INVESTIGATION OF THE VULNERABILITY OF AIRCRAFT ENGINE OIL TANKS TO ACCESSORY SECTION FIRES

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SUMMARY

Laboratory tests have been conducted to determine whether aluminum oil tanks located forward of aircraft power plant fire walls are potential fire hazards. Three series of tests were conducted on various types of oil tanks, both coated and uncoated.

The first test series was conducted on uncoated aluminum oil tanks ranging in size from 3 to 10 gallons. These tests indicated that even a small tank completely enveloped in flame would remain undamaged for as long as 20 minutes, provided it was full of oil. Tanks that were only partly filled with oil were damaged in a relatively short time. The fire used in this test series was small at the start and gradually increased in size and severity.

The second and third series of tests were conducted using a fire that was at its full size and severity within a few seconds after the start of the test. In the second series of tests aluminum alloy tanks coated with suitable heat-insulating materials withstood fires from 6 to 12 times as long as unprotected tanks. The third series of tests indicated that steel tanks can withstand fire for still greater periods of time, provided the gaskets are made of fireproof material and the filler cap is of such design that the tightness is not affected by fire.

INTRODUCTION

In the past few years, it has been shown that aluminum oil tanks forward of the fire wall can successfully withstand fires of short duration. The Technical Development and Evaluation Center of the Civil Aeronautics Administration has subjected such tanks to as many as 2,200 fires of 30 seconds duration each, without any damaging effects.

Due to the inquiries made by the Air Line Pilots Association, by the CAA Office of Aviation Safety, and by others concerning the resistance of such tanks when exposed to fire for longer periods of time; tests were conducted to obtain this information. Both aluminum alloy and steel oil tanks were included in the program to determine their abilities to withstand accessory section fires of long duration.

PROCEDURE

Preliminary tests were conducted in which three-, five-, and ten-gallon aluminum alloy tanks were subjected to a fire produced by blowing air over a pan fire and impinging that fire upon the test tank. In the first test, the tank installation included aluminum alloy straps and mounting brackets and a composition supply line of the type used in present aircraft. A 1/2-inch od copper vent line was used. Early failures of the lines, straps, and brackets made it necessary to revise the test set-up to preclude such failures. The opening for the supply line was plugged, and the mounting straps and brackets were made of iron. Tests were then conducted on three- and five-gallon aluminum alloy tanks that were 75, 33, and 20 per cent full of SAE No. 60 aircraft engine oil. The time required for each tank to fail, while subjected to fire, was determined. Included in this series were tests on ten-gallon elliptical tanks to determine the protection afforded a tank by a coating of Albi-RX fire-retardant paint.

Temperatures of the test flame were recorded at various locations near the outer surfaces of the tanks. Temperatures of the oil and of the unfilled air space above the oil were observed in the first few tests of this series.

A second test series was conducted on ten-gallon elliptical aluminum alloy tanks to determine the protection afforded by various types of heat-insulating materials. The flame producer, shown in Fig. 1, provided improved flame control and was used in this test series. This flame producer consisted of a small conversion-type oil burner that has a No. 12 oil nozzle and uses No. 3 fuel oil at 80 psi. A 1/2-hp centrifugal blower replaced the 1/6-hp blower provided with the conversion burner. A burner barrel extension, 11 inches long and 9 inches in diameter at the open end, was added to hold and direct the flame. At a temperature of over 2,000° F this burner produced a flame, as shown in Fig. 2, that enveloped the tanks tested within a few seconds, remained fairly constant throughout any one test, and was reproducible in all succeeding tests.

Flame temperatures surrounding the tanks were recorded; and, in a few cases, temperatures of the oil and the air space within the tank were observed. Tests were conducted on uncoated aluminum alloy tanks 80 per cent and 20 per cent full of SAE No. 60 aircraft engine oil and on aluminum alloy

