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ISR PERFORMANCE REPORT

Dynamic vacuum behaviour of the cold bore saturated with a thin and thick layer of hydrogen

(Run 1202, 14th June 1981)

1. Summary

The Cold Bore, saturated with about 4 monolayers of H_2, was exposed to a beam of 42.6 A and subsequently to a second beam of 45 A intensity. Upon raising the H_2 coverage to about 100 monolayers by a further H_2 injection, a third beam of 40 A was stacked. The three beams affected the pressure differently and appreciable differences were also observed at the two sides of the cryostat. This complex phenomenology will be discussed in more detail in this note. Neither ion induced pressure bumps, nor the sudden pressure spikes which were already noticed with condensed N_2, were observed.

2. The Experiment

Cooling of the cryostat started at 6.00 h and filling was completed at 10.00 h. Upon closing the sector valves and the diaphragms on the SP's of the Cold Bore sector, H_2 was injected at 11.00 h with the cryostat at 4.2 K. The amount injected was about 2 torr 1, corresponding to 4 monolayers. At the end of the injection, equal pressures on the two sides of the cryostat (about 3×10^{-6} torr) certified that saturation was obtained all along the Cold Bore. The temperature of the cryostat was then decreased to 2.3 K by reducing the pressure over the liquid He bath to 50 torr.

At 14.30 h the SV's were open and protons injected. The pressure was about 10^{-10} torr on both sides of the cryostat, and evolved with the beam intensity as shown in Figs. 1 and 2. Already at 5 A a small pressure increase was noticed and regular pressure rises appeared at each increase of the intensity. The effect was larger on the gauge 317.6 (opposite to the H_2 injection) than on the gauge 317.3 (H_2 injection side). The maximum pressures measured with a beam of 42.6 A were about 10^{-9} torr and 4×10^{-10} torr respectively. At constant beam intensity a pressure decrease was noticeable which was also more important at 317.6. These observations closely reproduce those obtained in a previous experiment, in which, however, the H_2 coverage was about 10 monolayers (see ISR Performance Report, ISR-VA/CB/sm dated 1.6.78). The first beam was dumped at 17.41 h and the pressures recovered very quickly almost completely to the initial values.

At 18.44 h stacking of a second beam was started, which ended at 21.00 h with a beam of 45 A. As Figs. 1 and 2 show, the pressure evolution was now completely different. The pressure rises were much smaller and practically identical on the two sides (about 2×10^{-10} torr at 45 A). Furthermore, the pressures were quite constant at constant current. The pressure falls were also smaller due to dumping the beam.

At 22.00 h the SV's were closed and a second H_2 injection was carried out for a total quantity which would correspond to 100 monolayers if uniformly spread on the cold surfaces. To save time and liquid helium this second injection was done with the cryostat at 2.3 K. After injection the pressure at 317.3 did not recover below 10^{-9} torr and the cryostat was heated up to about 4 K by means of the internal heaters. Heating affected the pressure at 317.3 in such a way that at 0 h 20 the reading on this gauge was 4 x 10^{-10} torr. At 317.6 the pressure was 10^{-10} torr and the SV's were opened.

Stacking the third beam started at 0 h 20 and a current of 40 A was reached at 1 h 50. The behaviour of the pressure on the two sides of the cryostat was again completely different (see Figs. 3 and 4). At 317.3 (injection side) the pressure was only marginally affected by the beam. A small rise to 2 x 10^{-10} torr was noticeable only at the maximum current. In contrast, at 317.6 the effect was similar but even larger than observed in presence of the first beam. All increases of beam current produced large pressure rises (up to 4 x 10^{-9} torr), which were followed by fast pressure decays at constant beam intensity. Similarly, dumping the beam at 2 h 11 was followed by a small pressure decrease at 317.3 ($\Delta P \simeq 2 \times 10^{-11}$ torr), while at 317.6 the decrease was about 4 x 10^{-10} torr.

3. Discussion

The present experiment was carried out for three distinct purposes:

(a) to obtain a confirmation of the intrinsic vacuum stability in the presence of condensed H_2, as resulting from a previous experiment (see ISR-VA/CB/sm, 1st June 1978).

(b) to determine whether the sudden pressure spikes which were noticed with large coverages of N_2 (100 monolayers, see ISR-VA/NH/gl dated 10th March 1980) only depend on coverage or rather on the condensed gas species.

