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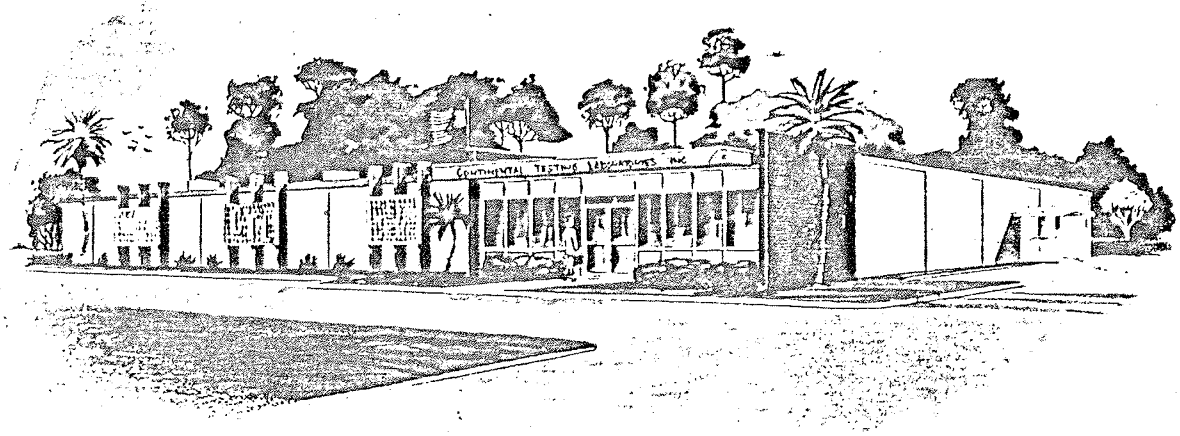
CONFIDENTIAL



CONTINENTAL TESTING LABORATORIES, INC.

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7 April 1971

Vulcan Iron Works
2725 N. Australian Avenue
West Palm Beach, Florida 33407

Attention: Mr. R. J. North, Vice President, Special Products Division

Reference: Purchase Order #F2514

Gentlemen:

Enclosed are three copies of our report #1009 on testing of your Pneumatic Vibrator Pile Driver in accordance with the referenced purchase order.

Please be assured of our continued cooperation.

Very truly yours,

CONTINENTAL TESTING LABORATORIES, INC.

M S Knott

M. S. Knott
Chief Engineer

dp
enc

Report #1009 Copy #1

REPORT OF TEST

on

PNEUMATIC VIBRATOR PILE DRIVER
P/N LV 103 M

for

VULCAN IRON WORKS
2725 N. Australian Avenue
West Palm Beach, Florida 33407

6 April 1971

CONTINENTAL TESTING LABORATORIES, INC.
763 U. S. Highway 17-92
Fern Park, Florida 32730

Prepared by Mahlon S. [signature]

TABLE OF CONTENTS

INTRODUCTION

The data included in this report was prepared for Vulcan Iron Works in accordance with Vulcan Iron Works purchase order #F2514, and was collected by Continental Testing Laboratories, Inc. personnel, on site, at the Vulcan plant in West Palm Beach, Florida. The tests were performed during the period of 3/29 through 3/31, 1971.

PURPOSE OF TEST

The purpose of this test was to collect actual data to support and/or confirm analytical design data already on hand. In addition, if discrepancies in performance were noted, it was desirable to have information sufficient for making necessary design changes.

EXPERIMENT DESIGN

The primary element of interest was the performance of the porting of the low pressure cylinder. For this reason, inlet pressure information was collected at the entrance port, and also in the low pressure cylinder. Since the exposure times of the ports would be a function of the relative velocities of the free piston and the main body of the vibrator, it was desirable to have the main body at low absolute velocity. To measure actual force output of the vibrator, it was desirable to allow a free body situation to exist, and measure the acceleration level of the total mass in motion.

To satisfy both requirements, with least compromise, the vibrator was placed in a wheeled dolly and rigidly attached to a wheeled non-resonant mass. The total weight of the system was chosen to be approximately 5,000 lb., which would result in approximately .15" double amplitude displacement at 16 Hz, with a vibrator force output of 10,000 force pounds. The vibrator would then be instrumented for acceleration level, and the low and high pressure cylinders monitored for pressure. The total reaction force on the cylinders should correspond to the forces evidenced by the acceleration level of the total mass.

TEST SETUP

A cylindrical reaction mass was fabricated for a load by Vulcan Iron Works personnel. The total weight of the vibrator and dolly and load was 4,900 lb. This weight was determined by the Vulcan Iron Works personnel by measuring empty and loaded truck weight at a nearby truck scale.

The rolling system was placed on a level, rigid platform. Displacement indicators were placed on various sections of the test system, and the vibrator operated to check for minimum lateral motion. The system was aligned along the longitudinal axis to minimize cross axis motion and the reaction mass was welded to the vibrator to minimize rattling of the interconnection hardware.

Accelerometers were cemented on the load and the vibrator with Eastman 910 cement, to provide measurements to insure non-resonance of the system. The system was operated, and the vibration levels present at both accelerometers were in phase and agreed in amplitude to within 10%. The noise present on both the vibrator and load signals prevented confirmation to closer accuracy. The displacement indicators confirmed to a similar accuracy that the vibration levels present on both the vibrator and the load were the same.

The accelerometers were connected to an amplifier, which normalized the sensitivity of the individual accelerometers, displayed on a meter an indication of the peak acceleration level, and provided an amplifier for the operation of the oscillograph galvanometer. The system was calibrated for a full scale sensitivity of 3 g (+3g, -3g) for approximately one inch deflection of the galvanometer trace. The mechanical noise present on this signal degrades the indication to the extent that the acceleration present is accurately known only to the order of ±10%.

The pressures present in the system were measured using a series of strain gage type pressure transducers. The strain gage bridges were excited with a 5V, 3KC signal, and the bridge deviation demodulated, and the output applied to a galvanometer. Two CEC Model 1-118 Carrier Amplifier systems were used to provide this function for the transducers. The 1-118 amplifier channels are limited to 5 mA drive, and were used to drive CEC 7-323 galvanometer, with a nominal sensitivity of 2.5 mA/inch. Therefore, all trace widths were limited to 2" deflection to preserve linearity. The frequency response of the carrier system is 600 Hz, as were the transducers and galvanometers. Therefore, the frequency response of the system for the analysis of the 16 Hz vibrator is considered to be quite adequate.

The pressure transducers were connected to the measurement points through nine-inch long, 2,000 psi rated 1/4" aircraft hoses. The hoses were used to isolate the transducers from the vibration present on the vibrator. The length of hose and volume effects of the hose were such as to have no measurable effect on the pressure signals present at the transducers. This was confirmed by mounting one transducer both directly into the system and on the hose. No difference in indication was detected.

Before each test run, the transducers were connected to a dead weight tester, and a two point calibration made of each transducer. The basic accuracy of the dead weight calibrator is 0.1%. This calibration was made using all elements of the instrumentation system, from transducer to oscillograph record. At several points during testing and upon completion of tests, similar recalibrations were performed. These recalibrations confirmed that the system was very stable.

It is conservatively estimated that the oscillograph record absolute accuracies are better than 1/4 of a small division, or .025". For the two deflection sensitivities used, 250 psi/in and 100 psi/in, this yields record accuracies of ±6 psi and ±2.5 psi, respectively.

The points of measurement and test setup are shown in Figures 1, 2 and 3 of this report. The full schedule of channel assignments for instrumentation are shown in Figure 4.

TEST RUNS

The test runs were performed in two basic test configurations. In the first test, the inlet manifold pressures were checked to insure that there were no pressure drops in the manifold (Test Record #1). The second test run instrumented the low pressure cylinder pressures, instead of the inlet manifold pressures (Test Records #2, #3 and #4).

The records included in this report are photo copies of the original, and are more permanent than the oscillograph records taken on Kodak 2022 Linagraph paper.

TEST RECORD #1

Channels 3 and 7 were located opposite the low pressure cylinder air inlet ports. Channel 5 was in the air supply line.