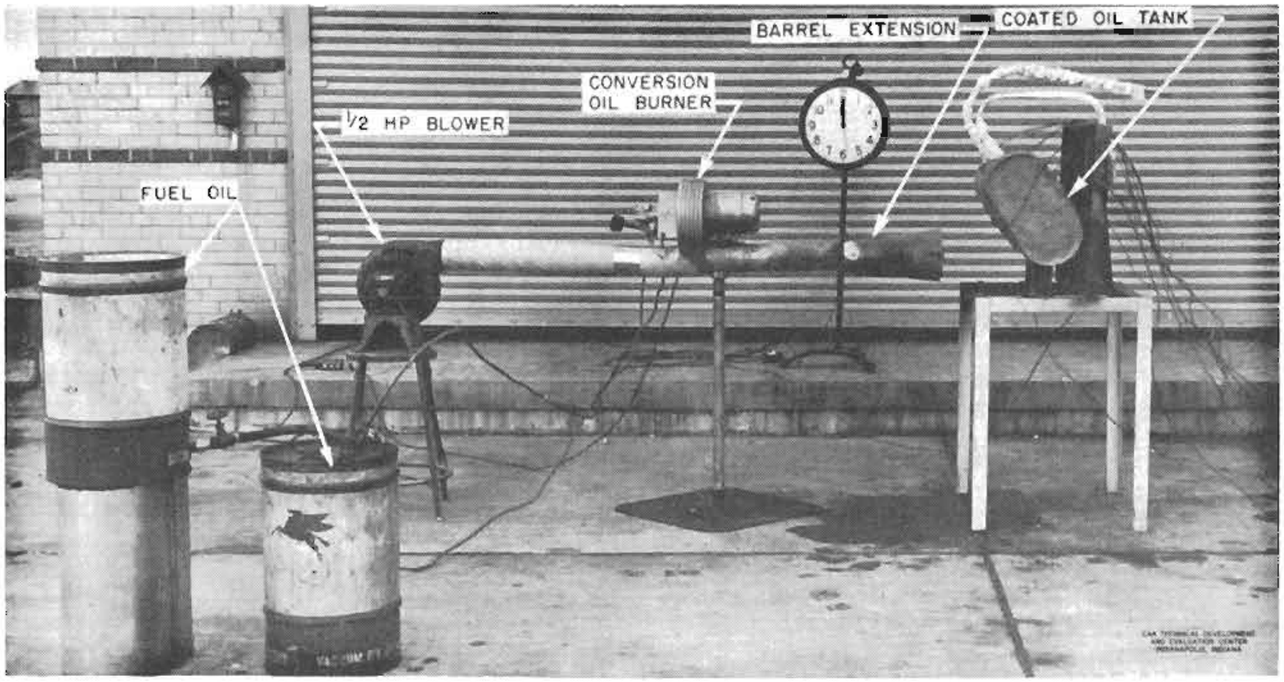

Fig. 1 Final Test Arrangement Used in Subjecting Aircraft Engine Oil Tanks to Simulated Accessory Section Fires.

