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DEVELOPMENT OF A TEST FACILITY AND PROCEDURES FOR EVALUATING AIRCRAFT HOSE ASSEMBLIES

FOR LIMITED DISTRIBUTION

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SUMMARY

In order to determine the fire resistance of flexible tubing assemblies under operating conditions without the necessity of conducting flight fire tests, a development project was undertaken to produce a test facility and test procedures for subjecting such assemblies to conditions that exist in flight. This facility produces a typical aircraft power plant fire, vibration of the type encountered during rough engine operation and the various flight conditions of oil flow, pressure and temperature.

During the conduct of this project, numerous fire tests were conducted on presently used and newly-developed types of hose assemblies, the results of which are presented in this report.

INTRODUCTION

In August 1947 the Civil Aeronautics Administration issued Safety Regulation Release No. 259 in order to acquaint industry with the fire prevention requirements of materials used in air carrier aircraft. The portion of this release pertaining to flexible tubing, with and without connections, in essence defines "fireproof" as withstanding a 2000°F flame for 15 minutes without severe damage and "fire resistant" as withstanding the same fire and remaining operable for not less than 5 minutes. At that time, it was generally believed that hose assemblies, complying with Specification MIL-H-5511 withstood such a fire test for at least 10 minutes. This was considered to be adequate for flexible tubing assemblies used for flammable fluids in potential fire zones. However, in 1950, both the Technical Development and Evaluation Center and the coupling manufacturers independently conducted fire tests on the Specification MIL-H-5511 assemblies in all sizes commonly used, and found that many of these assemblies failed in less than 2 minutes when subjected to the prescribed fire test. Few assemblies withstood the test conditions for even the required 5 minutes specified in the "fire resistant" requirements. This led to more extensive testing and investigations involving more realistic test conditions, and finally resulted in developing the test equipment and procedures which are described in this report.

DEVELOPMENT OF TEST EQUIPMENT

The burner used to produce the flame consists of a gun-type conversion oil burner Model TMC-P manufactured by the Bogue Electric Co, equipped with a Monarch No. 2, 80° spray angle nozzle. Kerosene is used as fuel. The return relief valve is set at 85 psi and at this pressure the nozzle delivers 2 gallons of kerosene per hour. The air consumed by the burner is controlled by five, 1-inch diameter holes in 1/16-inch thick sheet metal. The pressure differential across this sheet metal is 0.35 inch of water. Two deflector strips, each 3/4 inch wide, are fastened to the end of the barrel so that the ends of the strips are 1-1/2 inches apart and 1-1/2 inches beyond the oil nozzle. A barrel extension was added to the burner extending 10 inches beyond the end of the barrel. This has an opening 6 inches high and 11 inches wide. The burner is located so that the hose to be tested is 4 inches beyond the end of the barrel extension. The flame passes equally above and below the hose. This modified conversion oil burner produces an oil fire at a temperature of 2000°F and of the size and severity that can be expected in the event of a power plant fire.

The bench consists essentially of a heavy steel table 60 inches wide, 28 inches deep, and 32 inches high, weighing approximately 1000 pounds. Mounted on this bench is a vibrating mechanism, a hood, and a light-sensitive cell. The legs of the bench rest on 1/4 inch thick rubber pads. These prevent the transmission of the vibration to the floor and keep the bench from "walking." The bench and burner are shown in Fig. 1. The control panel and measuring equipment are shown in Fig. 2.

Details of the vibrating mechanism are shown in Fig. 3. This imparts a total lateral displacement of 5/32-inch and a total angular rotation of 9° at 2000 cpm at one end of the hose assembly. The other end of the hose is fixed. The vibrating end of the hose assembly is subjected to flame.

The hood which can be seen in Figs. 1 and 2 is 25 inches wide and 25 inches high. As shown in Fig. 3, the vibrated fitting is 7 inches back of the open front of the hood. The rear end of the hood is ducted to a fan which draws air through it at a velocity of 400 fpm. This air movement aids in keeping the flame horizontal and, when hose failure increases the fire size, it assures the travel of the flame past the light sensitive cell which is located 44 inches down wind of the vibrated end of the hose assembly. A dc amplifier and relays for effecting automatic shutdown and to stop the chronometer are arranged so as to operate when the cell senses the light of the enlarged flame.

Four chromel-alumel thermocouples of 22 gage wire, spaced 3 inches apart horizontally, are centrally located in the flame in a line normal to and 1/4 inch ahead of the hose assembly. These measure the flame temperature throughout each test.

The oil circulating and heating equipment shown in Fig. 2 comprises an electrically driven oil pump and a 20-gallon oil tank with a 3000-watt, thermostatically controlled, immersion heater. The pump is rated at 3000 psi and is capable of delivering either 10 gpm at 100 psi or 5 gpm at 1750 psi. The pressure relief valves, flow indicators, pressure gages, control and selector valves, are included in the plumbing of the oil system.

TEST PROCEDURE

The hose assemblies tested were 24 inches long and were mounted on the test bench as indicated in Fig. 3. Oil at the desired temperature was circulated through the assembly to remove all air from the piping system and to bring the temperature of the test assembly up to operating temperature. The oil flow and pressure were then regulated to the desired values. The vibrator was then started and the assembly checked to make certain that no resonant whipping occurred. The fan which effects the air movement over the assembly was then started. The fire test was then initiated by igniting the burner and starting the chronometer simultaneously. Two stages of failure were generally noted: (1) when the operator detected the first visible sign of an oil leak, and (2) when the automatic shutdown was triggered by the light sensitive cell. The second stage occurred when the photocell sensed a flame 44 inches beyond the assembly under test and so indicated a significant increase of fire size. This is independent of the operators judgment.

A slight variation in procedure was necessary in conducting tests on assemblies intended for a specific application such as the propeller feathering lines. To simulate the conditions to which such an assembly is subjected, it was necessary to effect a quick "switch-over" from low pressure low rate of flow to high pressure high rate of flow. In order to accomplish this, a high-low pressure range selector was installed. In order to prevent damage to instruments, it was necessary that the operator close the valve to the low pressure gage and turn the flow indicator selector to the high flow position, prior to the time for the switch-over.

