DETERMINATION OF THE AIR SPEED REQUIRED TO CONTROL LANDING GEAR FIRES

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TABLE OF CONTENTS

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INTRODUCTION

One type of fire which occurs rather frequently in air carrier aircraft is the landing gear fire which usually results from excessive braking or from hydraulic fluid leaks or a combination of both.

It has been the practice of some pilots when confronted with such an emergency to apply power to the engine directly ahead of the burning landing gear after the airplane has come to rest. This procedure has the effect of controlling the flames so that they do not damage adjoining parts of the aircraft. It is an effective procedure for keeping the fire under control until external apparatus can be brought in to effect extinguishment. However, the procedure has not been widely adopted because too little has been known about the air speed required, the length of time such a procedure can be safely used or what other factors, if any, are involved.

The Technical Development and Evaluation Center conducted a short series of tests for the purpose of studying the landing gear fire problem. To do this, a landing gear complete with wheel and tire was mounted in the fire test chamber at the Center where full-scale fire tests are being conducted on the XR60-1 power plant. The engine and propeller of this power plant furnished the air blast for the tests.

The air speeds encountered near the landing gear were determined and fires were started at a number of locations along the extent of the landing gear to observe the nature of such fires and the effect of the propeller air blast on them.

Without the use of the propeller, the nature and course of a fire at the landing gear depended on the wind, but this usually was not sufficiently strong to keep the flames from rising and doing damage to other parts of the aircraft structure.

The air blast of the propeller, when turning at slow speed, caused the flames to be blown backward from the landing gear and tire, but not with sufficient force to prevent damage to adjoining structure. As the speed of the propeller was increased, the flames tended to form into a ball. At approximately 70 mph air speed at the landing gear, the flames were under control. Higher speeds reduced the cross section and elongated the ball of flame, but even at 140 mph the fire was difficult to dislodge from the gear and tire.

Since large portions of the tire were enveloped in flame, it was desirable to determine both the time a tire could resist such flame, and the nature of the ultimate tire failure. A tire carrying 47 psi air pressure was subjected to a fire in a 15 mph wind. The tire exploded at the end of 2 min 16 1/2 sec, causing little damage in this particular instance. However, under certain conditions, such an explosion could have serious consequences for nearby personnel.

TEST APPARATUS

The study of landing gear fires was undertaken while an investigation of fire hazards was being conducted on the power plant of the XR60-1 Constitution, which is powered by a Pratt & Whitney R-4360 engine. This engine swings a 16 1/2-foot diameter propeller at a gear ratio of 0.381. The configuration of a landing gear in lowered position was simulated by mounting a large landing gear strut complete with tire beneath the nacelle in approximately normal position. This was done easily since no obstructions existed beneath the power plant test installation except at the sides where the wing was supported by columns, the clear space between columns being 19 feet. For mounting purposes, it was necessary to erect a channel between the columns and to attach the strut to this channel. When the landing gear was in place, it was located 18 feet aft of the propeller and 21 in. to the left of the center line of the nacelle. The position off center was used to remove the gear from the direct path of the engine exhaust. See Fig. 1.

Apparatus for measuring the air flow at various points in the same plane as the strut was installed. This consisted of a mounting bracket extending between the strut and the left hand supporting column to which