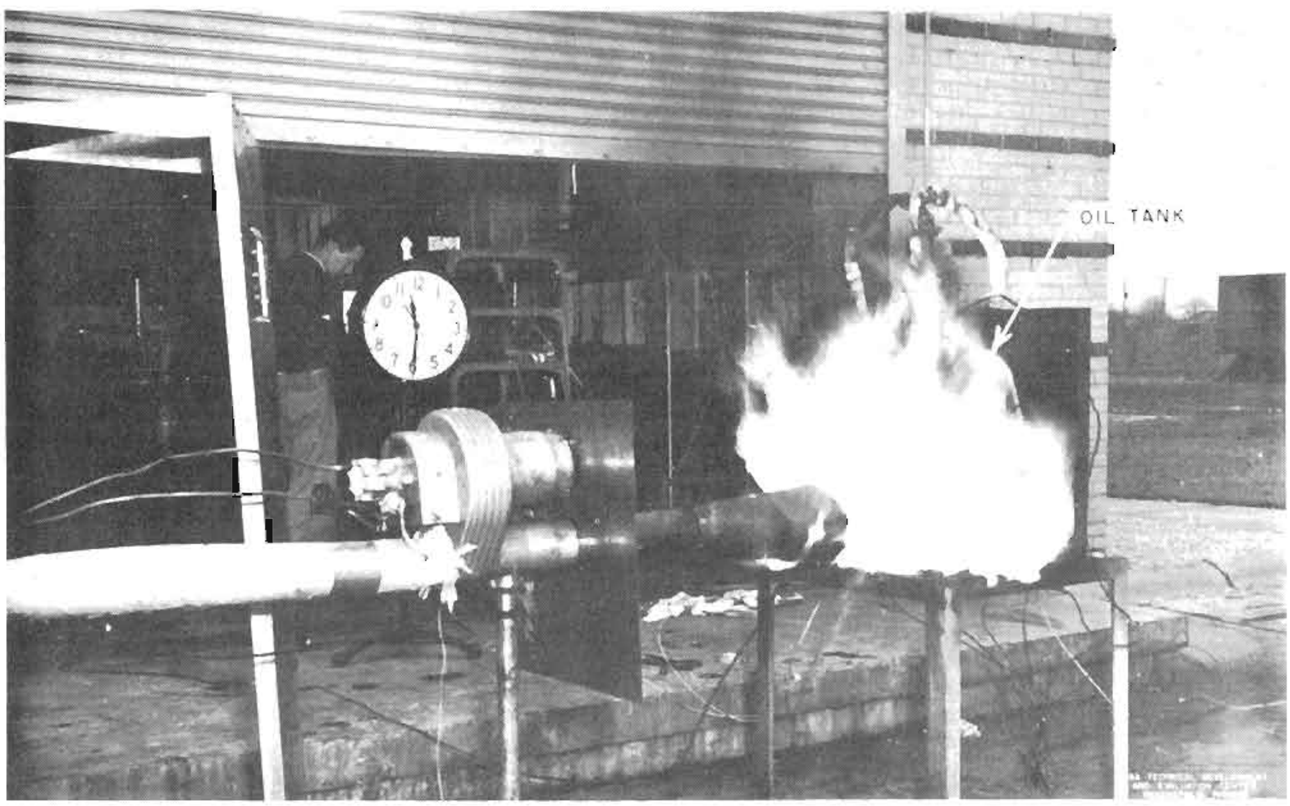

Fig. 2 Simulated Accessory Section Fire Produced by the Modified Conversion Oil Burner

coated tanks 20 per cent full of oil.

A third test series was conducted to compare the resistance of steel oil tanks to accessory section fires with that of aluminum alloy tanks, both coated and uncoated. In this series, the tanks tested were of the types used in B-45 aircraft. Both the aluminum alloy and the steel tanks were of approximately ten-gallon capacity.

Time for failure for all the tests was measured from the incidence of fire until molten aluminum could be seen dripping from the tank or until a noticeable increase in fire severity was observed.

RESULTS AND DISCUSSION

The fire produced by passing air over a gasoline pan fire required about two minutes to reach a temperature of 2,000° F and completely envelop the tank. This fire increased in severity as any one test progressed, and its size was not easily controlled from one test to the next.

The first test of the preliminary series was conducted on a five-gallon cylindrical oil tank mounted horizontally and three-fourths full of SAE No. 60 aircraft engine oil. The tank was mounted by its aluminum brackets and straps to a simulated fire wall. A composition supply line was connected to the tank and located so that it would also be enveloped in the fire. The first test lasted one minute. The tank itself was undamaged; but the aluminum straps failed, and the composition hose had begun to leak. The supply line was removed and the opening was plugged. The aluminum straps were replaced with iron straps. The second test lasted four minutes. Again the tank was undamaged, but failure occurred in the aluminum mounting bracket. The damaged bracket was replaced by one made of iron, and the third test was initiated. In this test the tank withstood the enveloping flame of approximately 2,000° F for 20 minutes at which time the upper portion of the tank, weakened by the flame, opened from the internal pressure and emitted oil vapors that produced a violent fire. Similar tests were conducted on oil tanks with various fill ratios to determine the effect of these ratios on the ability of a tank to resist fire. The results of these tests are shown in Table I.

Included in this preliminary series were tests conducted on two similar aluminum alloy oil tanks, one of which was coated with a fire-retardant coating, in order to determine whether such procedure warranted further investigation. The times required for failure of the tanks, each 20 per cent full of SAE No. 60 aircraft engine oil, were two minutes for the uncoated tank and seven

TABLE I

PRELIMINARY TEST RESULTS

Item	Tank Capacity (gallons)	Tank Shape	Fill Ratio (per cent)	Time Required For Failure (minutes)	Remarks
1	5	cylindrical	75	1	Tank undamaged. Aluminum alloy tank straps and composition hose failed.
2	5	cylindrical	75	4	Tank undamaged. Aluminum alloy tank brackets failed.
3	5	cylindrical	75	20	Tank failed. Ruptured at top from internal pressure. Large, violent fire resulted immediately.
4	3	cylindrical	33	8	Tank failed. Ruptured at top from internal pressure. Large, violent fire resulted immediately.
5	5	cylindrical	20	2	Tank failed. Aluminum wall melted above the oil level. No immediate change in fire size resulted.
6	10	elliptical	20	2	Tank failed. Aluminum wall melted above the oil level. No immediate change in fire size resulted.
7	10	elliptical	20	7	Tank failed. Coated with Albi-RX (water-base) fire retardant paint.

