UNCLASSIFIED

~~RESTRICTED~~

1

Copy No. 2

AD-A952 917

UNITED STATES NAVY

PROJECT SQUID

TECHNICAL MEMORANDUM No. CAL-29

AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF INLET DUCTS ON THE PERFORMANCE CHARACTERISTICS OF A PULSE JET

By

JOHN G. WILDER, JR.

ATI-204542

JULY 1949

A

CORNELL AERONAUTICAL LABORATORY

UNCLASSIFIED

~~RESTRICTED~~ 83 11 15 246

UNCLASSIFIED

UNCLASSIFIED
[redacted]

Report No. OD-420-A-28
Contract No. N6ori-119, Task Order I
NR 220-041

Copy No. 23

CORNELL AERONAUTICAL LABORATORY, INC.
BUFFALO 21, NEW YORK

SQUID TECHNICAL MEMORANDUM NO. CAL-29

AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF INLET DUCTS ON THE PERFORMANCE CHARACTERISTICS OF A PULSE JET

By

JOHN G. WILDER, JR.

JULY 1949

UNCLASSIFIED
[redacted]

This document has been approved to rel[...] distribution is un[...]

UNCLASSIFIED

[redacted]

CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo, New York

CONTENTS

[redacted]

UNCLASSIFIED

CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo, New York

SUMMARY

Preliminary experimentation (using an 8" McDonnell pulse jet and inlet ducts varying in length from 1 1/2 to 6 feet) indicates a serious loss in thrust due to the addition of an inlet duct. The thrust does not always decrease with increasing duct length, however; indeed, there exist regions where an increase in duct length actually results in a gain in thrust for a given fuel flow. The maximum thrust obtainable with a given inlet duct is always less than the maximum thrust obtainable without an inlet duct for the configurations tested.

CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo, New York

INTRODUCTION

In an effort to understand the effect of an inlet duct on the performance of a pulse jet engine and if possible find a means of rectifying any detrimental effects a theoretical and experimental research program was undertaken by the Cornell Aeronautical Laboratory, Inc. for the Office of Naval Research under Project Squid, Task Order 1. This report covers the first phase of the experimental work using an 8" McDonnel pulse jet engine with various lengths of inlet ducts as a test vehicle and essentially presents the test results with a few pertinent comments.

CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo, New York

DESCRIPTION OF EXPERIMENTAL APPARATUS

The McDonnell 8" pulse jet engine (Ref. 1) is a conventional pulse jet employing an intake valve bank similar to that of the German V-1 engine and a so called "augmentor" on the tailpipe. The combustion chamber was drilled and an adapter was welded on to permit the installation of a pressure pick-up. The bolts used for attaching the intake valve were replaced by longer bolts to permit the attachment of the various inlet ducts (this necessitated the removal of the "ram" cowl). Other than the above mentioned modifications no changes were made in the standard production model.

The four inlet ducts tested were simply 6" I.D. tubes flanged at one end for attachment to the pulse jet with an adapter for mounting a pressure pick-up near the flanged end and varying in length from 1 1/2 to 6 feet, (Fig. 20).

It became apparent early in the program that some means for cooling the complete jet tube would be necessary for prolonged testing, as the tailpipe and combustion chamber (without benefit of a cooling air stream) heated very rapidly to a red heat which resulted in distortion of the tube. It was decided that the most expedient cooling system would be water sprays impinging directly onto the jet tube. Accordingly four 1/2" diameter tubes parallel with the jet major axis and spaced at 90° intervals around the jet were mounted independently of the jet suspension system. Water injected under pressure into the ends of the tubes sprayed out of #70 drilled holes in the sides of the tubes toward the jet and completely covered the jet with a water film. Subsequent testing proved the cooling system to be entirely adequate.

Pressure-time histories of the pressure fluctuations in the inlet duct just forward of the intake valve and in the combustion chamber just aft of the intake valve were transmitted by means of condenser type pick-up developed at N.Y.U. (Ref. 2). The oscillograph traces were photographically recorded, and the complete system (including transmitter, receiver, etc.) was calibrated at the end of each run to allow the selection of the best sensitivity on the oscillograph for each pressure range.

All tests with the inlet ducts were run with an airstream of 188 f.p.s. blowing directly into the inlet duct intake. The airstream was six inches in diameter, so that spill-over which would result in external aerodynamic drag was minimized. It is not believed that fluctuating duct pressures affected the flow from the air supply to an appreciable extent causing undue "spill-over".

The thrust was measured by means of a hydraulic piston and a pressure gage as described in Ref. 3. The model was mounted on the C.A.L. one point suspension thrust stand as discussed in the above mentioned reference.

Mean pressures in the inlet duct and combustion chamber were read by means of a mercury and a water manometer. The pressure taps were located in the pressure pick-up adapters for convenience and to assure the reading of the mean pressures as near the point of reading of the cyclic pressures as possible.

CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo, New York

DISCUSSION OF RESULTS

Effect of Water Cooling

As mentioned above, it became apparent early in the program that some form of cooling would be necessary in order to prevent too rapid deterioration of the jet engine during the prolonged runs necessary for this experimentation. It was decided that water cooling would be used as described in the section Description of Experimental Apparatus. It was then desirable to determine the effect of cooling on the performance of this particular engine. Consequently two runs were made under static stream conditions with and without water cooling. The variation of thrust with fuel flow for these two conditions is presented graphically in Fig. 7. As would be expected, the thrust for a given fuel flow is less with the cooling than without. At maximum thrust the loss in thrust due to cooling is almost 7 per cent.

Effect of Inlet Ducts On Thrust

All tests with the inlet ducts were run with a stream of 188 f.p.s. velocity and a diameter of 6 inches blowing directly into the inlet ducts. Thrust was measured by means of a hydraulic piston device and fuel flow was measured with rotometers. The actual experimental data for thrust and fuel flow for the four inlet ducts are plotted in Fig. 4 and tabulated in Table I. A cross-plot of Fig. 4 for three fuel flows shows the effect of inlet duct length on thrust as graphed in Fig. 1. Maximum thrusts obtained with an inlet duct were never asgreat as the maximum thrust obtained with no inlet duct (of about 100#), but it is obvious from Fig. 1 that regions exist in which an increase in duct length is beneficial. In other words, thrust does not always decrease with increasing duct length.

Mean Pressures in the Inlet Ducts and Combustion Chamber

The variation of mean pressures in the inlet duct and combustion chamber as measured with a manometer for various ratesof fuel flow is presented in Figs. 5 and 6. In an effort to picture the pressure variations (for a given fuel flow) with inlet duct length, cross-plots of the above mentioned graphs were made resulting in Figs. 2 and 3. The combustion chamber mean pressure varies with inlet duct length about as one would expect from an inspection of the thrust versus inlet duct length graph. The variation of inlet duct mean pressure with inlet duct length (Fig. 2), however, shows no consistent trend.

Transient Inlet Duct and Combustion Chamber Pressures

As a double sweep oscillograph was not available, it was not possible to record the combustion chamber and inlet duct pressure cycles simultaneously. It was therefore necessary to determine the phase relation between the two. As a first attempt a photoelectric cell was installed in the inlet duct facing the pulse jet intake valve. It was thought that each pressure record might be correlated with valve position. This set-up was found to be impractical due to mechanical and acoustic vibrations which caused failure of the photoelectric cell. It was subsequently discarded and another approach, apparently successfully, employed. This second technique employed an electronic switch (of 2000 c.p.s. frequency) between the two pressure pick-ups and the oscillograph.

By switching back and forth from one pick-up to the other at the rate of 2000 c.p.s. the pressure record of the two pick-ups was recorded as shown in Figs. 8 through 19. This allows the determination of the phase relation between the two cycles. The question naturally arises, "Why was not this technique employed throughout the experimentation rather than making separate pressure-time histories of each location?" It was feared that this technique of using the electronic switch might obscure higher order fluctuations that might occur while the switch was in operation, although such fluctuations are unimportant in determining the phase relation. Therefore, separate traces of the pressure cycles of each pick-up were photographed for quantitative analysis.

The pressure-time histories of the combustion chamber and inlet ducts with the calibration traces (made using the electronics switch as discussed above) for the various inlet ducts with various fuel flows are presented in Figs. 8 through 19. The operating conditions corresponding to these pressure records are listed in Table I by run number. Certain discontinuities in the pressure traces are noted in Figs. 12, 14, 15 and 16. It is believed that these are due to a loose connection in the pressure pick-up which was discovered and repaired after run number 15. This need not invalidate the data, as the discontinuities can easily be eliminated in any quantitative use of the pressure traces by simply matching up the curves at the beginning and end of each "jump". In order to determine quantitative instantaneous pressures it is necessary to determine the mean pressure line for each pressure trace (by integration of the pertinent curve). This line then corresponds to the mean pressure that was measured on a manometer for each run as listed in Table I on page 9.

CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo, New York

TABLE I

RUN NO.	DUCT NO.	FUEL FLOW #/HR.	THRUST #	DUCT MEAN* PRES.#/IN^2	COMB. CH. * MEAN PRESS.#/IN^2	ATMOS.P. #/IN^2 *	ATMOS.T. °F	DUCT LENGTH FT.
1	1	290	90	14.62	18.74	14.42	70	1 1/2
2	1	170	40	14.56	16.83	14.42	70	1 1/2
3	1	141	15	14.71	15.70	14.42	70	1 1/2
4	1	290	95	14.72	18.89	14.42	70	1 1/2
5	1	221	72	14.67	17.91	14.42	70	1 1/2
6	1	137	17	14.79	15.60	14.42	70	1 1/2
7	2	220	78	15.08	18.48	14.60	67	3
8	2	156	39	14.88	17.20	14.60	67	3
9	2	92	15	14.72	15.93	14.60	67	3
10	2	190	75	15.03	18.09	14.60	67	3
11	2	115	30	14.73	16.32	14.60	67	3
12	2	76	14	14.76	15.34	14.60	67	3
13	3	172	63	15.28	18.07	14.58	71	4 1/2
14	3	134	15	15.02	15.12	14.58	71	4 1/2
15	3	163	41	15.15	16.15	14.58	71	4 1/2
16	4	268	72	14.68	17.98	14.40	87.3	6
17	4	240	67	14.74	17.74	14.40	87.3	6
18	4	205	32	14.65	15.58	14.40	87.3	6

* Absolute Values

All data listed were recorded with 188 f.p.s. air stream blowing into duct inlet and with water cooling.

CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo, New York

REFERENCES

1. House, Wm. C., Flight Tests of an Eight Inch Pulse Jet, USNAMTC Technical Report No. 11, 28 March 1947

2. Bulletin of the Instrumentation Panel, Project Squid, Number 1, 5 January 1948, p. 18

3. McDole, W., Description of an Overhead Suspension Thrust Stand for the Testing of Jet Units and Components, CAL Report No. 511,194 (to be published)

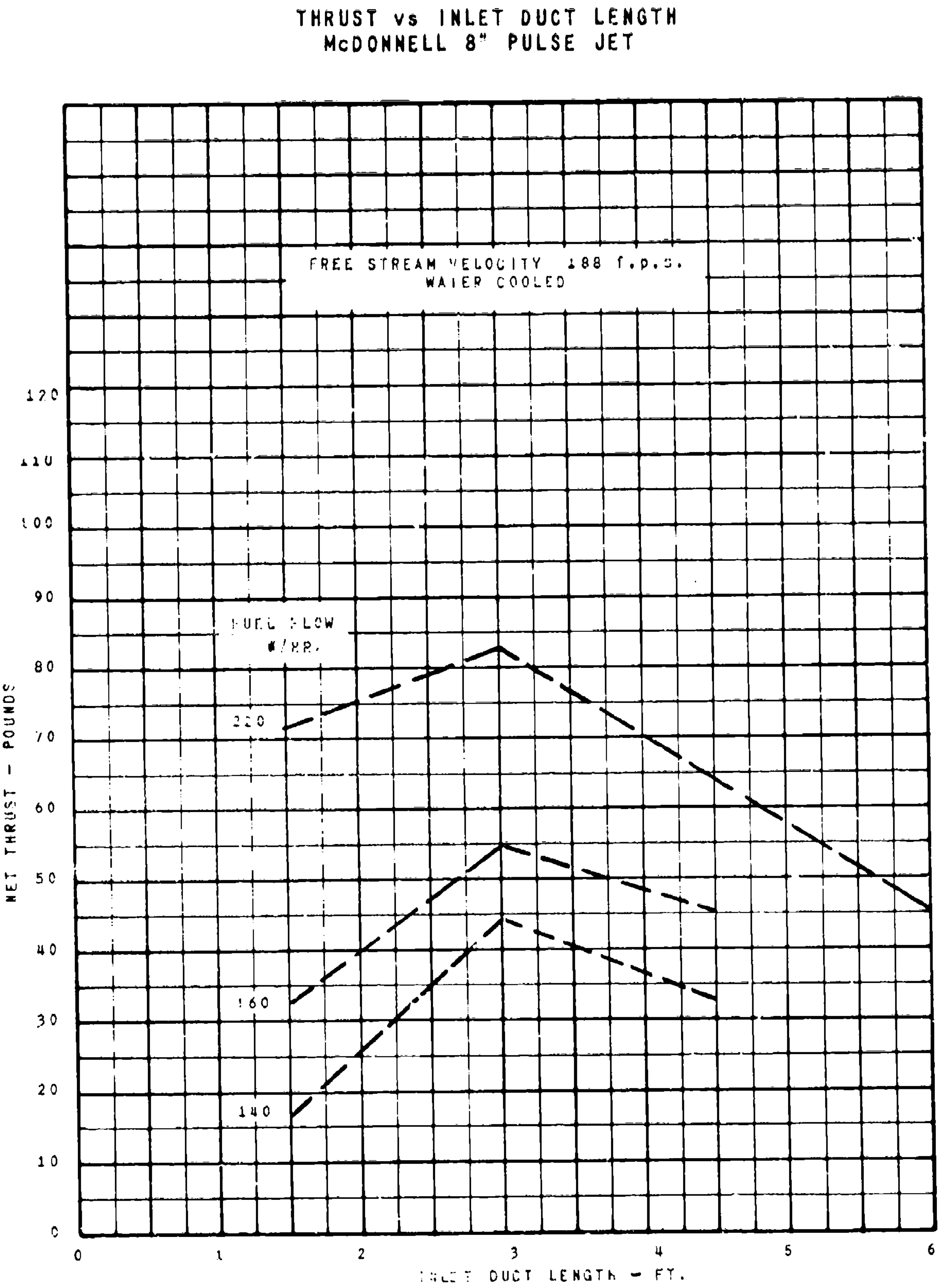

THRUST vs INLET DUCT LENGTH
McDONNELL 8" PULSE JET
FREE STREAM VELOCITY 188 f.p.s.
WATER COOLED
FUEL FLOW
#/HR.
220
160
140
NET THRUST - POUNDS
0
10
20
30
40
50
60
70
80
90
100
110
120
0
1
2
3
4
5
6
INLET DUCT LENGTH - FT.