The procedure used in fire testing assemblies intended for use in fire extinguishing systems was considerably different than those previously described. Such assemblies were mounted on the bench in the normal manner, but the oil lines to and from the bench were removed. In place of these, lines of appropriate size were attached so that an aircraft extinguishing agent bottle could be discharged through the assembly while it was being subjected to fire and vibration. A nozzle with an area equal to 65 per cent of the area of the hose assembly being tested was attached to the discharge side. In these tests, the assembly was subjected to fire and vibration for a prearranged period, usually 10 or 15 minutes, at which time the extinguishing agent was discharged. If the assembly transmitted the extinguishant without excessive leakage, it was considered to be satisfactory for use in an extinguishing system passing through a fire zone.

The types of hose and assemblies tested were:

(a) Hose meeting Specification ANH-35 - Synthetic rubber, cotton braid.
(b) Hose meeting fire preventative requirements - Synthetic rubber, cotton and asbestos braid.
(c) Hose meeting Specification MIL-H-5511 - Synthetic rubber, single steel braid.
(d) Assembly meeting Specification MS-28741 - same as (c) but with fixed end fittings.
(e) Assembly meeting Specification MIL-H-5512 - Synthetic rubber, double steel braid, with fixed end fittings.
(f) R-3800 assembly - Teflon liner, steel braid with fixed end fittings.
(g) SR-3800 assembly - Same as (f) but with asbestos and neoprene covering.
(h) SSFR-3800 assembly - Similar to (f) but with two coverings of asbestos and neoprene and slightly different method of end fitting attachment.
(i) Flexible metal assembly - All steel or inconel liner, braid and end fittings, welded, brazed or mechanically attached.

The term "standard flow" as used in Table II is defined as the flow of SAE No. 20 oil at 200°F through a hose assembly in the following quantities:

Hose Size	Oil Flow gpm
-4	0.31
-5	0.49
-6	0.70
-8	1.25
-10	1.95
-12	2.80
-16	5.00
-20	7.80

RESULTS AND DISCUSSION

The ability of the test facility described in this report to provide reliable and reproducible results was demonstrated by conducting high pressure, static flow fire tests on thin wall stainless steel flexible assemblies. Such assemblies are generally more uniform than composition assemblies since they are not effected by aging or by integrity differences of the connections between tubing and end fittings of the composition hose assemblies. Results of the tests on the stainless steel assemblies are given in Table I.

TABLE I

REPRODUCIBILITY TESTS

Sample Number	Size Nominal	Time for Failure Min:Sec.
1	-6	0:53
2	-6	0:52
3	-6	0:55
4	-10	2:45
5	-10	2:44

Results of fire tests on hose and hose assemblies frequently used in present day aircraft are given in Table II. The first two items in Table II give the results of fire tests on hoses of the type generally used with hose clamps. The remainder of the table gives the results of fire tests on MIL-H-5511 hose and the MS-28741 assemblies which are the general purpose fire resistant assemblies that have replaced the earlier hose and hose clamp arrangements. The results listed in Table II were obtained in tests conducted under the standard conditions set forth in this report for fire testing flexible tubing assemblies. Results of fire tests on hose assemblies of various types of construction and at various rates of oil flow at 30 psi are given in Figs. 4 to 9 inclusive. Results of similar tests at 1000 psi are given in Figs. 10 to 13 inclusive.

Table II shows the marked differences in fire resistance that can be expected of similar pieces of hose and the even greater spread that results when a number of assemblies of the same size are tested under the same conditions.

TABLE II

RESULTS OF FIRE TESTS ON SOME PRESENTLY USED AIRCRAFT HOSE AND HOSE ASSEMBLIES
(Test specimens subjected to lateral and torsional vibration and conducting oil at 35 psi, 200°F and standard flow rate)

Item	Nominal Size	No. of Tests	Time for Failure Min. Min:Sec.	Max.(a) Min:Sec.	Average Min:Sec.
ANH-35 (hose only)	-12	10	0:45	1:10	1:00
Fire Preventative (hose only)	-12	3	6:59	8:38	7:34
MIL-H-5511 (hose only)	-4	7	4:03	>10:00	6:21
MIL-H-5511 (hose only)	-6	10	8:42	>10:00	9:52
MIL-H-5511 (hose only)	-8	9	4:49	>10:00	8:00
MIL-H-5511 (hose only)	-12	10	3:50	10:00	7:05
MIL-H-5511 (hose only)	-16	6	1:25	5:25	3:32
MIL-H-5511 (hose only)	-20	7	1:27	1:50	1:38
MS-28741 assembly	-4	11	1:25	>10:00	6:02
MS-28741 assembly	-6	9	0:52	>10:00	5:52
MS-28741 assembly	-8	9	1:12	>10:00	2:24
MS-28741 assembly	-12	12	1:57	>10:00	4:15
MS-28741 assembly	-16	11	1:20	>10:00	2:53
MS-28741 assembly	-20	4	1:50	2:30	2:03

(a) A maximum time of >10:00 indicates that the test continued for a total of ten continuous minutes without any signs of failure to the hose or assembly.

This is clearly seen in the test which gave the minimum value for the MS-28741-6 assembly. This failure was not due to rupture of tubing but to the hose blowing off the end fitting. The test on the MS-28741-16 assembly that gave the maximum time for failure was of greater duration than similar tests for the hose only, less fittings. This was unusual, but did occur occasionally, possible due to the difference in the age of the assemblies. There were also instances when the fire resistance of a hose increased when the fire test was interrupted after one or two minutes of operation. In most cases where such an interruption in the test occurred, a much greater time until failure resulted. This preheating of the assembly seemed to improve the fire resistance of the hose body as well as the ability of the end fitting to remain attached to the body of the hose.

