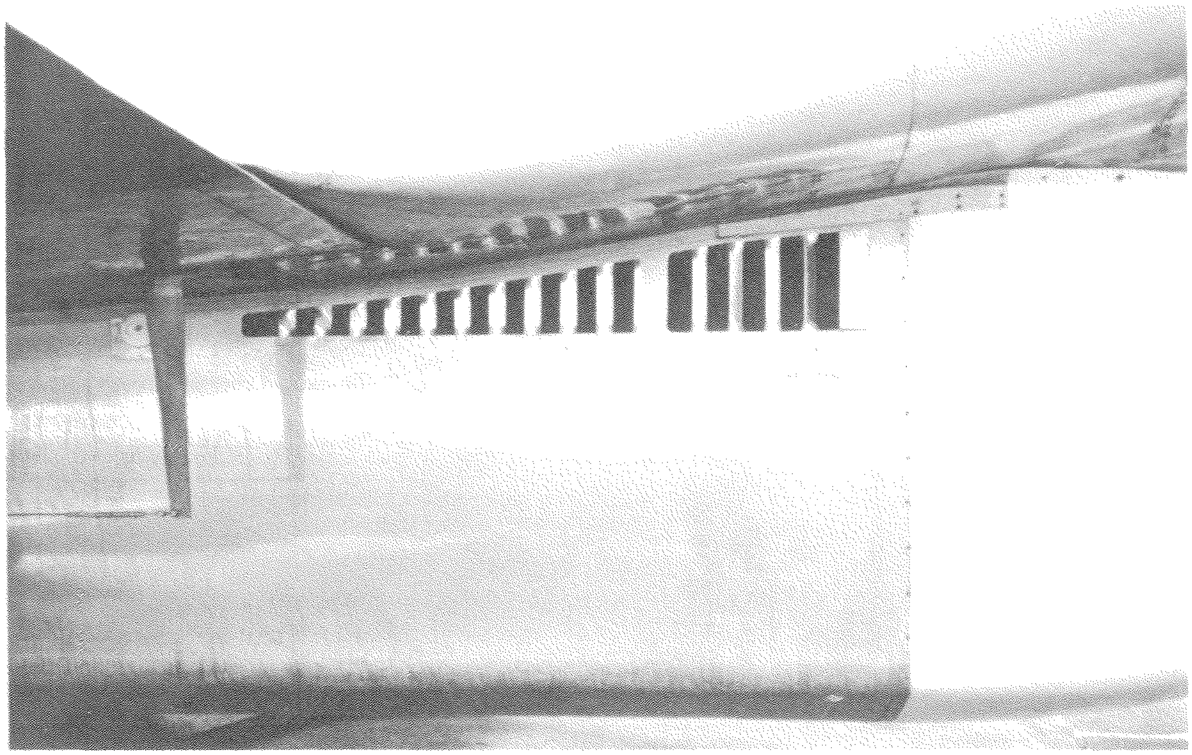

Figure 23. Air louvres on the belly-pod tank on the DC-6B provide air for venting systems. Louvres are mounted on the fore and aft of each side of the tank. Note circular spring-loaded air relief "valve" in upper left hand corner.

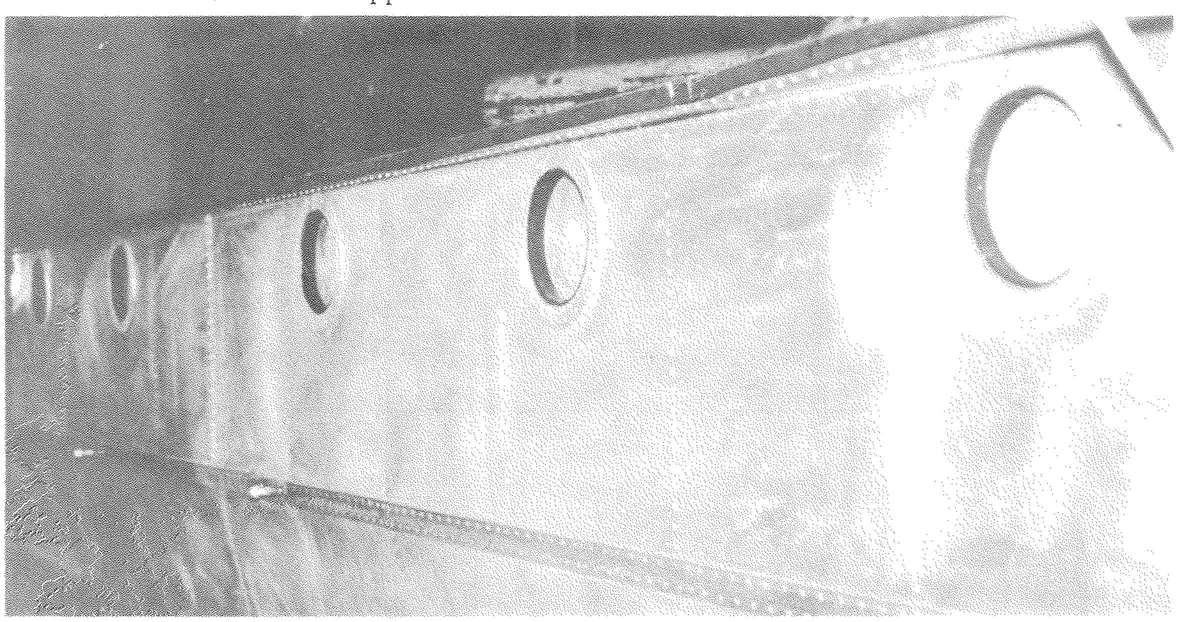

Figure 24. Fourteen 15.2-cm (6-in.) diameter air vents fitted with one-way flapper valves are mounted on the top of each side of the DC-6B tank. Only a portion of the tank is shown.

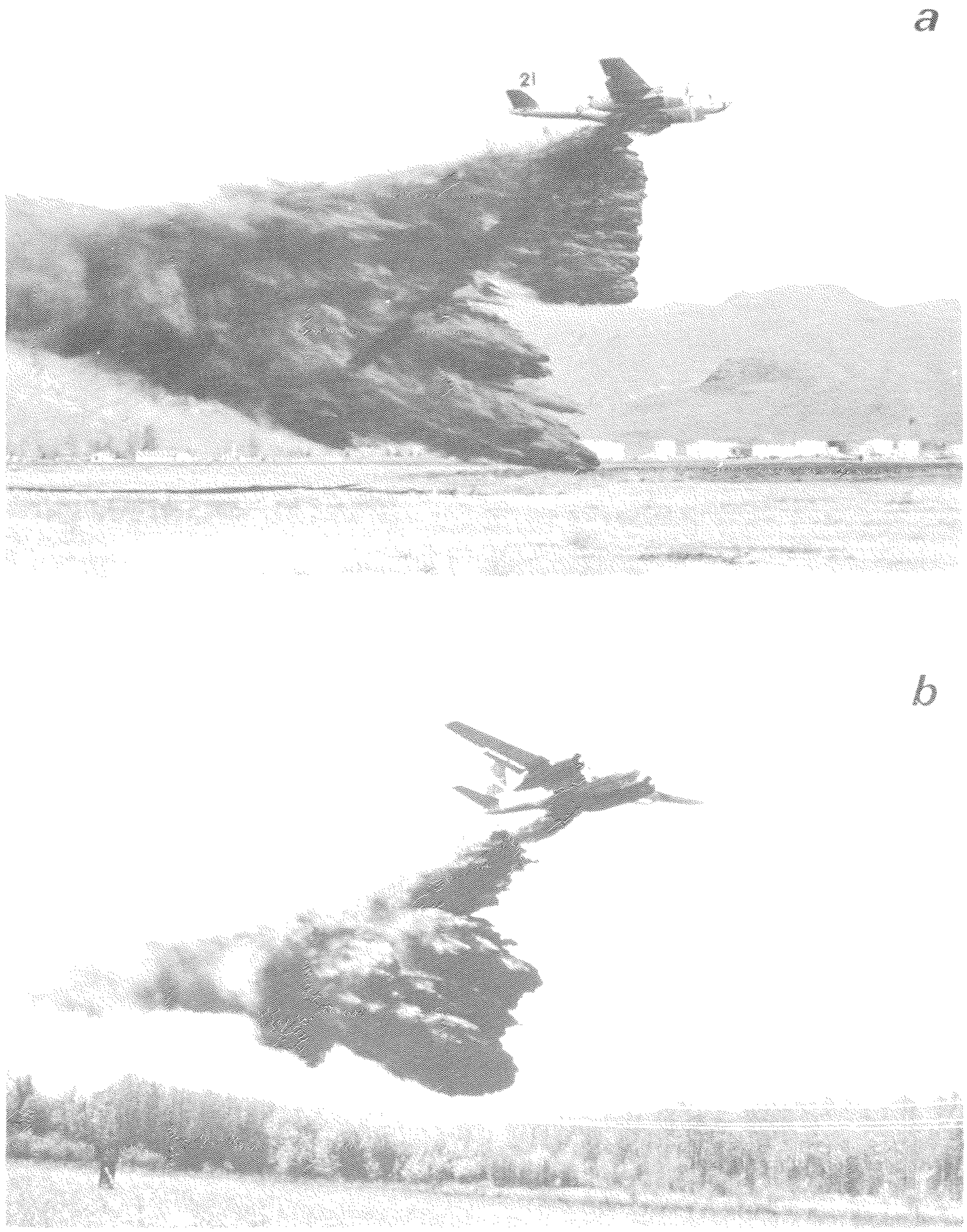

Figure 25. Sufficient venting is essential for efficient retardant exit.

