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TEST RESULTS OF A JET IMPINGEMENT FROM A 4 INCH PIPE UNDER BWR LOCA CONDITIONS

September 1982

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Hypothetical instantaneous pipe rupture is now considered to be one of the design basis accidents during the operation of the light water reactor. If a pipe rupture accident occurs, the pipe will start moving with the sudden discharge of internal fluid. So, the various apparatus such as pipe whip restraints and jet deflectors are being installed near the postulated break location to protect the nuclear power plants against the effect of postulated pipe rupture.

Pipe whipping test and jet discharge test are now being conducted at the Division of Reactor Safety of the Japan Atomic Energy Research Institute. This report describes the test results of the jet discharge from a 4 inch pipe under BWR LOCA condition. In front of the pipe exit the target disk of 1000 mm in diameter was installed. The distance between the pipe exit and the target was 500 mm. 13 pressure transducers and 13 thermocouples were mounted on the target disk to measure the pressure and temperature increase due to jet impingement on the target.

Keywords: Jet, Safety Research, LWR, Pipe Rupture, BWR, Jet Impingement, LOCA

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BWR LOCA条件下における4インチ管による ジェット衝突試験結果

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本報はＢＷＲ条件のもとで4インチ管，Sch 80配管を用い，ジェット放出試験を実施した試験結果についてまとめたものである。配管破断時に配管に作用する配管反力，ジェット流を受けるターゲット板上の圧力上昇，温度上昇等のデータが集録されている。すべてのデータはブローダウン初期における現象について集録されており，時間範囲は破断後200 msec までである。

CONTENTS

目　　次

1. Introduction

This report contains the test results of a jet impingement test implemented at the Division of Reactor Safety of the Japan Atomic Energy Research Institute. Testing apparatus, method and results are described but no discussions are presented here.

Hypothetical instantaneous pipe rupture is considered to be one of the design basis accidents during the operation of the nuclear power plants. Recent researches concerning the reactor safety include the effects of hypothetical accidents. Researches concerning the Emergency Core Cooling System, refill-reflood and pipe whip fall under the catesory of those generated from the hypothetical pipe break.

If a pipe rupture accident occurs, the pipe will start moving with the sudden discharge of internal fluid. And if the pipe is not restrained, the whipping pipe will cause damage to structures, equipments and pipes adjacent to the postulated break location. Furthermore, discharge jet will also cause damage to the surroundings. It is required that an accident does not affect the equipment installed in order to bring the plant to a safe shut down condition.

For this reason, in the existing nuclear power plant, pipe whip restraints are installed near the postulated pipe break location to prevent the pipe from whipping and jet deflectors are also installed to protect the components from jet impingement.

Under these circumstances, pipe whipping test and jet discharge test are now being conducted at the Division of Reactor Safety of the Japan Atomic Energy Research Institute. This report presents the test results of jet discharge from a 4 inch Schedule 80 pipe under BWR LOCA condition.

The purpose of this test is;

(1) To obtain experimentally the reaction thrust applied to the pipe due to the sudden discharge of the internal fluid. The reaction thrust is defined as the net force exerted by the stream. It is used as the external force applied to the pipe when the pipe whip analysis is made.

(2) To measure the pressure increase and temperature increase on the target subjected to jet stream.

The test pipe was 4 inch in diameter (Schedule 80) and made from AISI Type 304 stainless steel. At the exit of pipe, a weld type rupture disk was mounted. The internal volume of the pressure vessel was about 4 m^3. The test pipe was connected with the connecting pipe which had an 8 inch × 4 inch reducer. At the other end of the connecting pipe, an 8 inch connecting pipe and an 8 inch pipe from pressure vessel were connected each other.

Initial internal vessel pressure was 69 kg/cm^2g and temperature was 283 °C. Behind the exit pipe, a 10 ton load cell was installed to measure the reaction thrust. In front of the pipe exit, the target disk of 1000 mm in diameter was installed with 500 mm distance between the target and pipe exit. 13 pressure transducers and 13 thermocouples were mounted on the target.

2. Testing Apparatus

2.1 General description of the facilities for reliability study of pressure boundary component-II (FRPC-II)

FRPC-II is the testing apparatus so designed and fabricated that both pipe whipping test and jet discharge test could be done under both BWR and PWR LOCA conditions.

Table 1 shows the general design specifications. Maximum diameter of the test pipe available is 8 inch.

Fig. 1 shows the isometric diagram of the test facilities. The dimension of the pressure vessel is 1000 mm in inner diameter and 5400 mm in inner height. Its volume is about 4 m^3. The pressure vessel is void of internals. The internal dimension of heater is 560 mm by 2670 mm and the immersion electric heater of 400 kW power is installed in the vessel through the bottom flange. The pressurizer is 500 mm in inner diameter and 2670 mm in inner height. The immersion electric heater of 30 kW power is installed in the vessel. A circulation pump is installed between the pressure vessel and heater. Just after the pump and before the heater, a flow control valve is equipped to deliver the hot water to the test section through the warming-up line.

Two 8 inch nozzles are installed at the upper side and the lower side of the pressure vessel. The upper nozzle is used for the steam blowdown test and the lower nozzle is used for the water blowdown test, respectively. In this test, the test pipe was connected with the lower nozzle using the connecting pipe with an 8 inch × 4 inch reducer.

Fig. 2 shows the detail of the pressure vessel. The pressure vessel and its contents are suspended from a 25 ton load cell, which measures the mass flow from the pressure vessel during the blowdown.

Nozzles N-10 and N-11 are used to control the intial water level in the pressure vessel. Relationship between the differential pressure and the output voltage under BWR LOCA test condition is shown in Table 2.

2.2 Testing apparatus for jet discharge test

Fig. 3 shows a schematic of the testing apparatus for jet discharge test. Tag number of various kinds of transducers is also shown in this figure. An 8 inch GRAYLOC flange was used to connect the lower discharge nozzle with connecting pipe at 4300 mm from the pressure vessel center.

The diameters of the connecting pipe at both ends were 8 inch and 4 inch. A 4 inch GRAYLOC flange was also used to connect the test pipe. A 4 inch Schedule 80 test pipe was 4500 mm in length and 114.3 mm in outer diameter and it was made from AISI Type 304 stainless steel. Three pressure transducers and three thermocouples were mounted on the test pipe. Just behind the pipe exit, a 10 ton load cell was installed to measure the pipe reaction thrust during the blowdown. To maintain contact between the test pipe and the load cell, the pipe was loaded laterally with a constant weight of 130 kg as shown in Fig. 3.

Nearly at the end of the test pipe, rupture disk was mounted. Instead of the ordinary rupture disk of the flange type, a welded type rupture disk was used to decrease the superfluous mass of the test pipe at the exit. The rupture disk was broken with the electric arc compulsorily at the desired test pressure. This method of breaking the rupture disk has several merits as follows;

(a) Compact

(b) There is no need to worry about any obstacles in the flow during the blowdown from the pipe exit.

(c) Mass effect of the electrode on the pipe is negligible.

In front of the pipe exit, the target disk of 1000 mm in diameter was installed with 500 mm distance between the pipe exit and target disk. Fig. 4 shows the target and load cell column. 13 pressure transducers and 13 thermocouples were mounted on the target. Pressure transducers were fixed at the adapter which was filled with cooling water and was fixed at the target. Fig. 5 shows this adapter. Sheathed thermocouples of 1.6 mm in diameter were used and the tip protruded by 10 mm from the target surface. 3 load cell columns were sandwiched in between the target and support. The load cell columns were subjected to both the dead weight of the target and jet impingement load. On the load cell column, bi-axial strain gages were mounted diametrically opposite to measure the jet force when the jet impinged on the target. Load cell columns and a 10 ton load were wrapped with heat insulating tape and with vinyl tube in which cooling water flowed to avoid the temperature increase due to jet impingement and jet reflection.

Photo 1 shows the testing apparatus before the test. Photo 2 shows the exit pipe (center), load cell (left) and target disk (right) Photo 3 shows the test pipe and warming-up line.

Considering the thermal expansion of the test pipe, the center of the test pipe and that of a 10 ton load cell, the target disk was initially dislocated by 57 mm at the cold state of the system as shown in Fig. 3.

3. Test results

Table 3 shows the testing condition of RUN 5601. The pressure when the rupture occured was given by monitoring the Bourden type pressure indicator of class 0.5 which was installed at the pressure vessel directly.

Table 4 shows initial temperature distributions in the pressure vessel and in the test pipe. The data were obtained with a digital printer. Thermocouples were connected in parallel with a data recorder and the digital printer.

The data obtained during the blowdown process were the output of pressure transducers, thermocouples, load cells and differential pressure transducer in the pressure vessel. These data were recorded by five 14-channel data recorders with 20 KHz frequency response. Then, all the data were plotted with X-Y recorder.

Table 5 shows the relationship between the various kinds of transducers and the their numbers of figures, where WU signifies the amount concerning the load or diffential pressure and PU, pressure and TU, temperature, respectively. In Figs. 6.1 to 11.12, all these data are shown. Time range of data is 200 msec.

In addition to the above mentioned electrical measurement, photographic measurement was taken to observe the jet expansion from the exit pipe. Photo 4 shows the photographic record of jet expansion taken with a high speed camera. The camera was operated at a speed of 3000 frame/sec. Here, in Photo 4, the picture was printed every 20 frame. So the interframe time is 6.7 msec. We can see the test pipe at the center, a 10 ton load cell in the left and a target disk in the right. At frame 1, an electrode was charged. At frame 4, the jet impinged upon the target disk. At frame 11, a smooth parabolic jet was observed. At frame 18 and hereafter nothing could be seen owing to the steam.

Photo 5 shows the rupture disk after the test.

Table 1 Design specification

Main Specifications of FRPC-II	
Design temperature	355 °C
Design pressure	170 kg/cm^2g
Volume of pressure vessell	4 m^3
Maximum dia. of test pipe	8 in (216.3 mm O.D)
Electric power of heater	400 KW
Electric power of pressurizer	30 KW
Cooling power of condenser	70 KW
Cooling power of drain cooler	180 KW
Breaking method of rupture disk	Arc method

Table 2 Relationship between output voltage and differential pressure of WU115 under BWR LOCA condition

Water level	Height from the bottom of pressure vessel	Output voltage	Differential pressure
N - 11 nozzle	620 mm	0.38_V	4043 mm Aq.
N - 10 nozzle	4800 mm	1.25_V	1091 mm Aq.

Table 3 Test conditions

Run No.	5601
Date of the test	18 May 1981
Initial pressure in the pressure vessel	69.0 kg/cm^2g
Initial temperature in the pressure vessel	283 °C
Initial water level in the pressure vessel	4000 mm
Dimension of the test pipe	Length = 4500 mm O.D = 114.3 mm I.D = 97.0 mm 4 inch, sch 80
Material of the test pipe	AISI Type 304 SS
Distance between pipe exit and target	500 mm
Target diameter	1000 mm

Table 4 Initial temperature distribution

Tag NO.	Location	Temperature at $16^h38^m00^{sec}$	Temperature at $16^h41^m00^{sec}$
TU 101	Pressure vessel, upper 8B nozzle	284.1 (°C)	280.0 (°C)
102	Pressure vessel, lower 8B nozzle	284.5	283.5
120	Test pipe, near the exitt	280.0	279.0
121	Test pipe, 700 mm from exitt	284.4	269.5
122	Test pipe 2700 mm from exittt	278.6	267.6
123	Connecting pipe, 8B 4B reducer	282.2	280.4
124	Connecting pipe	281.2	280.0
125	Connecting pipe, 8B Grayloc flange	281.2	281.1

Table 5 List of transducers

Item	Tag. NO.	Specification	Capacity	Location	Object	Fig. NO.
Load	WU 111	KYOWA-LC10TFHM13	10 ton	behind the pipe exit	pipe reaction thrust force	6.1 (in KN)
	WU 112	KYOWA biaxial strain gage KFD-2-D16-11 G.F = 2.11, 120Ω		behind the target disk	jet force	6.2
	113					6.3
	114					6.4 (in KN)
	WU 111					6.5 (in ton)
	WU 112					6.6
	113					6.7
	114					6.8 (in ton)
Diffrential pressure	WU 115			pressure vessel	water level contrd and mass flow nate.	7.1 (in V)
Pressure	PU 101	BLH GP-H	200 kg/cm^2g	upper head of pressure vessel		8.1
	102	BLH GP-H	200 kg/cm^2g	pressure vessel upper 8B nozzle		8.2
	103	BLH GP-H	200 kg/cm^2g	pressure vessle lower 8B nozzle		8.3
	110	KYOWA PE-70kJ	70 kg/cm^2g	test pipe, exit		8.4
	111	KYOWA PE-70kJ	70 kg/cm^2g	test pipe, 800 mm from exit		8.5
	PU 112	KYOWA PE-70kJ	70 kg/cm^2g	test pipe, 1700 mm from exit		8.6
	113	KYOWA PE-70kJ	70 kg/cm^2g	connecting pipe, 8B × 4B reducer		8.7 (in MPa)
	114	KYOWA PE-70kJ	70 kg/cm^2g	connecting pipe, 8B		8.8 (in MPa)
	PU 101					8.9
	102					8.10
	103					8.11
	110					8.12
	111					8.13
	112					8.14
	113					8.15
	114					8.16
	115			connecting pipe, 8B		8.17 (in kg/cm^2g)
	PU 121	SHINKOH PR20C	20 kg/cm^2g	target, right	pressure increase due to jet impingement on the target	9.1
	122	SHINKOH PR20C	20 kg/cm^2g			9.2
	123	SHINKOH PR20C	20 kg/cm^2g			9.3
	124	SHINKOH PR20C	20 kg/cm^2g	center		9.4
	125	SHINKOH PR20C	20 kg/cm^2g			9.5
	126	SHINKOH PR20C	20 kg/cm^2g			9.6
	127	SHINKOH PR20C	20 kg/cm^2g			9.7
	128	SHINKOH PR20C	20 kg/cm^2g	target		9.8
	129	SHINKOH PR20C	20 kg/cm^2g			9.9
	130	SHINKOH PR20C	20 kg/cm^2g			9.10
	131	SHINKOH PR20C	20 kg/cm^2g	target, left		9.11
	132	SHINKOH PR20C	20 kg/cm^2g	center, above		9.12
	133	SHINKOH PR20C	20 kg/cm^2g	center, below		9.13 (in Mpa)
	PU 121					9.14
	122					9.15
	123					9.16
	124					9.17
	125					9.18
	126					9.19
	127					9.20
	128					9.21
	129					9.22
	130					9.23
	131					9.24
	132					9.25
	133					9.26 (in kg/cm^2g with 100 Hz low pass filtor

Table 5 List of transducers

Item	Tag NO.	Specification	Capacity	Location	Object	Fig. NO
Temperature	TU 101	theathed type, ungrounded C.A thermocouple, 3.2^{ϕ}		pressure vessel upper 8B nozzle		10.1
	105			pressure vessle centen		10.2
	120	theathed type, ungrounded C.A thermocouple, 3.2^{ϕ}		test pipe, exit		10.3
	TU 132	theathed type, ungrounded C.A thermocouple, 1.6^{ϕ}		target, right	temperature increase due to jet impingement on the target	11.1
	133					11.2
	134					11.3
	135			target, center		11.4
	136					11.5
	137					11.6
	138					11.7
	139					11.8
	140=					11.9
	141			target, left		11.10
	142					11.11
	143					11.12

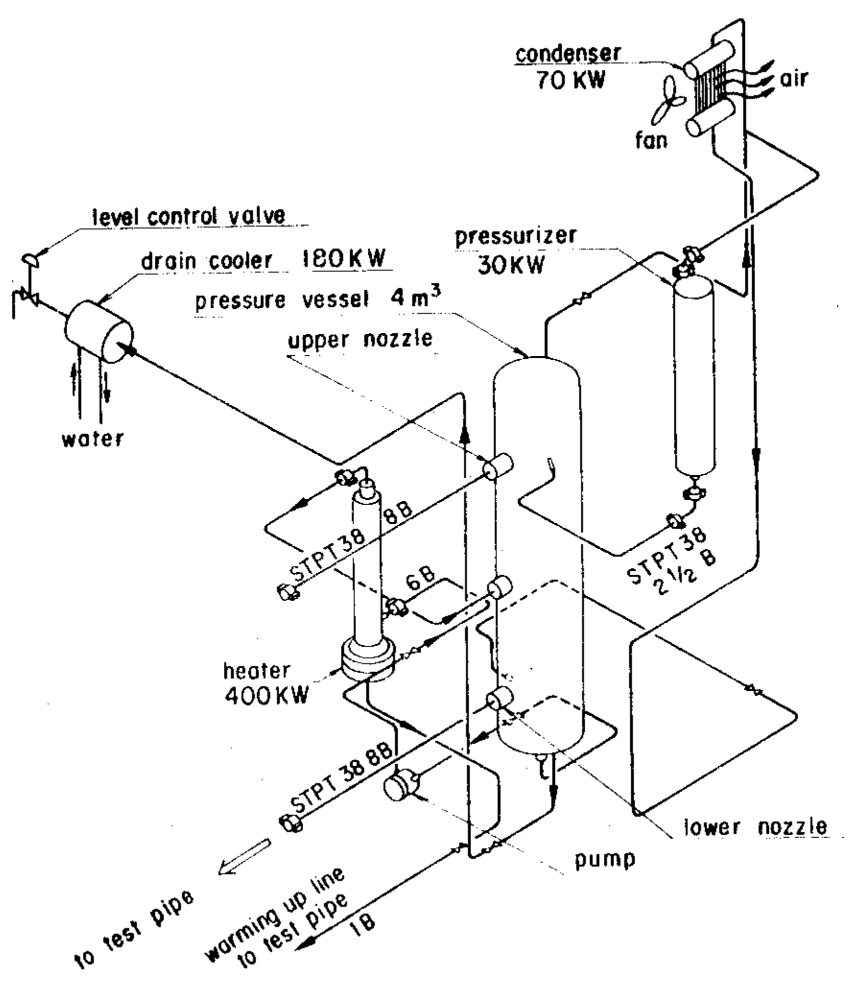


Fig. 1 Isometric diagram of the test facilities

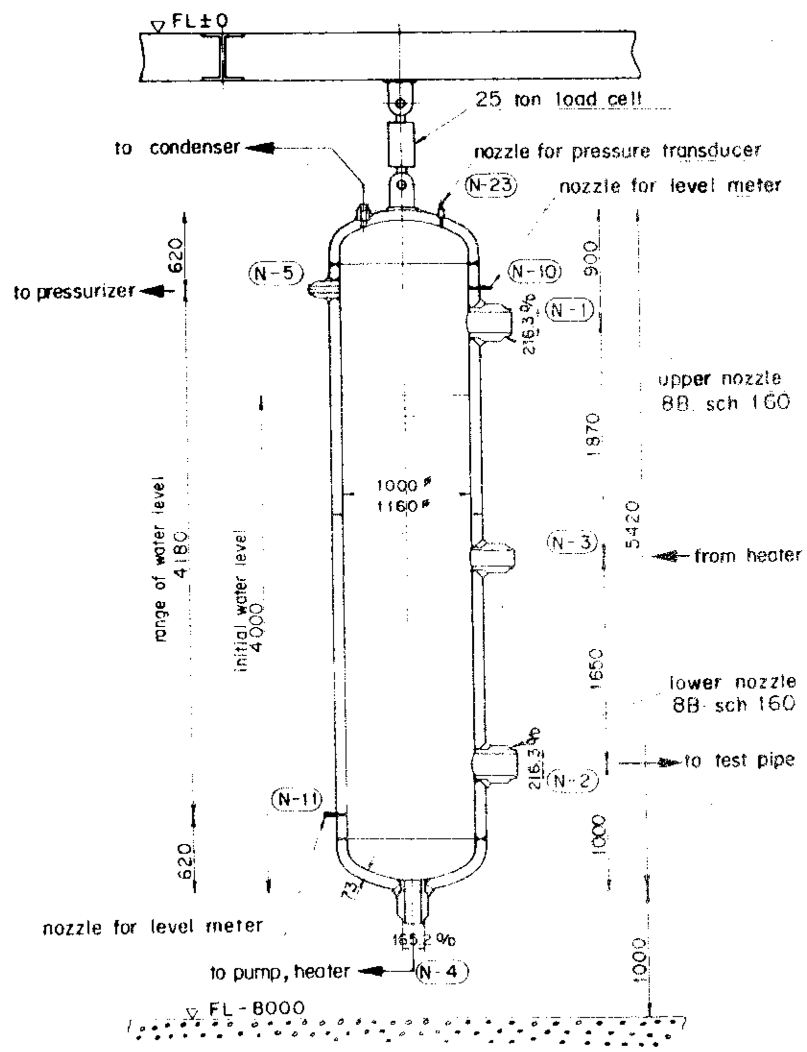


Fig. 2 Internal geometry and mounting of pressure vessel

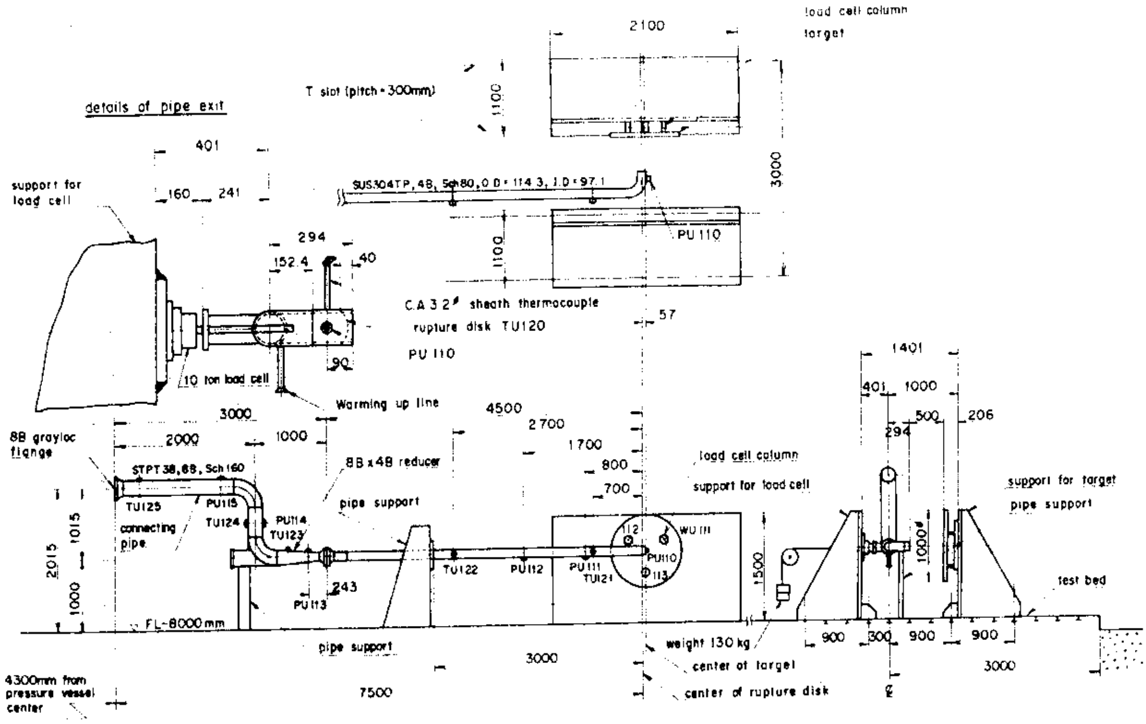


Fig.3 Schematic of the testing apparatus

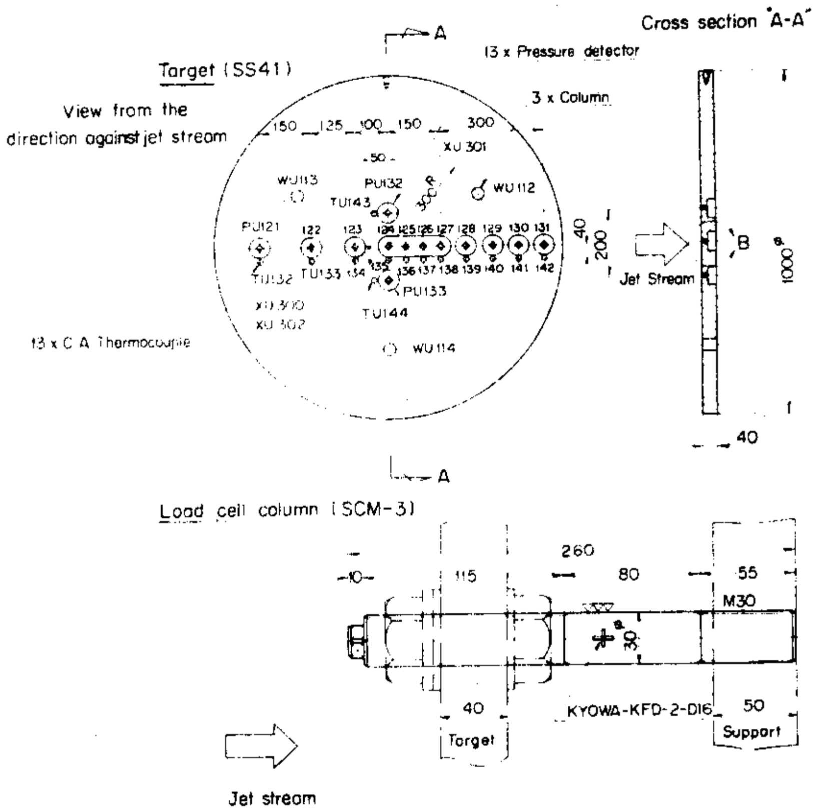


Fig.4 Target and load cell column

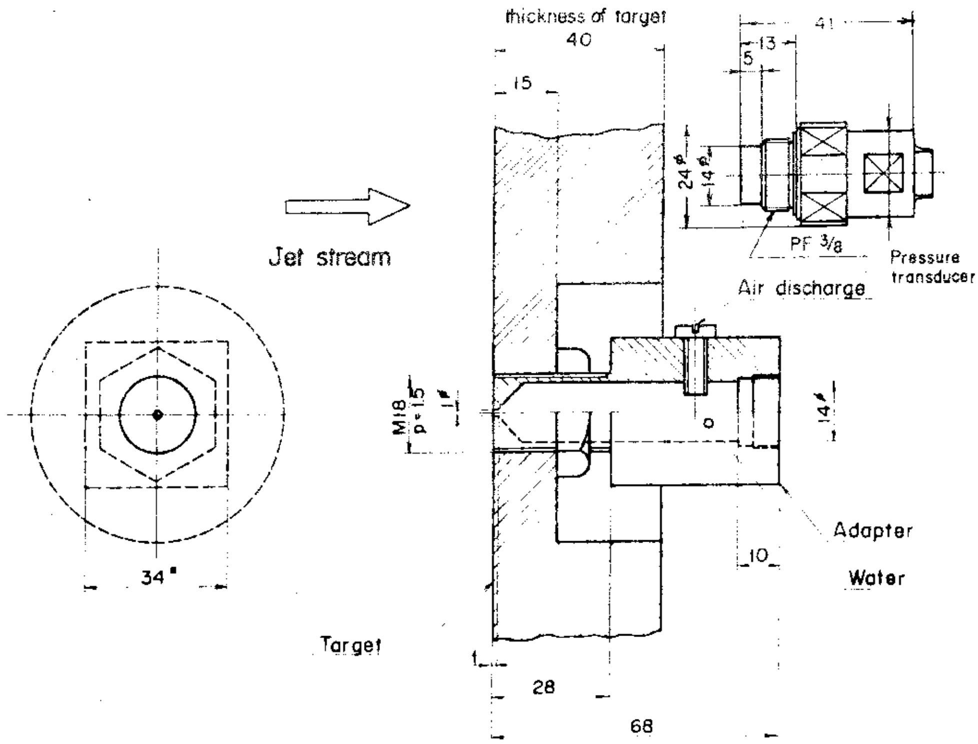
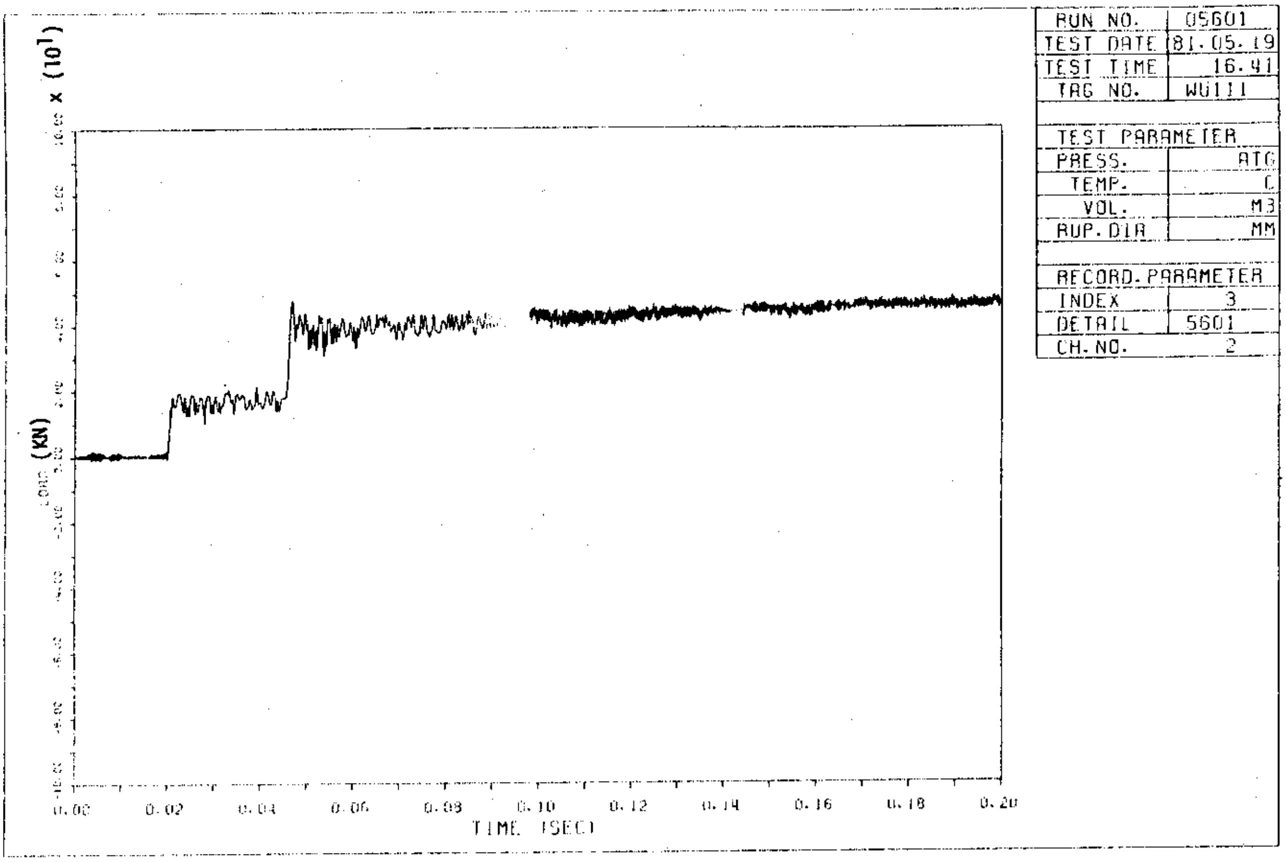


Fig.5 Pressure tranceducer mounting adapter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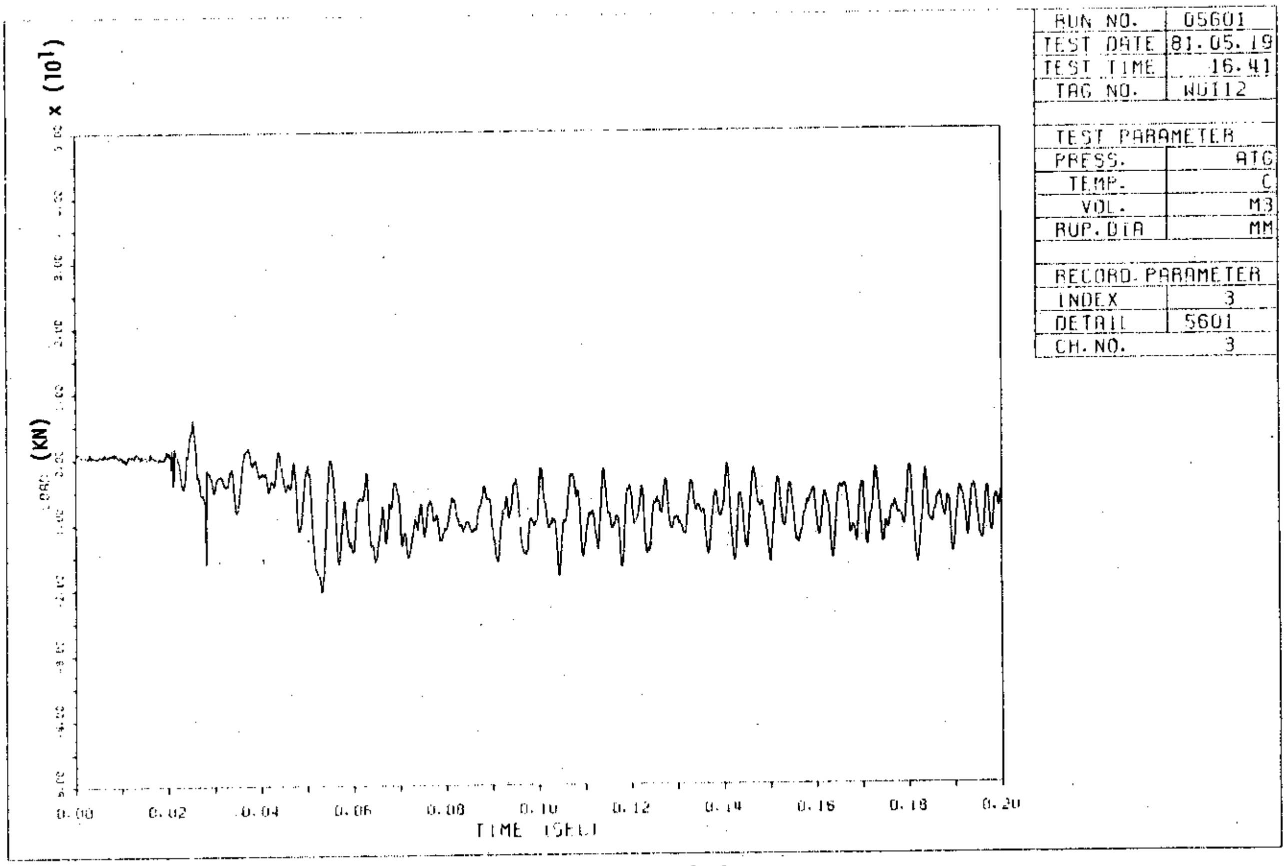
TIME (SEC)