Two types of failure occurred while fire testing the MS-28741 assemblies. One was the separation of the hose body from the end fitting and the other was the leakage resulting from the damaged hose body. Failure of the MIL-H-5512 and the teflon liner assemblies was due to leakage. In none of the tests conducted on those assemblies did the hose body separate from the end fitting.

Results of the fire tests conducted on assemblies intended for use in propeller feathering lines are listed in Table III. The conditions of fire and vibration were the same as used in previous tests except where noted. The conditions of oil flow and pressure were; 0.3 gpm at 150 psi for 4-1/2 minutes, immediately followed by 2.3 gpm at 1700 psi for 30 seconds. The MIL-H-5512 assemblies used in these tests had protective sleeves over the coupling nuts.

A few fire tests using a less complicated procedure were conducted on assemblies intended for use in propeller feathering systems. In these tests, the assemblies were subjected to fire and vibration while containing oil at 1700 psi and no flow. This method of test is more severe than the method which simulates operating conditions. However, results of this type of test can be depended upon regardless of the operating conditions, which are not always the same. Actually, this particular test represents the most severe operating condition. It also simplifies the procedure so that much less equipment and operating skill is required. Results of these tests where static oil at 1700 psi was contained in the line were:

MIL-H-5512-10 failed in 3 minutes and 25 seconds.
SSFR-3800-10 failed in 5 minutes and 24 seconds.

A few fire tests were conducted on hose assemblies to determine their suitability for use in extinguishing systems located in fire zones. In these tests, some -10 flexible metal assemblies were subjected to fire and vibration for 10 minutes, at which time 4 pounds of CO_2 was discharged through them without loss of agent. Similar tests on MS-28741-10 assemblies indicated failure in 1 to 3 minutes.

TABLE III

RESULTS OF FIRE TESTS ON PROPELLER FEATHERING LINES

Item	Time for Failure Min:Sec.	Remarks
MIL-H-5512-10	3:45	
MIL-H-5512-10	4:20	
MIL-H-5512-10	4:30	
MIL-H-5512-10	3:07	
MIL-H-5512-10	2:28	1900°F flame
MIL-H-5512-10	3:51	1900°F flame
MIL-H-5512-10	OK at 5:00	1900°F flame - no vibration
MIL-H-5512-10	OK at 5:00	2000°F flame - no vibration
SSFR-3800-10	OK at 5:00	
SSFR-3800-10	OK at 5:00	
SSFR-3800-10	OK at 5:00	

CONCLUSIONS

From the results of the tests conducted, it is concluded that the equipment and procedure described in this report comprise a suitable means for subjecting flexible tubing assemblies to simulated flight fire conditions.

RECOMMENDATIONS

It is recommended that:

1. The test facilities described in this report be used in conducting fire tests on hose and hose assemblies to determine their suitability for use in power plant installations.

2. The fluid pressure applied during the fire test be the same as the operating pressure of the line being tested instead of the previously specified 35 to 40 psi.

3. In conducting fire tests on lines intended for use in a propeller feathering system, static pressure (no flow) be employed.

4. Conditions of vibration simulating rough engine operation be incorporated in the conduct of the fire test.

ACKNOWLEDGMENT

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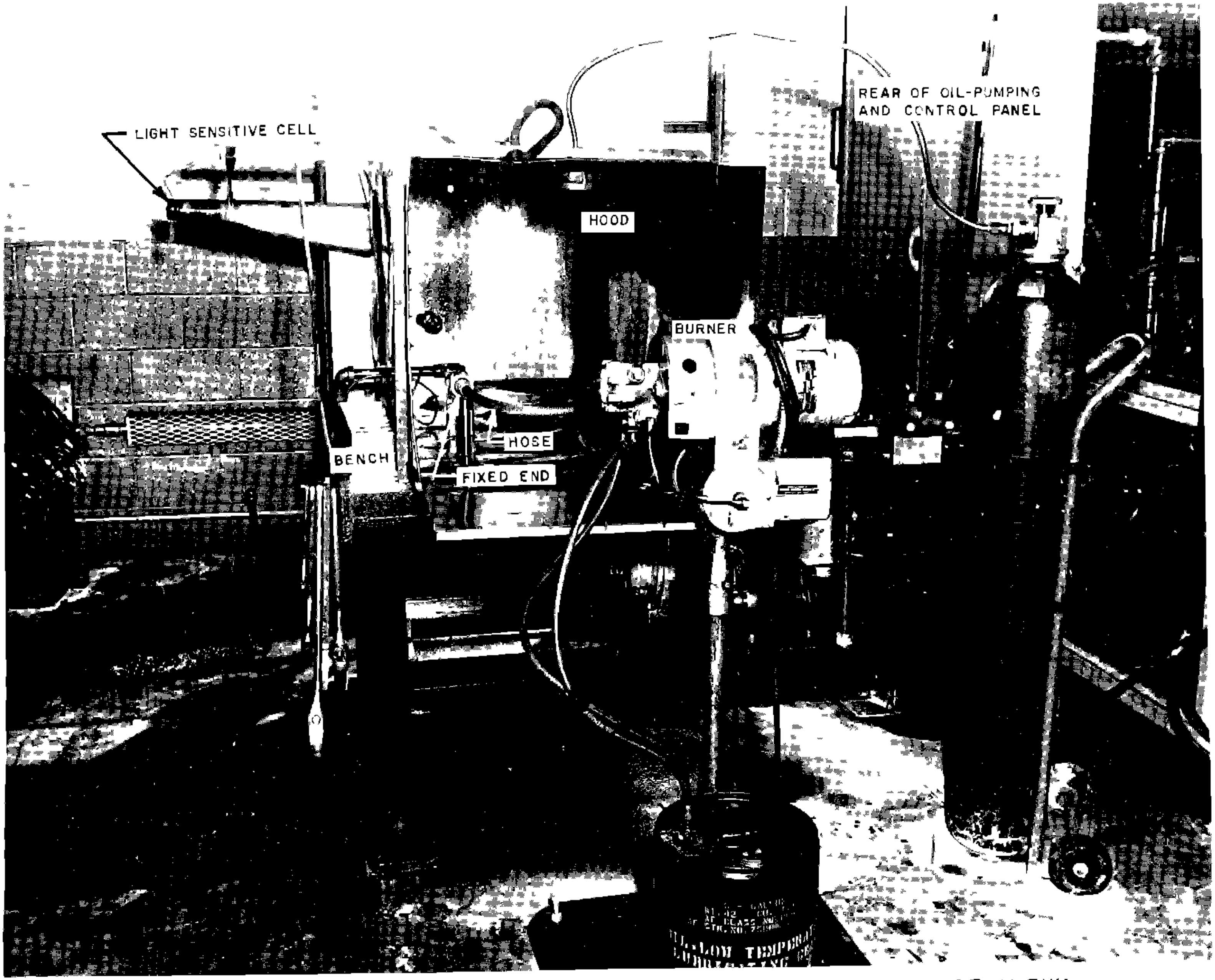