(c) to understand the causes of the transient pressure rises which were previously noticed not only with condensed H_2 but also with adsorbed He (see ISR-VA/CB/sm dated 1st August 1980).

(a) Vacuum Stability

In the attempt to increase the chance of producing an ion induced pressure bump, the beam intensity was pushed to 45 A, while in the previous experiment with H_2 the maximum current was 36 A. Furthermore, the coverage was decreased from 10 to 4 monolayers because the maximum desorption yield is located here. In spite of these changes, no pressure bumps leading to a pressure run-away were noticed. We may conclude that the Cold Bore is stable vacuum wise within the present experimental possibilities.

(b) Pressure spikes

The pressure spikes which were observed with condensed N_2 did not appear with a similar thickness of condensed H_2. These apparently contradictory results may find a justification under the assumption that the spikes are produced by electric breakdown. Experimental evidence exists that H_2 molecules maintain some mobility even at liquid He temperatures in contrast with molecules of heavier gases like N_2. Mobility may permit H_2 ions to migrate to the metal walls of the cryostat before the potential difference required to produce an electric breakdown is established.

(c) Transient pressure rises

The striking difference of the pressures evolution with the first and the second beam (see Figs. 1 anbd 2) is to be expected if, as previously suggested, the transient pressure rises are produced by cleaning out under ion bombardment of some parts of the cold surfaces. In the absence of a subsequent recontamination, as resulting for instance during gas injection, the surfaces which were cleaned should remain clean and produce little degassing when re-exposed to a proton beam.

After the first experiment with condensed H_2, doubts remained about the regions which are responsible for the observed degassing. One could imagine, for instance, that the density of the impinging ions is not uniform along the transverse profile of the chamber. In this case the ion bombardment would result in a rearrangement of the condensed molecules leading also to a non uniform transverse density profile and eventually to clean (i.e. low degassing) longitudinal bands of cold vacuum chamber. Alternatively, one could assume that the ions remove the H_2 adsorbed in the regions at intermediate temperature which link the cold bore to the chamber at room temperature. These regions adsorb H_2 during the injection and slowly release it even without beam, under the effect of the thermal radiation entering from both ends of the cryostat.

Previous experimental work has shown that clean metal surfaces at temperatures higher than 4.2 K cannot retain more than one monolayer when exposed to H_2 and subsequently brought to low pressures (lower than 10^{-7} torr). Any effect originated by these surfaces should consequently show only a marginal dependence on the amount of gas injected. In contrast a larger H_2 injection should directly affect the cleaning time of those regions which are at liquid He temperature. Comparing the pressure evolution as monitored by the gauge 317.6 in presence of the three different beams (i.e. Figs. 2 and 4) may permit one to conclude that transient pressure rises are indeed produced by beam cleaning of regions at intermediate temperature because the cleaning time after the second injection (gas coverage increased by a factor 25) did not change appreciably.

This interpretation may also lead to understand why, after both injections, the pressure rises at the H_2 injection side of 317.3 are smaller than at 317.6 (compare Figs. 1 to 2 and 3 to 4) and also why the pressure rises at 317.3 are larger after the first (smaller injection) than after the second one (compare Figs. 1 and 3). At temperatures higher than about 5 K the adsorption of heavier gases inhibits a further adsorption of H_2. Any impurity present in the injected gas would stick to the intermediate temperature regions at the entrance of the cryostat, which will therefore take up less H_2 than at the opposite end of the cryostat. Furthermore, injecting about 50 torr l (equivalent to 100 monolayers) of H_2 may easily result in impurity content large enough to saturate completely the entrance of the cryostat even at the measured impurity level of 3×10^{-3}; hence the almost unnoticeable pressure rise at 317.3 after the second injection.

Conclusions

This experiment completes the cycle of the planned tests in the ISR. Enough results are available to conclude that a cold bore design for a proton machine would be intrinsically safe. A deeper understanding of all processes observed during this investigation would require a bigger effort which is difficult to justify in the framework of the present CERN programs.