Fig. 6.1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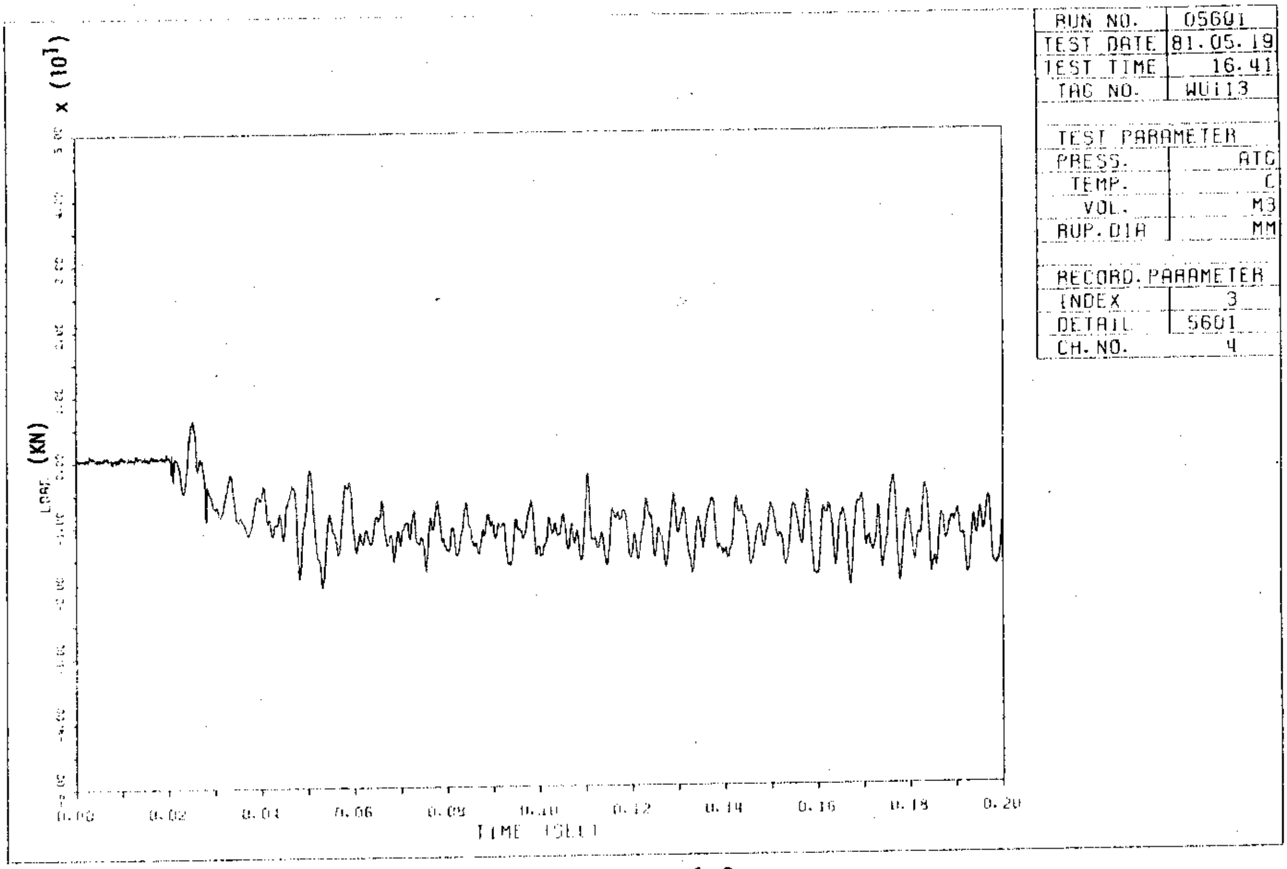
TIME (SEC)

Fig. 6.2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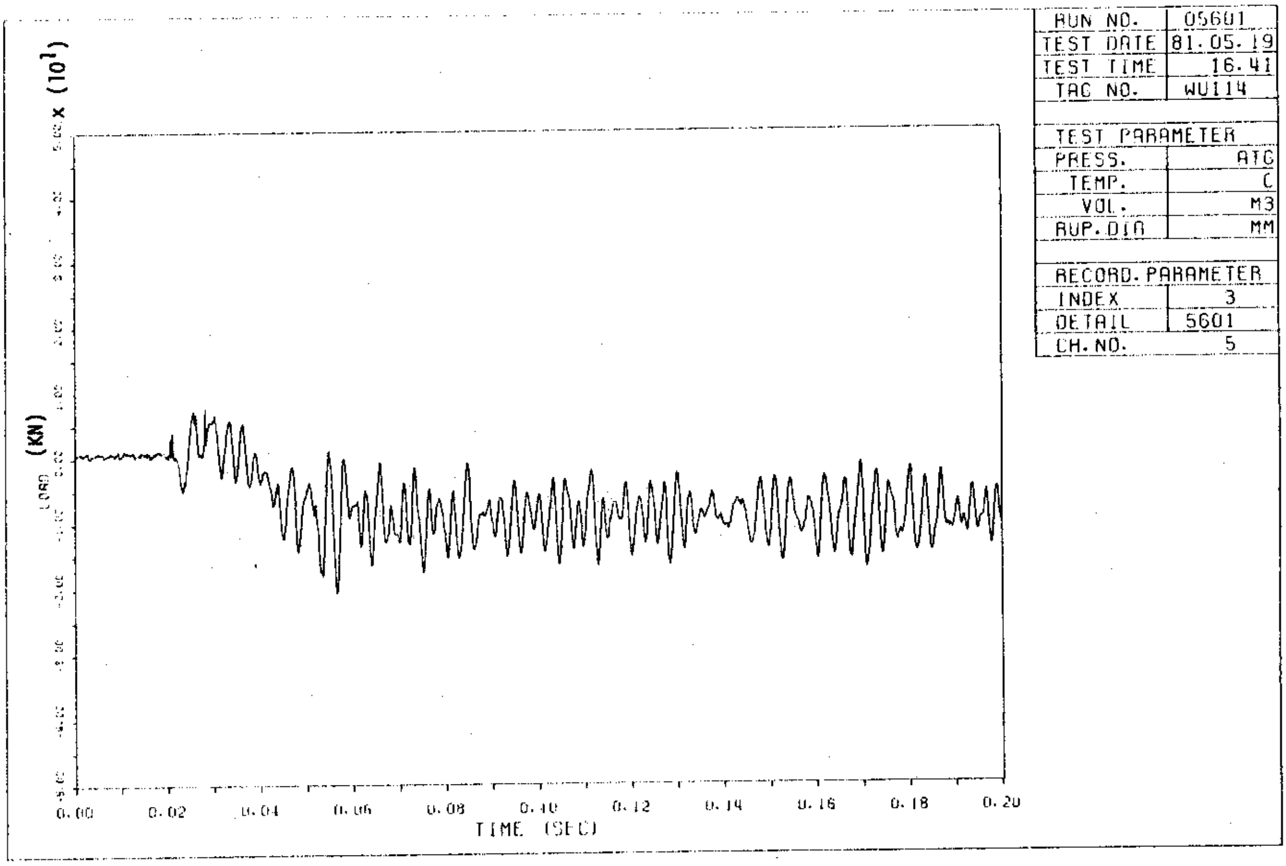
TIME (SEC)

Fig. 6.3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INDEX 3
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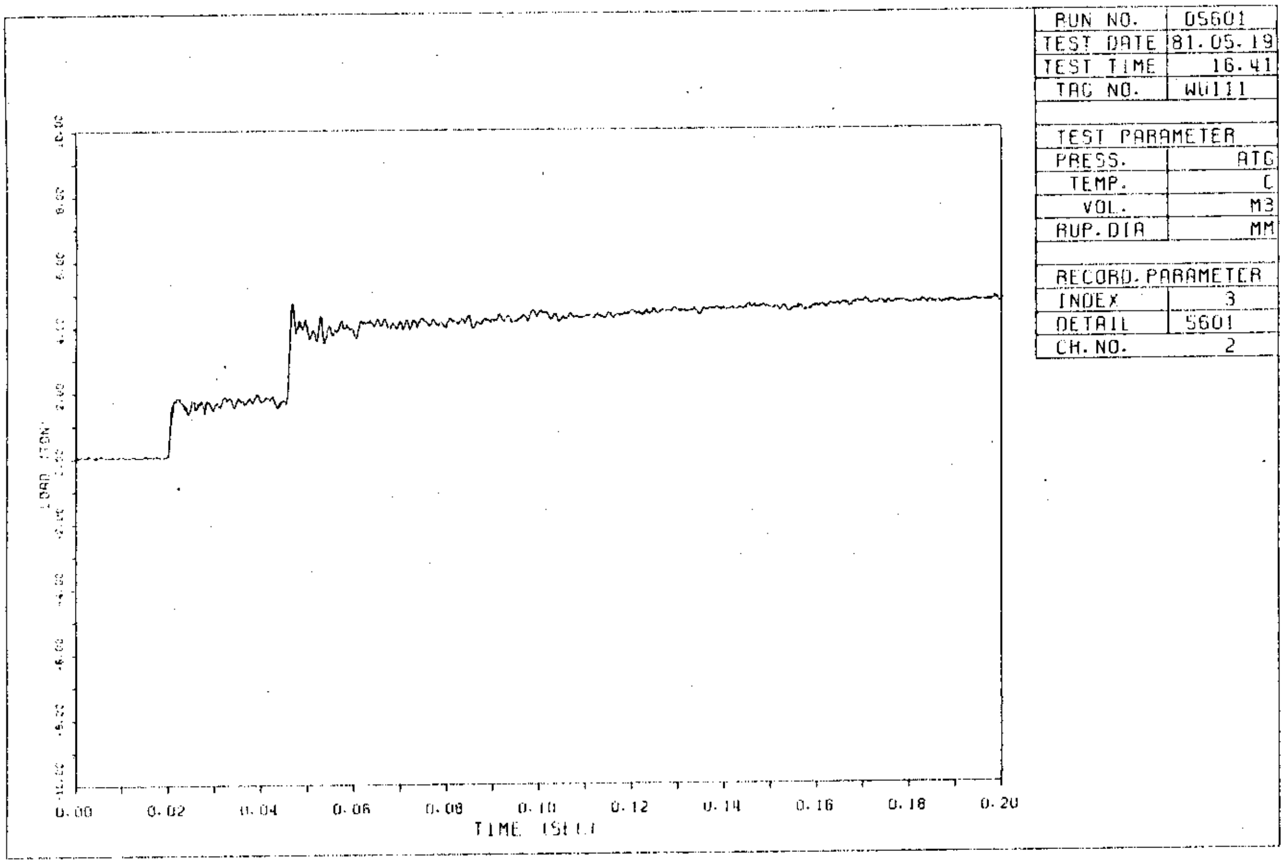
TIME (SEC)

Fig. 6.4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TEMP. C
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RUP.DIA MM
RECORD.PARAMETER
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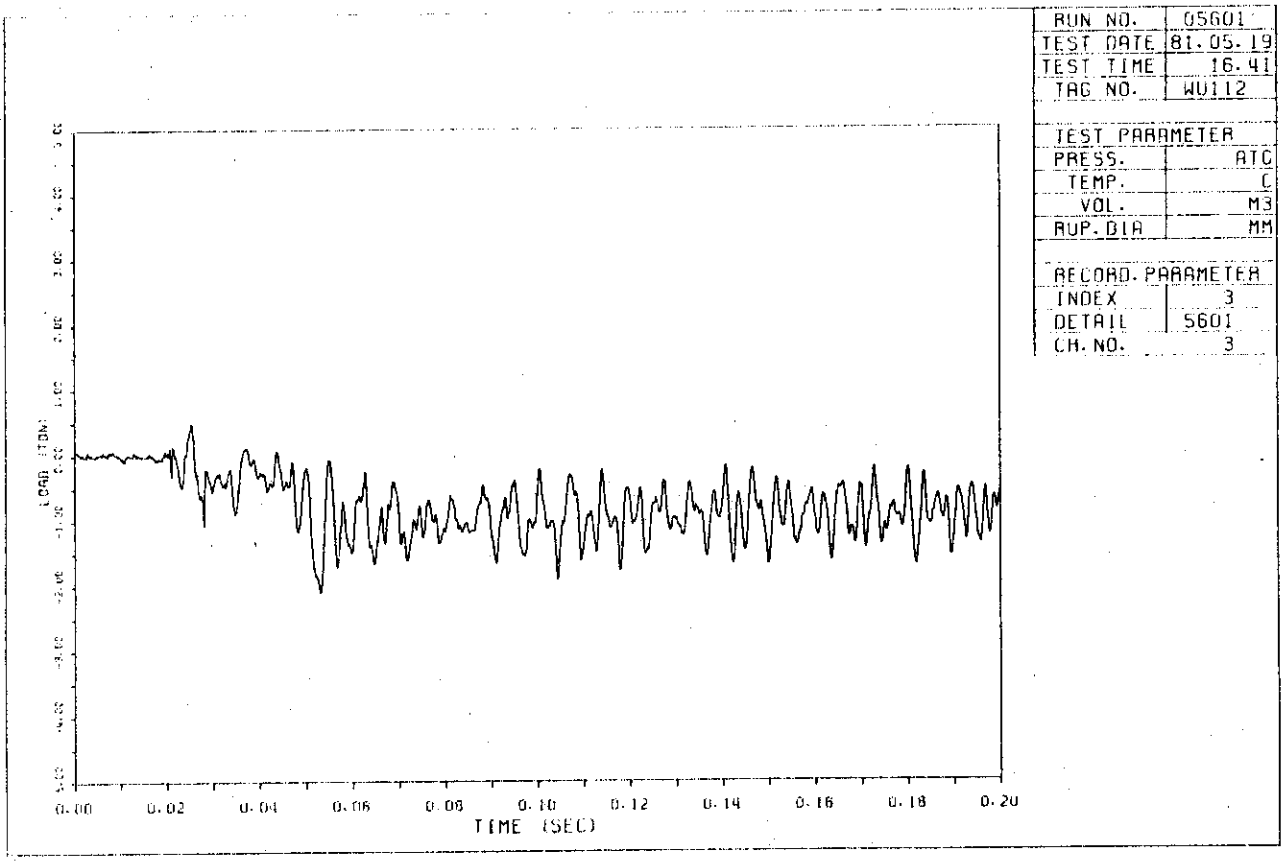
0.18
0.20
TIME (SEC)

Fig. 6.5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RECORD.PARAMETER
INDEX 3
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Fig. 6.6

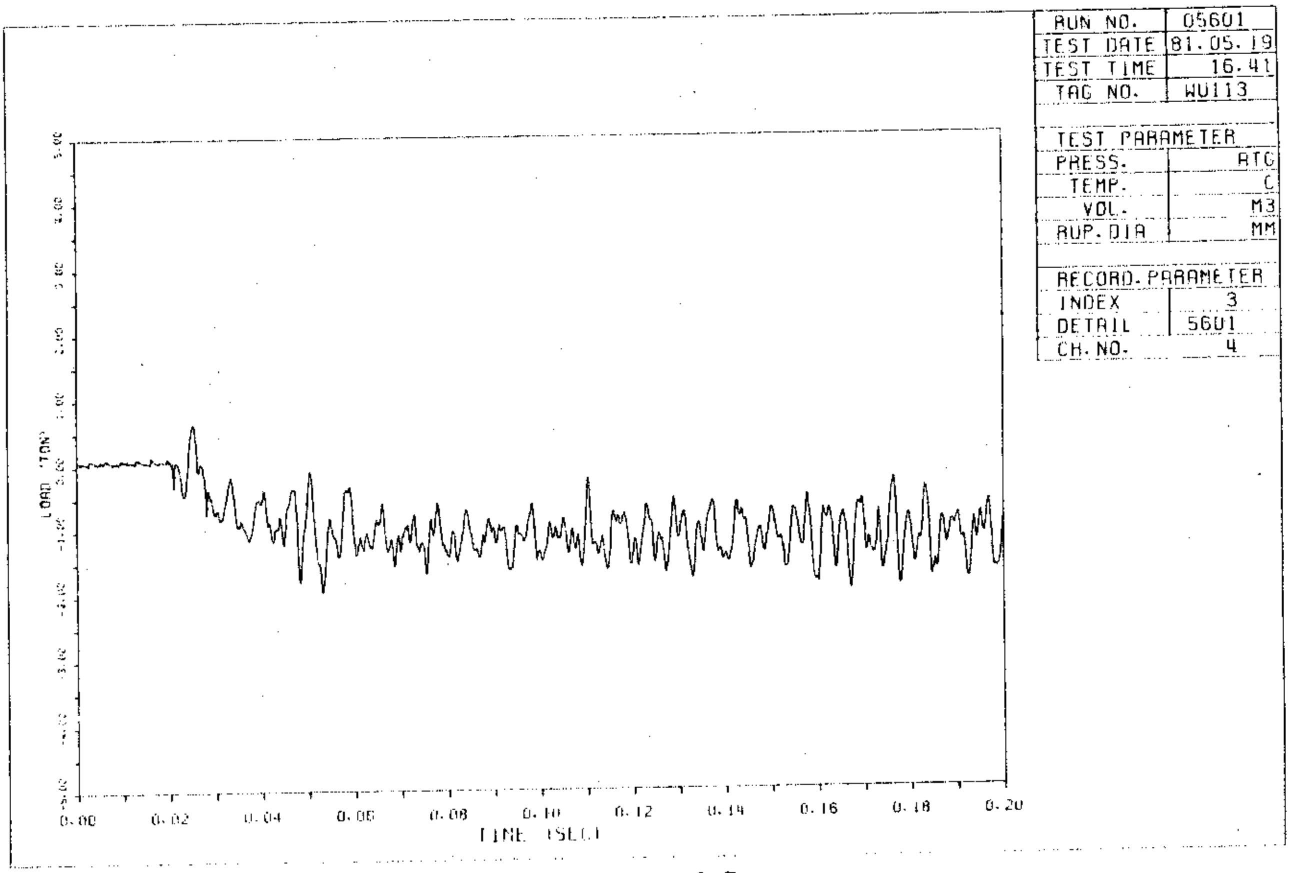
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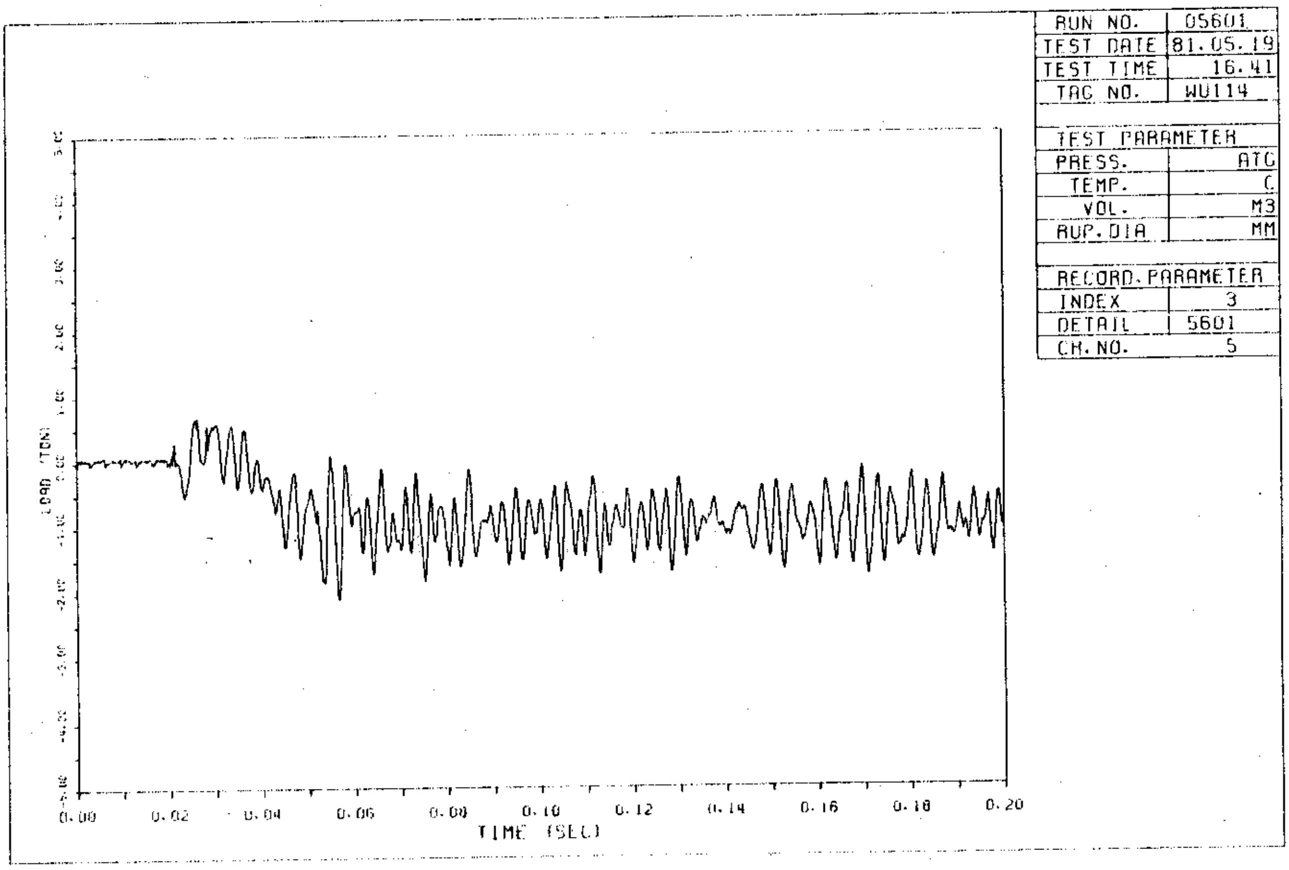
Fig. 6.7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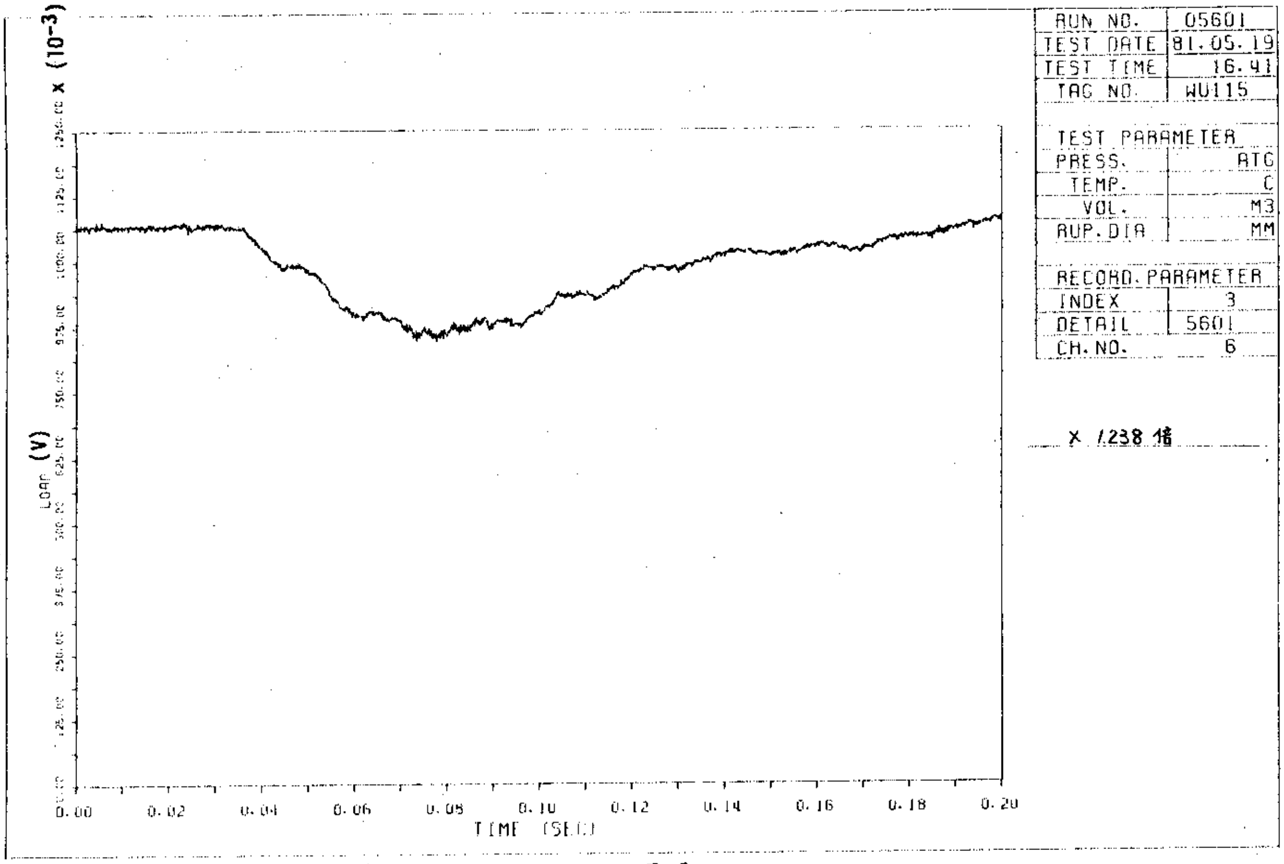
TIME (SEC)

Fig. 6.8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INDEX 3
DETAIL 5601
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LOAD (V) × (10⁻³)
TIME (SEC)
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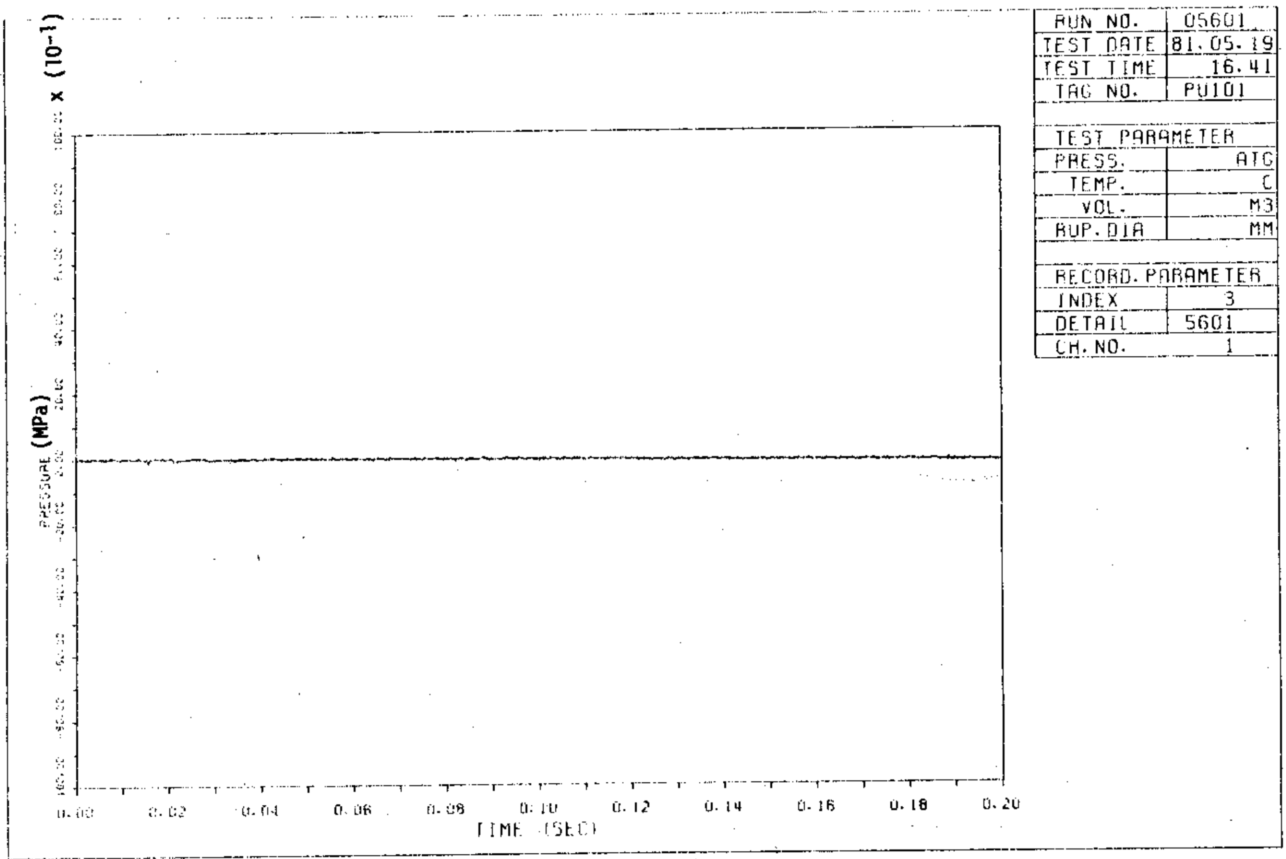
0.12
0.14
0.16
0.18
0.20

Fig. 7.1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RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 1
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TIME (SEC)
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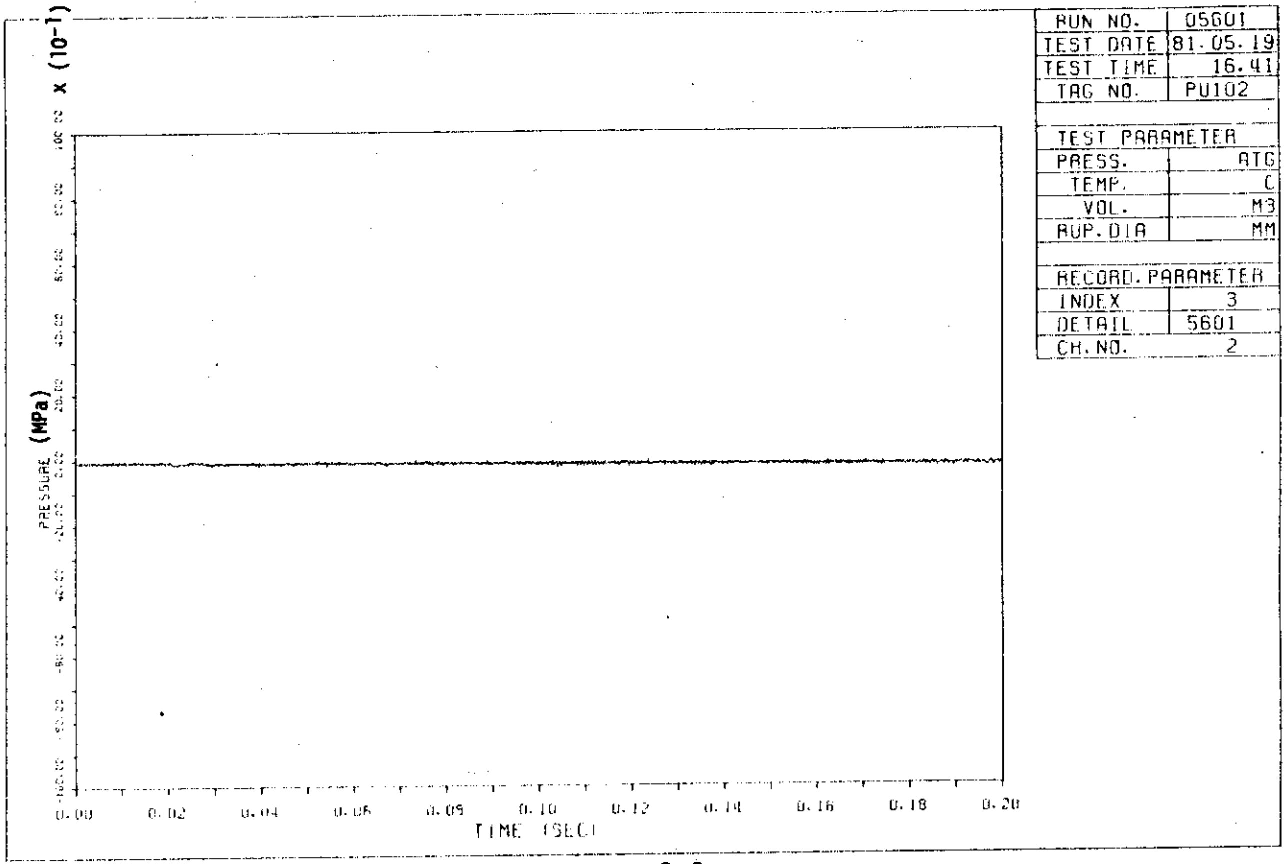
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20

