AIRCRAFT FIRE EXTINGUISHMENT

PART IV

EVALUATION OF A BROMOCHLOROMETHANE FIRE-EXTINGUISHING SYSTEM FOR THE XB-45 AIRPLANE

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SUMMARY

A bromochloromethane fire-extinguishing system, designed by Walter Kidde & Company, Inc., in accordance with USAF Specification MIL-E-5352, was fabricated and installed in an XB-45 airplane power plant. Fire-extinguishing tests were conducted under simulated flight-fire emergency conditions to check the validity of certain phases of the specification and of certain design practices. Quantity requirements for extinguishing fires in each nacelle compartment were determined for bromochloromethane and dibromodifluoromethane.

Present design practices were found to result in a system which meets the requirements of MIL-E-5352 specification for the duration of agent discharge and for agent distribution. The quantity of agent required by the specification (48.82 pounds) was found to be inadequate for extinguishing all nacelle fires. The minimum quantity of agent for extinguishing all fires was determined by test to be 66 pounds.

A system designed for bromochloromethane proved satisfactory for use with dibromodifluoromethane. On the basis of weight, the latter agent was somewhat more effective.

INTRODUCTION

Since August 10, 1950, the Department of the Air Force has made use of bromochloromethane in fixed fire-extinguishing systems for new aircraft. Requirements governing the installation of such systems are described in Military Specification MIL-E-5352 (USAF).

During fire-protection studies on an XB-45 airplane power plant at the Technical Development and Evaluation Center of the Civil Aeronautics Administration, the adequacy of certain requirements contained in the specification was checked by conducting full-scale fire tests. For this purpose, a bromochloromethane system, designed in accordance with Specification MIL-E-5352 (USAF) by Walter Kidde & Company, Inc., was installed in the XB-45 nacelle. Tests were conducted to determine the effectiveness of the system.

Because of present interest in dibromodifluoromethane as an extinguishing agent, the quantity requirement when using this agent in the system designed for bromochloromethane was determined.

TEST PROCEDURE

The fire-extinguishing tests were conducted in the right twin-engine nacelle of an XB-45 U. S. Air Force bomber. The extinguishing system used was of a configuration similar to the CO_2 system normally used in the airplane but utilizing line and nozzle sizes in accordance with bromochloromethane-system design. Design calculations of agent quantity requirements are given in Table I, and a schematic of the system is shown in Fig. 1.

The test procedure was intended to reproduce, as nearly as possible, those conditions which exist during and following flight fires in the XB-45 airplane. Engines were operated at normal cruising rpm (90 per cent of maximum rated) and with two inches Hg engine-inlet total air pressure. After fire detection by the nacelle detector system, both engines were shut down by closing the throttles and then discharging the extinguishing agent. This test procedure resulted in a fire duration of approximately seven seconds. Extinguishment occurred during the transient conditions of engine shut-down. Air flow under simulated cruising conditions was measured and found to be approximately 0.3 pound per second in each compressor compartment and approximately 12 pounds per second in the aft compartment. Air flow under the transient conditions of engine shut-down at the time of extinguishment was not measured.

Tests were conducted with fires at various locations within the nacelle compartments. These locations are shown in Fig. 2. Fires in the compressor compartment were those

