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# TESTING OF PROTOTYPICAL BOILING WATER REACTOR WATER LEVEL INSTRUMENTATION REFERENCE LEG DE-GASSING

Revision 1

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# EXECUTIVE SUMMARY

## Objective

The BWR Owners' Group embarked upon a program of water level testing to better understand the phenomena associated with degassing in water level instrumentation reference legs at operating plants and to provide a basis for individual plant solutions to the associated errors in indicated water level. The objective of the program was to obtain data for a variety of reference leg configurations. These data would then be used to support the validation of an analytical model that could then be used by each plant to evaluate their configuration and degassing potential.

It should be reemphasized that tests were not plant specific (with one exception); therefore, the test results do not form the basis for direct application to any other plant. Each plant should be evaluated separately for their individual configurations.

This testing did not address the plant specific effects of condensing chamber (CC) configurations and inlet steam piping on the non-condensables gas concentration in the CC.

## Testing

The testing program was conducted under a rigorous quality control program. This included one over one verifications and extensive documentation. Repeatability of results was confirmed.

The tests were performed in a manner to ensure the conservative nature of the results. A single gas (oxygen) was employed for a majority of the testing. This gas stays in solution longer than stoichiometric oxygen and hydrogen which are present in the reactor, thereby contributing to larger resultant errors. The depressurization rates were chosen to bound those of hypothetical Design Basis Accidents.

## General Conclusions

The test program results have yielded a better understanding of the degassing phenomena and the data can be utilized in individual plant evaluations to better understand the susceptibility to degassing errors. These results clearly demonstrate the potential for water level errors following plant depressurizations due to the concentration of dissolved gas in the water level instrumentation reference leg piping.

Specifically, some general conclusions that have been developed or reconfirmed by the test program include the following:

1. The test program identified a dissolved gas concentration below which insignificant level errors occur (nominally 150 ppm by volume).

2. As was expected, the higher the concentration of dissolved gas, the higher the indicated level error following depressurization. This was not directly linear due to dynamic effects and geometry differences.

3. Geometric variations of reference leg piping systems were shown to have a profound impact upon the level error resulting from degassing due to rapid depressurization.

4. The faster the depressurization rate, the larger the level error.

5. The gas remained supersaturated in solution down to low pressures. For the single gas testing, indicated level error were not induced until the pressure dropped below 220 psia.

6. Significant "notching" appears to be due to slug-flow migration of gas voids between horizontal and vertical segments of piping.

7. Orifices may impede the release of gas to the condensing chamber. This provides an increased volumetric expansion rate at lower pressure and correspondingly higher indicated level errors.

## SECTION 1 INTRODUCTION

### 1.1 Scope

This document describes the tests conducted on behalf of the Boiling Water Reactor Owner's Group (BWROG) to gather comprehensive data on the effect of non-condensable gases on potential water level loss in the water level reference lines during rapid depressurization. In addition, limited testing of slow depressurization events was included in this de-gas testing program. This testing program was conducted according to the testing plan outlined in Ref. 1, which was based upon the test specification described in Ref. 2.

### 1.2 Background

Ninety-four depressurization tests and fourteen shakedown tests were conducted over a period of approximately 8-1/2 weeks at the EPRI-NDE Center in Charlotte, North Carolina, on multiple piping geometries. These geometries are not representative of any plant layout with the exception of Configuration #7. Therefore, De-Gas test results cannot be directly correlated to plant response to dissolved non-condensable gases in the plant's water level reference legs. These test data were collected under a rigorous quality assurance program, described in Ref. 3.

### 1.3 Program Objectives

The objective of the test program was to provide insight into the water level error that occurs due to dissolved gas in the instrument lines. Test data was obtained for water level errors simulated when an amount of water is displaced during depressurization events using various piping geometries for a variety of dissolved gas types and concentrations and at various depressurization rates. These data would be used to support the validation of an analytical model, which could in turn be used in a plant-specific evaluation of the degassing phenomenon.

### 1.4 Impact of Non-condensable Gas

Pre-test calculations had shown that inventory may be lost from degassing of the cold reference leg of BWR water level instrumentation during a rapid depressurization event.

This loss is due to water carry-over as the non-condensable gas comes out of solution and expands as the pressure drops. The amount of inventory lost depends upon the actual cold leg piping geometry, amount and composition of initial non-condensable gas dissolved in the leg, and the depressurization rate. Inventory loss in the cold leg directly impacts the reference pressure sensed by the differential pressure instrumentation that determines the water level in the reactor pressure vessel (RPV), resulting in a non-conservative reading in the control room. A schematic of a BWR water level measurement system is shown in Figure 1.1.

Non-condensable gases may collect in the condensing chamber at the top of the water level reference legs in BWRs. As reactor steam condensate flows down the chamber walls and into the leg to maintain the reference leg liquid inventory, the gas may move down into the reference leg. These gases are primarily a stoichiometric mixture of hydrogen and oxygen, and arise from radiolysis in the BWR's generation of steam. Collection of gas and associated buildup of its partial pressure in the condensing chamber over time could allow the formation (via diffusion) of a high-concentration non-condensable gas solution in the water surface at the top of the reference leg. The concentration of dissolved gas is determined by Henry's law, which states that the concentration is a product of the gas solubility in water (a parameter dependent upon temperature) and the partial pressure of the gas above the water's free surface. This dissolved gas solution could be carried down into the reference leg via diffusion, thermal convection, or a leak in the reference leg.

The fastest means of conveying any high-concentration solution into the leg would be by a leak, which, if located near the water level instrumentation rack, would raise the concentration in the complete reference leg after time with a uniform concentration of dissolved non-condensable gas (assuming that the partial pressure of gas in the condensing chamber had reached a steady value). Thus, in order to provide bounding conditions for the experiments described herein, pre-mixed solutions of various concentrations of non-condensable gas were injected into the piping geometries tested.

### 1.5 Test Parameters

Design of the de-gas experiment involved the selection and duplication, as best as possible, of all the most important physical parameters that are understood to affect the degassing phenomenon that may occur in actual BWRs during depressurization. These

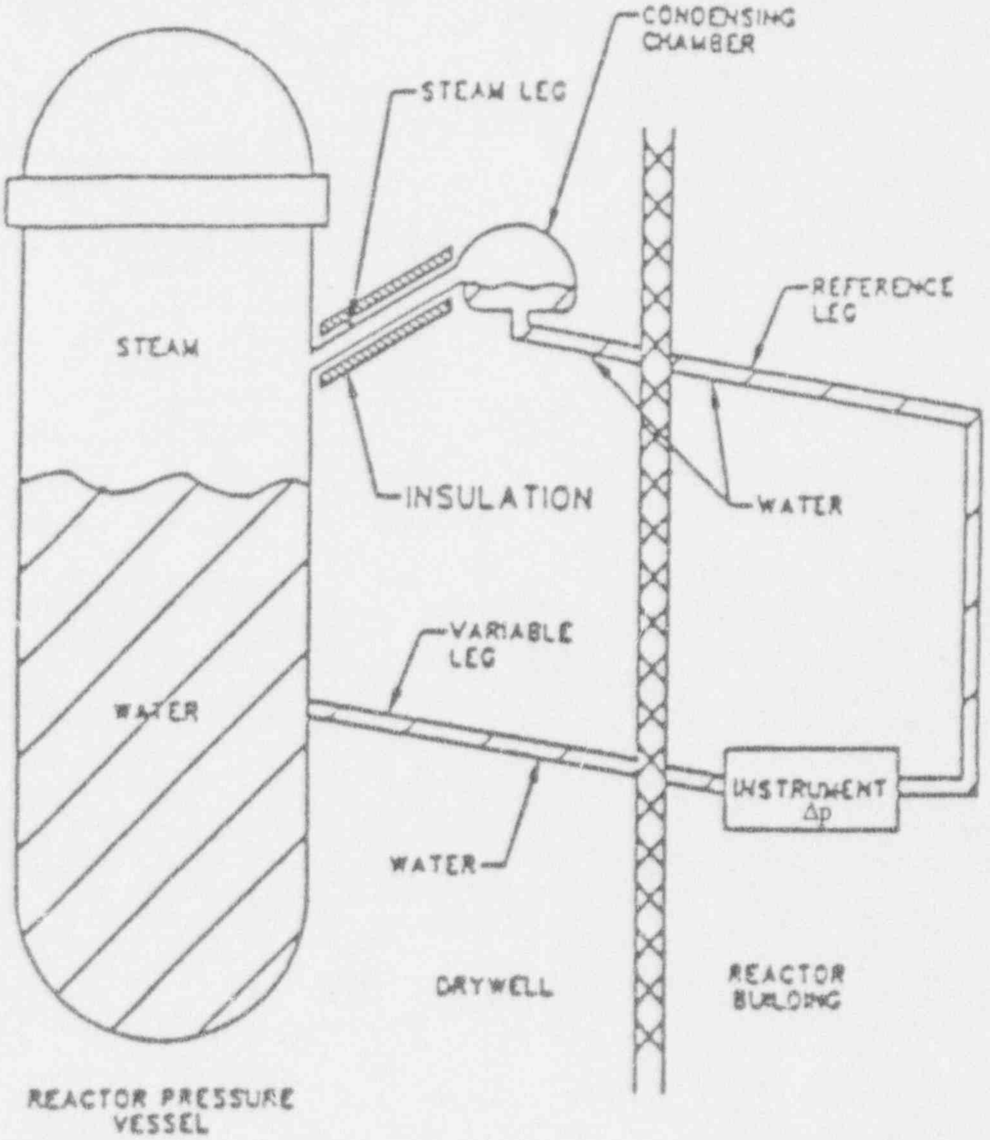

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Fig. 1.1: Simplified Diagram of a Typical BWR Water Level Monitoring Instrument

primary parameters were: the reference leg piping geometry, including flow constrictions, pipe diameters and surface (material) properties, horizontal segment slopes, and height-volume distributions; the type and concentration of non-condensable gas dissolved in the reference leg water; and the depressurization rate.

The depressurization rates selected included both generic worst-case design basis severe accident scenarios, and normal shutdown depressurization time histories, including shutdown cooling operations. The slow depressurization tests were added to the original test scope because of newly identified concerns to attempt to duplicate degassing phenomena observed during shutdown operations on some BWRs. Time histories of the rapid depressurization rates and the shutdown depressurization pressure time histories are shown in Figures 1.2 and 1.3.

No attempt was made to duplicate the processes by which non-condensable gases may actually enter the reference leg piping system at an operating BWR. This decision was made to provide bounding, worst-case degassing conditions, and to simplify the required experimental hardware by eliminating the need to produce steam at reactor conditions (approximately 540 °F for BWRs operating at 1000 psig). As a consequence, stratified concentrations of dissolved gas, with a higher concentration located near the condensing chamber (as would be present during a significant portion of steaming operations in BWRs), were not simulated. Such distributions would most likely lead to reduced degassing effects on the piping geometries tested than those reported here.

Other experimental parameters that were deemed of secondary importance were vibration and temperature effects on the degassing process. Vibration may impact the rate by which gas comes out of solution, but simulation of prototypical BWR reference leg vibration levels would require such extensive experimental sophistication to make other than in-plant testing physically impossible. Since limited benchtop testing of degassing in small pipe lengths indicated that the gas came out of solution (both with and without vibration) within a significantly shorter time period than the depressurization rate, it was concluded that simulation of vibratory inputs was unwarranted. Temperature variations exist along BWR reference leg piping. Segments within the drywell are typically approximately 150 °F and those outside the drywell remain at ambient reactor building temperature. The primary impact that temperature has on degassing is through the change of gas solubility with temperature, which is both fairly small over this range (150°F to ambient) and is well documented, and thus may be corrected for in an

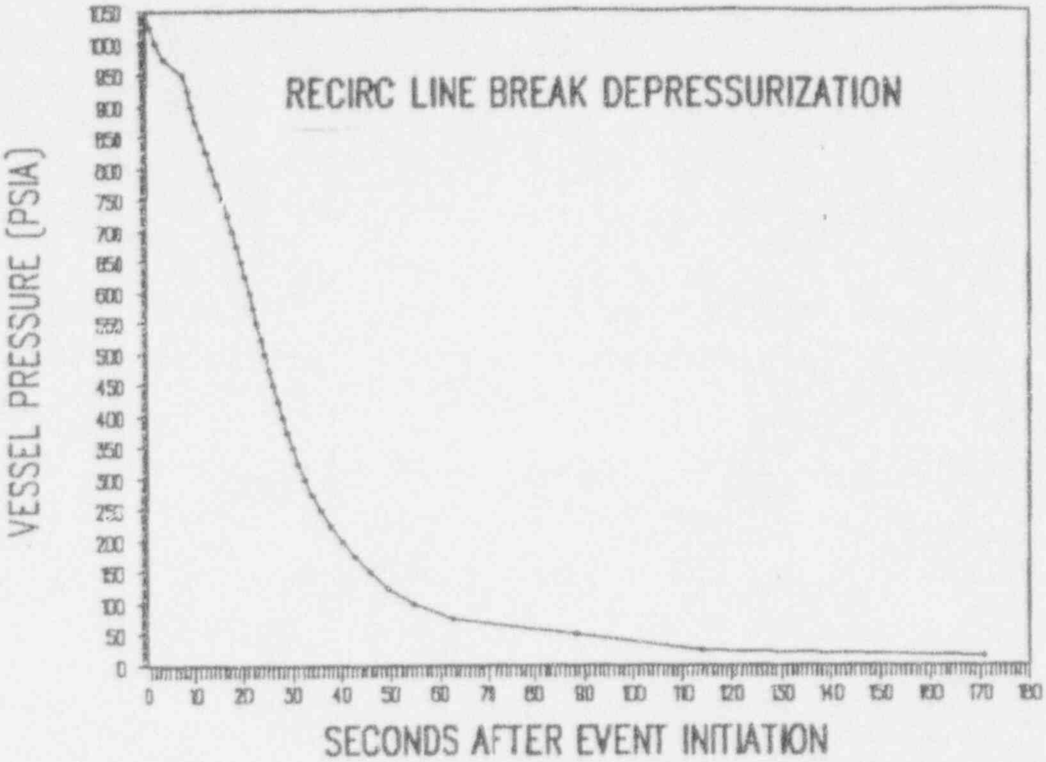

Fig. 1.2a: Generic LOCA-Event BWR Depressurization Curve

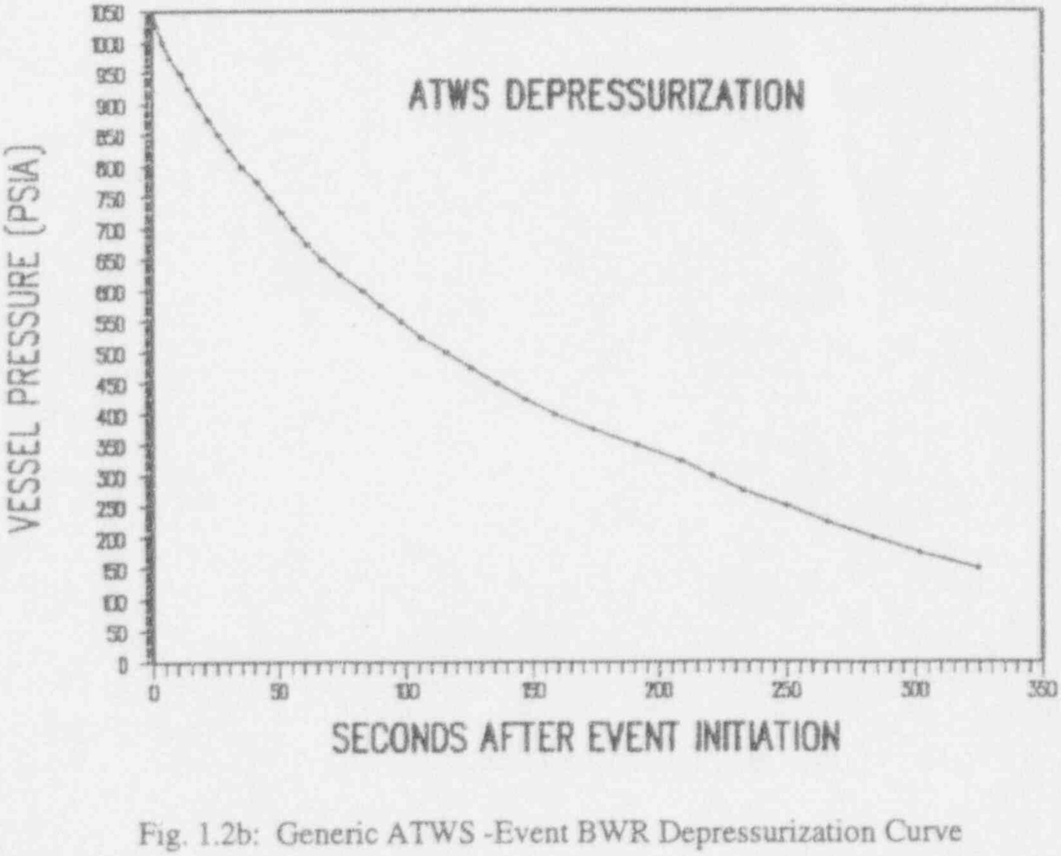

Fig. 1.2b: Generic ATWS -Event BWR Depressurization Curve

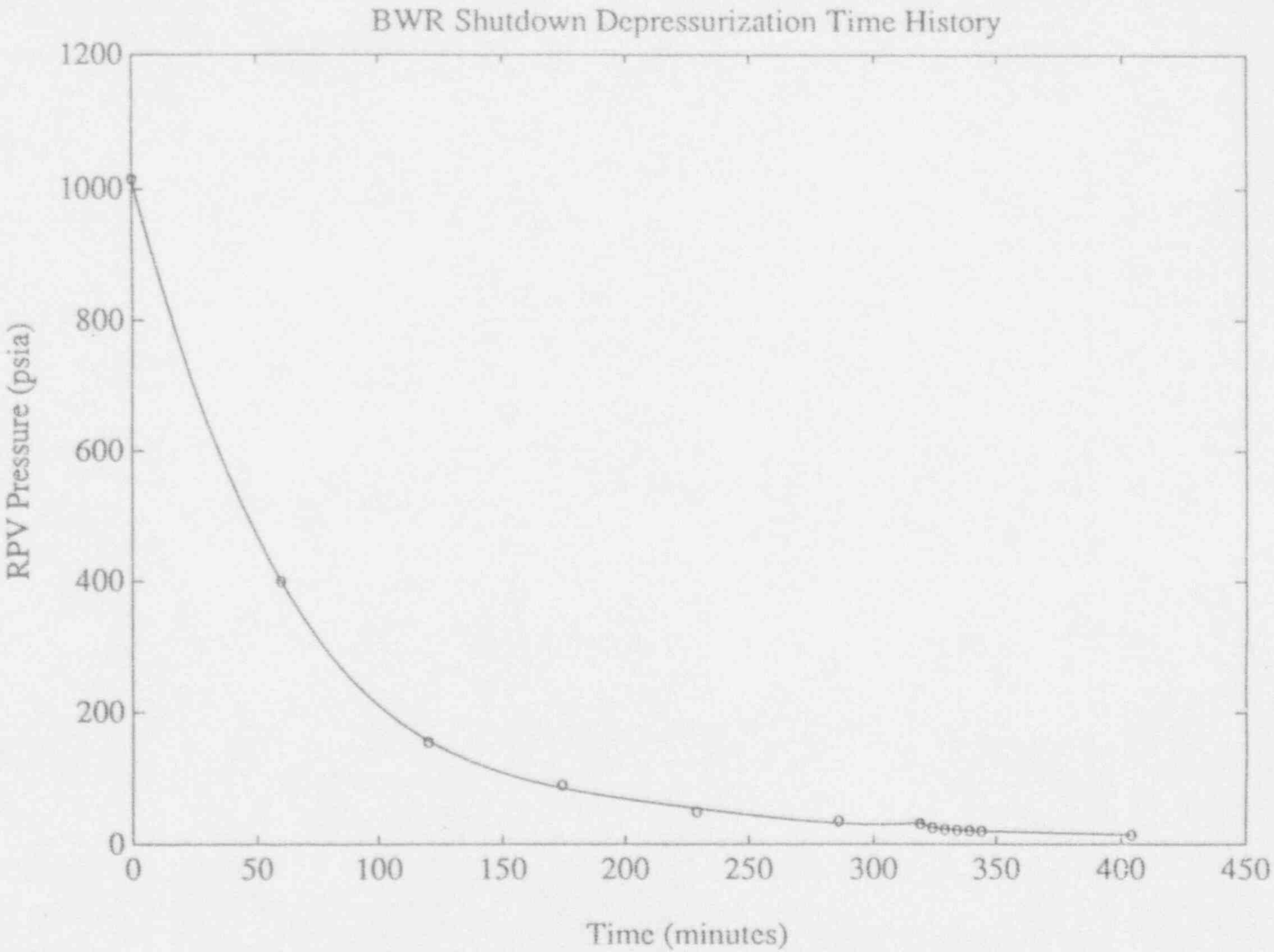

Fig. 1.3: Generic BWR Shutdown Depressurization Time History
(Including Shutdown Cooling)

analytical model. For this reason, all tests were performed at ambient room temperature, with gas concentration controlled through adjustment of saturation pressures.

Single-gas testing for preparation of the non-condensable gas solutions was done in order to avoid the safety impact of working with stochiometric mixtures of oxygen and hydrogen, and to provide bounding conditions for the dynamic expansion of the dissolved gas as it comes out of solution at reduced pressures. Supporting calculations have shown that the maximum dissolved gas concentration possible in the condensing chamber water surface is close to 1500 ppmv[1], based upon total pressure and temperature limitations of BWRs. However, as this solution is reduced in temperature below 300 °F during its migration into the reference leg, only a concentration of approximately 1100 ppmv may be supported without degassing at 1000 psig. Because the solubility of nitrogen and oxygen at room conditions is greater than that of hydrogen, the partial pressure required to maintain a concentration of 1100 ppmv in solution is less than 1000 psig, and hence single gas testing was possible at room temperature without requiring a depressurization event to initiate from pressures above those found in BWRs. Also, since the non-condensable gas used in the testing would not begin to come out of solution until its saturation pressure was reached in the depressurization event, the results from the test would generate level anomalies <u>higher</u> than those anticipated for similar conditions in BWR reference legs (degassing in the actual plant would take place immediately upon any loss in RPV pressure). This result is primarily due to the additional dynamic forces that would arise from the same volumetric expansion of the gas taking place in a shorter amount of time. This phenomenon is further discussed in Section 2 of this report.

### 1.6 Use of Test Results

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The data reported here serve two purposes. First, they provide an <u>upper</u> <u>bound</u> on the changes in indicated water level due to water column reference pressure loss on the water level reference leg. The majority of this program's piping systems tested do not represent actual reference leg instrumentation systems of BWRs, because these tested piping systems were designed to provide parameter sensitivities to water volume loss that would

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[1] ppmv is parts per million by <u>volume</u>. ppmv is defined as the moles of non-condensable gas x $10^6$ divided by the moles of water vapor or steam. For gas in solution, ppmv is defined as the moles of non-condensable gas x $10^6$ divided by the moles of water. The partial pressures of non-condensable gas and water vapor can be used instead of moles where convenient. To convert to ppmv from ppm by weight (ppmw), multiply by the molecular weight of water (18) divided by the molecular weight of the gas [for $H_2$, ppmv = ppmw x (18/2); for $O_2$, ppmv = ppmw x (18/32)]. See Appendix B for additional details.

provide conservative values on in plant potential water column reference pressure losses. Second, these data comprise a data base for correlation with water level instrumentation analysis codes to predict the plant specific water level errors during such depressurization scenarios.

The test program did identify, for a typical BWR water level reference leg, a dissolved gas concentration below which no level error could be induced. It should be emphasized, however, that use of these data to predict water level anomalies in specific operating plants cannot be made directly, because the gas concentration and distribution within a particular plant reference leg is not known, and the geometries tested as part of this program were selected to represent bounding configurations only.

### 1.7 Test Program Summary

Thirteen different reference leg piping systems were tested. Configurations were selected to provide both sufficient parametric variation for analytic model correlation, and conservative measurements on indicated water level changes. These piping systems were selected after 32 plant-specific water level reference legs were reduced from isometric drawings supplied by BWROG member utilities. The plant-specific geometric data were characterized in graphical form as the fraction of cumulative height from the condensing chamber output to a particular pipe location vs. the fraction of cumulative volume in the reference leg to the same location. Such characterization allows assessment of the sensitivity of indicated water level column height to percentage loss of leg water volume for all surveyed reference legs. This in turn provided a means to select piping systems that had equal or greater height to volume sensitivities, and thus a bounding indication on maximum reference leg indicated water level perturbations during depressurization events. A plot of the height-volume characteristics for the configurations tested is shown in Fig. 1.4 and that of the plant-specific height-volume characteristic is shown in Fig. 1.5.

Modifications to the originally proposed piping geometries to be tested were made during the test period, under BWROG approval, to assure the maximum usefulness of the resulting test data. This flexibility was deemed essential to provide usable, relevant, and high-quality data in support of the test objectives, and allowed observations made on previous configurations to guide the parametric choices on the tests that followed. Primary parametric variations in the test matrix, in addition to reference leg geometry, included the type of non-condensable gas dissolved in solution, the concentration of

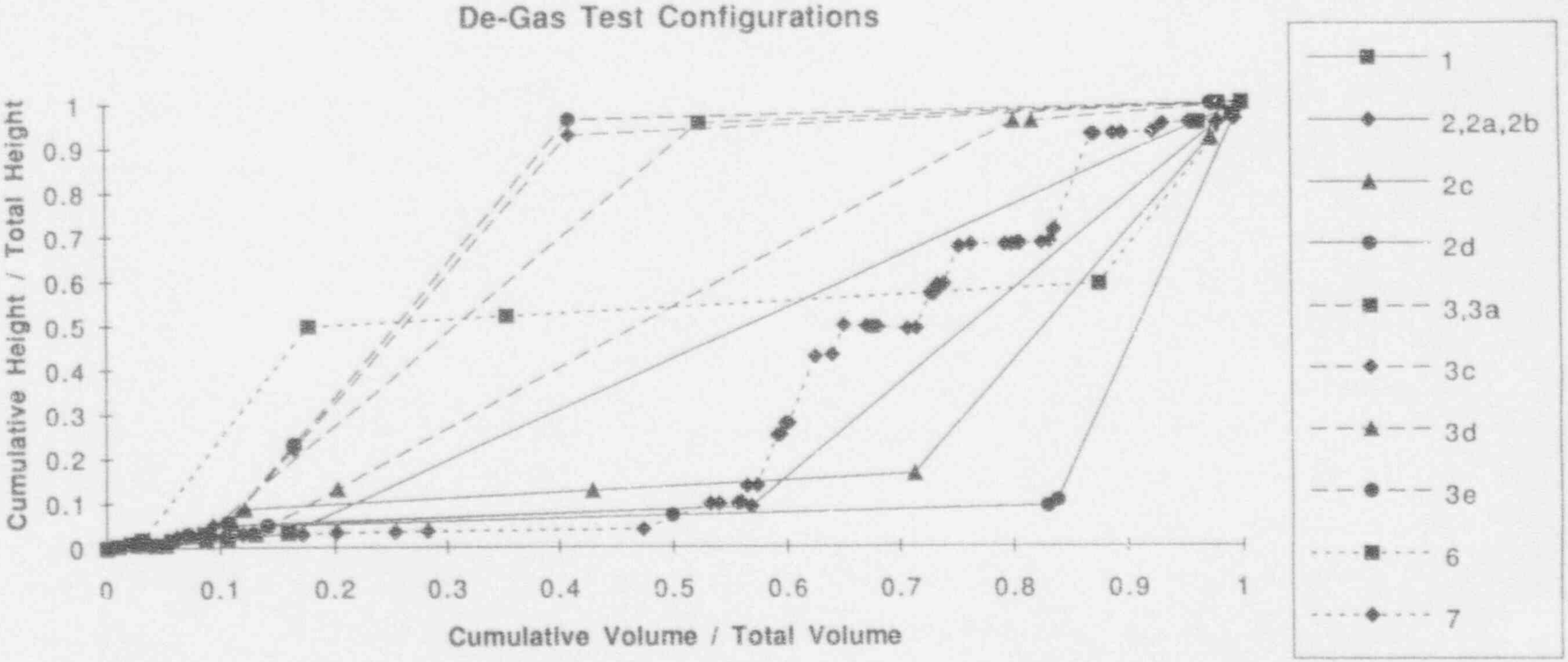

Fig. 1.4: Overlay of All Tested Configuration Height-Volume Characteristics

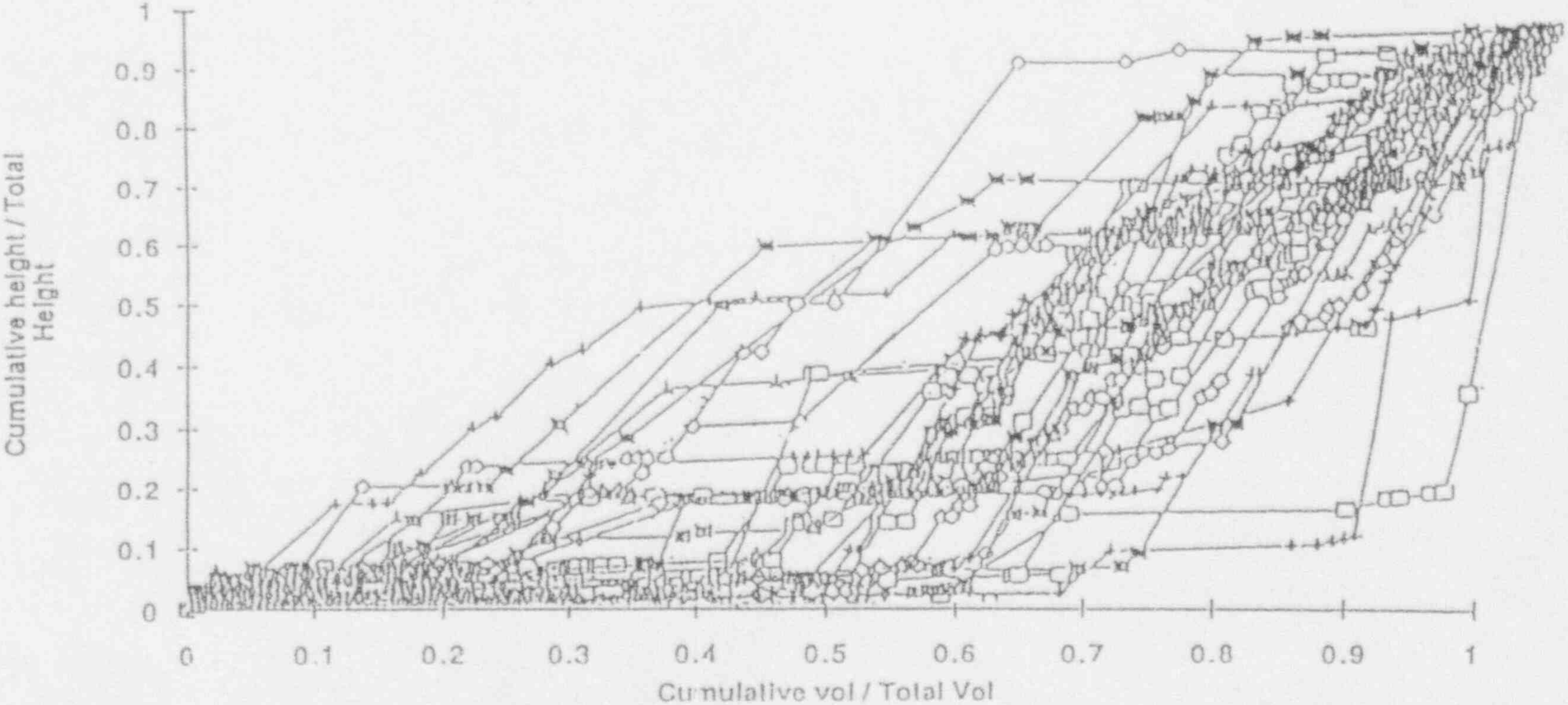

Fig. 1.5: Overlay of All Plant-Specific Height - Volume Characteristics

dissolved gas in the solutions, and the depressurization rate. A detailed list of the tests conducted on each configuration are presented in Table 2.1, and are described briefly below.

## 1.8 Test Equipment

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A pressure vessel of ten cubic feet volume was used to provide both an initial nominal reference pressure of 1000 psia on the reference leg, and to control the pressure time history during depressurization of the system. The depressurization rate was controlled by a valve actuated blowdown through an orifice whose size was chosen to set a depressurization rate and time history that is representative of a design basis reactor accident. The orifice was changed to allow variation of the depressurization rate, in order to investigate the influence of pressure rate effects on the amount of indicated water level lost in the test reference leg. Nitrogen was used as the working gas for the vessel pressurization.

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It should be noted that the test setup is such that the decrease in reference leg water level is measured as gas comes out of solution. This expansion of dissolved gases would correspond to an indicated increase in RPV level as observed on plant level instrumentation. It is necessary to understand this distinction when discussing decreasing water level in these test results.

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The pressure vessel was connected to the water level reference leg through a 2" vertical pipe, which in turn was connected to a coupling chamber having a shape similar to that of a conventional condensing chamber found on BWR water reference instrumentation lines. This coupling chamber was installed vertically, whereas more typically the chamber is installed in a horizontal plane. This chamber simulates the flow constrictions and spillway present in an actual system in order to ensure that geometric influences on the test data results are due only to the reference leg piping system itself.

Non-condensable gas was introduced into the reference leg piping by using a pre-mixed solution, made by combining demineralized water with the desired gas in a separate chamber under pressure. The concentration of dissolved gas was controlled by means of adjusting pressure in the separate chamber to achieve a particular equilibrium condition. After the solution had achieved the desired concentration, it was injected into the reference leg by using a gas blanket at slightly higher pressure. Verification that the proper concentration was in the reference leg piping was done by injecting the solution through a port at the bottom of the piping system near the differential pressure instrumentation, and sampling a small volume of solution that was extracted from an upper location near the free surface in the coupling chamber.

Geometric variations for the configurations tested are outlined below, and are more completely described in Section 6 of this report. That section provides detailed spreadsheet calculations that accurately represent the as-built configurations tested at the EPRI-NDE Center. Simple sketches of the piping geometries tested can be seen in Fig. 1.6 below. | Rev. 1

The first configuration tested, configuration #1, consisted of a straight vertical 30' (nominal) 1" SCH 80 stainless steel pipe. This configuration, due to its almost 1:1 sensitivity of percent volume loss to percent indicated height loss, provided a good baseline test case for analytical model correlation efforts. The second configuration tested, #2, had a short vertical stub connected to the coupling chamber, followed by a 30' nearly horizontal segment having a 1/2" per foot slope, which was then connected to a 28' vertical segment, all of 1" SCH 80 stainless steel pipe. Data from this configuration provided an indication of the effect of horizontal segments on potential water level loss, and was also used to investigate the effects of gas type on indicated water level transient and end point readings. This configuration was modified into configuration #2a to include an offset 1/4" orifice located approximately half way along the horizontal segment, to investigate the influence of an orifice on the measured level error. Configuration #2a was further modified by adding a second orifice in an attempt to simulate flow constrictions that may be present due to an excess flow check valve; this modified configuration was denoted #2b. Configuration #2c was then tested to examine the effect of a reduced vertical segment as compared to #2a, by shortening the 29' vertical pipe to a 17' length. Finally, the vertical pipe was completely replaced with 1/2" stainless steel tubing to assess the influence of smaller diameter tubing located in vertical runs in reference legs; this last modification became configuration #2d.

Configuration #3 was a "mirror image" of configuration #2, in that the 29' vertical segment was directly connected to the coupling chamber, followed by a 30' horizontal segment of 1/2" per foot slope. This variation, when compared to configuration #2, provides data that shows the influence of the sequence of piping segments on the indicated level error. Other parametric variations performed on this configuration were

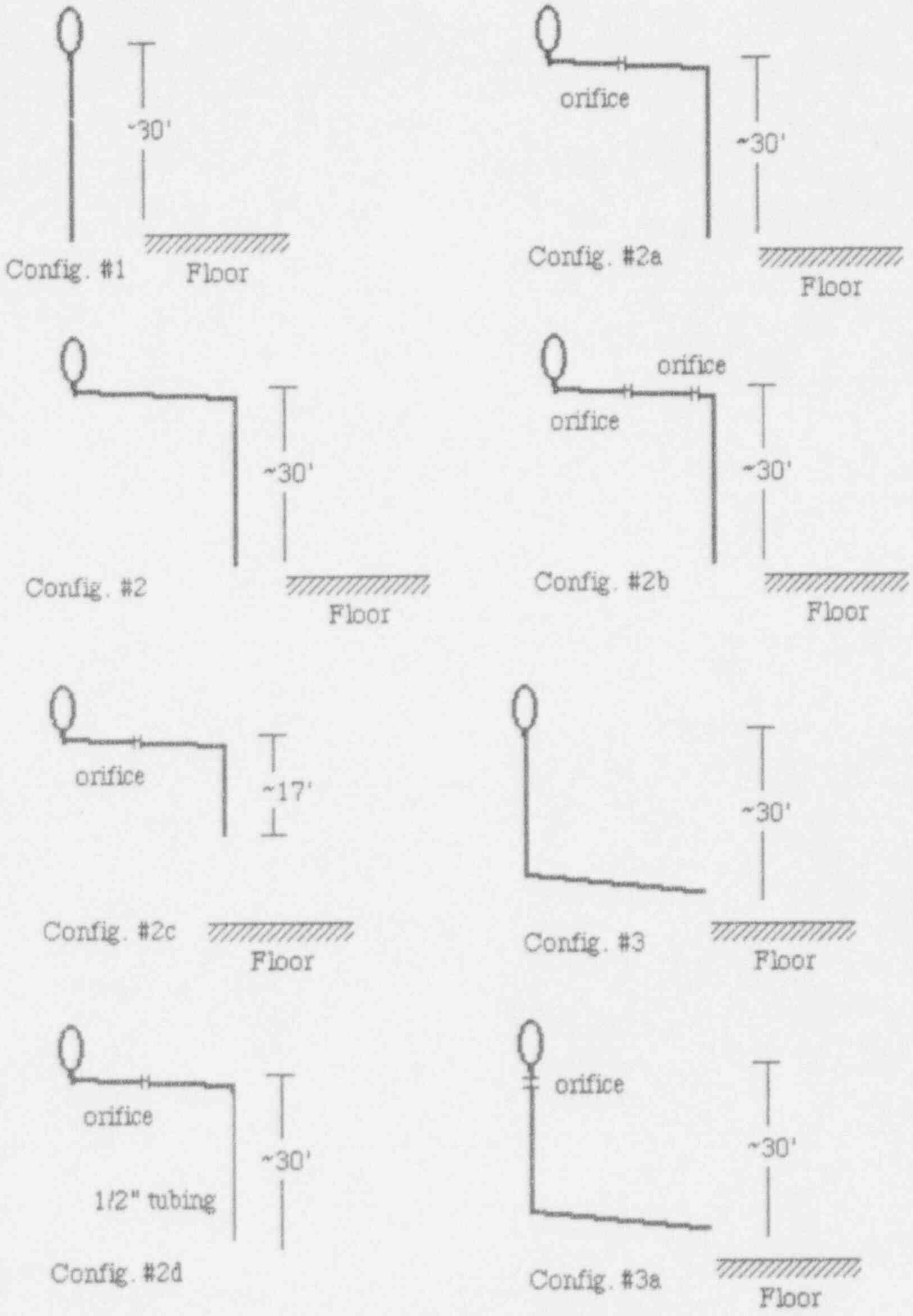
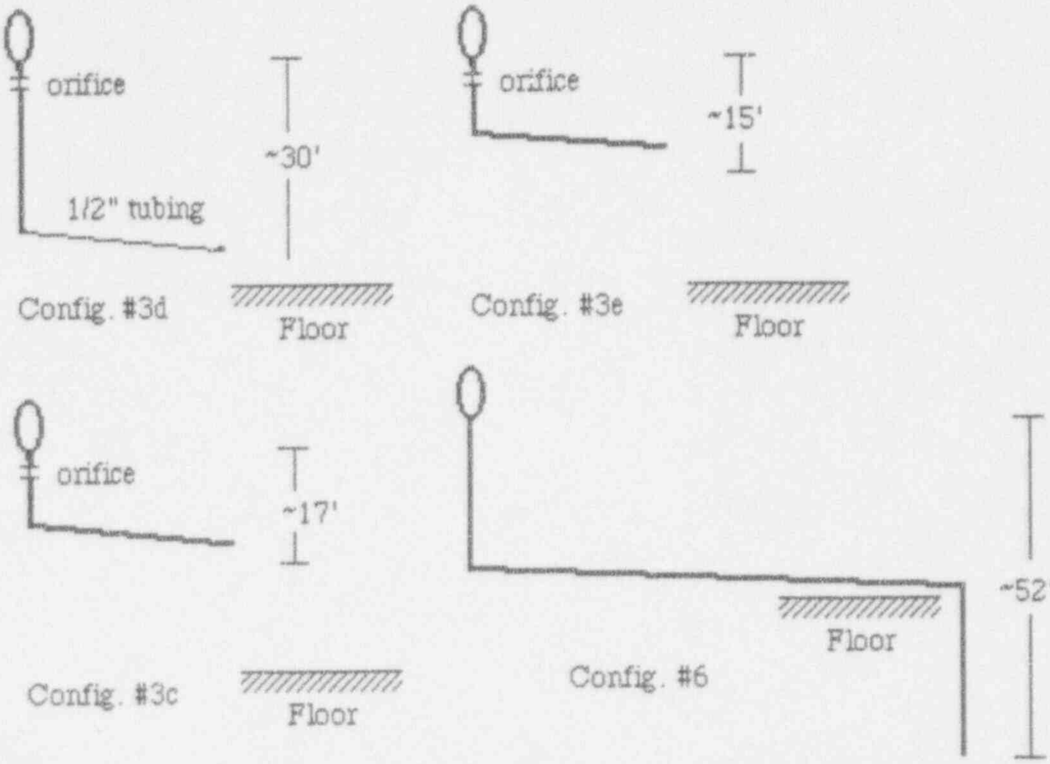


Fig. 1.6: Sketches of Tested Configurations (#1-#3a)



Config. #3d

Config. #3e

Config. #3c

Config. #6

Fig. 1.6 (cont.): Sketches of Tested Configurations (#3c, 3d, 3e and 6) |Rev. 1

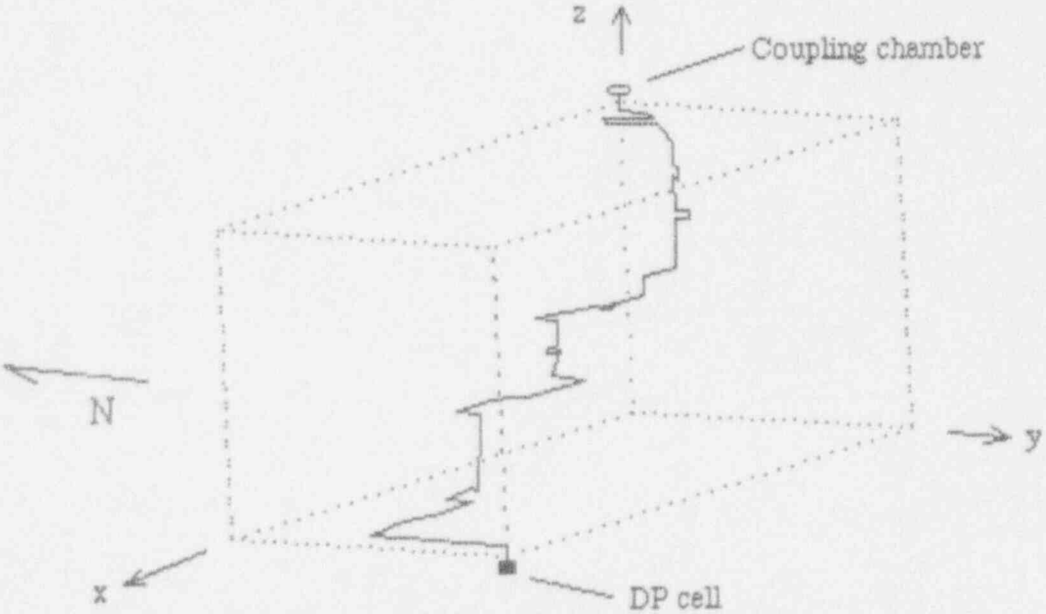


Fig. 1.6 (concl.): Sketches of Tested Configurations (#7)

selected so as to provide similar comparisons as was done for configuration #2: configuration #3a included a 1/4" orifice located 4' below the free surface of the coupling chamber; #3d replaced the nearly horizontal segment of configuration #3a with 1/2" tubing; #3c used a shortened vertical segment of approximately 17' length; and configuration #3e varied the horizontal slope of configuration #3c to 1/4" per foot to investigate effects of slope on level error.

Due to program scheduling limitations, the originally proposed configurations #4 and #5 of the Test Plan (Ref. 1) were skipped (with Model and Test Committee (MATC) approval), and configuration #6 was tested next. This configuration had a 25' vertical segment connected to the coupling chamber, followed by a 117' nearly horizontal segment having 1/2" per foot slope, and then another 22' vertical segment, all built from 1" SCH 80 stainless steel pipe. This configuration had an overall vertical drop of nearly 52', and a large horizontal pipe volume, and thus generated some of the largest level errors of the testing program. Rev. 1

The final configuration tested, #7, was a mock-up of the Hanford WNP-2 "C" channel reference leg, built from plant-supplied isometric drawings, and included an orifice and excess flow check valve as they exist on the actual plant water level reference leg. This geometry was tested at both rapid design basis accident depressurization rates, and at a slow depressurization rate that simulated a plant shutdown operation.

## 1.9 Description of Report Sections

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The remaining sections and Appendices of this report provide additional details on the results from and procedures used in the reference leg depressurization tests. Section 2 presents a summary of the results of the tests, including some general conclusions that may be drawn from the documented results. Section 3 provides additional background on the test facility and instrumentation used in the collection of the experimental data. Section 4 details the processes used in the reduction of the raw test data to correct for configuration influences and instrumentation calibration effects. Section 5 provides additional details on the as-measured configurations tested, and includes additional results of the test program. References for this report are listed in Section 6, the processed time histories of the pressure instrumentation for all tests are presented in Appendix A, documentation on the maximum concentration of non-condensable gas used Rev. 1

in the test program is in Appendix B, and Appendix C documents the test procedures and how the data were taken to assure that a quality-related testing program was employed.

## SECTION 2 SUMMARY OF RESULTS

### 2.1 General Observations

The following observations are for bounding data and are not plant specific. As shown in Fig. 2.1, of the 94 depressurization tests on 13 configurations, the largest indicated height loss was approximately 51% of total height sensed by the differential pressure cell for Configuration #6. As can be seen in Fig. 1.4, such a large percentage of total vertical height loss can be achieved for this configuration with only 18% of the total volume displaced. This high sensitivity of height loss to volume loss provides an extreme upper bound. Fig. 1.5 shows that for the majority of BWR reference legs, a 20% volume loss corresponds to only a 5% to 10% loss in indicated vertical height loss. The majority of the level errors recorded in the testing program reflected a similar 5% to 15% of total vertical column height reduction.

For most of the configurations tested, at least six runs per configuration were made using three dissolved gas concentrations of approximately 300, 600 and 1100 ppmv, and two rapid depressurization rates, corresponding to generic LOCA and ADS/ATWS accident events. This ppmv volumetric concentration measurement best represents the expansion capability of the non-condensable gases coming out of solution as the pressure is lowered, since it equates moles of gas per moles of water, and thus would produce the same volumetric expansion for the same concentration, regardless of gas type. The upper bound on the gas concentration used was based upon calculations (detailed in Appendix B) for an assumed stochiometric mixture of hydrogen and oxygen in the condensing chamber that showed the maximum level was limited by RPV pressure and temperature dependent gas solubility in the reference leg. The lower limit was selected after repeated testing of Configuration #1 showed no level error for dissolved gas concentrations of 100 ppmv and lower.

The two depressurization rates were selected as being typical of the postulated LOCA and ADS/ATWS events for the majority of operating BWRs, and were controlled through insertion of an orifice disk having either a 0.157" or 0.266" diameter hole into the vent line to the exhaust stack. While the actual accident scenarios for LOCA, ADS or ATWS events may include rapid depressurization to pressures other than one atmosphere, it was concluded that the testing schedule could be accelerated and the results could be made

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more bounding if the depressurization went directly to atmospheric conditions. End point pressures other than atmospheric were investigated during tests on Configuration #1. Rev. 1

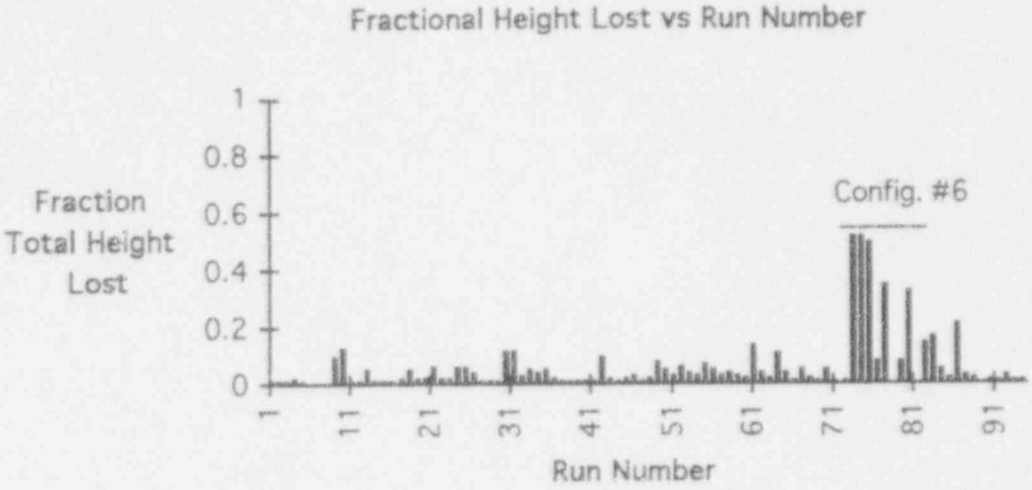

Fig. 2.1: Summary of Fractional Differential Pressure Losses

Both end-point level errors and transient pressure data were recorded as part of the experimental program. Due to the "accumulator" function of the coupling chamber located at the top of the piping configurations tested, most of the transient data showed a indicated level error greater than the final endpoint level error. This is primarily due to the migration of gas voids up the pipe, from areas of smaller cross-sectional area to those of greater area. Since the coupling chamber diameter was typically three times that of the pipe geometries tested, small resultant (or residual) level errors could show a transient level decrease as much as nine times the steady-state value. Thus, differential pressure data typically showed a reduction during depressurization, followed by a "recovery" process where the indicated test reference leg level would increase to its final steady-state value. Rev. 1

Tabulated end-point level errors are summarized in Table 2.1 for all 94 configurations. This table includes a cross-reference between test number and configuration, gas type, concentration, depressurization rate, and final level error. Inspection of this table, and the transient data of Appendix A, provide the basis for making several general observations on the influence of various effects on indicated level error.

Table 2.1: Summary of De-Gas Test End-Point Data

| De-Gas Testing Summary | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| Date | Run # | Test # | Cfg. | Gas | Conc. | Orifice | dt to Pf | P(initial) | P(final) | Level Err | Notes |
| 10-Mar | 1-1 | 1 | 1 | N2 | 597 | 0.25 | 210 | 1027 | 27 | 3.5 | |
| 10-Mar | | 2 | 1 | N2 | 637 | <0.25 | 500 | 1037 | 14.7 | 1.6 | 1 |
| 10-Mar | 1-2 | 3 | 1 | N2 | 617 | 0.25 | 210 | 1036 | 28 | 3.4 | |
| 10-Mar | | 4 | 1 | N2 | 647 | 0.313 | 130 | 1040 | 14.7 | 7.9 | |
| 11-Mar | 1-3 | 5 | 1 | N2 | 627 | 0.25 | 260 | 1036 | 14.7 | 3.4 | |
| 11-Mar | 1-5 | 6 | 1 | N2 | 109 | 0.25 | 210 | 1033 | 28 | 0.5 | |
| 11-Mar | 1-4 | 7 | 1 | N2 | 89 | 0.25 | 260 | 1037 | 14.7 | N.A. | 2 |
| 12-Mar | 1-4 | 8 | 1 | N2 | 79 | 0.266 | LOCA | 1032 | 14.7 | 0.2 | |
| 12-Mar | 1-7 | 9 | 1 | O2 | 1021 | 0.266 | LOCA | 1034 | 29 | 35.6 | |
| 12-Mar | 1-6 | 10 | 1 | O2 | 1051 | 0.266 | LOCA | 1030 | 14.7 | 44.8 | |
| 12-Mar | 1-10 | 11 | 1 | O2 | 1071 | 0.157 | ATWS | 1036 | 14.7 | 4.0 | |
| 15-Mar | 1-9 | 12 | 1 | N2 | 657 | 0.157 | ATWS | 1036 | 14.7 | 0.9 | |
| 16-Mar | 2-1 | 13 | 2 | O2 | 1160 | 0.157 | ATWS | 1035 | 14.7 | 17.9 | 3 |
| 16-Mar | 2-4 | 14 | 2 | N2 | 567 | 0.157 | ATWS | 1029 | 14.7 | 3.6 | |
| 16-Mar | 2-4 | 15 | 2 | N2 | 607 | 0.157 | ATWS | 1030 | 14.7 | 3.9 | |
| 17-Mar | 2-4 | 16 | 2 | N2 | 647 | 0.157 | ATWS | 1034 | 14.7 | 3.8 | |
| 17-Mar | 2-4 | 17 | 2 | O2 | 537 | 0.157 | ATWS | 1030 | 14.7 | 6.9 | |
| 17-Mar | 2-3 | 18 | 2 | N2 | 617 | 0.266 | LOCA | 1030 | 14.7 | 19.4 | |
| 18-Mar | 2-1 | 19 | 2 | O2 | 1110 | 0.157 | ATWS | 1031 | 14.7 | 6.9 | |
| 18-Mar | 2-1 | 20 | 2 | O2 | 1130 | 0.157 | ATWS | 1029 | 14.7 | 6.8 | |
| 18-Mar | 2-2 | 21 | 2 | O2 | 1170 | 0.266 | LOCA | 1030 | 14.7 | 21.5 | |
| 19-Mar | 2-5 | 22 | 2 | O2 | 307 | 0.266 | LOCA | 1032 | 14.7 | 9.0 | |
| 19-Mar | 2-6 | 23 | 2 | O2 | 307 | 0.157 | ATWS | 1034 | 14.7 | 8.4 | |
| 19-Mar | 2a-1 | 24 | 2a | O2 | 1110 | 0.266 | LOCA | 1032 | 14.7 | 20.5 | |
| 22-Mar | 2a-2 | 25 | 2a | O2 | 695 | 0.266 | LOCA | 1030 | 14.7 | 20.0 | |
| 22-Mar | 2a-3 | 26 | 2a | O2 | 297 | 0.266 | LOCA | 1031 | 14.7 | 14.5 | |
| 22-Mar | 2a-4 | 27 | 2a | O2 | 1141 | 0.157 | ATWS | 1030 | 14.7 | 3.7 | |
| 22-Mar | 2a-5 | 28 | 2a | O2 | 616 | 0.157 | ATWS | 1031 | 14.7 | 3.8 | |
| 23-Mar | 2a-6 | 29 | 2a | O2 | 287 | 0.157 | ATWS | 1031 | 14.7 | 5.2 | |
| 23-Mar | 2b-1 | 30 | 2b | O2 | 1130 | 0.266 | LOCA | 1031 | 14.7 | 41.7 | |
| 23-Mar | 2b-2 | 31 | 2b | O2 | 626 | 0.266 | LOCA | 1031 | 14.7 | 40.5 | |
| 23-Mar | 2b-3 | 32 | 2b | O2 | 297 | 0.266 | LOCA | 1031 | 14.7 | 10.8 | |
| 24-Mar | 2c-1 | 33 | 2c | O2 | 1200 | 0.266 | LOCA | 1032 | 14.7 | 10.7 | |
| 24-Mar | 2c-2 | 34 | 2c | O2 | 635 | 0.266 | LOCA | 1030 | 14.7 | 7.7 | |
| 24-Mar | 2c-3 | 35 | 2c | O2 | 346 | 0.266 | LOCA | 1030 | 14.7 | 9.7 | |
| 25-Mar | 2d-1 | 36 | 2d | O2 | 1110 | 0.266 | LOCA | 1030 | 14.7 | 8.0 | |
| 25-Mar | 2d-2 | 37 | 2d | O2 | 616 | 0.266 | LOCA | 1030 | 14.7 | 4.9 | |
| 25-Mar | 2d-3 | 38 | 2d | O2 | 317 | 0.266 | LOCA | 1030 | 14.7 | 2.1 | |
| 25-Mar | 2d-4 | 39 | 2d | O2 | 1110 | 0.157 | ATWS | 1030 | 14.7 | 2.9 | |
| 26-Mar | 2d-5 | 40 | 2d | O2 | 715 | 0.157 | ATWS | 1027 | 14.7 | 2.2 | |
| 26-Mar | 2d-6 | 41 | 2d | O2 | 317 | 0.157 | ATWS | 1031 | 14.7 | 1.9 | |
| 29-Mar | 3-1 | 42 | 3 | O2 | 1200 | 0.266 | LOCA | 1031 | 14.7 | 34.9 | |
| 29-Mar | 3-2 | 43 | 3 | O2 | 675 | 0.266 | LOCA | 1031 | 14.7 | 6.2 | |
| 29-Mar | 3-3 | 44 | 3 | O2 | 376 | 0.266 | LOCA | 1031 | 14.7 | 5.3 | |
| 29-Mar | 3-3 | 45 | 3 | O2 | 327 | 0.266 | LOCA | 1030 | 14.7 | 6.8 | |
| 30-Mar | 3-4 | 46 | 3 | O2 | 1150 | 0.157 | ATWS | 1030 | 14.7 | 10.0 | |
| 30-Mar | 3-5 | 47 | 3 | O2 | 675 | 0.157 | ATWS | 1030 | 14.7 | 5.5 | |
| 30-Mar | 3-6 | 48 | 3 | O2 | 336 | 0.157 | ATWS | 1030 | 14.7 | 6.2 | |
| 30-Mar | 3a-1 | 49 | 3a | O2 | 1140 | 0.266 | LOCA | 1030 | 14.7 | 26.8 | |
| 31-Mar | 3a-2 | 50 | 3a | O2 | 606 | 0.266 | LOCA | 1031 | 14.7 | 19.6 | |
| 31-Mar | 3a-3 | 51 | 3a | O2 | 346 | 0.266 | LOCA | 1031 | 14.7 | 11.7 | |
| 31-Mar | 3a-4 | 52 | 3a | O2 | 1091 | 0.157 | ATWS | 1031 | 14.7 | 20.6 | |
| 31-Mar | 3a-5 | 53 | 3a | O2 | 635 | 0.157 | ATWS | 1030 | 14.7 | 14.6 | |

Table 2.1 (cont.): Summary of De-Gas Test End-Point Data

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31-Mar | 3a-6 | 54 | 3a | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 9.6 | |
| 1-Apr | 3d-1 | 55 | 3d | O2 | 1130 | 0.266 | LOCA | 1030 | 14.7 | 25.5 | |
| 1-Apr | 3d-2 | 56 | 3d | O2 | 655 | 0.266 | LOCA | 1030 | 14.7 | 19.5 | |
| 1-Apr | 3d-3 | 57 | 3d | O2 | 307 | 0.266 | LOCA | 1030 | 14.7 | 11.7 | |
| 1-Apr | 3d-4 | 58 | 3d | O2 | 1120 | 0.157 | ATWS | 1029 | 14.7 | 13.7 | |
| 2-Apr | 3d-5 | 59 | 3d | O2 | 535 | 0.157 | ATWS | 1030 | 14.7 | 12.4 | |
| 2-Apr | 3d-6 | 60 | 3d | O2 | 336 | 0.157 | ATWS | 1030 | 14.7 | 7.0 | |
| 5-Apr | 3c-1 | 61 | 3c | O2 | 1081 | 0.266 | LOCA | 1030 | 14.7 | 28.7 | |
| 5-Apr | 3c-2 | 62 | 3c | O2 | 626 | 0.266 | LOCA | 1030 | 14.7 | 8.5 | |
| 5-Apr | 3c-3 | 63 | 3c | O2 | 297 | 0.266 | LOCA | 1030 | 14.7 | 5.0 | |
| 5-Apr | 3c-4 | 64 | 3c | O2 | 1150 | 0.157 | ATWS | 1030 | 14.7 | 21.9 | |
| 5-Apr | 3c-5 | 65 | 3c | O2 | 616 | 0.157 | ATWS | 1030 | 14.7 | 8.9 | |
| 6-Apr | 3c-6 | 66 | 3c | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 1.7 | |
| 6-Apr | 3e -1 | 67 | 3e | O2 | 1150 | 0.266 | LOCA | 1030 | 14.7 | 18.6 | |
| 6-Apr | 3e -2 | 68 | 3e | O2 | 616 | 0.266 | LOCA | 1030 | 14.7 | 6.1 | |
| 6-Apr | 3e -3 | 69 | 3e | O2 | 327 | 0.266 | LOCA | 1030 | 14.7 | 5.6 | |
| 6-Apr | 3e -4 | 70 | 3e | O2 | 1150 | 0.157 | ATWS | 1031 | 14.7 | 17.1 | |
| 7-Apr | 3e -5 | 71 | 3e | O2 | 596 | 0.157 | ATWS | 1030 | 14.7 | 4.0 | |
| 7-Apr | 3e -6 | 72 | 3e | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 5.1 | |
| 8-Apr | 6-1 | 73 | 6 | O2 | 1130 | 0.266 | LOCA | 1030 | 14.7 | 324.4 | |
| 8-Apr | 6-2 | 74 | 6 | O2 | 1021 | 0.266 | LOCA | 1030 | 14.7 | 324.3 | |
| 8-Apr | 6-3 | 75 | 6 | O2 | 556 | 0.266 | LOCA | 1030 | 14.7 | 313.8 | |
| 8-Apr | 6-4 | 76 | 6 | O2 | 268 | 0.266 | LOCA | 1030 | 14.7 | 51.8 | |
| 8-Apr | 6-5 | 77 | 6 | O2 | 1071 | 0.157 | ATWS | 1030 | 14.7 | 213.9 | |
| 9-Apr | 6-5 | 78 | 6 | O2 | 616 | 0.157 | ATWS | 1030 | 14.7 | n/a | 4 |
| 9-Apr | 6-6 | 79 | 6 | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 47.9 | |
| 9-Apr | 6-5 | 80 | 6 | O2 | 555 | 0.157 | ATWS | 1030 | 14.7 | 203.9 | |
| 13-Apr | 7-1 | 81 | 7 | O2 | 1091 | 0.266 | LOCA | 1031 | 14.7 | n/a | 5 |
| 13-Apr | 7-1 | 82 | 7 | O2 | 1130 | 0.266 | LOCA | 1030 | 14.7 | 70.1 | |
| 13-Apr | 7-1 | 83 | 7 | O2 | 1110 | 0.266 | LOCA | 1029 | 14.7 | 83.2 | |
| 14-Apr | 7-2 | 84 | 7 | O2 | 695 | 0.266 | LOCA | 1030 | 14.7 | 24.0 | |
| 14-Apr | 7-3 | 85 | 7 | O2 | 307 | 0.266 | LOCA | 1030 | 14.7 | 10.4 | |
| 14-Apr | 7-4 | 86 | 7 | O2 | 1209 | 0.157 | ATWS | 1030 | 14.7 | 104.7 | |
| 14-Apr | 7-5 | 87 | 7 | O2 | 616 | 0.157 | ATWS | 1030 | 14.7 | 14.4 | |
| 14-Apr | 7-6 | 88 | 7 | O2 | 317 | 0.157 | ATWS | 1030 | 14.7 | 11.1 | |
| 14-Apr | 7-7 | 89 | 7 | O2 | 42 | 0.266 | LOCA | 1030 | 14.7 | 0.0 | |
| 15-Apr | 7-8 | 90 | 7 | O2 | 715 | n/a | S.D. | 1015 | 14.7 | 7.1 | 6 |
| 16-Apr | 7-9 | 91 | 7 | O2 | 317 | n/a | S.D. | 1015 | 14.7 | 2.7 | 6 |
| 22-Apr | 7-10 | 92 | 7 | O2 | 513 | 0.266 | LOCA | 1030 | 14.7 | 14.7 | |
| 23-Apr | 7-11 | 93 | 7 | O2 | 179 | n/a | S.D. | 1015 | 14.7 | 0.8 | 6 |
| 23-Apr | 7-12 | 94 | 7 | O2 | 189 | 0.157 | ATWS | 1030 | 14.7 | 0.8 | |

Notes:

(1) A stuck solenoid valve forced a blowdown using the nitrogen injection port.

(2) Improper re-injection of pre-mixed solution following sample resulted in a reference leg that was not completely filled prior to blowdown.

(3) Pre-mixed tank ran "dry" during latter portion of solution injection, introducing gas into the reference leg and resulting in large errors.

(4) Suffered power outage during blowdown event.

(5) Noise on replacement data acquisition card invalidated transient data.

(6) Slow depressurization run to simulate 8 hr plant shutdown

## 2.2 Gas Concentration

As would be expected, in most cases tested, the higher concentration of dissolved gas, the larger the indicated level error, due to the larger volume that the gas can occupy when expanded to atmospheric conditions. The influence of concentration was not directly linear, due to dynamic effects associated with configuration geometry and at what time during the depressurization the gas came out of solution.

## 2.3 Gas Type

While two gas types (nitrogen and oxygen) were investigated in testing Configuration #1, the closest test points for gas type comparison are the data from tests #14 and #17 on Configuration #2, which were both ATWS-type depressurizations for gas concentrations near 550 ppmv. Since oxygen is more soluble than nitrogen, a nitrogen mixture would require a higher equilibrium partial pressure, and would begin to come out of solution sooner in the depressurization event. Nominally the same volume of gas would be released at one atmosphere, therefore the volumetric growth rate for the oxygen gas would be larger, and hence the dynamic expansion forces would be correspondingly greater, resulting in increased level error. This hypothesis was borne out by these data, and as a consequence all subsequent tests used oxygen as the non-condensable gas in order to provide more bounding estimates for the static and dynamic level errors.

## 2.4 Configuration Variations

Geometric variations of reference leg piping systems have a profound impact upon the level error resulting from degassing due to rapid depressurization. While some of the configuration variations explored in the test matrix were for piping systems having the same volume, the majority required a reduction of total reference leg volume in order to evaluate selected parameters. Because the amount of non-condensable gas is controlled on a volumetric basis for the tests, a reduction of reference leg volume at the same dissolved gas solution concentration is equivalent to a reduction in the total amount of gas in the system. Direct comparison of level errors between configurations of differing volumes would not necessarily provide a suitable basis to separate out the influence of geometry over simple volume displacement capability. In order to assess the geometric dependencies of level error, data in the comparisons below has been further reduced by calculating fractional height loss and corresponding fractional volume loss, based upon the configuration height - volume sensitivities presented in Section 6.

### *2.4.1 Horizontal - Vertical Segment Sequence*

The most obvious difference between horizontal and vertical piping segment sequences for similar volumes can be seen through comparison of results from Configurations #2 and #3. Configuration #2 has a greatly reduced sensitivity of height loss to volume loss compared to Configuration #3, and thus for the same displaced volume, one would expect the indicated height loss for Configuration #3 to be significantly larger. However, since the primary transport mechanism for gas bubbles is buoyancy, one would also expect that bubbles rising through vertical segments would provide additional momentum and mixing in any horizontal segments they may enter later, and thus help to "strip" gas out of horizontal segments that would otherwise form gas bubbles through diffusion to the pipe surface only. Both of these competing effects can be seen in comparison of tests #21 (Config. #2) and #42 (Config. #3). While test #21 shows a reduced level error, its orientation is such that the volume required to produce this level loss is <u>greater</u> than that for test #42. As a result, the level errors for these two configurations are not as different as one may think they should be based upon static displacement arguments alone.

### *2.4.2 Length Dependencies*

Effects of variations in lengths of vertical segments are illustrated between Configurations #2a and #2c, and #3a and #3c in Figs. 2.2 and 2.3 below. Since the volumes for these configurations are different, direct comparison of indicated level errors does not convey the differences due to dynamic effects such as "stripping" by bubbles in long vertical segments. Comparison of the equivalent fractional volume lost for each configuration shows that, for configurations #2a and #2c, the fractional volume for #2a is larger by almost a factor of two for the highest concentration tested, but approximately equal for configurations #3a and #3c. Thus, increased length of vertical segments has an additional impact if any horizontal segment is exposed to the dynamic migration of bubbles from these longer segments to the upper surface of the coupling chamber.

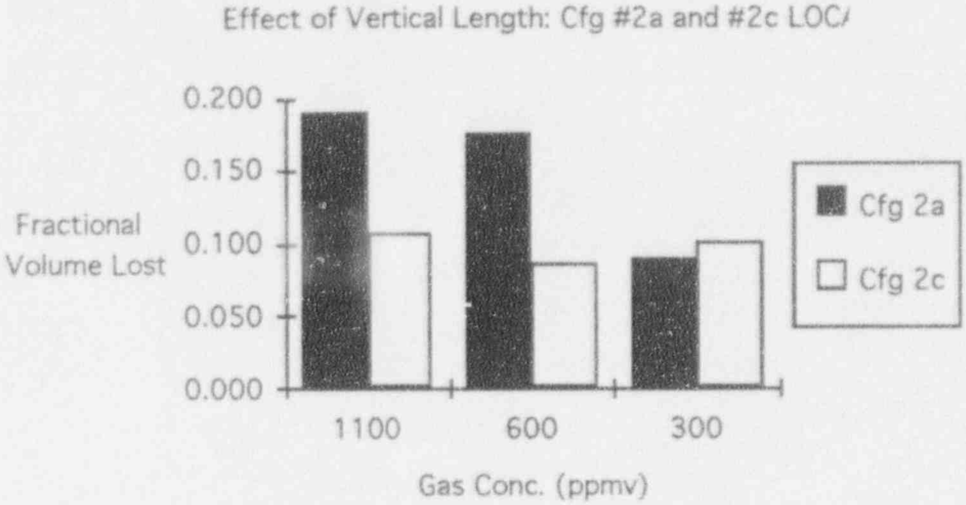

Fig. 2.2: Fractional Volume Lost as a Function of Vertical Length, Cfg. #2.

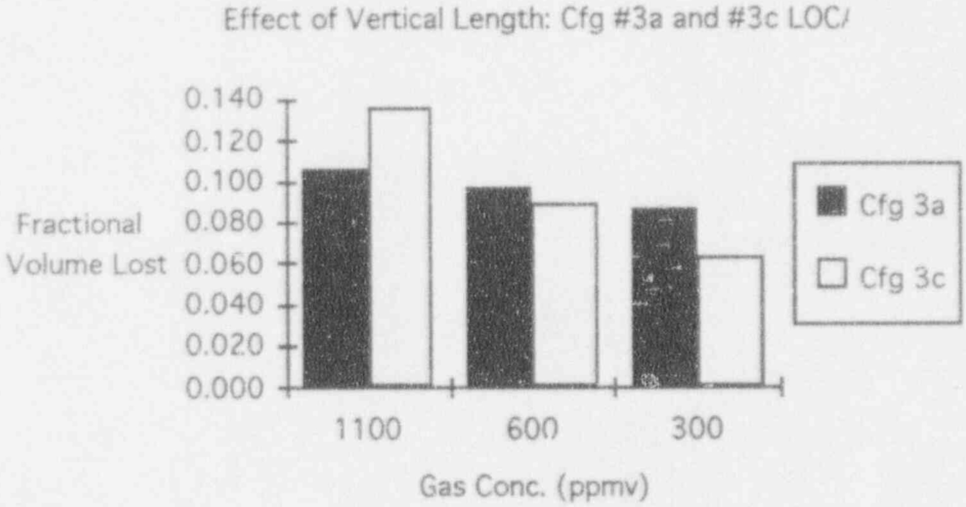

Fig. 2.3: Fractional Volume Lost as a Function of Vertical Length, Cfg. #3.

### *2.4.3 Orifice Effects*

Variations with and without orifices can be seen in comparisons between Configurations #2 and #2a, and #3 and #3a. While the offset 1/4" orifice of Configuration #2a only appears to increase the level error associated with lower concentrations of dissolved gas solutions (shown in Fig. 2.4), the orifice of Configuration #3 shows an increase in level error for the medium concentration test results as well. This orifice may impede the release of gas to the free surface of the coupling chamber, providing an increased volumetric expansion rate at lower pressure and correspondingly higher dynamic expansion forces, resulting in increased mass loss.

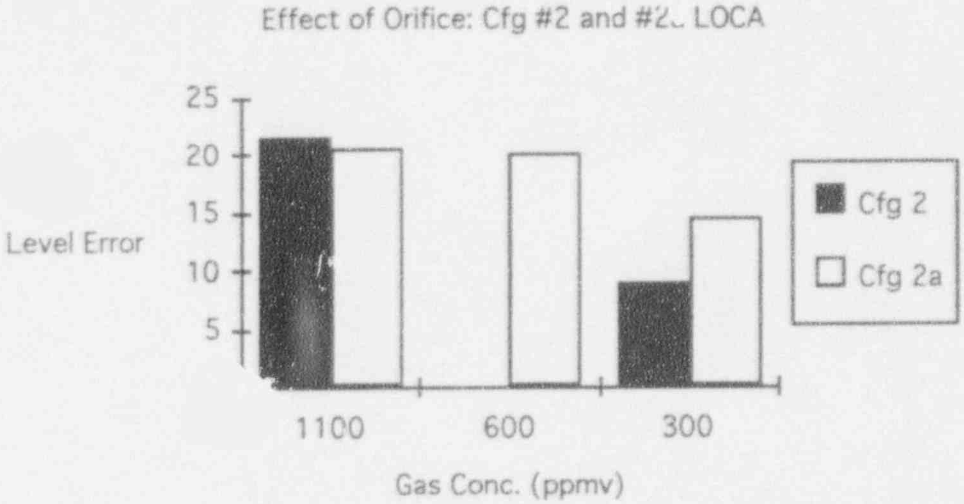

Fig. 2.4: Effect of Orifice on Level Errors for Config. #2

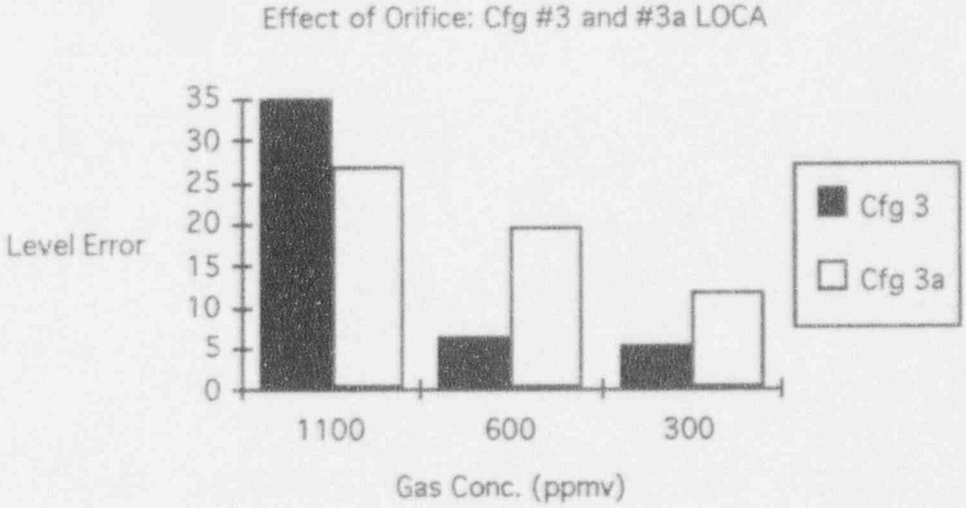

Fig. 2.5: Effect of Orifice on Level Errors for Config. #3

### *2.4.4 Slope Variations*

The only direct variation of slope in the test matrix was between Configurations #3c (1/2" per foot) and #3e (1/4" per foot). Most of the decrease in level error is associated with the higher concentration levels, as shown in Fig. 2.6 below. Slope would primarily affect the bubble rise velocity in nearly horizontal sections of pipe, but it appears that this effect is minimal for the slope variation investigated except for solutions having high concentrations of dissolved gas. Bubble rise velocity would be determined by a balance of buoyant forces with surface tension and friction effects, and could be significantly reduced in lines having only minimal slopes, such as certain segments of Configuration #7.

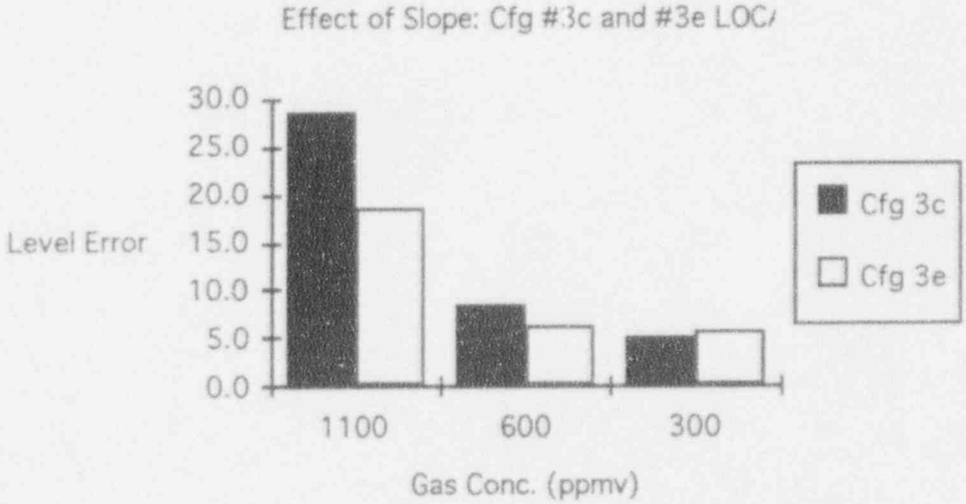

Fig. 2.6: Effect of Slope on Level Error, Config. #3.

### *2.4.5 Pipe Diameter Effects*

Changes to pipe diameter, from 1" SCH 80 pipe to 1/2" nominal s.s. tubing, were designed to show the influence of pipe cross section on level error. Since such reductions in area would also reduce the net volume, the fractional volume loss for Configurations #2 and #3 are shown in Figs. 2.7 and 2.8. Fig. 2.7 indicates that a reduction in pipe diameter in the vertical segment results in smaller nondimensional volume losses, which would be expected, since the corresponding height - volume characteristic for such a modified reference leg would exhibit a reduced sensitivity of indicated height to volume loss. A similar height - volume dependency would be expected, and is seen, in Fig. 2.8, since the change in area between Configurations #3a and #3d effectively redistributes more of the volume to the vertical segment of the configuration. Such a redistribution would thus have a larger fractional height error for the same fractional volume loss. As an additional comparison, the actual level errors associated with these changes for Configuration #3 are presented in Fig. 2.9, where it can be seen that essentially no role is played by this reduced horizontal segment area on the final indicated level loss.

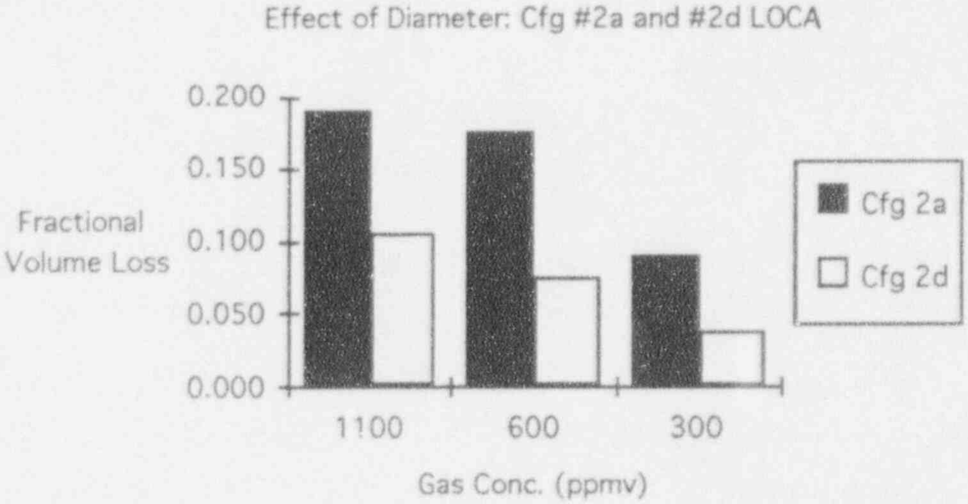

Fig. 2.7: Effect of Pipe Diameter on Fractional Volume Loss, Config. #2.

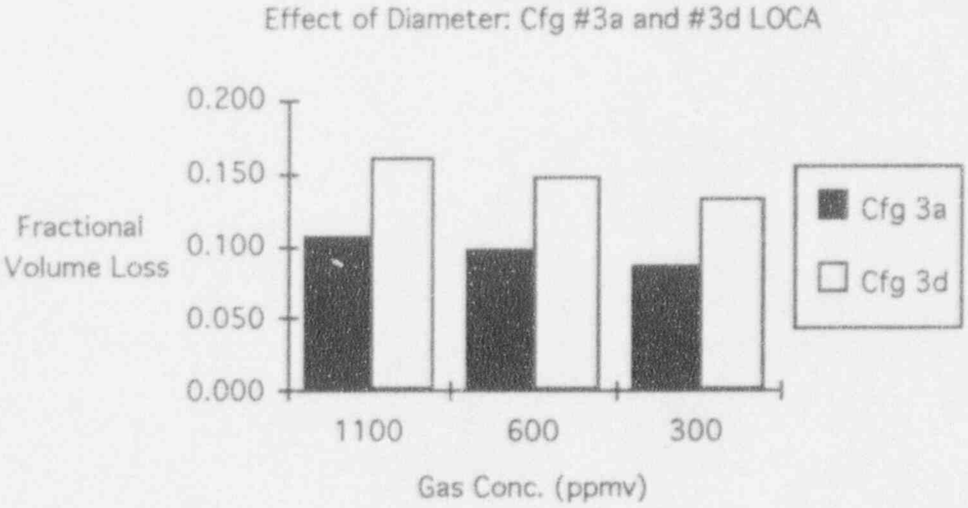

Fig. 2.8: Effect of Pipe Diameter on Fractional Volume Loss, Config. #3.

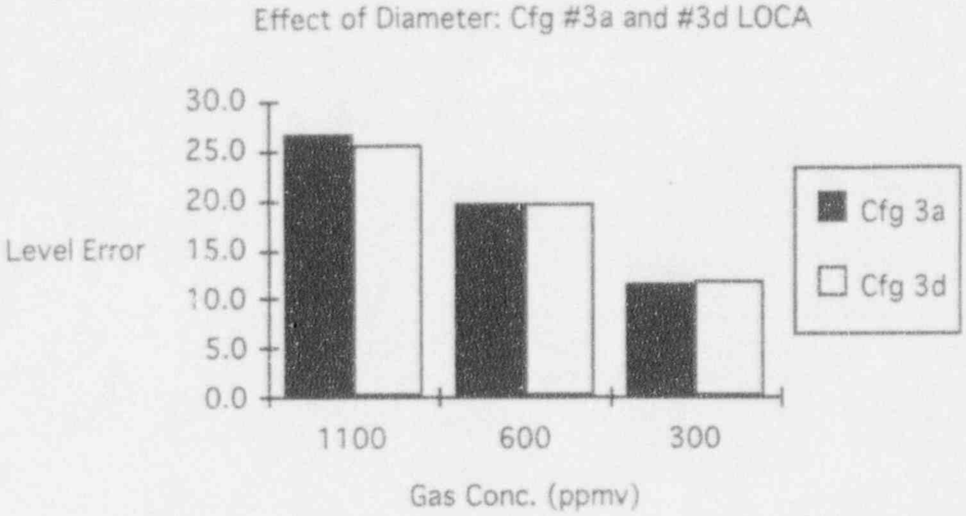

Fig. 2.9: Effect of Pipe Diameter on Level Error, Config. #3.

Pipe diameter was seen to play a substantial role in the end-point indications of the differential pressure transducer for tests on Configuration #7. As is explained in more detail in Section 6, the large indicated level errors for that configuration suggested that an exceptionally large mass of water had to have travelled out of the reference leg and down the spillway. Subsequent post-test measurements on the actual volume remaining in the leg indicated that the differential pressure reading was in fact not indicative of the water volume remaining in the leg, and thus, voids must exist in the piping system of this configuration to account for the discrepancy between indicated level and system water volume. Post-blowdown procedures were added to measure the remaining water in the leg, and these data are reported in tabular form in Section 6. It is theorized that the extensive 1/2" tubing present in this configuration allows voids of gas to remain fixed in vertical piping segments after the system is depressurized, resulting in a head loss indicated on the differential pressure transducer. The small diameter tubing appears to allow water surface tension to support these voids.

## 2.5 Depressurization Rate

Inspection of Table 2.1 reveals that, on average, the faster the depressurization rate, the larger the level error. This effect is primarily due to the added dynamic forcing on the water mass that results from a greater volumetric expansion rate for the non-condensable gases that come out of solution for the faster depressurization test points.

### 2.6 Notching Behavior

"Notching", or the fluctuation of indicated level due to gas release in the reference leg, was observed on a large number of configurations tested. High frequency fluctuations, seen on the data for Configurations #2 and #3, is thought to be random fluctuations in small bubble migration, whereas the slower, more discrete jumps in indicated level can be seen on the test for Configuration #7. It is believed that this latter behavior is caused by slug-flow migration of gas voids between horizontal and vertical segments of piping, and thus accounts for the significant activity seen on the transient data for tests on Configuration #7.

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### 2.7 Repeatability

Repeatability was investigated in the first two tests, and again whenever particularly unique transient data was recorded, such as for test #19 and #20. In every instance investigated, both the final level errors and the general shapes of the transient pressure time histories showed marked repeatability.

### 2.8 System Pressure at Initial De-gassing

The system pressure at which de-gassing was first observed in the transient data is shown in histogram format in Figure 2.10. In every test using oxygen, indicated reference leg water level did not decrease until the system pressure dropped below 220 psia. This pressure is to be compared to the equilibrium saturation pressures of 197, 395 and 733 psia for the solution concentrations of 300, 600 and 1100 ppmv respectively. While some of this behavior may be explained by the time lag associated with diffusion of the gas in solution to the reference leg inner pipe walls, the exact mechanism for this phenomenon is unexplained.

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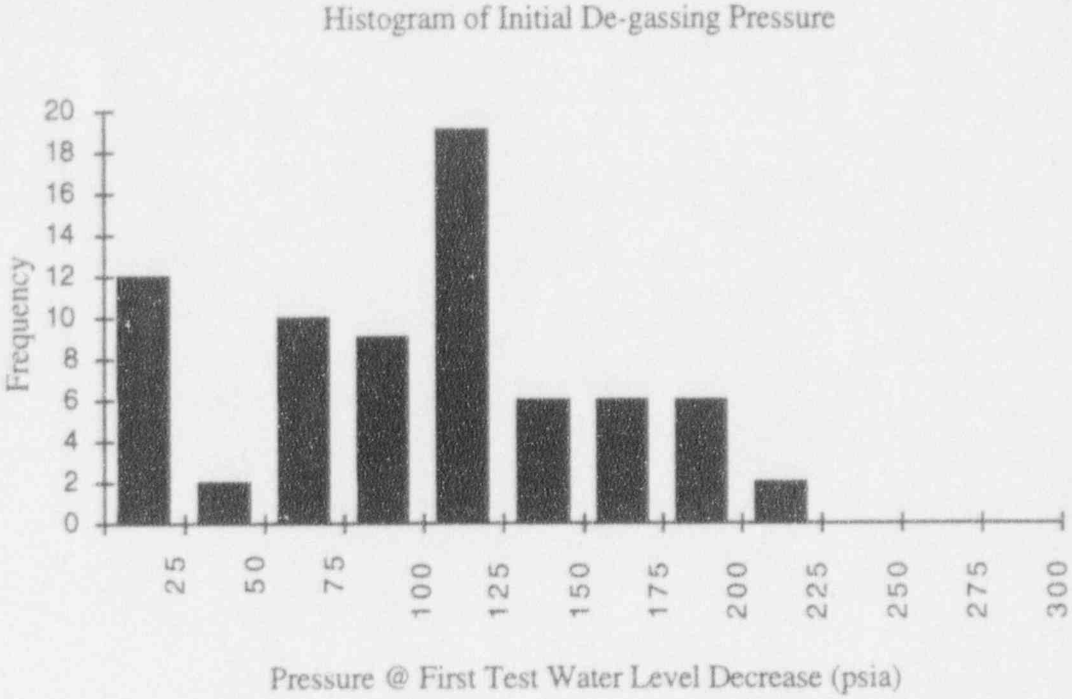

Rev. 1

Figure 2.10: Histogram of Pressure at Initial De-gassing

# SECTION 3 TEST FACILITY

## 3.1 Introduction

Design of the test facility was divided into three separate functional groups: (1) the reference leg piping geometries to be tested; (2) the pressure vessel simulator, to provide a desired depressurization time history and establish proper initial conditions; and (3) the pre-mixed gas-water solution preparation system, to control the concentration of non-condensable gases introduced into the reference leg piping.

## 3.2 General Description

A general schematic diagram of the experimental apparatus is shown in Fig. 3.1 below, along with instruments used in the recording of data for the experiment.

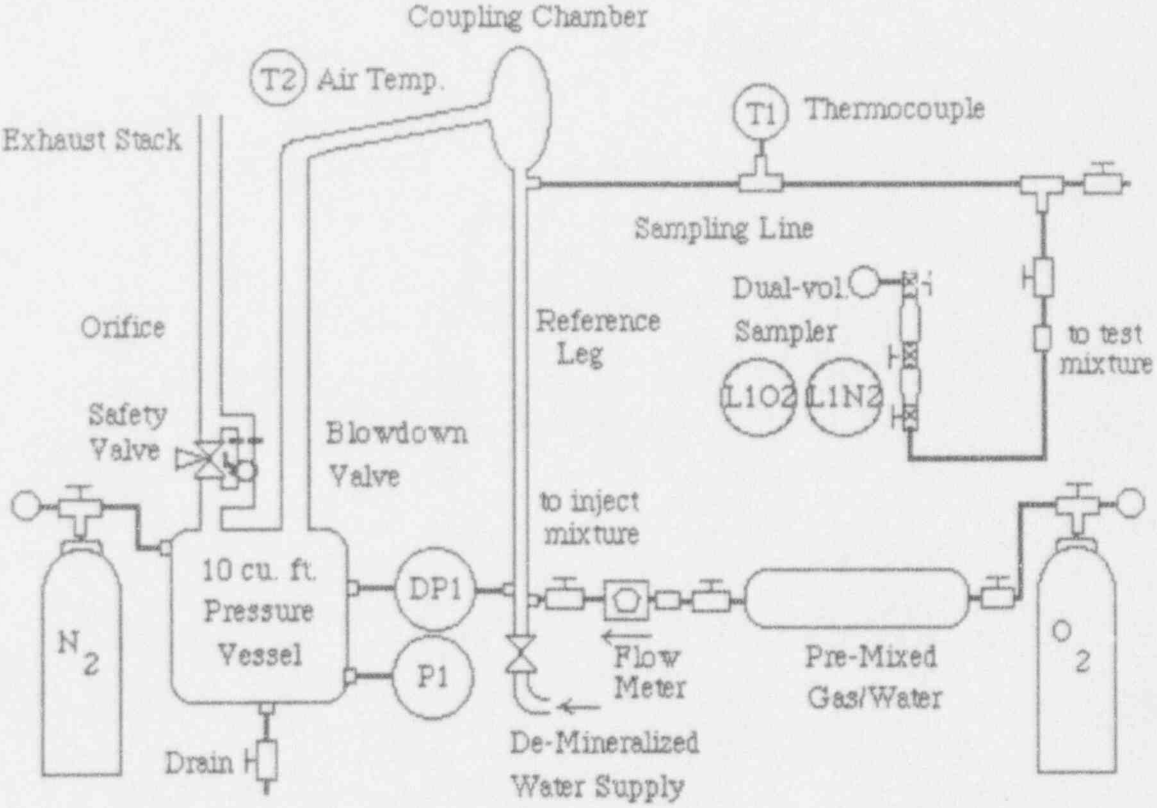

Figure 3.1 Schematic of De-Gas Test Apparatus.

### *3.2.1 Reference Leg Geometries*

Reference leg geometries were constructed from stainless steel pipe or tubing, in order to accurately reproduce the same internal wall roughness and hence provide similar conditions for potential nucleation sites where the non-condensable gas begins to come out of solution. Segments of pipe were joined using socket welded fittings, as is typically done on reference legs on operational BWRs.

### *3.2.2 Pressure Vessel*

The pressure vessel was build from 6" SCH 80 carbon steel pipe, folded back upon itself into an "S"-shape and supported by I-beams on the floor of the high-bay area at the EPRI-NDE Center. This arrangement allowed the proper sizing of the internal volume for an isentropic blowdown that followed the depressurization for LOCA and ADS/ATWS design-basis accidents for a BWR-4, but did not require the additional state licensing requirements of a standard pressure vessel. These vessel pressure time histories may be seen in the attached time histories in the Appendix. The pressure vessel was attached via a flange to a 2" vertical steel pipe that provided the connection to a "coupling chamber", a geometrically similar device to a conventional condensing chamber that was welded to the reference leg under test.

### *3.2.3 Pre-mixed Solution Source*

Pre-mixed solutions of non-condensable gas and demineralized water were prepared by pressurizing a partially filled tank, and then agitating until equilibrium saturation conditions were achieved. Three tanks were constructed from 6" SCH 80 stainless steel, each of approximately 20' in length, and the agitation was provided by rocking the tanks in see-saw fashion while suspended from an overhead crane. Approximately 20 to 30 low frequency oscillations were typically required to drive the gas blanket into solution and achieve equilibrium.

## **3.3 Instrumentation**

Primary instrumentation for these tests consisted of absolute pressure measurements of the pressure vessel, and differential pressure readings between the pressure vessel and the bottom of the filled reference leg under test. Indicated water level loss in the reference

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line was measured using differential pressure instrumentation calibrated for reading inches of water column height, much as it would be in the plant. As will be made more apparent in Section 6 of this report, this value did not always reflect the actual volume of water lost from the reference leg, but was still a valuable measurement because it would directly correlate with instrumentation a BWR operator would have available in the control room. Measurements were also made on the actual volume of water remaining in the reference leg for some of the later runs, and those are reported there as well. Table 3.1 lists the instrumentation used in the collection of both end point and transient level error data, along with other supplemental measurements.

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Table 3.1: Instrumentation List for De-Gas Experiment

| Measurement | Symbol | Instrument |
|---|---|---|
| Differential Pressure | DP1 | Rosemount 1151DP5S Pressure Transmitter |
| Absolute Pressure | P1 | Sensotec 440 Pressure Transmitter |
| Water Temperature | T1 | Type J Thermocouple with Omega DP41-TC meter |
| Air Temperature | T2 | Type J Thermocouple with Omega DP41-TC meter |
| Gas Concentration | L1O2<br>L1N2 | Dual-volume sampling system, with associated valves, tubing and graduated cylinders |
| Computer | | IBM Compatible PC |
| A/D | | Data Translation 2801 A/D Board |

### 3.4 Data Acquisition System

Transient pressure data was acquired using an IBM-PC compatible computer and a DT-2801 analog to digital interface card. The data acquisition unit was calibrated as a stand-alone turn-key device, and sampled the pressure transducer data at a 5Hz rate. Operator intervention was required in determining the length of recorded time history data, through monitoring the absolute and differential pressure instrumentation digital displays for when they reached steady-state conditions.

# SECTION 4 DATA REDUCTION

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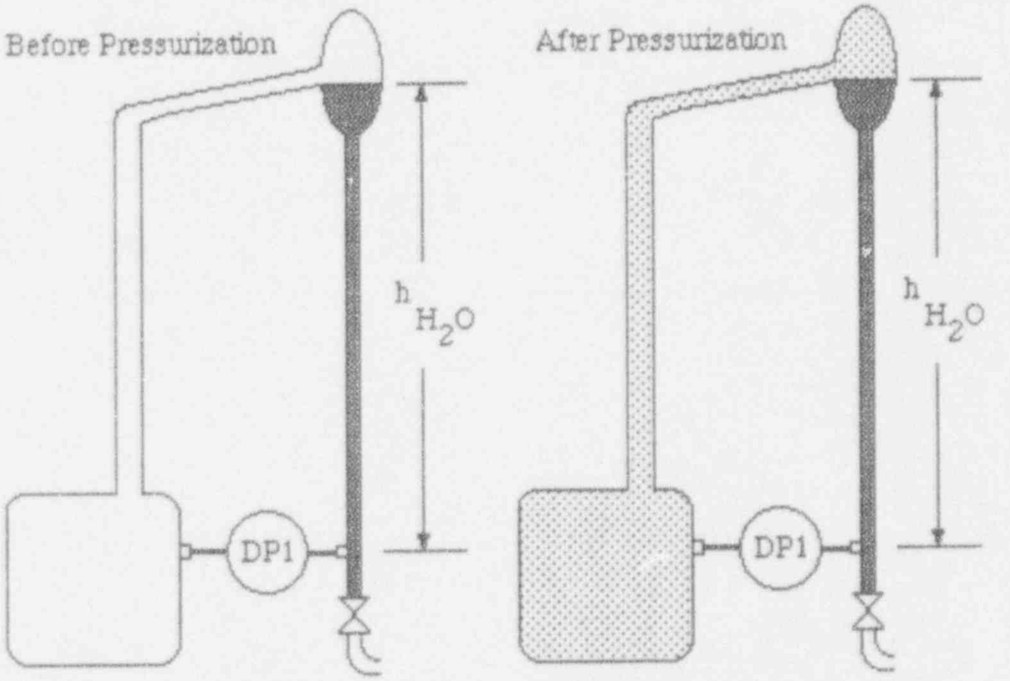
## 4.1 General Description

Rev. 1

Data for the De-Gas test was acquired both from calibrated digital display meters and from a personal-computer based data acquisition system. Both of these sources have traceable calibration documentation that has been maintained as part of this testing program. Corrections to these data include individual instrument calibration curves and adjustment for physical phenomena as a result of the particular orientation of the sensors for recording the transient pressure information.



$$DP1 = \rho_{H_2O}\, g\, h_{H_2O} \qquad DP1 = (\rho_{H_2O} - \rho_{gas})\, g\, h_{H_2O}$$

Figure 4.1: Illustration of DP Cell Reduction with System Pressurization

Rev. 1

During shakedown testing, it became apparent that an adjustment was required in the differential pressure cell that measured water column height by subtracting pressure in the pressure vessel from that measured at the low end of the reference leg. Since the gas-side of the differential sensor would also measure the increased pressure due to the added gas mass in the column connecting the cell to the upper surface of the reference leg, the differential reading would decrease as the total system was pressurized. Since the differential cell actually measures the difference in <u>density</u> of the two fluid columns on each side of its cell, this adjustment is strictly a function of the static pressure in the pressure vessel, and is easily accounted for. This adjustment was applied to the time history data plotted in Appendix A of this report, after the individual calibration curves were applied to the raw data. Appendix C identifies the details and control of the test process. Rev. 1

### 4.2 Quick-look Data Reduction

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Quick-look plots of time histories were made and distributed during the weeks of testing to BWROG Model and Test Committee (MATC) members using the advertised (not measured) gains for the instruments, with the understanding that such preliminary non-Quality related data would still be valuable in helping control the test matrix to deliver the largest possible set of useful data.