Fig. 1

359-115

INLET DUCT PRESSURE
vs
INLET DUCT LENGTH
McDONNELL 8" PULSE JET

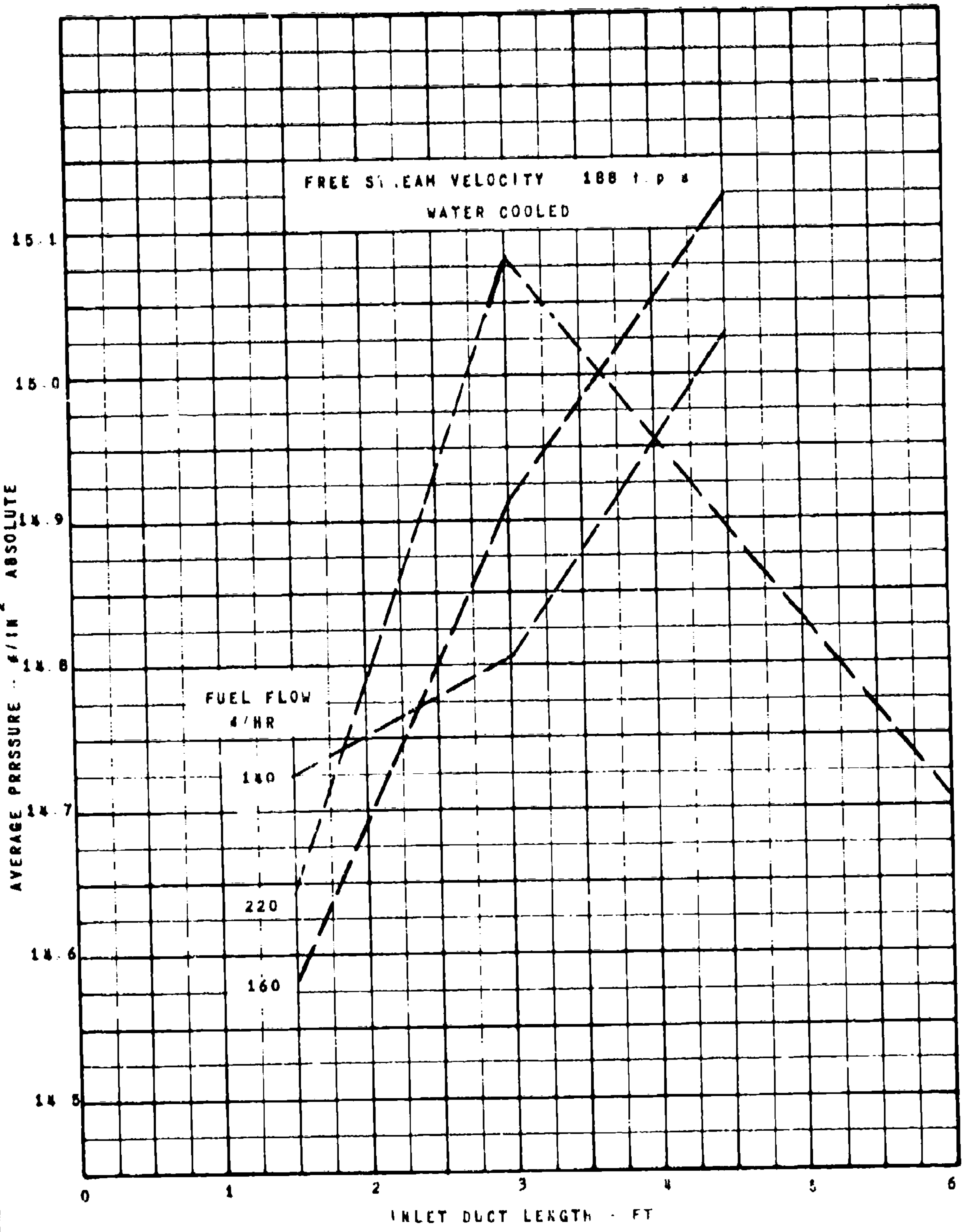


Fig. 2

359-11b

RESTRICTED

COMBUSTION CHAMBER PRESSURE
vs
INLET DUCT LENGTH
McDONNELL 8" PULSE JET

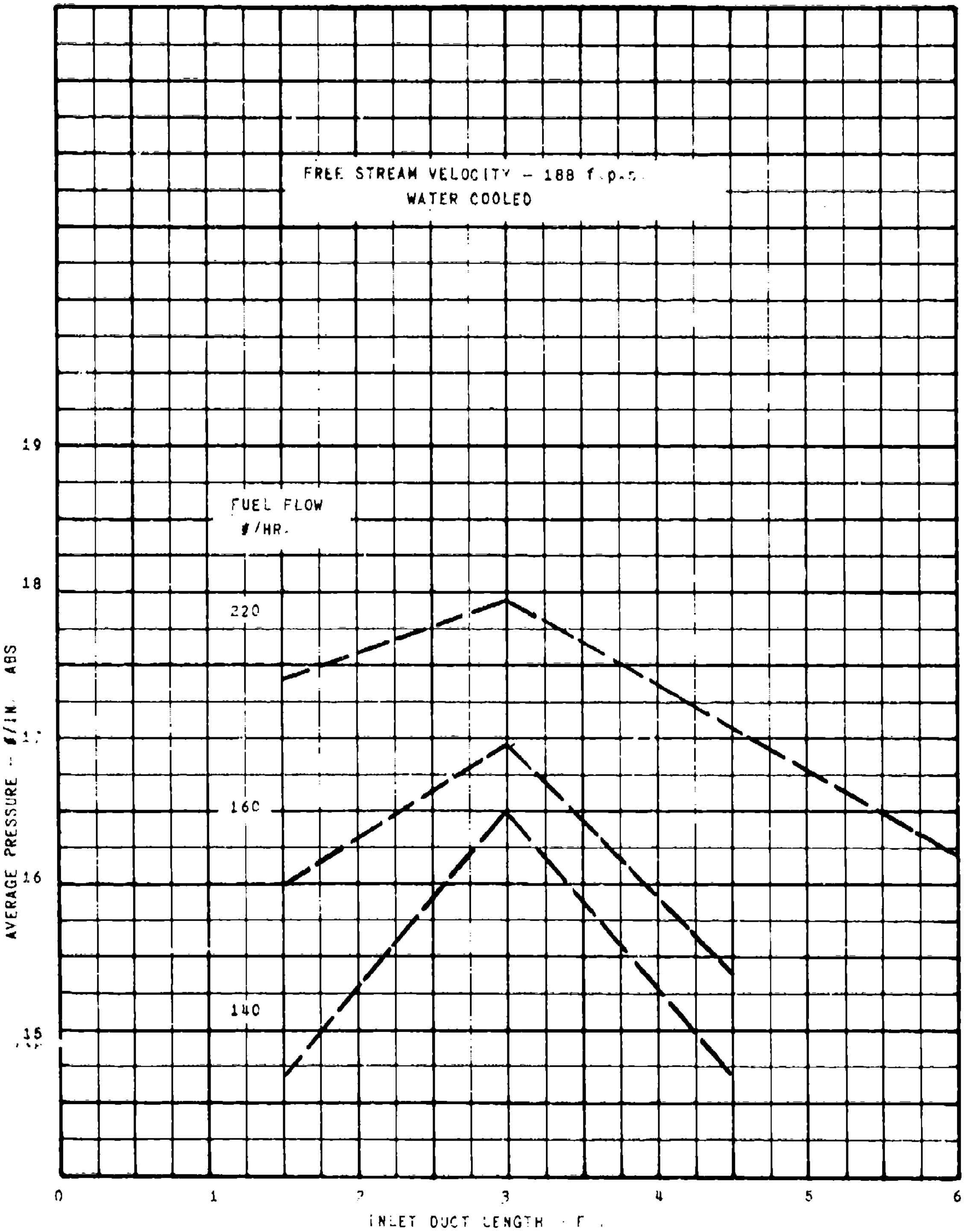


Fig. 3

RESTRICTED

359-IIb

THRUST vs FUEL FLOW

McDONNELL 8" PULSE JET

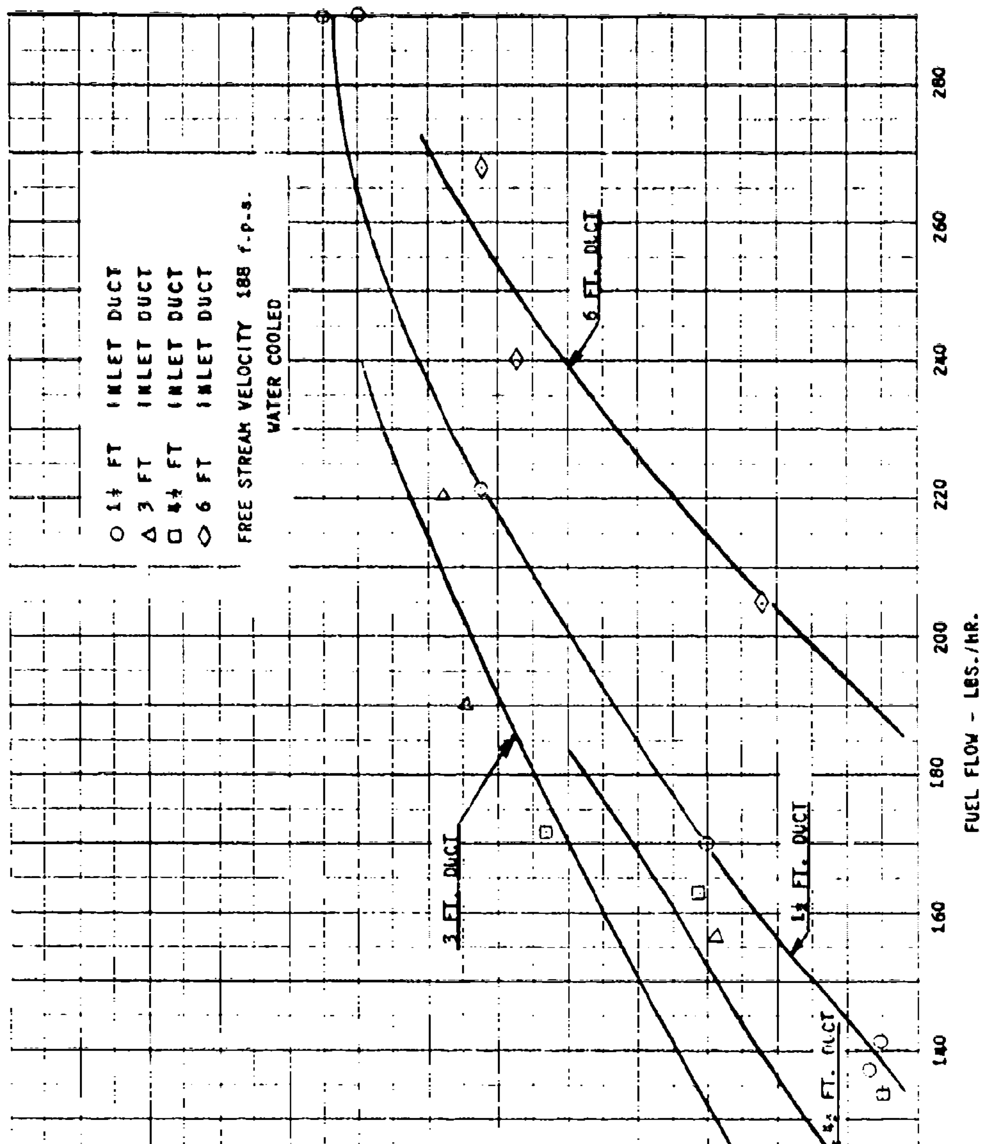


Fig. 4

RESTRICTED

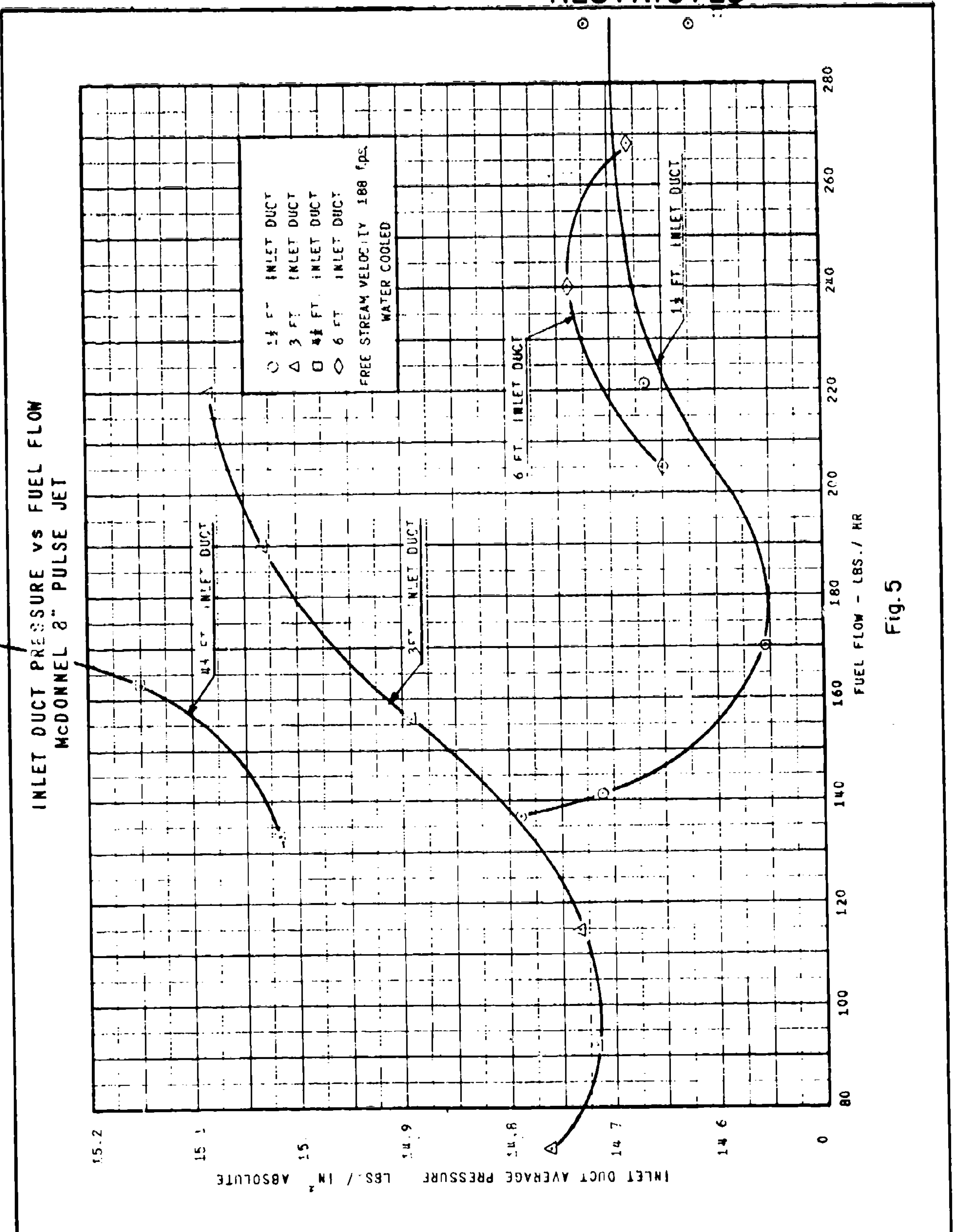


Fig.5

RESTRICTED

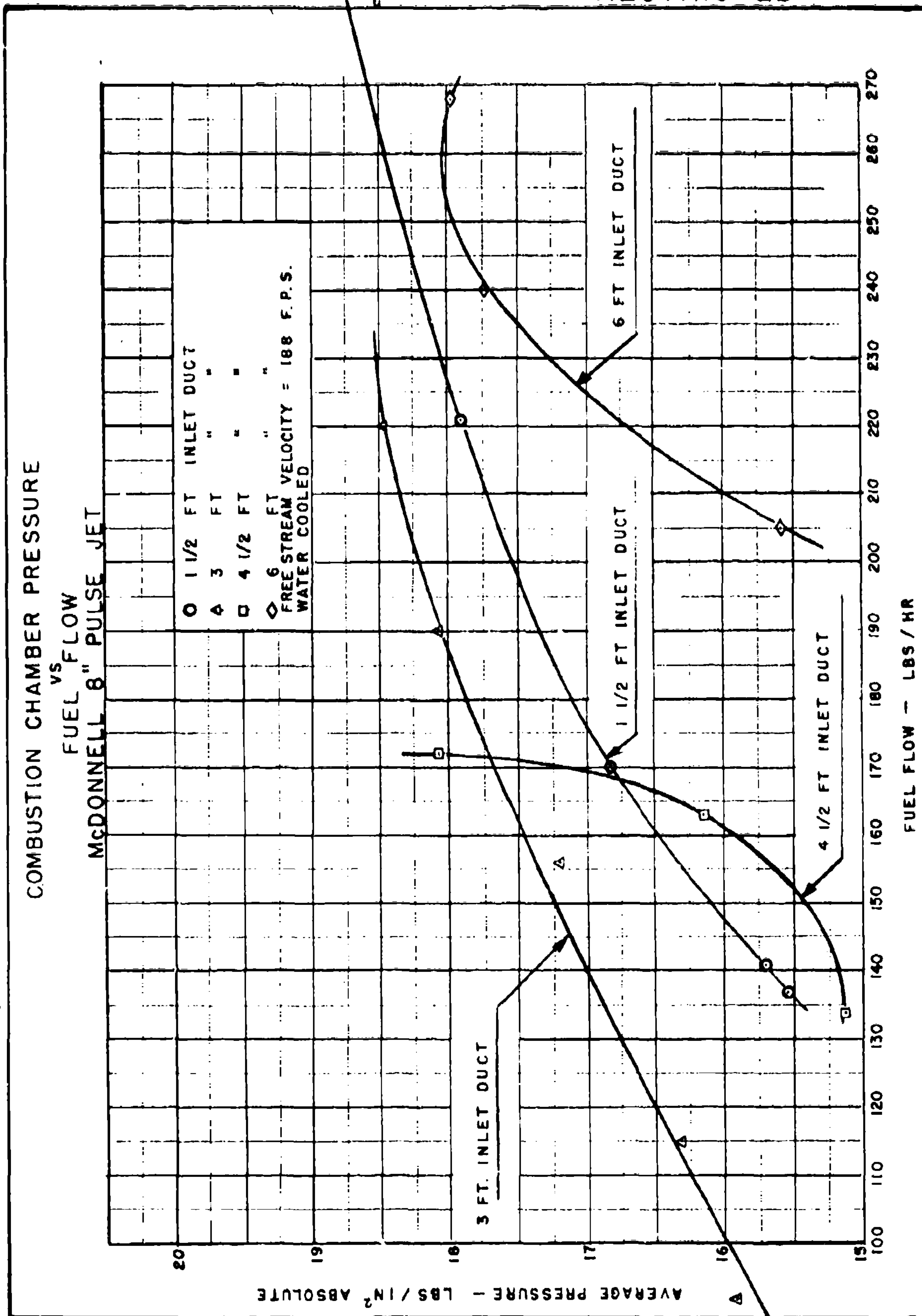

COMBUSTION CHAMBER PRESSURE
vs
FUEL FLOW
McDONNELL 8" PULSE JET
○ 1 1/2 FT INLET DUCT
△ 3 FT " "
□ 4 1/2 FT " "
◇ 6 FT " "
FREE STREAM VELOCITY = 188 F.P.S.
WATER COOLED
6 FT INLET DUCT
1 1/2 FT INLET DUCT
4 1/2 FT INLET DUCT
3 FT. INLET DUCT
AVERAGE PRESSURE – LBS / IN² ABSOLUTE
FUEL FLOW – LBS / HR
15
16
17
18
19
20
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270