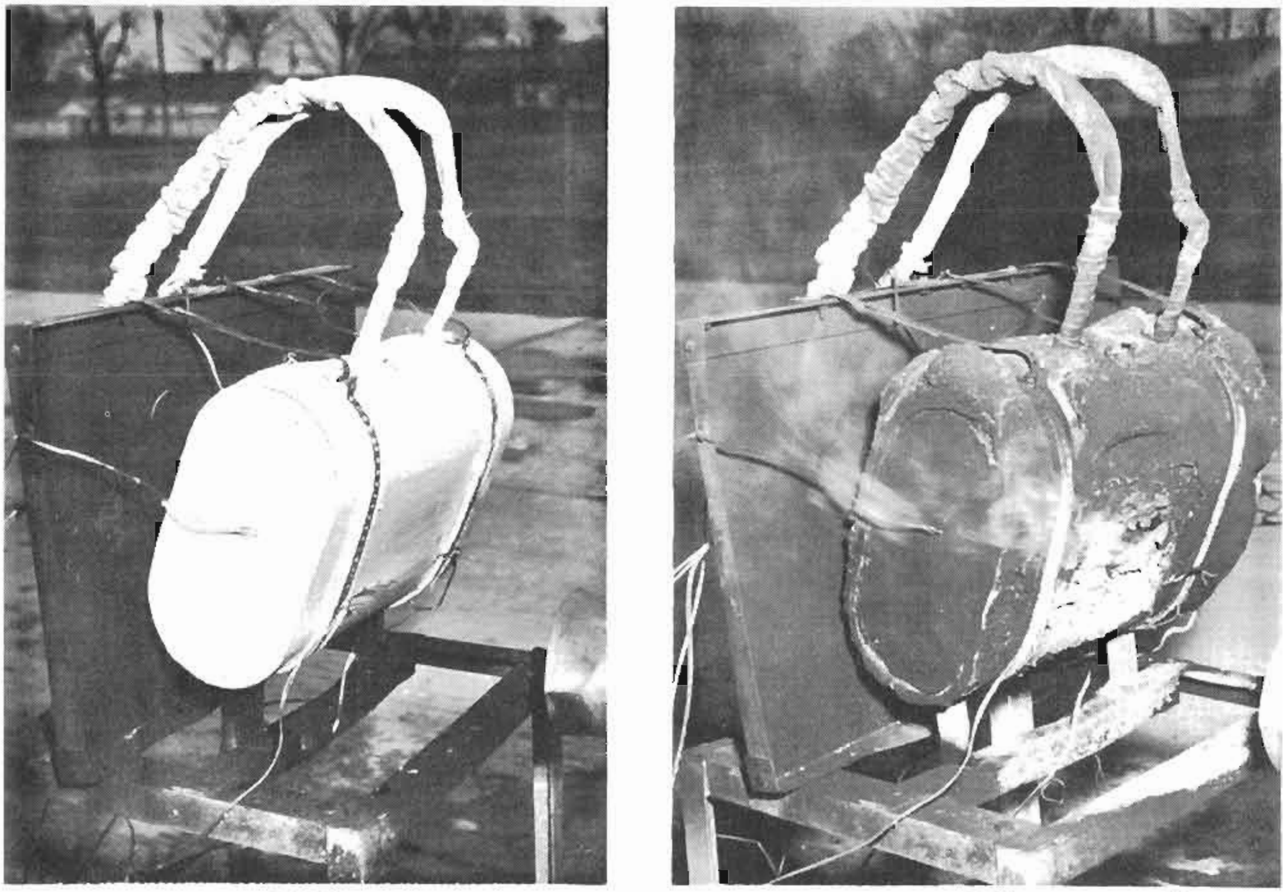

Fig. 3 Coated Aluminum Alloy Oil Tank, Before and After Fire Test

minutes for the tank coated with Albi-RX fire-retardant paint.