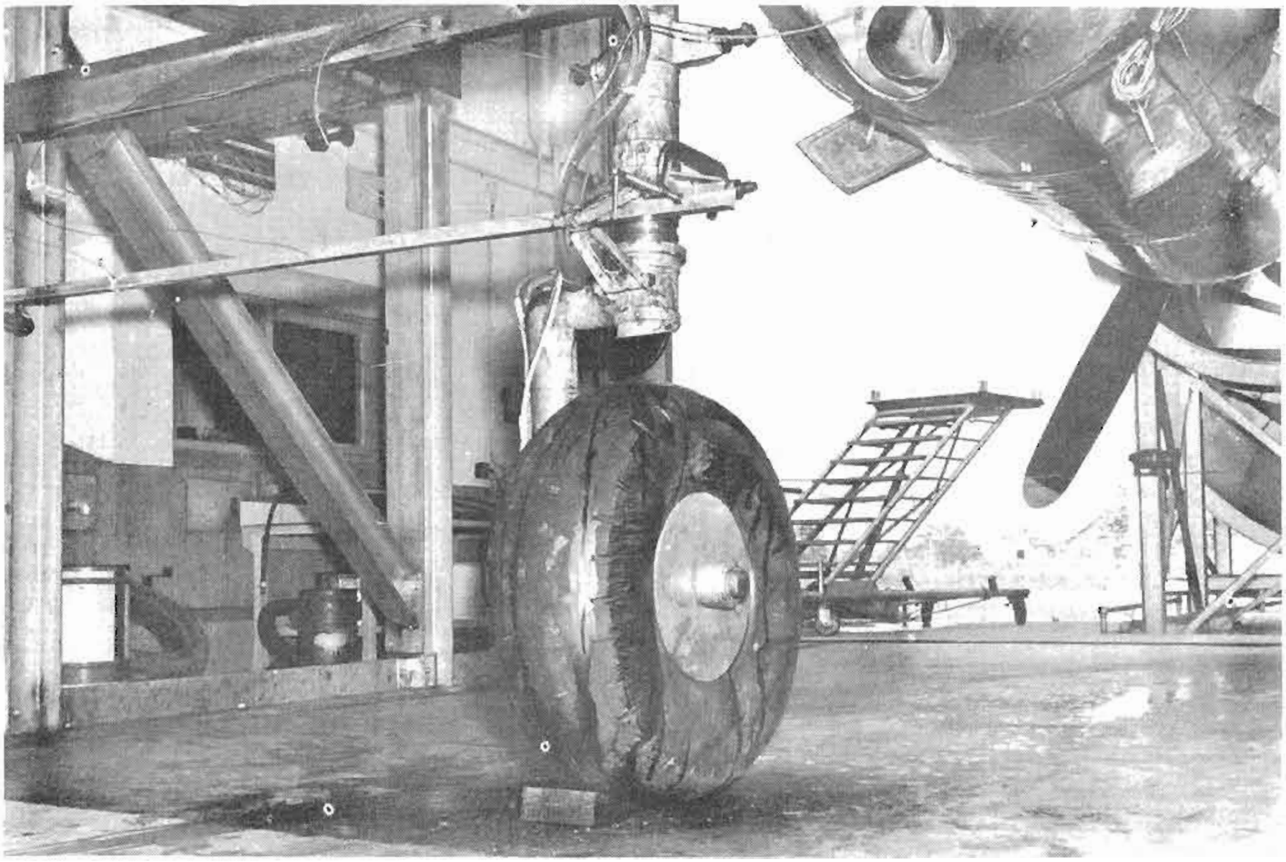

Fig. 1 Landing Gear in Place Ready for Tests

copper tubes of small diameter were fastened for measuring the air flow. The bracket could be raised up to the full height of the strut. The tube ends were spaced at selected points outward from the strut and all were pointed upstream to record total head pressures. The tubes were connected to a multiple water manometer which was balanced against the static air pressure in the test cell.

Spark ignited hydraulic fluid from a spray nozzle provided the fire. A pump supplied regular AN-VV-0-366b hydraulic fluid to the spray nozzle at 3/4 gpm under a pressure of 900 psi at the pump which was located 40 feet from the fire. The spark for the ignitor was supplied by a 15,000 v transformer.

A DC-3 wheel complete with inflated tire and tube were used for the destruction test carried out in the third phase of the investigation.

TEST PROCEDURE

The investigation was divided into three parts; viz.,

1. Air flow measurements adjacent to the landing gear
2. Study of fire patterns in connection with air flow
3. Study of the durability of a burning tire

The determination of the air flow in the region adjacent to the landing gear strut, in a plane perpendicular to the center line of the nacelle, was conducted in the following manner. Starting at a height above the floor corresponding to the center line of the landing gear wheel and, at each 6 in. level above that, up to the full exposed height of the strut, a series of readings were taken at each level. The diagram in Fig. 2 illustrates the extent of coverage obtained. Each location is numbered consecutively from the lowest to the highest position, and, each vertical series is identified by a letter. The system of numbering corresponds to that used in Table I, which gives the converted air speed at each location in miles per hour, for a number of different engine speed settings. These