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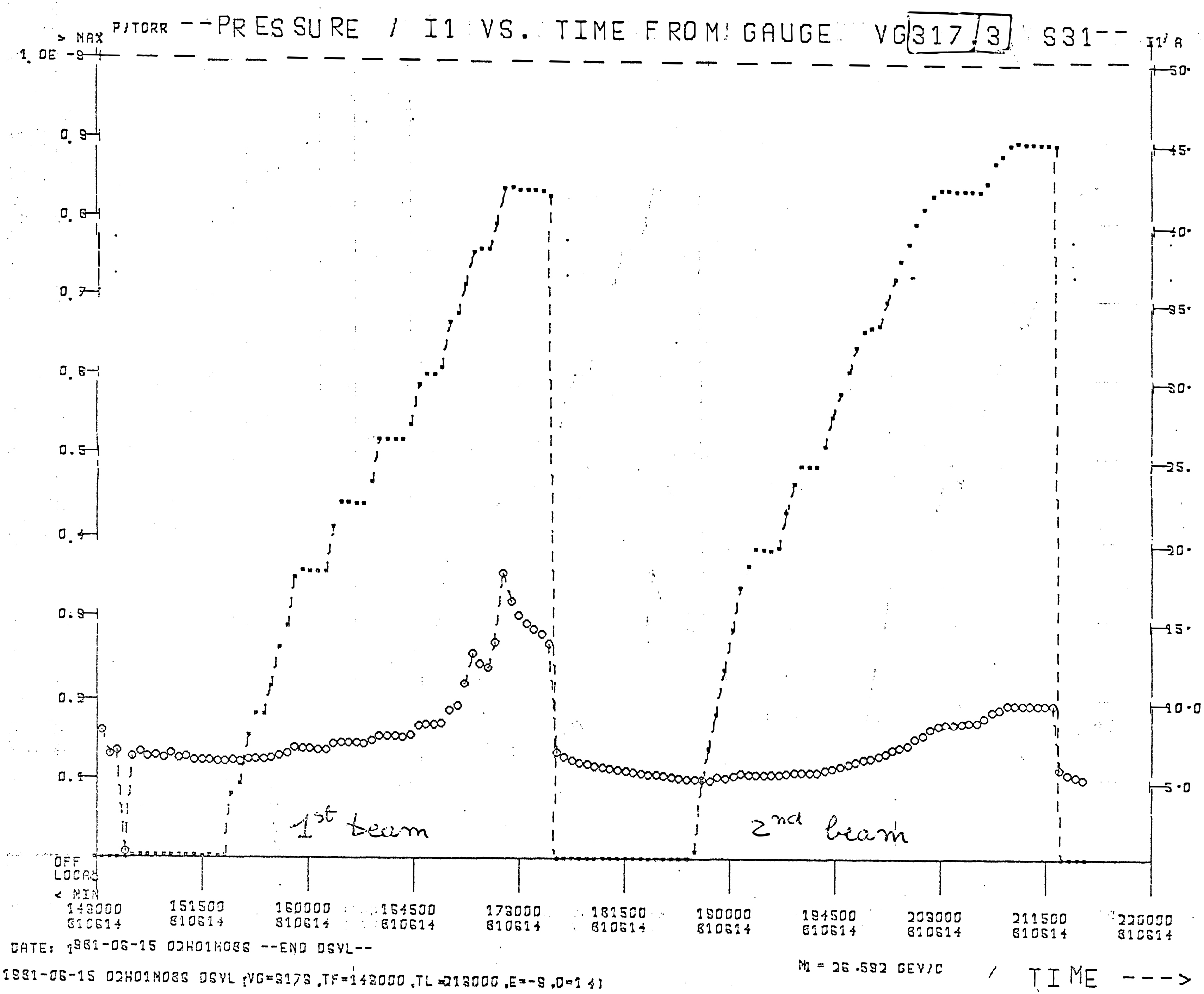
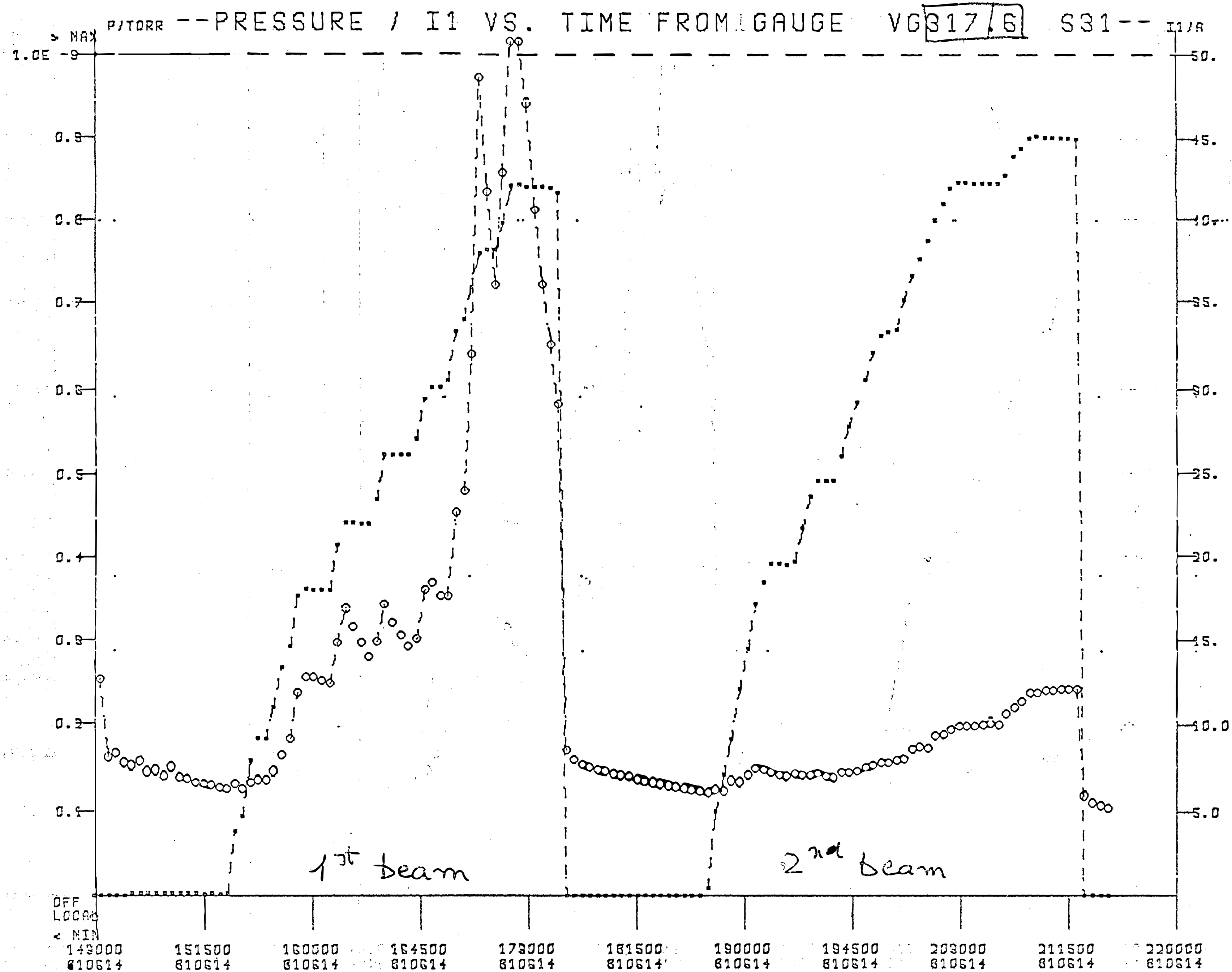
Fig. 1