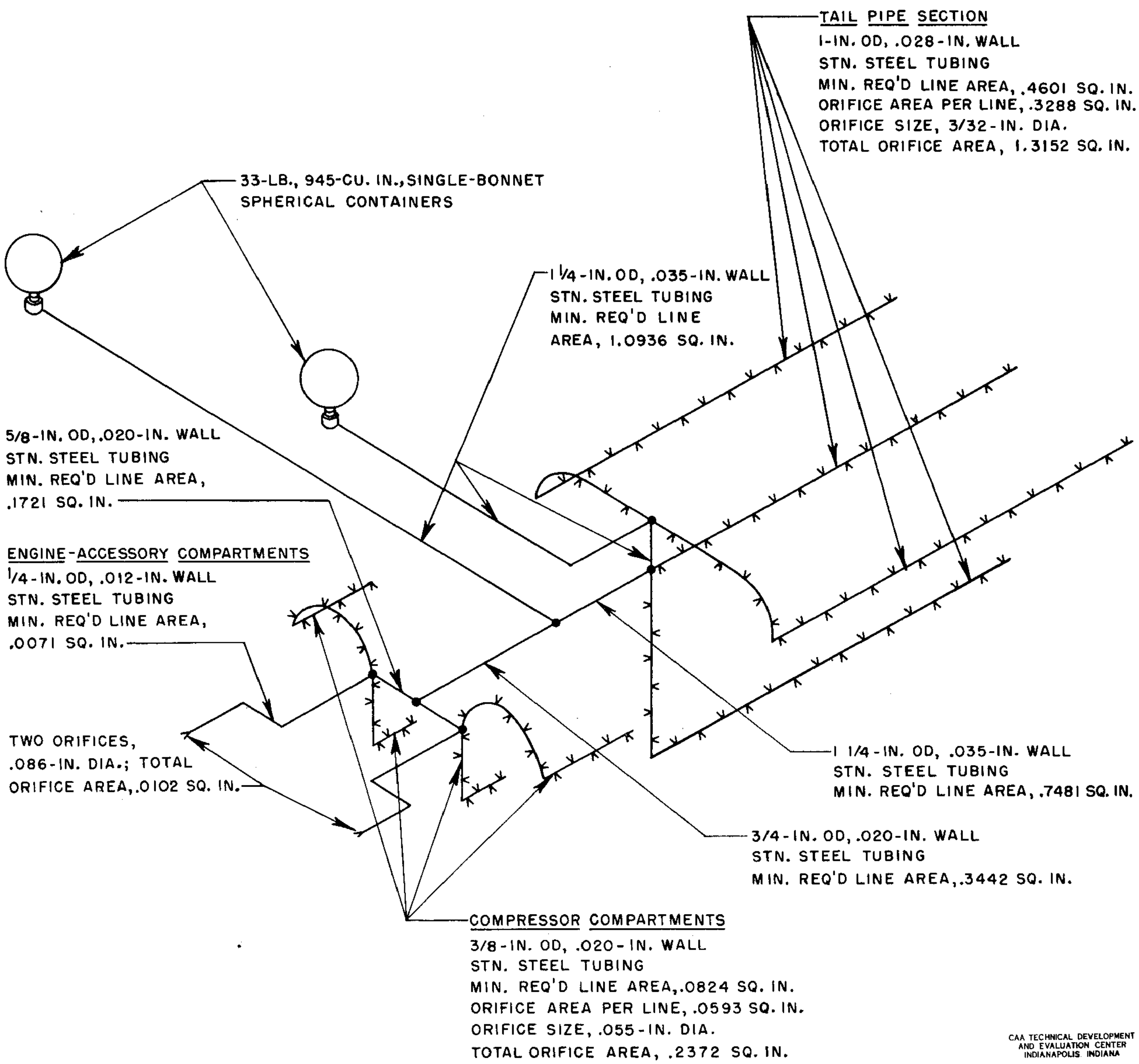

Fig. 1 Bromochloromethane Extinguishing System, XB-45 Nacelle

resulting from the ignition of aviation gasoline released at a rate of 2.5 gpm from a perforated ring. This ring surrounded the engine and was located at the forward end of the compartment. It was constructed of 3/8-inch copper tubing and contained 25 holes 1/64 inch in diameter. Test fires used in the nacelle aft compartment were those resulting from the ignition of aviation gasoline released at a rate of 3.6 gpm from a 1/2-inch OD open-end tube.