Fig. 8.1



PRESSURE (MPa) x (10^-1)
TIME (SEC)
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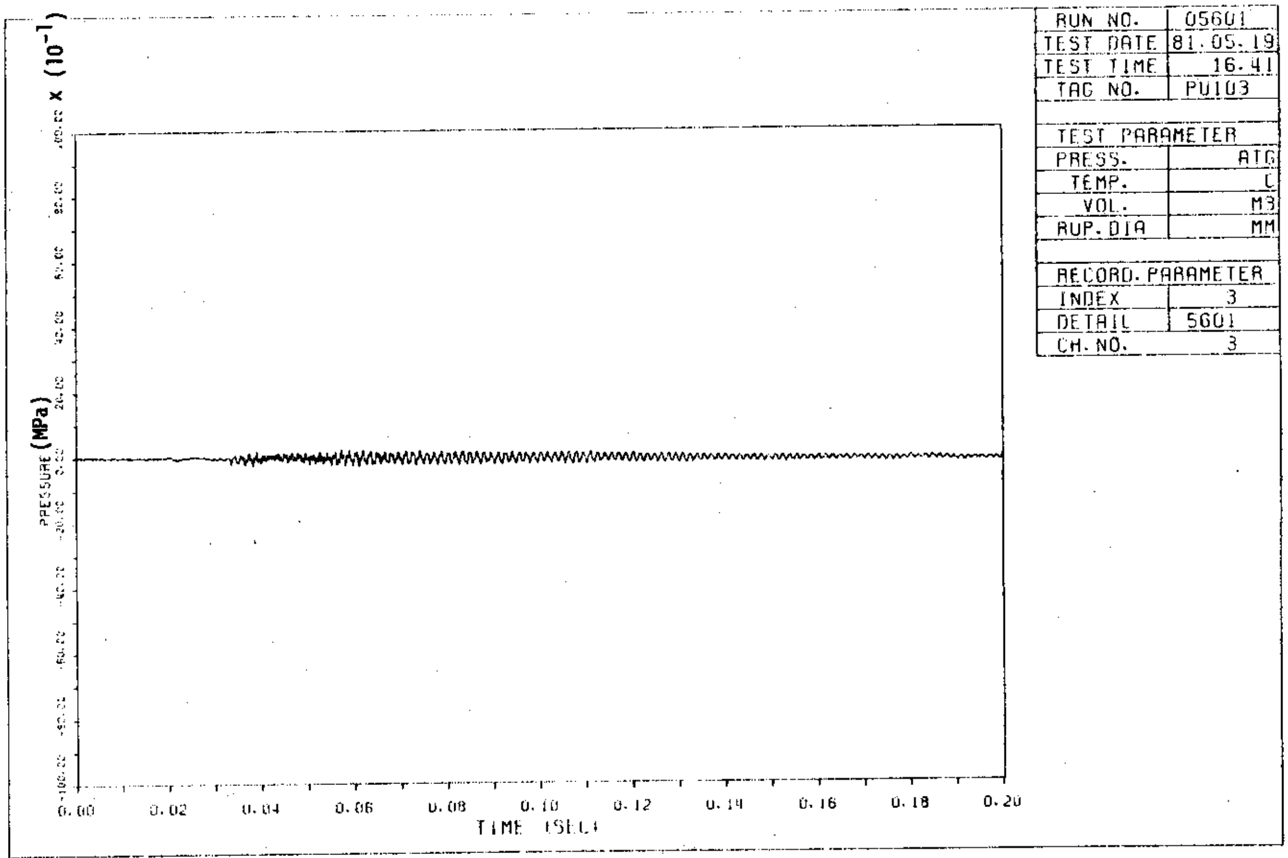
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
RUN NO. 05601
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU102
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 2

Fig. 8.2



PRESSURE (MPa) x (10^-1)
TIME (SEC)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
RUN NO. 05601
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU103
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 3

Fig. 8.3

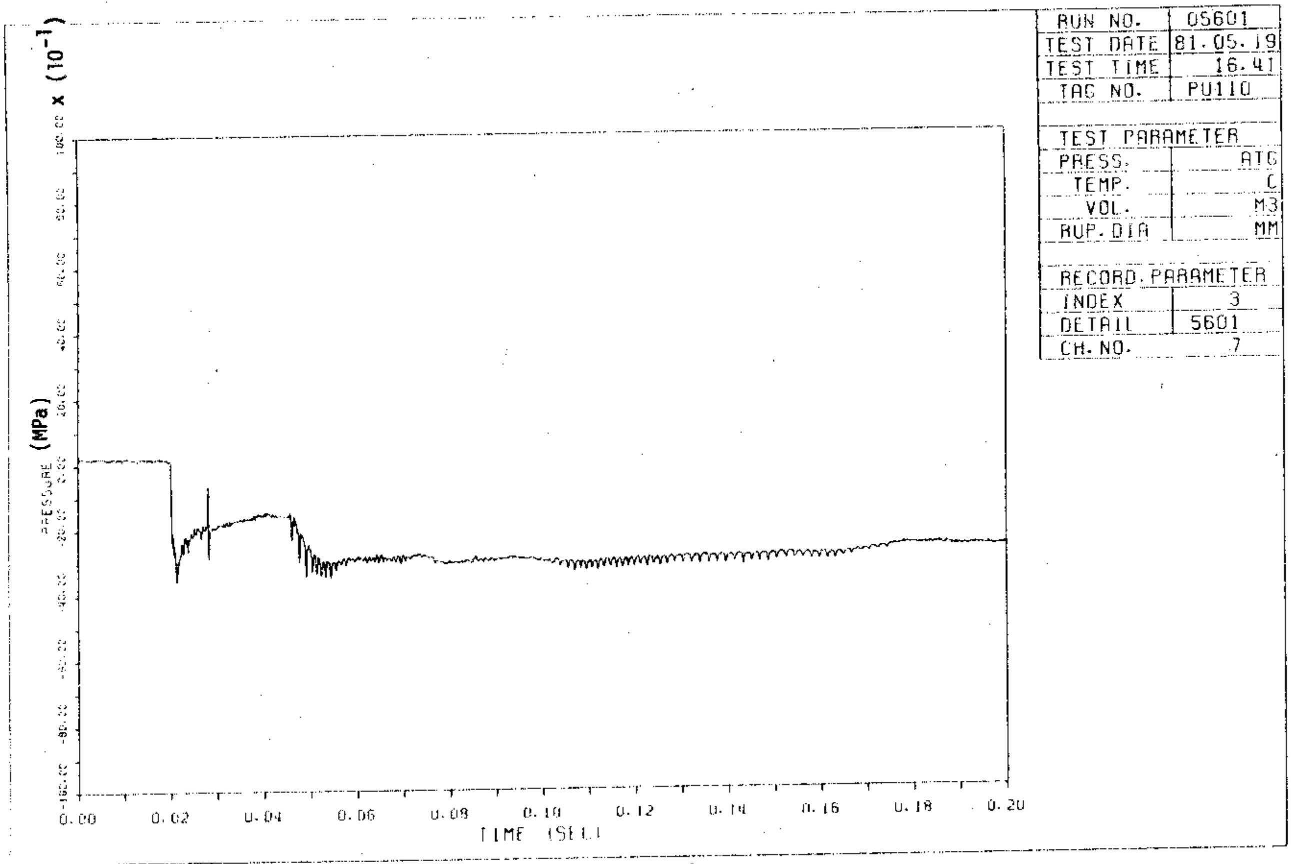

RUN NO. 05601
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU110
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 7
PRESSURE (MPa) x (10^{-1})
TIME (SEC)

Fig. 8.4

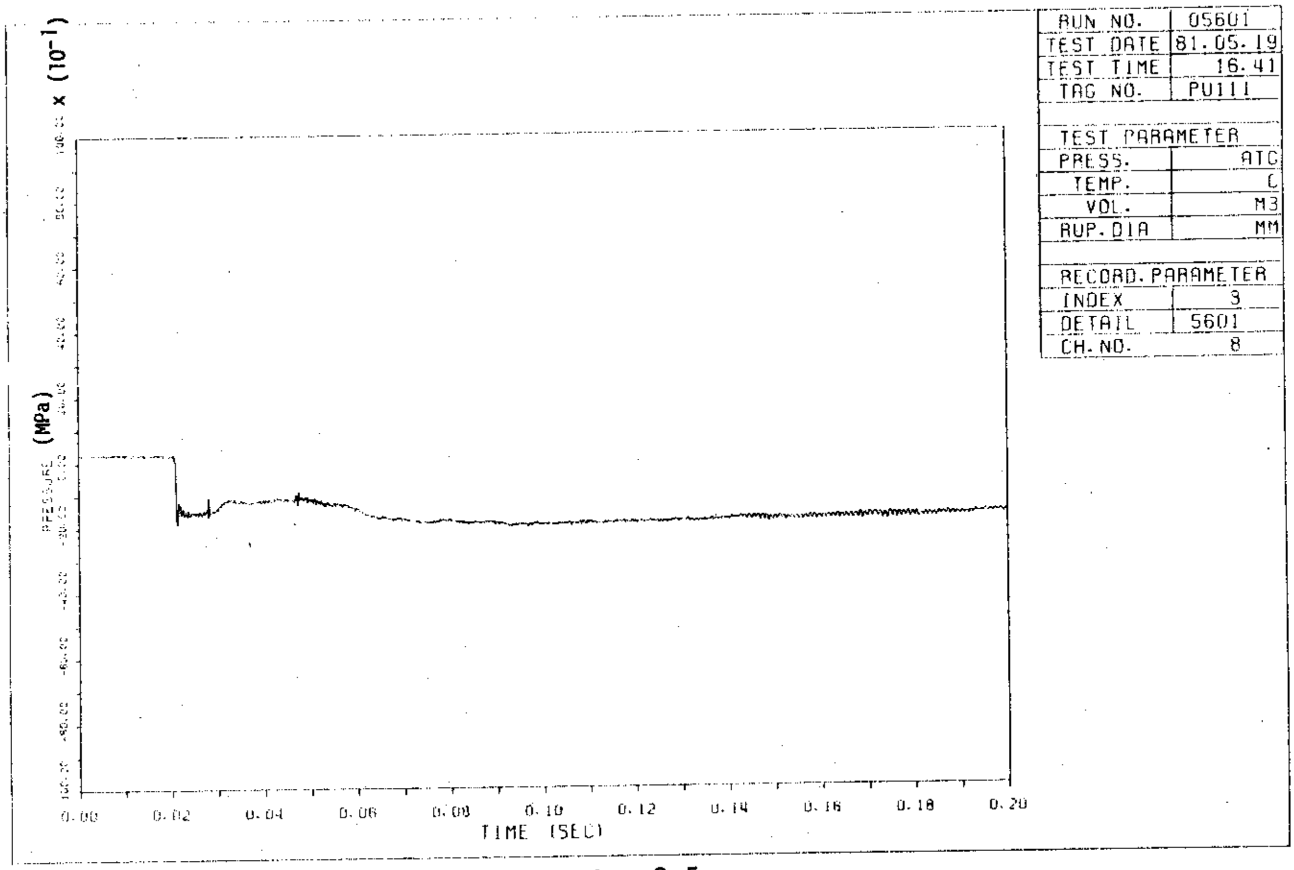
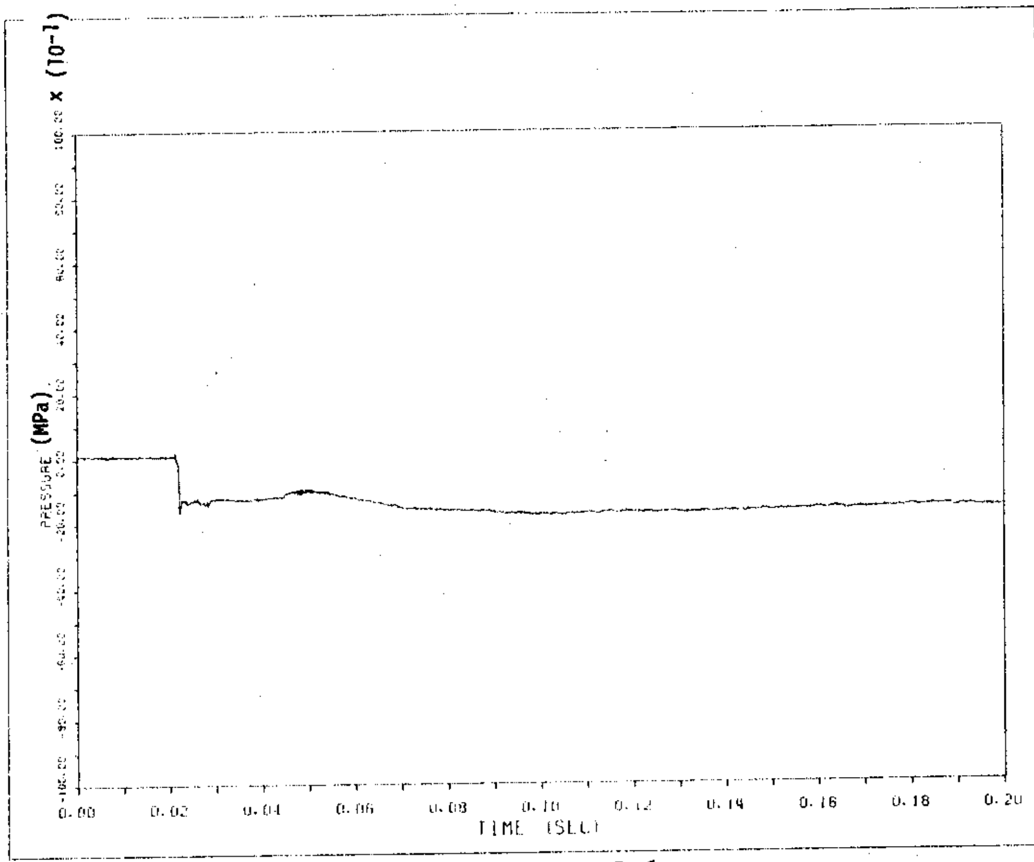
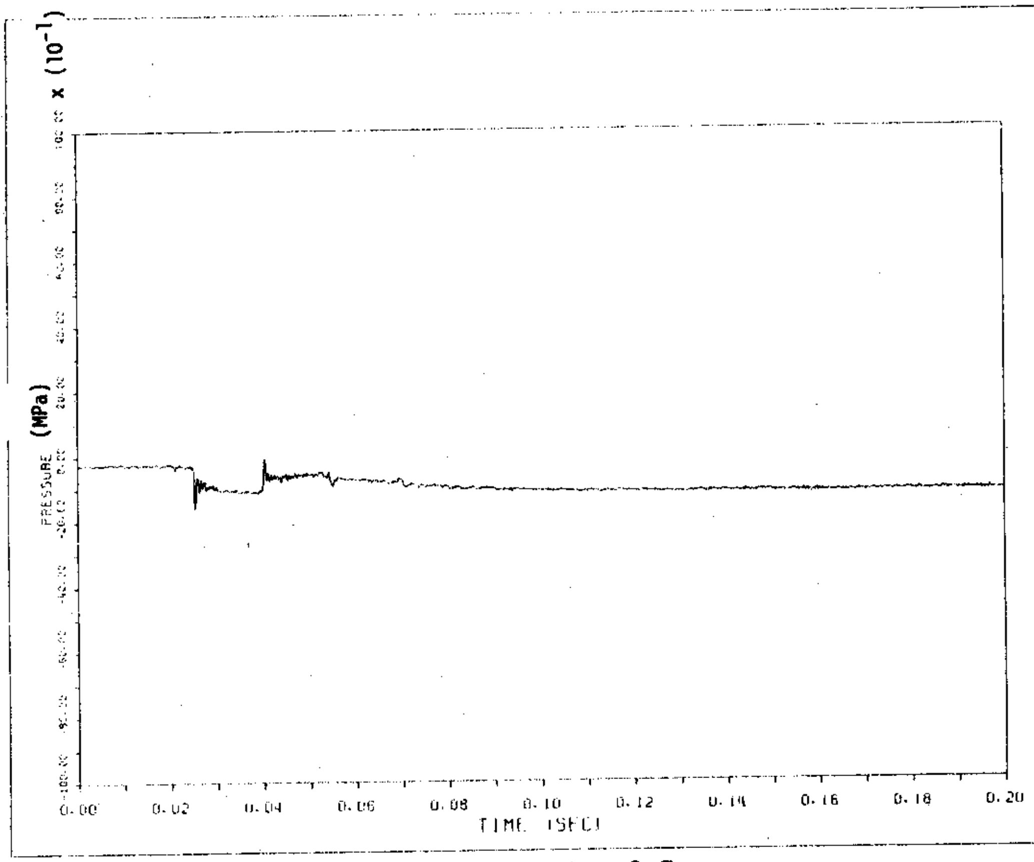

RUN NO. 05601
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU111
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 8
PRESSURE (MPa) x (10^{-1})
TIME (SEC)

Fig. 8.5



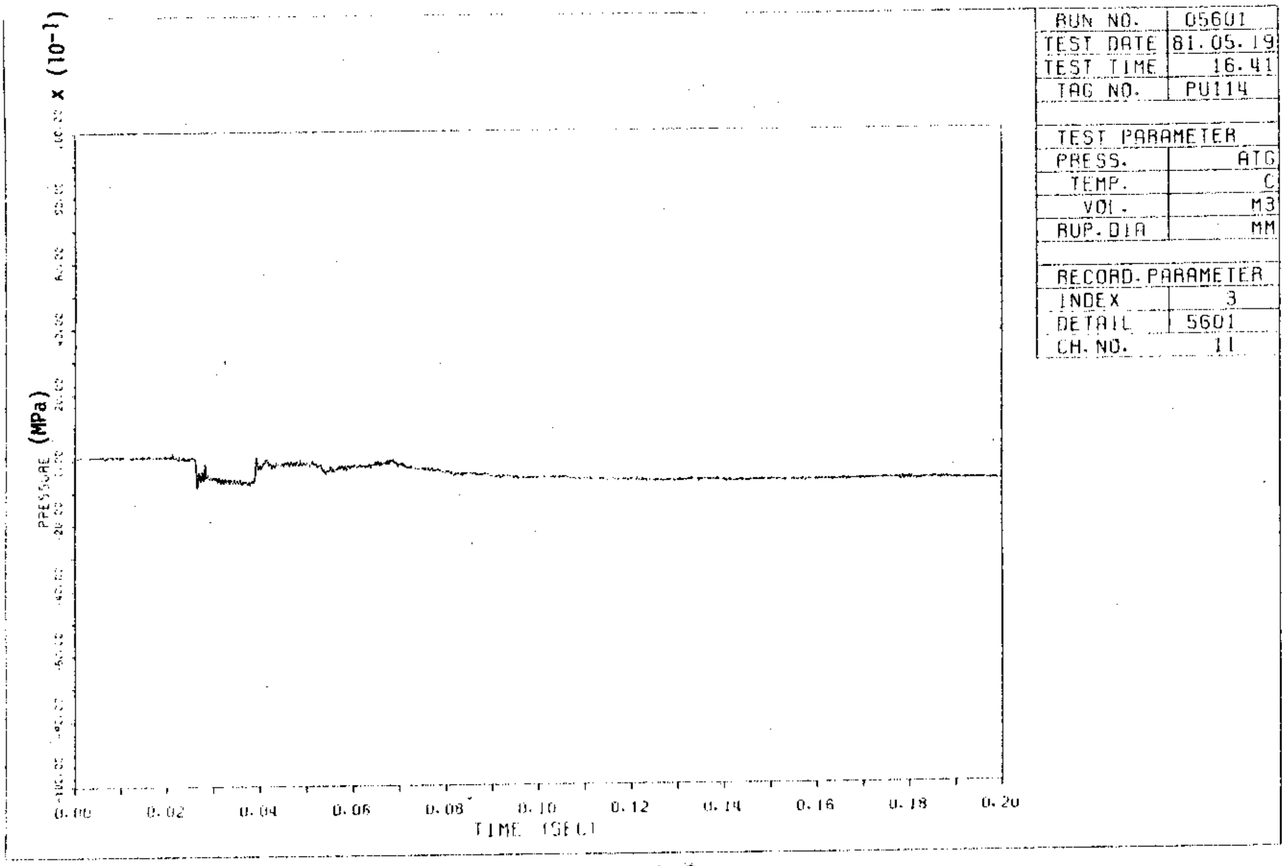
RUN NO.	05601
TEST DATE	81.05.19
TEST TIME	16.41
TAG NO.	PU112
TEST PARAMETER	
PRESS.	ATG
TEMP.	C
VOL.	M3
RUP.DIA	MM
RECORD. PARAMETER	
INDEX	3
DETAIL	5601
CH.NO.	9

Fig. 8.6



RUN NO.	05601
TEST DATE	81.05.19
TEST TIME	16.41
TAG NO.	PU113
TEST PARAMETER	
PRESS.	ATG
TEMP.	C
VOL.	M3
RUP.DIA	MM
RECORD. PARAMETER	
INDEX	3
DETAIL	5601
CH.NO.	10

Fig. 8.7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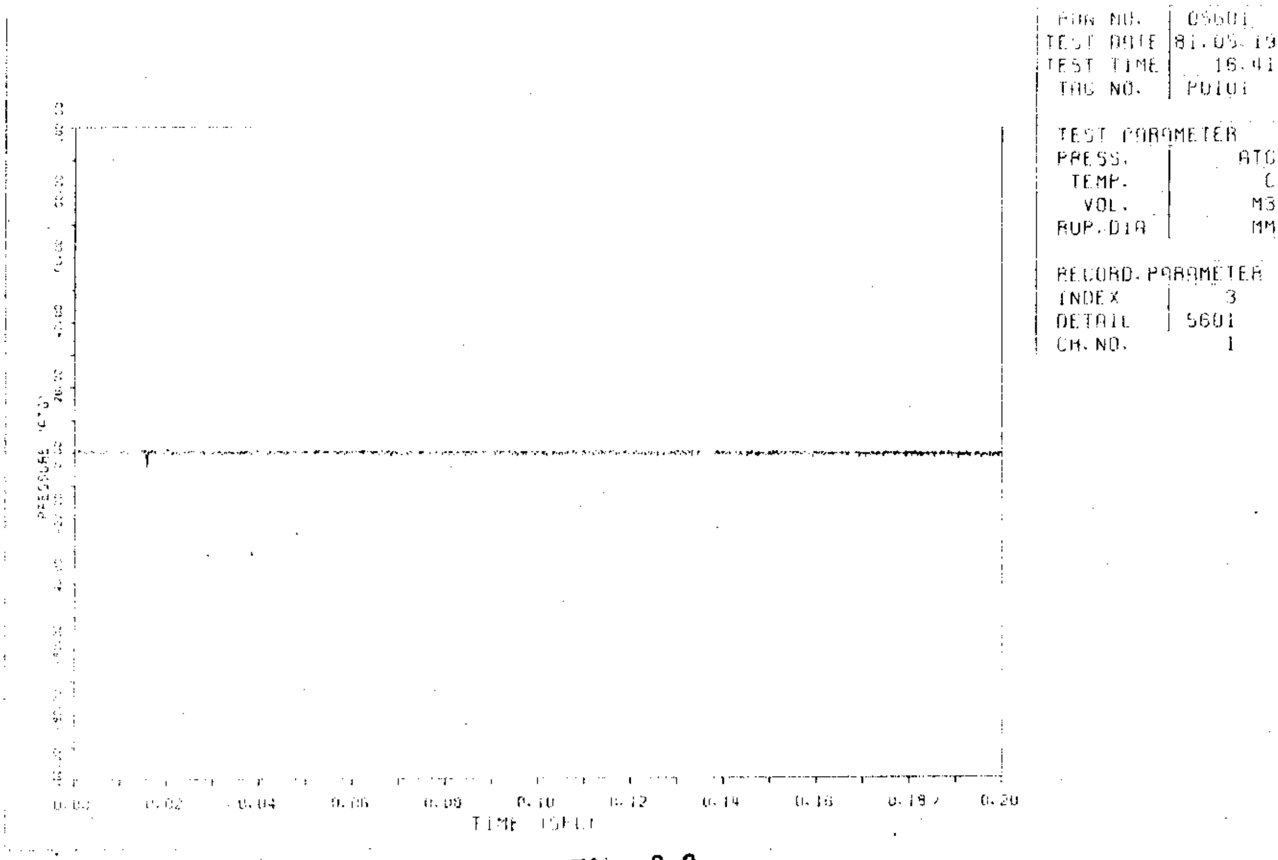
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU114
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 11
PRESSURE (MPa) x (10⁻¹)
TIME (SEC)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20

Fig. 8.8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TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU101
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 1
PRESSURE
TIME (SEC)
0.20