> MAX P/TORR --PRESSURE / I1 VS. TIME FROM GAUGE VG317/3 S31--
I1/A
1. 0E -9
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
OFF
LOCAL
< MIN
50.
45.
40.
35.
30.
25.
20.
15.
10.0
5.0
1st beam
2nd beam
143000 810614
151500 810614
160000 810614
164500 810614
173000 810614
181500 810614
190000 810614
194500 810614
203000 810614
211500 810614
220000 810614
DATE: 1981-06-15 02H01M08S --END DSVL--
1981-06-15 02H01M08S DSVL (VG=3173 ,TF=143000 ,TL =213000 ,E=-9 ,D=1 4)
M = 26.592 GEV/C / TIME --->

Fig. 2



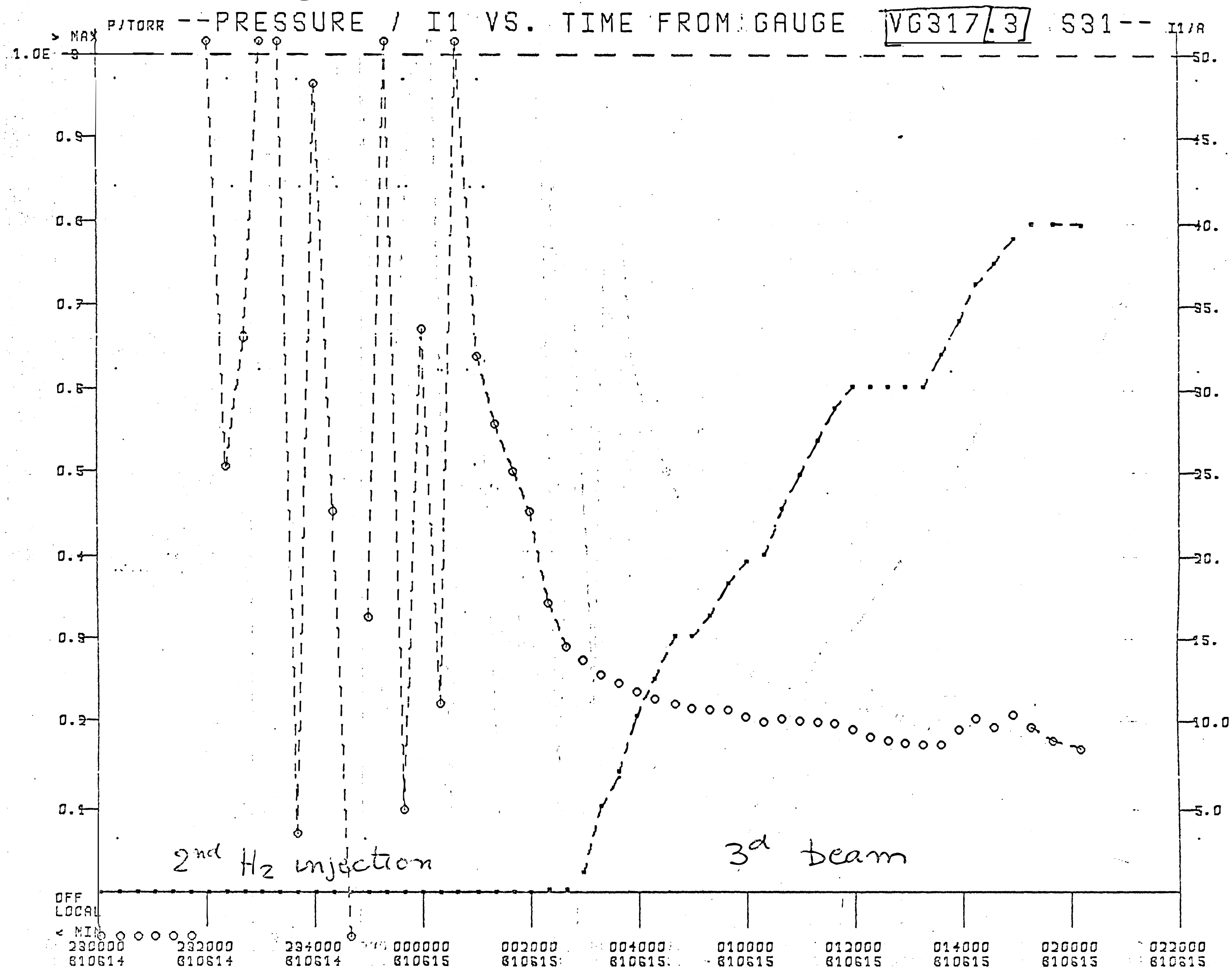
DATE: 1981-06-15 01H59M41S --END DSVL--

M1= 26.592 GEV/C

TIME --->

1981-06-15 01H59M41S DSVL(VG=31 TF=143000.TL=213000.E=-9.0=14)