In addition to the determination of the effectiveness of the bromochloromethane extinguishing system when the recommended quantity (66 pounds) of agent is used, the investigation included the determination of minimum quantity requirements. When these tests were conducted, the agent-container pressure used for each test run was calculated by use of the formula:

$$P_1 = \frac{P_2 V_2}{V_1} \qquad (1)$$

TABLE I

CALCULATED QUANTITY REQUIREMENTS*
(Bromochloromethane Extinguishing System for XB-45 Nacelle)

Hazard	Volume, V** (cu ft)	Air Flow, W_a*** (lbs per sec)	Factor	Amount of Bromochloromethane Required (lbs)	Allotted (lbs)
Aft Compartment	236	6.0	$0.16V + 0.56W_a$	41.12	55.6
Engine Compressor Compartment	44	0.6	$0.16V + 0.56W_a$	7.38	10.0
Engine Accessory Compartment	2		$0.16V + 0.56W_a$	0.32	0.4
Total				48.82	66.0

* Based on the requirements of Article 3.31 of Military Specification MIL-E-5352 (USAF)

** V = Gross volume of the compartment, in cubic feet

*** W_a = Expected air flow through the zone for normal cruising conditions, in pounds per second

where

P_1 = agent-container nitrogen charging pressure, in psi.

V_1 = initial gas volume = volume of container minus volume of agent used, in cubic inches.

V_2 = volume of container plus volume of extinguishing system, in cubic inches.

P_2 = final discharge pressure (static) at nozzle, in psi.

For the conditions of testing,

V_1 = (945 x 2) minus volume of agent used, in cubic inches,

= 1890 minus volume of agent used.

V_2 = 1890 plus 1274 = 3164 cubic inches.

$$P_2 = \frac{400 \times 930}{3164} = 117 \text{ psi.} \qquad (2)$$

$$\text{Thus } P_1 = \frac{117 \times 3164}{1890 - V_a} = \frac{370{,}188}{1890 - V_a} \qquad (3)$$

where V_a = volume of agent used, cubic inches.

By the use of this method to determine container pressure for each test, the nozzle-outlet pressure at the end of liquid discharge was maintained constant and the effect of variations in volume of pressurizing nitrogen was eliminated.

Upon completion of fire-extinguishing tests on bromochloromethane, a limited number of similar test runs were made using dibromodifluoromethane.