Fig. 6

8" McDONNELL PULSE JET
WITH RAM COWL
STATIC OPERATION

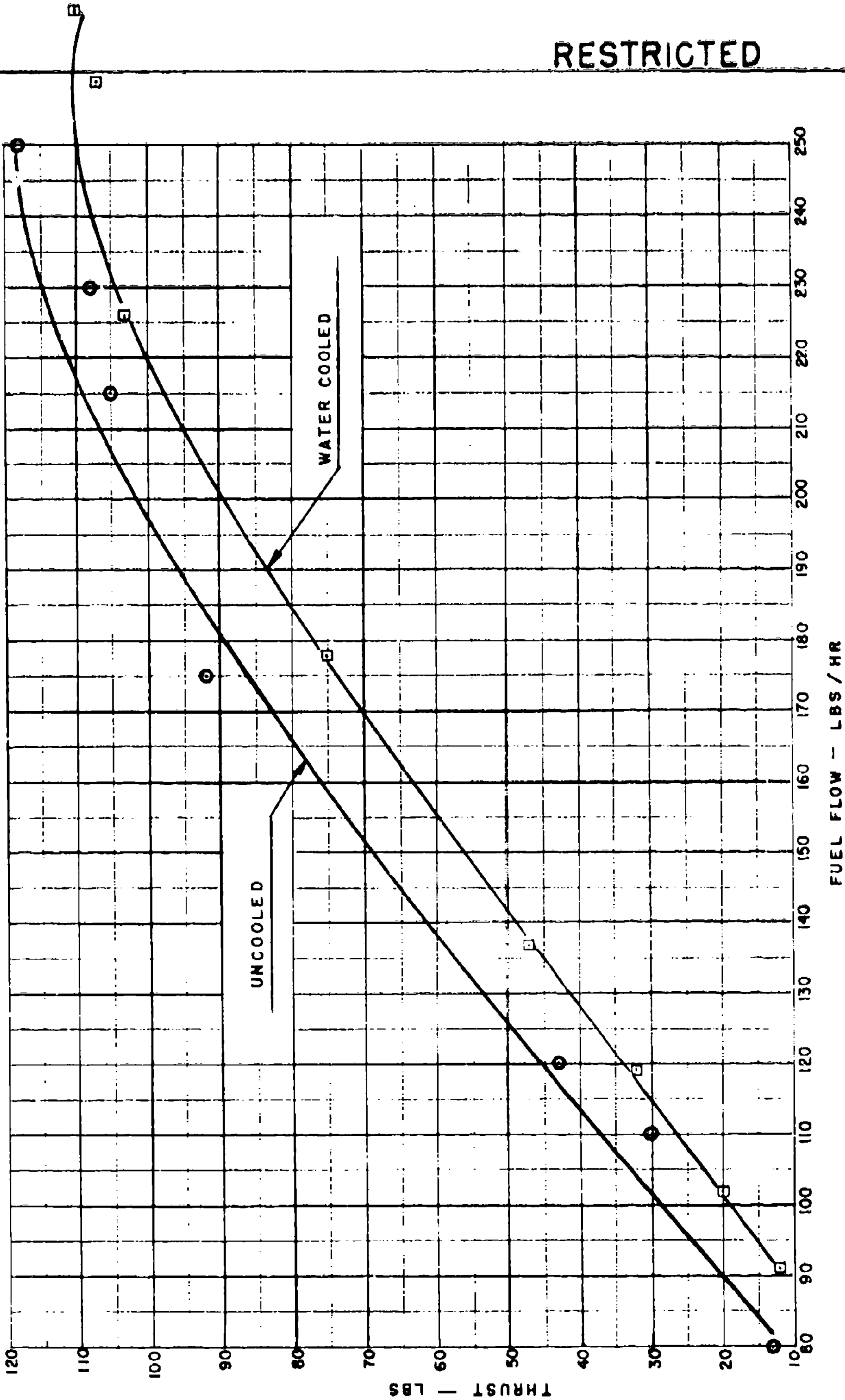


Fig. 7

PRESSURE CYCLE INLET DUCT # 1

RUN # 4

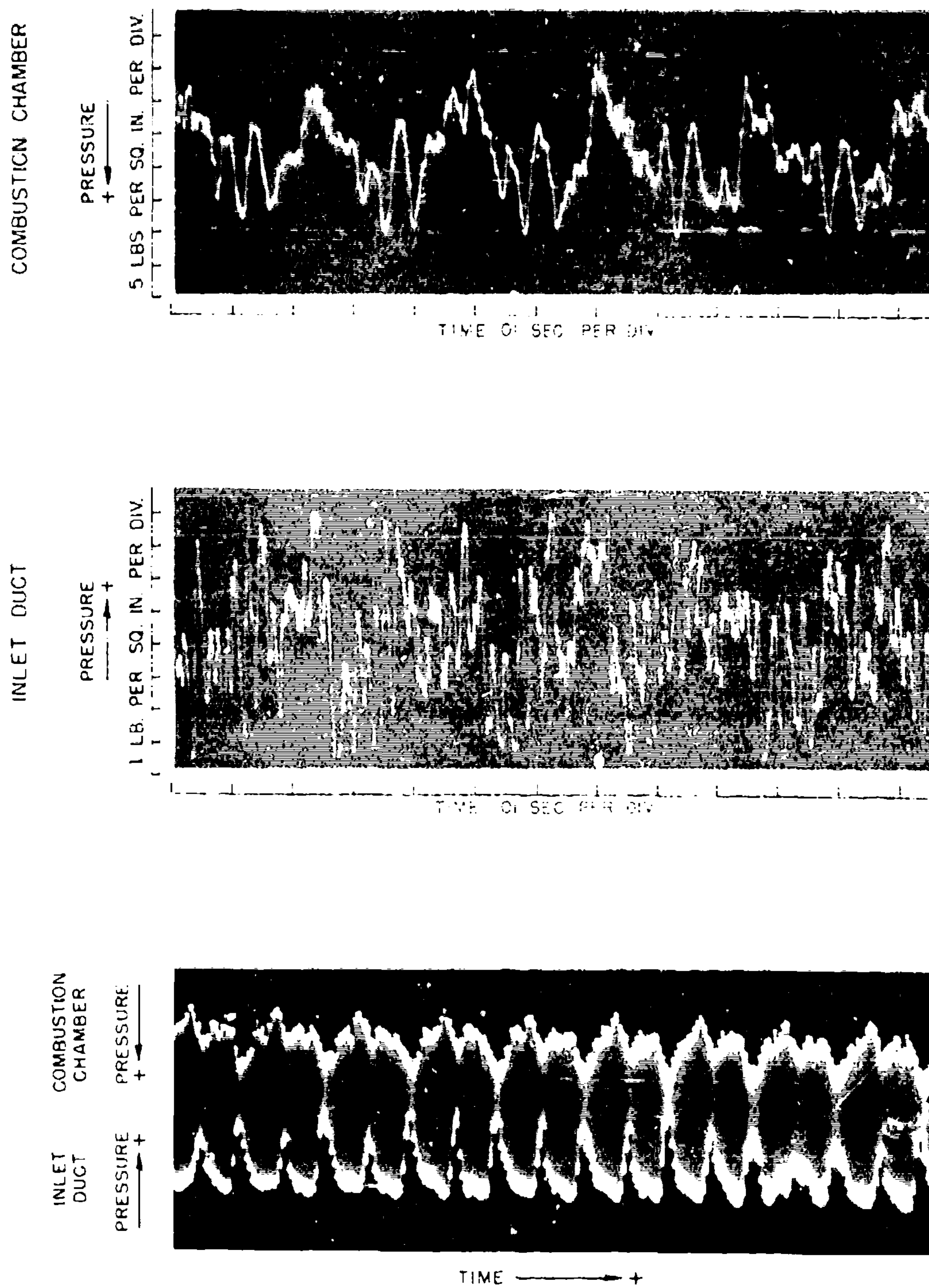


Fig. 8

PRESSURE CYCLE INLET DUCT # 1

RUN # 5

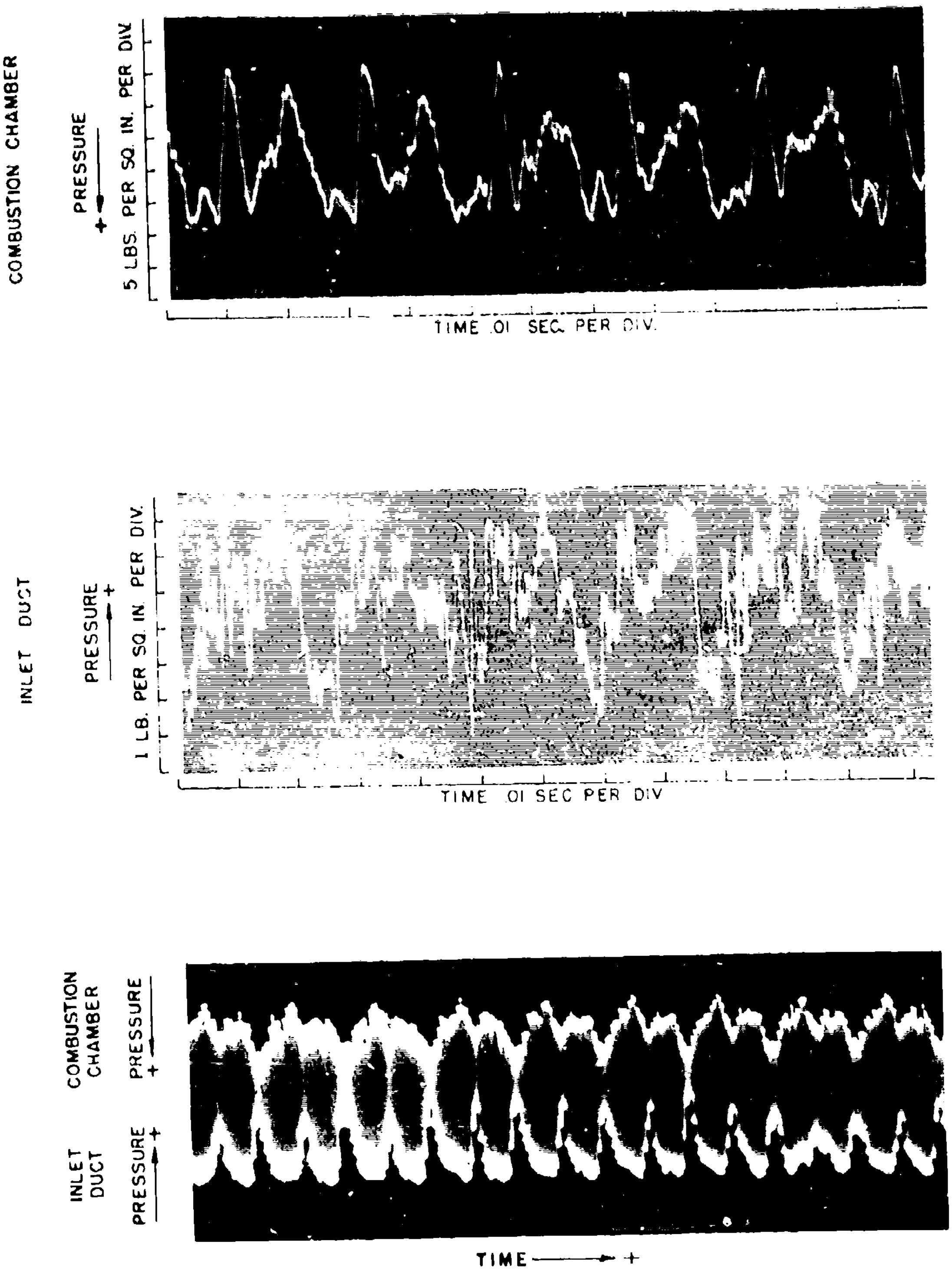