(a) Adequate venting permits a clean drop with a vertical front and minimal trailing (A-26).

(b) Inadequate venting produces a multi-headed retardant mass and a prominent "rooster-tail" (B-26).

Adequate venting provides a clean drop and produces a vertical front on the retardant mass. Proper venting also permits large loads from multi-compartmented tank to be cleanly dropped (Figure 26).

RETARDANT FLOW RATE AND BREAKUP

The geometry of the tank, the venting, and the area, shape, and rate-of-opening of the drop door combine to determine the rate of flow and geometrical shape of the emerging retardant mass.

Irregularly shaped or high and narrow tanks slow the exit of retardant. Slowly opening doors and doors which open to less than 90° from the horizontal restrict the retardant flow and contribute to reduced flow rate and to load breakup. The internal clutter resulting from door-supporting structures and activators, baffles, and door frames also affects the load exit. Inadequate venting produces uneven retardant exit.

With multi-compartmented tanks, several or all compartments may be released simultaneously for partial or full salvo drops. The physical separation of the compartments and the "mixing effect" produced when the retardant from the individual compartments converges affects the stability of the liquid mass (Figure 27). In addition, the tanks in several airtankers must be activated in a particular sequence to maintain the aircraft's center of gravity. For example, the four-compartmented tank in the S2F Tracker originally had to be activated in a delayed sequence for full salvo drops (Figure 28). The exiting load was thus physically separated, even though the overall door opening time for the four tanks was extremely

Figure 26. Sufficient venting permits large loads to be discharged "fast and clean", as with this four-door drop of 5682 litres (1250 gal) from a DC-6B.

Figure 27. Individual compartments released at the same time produce a separation in the retardant mass, as in this four-door double train drop from the DC-6B.

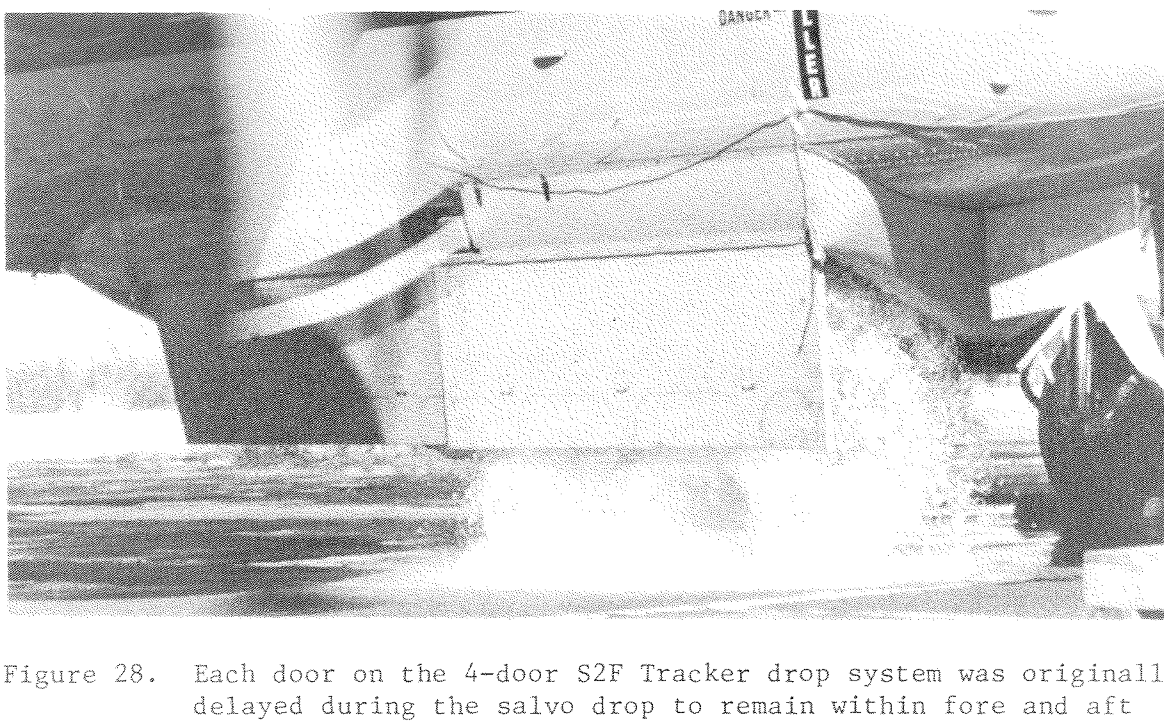

Figure 28. Each door on the 4-door S2F Tracker drop system was originally delayed during the salvo drop to remain within fore and aft center-of-gravity limits. Door 1 is shown open with load exiting, door 2 is open with load just showing, while door 3 is just opening. Total elapsed opening time was 0.5 sec.

short (i.e., approximately 0.5 sec).

All of these factors introduce turbulence and instabilities and contribute to the early breakup of the retardant mass. The physics of retardant breakup involves several complex hydrodynamic instabilities occurring both simultaneously and in phases (Swanson and Helvig 1973). Door opening shapes the emerging fluid. Drag acceleration deflects the fluid and introduces amplifying instabilities on both the front and side surfaces. The frontal, or Taylor, instability causes a fingering effect on the front of the liquid mass (see Figure 25). The emerging liquid surface also expands to the sides near the front and becomes effectively shorter as flow replaces some of the deceleration. The amplitude of the Taylor instability increases with time until air pressure on the front surfaces breaches the liquid mass, causing a series of reactions that end in the explosive-like breakup of the liquid. Rheological properties of currently used retardants damp out higher frequency instabilities and cause formation of larger droplets than would be produced with water alone. The rheological properties also help establish the time to breakup.

Higher aircraft velocity or smaller release quantities both have the effect of reducing the time to breakup and limiting pattern width. There are three stages in the breakup process (Swanson and Helvig 1974):

1. a discharge phase during which fluid is released continuously from the tank

2. a deformation phase characterized by frontal area expansion that contributes width to the pattern
3. a sudden breakup due to amplifying instabilities after which the retardant trajectory is essentially straight downward (see Figure 29).

RELEASE PROCEDURES

The use of multi-compartmented tanks, particularly in large airtankers, provides a variety of drop alternatives. The compartments can be released in salvo, in pairs, individually, or sequentially. With these alternatives, drops can be made which penetrate dense tree canopies or which paint a long, narrow retardant swath.

Activation of the individual compartments in a sequence permits the airtanker to assume the line-building role. For example, with the eight-compartmented 11 365-litre (2500-gal) DC-6B, either two 5628-litre (1250-gal), four 2841-litre (625-gal), or eight 1418-litre (312-gal) drops can be made in a train configuration (Figure 29). These drops establish a continuous retardant line at the 1.0 mm (9.5 litres/9.3 m^2) [.04-in. (2.1 gal/100 sq ft)] application rate of 231.6 x 16.8 m (760 x 55 ft), 274.3 x 10.7 m (900 x 35 ft), and 396.1 x 9.1 m (1300 x 30 ft), respectively, from a drop height of 45.7 m (150 ft) and a drop speed of 140 mph (Anon. 1973). By varying the airtanker drop height and speed and the drop sequence, an almost unlimited number of drop patterns can be established.

Figure 29. Four 1418-litre (312-gal) loads released in sequence from the DC-6B airtanker using manual control. Note the continuous line of retardant forming as the load reaches the ground.

With the sequential release method, individual bulk loads are dropped from the compartments. These loads resist erosion to a greater extent than retardant which is released from the entire tank at a regulated flow rate.[7] The tank compartments, however, must be fired uniformly to establish a continuous retardant line at the desired application rate. Inconsistent firing results in a discontinuous retardant line through which a fire can burn (Figure 30). Intervalometers and electronic firing devices for automatic sequencing of the doors are used on some airtankers. These devices are not foolproof, however, and one operator of large airtankers prefers to manually operate the drop system.[8] Manual control is especially effective in mountainous terrain and in patchy fuel types; the pilot can simultaneously trigger two or more compartments to apply a heavier retardant concentration in patches of heavy fuel or in uneven topography (e.g., gully or hillside).

ALTERNATIVE SYSTEMS

MODIFIED RIGID DOOR

The modified rigid door system is essentially a rigid door design in which the release rate is controlled through the use of flow regulators mounted at the bottom of the tank (Figure 31).[9]

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[7] On several B-17 and C-119 aircraft in the United States, small doors (or gates) which close against a head are used in conjunction with larger doors. Retardant is "trailed" from the small door(s) when a light concentration is required. The rate of flow decreases as the pressure (head) in the tank drops, resulting in a continuous decrease in retardant concentration on the ground. The stream of retardant is more subject to erosion than individual incremental salvo drops. Nevertheless the system has proved effective.

[8] Personal communication. B. Marsden, Operations Manager, Conair Aviation Ltd., Abbotsford, British Columbia.

[9] Firetrac (Fireline Extension by Transposition Refinement And Control) is the registered tradename for the flow regulation device designed and developed by J.K. Hawkshaw, Field Aviation Ltd., Toronto, Ontario.