Fig. 8.9

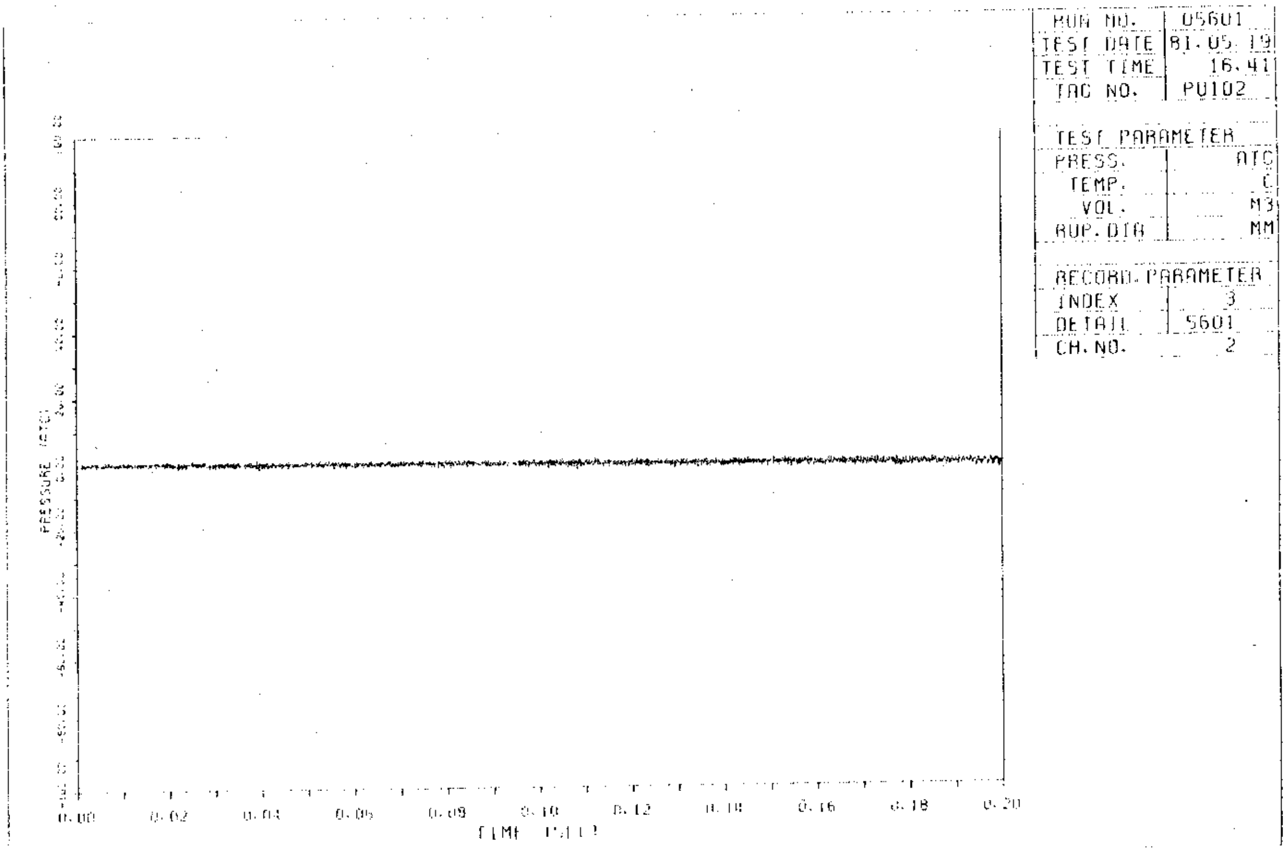


Fig. 8.10

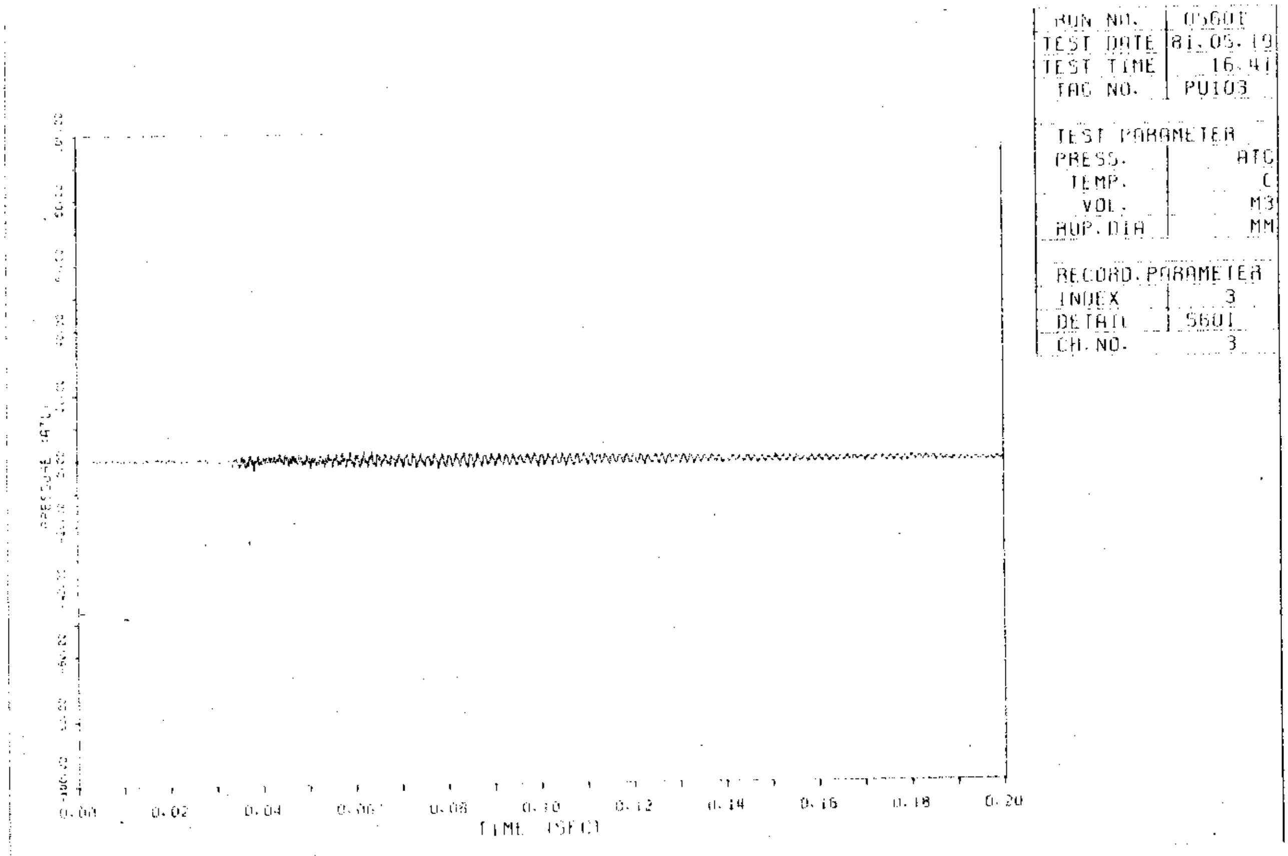


Fig. 8.11

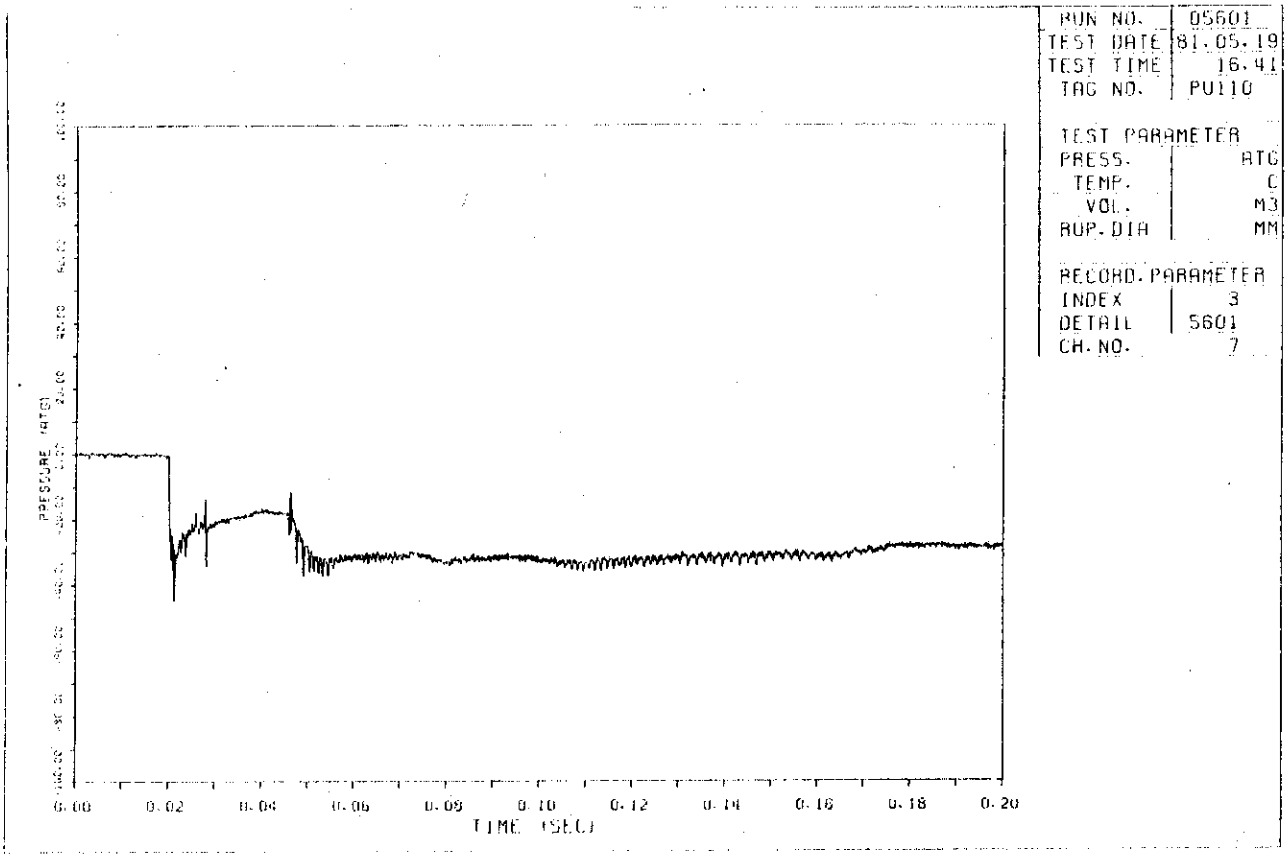


Fig. 8.12

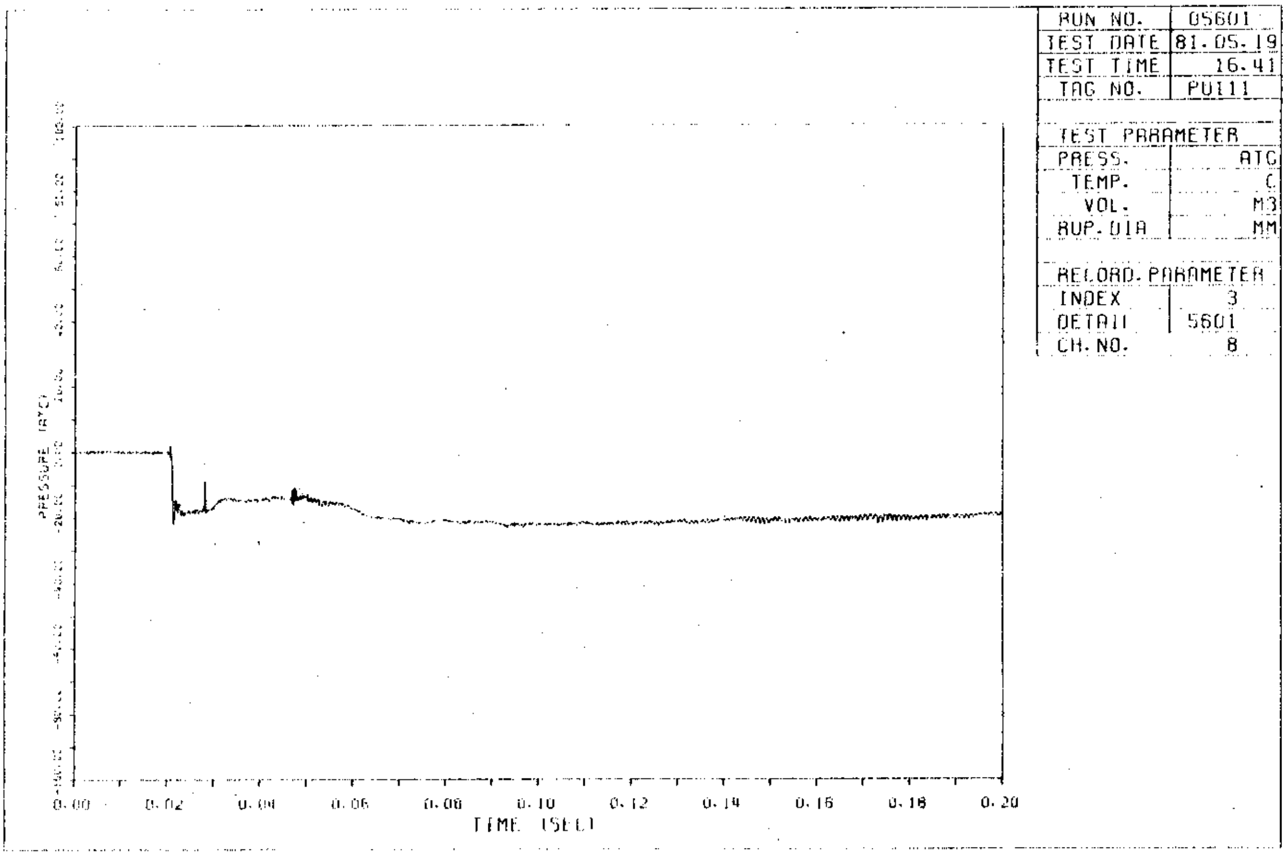


Fig. 8.13

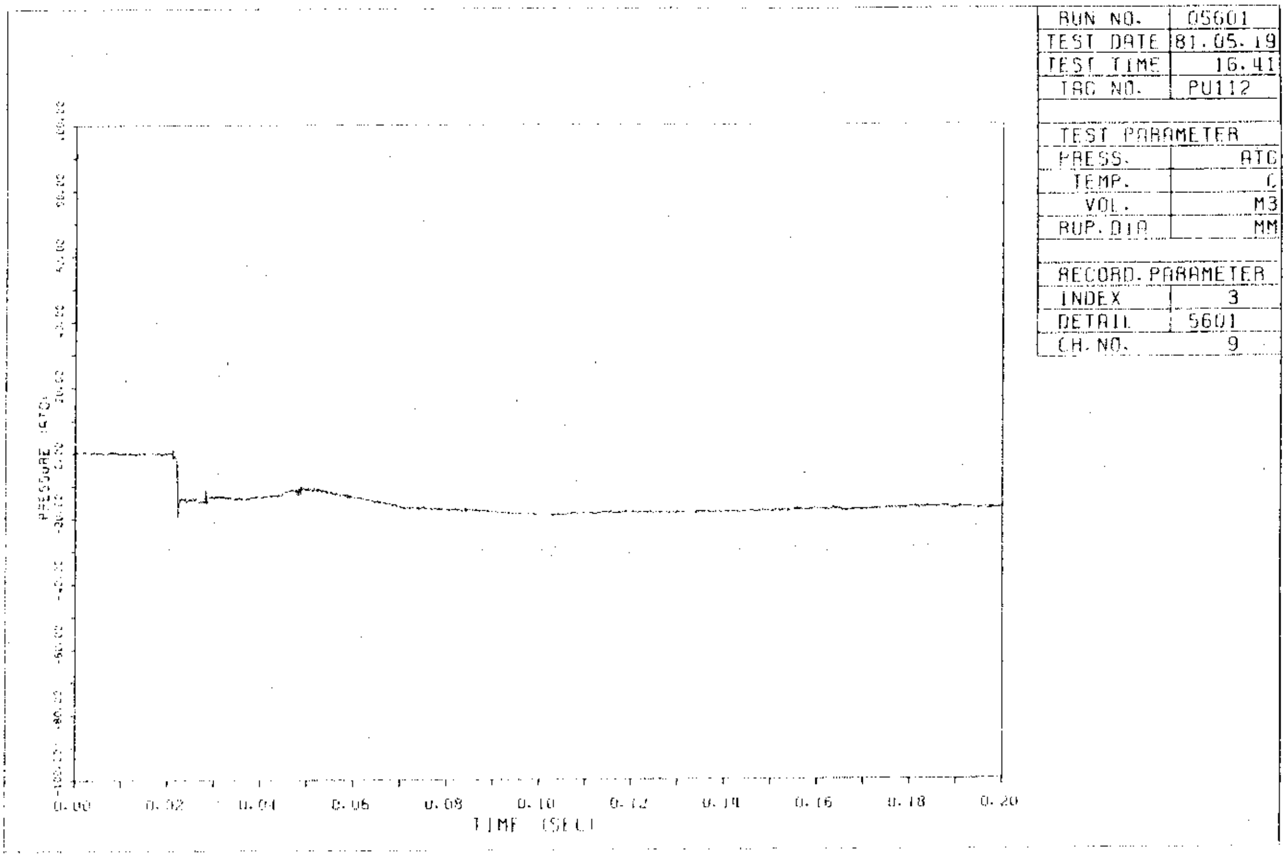


Fig. 8.14

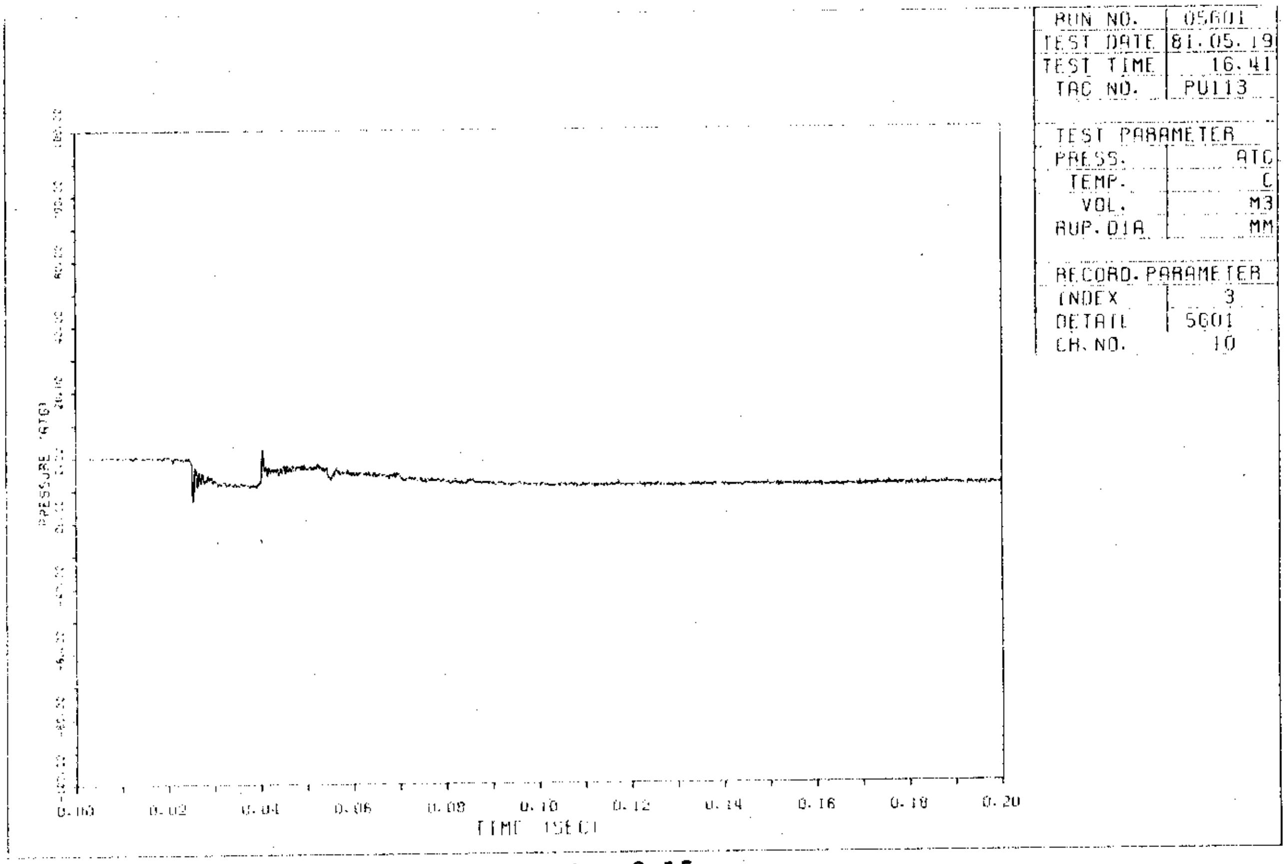


Fig. 8.15

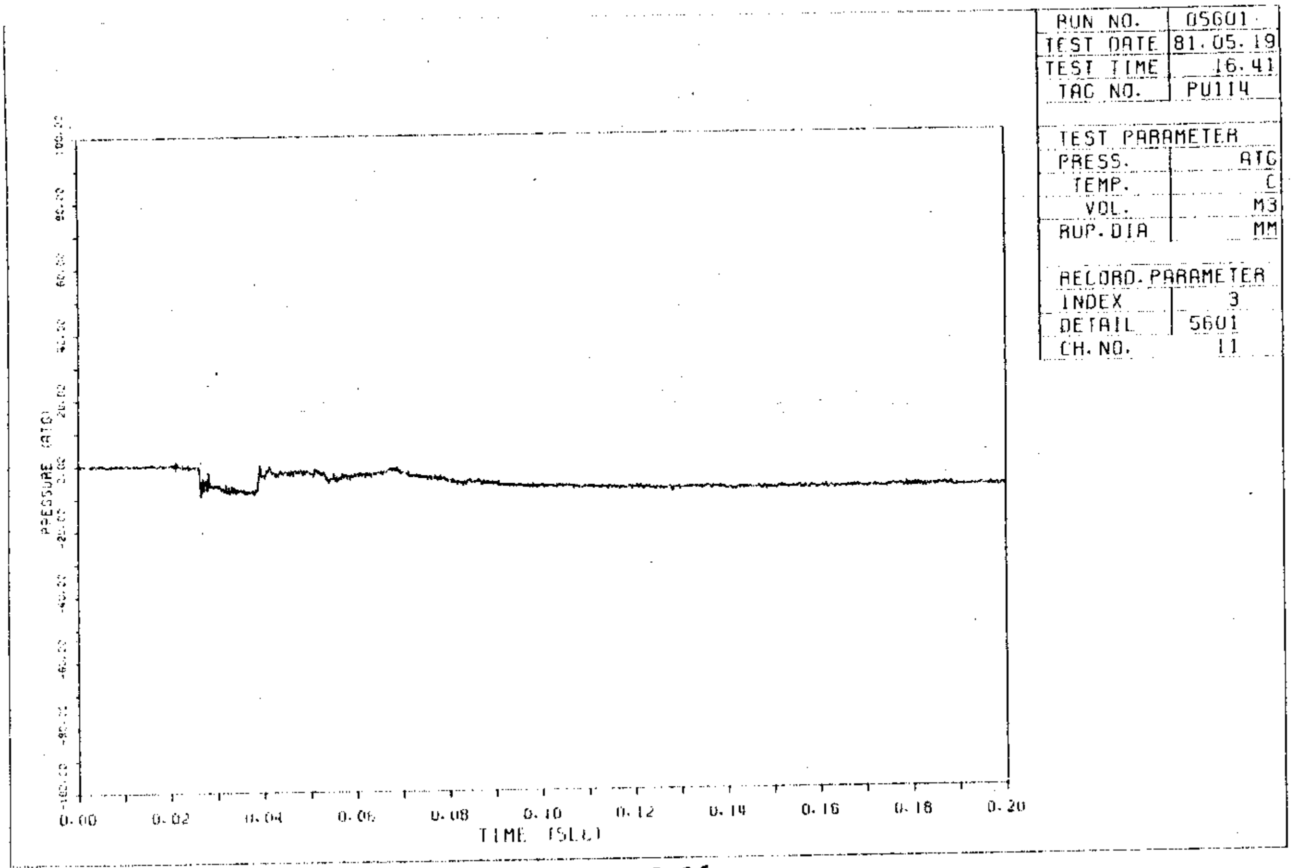


Fig. 8.16

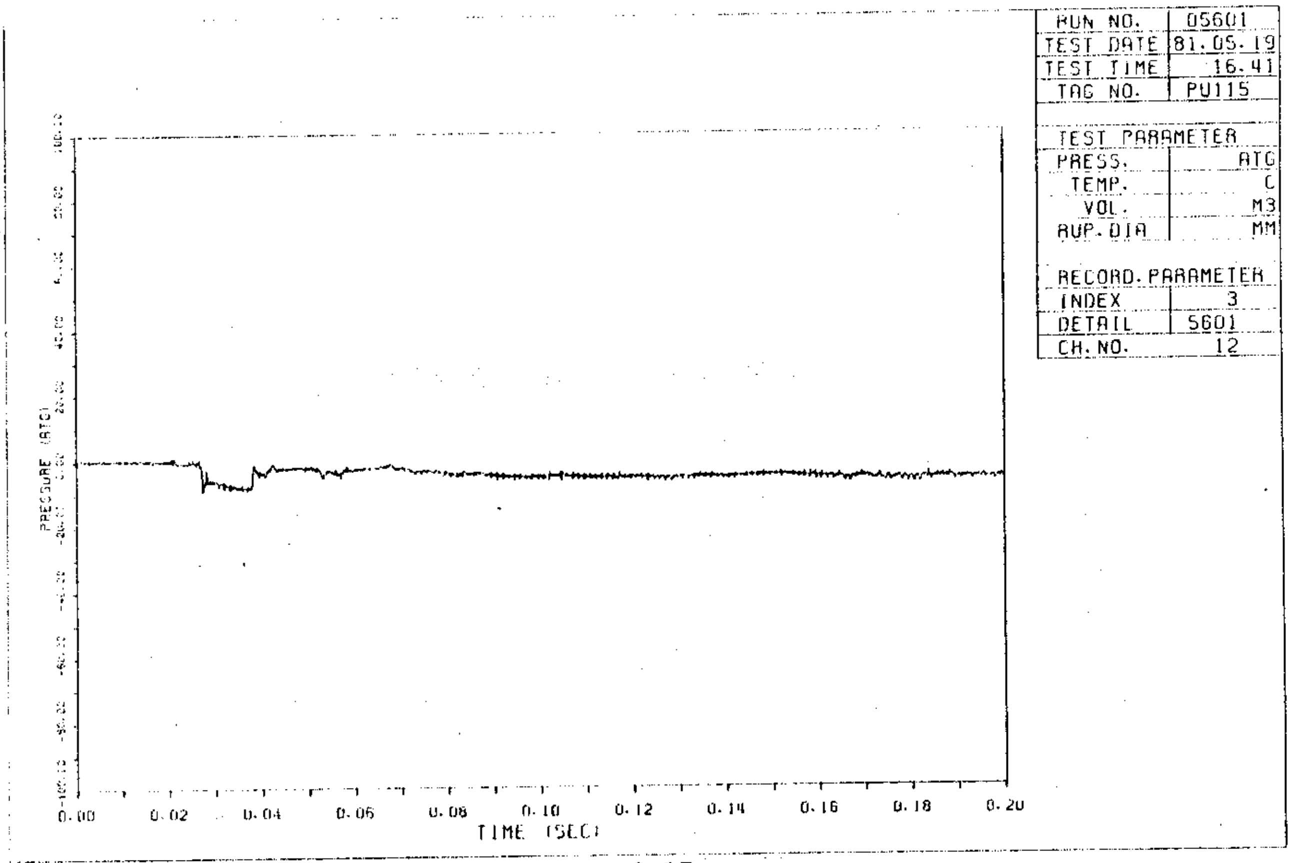
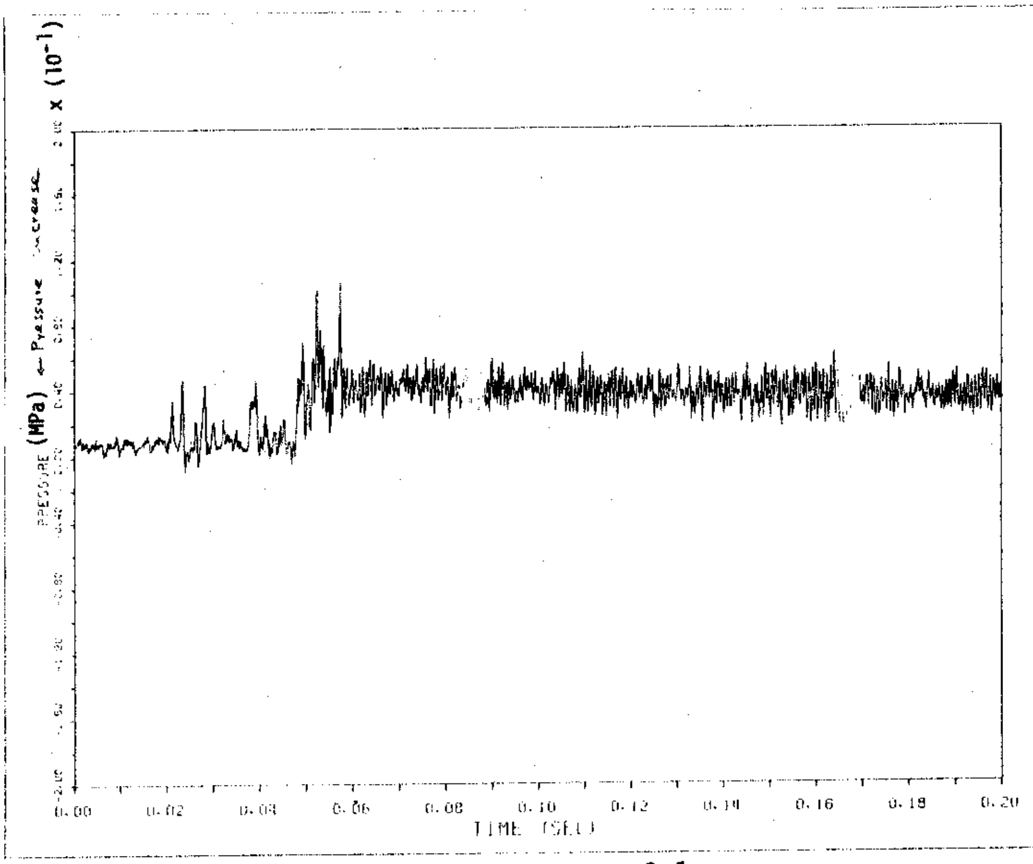


Fig. 8.17

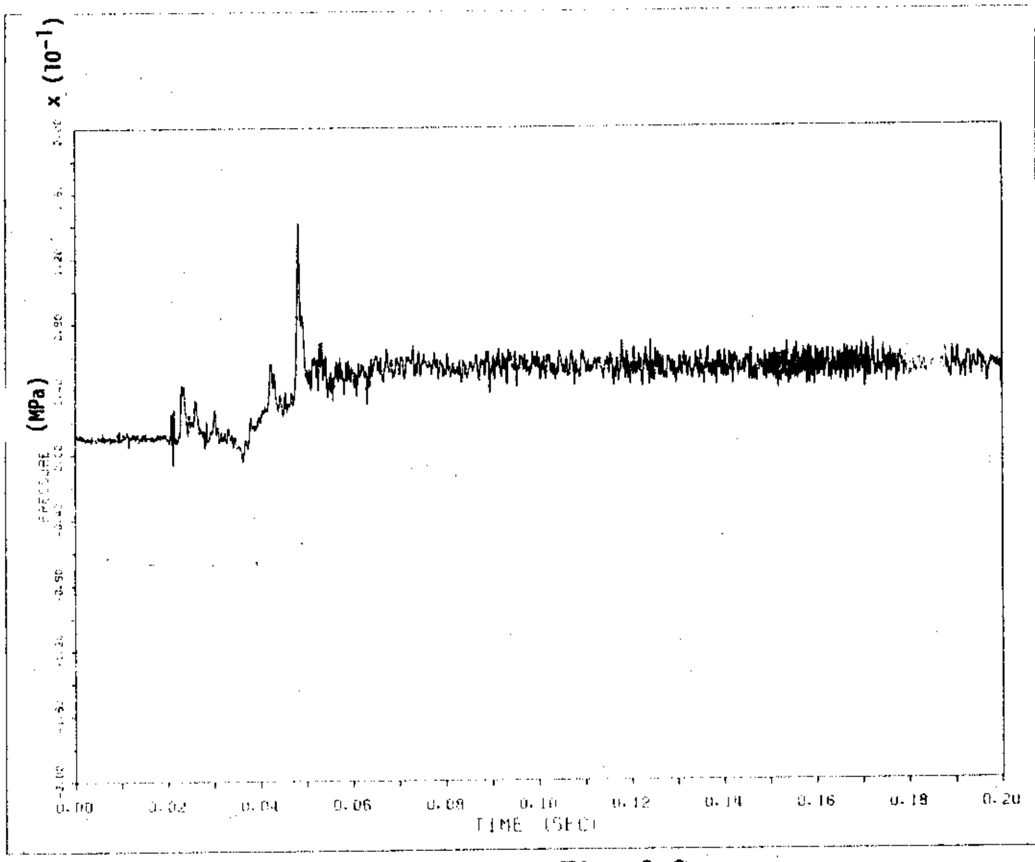


RUN NO.	05601
TEST DATE	81.05.19
TEST TIME	16.41
TAC NO.	PU121

TEST PARAMETER	
PRESS.	ATG
TEMP.	C
VOL.	M3
RUP.DIA	MM

RECORD.PARAMETER	
INDEX	3
DETAIL	5601
CH.NO.	1

Fig. 9.1

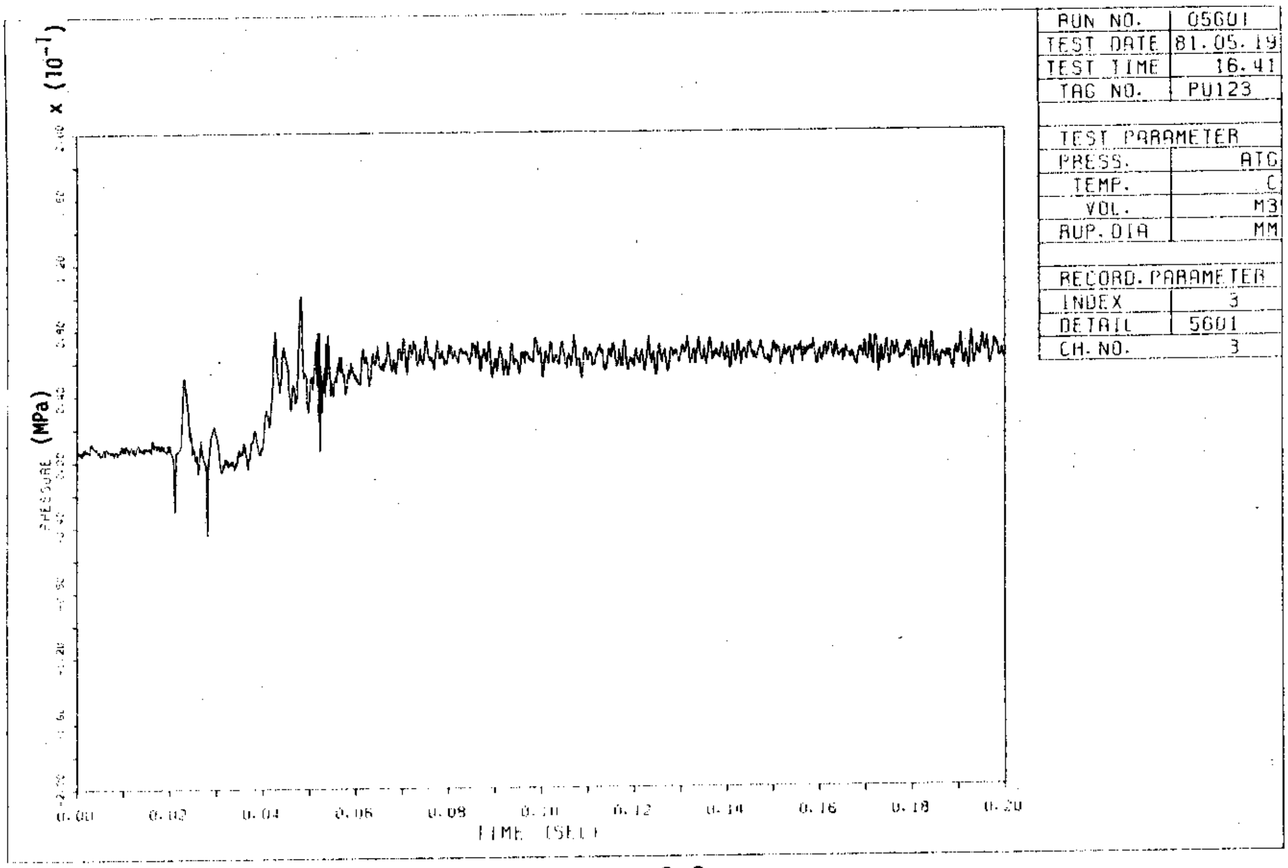


RUN NO.	05601
TEST DATE	81.05.19
TEST TIME	16.41
TAC NO.	PU122

TEST PARAMETER	
PRESS.	ATG
TEMP.	C
VOL.	M3
RUP.DIA	MM

RECORD.PARAMETER	
INDEX	3
DETAIL	5601
CH.NO.	2

Fig. 9.2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TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU123
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 3
PRESSURE (MPa) x (10^{-1})
TIME (SEC)

Fig. 9.3

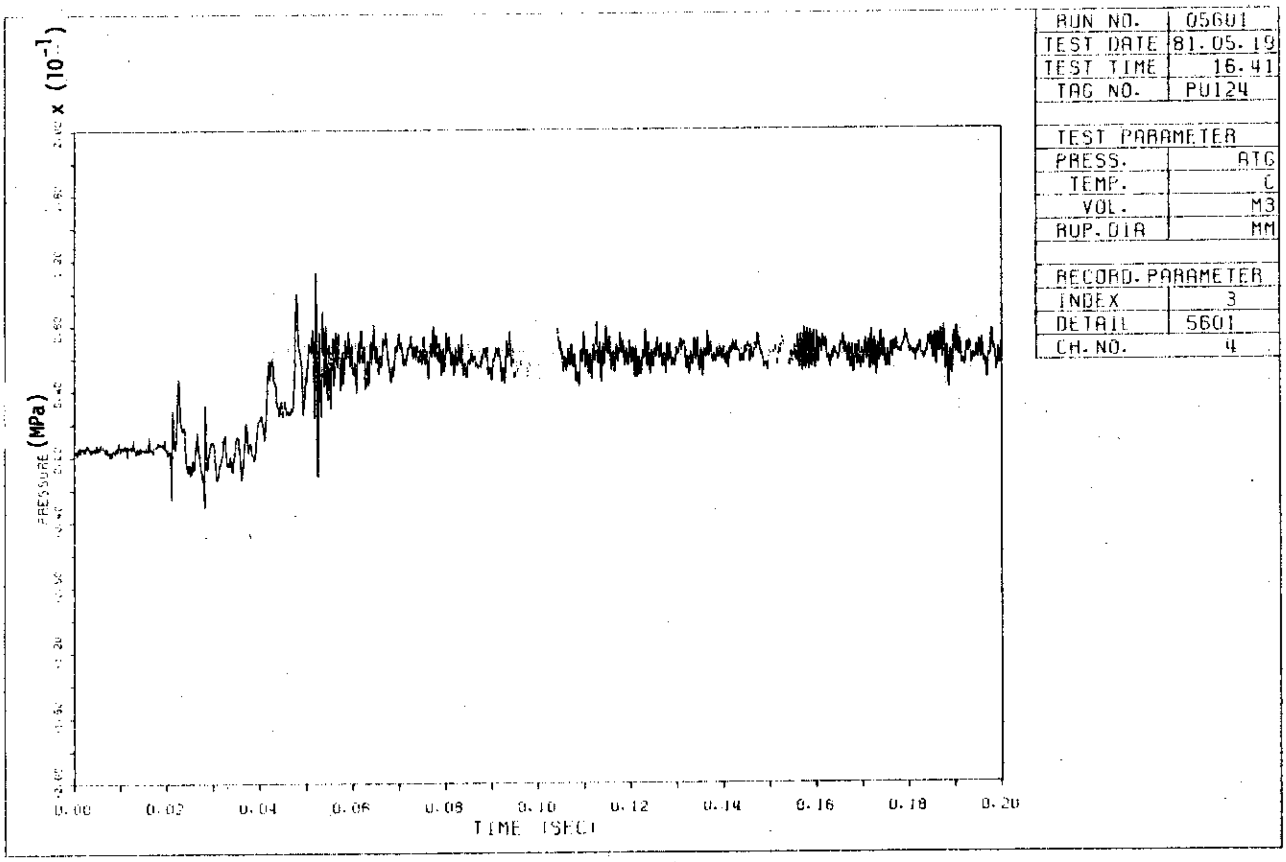

RUN NO. 05601
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU124
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 4
PRESSURE (MPa) x (10^{-1})
TIME (SEC)

Fig. 9.4

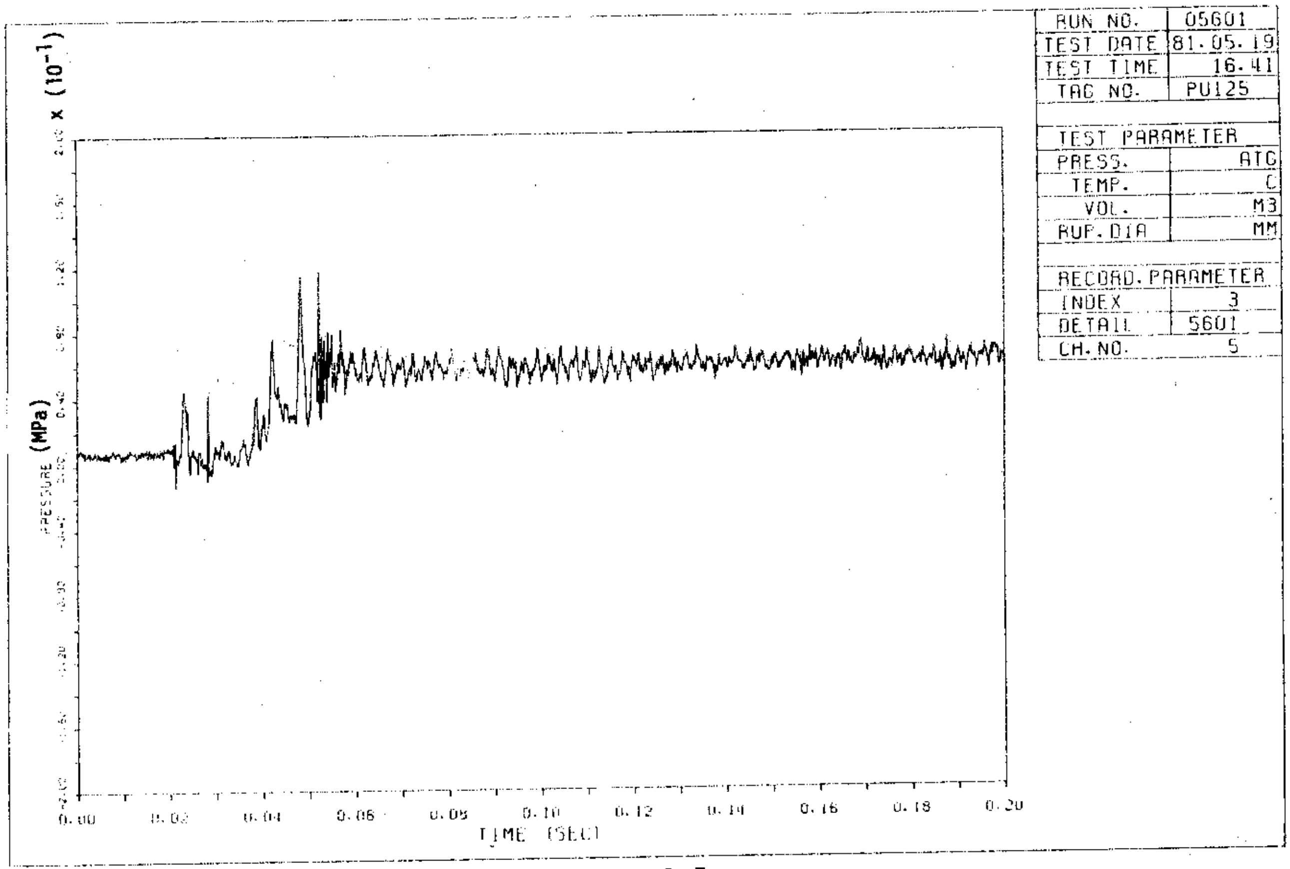

RUN NO. 05601
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU125
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 5
PRESSURE (MPa) x (10^{-1})
TIME (SEC)
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20