It appears that all three points indicate the same pressure. The ripple present on the signals is possibly from the vane compressor supplying the air to the system. The frequency of the ripple is approximately 300 Hz, and could be from a 5 or 10 vane rotary compressor running at 30 revolutions per second (1800 RPM).

Pressure drops are detectable at the inlet points, coincident with the high pressure cylinder peak pressures.

Peak to peak fluctuations in pressures at both inlet points are in the order of 50 psi.

The vibrator was operating well at this time, with lubrication present in the air line. Weather conditions for West Palm Beach at 3:00 P.M. on March 29, 1971, the time of this run, were as follows:

Temperature	73°F
Relative Humidity	32%
Atmospheric Pressure	29.83"

TEST RECORD #2

For this run, the two inlet pressure sensors were shifted to sense the low pressure cylinder pressures.

The vibrator was running with some irregularity on this day, March 30, and there were adjustments made in lubrication in an effort to achieve the force levels present on the previous day by attempting to blow the cylinders clear and through adjustments in the amount of oil introduced to the air supply.

The data on Record #2 was taken when the system was operating properly. The force level indicated was 9300 force pounds (1.9 g's x 4900 pounds) under these conditions. Lesser operating conditions referred to in the previous paragraph involved operation at force levels of 5000 to 8000 force pounds, indicated.

The data present on this record was reduced, and an attempt made to correlate indicated pressures and indicated force levels. The total reaction force present on the vibrator body should be equal to the peak forces present in the high and low pressure cylinders. The following is such a calculation:

Area of High Pressure Cylinder = 14 sq in = A_h

Peak Pressure in High Pressure Cylinder = 425 psi = P_h

Force = PA = (425)(14) = 5950 lb = F_h

Area of Low Pressure Cylinder = 30 sq in = A_L

Peak Pressure in Low Pressure Cylinder = 123 psi = P_L
(123 is average of 118 and 128)

Force = PA = (123 ×30) = 3690 lb = F_L

$F_{total} = F_h + F_L$ = 5950 lb x 3690 lb = 9640 lb

The force present as indicated by the accelerometer is as follows:

F = WA where F is in force lb
~~W is weight in lb, 4900 lb~~
A is acceleration level in g's which is

$$\frac{\text{Acceleration Level}}{\text{Acceleration Due to Gravity}}$$

F = (4900)(1.9)
= 9310 lb

The comparison of values indicates agreement within 3 1/2 percent.

TEST RECORD #2
(Continued)

A brief consideration of possible errors indicates that further refinement of these numbers is of little purpose:

$P_H = 425 \pm 1.4\%$
$P_L = 123 \pm 2\%$
$W = 4900 \pm 2\%$ (estimated)
$a = 1.9$ g's $\pm 10\%$*
A_H & A_L are within $\pm 1\%$

The real evaluation of this data must be made in terms of the theoretical predictions of performance.

Weather Bureau conditions for West Palm Beach at 10:00 A.M. on March 31, 1971, the time of this run, were as follows:

Temperature	68°F
Relative Humidity	40%
Atmospheric Pressure	30.15"

Much work was done to attempt to refine this tolerance. Unfortunately, it was just not possible to accurately simulate the actual signal, and therefore the absolute signal tolerance must remain at ±10%. All indications are that a triangular waveform, as opposed to a sinusoidal waveform, should read approximately 5% low, which would yield a true acceleration level of 2 g's, and closer agreement between the pressure derived force and the acceleration derived force.

TEST RECORDS 3 & 4

It was desirable to determine MEP in both low pressure and high pressure cylinders. To facilitate this, a rerun was made with the same instrumentation as in Record #2, but with a record speed of 64"/sec. This increased speed, and thus increased image size of the pressure pulse, would permit easier evaluation of MEP.

Some period of time was spent attempting to get the vibrator running at peak performance, but the system simply could not be brought quite up to the previous level. In the interest of time and economy, the test data was taken at the lesser performance level.

Record #3 is at 16"/sec, and Record #4 is at 64"/sec.

LIST OF EQUIPMENT

1. Recording Oscillograph, CEC, Model 5-124A, S/N 4275, Cal. 3/25/71
2. Carrier Amplifier, CEC, Model 1-118, S/N 319AF3, Cal. 3/25/71
3. Carrier Amplifier, CEC, Model 1-118, S/N 994AP4, Cal. 3/25/71
4. Dead Weight Pressure Tester, Mansfield & Green, Model 10-3525, S/N 869-8, Cal. 9/1/70, due 9/1/71
5. Dynamonitor, Endevco, Model 2704, S/N 154-24N, Cal. 3/8/71, due 6/8/71
6. Accelerometers (2), Endevco, Model 2215E, S/N's TC67 and TD08, Cal. 3/16/71, due 6/16/71
7. Galvanometer, CEC, Model 7-323, S/N's 18898, 14230, 6932, 5657, 17979
8. Galvanometer, CEC, Model 7-362, S/N's 7202, 11897
9. Pressure Transducers, 1000 psi, Model 176, S/N's 50465, 50542
10. Pressure Transducers, 200 psi, Model 217, S/N 612572, 581744, 614747