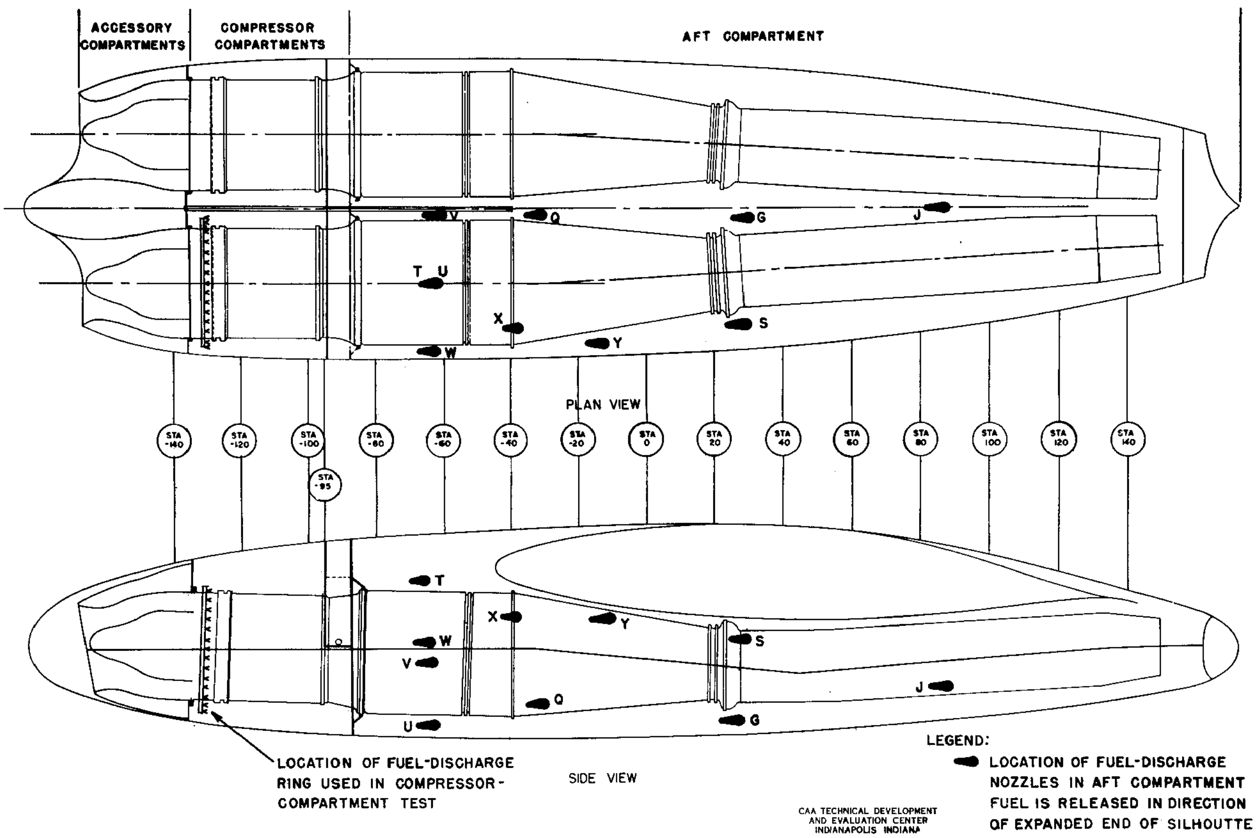

Fig. 2 Fire-Nozzle Locations for Bromochloromethane Extinguishing-System Studies, XB-45 Nacelle

In addition to the full-scale fire-extinguishing studies, tests were conducted to determine the duration of discharge of the agent and the distribution characteristics of the bromochloromethane extinguishing system. The duration measurements were made using a high-speed motion-picture camera and a timing clock. Distribution measurements were taken by discharging a volume of water equivalent to 66 pounds of bromochloromethane. The quantities discharged from those portions of the system which normally provide agent to the compressor and the accessory compartments were caught in large neoprene balloons and were weighed. The quantity discharged from the aft portion of the system was assumed to be the difference between the total charge and the measured quantities discharged from the forward portions of the system. It included the agent lost in the system during discharge.

RESULTS AND DISCUSSION

The results of tests conducted on the bromochloromethane extinguishing system are given in Tables II, III, and IV. The duration of dense discharge was determined to be 1.5 seconds, and the duration of visible discharge was 3.1 seconds. These values were the average of three tests, the results of which are as shown in Table II. The system was considered as meeting the discharge-duration requirement of Specification MIL-E-5352 (USAF) which states, "The duration of discharge of the agent shall be two seconds or less."

The results of distribution tests using water and a comparison of these results with expected design values are shown in Table III. When the proportional distribution of bromochloromethane is assumed to be the same as for water, the tests indicated that slightly greater quantities were discharged into the forward nacelle compartments than was expected from design calculations. Also, a somewhat smaller quantity than expected was discharged into the aft compartment.

TABLE II

DURATION OF DISCHARGE OF THE BROMOCHLOROMETHANE EXTINGUISHING SYSTEM USED IN THE XB-45 NACELLE

Test Conditions: Agent discharged, 66 pounds bromochloromethane; cylinders used, 2 cylinders of 945-cubic-inch capacity each; charging pressure, 400 psi nitrogen

	Test No. 1 (sec)	Test No. 2 (sec)	Test No. 3 (sec)	Average (sec)
Duration of Visible Discharge	3.1	3.2	3.1	3.1
Duration of Dense Discharge	1.6	1.5	1.5	1.5

TABLE III

DISTRIBUTION OF AGENT BY THE BROMOCHLOROMETHANE EXTINGUISHING SYSTEM*

Compartment	Measured Distribution				
	Test 1 (per cent)	Test 2 (per cent)	Test 3 (per cent)	Average (per cent)	Design Distribution (per cent)
Aft**	78.7	81.0	82.15	80.6	84.3
Compressor	18.6	17.25	16.1	17.3	15.1
Accessory	2.7	1.75	1.75	2.1	0.65

*The test values listed were based on the distribution resulting from discharging water.
**Test values listed for the aft compartment include the quantity lost in the system during discharge.