Fig. 9.5

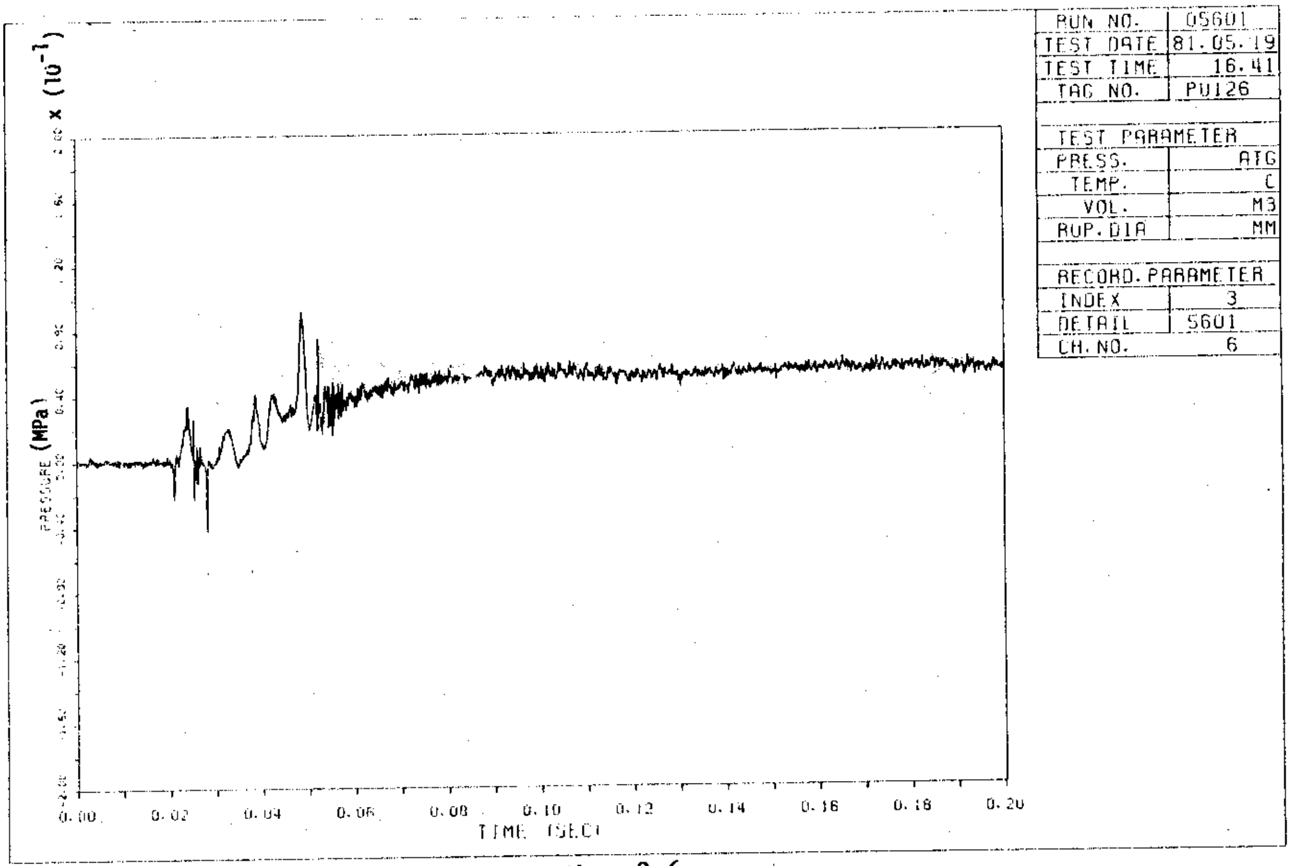

RUN NO. 05601
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU126
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 6
PRESSURE (MPa) x (10^{-1})
TIME (SEC)
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20

Fig. 9.6

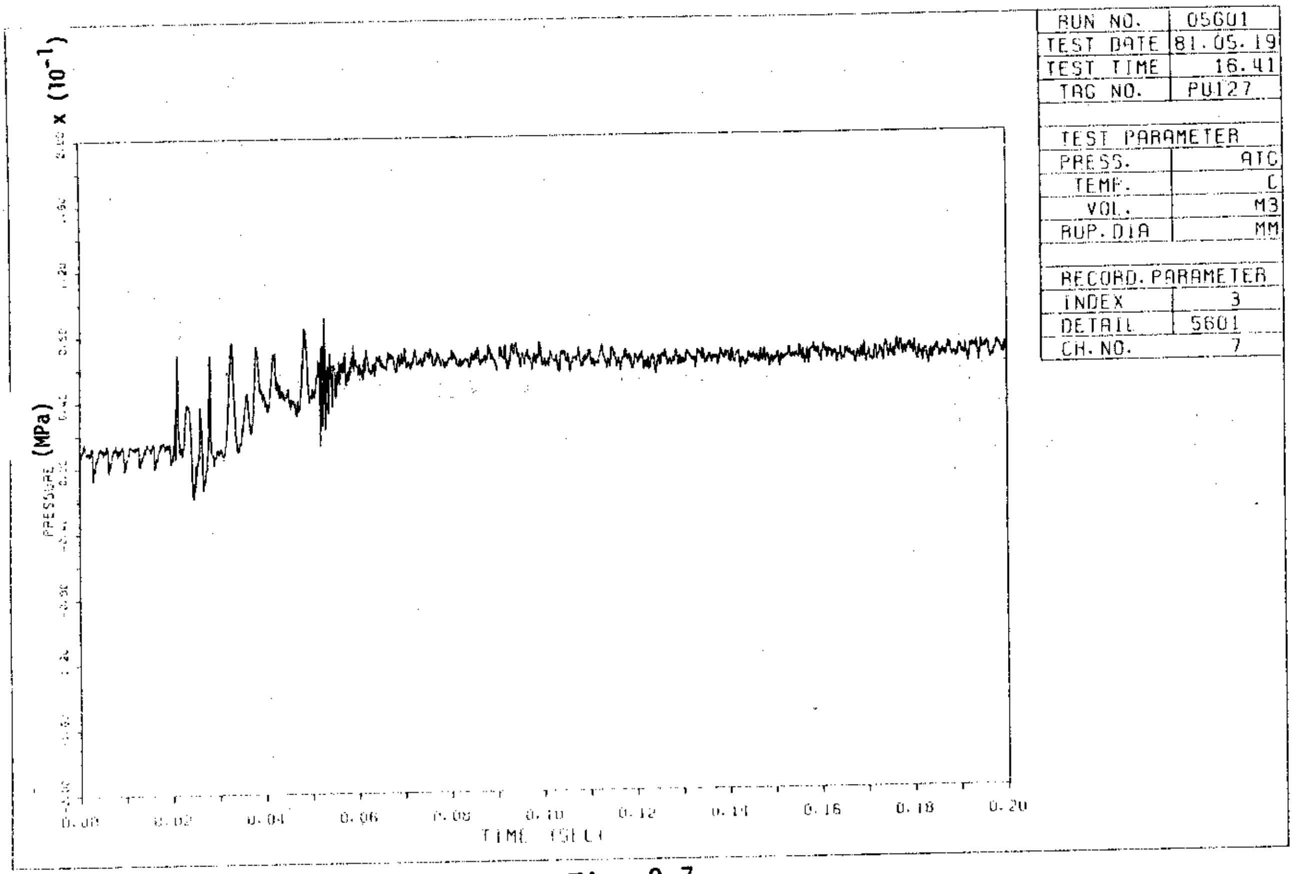

RUN NO. 05601
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU127
TEST PARAMETER
PRESS. ATC
TEMP. C
VOL. M3
RUP.DIA MM
RECORD. PARAMETER
INDEX 3
DETAIL 5601
CH. NO. 7
PRESSURE (MPa) x (10^-1)
TIME (SEC)

Fig. 9.7

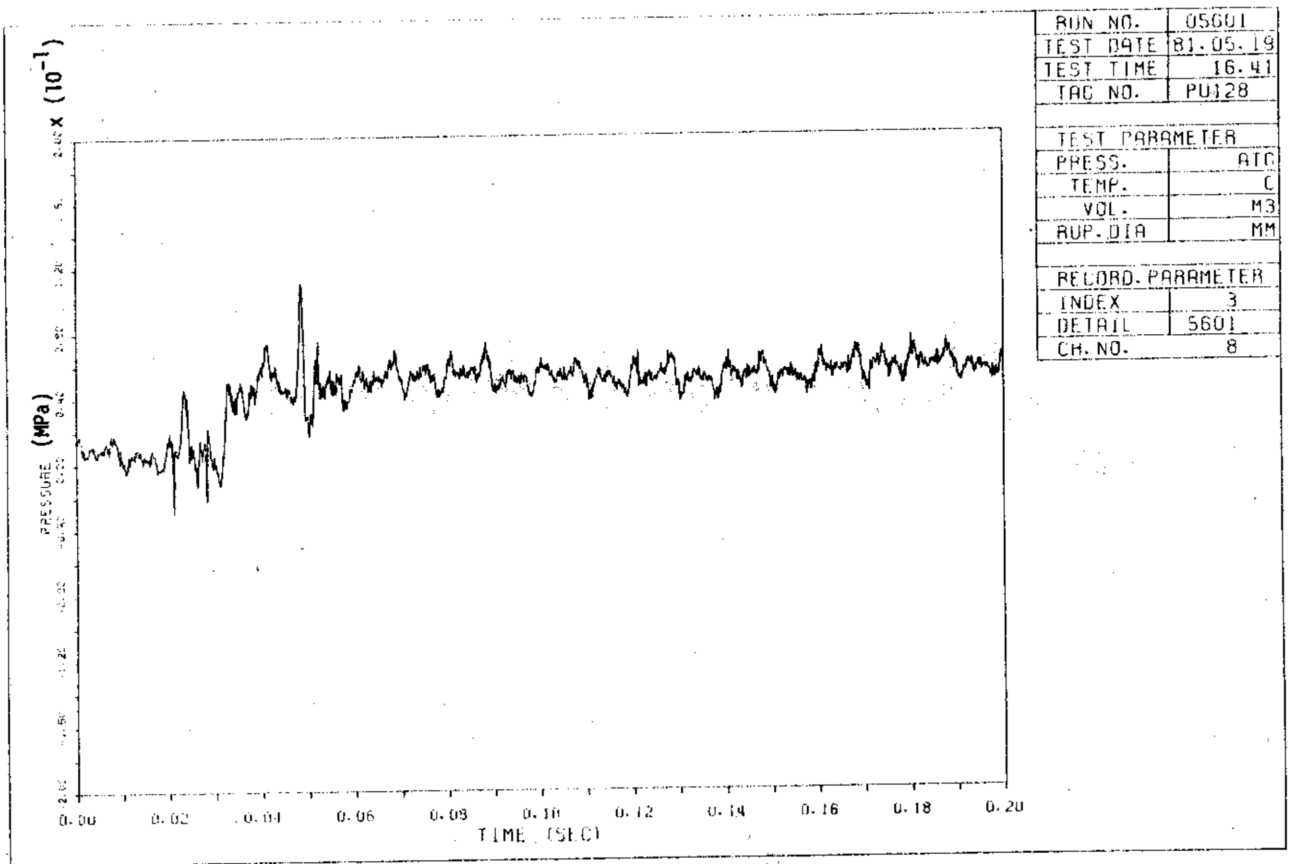

RUN NO. 05601
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. PU128
TEST PARAMETER
PRESS. ATC
TEMP. C
VOL. M3
RUP.DIA MM
RECORD. PARAMETER
INDEX 3
DETAIL 5601
CH. NO. 8
PRESSURE (MPa) x (10^-1)
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20
TIME (SEC)

Fig. 9.8

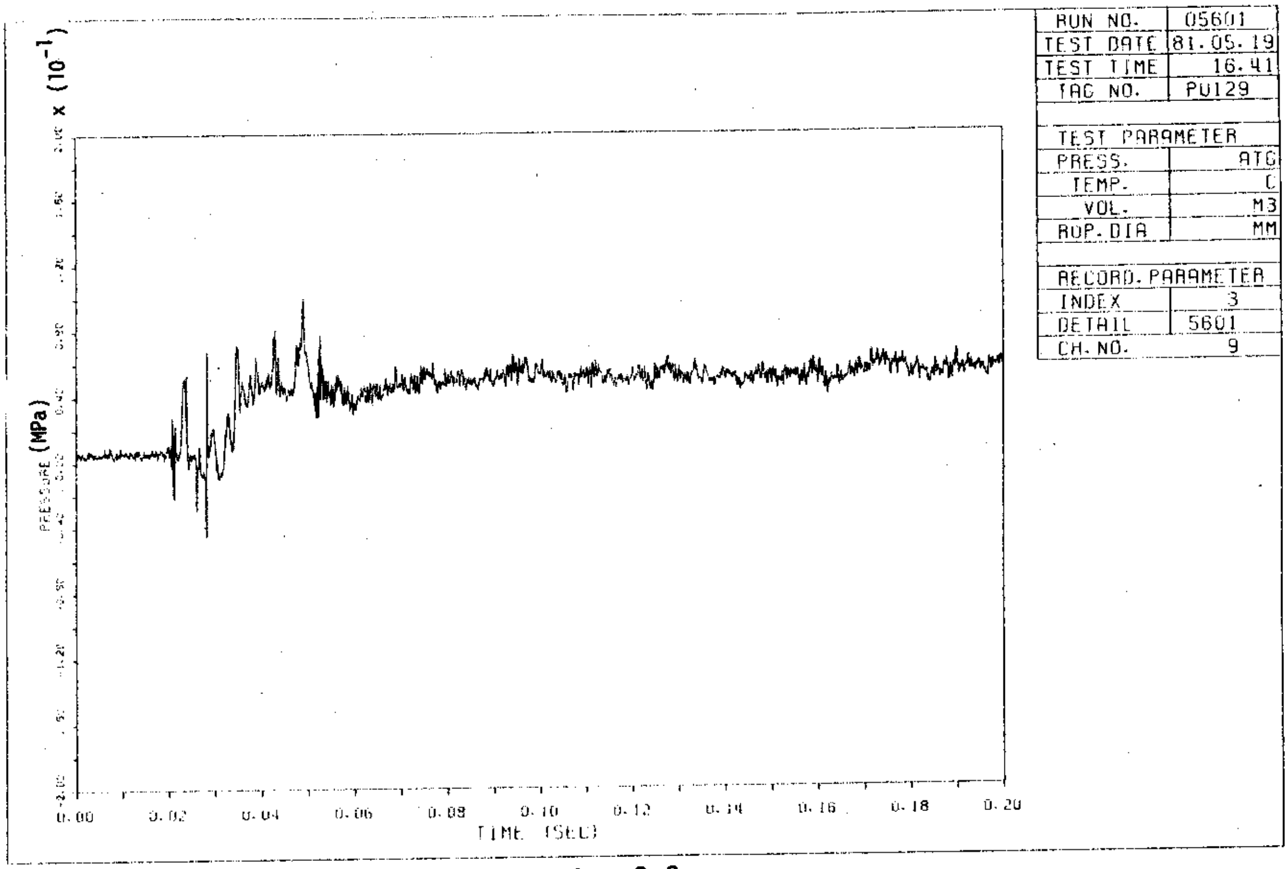


Fig. 9.9

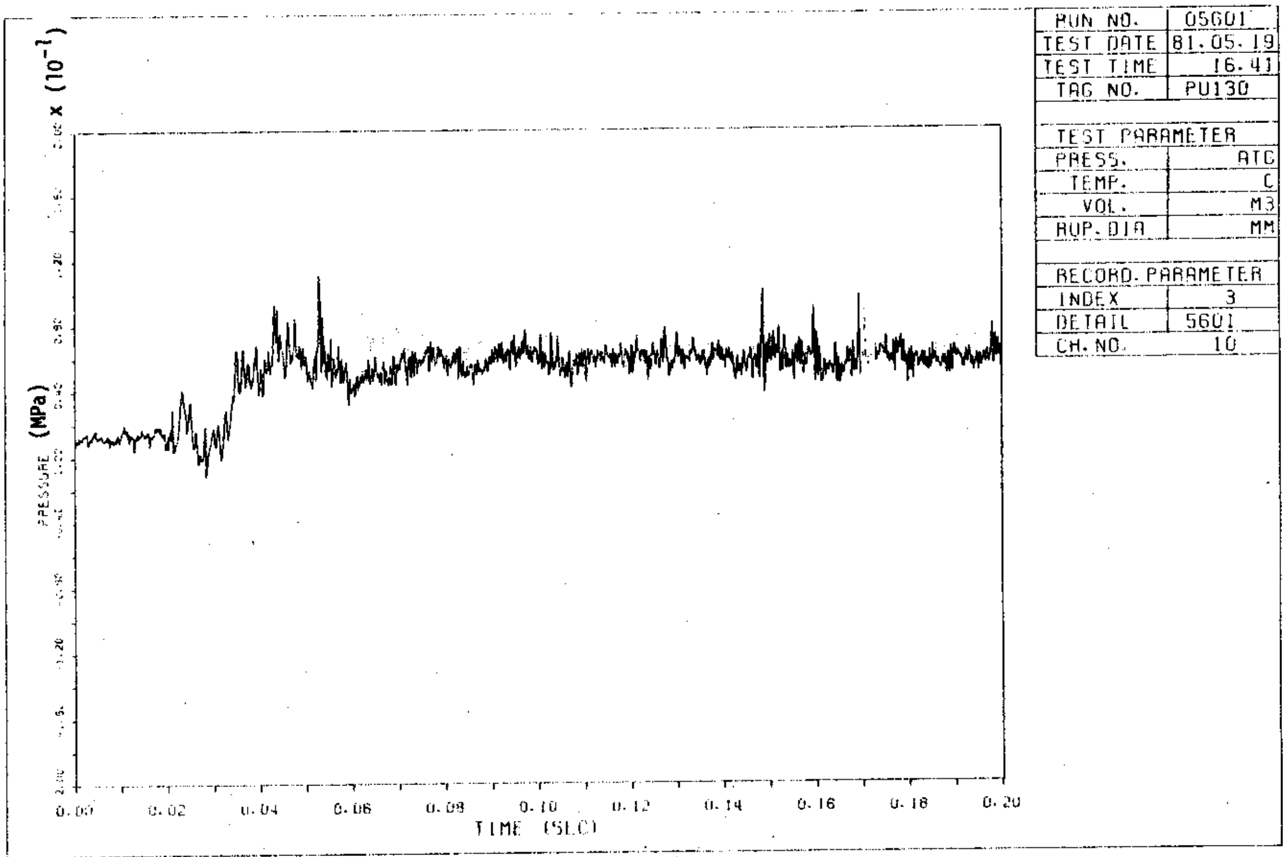


Fig. 9.10

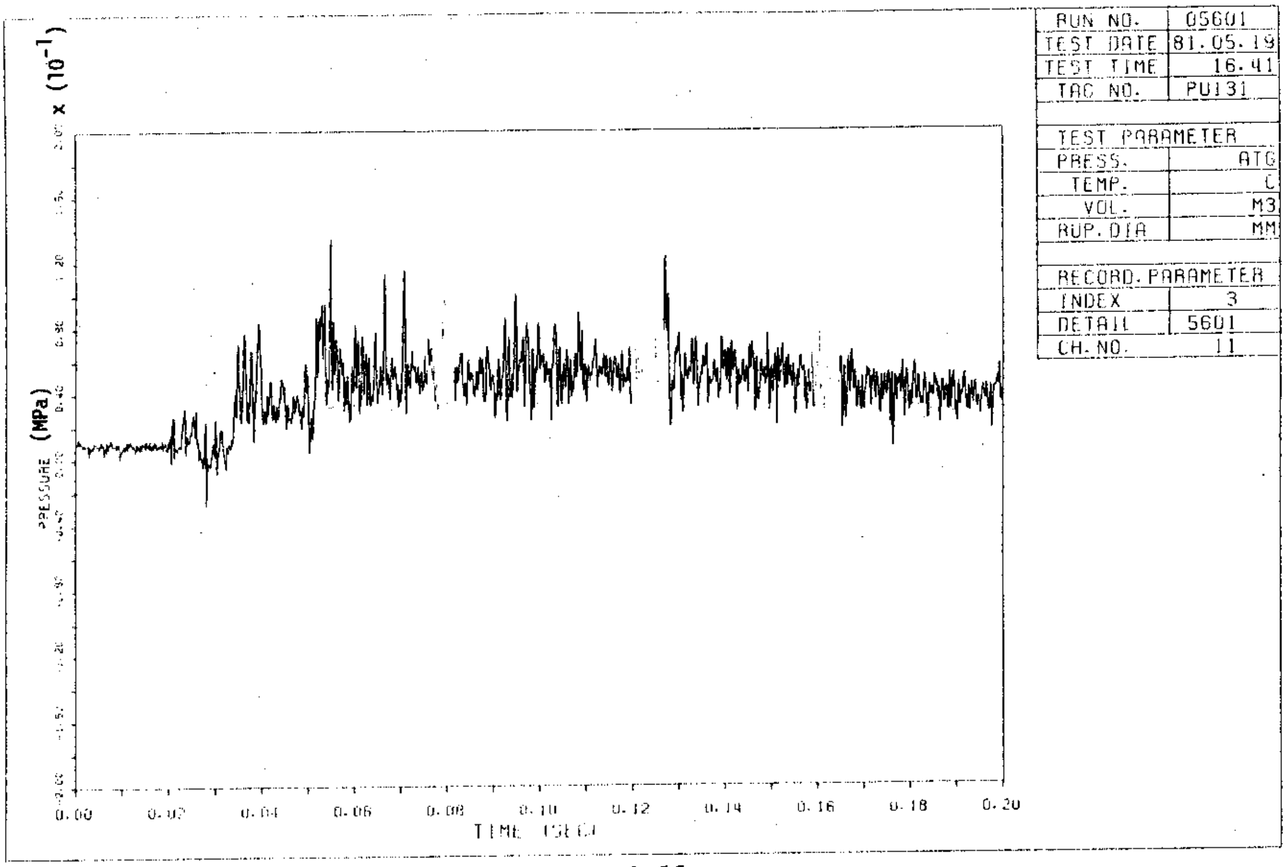


Fig. 9.11

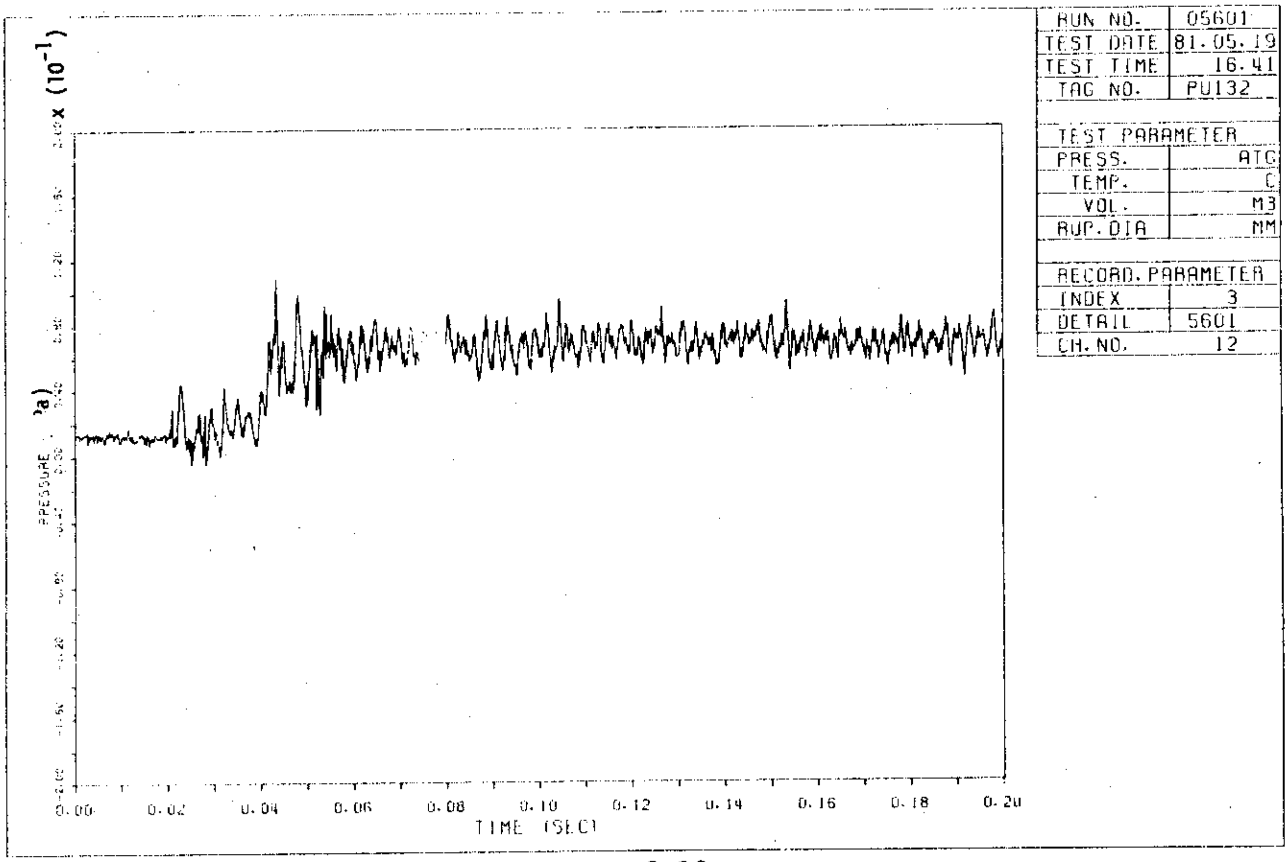
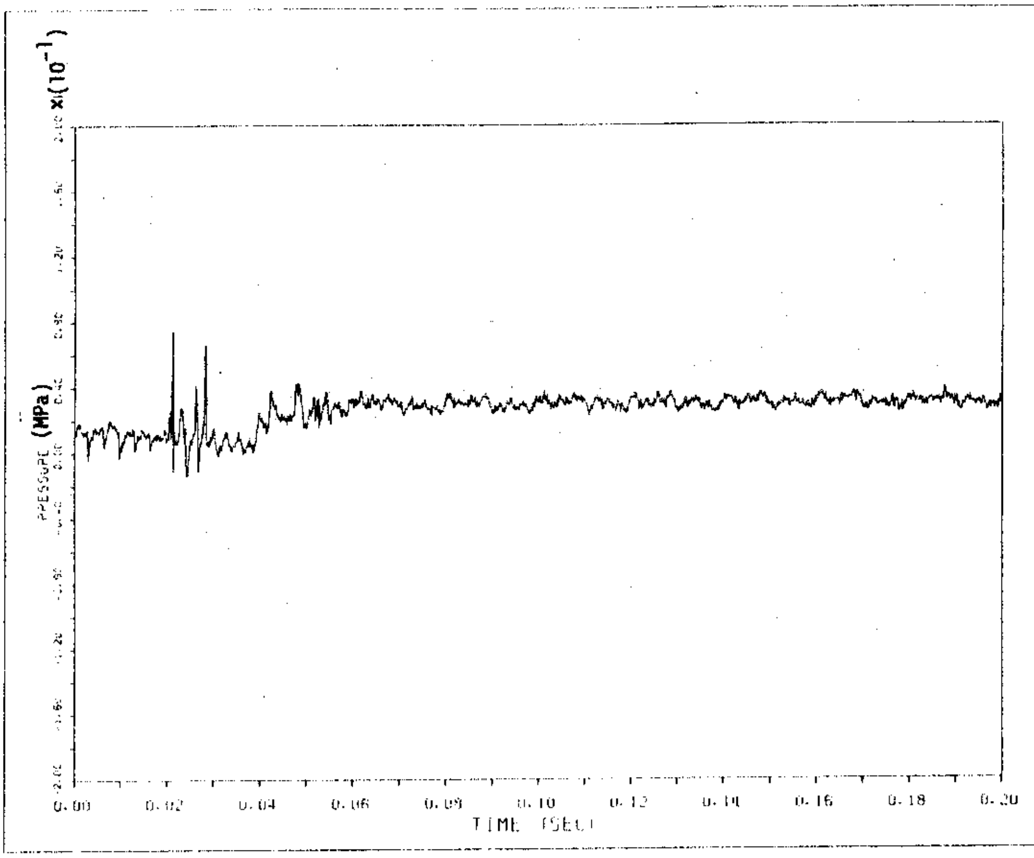
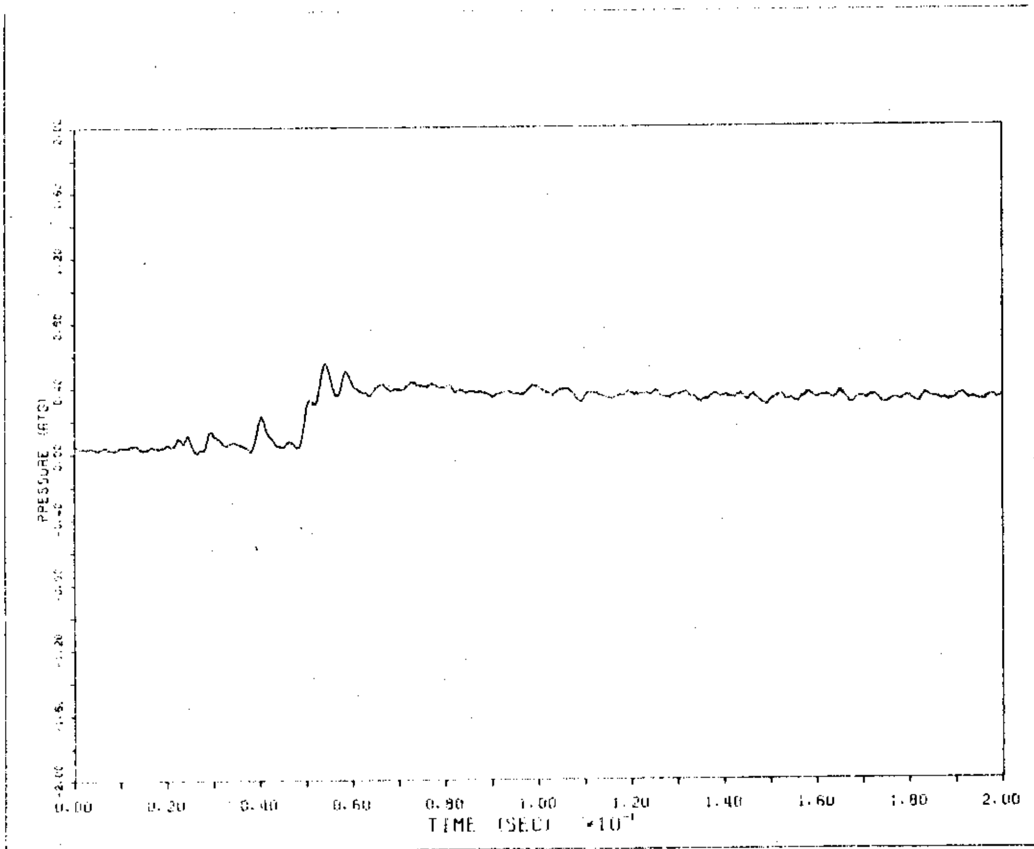


Fig. 9.12



RUN NO.	05601
TEST DATE	81.05.19
TEST TIME	16.41
TAG NO.	PU133
TEST PARAMETER	
PRESS.	ATG
TEMP.	C
VOL.	M3
RUP.DIA	MM
RECORD. PARAMETER	
INDEX	3
DETAIL	5601
CH.NO.	13

Fig. 9.13



RUN NO.	05601
TEST DATE	81.05.19
TEST TIME	16.41
TAG NO.	PU121
TEST PARAMETER	
PRESS.	ATG
TEMP.	C
VOL.	M3
RUP.DIA	MM
RECORD. PARAMETER	
INDEX	3
DETAIL	5601
CH.NO.	1