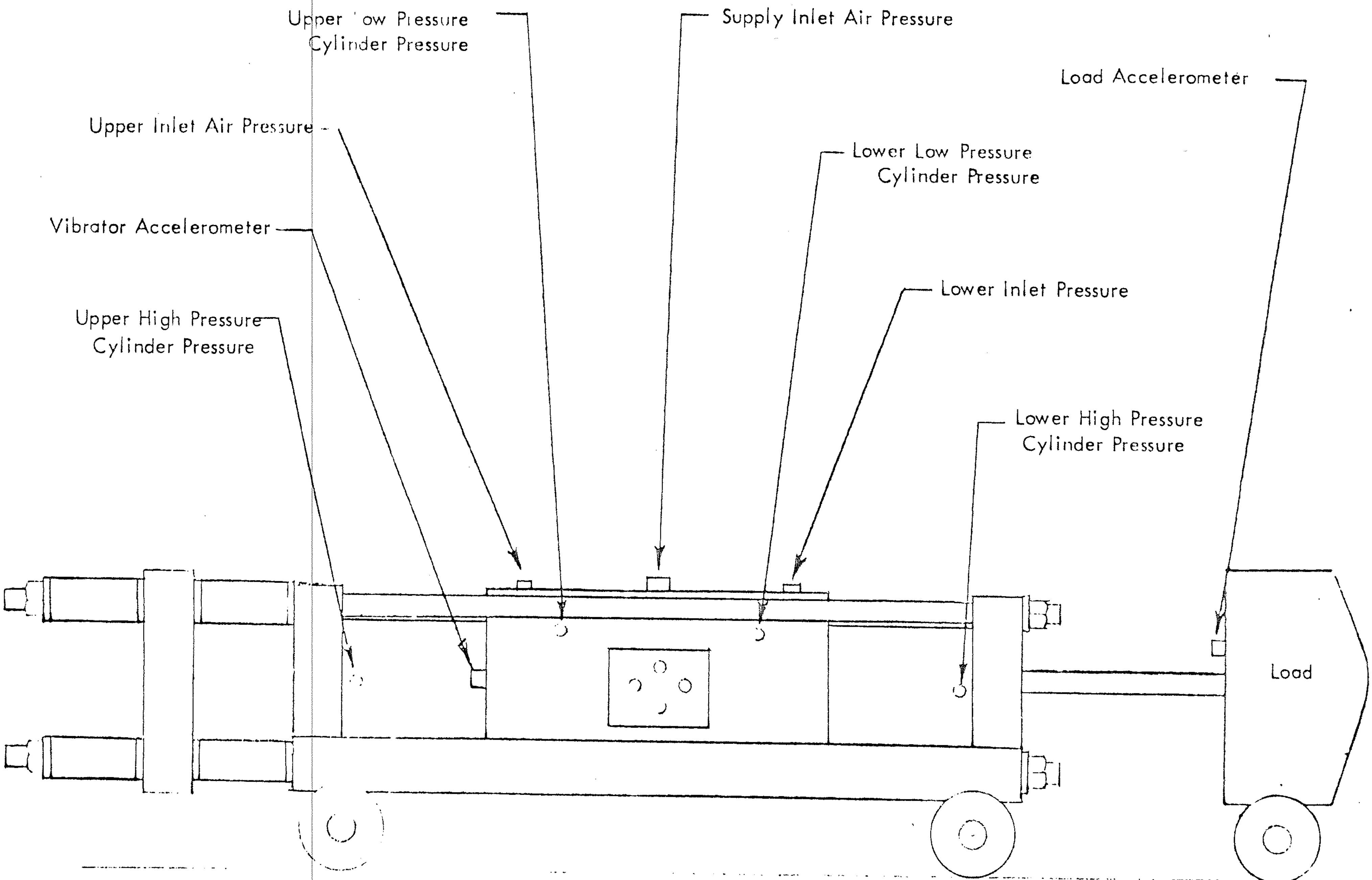


Figure 1

Schematic of Test Points Monitored

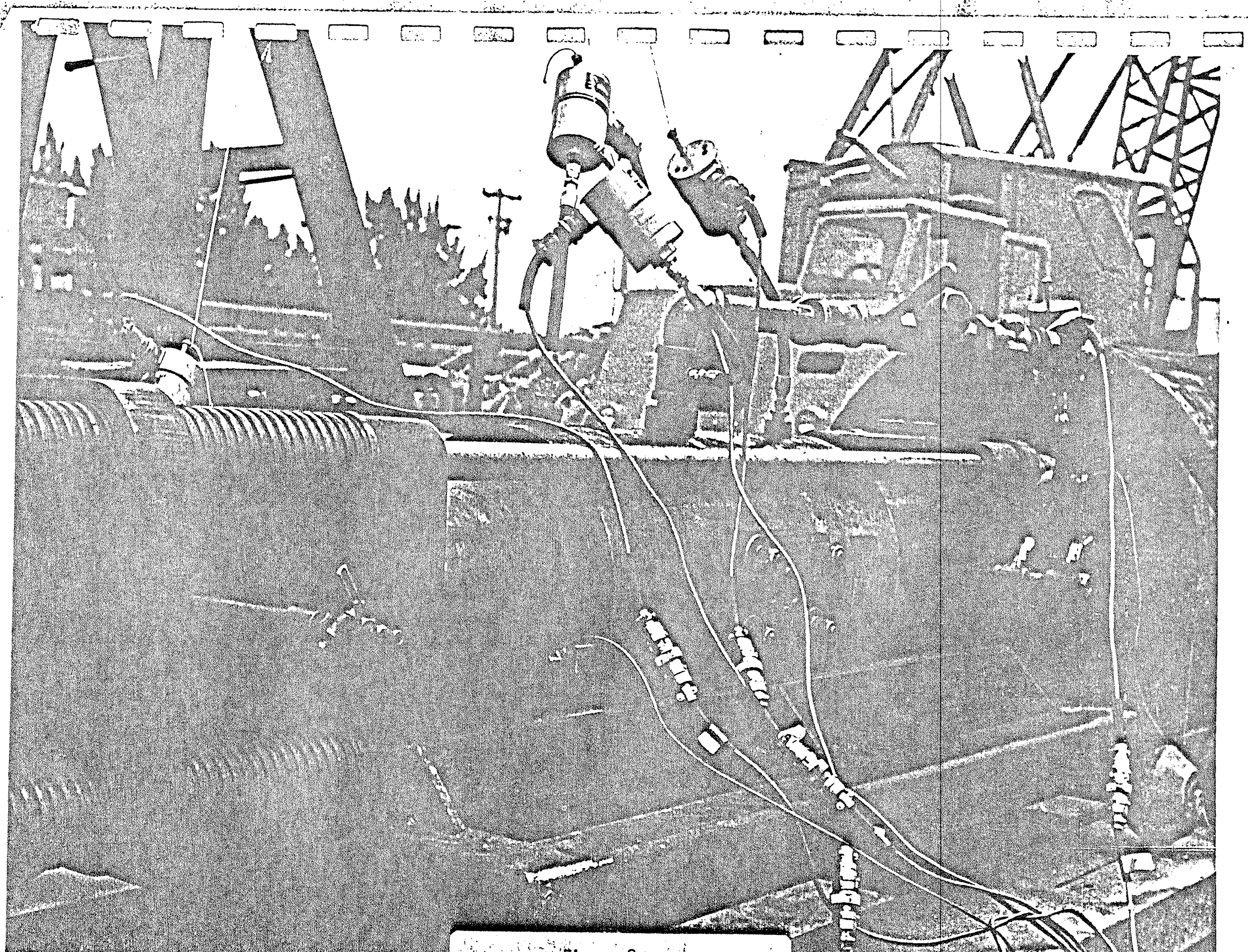


Figure 2
View of vibrator showing mounting method of pressure transducers and accelerometers