Figure 30. Four 1418-litre (312-gal) loads released in sequence from the DC-6B by an intervalometer. Note that the intervalometer is not firing evenly and a gap between tanks 2 and 3 has developed.

The doors are opened as quickly as possible to permit the flow regulators to control the rate of release. By changing the size of the regulators it is speculated that the emission rate can be either increased or decreased. A negative tank pressure (vacuum) can be employed in conjunction with the flow regulators to further delay the load exit and to provide additional control of the rate of flow.

The design is an attempt to produce a greater retardant line length at the desired application rate(s) by more uniformly applying (stringing-out) the load. The overkill (puddles) - underkill (spray) situation so prevalent with the majority of the rigid door systems is theoretically minimized. The modified rigid door system is currently being tested in the S2F Tracker airtanker (Figure 32).

PROGRESSIVE RELEASE

The progressive release system employs a rectangular tank; however, a sheet of fabric rather than an openable door is used to support the load (Hawkshaw 1970). Upon dumping, the fabric is cut around its edges and falls with the load. The cut begins at the front and travels rearward at any selected speed. Vertical bulkheads in the tank area prevent the rear part of the load from moving forward and so maintain the undropped portion free from influence of the dropping portion. Each particle is motionless until released and is freely dropped under the influence of gravity. The speed at which the membrane is cut regulates the flow rate and determines the

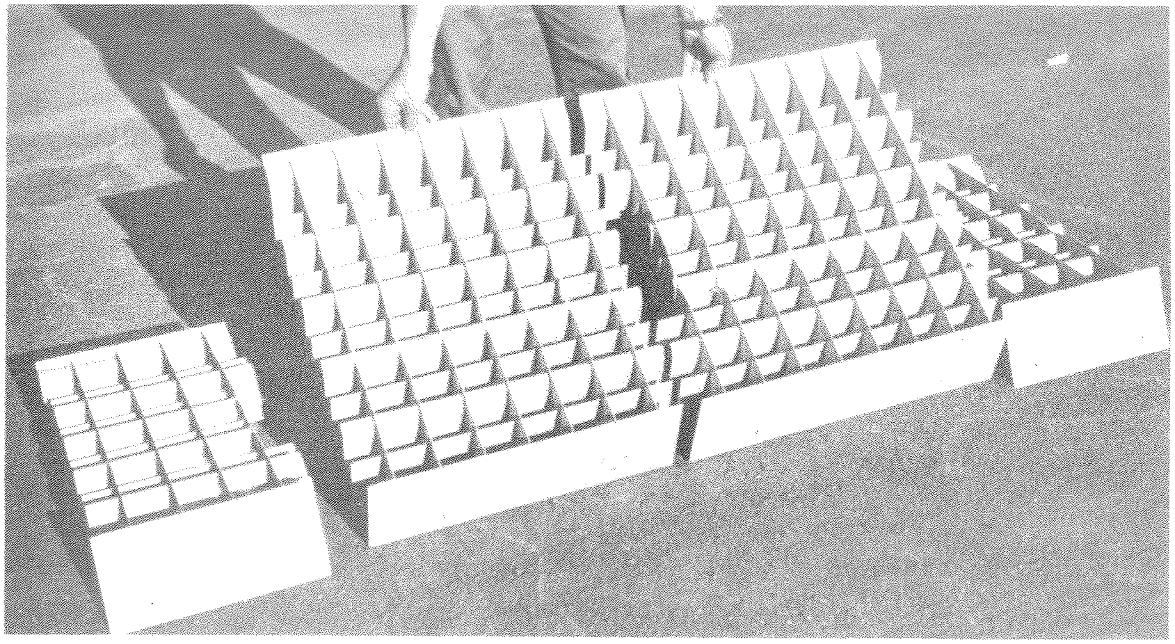

Figure 31. Flow regulators which fit into one of the four compartments of the S2F Tracker tank.

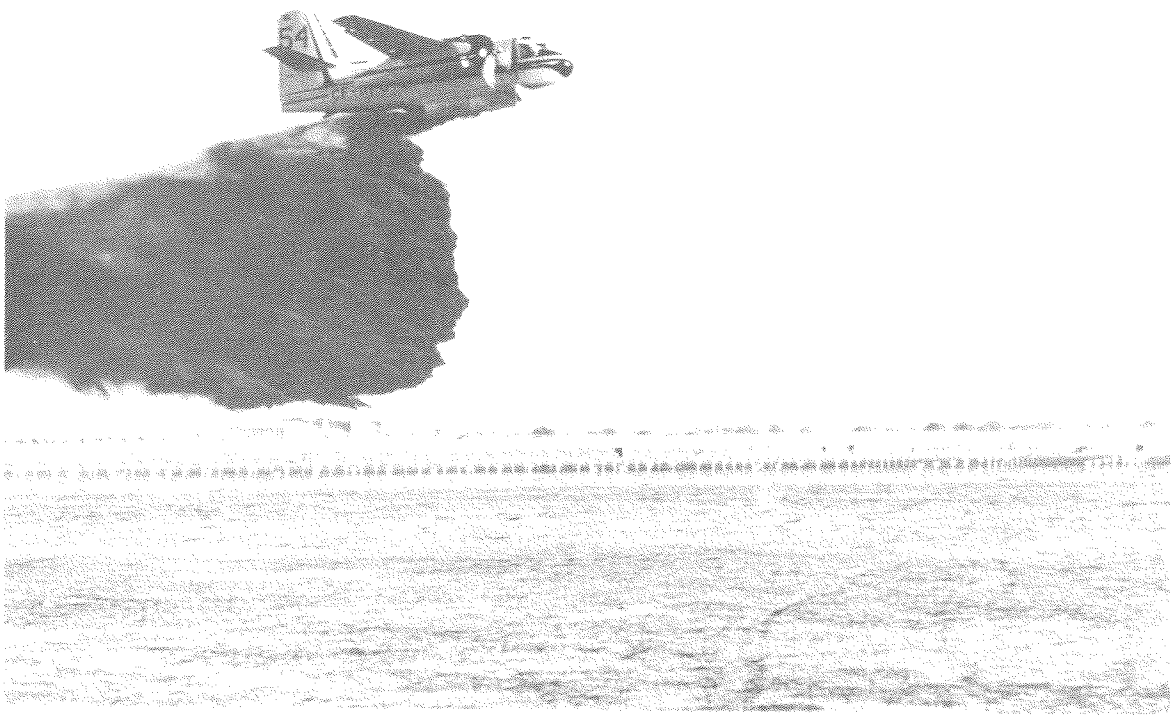

Figure 32. Air drop test with S2F Tracker fitted with a modified rigid door delivery system.

subsequent wetness level obtained in the drop pattern. A short (salvo) dump, a long (trail) dump, or any release rate between can be made with this system.

The progressive release system is designed to provide ideal load transposition (i.e., to apply the entire load uniformly). The width and height of the tank are equal to minimize the perimeter and erosion of the retardant mass. The length of the tank is four to eight times the width. With this type of tank and progressive release, the load will have no internal currents or turbulence, will have a smooth face and sides, and will be pointing directly into the airstream (Hawkshaw 1970).

The Membrane Tank System, which incorporates progressive release, has been installed on a Twin Otter aircraft (Figure 33). The system contains two 3.65 m by 71.1 cm (12 ft by 28 in.) rectangular tanks, each with a capacity of 1136 litres (250 gal). The fabric/plastic membrane forming the bottom of the tanks is pulled from rolls positioned at the rear of the aircraft and is secured and locked into position by clamps. When pulled, stretched, and secured by the clamps,the membrane forms both the bottom and a portion of the sides of each tank. Although the system is operational, difficulties have been encountered in obtaining a uniform longitudinal wetness level due to a non-linear rate of cut from front to back (Figure 34) (Lieskovsky 1971).

AFT (TAIL) RELEASE

The aft, or tail, release system uses pressure to regulate the retardant flow rate. The physical principle associated with rearward

Figure 33. The Membrane Tank System installed on a Twin Otter aircraft.

Figure 34. A long (trail) dump with the Membrane Tank System.

ejection of the retardant mass is the relative reduction of the retardant velocity with respect to the free airstream, which suggests the formation of larger and consequently more stable drops. However, the main advantage of rear ejection is that it permits a modular tank approach. Pressurization is required since gravity alone is insufficient to assure adequate flow from the center of gravity to the aft release point.

A Modular Airborne Fire Fighting System (MAFFS) has been developed and operationally used with the Lockheed C-130 aircraft (Covault 1973).[10] The 11 355-litre (3000-US gal) system consists of five modular 1892-litre (500-gal) tanks coupled to twin 45.7 cm (18-in.) exhaust lines; the latter add about 1892 litres (500 US gal) to the system's capacity. The exhaust lines extend from the rear of the C-130 when its cargo doors are open, but fold within the aircraft for flight to and from fires when the cargo doors are shut (Figure 35).

Advantages of the MAFFS lie in the modular design that permits its onloading and offloading without modification to the aircraft; the system utilizes the standard USAF 463L cargo loading system. The MAFFS can be triggered either from the cockpit or by the loadmaster, who monitors the tank pressures from a seat between the two chemical expulsion nozzles. The system is reported to deliver retardants at a more uniform rate than is generally achieved by commercial fire fighting aircraft. Discharging the retardant at different pressures can

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[10] The MAFFS unit can be compatible with virtually any twin or four-engine transport aircraft, including the Lockheed C-141 Starlifter and Boeing Vertol CH-47 helicopter.

place concentrations on an area up to 24.4 m (80 ft) wide by 3.2 km (2 miles) long, depending upon the amount of concentration desired (Figure 36). Various pressures can produce concentrations of 3.8-15.1 litres per 9.3 m^2 (1-4 US gal per 100 sq ft) (Covault 1973).