The conditions and results of full-scale fire-extinguishing tests are shown in Table IV. A summary of results and a comparison of these results with calculated design requirements are shown in Table V. The full-scale fire tests indicated that total system requirements were 32.4 pounds of bromochloromethane for extinguishing aft-compartment fires and 66 pounds for extinguishing compressor-compartment fires. Based on distribution studies of the system, these values indicate that a discharge of 22.9 pounds of bromochloromethane into the aft compartment and of 11.4 pounds into both compressor compartments was required. In comparison, the specification requirements, as shown in Table I, were 41 pounds and 7.38 pounds, respectively.

In the course of testing, the air flow within the compressor compartments was noted to increase very much during engine shutdown from normal cruising operation. This was due to an increase in static pressure at the engine inlets and to air leakage around the engine air-guide seals. See Fig. 3. Air flow in the aft compartment, however, was greatly reduced during engine shutdown. Thus, under the conditions of extinguishment, air flow in the compressor compartments was in excess of that existing for normal cruising and in the aft compartment it was less. The use of compartment air flow at normal cruising conditions was therefore inappropriate for computing agent quantity requirements for the XB-45 airplane.

Tables IV and V also give the results of fire-extinguishing tests when dibromodifluoromethane instead of bromochloromethane is used. A comparison of quantity requirements for the two agents indicated that dibromodifluoromethane was more effective by weight than bromochloromethane under the conditions of testing.

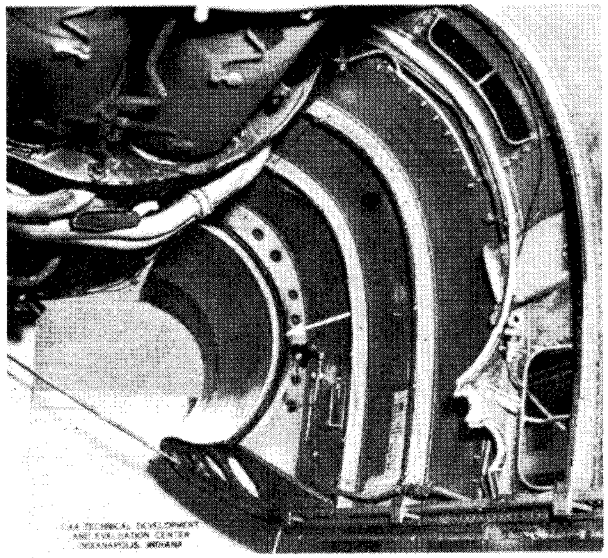

Fig. 3 Lower Portion of Seal Between Engine Air Inlet and Compressor Compartment

CONCLUSIONS

Evaluation of the bromochloromethane fire-extinguishing system, designed for the XB-45 airplane nacelle in accordance with Military Specification MIL-E-5352 (USAF), indicated that:

1. The duration of effective discharge was within the two seconds required by Article 3.3.2 of the specification.
2. Apportionment of agent to the various nacelle compartments was generally in accordance with design calculations, although the quantities discharged to the forward compartments were slightly greater and the quantities discharged into the aft compartment were somewhat less than calculated design values.
3. Agent quantity requirements determined for the aft compartment in accordance with Article 3.3.1 of the specification are in excess of actual requirements determined by fire-extinguishing tests.
4. Agent quantity requirements determined for the compressor compartments in accordance with Article 3.3.1 of the specification are less than actual requirements determined by fire-extinguishing tests.
5. The extinguishing system designed for bromochloromethane proved satisfactory for use with dibromodifluoromethane.