### 4.3 Post-test Data Reduction

Rev. 1

Actual instrument calibration curves supplied from approved instrument calibrators have been used in the reduction of the raw time history data given in the Appendix. Best-fit straight line calibration curves were developed from calibrator supplied reference data, and these were applied to the transient pressure data prior to plotting. Corrections were also made to adjust indicated differential pressure when the system was at other than atmospheric pressure. Note that the transient data still show some evidence of differential pressure fluctuation during the initial blowdown transients; these are most likely due to the high flow rates of the nitrogen gas past the pressure port on the pressure vessel during the blowdown process.

## SECTION 5 TESTED CONFIGURATIONS

As-built specifications for reference leg configurations were recorded per the De-Gas test procedures, and these data were converted to spreadsheet format to both aid interpretation of the transient pressure data and provide a basis for possible future correlation efforts against an analytical model. These spreadsheets are presented below for each configuration, along with any additional data that may be pertinent to the correlation and interpretation effort. Reference leg geometries are represented by straight pipe segments connecting identified node points. These nodes are represented by elevation reference (in feet and inches) relative to a fixed reference point, length of pipe or tube (in feet and inches) from the previous node point to the current node point, azimuth orientation of the connecting pipe segment (in degrees) relative to a reference compass orientation, and nominal pipe diameter and schedule of the connecting segment. These geometry data were then used to compute the Cartesian coordinates of the node points (given in feet) and the cumulative volume ("sigma-v", in cubic feet), cumulative volume fraction ("sigma-v/V") and cumulative fractional height ("sigma-h/H") at each node point. These fractional volume and height data were used to characterize the configuration geometries in Figure 1.4 of Section 1. For Configuration #7, the node points are represented by Cartesian coordinates directly (in inches), since these were measured relative to the North corner in the hi-bay at the EPRI-NDE Center in Charlotte, N.C. Slopes (measured in degrees) for some of the segments that were located above the roofline at that facility are also included, where these were used to compute Cartesian coordinates that were not directly measurable. Additional information identifying particular locations of orifices, valves, couplings and instrumentation are given in the "reference" column of each spreadsheet.

Additional measurements of Configuration #7 volume was made after high concentration testing indicated a surprisingly large level error, which would suggest that over half the internal water volume had been voided for a particular test. The system of Configuration #7 was repressurized after all blowdown pressure transients had died down, and an additional end point was taken while the system was at pressure. In addition, the remaining volume was drained and measured using a graduated beaker, in order to assess how the large indicated level errors were possible for this configuration. The conclusions based upon these observed results is that the small diameter (1/2") tubing that is present on a majority of the piping system can sustain sufficient surface tensions to allow trapped voids in vertical segments that do not rise to the reference leg free surface with time.

These trapped voids in the vertical lines, then, would have a net decrease in density sufficient to cause significant indicated level errors on the differential pressure transducer. The post-test volume measurements are given in the table below.

Table 5.1 Post-Test Volume Measurements for Configuration #7 | Rev. 1

De-Gas Testing - Post test reference leg
volume measurement summary
Full leg = 5750 ml

| Date | Run # | Test # | Measured Vol. |
|---|---|---|---|
| 14-Apr | 7-2 | 84 | 4700 |
| 14-Apr | 7-3 | 85 | 5100 |
| 14-Apr | 7-4 | 86 | 4000 |
| 14-Apr | 7-5 | 87 | 5000 |
| 14-Apr | 7-6 | 88 | 5250 |
| 14-Apr | 7-7 | 89 | N.A. |
| 15-Apr | 7-8 | 90 | 5100 |
| 16-Apr | 7-9 | 91 | 5400 |
| 22-Apr | 7-10 | 92 | 5250 |
| 23-Apr | 7-11 | 93 | 5650 |
| 23-Apr | 7-12 | 94 | 5650 |

## Table 5.2: Configuration #1 As-Built Geometry

|Rev. 1

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 1 | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.009695 | 0.052253 | 0.006691 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.48917 | 0.019877 | 0.107136 | 0.016573 |
| | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.029658 | 0.159855 | 0.031762 |
| | | -337.7 | | 326.45 | | 1 | 80 | 0 | 0 | -28.1417 | 0.178034 | 0.959579 | 0.953416 |
| DP1 | | -338.7 | | 1 | | 1 | 80 | 0 | 0 | -28.225 | 0.178489 | 0.962029 | 0.956239 |
| ball vlv | | -354.2 | | 15.5 | | 1 | 80 | 0 | 0 | -29.5167 | 0.185534 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Tot. Vol.: | | 1.391687 | gal | |

## Table 5.3: Configuration #2 As-Built Geometry

|Rev. 1

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 2 | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.009695 | 0.028123 | 0.006589 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.48917 | 0.019877 | 0.057662 | 0.01632 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.029658 | 0.086036 | 0.031277 |
| | | -17.4375 | | 6.1875 | | 1 | 80 | 0 | 0 | -1.45313 | 0.032471 | 0.094194 | 0.04848 |
| | | -32.4375 | 29 | 11.75 | | 1 | 80 | 0 | 29.9531 | -2.70313 | 0.195982 | 0.568523 | 0.090182 |
| .5" above dp1 | | -342.938 | 25 | 10.5 | | 1 | 80 | 0 | 29.9531 | -28.5781 | 0.337108 | 0.977915 | 0.953432 |
| .5 below dp1 | | -343.938 | | 1 | | 1 | 80 | 0 | 29.9531 | -28.6615 | 0.337562 | 0.979234 | 0.956212 |
| ball vlv | | -359.688 | | 15.75 | | 1 | 80 | 0 | 29.9531 | -29.974 | 0.344721 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Tot Vol: | | 2.585752 | gals | |

## Table 5.4: Configuration #2a As-Built Geometry

|Rev. 1

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 2a | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.009695 | 0.028123 | 0.006589 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.48917 | 0.019877 | 0.057662 | 0.01632 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.029658 | 0.086036 | 0.031277 |
| | | -17.4375 | | 6.1875 | | 1 | 80 | 0 | 0 | -1.45313 | 0.032471 | 0.094194 | 0.04848 |
| .25" offset orfc | | -24.9427 | 15 | 0 | | 1 | 80 | 0 | 14.98696 | -2.07856 | 0.114283 | 0.331523 | 0.069346 |
| | | -32.4375 | 14 | 11.75 | | 1 | 80 | 0 | 29.9531 | -2.70313 | 0.195982 | 0.568523 | 0.090182 |
| .5" above dp1 | | -342.938 | 25 | 10.5 | | 1 | 80 | 0 | 29.9531 | -28.5781 | 0.337108 | 0.977915 | 0.953432 |
| .5 below dp1 | | -343.938 | | 1 | | 1 | 80 | 0 | 29.9531 | -28.6615 | 0.337562 | 0.979234 | 0.956212 |
| ball vlv | | -359.688 | | 15.75 | | 1 | 80 | 0 | 29.9531 | -29.974 | 0.344721 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Tot Vol: | | 2.585752 | gals | |

## Table 5.5: Configuration #2b As-Built Geometry

|Rev. 1

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 2b | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.009695 | 0.028123 | 0.006589 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.48917 | 0.019877 | 0.057662 | 0.01632 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.029658 | 0.086036 | 0.031277 |
| | | -17.4375 | | 6.1875 | | 1 | 80 | 0 | 0 | -1.45313 | 0.032471 | 0.094194 | 0.04848 |
| .25" offset orfc | | -24.9427 | 15 | 0 | | 1 | 80 | 0 | 14.98696 | -2.07856 | 0.114283 | 0.331523 | 0.069346 |
| xfc vlv orfc | | -31.9684 | 14 | 0.5 | | 1 | 80 | 0 | 29.01641 | -2.66404 | 0.190868 | 0.55369 | 0.088878 |
| elbow | | -32.4375 | | 11.25 | | 1 | 80 | 0 | 29.9531 | -2.70313 | 0.195982 | 0.568523 | 0.090182 |
| .5" above dp1 | | -342.938 | 25 | 10.5 | | 1 | 80 | 0 | 29.9531 | -28.5781 | 0.337108 | 0.977915 | 0.953432 |
| .5 below dp1 | | -343.938 | | 1 | | 1 | 80 | 0 | 29.9531 | -28.6615 | 0.337562 | 0.979234 | 0.956212 |
| ball vlv | | -359.688 | | 15.75 | | 1 | 80 | 0 | 29.9531 | -29.974 | 0.344721 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Tot Vol: | | 2.585752 | gals | |

Table 5.6: Configuration #2c As-Built Geometry

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 2c | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.009695 | 0.036403 | 0.01178 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.48917 | 0.019877 | 0.074638 | 0.029177 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.029658 | 0.111365 | 0.055918 |
| | | -17.4375 | | 6.1875 | | 1 | 80 | 0 | 0 | -1.45313 | 0.032471 | 0.121925 | 0.086673 |
| .25" offset orfc | | -25.4953 | 15 | 0 | | 1 | 80 | 0 | 14.98496 | -2.12461 | 0.114283 | 0.429123 | 0.126724 |
| elbow | | -32.9375 | 13 | 10.25 | | 1 | 80 | 0 | 28.82524 | -2.74479 | 0.189846 | 0.712855 | 0.163715 |
| .5" above dp1 | | -184.438 | 12 | 7.5 | | 1 | 80 | 0 | 28.82524 | -15.3698 | 0.258704 | 0.971413 | 0.916744 |
| .5 below dp1 | | -185.438 | | 1 | | 1 | 80 | 0 | 28.82524 | -15.4531 | 0.259159 | 0.97312 | 0.921715 |
| ball vlv | | -201.188 | | 15.75 | | 1 | 80 | 0 | 28.82524 | -16.7656 | 0.266318 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Tot Vol: | | 1.997648 | gals | |

# Table 5.7: Configuration #2d As-Built Geometry

Rev. 1

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 2d | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.009695 | 0.042376 | 0.00655 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.48917 | 0.019877 | 0.086884 | 0.016224 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.029658 | 0.129637 | 0.031093 |
| | | -17.4375 | | 6.1875 | | 1 | 80 | 0 | 0 | -1.45313 | 0.032471 | 0.141929 | 0.048195 |
| .25" offset orfc | | -25.4953 | 15 | 0 | | 1 | 80 | 0 | 14.98496 | -2.12461 | 0.114283 | 0.499531 | 0.070465 |
| elbow | | -32.9375 | 13 | 10.25 | | 1 | 80 | 0 | 28.82524 | -2.74479 | 0.189846 | 0.829815 | 0.091035 |
| top of tubing | | -37.4375 | | 4.5 | | 1 | 80 | 0 | 28.82524 | -3.11979 | 0.191891 | 0.838755 | 0.103472 |
| .5" above dp1 | | -359.188 | 26 | 9.75 | | 0.5 | 80 | 0 | 28.82524 | -29.9323 | 0.228451 | 0.998558 | 0.992745 |
| .5 below dp1 | | -360.188 | | 1 | | 0.5 | 80 | 0 | 28.82524 | -30.0156 | 0.228565 | 0.999055 | 0.995509 |
| ball vlv | | -361.813 | | 1.625 | | 0.541 | 80 | 0 | 28.82524 | -30.151 | 0.228781 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Tot Vol: | | 1.716084 | gals | |

## Table 5.8: Configuration #3 As-Built Geometry

|Rev. 1

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 3 | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.009695 | 0.028126 | 0.006595 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.48917 | 0.019877 | 0.057667 | 0.016334 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.029658 | 0.086043 | 0.031304 |
| elbow | | -343.75 | 27 | 8.5 | | 1 | 80 | 0 | 0 | -28.6458 | 0.180784 | 0.524479 | 0.956522 |
| .5" above dp1 | | -358.649 | 28 | 7.875 | | 1 | 80 | 0 | 28.62934 | -29.8874 | 0.33708 | 0.977913 | 0.997981 |
| .5 below dp1 | | -358.693 | | 1 | | 1 | 80 | 0 | 28.71259 | -29.891 | 0.337534 | 0.979232 | 0.998101 |
| ball vlv | | -359.375 | | 15.75 | | 1 | 80 | 0 | 30.02386 | -29.9479 | 0.344693 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Tot Vol: | | 2.585539 | gals | |

Table 5.9: Configuration #3a As-Built Geometry

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 3a | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/\ | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.00969 | 0.028126 | 0.006595 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.4892 | 0.01988 | 0.057667 | 0.016334 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.02966 | 0.086043 | 0.031304 |
| .25" orifice | | -46.75 | | 35.5 | | 1 | 80 | 0 | 0 | -3.8958 | 0.04579 | 0.132853 | 0.130087 |
| elbow | | -343.75 | 24 | 9 | | 1 | 80 | 0 | 0 | -28.646 | 0.18078 | 0.524479 | 0.956522 |
| .5" above dp1 | | -358.649 | 28 | 7.875 | | 1 | 80 | 0 | 28.629 | -29.887 | 0.33708 | 0.977913 | 0.997981 |
| .5 below dp1 | | -358.693 | | 1 | | 1 | 80 | 0 | 28.713 | -29.891 | 0.33753 | 0.979232 | 0.998101 |
| ball vlv | | -359.375 | | 15.75 | | 1 | 80 | 0 | 30.024 | -29.948 | 0.34469 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Tot Vol: | | 2.58554 | gals | |

## Table 5.10: Configuration #3d As-Built Geometry

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 3d | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.00969 | 0.04298 | 0.006606 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.4892 | 0.01988 | 0.088123 | 0.016362 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.02966 | 0.131486 | 0.031359 |
| .25" orifice | | -46.75 | | 35.5 | | 1 | 80 | 0 | 0 | -3.8958 | 0.04579 | 0.20302 | 0.130314 |
| elbow | | -343.75 | 24 | 9 | | 1 | 80 | 0 | 0 | -28.646 | 0.18078 | 0.801481 | 0.958188 |
| coupling | | -344.074 | | 8 | | 1 | 80 | 0 | 0.6661 | -28.673 | 0.18442 | 0.817601 | 0.959093 |
| .5" above dp1 | | -358.646 | | 359.25 | | 0.5 | 80 | 0 | 30.579 | -29.887 | 0.22524 | 0.998575 | 0.99971 |
| .5 below dp1 | | -358.687 | | 1 | | 0.5 | 80 | 0 | 30.662 | -29.891 | 0.22535 | 0.999079 | 0.999823 |
| ball vlv | | -358.75 | | 1.5625 | | 0.541 | 80 | 0 | 30.792 | -29.896 | 0.22556 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Tot Vol: | | 1.69194 | gals | |

## Table 5.11: Configuration #3c As-Built Geometry

|Rev. 1

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 3c | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.009695 | 0.034996 | 0.011259 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.48917 | 0.019877 | 0.071752 | 0.027886 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.029658 | 0.10706 | 0.053444 |
| .25" orifice | | -46.75 | | 35.5 | | 1 | 80 | 0 | 0 | -3.89583 | 0.045794 | 0.165304 | 0.22209 |
| elbow | | -195.5 | 12 | 4.75 | | 1 | 80 | 0 | 0 | -16.2917 | 0.113402 | 0.409355 | 0.928741 |
| .5" above dp1 | | -209.802 | 28 | 7.25 | | 1 | 80 | 0 | 28.57933 | -17.4835 | 0.269414 | 0.972519 | 0.996684 |
| .5 below dp1 | | -209.844 | | 1 | | 1 | 80 | 0 | 28.66259 | -17.487 | 0.269868 | 0.974159 | 0.996882 |
| ball vlv | | -210.5 | | 15.75 | | 1 | 80 | 0 | 29.97395 | -17.5417 | 0.277027 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Total Vol.: | | 2.07798 | gal | |

## Table 5.12: Configuration #3e As-Built Geometry

|Rev. 1

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 3e | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.009695 | 0.034996 | 0.011682 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.48917 | 0.019877 | 0.071752 | 0.028934 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.029658 | 0.10706 | 0.055453 |
| .25" orifice | | -46.75 | | 35.5 | | 1 | 80 | 0 | 0 | -3.89583 | 0.045794 | 0.165304 | 0.230437 |
| elbow | | -195.5 | 12 | 4.75 | | 1 | 80 | 0 | 0 | -16.2917 | 0.113402 | 0.409355 | 0.963648 |
| .5" above dp1 | | -202.532 | 28 | 7.25 | | 1 | 80 | 0 | 28.59816 | -16.8777 | 0.269414 | 0.972519 | 0.998309 |
| .5 below dp1 | | -202.552 | | 1 | | 1 | 80 | 0 | 28.68148 | -16.8794 | 0.269868 | 0.974159 | 0.99841 |
| ball vlv | | -202.875 | | 15.75 | | 1 | 80 | 0 | 29.9937 | -16.9063 | 0.277027 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | | Tot Vol | 2.07798 | gal | |

Table 5.13: Configuration #6 As-Built Geometry

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Config. 6 | | | | | | | | | | | | | |
| De-Gas Test Geometry | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Ref. | Elev. (ft) | (in) | d-l (ft) | (in) | azim | dia | Sched | x(ft) | y(ft) | z(ft) | sigma-v | (sigma-v)/V | sigma-h/H |
| CC. top | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | -2.37 | | 2.37 | | 3 | 80 | 0 | 0 | -0.1975 | 0.009695 | 0.010402 | 0.003785 |
| | | -5.87 | | 3.5 | | 2.53 | 0 | 0 | 0 | -0.48917 | 0.019877 | 0.021327 | 0.009375 |
| pipe top | | -11.25 | | 5.38 | | 2 | 80 | 0 | 0 | -0.9375 | 0.029658 | 0.031821 | 0.017968 |
| elbow | | -311.75 | | 300.5 | | 1 | 80 | 0 | 0 | -25.9792 | 0.166239 | 0.178362 | 0.497904 |
| 40 deg | | -326.75 | 30 | 0 | | 1 | 80 | 0 | 29.97395 | -27.2292 | 0.329864 | 0.353917 | 0.521861 |
| 2nd elbow | | -370.75 | 89 | 1.5 | 40 | 1 | 80 | 57.23994 | 98.18985 | -30.8958 | 0.815966 | 0.875465 | 0.592134 |
| .5" above dp1 | | -609.375 | 19 | 10.625 | 40 | 1 | 80 | 57.23994 | 98.18985 | -50.7813 | 0.924424 | 0.991832 | 0.973248 |
| .5 below dp1 | | -610.375 | | 1 | 40 | 1 | 80 | 57.23994 | 98.18985 | -50.8646 | 0.924878 | 0.992319 | 0.974845 |
| ball vlv | | -626.125 | | 15.75 | 40 | 1 | 80 | 57.23994 | 98.18985 | -52.1771 | 0.932037 | 1 | 1 |
| | | | | | | | | | | | | | |
| | | | | | | | | | Tot Vol: | | 6.991208 | gals | |

Table 5.14: Configuration #7 As-Built Geometry

Rev. 1

| Config. 7 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| De-Gas Test Geometry | | | | | | | | | |
| | | | | | | | | | |
| Ref. | dia | Sched | v slope | x | y | z | sigma-v | v/V | h/H |
| CC. top surf | | | | 13 | 12.5 | 510 | 0 | 0 | 0 |
| 1 | 2 | 80 | | 13 | 12.5 | 504 | 0.0109 | 0.054787 | 0.012072 |
| elbow 2 | 0.742 | 80 | | 13 | 12.5 | 498 | 0.0124 | 0.062328 | 0.024145 |
| orifice 2a | 0.742 | 80 | 3.6 | 37 | 16.5 | 496.47 | 0.0185 | 0.092969 | 0.027219 |
| 3 | 0.742 | 80 | 2.5 | 46.25 | 18.75 | 496.06 | 0.0209 | 0.104945 | 0.028054 |
| 4 | 0.742 | 80 | 1.7 | 53 | 29 | 495.69 | 0.024 | 0.120376 | 0.028787 |
| 5 | 0.742 | 80 | 0.5 | 19.5 | 53.5 | 495.33 | 0.0344 | 0.172541 | 0.029515 |
| 6 | 0.742 | 80 | 4 | 32 | 73 | 493.72 | 0.0402 | 0.201723 | 0.032766 |
| 7 | 0.742 | 80 | 1.4 | 68 | 53.5 | 492.72 | 0.0504 | 0.253195 | 0.034779 |
| 8 | 0.742 | 80 | 0.8 | 82 | 72.5 | 492.39 | 0.0563 | 0.28286 | 0.035441 |
| 14 | 0.957 | 80 | 1.5 | 131 | 149.5 | 490 | 0.0943 | 0.473742 | 0.040248 |
| 15 | 0.957 | 80 | 90 | 131 | 149.5 | 462 | 0.106 | 0.532282 | 0.096586 |
| xfc inlet 16 | 0.957 | 80 | 0 | 133 | 152.5 | 462 | 0.1075 | 0.53982 | 0.096586 |
| xfc out 17 | 0.957 | tube | 5.8 | 137.5 | 159 | 461.2 | 0.1106 | 0.556432 | 0.098194 |
| 18 | 0.37 | | 5.8 | 144 | 166.5 | 460.19 | 0.1114 | 0.55955 | 0.100212 |
| 19 | 0.37 | | | 144.5 | 169 | 442.69 | 0.1125 | 0.565076 | 0.135423 |
| 20 | 0.37 | | 2 | 129.5 | 146 | 441.74 | 0.1142 | 0.573663 | 0.137351 |
| 21 | 0.37 | | | 131.5 | 148 | 385.75 | 0.1177 | 0.591182 | 0.25 |
| 22 | 0.37 | | | 139.5 | 142.5 | 385.25 | 0.1183 | 0.59422 | 0.251006 |
| 23 | 0.37 | | | 140.25 | 142.5 | 372.5 | 0.1191 | 0.598212 | 0.27666 |
| 24 | 0.37 | | | 131.25 | 148 | 372 | 0.1198 | 0.601512 | 0.277666 |
| 25 | 0.37 | | | 130.25 | 154 | 297 | 0.1244 | 0.625027 | 0.428571 |
| 26 | 0.37 | | | 124 | 201 | 295.75 | 0.1274 | 0.63985 | 0.431087 |
| 27 | 0.37 | | | 125.5 | 201 | 262 | 0.1295 | 0.650408 | 0.498994 |
| 28 | 0.37 | | | 118.5 | 264.5 | 263.25 | 0.1335 | 0.670377 | 0.496479 |
| 29 | 0.37 | | | 129.5 | 265.5 | 263.75 | 0.1342 | 0.673832 | 0.495473 |
| 30 | 0.37 | | | 128.5 | 276.5 | 264 | 0.1348 | 0.677285 | 0.49497 |
| 31 | 0.37 | | | 118 | 275.5 | 263.75 | 0.1355 | 0.680582 | 0.495473 |
| 32 | 0.37 | | | 104 | 359.5 | 266.25 | 0.1408 | 0.707207 | 0.490443 |
| 33 | 0.37 | | | 128 | 364.5 | 265.75 | 0.1423 | 0.71487 | 0.491449 |
| 34 | 0.37 | | | 125.5 | 365.25 | 226.5 | 0.1448 | 0.727163 | 0.570423 |
| 35 | 0.37 | | | 124 | 376.25 | 226.75 | 0.1455 | 0.730634 | 0.56992 |
| 36 | 0.37 | | | 122 | 376.25 | 217.25 | 0.1461 | 0.733668 | 0.589034 |
| 37 | 0.37 | | | 125.5 | 357.25 | 215.75 | 0.1473 | 0.739723 | 0.592052 |
| 38 | 0.37 | | | 116.5 | 357.25 | 175 | 0.1499 | 0.752765 | 0.674044 |
| 39 | 0.37 | | | 149.5 | 364.25 | 172 | 0.152 | 0.763349 | 0.68008 |
| 40 | 0.37 | | | 142 | 460.25 | 172 | 0.158 | 0.793442 | 0.68008 |

Table 5.14 (con't.): Configuration #7 As-Built Geometry |Rev. 1

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 41 | 0.37 | | | 125 | 461.25 | 172 | 0.159 | 0.798764 | 0.68008 |
| 42 | 0.37 | | | 125 | 477.25 | 171 | 0.16 | 0.803774 | 0.682093 |
| 43 | 0.37 | | | 122 | 483.25 | 171 | 0.1605 | 0.805871 | 0.682093 |
| 44 | 0.37 | | | 121 | 545.25 | 170.25 | 0.1643 | 0.825251 | 0.683602 |
| 45 | 0.37 | | | 143.75 | 547.25 | 168.5 | 0.1657 | 0.832409 | 0.687123 |
| 46 | 0.37 | | | 143 | 547.25 | 157 | 0.1665 | 0.83601 | 0.710262 |
| 47 | 0.37 | | | 142.75 | 546.25 | 155 | 0.1666 | 0.836714 | 0.714286 |
| 48 | 0.37 | | | 139.25 | 548.75 | 48.25 | 0.1732 | 0.870102 | 0.929074 |
| 49 | 0.37 | | | 131.5 | 549.25 | 48.25 | 0.1737 | 0.872529 | 0.929074 |
| 50 | 0.37 | | | 135 | 600.25 | 47.5 | 0.1769 | 0.888506 | 0.930584 |
| 51 | 0.37 | | | 160.5 | 600.75 | 47.25 | 0.1785 | 0.896477 | 0.931087 |
| 52 | 0.37 | | | 161.5 | 684.75 | 45.5 | 0.1837 | 0.922736 | 0.934608 |
| 53 | 0.37 | | | 135.5 | 686.75 | 36.5 | 0.1854 | 0.931357 | 0.952716 |
| 54 | 0.37 | | | 141.5 | 759.25 | 35 | 0.19 | 0.954097 | 0.955734 |
| 55 | 0.37 | | | 266.5 | 759.25 | 31 | 0.1977 | 0.993182 | 0.963783 |
| 56 | 0.37 | | | 270 | 758.75 | 31 | 0.198 | 0.994286 | 0.963783 |
| 57 | 0.37 | | | 272 | 761.25 | 13 | 0.1991 | 1 | 1 |
| | | | | | | | | | |
| | | | | | | Tot vol | 1.4935 | gal | |

# SECTION 6 REFERENCES

1. Continuum Dynamics, Inc., "Plan for Testing Prototypical Boiling Water Reactor Water Level Instrumentation Reference Leg Geometries During Rapid Depressurization Events, Rev. 1", March 8, 1993.

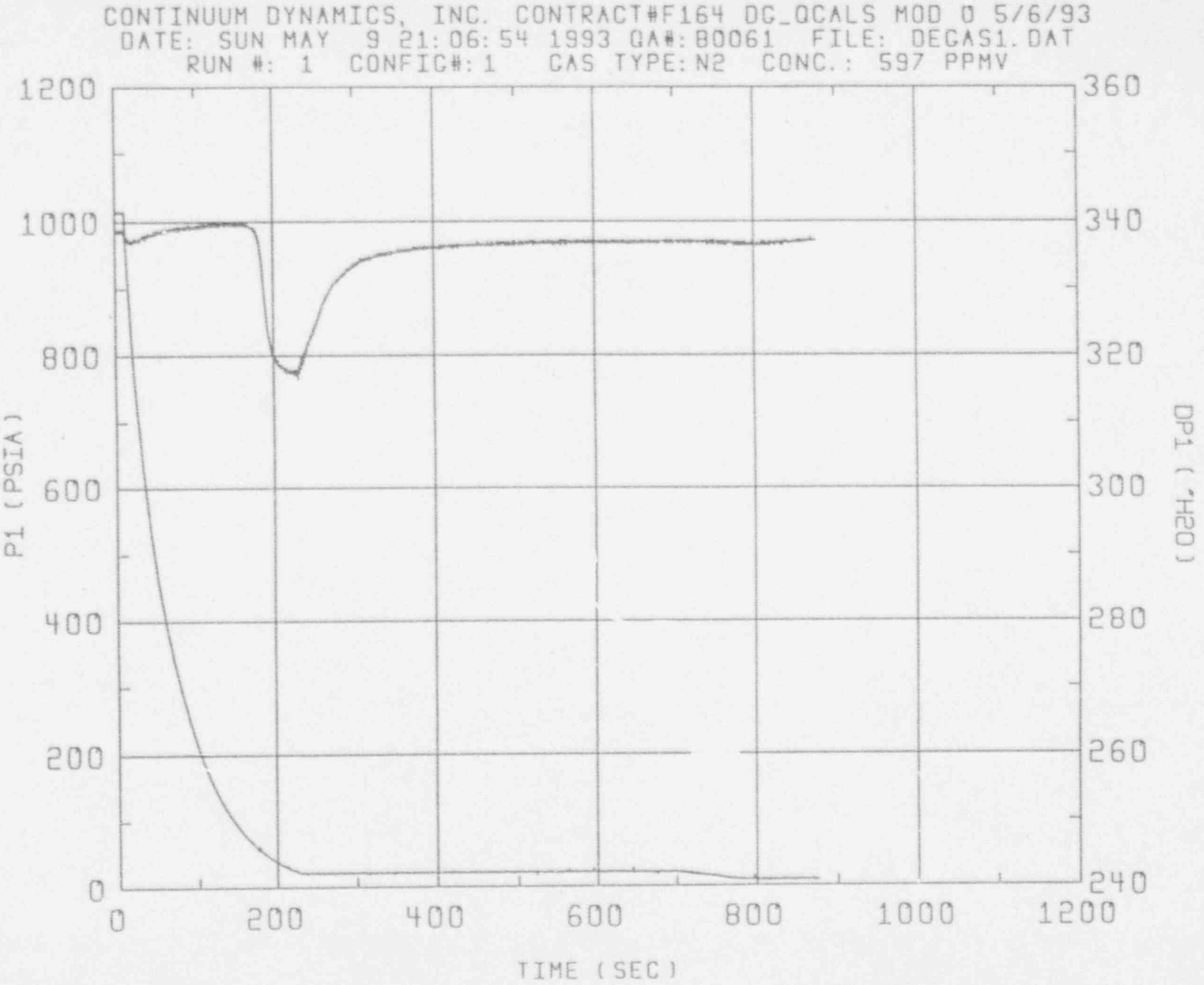
2. Continuum Dynamics, Inc., "Scope of Work for Testing Prototypical Boiling Water Reactor Water Level Instrumentation Reference Leg Geometries During Rapid Depressurization Events, Rev. E.," prepared for the Boiling Water Reactor Owners' Group, for the Electric Power Research Institute, Charlotte, NC, April 8, 1993.

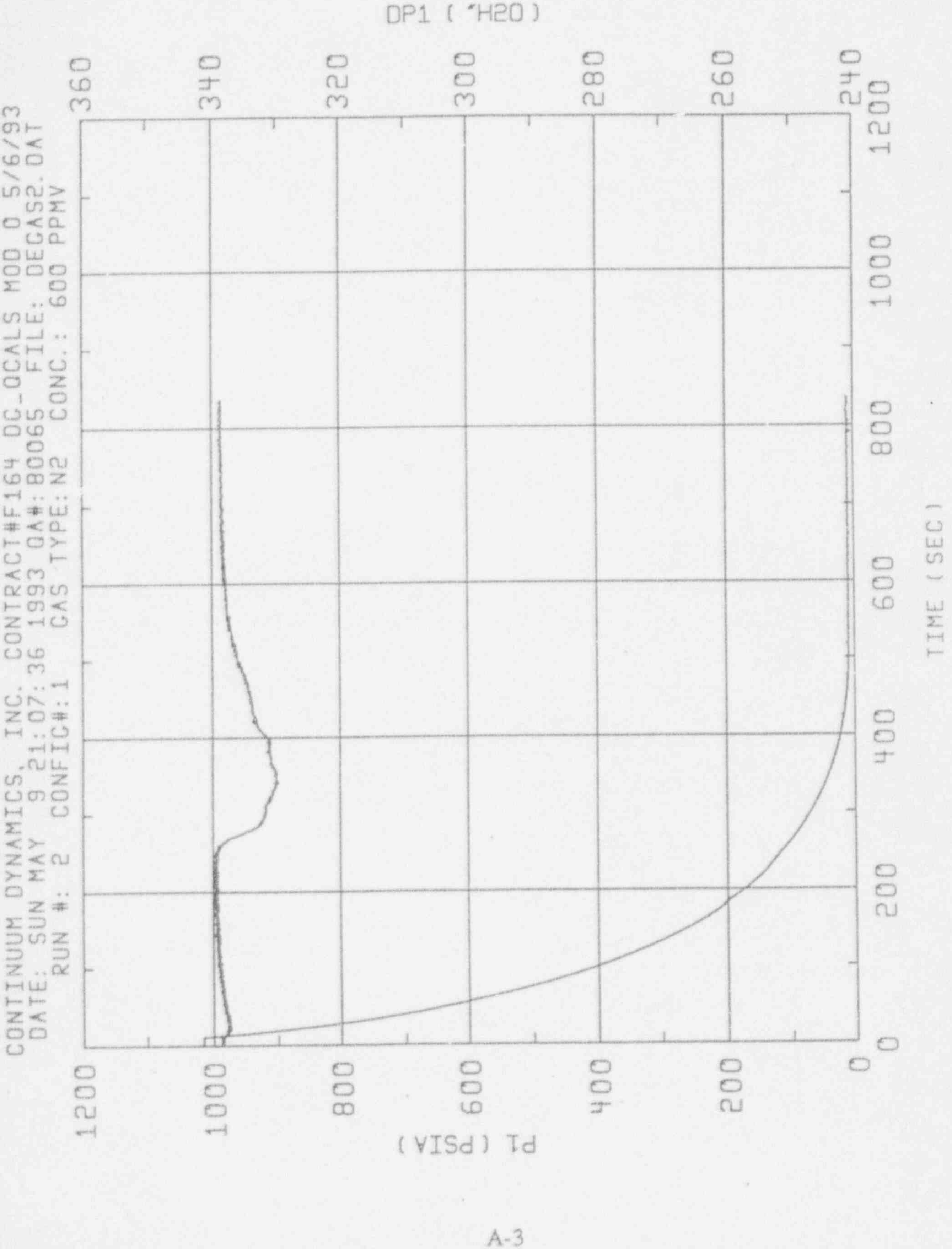
3. Continuum Dynamics, Inc., Quality Assurance Manual, Rev. 10, December 1992.

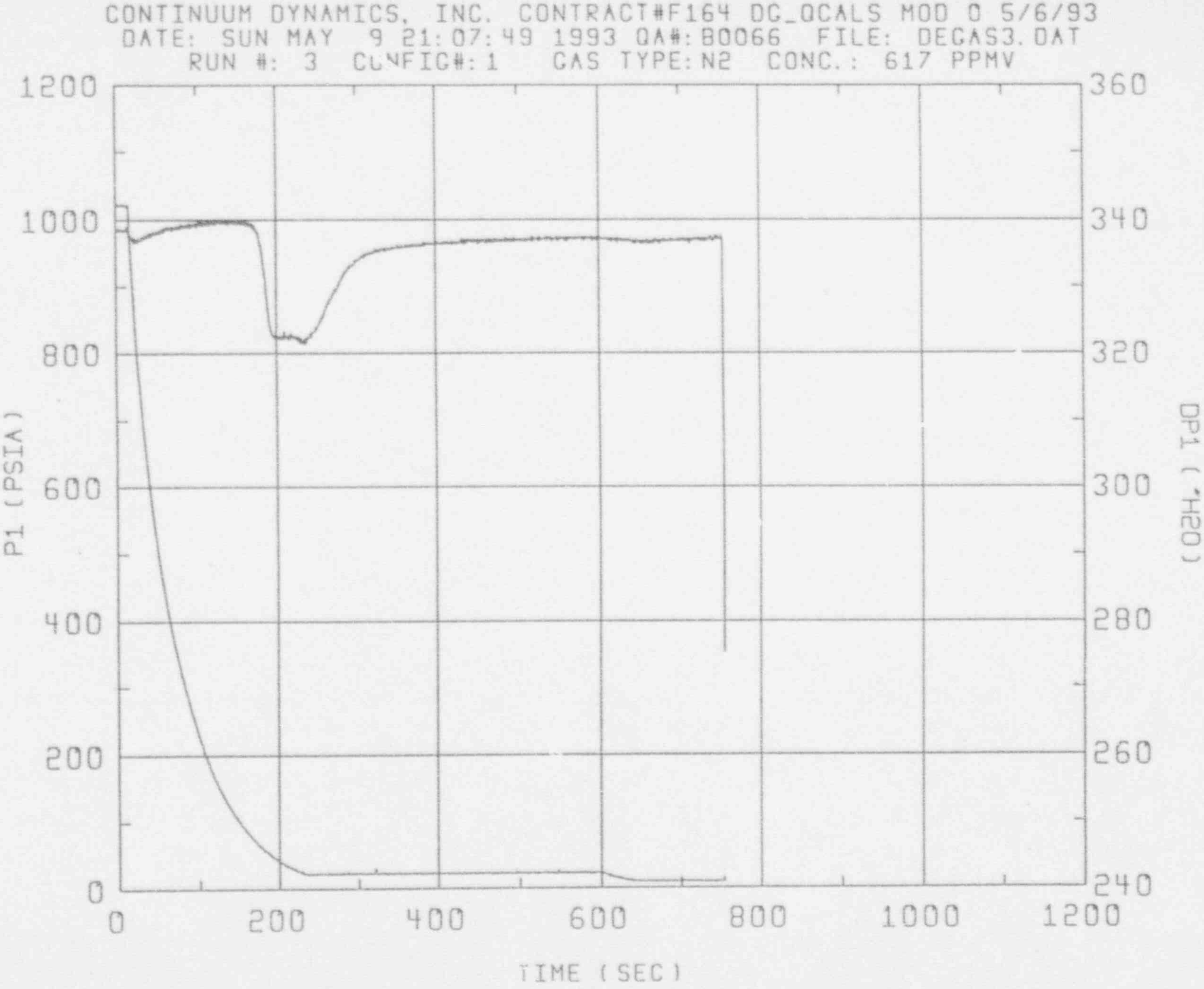
## APPENDIX A: TRANSIENT PRESSURE DATA TIME HISTORIES

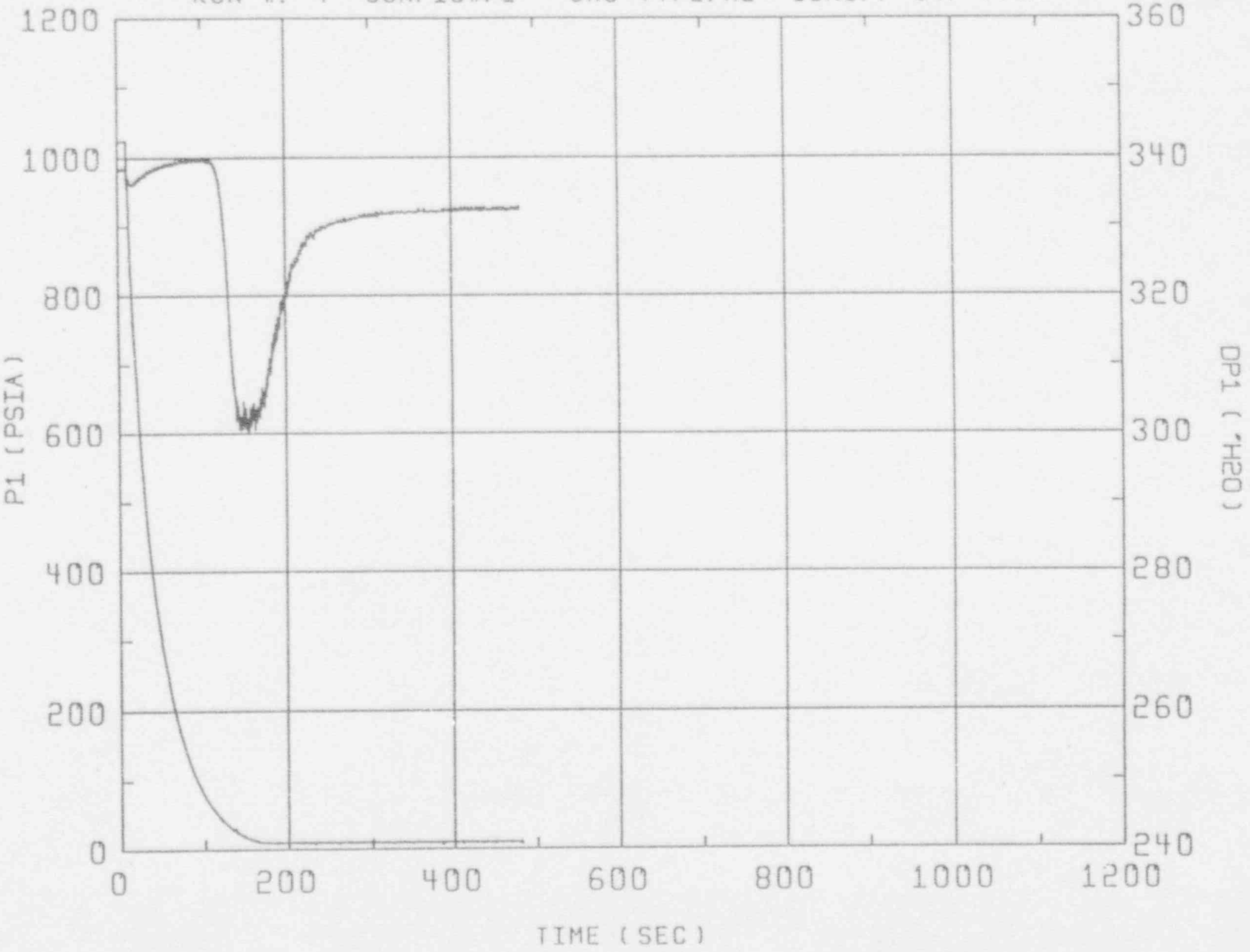
Raw data from the absolute and differential pressure instrumentation has been processed using the calibrations measured on these transducers prior to the start of the de-gas testing period. These data have also been corrected for effects of increased nitrogen density when the system is at pressure, in order to aid in the interpretation of the differential pressure reading as the reference leg water column height. The time history plots of these data show both corrected pressures as a function of time (in seconds) for each run, with the left scale representing the absolute pressure reading (in psia), and the right scale the differential pressure (in inches of water).

Data from the slow depressurization tests has been plotted on a compressed time scale, in order to fit the entire run on a single page. The plot header field, aside from providing a traceable record of when the plot was made, includes the configuration number, test number, gas type and concentration measured in the sample line prior to the blowdown event. The absolute pressure time history may be consulted to determine if the event simulated a LOCA or an ADS/ATWS depressurization time history.

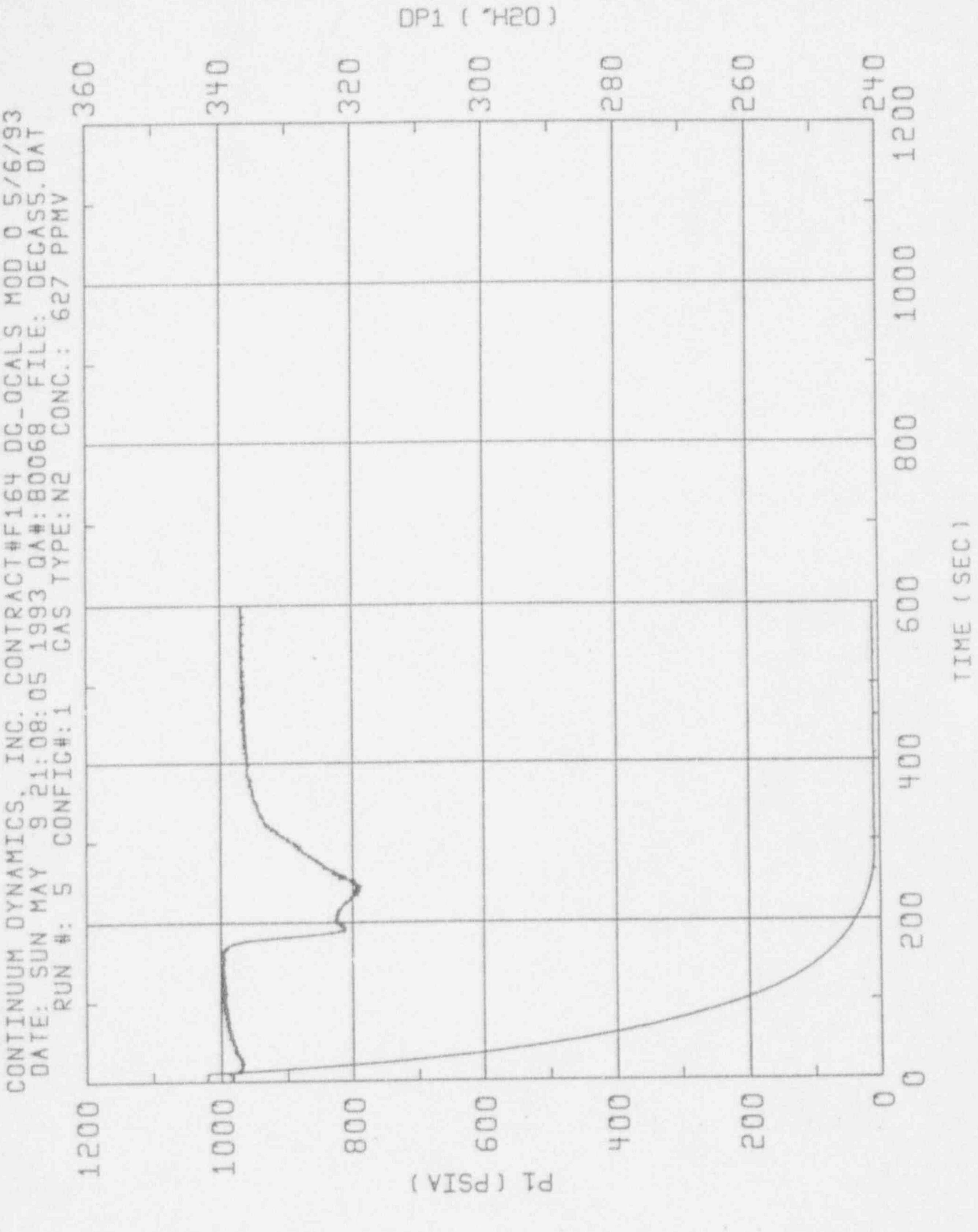

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:06:54 1993 QA#: B0061 FILE: DEGAS1.DAT
RUN #: 1 CONFIG#: 1 GAS TYPE: N2 CONC.: 597 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ("H2O)
360
340
320
300
280
260
240
0
200
400
600
800
1000
1200
TIME (SEC)

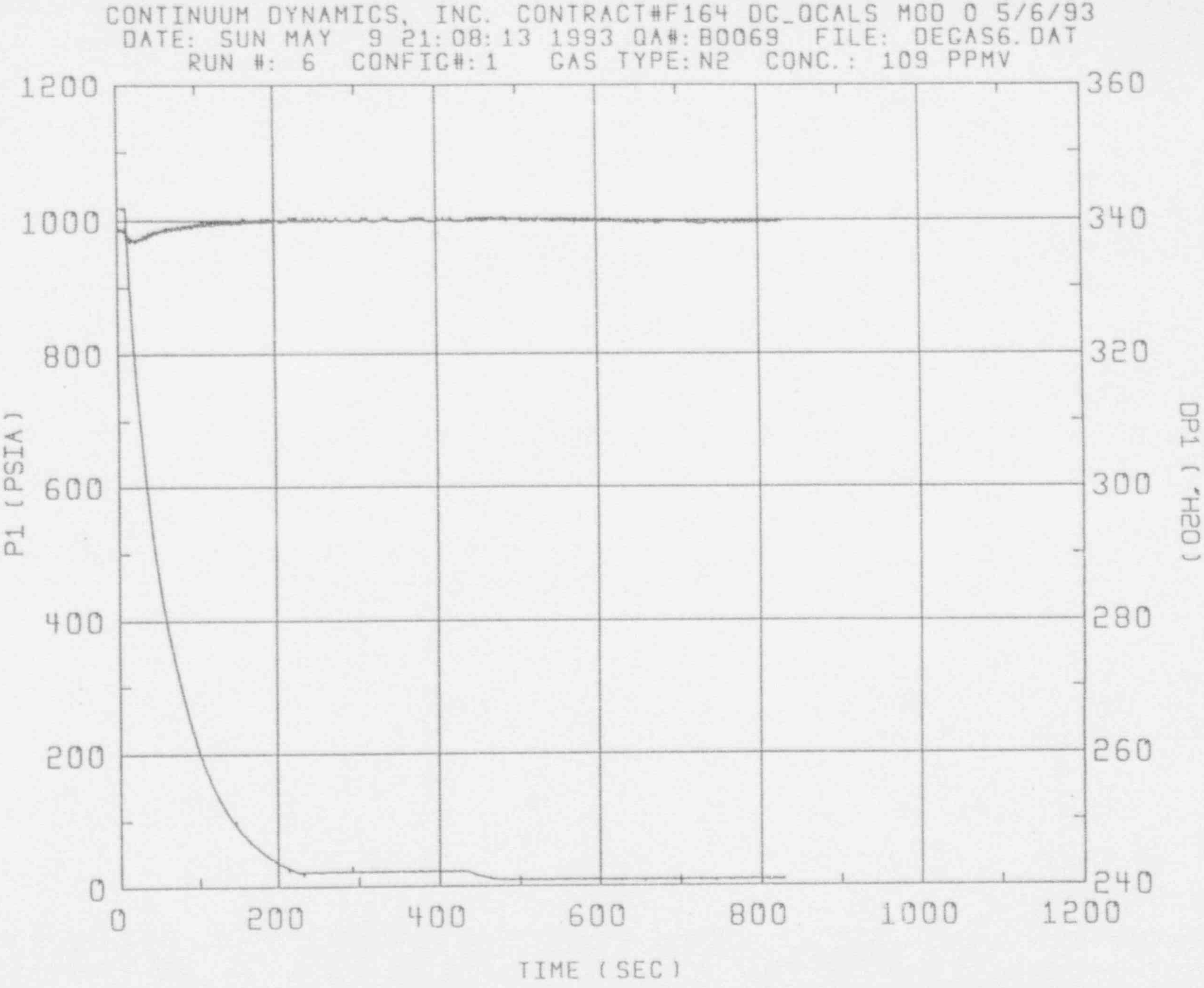

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_OCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:07:36 1993 QA#: B0065 FILE: DEGAS2.DAT
RUN #: 2 CONFIG#:1 GAS TYPE: N2 CONC.: 600 PPMV
DP1 ("H2O)
360
340
320
300
280
260
240
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
200
400
600
800
1000
1200


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:07:49 1993 QA#: B0066 FILE: DEGAS3.DAT
RUN #: 3 CONFIG#: 1 GAS TYPE: N2 CONC.: 617 PPMV
P1 (PSIA)
DP1 ("H2O)
TIME (SEC)
1200
1000
800
600
400
200
0
360
340
320
300
280
260
240
0
200
400
600
800
1000
1200

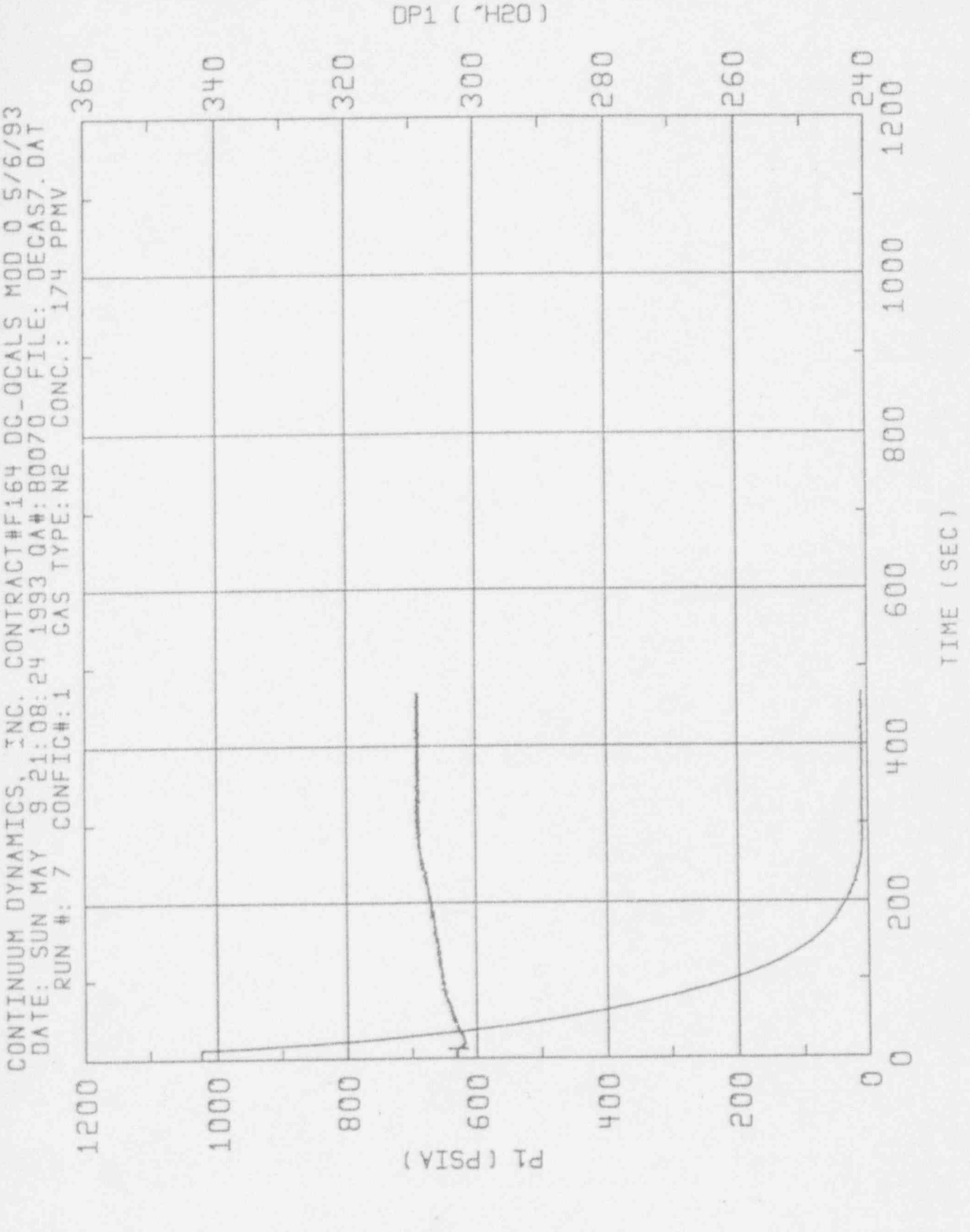


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:07:58 1993 QA#:B0067 FILE: DEGAS4.DAT
RUN #: 4 CONFIG#:1 GAS TYPE:N2 CONC.: 647 PPMV

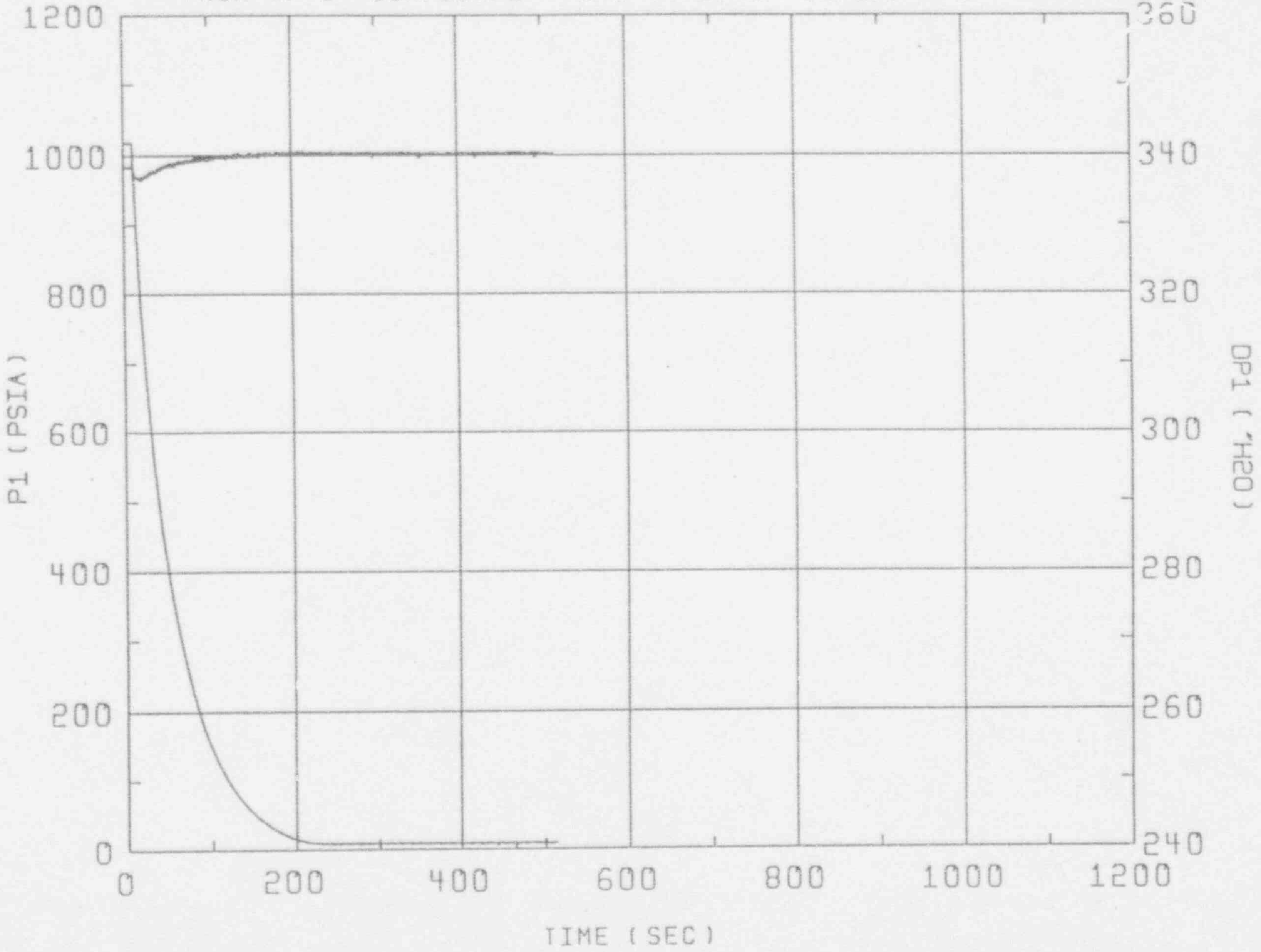

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_OCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:08:05 1993 QA#: B0068 FILE: DEGAS5.DAT
RUN #: 5 CONFIG#:1 GAS TYPE: N2 CONC.: 627 PPMV
DP1 ("H2O)
360
340
320
300
280
260
240
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
200
400
600
800
1000
1200



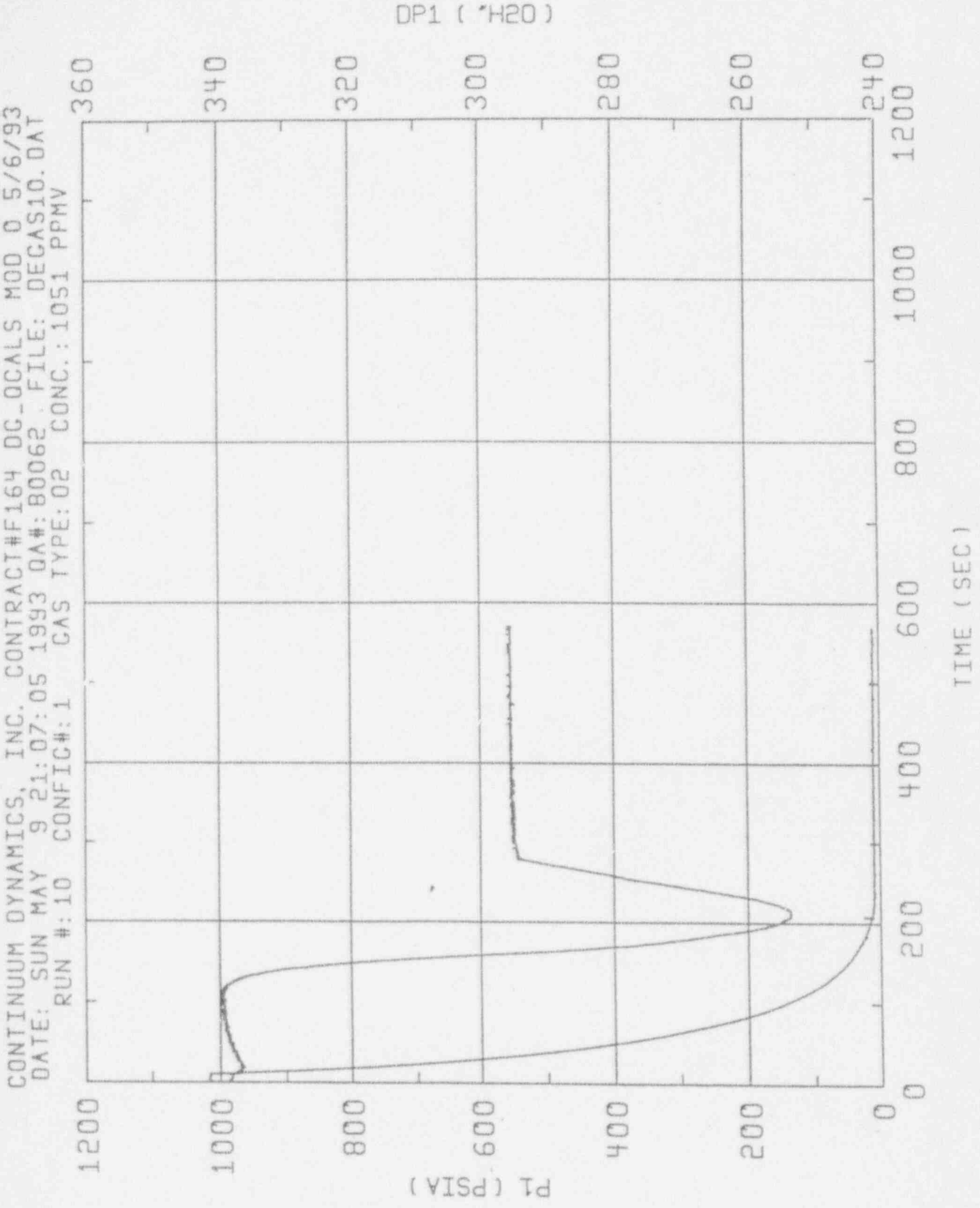
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:08:13 1993 QA#:B0069 FILE: DEGAS6.DAT
RUN #: 6 CONFIG#:1 GAS TYPE:N2 CONC.: 109 PPMV


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_OCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:08:24 1993 QA#:B0070 FILE: DEGAS7.DAT
RUN #: 7 CONFIG#:1 GAS TYPE: N2 CONC.: 174 PPMV
DP1 ('H2O)
360
340
320
300
280
260
240
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
200
400
600
800
1000
1200

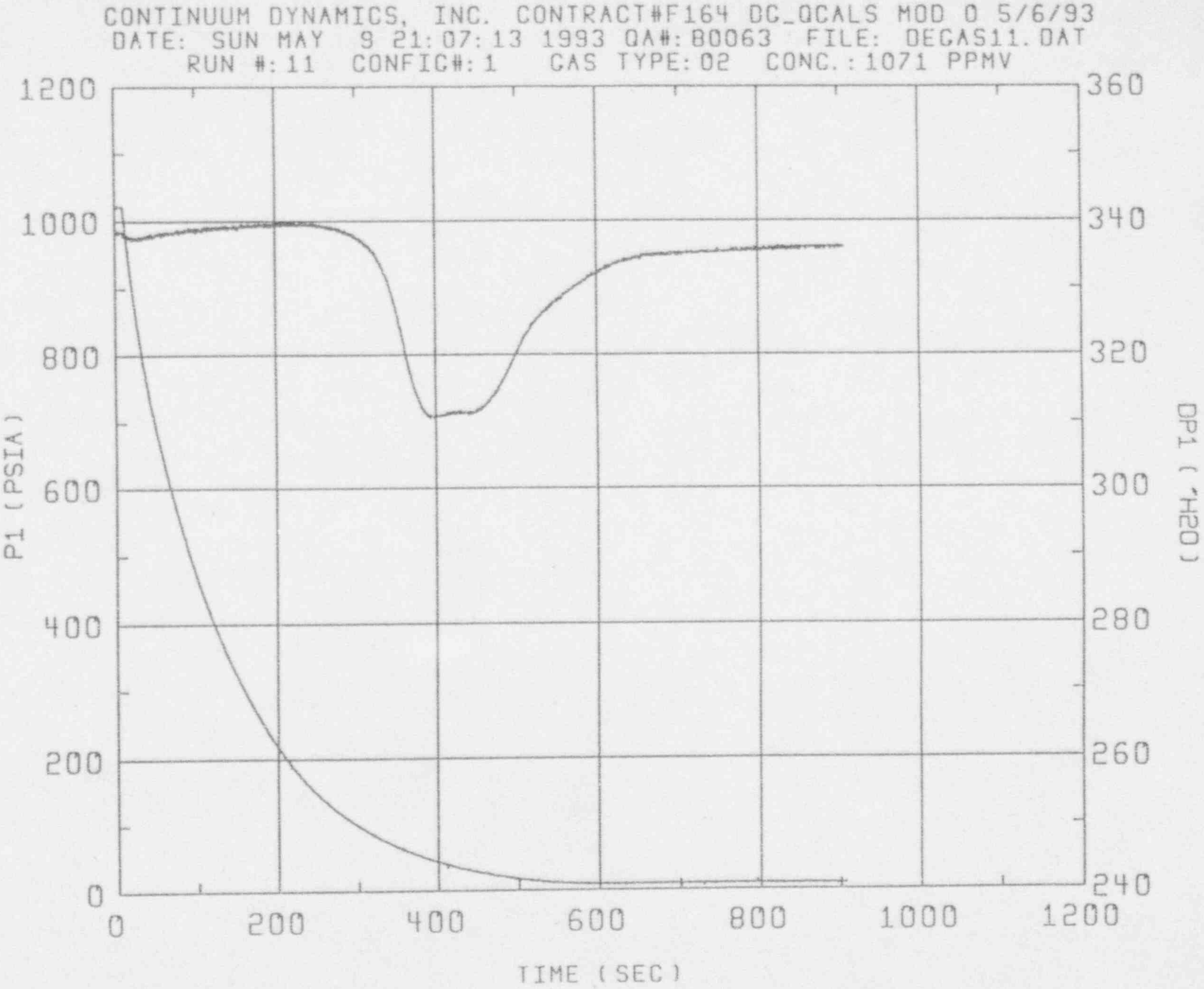
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_OCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:08:30 1993 QA#:B0071 FILE: DEGAS8.DAT
RUN #: 8 CONFIG#:1 GAS TYPE:N2 CONC.: 79 PPMV

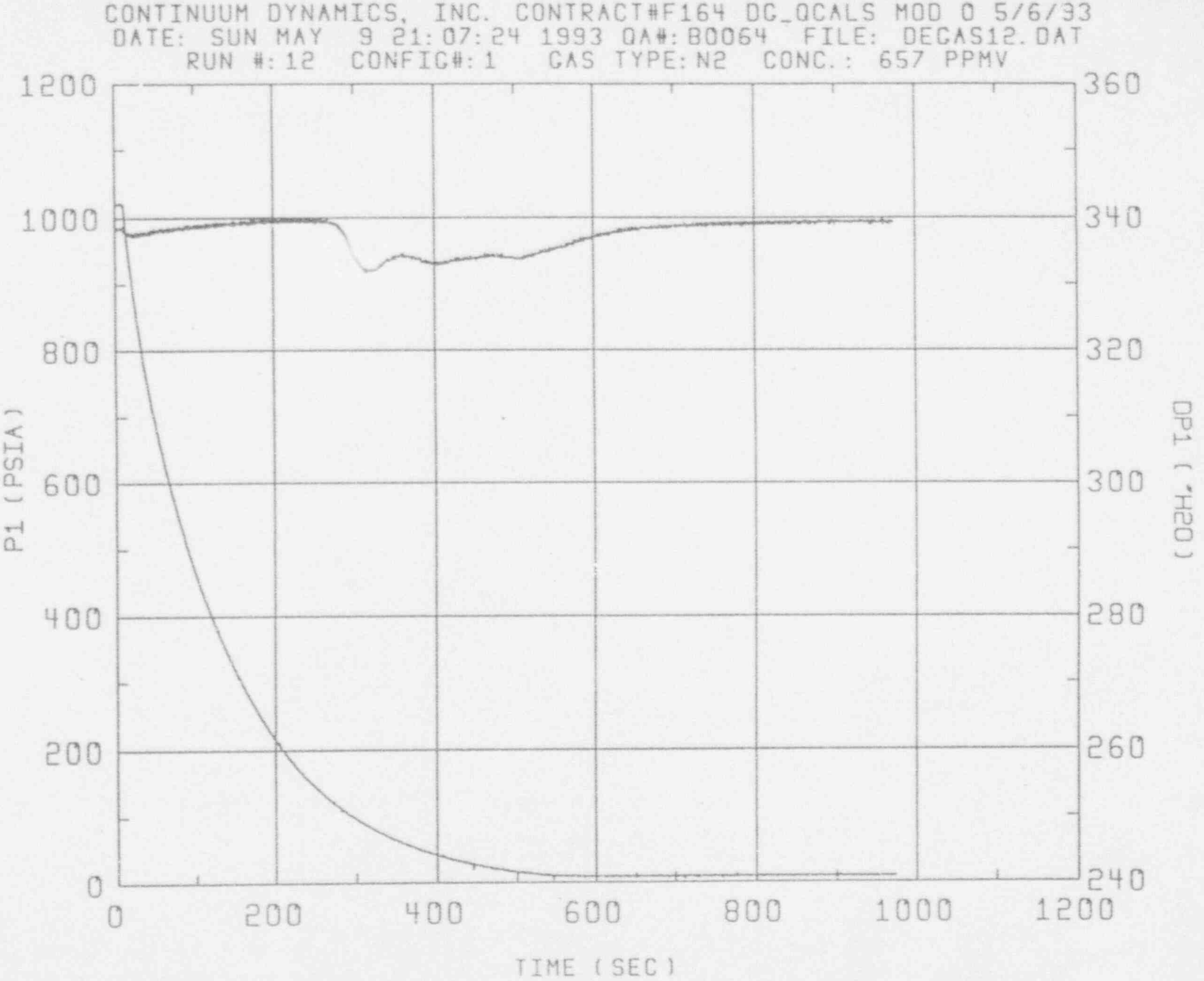



CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:08:37 1993 QA#:B0072 FILE: DEGAS9.DAT
RUN #: 9 CONFIG#:1 GAS TYPE:02 CONC.:1021 PPMV
P1 (PSIA)
0
200
400
600
800
1000
1200
DP1 ("H2O)
240
260
280
300
320
340
360
TIME (SEC)
0
200
400
600
800
1000
1200



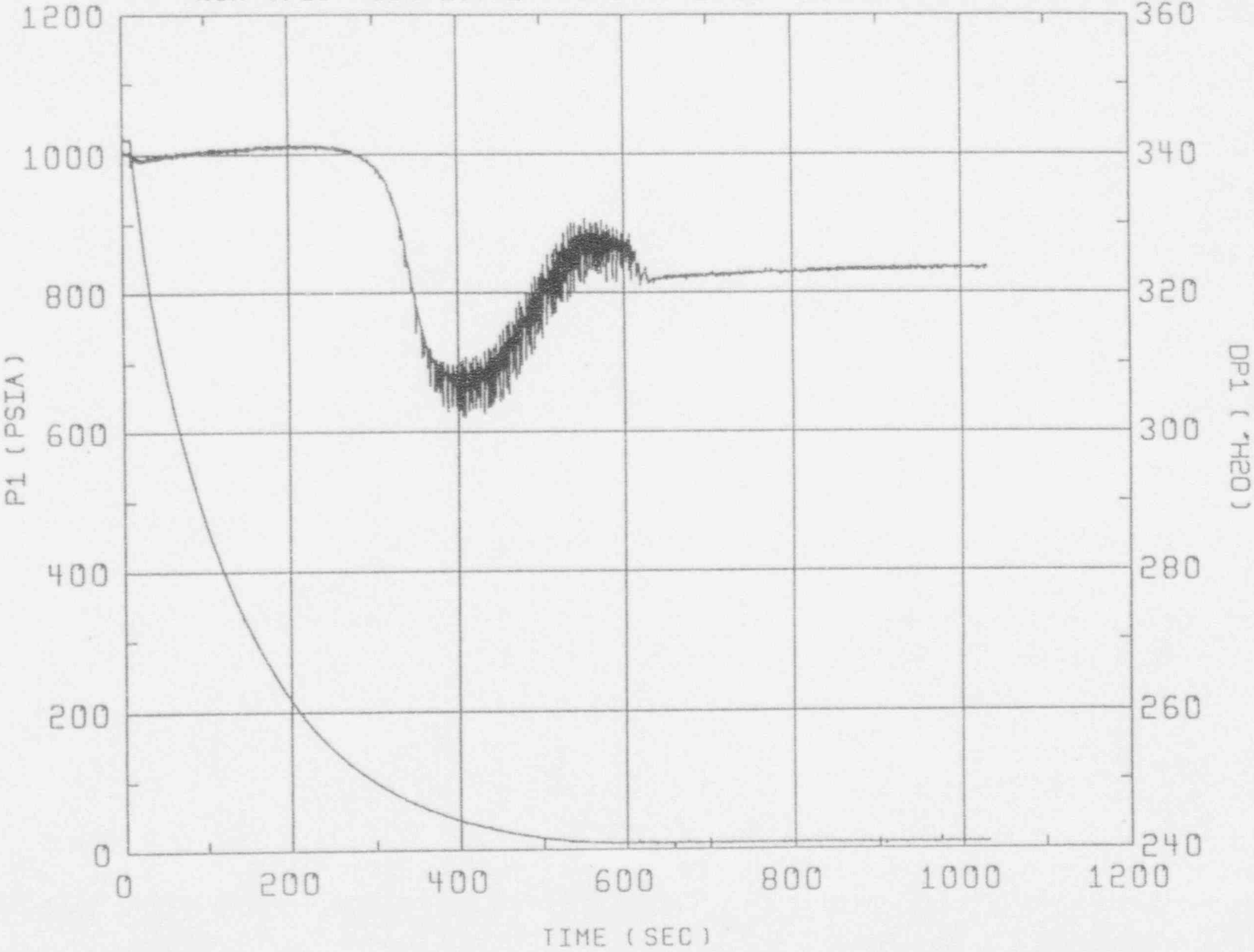
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_OCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:07:05 1993 QA#: B0062 FILE: DEGAS10.DAT
RUN #: 10 CONFIG#: 1 GAS TYPE: 02 CONC.: 1051 PPMV

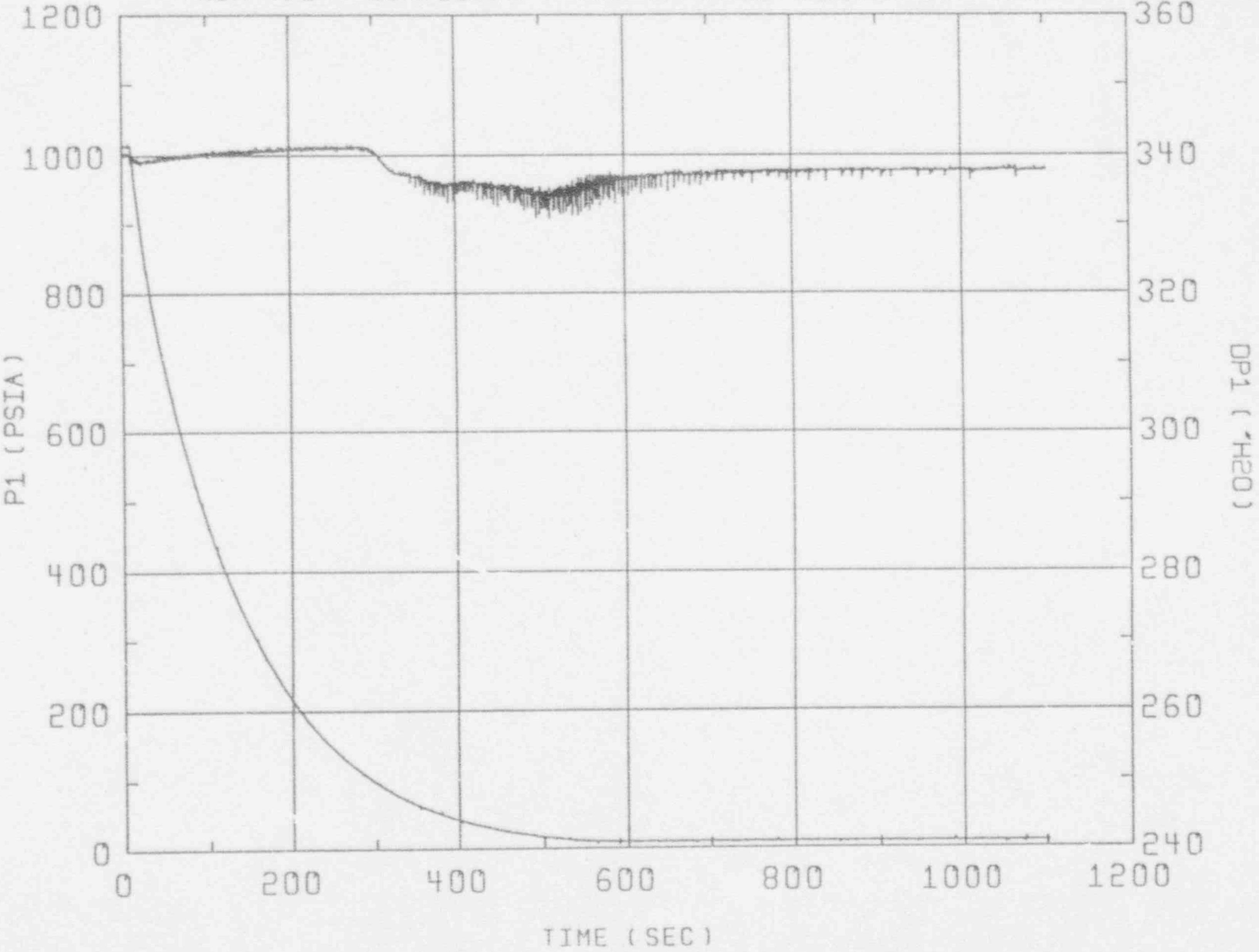

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:07:13 1993 QA#:B0063 FILE: DEGAS11.DAT
RUN #:11 CONFIG#:1 GAS TYPE:02 CONC.:1071 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ("H2O)
360
340
320
300
280
260
240
0
200
400
600
800
1000
1200
TIME (SEC)



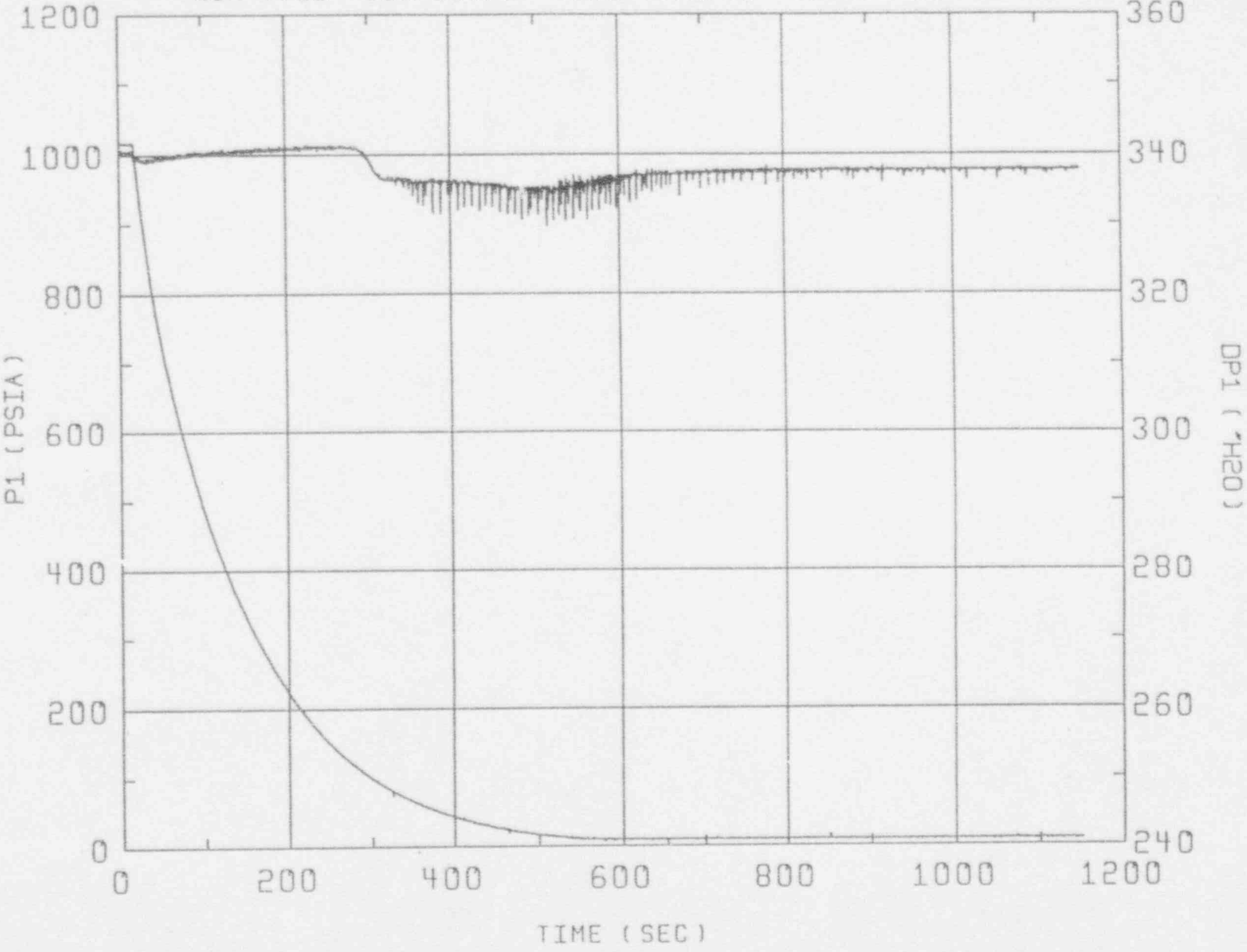
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:07:24 1993 QA#:B0064 FILE: DEGAS12.DAT
RUN #:12 CONFIG#:1 GAS TYPE:N2 CONC.: 657 PPMV

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:08:49 1993 QA#:B0073 FILE: DEGAS13.DAT
RUN #:13 CONFIG#:2 GAS TYPE:02 CONC.:1170 PPMV

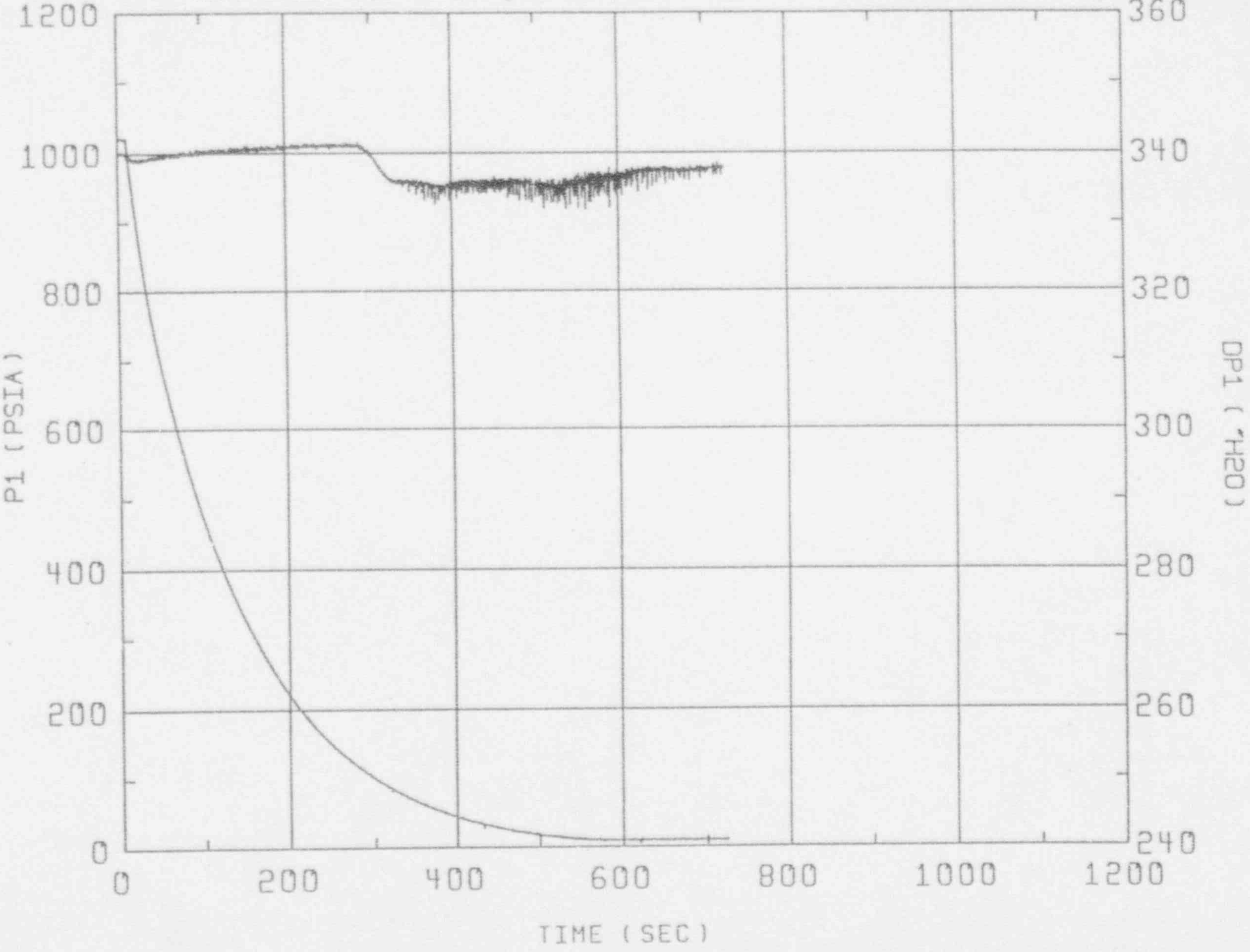


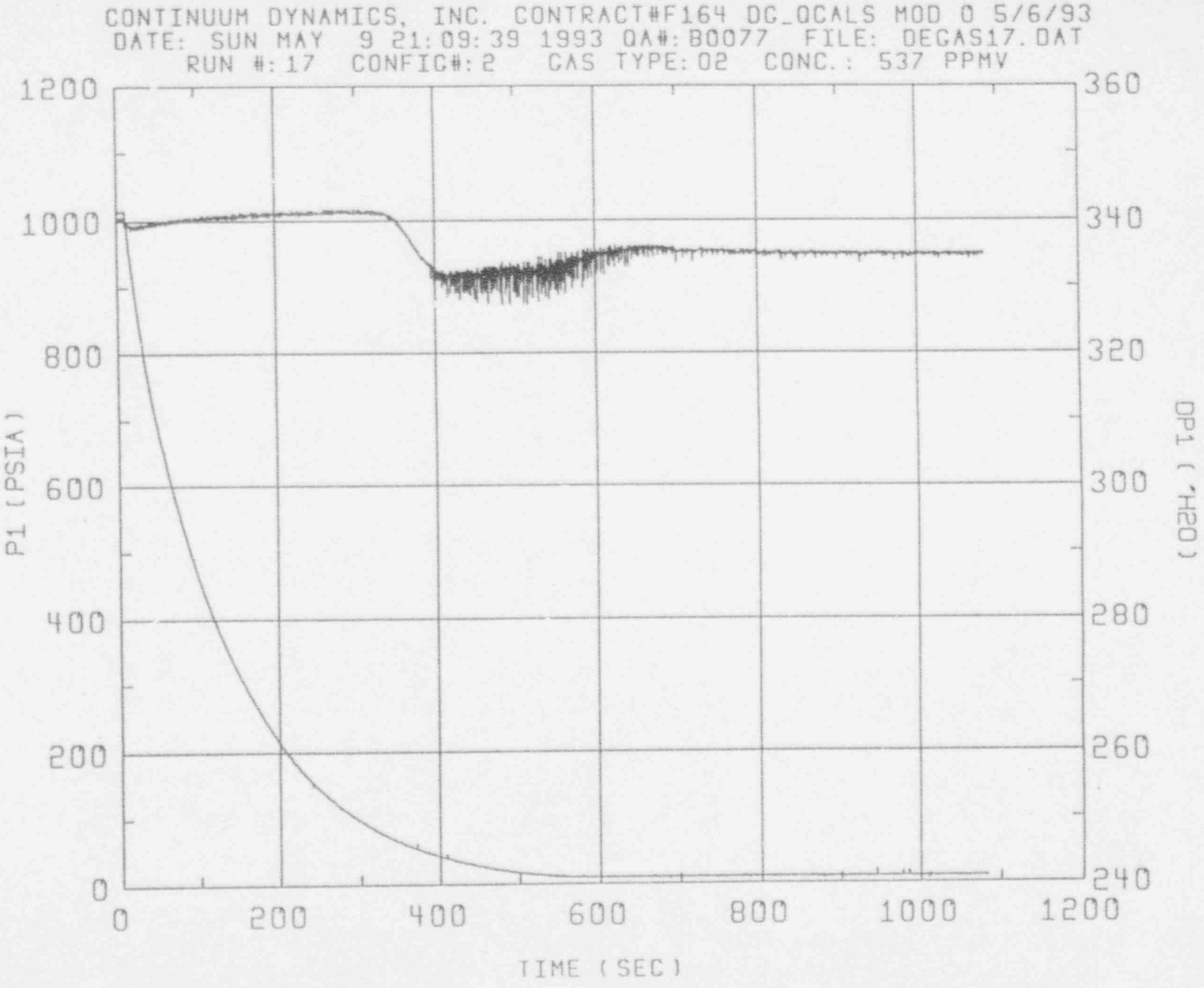

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_OCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:09:02 1993 QA#:80074 FILE: DEGAS14.DAT
RUN #:14 CONFIG#:2 GAS TYPE:N2 CONC.: 567 PPMV

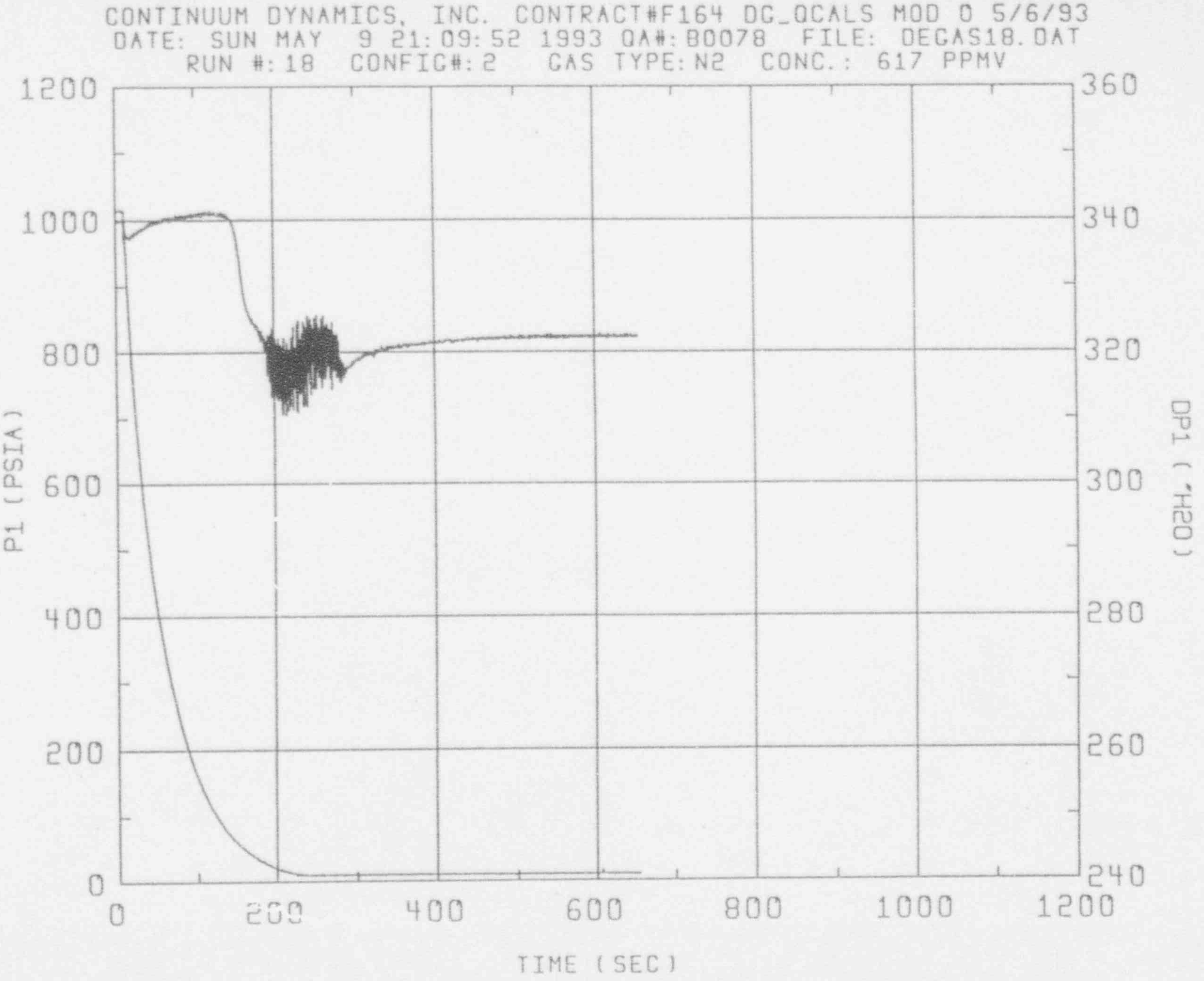
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC.QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:09:15 1993 QA#:B0075 FILE: DEGAS15.DAT
RUN #:15 CONFIG#:2 GAS TYPE:N2 CONC.: 607 PPMV



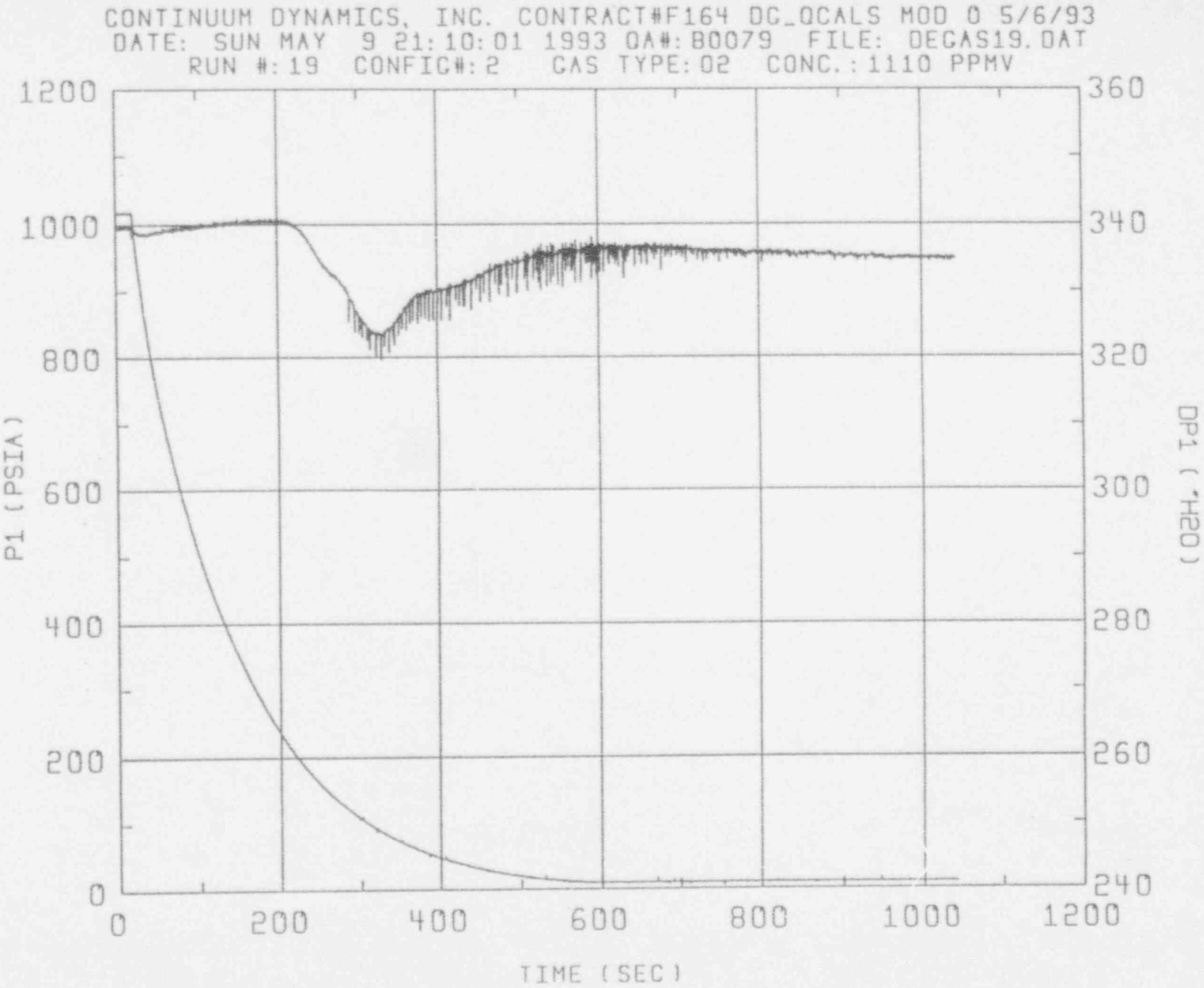
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:09:30 1993 QA#:B0076 FILE: DEGAS16.DAT
RUN #:16 CONFIG#:2 GAS TYPE:N2 CONC.: 647 PPMV