With the MAFFS, the entire 11 355-litre (3000-US gal) load must be discharged once the tank valves are opened. The nature of the unit suggests potentially high-volume capacity requirements, the kind usually required for line-building on large fires.

CONCLUSIONS

1. The retardant delivery systems in several airtankers are inadequate. Modifications are required; however, with some airtankers little can be done to increase the efficiency short of replacing the entire delivery system.
2. The irregular design of tanks is primarily due to the structural design of the aircraft (e.g., B-26 and A-26). Little can be done to modify the tank design in these aircraft.
3. Cross-flow ports in many of the present tanks are inadequate to accommodate the high-volume pumps used.
4. The 7.6-cm (3-in.) male Kamlok coupler is the standard fitting for retardant loading. The number of couplers used on airtankers varies, due to either the tank design or the lack of cross-flow ports.
5. Systems to measure the retardant level in tanks vary and are generally inadequate.
6. The exact capacity of the tanks in numerous airtankers is unknown.

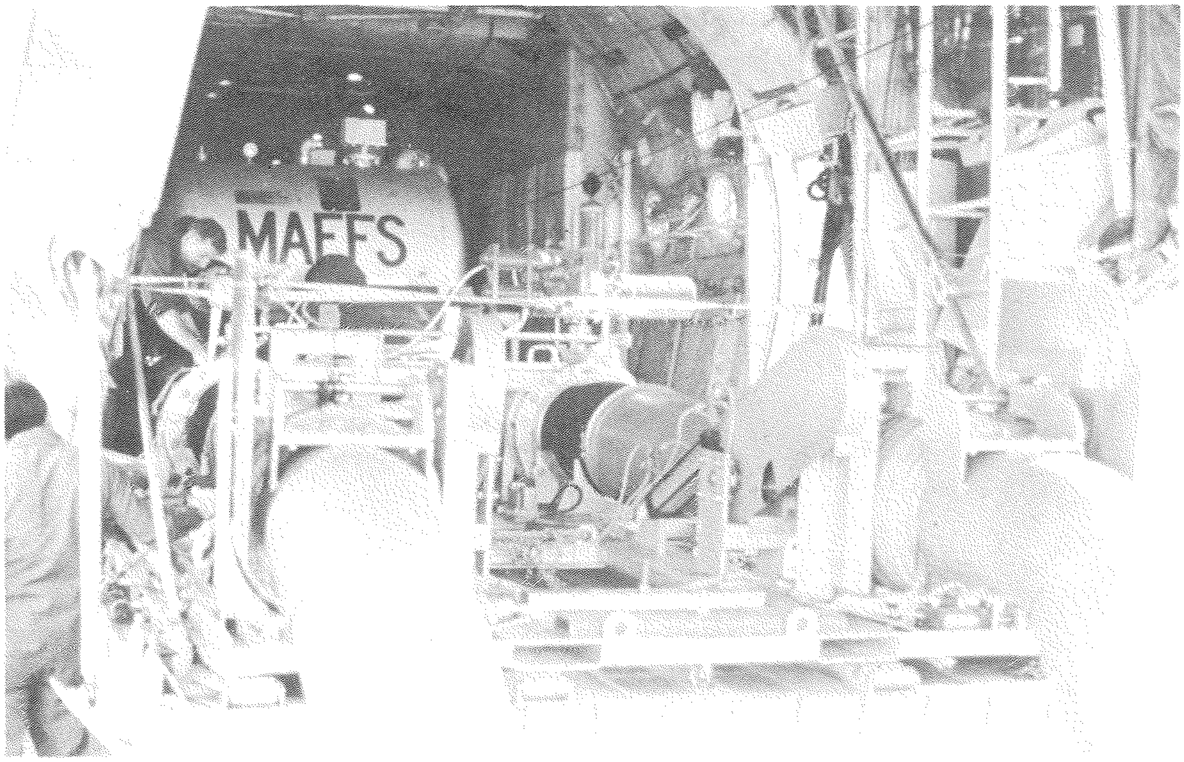

Figure 35. MAFFS unit installed in C-130 Hercules aircraft. Retardant is discharged through the two 45.7-cm (18-in.) nozzles.
Photo: Courtesy U.S.D.A. Forest Service.

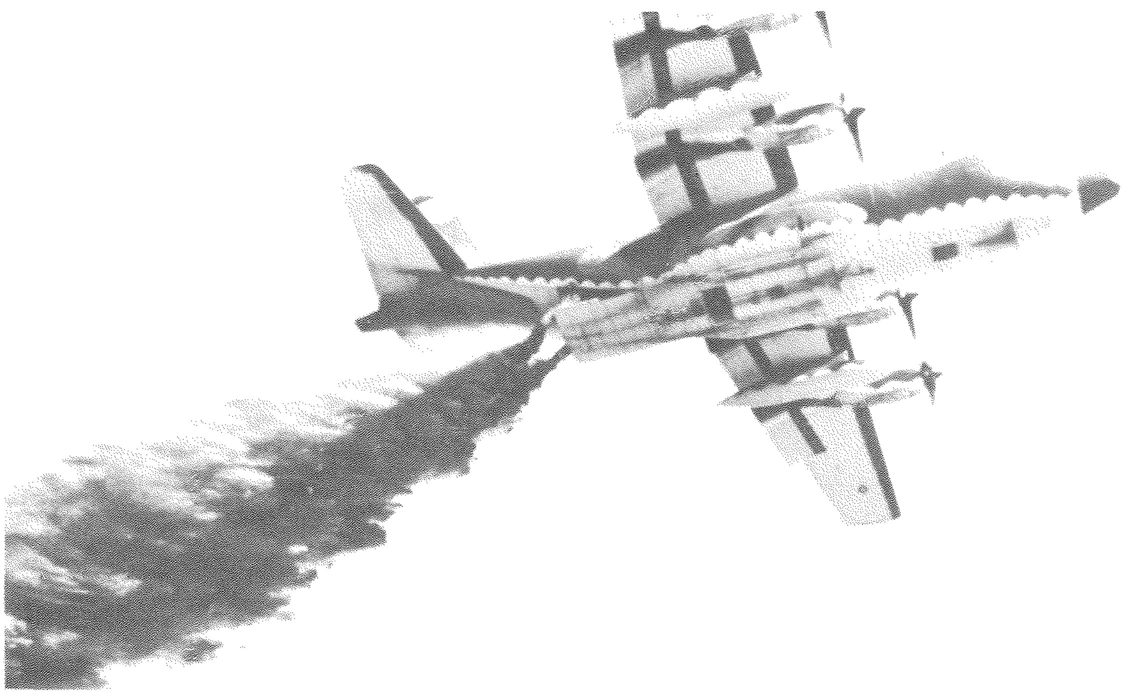

Figure 36. Retardant being discharged from the MAFFS unit mounted in the C-130 Hercules aircraft.
Photo: Courtesy U.S.D.A. Forest Service.

7. The drop systems on several airtankers are inadequate; doors open at various rates and some do not open to 90° from the horizontal.
8. The seals on many drop doors are unsatisfactory.
9. Venting on several delivery systems is inadequate. Retardant rate of flow is affected, resulting in "unclean" drops and discontinuous drop patterns.
10. Specifications for retardant delivery systems are not available.

RECOMMENDATIONS

1. Tank design in newer aircraft (e.g., DC-6B and S2F Tracker) should incorporate the latest developments. The system in some of the TBM Avengers and the DC-6B currently used could serve as the standard.
2. Modifications should be made to the drop system and venting on several airtankers currently used.
3. Cross-flow ports capable of handling 1591 litres (350 gal) of retardant per minute should be required in all tanks.
4. Medium-capacity airtankers (e.g., B-26) should be equipped with one 7.6 cm (3-in.) male Kamlock coupler; large-capacity airtankers (e.g., DC-6B) should be equipped with two 7.6-cm (3-in.) male Kamlok couplers for loading. The aircraft manifold system for loading should be capable of accepting 1591 litres (350 gal) of retardant per minute.
5. Retardant level indicators should be mandatory for all airtankers. The indicators should be simple, dependable, easy to maintain and inexpensive (e.g., overflow type).

6. Tanks in all airtankers should be calibrated with a certified water meter prior to each fire season. The capacity should be intermittently checked by user agencies to determine if modifications (e.g., ballast material, change in level indicators) have been made.
7. Maximum opening times and minimum rates-of-opening should be established for drop doors. The doors should open to at least 90^{o} from the horizontal.
8. The aircraft operator should maintain the drop system, including the door-closing apparatus, and seals at all times. Cleanup of retardant spills due to faulty seals and malfunctioning doors on both the airport and climb-out route should be made the responsibility of the aircraft operator.
9. Minimum standards for tank venting should be established. The venting system should permit clean drops and should preferably activate shortly before the drop (e.g., "ram-air" system).
10. Standards for the performance of retardant delivery systems should be prepared and enforced by user agencies. These can later be prepared as specifications if considered necessary. Static testing of tank and gating systems would serve to quantify the capabilities of delivery systems presently in use in Canada.