Fig. 9

PRESSURE CYCLE INLET DUCT # 1

RUN # 6

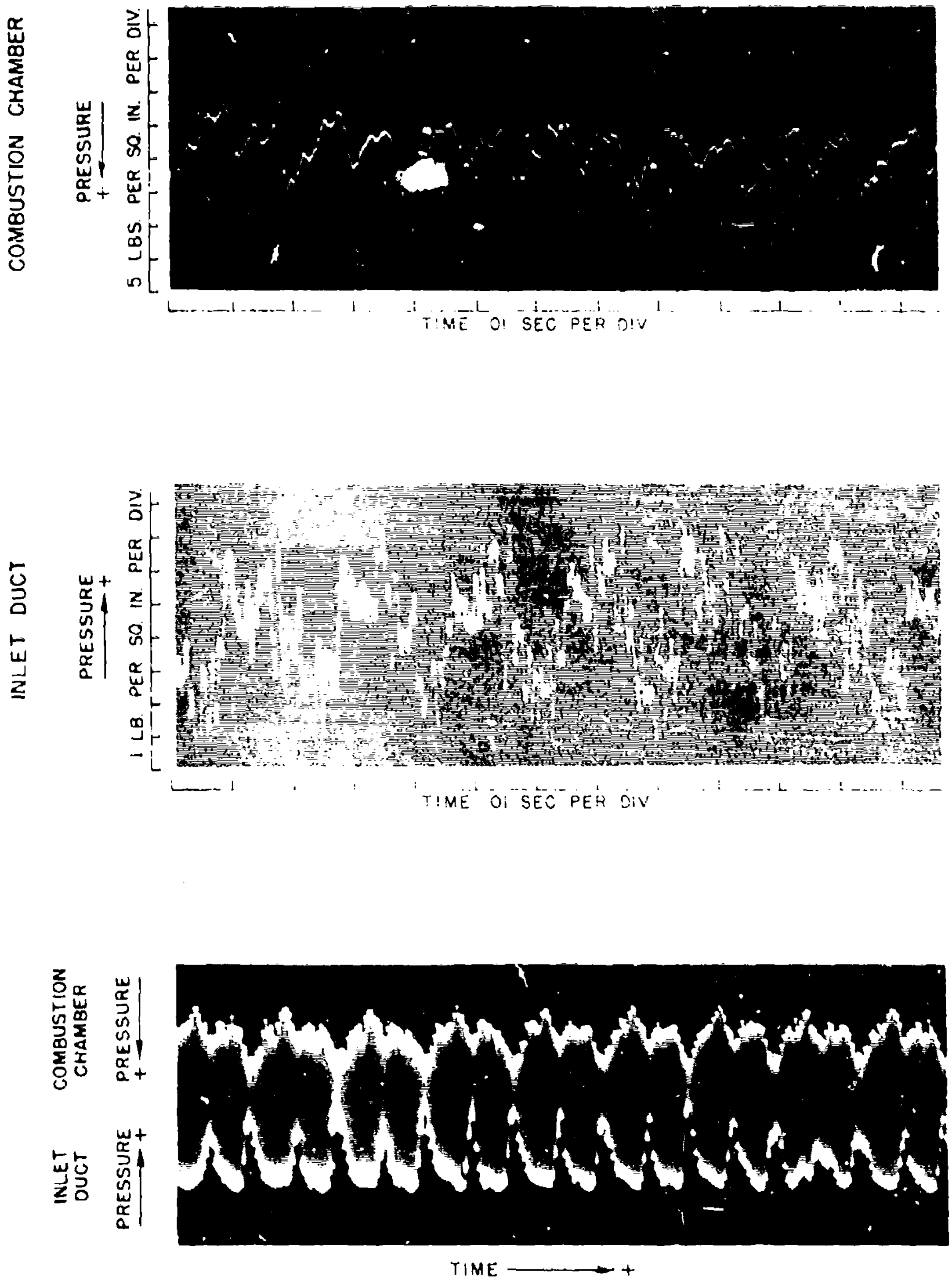


Fig. 10

PRESSURE CYCLE INLET DUCT # 2

RUN # 10

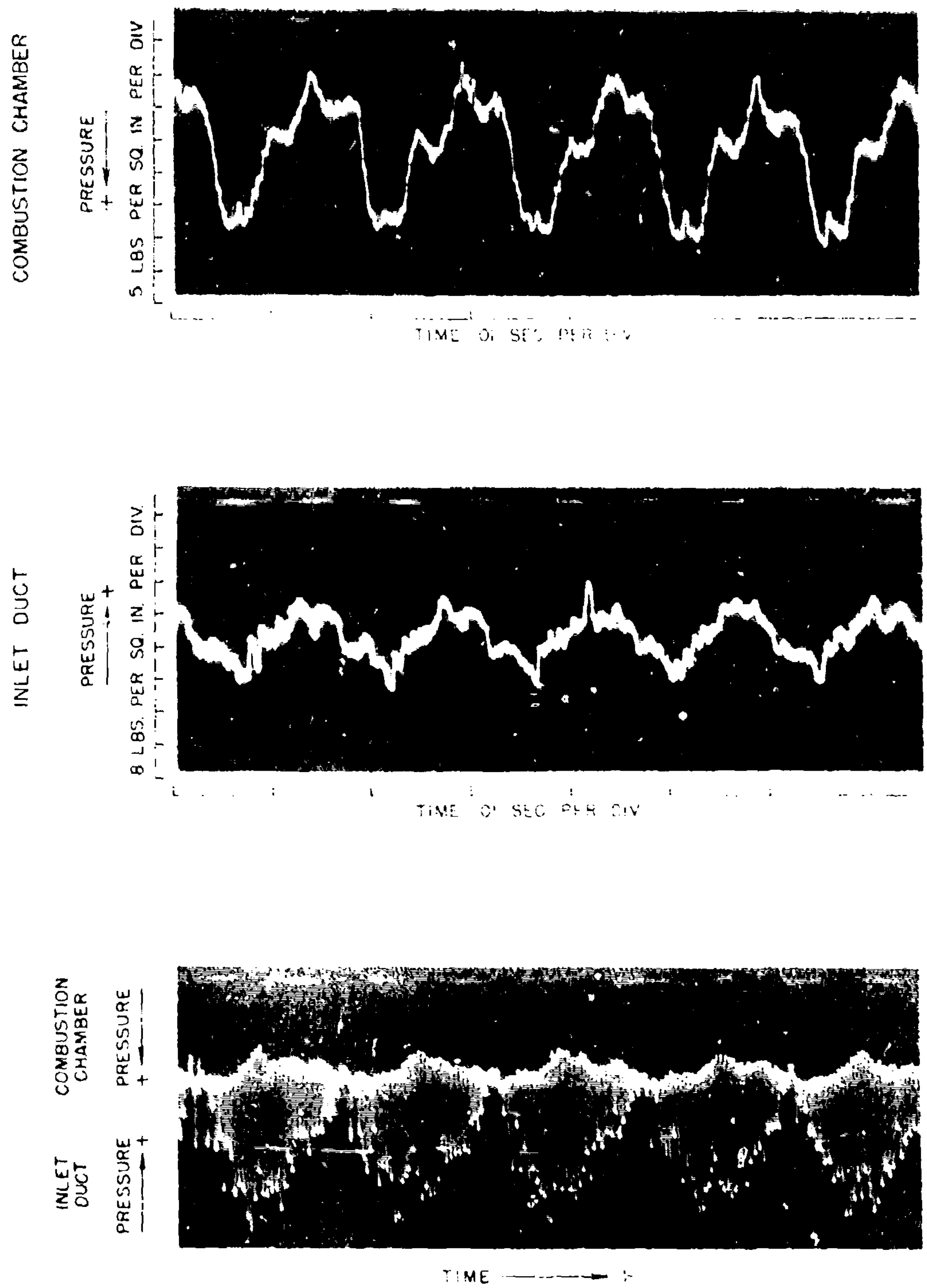


Fig 11

PRESSURE CYCLE INLET DUCT # 2

RUN # 11

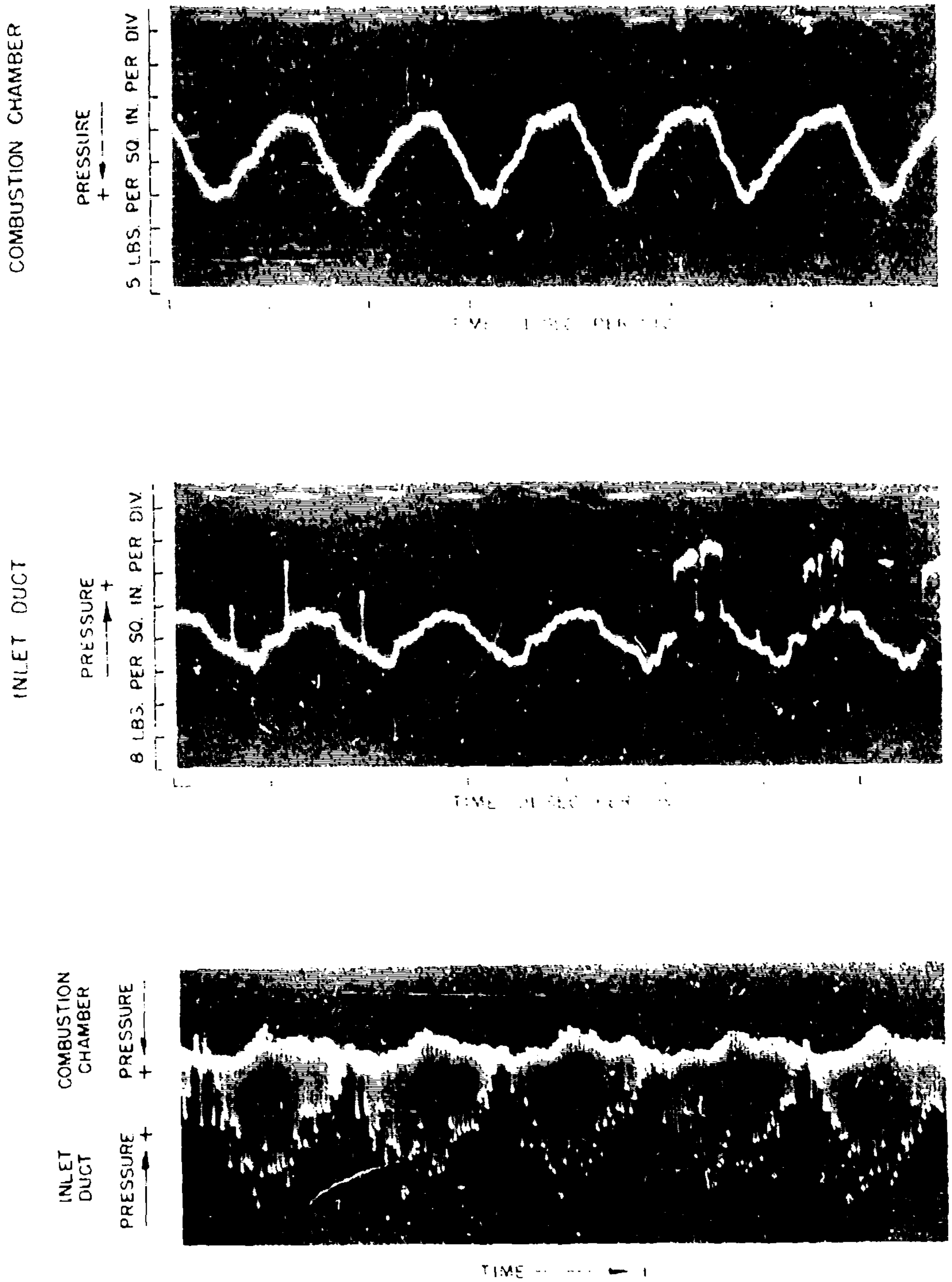