In general, it was concluded that the design methods used were such that they produced an extinguishing system which meets the requirements of Military Specification MIL-E-5352 (USAF). It was further concluded that Article 3.3.1 of the specification is inadequate because of the lack of any relationship between the actual air flow that may exist in a compartment during extinguishment under shutdown conditions and the air flow W_a under normal cruising conditions.

TABLE IV

RESULTS OF FULL-SCALE FIRE TESTS

Test Conditions: Engine-inlet total air pressure, one inch Hg at simulated cruising speed; recommended fire-emergency procedure used.

Test No.	Test Fire Location		Agent		Pressurization (psi)	Extinguishment
	Compartment	Station	Type	Quantity (lbs)		
1	Aft	J	CH_2BrCl	66	400	Yes
2	Aft	S	CH_2BrCl	66	400	Yes
3	Aft	G	CH_2BrCl	66	400	Yes
4	Aft	Y	CH_2BrCl	66	400	Yes
5	Aft	O	CH_2BrCl	66	400	Yes
6	Aft	X	CH_2BrCl	66	400	Yes
7	Aft	W	CH_2BrCl	66	400	Yes
8	Aft	T	CH_2BrCl	66	400	Yes
9	Aft	V	CH_2BrCl	66	400	Yes
10	Aft	J	CH_2BrCl	40	285	Yes
11	Aft	J	CH_2BrCl	23.1	240	No
12	Aft	J	CH_2BrCl	27.4	249	No
13	Aft	J	CH_2BrCl	32.4	260	Yes
14	Aft	J	CH_2BrCl	31	260	No
15	Aft	S	CH_2BrCl	32.4	260	Yes
16	Aft	G	CH_2BrCl	32.4	260	Yes
17	Aft	Y	CH_2BrCl	32.3	260	Yes
18	Aft	Q	CH_2BrCl	32.4	260	Yes
19	Aft	X	CH_2BrCl	32.4	260	Yes
20	Aft	W	CH_2BrCl	32.4	260	Yes
21	Aft	T	CH_2BrCl	32.4	260	Yes
22	Aft	V	CH_2BrCl	32.4	260	Yes
23	Aft	J	CF_2Br_2	66	400	Yes
24	Aft	J	CF_2Br_2	32.4	260	Yes
25	Aft	J	CF_2Br_2	22	235	No
26	Aft	J	CF_2Br_2	26	245	No
27	Aft	J	CF_2Br_2	27.2	250	Yes
28	Compressor	*	CH_2BrGl	66	400	Yes
29	Compressor	*	CH_2BrCl	66	400	Yes
30	Compressor	*	CH_2BrCl	64	390	Yes
31	Compressor	*	CH_2BrCl	60	365	No
32	Compressor	*	CH_2BrCl	64	390	No
33	Compressor	*	CH_2BrCl	66	400	Yes
34	Compressor	*	CF_2Br_2	66	400	Yes
35	Compressor	*	CF_2Br_2	50	320	No
36	Compressor	*	CF_2Br_2	54.2	340	Yes
37	Compressor	*	CF_2Br_2	54	340	Yes

*Entire Compartment

TABLE V

MINIMUM AGENT REQUIREMENTS FOR EXTINGUISHING XB-45 NACELLE FIRES

	System Requirements				Compartment Requirements*			
	Compressor-Compartment Fires		Aft-Compartment Fires		Compressor-Compartment Fires		Aft-Compartment Fires	
	CH_2BrCl (lbs)	CF_2Br_2 (lbs)	CH_2BrCl (lbs)	CF_2Br_2 (lbs)	CH_2BrCl (lbs)	CF_2Br_2 (lbs)	CH_2BrCl (lbs)	CF_2Br_2 (lbs)
Test Results	66	54	32.4	27.2	5.7	4.7	22.9	19.2
Design Calculations	48.8		48.8		3.7		41.1	

*Values listed are based on system-distribution tests using water with a ten per cent loss of agent during discharge assumed. The quantities listed for compressor-compartment fires are for one of the two compressor compartments.

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