FIG 1 AIRCRAFT HOSE-ASSEMBLY FIRE-TEST FACILITY (WEST VIEW)

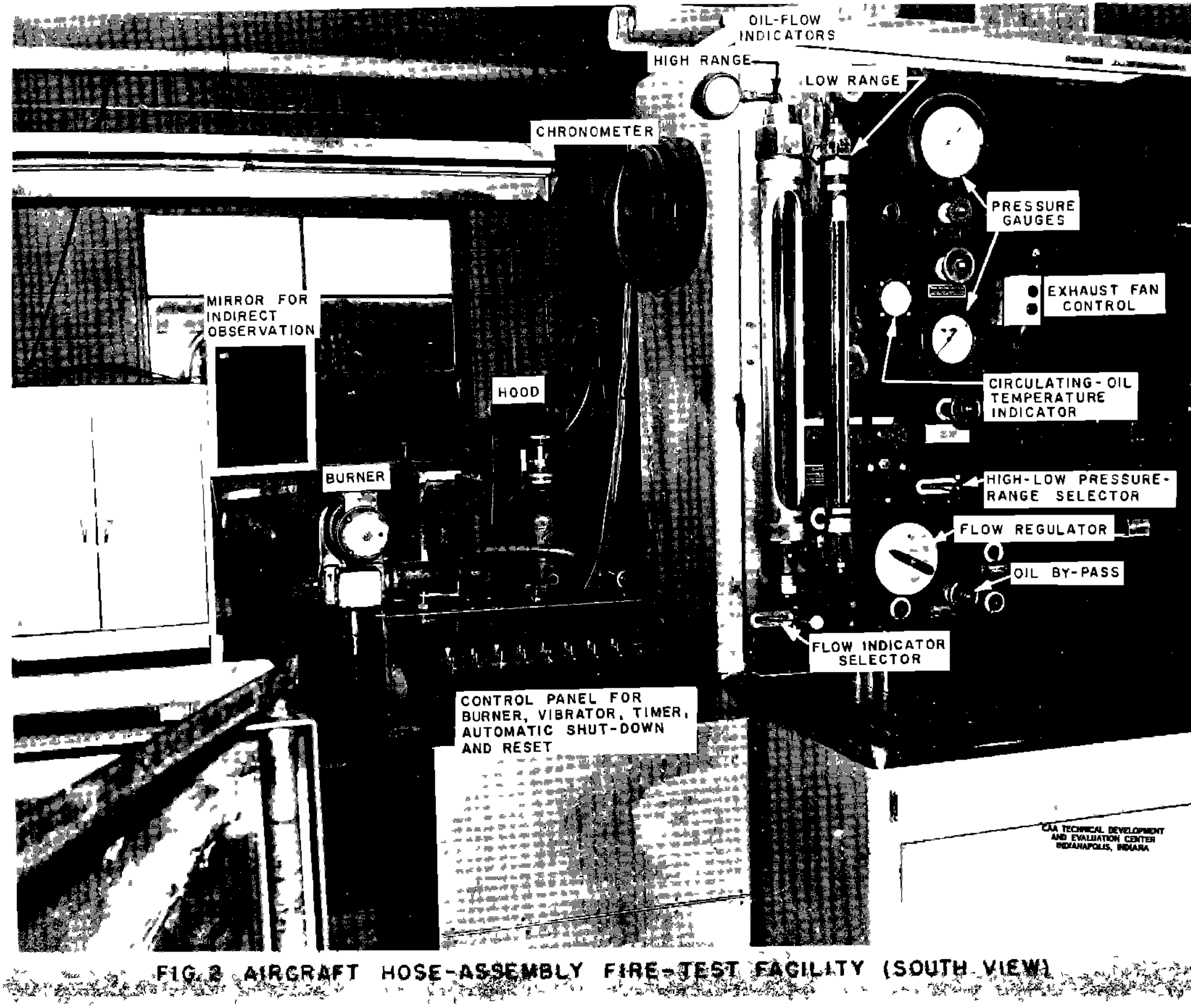