The second series of tests was conducted to determine accurately the protection afforded by various types of heat-insulating materials. The tanks used were ten-gallon elliptical aluminum alloy oil tanks. Fig. 3 shows one of these tanks before and after the fire test. The types of heat-insulating materials, the per cent of fill, and the results of this test series are given in Table II.

The third series of tests was conducted on aircraft engine oil tanks of the type used in B-45 aircraft. The same flame producer and procedure were used in conducting these tests as were used in the second test series. The aluminum alloy tank was of the type used in B-45A aircraft, and the corrosion-resistant steel tanks were of the type used in the B-45C aircraft.

The results, shown in Table III, indicate that failure of the uncoated aluminum alloy oil tank of the type used in B-45 aircraft occurred in the same length of time as that of the uncoated elliptically-shaped aluminum alloy oil tank used in the second test series. The uncoated, corrosion-resistant steel tank withstood fire for six minutes. Failure was due to the inability of the sump and filler-cap assembly gaskets to withstand the fire. By comparing this result with the results in Table II, it will be noted that the unprotected steel tank showed better resistance to fire than any of the coated aluminum alloy tanks. The test on the corrosion-resistant steel tank was repeated after the defective gaskets were replaced with gaskets made of Johns-Manville No. 76 gasket material. After seven minutes, the spring-type retainer in the quick-opening filler cap failed. The failure permitted the escape of oil vapor, which fact contributed greatly to the severity and size of the existing fire. The tank was then modified by replacing the quick-opening filler-cap assembly with a screw-type filler-cap assembly, as shown in Fig. 4.

TABLE II

EFFECTS OF VARIOUS COATING SYSTEMS
ON FIRE RESISTANCE OF ALUMINUM ALLOY OIL TANKS*

Item	Coating System	Fill Ratio (per cent)	Dry Weight Tank Plus Coating (pounds)	Time Required For Failure (minutes)	Remarks
1	uncoated	20	7.5	0.35	
2	B. F. Goodrich	20	10.3	2	Tank coated by B.F. Goodrich Co., Akron, Ohio.
3	Stabond Compound	20	10.3	4	Stabond compound No. HT-2 manufactured by American Latex Products Corp., Los Angeles, Calif.
4	Albi-RX (water-base)	20	9.0	4.5	Coated with Albi-RX paint and overcoated with Amercoat Solution No. 1322.
5	uncoated	80	7.5	15	

* Elliptically shaped tanks of 10 gallons capacity

TABLE III

COMPARISON OF FIRE RESISTANCE OF UNCOATED
ALUMINUM ALLOY AND STAINLESS STEEL OIL TANKS*

Item	Tank Material	Fill Ratio (per cent)	Dry Weight of Tank (pounds)	Time Required For Failure (minutes)	Remarks
1	Aluminum Alloy	20	8	0.35	
2	Steel	20	10	6	Tank undamaged. Filler and sump gaskets failed.
3	Steel	20	10	7	Tank undamaged. Filler cap failed.
4	Steel	20	10	12	Tank undamaged. Test discontinued. No oil remained in tank.

*Aluminum alloy oil tank 10.6 gallons capacity as installed in B-45A aircraft. Corrosion-resistant steel oil tank 11.6 gallons capacity as installed in B-45C aircraft.