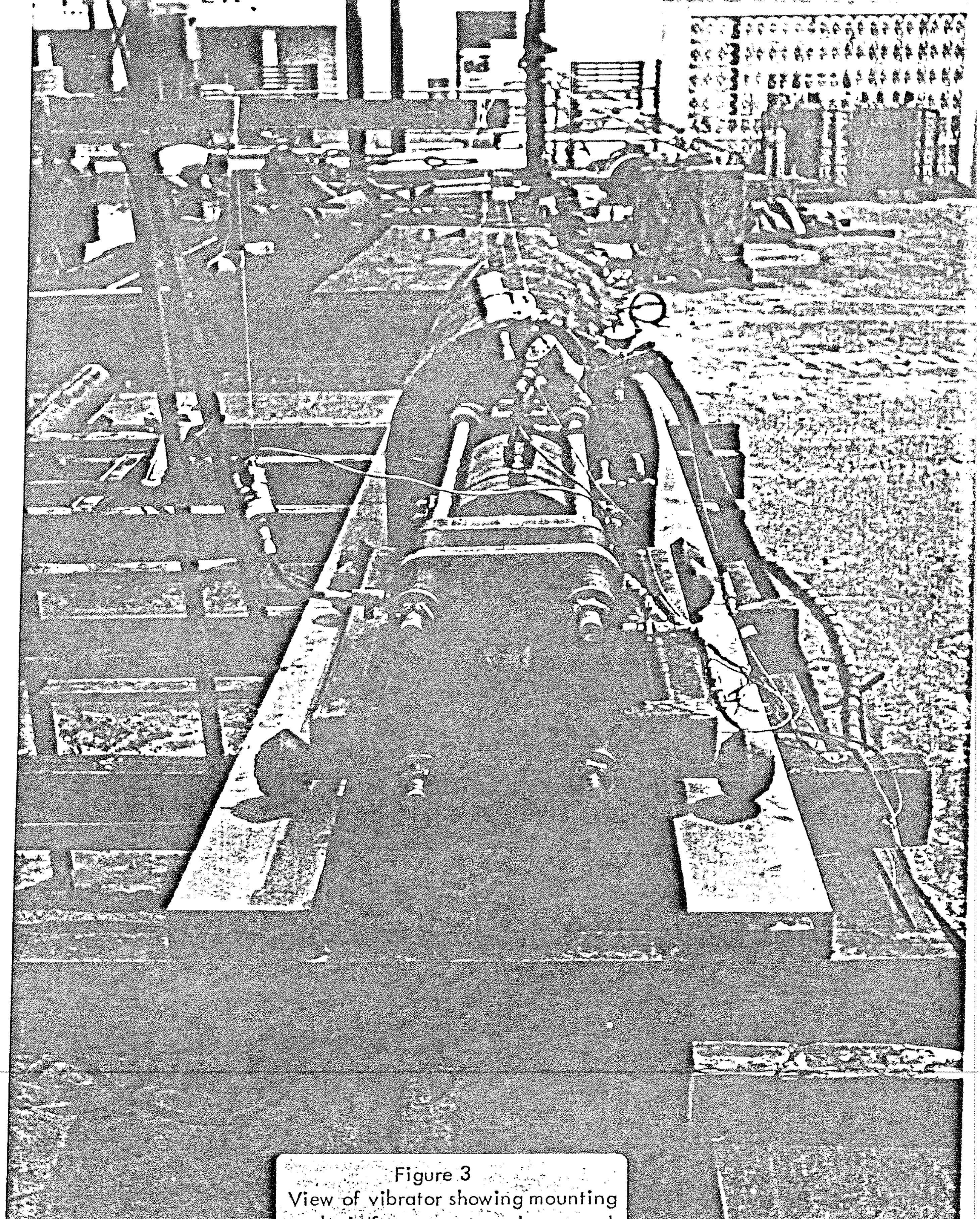
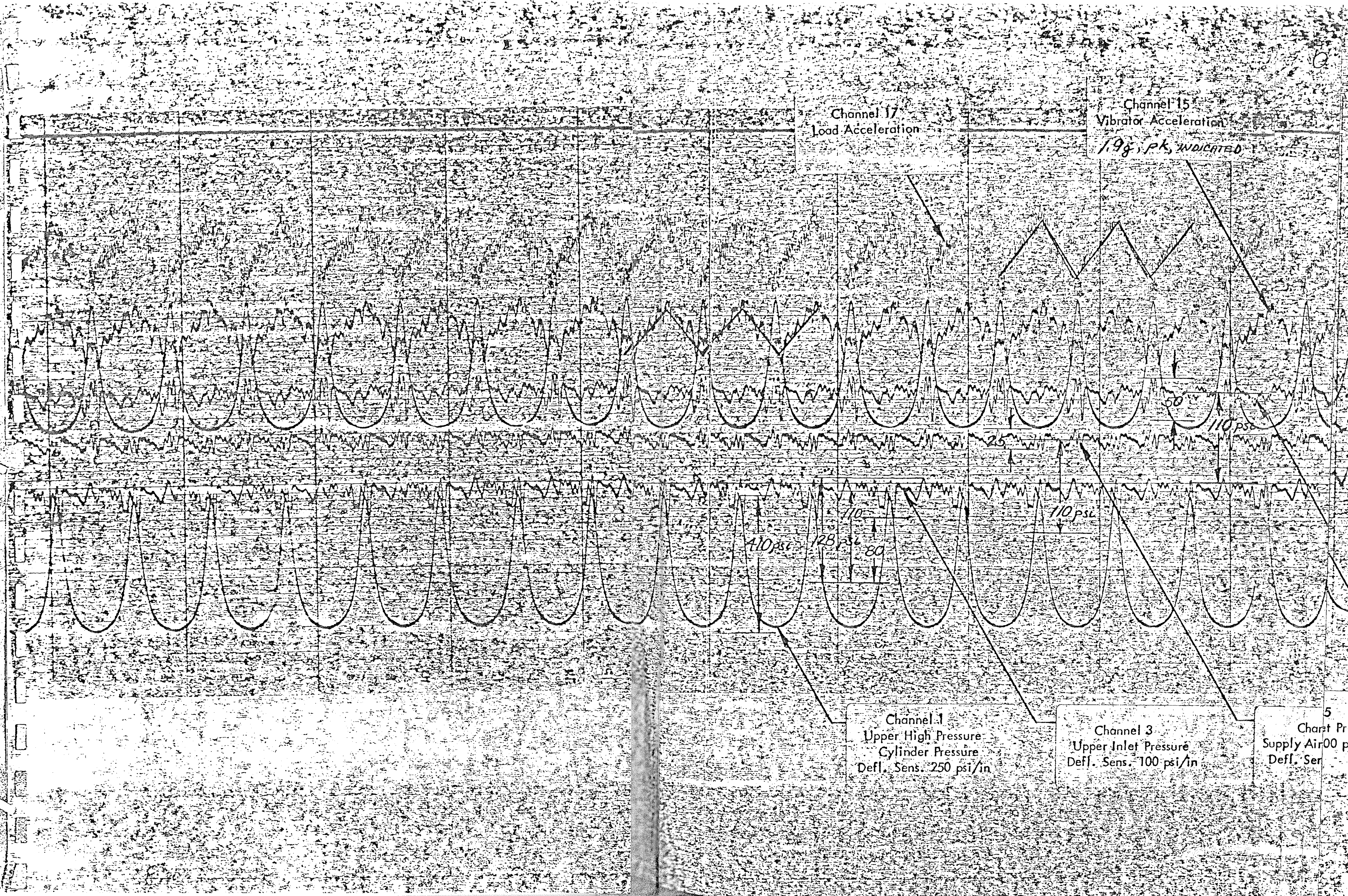


Figure 3
View of vibrator showing mounting method of pressure transducers and accelerometers

INSTRUMENTATION CHANNEL LOG

Channel	Record #		Transducer	Amplifier Channel	Galvonometer	Deflection Sensitivity	Sensitivity/ Division
1	All	Upper High Pressure Cylinder Pressure	S/N 50465 1,000 psi fs	A-1	S/N 18898	250 psi/in	25 psi/div
3	2,3,4	Upper Low Pressure Cylinder Pressure	S/N 612572 200 psi fs	A-2	S/N 14230	100 psi/in	10 psi/div
	1	Upper Inlet Pressure	S/N 612572 200 psi fs	A-2	S/N 14230	100 psi/in	10 psi/div
5	All	Supply Air Inlet Pressure	S/N 581744 200 psi fs	A-3	S/N 6932	100 psi/in	10 psi/div
7	2,3,4	Lower Low Pressure Cylinder Pressure	S/N 614747 200 psi fs	A-4	S/N 5657	100 psi/in	10 psi/div
7	1	Lower Inlet Pressure	S/N 614747 200 psi fs	A-4	S/N 5657	100 psi/in	10 psi/div
9	All	Lower High Pressure Cylinder Pressure	S/N 50542 1,000 psi fs	B-1	S/N 17979	250 psi/in	25 psi/div
15	All	Vibrator Acceleration	S/N TD08	1			
17	1	Load Acceleration	S/N TC67	3			

Figure 4


Channel 17
Load Acceleration
Channel 15
Vibrator Acceleration
1.9g, pk, INDICATED
50
110 psi
25
110 psi
410 psi
128 psi
110
80
Channel 1
Upper High Pressure
Cylinder Pressure
Defl. Sens. 250 psi/in
Channel 3
Upper Inlet Pressure
Defl. Sens. 100 psi/in

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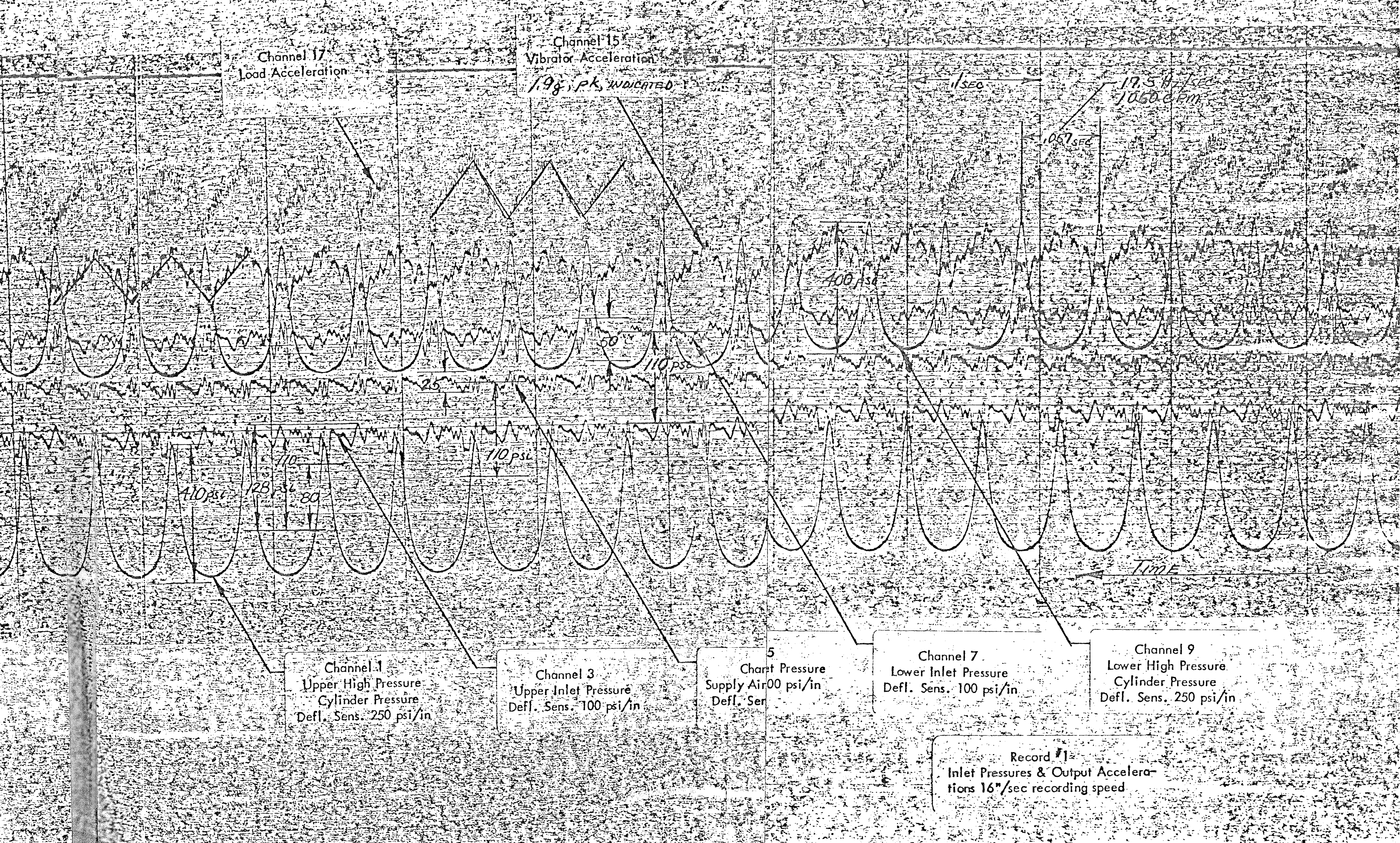