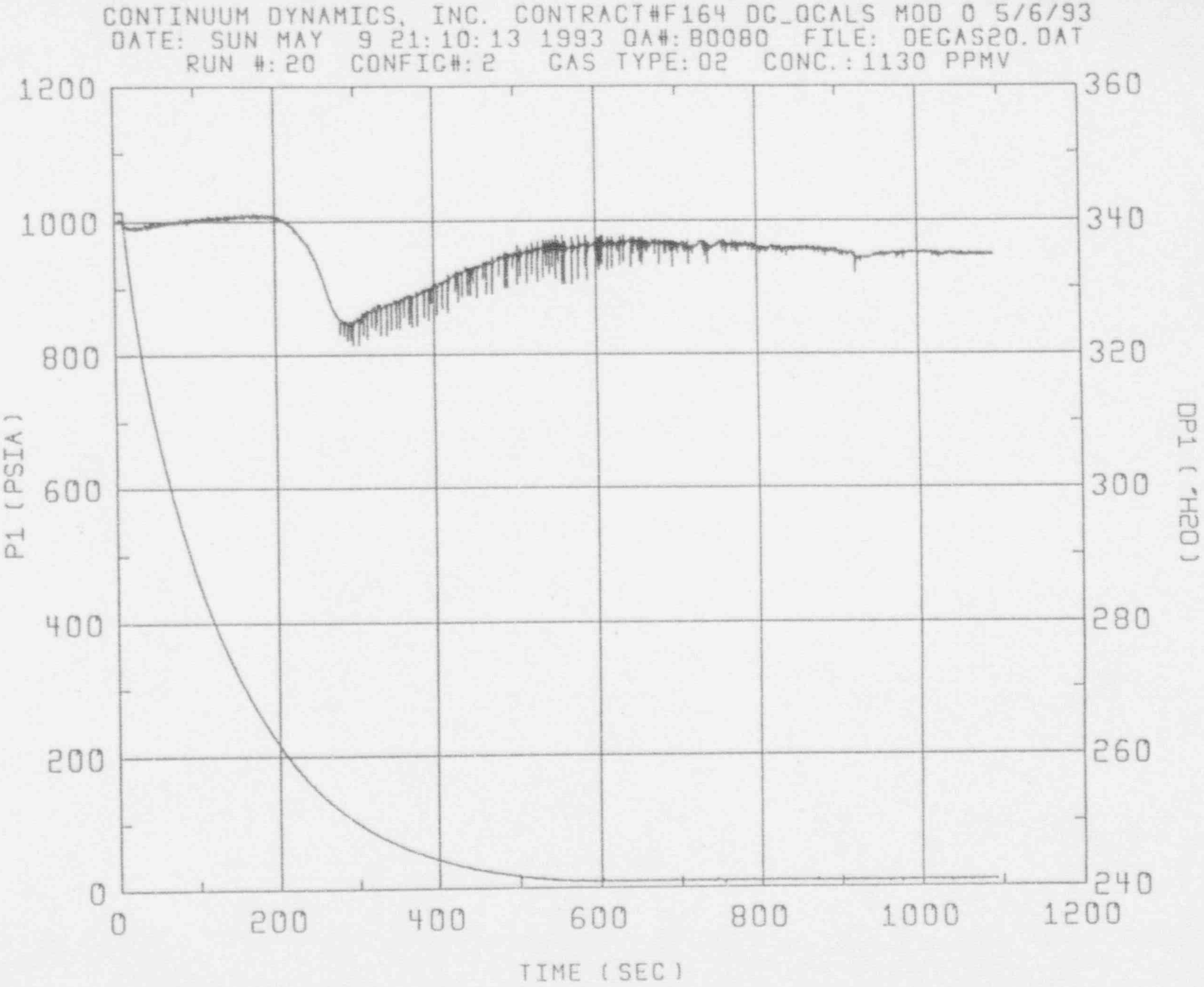



CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:09:39 1993 QA#:B0077 FILE: DEGAS17.DAT
RUN #:17 CONFIG#:2 GAS TYPE:02 CONC.: 537 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ('H2O)
360
340
320
300
280
260
240
TIME (SEC)
0
200
400
600
800
1000
1200

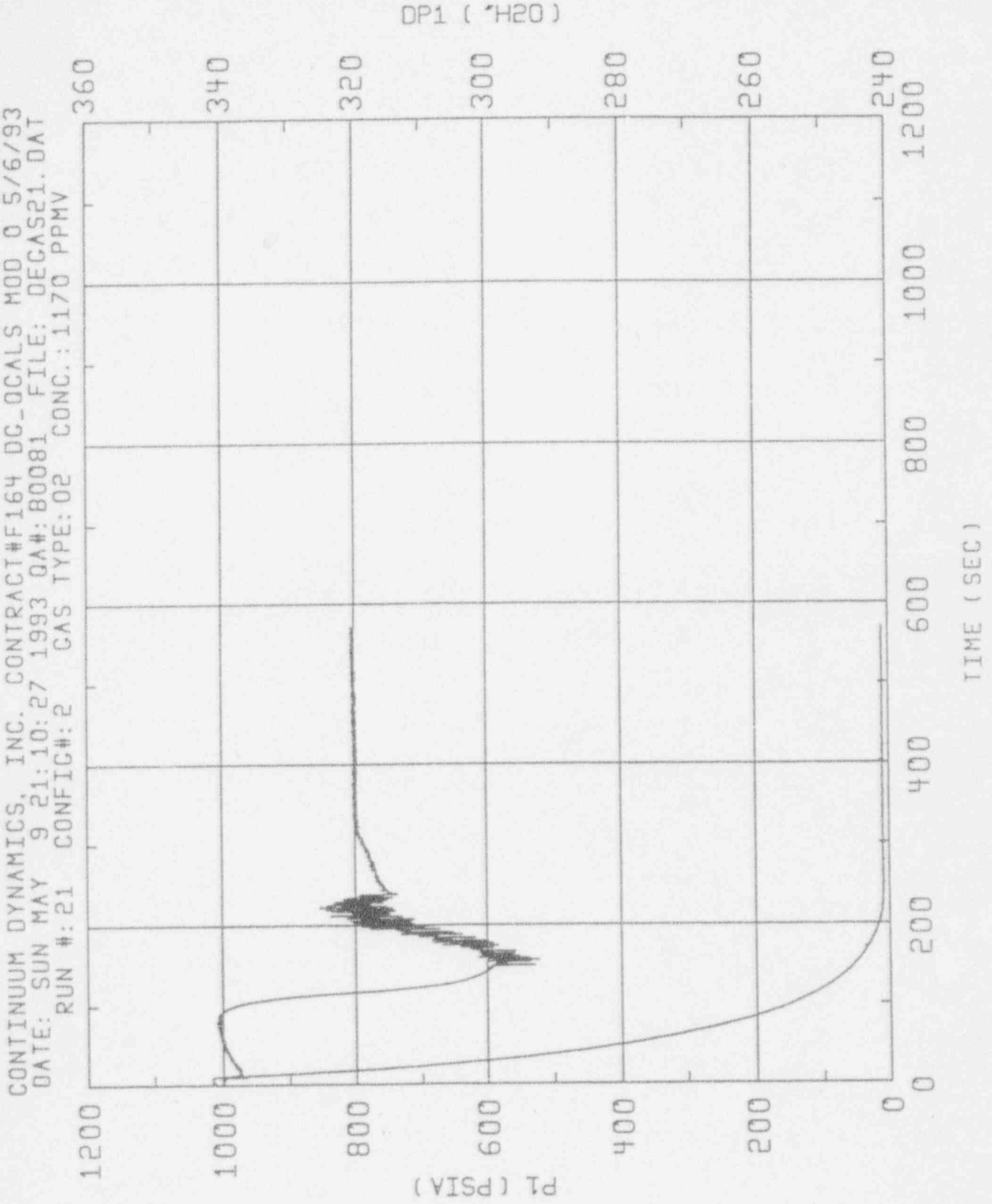


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:09:52 1993 QA#:B0078 FILE: DEGAS18.DAT
RUN #:18 CONFIG#:2 GAS TYPE:N2 CONC.: 617 PPMV

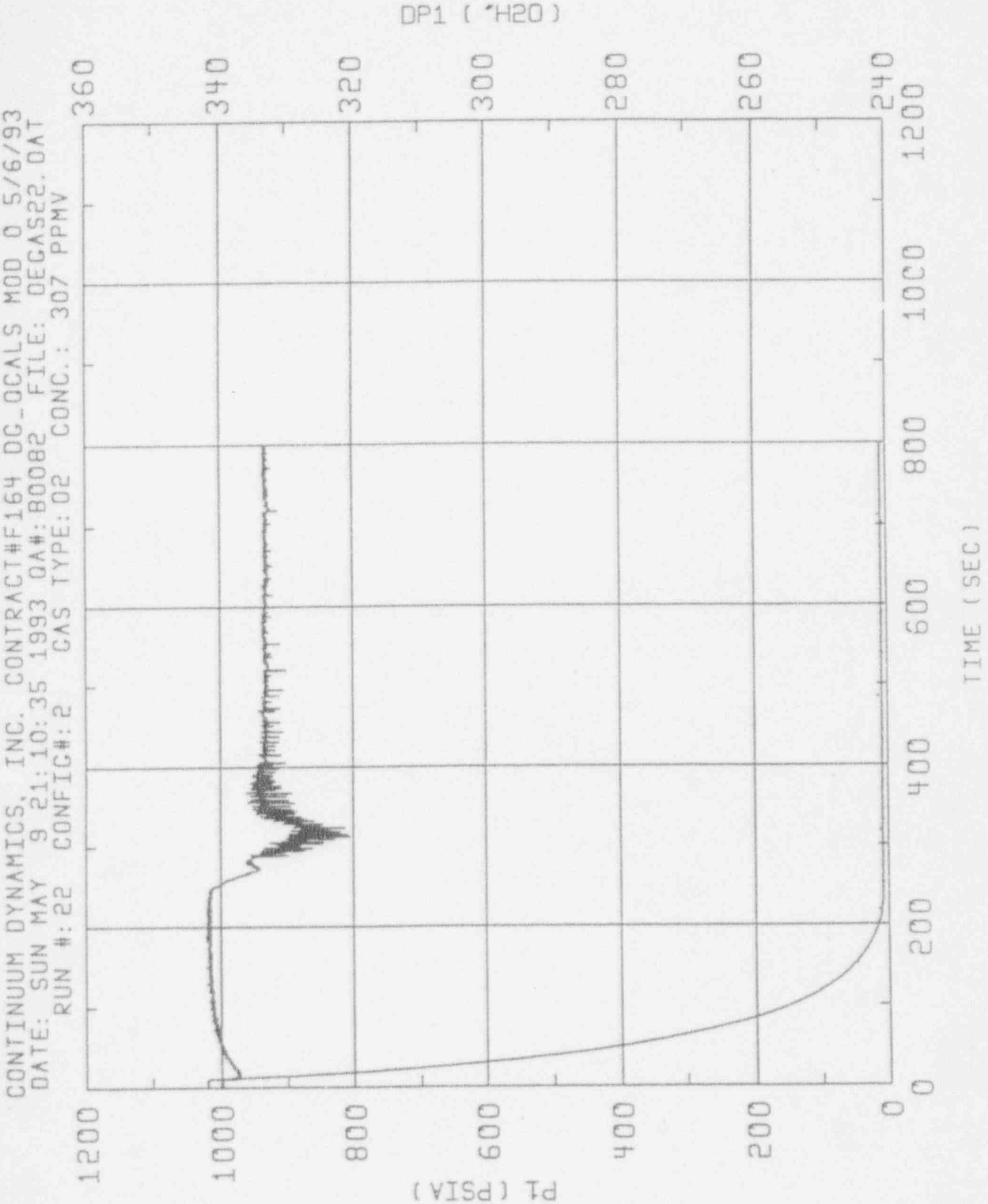

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:10:01 1993 QA#:B0079 FILE: DEGAS19.DAT
RUN #:19 CONFIG#:2 GAS TYPE:02 CONC.:1110 PPMV
P1 (PSIA)
DP1 ("H2O)
TIME (SEC)
1200
1000
800
600
400
200
0
360
340
320
300
280
260
240
0
200
400
600
800
1000
1200

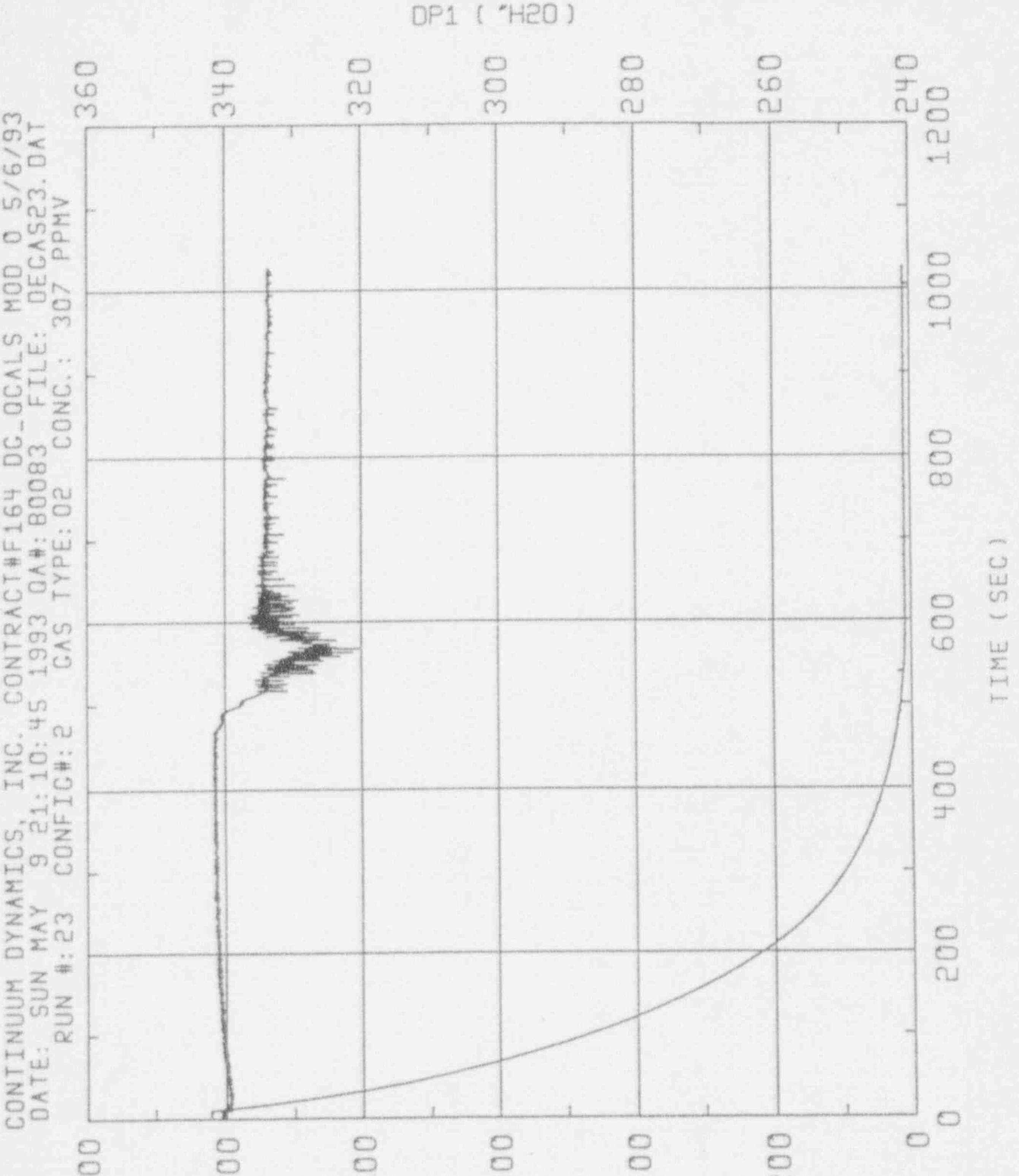


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:10:13 1993 QA#:B0080 FILE: DEGAS20.DAT
RUN #:20 CONFIG#:2 GAS TYPE:02 CONC.:1130 PPMV

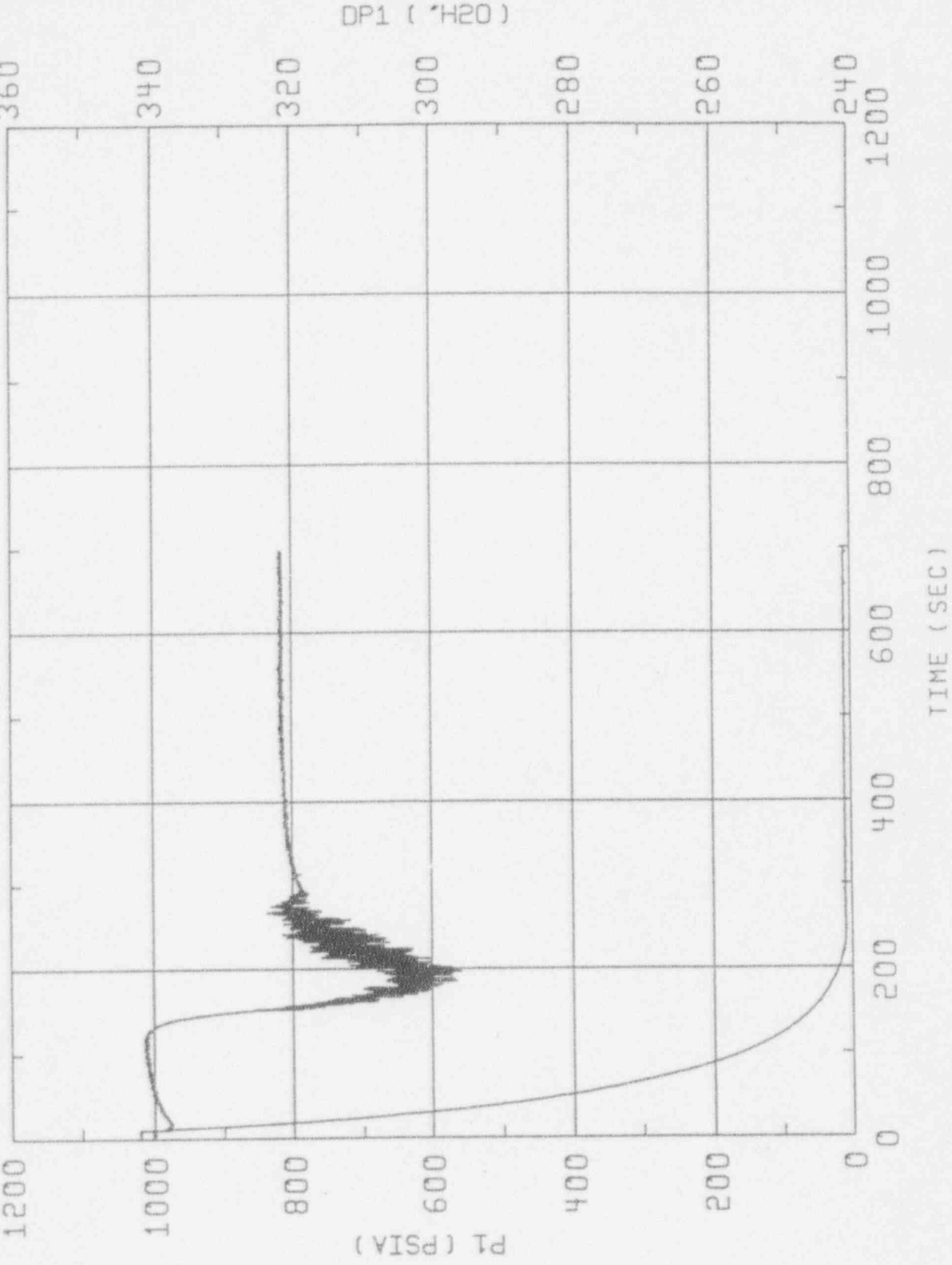


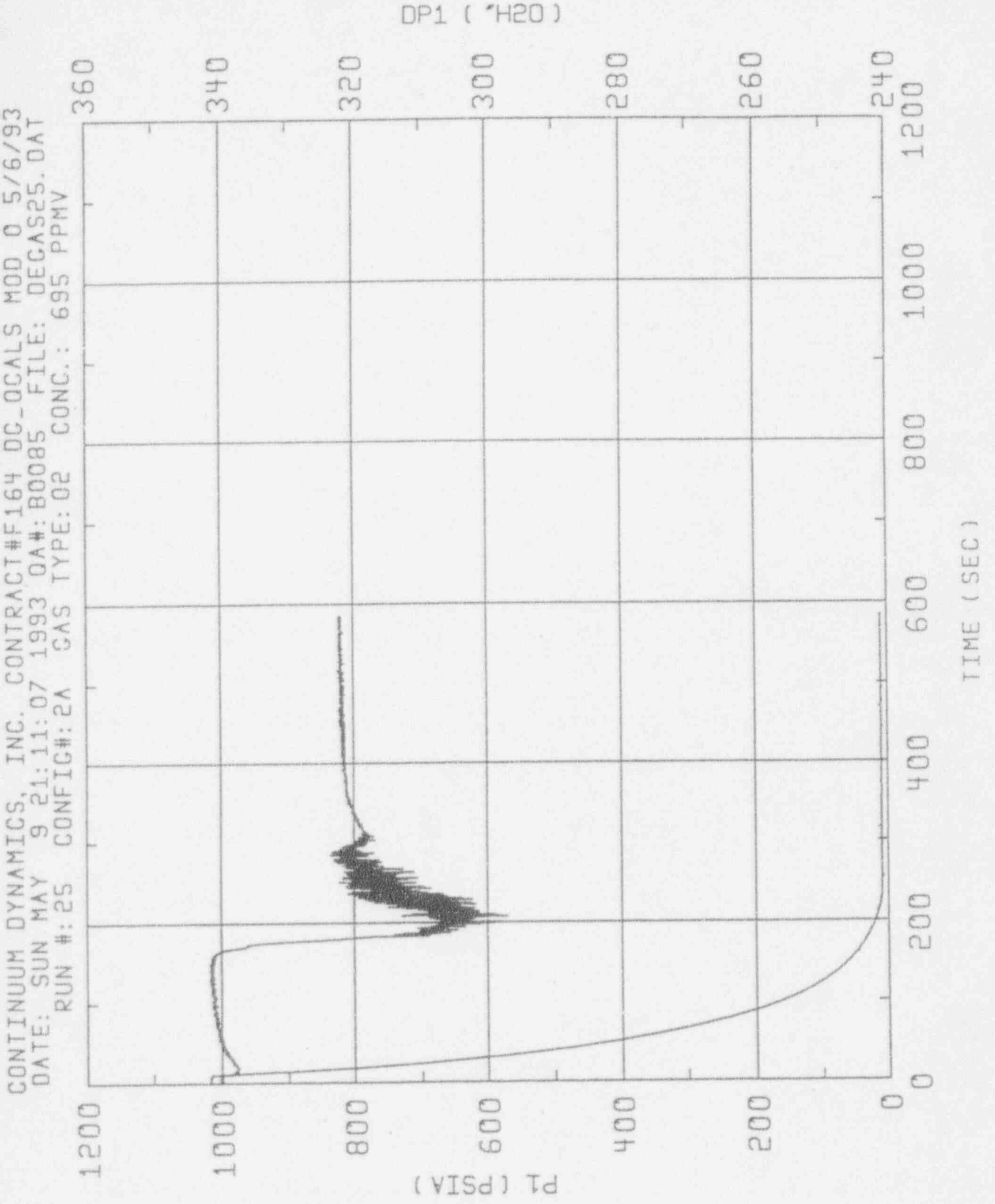
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_OCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:10:27 1993 QA#:B0081 FILE: DECAS21.DAT
RUN #:21 CONFIG#:2 GAS TYPE:02 CONC.:1170 PPMV

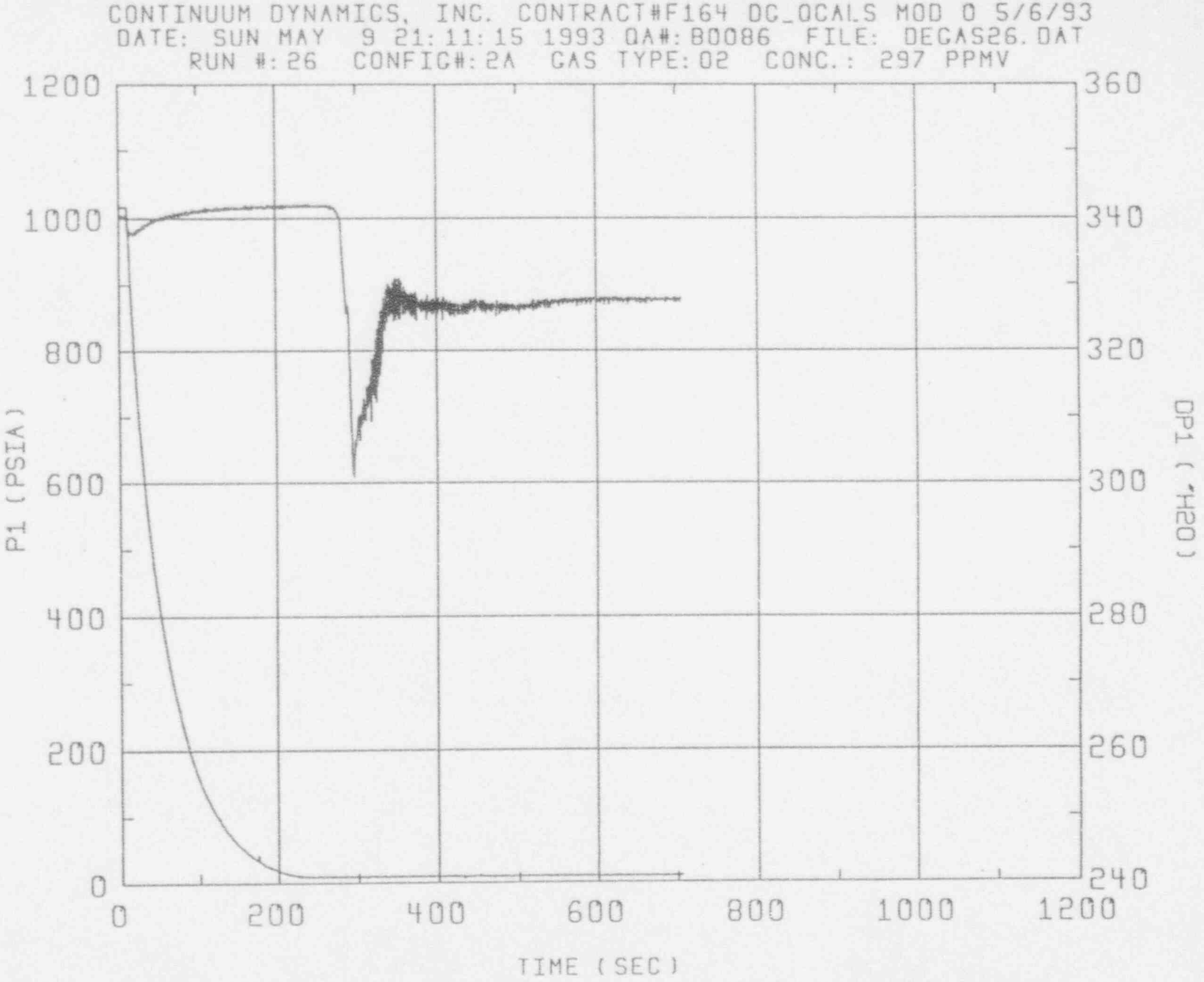

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_OCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:10:35 1993 QA#: B0082 FILE: DEGAS22.DAT
RUN #: 22 CONFIG#: 2 GAS TYPE: 02 CONC.: 307 PPMV
DP1 ('H2O)
360
340
320
300
280
260
240
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
200
400
600
800
1000
1200

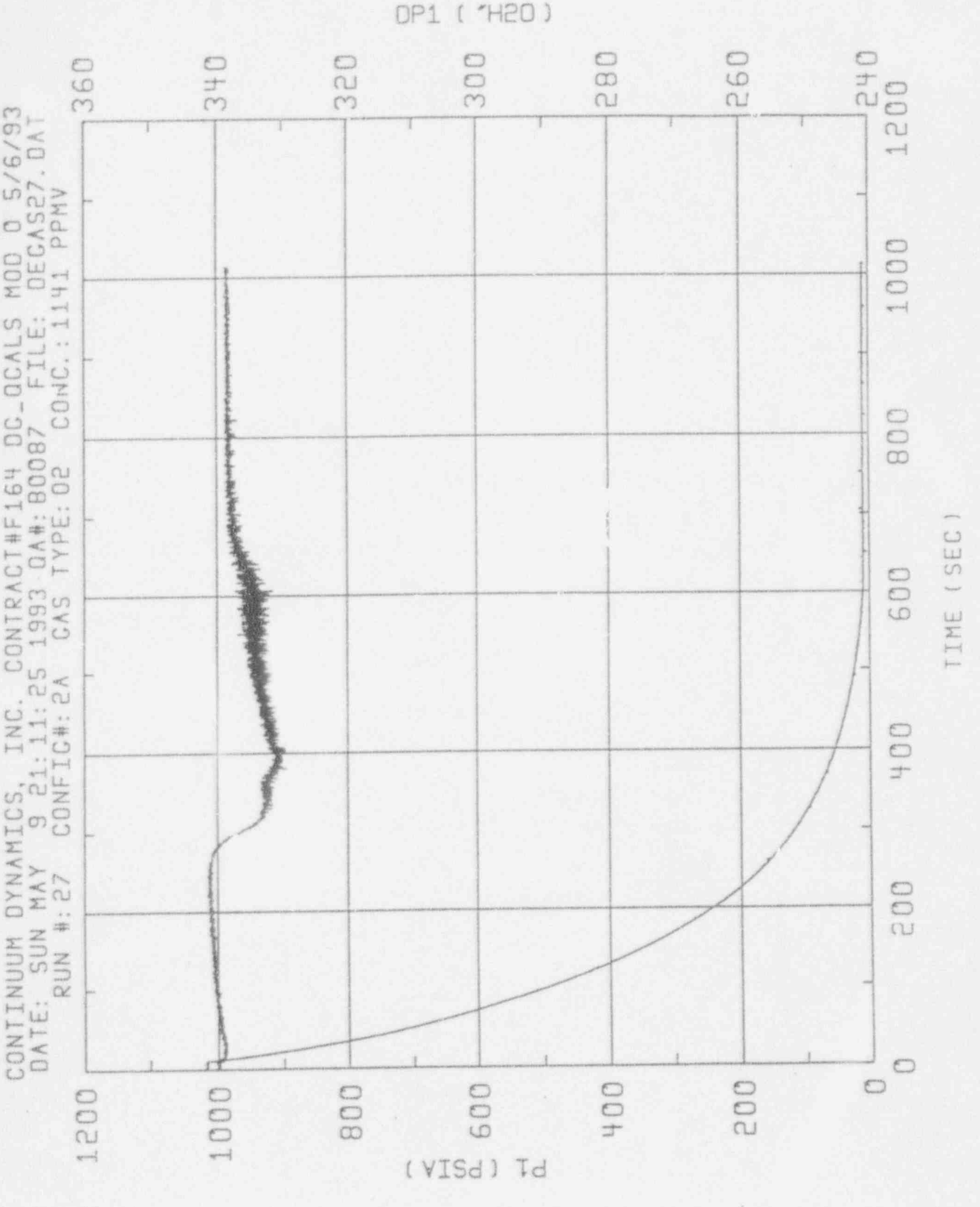

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:10:45 1993 QA#:B0083 FILE: DECAS23.DAT
RUN #:23 CONFIG#:2 GAS TYPE:02 CONC.: 307 PPMV
DP1 ( "H2O )
360
340
320
300
280
260
240
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
200
400
600
800
1000
1200

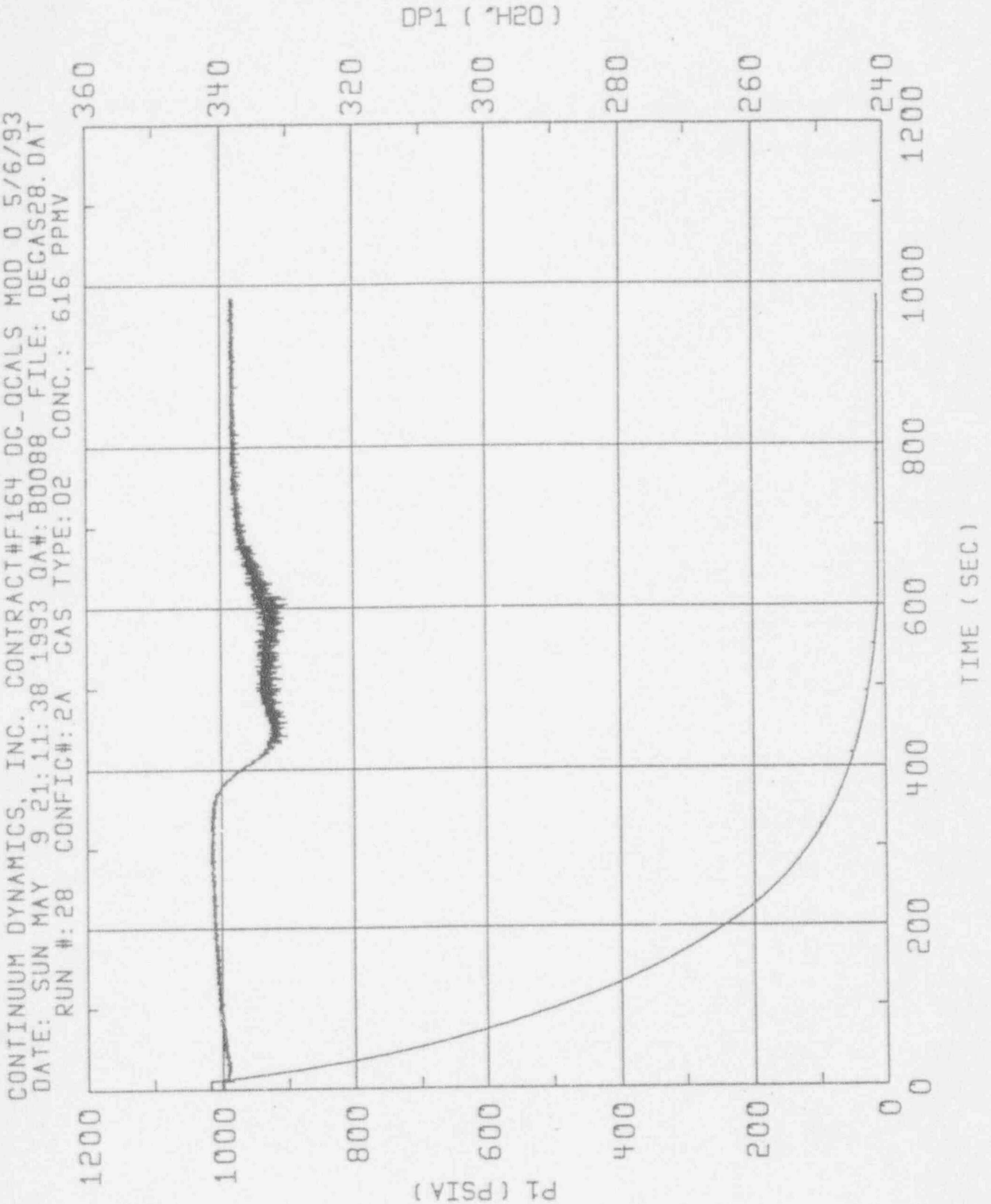
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:10:58 1993 QA#:80084 FILE: DEGAS24.DAT
RUN #:24 CONFIG#:2A GAS TYPE:02 CONC.:1110 PPMV



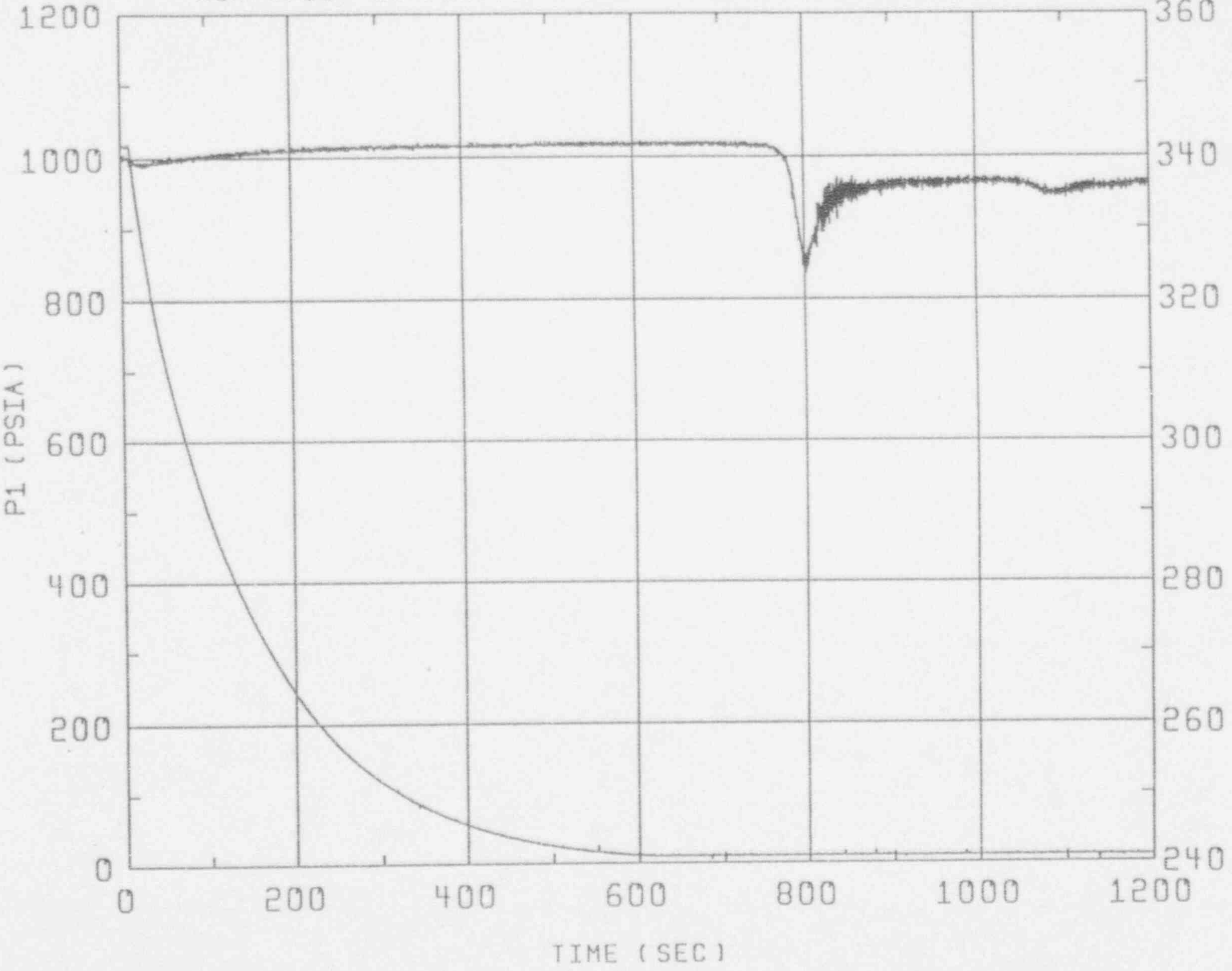

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:11:07 1993 QA#: B0085 FILE: DEGAS25.DAT
RUN #: 25 CONFIG#: 2A GAS TYPE: 02 CONC.: 695 PPMV
DP1 ( "H2O )
360
340
320
300
280
260
240
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
200
400
600
800
1000
1200


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_OCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:11:15 1993 QA#:B0086 FILE: DEGAS26.DAT
RUN #:26 CONFIG#:2A GAS TYPE:02 CONC.: 297 PPMV
P1 (PSIA)
DP1 ("H2O)
TIME (SEC)
0
200
400
600
800
1000
1200
240
260
280
300
320
340
360

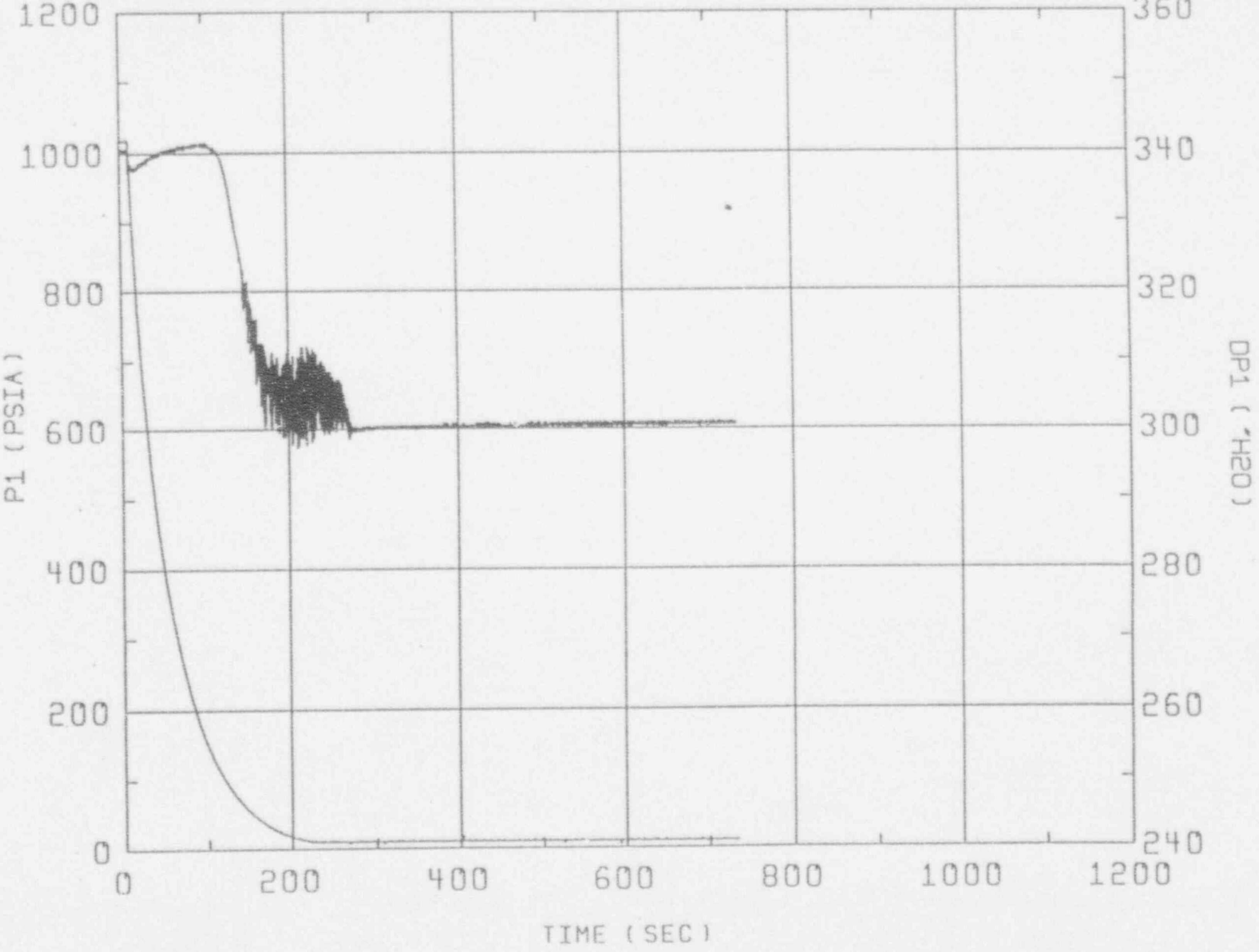

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:11:25 1993 QA#: B0087 FILE: DEGAS27.DAT
RUN #: 27 CONFIG#: 2A GAS TYPE: 02 CONC.: 1141 PPMV
P1 (PSIA)
0
200
400
600
800
1000
1200
DP1 ("H2O)
240
260
280
300
320
340
360
TIME (SEC)
0
200
400
600
800
1000
1200

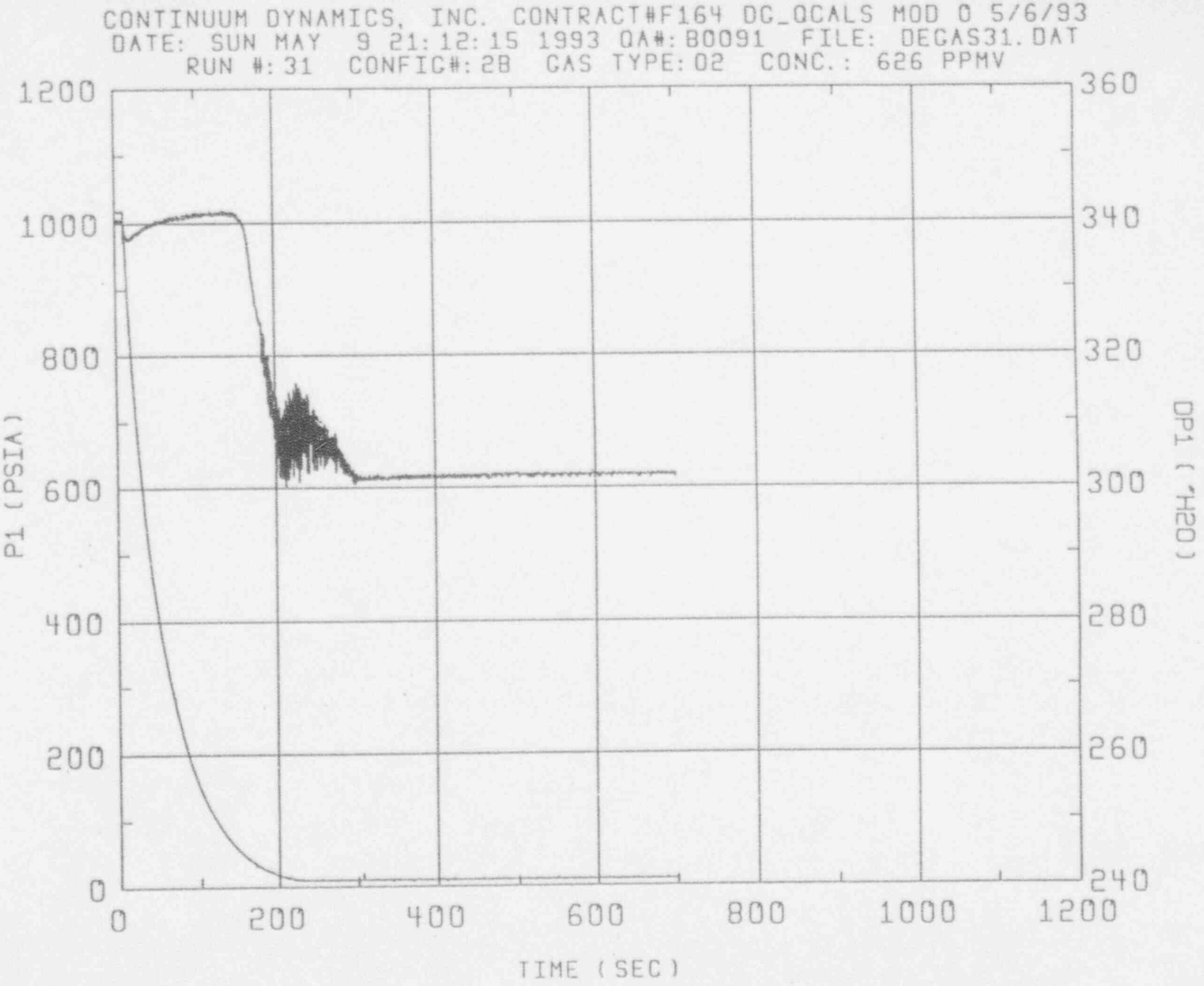

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:11:38 1993 QA#:B0088 FILE: DEGAS28.DAT
RUN #:28 CONFIG#:2A GAS TYPE:02 CONC.: 616 PPMV
DP1 ( "H2O )
360
340
320
300
280
260
240
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
200
400
600
800
1000
1200

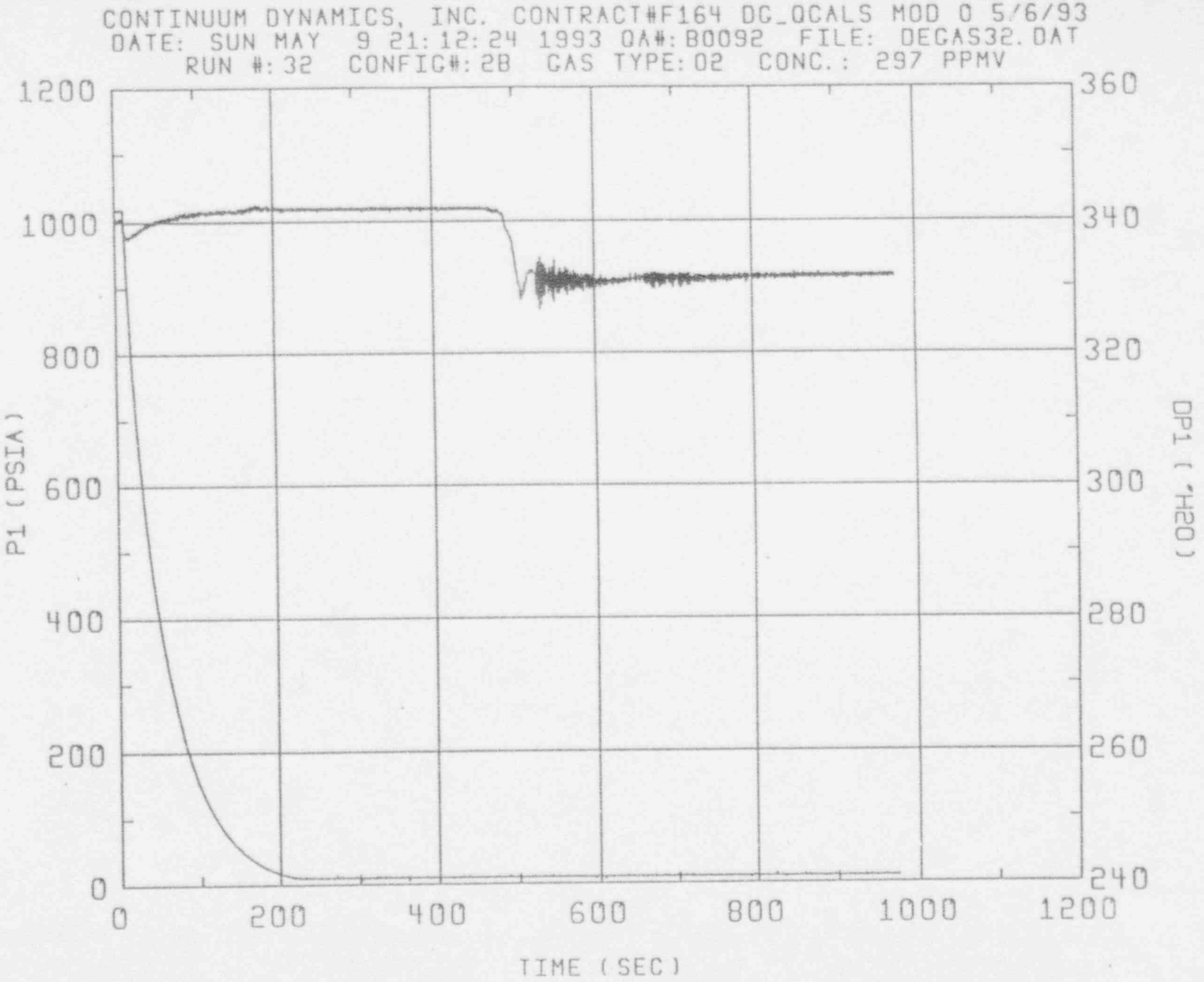
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:11:50 1993 QA#:B0089 FILE: DEGAS29.DAT
RUN #:29 CONFIG#:2A GAS TYPE:02 CONC.: 287 PPMV

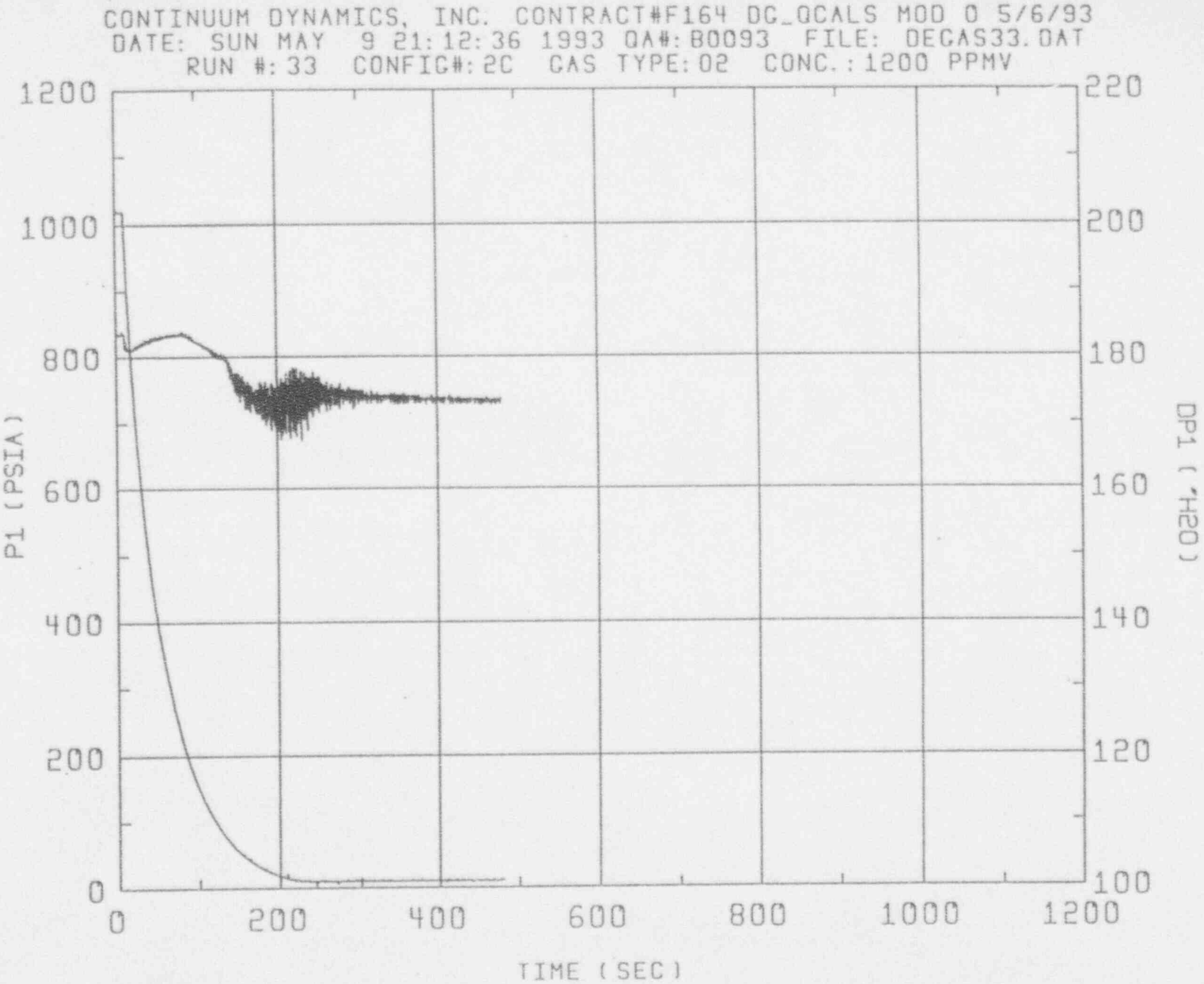


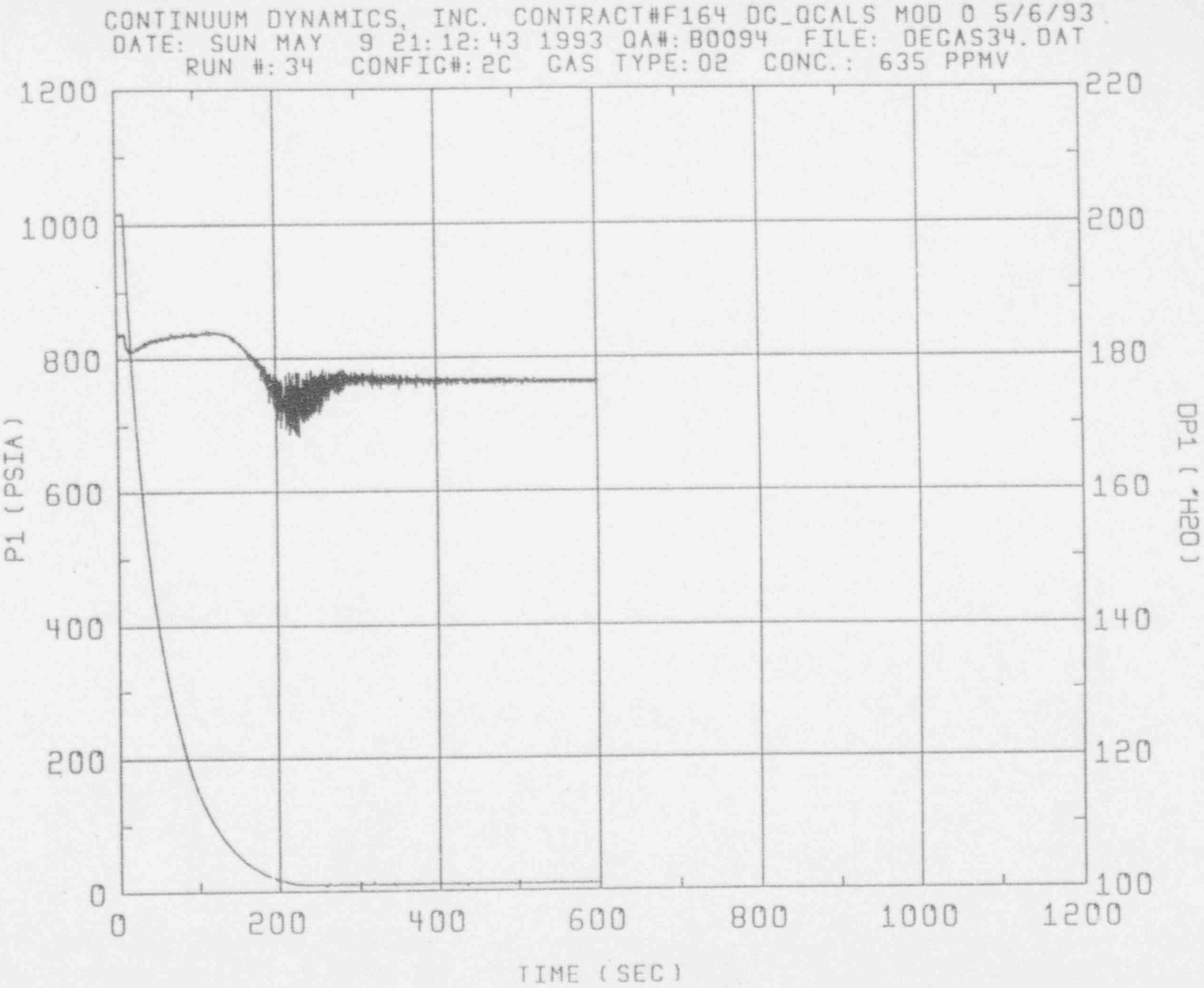
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:12:05 1993 QA#: B0090 FILE: DEGAS30.DAT
RUN #: 30 CONFIG#: 2B GAS TYPE: 02 CONC.: 1130 PPMV



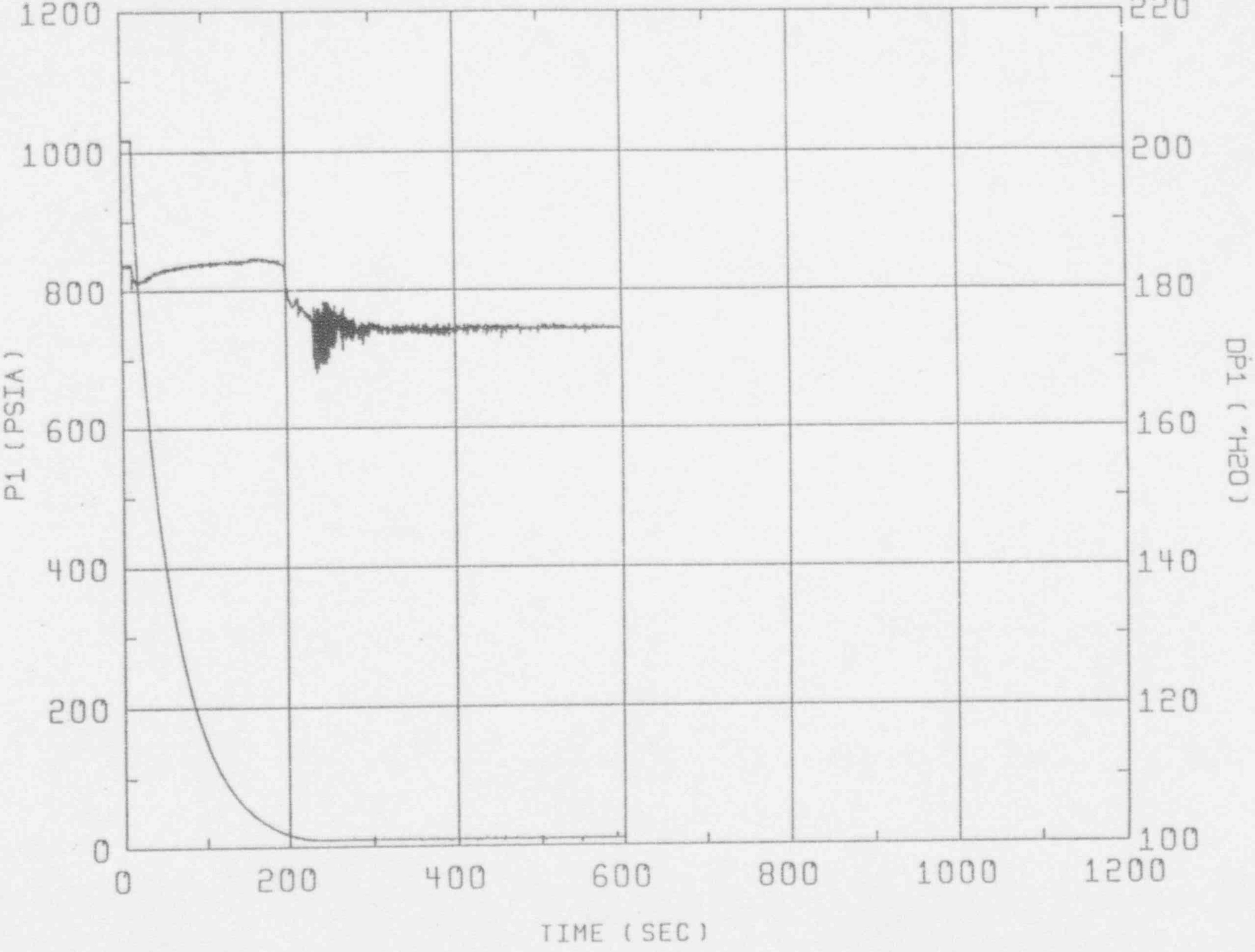

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:12:15 1993 QA#:B0091 FILE: DEGAS31.DAT
RUN #:31 CONFIG#:2B GAS TYPE:02 CONC.: 626 PPMV
1200
1000
800
600
400
200
0
P1 (PSIA)
360
340
320
300
280
260
240
DP1 ("H2O)
0
200
400
600
800
1000
1200
TIME (SEC)

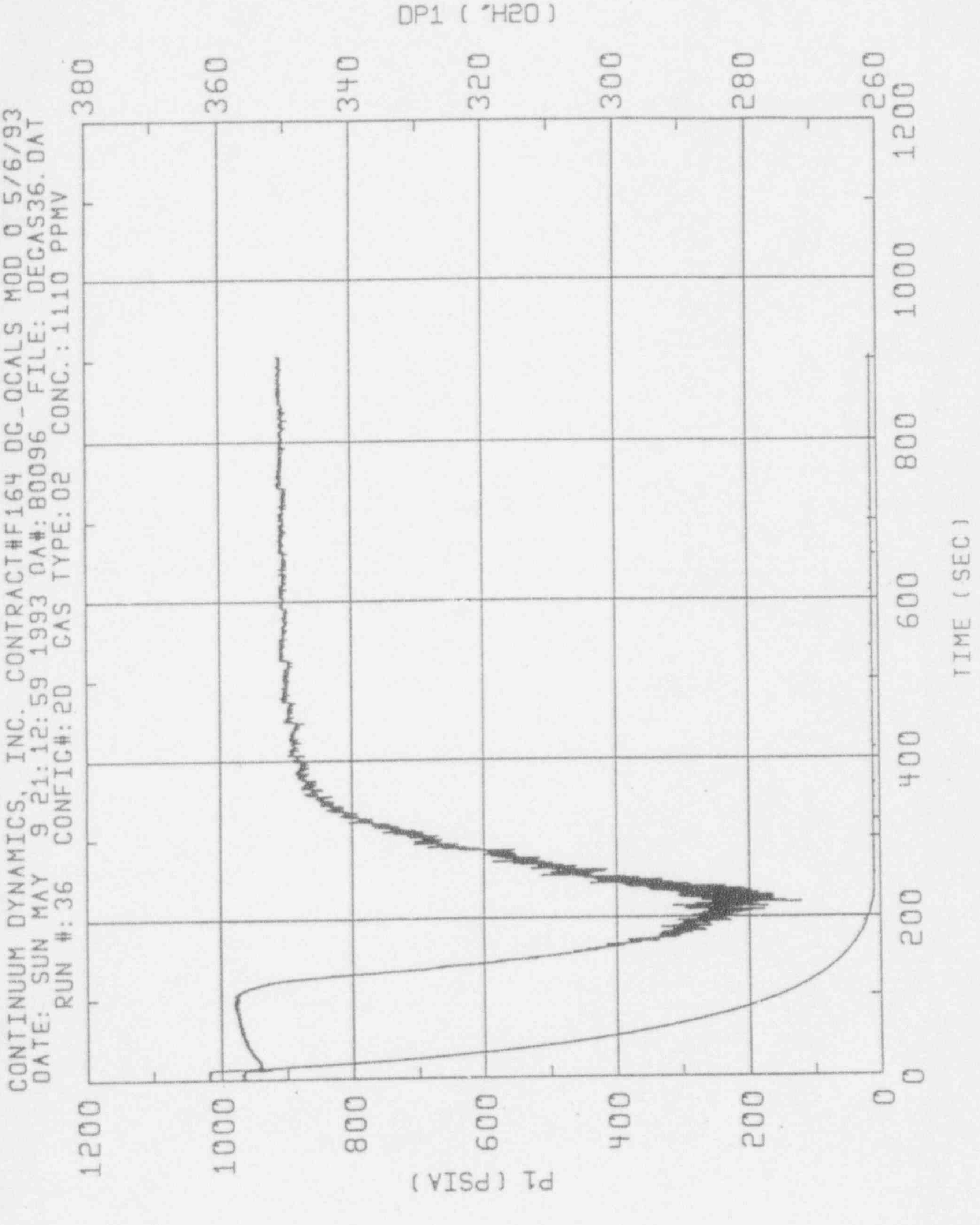

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:12:24 1993 QA#:B0092 FILE: DEGAS32.DAT
RUN #:32 CONFIG#:2B GAS TYPE:02 CONC.: 297 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ('H2O)
360
340
320
300
280
260
240
0
200
400
600
800
1000
1200
TIME (SEC)


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:12:36 1993 QA#:B0093 FILE: DEGAS33.DAT
RUN #: 33 CONFIG#: 2C GAS TYPE: 02 CONC.: 1200 PPMV

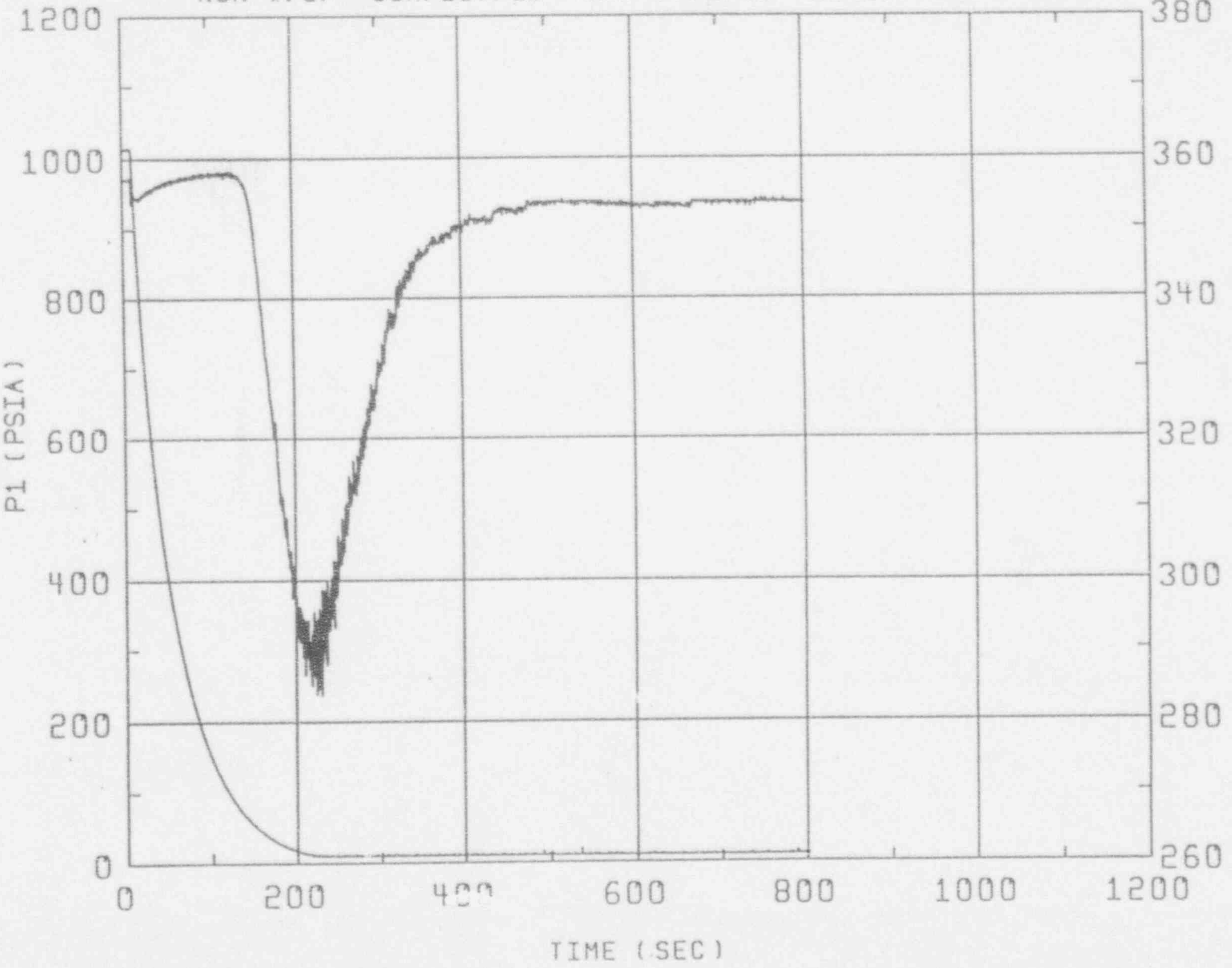

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:12:43 1993 QA#: B0094 FILE: DEGAS34.DAT
RUN #: 34 CONFIG#: 2C GAS TYPE: 02 CONC.: 635 PPMV
1200
1000
800
600
400
200
0
P1 (PSIA)
220
200
180
160
140
120
100
DP1 ("H2O)
0
200
400
600
800
1000
1200
TIME (SEC)

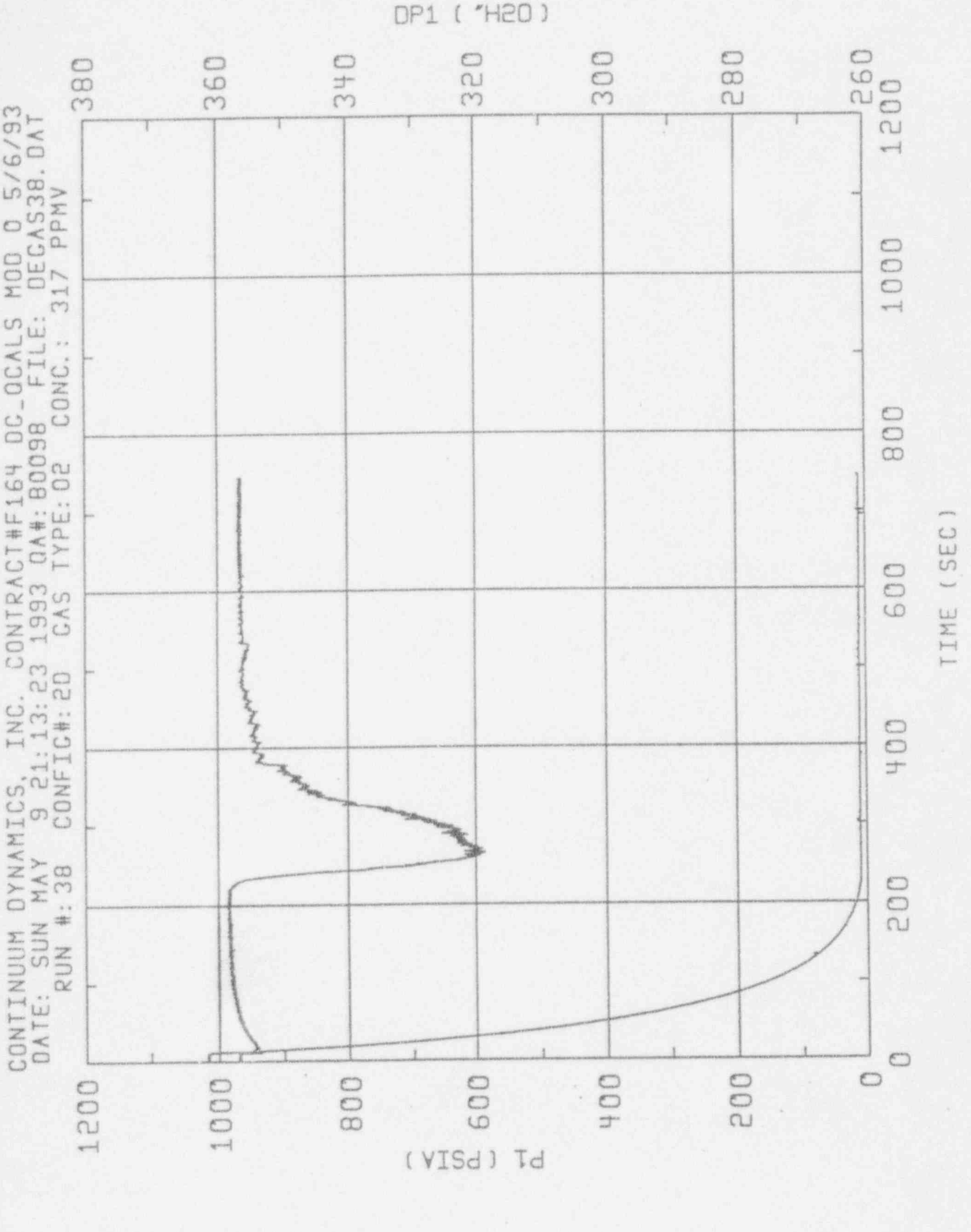
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:12:51 1993 QA#:B0095 FILE: DEGAS35.DAT
RUN #:35 CONFIG#:2C GAS TYPE:02 CONC.: 346 PPMV



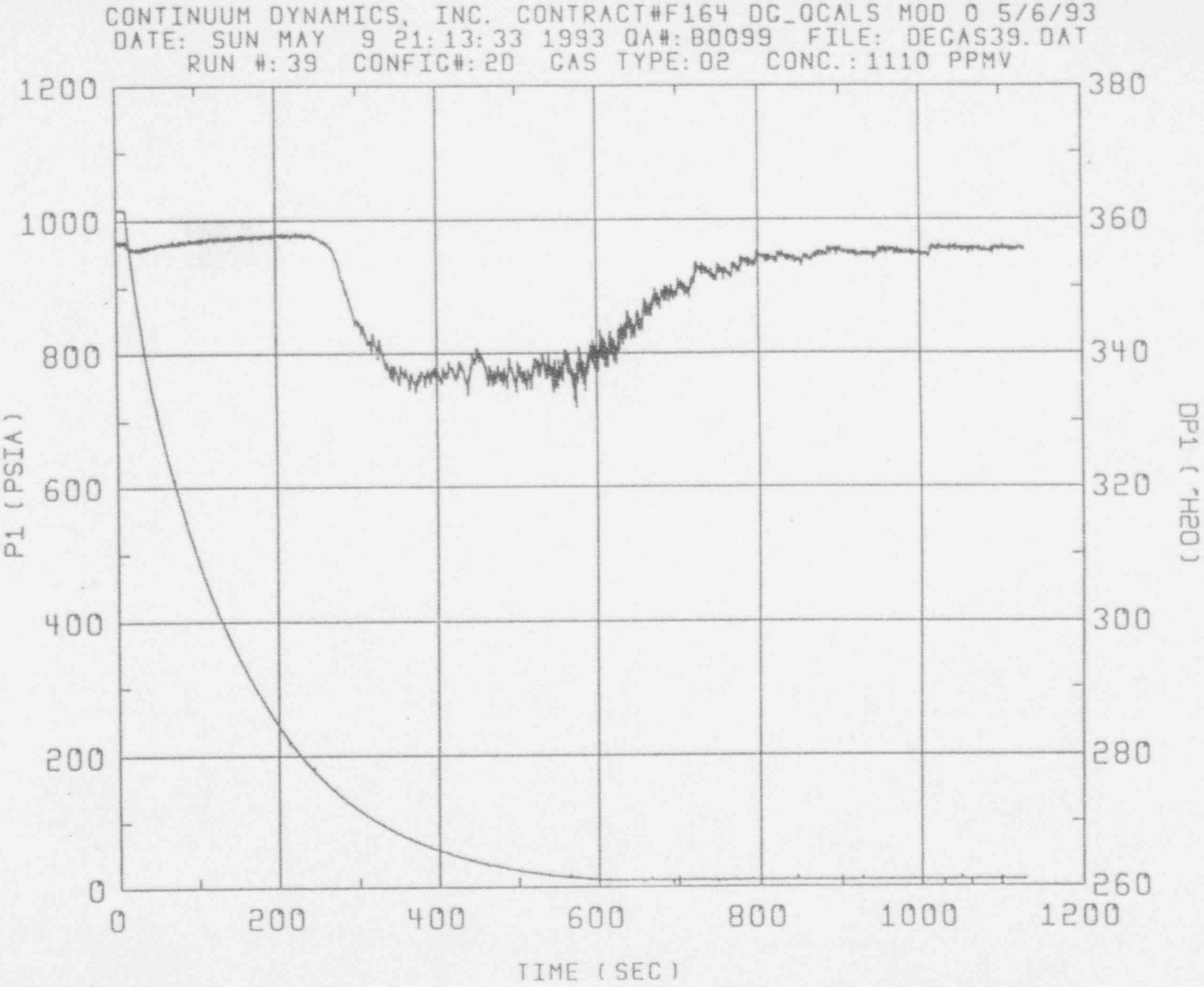

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:12:59 1993 QA#: B0096 FILE: DEGAS36.DAT
RUN #: 36 CONFIG#: 2D GAS TYPE: 02 CONC.: 1110 PPMV
DP1 ( "H2O )
380
360
340
320
300
280
260
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
200
400
600
800
1000
1200

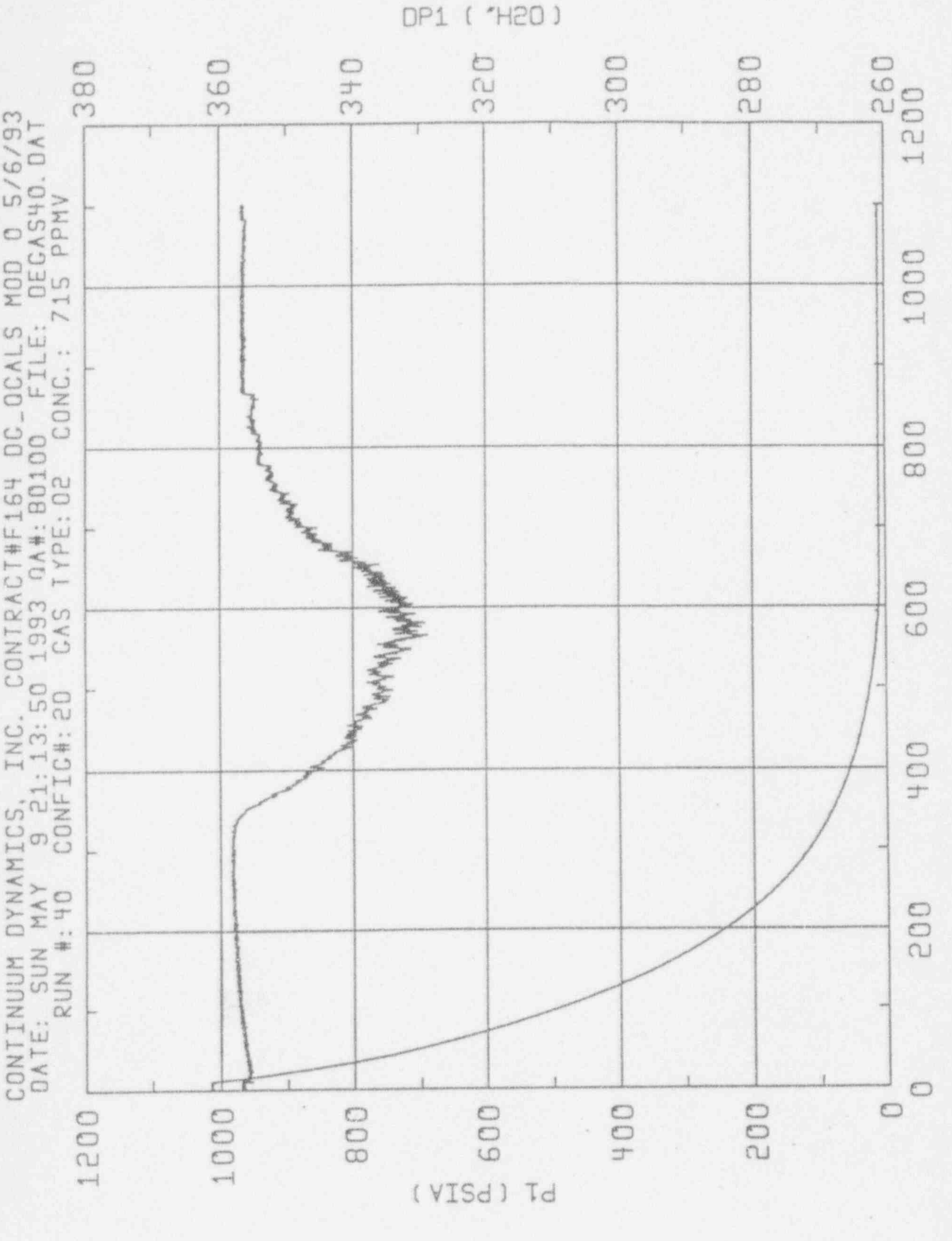
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:13:13 1993 QA#:B0097 FILE: DEGAS37.DAT
RUN #:37 CONFIG#:2D GAS TYPE:02 CONC.: 616 PPMV

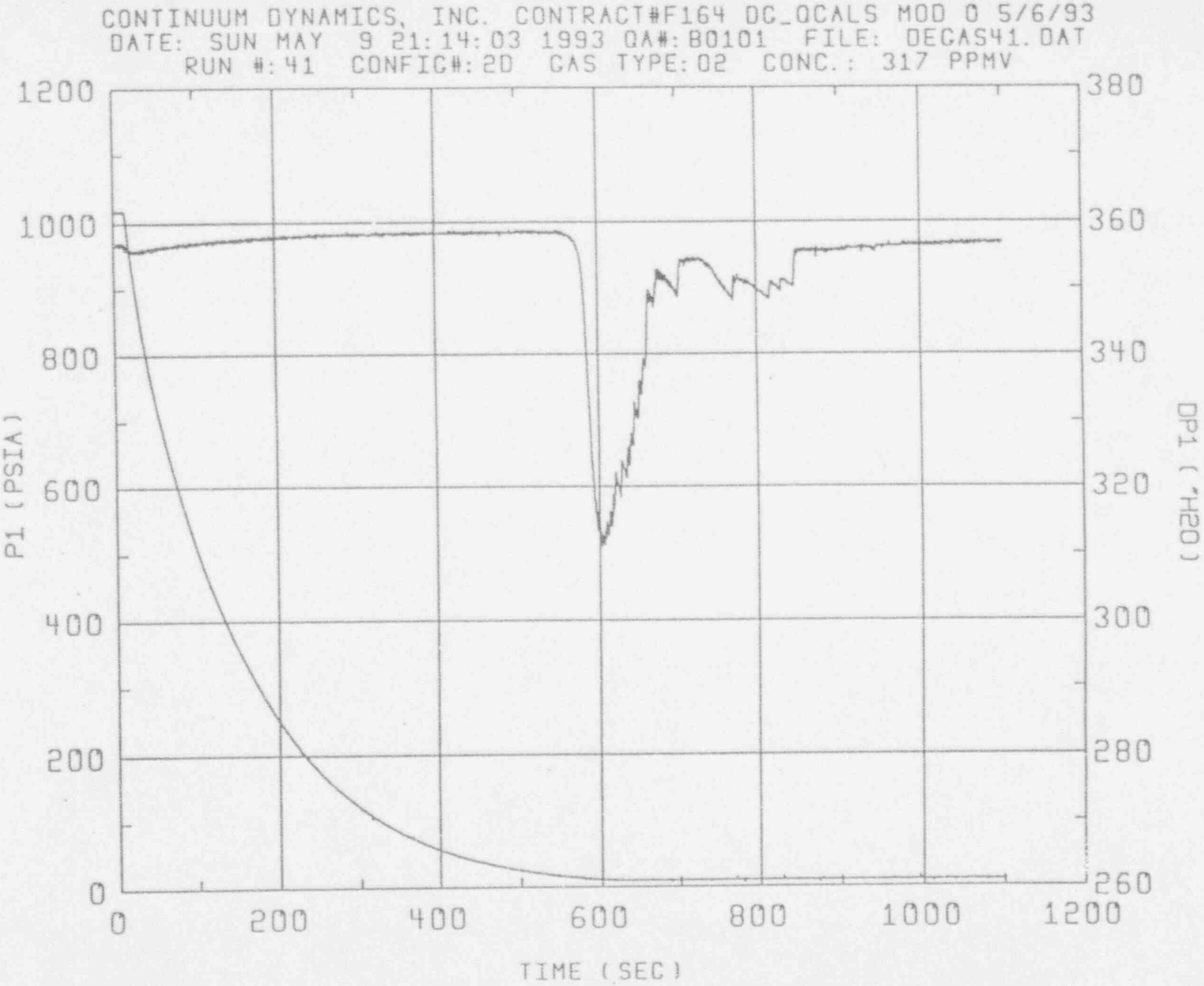


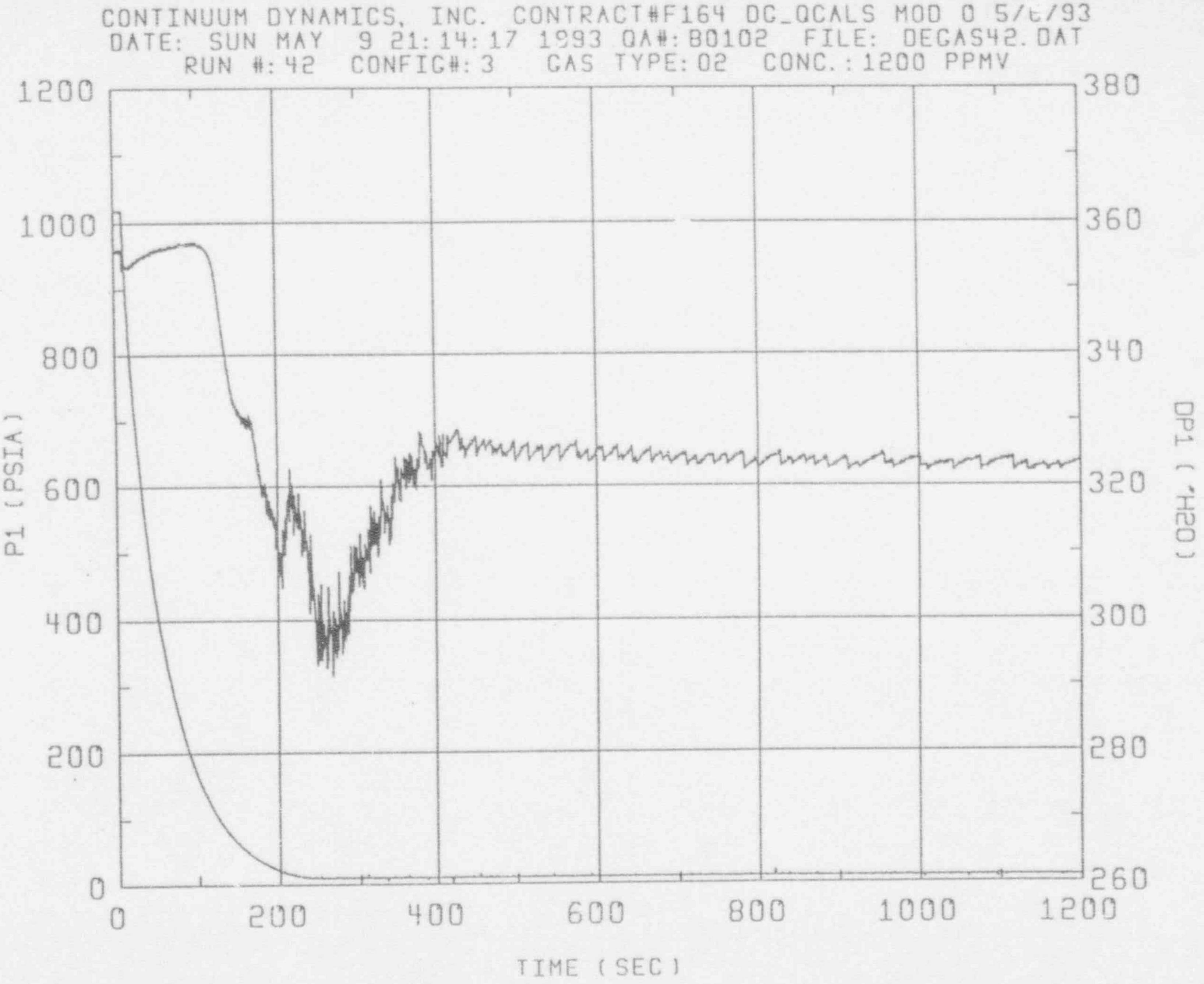


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:13:23 1993 QA#:B0098 FILE: DEGAS38.DAT
RUN #:38 CONFIG#:2D GAS TYPE:02 CONC.: 317 PPMV

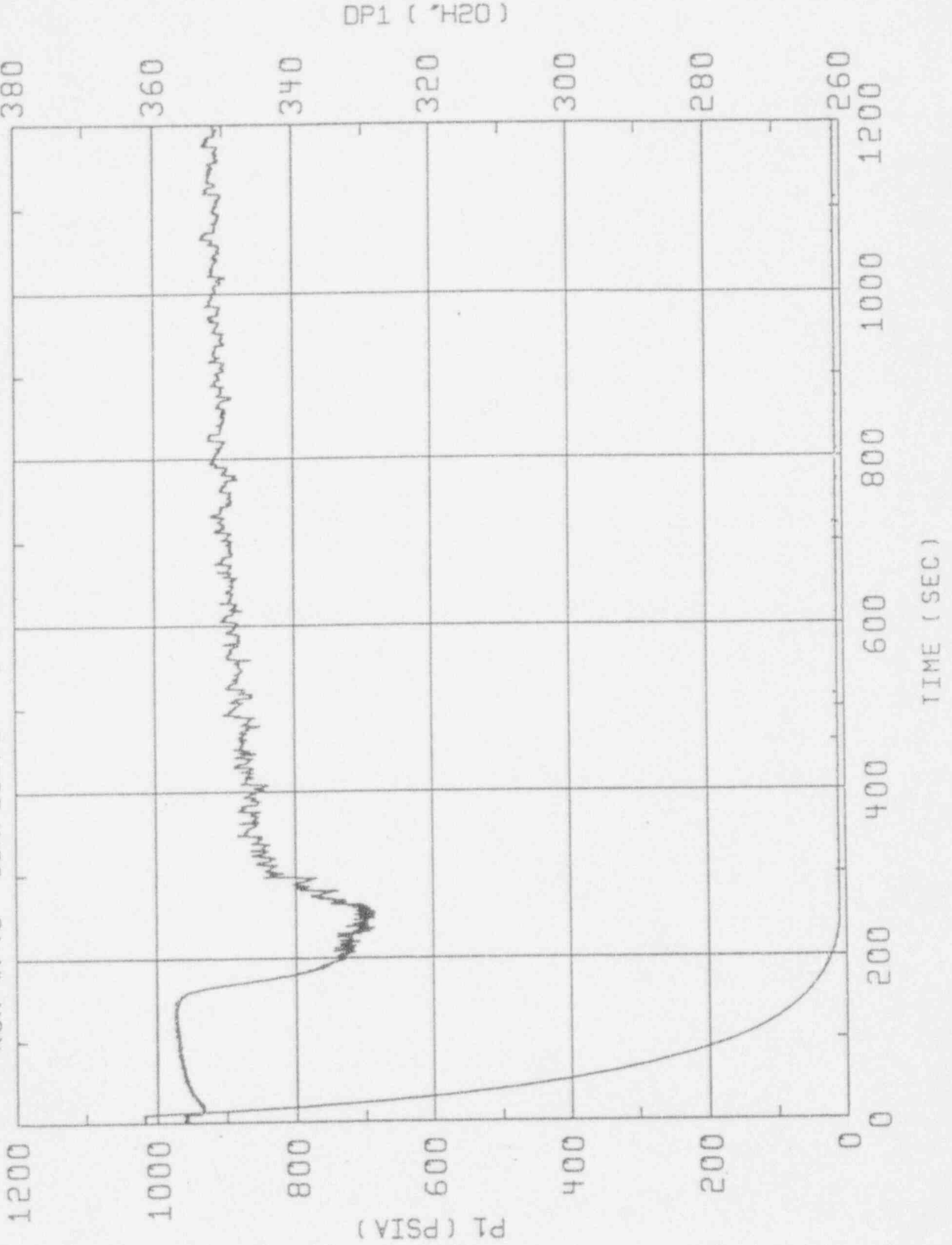

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:13:33 1993 QA#:B0099 FILE: DEGAS39.DAT
RUN #:39 CONFIG#:20 GAS TYPE:02 CONC.:1110 PPMV
P1 (PSIA)
0
200
400
600
800
1000
1200
DP1 ("H2O)
260
280
300
320
340
360
380
TIME (SEC)
0
200
400
600
800
1000
1200

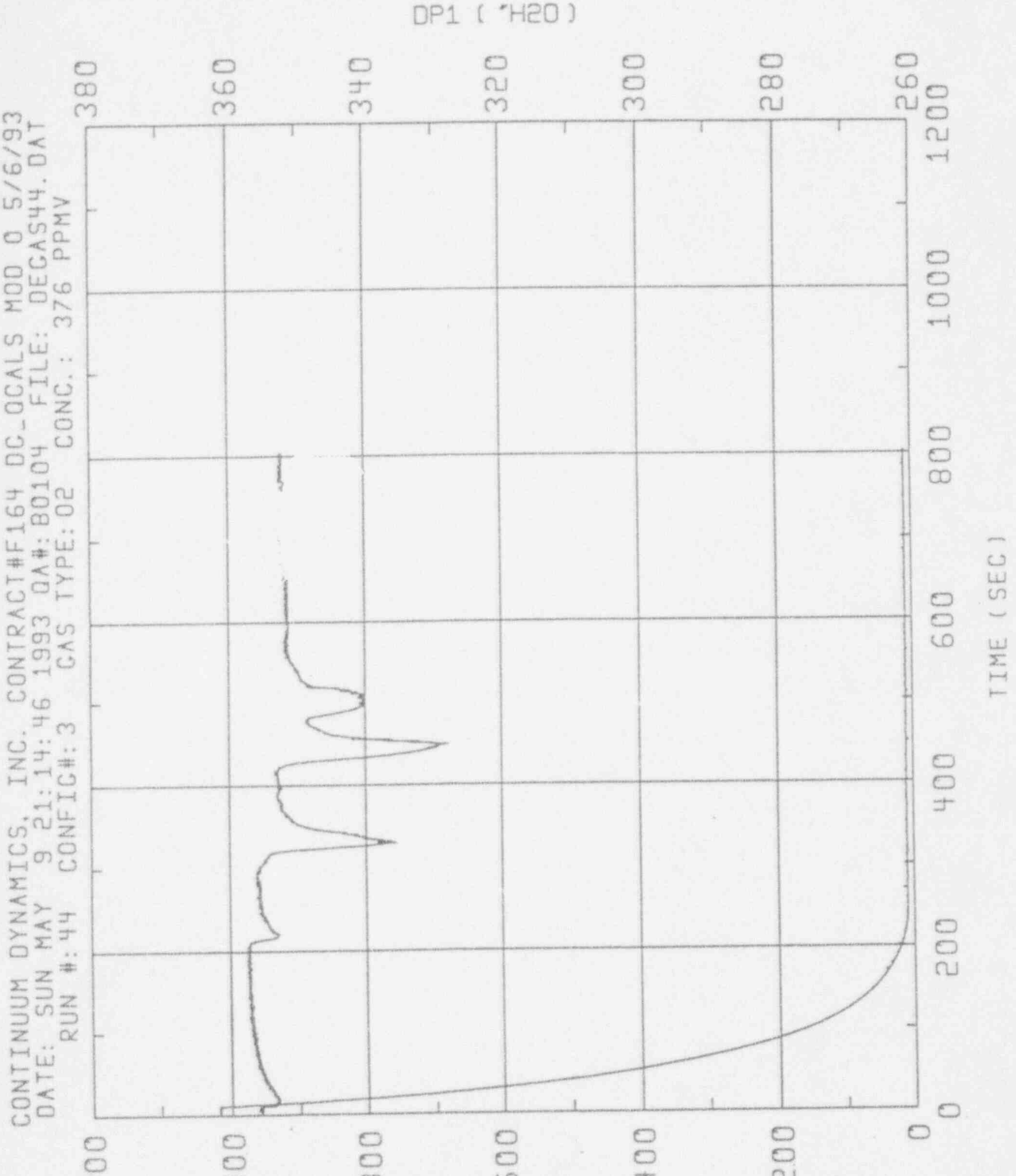

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:13:50 1993 QA#: B0100 FILE: DEGAS40.DAT
RUN #:40 CONFIG#:20 GAS TYPE:02 CONC.: 715 PPMV
DP1 ( "H2O )
380
360
340
320
300
280
260
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
200
400
600
800
1000
1200


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:14:03 1993 QA#: B0101 FILE: DEGAS41.DAT
RUN #: 41 CONFIG#: 2D GAS TYPE: 02 CONC.: 317 PPMV
1200
1000
800
600
400
200
0
P1 (PSIA)
380
360
340
320
300
280
260
DP1 ("H2O)
0
200
400
600
800
1000
1200
TIME (SEC)