TABLE I

AIR SPEEDS OBTAINED WITH VARIOUS ENGINE SPEEDS
AT SELECTED POINTS NEAR THE LANDING GEAR

Air Speed at Pickup Points (mph)

Engine RPM	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
1,000	25	45	45	41	38	35	32	32	32	25	0
1,200	32	47	53	53	45	50	53	50	43	25	15
1,400	38	66	70	60	69	59	65	57	60	32	20
1,600	50	69	81	76	84	78	78	76	67	43	29
1,800	63	71	82	86	86	83	84	83	70	51	38
2,000	71	77	85	89	90	88	84	84	76	57	43
2,800	84		110		120		140				

Engine RPM	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
1,000	0	25	45	45	45	51	47	47	62	59	57
1,200	0	25	43	51	53	55	60	62	71	69	64
1,400	15	35	53	59	60	71	76	73	81	77	75
1,600	20	29	47	55	57	73	83	76	84	83	85
1,800	26	26	43	51	60	73	86	84	91	89	95
2,000	29	32	41	45	53	71	84	88	89	92	99

Engine RPM	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
1,000	0	0	25	35	32	29	45	38	43	41	32
1,200	0	0	25	25	35	41	35	45	41	41	38
1,400	0	0	20	20	15	38	38	45	51	55	43
1,600	*	0	15	20	20	29	41	57	60	66	49
1,800	*	*	0	0	20	20	41	71	55	78	53
2,000	*	*	*	0	25	25	43	73	55	76	67

Engine RPM	D1	D2	D3	D4	D5
1,000	43	38	35	25	20
1,200	57	69	49	29	25
1,400	67	69	64	38	32
1,600	76	71	73	45	35
1,800	93	71	83	49	41
2,000	104	77	95	67	41
2,800	140		128		93

* reverse air flow

Engine RPM	E1	E2	E3	E4	E5
1,000	47	45	45	49	49
1,200	60	63	69	67	59
1,400	69	75	80	81	70
1,600	82	82	84	88	81
1,800	89	98	103	94	92
2,000	93	103	108	106	100

Engine RPM	F1	F2	F3	F4	F5
1,000	38	41	49	49	53
1,200	41	43	55	55	51
1,400	45	45	60	67	55
1,600	45	43	70	76	62
1,800	43	47	68	84	81
2,000	45	71	103	94	89