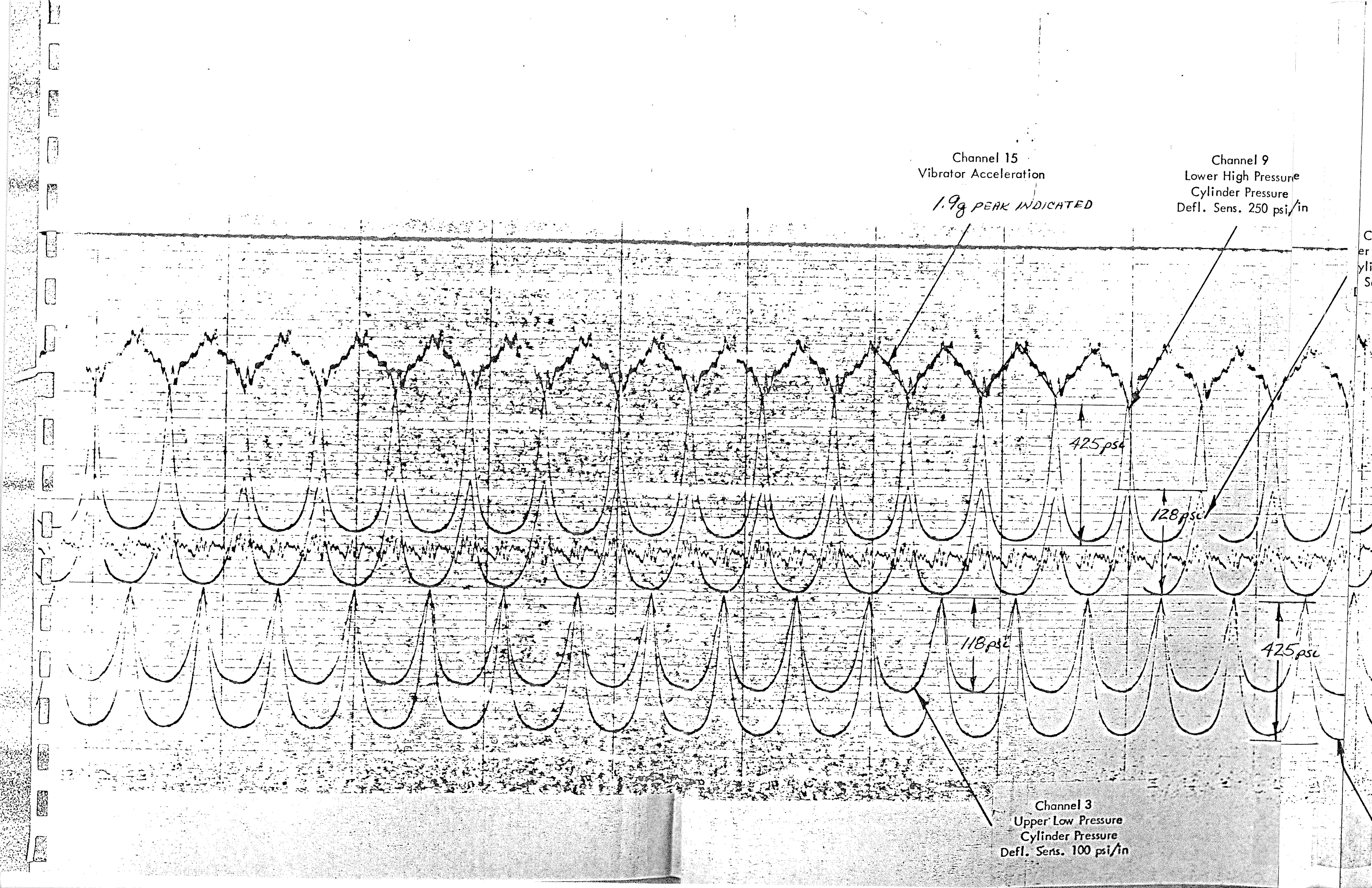
Channel 15
Vibrator Acceleration
1.9g PEAK INDICATED
Channel 9
Lower High Pressure
Cylinder Pressure
Defl. Sens. 250 psi/in
425 psi
128 psi
118 psi
425 psi
Channel 3
Upper Low Pressure
Cylinder Pressure
Defl. Sens. 100 psi/in