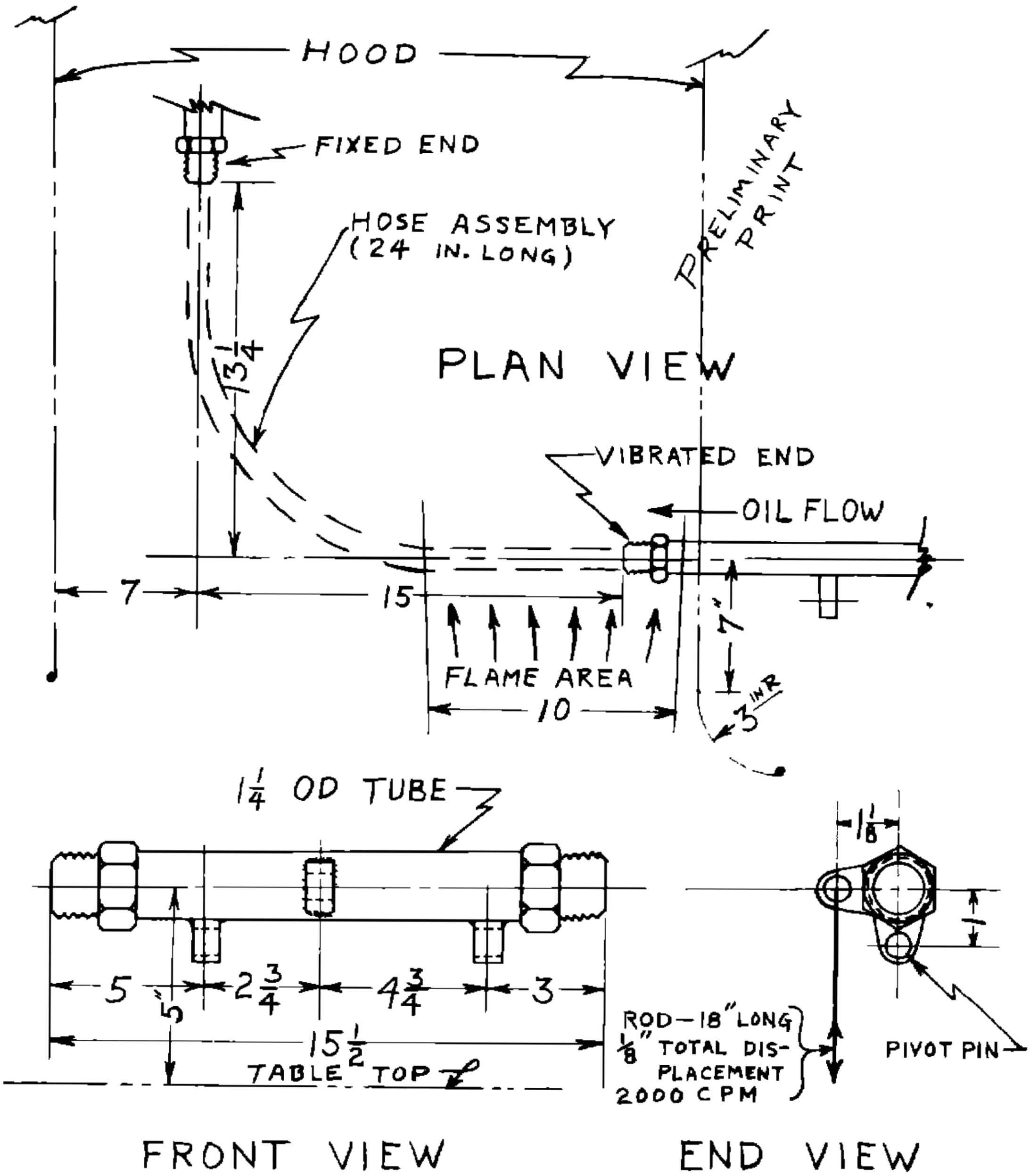
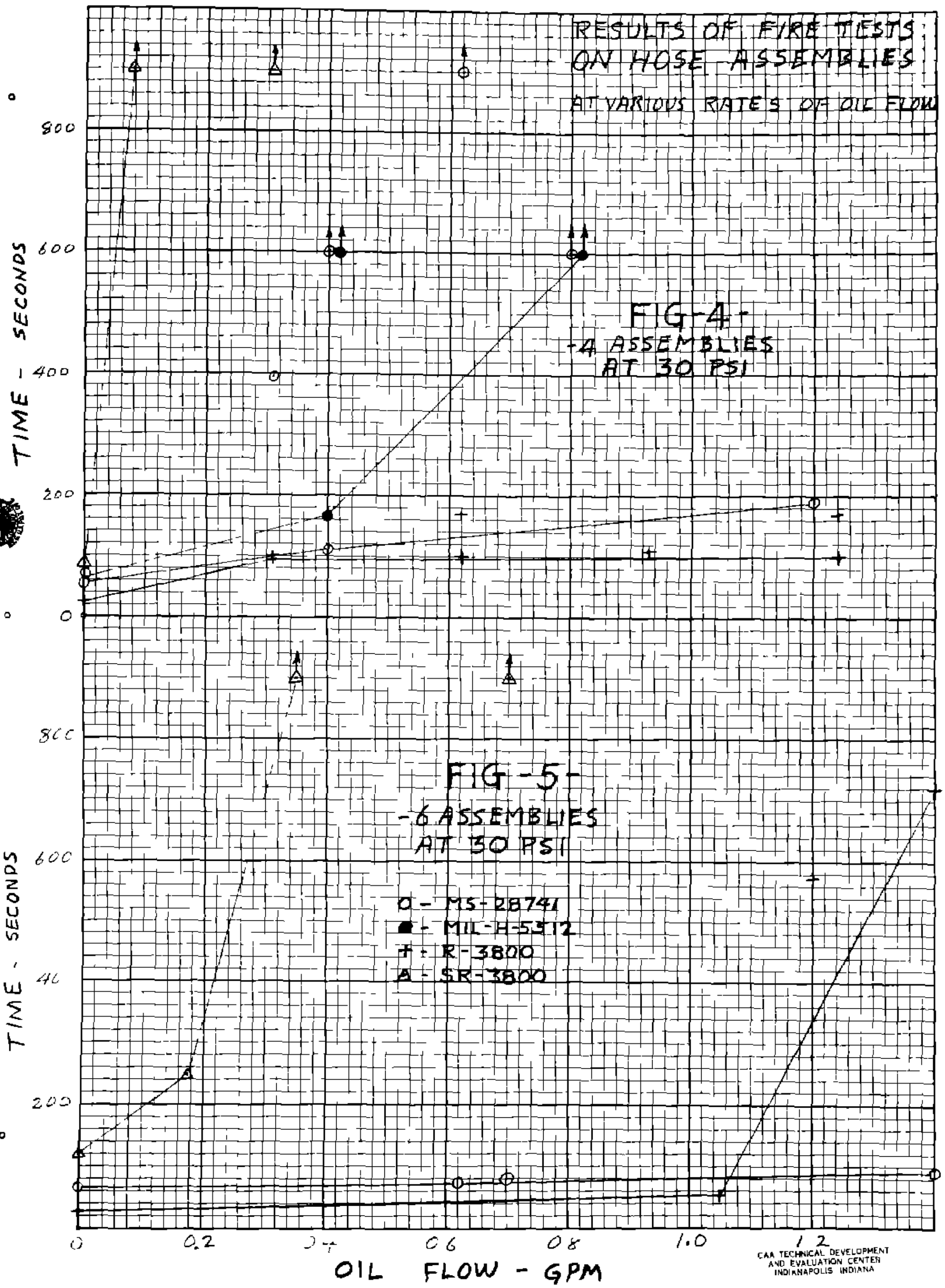