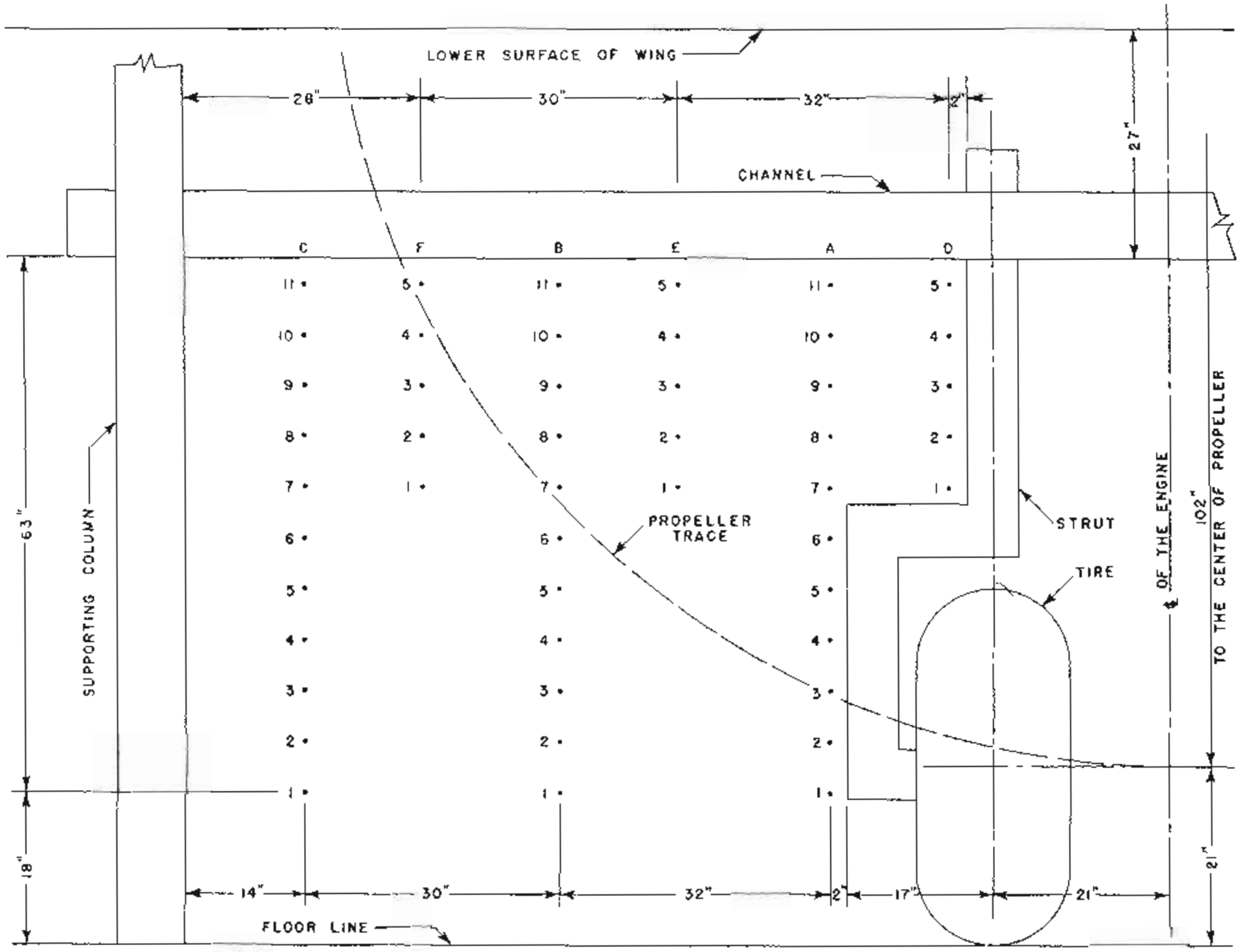

Fig. 2 Location of Air Speed Pickups

speed settings were used merely to change the speed of the propeller by uniform amounts for each reading.

The distance from the propeller to the landing gear strut was 18 feet in this particular installation. If the strut had been closer to, or more remote from the propeller, the air speed furnished by the propeller in each case would have differed. Therefore, the engine speed cannot be used as a guide in attempting to establish a procedure for controlling landing gear fires in other types of aircraft. Only the air speed at the landing gear of the aircraft to be protected has any significance.

The high speed air leaving the propeller moves like a continuous cylinder having a slightly larger diameter than the propeller. See the propeller trace, Fig. 2, for an approximate line of demarcation. Outside of the bounds of this cylinder, the air speed was relatively lower and in some areas the air flow was reversed. Such areas are noted on Table I by an asterisk. Near the strut, however, sufficiently high air flow could always be obtained with this engine and propeller combination at the distance established in the tests to control the fires.

At the completion of the air speed survey, fires were ignited at each of the locations on the strut corresponding to A1 through A6 and D1 through D5, Fig. 2. When the fire at any particular location appeared to be under control, the air speed was noted. A fire was considered to be under control when it had been reduced in size to such an extent that the flames did not impinge upon surrounding structure such as the wing, flaps or nacelle skin. The appearance of the fire under such