FIG. 5



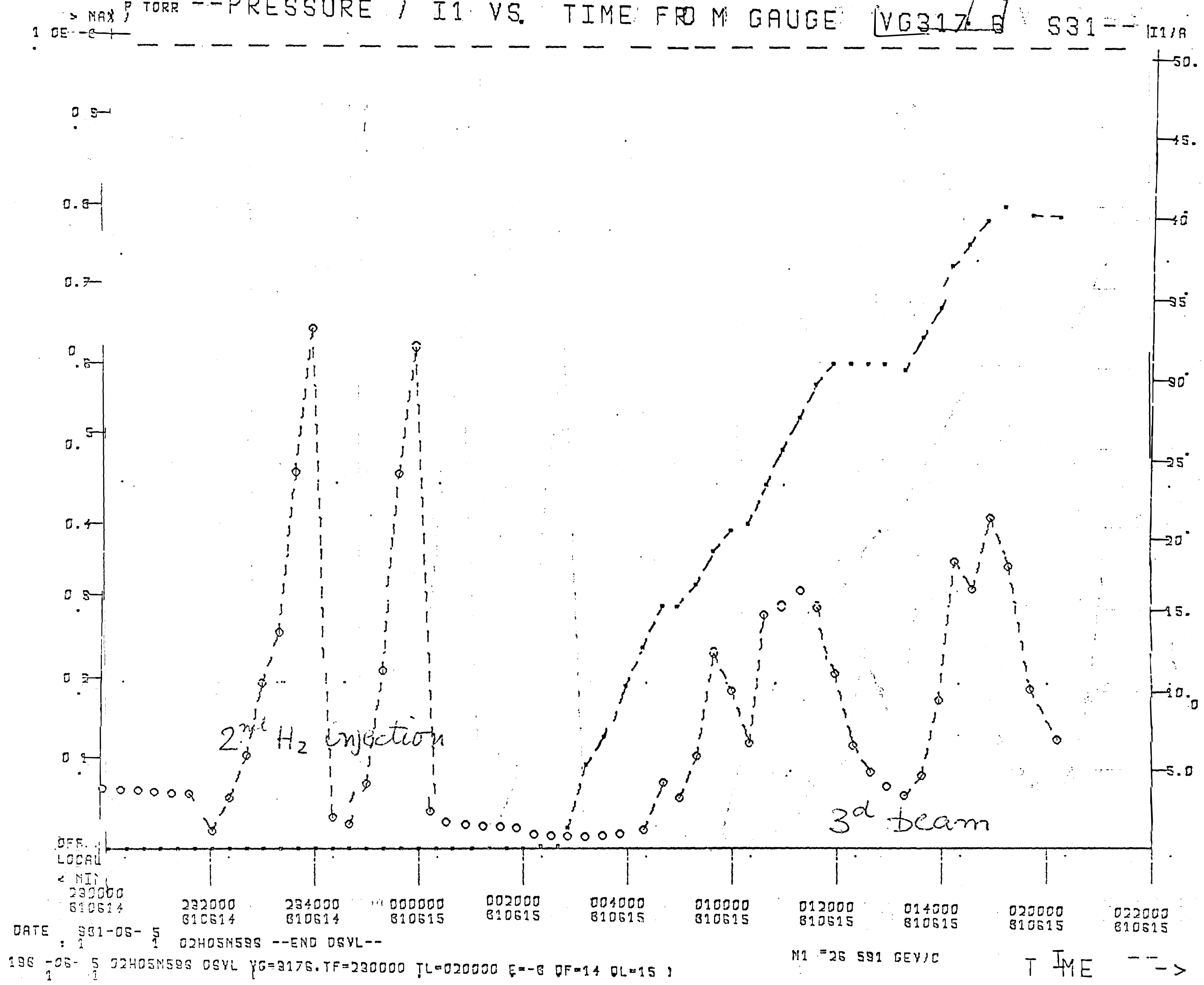
DATE: 1981-06-15 02H06M34S --END DSVL--

M1= 26.591 GEV/C

TIME --->

1981-06-15 02H06M34S DSVL(VG=3173.TF=230000.TL=020000.E=-9.DF=14.DL=15)

FIG 7



MAX P TORR --PRESSURE / I1 VS. TIME FROM GAUGE VG317 B S31--
I1/A
1 OE-6
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
50.
45.
40
35
30
25
20
15.
10.
5.0
2nd H2 injection
3d beam
OFF. LOCAL < MIN 230000 810614
232000 810614
234000 810614
000000 810615
002000 810615
004000 810615
010000 810615
012000 810615
014000 810615
020000 810615
022000 810615
DATE S31-06- 5 02H05M59S --END DSVL--
196 -06- 5 02H05M59S DSVL VG=317B.TF=230000 TL=020000 E=-6 DF=14 DL=15)
M1 =26 S91 GEV/C
TIME -->