100 Hz Low pass

Fig. 9.14

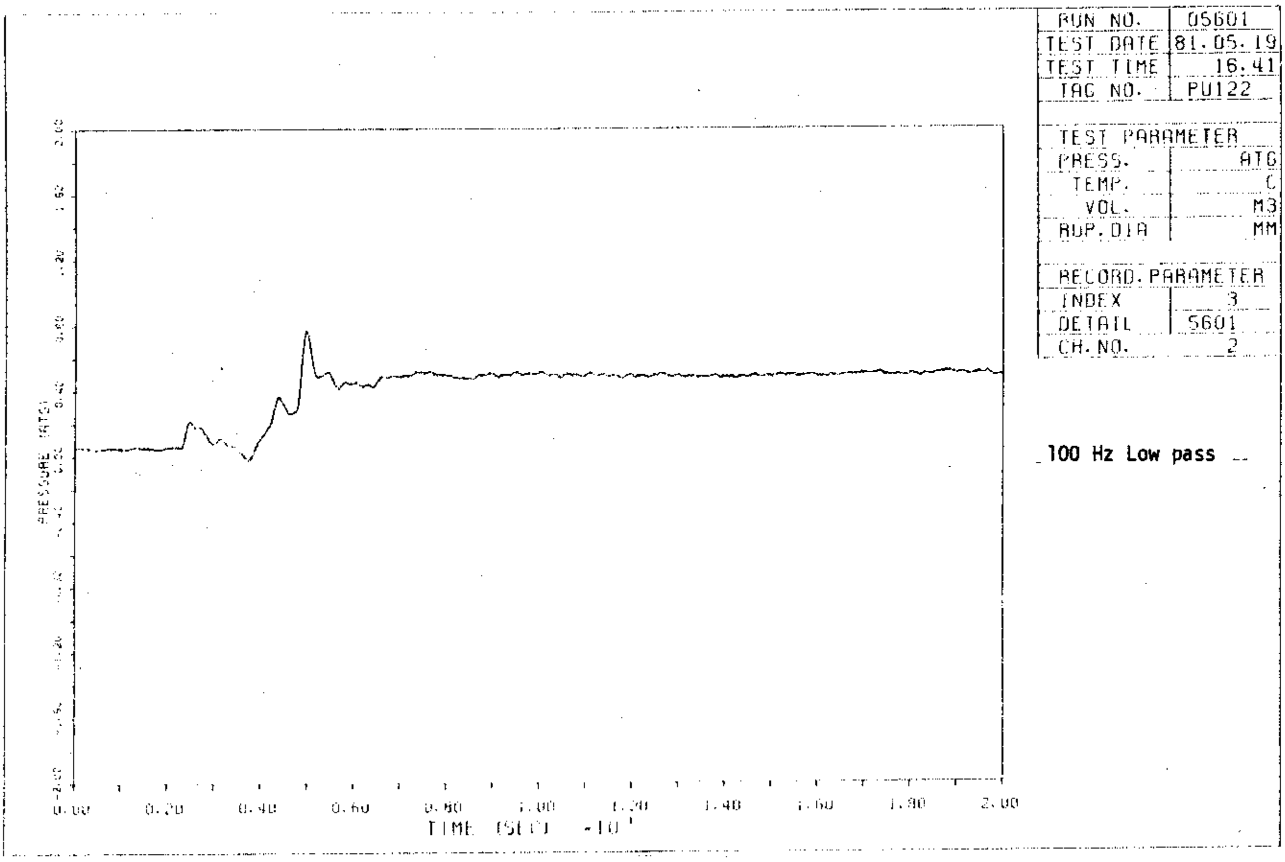


Fig. 9.15

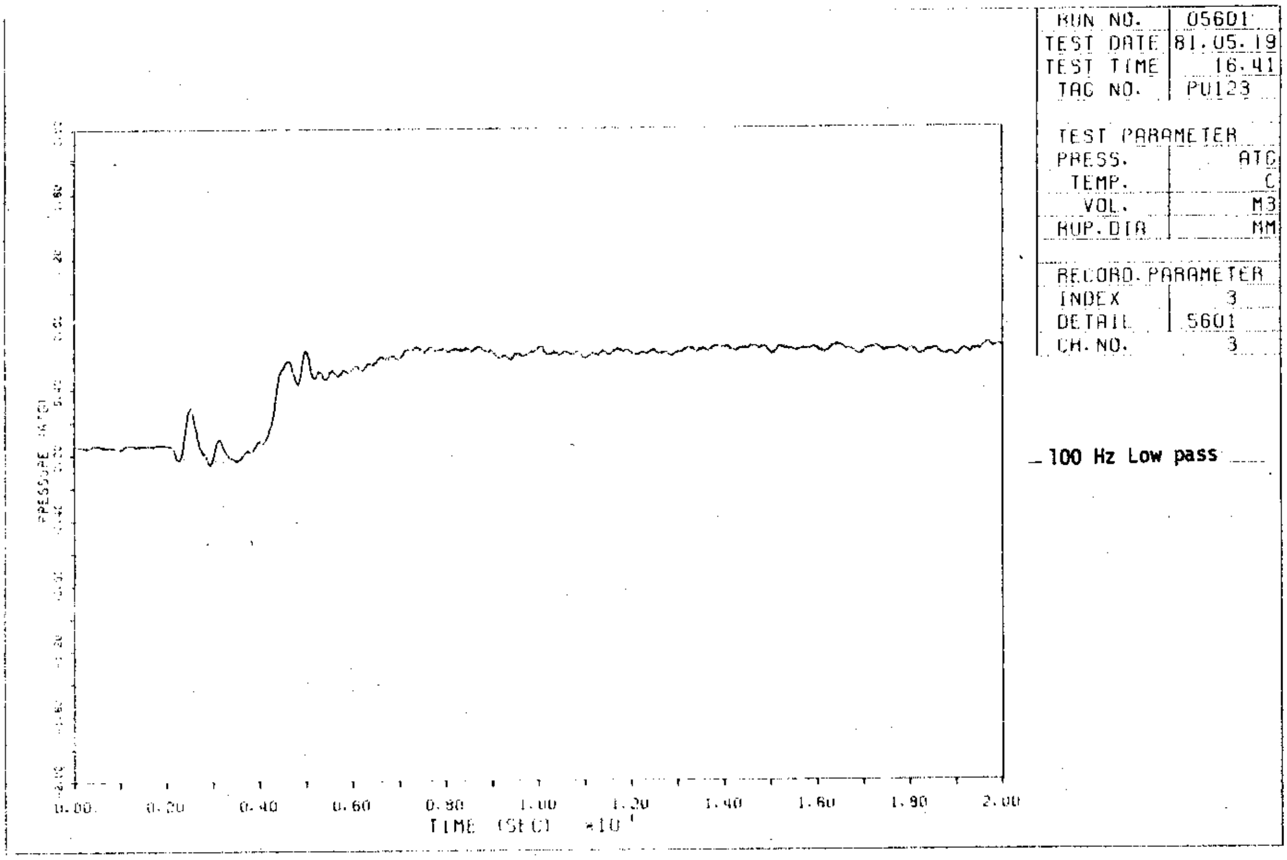


Fig. 9.16

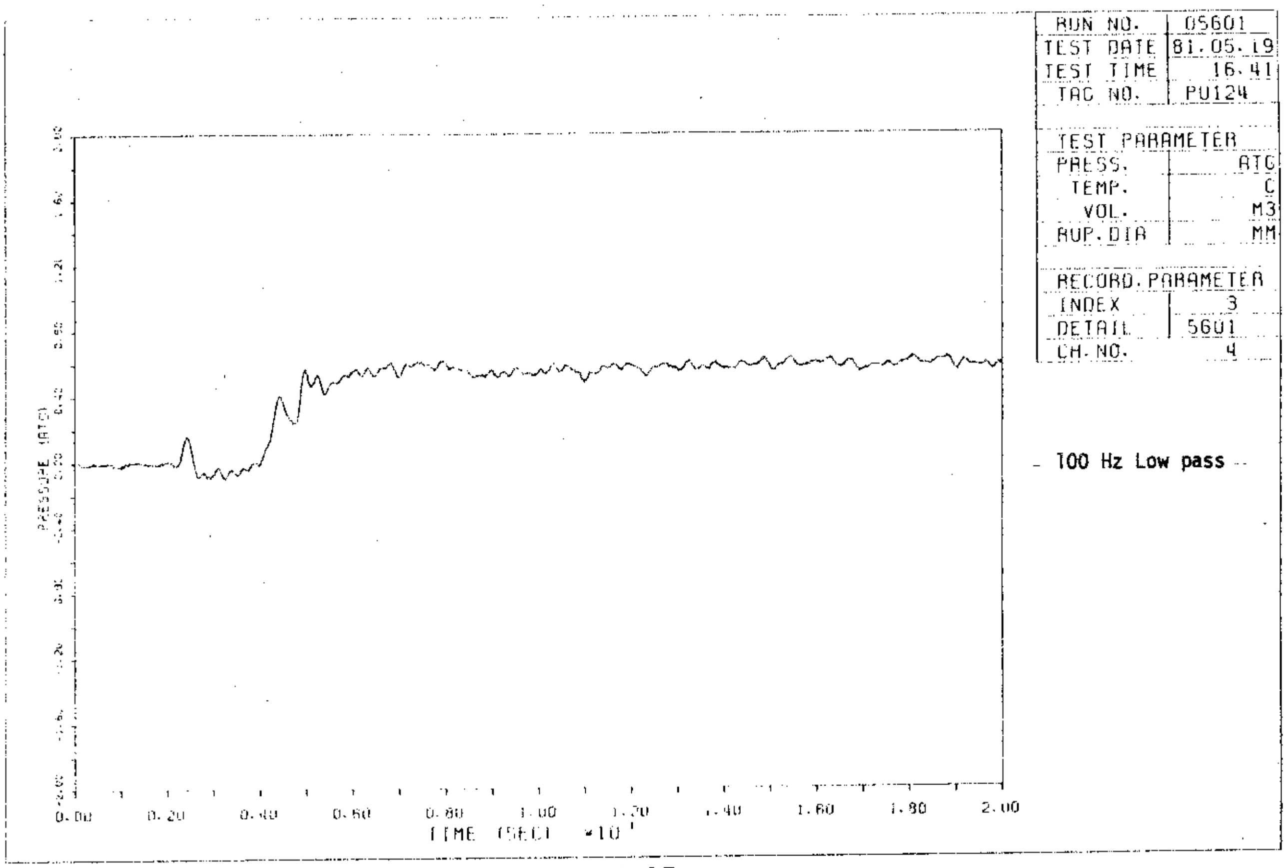


Fig. 9.17

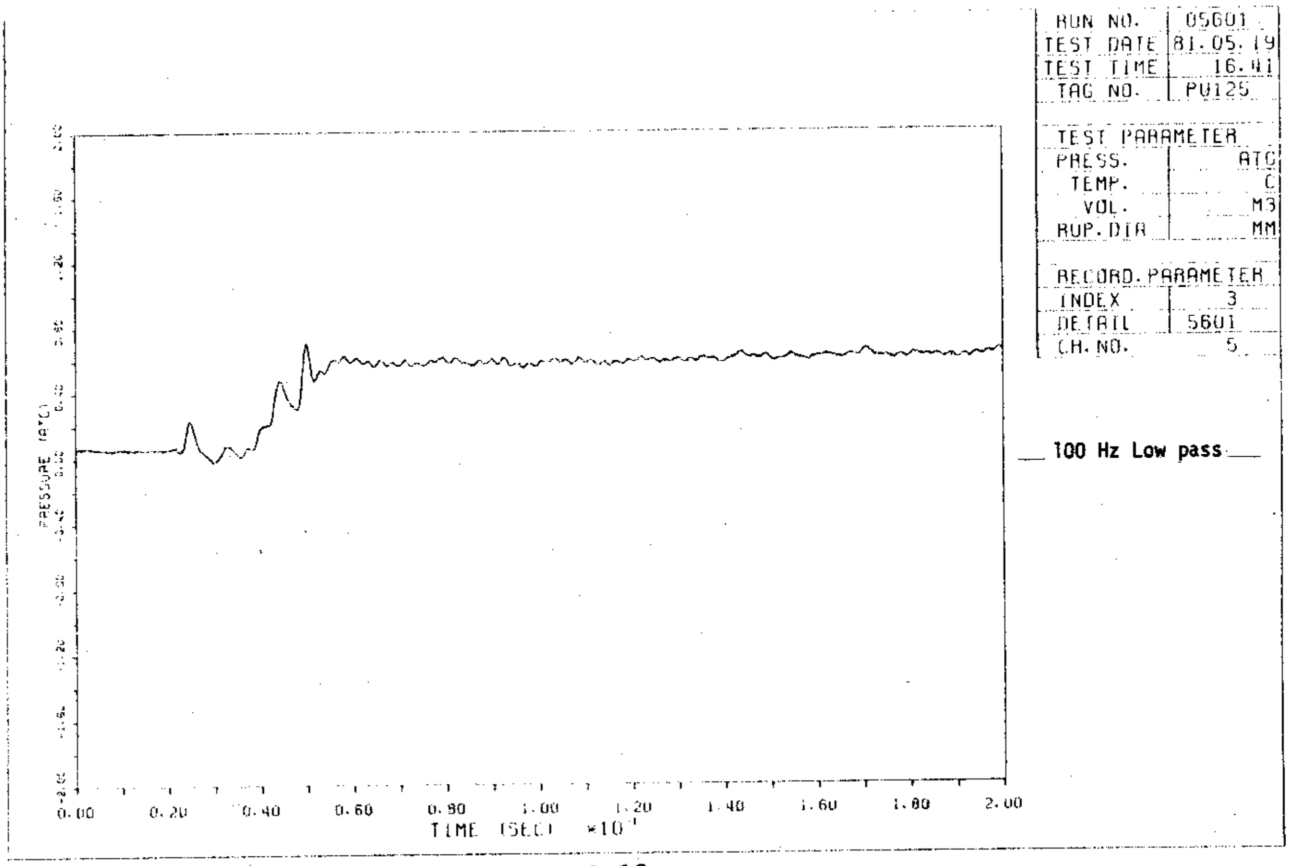


Fig. 9.18

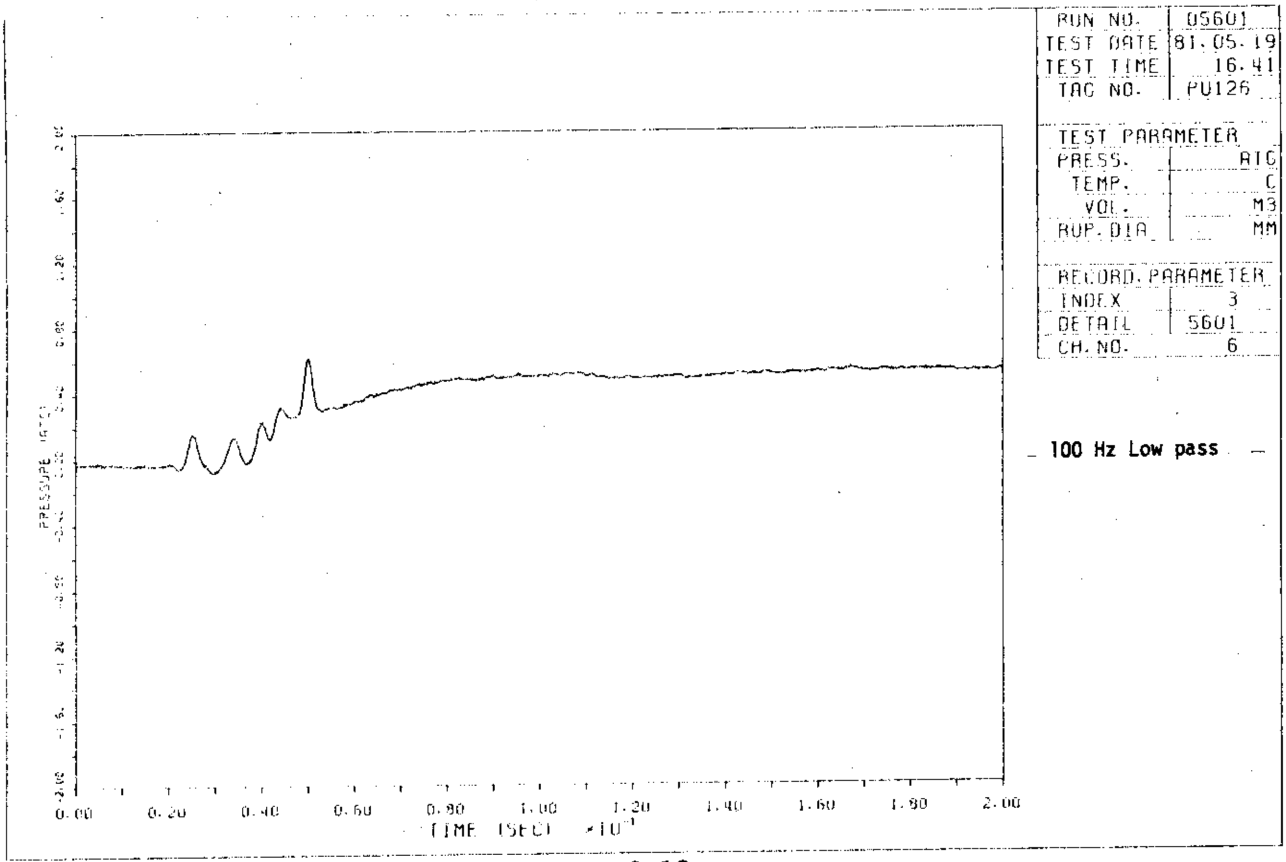


Fig. 9.19

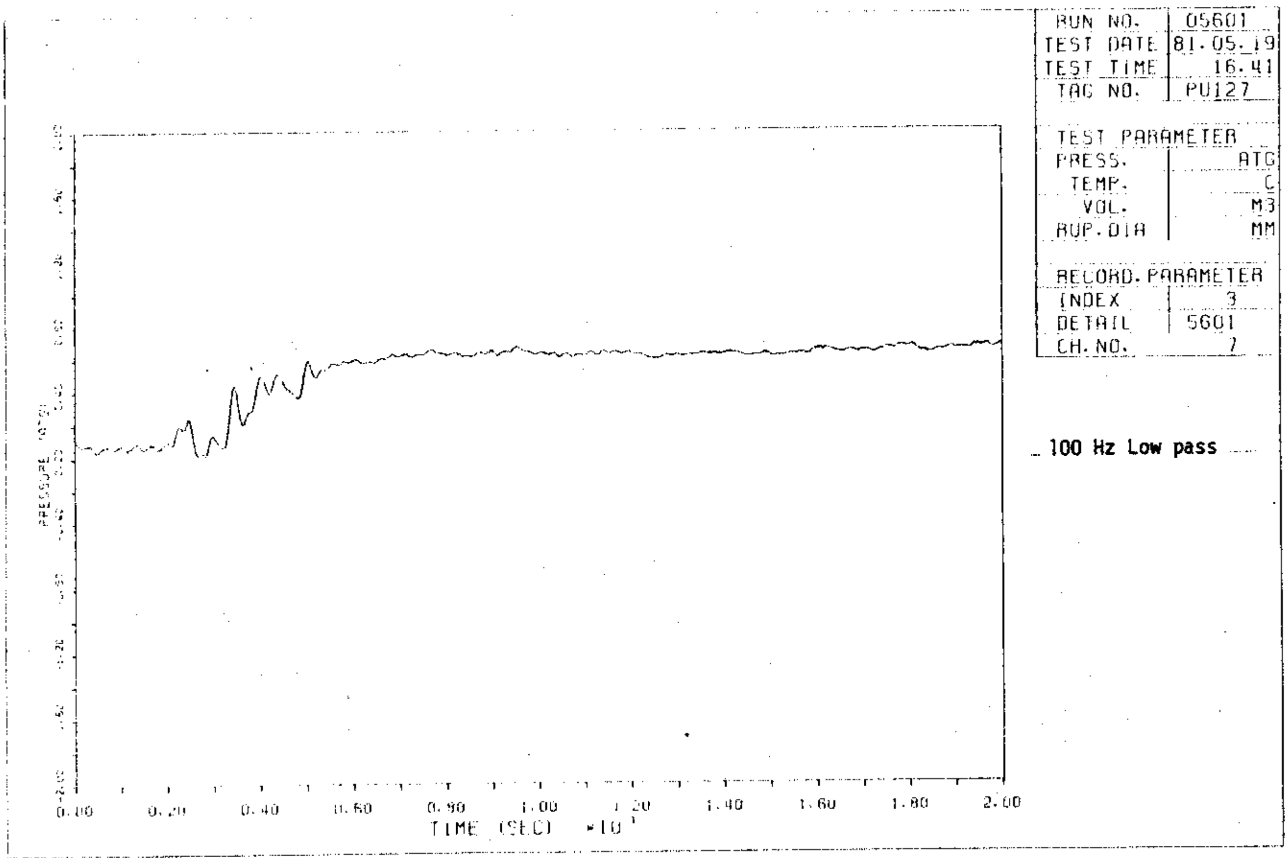
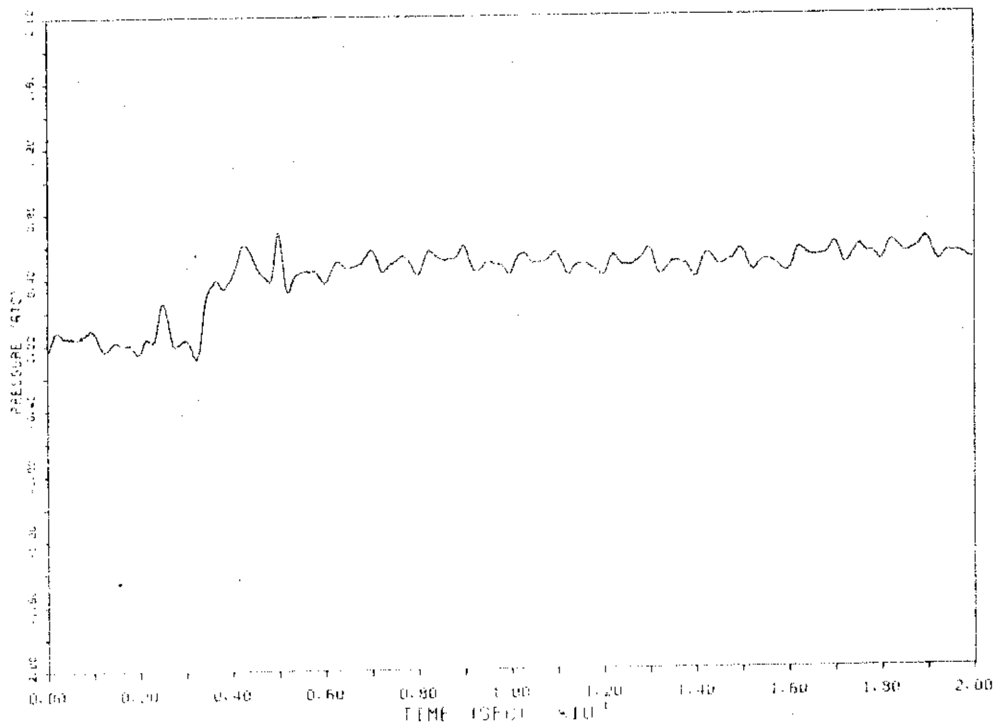


Fig. 9.20



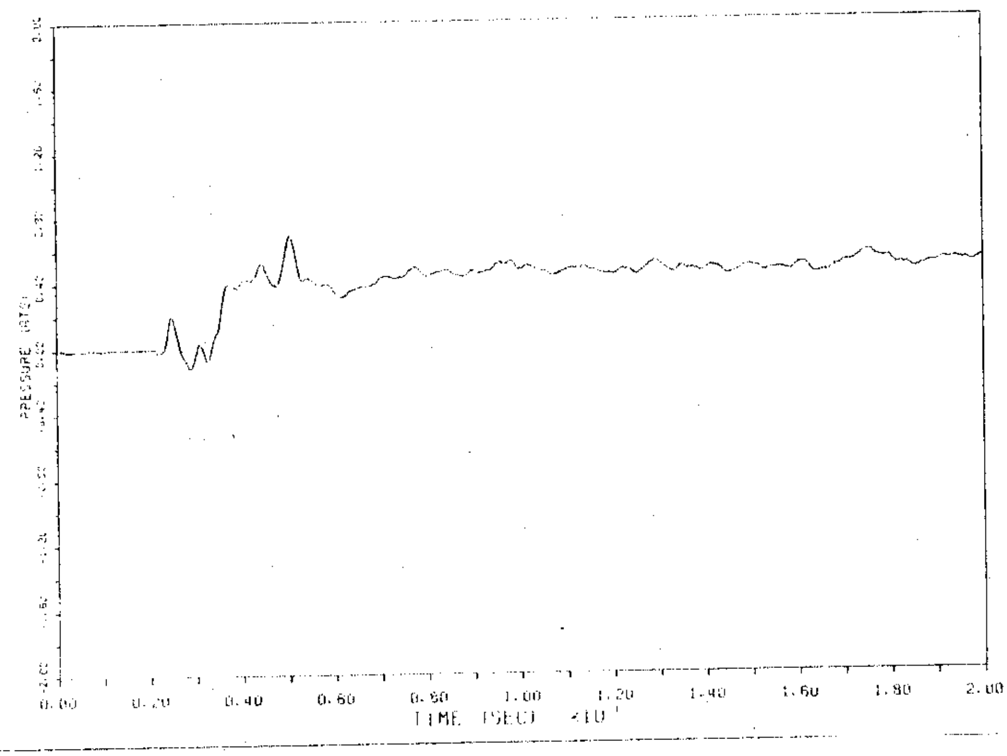
RUN NO.	05601
TEST DATE	81.05.19
TEST TIME	16.41
TAG NO.	PU128