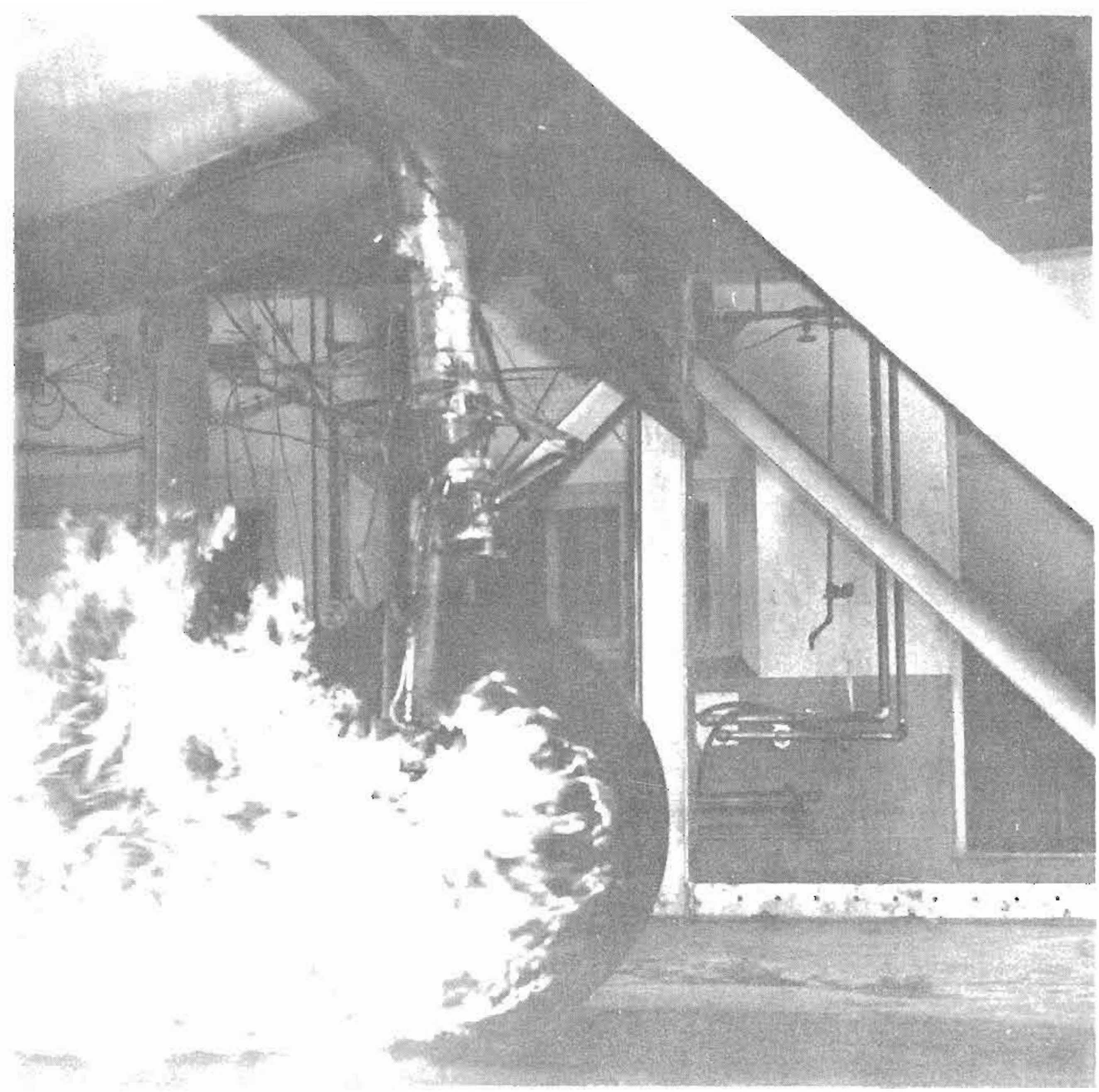

Fig. 3 Destructive Wheel Fire Fanned by 15 mph Wind

conditions was a large ball attached to the leeward side of the strut and tire.

Without the use of the propeller, a fire might take any direction depending on the direction of the wind. This is illustrated in Fig. 3 where the fire was not under control and, although the picture does not show the full length of the flames, the fire was entering the oil cooler flaps in this installation and impinging on parts of the nacelle and wing. As soon as the propeller was started, the flames were blown backward and away from the adjoining structure. However, the propeller rotating at idling speed was incapable of preventing the fire from doing damage to adjoining structure. Fig. 4 shows the change in flame pattern as the air speed was increased from idling to maximum.