FIG. 2 AIRCRAFT HOSE-ASSEMBLY FIRE-TEST FACILITY (SOUTH VIEW)



NOT TO SCALE — ALL DIMENSIONS IN INCHES

FIG -3- VIBRATOR DETAILS AND TEST ASSEMBLY ORIENTATION



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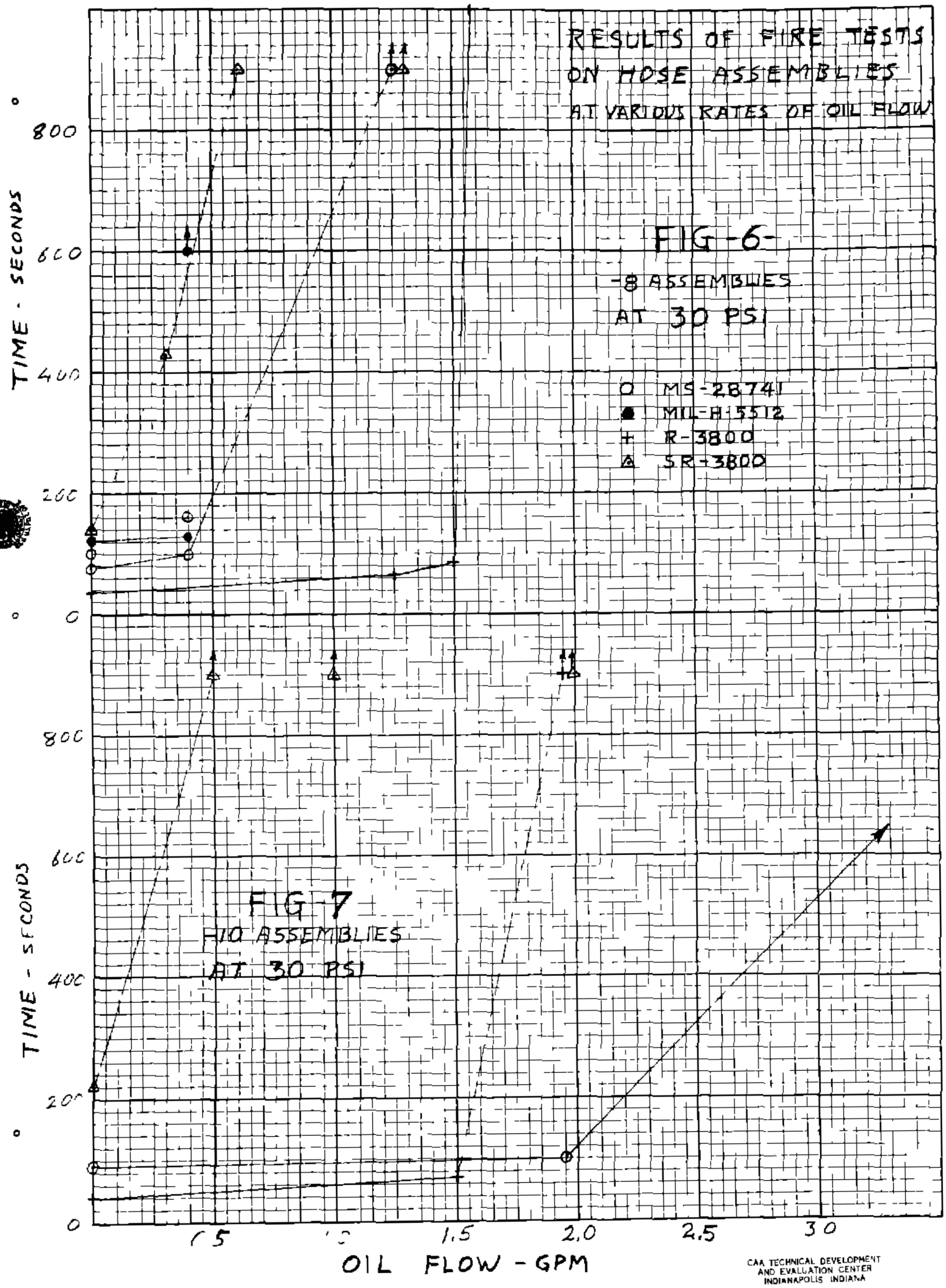