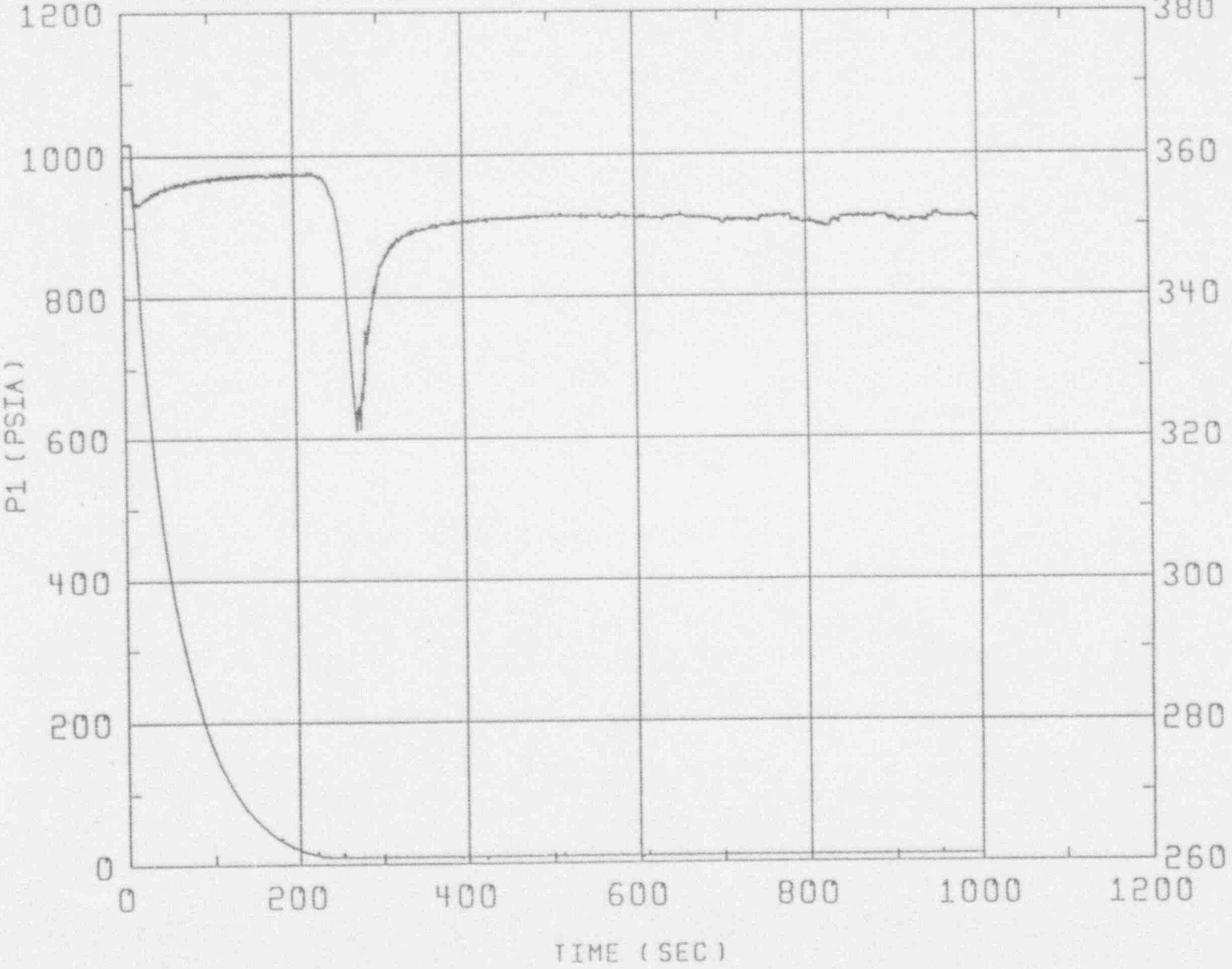

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:14:17 1993 QA#: B0102 FILE: DEGAS42.DAT
RUN #: 42 CONFIG#: 3 GAS TYPE: 02 CONC.: 1200 PPMV
P1 (PSIA)
0
200
400
600
800
1000
1200
DP1 ('H2O)
260
280
300
320
340
360
380
TIME (SEC)
0
200
400
600
800
1000
1200

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:14:31 1993 QA#: B0103 FILE: DEGAS43.DAT
RUN #: 43 CONFIG#: 3 GAS TYPE: O2 CONC.: 675 PPMV

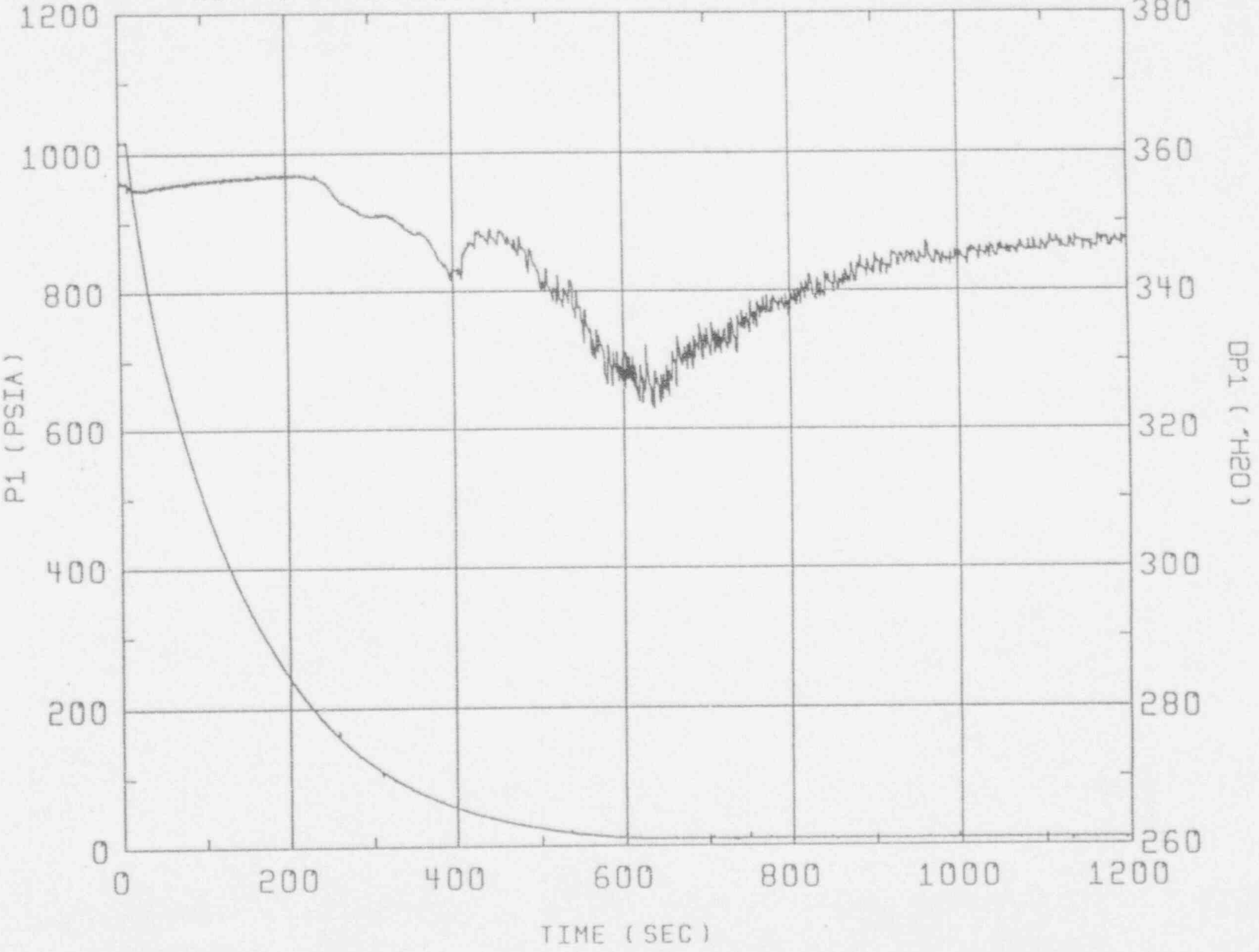



CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:14:46 1993 QA#: B0104 FILE: DECAS44.DAT
RUN #: 44 CONFIG#: 3 GAS TYPE: 02 CONC.: 376 PPMV
DP1 ( "H2O )
380
360
340
320
300
280
260
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
200
400
600
800
1000
1200

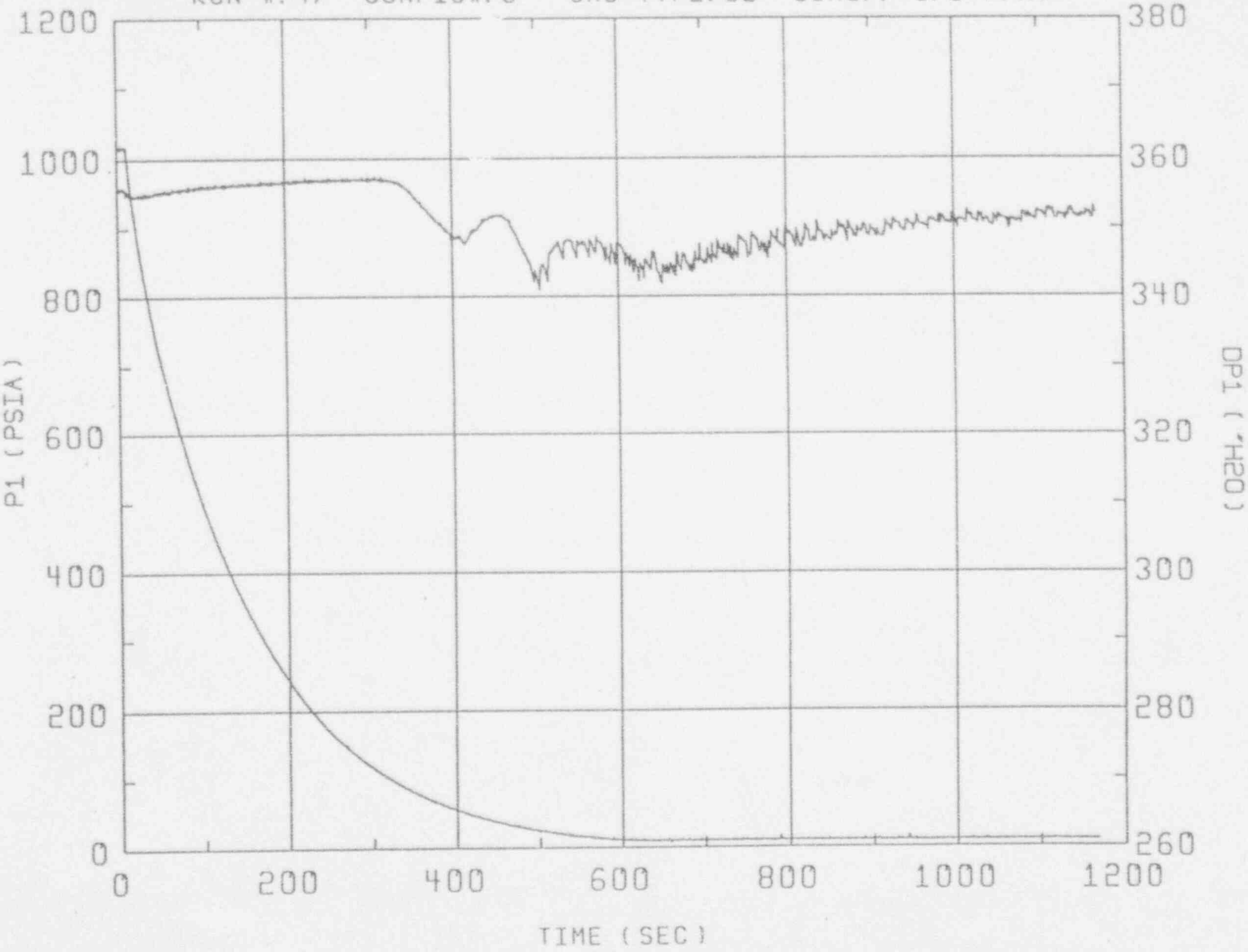
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:14:56 1993 QA#:B0105 FILE: DEGAS45.DAT
RUN #:45 CONFIG#:3 GAS TYPE:02 CONC.: 327 PPMV



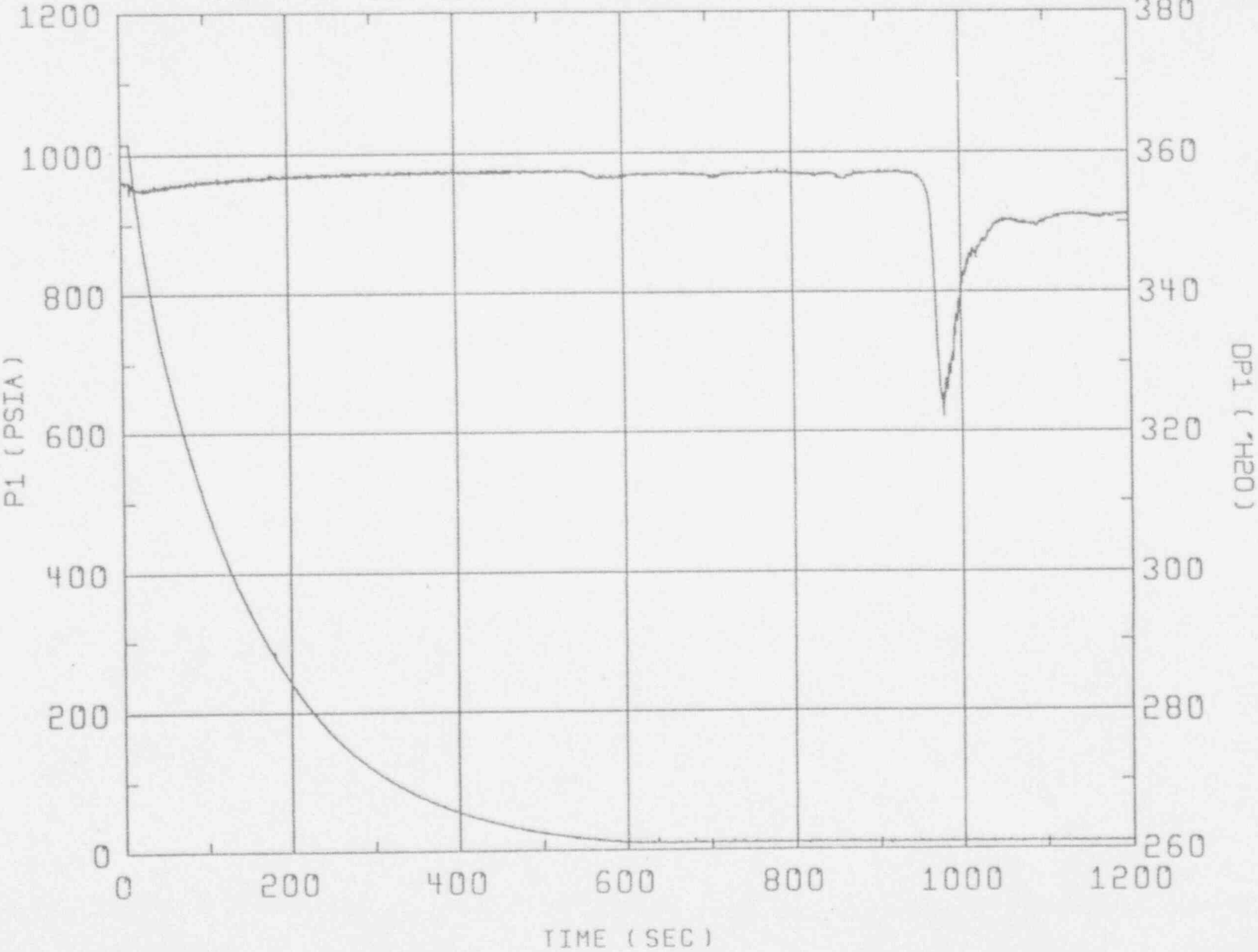
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:15:09 1993 QA#: B0106 FILE: DEGAS46.DAT
RUN #: 46 CONFIG#: 3 GAS TYPE: 02 CONC.: 1150 PPMV

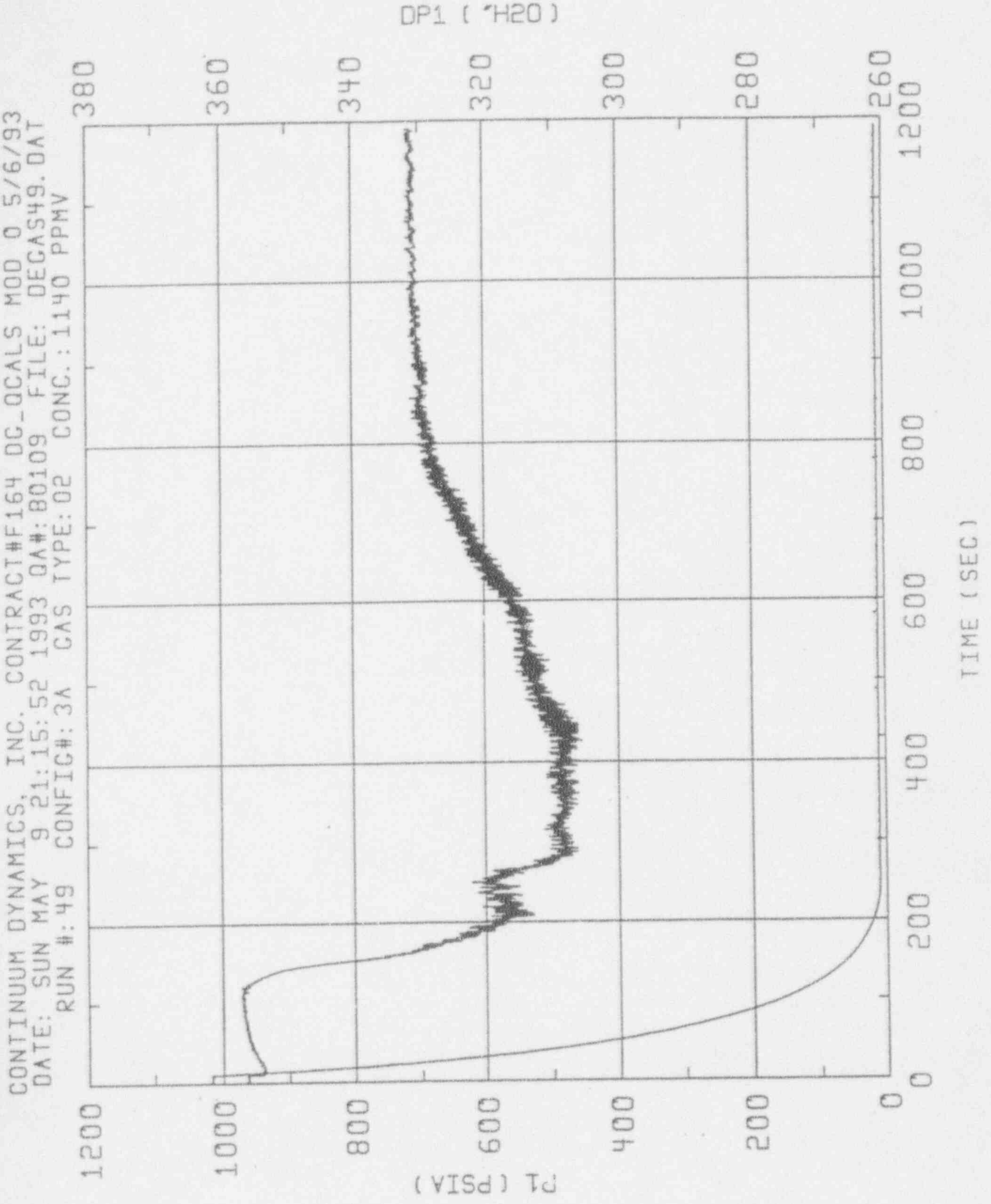


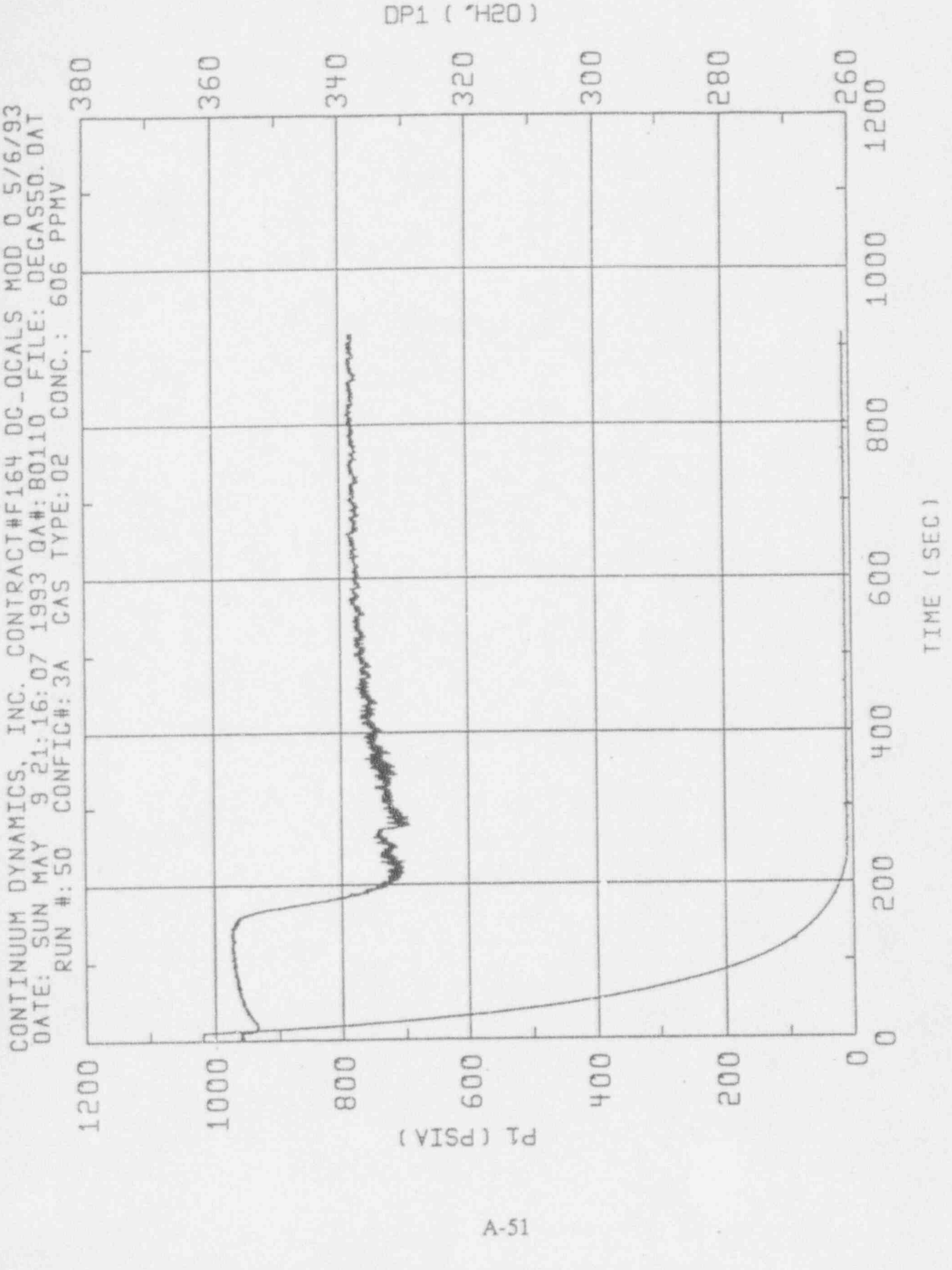
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:15:24 1993 QA#: B0107 FILE: DEGAS47.DAT
RUN #: 47 CONFIG#: 3 GAS TYPE: 02 CONC.: 675 PPMV



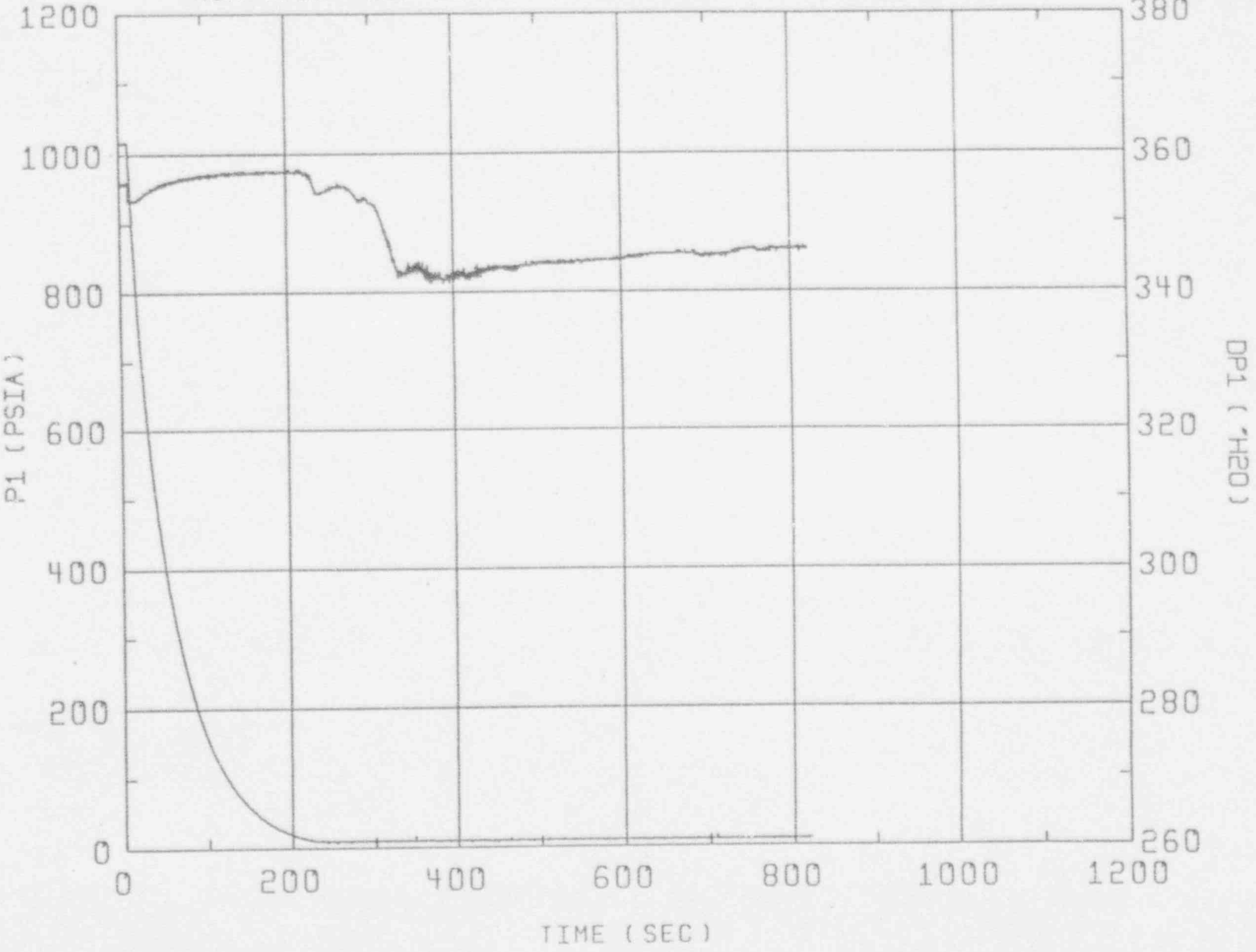
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:15:38 1993 QA#:B0108 FILE: DEGAS48.DAT
RUN #:48 CONFIG#:3 GAS TYPE:02 CONC.: 336 PPMV

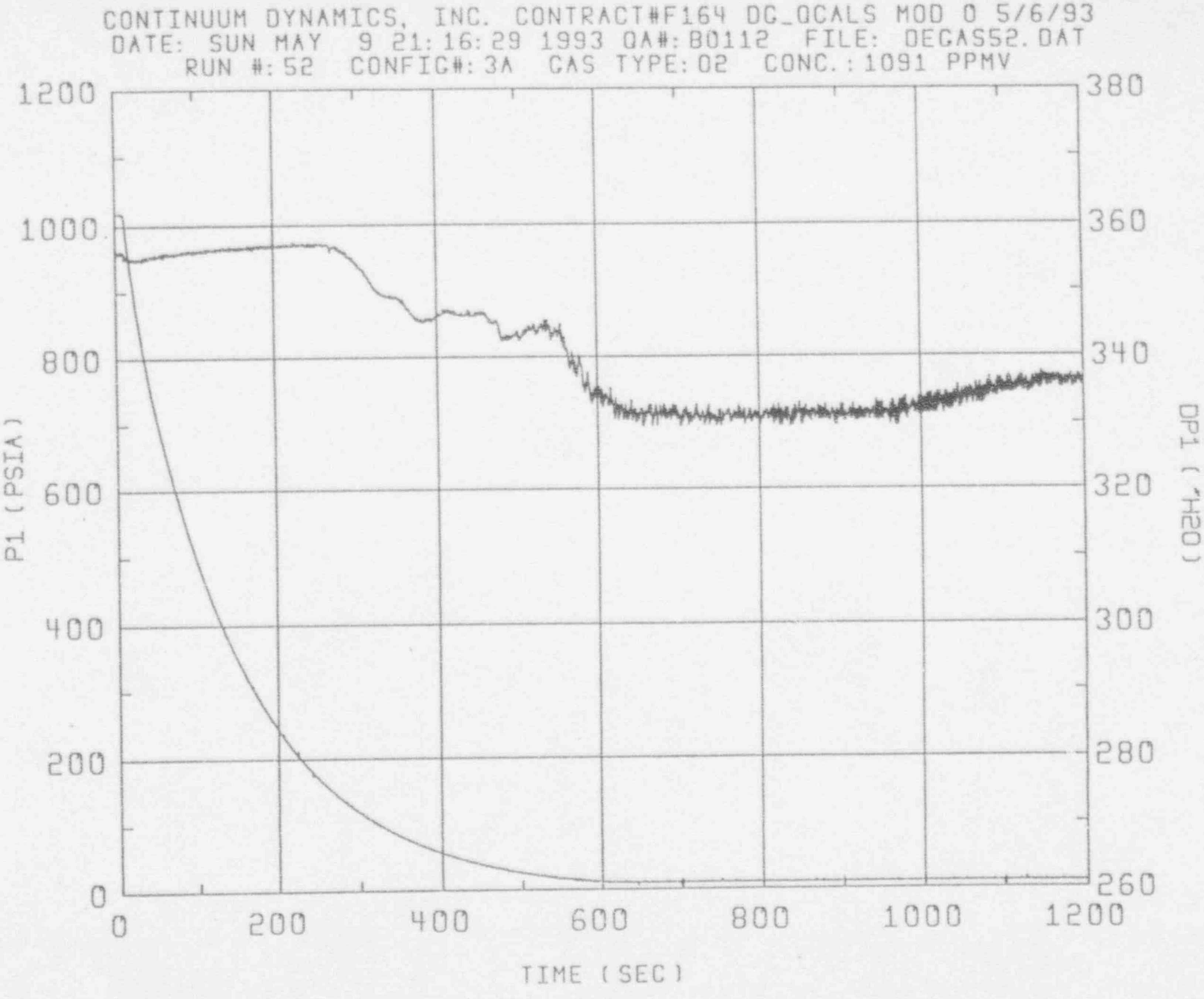



CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:15:52 1993 QA#:80109 FILE: DEGAS49.DAT
RUN #:49 CONFIG#:3A GAS TYPE:02 CONC.:1140 PPMV
DP1 ("H2O)
380
360
340
320
300
280
260
P1 (PSIA)
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
TIME (SEC)

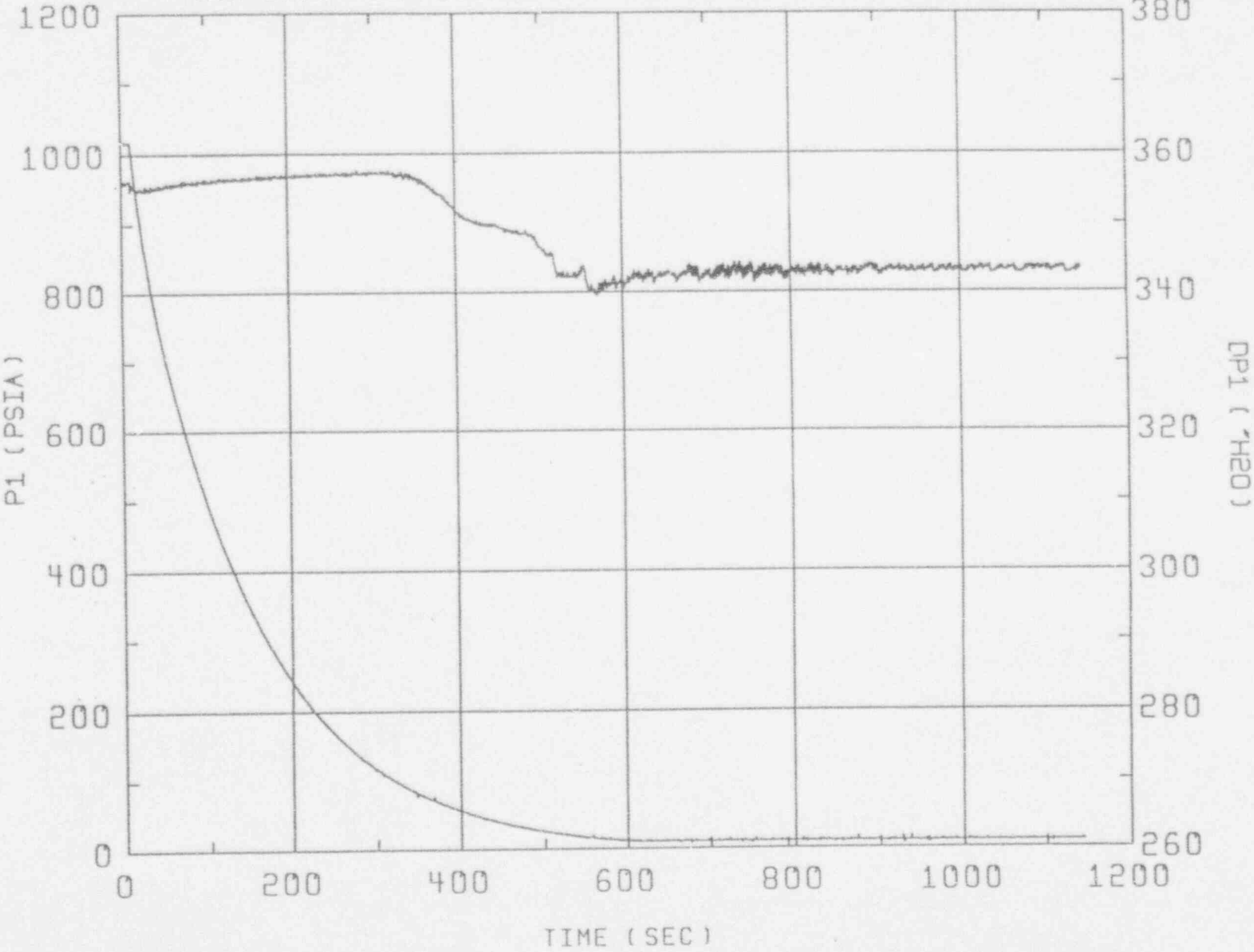

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:16:07 1993 QA#: B0110 FILE: DEGAS50.DAT
RUN #: 50 CONFIG#: 3A GAS TYPE: 02 CONC.: 606 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ( "H2O )
380
360
340
320
300
280
260
TIME (SEC)
0
200
400
600
800
1000
1200

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:16:19 1993 QA#: B0111 FILE: DEGAS51.DAT
RUN #: 51 CONFIG#: 3A GAS TYPE: 02 CONC.: 346 PPMV

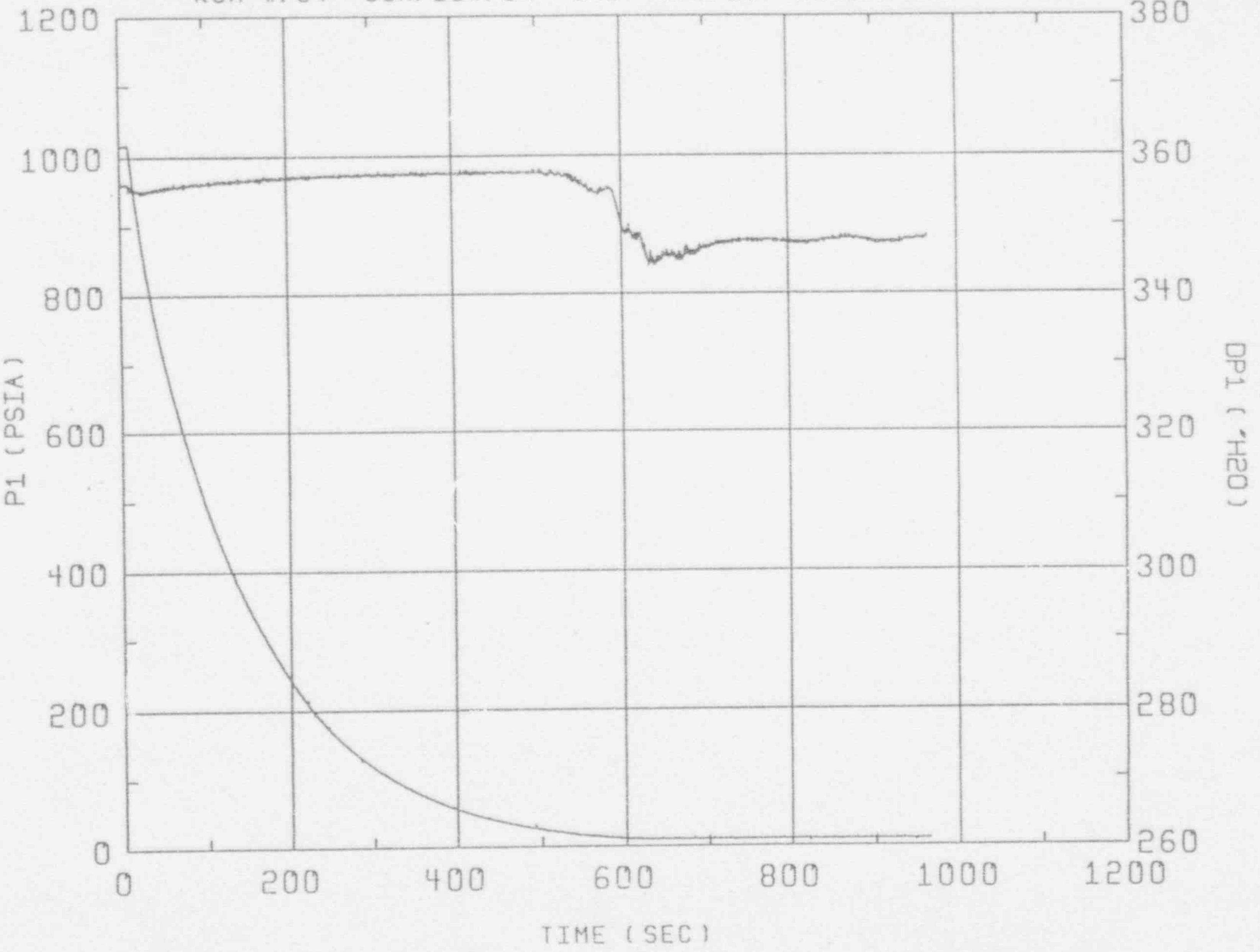


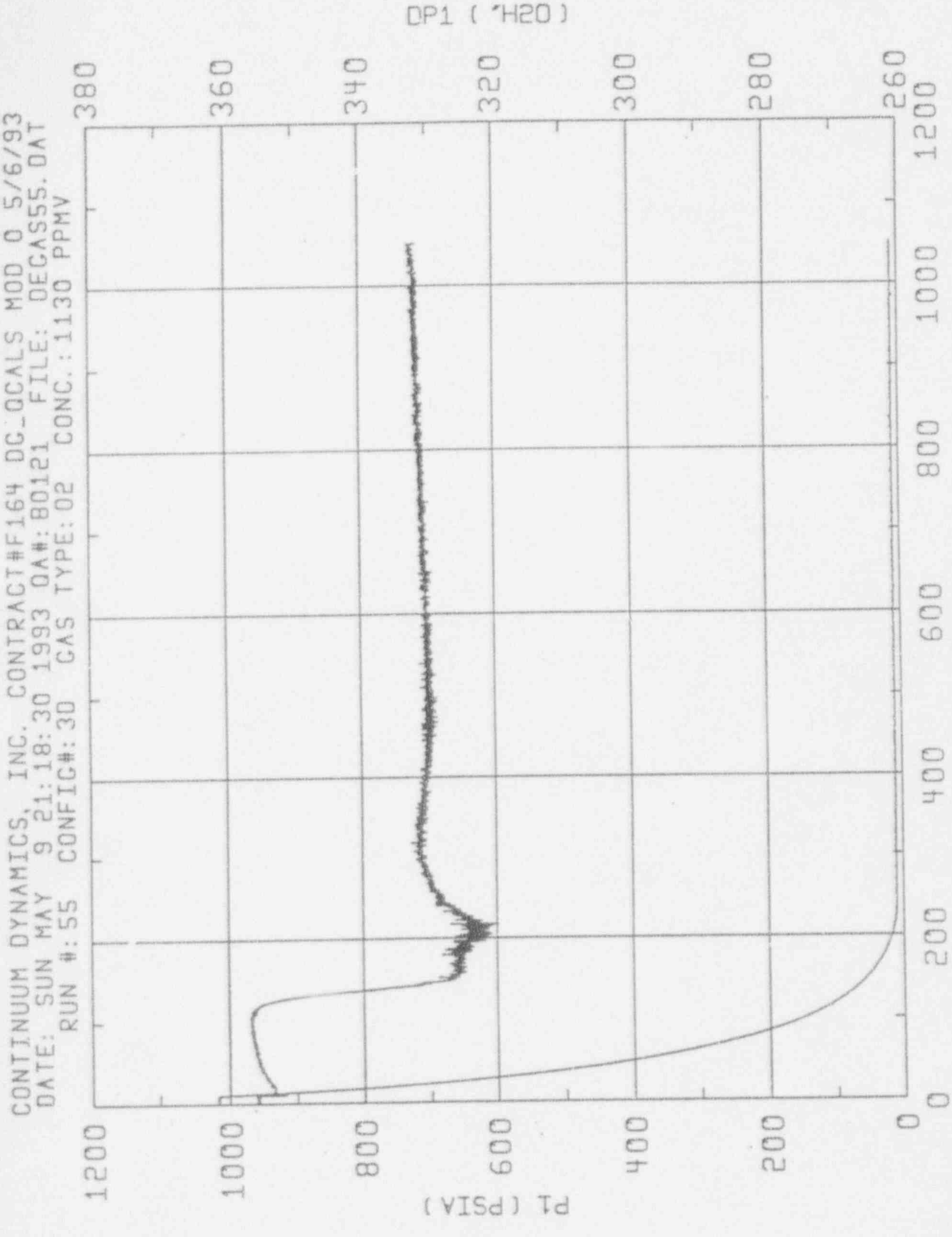

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:16:29 1993 QA#:B0112 FILE: DEGAS52.DAT
RUN #:52 CONFIG#:3A GAS TYPE:02 CONC.:1091 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ("H2O)
380
360
340
320
300
280
260
0
200
400
600
800
1000
1200
TIME (SEC)

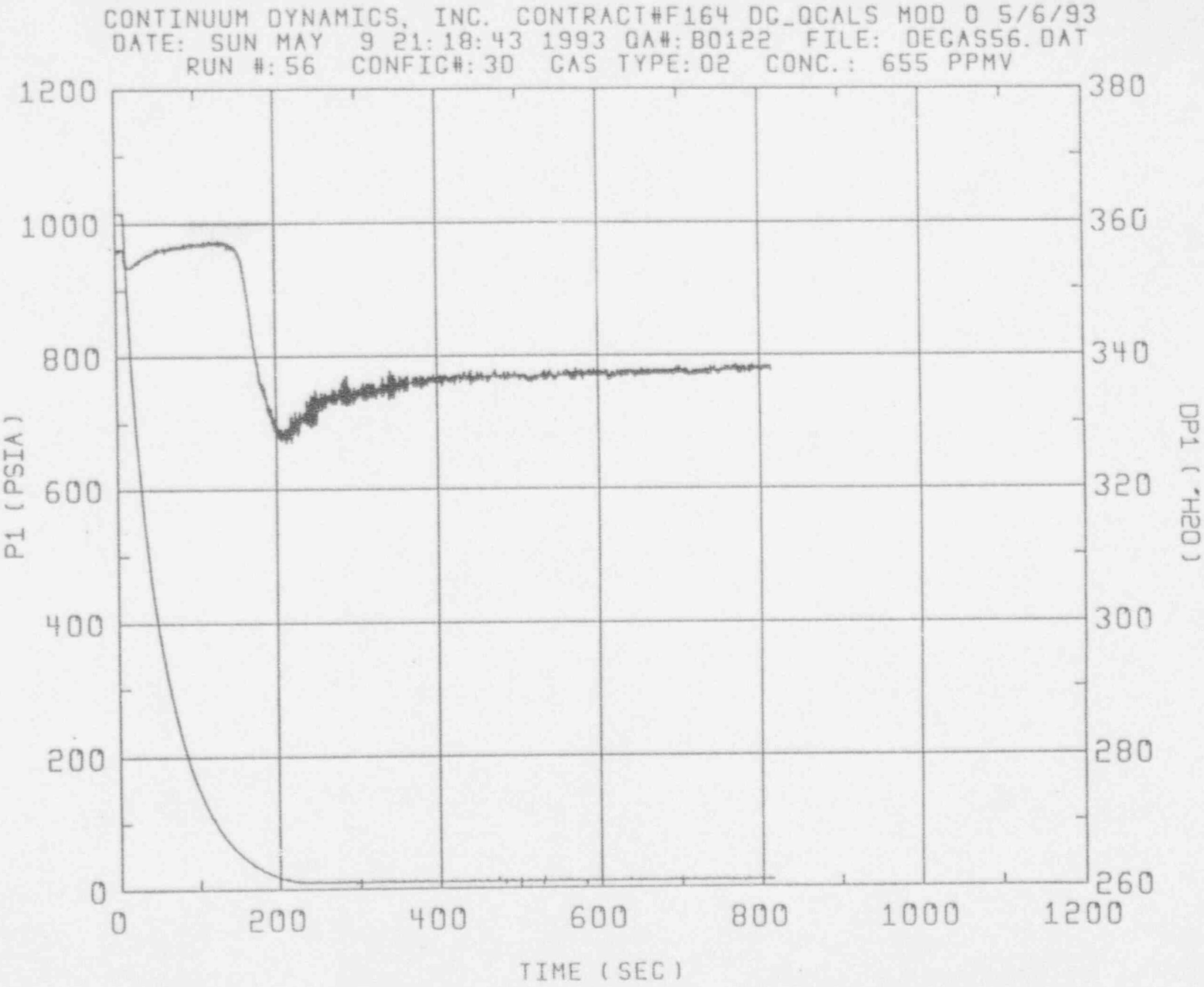
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:16:44 1993 QA#: B0113 FILE: DEGAS53.DAT
RUN #: 53 CONFIG#: 3A GAS TYPE: O2 CONC.: 635 PPMV



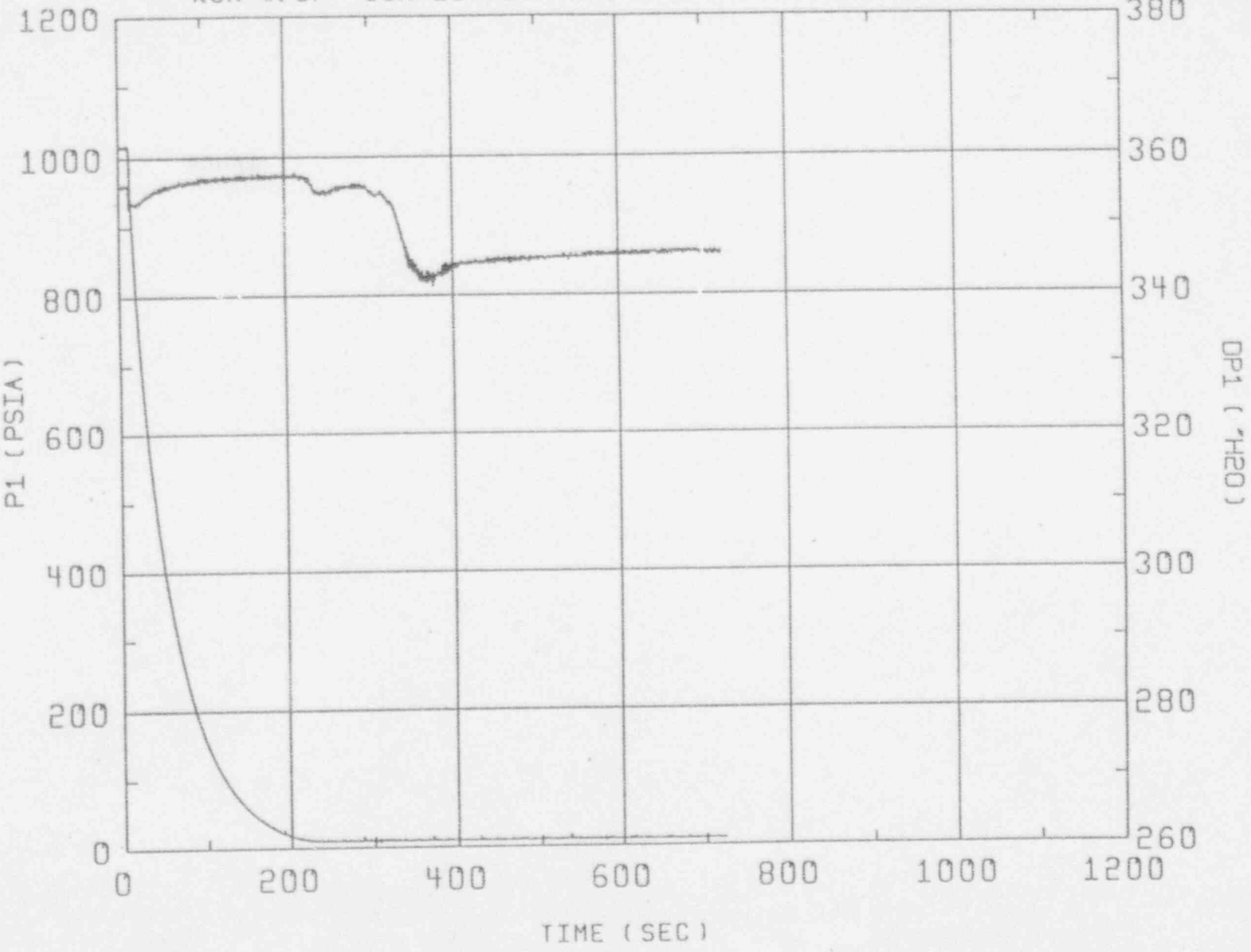
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:16:58 1993 QA#:80114 FILE: DEGAS54.DAT
RUN #:54 CONFIG#:3A GAS TYPE:02 CONC.: 287 PPMV



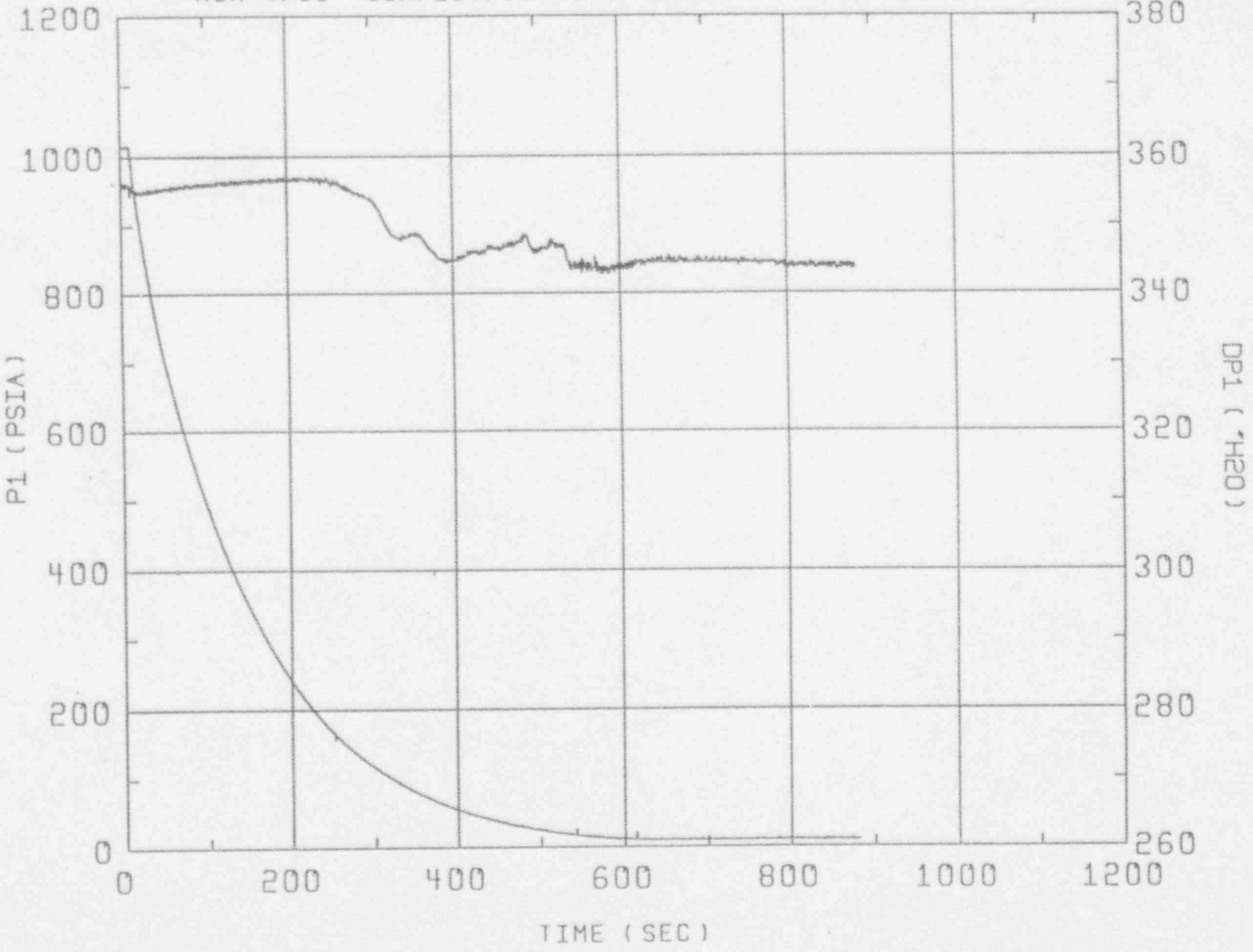

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:18:30 1993 QA#: B0121 FILE: DEGAS55.DAT
RUN #:55 CONFIG#:30 GAS TYPE: 02 CONC.:1130 PPMV
P1 (PSIA)
0
200
400
600
800
1000
1200
DP1 ('H2O)
260
280
300
320
340
360
380
TIME (SEC)
0
200
400
600
800
1000
1200

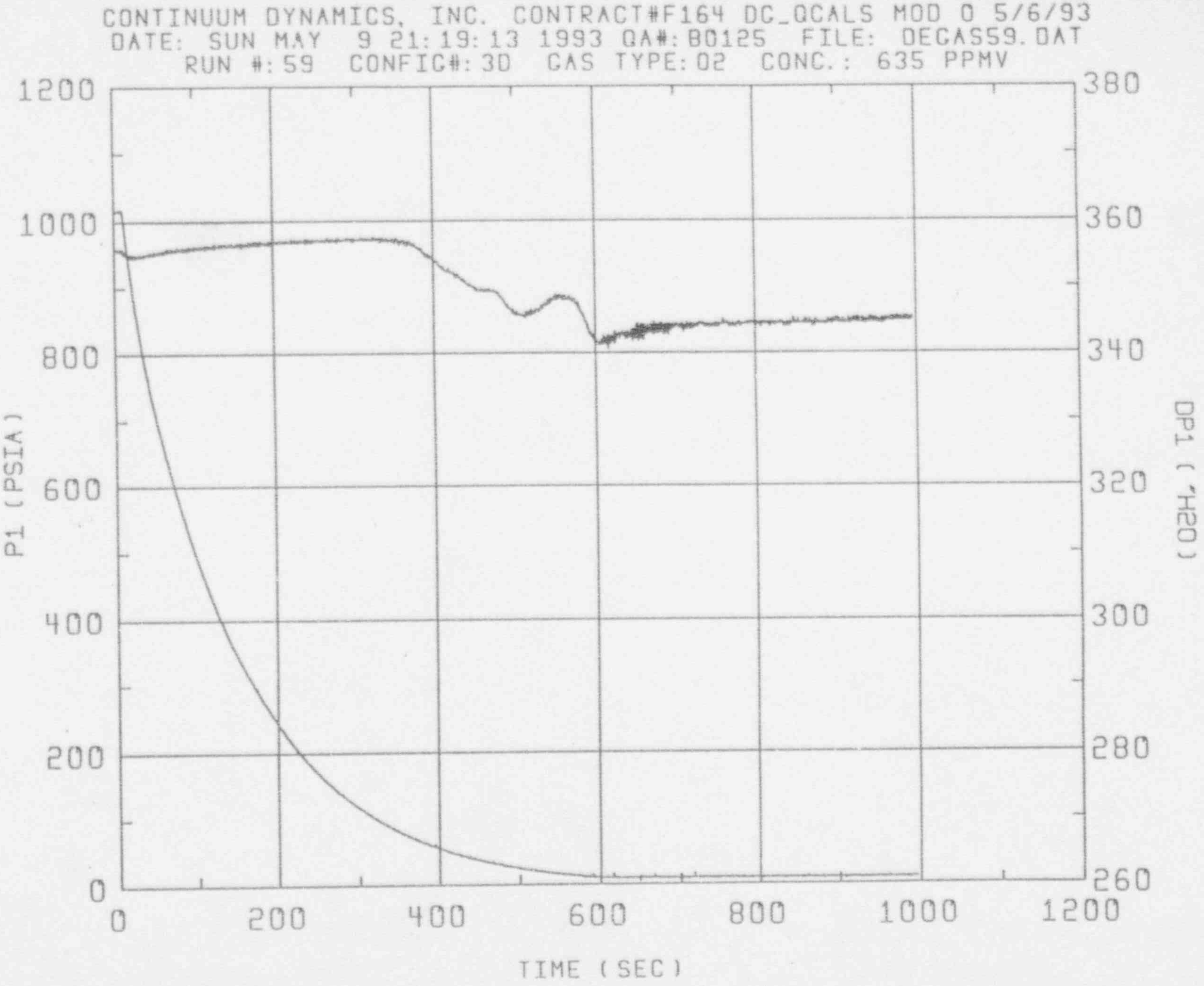

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:18:43 1993 QA#:B0122 FILE: DEGAS56.DAT
RUN #:56 CONFIG#:3D GAS TYPE:O2 CONC.: 655 PPMV
P1 (PSIA)
0
200
400
600
800
1000
1200
DP1 ("H2O)
260
280
300
320
340
360
380
TIME (SEC)
0
200
400
600
800
1000
1200

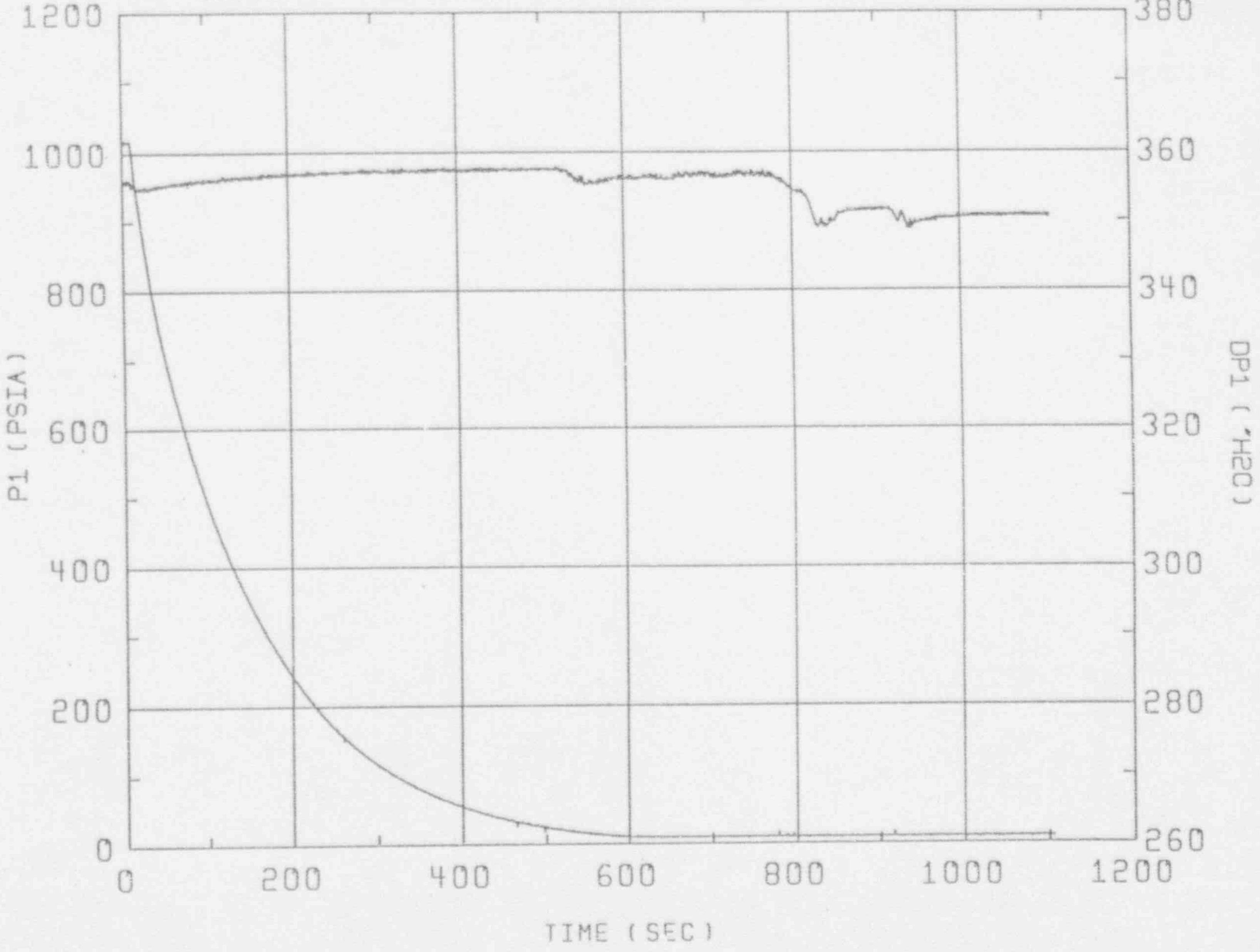
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:18:53 1993 QA#: B0123 FILE: DEGAS57.DAT
RUN #: 57 CONFIG#: 3D GAS TYPE: 02 CONC.: 307 PPMV

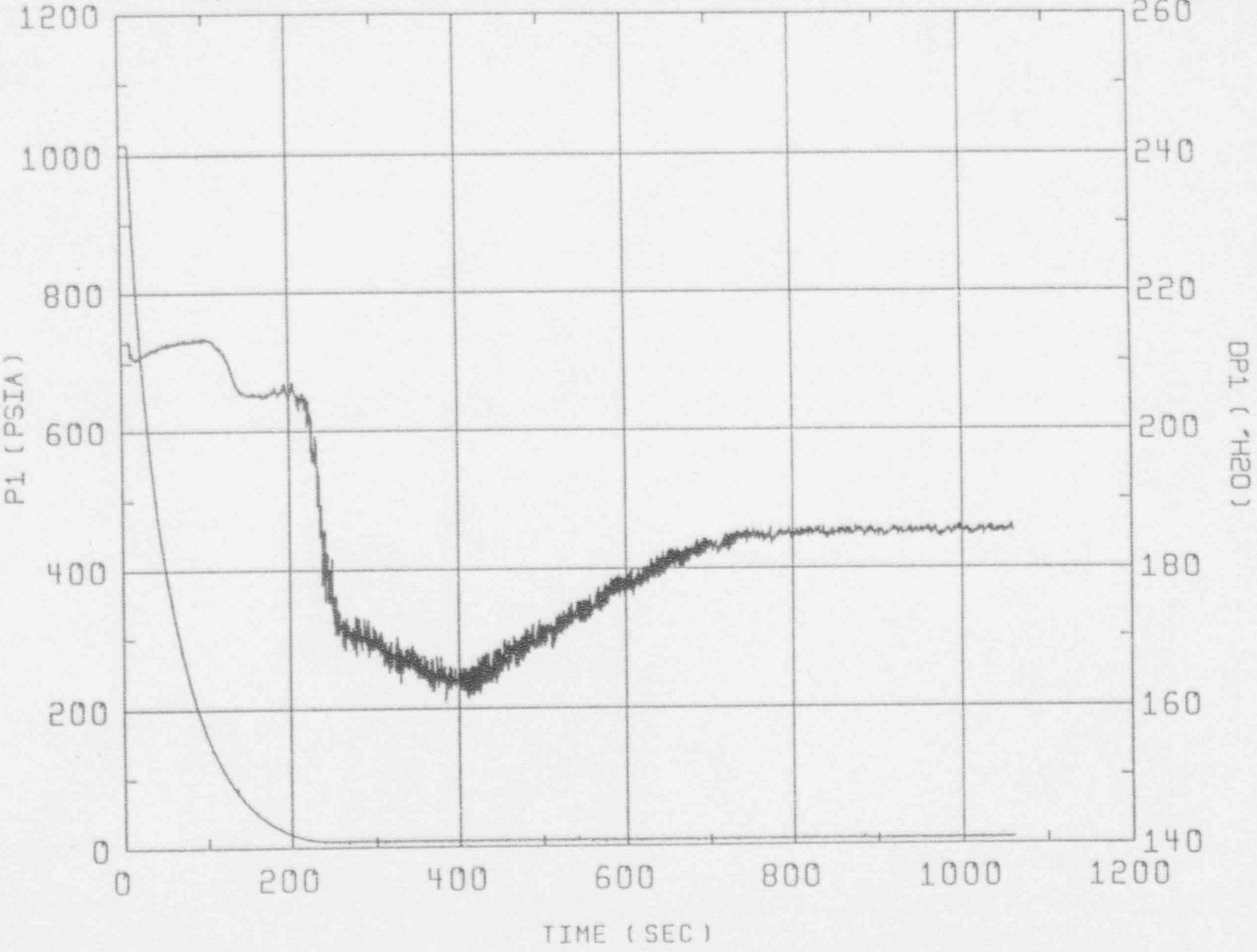


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:19:02 1993 QA#:B0124 FILE: DEGAS58.DAT
RUN #:58 CONFIG#:30 GAS TYPE:02 CONC.:1120 PPMV

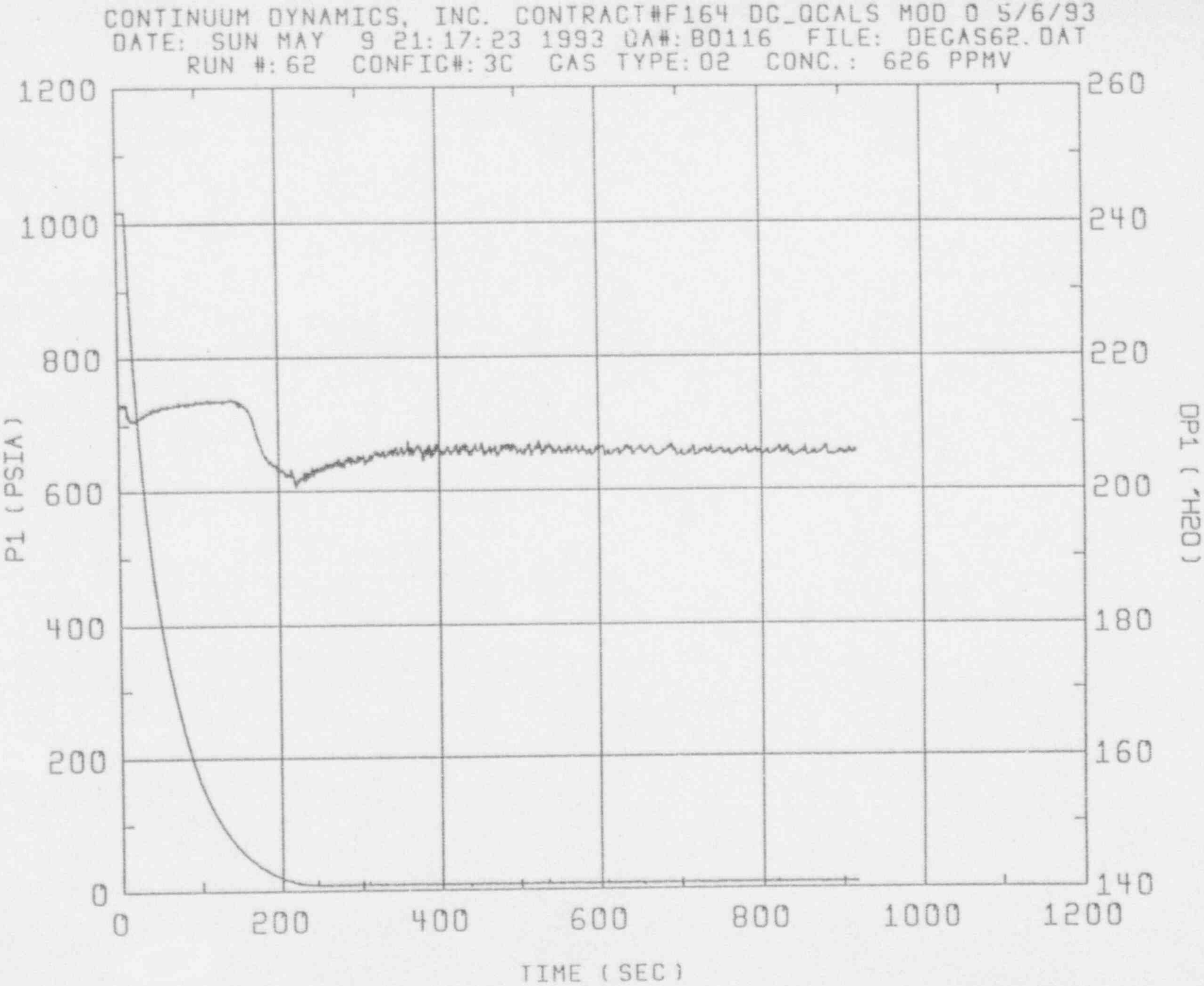



CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:19:13 1993 QA#:B0125 FILE: DEGAS59.DAT
RUN #:59 CONFIG#:3D GAS TYPE:02 CONC.: 635 PPMV
1200
1000
800
600
400
200
0
P1 (PSIA)
380
360
340
320
300
280
260
DP1 ('H2O)
0
200
400
600
800
1000
1200
TIME (SEC)


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_OCALS MOD 0 5/6/93
DATE: MON MAY 10 16:17:11 1993 QA#: 80163 FILE: DEGAS60.DAT
RUN #: 60 CONFIG#: 30 GAS TYPE: 02 CONC.: 336 PPMV

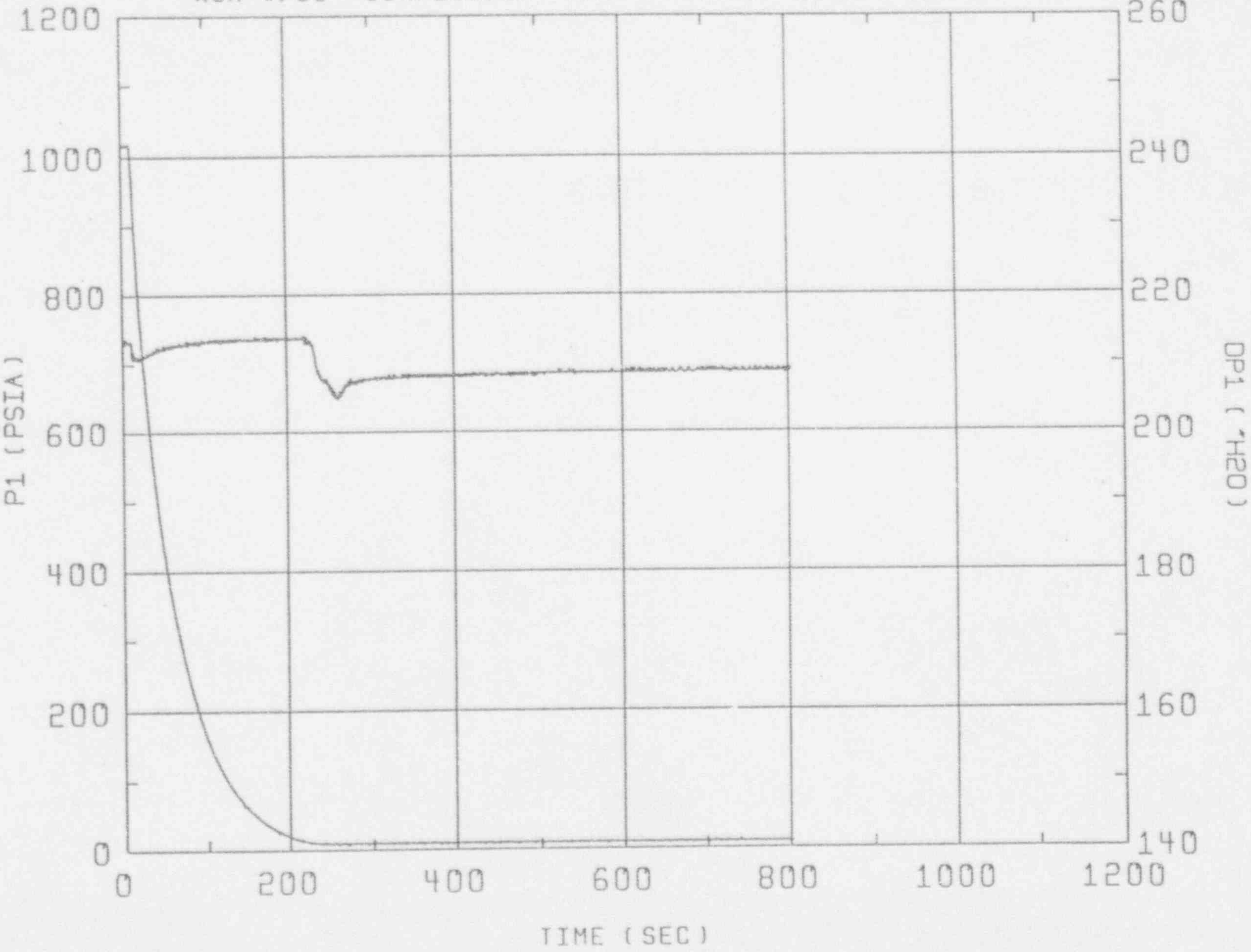


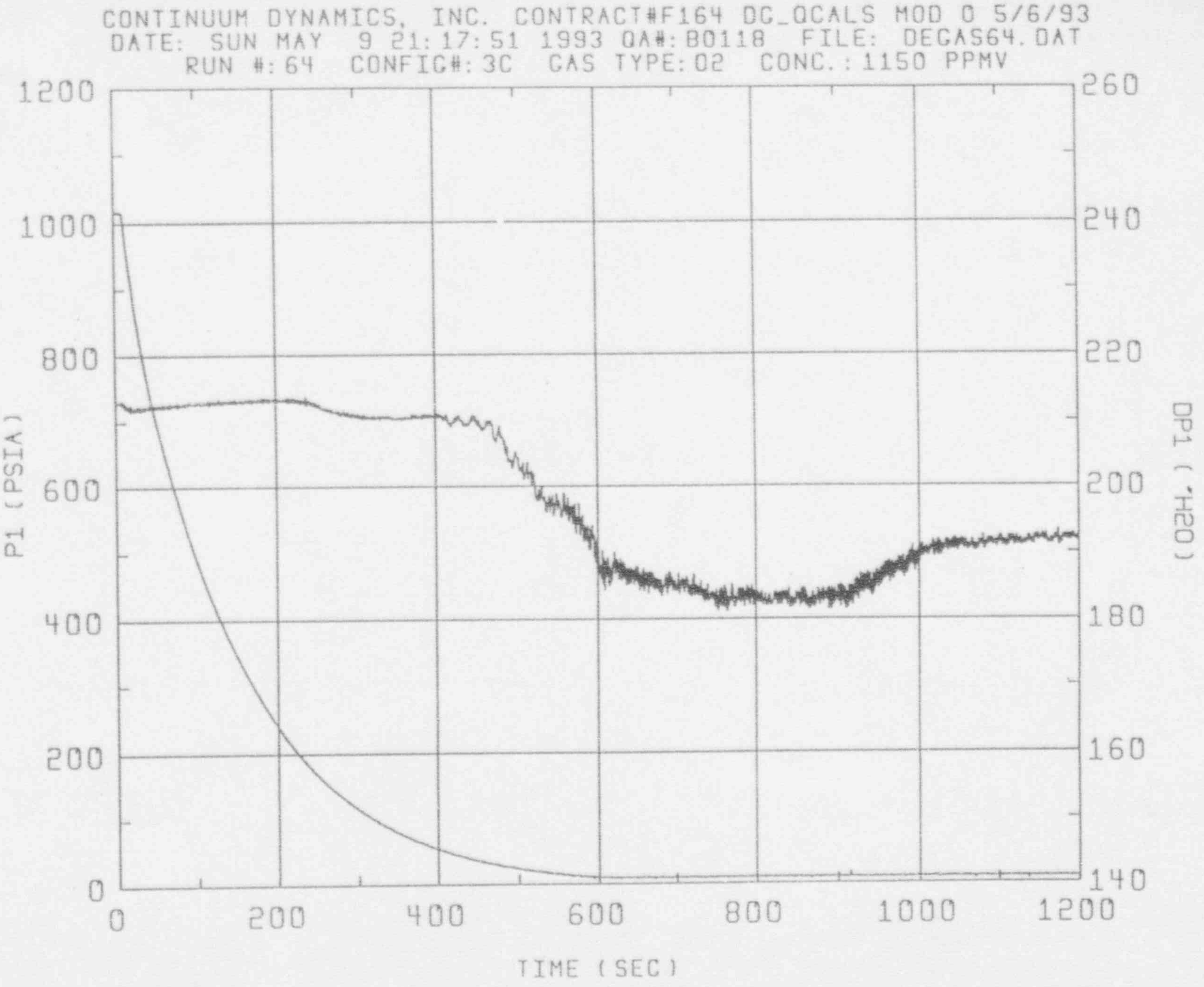
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:17:10 1993 QA#:B0115 FILE: DEGAS61.DAT
RUN #:61 CONFIG#:3C GAS TYPE:02 CONC.:1081 PPMV

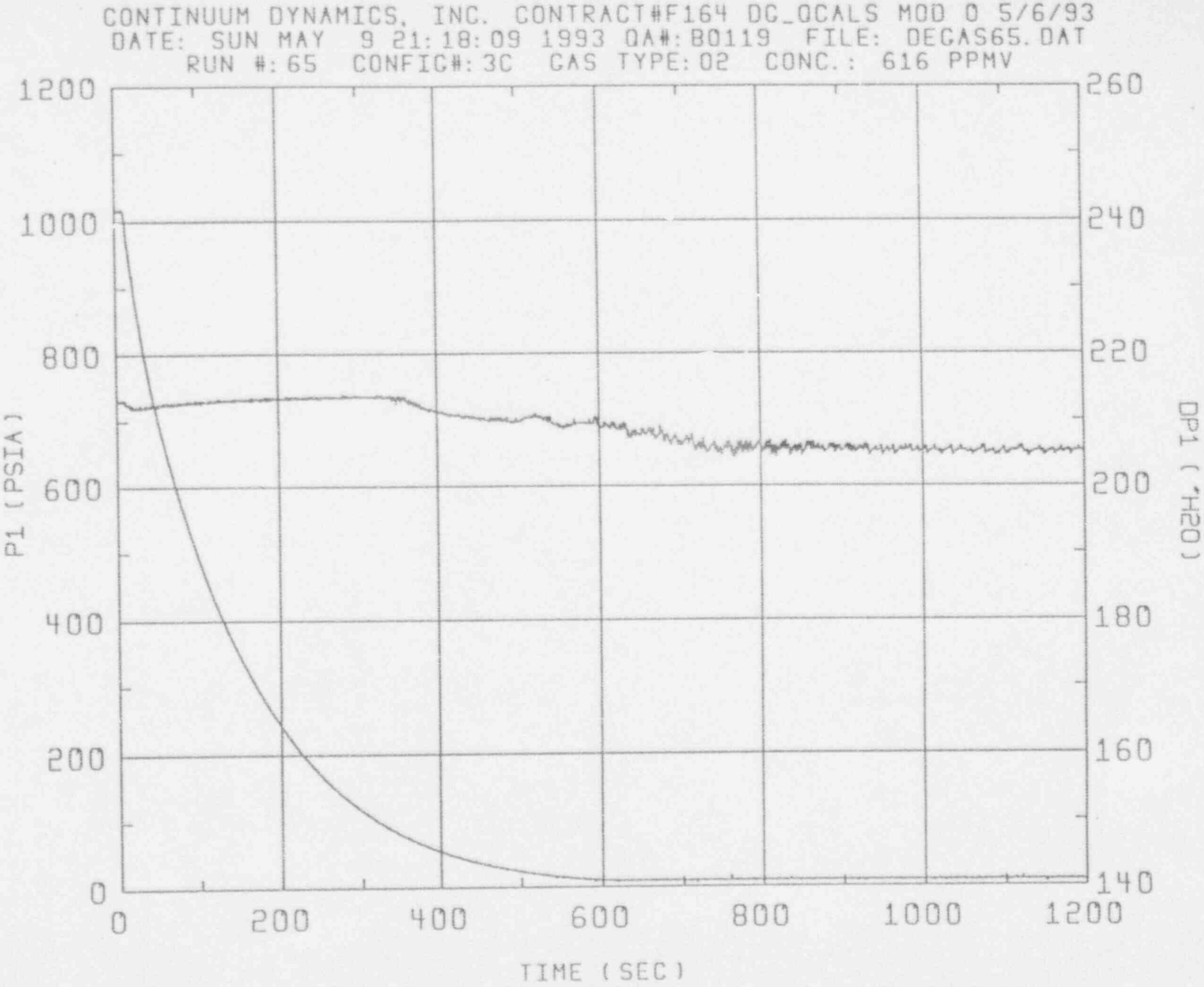


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:17:23 1993 QA#: B0116 FILE: DEGAS62.DAT
RUN #: 62 CONFIG#: 3C GAS TYPE: O2 CONC.: 626 PPMV

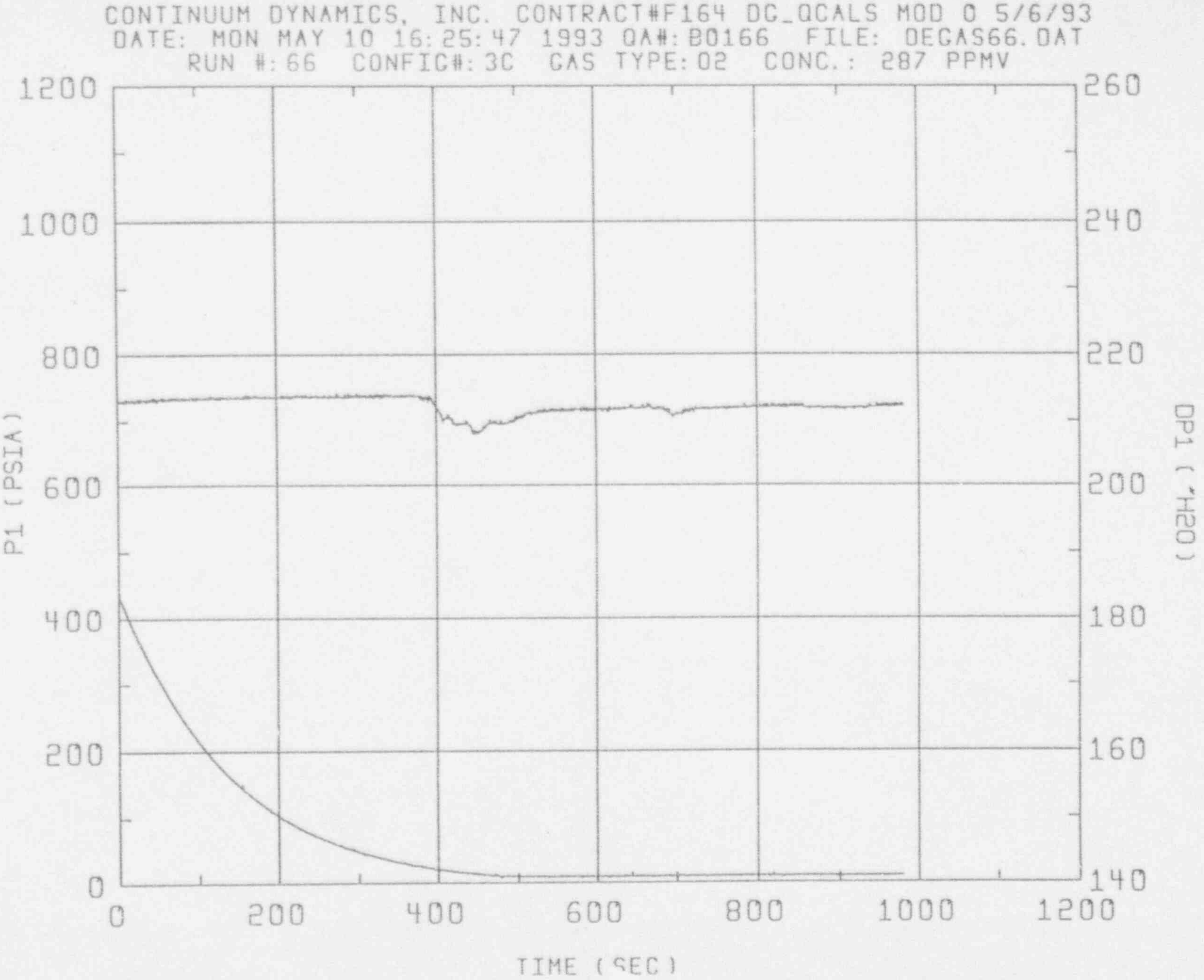
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_OCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:17:41 1993 QA#: B0117 FILE: DEGAS63.DAT
RUN #: 63 CONFIG#: 3C GAS TYPE: 02 CONC.: 297 PPMV



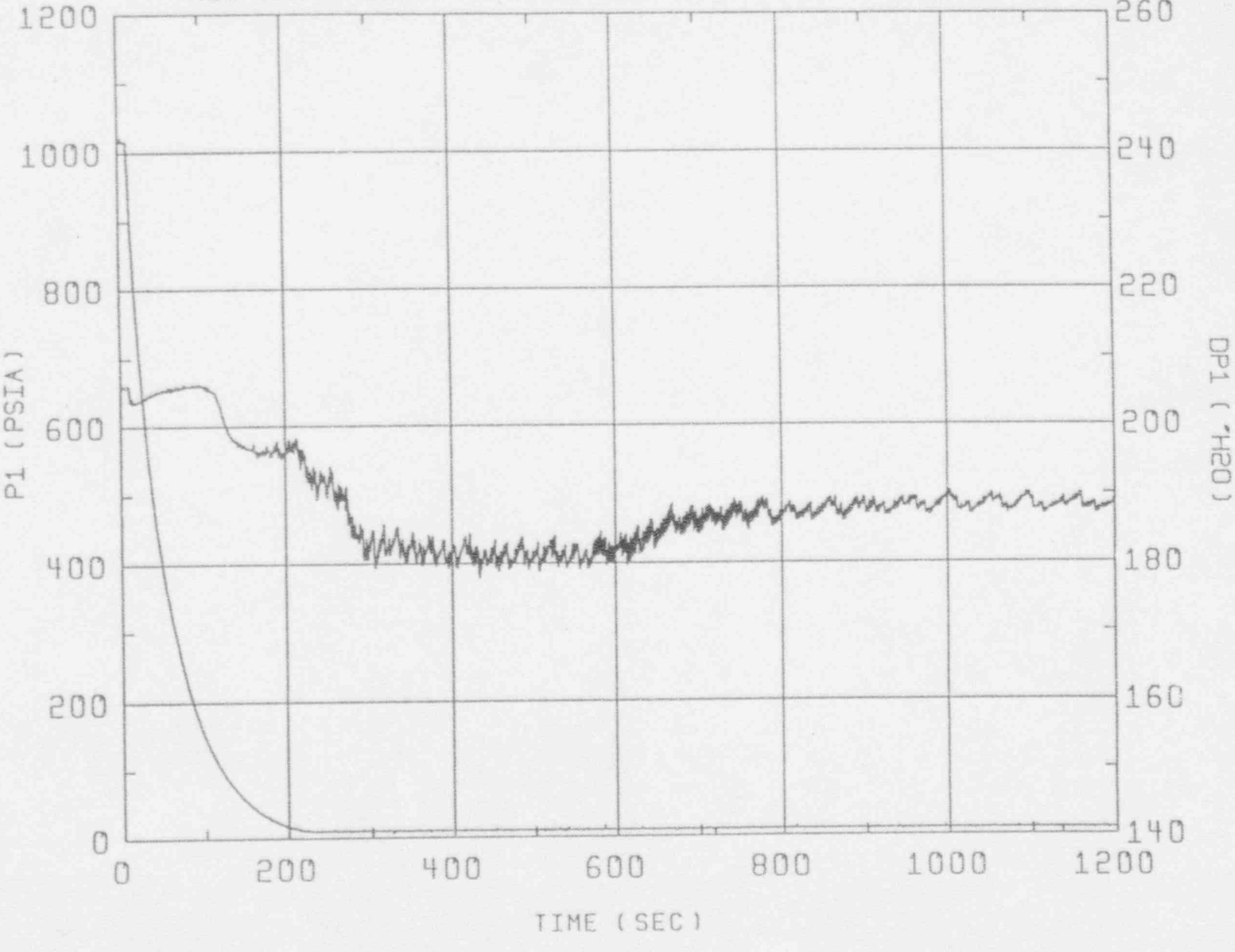

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:17:51 1993 QA#: B0118 FILE: DEGAS64.DAT
RUN #: 64 CONFIG#: 3C GAS TYPE: O2 CONC.: 1150 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ('H2O)
260
240
220
200
180
160
140
0
200
400
600
800
1000
1200
TIME (SEC)



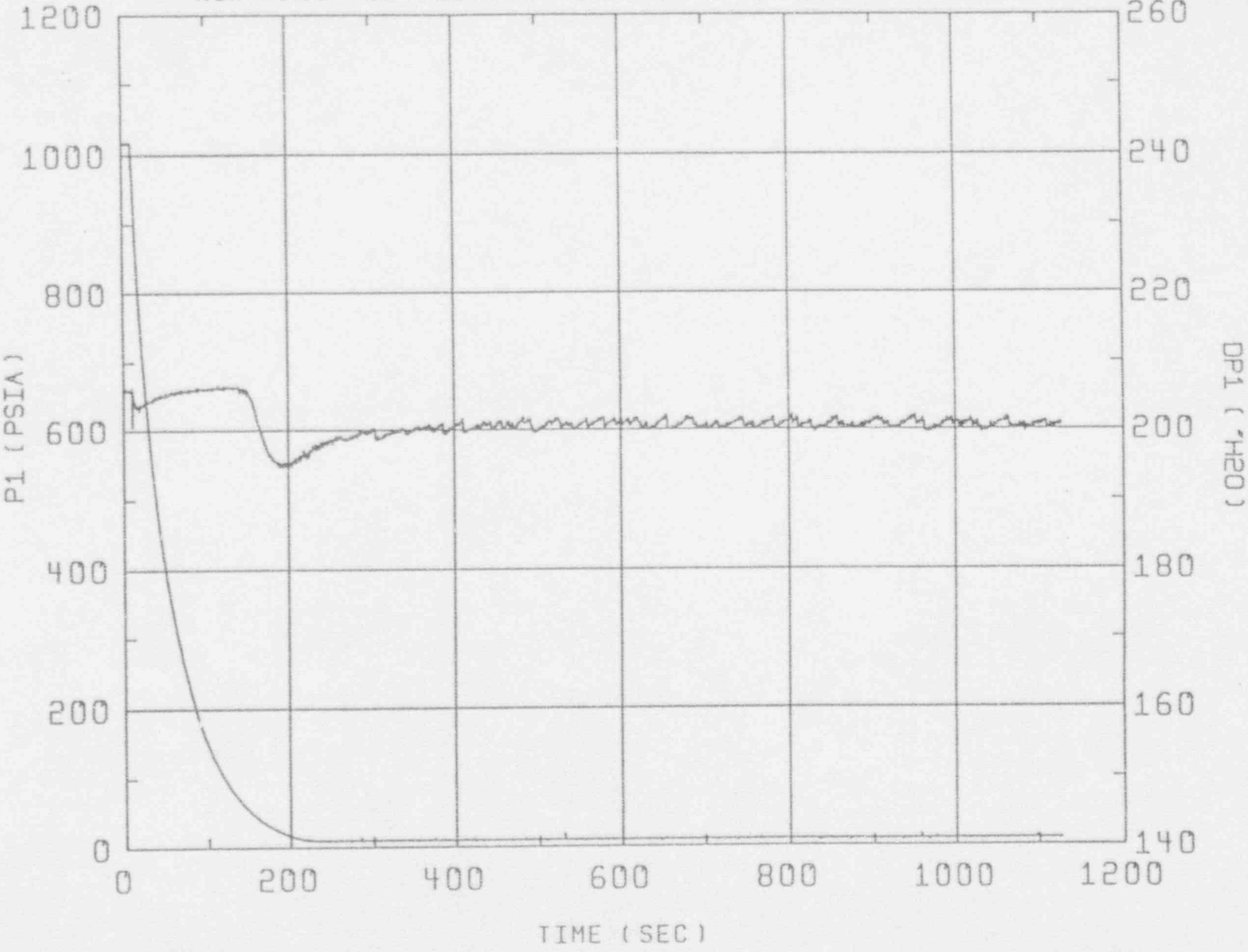
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:18:09 1993 QA#:B0119 FILE: DEGAS65.DAT
RUN #:65 CONFIG#:3C GAS TYPE:02 CONC.: 616 PPMV

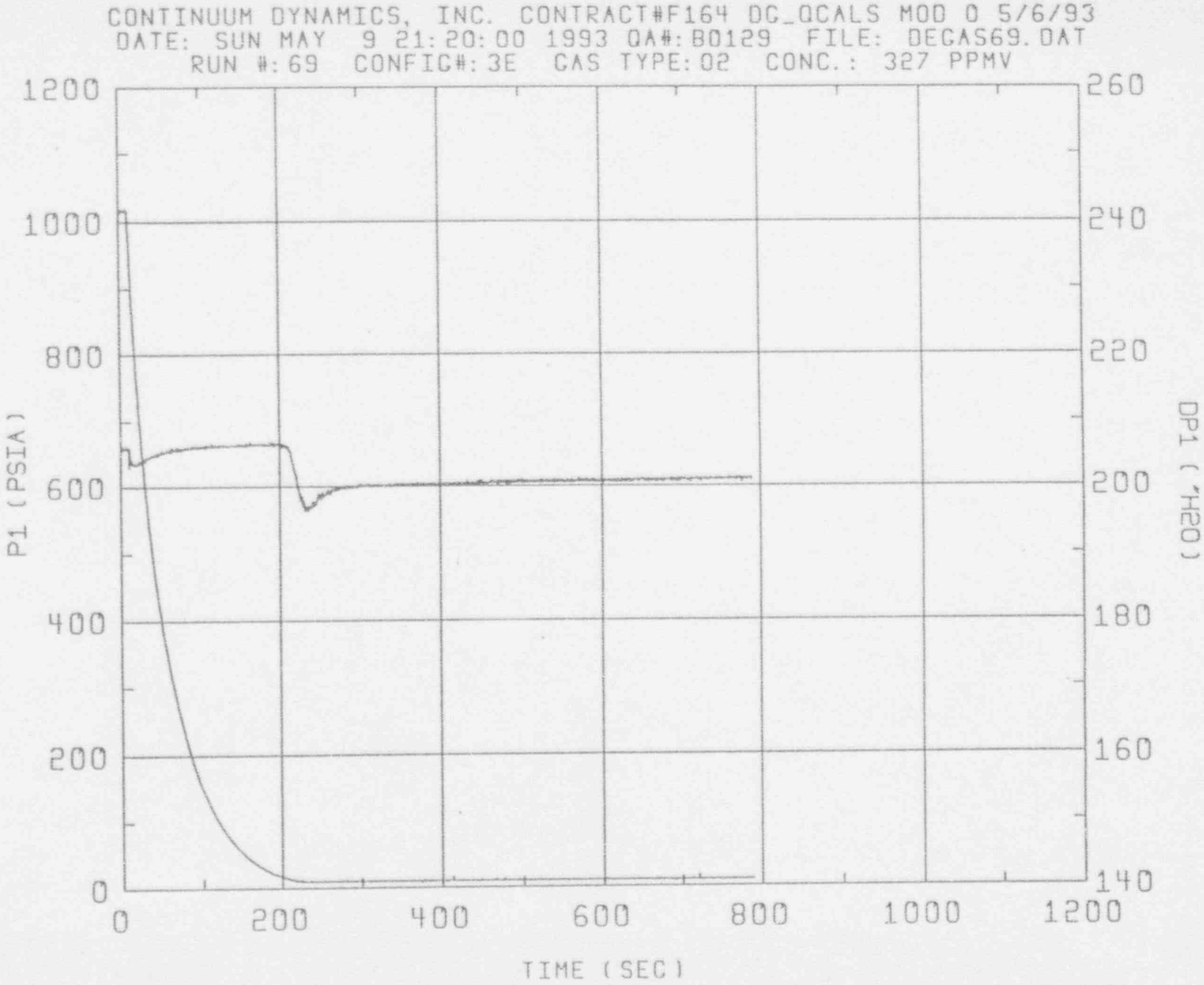

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:25:47 1993 QA#:B0166 FILE: DEGAS66.DAT
RUN #:66 CONFIG#:3C GAS TYPE:02 CONC.: 287 PPMV
1200
1000
800
600
400
200
0
P1 (PSIA)
260
240
220
200
180
160
140
DP1 ("H2O)
0
200
400
600
800
1000
1200
TIME (SEC)

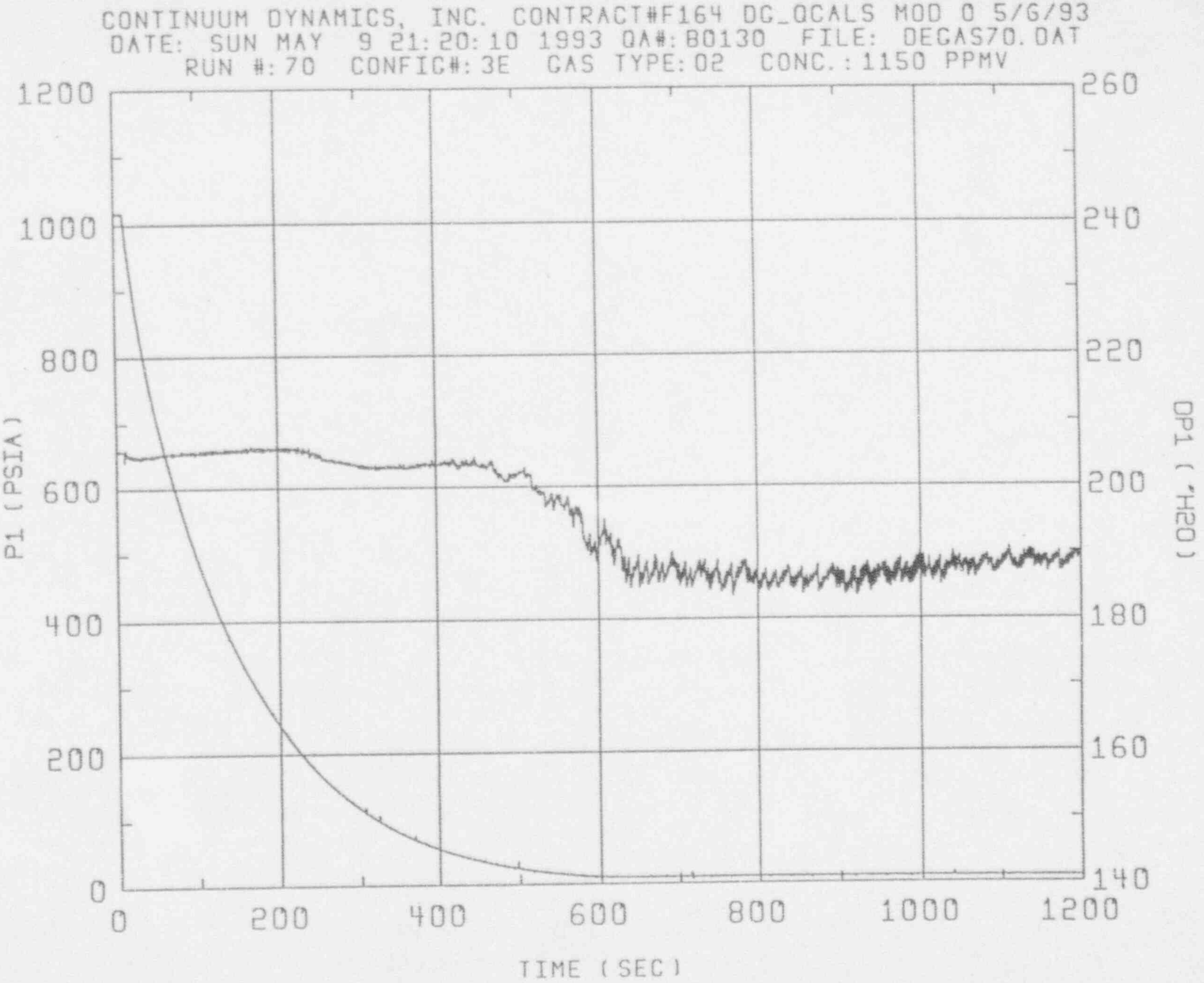
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:19:32 1993 QA#:B0127 FILE: DEGAS67.DAT
RUN #:67 CONFIG#:3E GAS TYPE:02 CONC.:1150 PPMV



CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:19:46 1993 QA#: B0128 FILE: DEGAS68.DAT
RUN #: 68 CONFIG#: 3E GAS TYPE: 02 CONC.: 616 PPMV

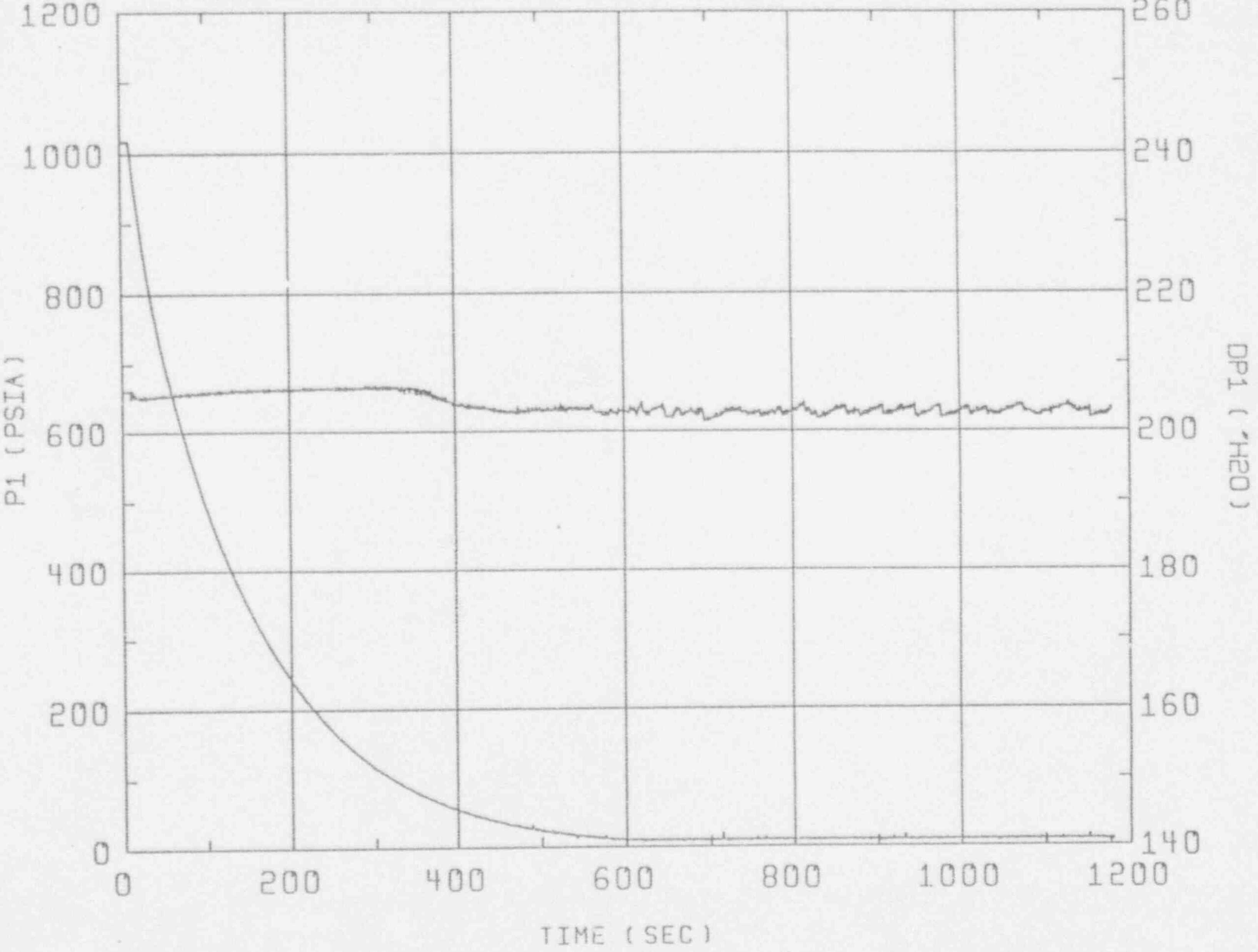



CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:20:00 1993 QA#:B0129 FILE: DEGAS69.DAT
RUN #:69 CONFIG#:3E GAS TYPE:02 CONC.: 327 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ('H2O)
260
240
220
200
180
160
140
0
200
400
600
800
1000
1200
TIME (SEC)

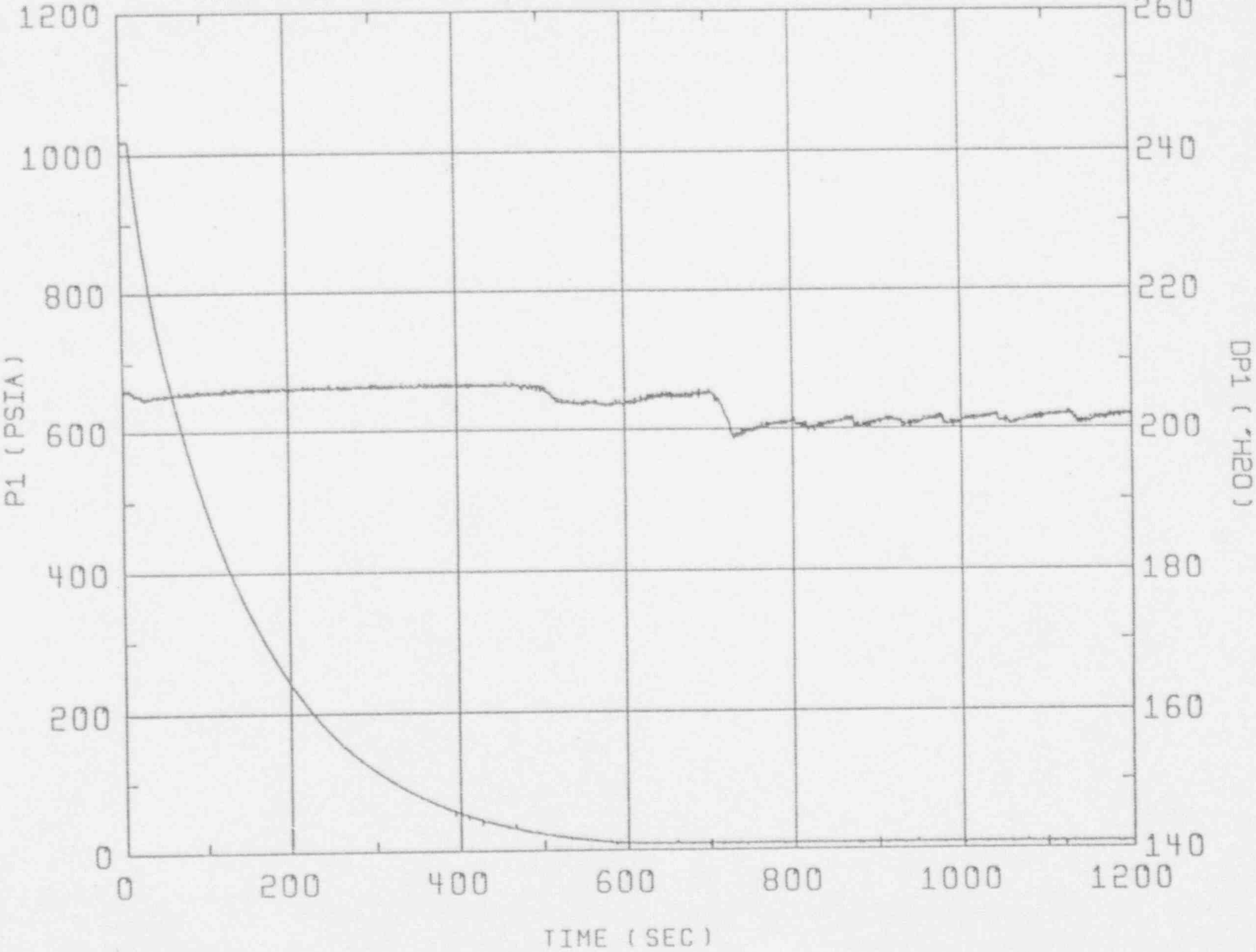


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:20:10 1993 QA#: B0130 FILE: DEGAS70.DAT
RUN #: 70 CONFIG#: 3E GAS TYPE: 02 CONC.: 1150 PPMV

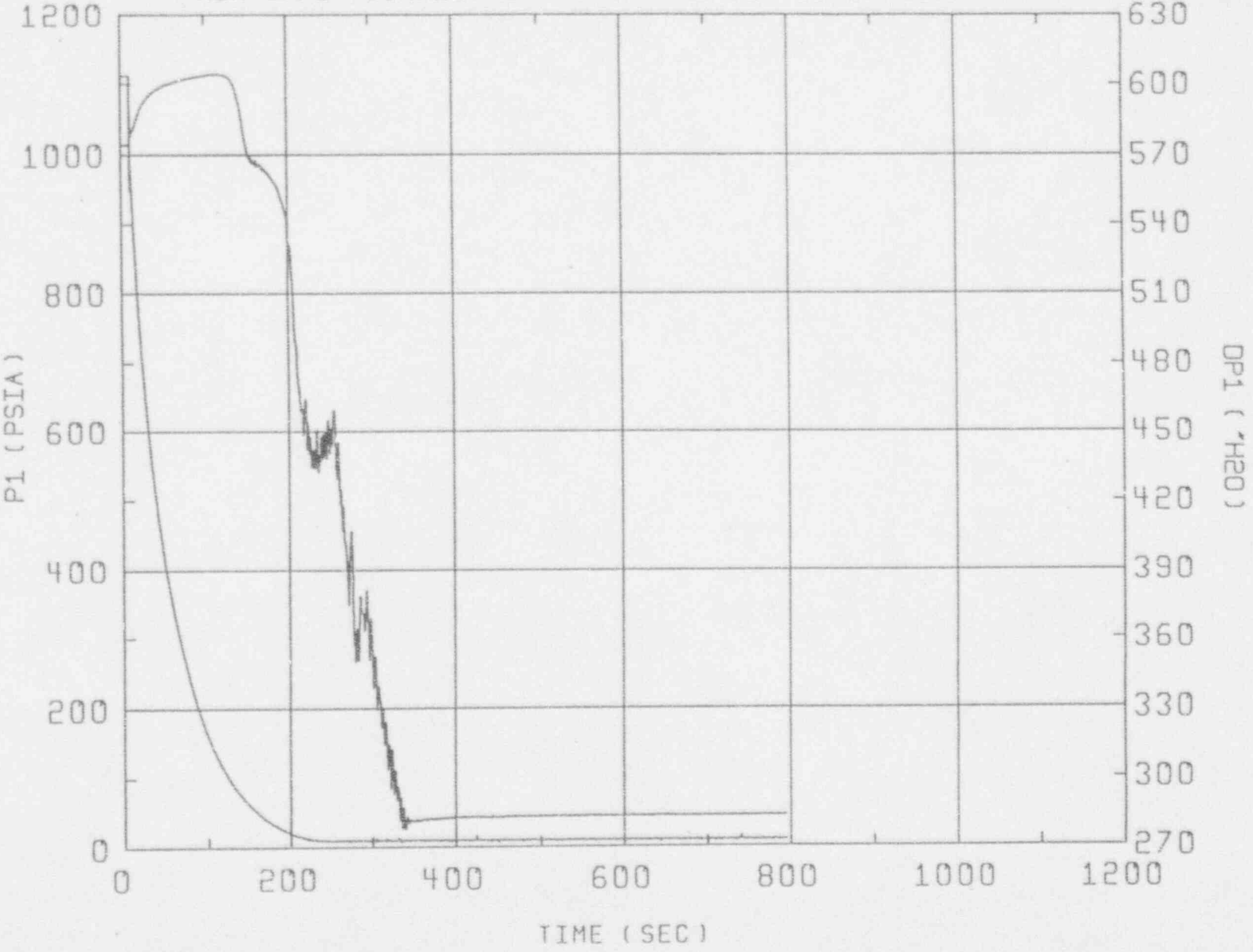
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:20:25 1993 QA#: B0131 FILE: DEGAS71.DAT
RUN #: 71 CONFIG#: 3E GAS TYPE: O2 CONC.: 596 PPMV

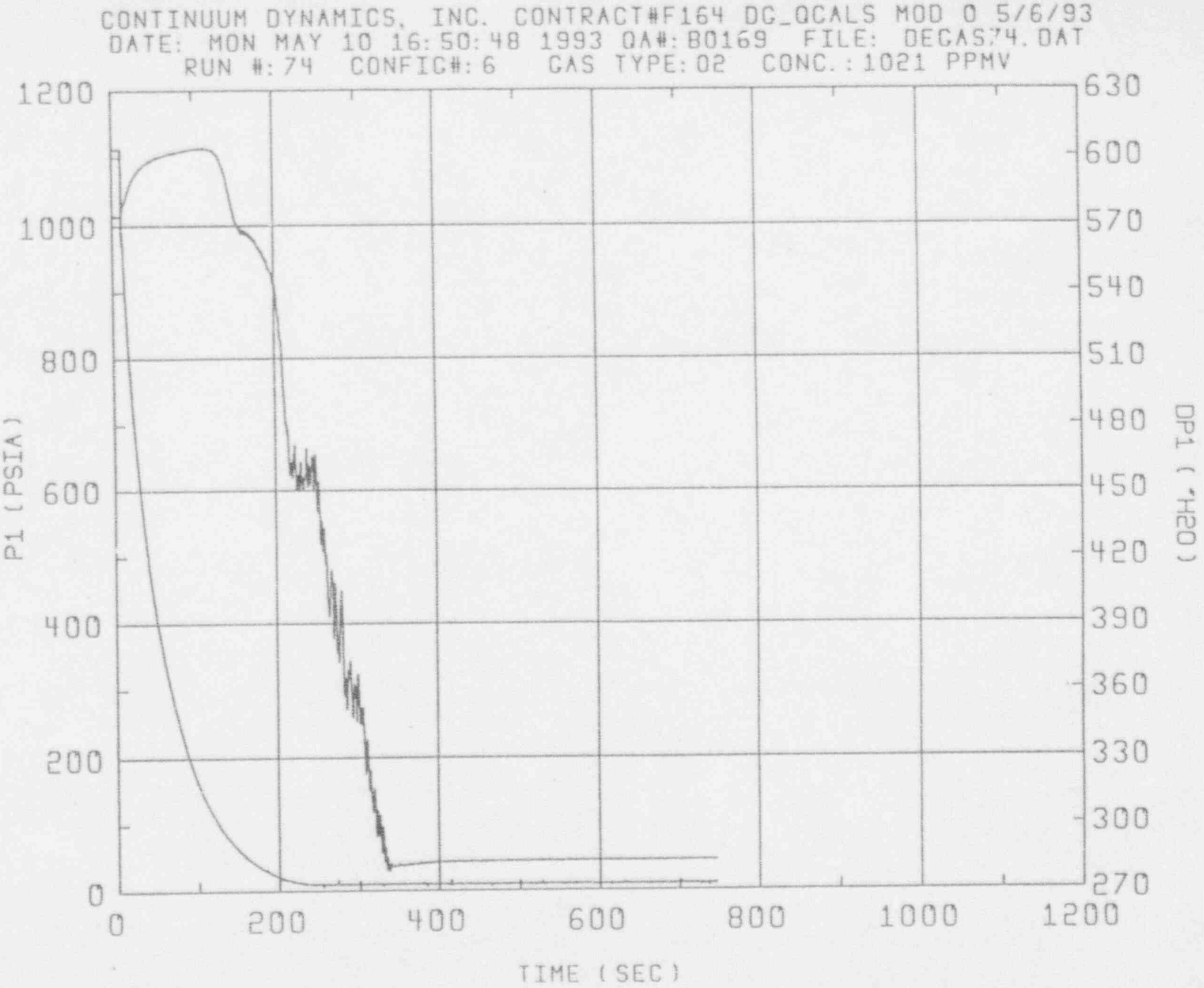


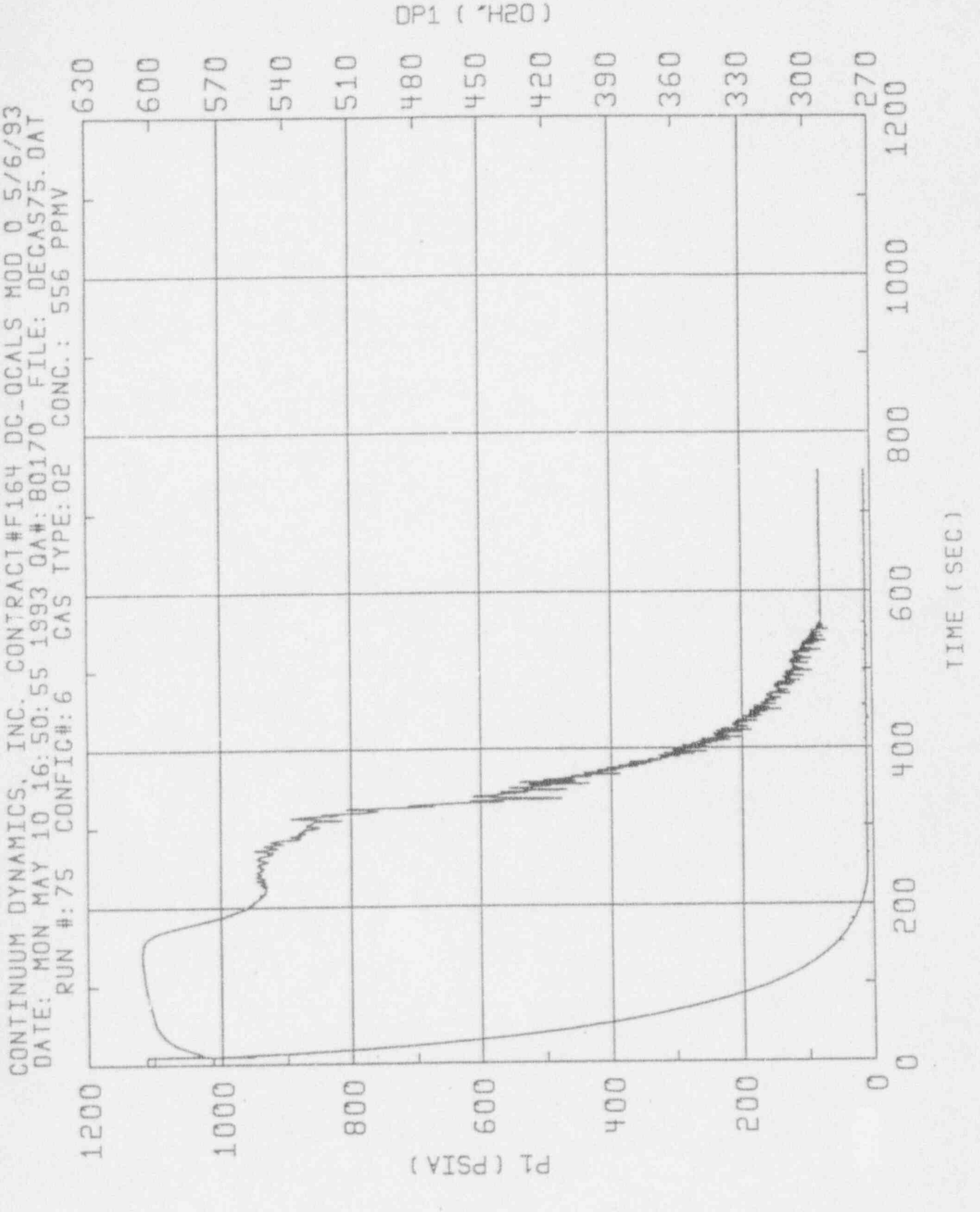
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:20:40 1993 QA#:80132 FILE: DEGAS72.DAT
RUN #:72 CONFIG#:3E GAS TYPE:02 CONC.: 287 PPMV



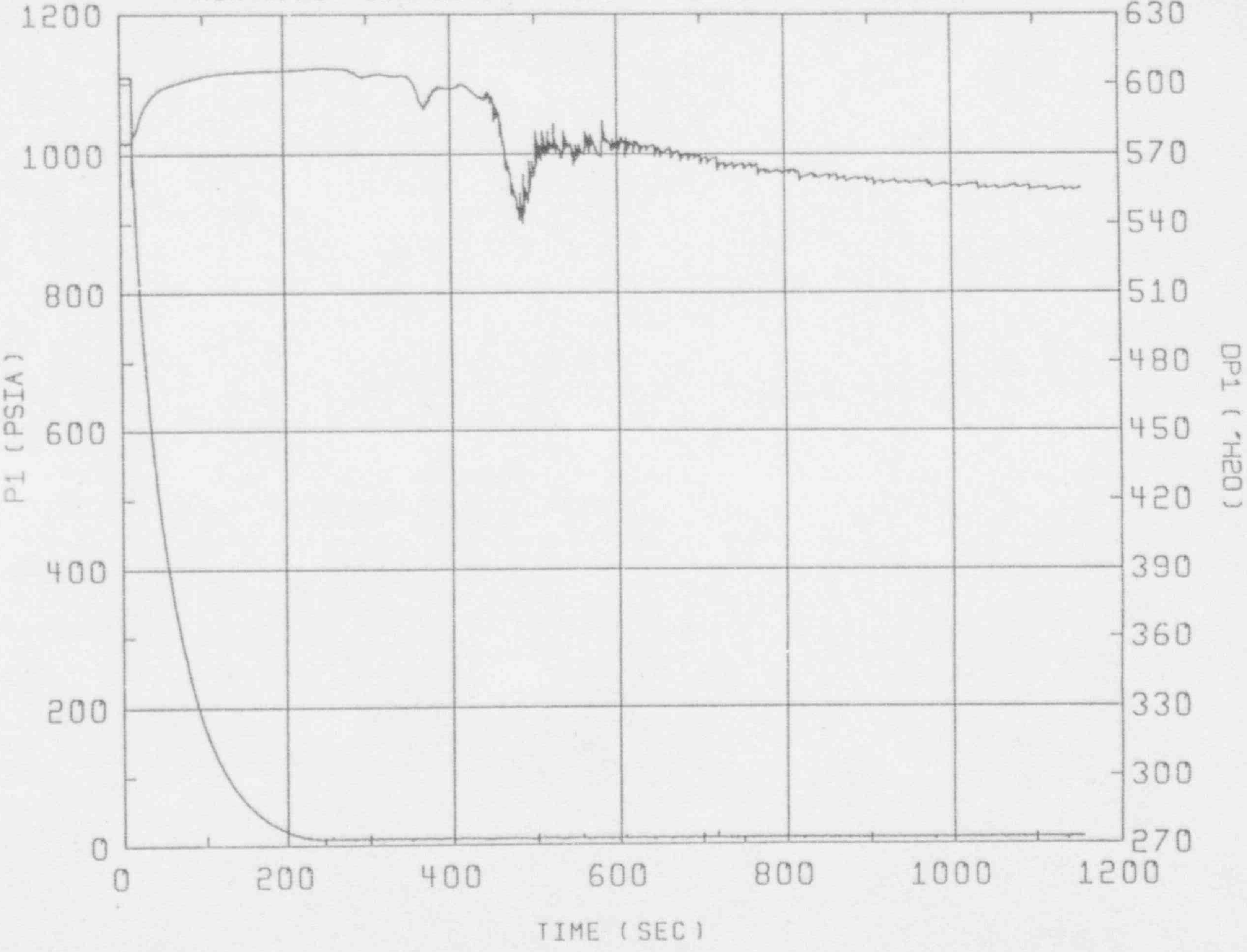
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:50:28 1993 QA#: B0168 FILE: DEGAS73.DAT
RUN #: 73 CONFIG#: 6 GAS TYPE: 02 CONC.: 1130 PPMV

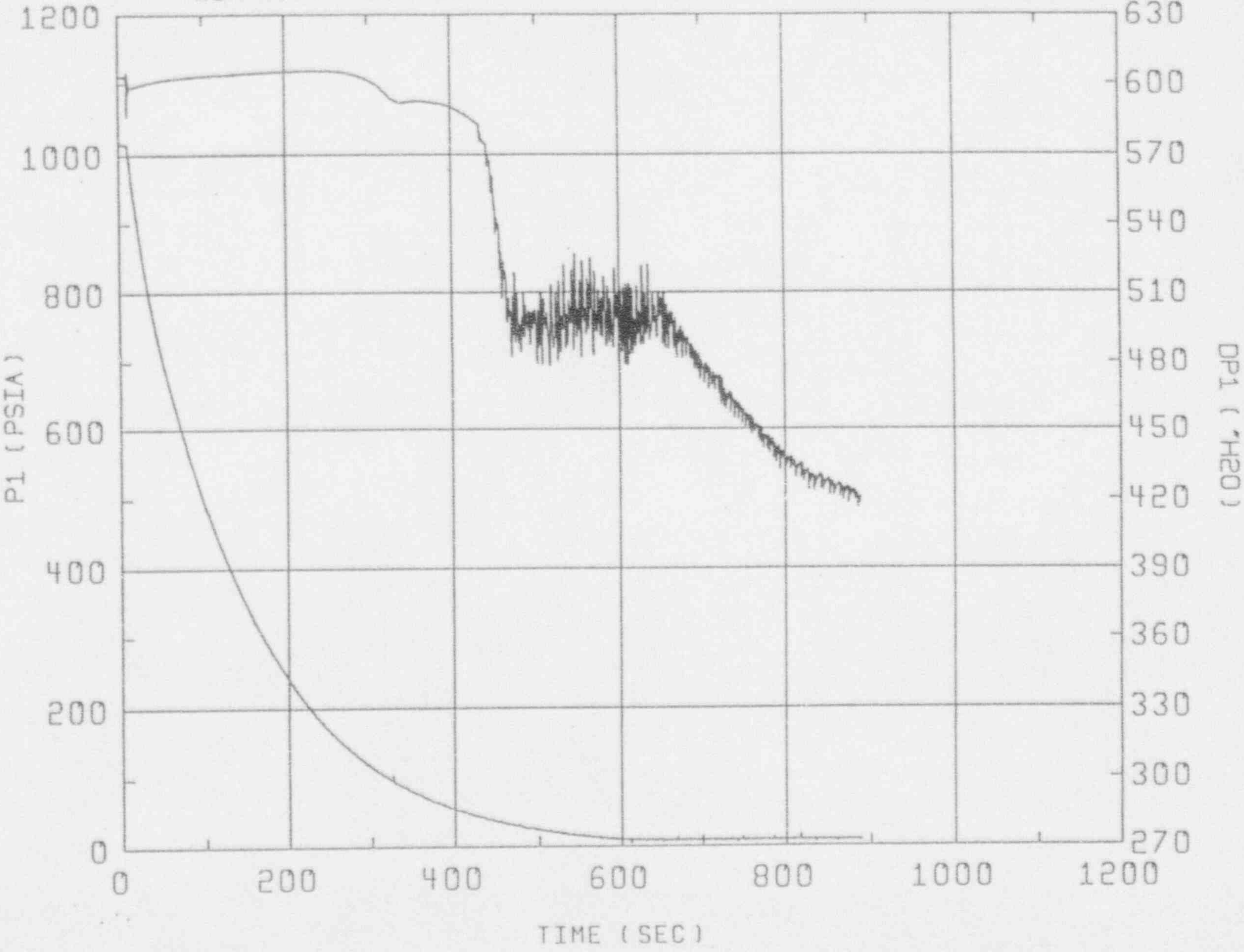



CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:50:48 1993 QA#:B0169 FILE: DEGAS74.DAT
RUN #:74 CONFIG#:6 GAS TYPE:02 CONC.:1021 PPMV
P1 (PSIA)
0
200
400
600
800
1000
1200
DP1 ("H2O)
270
300
330
360
390
420
450
480
510
540
570
600
630
TIME (SEC)
0
200
400
600
800
1000
1200

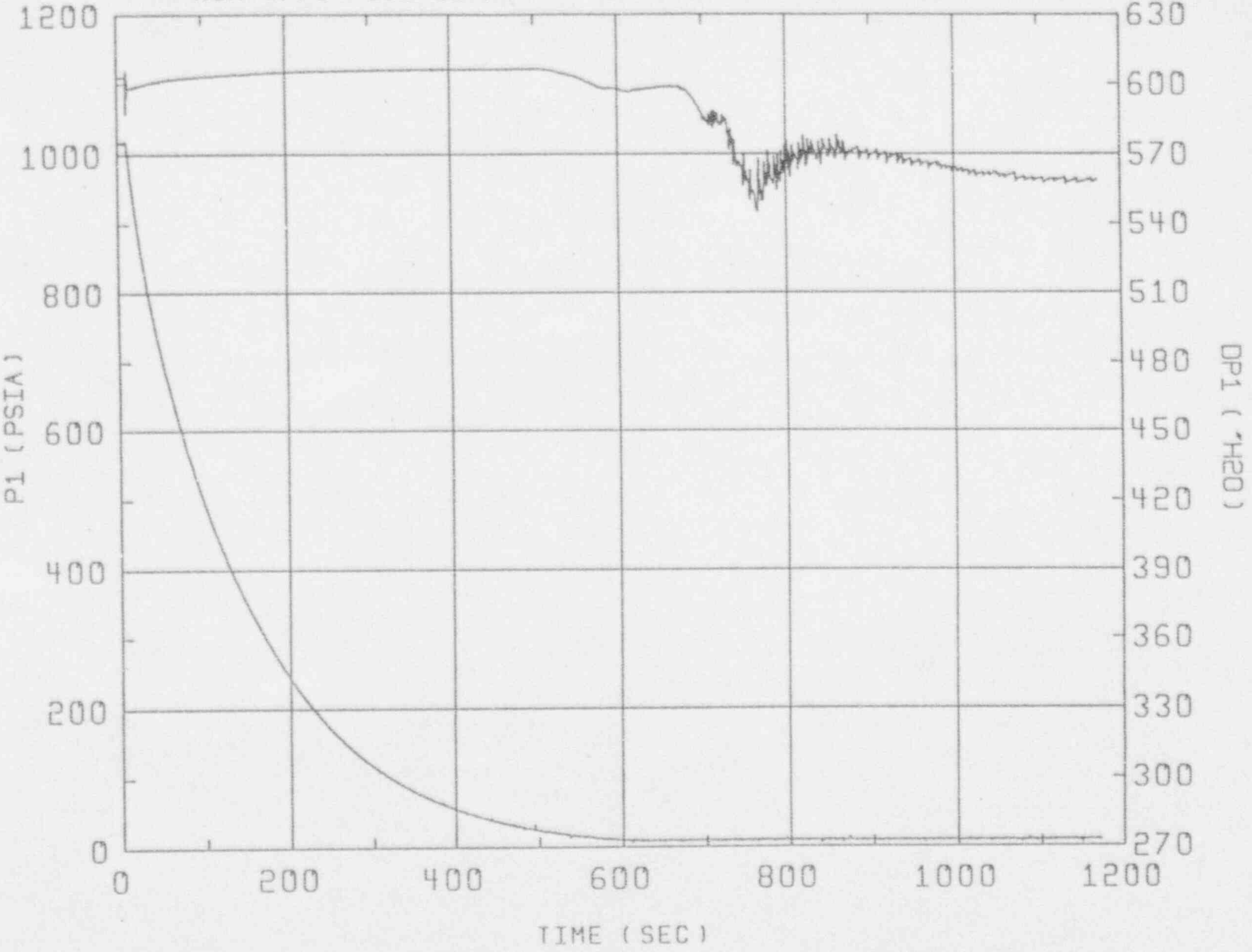

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:50:55 1993 QA#: 80170 FILE: DEGAS75.DAT
RUN #: 75 CONFIG#: 6 GAS TYPE: 02 CONC.: 556 PPMV
P1 (PSIA)
0
200
400
600
800
1000
1200
DP1 ("H2O)
270
300
330
360
390
420
450
480
510
540
570
600
630
TIME (SEC)
0
200
400
600
800
1000
1200

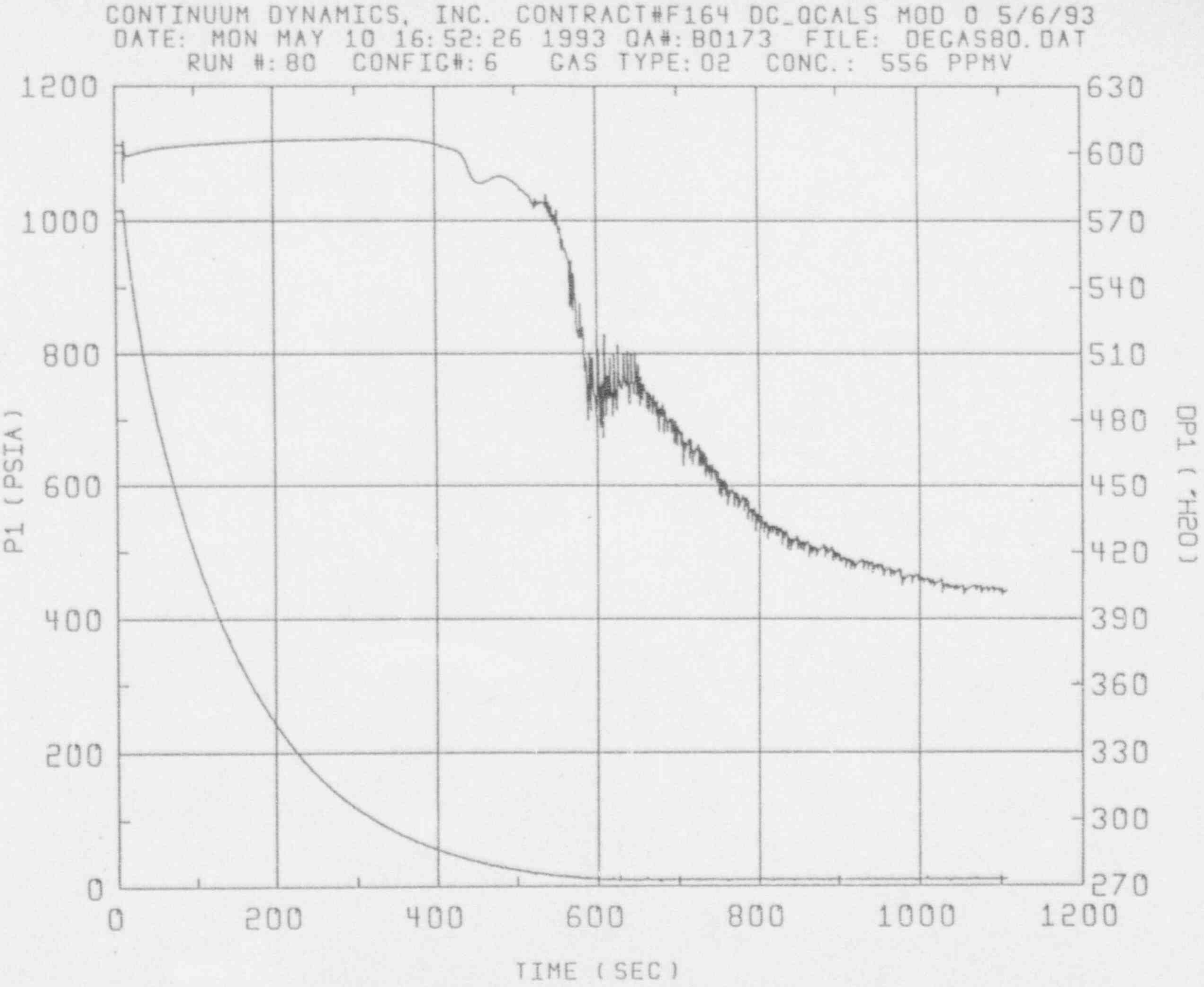
CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:51:02 1993 QA#:B0171 FILE: DEGAS76.DAT
RUN #:76 CONFIG#:6 GAS TYPE:02 CONC.: 268 PPMV

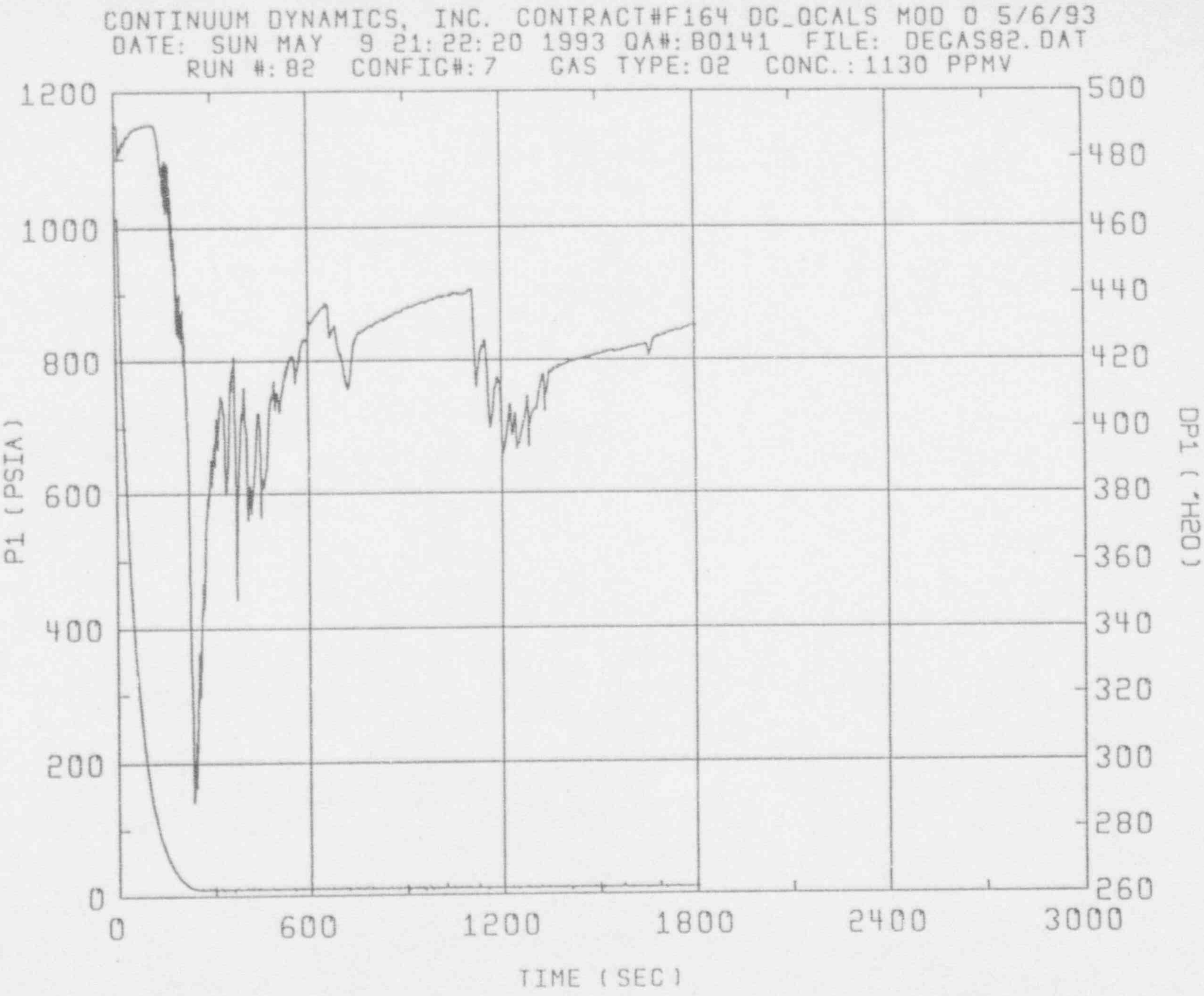


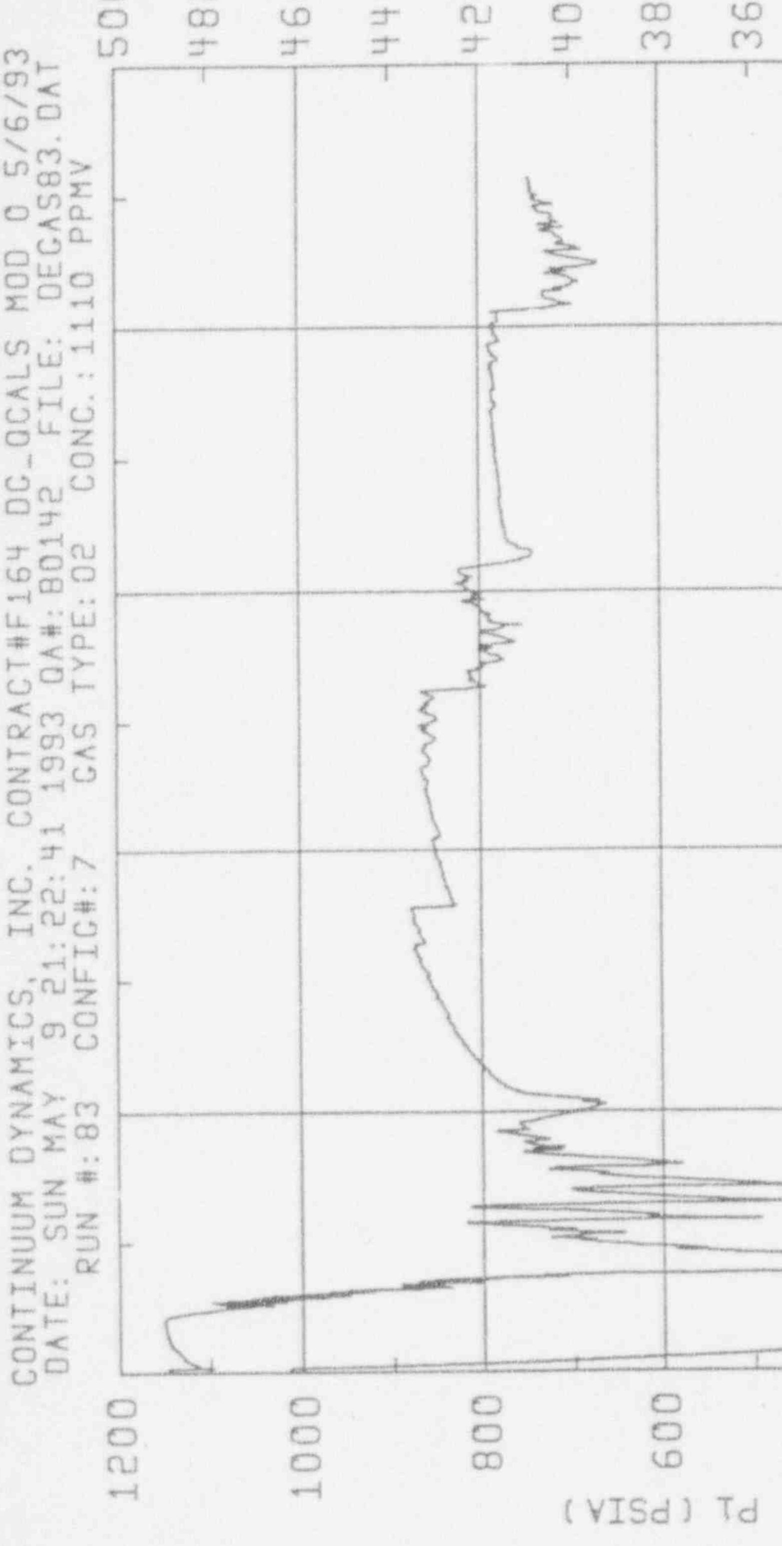

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:30:48 1993 QA#:B0167 FILE: DEGAS77.DAT
RUN #:77 CONFIG#:6 GAS TYPE:02 CONC.:1071 PPMV

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:52:16 1993 QA#:B0172 FILE: DEGAS79.DAT
RUN #:79 CONFIG#:6 GAS TYPE:02 CONC.: 287 PPMV

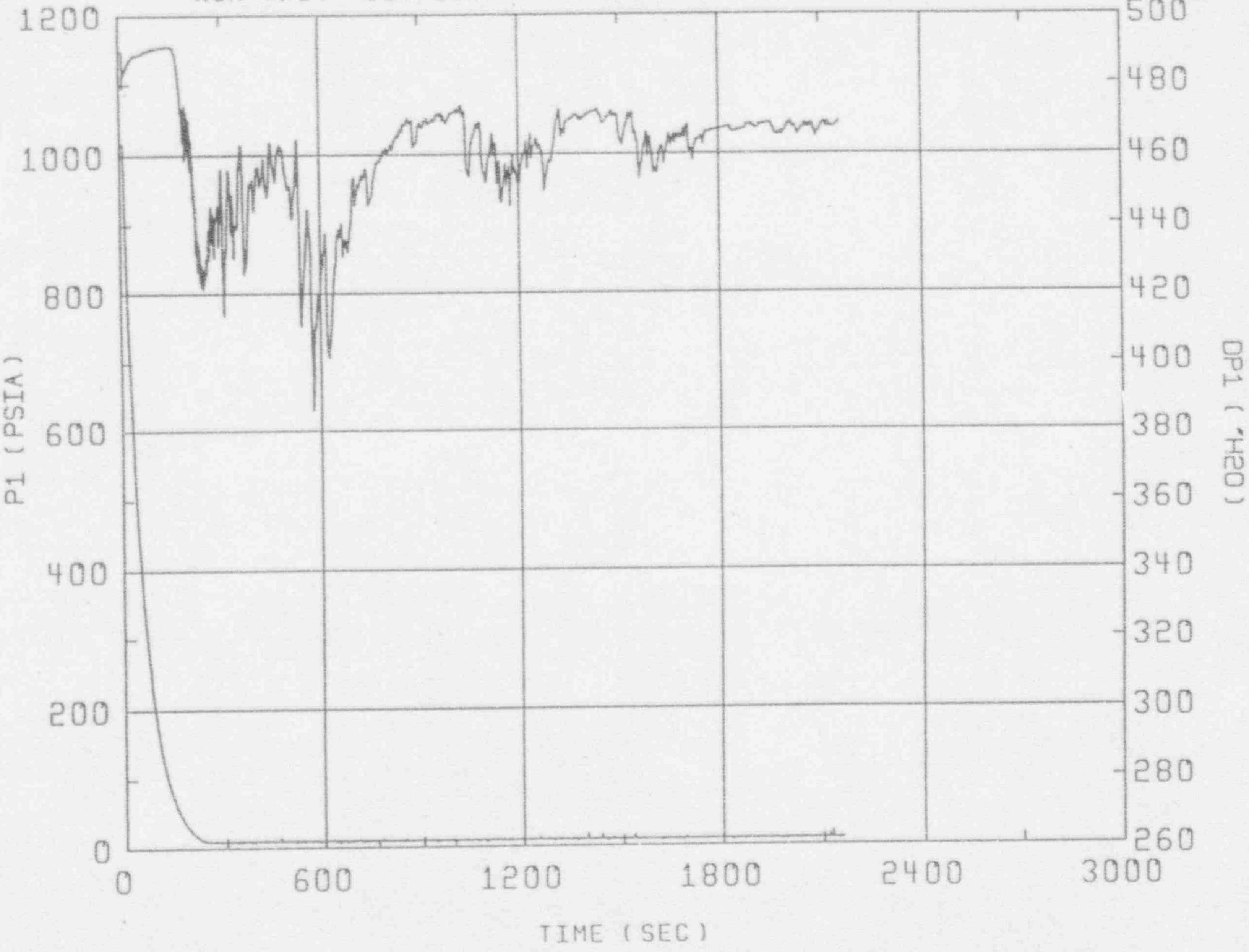


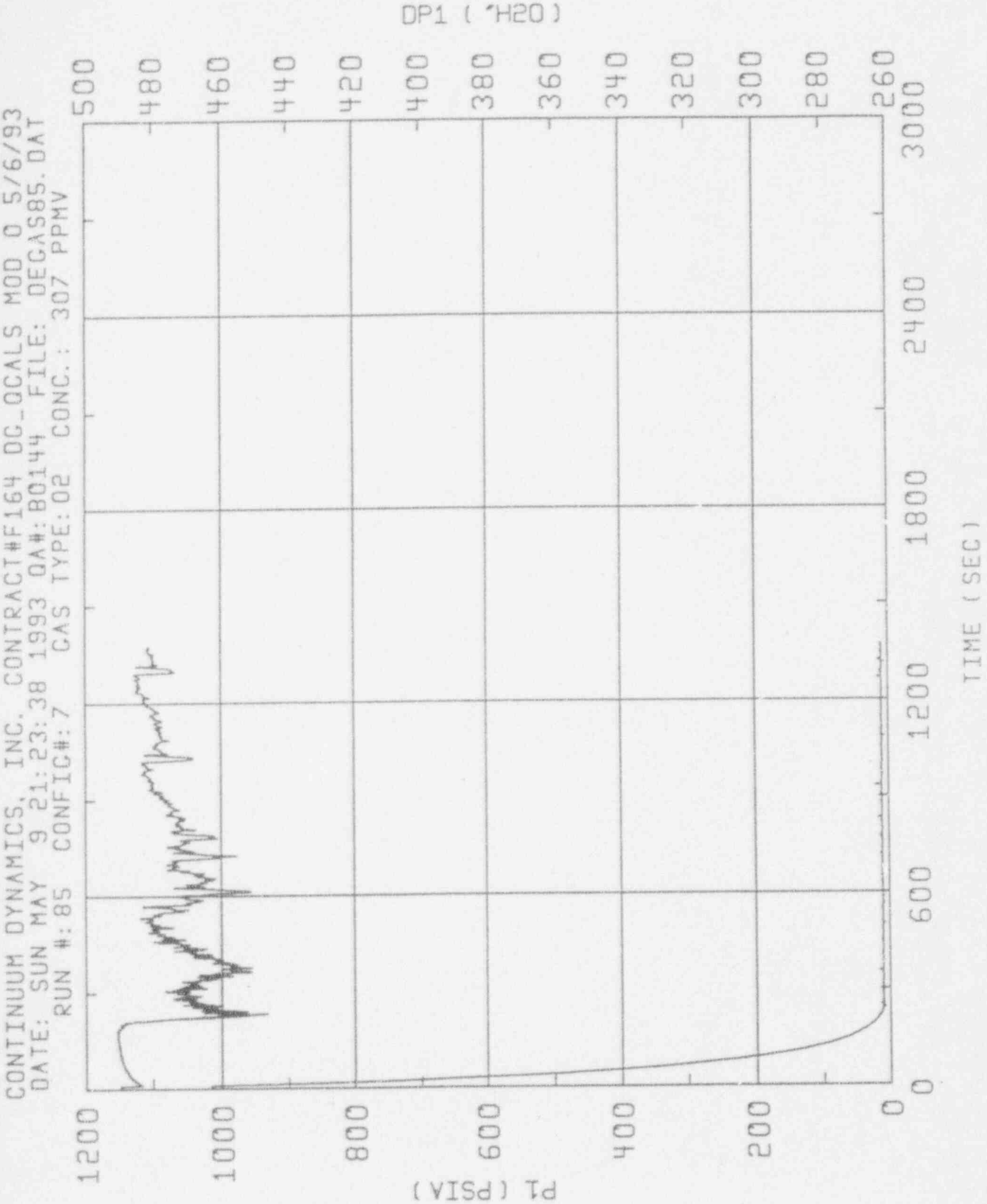

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:52:26 1993 QA#: B0173 FILE: DEGAS80.DAT
RUN #: 80 CONFIG#: 6 GAS TYPE: O2 CONC.: 556 PPMV
P1 (PSIA)
0
200
400
600
800
1000
1200
DP1 ("H2O)
270
300
330
360
390
420
450
480
510
540
570
600
630
TIME (SEC)
0
200
400
600
800
1000
1200

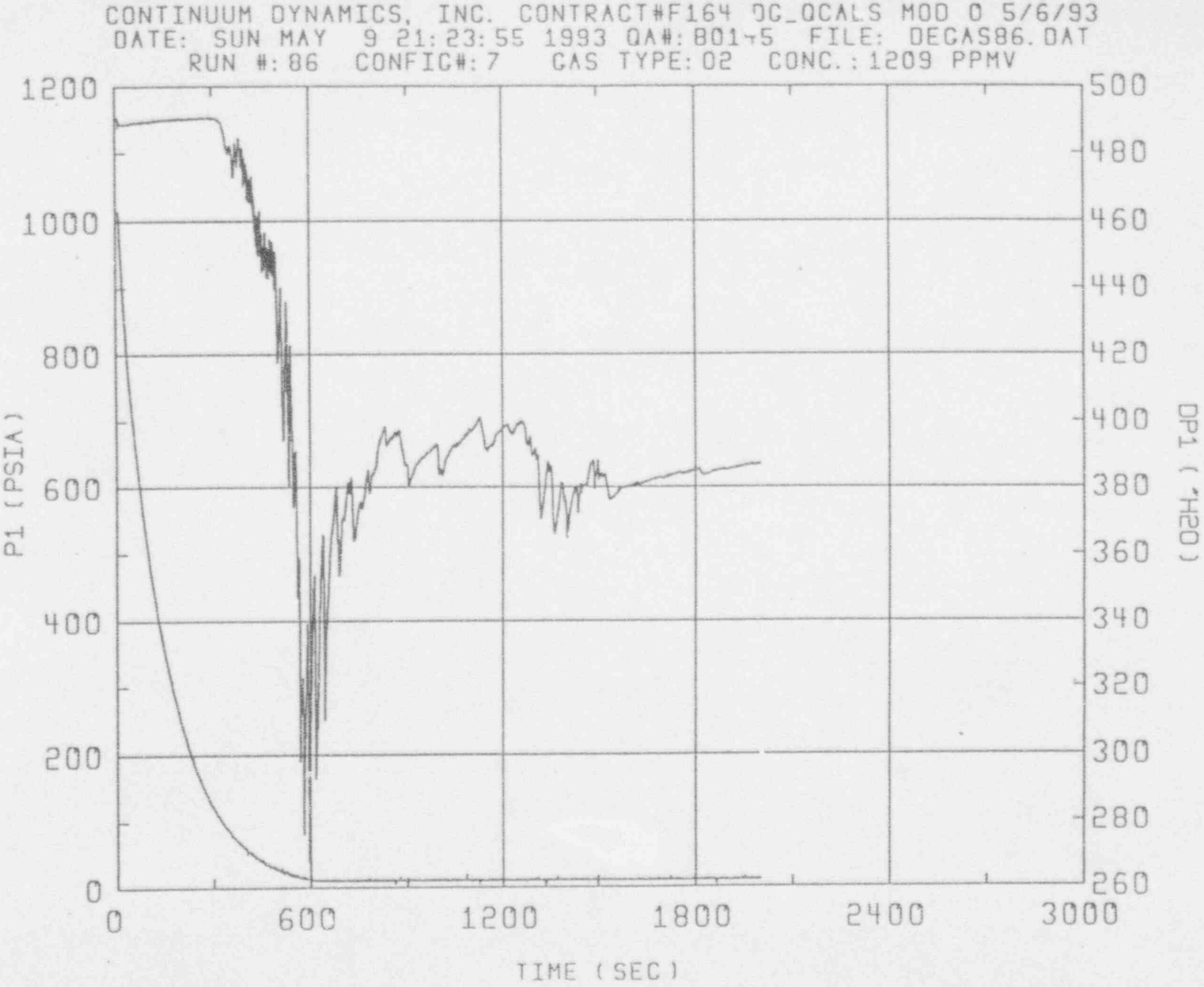

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:22:20 1993 QA#:B0141 FILE: DEGAS82.DAT
RUN #:82 CONFIG#:7 GAS TYPE:02 CONC.:1130 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ('H2O)
500
480
460
440
420
400
380
360
340
320
300
280
260
0
600
1200
1800
2400
3000
TIME (SEC)

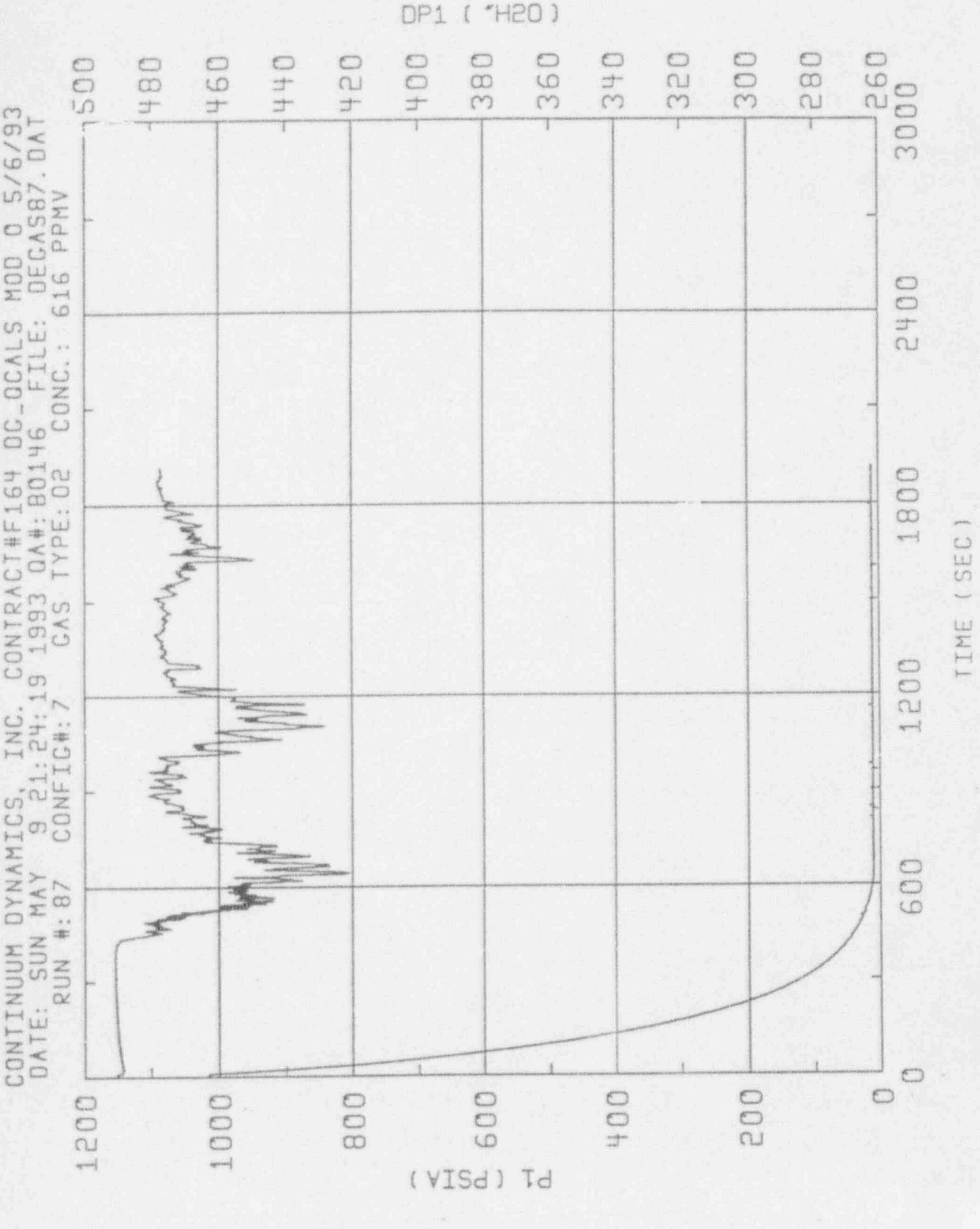

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:22:41 1993 QA#: B0142 FILE: DEGAS83.DAT
RUN #:83 CONFIG#:7 GAS TYPE:02 CONC.:1110 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ('H2O)
500
480
460
440
420
400
380
360
340
320
300
280
260
0
600
1200
1800
2400
3000
TIME (SEC)

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:23:13 1993 QA#:B0143 FILE: DEGAS84.DAT
RUN #:84 CONFIG#:7 GAS TYPE:02 CONC.: 695 PPMV

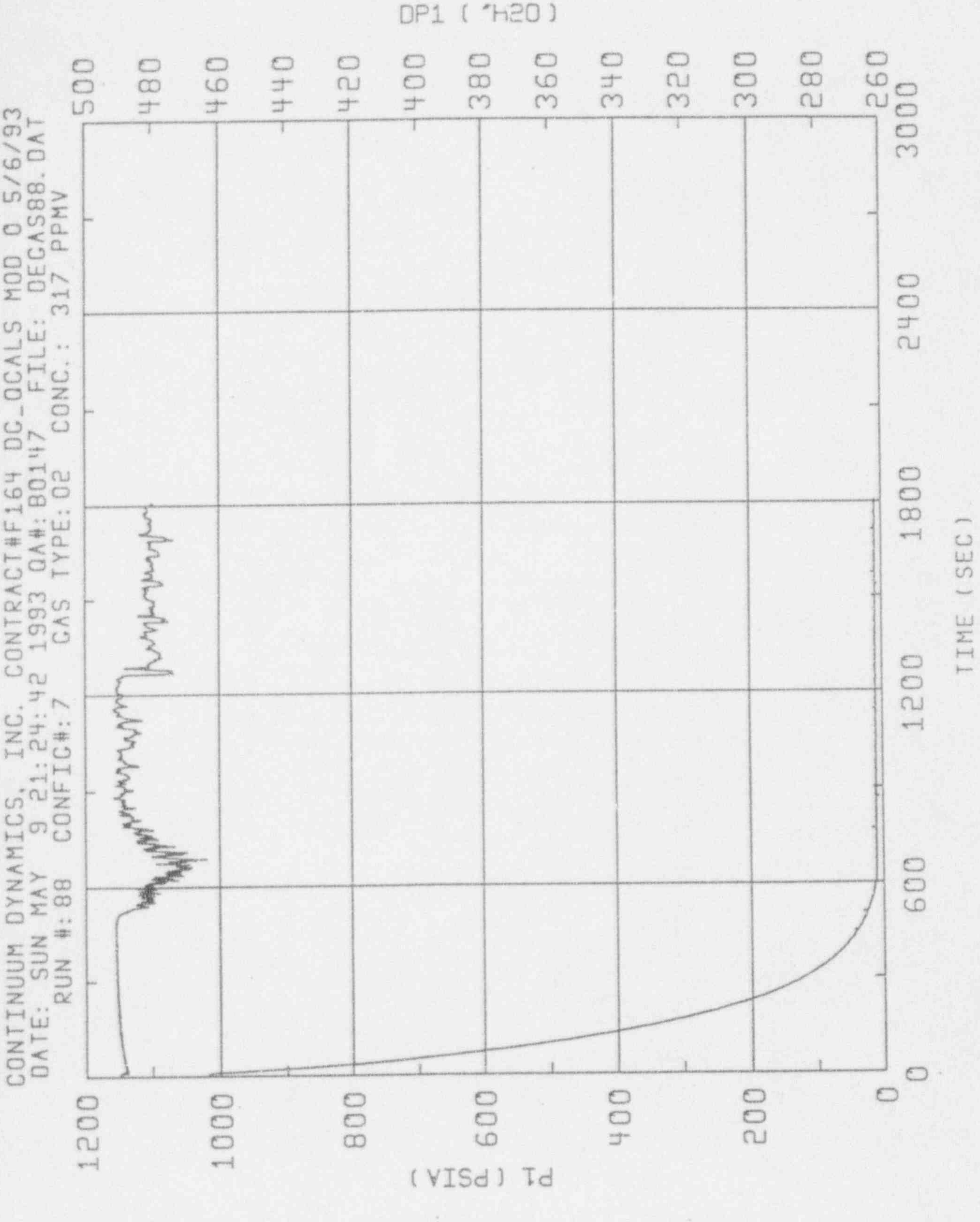



CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:23:38 1993 QA#: B0144 FILE: DEGAS85.DAT
RUN #:85 CONFIG#:7 GAS TYPE:02 CONC.: 307 PPMV
DP1 ( "H2O )
500
480
460
440
420
400
380
360
340
320
300
280
260
P1 (PSIA)
1200
1000
800
600
400
200
0
0
600
1200
1800
2400
3000
TIME (SEC)


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:23:55 1993 QA#: 80145 FILE: DECAS86.DAT
RUN #: 86 CONFIG#: 7 GAS TYPE: 02 CONC.: 1209 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ("H2O)
500
480
460
440
420
400
380
360
340
320
300
280
260
0
600
1200
1800
2400
3000
TIME (SEC)



CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: SUN MAY 9 21:24:19 1993 QA#:B0146 FILE: DEGAS87.DAT
RUN #:87 CONFIG#:7 GAS TYPE:02 CONC.: 616 PPMV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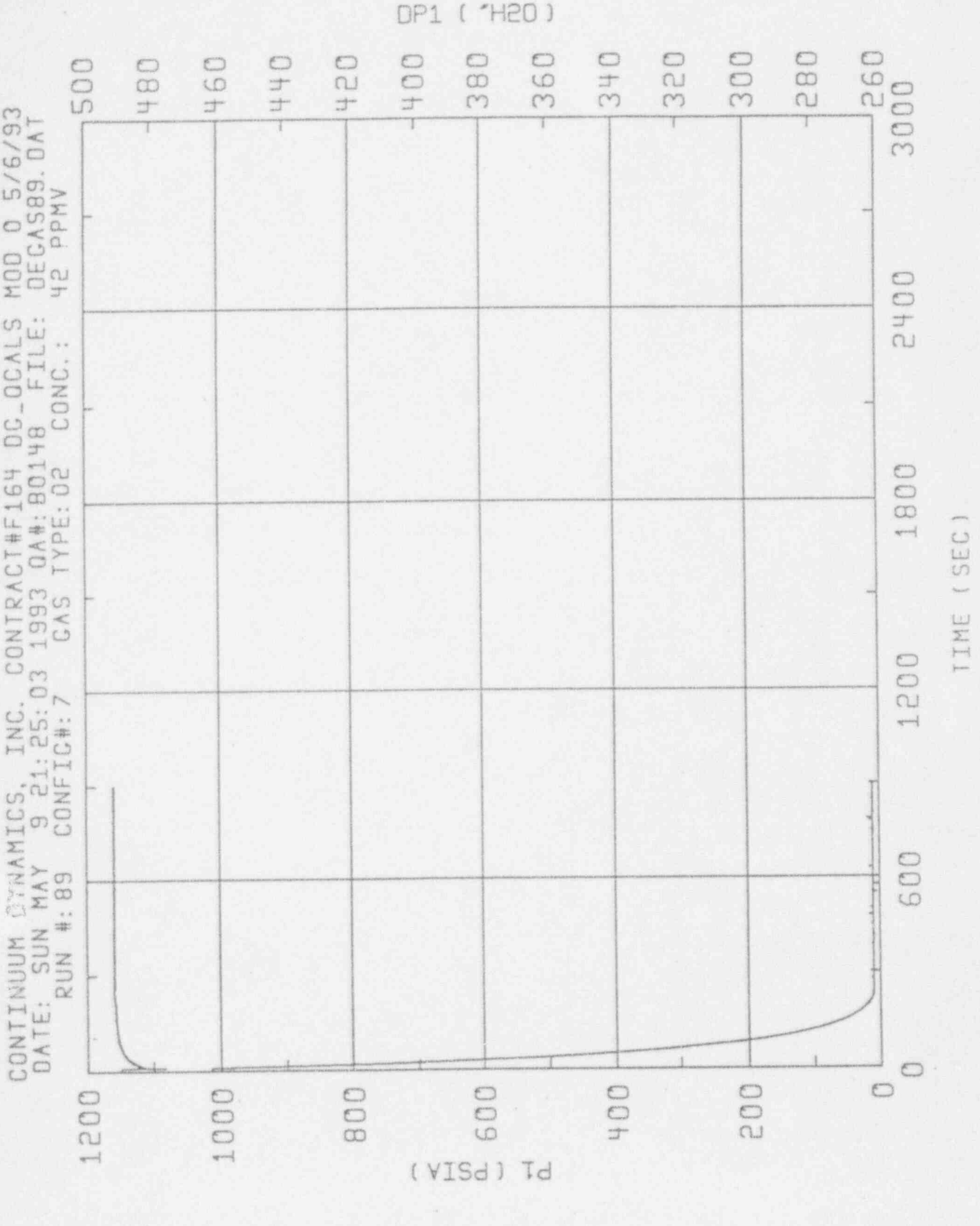
DATE: SUN MAY 9 21:24:42 1993 QA#:B0147 FILE: DEGAS88.DAT
RUN #:88 CONFIG#:7 GAS TYPE:02 CONC.: 317 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ("H2O)
500
480
460
440
420
400
380
360
340
320
300
280
260
TIME (SEC)
0
600
1200
1800
2400
3000



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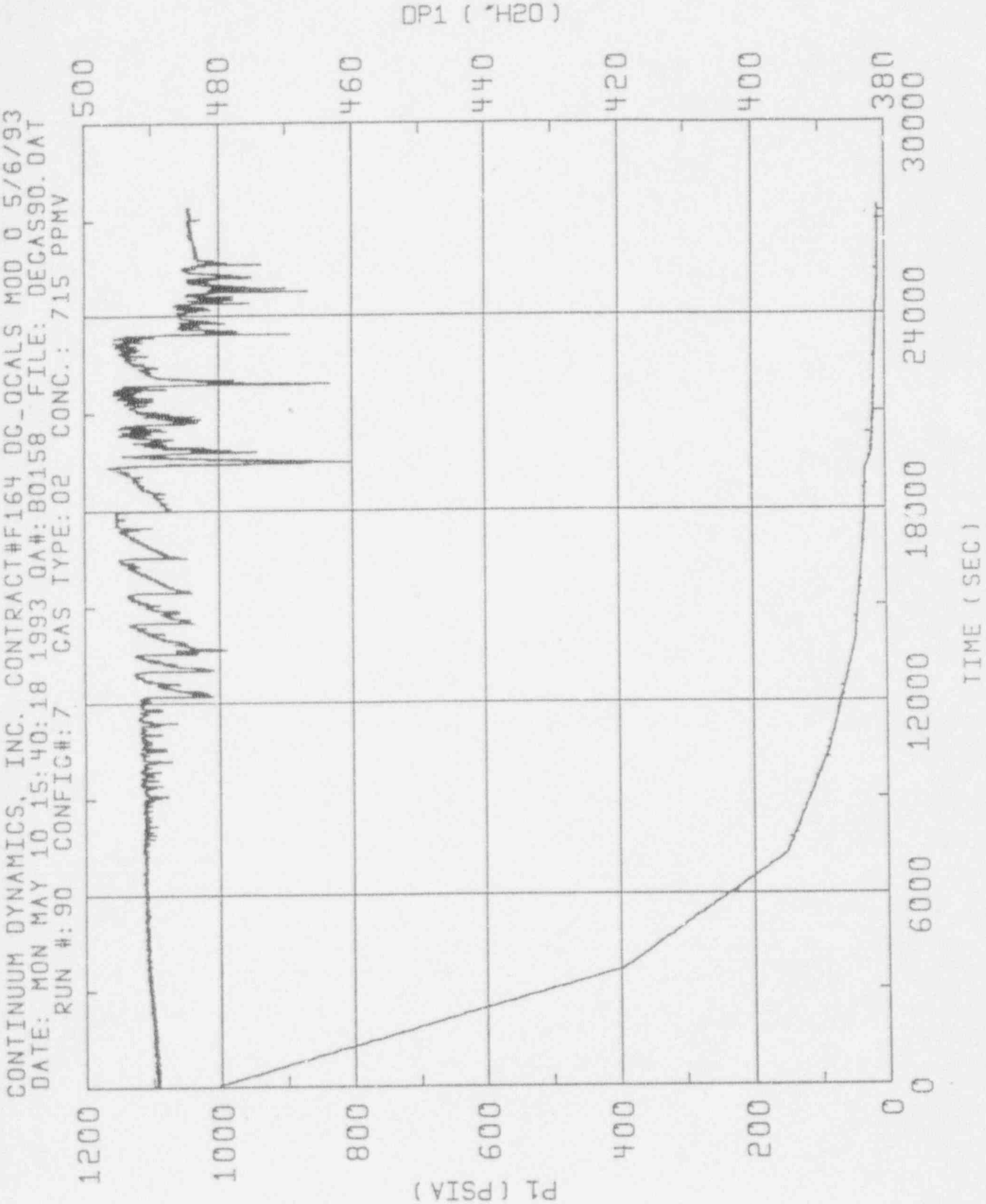
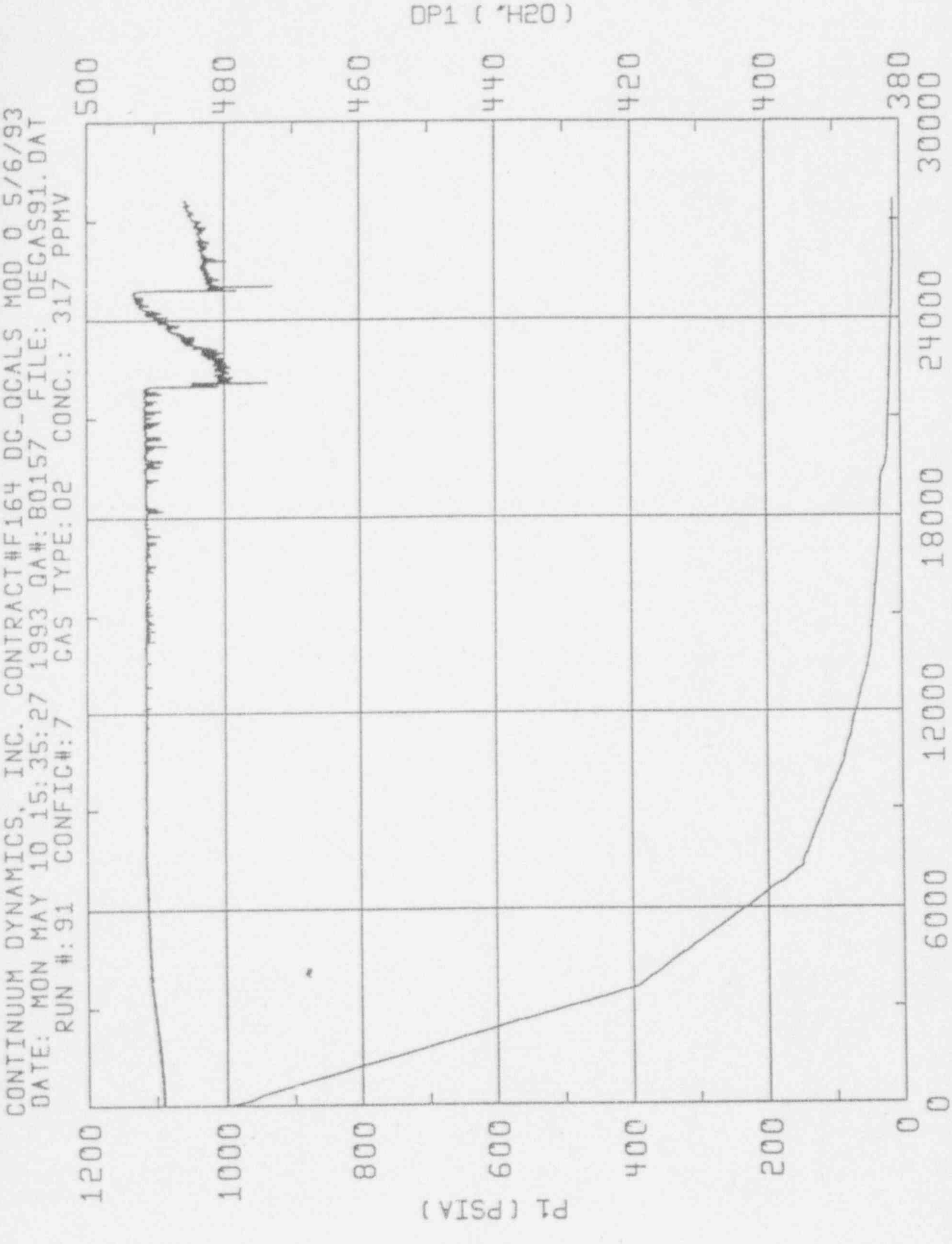
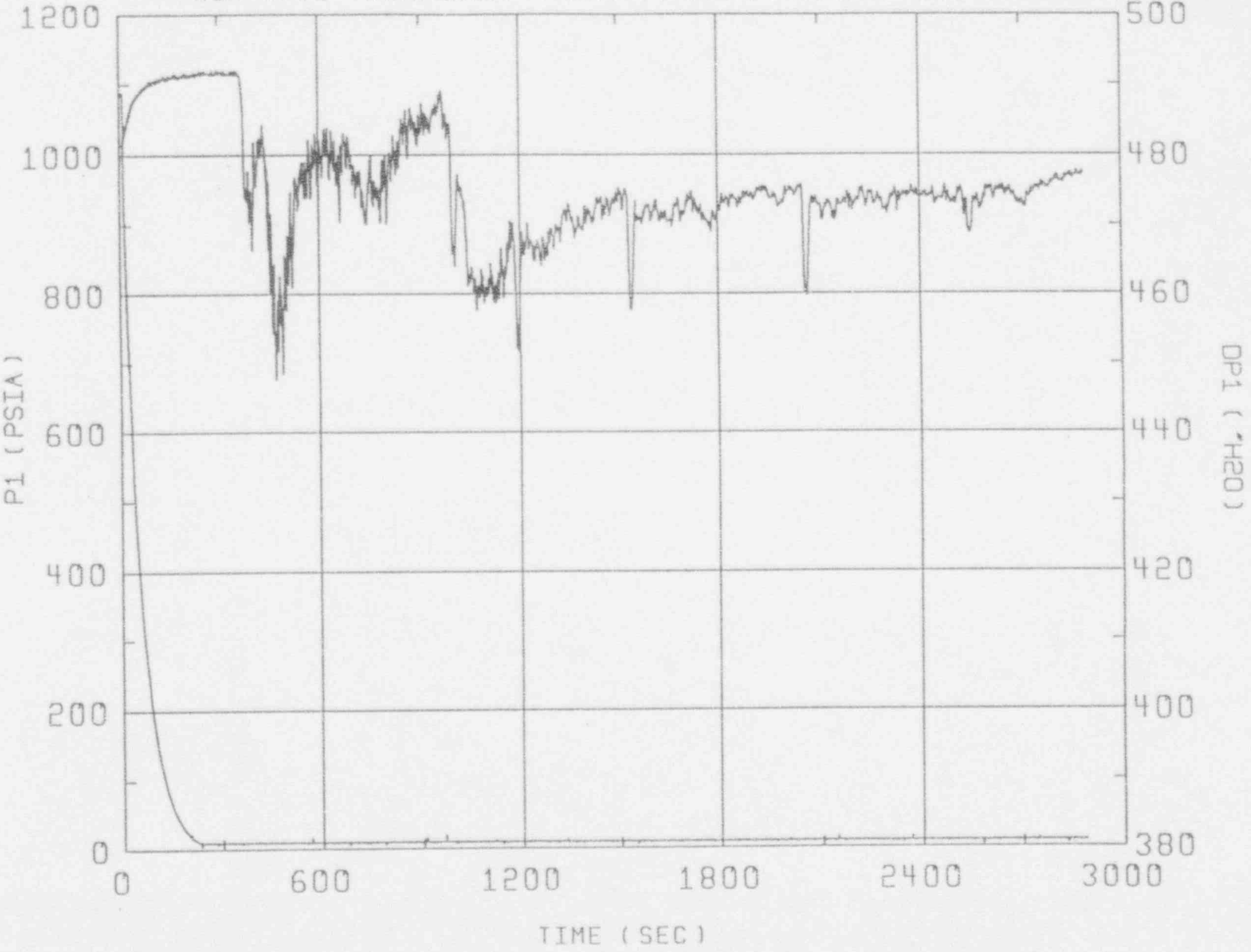
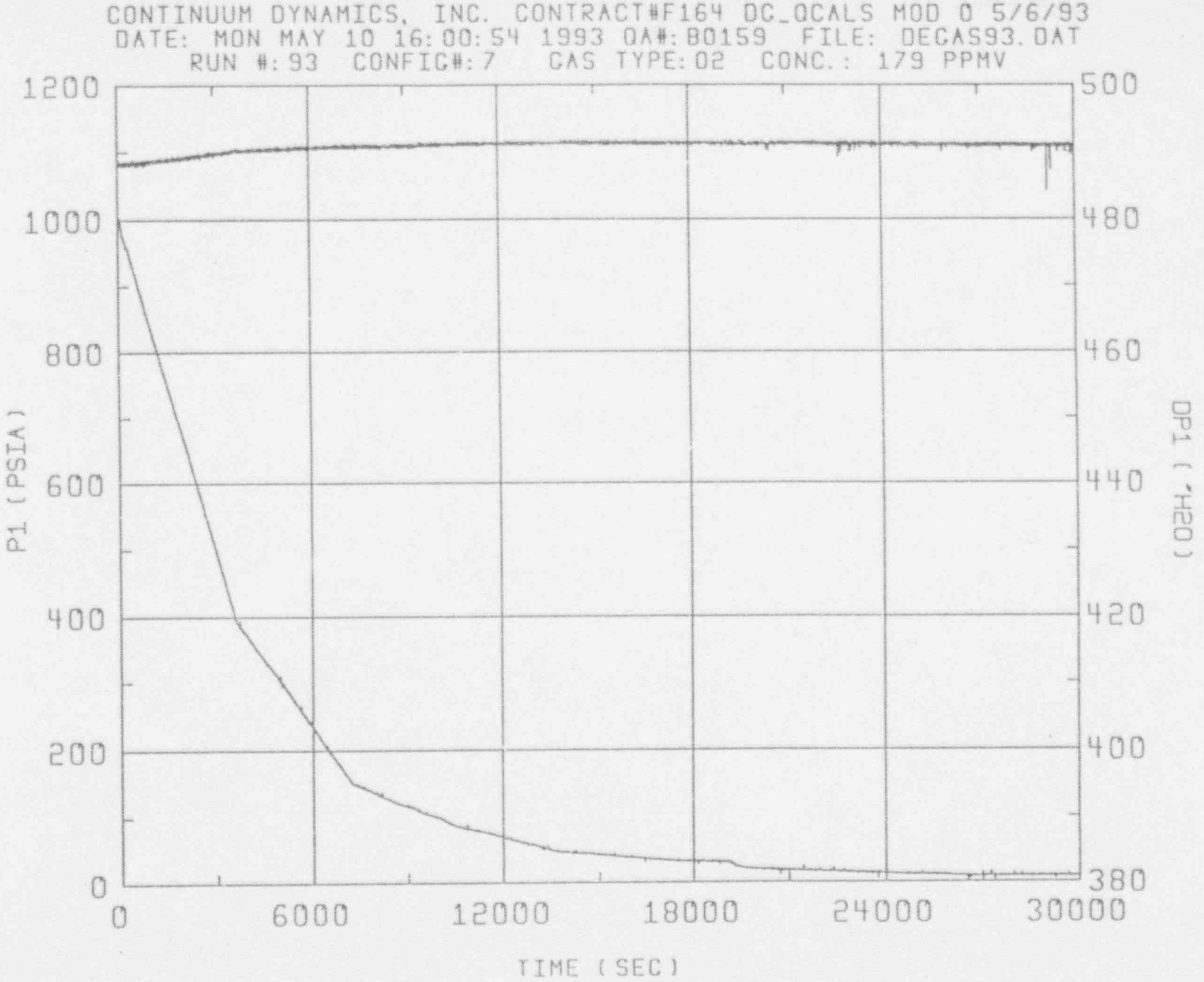
DATE: SUN MAY 9 21:25:03 1993 QA#:80148 FILE: DEGAS89.DAT
RUN #:89 CONFIG#:7 GAS TYPE:02 CONC.: 42 PPMV


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: MON MAY 10 15:40:18 1993 QA#: B0158 FILE: DEGAS90.DAT
RUN #: 90 CONFIG#: 7 GAS TYPE: 02 CONC.: 715 PPMV
DP1 ( "H2O )
500
480
460
440
420
400
380
P1 (PSIA)
1200
1000
800
600
400
200
0
0
6000
12000
18000
24000
30000
TIME (SEC)


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: MON MAY 10 15:35:27 1993 QA#:80157 FILE: DEGAS91.DAT
RUN #:91 CONFIG#:7 GAS TYPE:02 CONC.: 317 PPMV
DP1 ( "H2O )
500
480
460
440
420
400
380
P1 (PSIA)
1200
1000
800
600
400
200
0
TIME (SEC)
0
6000
12000
18000
24000
30000

CONTINUUM DYNAMICS, INC. CONTRACT#F164 DG_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:03:29 1993 QA#: B0160 FILE: DEGAS92.DAT
RUN #: 92 CONFIG#: 7 GAS TYPE: 02 CONC.: 513 PPMV




CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:00:54 1993 QA#:B0159 FILE: DECAS93.DAT
RUN #:93 CONFIG#:7 GAS TYPE:02 CONC.: 179 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ('H2O)
500
480
460
440
420
400
380
0
6000
12000
18000
24000
30000
TIME (SEC)


CONTINUUM DYNAMICS, INC. CONTRACT#F164 DC_QCALS MOD 0 5/6/93
DATE: MON MAY 10 16:04:00 1993 QA#: B0161 FILE: DEGAS94.DAT
RUN #: 94 CONFIG#: 7 GAS TYPE: 02 CONC.: 189 PPMV
P1 (PSIA)
1200
1000
800
600
400
200
0
DP1 ("H2O)
500
480
460
440
420
400
380
0
600
1200
1800
2400
3000
TIME (SEC)

## APPENDIX B: MAXIMUM NON-CONDENSABLE GAS CONCENTRATIONS

In order to support single gas testing in the De-Gas Test program and to design a test matrix, calculations were performed to determine the maximum concentration of non-condensable gas that may be present in the condensing chamber and in the reference leg water. These are repeated in this Appendix to provide documentation on how this maximum concentration was determined.

Dalton's Law of Partial Pressures states that the sum of the partial pressures of the various gases in any volume must equal the total pressure in that volume. In the vapor/gas space of the condensing chamber, these gases are saturated steam (water vapor), hydrogen, and oxygen gas, the latter a result of radiolysis that occurs in the BWR pressure vessel, such that:

$$P_{TOTAL} = P_{vapor}(T) + P_{H2} + P_{O2}$$

Because these non-condensable gases are produced in a stochiometric ratio in the BWR, it is reasonable to assume they will collect in the condensing chamber in this same ratio. Thus, for a stochiometric mixture, $P_{H2} = 2\,P_{O2}$, and since $P_{TOTAL} = 1000$ psig (approximately), then:

$$P_{O2}\,|_{max} = \frac{[\,1000 \text{ psig} - P_{vapor}(T)\,]}{3}$$

From Henry's Law, this gas will enter into solution in the water surface at the top of the reference leg according to:

$$mass_{gas} = mass_{water} \times S_{gas}(T) \times P_{gas},$$

where $S_{gas}(T)$ is the solubility of the gas (on a <u>mass</u> basis), which is a function of gas type and temperature, T. Because the <u>volume</u> of gas dissolved directly determines the amount of water that may be displaced when the gas comes out of solution, the concentration on a <u>volume</u> basis is determined by multiplying this solubility by the ratio of molecular weights of water to the gas. Thus the concentration of oxygen and hydrogen are:

$$\text{conc}_{O2} = \frac{\omega_{H2O}}{\omega_{O2}} S_{O2}(T)\,\frac{1}{3}\,[\,1000\text{ psig} - P_{vapor}(T)\,]\text{, and}$$

$$\text{conc}_{H2} = \frac{\omega_{H2O}}{\omega_{H2}} S_{H2}(T)\,\frac{2}{3}\,[\,1000\text{ psig} - P_{vapor}(T)\,]\text{,}$$

and the total volumetric concentration of non-condensable gas is thus:

$$\text{conc}_{stoc.\ H2+O2} = [\,2\,\frac{\omega_{H2O}}{\omega_{H2}} S_{H2}(T) + \frac{\omega_{H2O}}{\omega_{O2}} S_{O2}(T)]\,\frac{1}{3}\,[\,1000\text{ psig} - P_{vapor}(T)\,]$$

where $\omega_{gas}$ is the molecular weight of the gas. Using published steam tables and solubility data from two different sources[1,2], this concentration is plotted against temperature in Figure B.1. While the maximum concentration is shown to be approximately 1500 ppmv (parts per million by volume), the maximum concentration expected in the reference leg would be closer to 1100 ppmv, because any higher concentration at elevated temperatures would degas due to the temperature drop as the condensate is cooled and flows down into the reference leg.

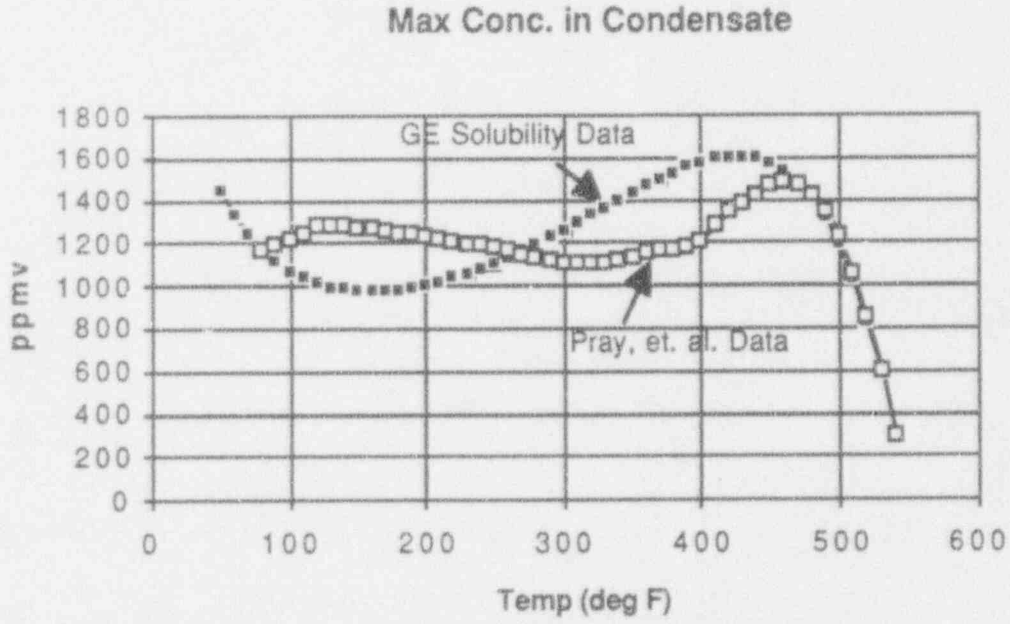


Figure B.1: Maximum Dissolved Gas Concentration vs. Temperature

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[1] Pray, et. al., "Solubility of Hydrogen, Oxygen, Nitrogen, and Helium in Water at Elevated Temperatures," Industrial and Engineering Chemistry, Vol. 44, n. 5, May 1952.

[2] Presberry, C., "Solubility of Ideal Gases in Water," General Electric Nulear Energy Rept. Y1002E101, February 1977.

# APPENDIX C: TEST OPERATIONS

Rev. 1

## C.1 Test Procedures

Rev. 1

### *C.1.1 Reference Leg Configuration Measurement*

Rev. 1

Prior to the testing of any reference leg, a procedure was in place to measure and identify the as-installed configuration. Identification of the configuration was denoted by the configuration number as well as a sketch of the piping.

The size and type of pipe and/or tube was identified on the procedure sheet. The lengths and elevations of all of the relevant points on the configuration was measured, and the slope of the runs was noted where applicable. On the more complex configurations the nodes were located using a string and plumb bob. At the completion of the identification and measurement, the date and time was recorded along with the signatures of the preparer and verifier.

### *C.1.2 Pre-mixed Dissolved Gas Solution Preparation*

Rev. 1

The pre-mixed solutions were prepared in any one of three mixing tanks. The tanks were constructed of 6" diameter stainless steel pipe with welded end caps. A fitting was welded on each end to accommodate a valve and quick connect fitting, and the entire valve assembly was surrounded by a protective cylinder.

The solutions were prepared by combining a known volume of liquid in a given tank with pressurized gas, agitating the tank, and monitoring the pressure drop to ensure a saturated solution. The first part of the procedure consisted of filling the tank solid with demineralized water of a known conductivity and then draining out a specified amount of water via a turbine flow meter. The amount of water to be drained was calculated based on the tank volume required for a 10% drop in pressure following gas addition and the associated dissolution process.

The next step consisted of pressurizing the tank to a specific starting pressure. The required starting pressure was calculated based on the desired solution concentration and gas solubility of the solute gas. The endpoint target pressure was calculated to achieve the 10% pressure drop once equilibrium conditions were established. The tank was then agitated by suspending it about its center with the use of an overhead crane and tipping the ends in a "see-saw" motion with an approximately 5-6 second period. The duration of the agitation was between 20 to 25 cycles. The tank was then slowly rolled in order to strip off any bubbles from the walls of the tank which may have formed during mixing.

To ensure that the solution was saturated, the endpoint pressure of the tank was then measured. If the pressure was no greater than 5% above the endpoint target, the procedure was complete. If the pressure was higher than 5% of the endpoint target, the tank was agitated further until the desired pressure was obtained. The procedure was completed by recording the date and time along with signatures of the preparer and verifier.

### *C.1.3 Volumetric-Based Dissolved Gas Concentration Measurement* Rev. 1

This procedure provided a method for measuring the amount of dissolved gas contained in a liquid sample. This technique was used to measure the solution concentration in the pre-mixed tanks as well as in the reference leg. The measurement required the use of a sampling device as well as a measurement apparatus, illustrated in Figure C.1. Rev. 1 The sampling device consisted of two sample cylinders separated by an isolation valve. The bottom of the device utilized a quick connect fitting to facilitate attachment to either the reference leg sampling line or a pre-mixed tank. The top of the device consisted of a detachable gauge to monitor the pressure and a needle valve to control the flow through the device. The measurement apparatus consisted of two inverted graduated cylinders of different capacity with the open ends immersed in a bath of water. A three way valve connected the selected graduates via a universal tube which was attached to the top of the sampling device. The cylinder chosen for the measurement was dependent on the anticipated gas concentration of the sample. The water was drawn up into the graduates with the use of a hand operated vacuum pump.

The first part of the procedure involved clearing the sampling device of any remaining sample and pressurizing it. This was accomplished by opening the isolation valve and needle valve on the device and attaching a nitrogen source via the bottom quick connect. The device was then purged with gas until it was free of any solution. With the gas source still attached, the needle valve was then closed and the cylinders were pressurized to a pressure approximately 50 psia above that of the sample source. The reason for this pre-pressurization is to guarantee that the sample does not degas upon injection into the device.

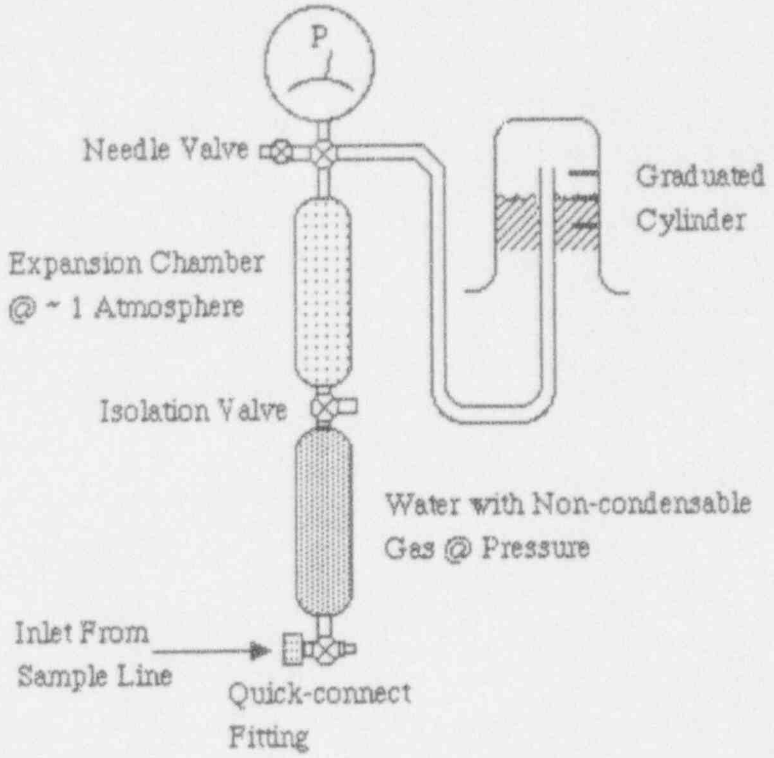

Figure C.1: Schematic of Gas Concentration Sampling Device

|Rev. 1

The sampling device was then attached to the sample source via the bottom quick connect. The necessary valves were then opened in the flow path leading to the device. The top needle valve was cracked open to allow flow through the device, while at the same time monitoring the pressure in the device so as not to allow it to go below that of the solution saturation pressure and hence cause degassing. When the sample solution reached the needle valve, which was evident by the absence of gas hissing from the device, the isolation valves on the bottom chamber as well as the upper needle valve were closed. The device was then disconnected from the sample source, and solution temperature, as measured by an in-line thermocouple probe, was recorded.

The upper surge volume of water was then emptied, and the gas line to the inverted cylinder was checked so that no water was trapped in it. The line was then attached to the top of the sampling device and the vacuum pump was connected to the valve at the bottom of the upper chamber. The water was then pulled up into the graduated cylinder to a convenient starting point, and the graduated cylinder level was recorded and verified by two operators. The isolation valve was then opened, the device agitated, and all the gas coming out of solution was trapped in the inverted cylinder. The final volume was measured and the differential was used to compute the resulting solution concentration. The procedure was completed by recording the date and time along with the signature of the preparer and verifier.

### *C.1.4 De-Gas Test Procedure*

Rev. 1

The test procedure used to test a reference leg configuration consisted of detailed instructions involving many steps. Where necessary, the steps were checked by two people to ensure that quality was maintained.

A test was initiated by entering on to the procedure sheet all pertinent information relevant to the test. This information included the date, time, run number, piping configuration number, blowdown orifice diameter, pre-mixed solution gas and nominal concentration, nominal starting pressure and the endpoint pressure.

The piping configuration to be tested was verified prior to each test. The verification of the configuration was done by checking that the piping in place was in fact representative of the system measured and identified by the configuration procedure. The date of the configuration measurement form was entered to provide a reference.

Rev. 1

The pre-mixed solution tank to be used was verified to be the desired solution required for testing by cross checking the tank identification and the appropriate solution preparation procedure form. A reference of the date of the mixture preparation was included. The tank was also verified to have enough solution to carry out the test by checking the pre-mixed solution log.

The first dynamic step in the procedure involved the demineralized water injection. The water supply source was connected to the instrument spool piece via a quick connect coupling. The pressure vessel drain valve was opened to allow the water flowing over the spillway to drain out of the system. The water was then injected into the reference leg by opening the valves in the flow path. Flow continued into the leg until it was deemed full by a constant reading indicated by the differential pressure cell. The valves in the flow path were shut off and the remaining water was allowed to drain from the pressure vessel. The differential pressure cell reading was then recorded.