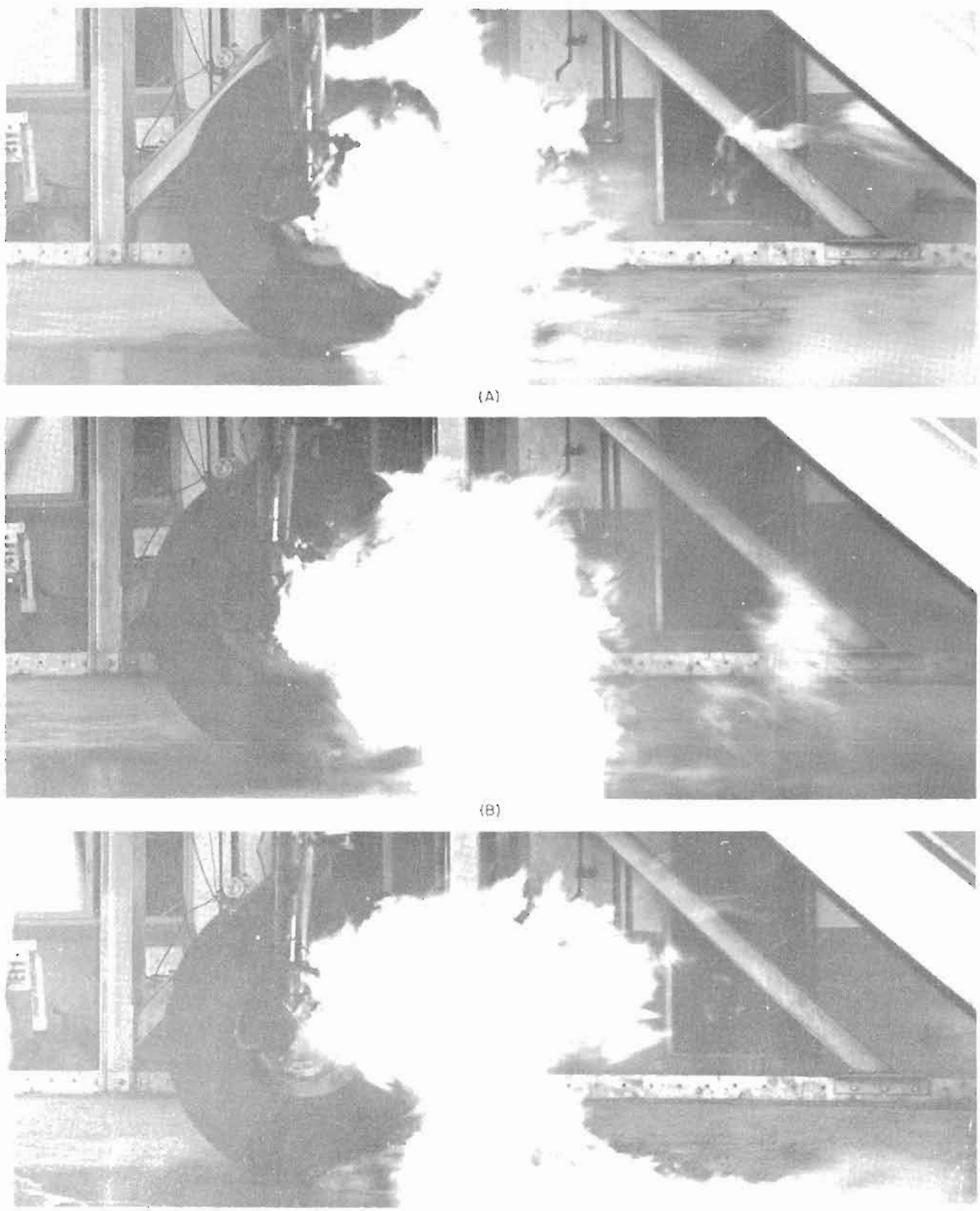

Fig. 4 Landing Gear Fire During Progressively Increasing Air Flows

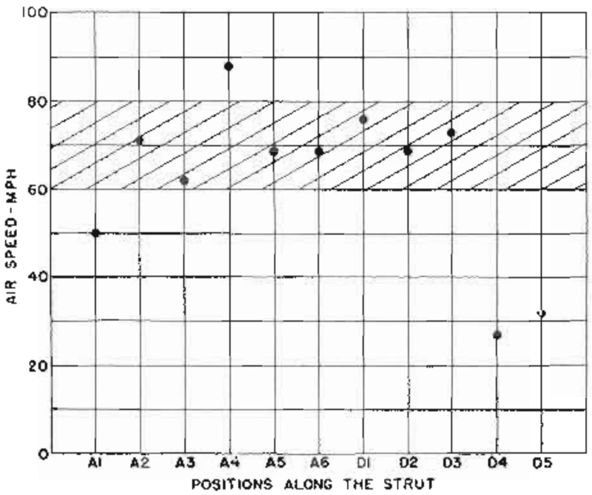

Fig. 5 Chart Showing Approximate Air Speed Required to Keep Landing Gear Fires Under Control With the Propeller