TEST PARAMETER	
PRESS.	ATG
TEMP.	C
VOL.	M3
RUP.DIA	MM

RECORD.PARAMETER	
INDEX	3
DETAIL	5601
CH.NO.	8

100 Hz Low pass

Fig. 9.21



RUN NO.	05601
TEST DATE	81.05.19
TEST TIME	16.41
TAG NO.	PU129

TEST PARAMETER	
PRESS.	ATG
TEMP.	C
VOL.	M3
RUP.DIA	MM

RECORD.PARAMETER	
INDEX	3
DETAIL	5601
CH.NO.	9

100 Hz Low pass

Fig. 9.22

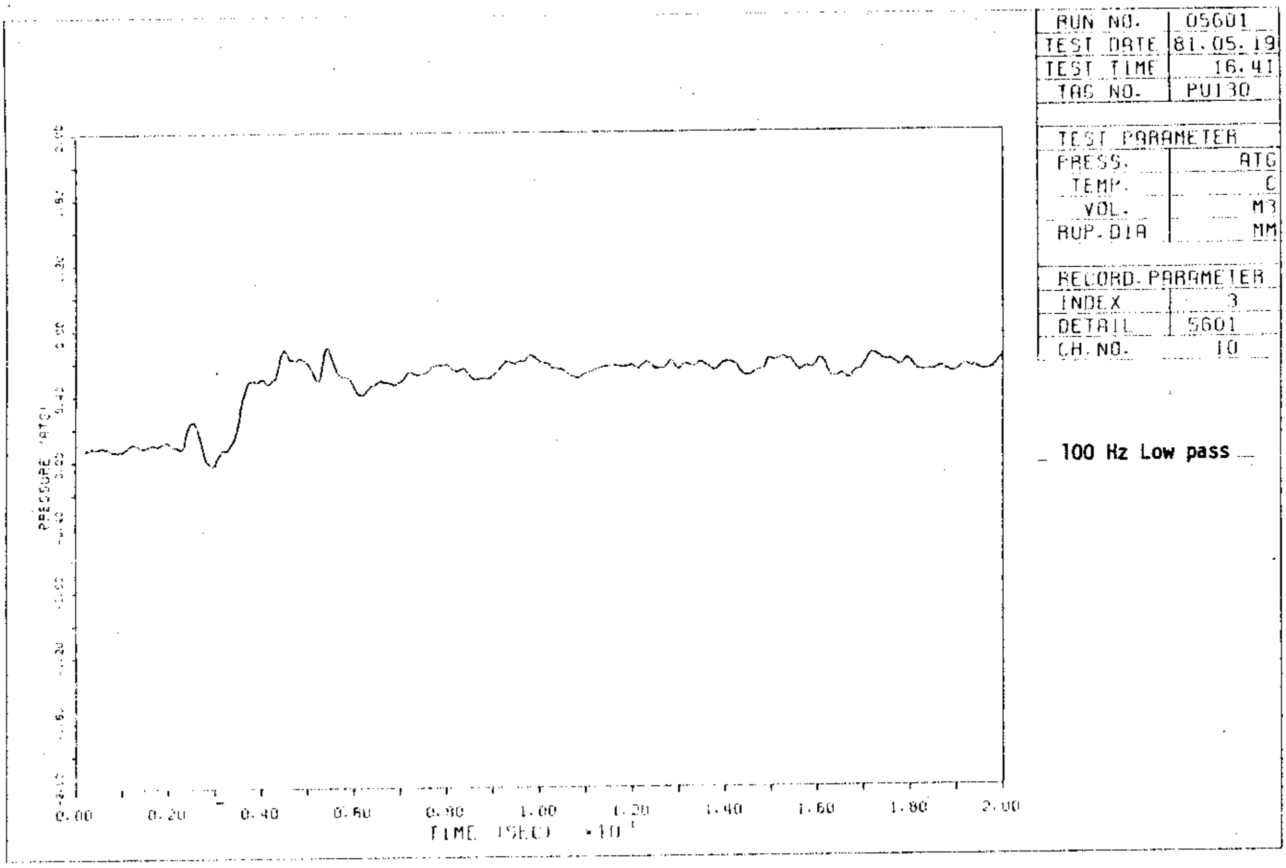


Fig. 9.23

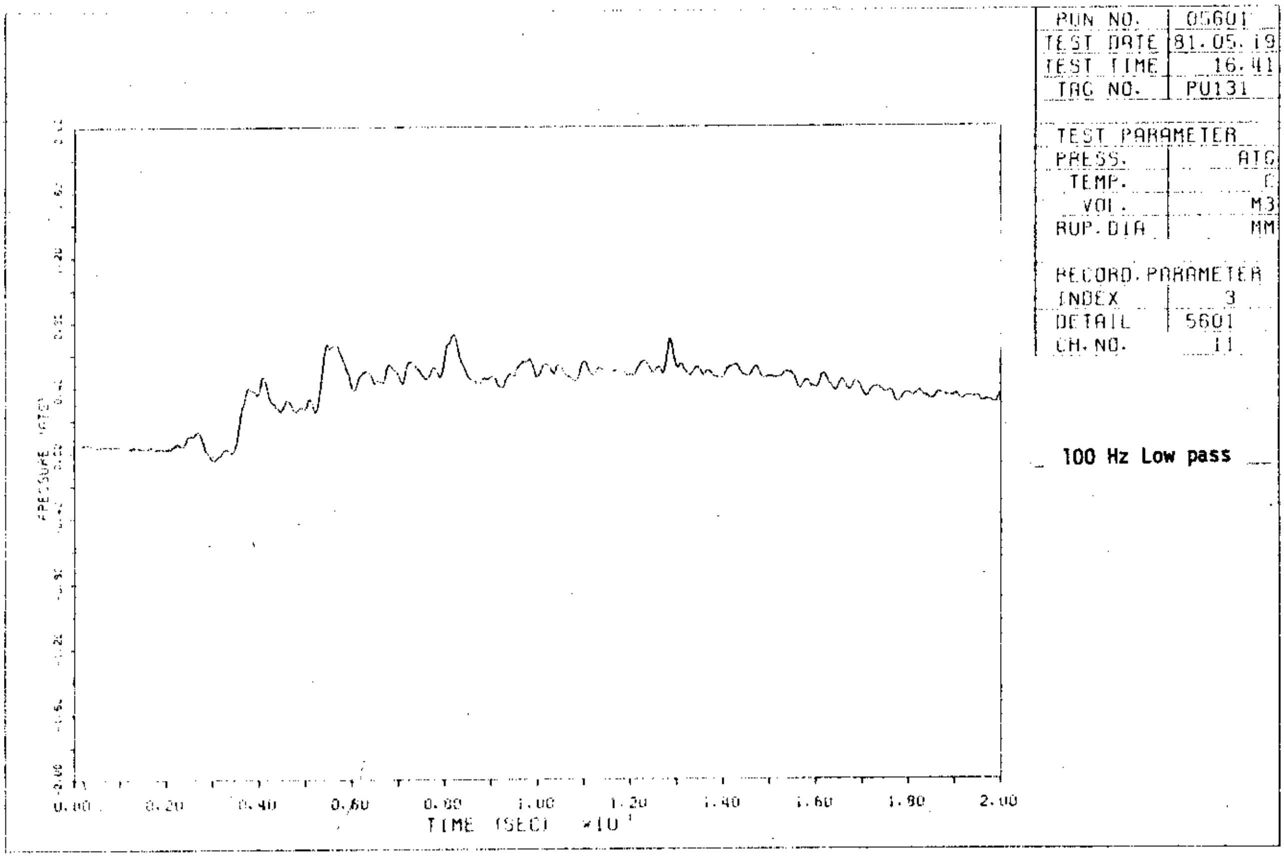


Fig. 9.24

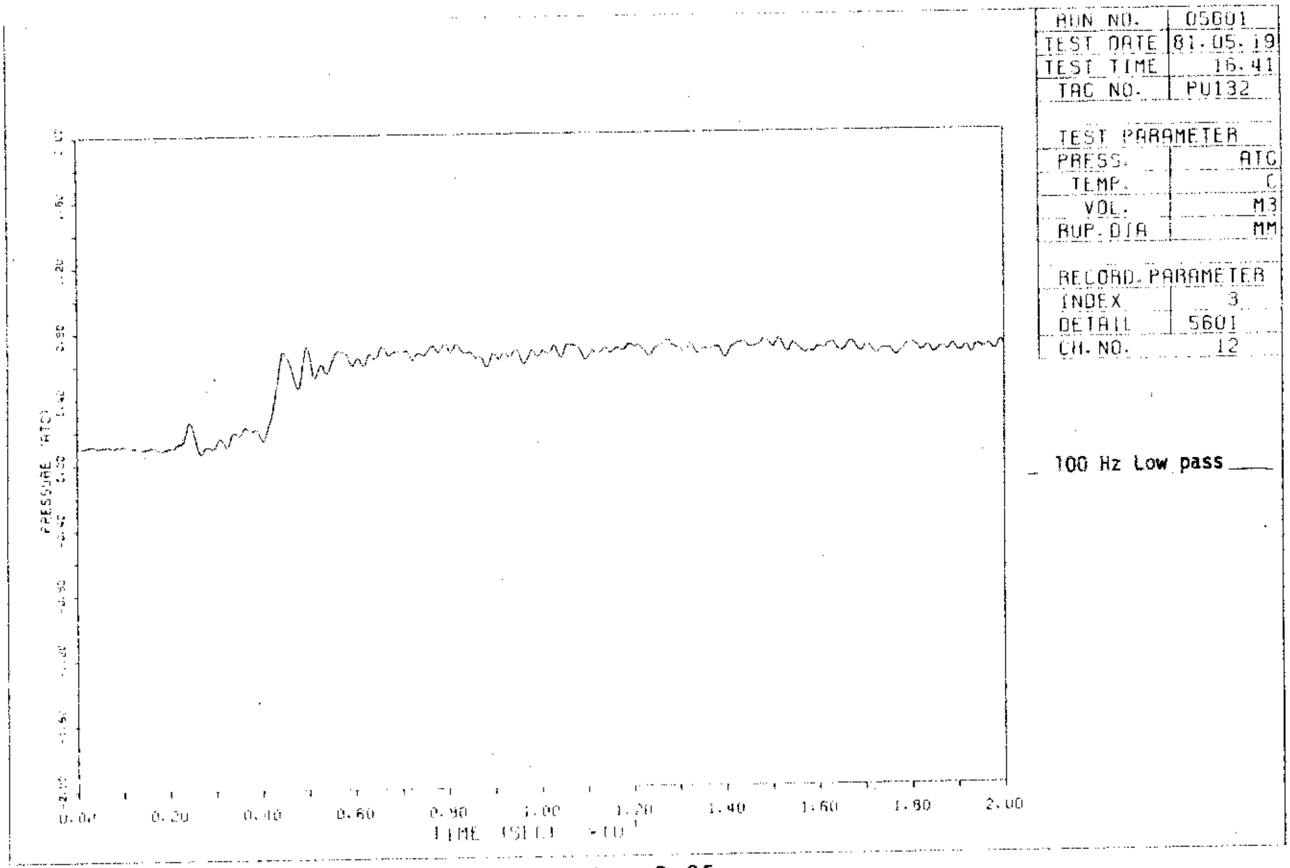


Fig. 9.25

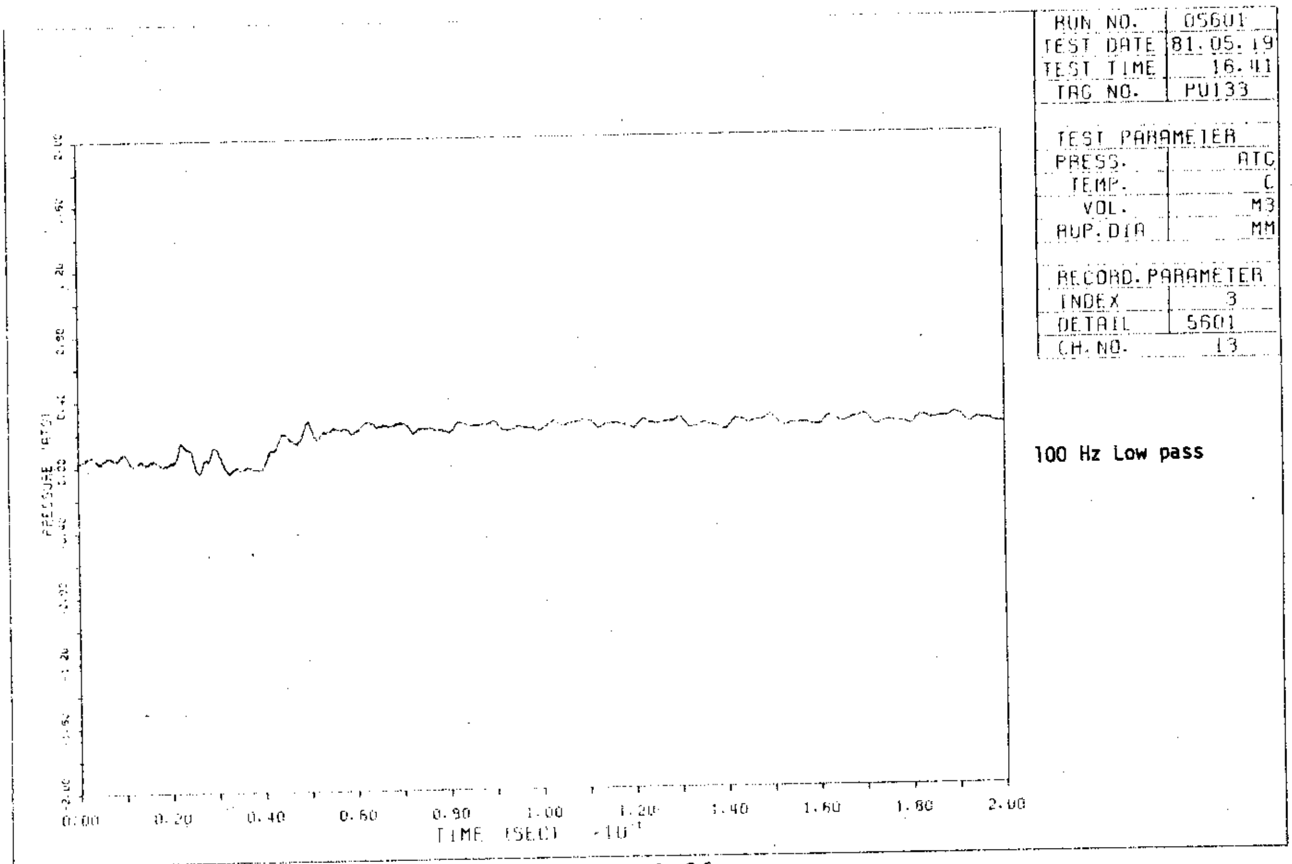


Fig. 9.26

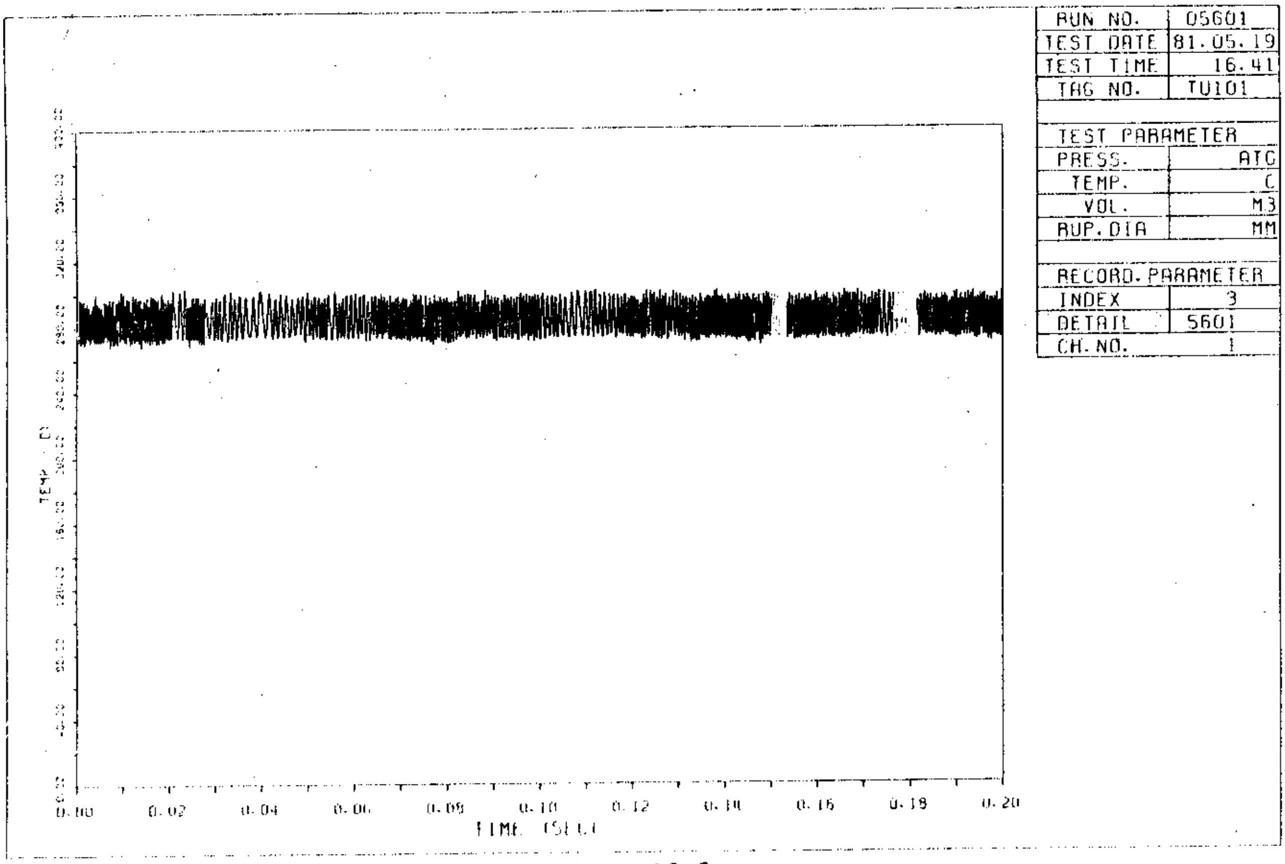


Fig. 10.1

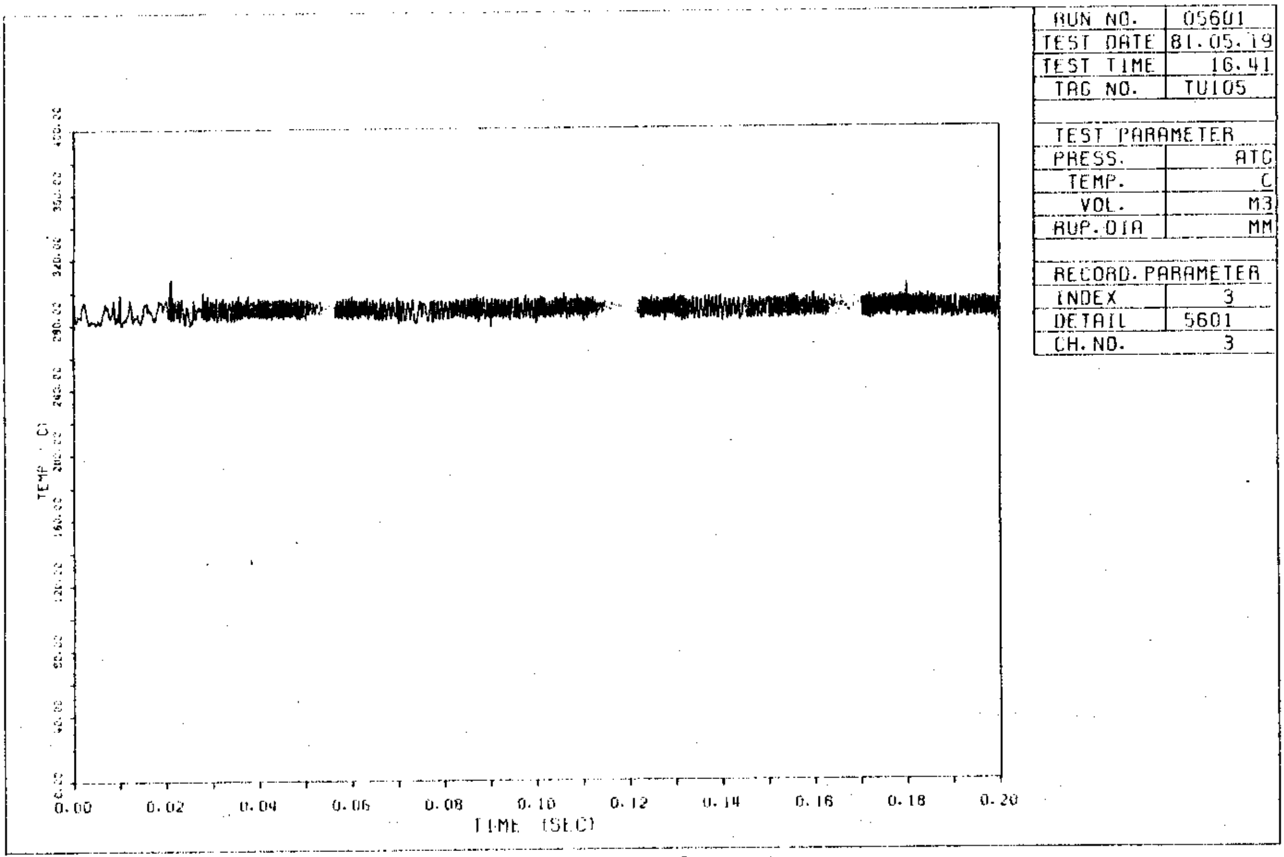


Fig. 10.2

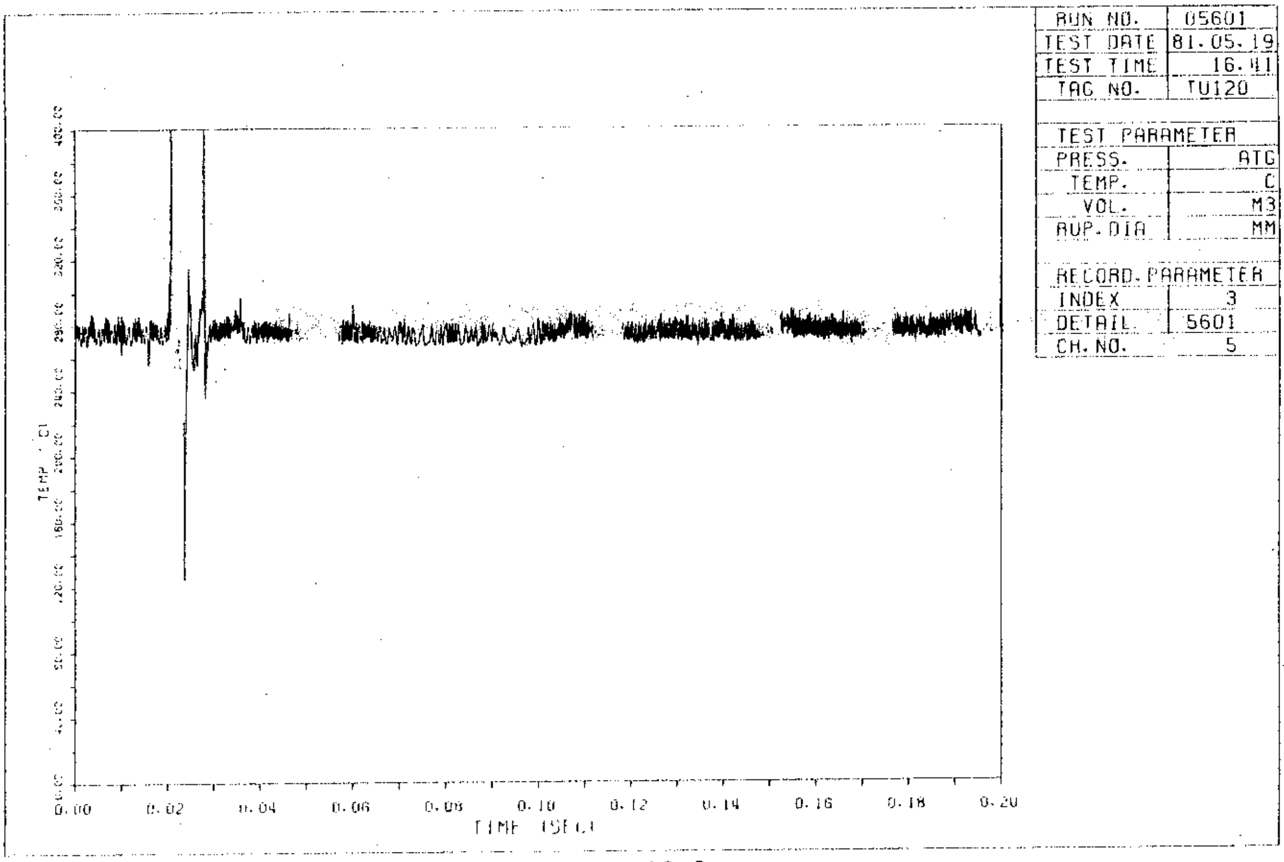


Fig. 10.3

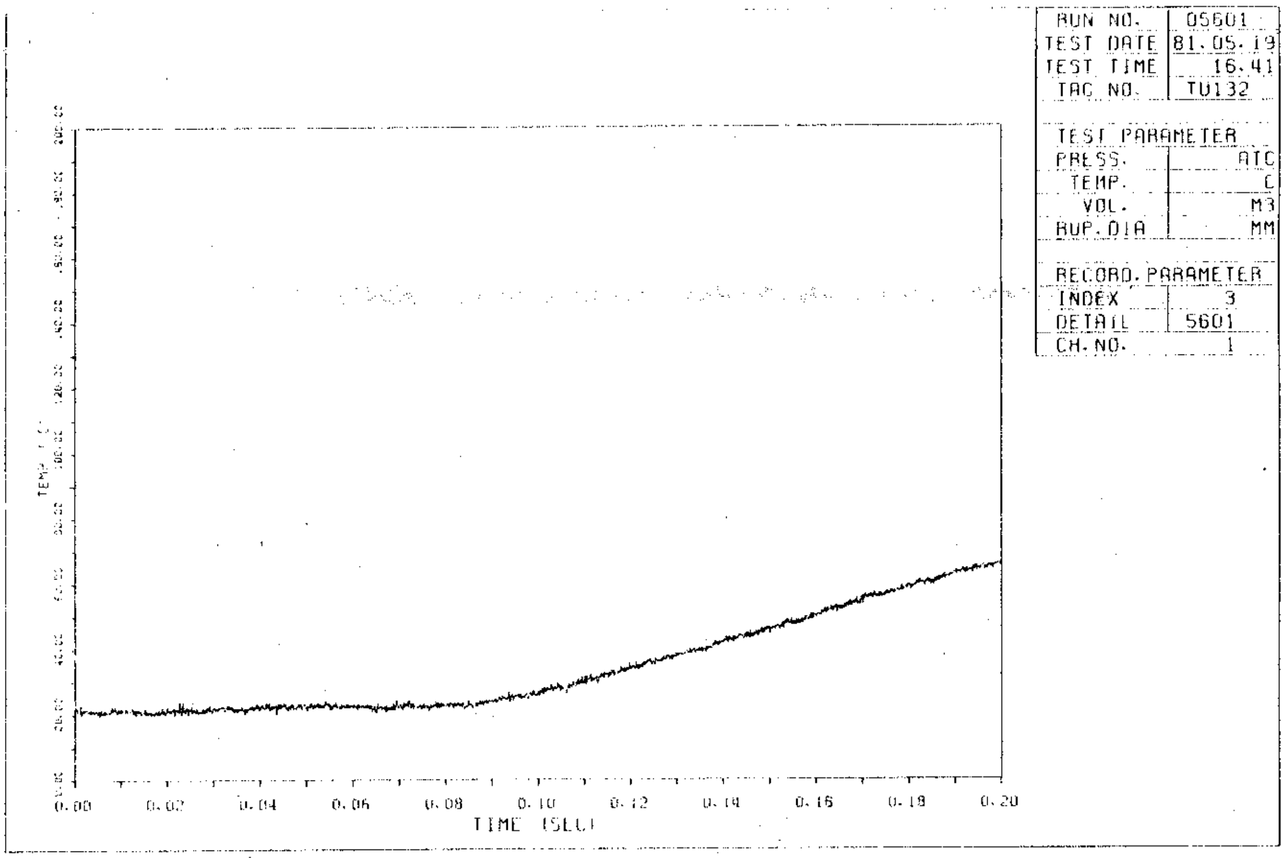


Fig. 11.1

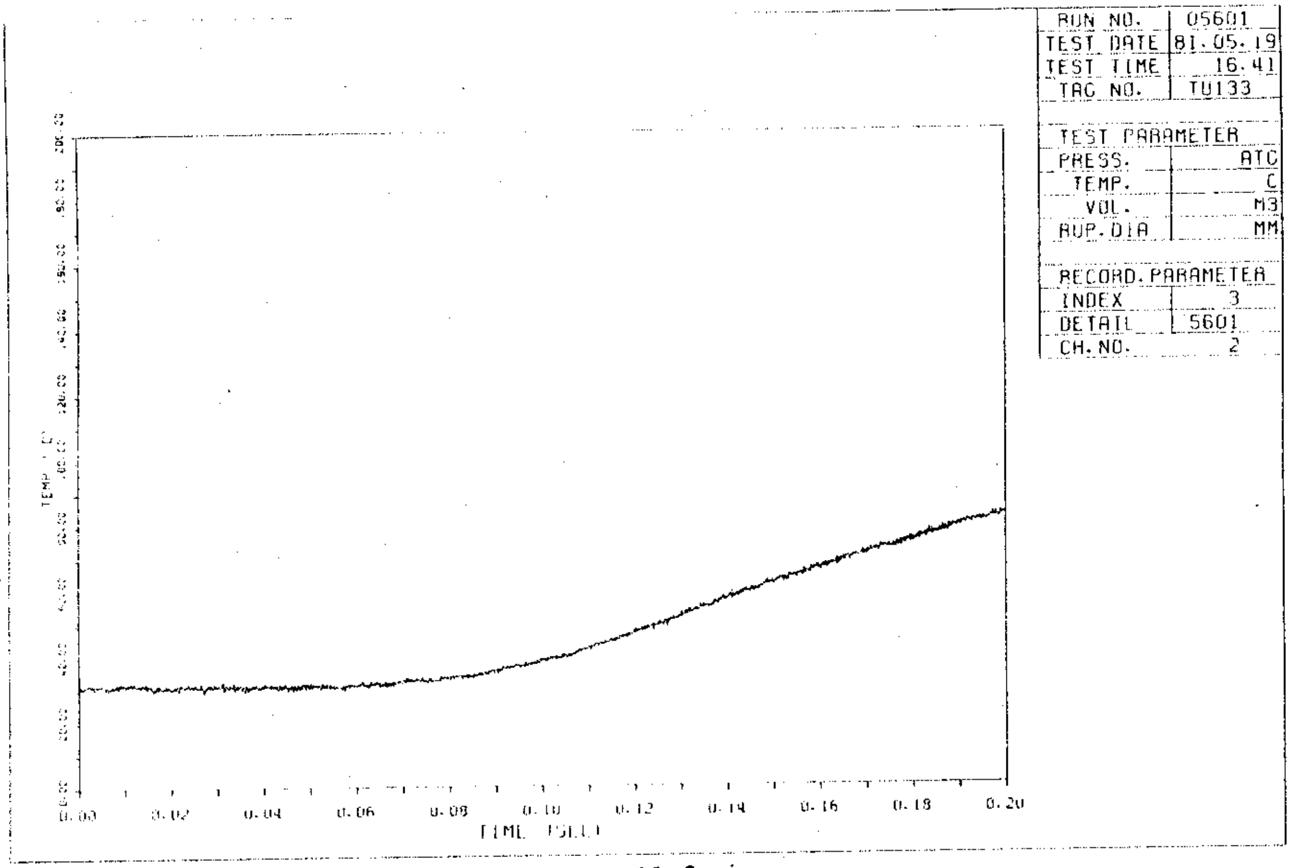


Fig. 11.2

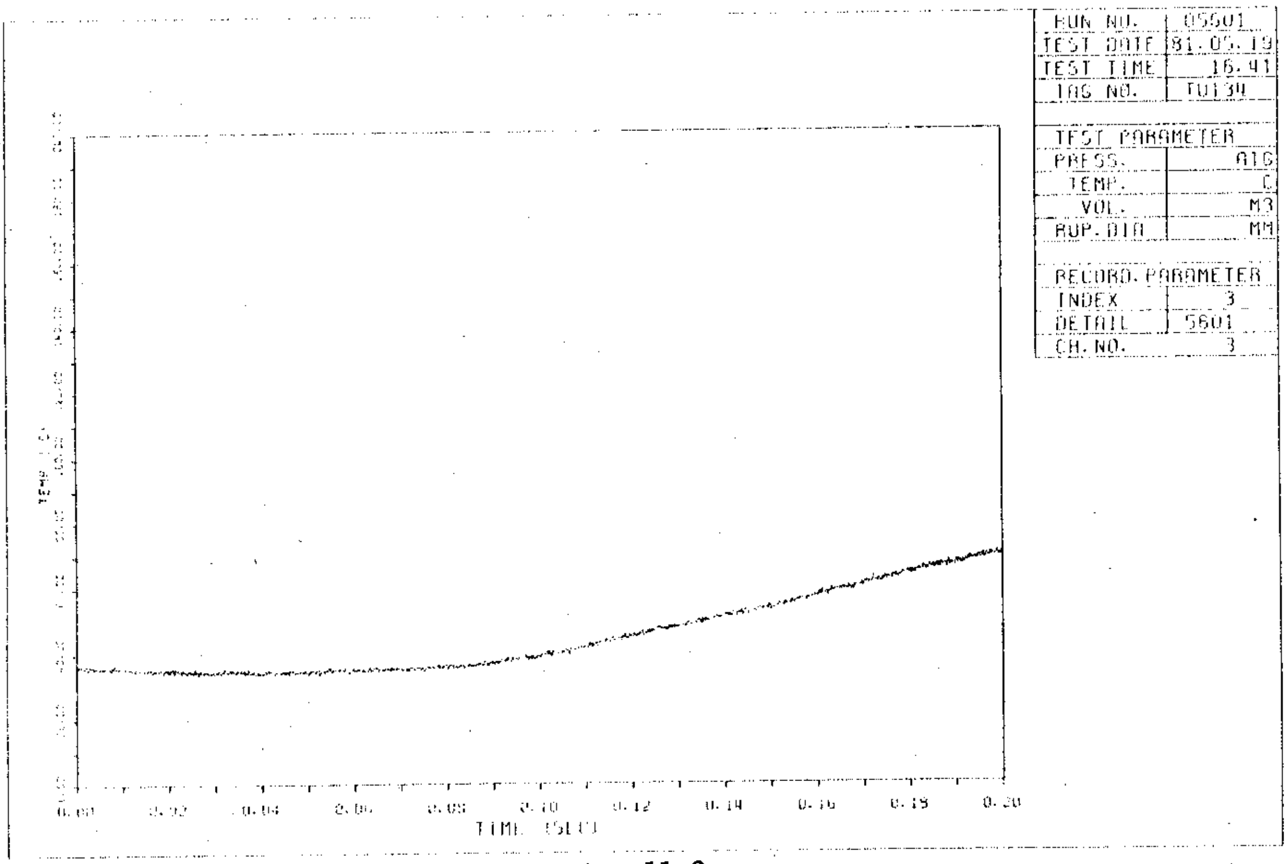


Fig. 11.3

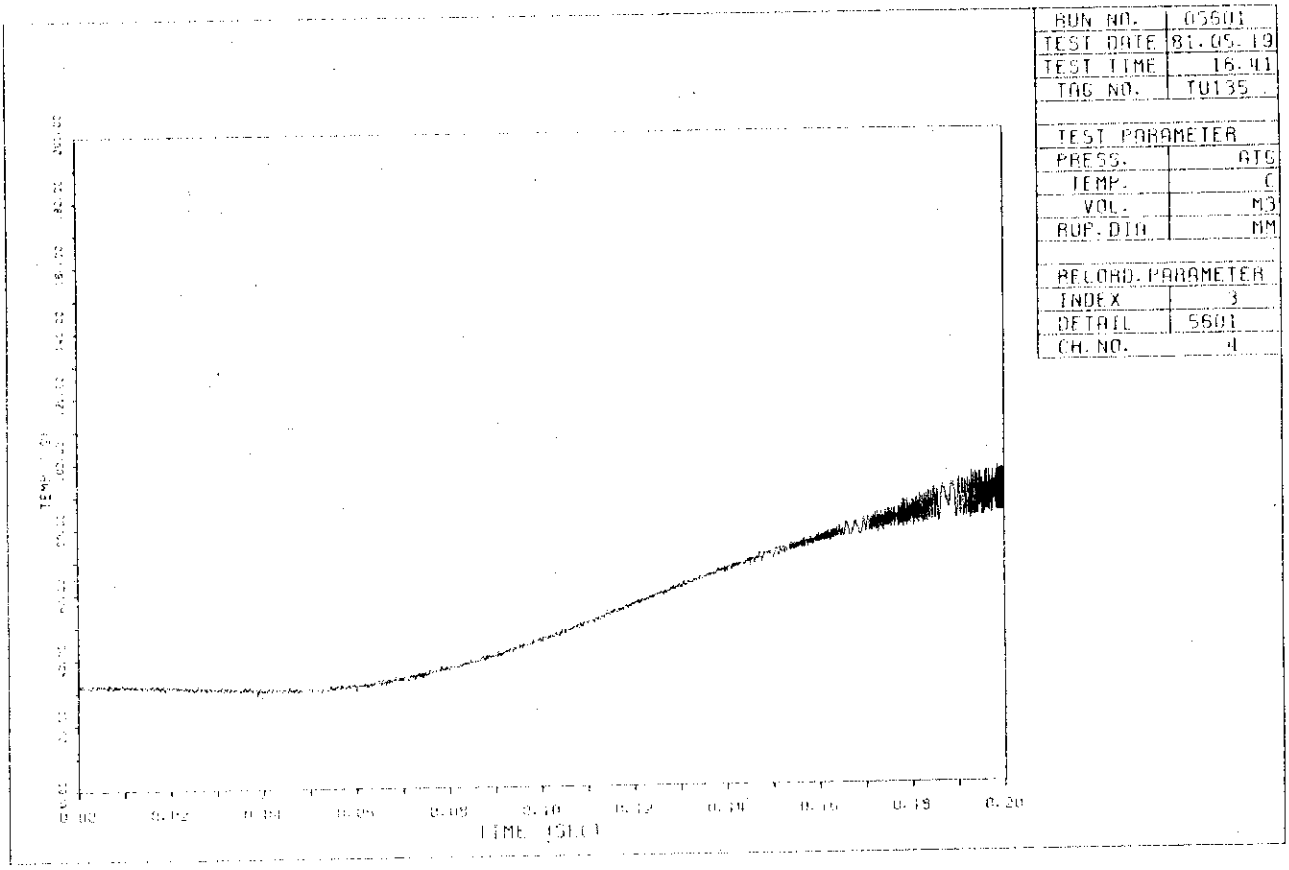


Fig. 11.4

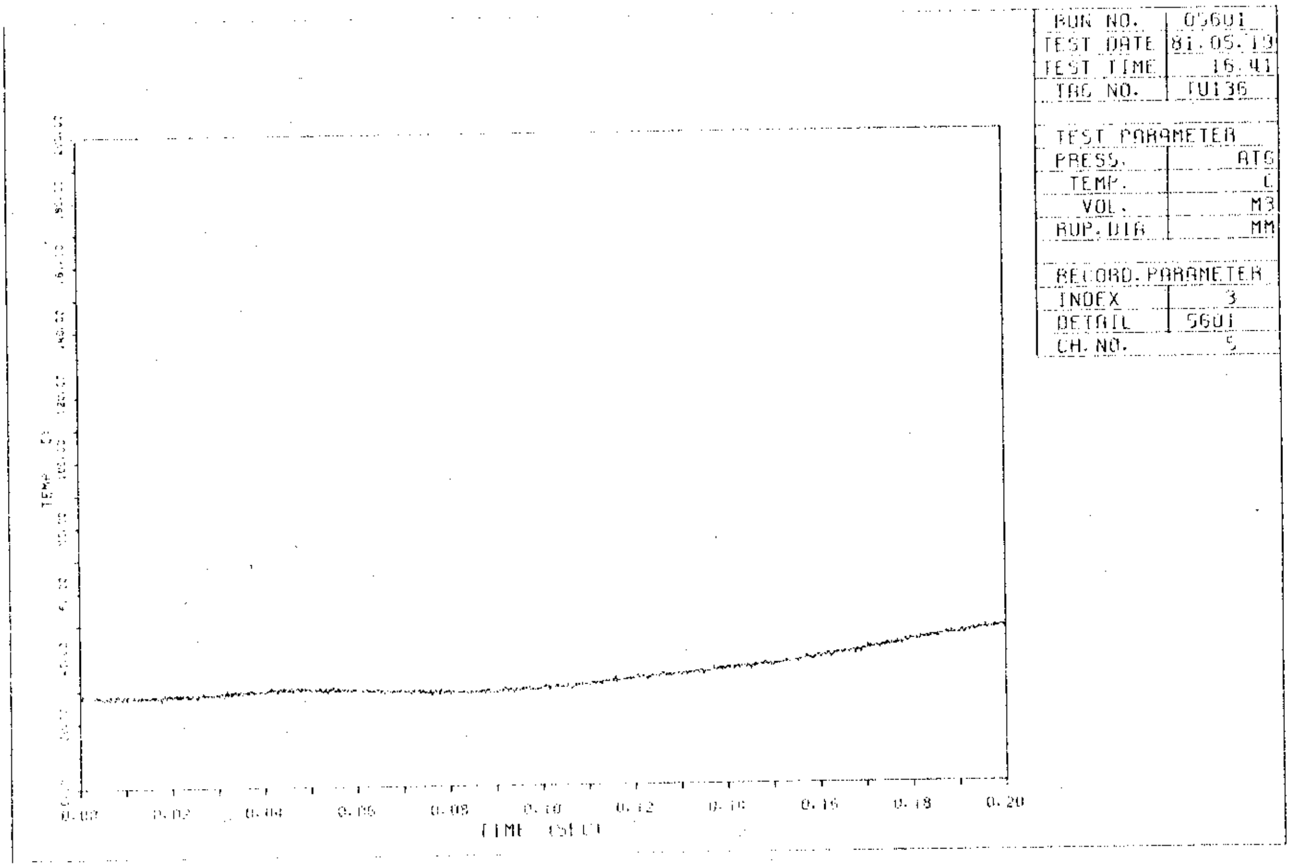


Fig. 11.5

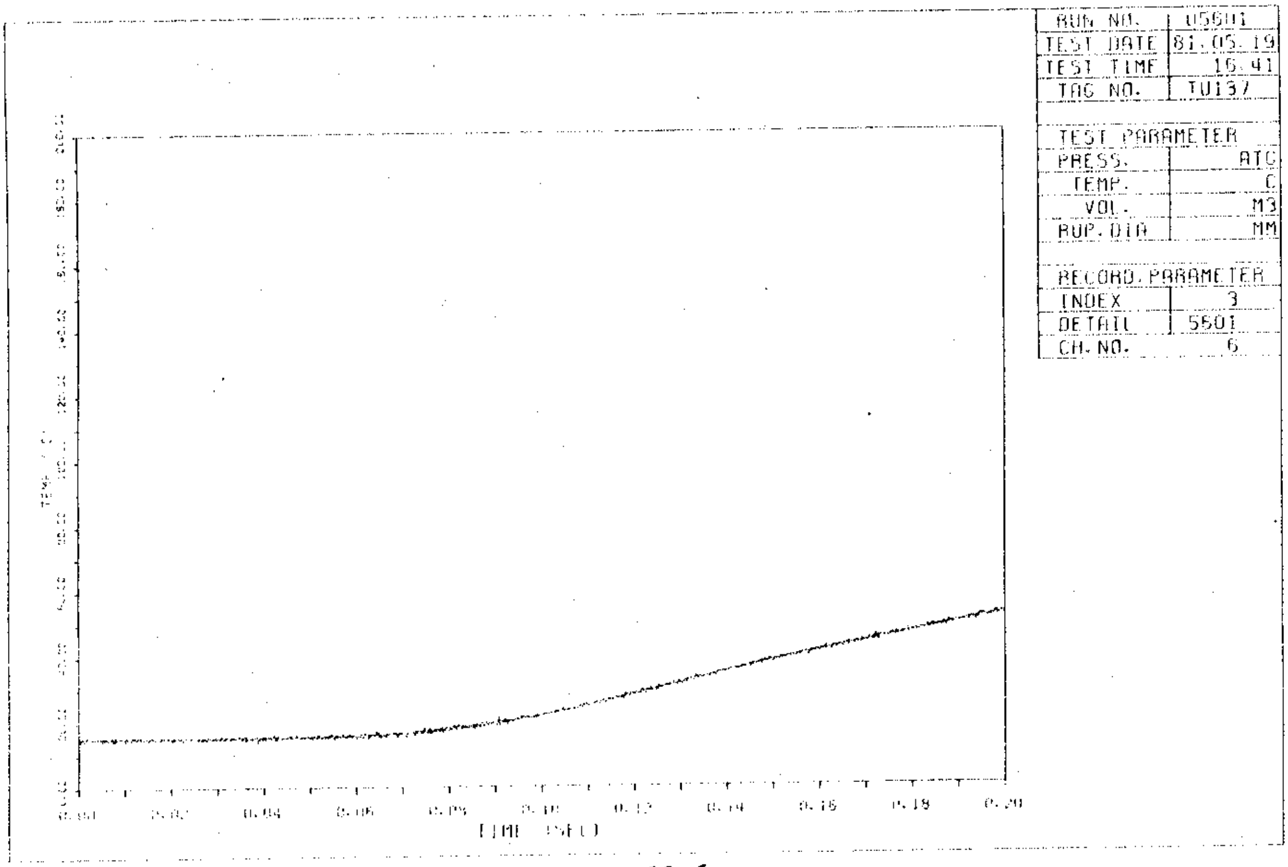


Fig. 11.6