The next part of the procedure involved pressurizing the system in preparation for the pre-mixed solution injection. The blowdown valve, sampling line valve and both ball valves on the instrument spool piece were checked to be in the shut off position. The nitrogen supply line was coupled to the ball valve on the pressure vessel and the absolute pressure cell was checked for operation. The system was then pressurized to the desired pressure as determined by the solution equilibrium saturation pressure.

The reference leg was then filled with the pre-mixed solution from the mixing tank. The injection line from the mixing tank to the reference leg was filled solid with demineralized water to eliminate any gas voids. The input end of the line was connected to the mixing tank and the output to the ball valve on the instrument spool piece. The opposite end of the mixing tank was attached to a gas supply line which was used to boost the tank pressure approximately 100 psia above that of the pressure vessel. This differential was necessary in order to inject the solution into the reference leg. The ball valves on the mixing tank and instrument spool piece were opened. Flow was initiated by opening the needle valve on the flow assembly in the injection line. The flow meter was monitored to ensure that at least twice the reference leg volume was injected into the system and the needle valve was then shut off. The water displaced by the solution injection traveled down the spillway into the pressure vessel.

The system was then prepared for a gas concentration measurement. This was done by opening the sampling line solenoid valve and purging approximately 100 ml of solution through the line in order to eliminate any voids. During purging, care was taken not to go below the solution saturation pressure by monitoring the sampling line pressure gauge and adjusting the needle valve as required.

The next step was to perform the dissolved gas analysis procedure on a sample from the reference leg. If the measurement was within 20% of the predicted concentration in the pre-mixed bottle, the sampling line solenoid valve was closed and the test continued. If the measurement was not within the tolerance it was either repeated or a sample was taken directly from the tank if it was suspected that the concentration in the mixing tank had increased.

The final step in the sampling procedure was to re-inject solution into the reference leg to replace what was drained during sampling. The injection line needle valve was closed to stop the flow, and the injection ball valve on the instrument spool piece was shut off to isolate the injection line from the reference leg.

Pressurization of the system was resumed until the desired starting pressure was reached. The drain port valve on the pressure vessel was opened in order to drain the water that had been displaced during solution injection. Upon completion of draining, the drain valve on the pressure vessel was closed.

In preparation for depressurization the settings of the absolute pressure cell, the differential pressure cell, the water temperature and the ambient temperature of the room were recorded. If it was desired to stop the depressurization at any pressure other than atmospheric, the comparitor potentiometer was adjusted as required. The date and time was checked on the data acquisition computer, and all pertinent test information was recorded into the test data file. The test data filename was recorded on the procedure sheet and the data acquisition program was started.

Approximately ten seconds after initiation of the program, the solenoid blowdown valve was opened and the depressurization event was begun. The pressure readings were monitored to ensure properly functioning instruments during the blowdown. At the completion of any transient events the data acquisition program was stopped, and the settings of the absolute and differential pressure cell and the room temperature were recorded. Also, in order to ensure proper recording of the data, the time history file was verified and a backup was made to a floppy disk.

The final step in the procedure involved draining the system and refilling the reference leg to take an endpoint reading. The pressure vessel drain port was opened to drain any water which may have spilled over due to a level error. The reference leg was drained of the remaining solution via the instrument spool piece and the differential pressure cell "zero" reading was recorded. The reference leg was then re-injected to completely fill it with demineralized water and the reading on the differential pressure cell was recorded. The level error was then calculated by taking an average of the differential pressure before and after the test and subtracting it from the endpoint reading after the completion of the blowdown event.

The final step in the procedure was altered for Configuration #7 because of observed anomalies associated with the level depicted by the differential pressure cell. After the blowdown event was finished, the system was repressurized to the initial starting pressure and the differential cell output was recorded. The remaining water in the reference leg was drained and measured in a graduated beaker and the resulting volume was recorded. Lastly, as with the other configurations, the reference leg was refilled with demineralized water and the end point level error was calculated in the same manner.

The test was completed by indicating whether the test fell under pass or fail criteria. If there were any deficiencies associated with the test they were noted along with the respective nonconformance report numbers. The cause and corrective action associated with any deficiencies was recorded if necessary. As with all of the procedures, the date and time of completion was recorded along with the signatures of the preparer and verifier.

## C.2 Quality Assurance

Rev. 1

All controlled activities were performed in accordance with the procedures and guidelines for testing specified in the C.D.I. Quality Assurance Manual (Ref. 3). Controlled activities are those which are directly related to the planning, execution and evaluation of tests intended to produce data necessary to achieve the program objectives. Supporting activities such as test apparatus design and fabrication were not controlled by these test procedures or the reference Quality Assurance Manual; however, prior to the initiation of testing any piping configuration, C.D.I. personnel extensively documented the as-built condition of the reference leg configuration to provide traceability of the data to the piping system being tested.

Test procedures for the De-Gas Test as described above were developed under the guidelines outlined in the Quality Assurance plan of Continuum Dynamics, Inc., Ref. 3. Any modifications and revisions to these procedures were made after independent review, and then approved by the Principal Investigator and the Quality Assurance Manager.

## C.3 Test Matrix

Rev. 1

Control of the test matrix was done through a combination of verbal change orders with written confirmation for follow-up. This was done so as to provide timely preliminary results from the previous tests to help guide the selection of test points that would have the largest payoff in information and understanding of the de-gassing phenomena observed as part of the experimental program. The testing was performed sequentially by test number, and is listed in Section 2 where the results of the test program are summarized in tabular form.

ENCLOSURE 2

# De-Gas Test Shakedown Progress Report
3/7/93

**Testing Dates**: 2/15 through 3/7

**Goals:**
Runs were conducted to verify that methods and procedures are correct and appropriate for conducting Quality-related testing.

**Tests Completed**:

| Run # | Config # | Gas & Conc. (in ppmv) | dP/dt(init) (psia/sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|
| SD7 | 1 (carbon) | N2 @ 250 | -100 | 1000 | 14.7 | 2.4" |
| SD8 | 1 (carbon) | N2 @ 320 | -100 | 1000 | 50 | 0.5" |
| SD10 | 1 (carbon) | N2 @ 300 | -100 | 1000 | 50 | 2.1" |
| SD11 | 1 (stainless) | N2 @ 380 | -100 | 1000 | 53 | 2.4" |
| SD12 | 1 (stainless) | N2 @ 330 | -100 | 1000 | 44 | 1.25" |
| SD13 | 1 (stainless) | N2 @ 380 | -100 | 1000 | 53 | 1.55" |

**Observations:**
The following major results were noted as a result of this shakedown testing:

(1) Differential pressure measurements show a <u>static</u> <u>decrease</u> of 0.028"/psia due to the increase of gas mass in the vertical 2" pipe that connects the pressure vessel (PV) to the coupling chamber. Thus, all data that are taken at end point pressures other that 1 atm must be properly corrected to account for this "head" of pressurized gas on the gas side of the differential pressure transducer.

(2) End point pressure may be easily controlled using simple electronic comparitor circuits coupled to a solenoid actuated blowdown valve. Adjustment of a potentiometer allows one to set the endpoint to more prototypical ending pressures for simulating severe reactor accident depressurizations.

(3) Gas may be driven into solution quite quickly, provided sufficient wave motion is set up in the pre-mixing tanks. Approximately 30 tipping oscillations of a mixing tank drive the gas to saturated conditions, as determined by the predicted pressure drop as the pressurized gas enters solution.

(4) Measurement of dissolved gas concentration is easier, more consistent, and faster by using a split-volume device similar to that used on the benchtop testing program. Gas volume is measured after a fixed volume of solution is expanded to atmospheric conditions.

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(5) Level error is repeatable (within instrument accuracy) for the same concentrations and depressurization time histories. This will allow single-point testing of items in the test matrix. Pressure transducer drift appears to be negligible.

(6) The PC used with the gas chromatograph appears to have disk reliability problems, and is being replaced with a different model.

(7) A Quality-Assurance audit of the testing procedures and test plan is currently underway.

R. McKillip, Test Conductor & Principal Investigator

# De-Gas Test Progress Report - 02
3/11/93

**Testing Dates**: 3/10 through 3/11 (AM)

**Goals:**
Initial Quality-related data for Configuration #1.

**Tests Completed**:

| Run # | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Δt to P(final) (sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | .25" | N2 @ 597 | 210 | 1027 | 23 | 3.1" |
| 2 | 1 | <.25" | N2 @ 637 | 500 | 1037 | 14.7 | 1.5" |
| 3 | 1 | .25" | N2 @ 617 | 210 | 1036 | 24 | 3.1" |
| 4 | 1 | .313" | N2 @ 647 | 130 | 1040 | 14.7 | 7.8" |
| 5 | 1 | .25" | N2 @ 627 | 260 | 1036 | 14.7 | 3.4" |

**Observations:**
The following major results were noted as a result of this shakedown testing:

(1) A successful Quality-Assurance review of the test procedures and documentation has allowed the collection of safety-related test data.

(2) Repeatability was demonstrated through comparison of nominal 600 ppmv nitrogen solution depressurization through a 0.25" diameter orifice to an end point of approximately 23 psia. The time histories of the differential pressure readings for these two tests lie almost on top of each other.

(3) Run 2 had a very slow depressurization rate, due to a stuck solenoid valve; the system was depressurized through a hand-operated ball valve. The solenoid has been repaired and functions properly.

(3) Depressurization rate, as shown by the above results, has a significant impact on the resultant level error, as does end point pressure. Run 1, 3, and 5 have the same depressurization rate, only 5 has a different endpoint pressure. Run 1 also included a further depressurization down to 14.7 psia after staying at 23 psia for several minutes, with no additional level error.

R. McKillip, Test Conductor & Principal Investigator

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PRELIMINARY INFORMATION

# De-Gas Test Progress Report - 03
3/12/93

**Testing Dates**: 3/11 (PM)

**Goals:**

Continued Quality-related data for Configuration #1.

**Tests Completed**:

| Test # | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Δt to P(final) (sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|
| 5 | 1 | .25" | N2 @ 109 | | 1033 | 24 | 0" |
| 4 | 1 | .25" | N2 @ 100 (target) | | 1037 | 14.7 | N.A. |

**Observations/Comments:**

(1) Identifiers for tests numbers will henceforth be used that reflect approved test points in the test matrix, to avoid confusion. Thus, although the tests were run in the order shown, the test number reflects the order given in the test matrix.

(2) Test 5 depressurized down to 24 psia with no level error, stabilized at that pressure for several minutes, and then continued down to 1 atm, with no level error. This would tend to confirm suspicions that levels of 100 ppmv are not significant contributors to level error.

(3) Test 4 was a failed test, as subsequent calculations showed that sufficient pre-mixed solution was not injected to "top off" the coupling chamber level to the level of the spillway. A revision to the test procedures is in place to ensure this discrepancy does not happen again, through cross-checks of DP1 cell reading with absolute pressure (P1) indication. This test will be re-run on 3/12/93.

(4) An orifice of 0.265" diameter is being fabricated to provide an isentropic depressurization rate down to 21 psia in 170 seconds, based upon new prototypical depressurization information for LOCA-type events.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 04

3/15/93

**Testing Dates**: 3/12, 3/15

**Goals:**

Continued Quality-related data for Configuration #1, at various depressurization rates.

**Tests Completed**:

| Test # | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Δt to P(final) (sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|
| 1-4 | 1 | .266 | N2 @ 79 | LOCA | 1032 | 14.7 | 0" |
| 1-7 | 1 | .266 | O2 @ 1021 | LOCA | 1021 | 24 | 35.3" |
| 1-6 | 1 | .266 | O2 @ 1051 | LOCA | 1030 | 14.7 | 44.8" |
| 1-10 | 1 | .157 | O2 @ 1071 | ATWS | 1036 | 14.7 | 4.0" |
| 1-9 | 1 | .157 | N2 @ 657 | ATWS | 1036 | 14.7 | 0.9" |

**Observations/Comments:**

(1) Orifice sizes were fabricated to closely approximate both the LOCA and ATWS depressurization rates.

(2) Test #1-4 was a repeat of the failed test #1-4 from 3/11/93, and showed no level error, as anticipated for this low concentration level.

(3) Test #1-7 depressurized down to 24 psia, held at that pressure for several minutes, and then dropped to 1 atm, with no additional level error.

(4) High concentrations of dissolved gas and high depressurization rates produced significant level errors for this configuration. It is believed that the stripping action of the vertically rising gas bubbles is largely responsible for the water carry-over into the spillway from the coupling chamber. Lower depressurization rates, such at those for ATWS-type events, produce substantially smaller level loss.

R. McKillip, Test Conductor & Principal Investigator

[illegible]
PRELIMINARY INFORMATION

# De-Gas Test Progress Report - 05

3/16/93

**Testing Date**: 3/16

**Goals:**

First Quality-related data for Configuration #2.

**Tests Completed**:

| Test # | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Δt to P(final) (sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|
| 2-1 | 2 | .157 | O2 @ 1160 | ATWS | 1035 | 14.7 | 17.9" |
| 2-4 | 2 | .157 | N2 @ 567 | ATWS | 1029 | 14.7 | 3.6" |
| 2-4 | 2 | .157 | N2 @ 607 | ATWS | 1030 | 14.7 | 3.8" |

**Observations/Comments:**

(1) Run 1-4 was repeated per MATC request, to show that observed level losses were as a result of gas concentration and piping geometry, and not instrumentation anomalies due to switching to a new configuration.

(2) Recorded pressure time histories for the repeat runs showed very similar transient behavior.

(3) DP readings for Run 2-1 showed significant oscillations about the mean value when the absolute pressure was between 70 and approximately 20 psia levels.

R. McKillip, Test Conductor & Principal Investigator

PRELIMINARY INFORMATION

# De-Gas Test Progress Report - 06

3/18/93

**Testing Date**: 3/17

**Goals:**

Continued Quality-related data for Configuration #2.

**Tests Completed**:

| Test # | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Δt to P(final) (sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|
| 2-4 | 2 | .157 | N2 @ 647 | ATWS | 1034 | 14.7 | 3.7" |
| 2-4 | 2 | .157 | O2 @ 567 | ATWS | 1030 | 14.7 | 6.8" |
| 2-3 | 2 | .266 | N2 @ 617 | LOCA | 1030 | 14.7 | 19.5" |

**Observations/Comments:**

(1) Run 2-4 was repeated as a demonstration for the NRC visit and tour of the de-gas test facility.

(2) Run 2-4 was also repeated using oxygen as the test gas at the same concentration as used for nitrogen, and showed an increase in final level error, as well as a delay in the transient portion of the DP1 cell reading. This is most likely due to solubility differences, as oxygen's increased solubility reduces its saturation pressure (for the same concentration) and hence the same amount of gas comes out of solution at a later point in the depressurization time history.

(3) Run 2-3 showed the sensitivity of this configuration to increases in depressurization rate.

(4) Run 2-1 (O2 @ 1100 ppmv ATWS) has been allowed to sit at pressure overnight to investigate if "microbubbles" (if they exist) may be driven into solution over time if the system is over-pressurized above saturation conditions for extended periods. This test will be run early on 3/18.

R. McKillip, Test Conductor & Principal Investigator

PRELIMINARY INFORMATION

## De-Gas Test Progress Report - 07

3/19/93

**Testing Date**: 3/18

**Goals:**

"Microbubble" Investigations and Continued Quality-related data for Configuration #2.

**Tests Completed**:

| Test # | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Δt to P(final) (sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|
| 2-1 | 2 | .157 | O2 @ 1110 | ATWS | 1031 | 14.7 | 6.9" |
| 2-1 | 2 | .157 | O2 @ 1130 | ATWS | 1029 | 14.7 | 6.9" |
| 2-2 | 2 | .266 | O2 @ 1170 | LOCA | 1030 | 14.7 | 21.4" |

**Observations/Comments:**

(1) Run 2-1 (of 3/16) was repeated after having been allowed to sit at pressure overnight to investigate [illegible] microbubbles" (if they exist) would be driven into solution over time if the system [illegible] over-pressurized above saturation conditions for extended periods. The resulting reduction in level error from the result of 3/16 prompted an immediate repeat of these test conditions to determine if this "soaking" process had any influence on the test results. The repeat run showed not only an exact level loss match, but similar transient behavior of the differential pressure cell (DP1). Investigation into the cause for the discrepancy between these two runs, and the run of 3/16, revealed that the tank of 1100 ppmv pre-mixed solution probably ran "dry" during injection on 3/16, and thus gas was inadvertantly introduced in the original 1100 ppmv ATWS test on configuration 2. A new procedure has been added to systematically record tank mixture usage to prevent further occurances of this problem.

(2) The fact that the same result was achieved in the first two tests above, regardless of how long the system was allowed to sit at pressure, suggests that there is no physical observation that suggests the presence of "microbubbles" in the pre-mixed solution, and hence the level errors are due to gas coming out of solution during depressurization only.

(3) Run 2-2 also showed the sensitivity of this configuration to increases in depressurization rate.

R. McKillip, Test Conductor & Principal Investigator

CONTINUUM DYNAMICS, INC.
PRELIMINARY INFORMATION

# De-Gas Test Progress Report - 08

3/22/93

**Testing Date**: 3/19

**Goals:**

Quality-related data for Configuration #2 and #2a.

**Tests Completed**:

| Test # | Cfg # | Orifice | Gas & Conc. | Δt to P(final) | P(init) | P(final) | Level Error |
|---|---|---|---|---|---|---|---|
| | | (dia) | (in ppmv) | (sec) | (psia) | (psia) | (" H2O) |
| 2-5 | 2 | .266 | O2 @ 307 | LOCA | 1032 | 14.7 | 9.0" |
| 2-6 | 2 | .157 | O2 @ 307 | ATWS | 1034 | 14.7 | 8.3" |
| 2a-1 | 2 | .266 | O2 @ 1110 | LOCA | 1032 | 14.7 | 20.5" |

**Observations/Comments:**

(1) The horizontal-line .25" offset orifice was added to transform Configuration 2 to 2a.

(2) Run 2-5 and 2-6 were added to investigate lower-level concentration effects.

(3) Run 2a-1 shows nearly the same level error as Run 2-2, indicating that the horizontal orifice in Configuration 2a does not appear to have any significant effect on level error. This would suggest that flow velocities through this orifice in the horizontal section are low.

(4) Runs 2-5 and 2-6 show only a modest dependency on depressurization rate. Oxygen apprears to be less sensitive to depressurization rate than nitrogen (at the same volumetric concentrations), due to the fact that it comes out of solution at a later time in the depressurization time history.

R. McKillip, Test Conductor & Principal Investigator

PRELIMINARY INFORMATION

# De-Gas Test Progress Report - 09

3/23/93

**Testing Date:** 3/22

**Goals:**

Quality-related data for Configuration #2a.

**Tests Completed:**

| Test # | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Δt to P(final) (sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|
| 2a-2 | 2a | .266 | O2 @ 695 | LOCA | 1030 | 14.7 | 20.0" |
| 2a-3 | 2a | .266 | O2 @ 297 | LOCA | 1031 | 14.7 | 14.5" |
| 2a-4 | 2a | .157 | O2 @ 1141 | ATWS | 1030 | 14.7 | 3.7" |
| 2a-5 | 2a | .157 | O2 @ 616 | ATWS | 1031 | 14.7 | 3.8" |

**Observations/Comments:**

(1) Yesterday's comments on the influence of an orifice appear to have been premature. While the high-concentration LOCA results were close between Configurations #2 and 2a, the low (~300 ppmv O2) concentration LOCA runs actually showed an increase in level error with the added orifice. This may be due to the collection of gases near the orifice, with a subsequent release of some or most of this gas volume after a sufficient quantity had built up behind the orifice area. As with the differences between nitrogen and oxygen, the later that gas is released, the more detremental the effect on final level error.

(2) The orifice appears to reduce level errors for ATWS depressurization rates on this configuration, by almost a factor of two, when comparing the medium and high concentration results for oxygen gas of Configuration #2.

R. McKillip, Test Conductor & Principal Investigator

CONTINUUM DYNAMICS, INC.
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# De-Gas Test Progress Report - 10

3/24/93

**Testing Date**: 3/23

**Goals:**

Quality-related data for Configuration #2a and 2b.

**Tests Completed**:

| Test # | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Δt to P(final) (sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|
| 2a-6 | 2a | .157 | O2 @ 287 | ATWS | 1031 | 14.7 | 5.2" |
| 2b-1 | 2b | .266 | O2 @ 1130 | LOCA | 1031 | 14.7 | 41.7" |
| 2b-2 | 2b | .266 | O2 @ 626 | LOCA | 1031 | 14.7 | 40.5" |
| 2b-3 | 2b | .266 | O2 @ 297 | LOCA | 1031 | 14.7 | 10.8" |

**Observations/Comments:**

(1) Run 2a-6 actually showed a higher level error than the higher concentration tests at the ATWS rate. The time history for the DP1 cell showed the usual "dip", but at a sharper rate and much later time (near 750 seconds into the run), and then subsequent recovery, but in addition a secondary "dip" was observed after 1100 seconds into the depressurization.

(2) Discussions with the MATC Chairman and the Program Manager suggested that the original location for the orifice that simulates an excess flow check valve (in the vertical segment of Configuration 2b) was non-prototypical, since these devices are always found in the plant to be installed on horizontal pipe runs. As a result, this orifice was relocated to a point approximately 1 foot ahead of the elbow that connects the horizontal segment to the vertical segment. Since this orifice has a center-drilled hole, this location provided a "dam" behind which water could accumulate without flowing back down the horizontal segment into the vertical piece. Thus, when Configuration 2b was tested, large level errors were recorded, since there was no "recovery" of indicated level as the solution expanded in volume through this orifice and then did not return to refill all of the vertical segment of the reference leg. The time histories for tests 2b-1 through 2b-3 show the DP1 cell drop down and never recover from its low point, suggesting that water remained trapped in the horizontal segment, but not able to influence the "head" sensed by the DP1 cell. Since an actual excess flow check valve would allow flow in both directions, albeit at a reduced rate, these tests were deemed <u>non-prototypical</u>, and thus continued testing of Configuration 2b was not warranted.

R. McKillip, Test Conductor & Principal Investigator

CONTINUUM DYNAMICS, INC.
PRELIMINARY INFORMATION

# De-Gas Test Progress Report - 11

3/23/93

**Testing Date**: 3/24

**Goals:**

Quality-related data for Configuration #2c. A description of this configuration is provided below.

**Tests Completed**:

| Test # | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Δt to P(final) (sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|
| 2c-1 | 2c | .266 | O2 @ 1200 | LOCA | 1032 | 14.7 | 10.6" |
| 2c-2 | 2c | .266 | O2 @ 635 | LOCA | 1030 | 14.7 | 7.7" |
| 2c-3 | 2c | .266 | O2 @ 346 | LOCA | 1030 | 14.7 | 9.7" |

**Observations/Comments:**

(1) Configuration 2c was a modified form of Configuration 2a, with the same offset 1/4" orifice in the horizontal section, but a reduced vertical section of approximately 14 feet length (versus the nominal 28 foot vertical leg of Configuration 2a). This was done by cutting out the orifice piece for the simulation of the excess flow check valve (added in Configuration 2b), and cutting the vertical section roughly in half, with the instrument spool piece located approximately 13 feet off the floor. The purpose of this modification was to investigate the effect of having a shorter vertical segment on the resultant level error, since it is believed that the maximum continuous straight vertical section in a plant's reference leg is approximately 18 feet.

(2) Configuration 2c data show reductions in level error relative to 2a data ranging from roughly 30% to 50%. It is expected that these data will further help the correlation effort with the analytical model.

(3) Potential anomalies that may have produced the increase in level error for Test 2c-3 over 2c-2 have been investigated and discounted. It is this investigator's opinion that these data accurately reflect the physics of the de-gassing process for this configuration.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 12
3/26/93

**Testing Date**: 3/25

**Goals:**
Quality-related data for Configuration #2d. A description of this configuration is provided below.

**Tests Completed**:

| Test # | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Δt to P(final) (sec) | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|
| 2d-1 | 2d | .266 | O2 @ 1110 | LOCA | 1030 | 14.7 | 8.0" |
| 2d-2 | 2d | .266 | O2 @ 616 | LOCA | 1030 | 14.7 | 4.9" |
| 2d-3 | 2d | .266 | O2 @ 317 | LOCA | 1030 | 14.7 | 2.1" |
| 2d-4 | 2d | .157 | O2 @ 1110 | ATWS | 1030 | 14.7 | 2.9" |

**Observations/Comments:**

(1) Configuration 2d was also modified form of Configuration 2a, with the same offset 1/4" orifice in the horizontal section, but replacing the approximately 28 foot vertical segment with 1/2" stainless tubing. A new instrument spool piece was also fashioned from 1/4" tees and fittings, so as not to add any appreciable volume at the base of the stainless tubing. The purpose of this modification was to investigate the effect of having a different diameter vertical segment on the resultant level error.

(2) Configuration 2d data show reductions in steady-state level error relative to 2a data, but the transient DP1 cell time histories show large increases in magnitude change during depressurization. For example, the maximum transient swing for test 2a-1 (1100 ppmv O2 LOCA) was down to almost 40" indicated level decrease, whereas test 2d-1 had approximately twice that value.

(3) Time histories for the DP1 cell also showed notching-type behavior during the indicated level "recovery" portion of the test, with levels having a skewed triangle-wave like shape.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 13

3/29/93

**Testing Date**: 3/26

**Goals:**

Completion of quality-related data for Configuration #2d.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 40 | 2d-5 | 2d | .157 | O2 @ 715 | ATWS | 1027 | 14.7 | 2.2" |
| 41 | 2d-6 | 2d | .157 | O2 @ 317 | ATWS | 1031 | 14.7 | 1.9" |

**Observations/Comments:**

(1) The above completed the ATWS-rate runs for configuration 2d. Tests 2d-5 and 2d-6 showed transient level errors of 30 and 45 inches respectively, with the transient for 2d-6 occurring after almost 550 seconds into the depressurization event. 2d-6 also showed significant notching-type behavior.

(2) The remainder of 3/26 was devoted to the installation of Configuration 3 into the EPRI-NDE Center high-bay area..

(3) The above test # has been added for correlation with the transient pressure data plots that have been distributed, and refers to the number of the data file shown at the top of these plots.

R. McKillip, Test Conductor & Principal Investigator

# De-Gas Test Progress Report - 14

3/30/93

**Testing Date**: 3/29

**Goals:**

Start of quality-related data for Configuration #3.

**Tests Completed:**

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 42 | 3-1 | 3 | .266 | O2 @ 1200 | LOCA | 1031 | 14.7 | 34.9" |
| 43 | 3-2 | 3 | .266 | O2 @ 675 | LOCA | 1031 | 14.7 | 6.2" |
| 44 | 3-3 | 3 | .266 | O2 @ 376 | LOCA | 1031 | 14.7 | 5.3" |
| 45 | 3-3 | 3 | .266 | O2 @ 327 | LOCA | 1030 | 14.7 | 6.75" |

**Observations/Comments:**

(1) Runs 3-1 and 3-2 showed continued fluctuations of up to 2 inches in indicated level even after 20 minutes after depressurization.

(2) Run 3-3 was repeated in order to see if the transient data, which showed multiple notches, was repeatable, or if these fluctuations are somewhat random in nature. While the final level errors are close, the several notches seen in the transients in test 44 were replaced by a single, larger notch in test 45.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 15
3/31/93

**Testing Date**: 3/30

**Goals:**

Complete quality-related data for Configuration #3, and start #3a.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 46 | 3-4 | 3 | .157 | O2 @ 1150 | ATWS | 1030 | 14.7 | 10.0" |
| 47 | 3-5 | 3 | .157 | O2 @ 675 | ATWS | 1031 | 14.7 | 5.5" |
| 48 | 3-6 | 3 | .157 | O2 @ 336 | ATWS | 1030 | 14.7 | 6.2" |
| 49 | 3a-1 | 3a | .266 | O2 @ 1140 | LOCA | 1030 | 14.7 | 26.75" |

**Observations/Comments:**

(1) Runs 3-4 and 3-5 also showed continued fluctuations of 1 to 2 inches in indicated level after 20 minutes after depressurization.

(2) Run 3-6 had a single steep notch of almost 35" in depth, after 950 seconds into the depressurization,.with an equally steep recovery to its steady level of 6.2".

(3) Configuration 3a has an orifice located in the vertical segment approximately 4 feet below the spillway at the coupling chamber. Run 3a-1 had a level error that settled out to a few inches above the orifice location.

R. McKillip, Test Conductor & Principal Investigator

# De-Gas Test Progress Report - 16

4/1/93

**Testing Date**: 3/31

**Goals:**

Continue and complete collection of quality-related data for Configuration #3a.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|---|
| 50 | 3a-2 | 3a | .266 | O2 @ 606 | LOCA | | 1031 | 14.7 | 19.6" |
| 51 | 3a-3 | 3a | .266 | O2 @ 346 | LOCA | | 1031 | 14.7 | 11.7" |
| 52 | 3a-4 | 3a | .157 | O2 @ 1091 | ATWS | | 1031 | 14.7 | 20.6" |
| 53 | 3a-5 | 3a | .157 | O2 @ 635 | ATWS | | 1030 | 14.7 | 14.6" |
| 54 | 3a-6 | 3a | .157 | O2 @ 287 | ATWS | | 1030 | 14.7 | 9.6" |

**Observations/Comments:**

(1) Runs 3a-2 through 3a-5 were all characterized by a very slow, oscillatory recovery of the DP1 cell to its steady state value. The oscillations were also on the order of an inch in magnitude. Run 3a-6 had a similar transient shape, but was less oscillatory.

R. McKillip, Test Conductor & Principal Investigator

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PRELIMINARY INFORMATION

## De-Gas Test Progress Report - 17

4/2/93

**Testing Date**: 4/1

**Goals:**

Collection of quality-related data for Configuration #3d. See description below for this geometry.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|---|
| 55 | 3d-1 | 3a | .266 | O2 @ 1130 | LOCA | | 1030 | 14.7 | 25.5" |
| 56 | 3d-2 | 3a | .266 | O2 @ 655 | LOCA | | 1030 | 14.7 | 19.5" |
| 57 | 3d-3 | 3a | .266 | O2 @ 307 | LOCA | | 1031 | 14.7 | 11.7" |
| 58 | 3d-4 | 3a | .157 | O2 @ 1120 | ATWS | | 1030 | 14.7 | 13.7" |

**Observations/Comments:**

(1) Configuration 3d is a modified form of 3a, that also has an orifice approximately four feet below the center of the coupling chamber, but replaces the horizontal segment of 1" pipe with 1/2" diameter tubing.

(2) Comparison between configuration 3a and 3d LOCA end-point level errors shows almost no difference due to this reduction.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 18
4/5/93

**Testing Date**: 4/2

**Goals:**
Collection of quality-related data for Configuration #3d.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 59 | 3d-5 | 3d | .157 | O2 @ 635 | ATWS | 1030 | 14.7 | 12.4" |
| 60 | 3d-6 | 3d | .157 | O2 @ 336 | ATWS | 1030 | 14.7 | 7.0" |

**Observations/Comments:**

(1) Comparison between configuration 3a and 3d ATWS end-point level errors shows a modest decrease due to this change in horizontal segment diameter.

(2) A significant portion of the afternoon was required to install configuration 3c, which is similar to configuration 3a but with a vertical segment of approximately half its original vertical length.

R McKillip

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 19

4/6/93

**Testing Date**: 4/5

**Goals:**

Start of collection of quality-related data for Configuration #3c.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 61 | 3c-1 | 3c | .266 | O2 @ 1081 | LOCA | 1030 | 14.7 | 28.7" |
| 62 | 3c-2 | 3c | .266 | O2 @ 626 | LOCA | 1030 | 14.7 | 8.5" |
| 63 | 3c-3 | 3c | .266 | O2 @ 297 | LOCA | 1030 | 14.7 | 5.0" |
| 64 | 3c-4 | 3c | .157 | O2 @ 1150 | ATWS | 1030 | 14.7 | 21.9" |
| 65 | 3c-5 | 3c | .157 | O2 @ 616 | ATWS | 1030 | 14.7 | 8.9" |

**Observations/Comments:**

(1) Configuration 3c is similar to configuration 3a but with a vertical segment of approximately half its original vertical length. This configuration modification will help provide similar data as was done in the modification of configuration 2 to investigate degassing effects of shortened vertical runs.

(2) Comparison between the above end point levels and those of 3a show that reductions are present in the medium and low concentration levels tested, but no significant change was seen when solutions of 1100 ppmv nominal concentration were tested.

(3) Only a weak sensitivity is shown to depressurization rate in the above data, which parallels that seen in configuration 3a.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 20

4/7/93

**Testing Date**: 4/6

**Goals:**

Completion of testing for Configuration #3c and start of collection of quality-related data for Configuration #3e. A description of this configuration is below.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 66 | 3c-6 | 3c | .157 | O2 @ 287 | ATWS | 1030 | 14.7 | 1.7" |
| 67 | 3e-1 | 3e | .266 | O2 @ 1150 | LOCA | 1030 | 14.7 | 18.6" |
| 68 | 3e-2 | 3e | .266 | O2 @ 616 | LOCA | 1030 | 14.7 | 6.1" |
| 69 | 3e-3 | 3e | .266 | O2 @ 327 | LOCA | 1030 | 14.7 | 5.6" |
| 70 | 3e-4 | 3e | .157 | O2 @ 1150 | ATWS | 1031 | 14.7 | 17.1" |

**Observations/Comments:**

(1) Configuration 3e is similar to configuration 3c but with a horizontal segment sloped at 1/4" per foot. This configuration modification will provide data to investigate degassing effects of differently sloped horizontal runs.

(2) Comparison between the above end point levels and those of 3c show that, in general, reductions in end point level errors may be realized in reduced sloped horizontal segments, but the transient data exhibits an increased "notching" behavior.

(3) Test #66 (Run 3c-6) has a time history that does not start at the instant of depressurization. The data acquisition card created a hardware I/O fault 14 seconds into the run, and the program was restarted after a few seconds into the depressurization. No portion of the degassing transient observed on the DP1 cell was missed due to this problem, however. This card is being replaced with one that has a suitably large data buffer to eliminate this problem.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 21

4/8/93

**Testing Date**: 4/7

**Goals:**

Completion of testing for Configuration #3e.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 71 | 3e-5 | 3e | .157 | O2 @ 596 | ATWS | 1030 | 14.7 | 4.0" |
| 72 | 3e-6 | 3e | .157 | O2 @ 287 | ATWS | 1030 | 14.7 | 5.1" |

**Observations/Comments:**

(1) These two ATWS runs at the middle and low concentration levels showed mixed results compared with Configuration 3c, in that the 600 ppmv test showed a reduction in level error, while the 300 ppmv test showed an increase. The time history for the 300 ppmv test showed increased triangular-wave type of notching.

(2) The remainder of the day was used in the installation of Configuration #5, which involves an approximately 30 foot vertical drop from the coupling chamber, followed by a long horizontal run of almost 120 feet, and ending in a 22 foot vertical drop into the HIPS pit to the DP1 cell location.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 22

4/9/93

**Testing Date**: 4/8

**Goals:**

Start of testing for Configuration #6. This configuration is described in the comments below.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 73 | 6-1 | 6 | .266 | O2 @ 1130 | LOCA | 1030 | 14.7 | 324.4" |
| 74 | 6-1 | 6 | .266 | O2 @ 1021 | LOCA | 1030 | 14.7 | 324.3" |
| 75 | 6-2 | 6 | .266 | O2 @ 556 | LOCA | 1030 | 14.7 | 313.8" |
| 76 | 6-3 | 6 | .266 | O2 @ 268 | LOCA | 1030 | 14.7 | 51.8" |
| 77 | 6-4 | 6 | .157 | O2 @ 1071 | ATWS | 1030 | 14.7 | 213.9" |

**Observations/Comments:**

(1) Configuration #6 consists of 1" SCH 80 stainless steel pipe, that has an approximately 30' vertical drop from the coupling chamber, followed by a 120' horizontal run at 1/2" per foot slope, and then a 22' vertical drop to the DP1 cell.

(2) The level errors shown above indicate that the first vertical leg out of the coupling chamber is voided after all transients have decayed.

(3) Run 5-1 was repeated to assess whether the result was an anomaly, or if it reflected the physics of the process. Almost exact repeatability was achieved on both the final level error and the transient DP1 reading.

R. McKillip, Test Conductor & Principal Investigator

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# MEMORANDUM

April 9, 1993

To: Model and Test Committee Members

From: J Munchausen

SUBJECT: CONFIGURATION 6 TEST RESULTS

Results from the Loss of Coolant Accident (LOCA) depressurization rate tests performed on configuration 6 yielded results of a magnitude not previously seen during the testing program. Though these test results yielded level errors that are substantially greater than those seen before, careful analysis of the results show that they are very geometry dependent and predictable.

Recall that in testing previous configurations in which a vertical run was directly connected to the condensing chamber, substantial level errors resulted from the 1100 ppmv gas concentration tests (particularly at the LOCA depressurization rates). Configuration 6 represents a test configuration which has over 2/3 of the total volume in the horizontal run. The gas contained in this horizontal run, if released from solution and expanded to atmospheric pressure, is sufficient to displace all the mass in the 27 foot vertical pipe connected to the condensing chamber. The level error observed in the Configuration 6 tests represents the total volume of the vertical leg voided of water. The level error would have been the same for any gas concentration above approximately 700 ppmv. It would have been no better at 800 ppmv nor worse at 1500 ppmv. Had the first vertical leg been 2 feet, a much smaller error (on the order of 2 feet) would have been the final result. Recognize that, once the water mass in the condensing chamber and first vertical leg has been evacuated (returned to the pressure vessel through the steam inlet piping), additional level error beyond the first vertical run length connecting the condensing chamber to the first horizontal run is difficult to achieve, because a path with essentially no resistance now exists to the RPV for additional gas which is subsequently released. Therefore remaining gas transiting through the horizontal pipe run will be vented back to the pressure vessel.

No plant has a contiguous vertical rise of more than 19 feet. Most plants have a very short vertical "stub" connecting the condensing chamber to a substantial horizontal pipe run. This generic design configuration limits the potential level error that might be realized during a worst case transient (LOCA depressurization rate with homogeneous 1100 ppmv gas concentration) to several orders of magnitude less than that seen in the Configuration 6 tests.

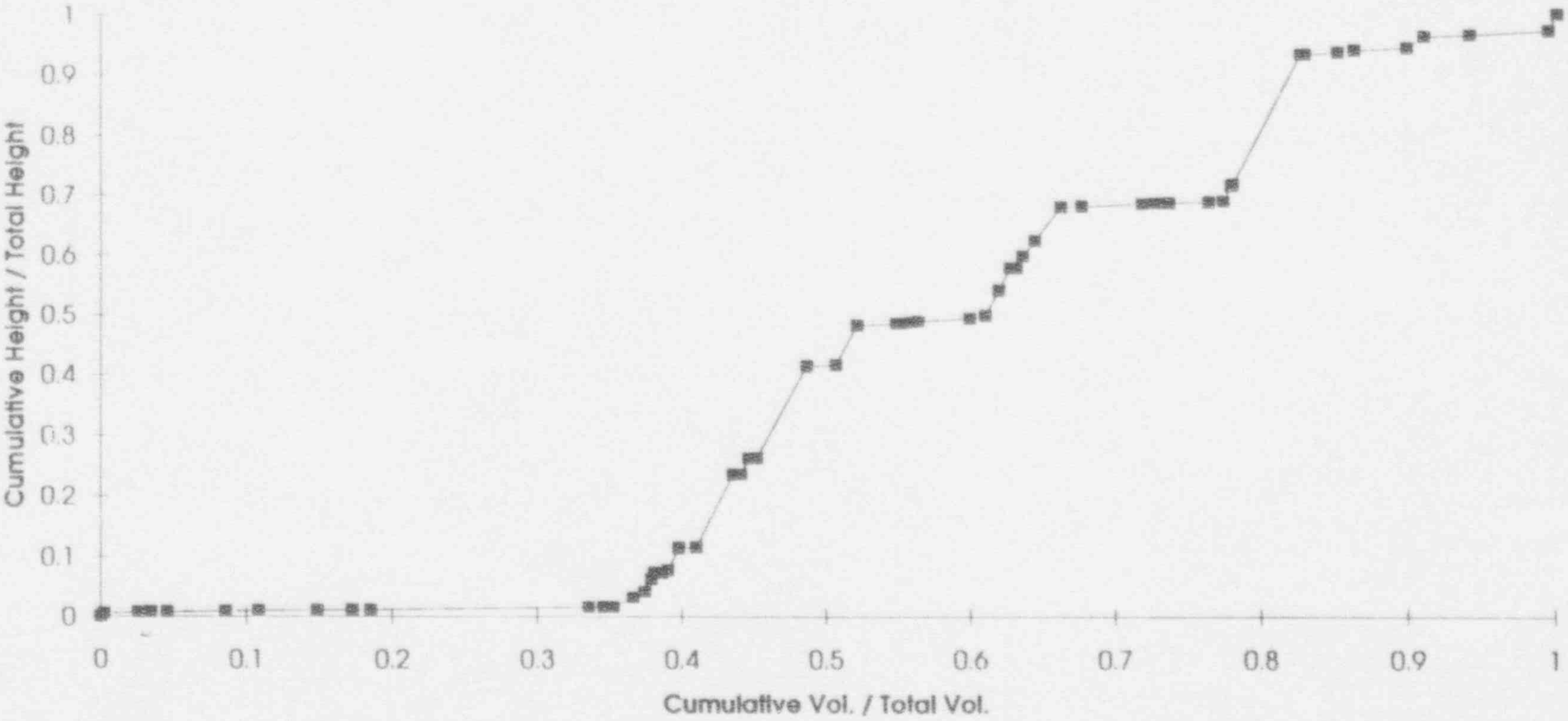
Beginning Monday, April 12, and culminating the testing program on Friday, April 16, we will test a full scale mock-up of the Washington Public Power Supply System WNP2 "C" leg. The testing will include the same gas concentrations and depressurization rates previously tested with the addition of a slow, typical shutdown rate similar to that observed during their January 21 event. *If the above observations on geometry dependence are essentially correct, we anticipate a 2 foot level error for the WNP2 "C" leg during LOCA depressurization rate, with dissolved gas concentration of 1100 ppmv (see Attachment 1).*

If there are any questions regarding the test results seen to date please feel free to call me at (704) 547-6058. A complete package containing all testing results, plots from individual tests, and specific geometry for all tests will be provided during the MATC meetings on April 19 and 20.

JHM\93240001.24

Attachment 1

WNP-2 Channel "C"



## De-Gas Test Progress Report - 23
4/12/93

**Testing Date**: 4/9

**Goals:**
Completion of testing for Configuration #6.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 78 | 6-5 | 6 | .157 | O2 @ 616 | ATWS | 1030 | 14.7 | N/A |
| 79 | 6-6 | 6 | .157 | O2 @ 287 | ATWS | 1030 | 14.7 | 47.9" |
| 80 | 6-5 | 6 | .157 | O2 @ 556 | ATWS | 1030 | 14.7 | 203.9" |

**Observations/Comments:**

(1) Test #78 suffered a power outage during the blowdown, due to concurrent installation of Configuration #7 piping, and so the test conditions were repeated.

(2) The ATWS rate shows reduction in final level error, consistent with results from previous testing.

R. McKillip, Test Conductor & Principal Investigator

# De-Gas Test Progress Report - 24

4/14/93

**Testing Date**: 4/13

**Goals:**

Start of testing for Configuration #7. This configuration is described below.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 81 | 7-1 | 7 | .266 | O2 @ 1091 | LOCA | 1031 | 14.7 | N/A |
| 82 | 7-1 | 7 | .266 | O2 @ 1130 | LOCA | 1030 | 14.7 | 70.1" |
| 83 | 7-1 | 7 | .266 | O2 @ 1110 | LOCA | 1029 | 14.7 | 83.2" |

**Observations/Comments:**

(1) Configuration #7 is a mock-up of the WNP-2 "C" channel. This configuration has a total vertical drop of 42', comprised of 15' of 3/4" pipe, 8' of 1" pipe, and 120' of 1/2" 0.065" wall tubing. The piping bends, horizontal runs, and elevations are physically correct for the WNP-2 C-channel reference leg.

(2) Test # 81 was aborted due to noise on the pressure transducer signals when using the replacement data acquisition card. The original data acquisition unit was reinstalled and shows no such oscillations.

(3) On run 83, water was drained from the leg at the completion of the test to verify the final level error. The measured volume was significantly higher than the differential pressure transducer reading would suggest, based upon volume calculations from the as-installed piping. Based upon this remaining mass in the reference leg, the final level error should be near 30". Additional post-test procedures have been added to further investigate this discrepancy.

(4) Notching behavior was observed well after the LOCA depressurization reached atmospheric pressure. Transients were recorded after almost 40 minutes into the depressurization event, as shown on the continuation of the pressure transducer transient time history for run 83.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 25
4/15/93

**Testing Date**: 4/14

**Goals:**

Continuation of testing for Configuration #7, the WNP-2 mock-up.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 84 | 7-2 | 7 | .266 | O2 @ 695 | LOCA | 1030 | 14.7 | 24.0" |
| 85 | 7-3 | 7 | .266 | O2 @ 307 | LOCA | 1030 | 14.7 | 10.4" |
| 86 | 7-4 | 7 | .157 | O2 @ 1209 | ATWS | 1030 | 14.7 | 104.7" |
| 87 | 7-5 | 7 | .157 | O2 @ 616 | ATWS | 1030 | 14.7 | 14.4" |
| 88 | 7-6 | 7 | .157 | O2 @ 317 | ATWS | 1030 | 14.7 | 11.1" |
| 89 | 7-7 | 7 | .266 | O2 @ 42 | LOCA | 1030 | 14.7 | 0.0" |

**Observations/Comments:**

(1) Post-blowdown repressurization was performed after each run to collapse any bubbles still remaining in any vertical piping/tubing segments, and the indicated DP1 level was recorded at pressure. This was then corrected for the "head" of gas in the 2" pipe supporting the coupling chamber, which would give an indication of the water level if all the gas remaining in the line were to vent through the free surface at the coupling chamber. These "calculated" levels compared favorably with the calculated level errors based upon the water volume measured when the reference leg was drained.

(2) Notching was seen on all transients except for Run #89, which showed no level error.

(3) This aggressive testing program has allowed the collection of slow depressurization transient data on the remaining testing days.

R. McKillip, Test Conductor & Principal Investigator

CONTINUUM DYNAMICS, INC.
PRELIMINARY INFORMATION

## De-Gas Test Progress Report - 26
4/16/93

**Testing Date**: 4/15

**Goals:**
Slow depressurization testing for Configuration #7, the WNP-2 mock-up.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 90 | 7-8 | 7 | n/a | O2 @ 715 | see below | 1015 | 14.7 | 7.1" |

**Observations/Comments:**

(1) A slow depressurization test lasting almost eight hours was performed on Configuration #7 to simulate reactor pressure over a shutdown event. The pressure vessel time history simulates the shutdown and cooldown for WNP-2 during their January 21 event..

(2) Small notching was observed when the pressure reached 120 psia, with the largest notches (of approximately 32-35" ) occuring during the shutdown cooling portion of the depressurization curve.

(3) The recorded transient data plots cover 29 pages, and will be distributed to MATC members at next week's meeting.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 25
4/15/93

**Testing Date**: 4/14

**Goals:**
Continuation of testing for Configuration #7, the WNP-2 mock-up.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 84 | 7-2 | 7 | .266 | O2 @ 695 | LOCA | 1030 | 14.7 | 24.0" |
| 85 | 7-3 | 7 | .266 | O2 @ 307 | LOCA | 1030 | 14.7 | 10.4" |
| 86 | 7-4 | 7 | .157 | O2 @ 1209 | ATWS | 1030 | 14.7 | 104.7" |
| 87 | 7-5 | 7 | .157 | O2 @ 616 | ATWS | 1030 | 14.7 | 14.4" |
| 88 | 7-6 | 7 | .157 | O2 @ 317 | ATWS | 1030 | 14.7 | 11.1" |
| 89 | 7-7 | 7 | .266 | O2 @ 42 | LOCA | 1030 | 14.7 | 0.0" |

**Observations/Comments:**

(1) Post-blowdown repressurization was performed after each run to collapse any bubbles still remaining in any vertical piping/tubing segments, and the indicated DP1 level was recorded at pressure. This was then corrected for the "head" of gas in the 2" pipe supporting the coupling chamber, which would give an indication of the water level if all the gas remaining in the line were to vent through the free surface at the coupling chamber. These "calculated" levels compared favorably with the calculated level errors based upon the water volume measured when the reference leg was drained.

(2) Notching was seen on all transients except for Run #89, which showed no level error.

(3) This aggressive testing program has allowed the collection of slow depressurization transient data on the remaining testing days.

R. McKillip, Test Conductor & Principal Investigator

## De-Gas Test Progress Report - 26

4/16/93

**Testing Date**: 4/15

**Goals:**
Slow depressurization testing for Configuration #7, the WNP-2 mock-up.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 90 | 7-8 | 7 | n/a | O2 @ 715 | see below | 1015 | 14.7 | 7.1" |

**Observations/Comments:**

(1) A slow depressurization test lasting almost eight hours was performed on Configuration #7 to simulate reactor pressure over a shutdown event. The pressure vessel time history simulates the shutdown and cooldown for WNP-2 during their January 21 event..

(2) Small notching was observed when the pressure reached 120 psia, with the largest notches (of approximately 32-35" ) occuring during the shutdown cooling portion of the depressurization curve.

(3) The recorded transient data plots cover 29 pages, and will be distributed to MATC members at next week's meeting.

R. McKillip, Test Conductor & Principal Investigator

# De-Gas Test Progress Report - 27

4/26/93

CONTINUUM DYNAMICS, INC.
PRELIMINARY INFORMATION

**Testing Date**: 4/16, 4/22, and 4/23

**Goals:**
Various concentration and depressurization tests for Configuration #7, the WNP-2 mock-up, including a demonstration test for the BWROG Water Level Committee.

**Tests Completed**:

| Test # | Run# | Cfg # | Orifice (dia) | Gas & Conc. (in ppmv) | Rate | P(init) (psia) | P(final) (psia) | Level Error (" H2O) |
|---|---|---|---|---|---|---|---|---|
| 91 | 7-9 | 7 | n/a | O2 @ 715 | see below | 1015 | 14.7 | 7.1" |
| 92 | 7-10 | 7 | .266 | O2 513 | LOCA | 1030 | 14.7 | 14.7" |
| 93 | 7-11 | 7 | n/a | O2 179 | see below | 1015 | 14.7 | 0.8" |
| 94 | 7-12 | 7 | .157 | O2 179 | ATWS | 1015 | 14.7 | 0.8" |

Observations/Comments:

1) Friday, April 16 a test run was made on Configuration 7 using an O2 concentration of 317 ppmv at a simulated normal shutdown rate. The run yielded a 2.7" resultant error.

2) On Thursday, April 22 run 92 was performed as a demonstration run for the BWROG Water Level Committee. This test used an O2 concentration of 513 ppmv at a LOCA depressurization rate. The test produced transient errors of approximately 32 inches and an endpoint error of 14.7 inches. Note that the first occurrence of "notching" did not occur until more than 5 minutes had elapsed after reaching atmospheric pressure.

3) At the request of the BWROG Model and Test Committee, two additional test runs were performed on Friday, April 23. The purpose of these tests were to determine a possible lower gas concentration at which non-condensible gases would not provide level errors at ATWS and normal S/D depressurization rates. Both tests yielded errors of 0.8 inches. Note the two "spikes" in run 93 at approximately 28,500 seconds is the result of an arc from an arc welder being struck near the test rig.

J.H. Munchausen

De-Gas Testing Summary

| Date | Run # | Test # | Config. | Gas Type | Conc. | Orifice | dt to Pfinal | P(initial) | P(final) | Level Err | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10-Mar | 1-1 | 1 | 1 | N2 | 597 | 0.25 | 210 | 1027 | 23 | 3.1 | |
| 10-Mar | | 2 | 1 | N2 | 637 | <.25 | 500 | 1037 | 14.7 | 1.5 | 1 |
| 10-Mar | 1-2 | 3 | 1 | N2 | 617 | 0.25 | 210 | 1036 | 24 | 3.1 | |
| 11-Mar | | 4 | 1 | N2 | 647 | 0.313 | 130 | 1040 | 14.7 | 7.8 | |
| 11-Mar | 1-3 | 5 | 1 | N2 | 627 | 0.25 | 260 | 1036 | 14.7 | 3.4 | |
| 11-Mar | 1-5 | 6 | 1 | N2 | 109 | 0.25 | 210 | 1033 | 24 | 0.0 | |
| 11-Mar | 1-4 | 7 | 1 | N2 | 100 | 0.25 | 260 | 1037 | 14.7 | n/a | 2 |
| 12-Mar | 1-4 | 8 | 1 | N2 | 79 | 0.266 | LOCA | 1032 | 14.7 | 0.0 | |
| 12-Mar | 1-7 | 9 | 1 | O2 | 1021 | 0.266 | LOCA | 1021 | 24 | 36.3 | |
| 12-Mar | 1-6 | 10 | 1 | O2 | 1061 | 0.266 | LOCA | 1030 | 14.7 | 44.8 | |
| 15-Mar | 1-10 | 11 | 1 | O2 | 1071 | 0.157 | ATWS | 1036 | 14.7 | 4.0 | |
| 15-Mar | 1-9 | 12 | 1 | N2 | 657 | 0.157 | ATWS | 1036 | 14.7 | 0.9 | |
| 16-Mar | 2-1 | 13 | 2 | O2 | 1160 | 0.157 | ATWS | 1035 | 14.7 | 17.9 | 3 |
| 16-Mar | 2-4 | 14 | 2 | N2 | 567 | 0.157 | ATWS | 1029 | 14.7 | 3.6 | |
| 16-Mar | 2-4 | 15 | 2 | N2 | 607 | 0.157 | ATWS | 1030 | 14.7 | 3.8 | |
| 17-Mar | 2-4 | 16 | 2 | N2 | 647 | 0.157 | ATWS | 1034 | 14.7 | 3.7 | |
| 17-Mar | 2-4 | 17 | 2 | O2 | 547 | 0.157 | ATWS | 1030 | 14.7 | 6.8 | |
| 17-Mar | 2-3 | 18 | 2 | N2 | 617 | 0.266 | LOCA | 1030 | 14.7 | 19.5 | |
| 18-Mar | 2-1 | 19 | 2 | O2 | 1110 | 0.157 | ATWS | 1031 | 14.7 | 6.9 | |
| 18-Mar | 2-1 | 20 | 2 | O2 | 1130 | 0.157 | ATWS | 1029 | 14.7 | 6.9 | |
| 18-Mar | 2-2 | 21 | 2 | O2 | 1170 | 0.266 | LOCA | 1030 | 14.7 | 21.4 | |
| 19-Mar | 2-5 | 22 | 2 | O2 | 307 | 0.266 | LOCA | 1032 | 14.7 | 9.0 | |
| 19-Mar | 2-6 | 23 | 2 | O2 | 307 | 0.157 | ATWS | 1034 | 14.7 | 8.3 | |
| 19-Mar | 2a-1 | 24 | 2a | O2 | 1110 | 0.266 | LOCA | 1032 | 14.7 | 20.5 | |
| 22-Mar | 2a-2 | 25 | 2a | O2 | 695 | 0.266 | LOCA | 1030 | 14.7 | 20.0 | |
| 22-Mar | 2a-3 | 26 | 2a | O2 | 297 | 0.266 | LOCA | 1031 | 14.7 | 14.5 | |
| 22-Mar | 2a-4 | 27 | 2a | O2 | 1141 | 0.157 | ATWS | 1030 | 14.7 | 3.7 | |
| 22-Mar | 2a-5 | 28 | 2a | O2 | 616 | 0.157 | ATWS | 1031 | 14.7 | 3.8 | |
| 23-Mar | 2a-6 | 29 | 2a | O2 | 287 | 0.157 | ATWS | 1031 | 14.7 | 5.2 | |
| 23-Mar | 2b-1 | 30 | 2b | O2 | 1130 | 0.266 | LOCA | 1031 | 14.7 | 41.7 | |
| 23-Mar | 2b-2 | 31 | 2b | O2 | 626 | 0.266 | LOCA | 1031 | 14.7 | 40.5 | |
| 23-Mar | 2b-3 | 32 | 2b | O2 | 297 | 0.266 | LOCA | 1031 | 14.7 | 10.8 | |
| 24-Mar | 2c-1 | 33 | 2c | O2 | 1200 | 0.266 | LOCA | 1032 | 14.7 | 10.6 | |
| 24-Mar | 2c-2 | 34 | 2c | O2 | [illegible] | [illegible] | LOCA | 1030 | [illegible] | 7.7 | |
| 24-Mar | 2c-3 | 35 | 2c | O2 | [illegible] | [illegible] | LOCA | [illegible] | [illegible] | [illegible] | |
| 25-Mar | 2d-1 | 36 | 2d | O2 | 1110 | 0.266 | LOCA | 1030 | 14.7 | 8.0 | |
| 25-Mar | 2d-2 | 37 | 2d | O2 | 616 | 0.266 | LOCA | 1030 | 14.7 | 4.9 | |
| 25-Mar | 2d-3 | 38 | 2d | O2 | 317 | 0.266 | LOCA | 1030 | 14.7 | 2.1 | |
| 25-Mar | 2d-4 | 39 | 2d | O2 | 1110 | 0.157 | ATWS | 1030 | 14.7 | 2.9 | |
| 26-Mar | 2d-5 | 40 | 2d | O2 | 715 | 0.157 | ATWS | 1027 | 14.7 | 2.2 | |
| 26-Mar | 2d-6 | 41 | 2d | O2 | 317 | 0.157 | ATWS | 1031 | 14.7 | 1.9 | |
| 29-Mar | 3-1 | 42 | 3 | O2 | 1200 | 0.266 | LOCA | 1031 | 14.7 | 34.9 | |
| 29-Mar | 3-2 | 43 | 3 | O2 | 675 | 0.266 | LOCA | 1031 | 14.7 | 6.2 | |
| 29-Mar | 3-3 | 44 | 3 | O2 | 376 | 0.266 | LOCA | 1031 | 14.7 | 5.3 | |
| 29-Mar | 3-3 | 45 | 3 | O2 | 327 | 0.266 | LOCA | 1030 | 14.7 | 6.8 | |
| 30-Mar | 3-4 | 46 | 3 | O2 | 1150 | 0.157 | ATWS | 1030 | 14.7 | 10.0 | |
| 30-Mar | 3-5 | 47 | 3 | O2 | 675 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
| 30-Mar | 3-6 | 48 | 3 | [illegible] | [illegible] | 0.157 | [illegible] | [illegible] | [illegible] | [illegible] | |
| 30-Mar | 3a-1 | 49 | 3a | O2 | 1140 | 0.266 | LOCA | 1030 | 14.7 | 26.8 | |
| 31-Mar | 3a-2 | 50 | 3a | O2 | 606 | 0.266 | LOCA | 1031 | 14.7 | 19.6 | |
| 31-Mar | 3a-3 | 51 | 3a | O2 | 346 | 0.266 | LOCA | 1031 | 14.7 | 11.7 | |
| 31-Mar | 3a-4 | 52 | 3a | O2 | 1091 | [illegible] | ATWS | 1031 | 14.7 | 20.6 | |
| 31-Mar | 3a-5 | 53 | 3a | O2 | 635 | [illegible] | ATWS | 1030 | 14.7 | 14.6 | |
| 31-Mar | 3a-6 | 54 | 3a | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 9.6 | |
| 01-Apr | 3d-1 | 55 | 3d | O2 | 1130 | 0.266 | LOCA | 1030 | 14.7 | 25.5 | |
| 01-Apr | 3d-2 | 56 | 3d | O2 | 655 | 0.266 | LOCA | 1030 | 14.7 | 19.5 | |
| 01-Apr | 3d-3 | 57 | 3d | O2 | 307 | 0.266 | LOCA | 1030 | 14.7 | 11.7 | |
| 01-Apr | 3d-4 | 58 | 3d | O2 | 1120 | 0.157 | ATWS | 1029 | 14.7 | 13.7 | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 02-Apr | 3d-5 | 59 | 3d | O2 | 636 | 0.157 | ATWS | 1030 | 14.7 | 12.4 | |
| 02-Apr | 3d-6 | 60 | 3d | O2 | 336 | 0.157 | ATWS | 1030 | 14.7 | 7.0 | |
| 05-Apr | 3c-1 | 61 | 3c | O2 | 1081 | 0.266 | LOCA | 1030 | 14.7 | 28.7 | |
| 05-Apr | 3c-2 | 62 | 3c | O2 | 626 | 0.266 | LOCA | 1030 | 14.7 | 8.5 | |
| 05-Apr | 3c-3 | 63 | 3c | O2 | 297 | 0.266 | LOCA | 1030 | 14.7 | 5.0 | |
| 06-Apr | 3c-4 | 64 | 3c | O2 | 1150 | 0.157 | ATWS | 1030 | 14.7 | 21.9 | |
| 06-Apr | 3c-5 | 65 | 3c | O2 | 616 | 0.157 | ATWS | 1030 | 14.7 | 8.9 | |
| 06-Apr | 3c-6 | 66 | 3c | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 1.7 | |
| 06-Apr | 3e -1 | 67 | 3e | O2 | 1150 | 0.266 | LOCA | 1030 | 14.7 | [illegible] | |
| 06-Apr | 3e -2 | 68 | 3e | O2 | 616 | 0.266 | LOCA | 1030 | 14.7 | 6.1 | |
| 06-Apr | 3e -3 | 69 | 3e | O2 | 327 | 0.266 | LOCA | 1030 | 14.7 | 5.6 | |
| 06-Apr | 3e -4 | 70 | 3e | O2 | 1150 | 0.157 | ATWS | 1031 | 14.7 | 17.1 | |
| 07-Apr | 3e -5 | 71 | 3e | O2 | 596 | 0.157 | ATWS | 1030 | 14.7 | 4.0 | |
| 07-Apr | 3e -6 | 72 | 3e | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 5.1 | |
| 08-Apr | 6-1 | 73 | 6 | O2 | 1130 | 0.266 | LOCA | 1030 | 14.7 | 324.4 | |
| 08-Apr | 6-2 | 74 | 6 | O2 | 1021 | 0.266 | LOCA | 1030 | 14.7 | 324.3 | |
| 08-Apr | 6-3 | 75 | 6 | O2 | 556 | 0.266 | LOCA | 1030 | 14.7 | 313.8 | |
| 08-Apr | 6-4 | 76 | 6 | O2 | 268 | 0.266 | LOCA | 1030 | 14.7 | 51.8 | |
| 08-Apr | 6-5 | 77 | 6 | O2 | 1071 | 0.157 | ATWS | 1030 | 14.7 | 213.9 | |
| 09-Apr | 6-5 | 78 | 6 | O2 | 616 | 0.157 | ATWS | 1030 | 14.7 | n/a | 4 |
| 09-Apr | 6-6 | 79 | 6 | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 47.9 | |
| 09-Apr | 6-5 | 80 | 6 | O2 | 556 | 0.157 | ATWS | 1030 | 14.7 | 203.9 | |
| 13-Apr | 7-1 | 81 | 7 | O2 | 1091 | 0.266 | LOCA | 1031 | 14.7 | n/a | 5 |
| 13-Apr | 7-1 | 82 | 7 | O2 | 1130 | 0.266 | LOCA | 1030 | 14.7 | 70.1 | |
| 13-Apr | 7-1 | 83 | 7 | O2 | 1110 | 0.266 | LOCA | 1029 | 14.7 | 83.2 | |
| 14-Apr | 7-2 | 84 | 7 | O2 | 695 | 0.266 | LOCA | 1030 | 14.7 | 24.0 | |
| 14-Apr | 7-3 | 85 | 7 | O2 | 307 | 0.266 | LOCA | 1030 | 14.7 | 10.4 | |
| 14-Apr | 7-4 | 86 | 7 | O2 | 1209 | 0.157 | ATWS | 1030 | 14.7 | 104.7 | |
| 14-Apr | 7-5 | 87 | 7 | O2 | 616 | 0.157 | ATWS | 1030 | 14.7 | 14.4 | |
| 14-Apr | 7-6 | 88 | 7 | O2 | 317 | 0.157 | ATWS | 1030 | 14.7 | 11.1 | |
| 14-Apr | 7-7 | 89 | 7 | O2 | 42 | 0.266 | LOCA | 1030 | 14.7 | 0.0 | |
| 15-Apr | 7-8 | 90 | 7 | O2 | 715 | n/a | S.D. | 1015 | 14.7 | 7.1 | |
| 16-Apr | 7-9 | 91 | 7 | O2 | 327 | n/a | S.D. | 1015 | 14.7 | 6.8 | |

Notes:

(1) A stuck solenoid valve forced a blowdown using the nitrogen injection port.

(2) Improper re-injection of pre-mixed solution following sample resulted in a reference leg that was not completely filled prior to blowdown.

(3) Pre-mixed tank ran "dry" during latter portion of solution injection, introducing gas into the reference leg and resulting in large errors.

(4) Suffered power outage during blowdown event.

(5) Noise on replacement data acquisition card invalidated transient data.

PRELIMINARY INFORMATION

## De-Gas Testing Summary

| Date | Run # | Test # | Config. | Gas Type | Conc. | Orifice | dt to Pfinal | P(initial) | P(final) | Level Err | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10-Mar | 1-1 | 1 | 1 | N2 | 597 | 0.25 | 210 | 1027 | 23 | 3.1 | |
| 10-Mar | | 2 | 1 | N2 | 637 | <.25 | 500 | 1037 | 14.7 | 1.5 | 1 |
| 10-Mar | 1-2 | 3 | 1 | N2 | 617 | 0.25 | 210 | 1036 | 24 | 3.1 | |
| 11-Mar | | 4 | 1 | N2 | 647 | 0.313 | 130 | 1040 | 14.7 | 7.8 | |
| 11-Mar | 1-3 | 5 | 1 | N2 | 627 | 0.25 | 260 | 1036 | 14.7 | 3.4 | |
| 11-Mar | 1-5 | 6 | 1 | N2 | 109 | 0.25 | 210 | 1033 | 24 | 0.0 | |
| 11-Mar | 1-4 | 7 | 1 | N2 | 100 | 0.25 | 260 | 1037 | 14.7 | n/a | 2 |
| 12-Mar | 1-4 | 8 | 1 | N2 | 79 | 0.266 | LOCA | 1032 | 14.7 | 0.0 | |
| 12-Mar | 1-7 | 9 | 1 | O2 | 1021 | 0.266 | LOCA | 1021 | 24 | 35.3 | |
| 12-Mar | 1-6 | 10 | 1 | O2 | 1051 | 0.266 | LOCA | 1030 | 14.7 | 44.5 | |
| 15-Mar | 1-10 | 11 | 1 | O2 | 1071 | 0.157 | ATWS | 1036 | 14.7 | 4.0 | |
| 15-Mar | 1-9 | 12 | 1 | N2 | 657 | 0.157 | ATWS | 1036 | 14.7 | 0.9 | |
| 16-Mar | 2-1 | 13 | 2 | O2 | 1160 | 0.157 | ATWS | 1035 | 14.7 | 17.9 | 3 |
| 16-Mar | 2-4 | 14 | 2 | N2 | 567 | 0.157 | ATWS | 1029 | 14.7 | 3.6 | |
| 16-Mar | 2-4 | 15 | 2 | N2 | 607 | 0.157 | ATWS | 1030 | 14.7 | 3.8 | |
| 17-Mar | 2-4 | 16 | 2 | N2 | 647 | 0.157 | ATWS | 1034 | 14.7 | 3.7 | |
| 17-Mar | 2-4 | 17 | 2 | O2 | 547 | 0.157 | ATWS | 1030 | 14.7 | 6.8 | |
| 17-Mar | 2-3 | 18 | 2 | N2 | 617 | 0.266 | LOCA | 1030 | 14.7 | 19.5 | |
| 18-Mar | 2-1 | 19 | 2 | O2 | 1110 | 0.157 | ATWS | 1031 | 14.7 | 6.9 | |
| 18-Mar | 2-1 | 20 | 2 | O2 | 1130 | 0.157 | ATWS | 1029 | 14.7 | 6.9 | |
| 18-Mar | 2-2 | 21 | 2 | O2 | 1170 | 0.266 | LOCA | 1030 | 14.7 | 21.4 | |
| 19-Mar | 2-5 | 22 | 2 | O2 | 307 | 0.266 | LOCA | 1032 | 14.7 | 9.0 | |
| 19-Mar | 2-6 | 23 | 2 | O2 | 307 | 0.157 | ATWS | 1034 | 14.7 | 8.3 | |
| 19-Mar | 2a-1 | 24 | 2a | O2 | 1110 | 0.266 | LOCA | 1032 | 14.7 | 20.5 | |
| 22-Mar | 2a-2 | 25 | 2a | O2 | 695 | 0.266 | LOCA | 1030 | 14.7 | 20.0 | |
| 22-Mar | 2a-3 | 26 | 2a | O2 | 297 | 0.266 | LOCA | 1031 | 14.7 | 14.5 | |
| 22-Mar | 2a-4 | 27 | 2a | O2 | 1141 | 0.157 | ATWS | 1030 | 14.7 | 3.7 | |
| 22-Mar | 2a-5 | 28 | 2a | O2 | 616 | 0.157 | ATWS | 1031 | 14.7 | 3.8 | |
| 23-Mar | 2a-6 | 29 | 2a | O2 | 287 | 0.157 | ATWS | 1031 | 14.7 | 5.2 | |
| 23-Mar | 2b-1 | 30 | 2b | O2 | 1130 | 0.266 | LOCA | 1031 | 14.7 | 41.7 | |
| 23-Mar | 2b-2 | 31 | 2b | O2 | 626 | 0.266 | LOCA | 1031 | 14.7 | 40.5 | |
| 23-Mar | 2b-3 | 32 | 2b | O2 | 297 | 0.266 | LOCA | 1031 | 14.7 | 10.8 | |
| 24-Mar | 2c-1 | 33 | 2c | O2 | 1200 | 0.266 | LOCA | 1032 | 14.7 | 10.6 | |
| 24-Mar | 2c-2 | 34 | 2c | O2 | 635 | 0.266 | LOCA | 1030 | 14.7 | 7.7 | |
| 24-Mar | 2c-3 | 35 | 2c | O2 | 346 | 0.266 | LOCA | 1030 | 14.7 | 9.7 | |
| 25-Mar | 2d-1 | 36 | 2d | O2 | 1110 | 0.266 | LOCA | 1030 | 14.7 | 8.0 | |
| 25-Mar | 2d-2 | 37 | 2d | O2 | 616 | 0.266 | LOCA | 1030 | 14.7 | 4.9 | |
| 25-Mar | 2d-3 | 38 | 2d | O2 | 317 | 0.266 | LOCA | 1030 | 14.7 | 2.1 | |
| 25-Mar | 2d-4 | 39 | 2d | O2 | 1110 | 0.157 | ATWS | 1030 | 14.7 | 2.7 | |
| 26-Mar | 2d-5 | 40 | 2d | O2 | 715 | 0.157 | ATWS | 1027 | 14.7 | 2.2 | |
| 26-Mar | 2d-6 | 41 | 2d | O2 | 317 | 0.157 | ATWS | 1031 | 14.7 | 1.9 | |
| 29-Mar | 3-1 | 42 | 3 | O2 | 1200 | 0.266 | LOCA | 1031 | 14.7 | 34.9 | |
| 29-Mar | 3-2 | 43 | 3 | O2 | 675 | 0.266 | LOCA | 1031 | 14.7 | 6.2 | |
| 29-Mar | 3-3 | 44 | 3 | O2 | 376 | 0.266 | LOCA | 1031 | 14.7 | 5.3 | |
| 29-Mar | 3-3 | 45 | 3 | O2 | 327 | 0.266 | LOCA | 1030 | 14.7 | 6.8 | |
| 30-Mar | 3-4 | 46 | 3 | O2 | 1150 | 0.157 | ATWS | 1030 | 14.7 | 10.0 | |
| 30-Mar | 3-5 | 47 | 3 | O2 | 675 | 0.157 | ATWS | 1030 | 14.7 | 5.5 | |
| 30-Mar | 3-6 | 48 | 3 | O2 | 336 | 0.157 | ATWS | 1030 | 14.7 | 6.2 | |
| 30-Mar | 3a-1 | 49 | 3a | O2 | 1140 | 0.266 | LOCA | 1030 | 14.7 | 26.8 | |
| 31-Mar | 3a-2 | 50 | 3a | O2 | 606 | 0.266 | LOCA | 1031 | 14.7 | 19.6 | |
| 31-Mar | 3a-3 | 51 | 3a | O2 | 346 | 0.266 | LOCA | 1031 | 14.7 | 11.7 | |
| 31-Mar | 3a-4 | 52 | 3a | O2 | 1091 | 0.157 | ATWS | 1031 | 14.7 | 20.6 | |
| 31-Mar | 3a-5 | 53 | 3a | O2 | 635 | 0.157 | ATWS | 1030 | 14.7 | 14.6 | |
| 31-Mar | 3a-6 | 54 | 3a | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 9.6 | |
| 01-Apr | 3d-1 | 55 | 3d | O2 | 1130 | 0.266 | LOCA | 1030 | 14.7 | 25.5 | |
| 01-Apr | 3d-2 | 56 | 3d | O2 | 655 | 0.266 | LOCA | 1030 | 14.7 | 19.5 | |
| 01-Apr | 3d-3 | 57 | 3d | O2 | 307 | 0.264 | LOCA | 1030 | 14.7 | 11.7 | |
| 01-Apr | 3d-4 | 58 | 3d | O2 | 1120 | 0.157 | ATWS | 1029 | 14.7 | 13.7 | |

CONTINUUM DYNAMICS, INC.
PRELIMINARY INFORMATION

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 02-Apr | 3d-5 | 59 | 3d | O2 | 635 | 0.157 | ATWS | 1030 | 14.7 | 12.4 | |
| 02-Apr | 3d-6 | 60 | 3d | O2 | 336 | 0.157 | ATWS | 1030 | 14.7 | 7.0 | |
| 05-Apr | 3c-1 | 61 | 3c | O2 | 1081 | 0.266 | LOCA | 1030 | 14.7 | 28.7 | |
| 05-Apr | 3c-2 | 62 | 3c | O2 | 626 | 0.266 | LOCA | 1030 | 14.7 | 8.5 | |
| 05-Apr | 3c-3 | 63 | 3c | O2 | 297 | 0.266 | LOCA | 1030 | 14.7 | 5.0 | |
| 05-Apr | 3c-4 | 64 | 3c | O2 | 1150 | 0.157 | ATWS | 1030 | 14.7 | 21.9 | |
| 05-Apr | 3c-5 | 65 | 3c | O2 | 616 | 0.157 | ATWS | 1030 | 14.7 | 8.9 | |
| 06-Apr | 3c-6 | 66 | 3c | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 1.7 | |
| 06-Apr | 3e-1 | 67 | 3e | O2 | 1150 | 0.266 | LOCA | 1030 | 14.7 | 18.6 | |
| 06-Apr | 3e-2 | 68 | 3e | O2 | 616 | 0.266 | LOCA | 1030 | 14.7 | 6.1 | |
| 06-Apr | 3e-3 | 69 | 3e | O2 | 327 | 0.266 | LOCA | 1030 | 14.7 | 5.6 | |
| 06-Apr | 3e-4 | 70 | 3e | O2 | 1150 | 0.157 | ATWS | 1031 | 14.7 | 17.1 | |
| 07-Apr | 3e-5 | 71 | 3e | O2 | 596 | 0.157 | ATWS | 1030 | 14.7 | 4.0 | |
| 07-Apr | 3e-6 | 72 | 3e | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 5.1 | |
| 08-Apr | 6-1 | 73 | 6 | O2 | 1130 | 0.266 | LOCA | 1030 | 14.7 | 324.4 | |
| 08-Apr | 6-2 | 74 | 6 | O2 | 1021 | 0.266 | LOCA | 1030 | 14.7 | 324.3 | |
| 08-Apr | 6-3 | 75 | 6 | O2 | 556 | 0.266 | LOCA | 1030 | 14.7 | 313.8 | |
| 08-Apr | 6-4 | 76 | 6 | O2 | 268 | 0.266 | LOCA | 1030 | 14.7 | 51.8 | |
| 08-Apr | 6-5 | 77 | 6 | O2 | [illegible]71 | 0.157 | ATWS | 1030 | 14.7 | 213.9 | |
| 09-Apr | 6-5 | 78 | 6 | O2 | [illegible]16 | 0.157 | ATWS | 1030 | 14.7 | n/a | 4 |
| 09-Apr | 6-6 | 79 | 6 | O2 | 287 | 0.157 | ATWS | 1030 | 14.7 | 47.9 | |
| 09-Apr | 6-5 | 80 | 6 | O2 | 556 | 0.157 | ATWS | 1030 | 14.7 | 203.9 | |
| 13-Apr | 7-1 | 81 | 7 | O2 | 1091 | 0.266 | LOCA | 1031 | 14.7 | n/a | 5 |
| 13-Apr | 7-1 | 82 | 7 | O2 | 1130 | 0.266 | LOCA | 1030 | 14.7 | 70.1 | |
| 13-Apr | 7-1 | 83 | 7 | O2 | 1110 | 0.266 | LOCA | 1029 | 14.7 | 83.2 | |
| 14-Apr | 7-2 | 84 | 7 | O2 | 695 | 0.266 | LOCA | 1030 | 14.7 | 24.0 | |
| 14-Apr | 7-3 | 85 | 7 | O2 | 307 | 0.266 | LOCA | 1030 | 14.7 | 10.4 | |
| 14-Apr | 7-4 | 86 | 7 | O2 | 1209 | 0.157 | ATWS | 1030 | 14.7 | 104.7 | |
| 14-Apr | 7-5 | 87 | 7 | O2 | 616 | 0.157 | ATWS | 1030 | 14.7 | 14.4 | |
| 14-Apr | 7-6 | 88 | 7 | O2 | 317 | 0.157 | ATWS | 1030 | 14.7 | 11.1 | |
| 14-Apr | 7-7 | 89 | 7 | O2 | 42 | 0.266 | LOCA | 1030 | 14.7 | 0.0 | |
| 15-Apr | 7-8 | 90 | 7 | O2 | 715 | n/a | S.D. | 1015 | 14.7 | 7.1 | |
| 16-Apr | 7-9 | 91 | 7 | O2 | 327 | n/a | S.D. | 1015 | 14.7 | 7.1 | |
| 22-Apr | 7-10 | 92 | 7 | O2 | 513 | 0.266 | LOCA | 1030 | 14.7 | 14.7 | |
| 23-Apr | 7-11 | 93 | 7 | O2 | 179 | n/a | S.D. | 1015 | 14.7 | 0.8 | |
| 23-Apr | 7-12 | 94 | 7 | O2 | 179 | n/a | S.D. | 1015 | 14.7 | 0.8 | |

Notes:

(1) A stuck solenoid valve forced a blowdown using the nitrogen injection port.

(2) Improper re-injection of pre-mixed solution following sample resulted in a reference leg that was not completely filled prior to blowdown.

(3) Pre-mixed tank ran "dry" during latter portion of solution injection, introducing gas into the reference leg and resulting in large errors.

(4) Suffered power outage during blowdown event.

(5) Noise on replacement data acquisition card invalidated transient data.

PROPRIETARY INFORMATION

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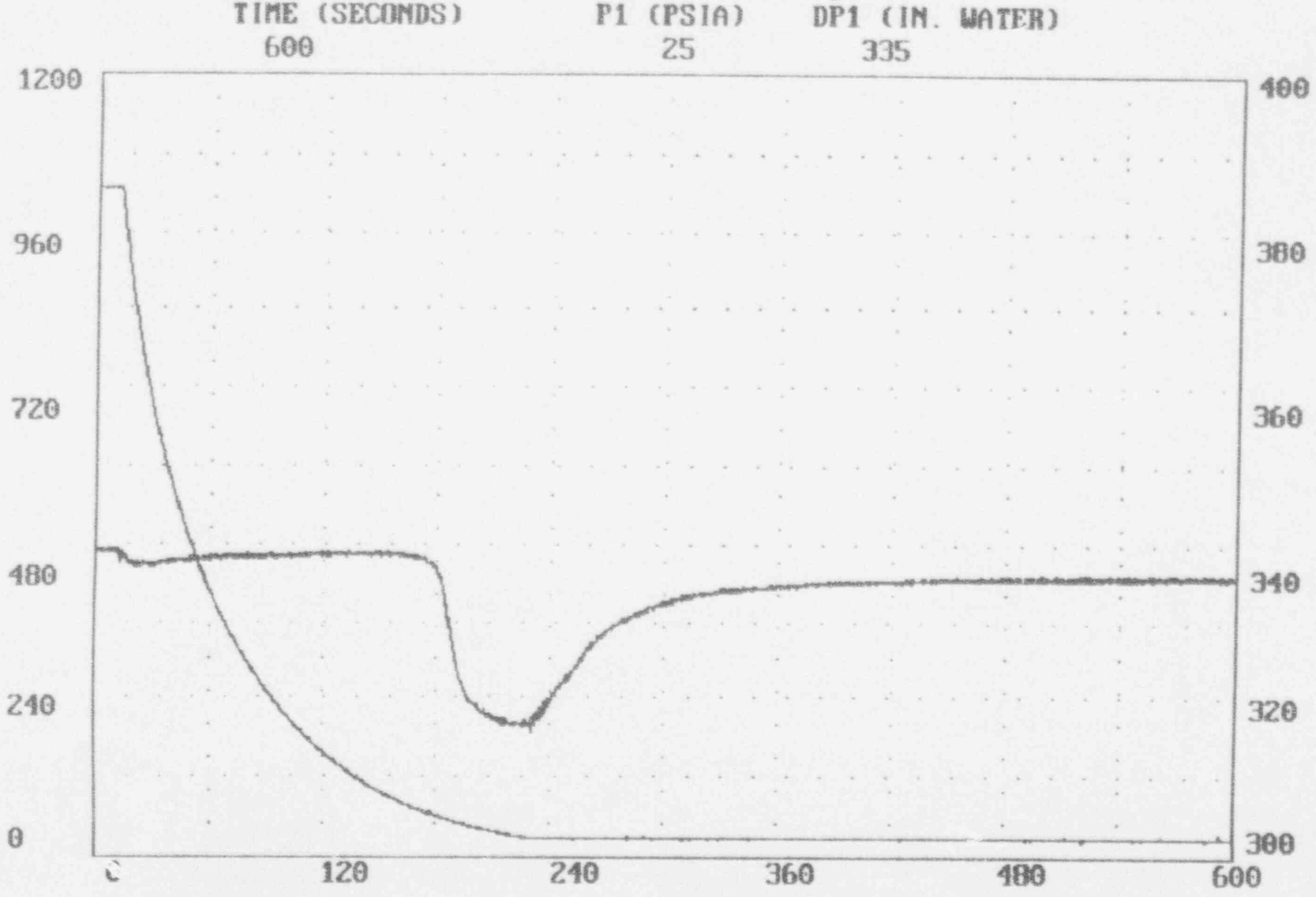
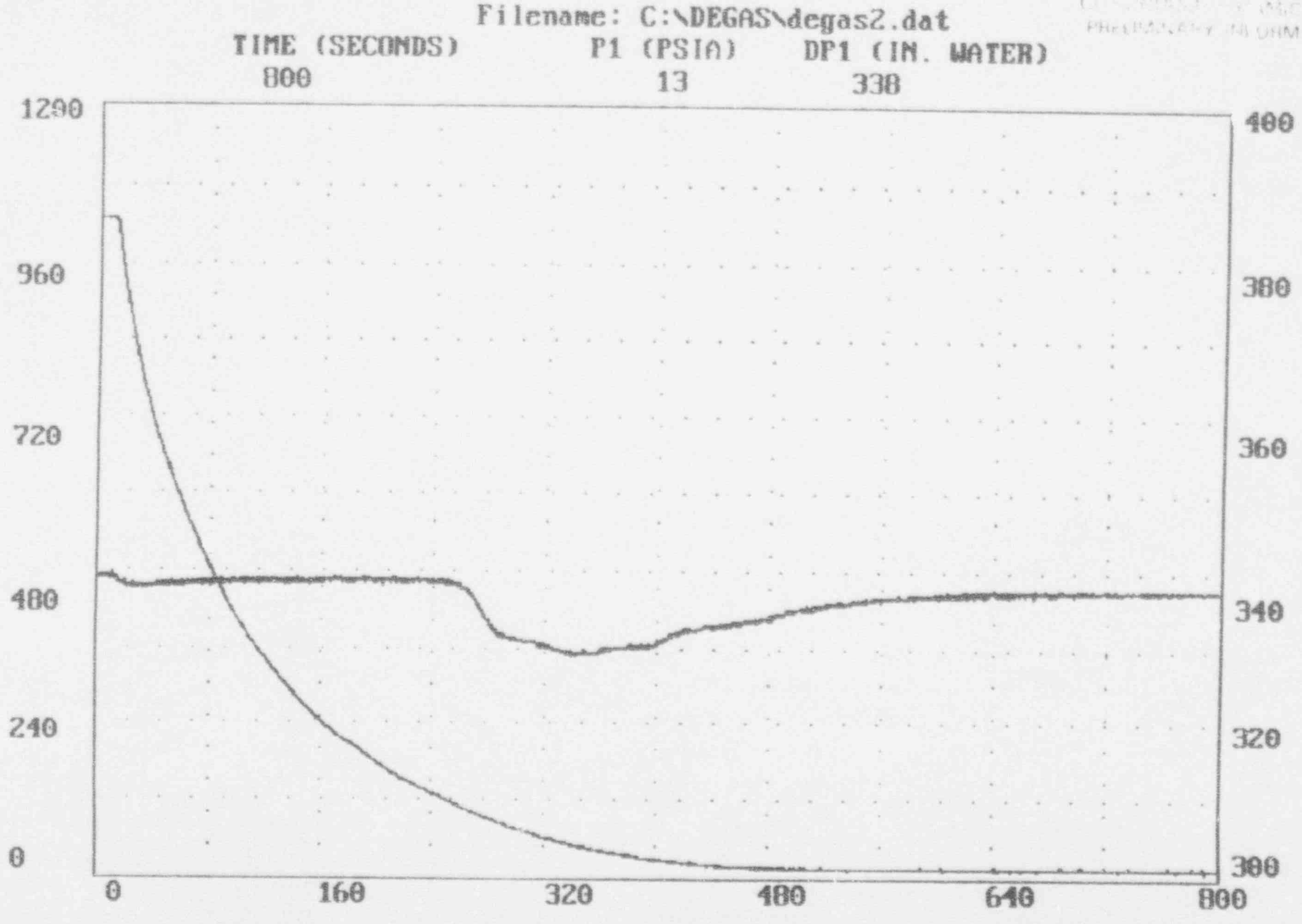
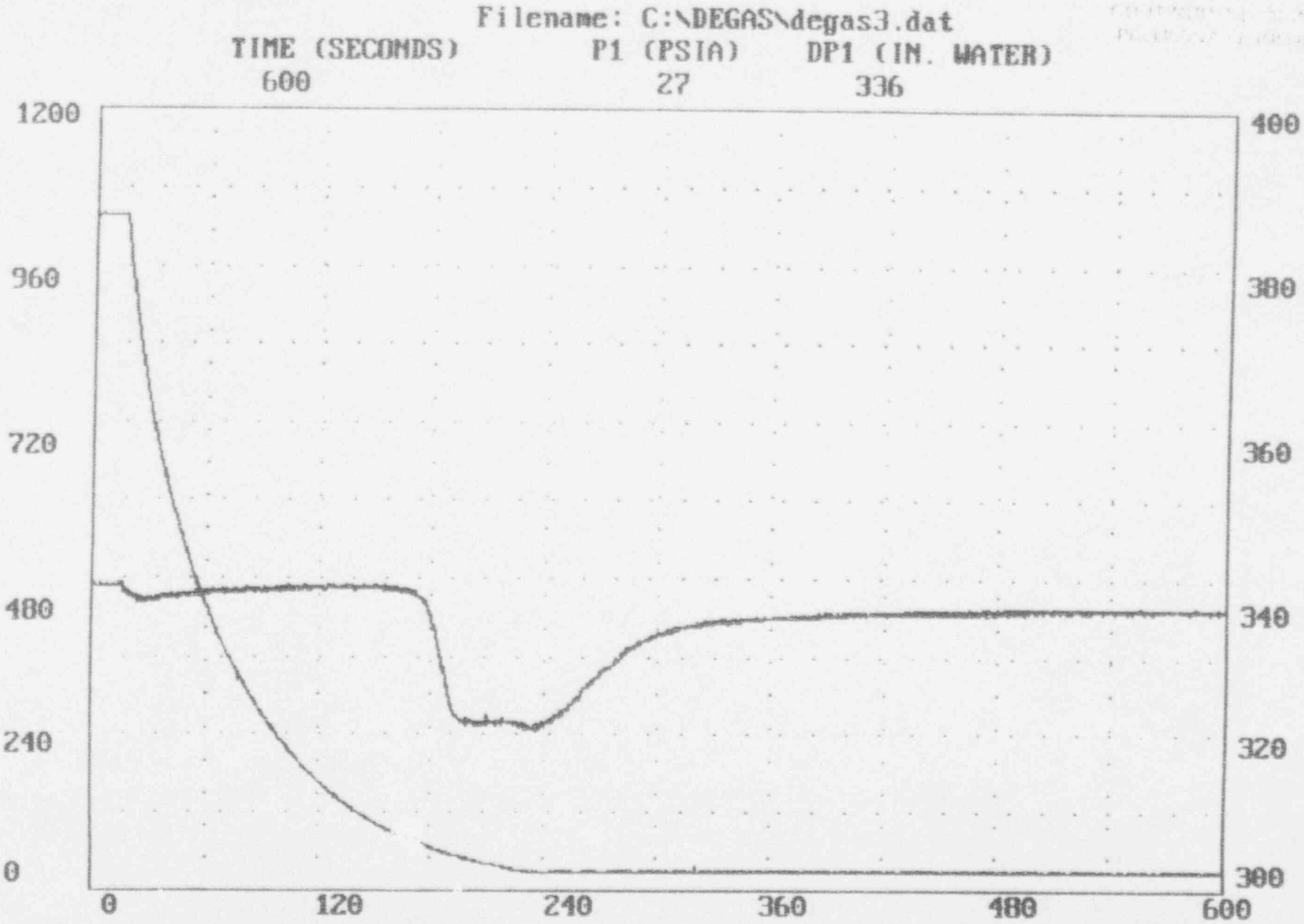