ACKNOWLEDGMENTS

The assistance of the numerous airtanker owners and operators is gratefully acknowledged. Without their co-operation this report would not have been possible.

REFERENCES

ANON. 1955. Aerial firefighting--Bulk water drop by fixed wing aircraft. Operation Firestop, Prog. Rep. No. 9.

ANON. 1973. Recent airtanker drop tests. In Forestry Report 3(1):4. Environ. Can., For. Serv., North. For. Res. Cent., Edmonton, Alberta.

COVAULT, C. 1973. C-130 adapted for fire fighting. Aviat. Week Space Technol. March 12.

ELY, J.B. and A.W. JENSEN. 1956. Air delivery of water helps control brush and grass fires. U.S. Dep. Agric., For. Serv. Fire Contr. Notes 17(2): 22-25.

ELY, J.B., A.W. JENSEN, L.R. CHATTEN, and H.W. JORI. Air tankers--a new tool for forest fire fighting. U.S. Dep. Agric., For. Serv., Fire Contr. Notes 18(3): 103-109.

FRASER, D.G. 1964. Aircraft for forest fire control in Canada. Can. Dep. For., For. Res. Br. Rep. 64-H-20.

GRIGEL, J.E. 1974. Long-term fire retardants and their use in Canada. Environ. Can., For. Serv., North. For. Res. Cent. Unpubl. rep.

HAWKSHAW, J.K. 1970. The airtanker: optimum characteristics. Paper presented at National Forest Fire Seminar on Aircraft Management, Petawawa Forest Exp. Stn., Chalk River, Ont., October 25-30, 1970.

LIESKOVSKY, R.J. 1971. Drop pattern for Twin Otter Membrane Tank System. Environ. Can., For. Serv., North. For. Res. Cent. Intern. Rep. NOR-2.

LINKEWICH, A. 1972. D. W. Friesen & Sons Ltd., Calgary, Alberta. 321pp.

SWANSON, D.H. and T.N. HELVIG. 1973. High altitude drop mechanization study. Honeywell, Inc. for U.S. Dep. Agric., For. Serv., Intermt. For. Range Exp. Stn. Final Rep., Vol. I.

SWANSON, D.H. and T.N. HELVIG. 1974. Extended high-altitude retardant drop mechanization study. Honeywell, Inc. for U.S. Dep. Agric., For. Serv., Intermountain For. Range Exp. Stn. Final Rep.

APPENDIX I

TANK AND GATING SYSTEMS IN USE IN CANADA

AIRTANKER MAKE AND MODEL: TBM Avenger

OWNER OPERATOR(S): Conair Aviation Ltd.

SYSTEM - DESIGNED BY: Fairey Aviation and Conair Aviation

- CONSTRUCTED BY: Same as above

PHYSICAL CHARACTERISTICS

(A) TANK: All tanks have a maximum capacity of 590 gal (2,682 l) -- Fairey and Conair (Skyway) V-bottom tanks are blocked-off to 500 gal (2,273 l) -- Conair flat-bottom tanks are blocked-off to 550 gal (2,500 l) -- Tanks are primarily internally mounted and sloped towards tail -- Two equal compartments in each tank.

(B) LOAD LEVEL INDICATOR: External overflow orifice with spring activated ball valve at point of maximum tank capacity as in Conair A-26.

(C) LOADING AND TRANSFER: As in Conair A-26.

(D) DROP GATES (DOORS): Two 142 in. x 19 in. (360.7 cm x 48.3 cm) gates open outboard to a full vertical position -- Gates are activated differently for each system -- i.e. (a) Fairey V-bottom has solenoid operated latches, free-fall opening and hydraulically closed; (b) Conair V-bottom has hydraulic jacks and torque tubes for opening and closing; (c) Conair flat-bottom has pneumatic torque tubes and over-centre locking mechanisms for opening and closing.

(E) VENTING: One 14 in. x 12 in. (35.6 cm x 30.5 cm) vent located on each side of fuselage behind wing -- Vent covers open outboard to act as ram-air scoops and are electrically operated when gates are armed prior to opening.

(F) LOAD RELEASE: As in Conair A-26.

REMARKS: These systems are indicative of progress in development of tank and gating design and efficiency in Canada.

TANK AND GATING SYSTEMS IN USE IN CANADA

AIRTANKER MAKE AND MODEL: S2F Tracker

OWNER OPERATOR(S): Ontario Ministry of Natural Resources

SYSTEM - DESIGNED BY: Field Aviation

- CONSTRUCTED BY: Ontario Ministry of Natural Resources

PHYSICAL CHARACTERISTICS

(A) TANK: 780 gal (3,546 l) max. capacity with three 200-gal (909 l) compartments and one 180-gal (818 l) compartment -- Tank is partially externally mounted and V-shaped towards the centre of the hull -- Tank is sloped slightly towards the aft when aircraft is at rest.

(B) LOAD LEVEL INDICATOR: Signal lights activated by (retardant) pressure sensitive switches are located at each loading coupler to indicate maximum and partial load volumes.

(C) LOADING AND TRANSFER: A single 3-in. (7.6 cm) male loading coupler with one-way flapper valve is located on each side of aircraft aft of the tank -- A 3-in. (7.6 cm) dia. perforated plastic transfer line connects loading couplers to compartment #1 -- All compartments are interconnected by one or more 16 sq. in. (103.2 sq cm) flapper valves.

(D) DROP GATES (DOORS): Four 6 ft x 20.5 in. (1.8 m x 52.1 cm) gates open outboard to a full vertical position -- Flat edges of doors seal against half-round beaded tank seals -- Gates are individually electrically activated and actuated by hydraulically operated torque tubes.

(E) VENTING: There are two 6-in. (15.2 cm) dia. static vents in the top of compartments 1, 2 and 3 while compartment 4 has four -- Vent covers are to be constructed to replace flex-hoses over vent openings to eliminate retardant overflow during take-off -- Slightly negative pressure accompanies "FIRETRAC" load modification device if installed.

(F) LOAD RELEASE: Starboard front compartment #1 discharged initially and followed by starboard aft compartment #2 -- Similar sequence occurs with port side compartments #3 front and #4 aft -- Load increments of 200 gal (909 l) offer versatility to meet various mission requirements -- Electronic timing device built into load selector controls drop sequence timing.

REMARKS: Tanking system is "clean" and efficient -- Hydraulic door opening is almost instantaneous -- Narrow fore and aft centre of gravity range accompanies design of this aircraft.

TANK AND GATING SYSTEMS IN USE IN CANADA

AIRTANKER MAKE AND MODEL: Douglas DC-6B

OWNER OPERATOR(S): Conair Aviation Ltd.

SYSTEM - DESIGNED BY: Aero-Union Corp'n and Conair Aviation Ltd.

- CONSTRUCTED BY: Conair Aviation Ltd.

PHYSICAL CHARACTERISTICS

(A) TANK: 2,500 gal (11,365 l) maximum capacity externally mounted tank -- 8 equal-sized compartments with a solid divider between the four forward and four aft compartments -- Each compartment 135 in. L x 16 in. W x 35 in. H (342.9 cm L x 40.6 cm W x 88.9 cm H) -- Total tank dimensions 23 ft L x 84 in W x 35 in H. (7.0 m L x 213.4 cm W x 88.9 cm H).

(B) LOAD LEVEL INDICATOR: External overflow orifice with spring-activated stopper located at each loading coupler -- Overflow lines are connected to compartments 7 and 8 to indicate full or partially full load volumes for each of the fore and aft tank sections.

(C) LOADING AND TRANSFER: Two 3-in. (7.6 cm) male "Kamlock" loading couplers on each side of tank for forward and aft sections -- Each coupler has a one-way flapper valve -- Loading is accomplished from either side of the aircraft and transferred by way of a connecting line to port side compartments 1 and 2 -- 6-in. (15.2 cm) dia. flapper valves interconnect remaining compartments.

(D) DROP GATES (DOORS): Eight 138 in. x 21 in. (350.5 cm x 53.3 cm) gates open outboard to 90° from the horizontal (closed) position -- Each gate opening is activated from the pneumatically actuated torque tube with over-centre locking capability -- Flat edge gates seal against knife edge of tank.

(E) VENTING: Fourteen 10-in. (25.4 cm) dia. vents are located along each side of the top surface of the tank -- Vent covers are circular flapper valves under spring tension -- Vent covers open inwards with induced vacuum at load release -- Louvred ram-air intakes along each side of the tank assist air flow to vents.

(F) LOAD RELEASE: Variable load release arrangements may be pre-selected starting from port side of tank and progressing to starboard to discharge fore and aft compartments individually, sequentially or in salvo combinations -- Load release selection and timing accomplished by selector and intervalometer or by manual triggering.

REMARKS: This system is "clean", efficient and versatile.