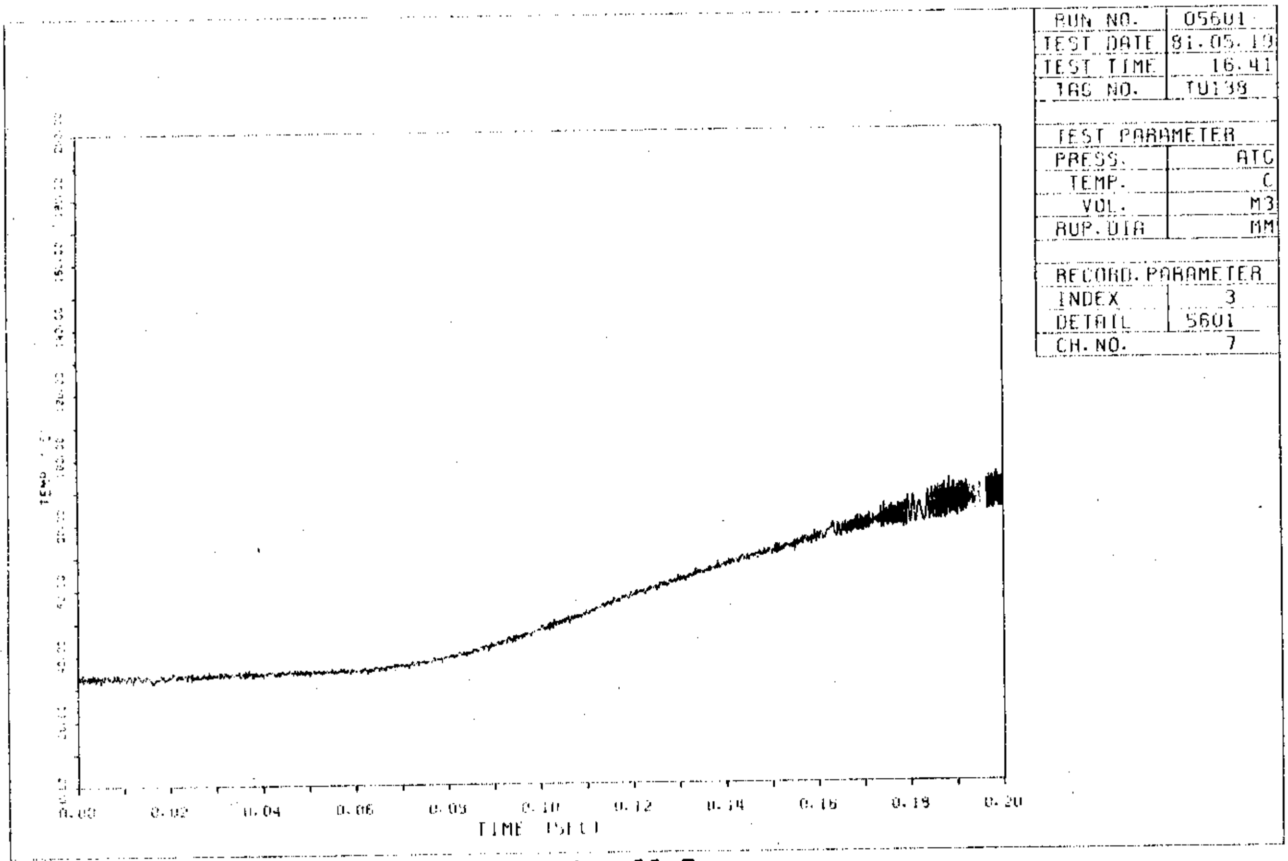


Fig. 11.7

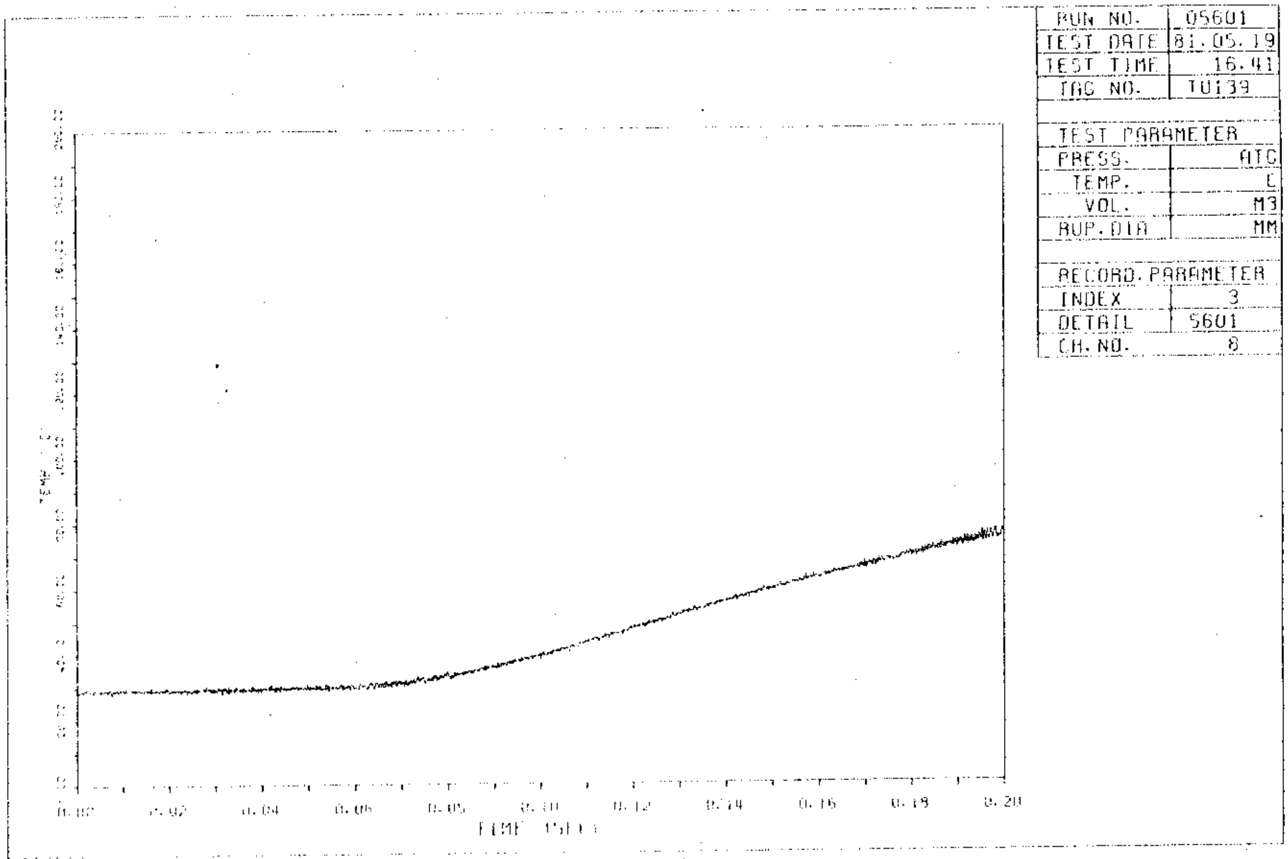


Fig. 11.8

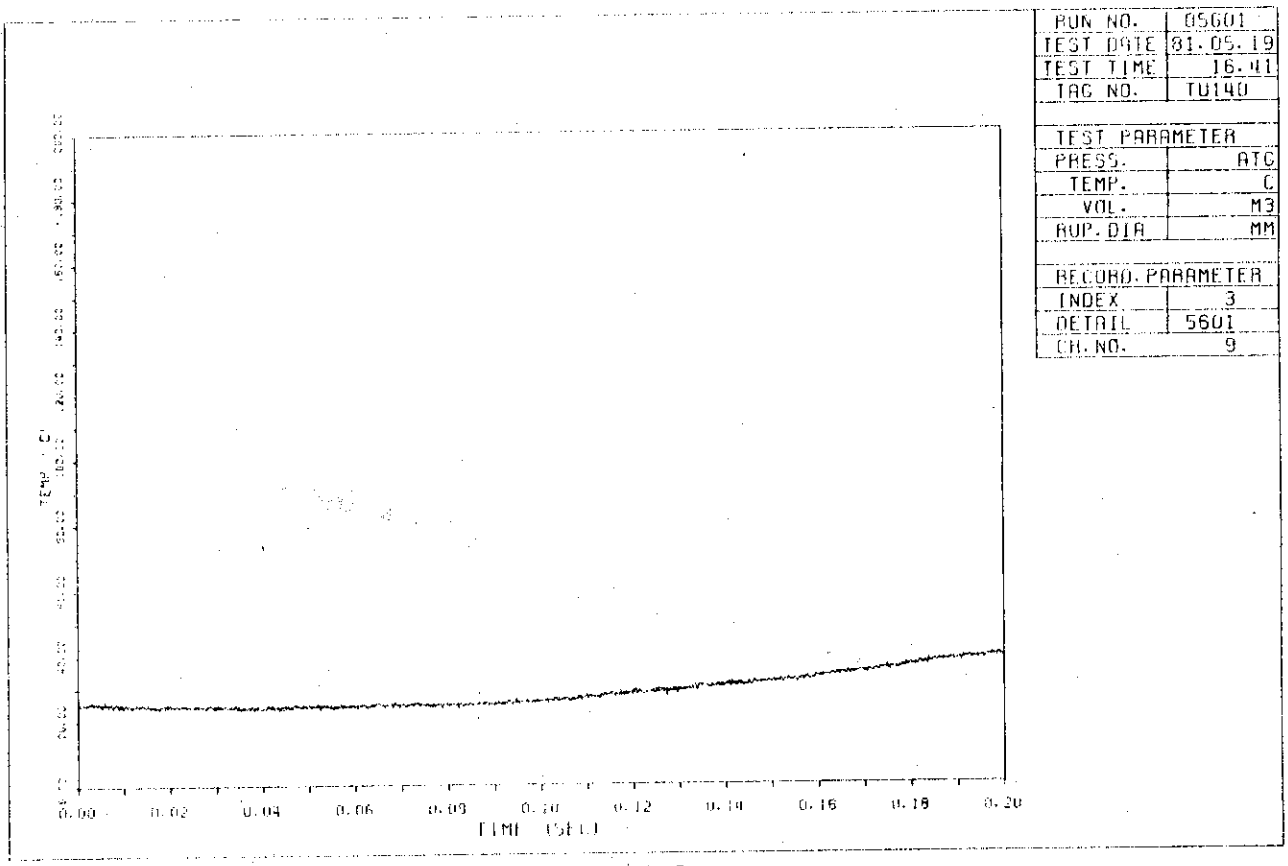


Fig. 11.9

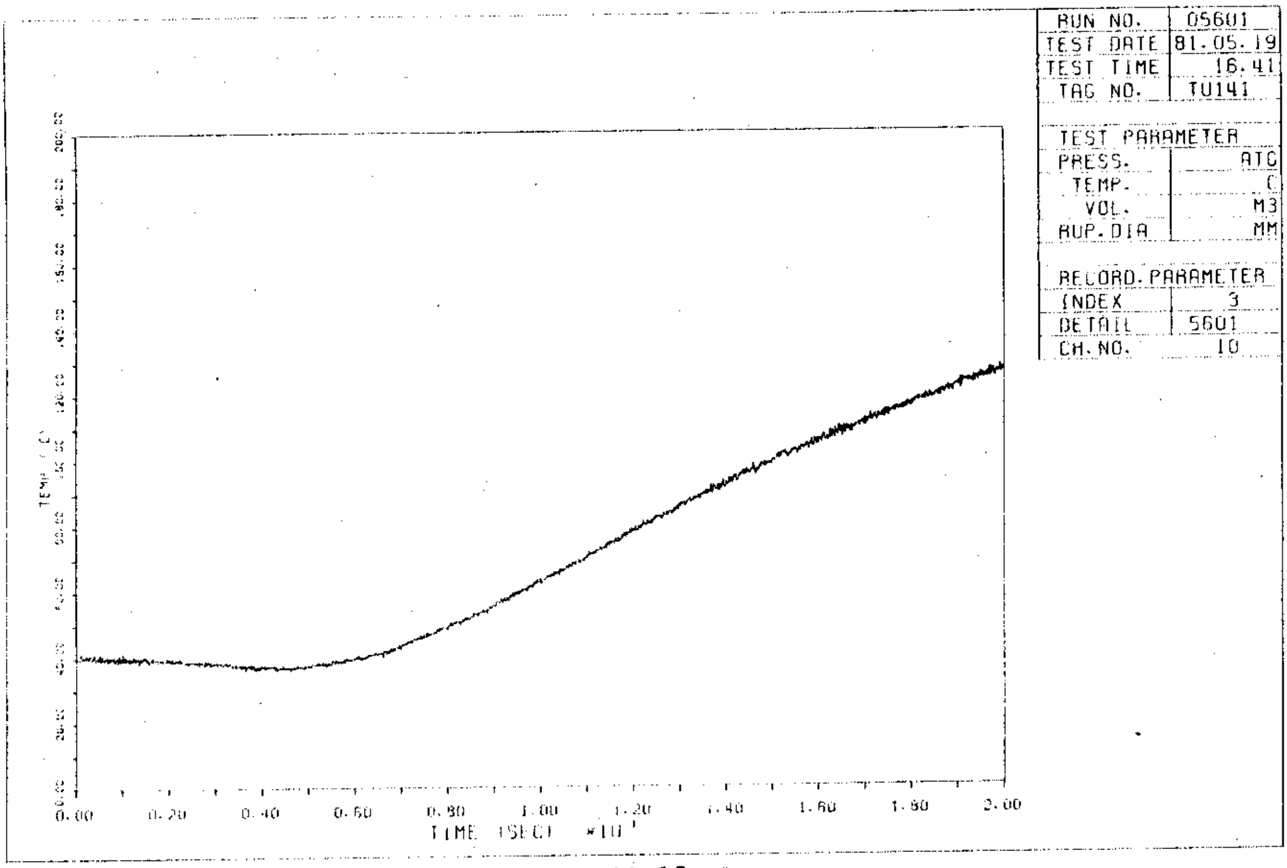


Fig. 11.10

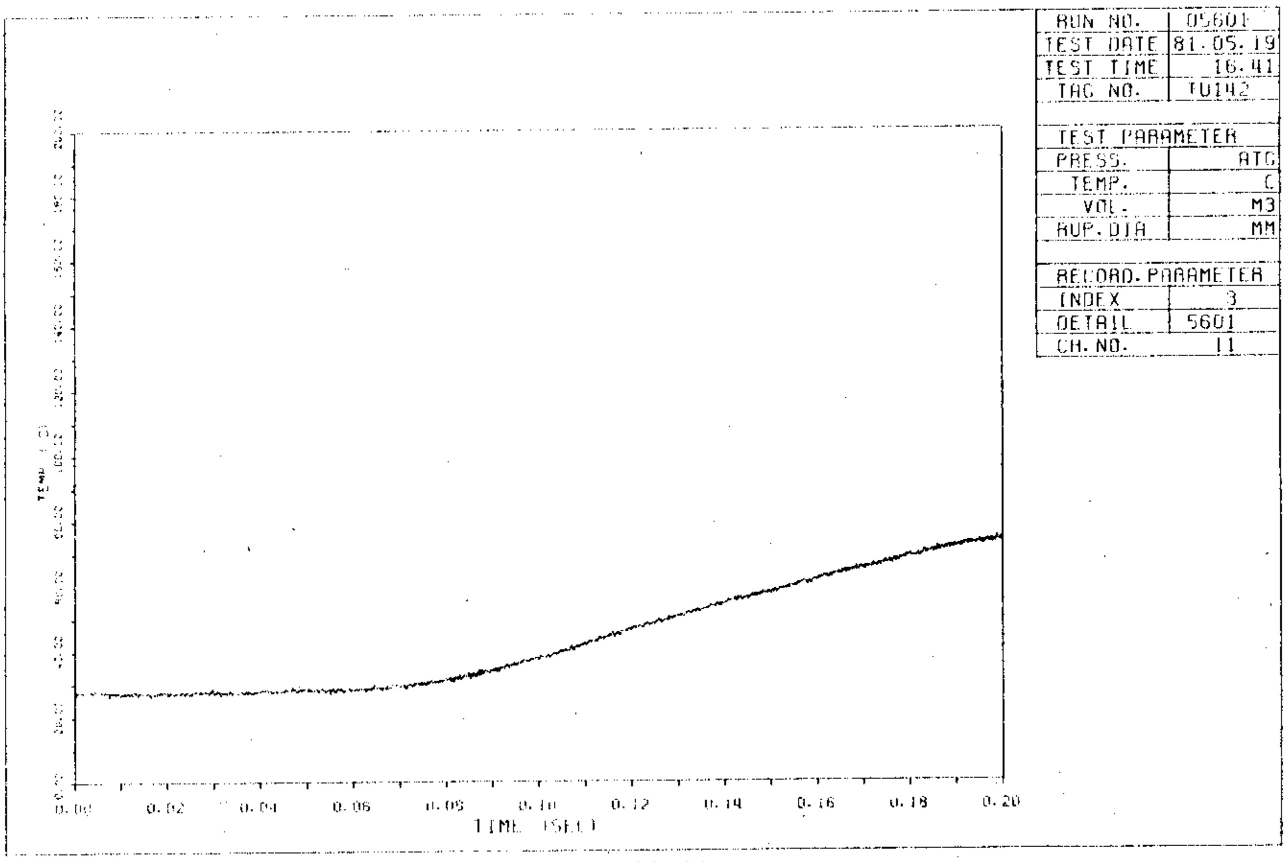


Fig. 11.11

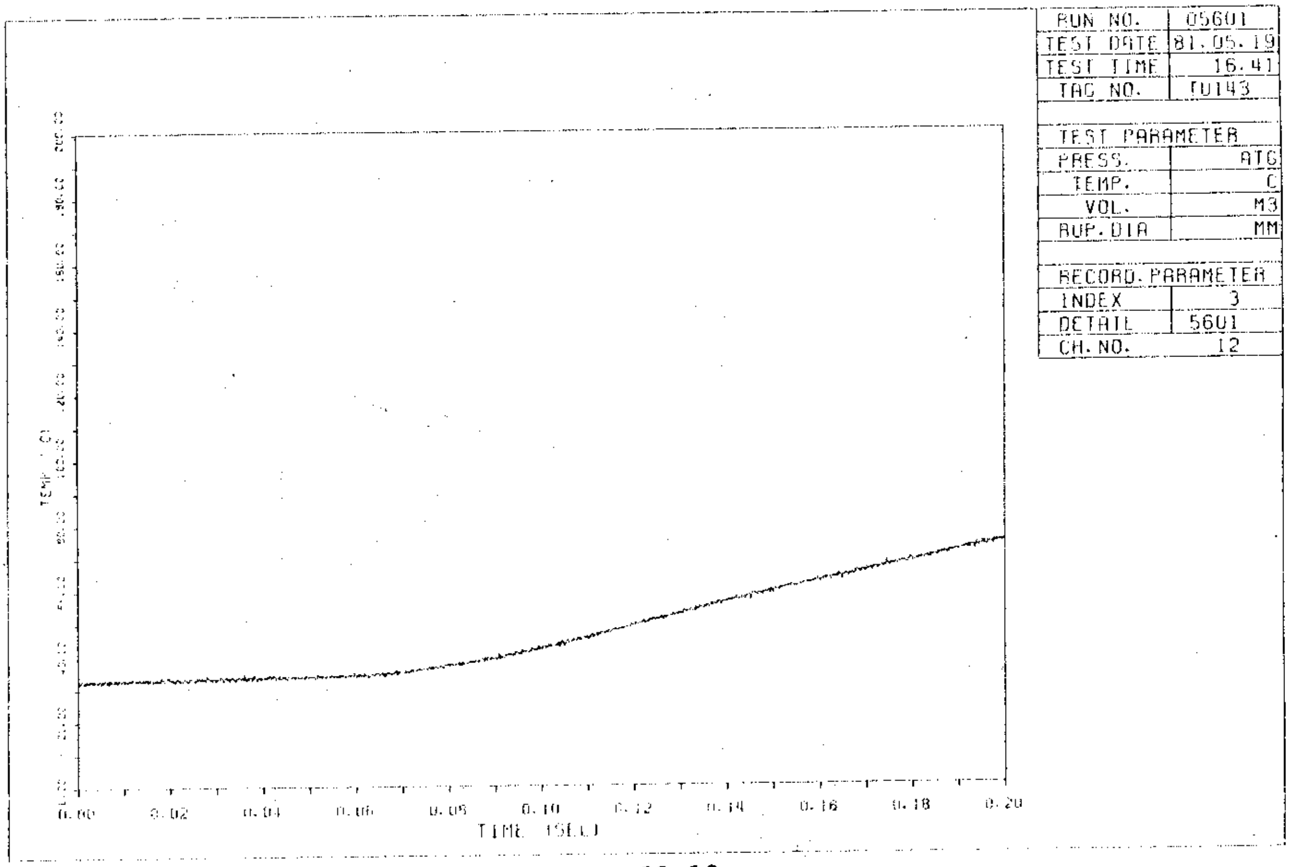

RUN NO. 05601
TEST DATE 81.05.19
TEST TIME 16.41
TAG NO. TU143
TEST PARAMETER
PRESS. ATG
TEMP. C
VOL. M3
RUP.DIA MM
RECORD.PARAMETER
INDEX 3
DETAIL 5601
CH.NO. 12
TEMP (C)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
TIME (SEC)

Fig. 11.12

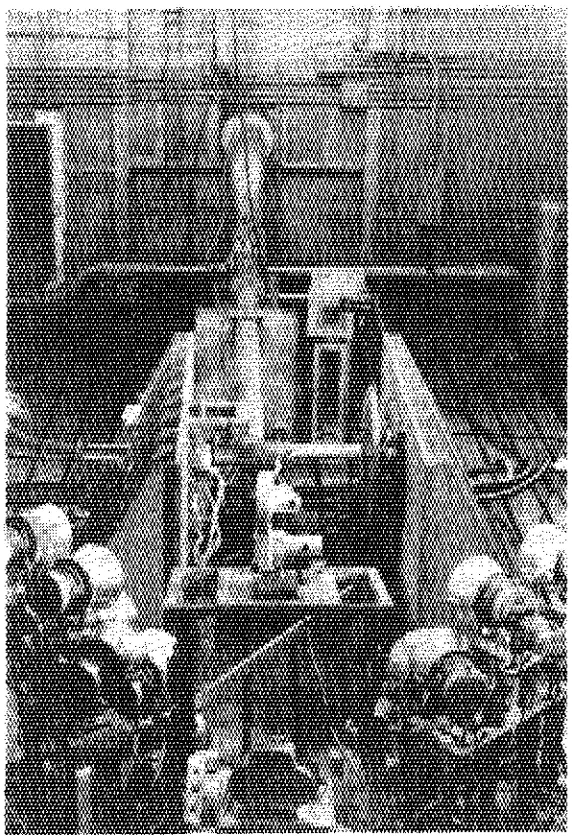


Photo. 1 Testing apparatus before test

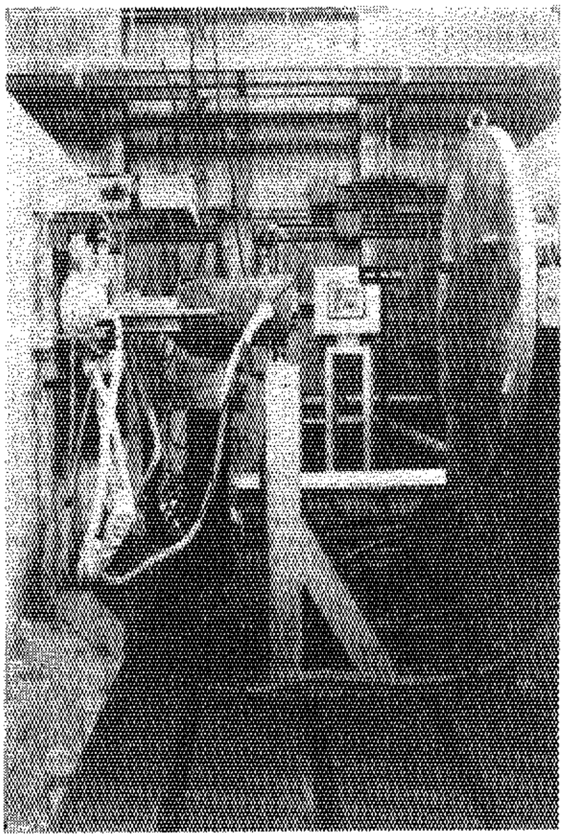


Photo. 2 Exit pipe (center), load cell (left) and tanget disk (right)

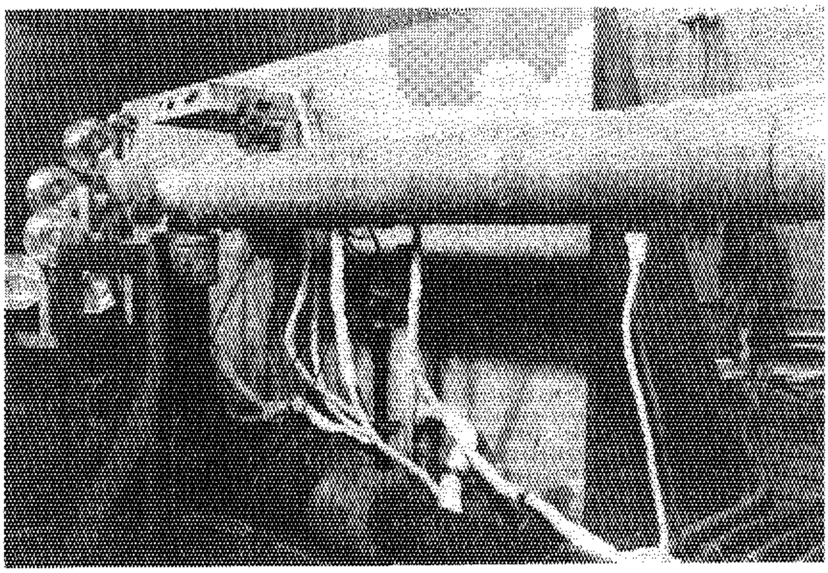


Photo. 3 Test pipe and warming -up line

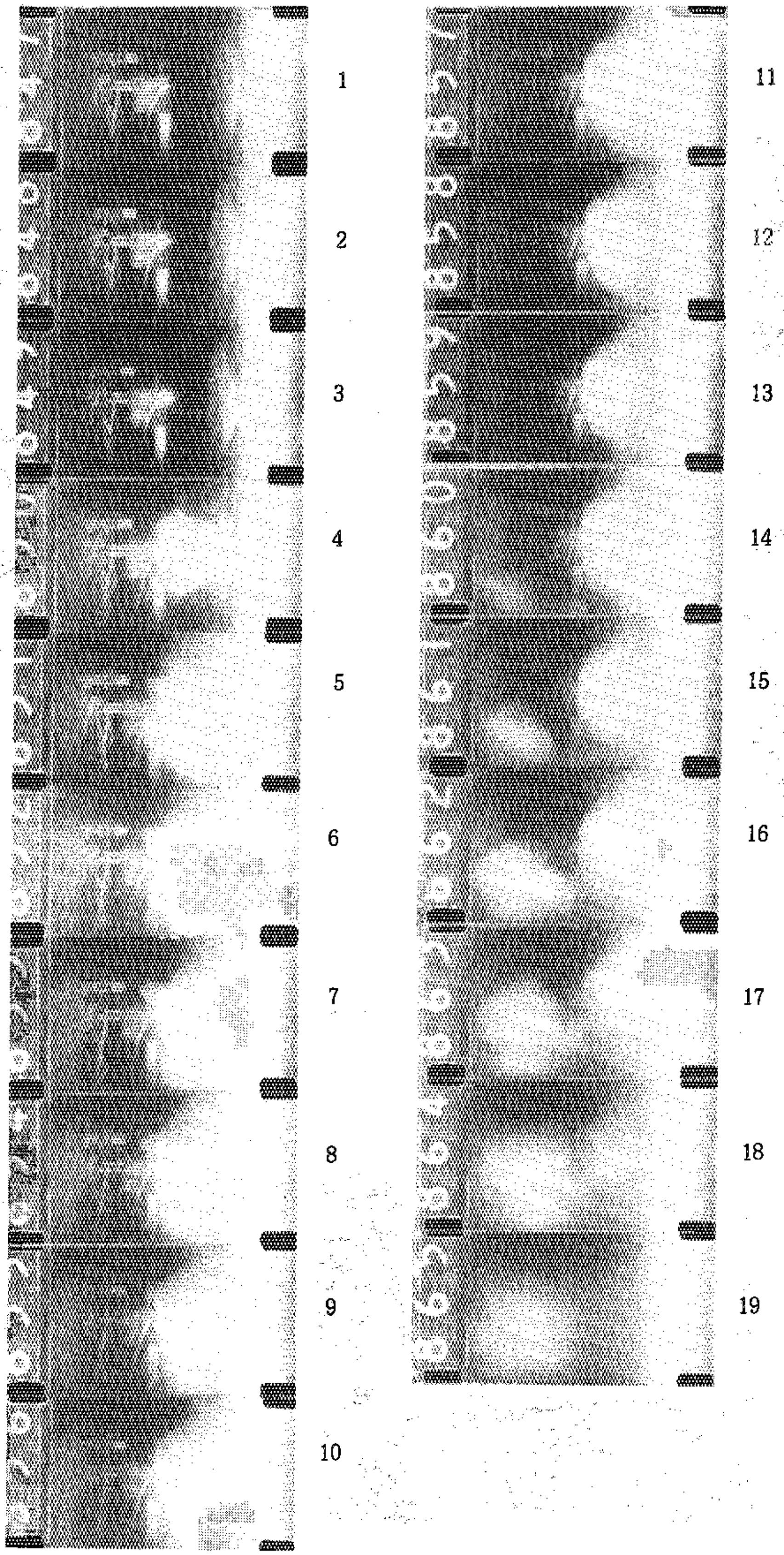


Photo. 4 Views by high speed camera
(speed = 3000 frame/sec, interframe time = 6.7 msec)

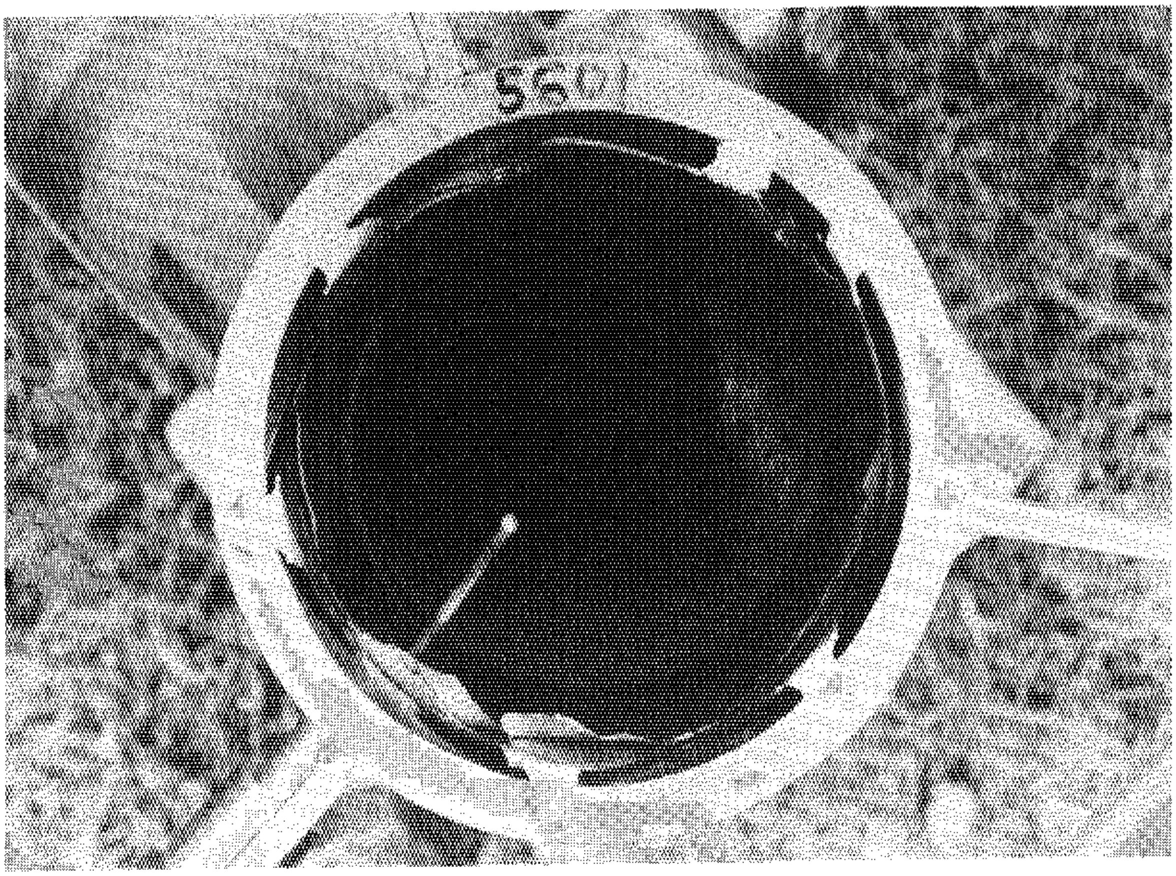


Photo. 5 rupture disk after the test