[illegible] INC
PRELIMINARY INFORMATION

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DP1 (IN. WATER)
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480
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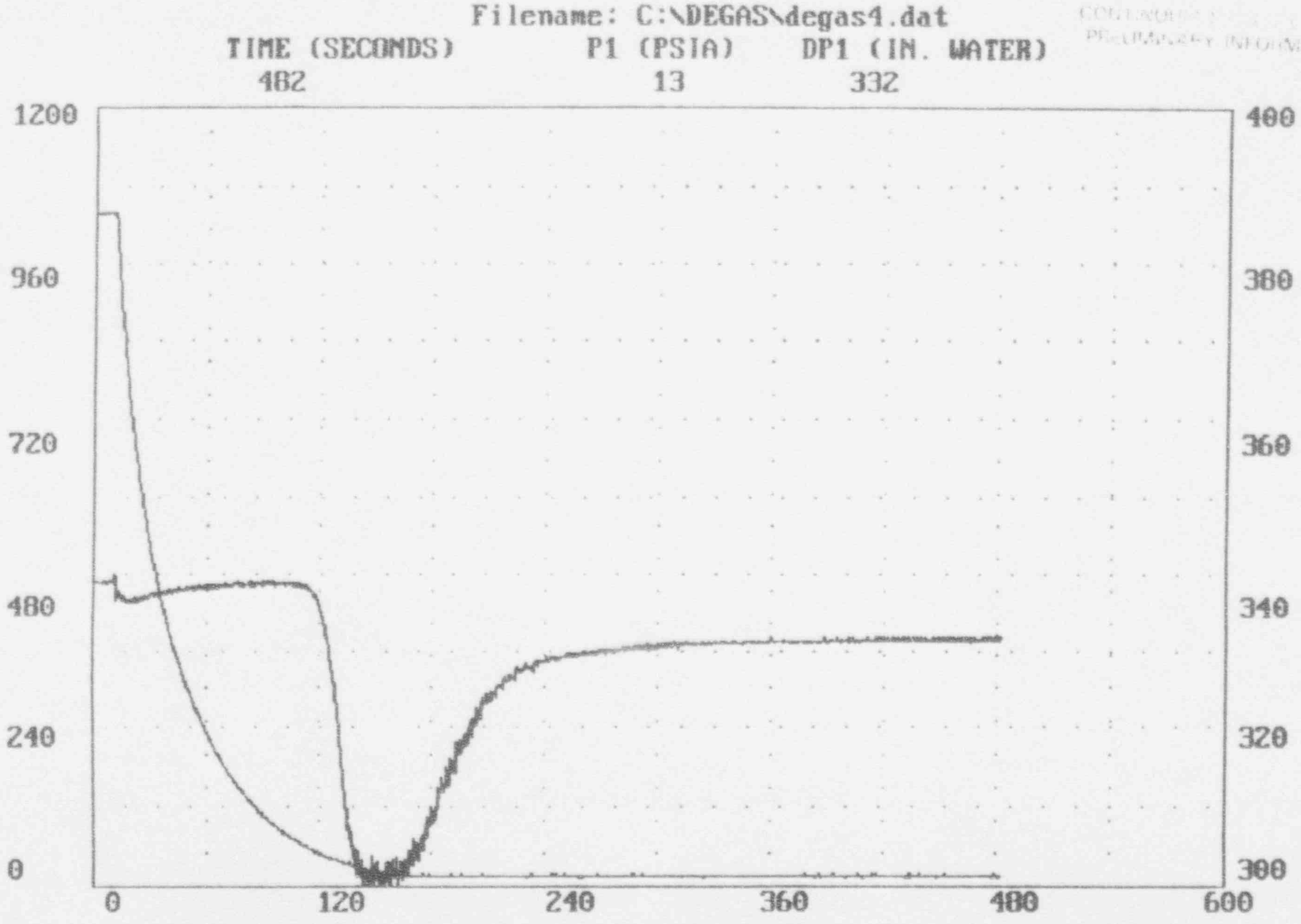
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DP1 (IN. WATER)
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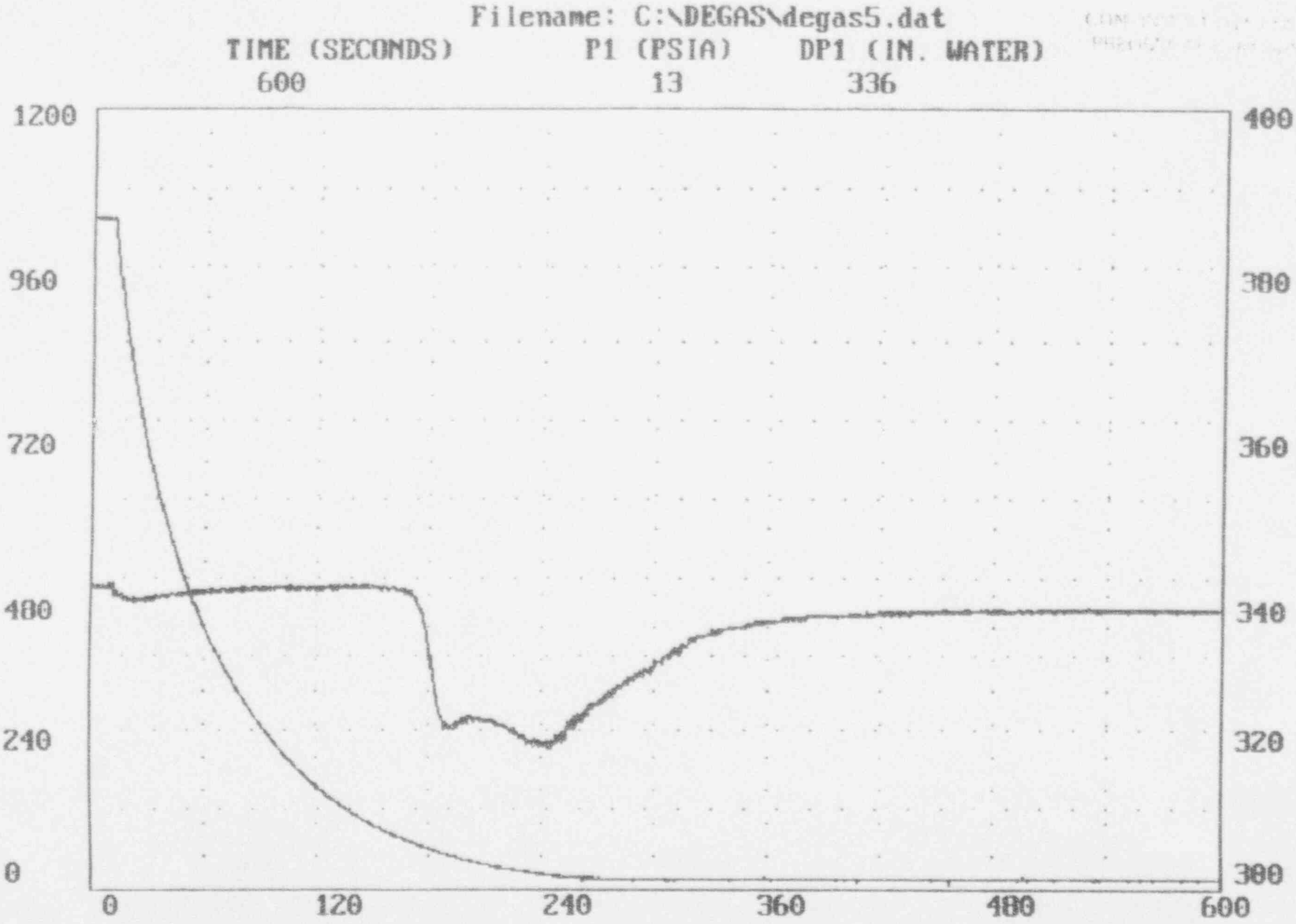
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DP1 (IN. WATER)
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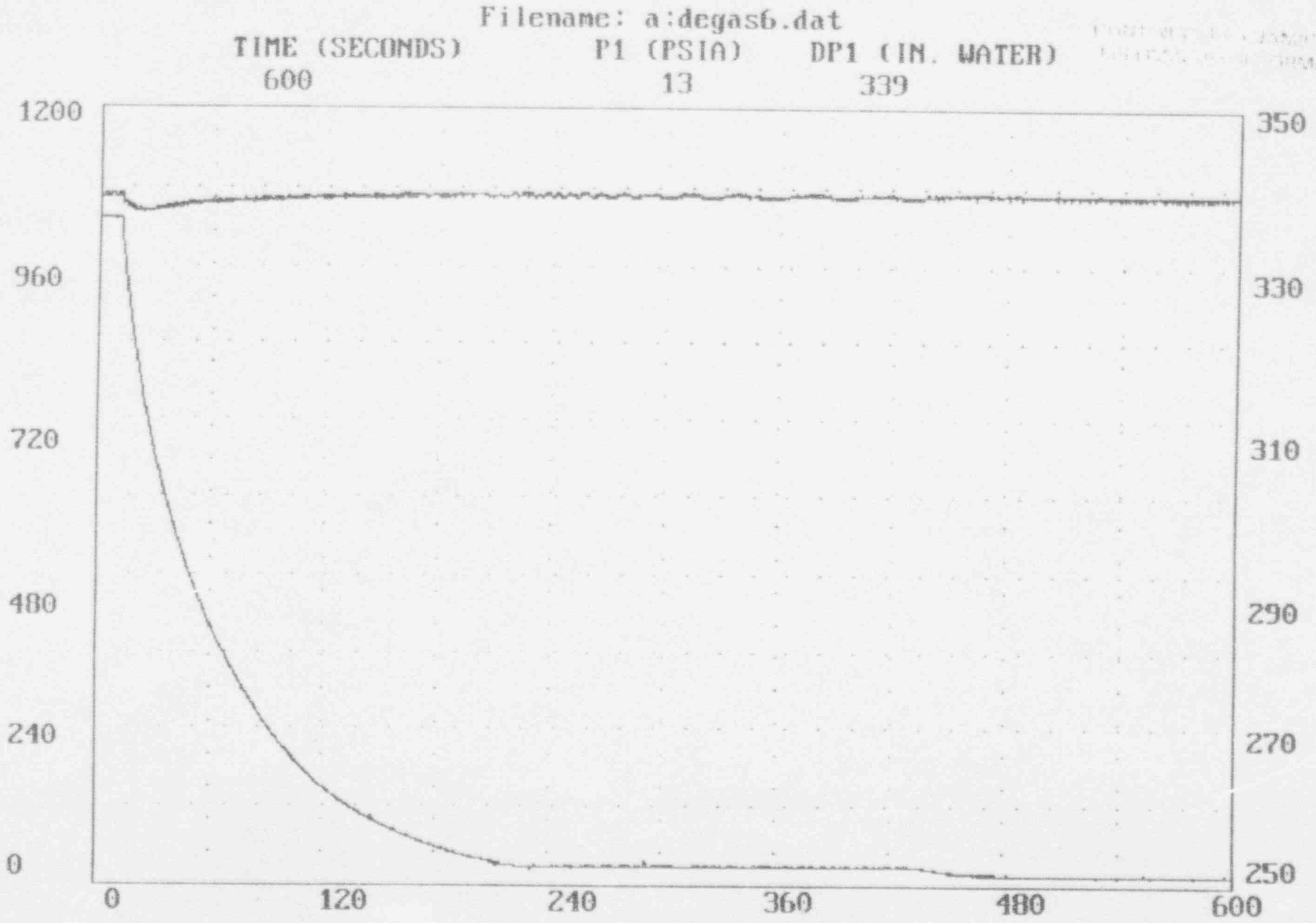
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P1 (PSIA)
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DP1 (IN. WATER)
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310
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240
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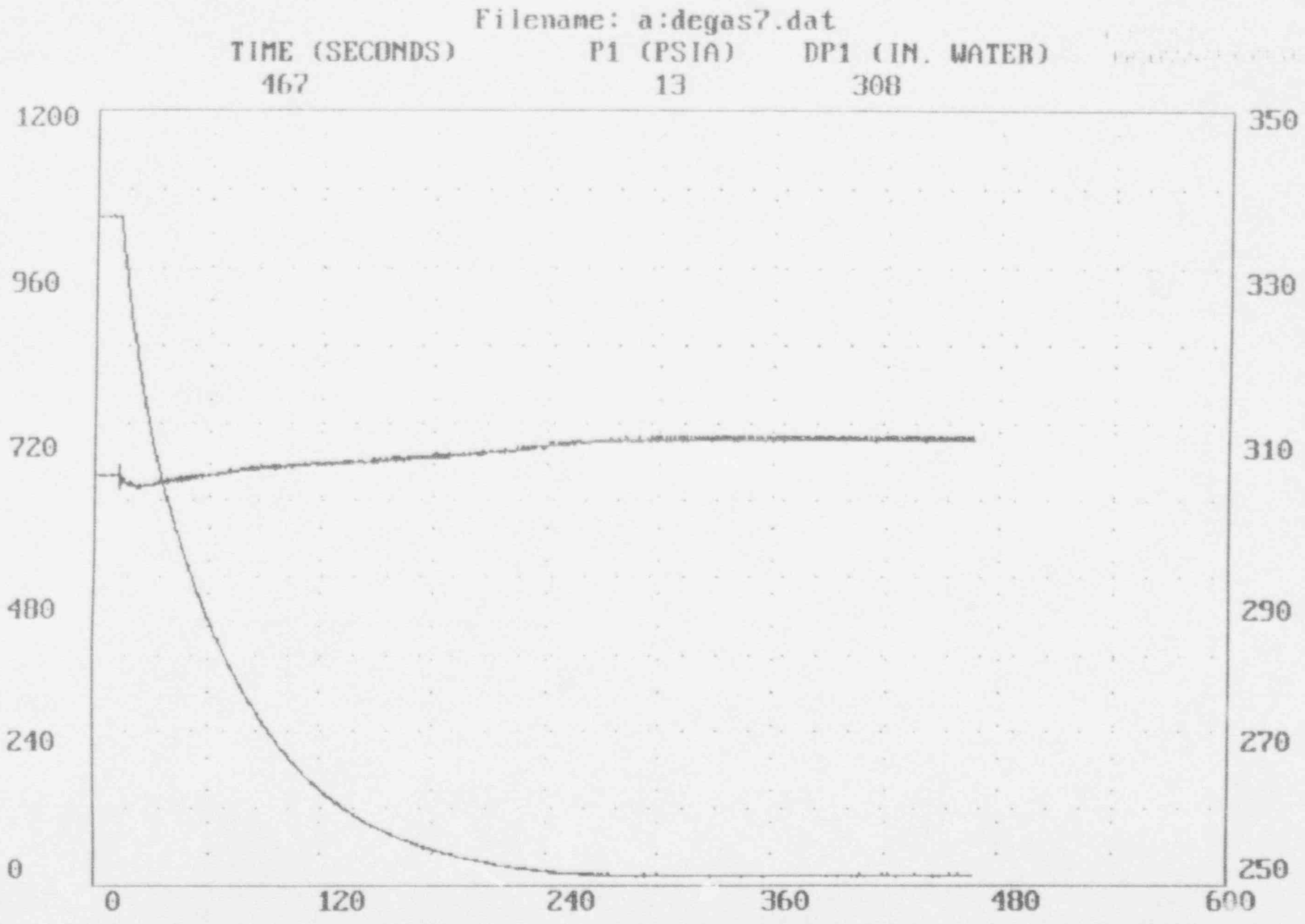
600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P1 (PSIA)
13
DP1 (IN. WATER)
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240
0
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330
310
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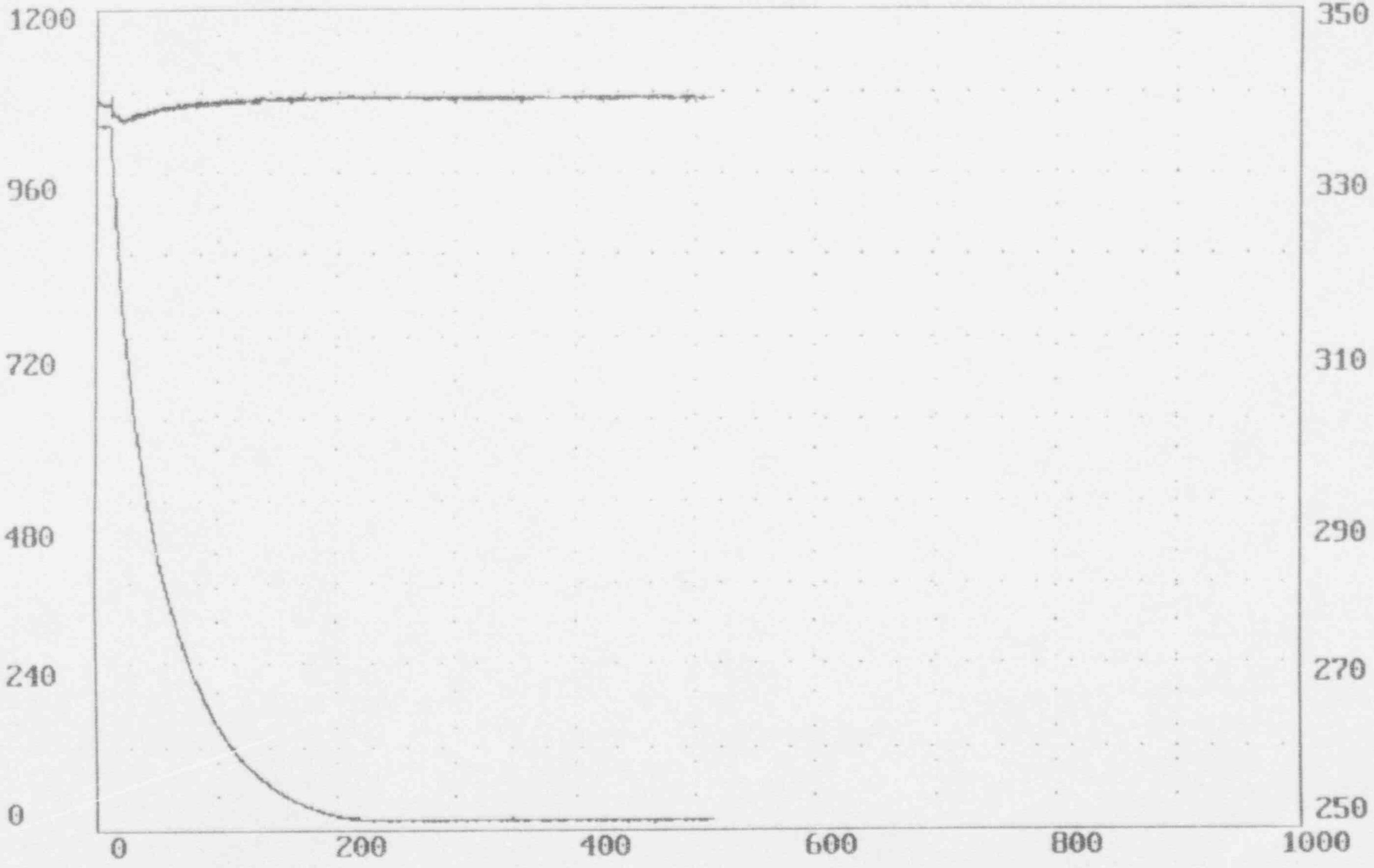
600

Filename: a:degas8.dat

TIME (SECONDS) 514 P1 (PSIA) 12 DP1 (IN. WATER) 339



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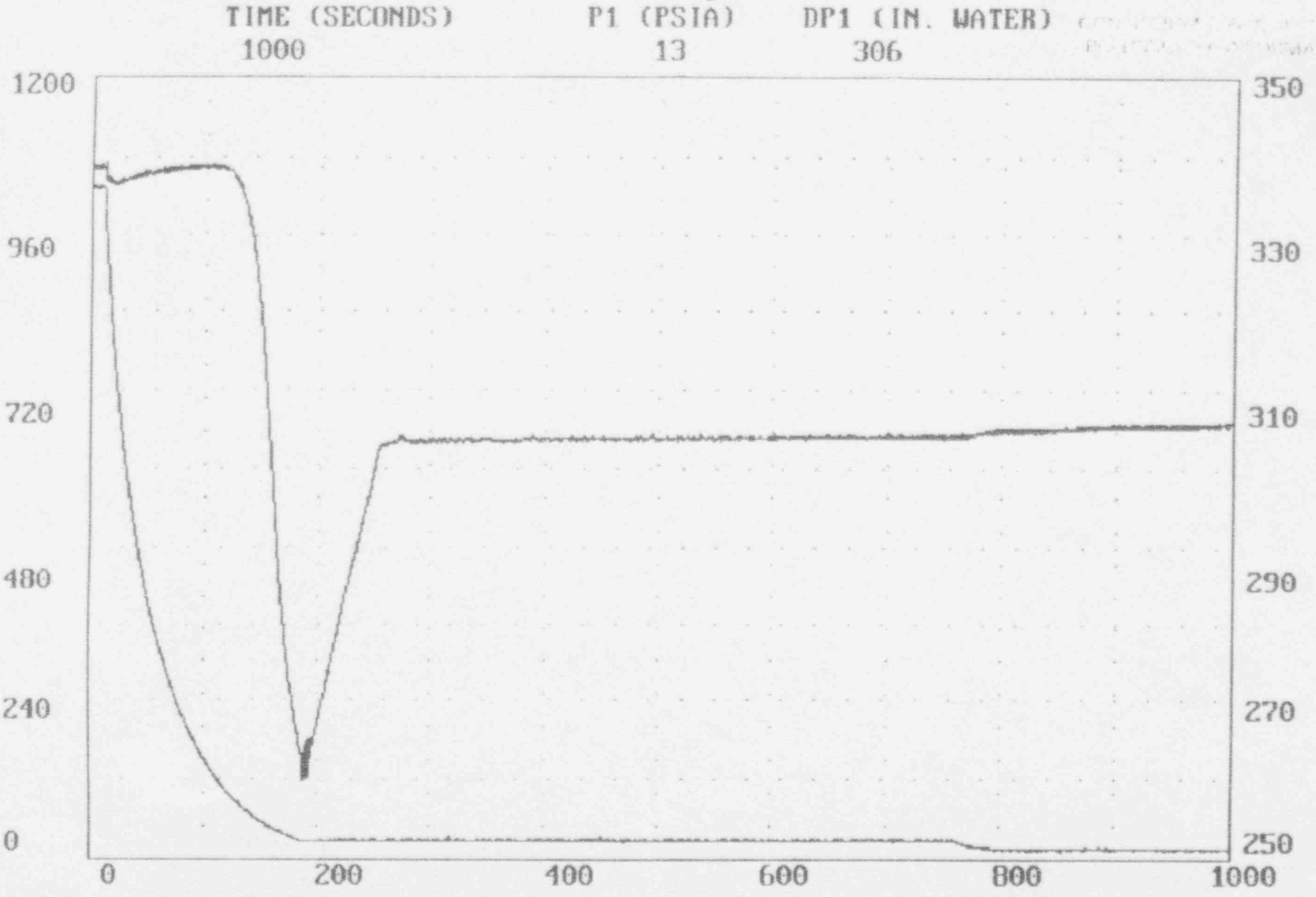

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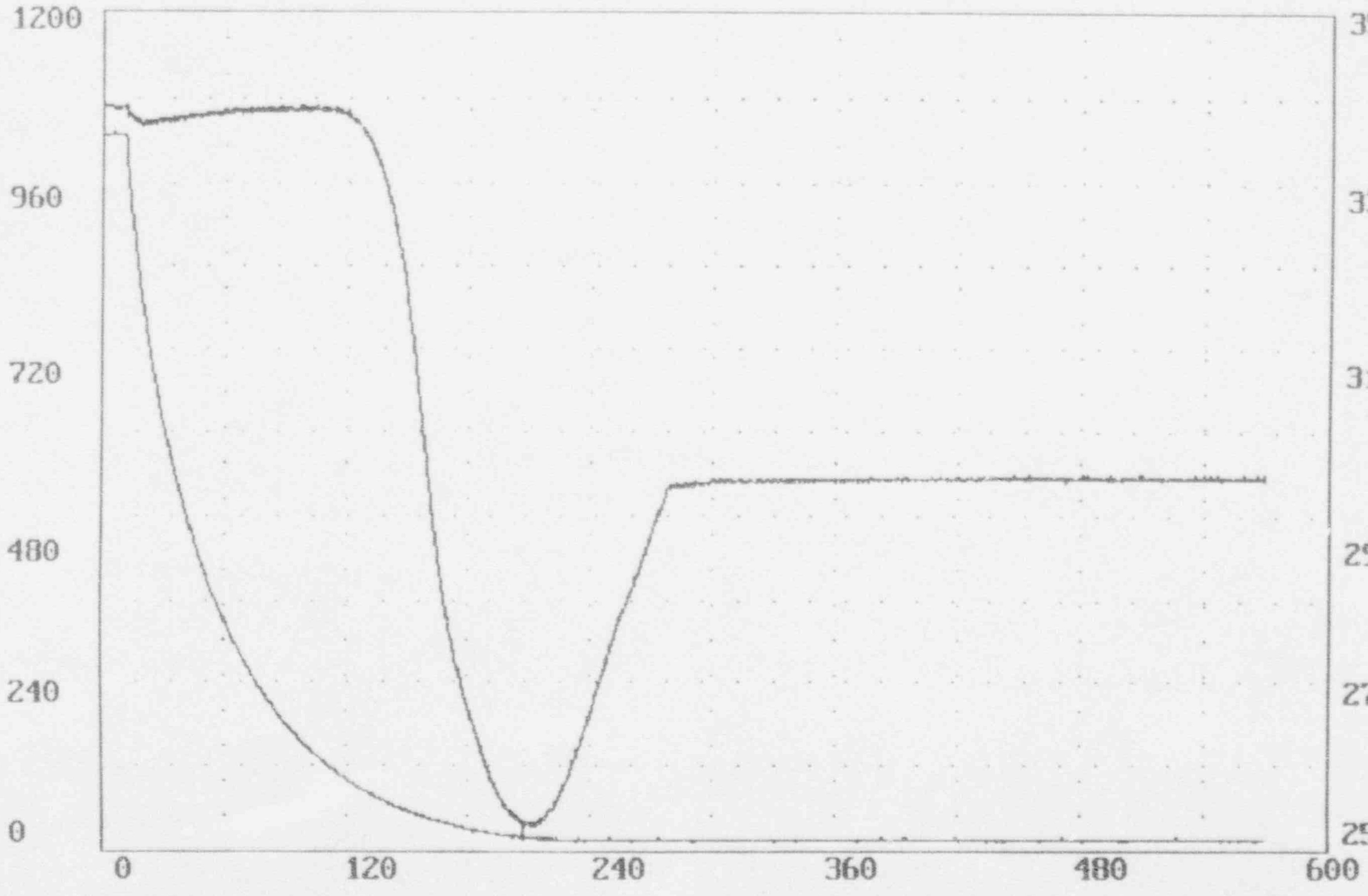
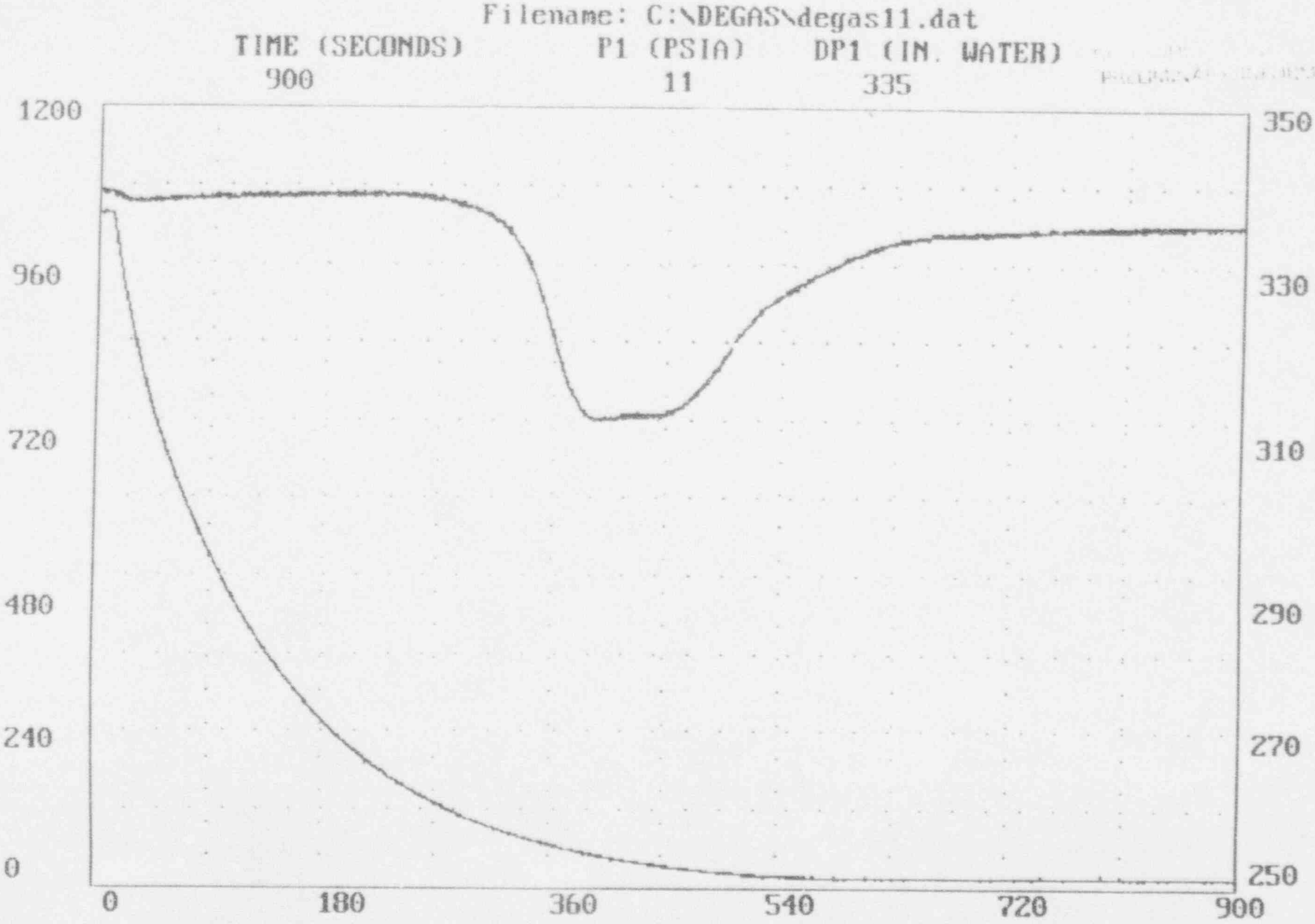
```



PRELIMINARY INFORMATION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DP1 (IN. WATER)
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540
720
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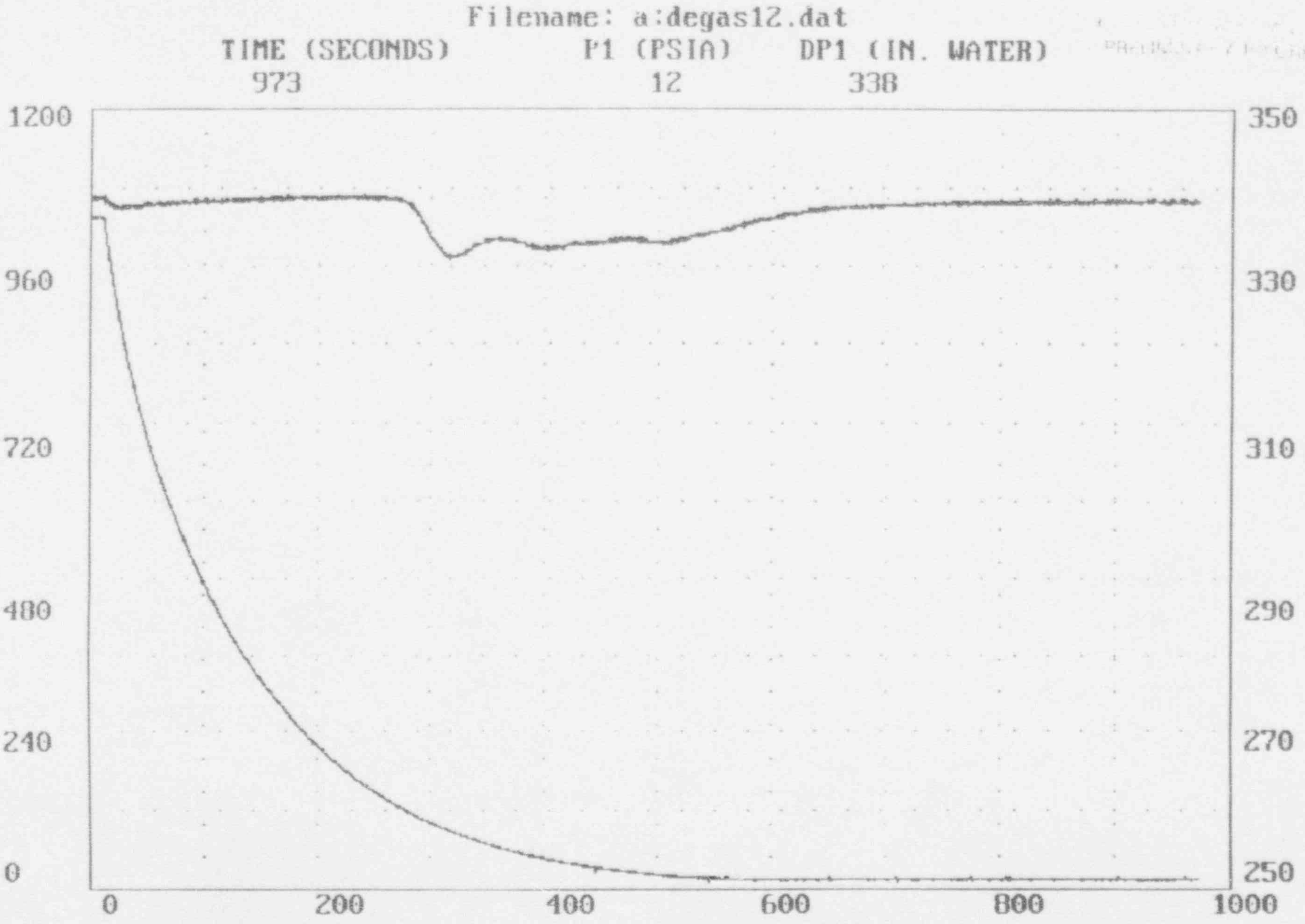
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P1 (PSIA)
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DP1 (IN. WATER)
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800
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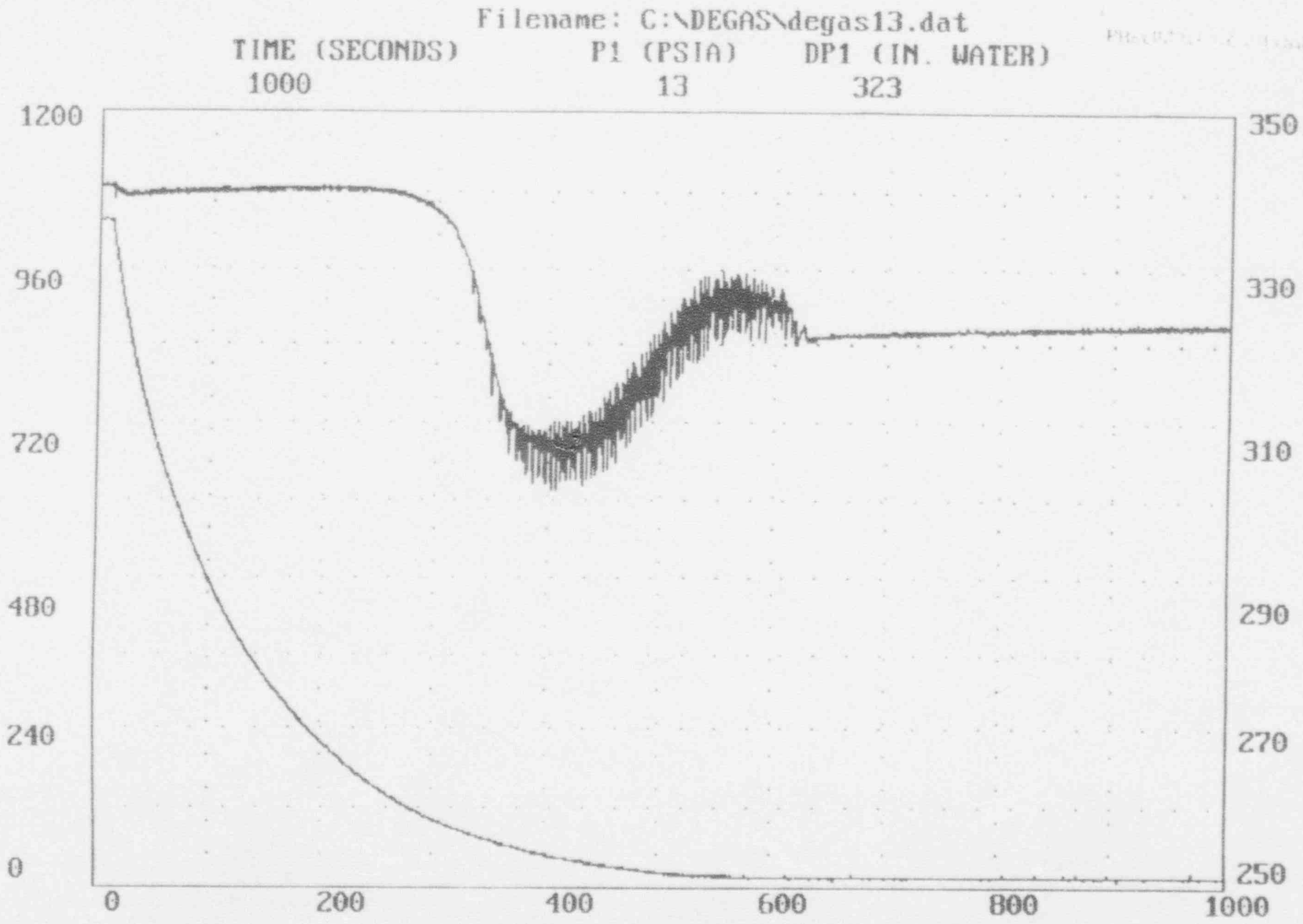
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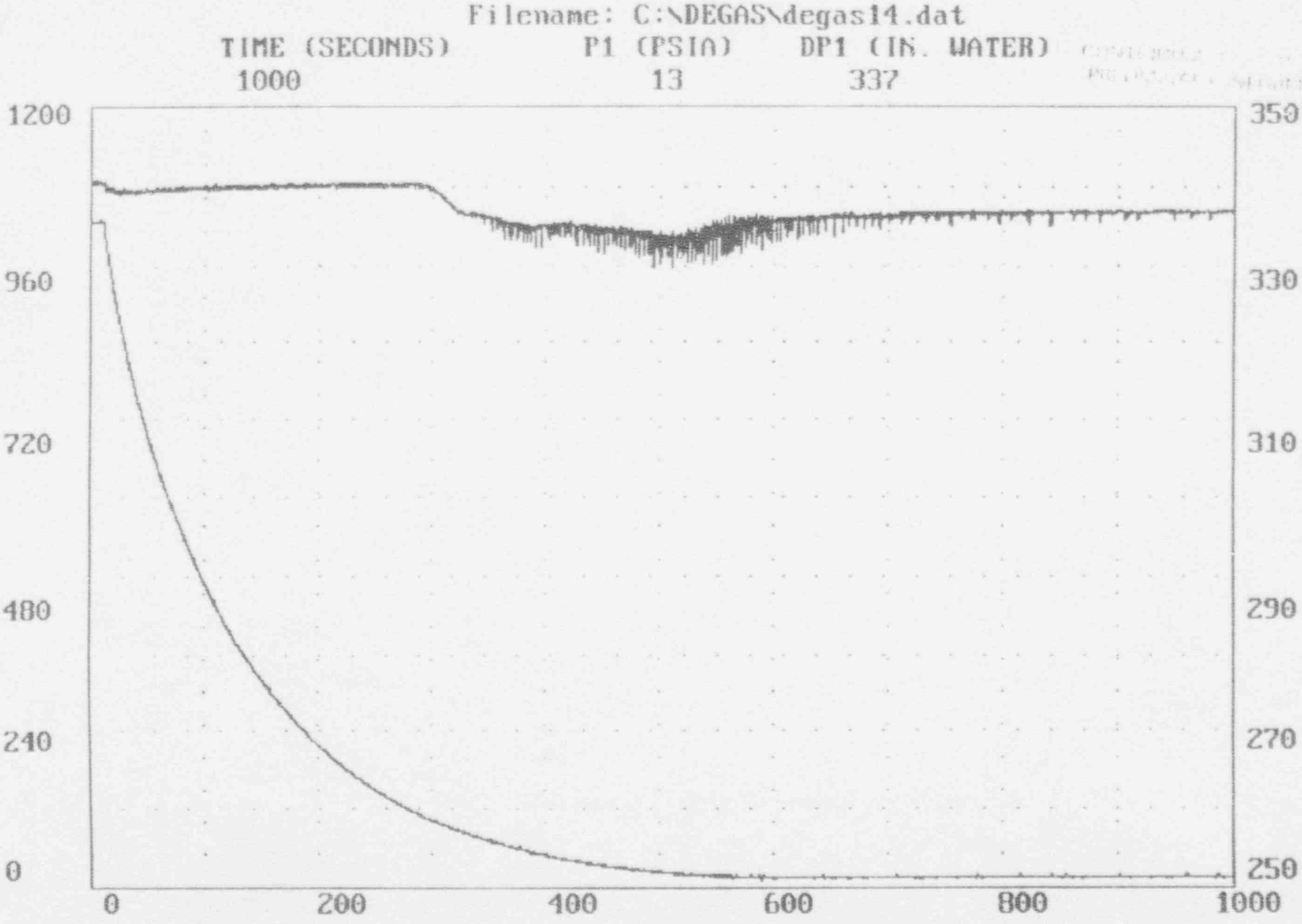
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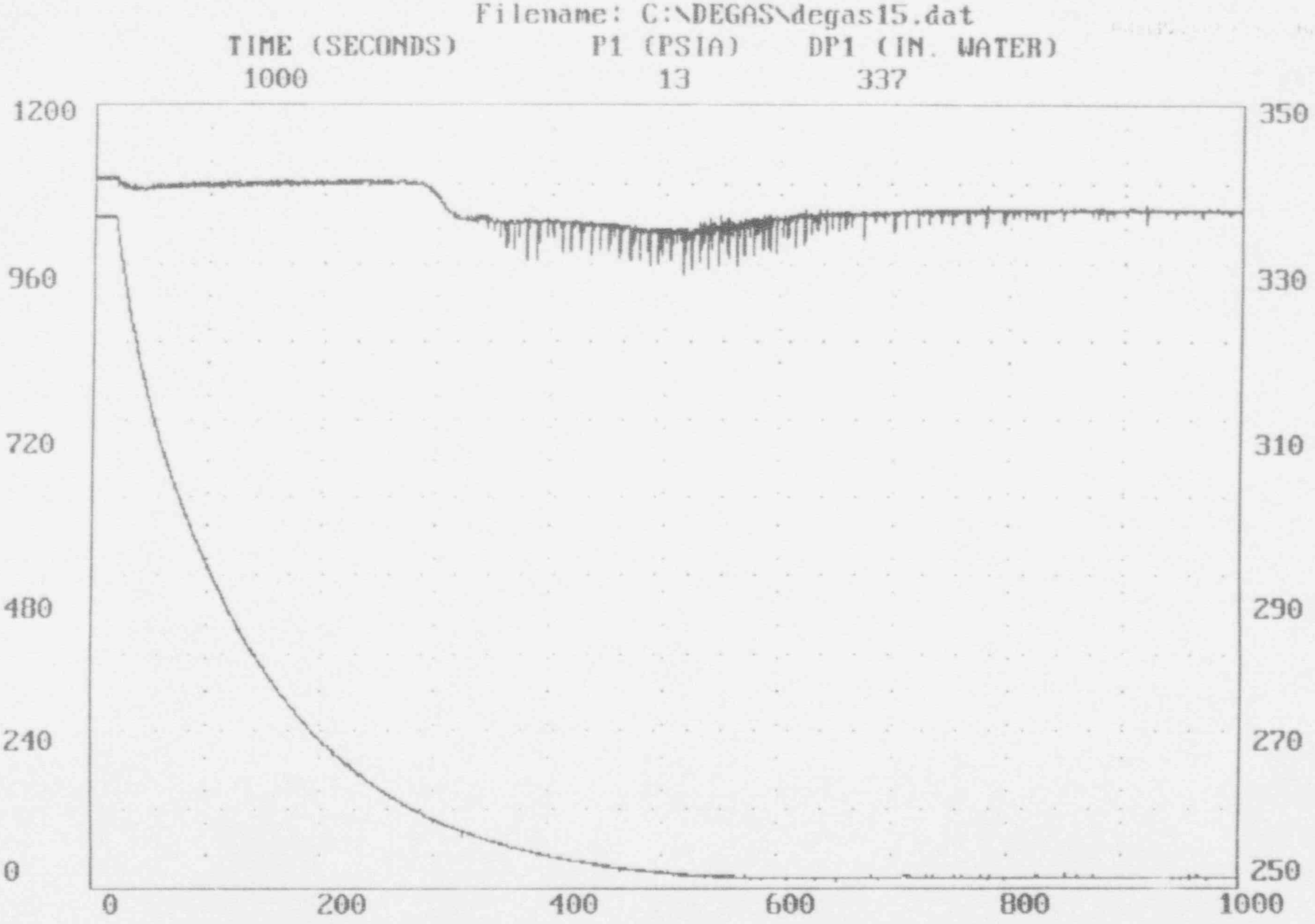
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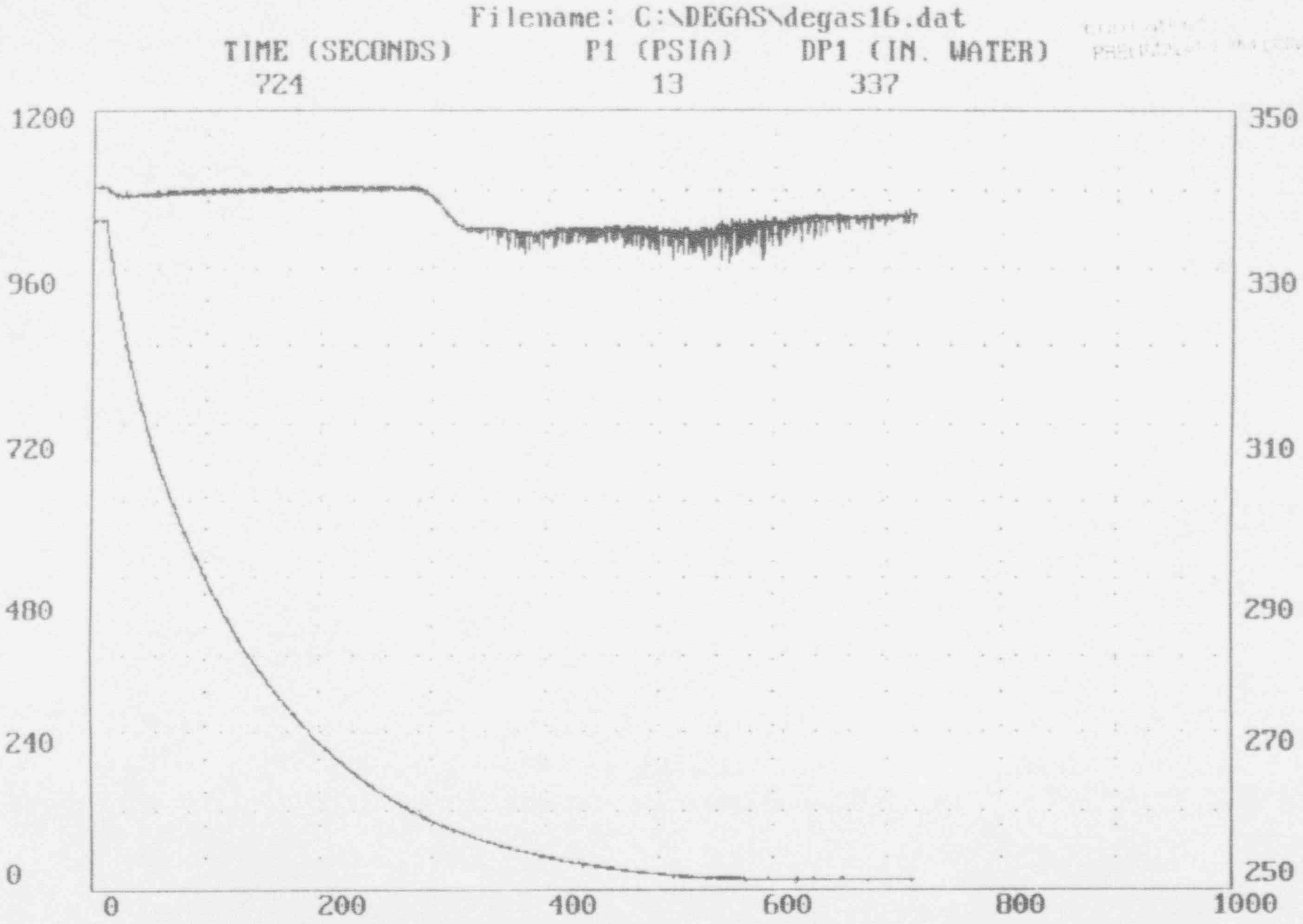
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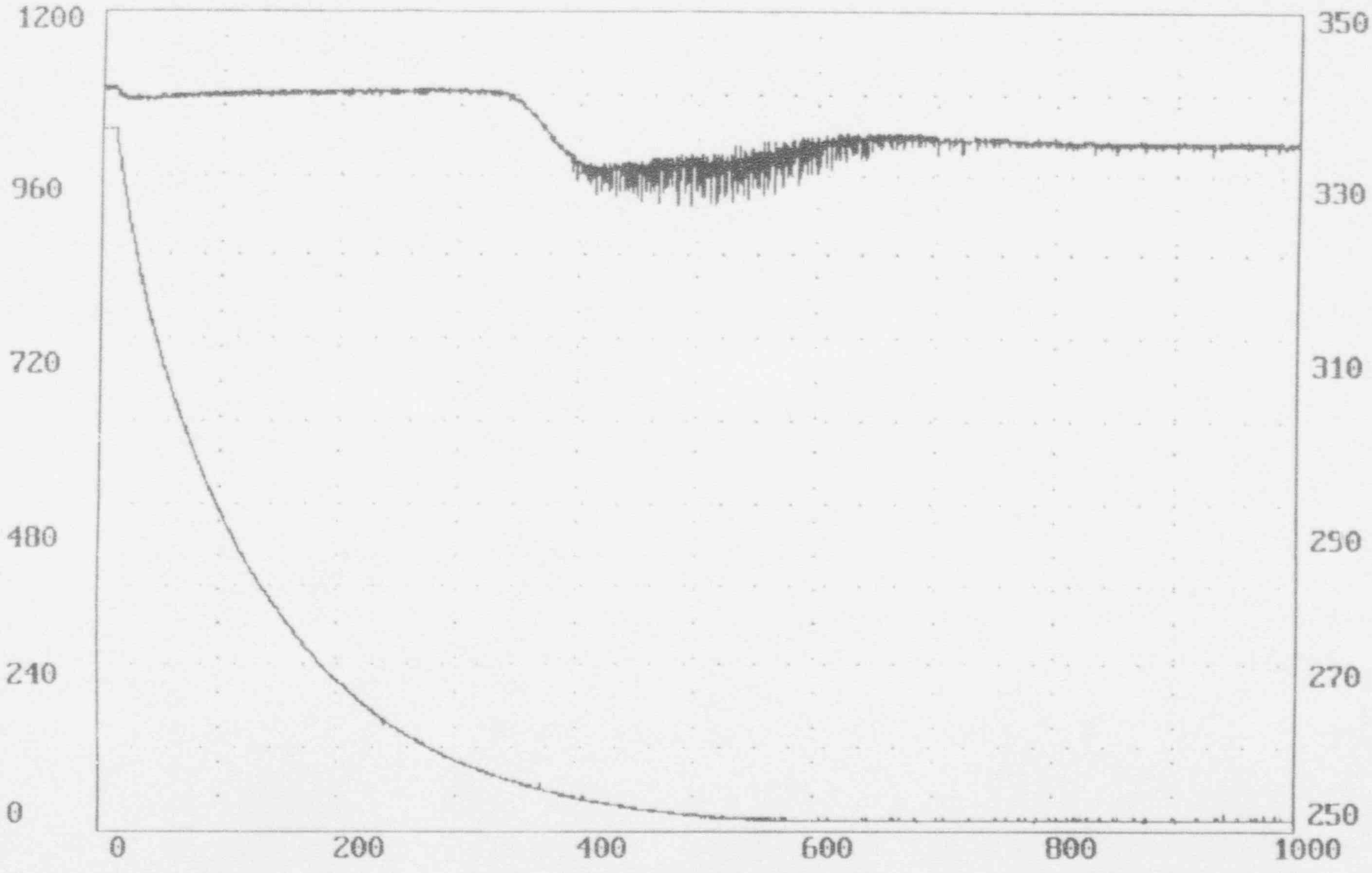

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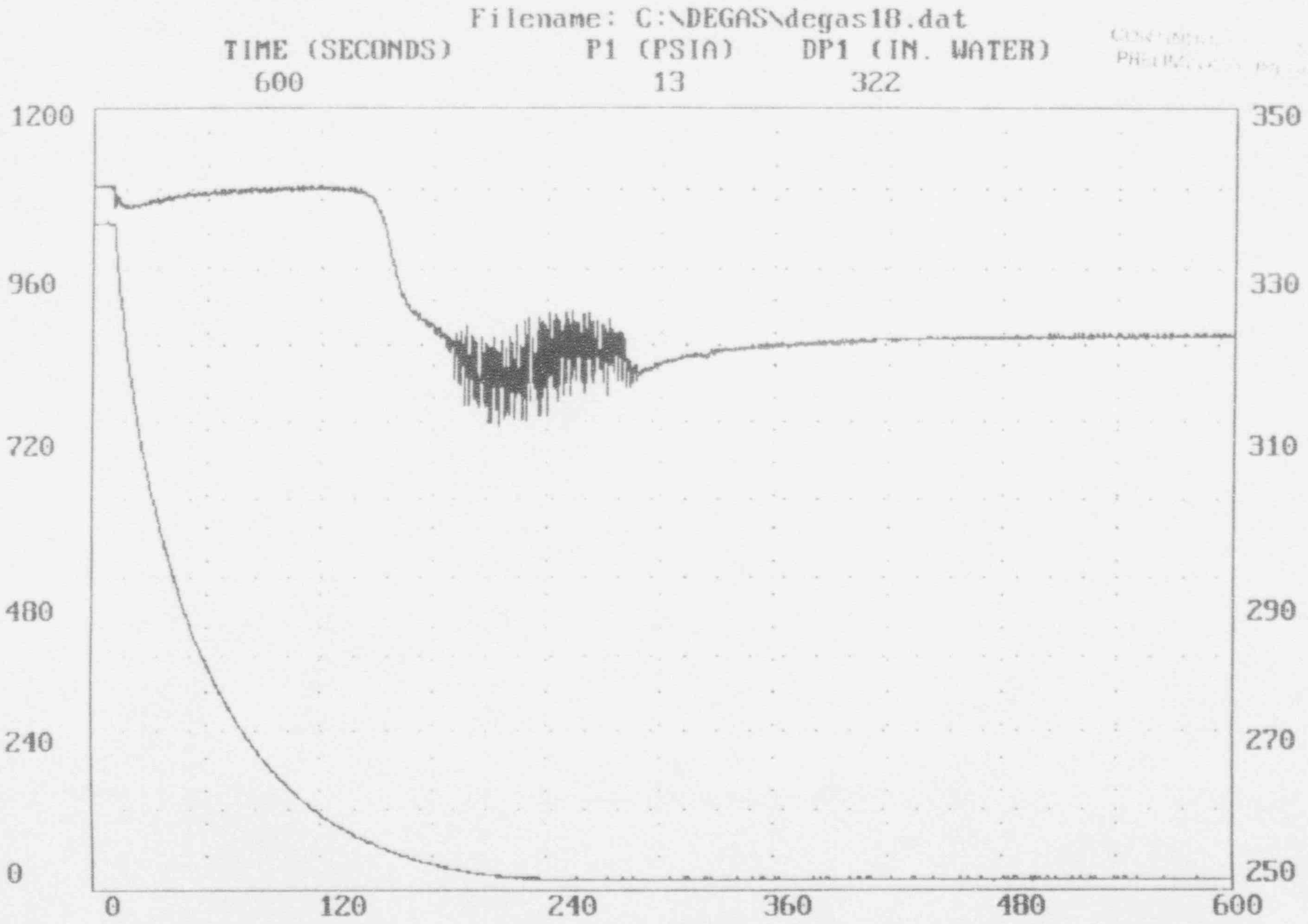
TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

1000 13 334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DP1 (IN. WATER)
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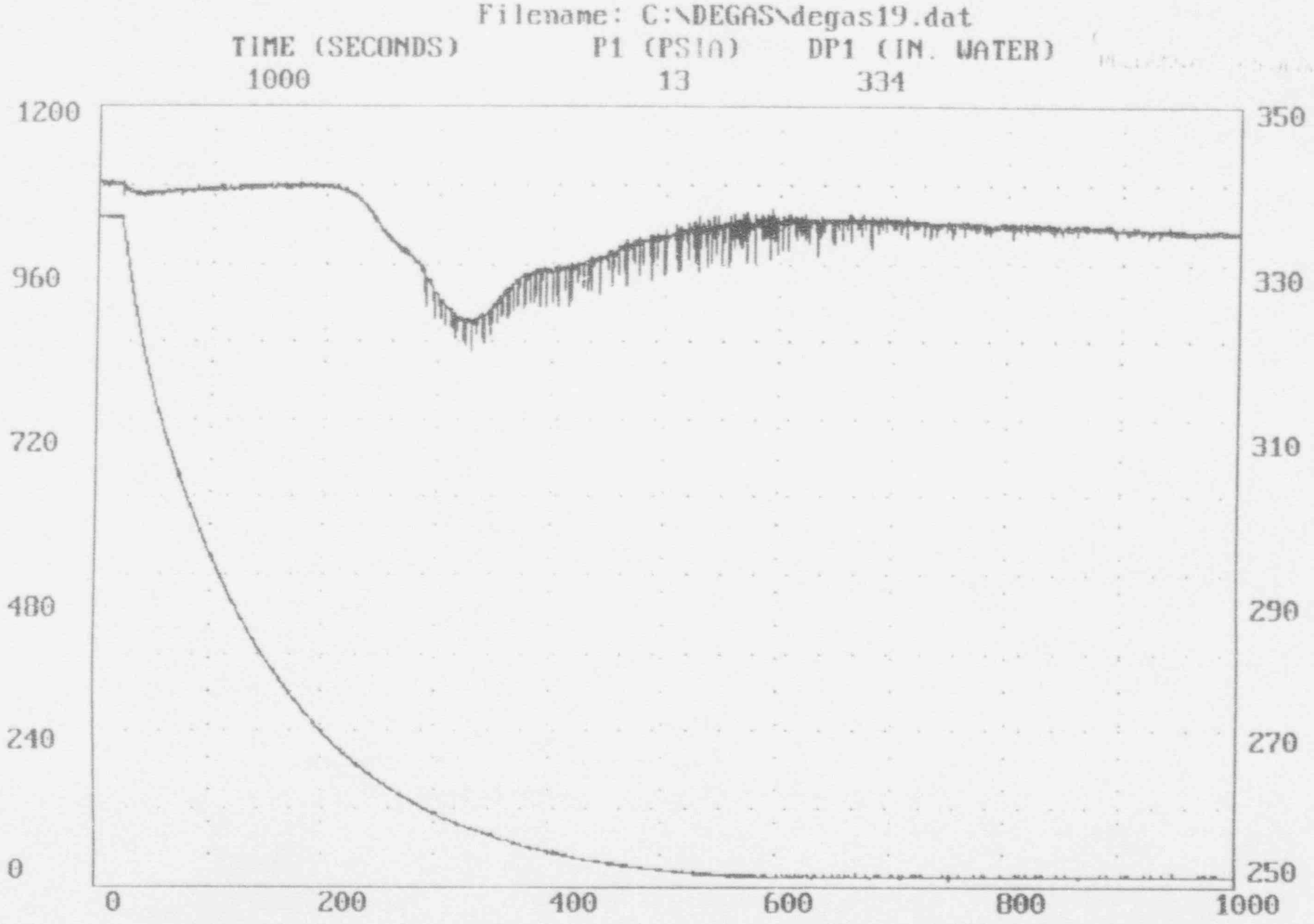
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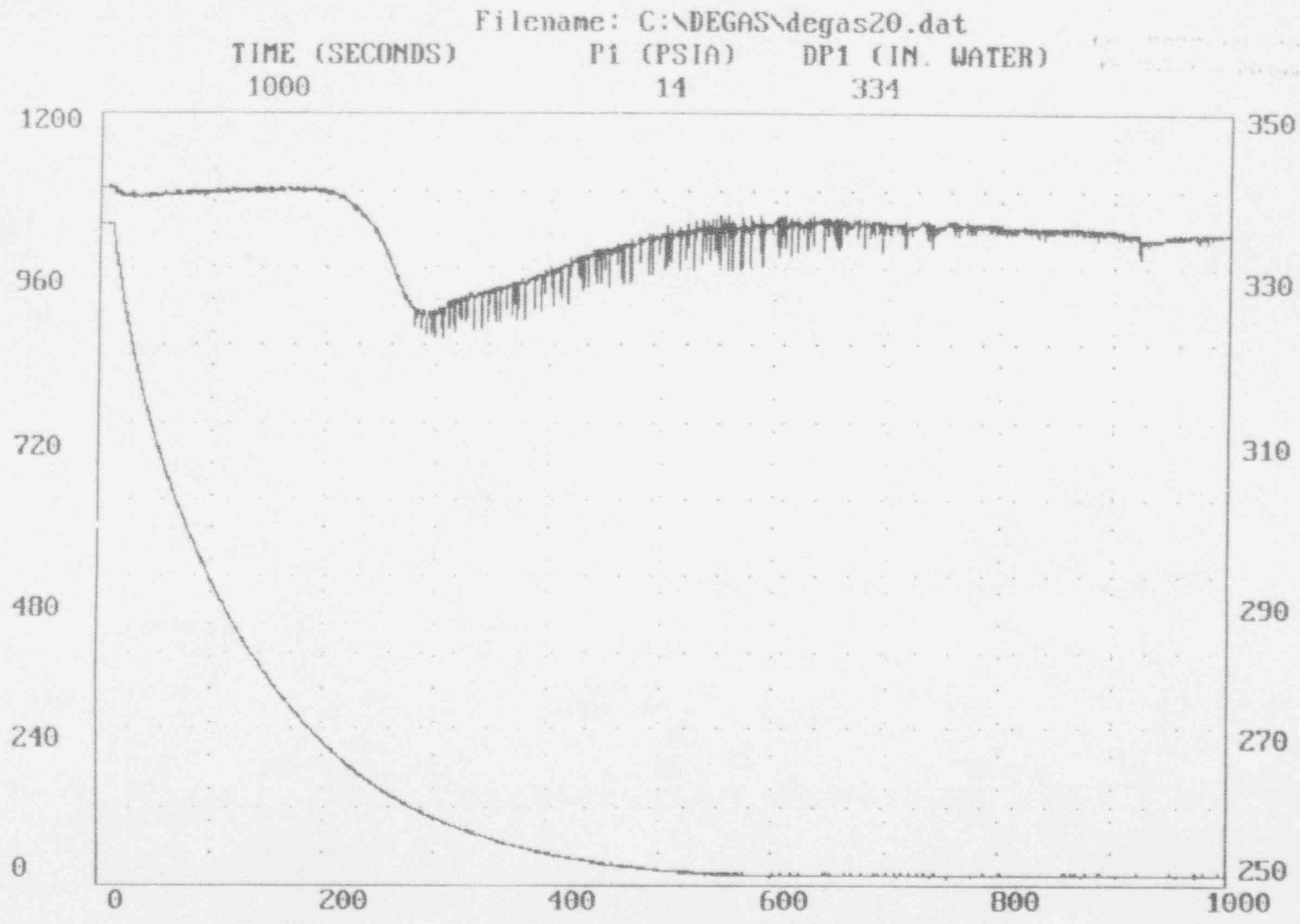
800
1000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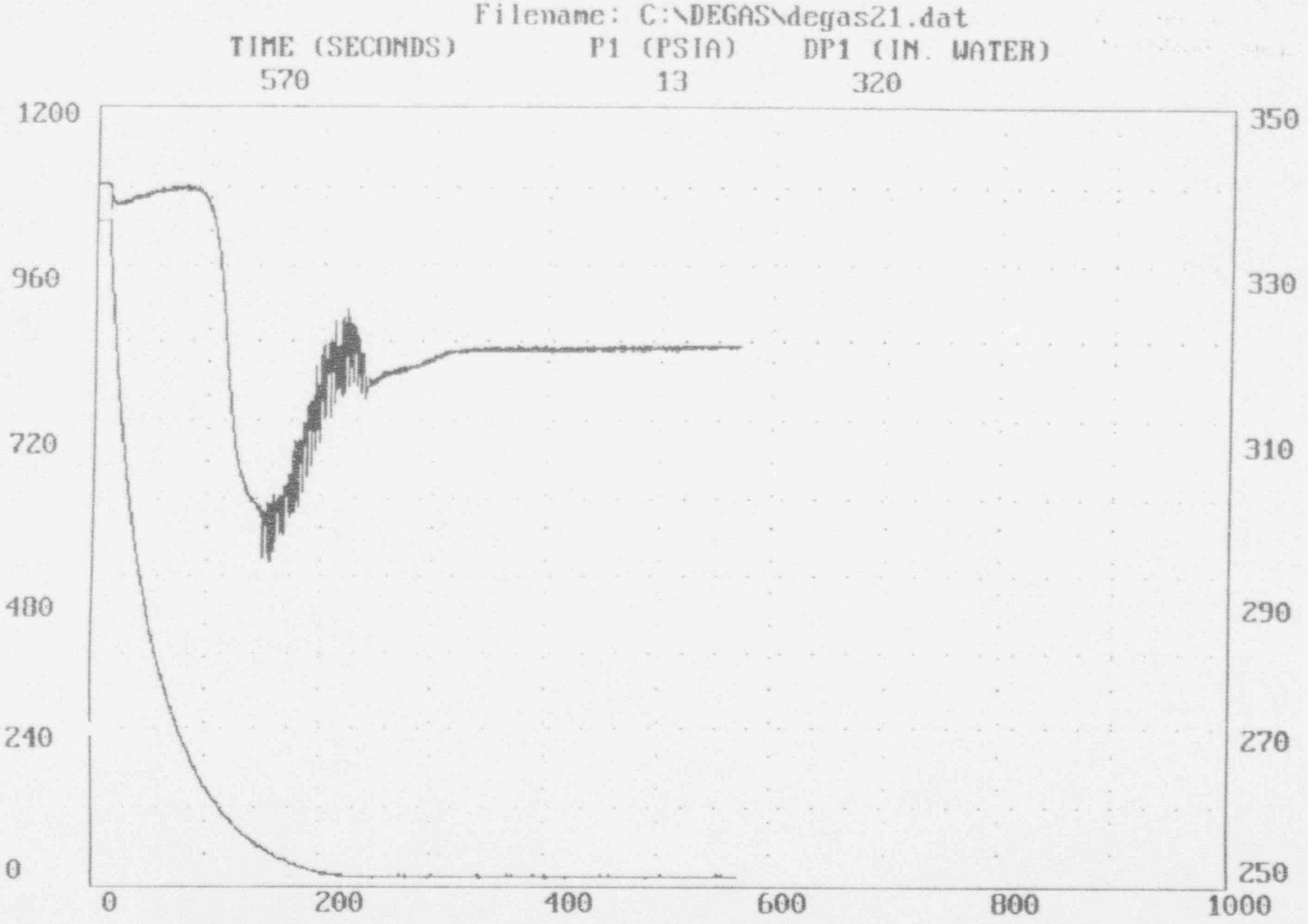
1000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TIME (SECONDS)
570
P1 (PSIA)
13
DP1 (IN. WATER)
320
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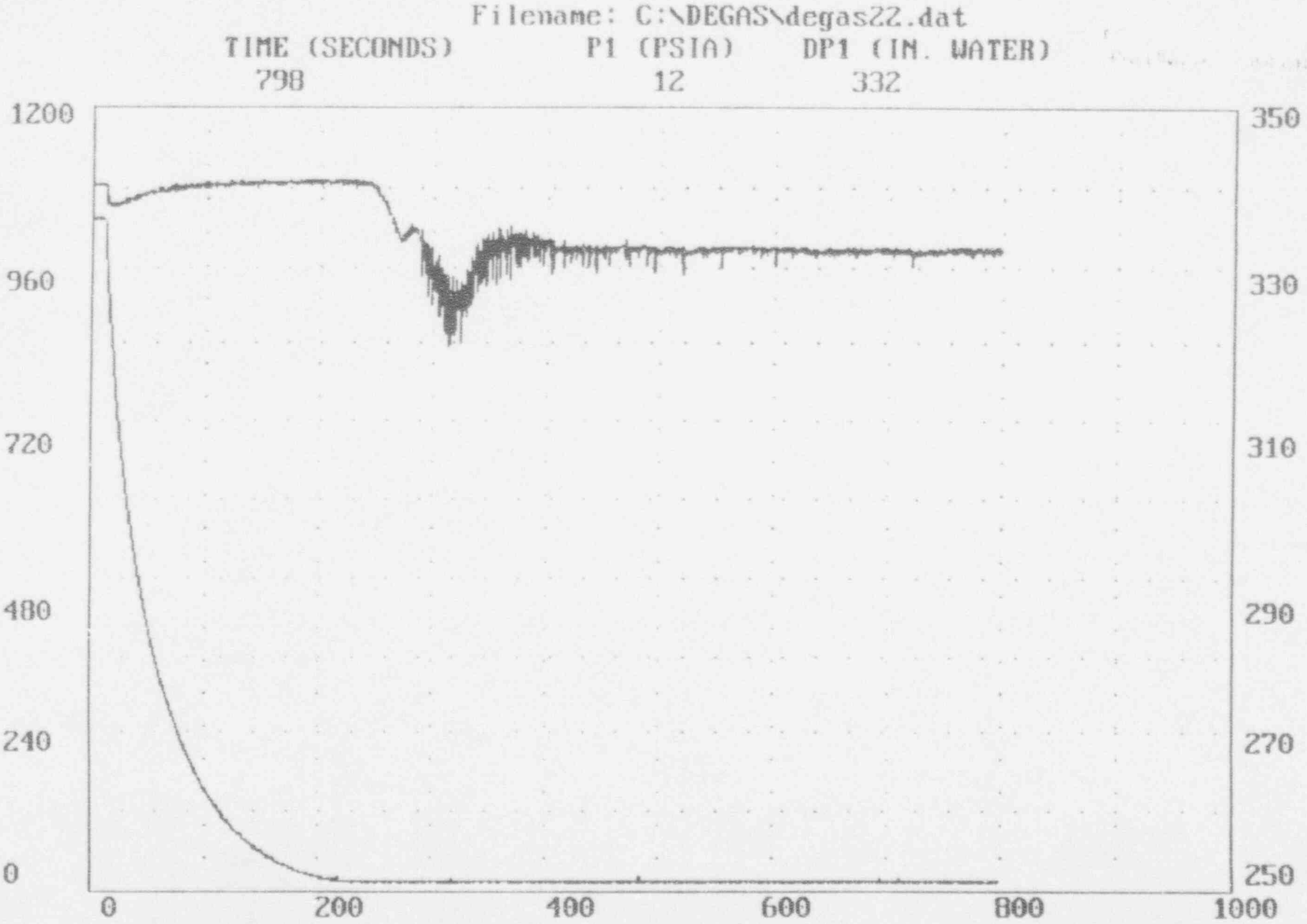
960
720
480
240
0
350
330
310
290
270
250
0
200
400
600
800
1000


Filename: C:\DEGAS\degas22.dat
TIME (SECONDS)
798
P1 (PSIA)
12
DP1 (IN. WATER)
332
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960
720
480
240
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330
310
290
270
250
0
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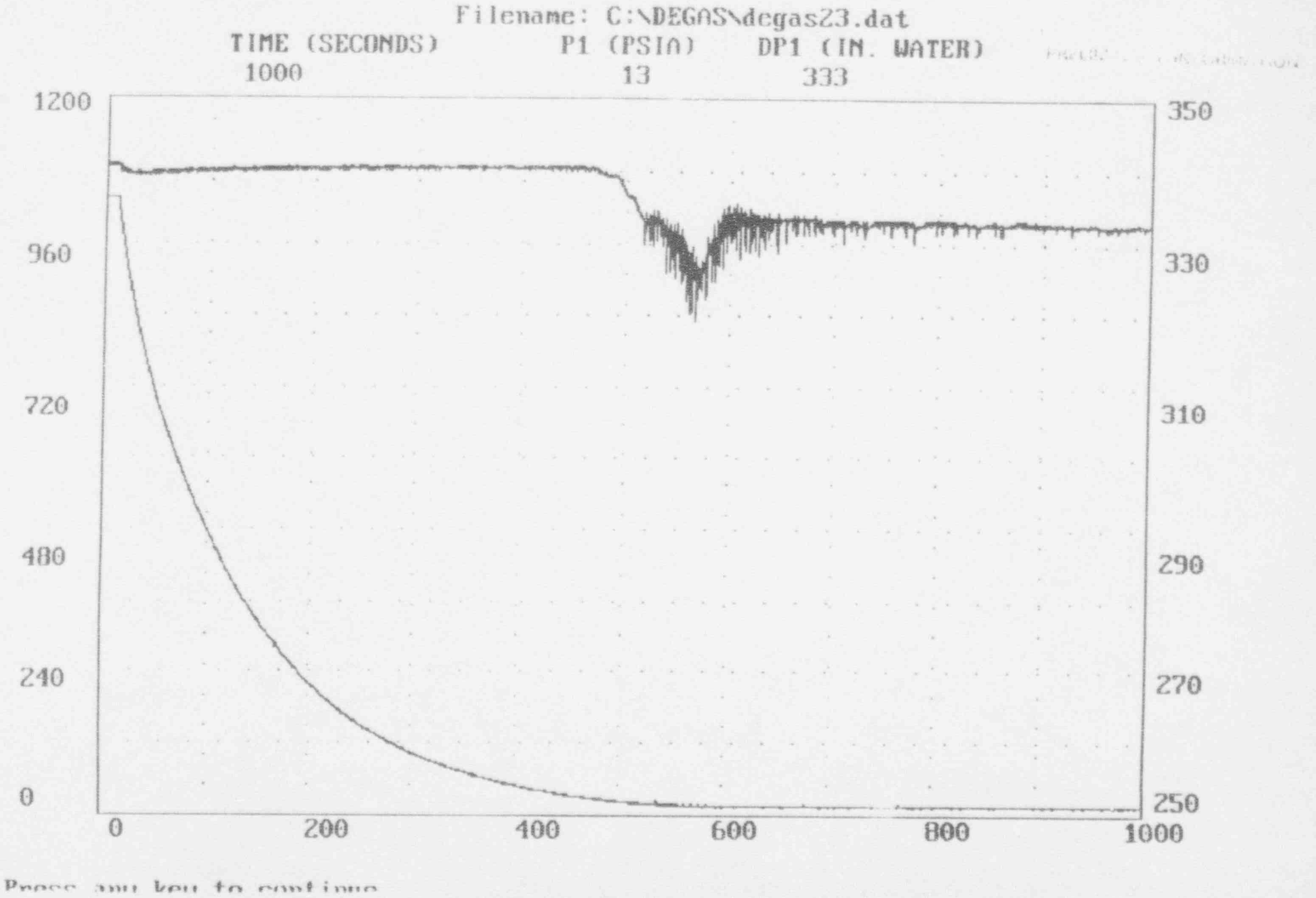
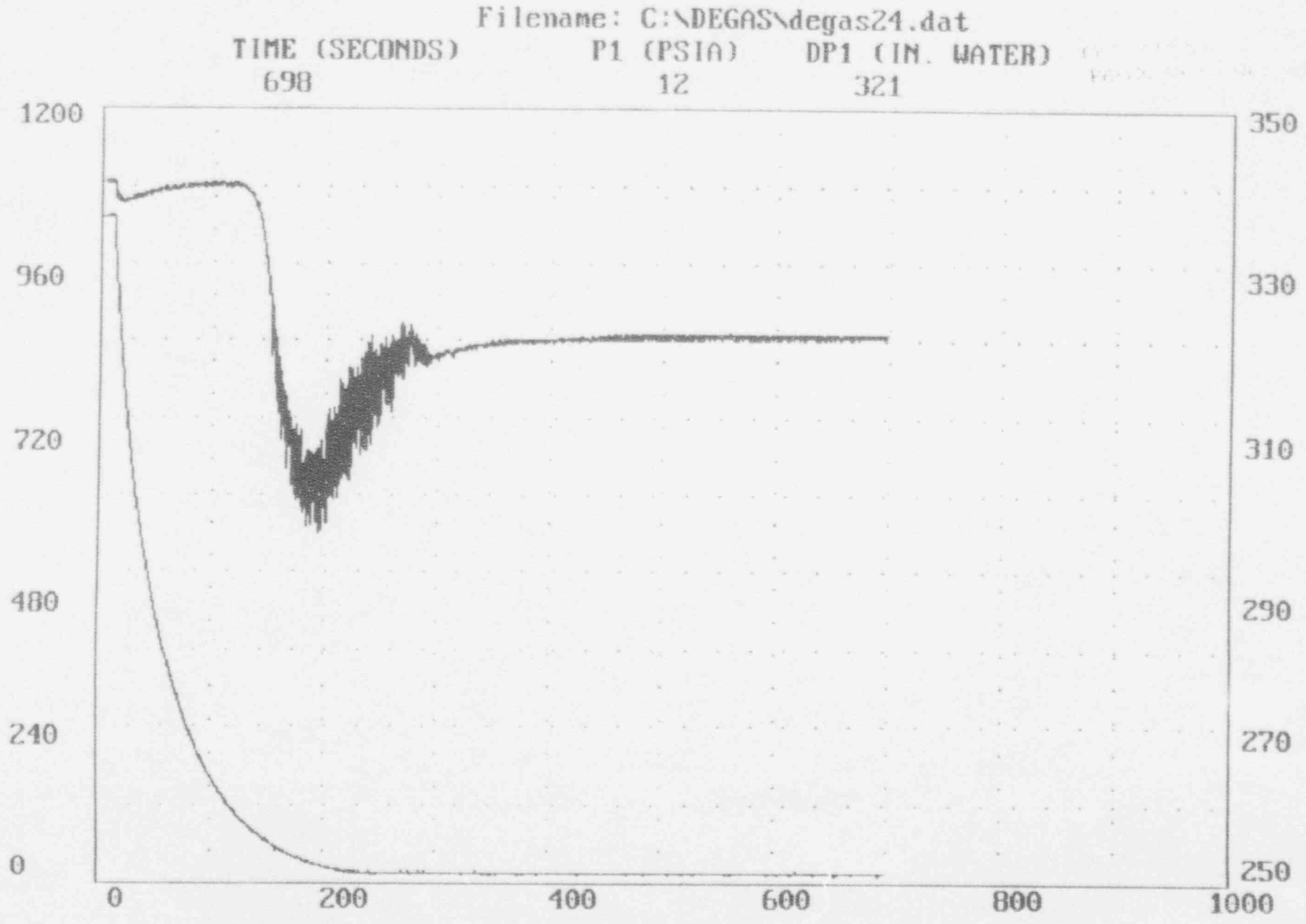
400
600
800
1000



```
                 Filename: C:\DEGAS\degas23.dat
    TIME (SECONDS)          P1 (PSIA)    DP1 (IN. WATER)
     1000                      13             333

Press any key to continue
```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TIME (SECONDS)
698
P1 (PSIA)
12
DP1 (IN. WATER)
321
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720
480
240
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330
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270
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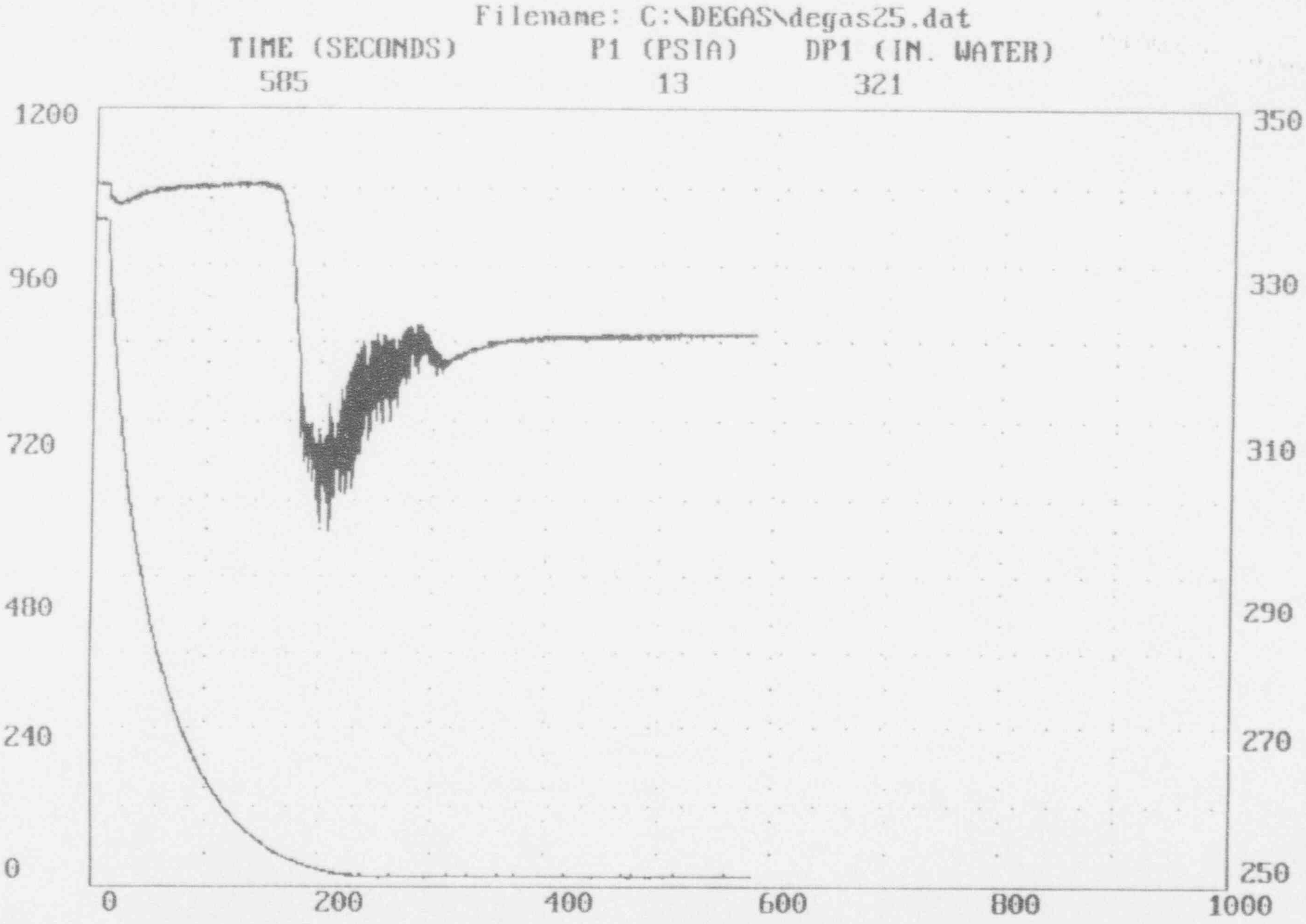
400
600
800
1000


Filename: C:\DEGAS\degas25.dat
TIME (SECONDS)
585
P1 (PSIA)
13
DP1 (IN. WATER)
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480
240
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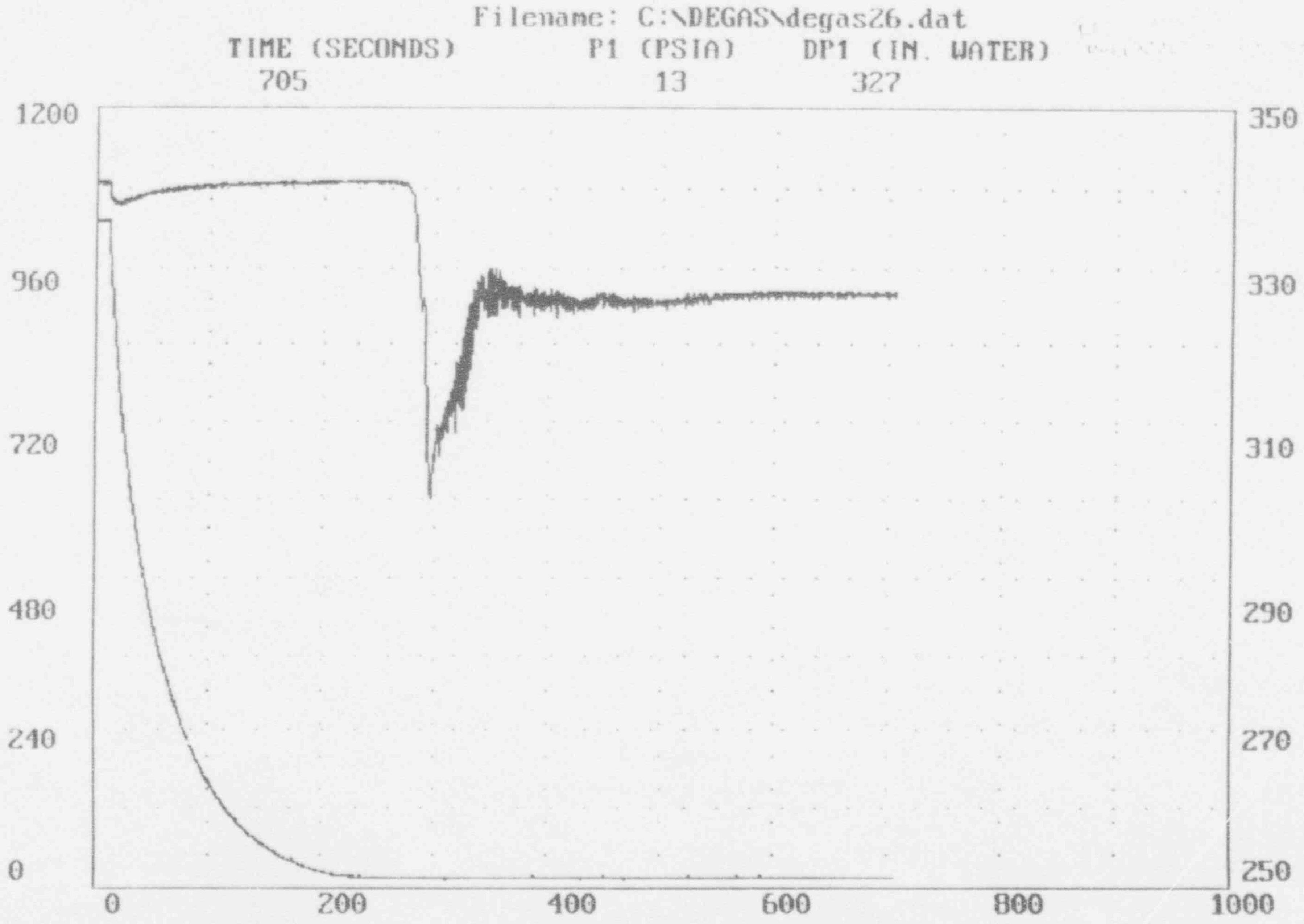
400
600
800
1000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TIME (SECONDS)
705
P1 (PSIA)
13
DP1 (IN. WATER)
327
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720
480
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270
250
0
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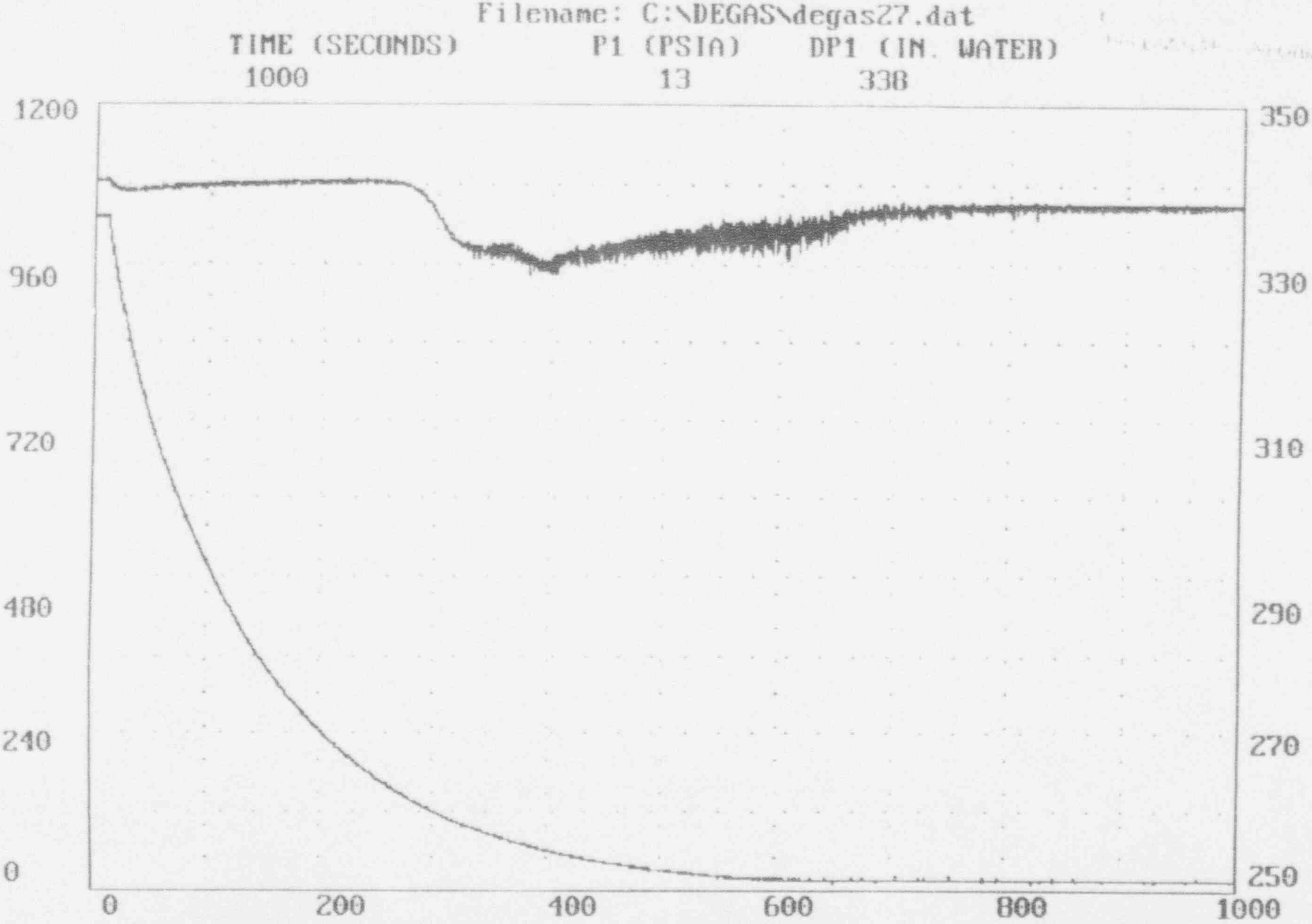
400
600
800
1000


Filename: C:\DEGAS\degas27.dat
TIME (SECONDS)
1000
P1 (PSIA)
13
DP1 (IN. WATER)
338
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720
480
240
0
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330
310
290
270
250
0
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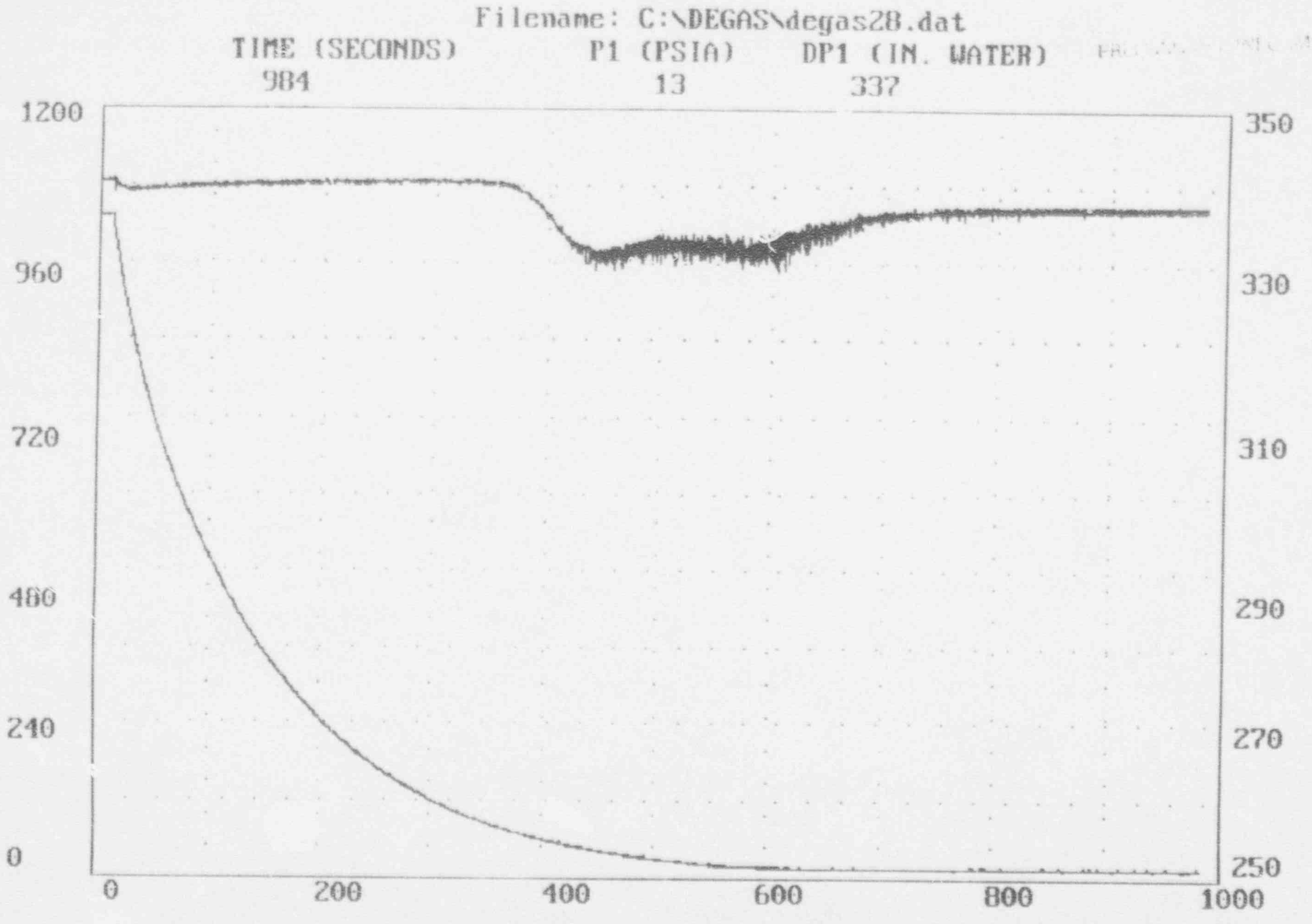
400
600
800
1000


Filename: C:\DEGAS\degas28.dat
TIME (SECONDS)
984
P1 (PSIA)
13
DP1 (IN. WATER)
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720
480
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270
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0
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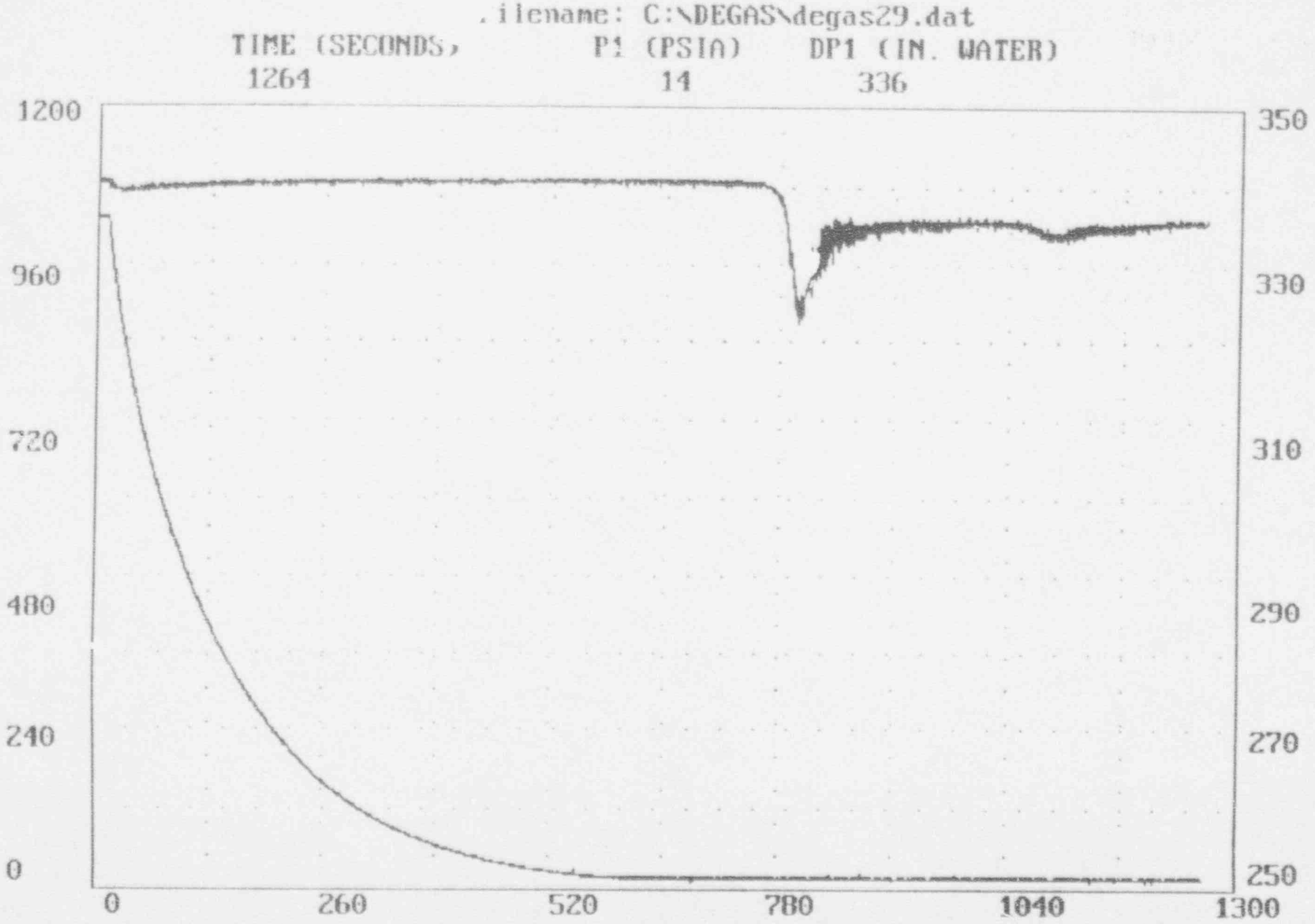
400
600
800
1000


.ilename: C:\DEGAS\degas29.dat
TIME (SECONDS,
1264
P1 (PSIA)
14
DP1 (IN. WATER)
336
1200
960
720
480
240
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350
330
310
290
270
250
0
260
520
780
1040
1300

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Filename: C:\DEGAS\degas30.dat
TIME (SECONDS)            P1 (PSIA)    DP1 (IN. WATER)
   733                       13             300
```
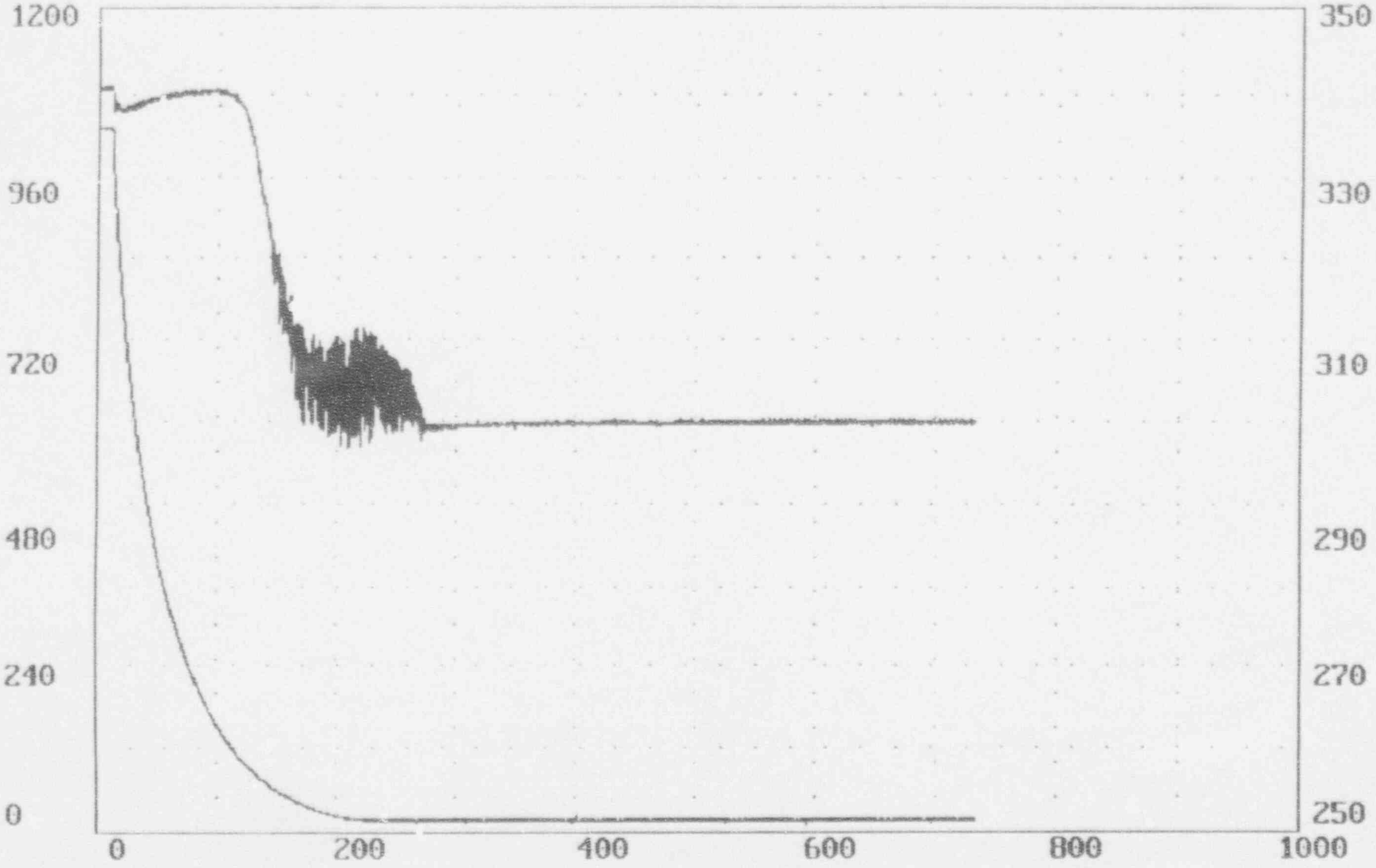
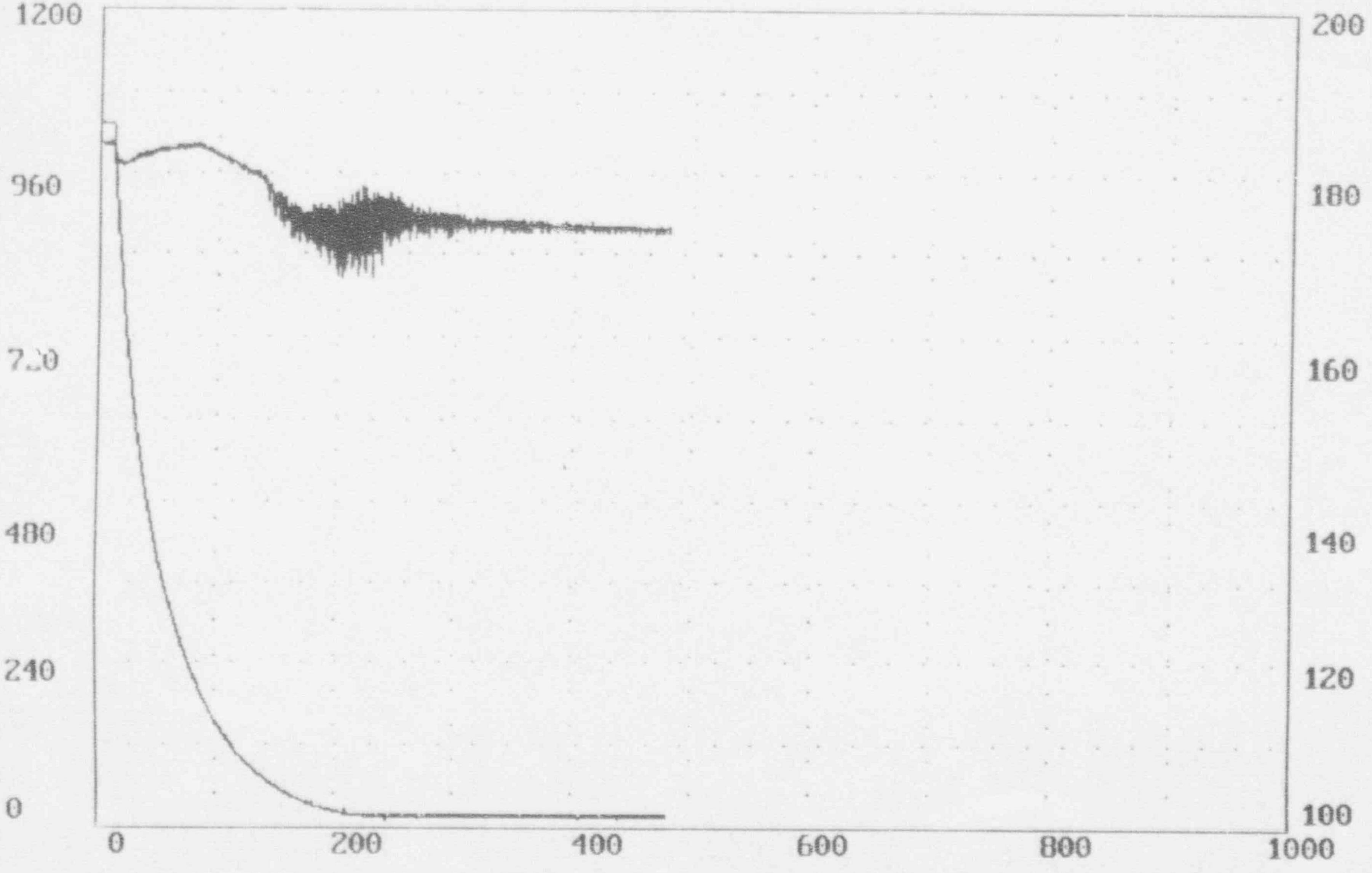
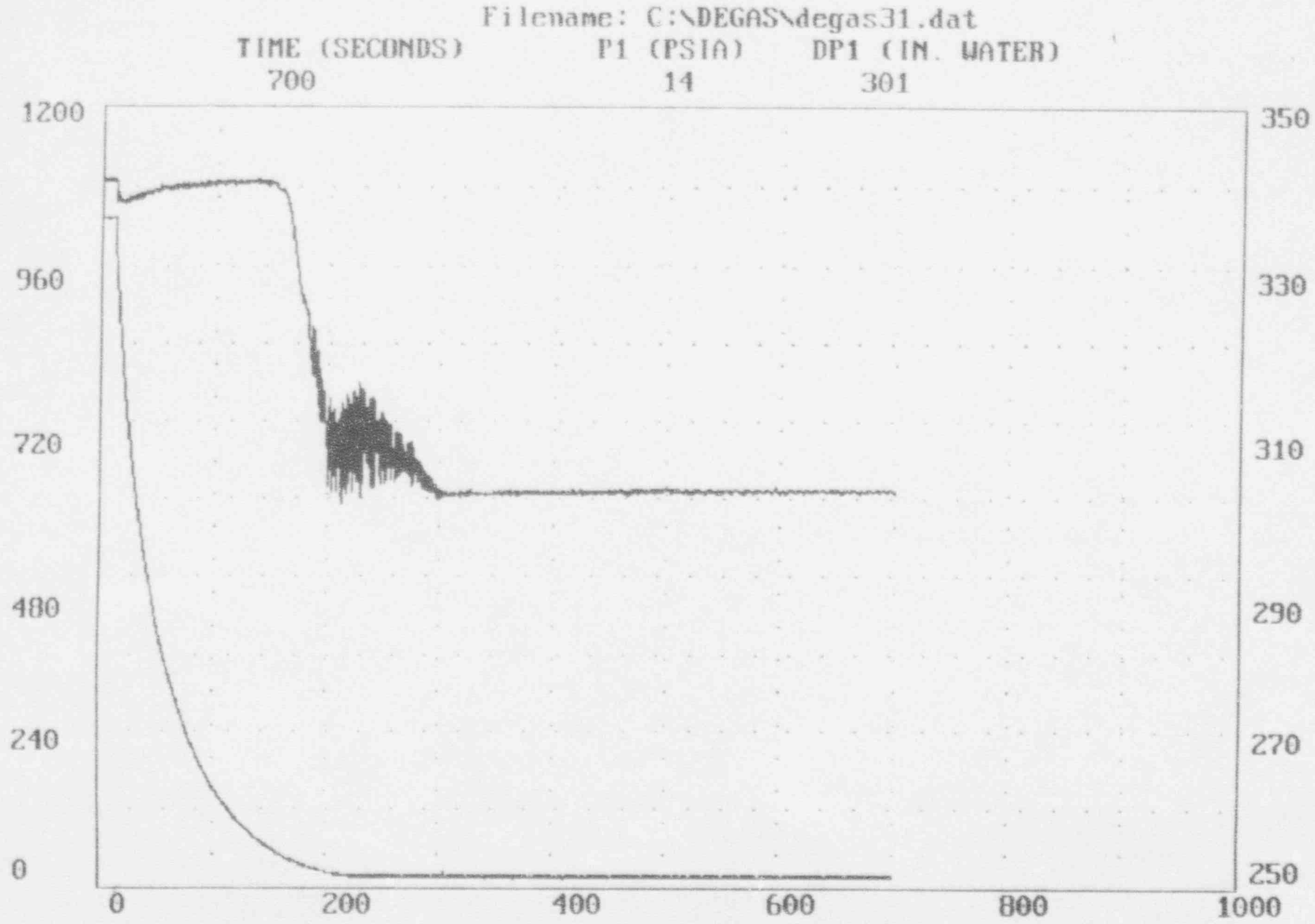