Fig 12

PRESSURE CYCLE INLET DUCT # 2

RUN # 12

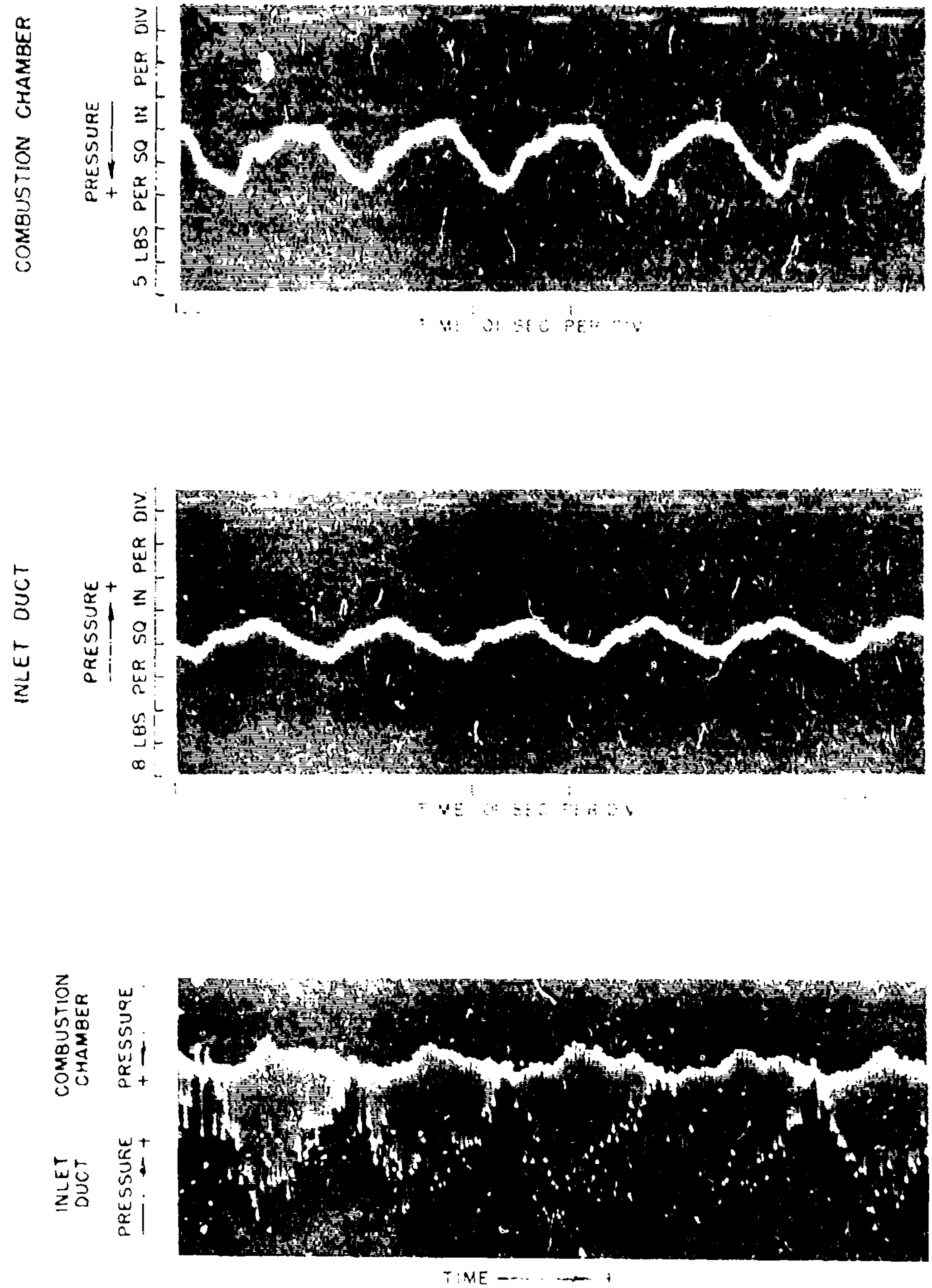


Fig 13

PRESSURE CYCLE INLET DUCT # 3

RUN # 13

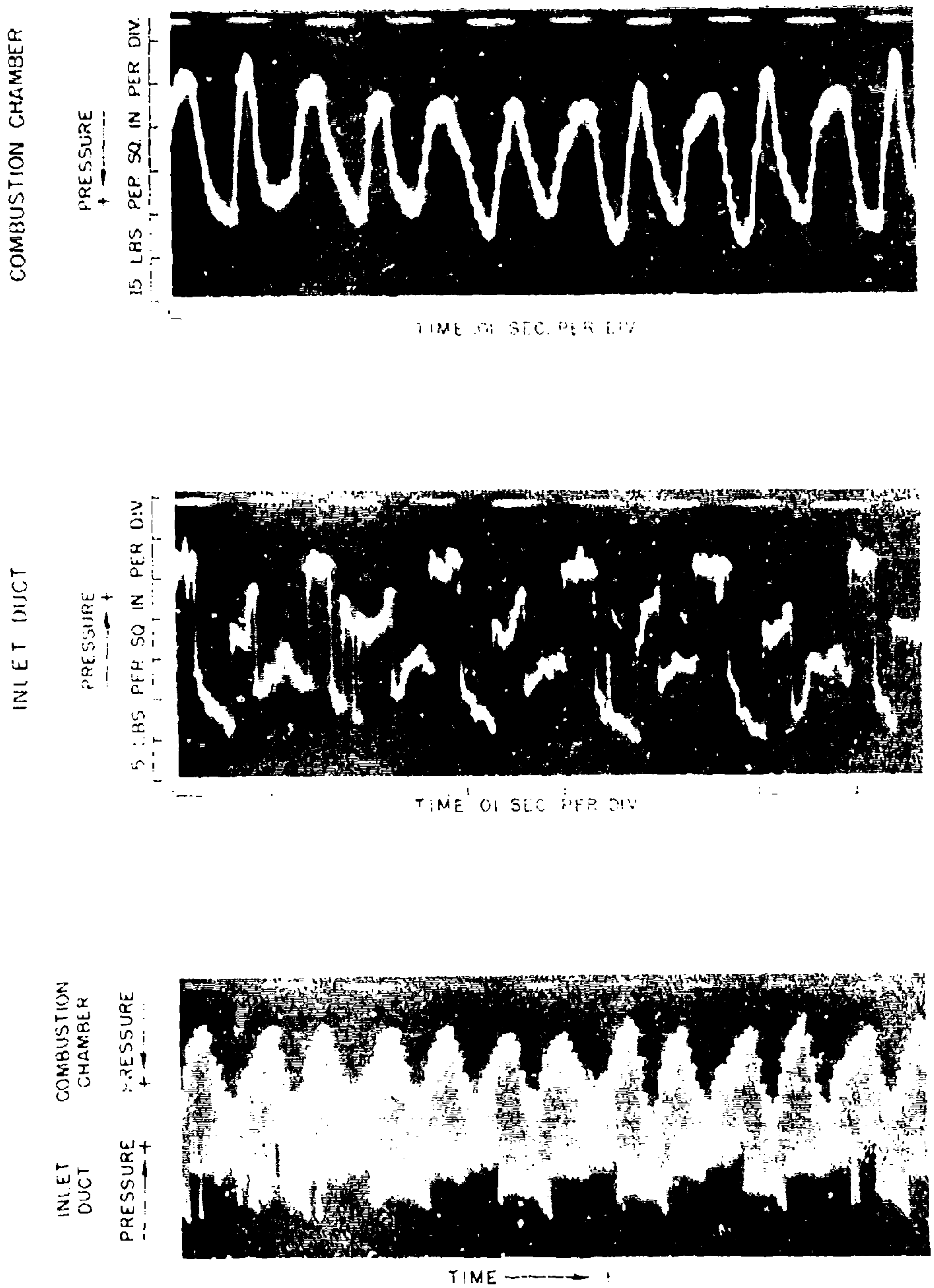
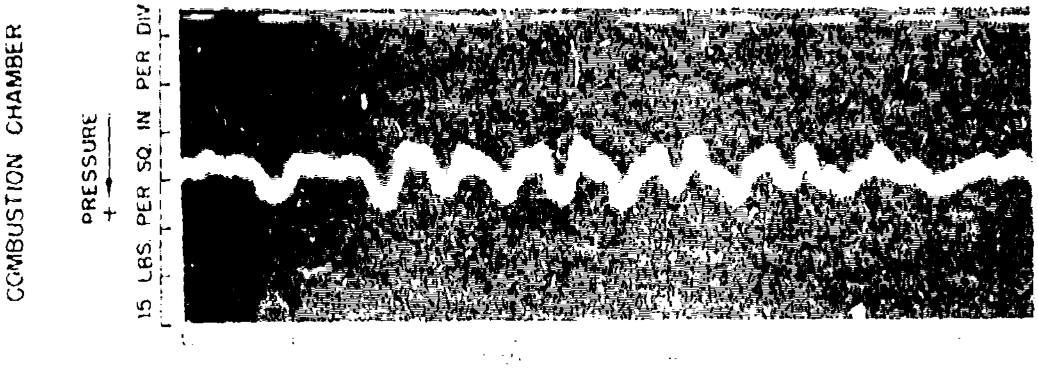
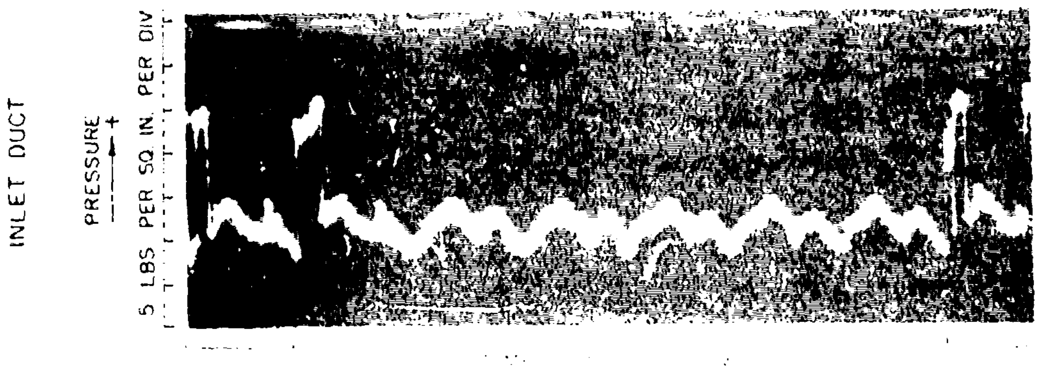