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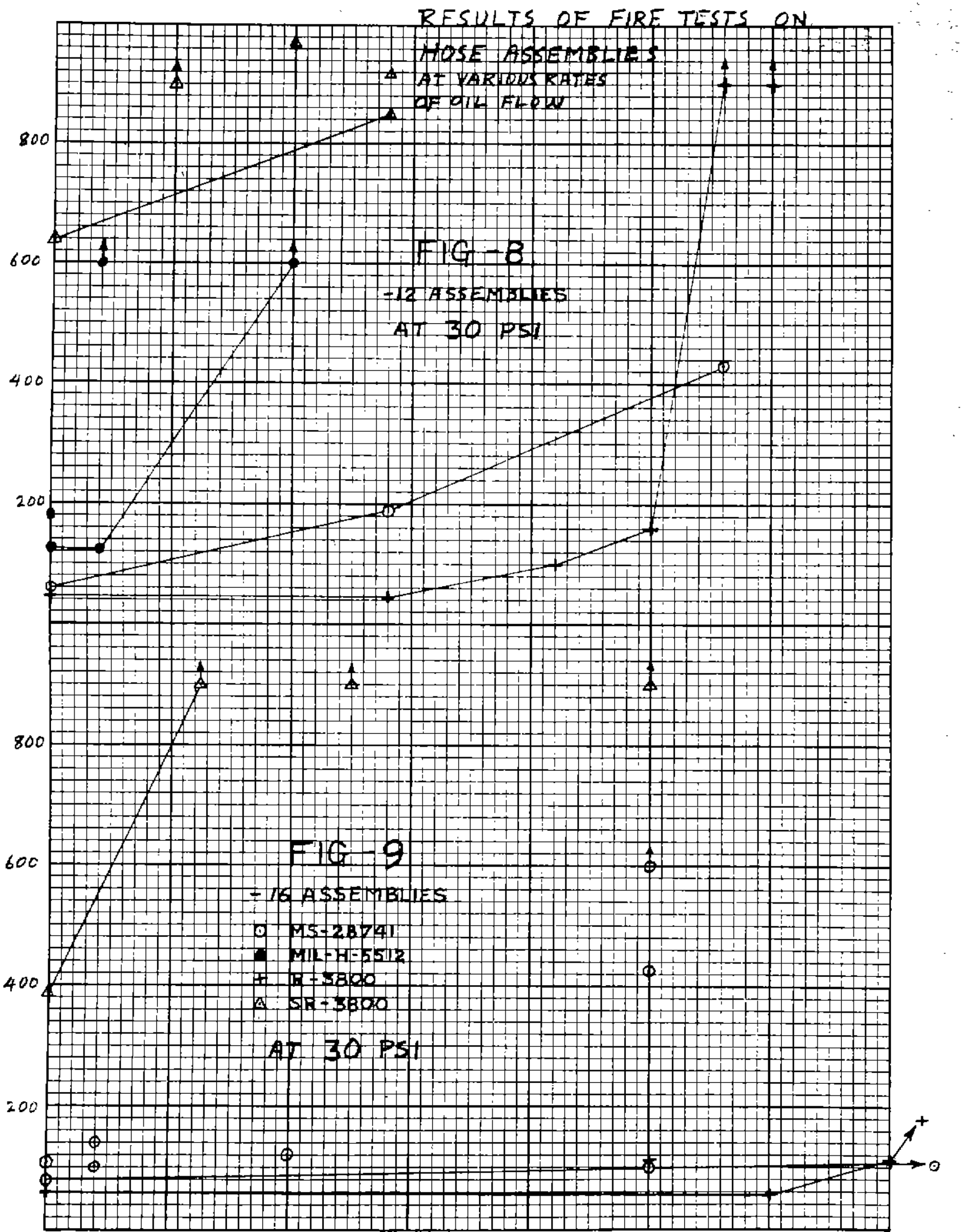
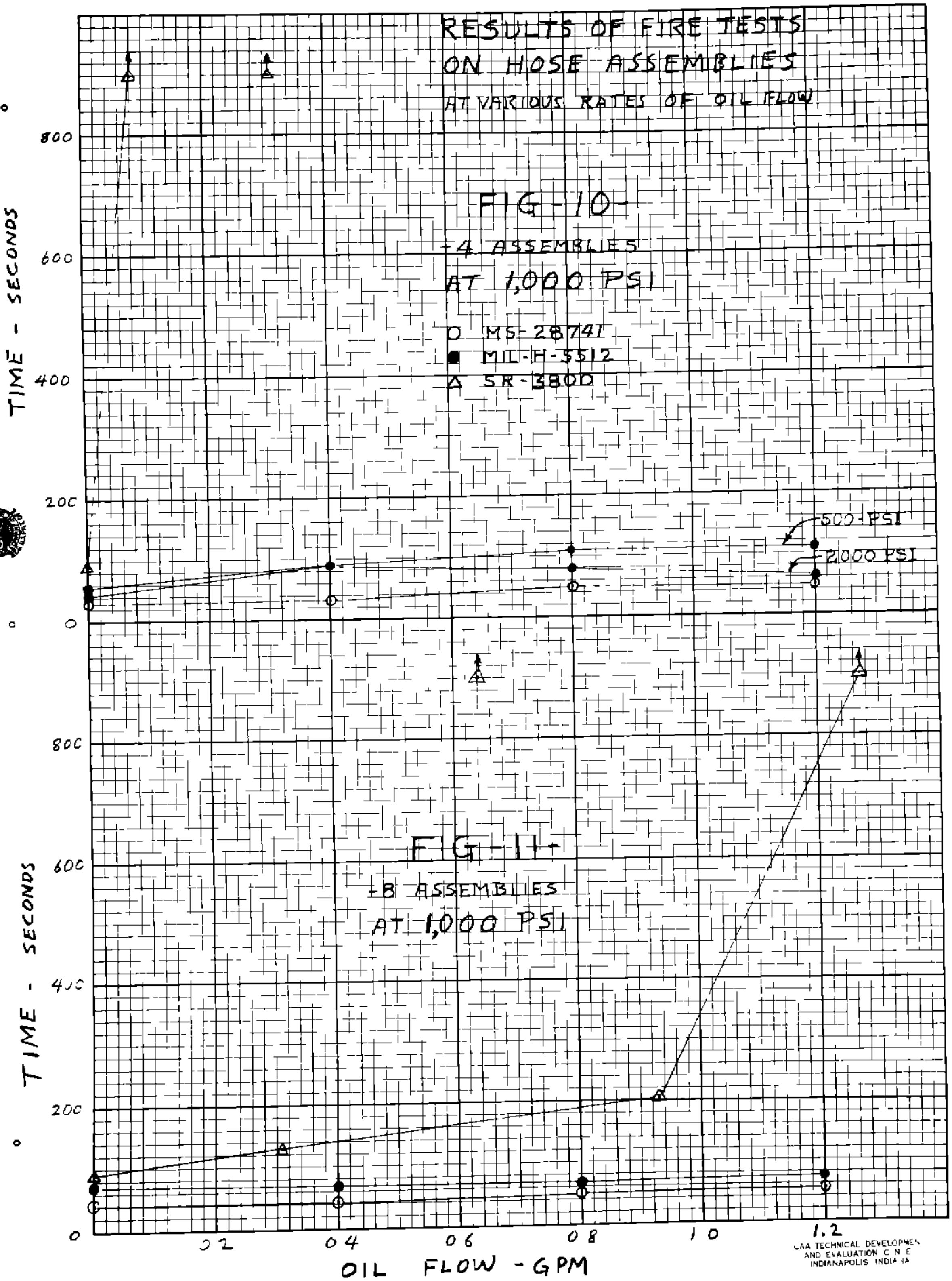