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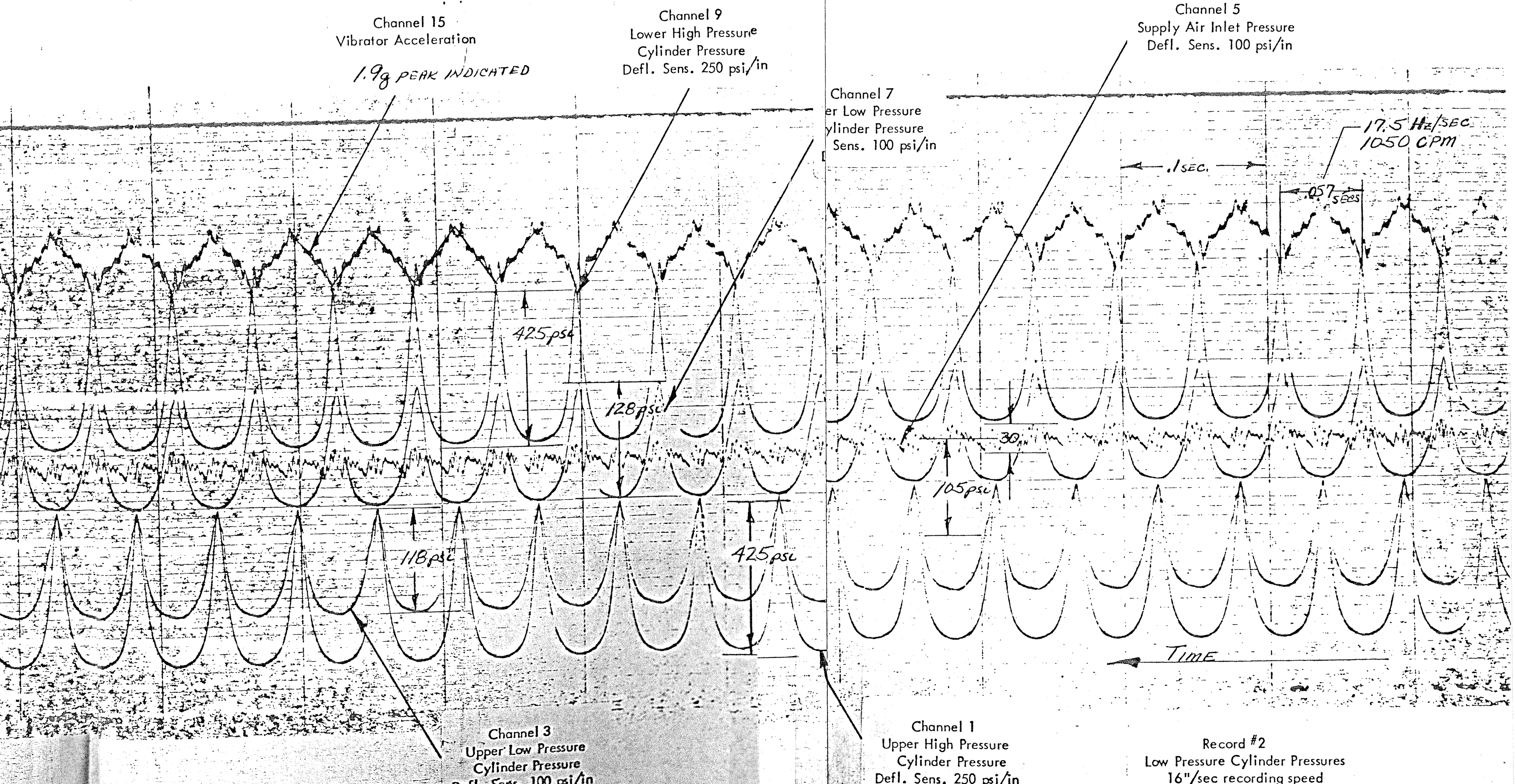
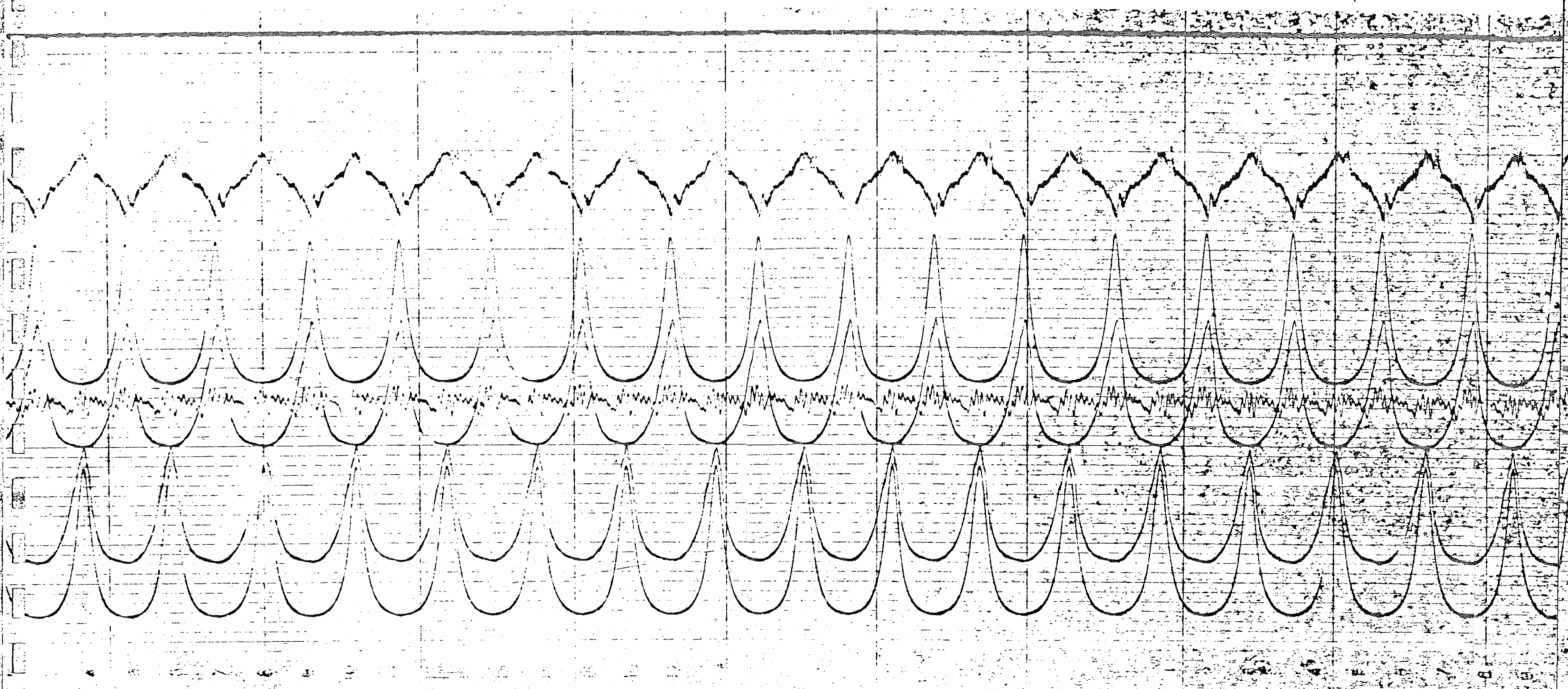