Fig 14

PRESSURE CYCLE INLET DUCT # 3

RUN # 14





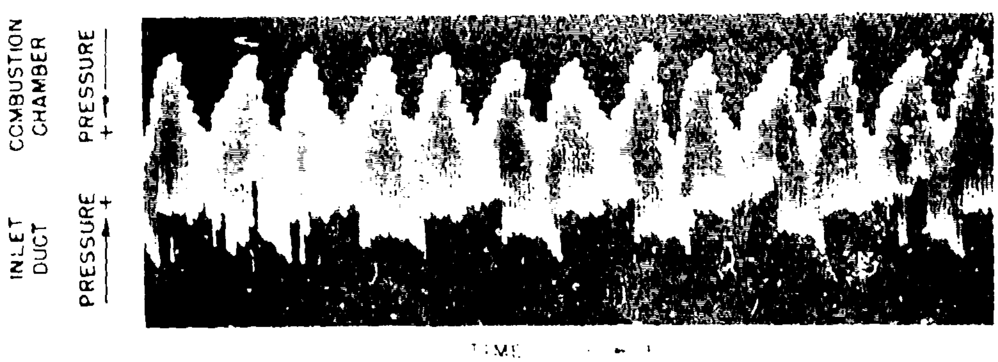


Fig. 15

PRESSURE CYCLE INLET DUCT # 3

RUN # 15

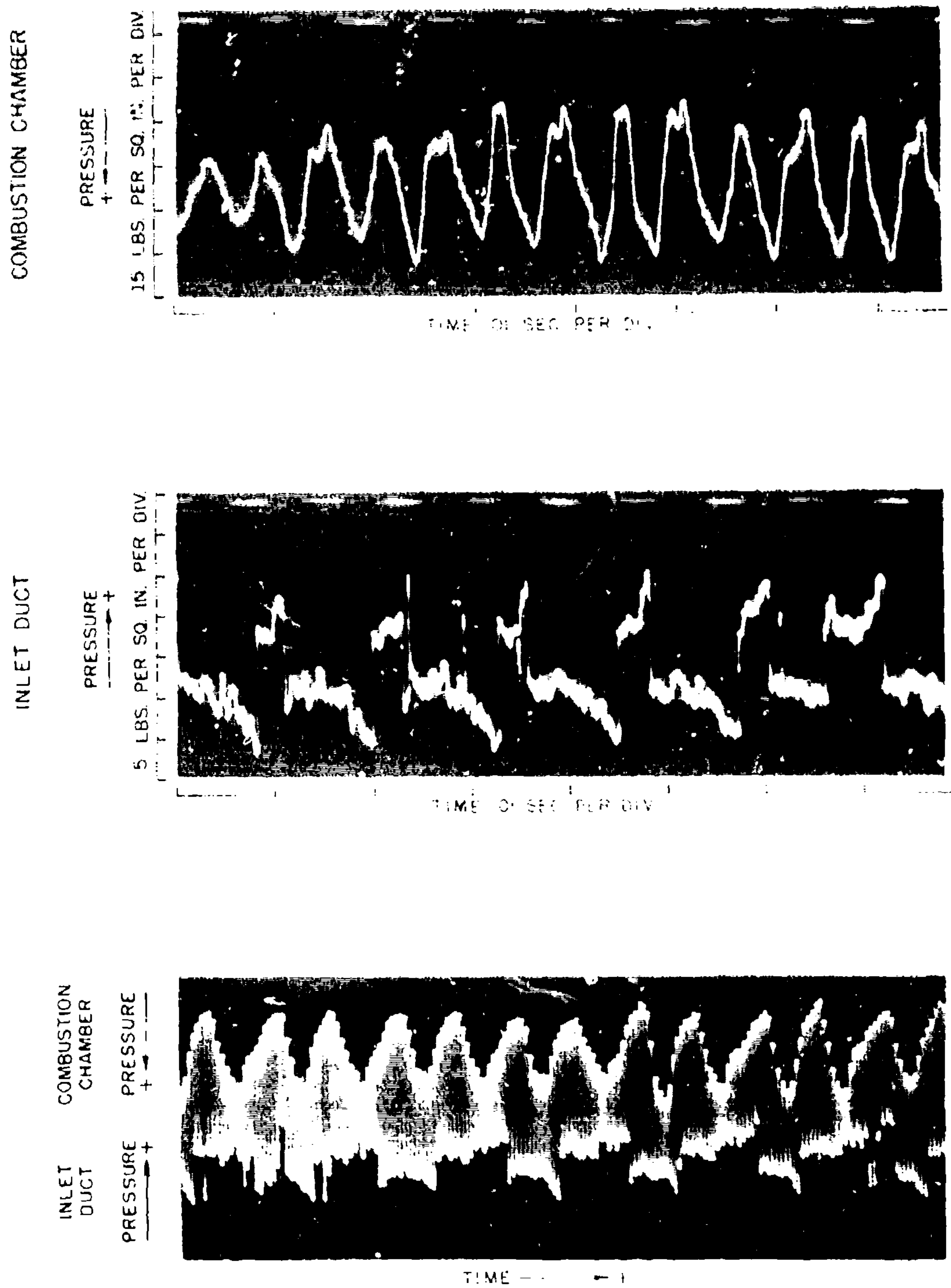
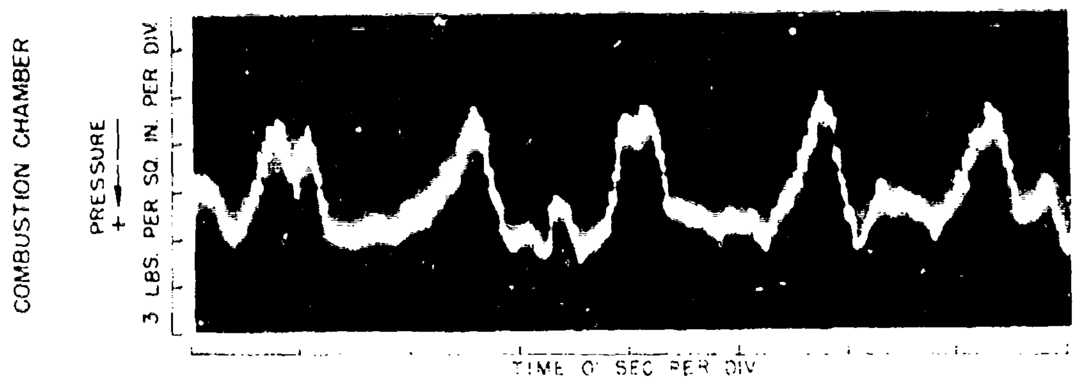
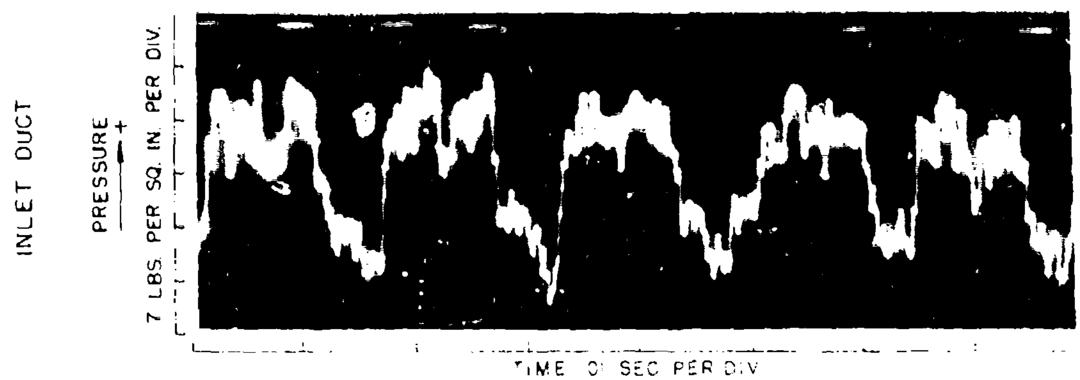