LEGEND

Schematic Diagrams of Tank and Gating Systems[1]

NOTE:

All Diagrams Represent Top View with Front of Tank Facing Top of Page

A) Compartment Number (1)

B) Load Intake → FLOW DIRECTION

C) Vents: Ram Air , , R

Static , (S), S

B-26 Optional Static

DC-6 Crossover Vents

D) Crossflow:

[Through one-way flapper valves]

:

[Over top of compartment divider (optional)]

E) Load Level Indicator (overflow):

F) Load Level Indicator (visual):

[lights, windows, or visible load markers in tank

G) Drop gate outline:

[where gate area is less than basal area of compartment]

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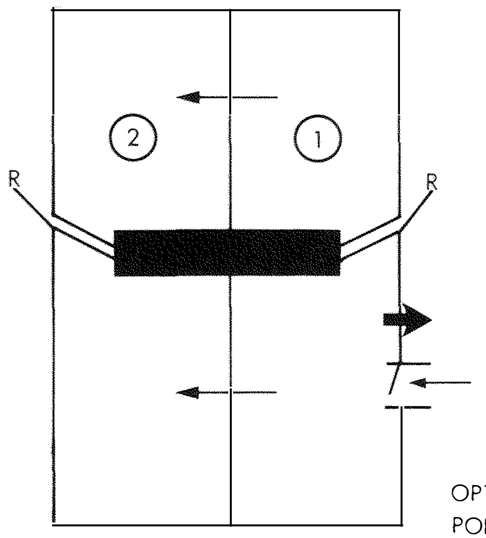
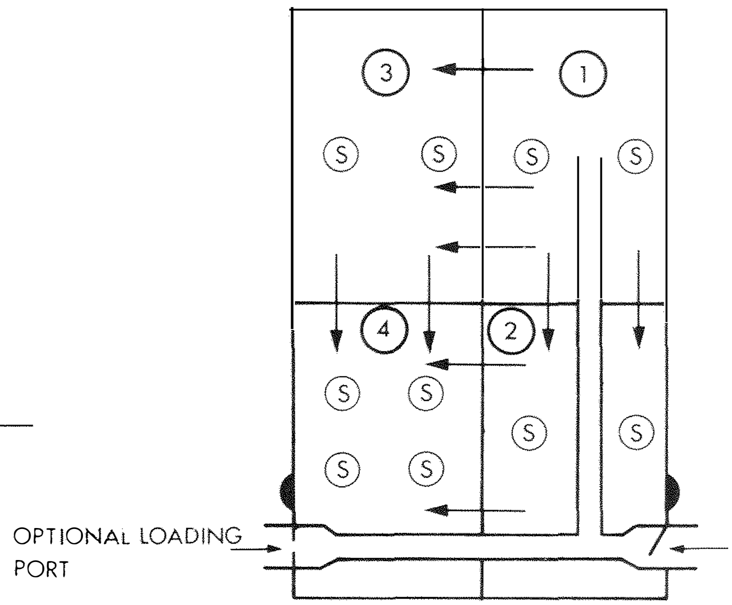
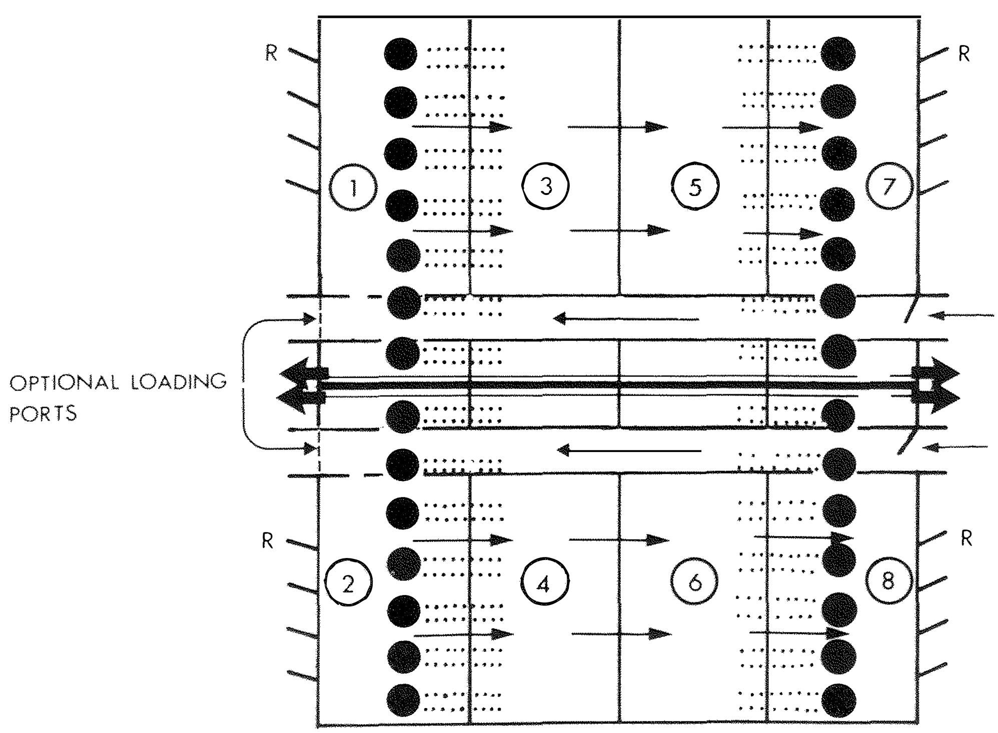
[1] Diagrams based upon data gathered in 1974.



GRUMMAN TBM AVENGER



S2F TRACKER



DOUGLAS DC-6B

TANK AND GATING SYSTEMS IN USE IN CANADA

AIRTANKER MAKE AND MODEL: Douglas A-26 (Two-door system).

OWNER OPERATOR(S): Conair Aviation Ltd.

SYSTEM - DESIGNED BY: Aero-Union Corp'n

- CONSTRUCTED BY: Conair Aviation Ltd.

PHYSICAL CHARACTERISTICS

(A) TANK: 900 gal (4,091 l) maximum capacity blocked off to 800 gal. (3,637 l) -- Tw• 400-gal (1,818 l) compartments -- Mounted internally and level within fuselage.

(B) LOAD LEVEL INDICATOR: External overflow orifice located aft of tank -- A ball valve at the top of the starboard compartment permits overflow -- A stand pipe connects this control valve to the external orifice -- Ball valve is opened by pulling spring activated connecting cable during loading.

(C) LOADING AND TRANSFER: Single 3-in. (7.6 cm) male "Kamlock" loading coupler at aft end of starboard compartment with one-way flapper valve -- Two 6 in. (15.2 cm) dia. flapper valves interconnect starboard and port compartments to permit starboard to port one-way cross-flow.

(D) DROP GATES (DOORS): A 10 ft x 2 ft (3.0 m x .6 m) gate forms the bottom of each tank compartment -- Both gates open outboard to 90° from horizontal (closed) position -- Flat edge gates seal against knife edge of tank -- Gate opening controlled by pneumatically actuated torque tube and over-centre locking capability.

(E) VENTING: Two 24 in. x 6 in. (61.0 cm x 15.2 cm) ram-air vents at top of fuselage provide air replacement to fore and aft tank sections simultaneously at load release -- Vents are activated by a connecting rod between torque tube and vent covers.

(F) LOAD RELEASE: Starboard compartment discharged initially, followed by port compartment for single salvos or sequential (train) drops -- Both compartments are released simultaneously for 800 gal (3,637 l) salvo -- Gate opening sequences are selected and triggered manually.

REMARKS: "Clean", efficient, well maintained tanking system -- Pneumatic gates provide almost instantaneous opening.

TANK AND GATING SYSTEMS IN USE IN CANADA

AIRTANKER MAKE AND MODEL: Douglas B-26 (Four-door system)

OWNER OPERATOR(S): Airspray "67" Ltd.

SYSTEM - DESIGNED BY: Various companies

- CONSTRUCTED BY: As above

PHYSICAL CHARACTERISTICS

(A) TANK: 1,000 gal (4,546 l) maximum capacity blocked off to average of 900 gal (4,091 l) -- Four compartments avg. 520 gal (2,364 l) for and 380 gal (1,727 l) aft sections -- All tanks but one are internal and level mounted -- CF-TFB partially external -- Rigid divider separates fore and aft sections.

(B) LOAD LEVEL INDICATOR: Overflow type with 1 inch stand pipes located within tank -- Fore and aft tank sections have independent load level indicator valves located adjacent to loading couplers.

(C) LOADING AND TRANSFER: Two 3-in. (7.6 cm) male "Kamlock" loading couplers on starboard side -- One coupler for each of fore and aft tank sections located adjacent to central tank divider -- Various internal transfer systems including one-way flapper valves and cross-flow over or through holes at top of tank section dividers.

(D) DROP GATES (DOORS): Four independent 5 ft x 2 ft (1.5 m x .6 m) pneumatically actuated gates with torque tubes and over-centre locking capability -- All but CF - EZX open outboard to 90° from the horizontal (closed) position -- All but CF-EZX have knife edge (gate) on flat surface (tank) seals -- CF-EZX has flat edge (gate) on flat surface (tank) seals.

(E) VENTING: Variable including both ram-air and static systems -- Some vent covers open inward when activated by connecting rods -- Others under spring tension in closed position, open under influence of negative pressure at load release -- Majority of tanks have ram-air vents 4 in. (10.2 cm) dia. (one per compartment) -- CF-TFB and CF-FIM have static vents 12 in. x 5½ in. (30.5 cm x 14.0 cm) (one per fore and aft section).

(F) LOAD RELEASE: Variable release sequences dependent upon cross-flow system but generally starboard rear compartment followed by starboard front and similar sequence on port side -- Tanks with inter-compartmental dividers and overtop cross-flow permit load release in any sequence of the four independent compartments but generally starting from rear for centre of gravity control.

REMARKS: Non-uniformity among these tanking systems can be confusing to users. New two-door tanking systems of Aero-Union design to be installed in some of these aircraft in 1975.