Record #2
Low Pressure Cylinder Pressures
16"/sec recording speed



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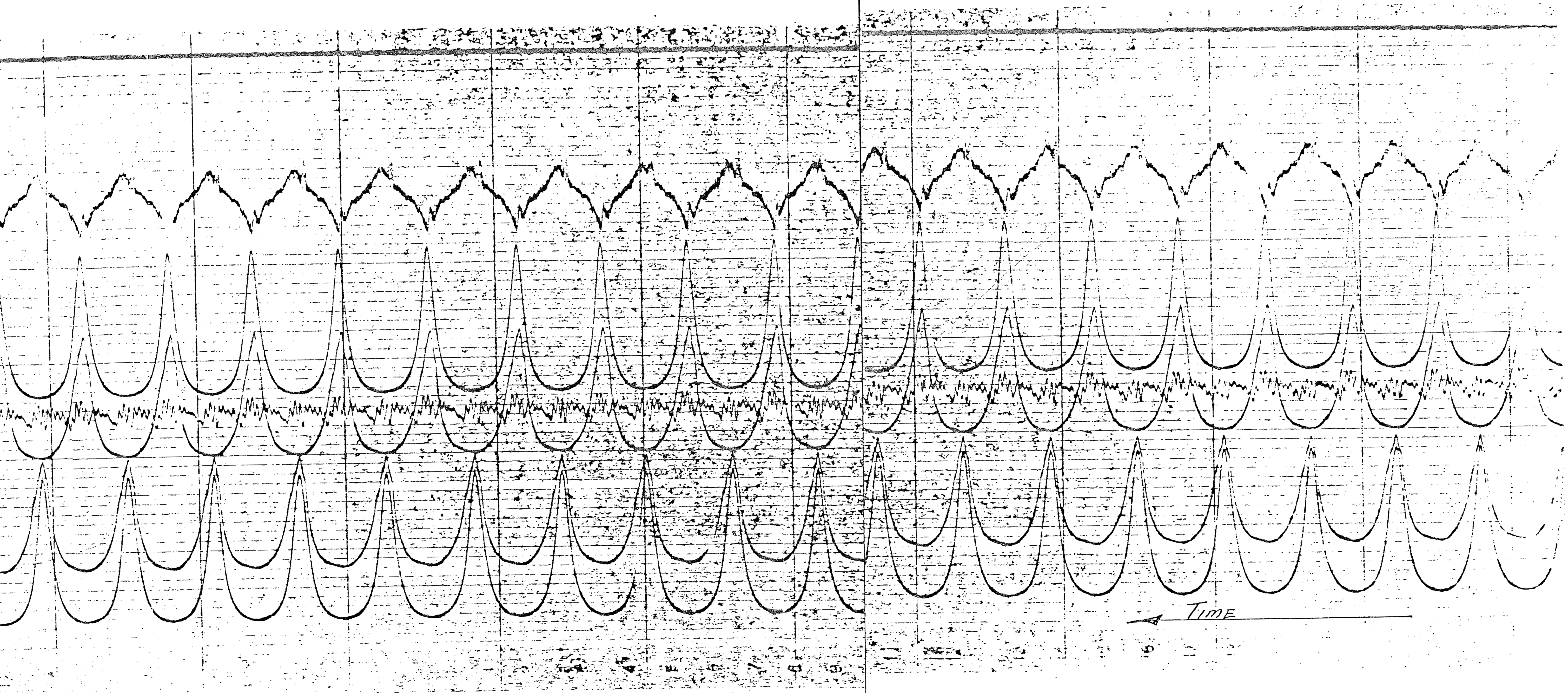
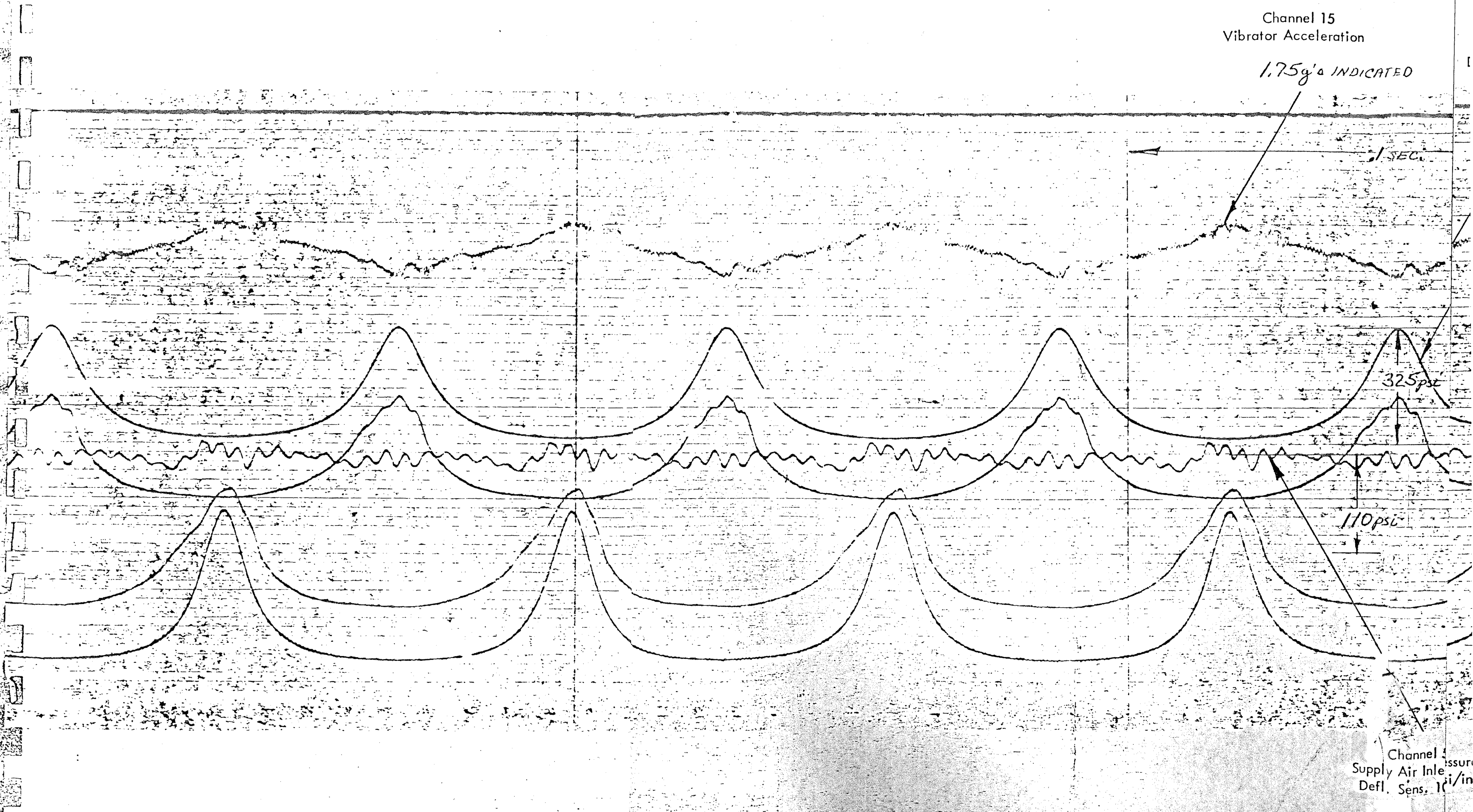


Record #3
Low Pressure Cylinder, just prior to Record #4. 16"/sec recording speed


Channel 15
Vibrator Acceleration
1.75g's INDICATED
1 SEC.
325psi
110psi
Channel
Supply Air Inle
Defl. Sens.

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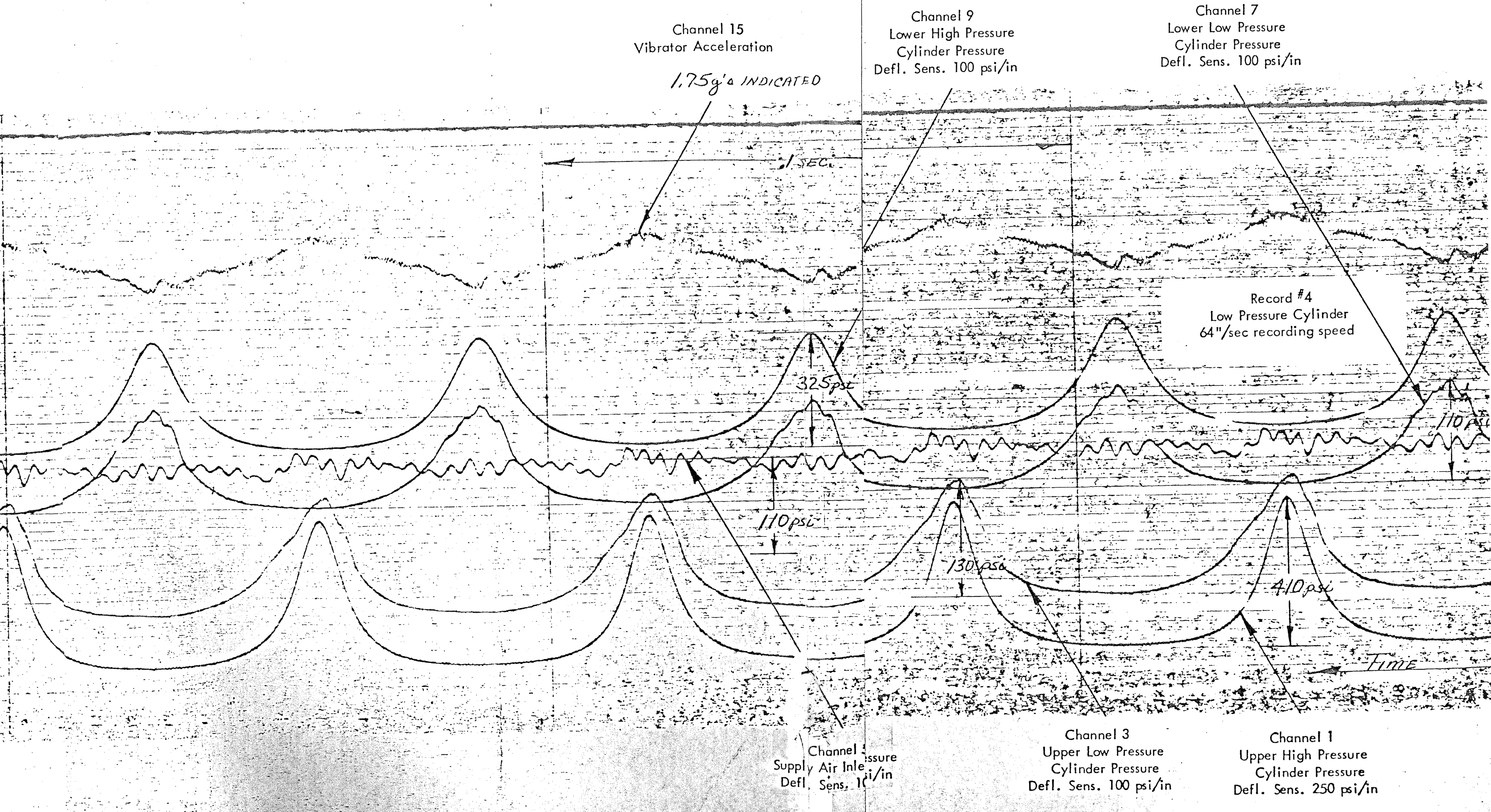