Fig 16

PRESSURE CYCLE INLET DUCT # 4

RUN # 16





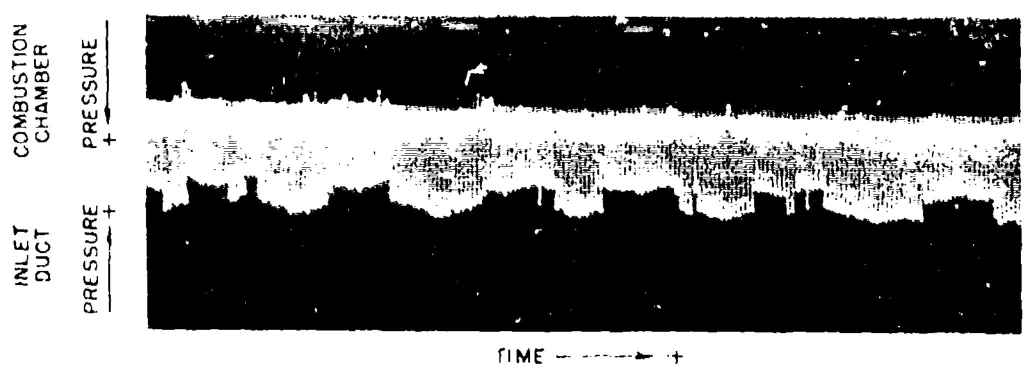


Fig 17

PRESSURE CYCLE INLET DUCT # 4

RUN # 17

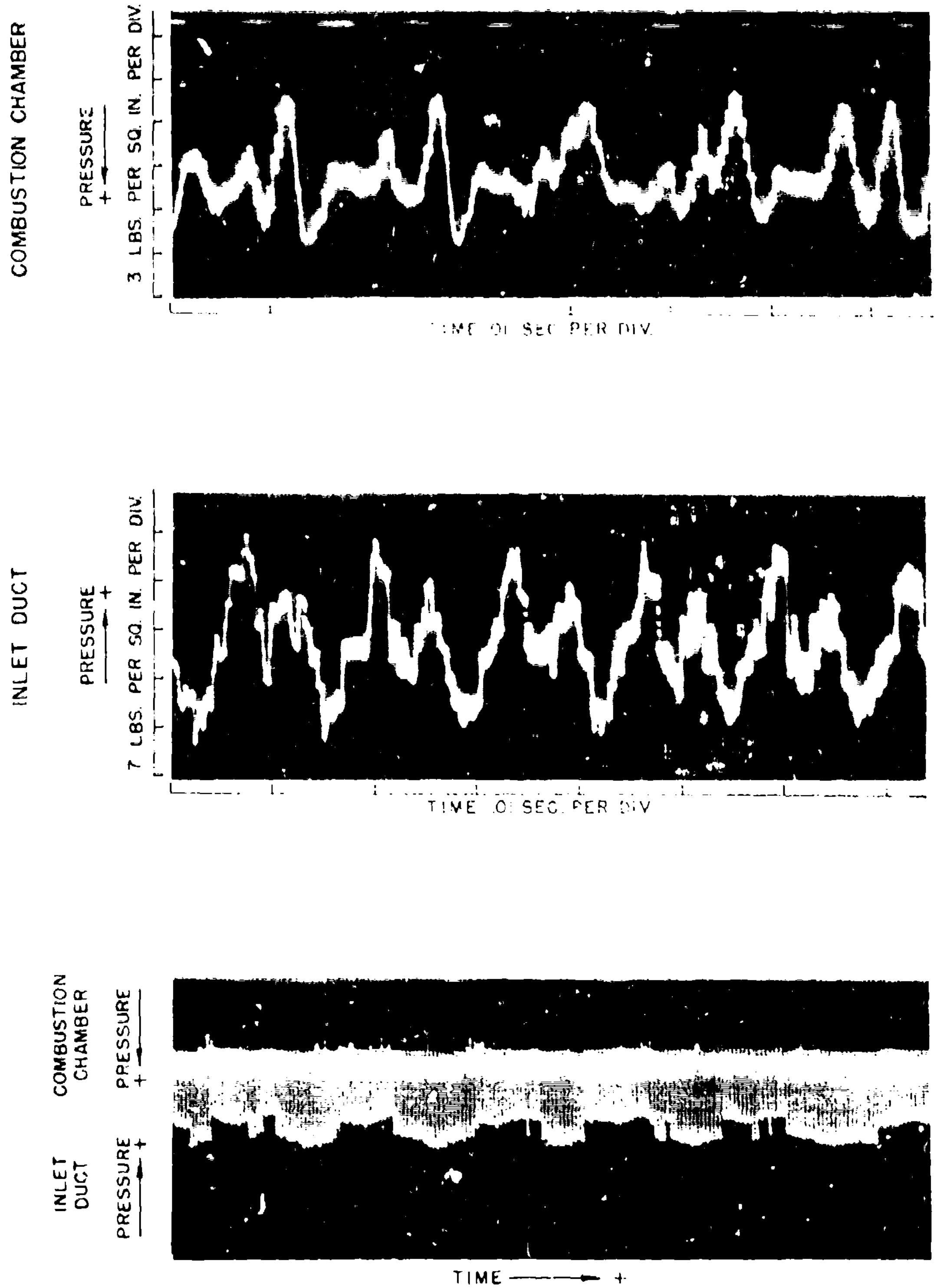


Fig. 18

PRESSURE CYCLE INLET DUCT # 4

RUN # 18

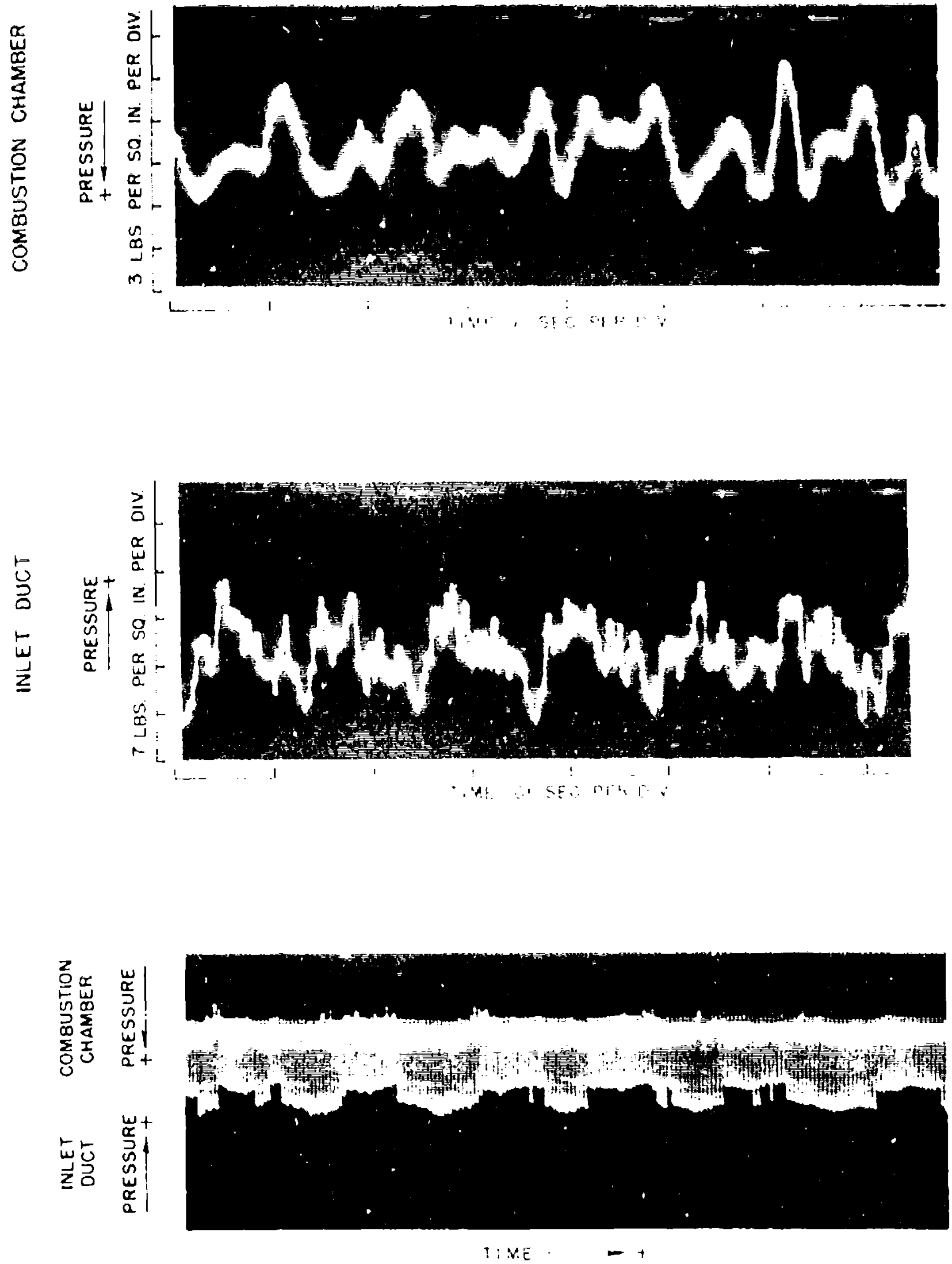


Fig 19