TANK AND GATING SYSTEMS IN USE IN CANADA

AIRTANKER MAKE AND MODEL: Mitchell B-25

OWNER OPERATOR(S): Northwestern Air Lease Ltd.

SYSTEM - DESIGNED BY: N/A

- CONSTRUCTED BY: Various companies

PHYSICAL CHARACTERISTICS

(A) TANK: 1,000 gal (4,546 l) maximum capacity -- Two equal capacity compartments of 500 gal (2,273 l) -- Operational capacity is 940 gal (4,273 l) to top of central tank divider -- Tank dimensions 72 in. L x 40 in. W x 80 in. H (182.9 cm L x 101.6 cm W x 203.2 cm H).

(B) LOAD LEVEL INDICATOR: Visual level confirmation via front static vent opening at top of fuselage.

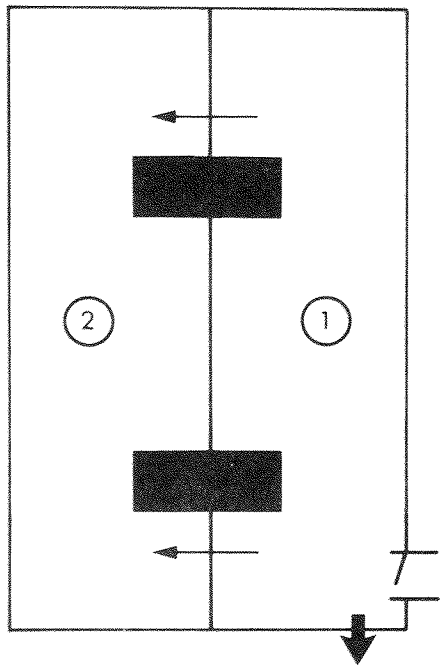
(C) LOADING AND TRANSFER: Two 3-in. (7.6 cm) male "Kamlock" loading couplers (starboard and port) at aft end of tank with one-way flapper valves -- Cross-flow between compartments over top of central tank divider.

(D) DROP GATES (DOORS): Two 6 ft x 20 in. (1.8 m x 50.8 cm) hydraulic gates open outboard to 90° from horizontal (closed) position and are actuated by torque tubes and over-centre locking capability -- Flat edge gates close against flat rubber seal on edge of tank.

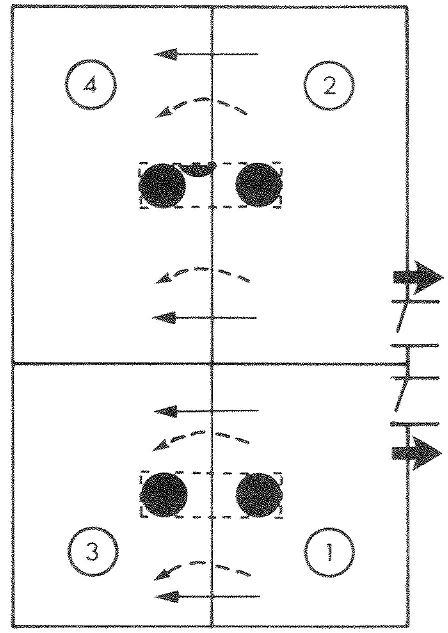
(E) VENTING: Two 12 in. x 9 in. (30.5 cm x 22.9 cm) static vents located towards the front and rear of the tank top on the upper surface of the fuselage -- Vents are continuously open to permit air release, overflow, and air intake during loading and dropping respectively.

(F) LOAD RELEASE: Starboard gate opens initially, followed by port for single salvos or sequential (train) drops -- Both gates are opened simultaneously for full salvo -- Manual gate selection and triggering.

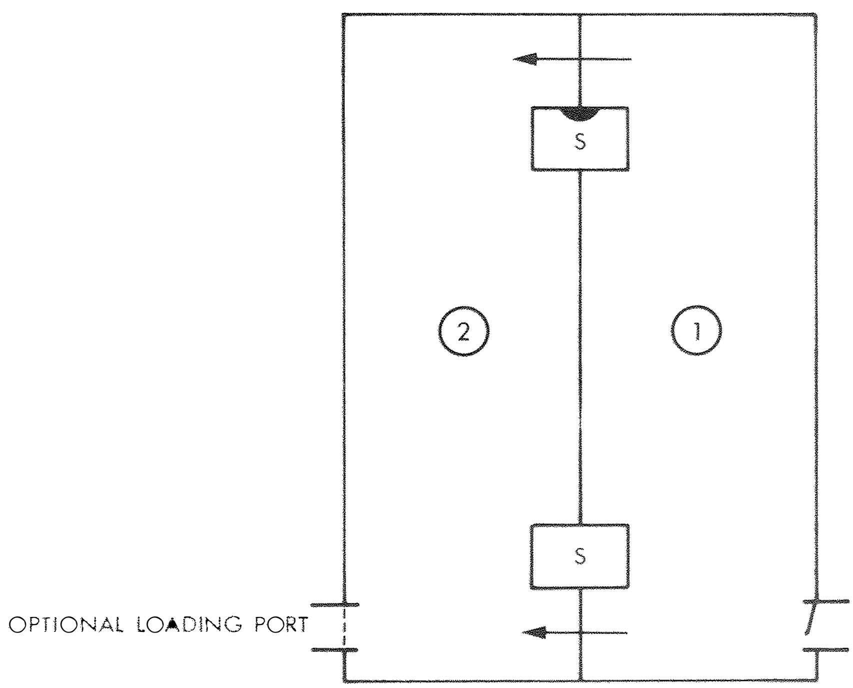
REMARKS: Possible retardant trail-off from open vents during take-off and climb-out with full tank.



DOUGLAS A-26 (TWO-DOOR)



DOUGLAS B-26 (FOUR-DOOR)



MITCHELL B-25

TANK AND GATING SYSTEMS IN USE IN CANADA

AIRTANKER MAKE AND MODEL: PBY-5A Canso

OWNER OPERATOR(S): The Flying Fireman Ltd.

SYSTEM - DESIGNED BY: Fairey Aviation

- CONSTRUCTED BY: Fairey and Flying Fireman

PHYSICAL CHARACTERISTICS

(A) TANK: 900 gal (4,091 l) maximum capacity [800 gal (3,637 l) operational]-- Two equal sized compartments -- Tank is internal and level mounted within the hull.

(B) LOAD LEVEL INDICATOR: External overflow through openings in each side of fuselage at maximum tank capacity -- Also visual load level indicator window built into front end of tank facing cockpit to indicate 800 gal (3,637 l) capacity.

(C) LOADING AND TRANSFER: Water probe located on starboard side of keel aft of tank can fill tank in 18 s while skimming -- Water thickening (short-term) retardant can be injected while skim-loading -- Land fill via 3 in. (7.6 cm) male "Kamlock" loading couplers at overflow openings in sides of fuselage -- Cross-flow from starboard to port compartments via 3 flapper valves and 6 in. x 10 in. (15.2 cm x 25.4 cm) opening at top of tank divider.

(D) DROP GATES (DOORS): Two 64 in. x 19 in. (162.6 cm x 48.3 cm) rectangular gates in V-shaped hull open outboard to full vertical position -- Gate opening controlled by hydraulically actuated torque tubes.

(E) VENTING: Two 14 in. x 8 in. (35.6 cm x 20.3 cm) vent openings are located at overflow ports in sides of fuselage at tank top -- Continuously open for overflow, air release and static (atmospheric) venting during loading and dropping phases.

(F) LOAD RELEASE: Starboard compartment discharged initially in train or single salvo drops, followed by port compartment -- Both gates discharged simultaneously for full salvo -- Gate activation is selected and triggered manually by the pilot.

REMARKS: Single pressurized short-term retardant hopper and injector located behind tank on starboard side -- Back-up air pressure pumps and air dessicators are employed.

TANK AND GATING SYSTEMS IN USE IN CANADA

AIRTANKER MAKE AND MODEL: PBY-5A Canso

OWNER OPERATOR(S): Various - including Kenting Aviation, Avalon Aviation, Norcanair Ltd., and Trans-Air Ltd. (Midwestern).

SYSTEM - DESIGNED BY: Field Aviation Ltd.

- CONSTRUCTED BY: Field Aviation Ltd.

PHYSICAL CHARACTERISTICS

(A) TANK: 800 gal (3,637 l) maximum capacity -- Single internal level mounted tank with two independent 400 gal (1,818 l) compartments.

(B) LOAD LEVEL INDICATOR: External overflow through openings in each side of fuselage connected to top of each compartment at max. tank capacity -- Also visual load level indicator window at front end of each compartment within sight of cockpit.

(C) LOADING AND TRANSFER: Water probe located at aft end of tank to starboard of keel for skim-loading (14 s) -- Probe intake divided into two lines at "T" connection to fill each compartment simultaneously -- Water thickening (short-term) retardant can be injected into each compartment -- Land-fill accomplished at overflow ports.

(D) DROP GATES (DOORS): Two 10.15 sq ft (.9 sq m) oval gates open outboard to full vertical position and are located at the bottom of the V-shaped hull on either side of the central keel -- Gates are mechanically actuated but "free-fall" open under gravitational and load influence -- Gates are closed hydraulically.

(E) VENTING: The top of each compartment has a 14 in. x 8 in. (35.6 cm x 20.3 cm) vent which is connected directly to the overflow ports in the sides of the fuselage to provide continuous (atmospheric) venting, air release, and overflow -- Vent-to-gate size ratio approximately 1:13.