RESULTS OF FIRE TESTS ON
HOSE ASSEMBLIES
AT VARIOUS RATES
OF OIL FLOW
800
600
400
200
FIG-8
-12 ASSEMBLIES
AT 30 PSI
800
600
400
200
FIG-9
-16 ASSEMBLIES
MS-28741
MIL-H-5512
R-3800
SR-3800
AT 30 PSI


RESULTS OF FIRE TESTS
ON HOSE ASSEMBLIES
AT VARIOUS RATES OF OIL FLOW
FIG-10-
-4 ASSEMBLIES
AT 1,000 PSI
MS-28741
MIL-H-5512
SR-3800
500 PSI
2000 PSI
FIG-11-
-8 ASSEMBLIES
AT 1,000 PSI
TIME - SECONDS
OIL FLOW - GPM
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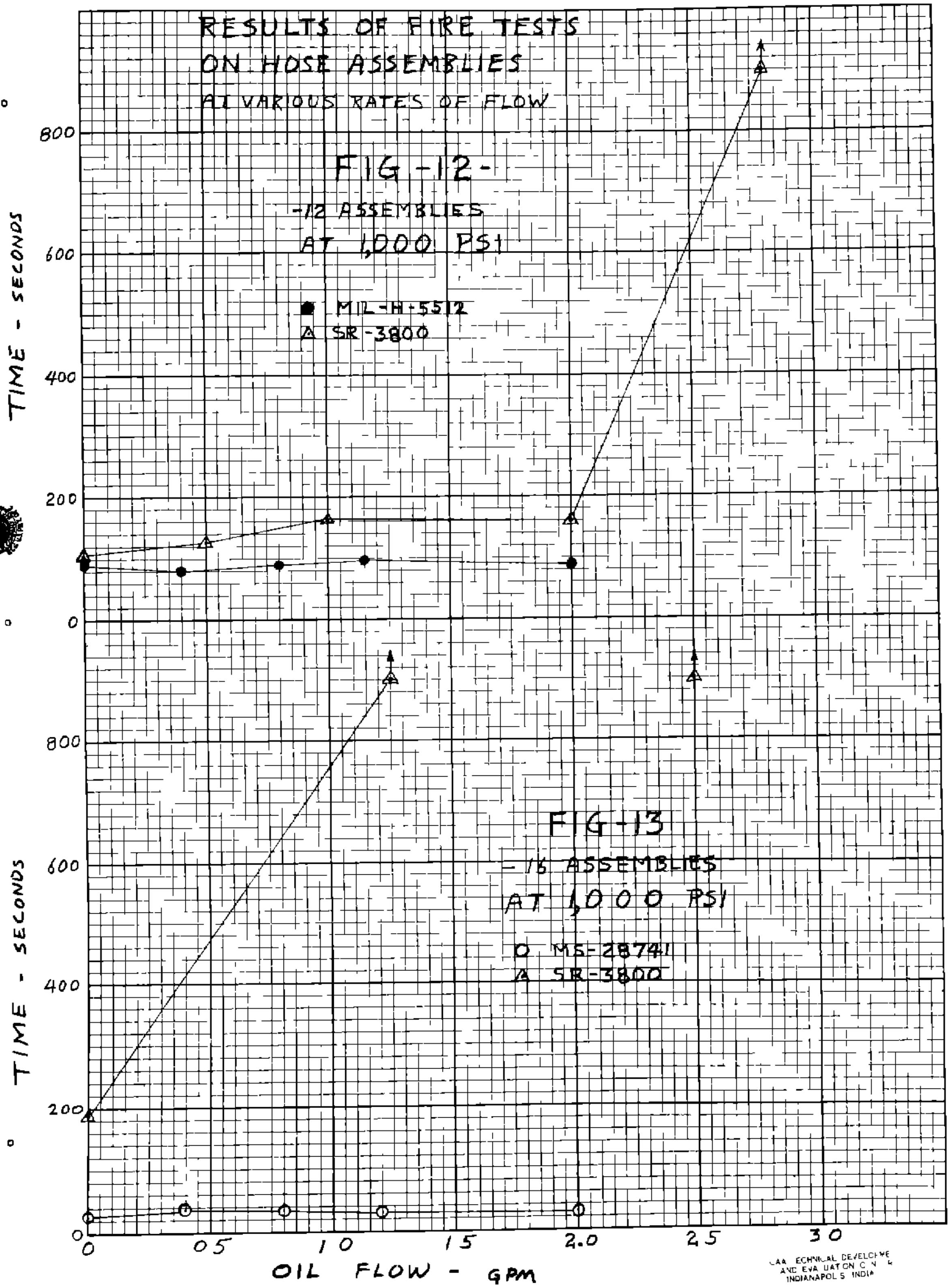
RESULTS OF FIRE TESTS
ON HOSE ASSEMBLIES
AT VARIOUS RATES OF FLOW
FIG -12-
-12 ASSEMBLIES
AT 1,000 PSI
MIL-H-5512
SR-3800
FIG -13
-16 ASSEMBLIES
AT 1,000 PSI
MS-28741
SR-3800
TIME - SECONDS
800
600
400
200
0
TIME - SECONDS
800
600
400
200
0
0
0.5
1.0
1.5
2.0
2.5
3.0
OIL FLOW - GPM