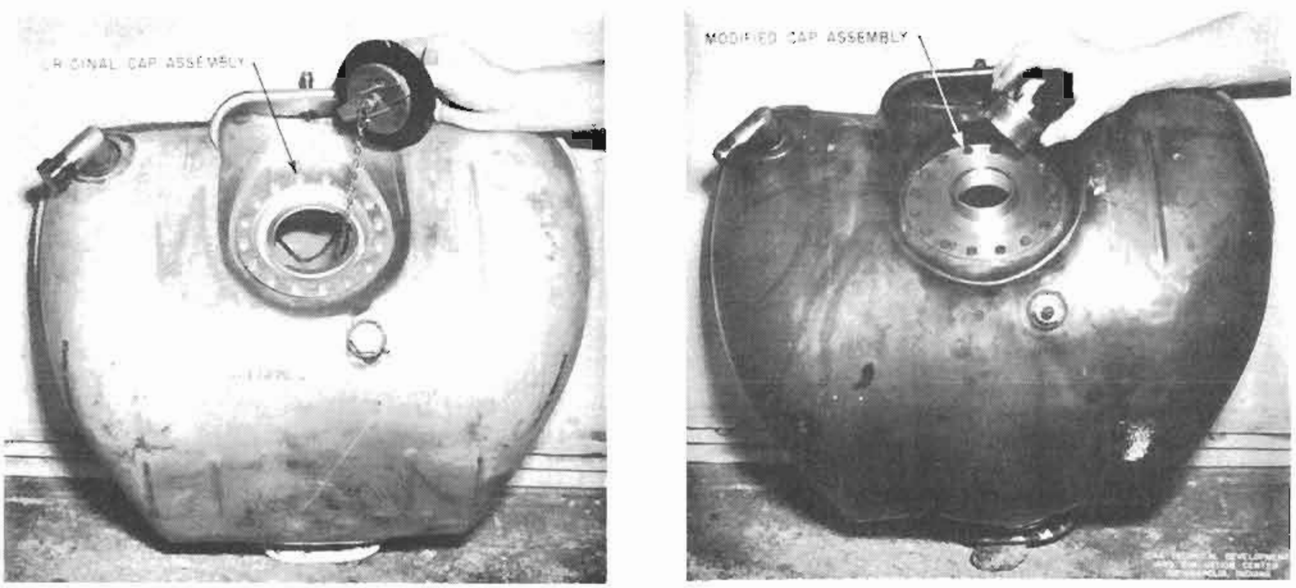

Fig. 4 Steel Oil Tanks, Showing the Quick-Opening Filler Cap and the More Fire-Resistant Screw Type Filler Cap

The modified tank was then subjected to the same fire and test conditions. This test was terminated 12 minutes after fire ignition, because all the oil had boiled away. The tank, gaskets, and filler-cap assembly were undamaged.

One phenomenon encountered, while conducting fire tests on the corrosion-resistant tanks, was the explosion of one tank approximately 15 seconds after fire ignition. In order to determine the cause of the explosion ten additional tests were conducted on similar steel tanks and other steel vessels with capacities of five gallons. It was determined that an explosion occurred only when the interior walls of the unfilled portion of the oil tank were dry. Four tests were conducted on the corrosion-resistant steel oil tanks. During two of these tests, no explosion occurred. During another test, a slight explosion occurred; but it did not rupture or even deform the tank. Only one of these four tests resulted in an explosion of sufficient violence to cause the tank to burst open. The oil used in these tests was at approximately 75° F at the start of the fires, and the tanks were 20 per cent full of oil.

It is believed unlikely that dry internal tank surfaces, low oil temperature, and low oil quantity would exist in practice. Therefore, the possibility of a ruptured oil tank resulting from an internal explosion caused by an external fire is remote.

Although the reported tests were confined to flight or ground fire conditions, it is pointed out that consideration should be given to properly locating flammable fluid tanks from the crash fire standpoint. Regardless of the material used in constructing the tank, any flammable fluid tank installed in line with and immediately aft of the engine can be a serious crash fire hazard. The relatively low spontaneous ignition temperatures of lubricating oils and hydraulic fluids make them particularly dangerous when exposed to hot metal parts.

CONCLUSIONS

From the tests conducted, it is concluded that:

1. Aluminum alloy oil tank brackets and straps and oil lines of little fire resistance constitute a greater fire hazard in the accessory section than the aluminum alloy oil tank itself.
2. An aluminum alloy oil tank can fail in as little as 20 seconds when subjected to a severe accessory section fire, provided the tank is filled to less than 25 per cent of its oil capacity.
3. An aluminum alloy oil tank can withstand a severe accessory section fire for an average of over 10 minutes, provided the tank is filled to more than 75 per cent of its oil capacity.
4. An aluminum alloy oil tank can withstand a severe accessory section fire for two or more minutes, if protected by a suitable heat-insulating material, regardless of the amount of oil contained in the tank. This

should be more than enough time to perform proper extinguishing procedures.

5. A steel oil tank can withstand a severe accessory section fire until all the oil has boiled away, provided the vent line is of sufficient size and the gaskets and filler cap are of such design and material as to withstand the fire. Generally a steel oil tank will withstand severe fire for more than 15 minutes.

RECOMMENDATIONS

It is recommended that:

1. Aluminum alloy tank brackets, straps, and supports be replaced by parts made of more fire-resistant metals in any potential fire zone.

2. A fireproof material be required for gaskets in any aircraft oil tank.

3. A filler cap, which will remain vapor-tight at temperatures up to 2,000° F, be used in any flammable fluid tank located in a potential fire zone.

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