(F) LOAD RELEASE: Tank compartments can be discharged independently, in sequence, or simultaneously for full salvo drops -- Gate opening is selected and triggered manually by the pilot.

REMARKS: First Canso tanked by Field Aviation circa 1961.

TANK AND GATING SYSTEMS IN USE IN CANADA

AIRTANKER MAKE AND MODEL: Canadair CL-215

OWNER OPERATOR(S): Province of Quebec

SYSTEM - DESIGNED BY: Canadair Ltd.

- CONSTRUCTED BY: Canadair Ltd.

PHYSICAL CHARACTERISTICS

(A) TANK: 1,176 gal (5,346 l) maximum capacity -- Comprised of two individual compartments of equal size located within the hull on each side of a central divider -- Above floor domes mounted over each compartment.

(B) LOAD LEVEL INDICATOR: Outboard overflow from top of tanks through opening in fuselage -- Load volume gauges are also located in the cockpit.

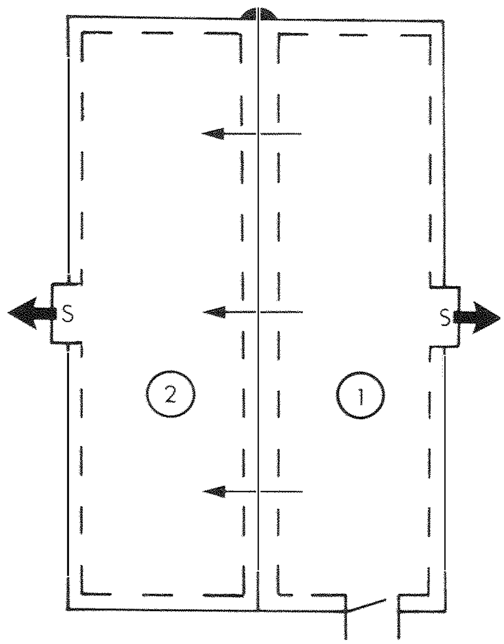
(C) LOADING AND TRANSFER: Individual water probes located aft of each compartment for skim-loading -- Land fill for each individual compartment at external connectors at overflow ports -- Water thickening (short-term) retardant can be injected into tank while skimming -- There is no cross-flow between tank compartments.

(D) DROP GATES (DOORS): Two 61 in. x 31 in. (154.9 cm x 78.7 cm) electrically controlled hydraulically actuated gates are located in the bottom of the V-shaped hull on either side of the central keel -- Gates are somewhat smaller than basal tank dimensions (63 in. x 56 in.) (160.0 cm x 142.2 cm) and open outboard to 74^{o} - 79^{o} from horizontal.

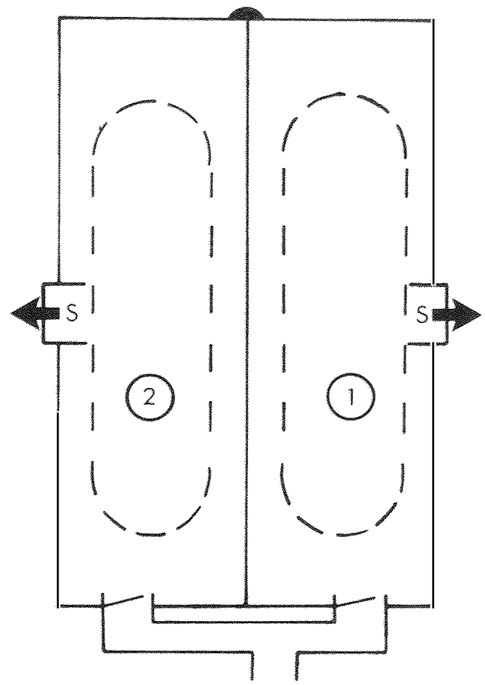
(E) VENTING: A 21 in. x 12 3/4 in. (53.3 cm x 32.4 cm) vent is located at the overflow port on either side of the hull at the top of each tank compartment -- Vents are continuously open for overflow, air release, and static (atmospheric) venting during loading and dropping phases.

(F) LOAD RELEASE: Each compartment is discharged individually for salvo or sequential drops, or together for a full salvo -- Gates are manually selected and triggered.

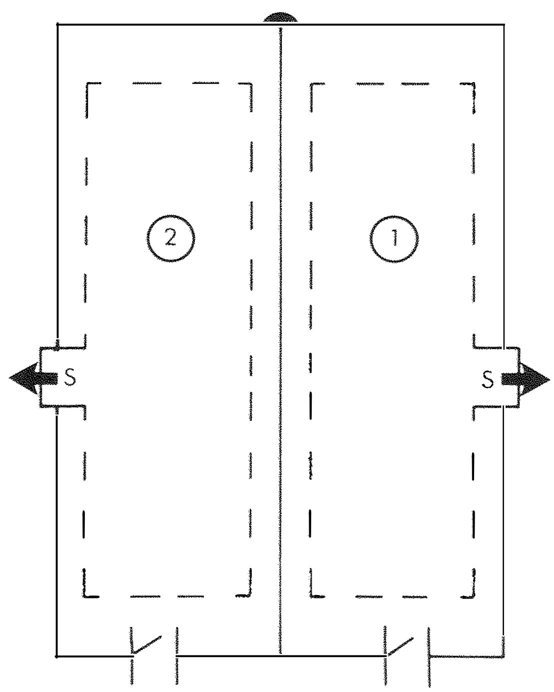
REMARKS: Delivery system modifications currently underway are expected to improve the operational capability of this airtanker.



PBY-5A CANSO (FAIREY)



PBY-5A CANSO (FIELD)



CANADAIR CL-215

APPENDIX II

SUMMARY OF PERFORMANCE CRITERIA FOR AIRTANKERS COMMONLY USED IN CANADA

PERFORMANCE CRITERIA / AIRTANKER		DOUGLAS DC-6B	DOUGLAS B-26 (4-DOOR)	DOUGLAS A-26 (2-DOOR)	MITCHELL B-25	S2F TRACKER	TBM AVENGER	CANADAIR CL-215	PBY-5A CANSO
Number of Piston Engines		4	2	2	2	2	1	2	2
Oil -: Grade		Dispersant 100 W	Non-Disp. 100-120 W	Dispersant 120 W	Non-Disp. 120 W	Dispersant 120 W	Dispersant 100 W	Dispersant 100 W	Various-Disp. & N.-Disp. 100-120 W
Oil -: Consumption[1]	(gal/hr)	8	3	5	2	1	1	1	2
Fuel -: Capacity (with Retardant tank full)	(gal.)	1,500	500	666	558	177	200	(625)[2] 460	(400) 300
	(lb.)	10,800	3,600	4,800	4,018	1,200	1,440	(4,500) 3,300	(2,880) 2,160
	(hr.)	4.5	3.6	4.8	4.5	1.6	3.3	(4.5) 3.3	(5.0) 3.8
Fuel -: Capacity (with Retardant tank empty)	(gal.)	4,500	666	666	812	434	271	987	1,460
	(lb.)	32,400	4,800	4,800	5,846	3,100	1,950	7,106	10,500
	(hr.)	13.6	4.8	4.8	6.5	5.0	4.5	6.9	18.3
Fuel -: Grade (octane)		100-130	100-130	100-130	100-130	100-130	100-130	100-130	100-130
Fuel -: Consumption	(gal/hr)	330	140	140	125	104	60	140	100[3]
	(lb/hr)	2,375	1,000	975	900	750	432	1,000	575
Retardant Capacity Design Maximum	(gal)	2,500	1,000	900	940	760	590	1,200	900 Fairey 800 Field
[4]Normal operations	(gal)	2,500	900	800	940	710	500 V-Bottom 550 Flat-Bot.	(1,200) 1,140	(800) 650
Gross Take Off Weight	(lb.)	107,000	35,000	35,000	34,000	26,000	17,600	43,500	30,500
Empty Weight[5] -:	(lb.)	55,000	20,000	19,000	19,000	16,100	10,000	27,000	Variable 20-21,000
Take-Off Distance[6]	(ft.)	5,200	5,850	5,850	5,000	3,200	2,800	(3,200) 3,100	(5-7,000) 3,600
Rate of Climb	(ft./min)	900	900	900	1,075	1,500	1,000	880	500
Wheel Bearing Pressure[7]	(lb/sq. in)	100	75	75	75	75	90	95	50
One-Hour Block Speed[8]	(mi/hr.)	240	230	250	190	180	160	160	115

[1] All engines excluding oil changes

[2] Figures in parentheses ( ) valid while performing in water skimming mode

[3] Averages cruising and bombing (skimming) rates

[4] Assumes 3 hours plus ½ hour reserve

[5] Includes residual fuel and oil pilots and equipment

[6] Assumes surfaced runway, 2,000'ASL, nil wind, 30% RH, 70°F Temp. and approx. ½ mile clearing in addition to take-off distance in order to safely clear a minimum 50 ft. obstacle

[7] Main wheels

[8] One-hour turn around (includes wheels off - climb - cruise - descent - wheels on)

Metric Equivalents

1 gal = 4.54 litres
1 lb = .453 kg
1 ft = 0.3048 m
1 mile = 1.60934 km
1 sq in. = 6.4516 cm
1°F = 1.8°C + 32