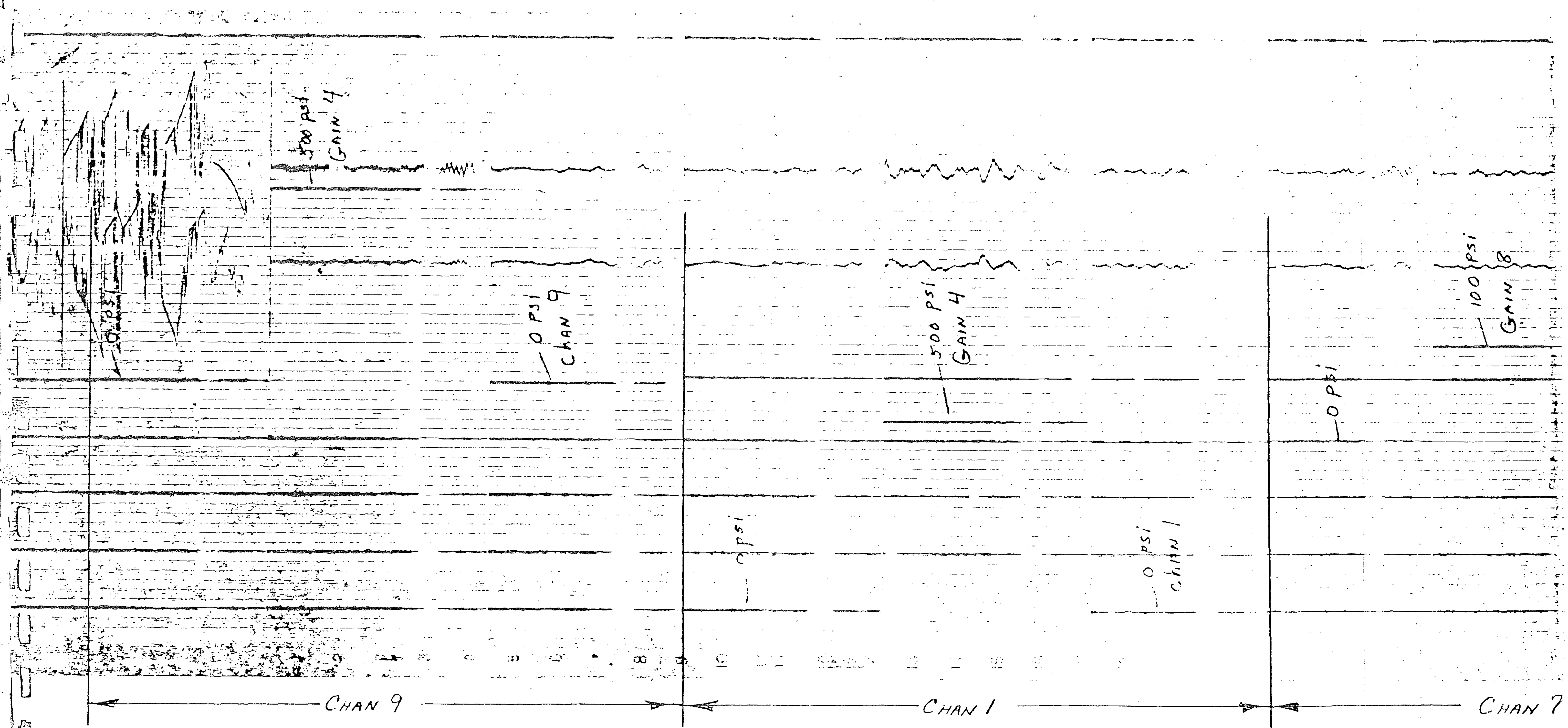

500 psi
GAIN 4
0 psi
0 psi
CHAN 9
500 psi
GAIN 4
100 psi
GAIN 8
0 psi
0 psi
0 psi
CHAN 1
CHAN 9
CHAN 1
CHAN 7

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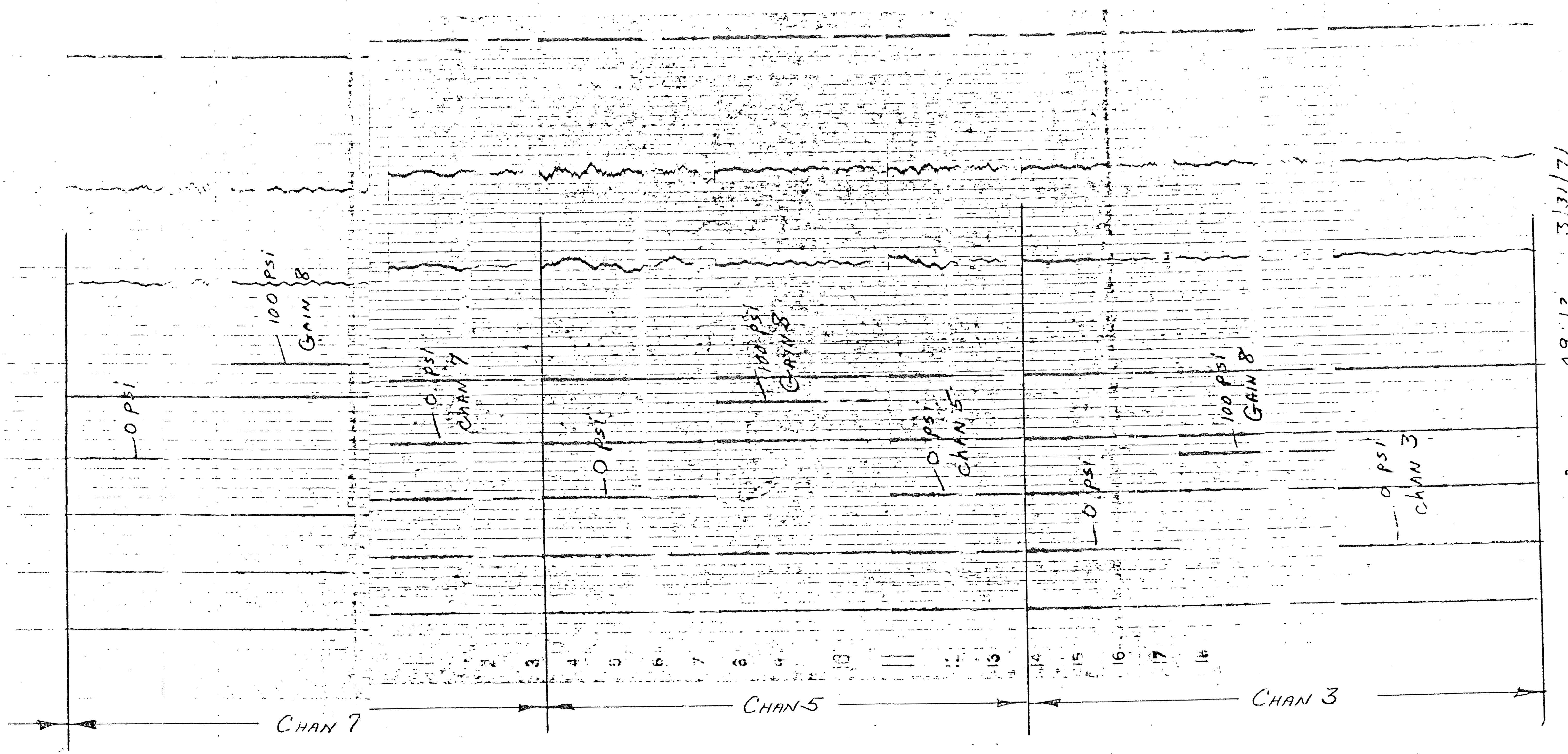

Calibration Record