In the first stage, Fig. 4A, the fire as viewed from the side has no particular shape; it simply clings to the tire and part of the gear. As the air speed increases, the flame area appears to be circular and finally assumes an elliptical shape, as shown in the second and third stages, Figs. 4B and 4C respectively.

When the fire in each test of this particular series was considered under control, the air speed was noted. The speed was usually on the order of 60 to 80 mph. Allowing some margin for error in observation, 70 mph seemed to be a good average air speed to maintain at the strut for the size of fire used. See Fig. 5. When the engine speed was increased to 2,800 rpm (140 mph air speed at the strut), the fire occasionally could be blown out.

It should be noted that the quantity of hydraulic fluid feeding the fire in these tests was 3/4 gpm, which may well be more than that usually encountered in actual line breaks. Also, the pressure of 900 psi at the pump was continuous while in actual hydraulic leaks the pressure would undoubtedly diminish rapidly. Thus, an actual fire on an airplane in service might be considerably smaller than the test fires and thus require less than 70 mph to be brought under control. On the other hand, even if the fire is smaller, difficulty may be experienced in blowing it out as long as the hydraulic fluid continues to flow in any quantity. Experience has shown that flames on the leeward side of an obstructing member are always difficult to blow out.

It is well to point out also that in the test installation the landing gear was 18 feet behind the propeller, which is undoubtedly a greater distance than is usually found in operating aircraft. A lesser distance would of course be advantageous in creating and maintaining a 70 mph air blast.

The severity of the fires observed during the tests made it desirable to determine how long an inflated tire could be subjected to such heat and still remain intact. In order to obtain the desired information, the investigation was expanded to include a third phase dealing specifically with this aspect of the problem.

A wheel, complete with inflated tire and tube, such as is normally used on DC-3 type aircraft, was erected in an upright position on a concrete surface. The same nozzle operating under the same conditions as in the previous tests was attached near the rim of the wheel. When the hydraulic fluid flowing from the nozzle was ignited, the flames impinged on the rim, entered through holes near the center of the wheel, and enveloped nearly one-half the tire. Although the tire was initially filled with air to 47 psi pressure, the heat generated by the fire undoubtedly caused the pressure to increase greatly as the burning continued. No air blast from the propeller was used in this test. However, a 15 mph wind which happened to be blowing at the time performed a similar function.

Under these conditions, the tire remained intact for 2 min 16 1/2 sec. Failure occurred near the bead of the tire where the adjacent metal had already started to disintegrate. Failure was accompanied by a definite explosion. Although no widespread effects were noted in this particular instance, it is well known that tire blow-outs can be dangerous to near-by personnel. The explosion did not extinguish the fire.

CONCLUSIONS

1. The average safe air speed required to control a landing gear fire is on the order of 70 mph at the gear.
2. An air speed of 70 mph is easily obtainable with the propeller located directly ahead of the landing gear.

3. Landing gear fires occasionally can be blown out by a very strong blast of air from the propeller.
4. The length of time that a burning tire can remain intact will depend on the size of the fire, but it can be expected to rupture within as little as two to five minutes.
5. It is highly dangerous for exposed personnel to approach any closer than 25 feet to a burning tire prior to the time the tire explodes.

RECOMMENDATIONS

It is recommended that:

1. Measurements be made near the landing gear of various types of aircraft to determine what engine speed (rpm) will produce an air blast of 70 mph at that location.
2. If conditions permit, the propeller directly ahead of a burning landing gear be kept rotating at sufficiently high rpm to produce a blast of 70 mph at the landing gear.
3. If conditions permit, the propeller be operated at high rpm in an effort to blow out a landing gear fire.
4. Personnel remain at least 25 feet away from a burning tire prior to the time the tire explodes.

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