Filename: degas33.dat

TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

480 13 173


Filename: C:\DEGAS\degas31.dat
TIME (SECONDS)
700
P1 (PSIA)
14
DP1 (IN. WATER)
301
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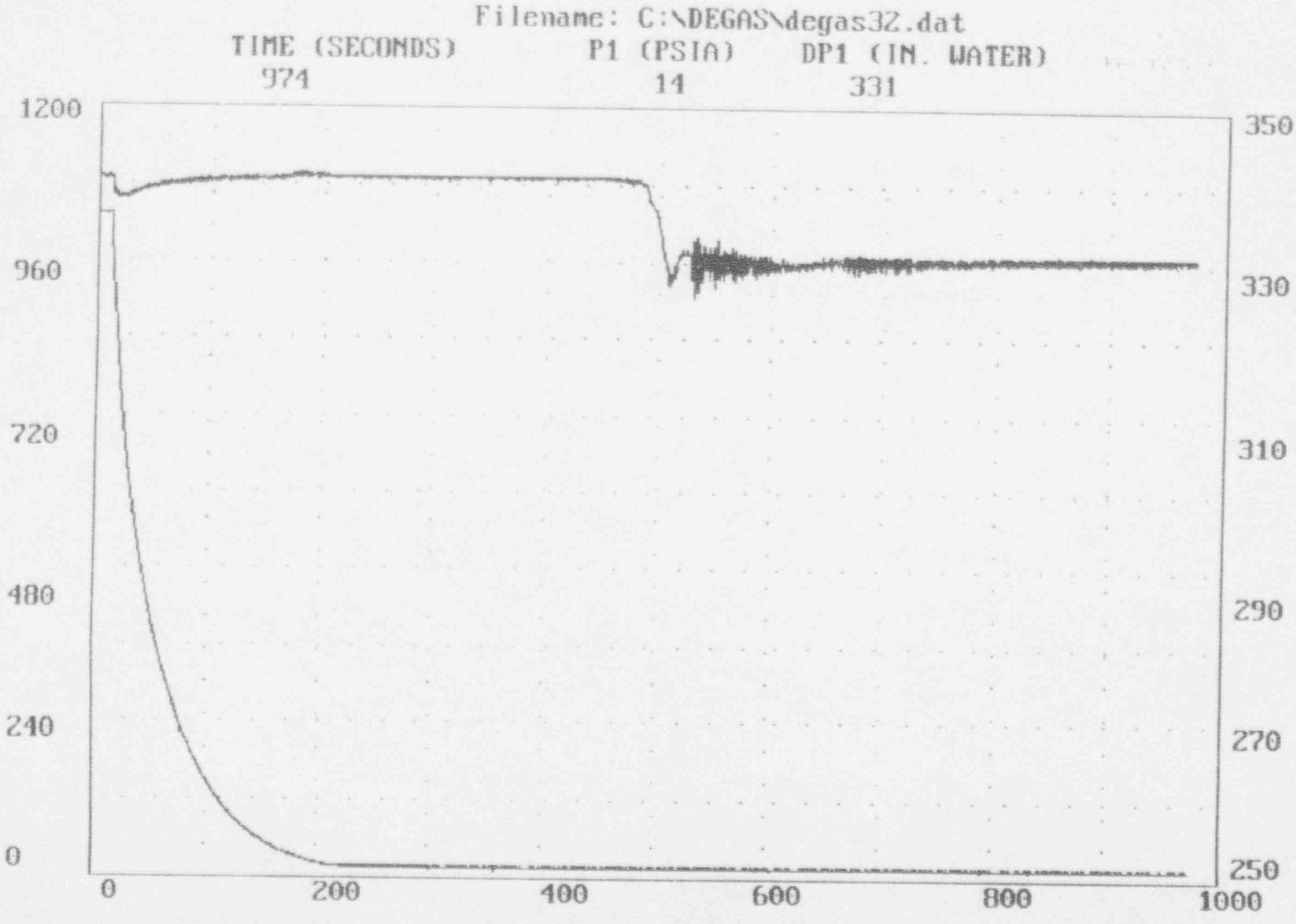
960
720
480
240
0
350
330
310
290
270
250
0
200
400
600
800
1000


Filename: C:\DEGAS\degas32.dat
TIME (SECONDS)
974
P1 (PSIA)
14
DP1 (IN. WATER)
331
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960
720
480
240
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330
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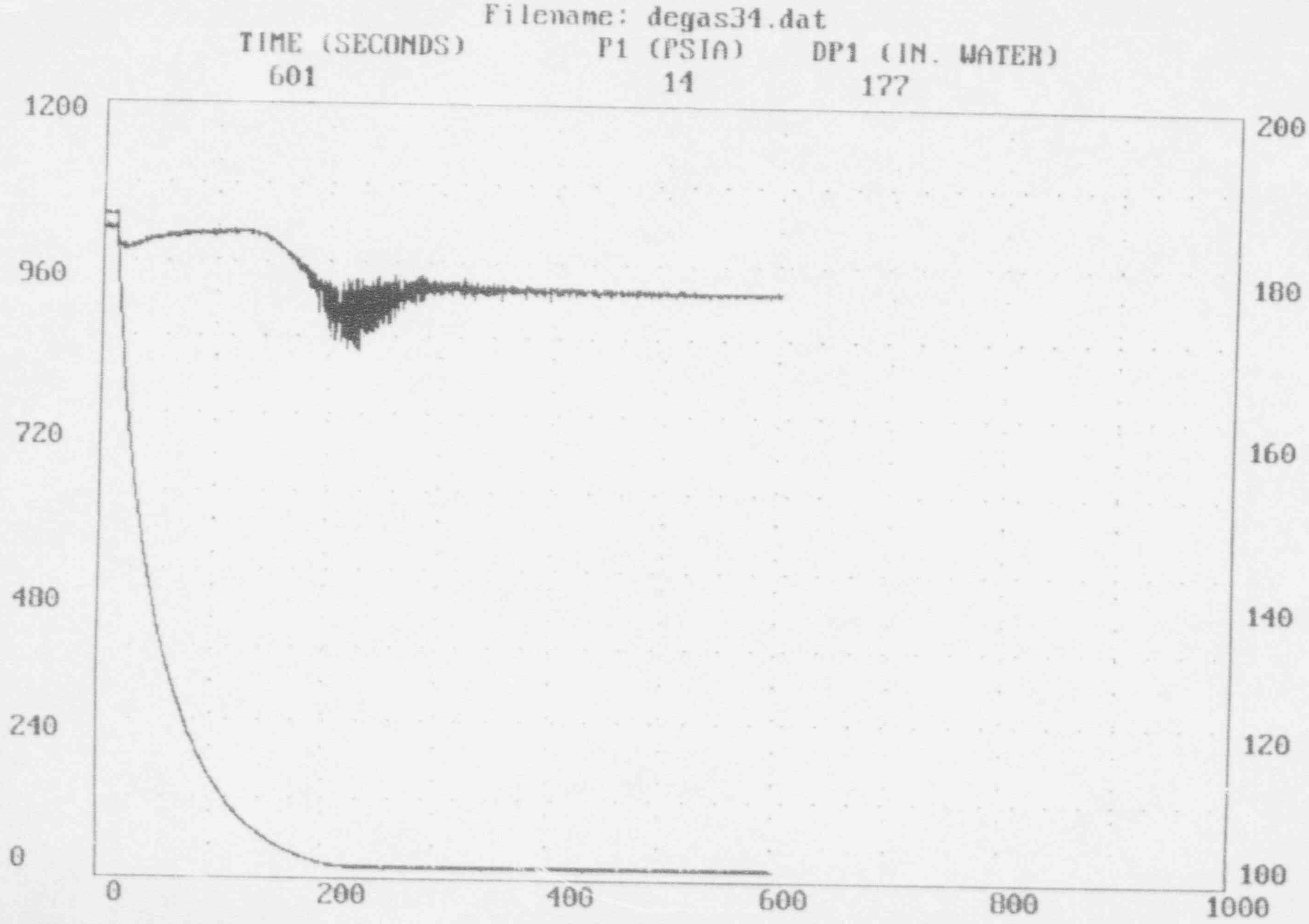
270
250
0
200
400
600
800
1000


Filename: degas34.dat
TIME (SECONDS)
601
P1 (PSIA)
14
DP1 (IN. WATER)
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960
720
480
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0
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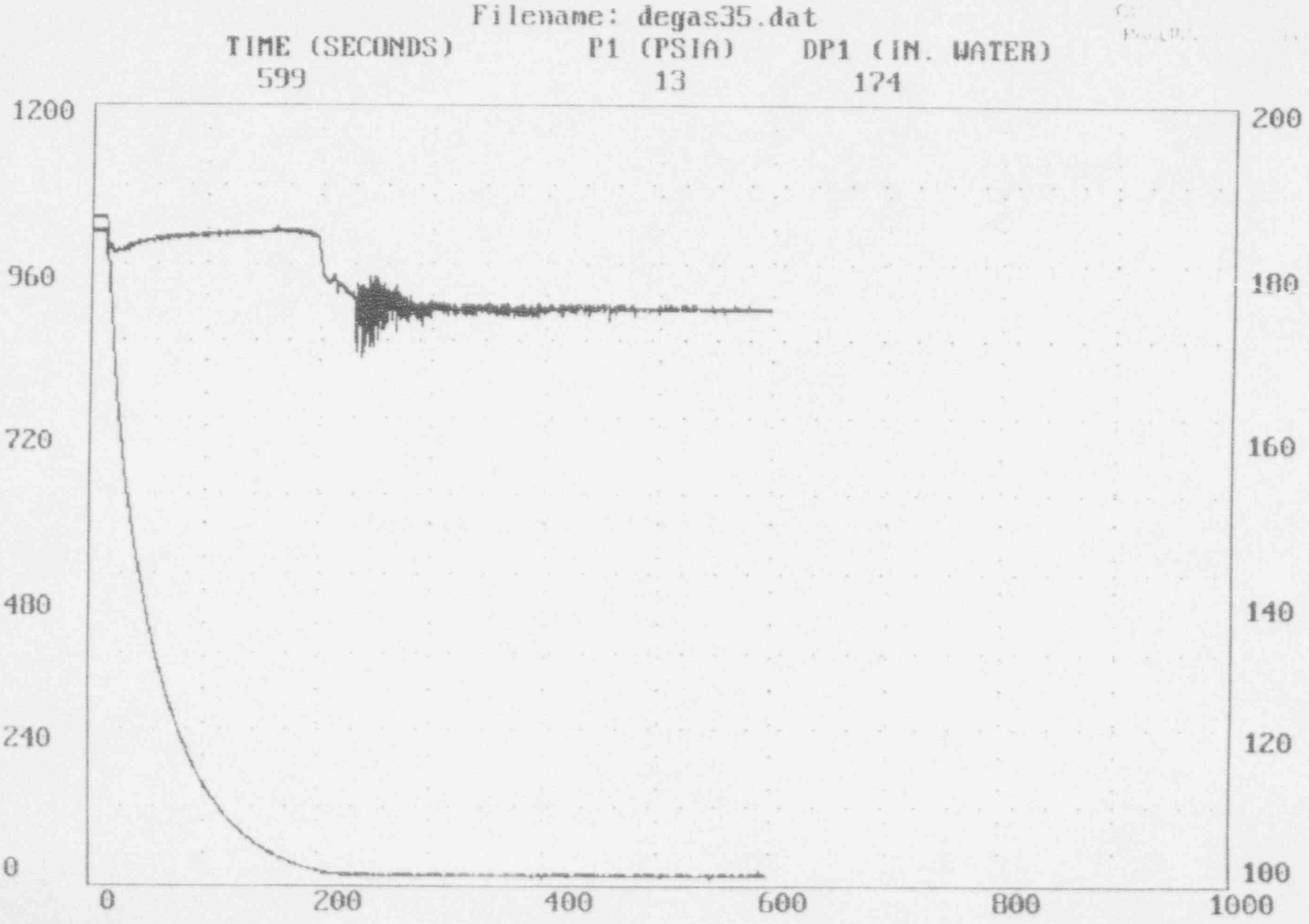
120
100
0
200
400
600
800
1000


Filename: degas35.dat
TIME (SECONDS)
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P1 (PSIA)
13
DP1 (IN. WATER)
174
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720
480
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120
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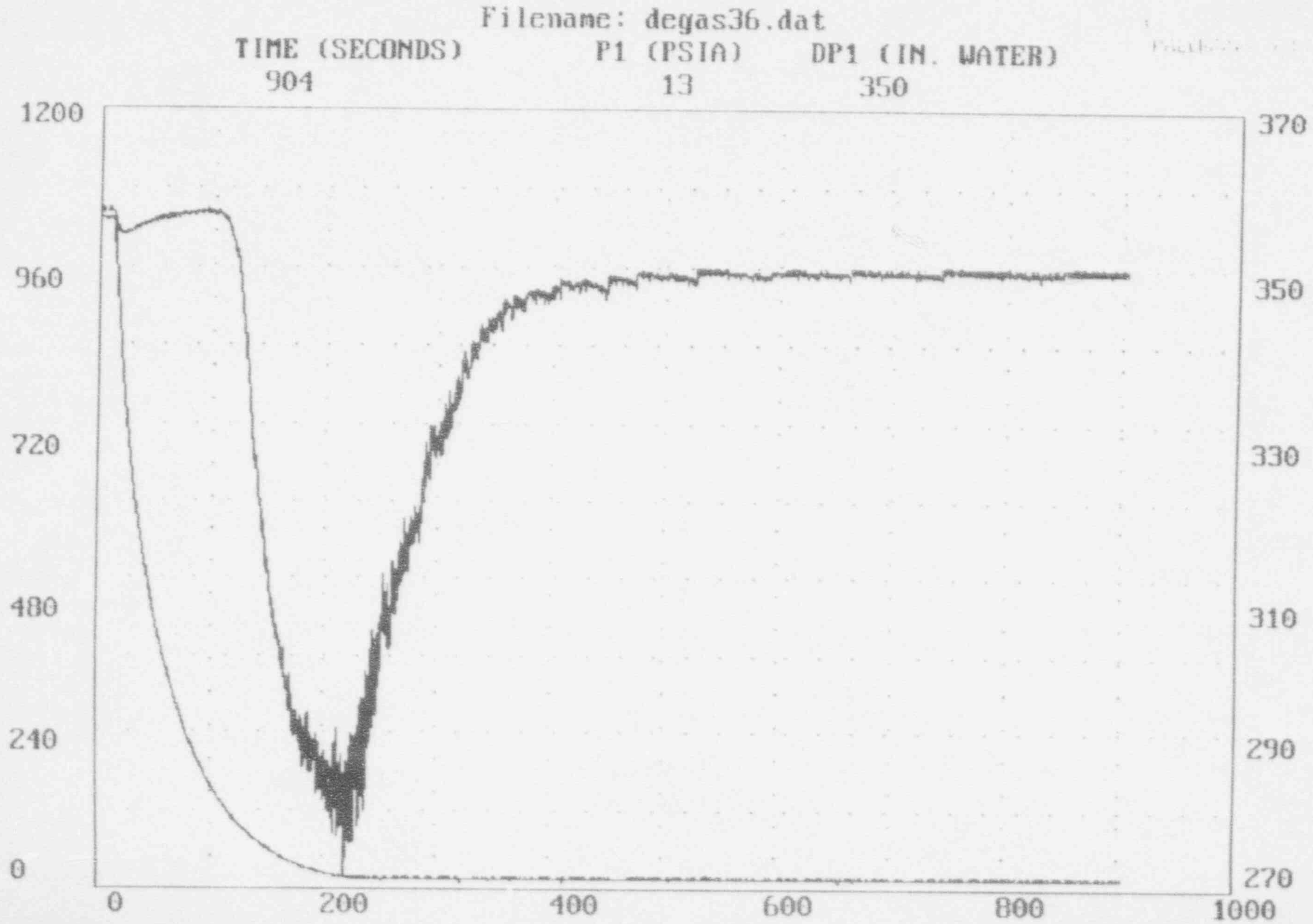
400
600
800
1000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TIME (SECONDS)
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P1 (PSIA)
13
DP1 (IN. WATER)
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720
480
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600
800
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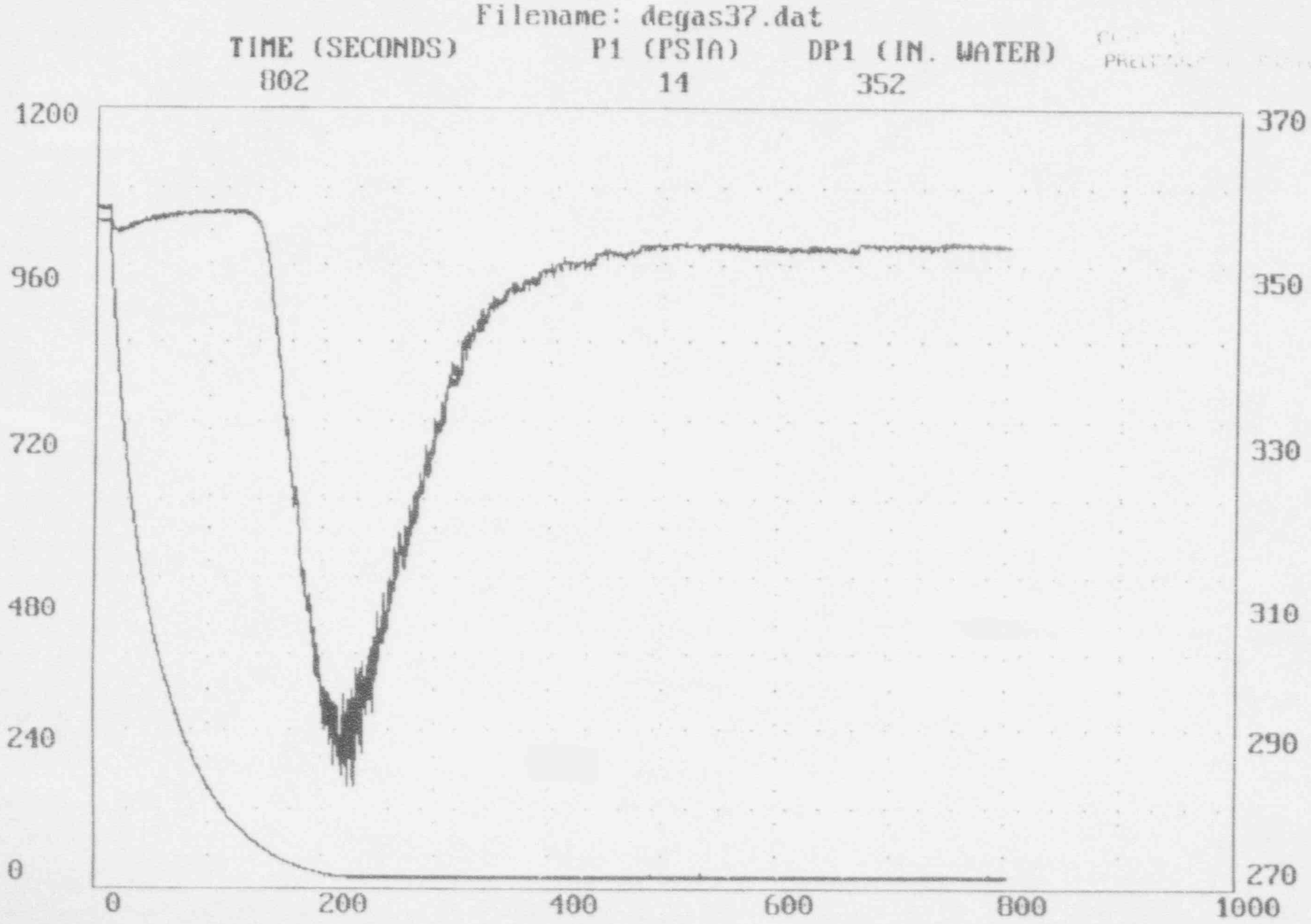
Filename: degas37.dat
TIME (SECONDS)
802
P1 (PSIA)
14
DP1 (IN. WATER)
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960
720
480
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0
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350
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290
270
0
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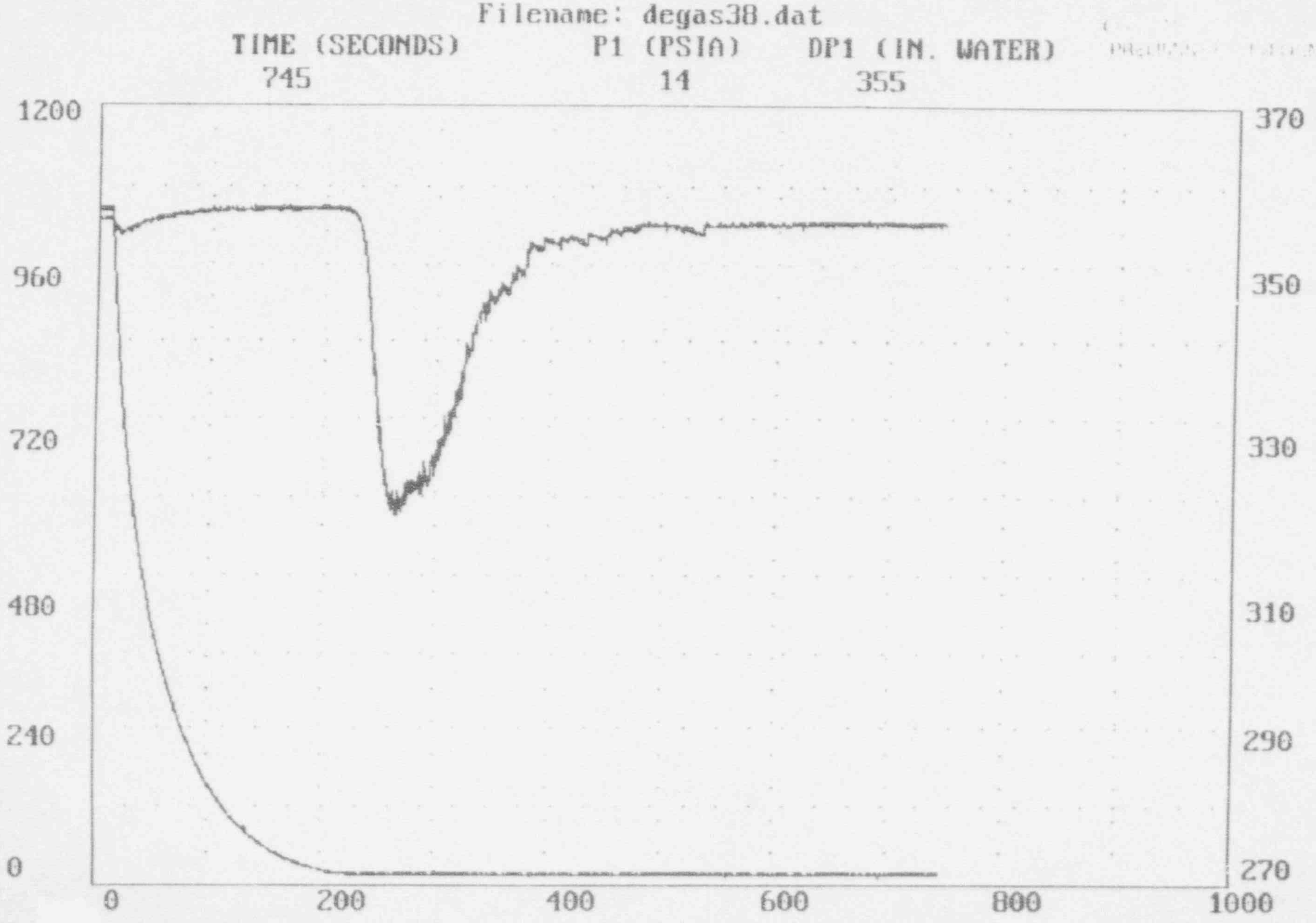
400
600
800
1000


Filename: degas38.dat
TIME (SECONDS)
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P1 (PSIA)
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DP1 (IN. WATER)
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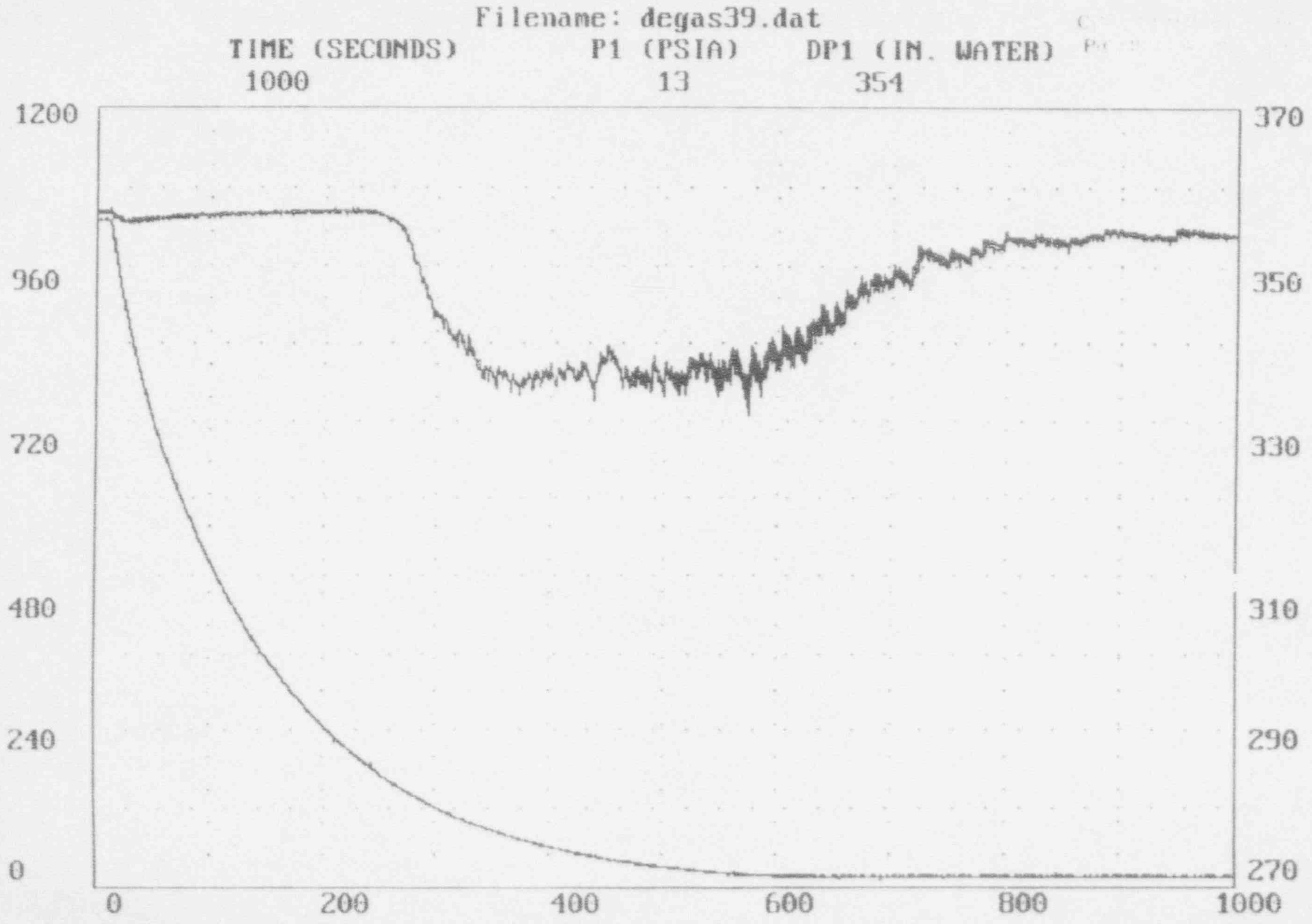
400
600
800
1000


Filename: degas39.dat
TIME (SECONDS)
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DP1 (IN. WATER)
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720
480
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290
270
0
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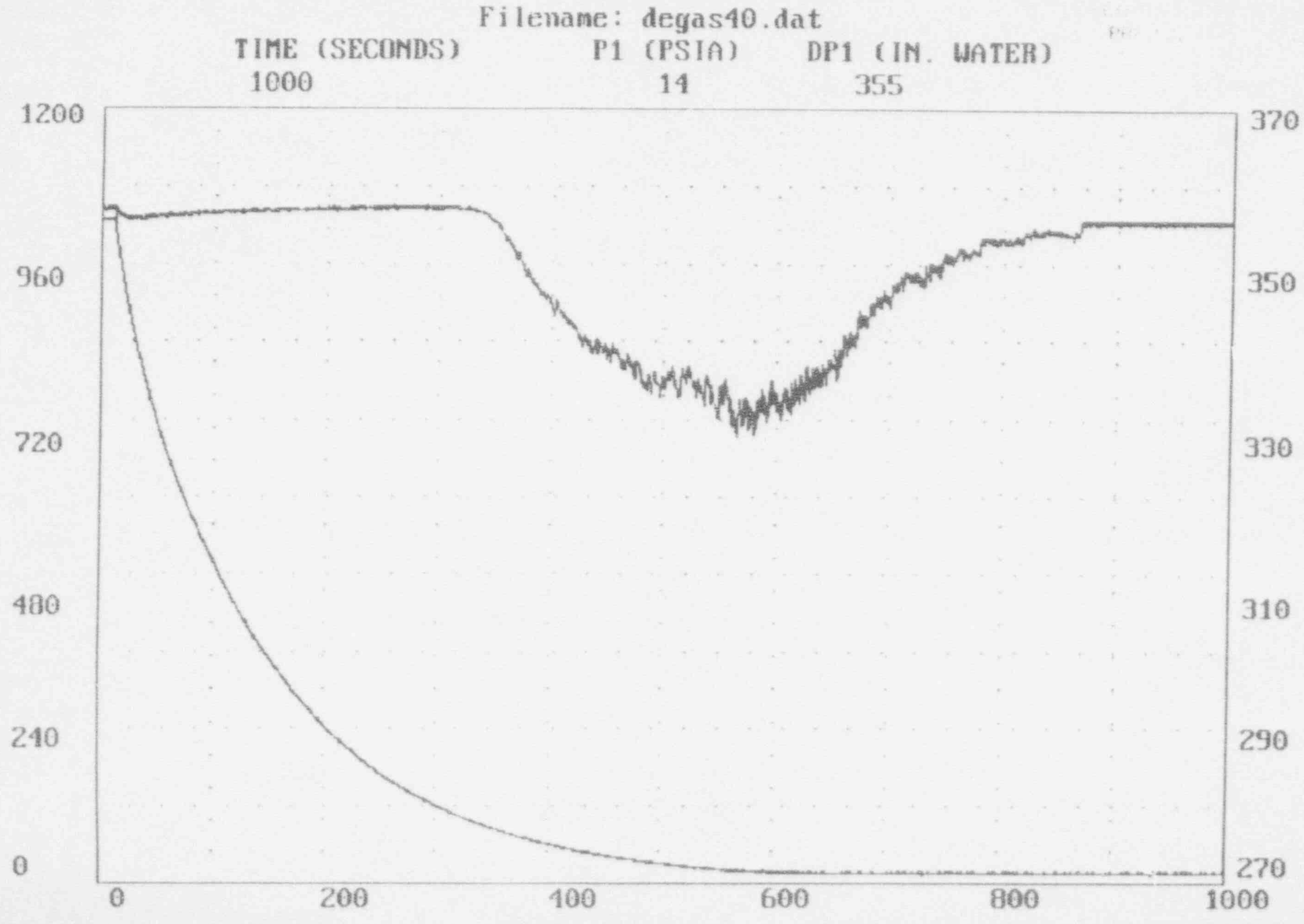
400
600
800
1000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DP1 (IN. WATER)
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720
480
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290
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0
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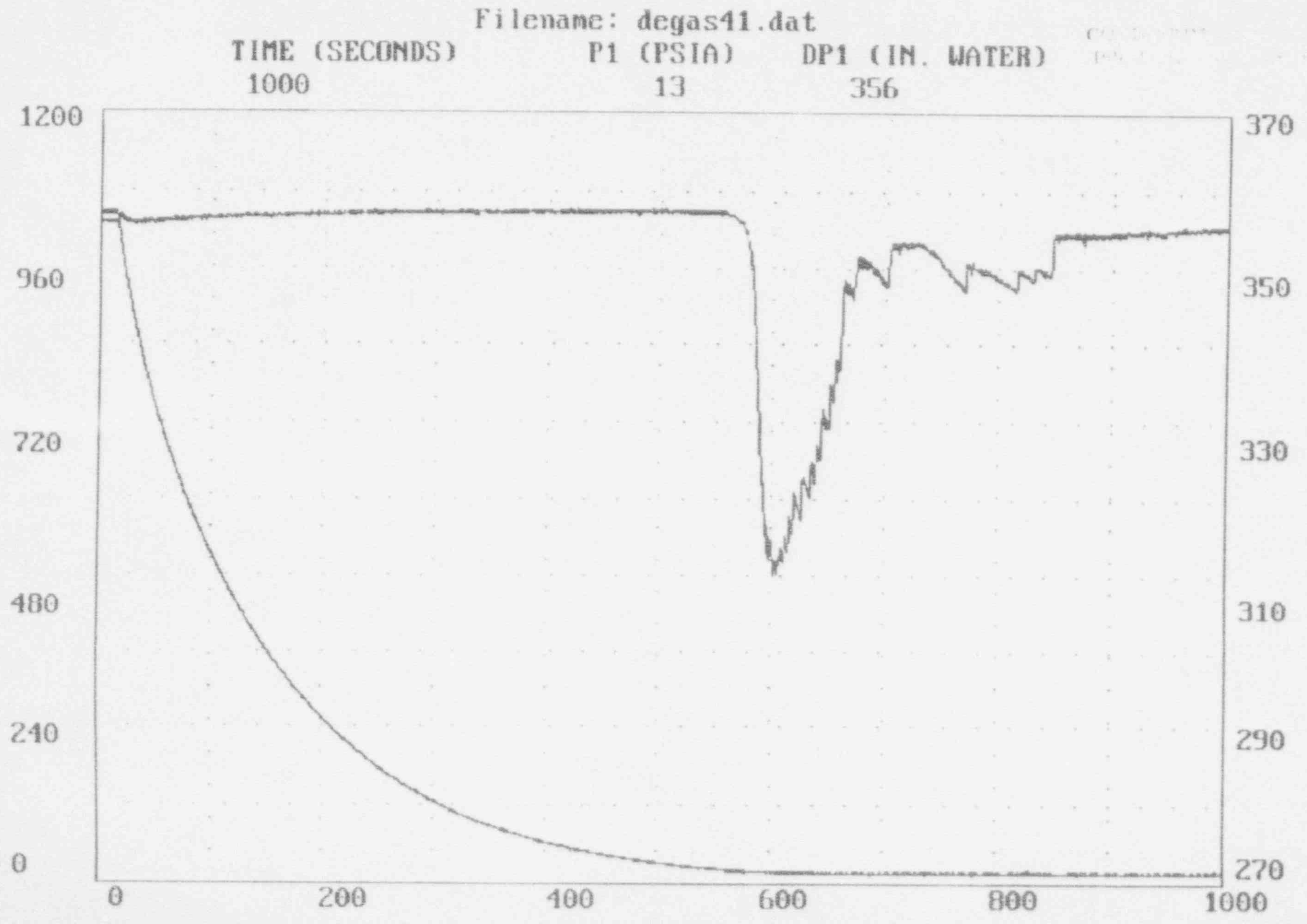
400
600
800
1000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DP1 (IN. WATER)
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720
480
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290
270
0
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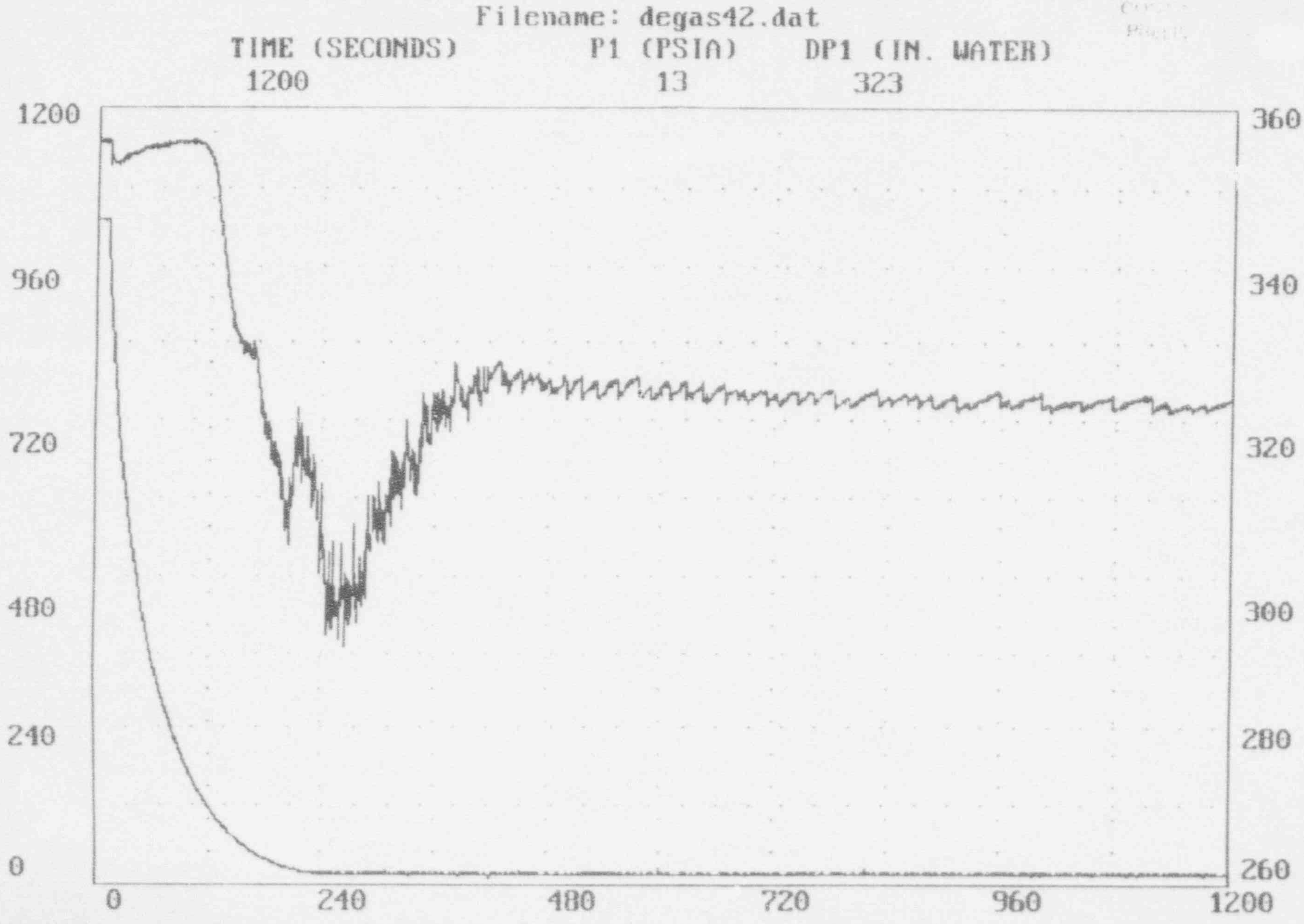
400
600
800
1000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TIME (SECONDS)
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P1 (PSIA)
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DP1 (IN. WATER)
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720
480
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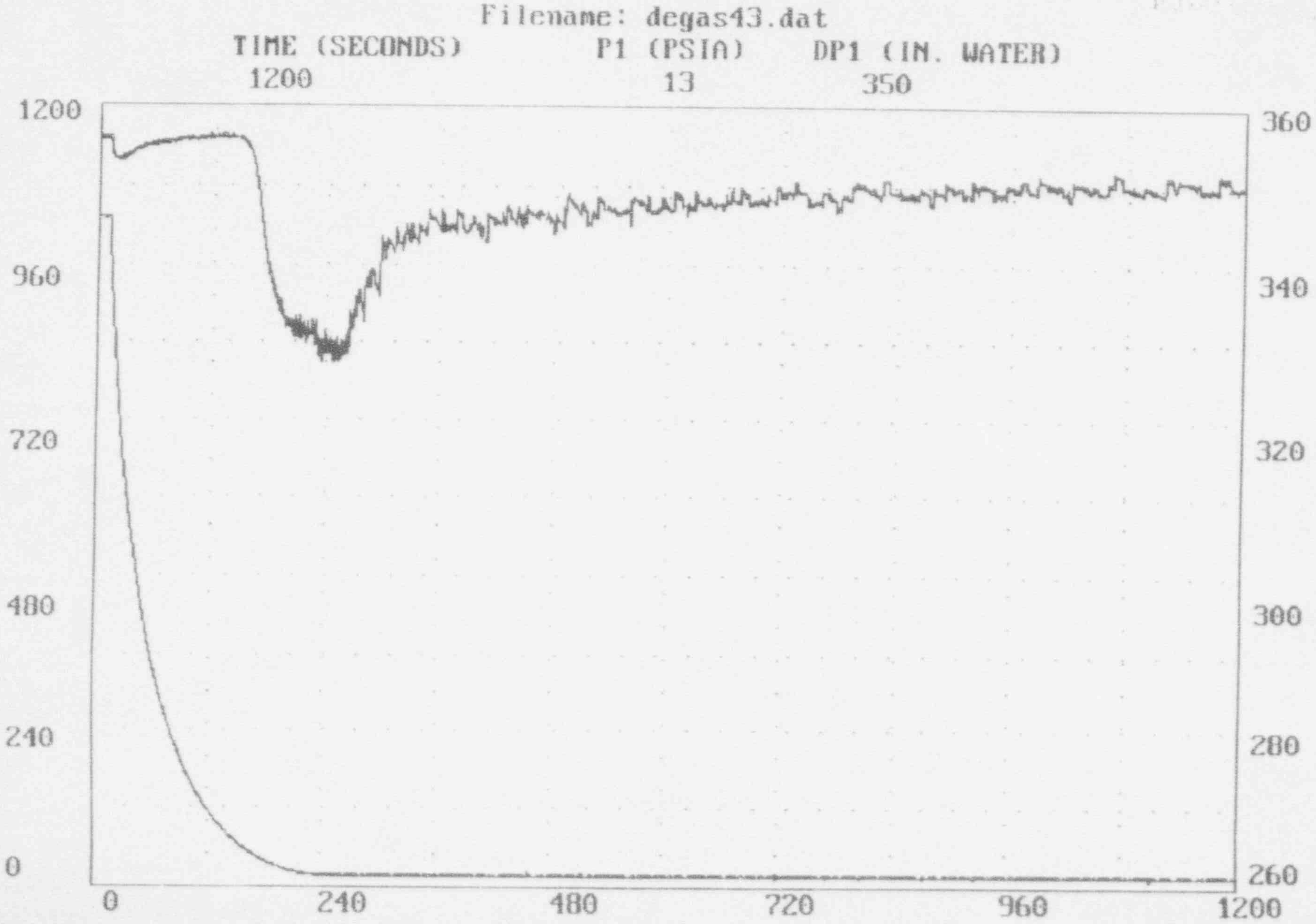
480
720
960
1200


Filename: degas43.dat
TIME (SECONDS)
1200
P1 (PSIA)
13
DP1 (IN. WATER)
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720
480
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280
260
0
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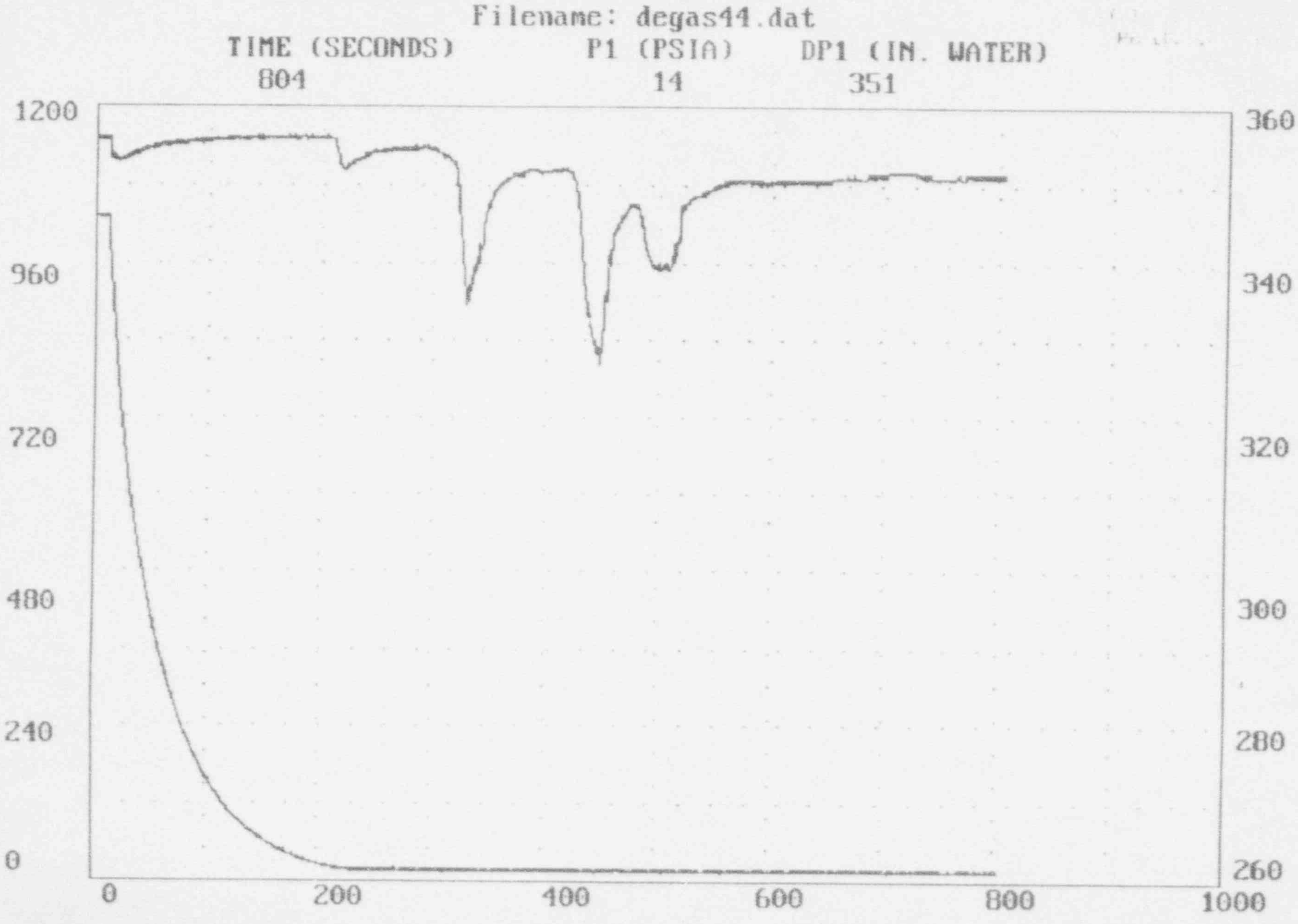
480
720
960
1200


Filename: degas44.dat
TIME (SECONDS)
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P1 (PSIA)
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DP1 (IN. WATER)
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400
600
800
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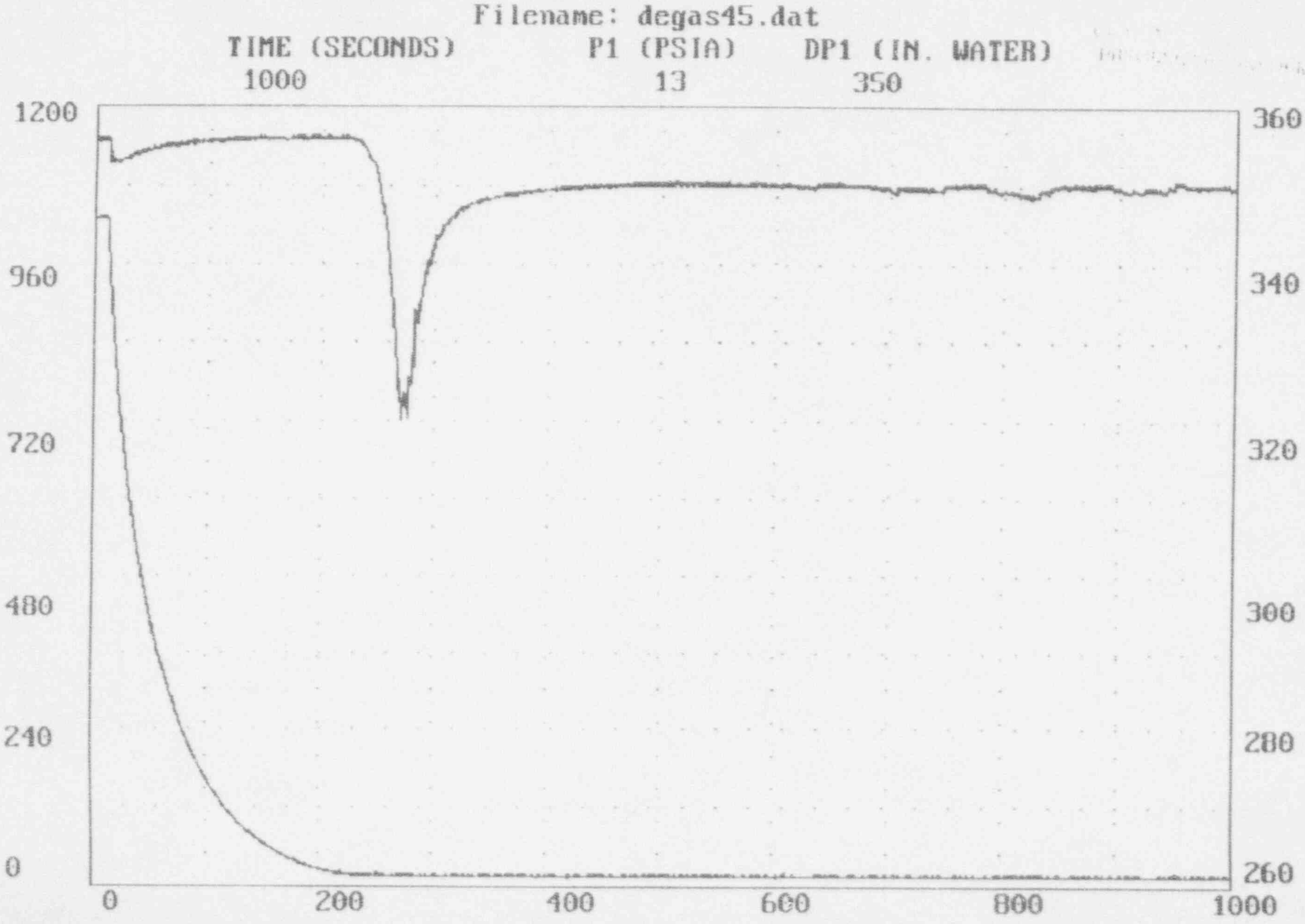
Filename: degas45.dat
TIME (SECONDS)
P1 (PSIA)
DP1 (IN. WATER)
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720
480
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340
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280
260
0
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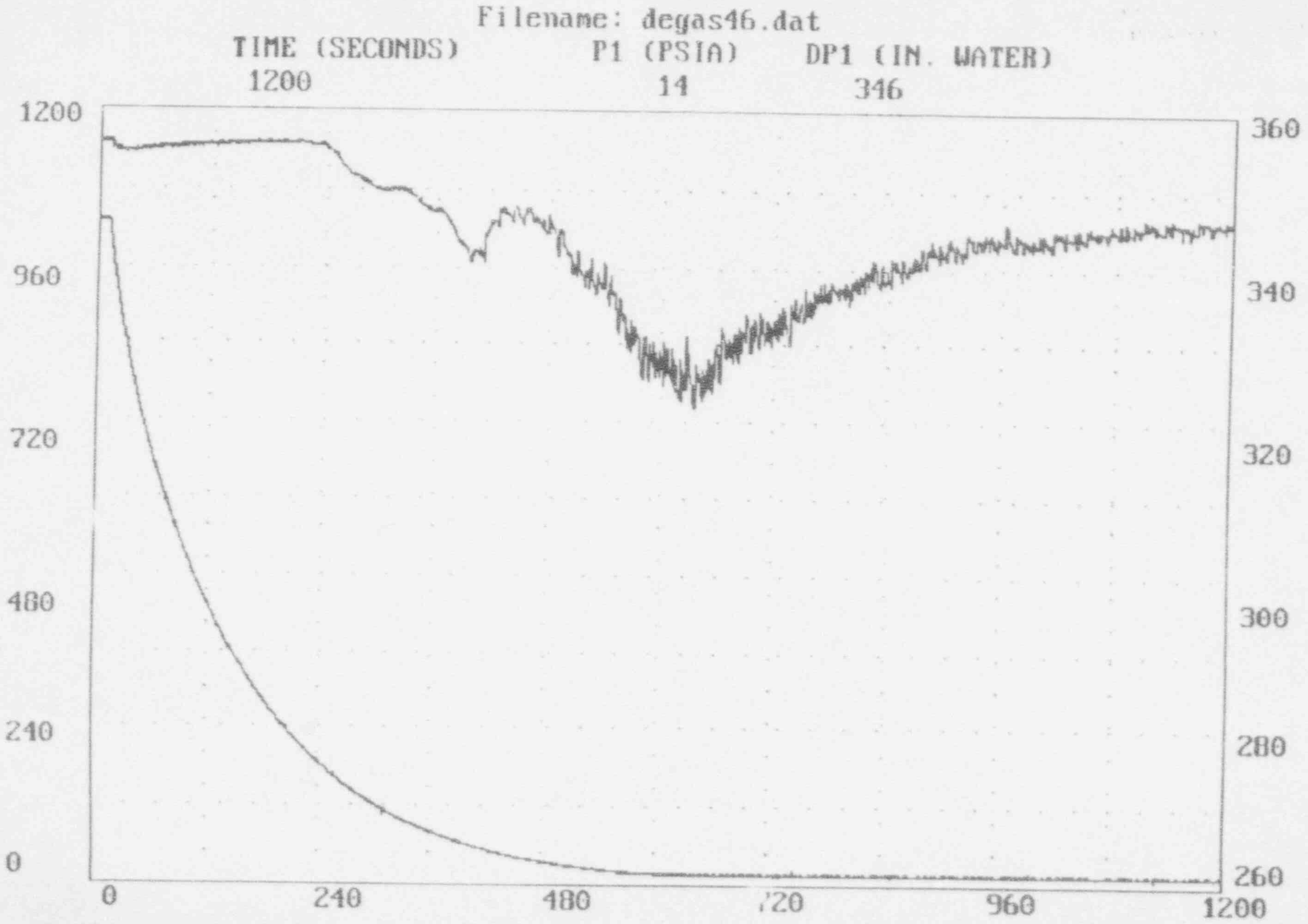
400
600
800
1000


Filename: degas46.dat
TIME (SECONDS)
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P1 (PSIA)
14
DP1 (IN. WATER)
346
1200
960
720
480
240
0
360
340
320
300
280
260
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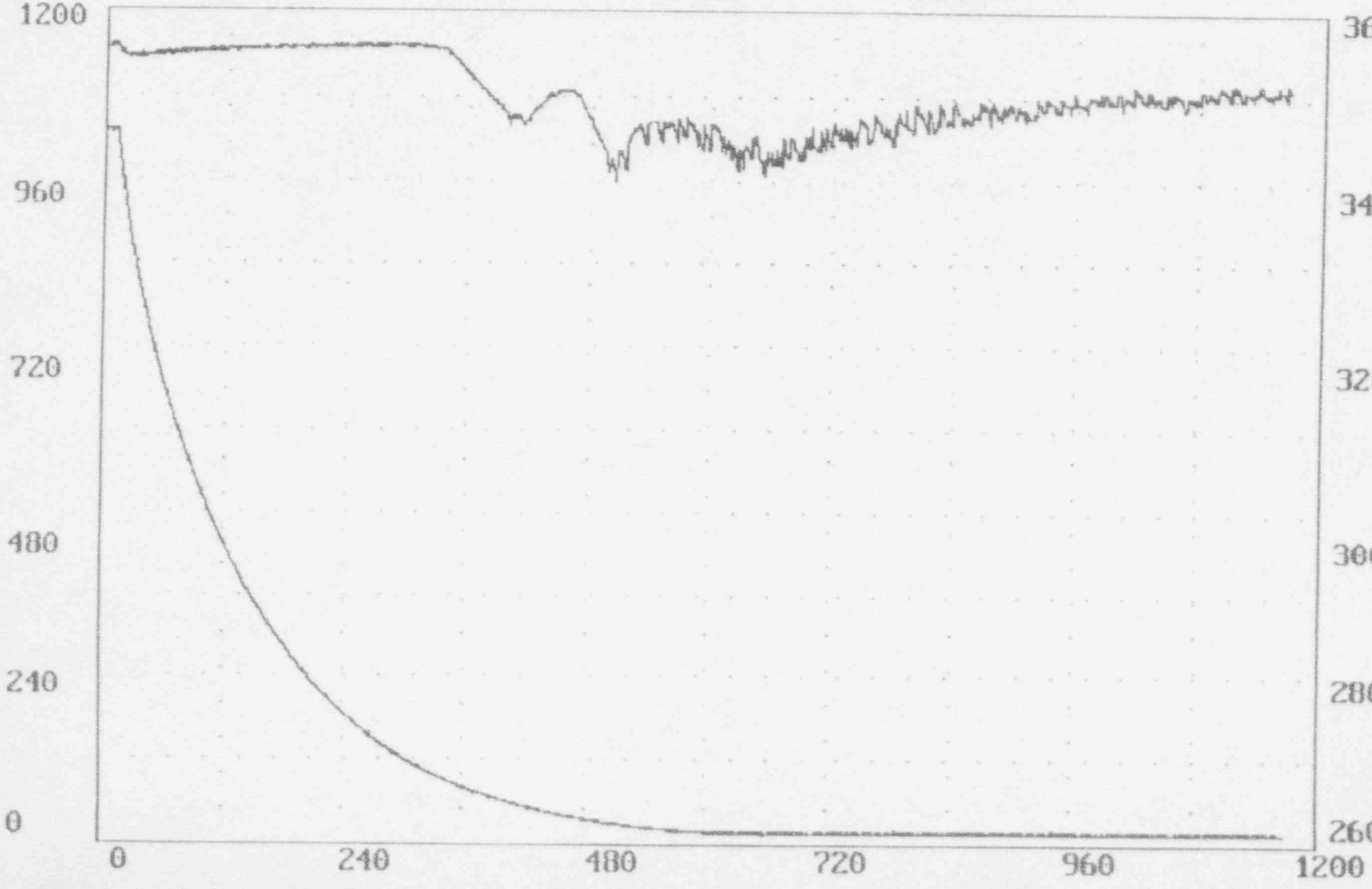
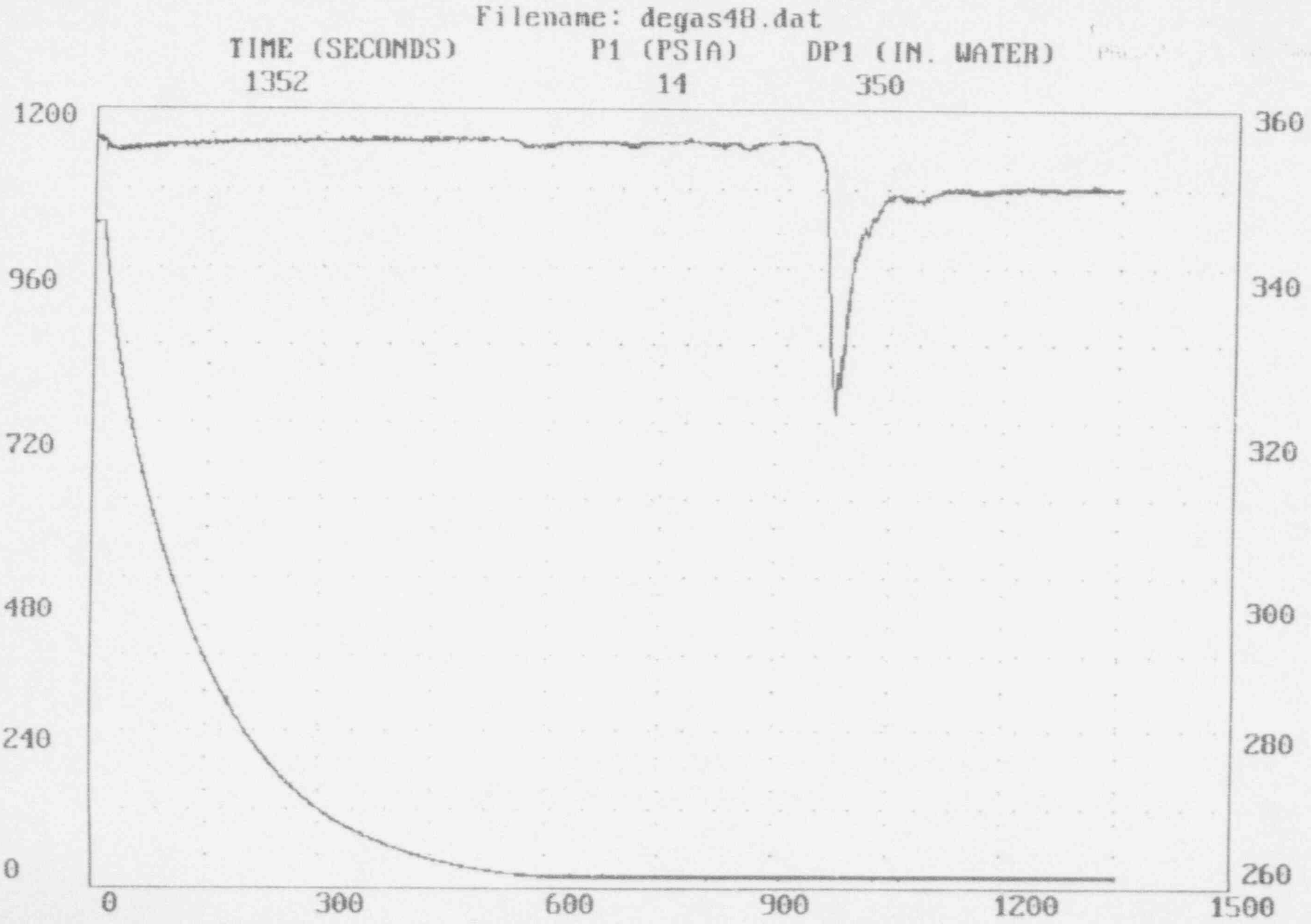
480
720
960
1200

Filename: degas47.dat

TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

1169 13 351

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TIME (SECONDS)
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P1 (PSIA)
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DP1 (IN. WATER)
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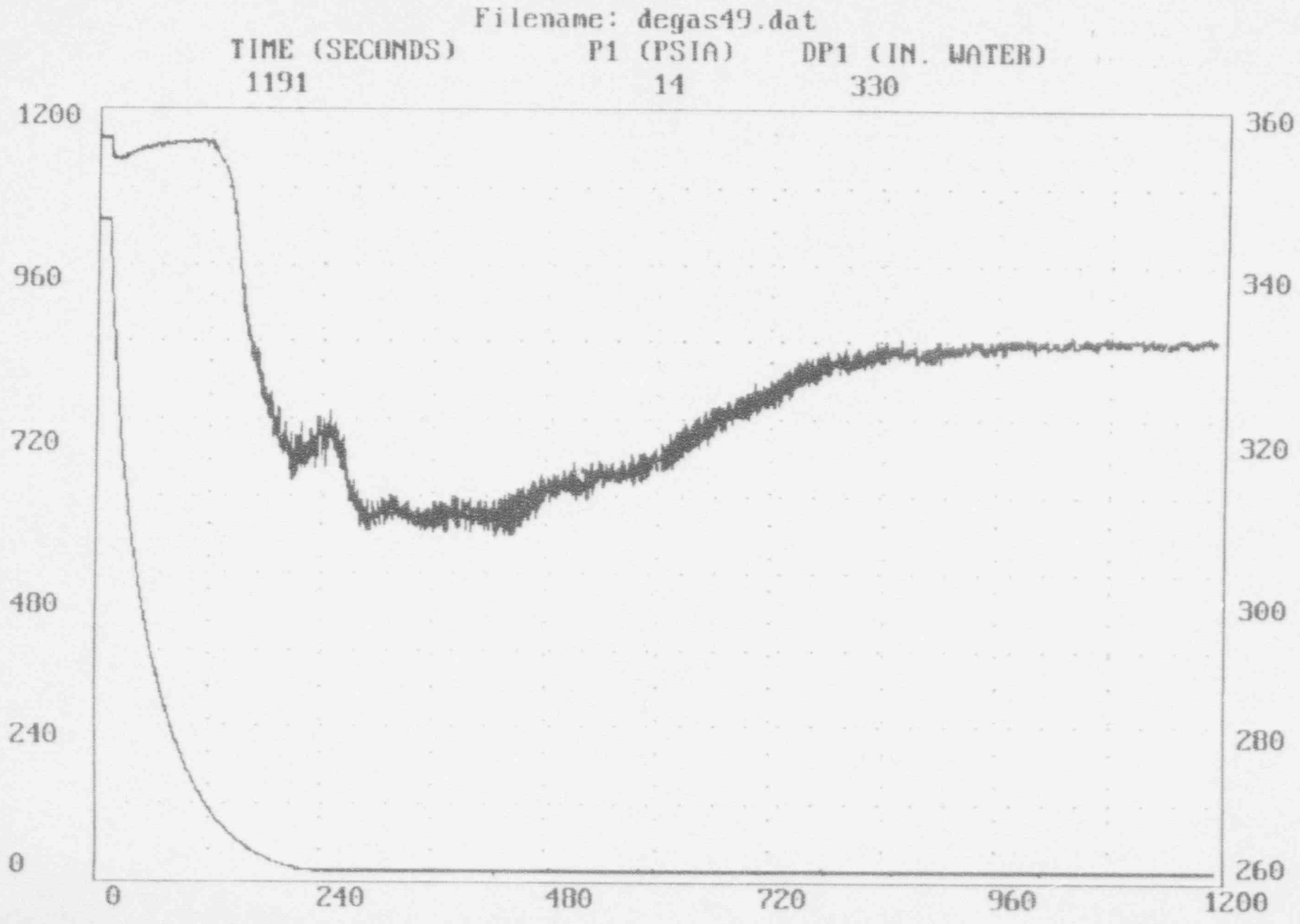
600
900
1200
1500


Filename: degas49.dat
TIME (SECONDS)
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P1 (PSIA)
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DP1 (IN. WATER)
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480
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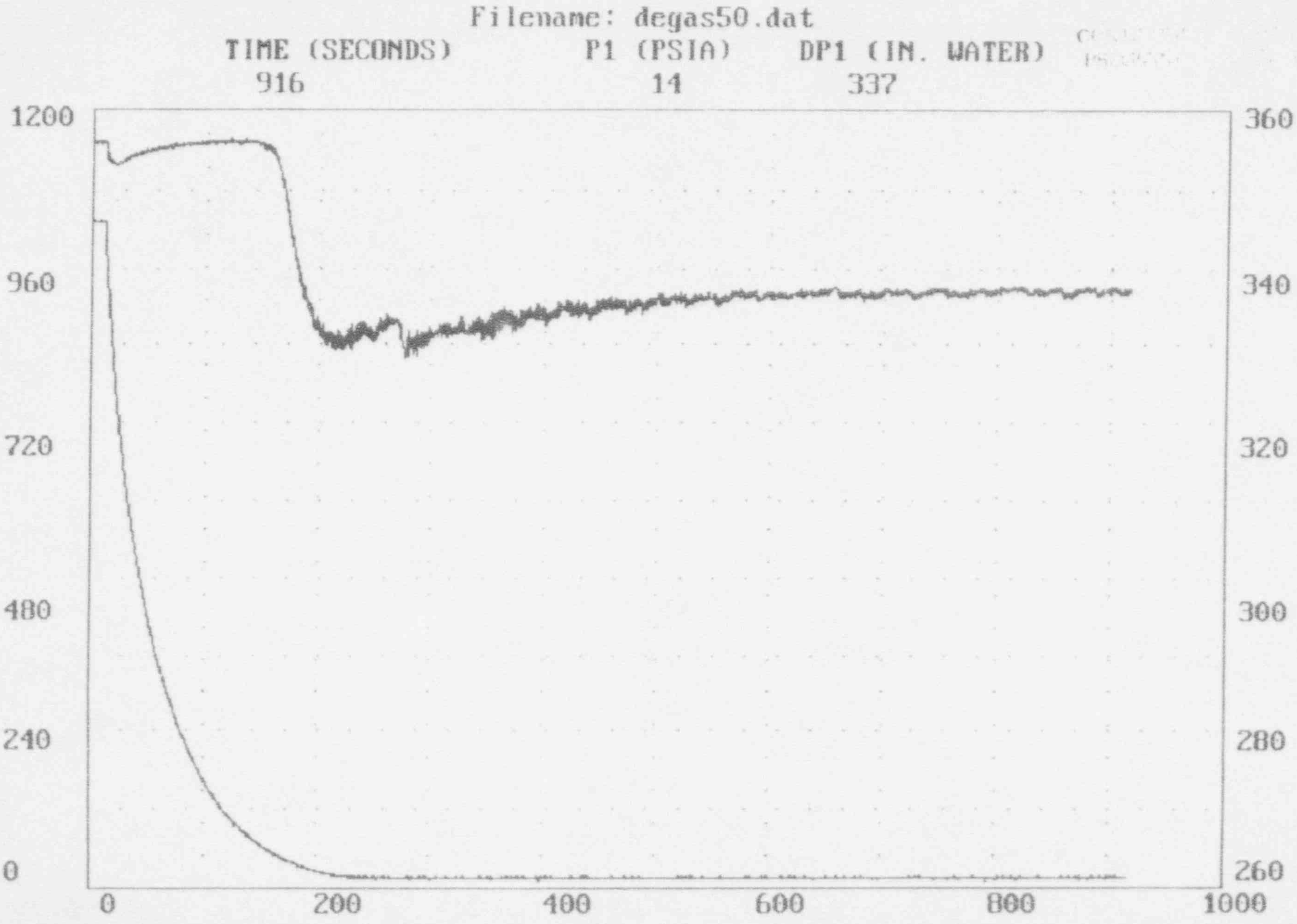
960
1200


Filename: degas50.dat
TIME (SECONDS)
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P1 (PSIA)
14
DP1 (IN. WATER)
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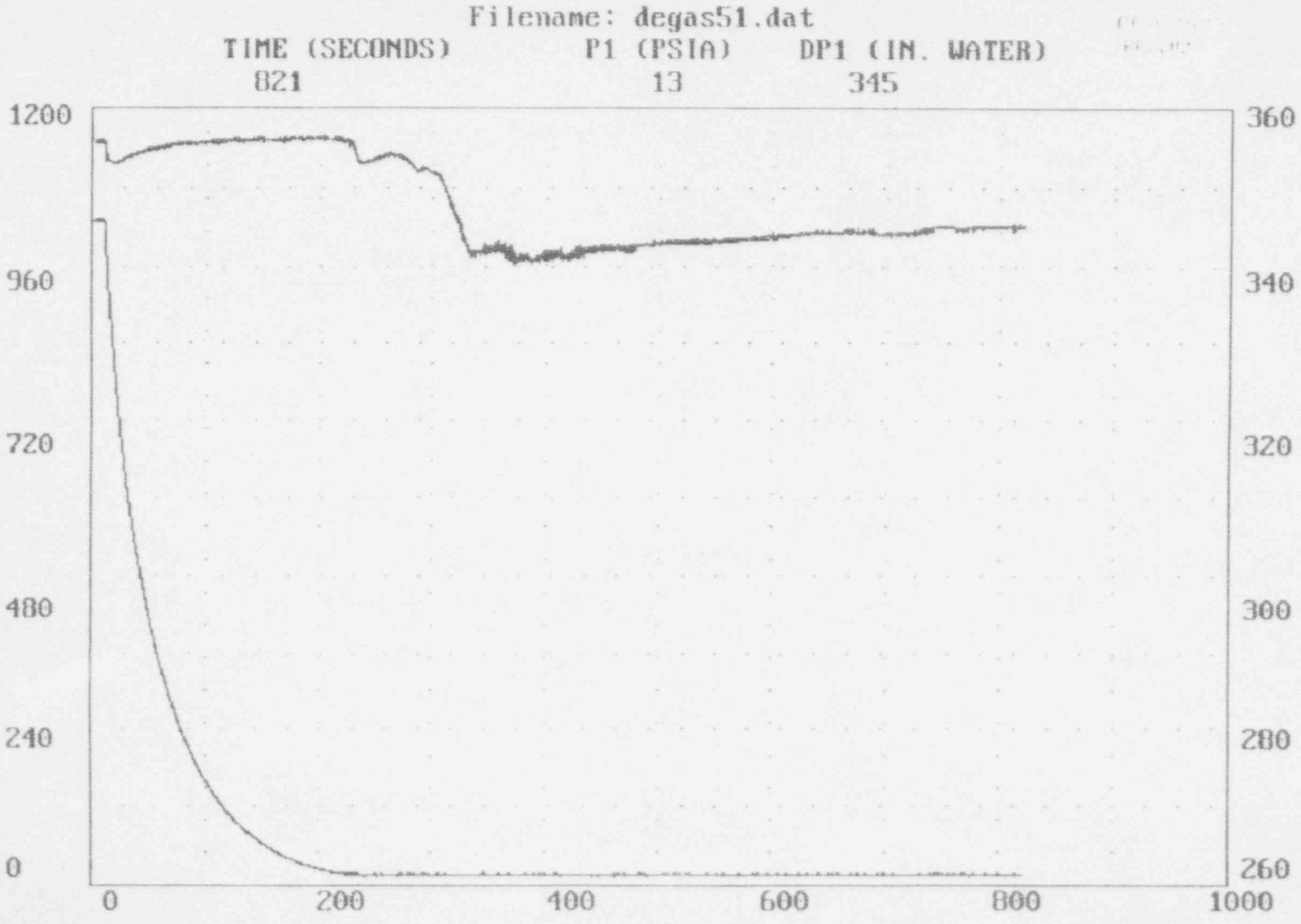
400
600
800
1000


Filename: degas51.dat
TIME (SECONDS)
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P1 (PSIA)
13
DP1 (IN. WATER)
345
1200
960
720
480
240
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280
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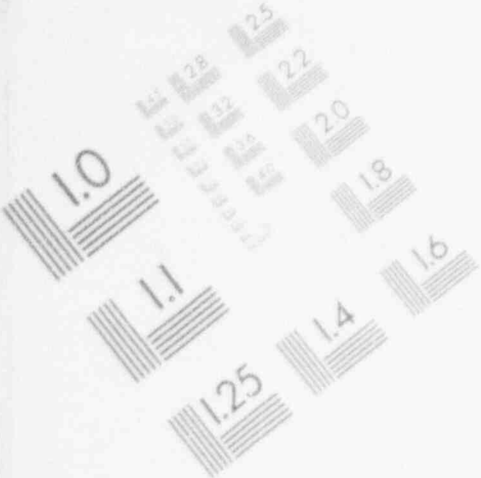
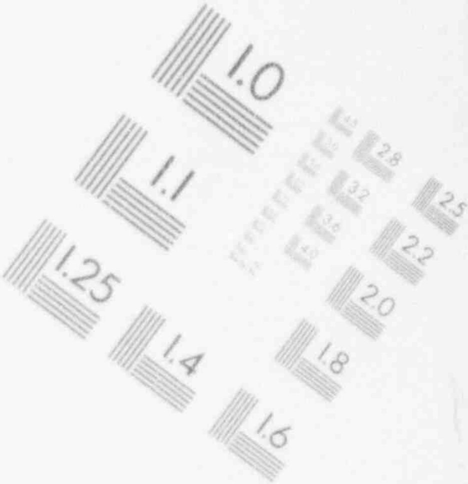
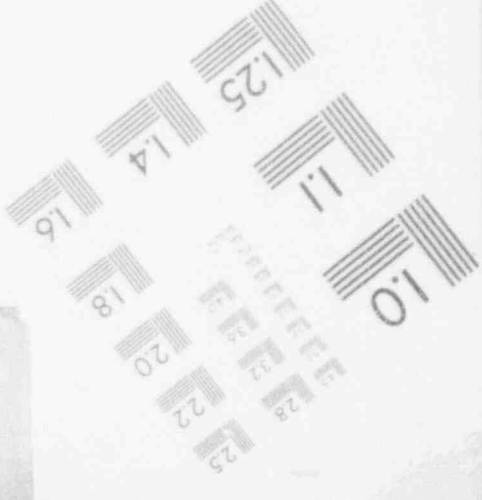
200
400
600
800
1000

# 1

# IMAGE EVALUATION
# TEST TARGET (MT-3)

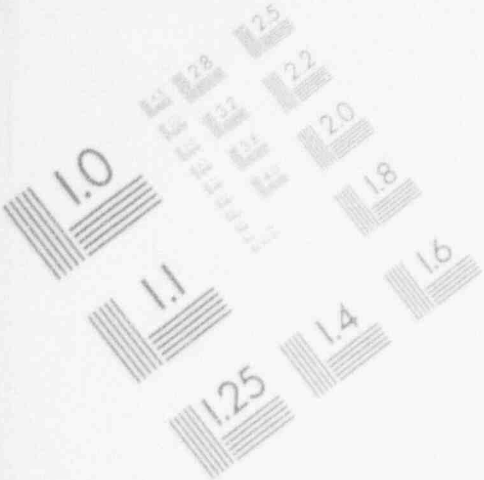


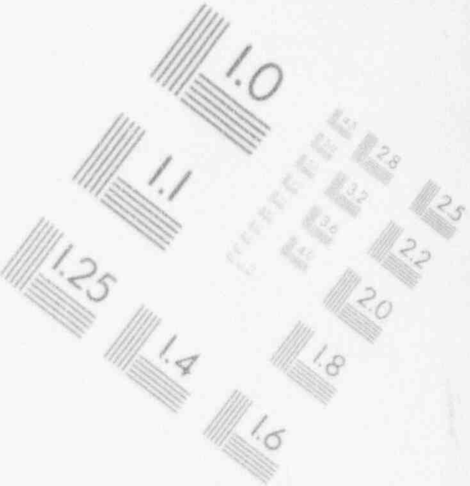


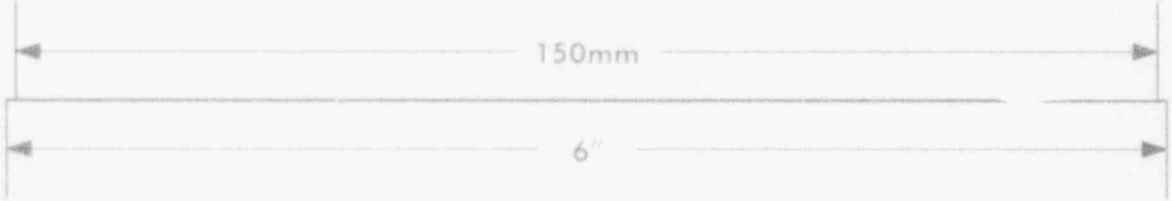


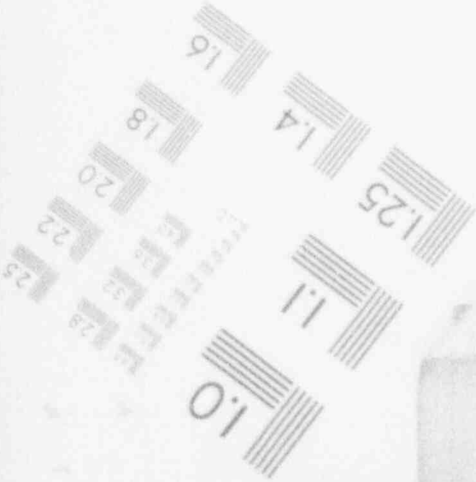
# 1

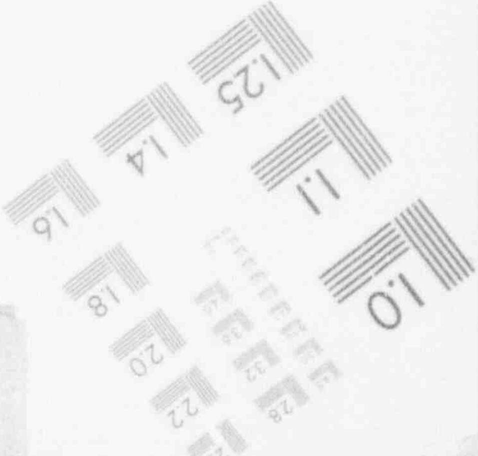
# IMAGE EVALUATION TEST TARGET (MT-3)





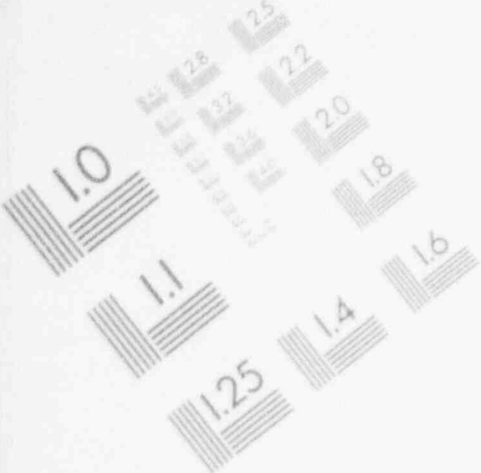


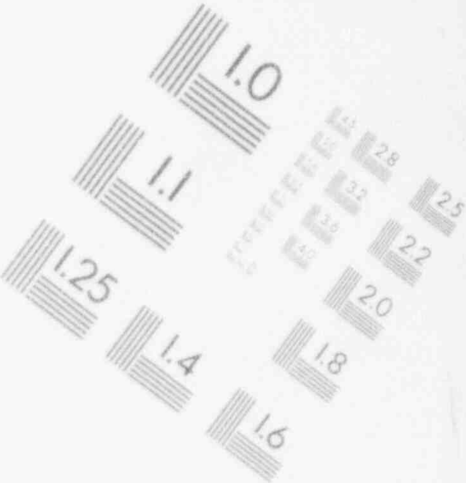


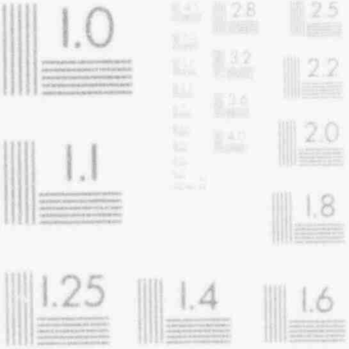


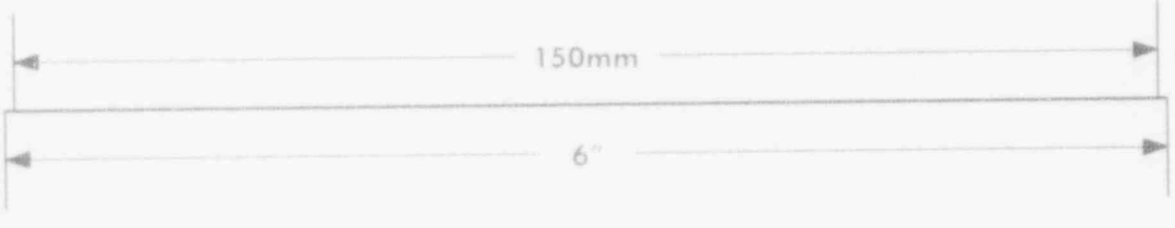
# 1

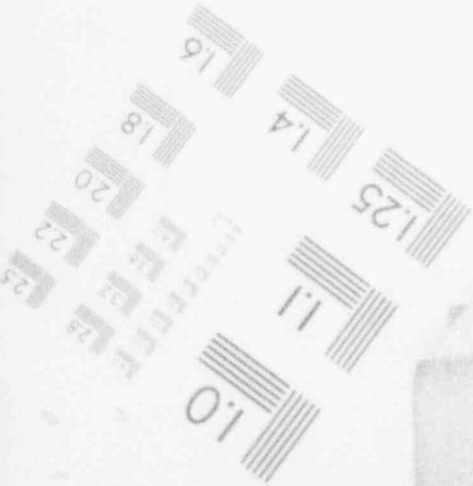
# IMAGE EVALUATION
# TEST TARGET (MT-3)

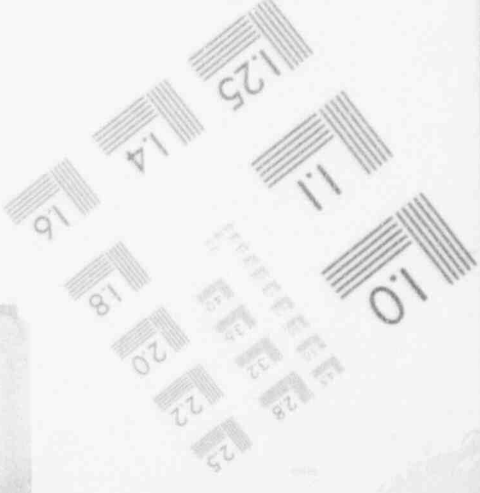












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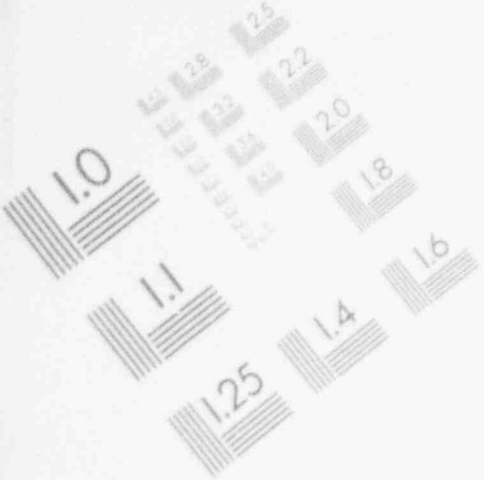
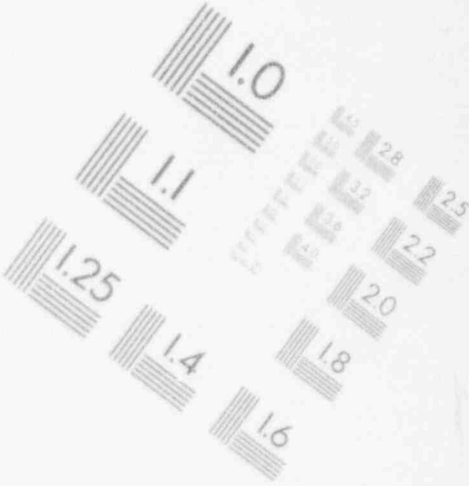
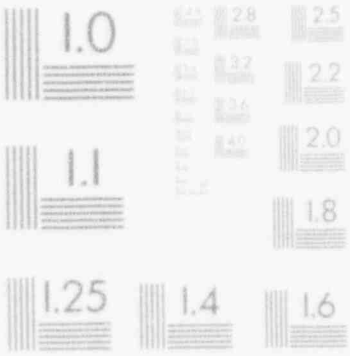
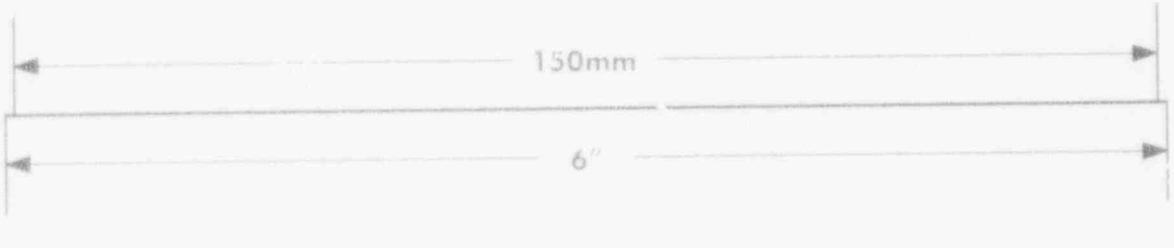
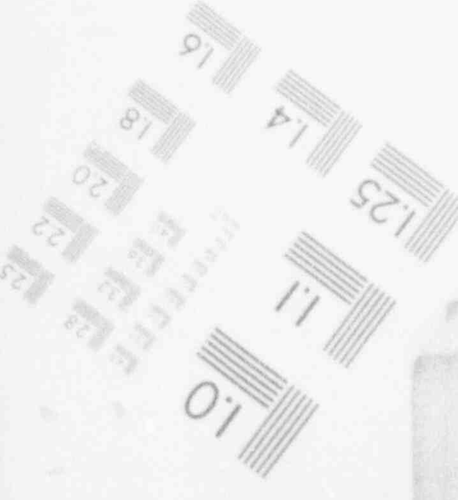
## IMAGE EVALUATION
## TEST TARGET (MT-3)

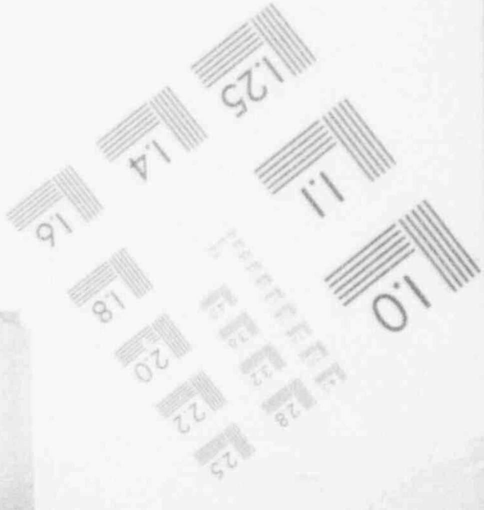


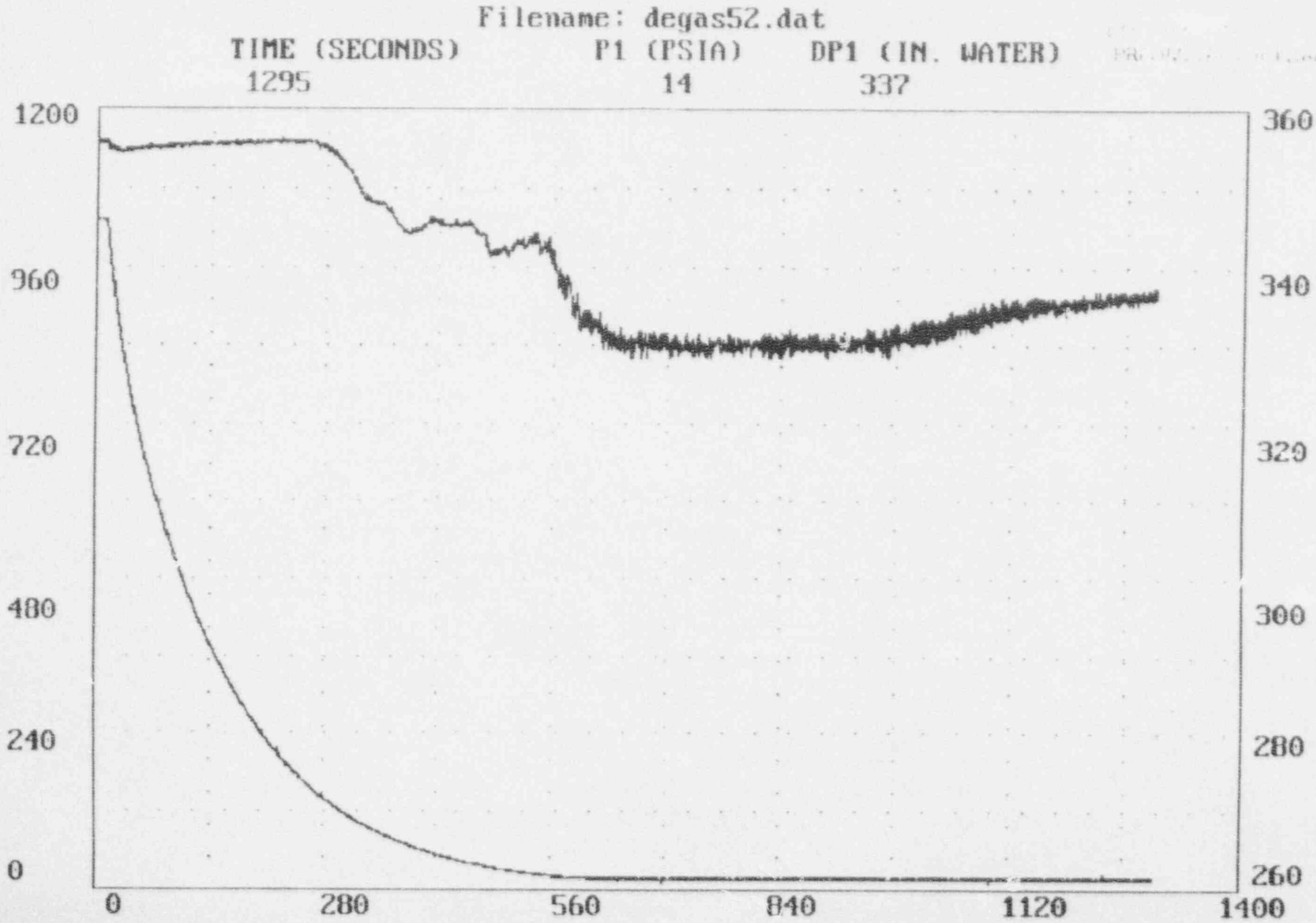


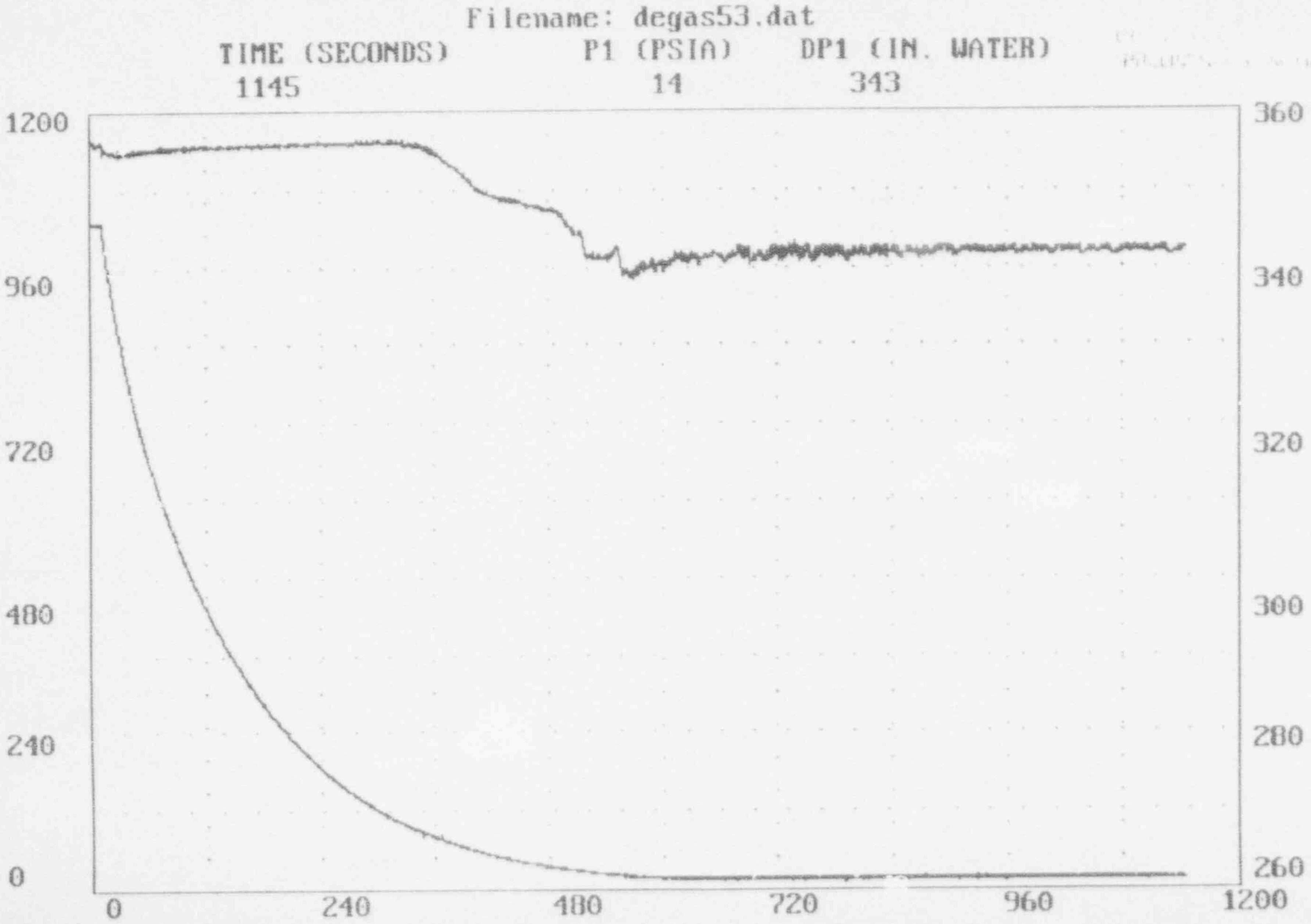


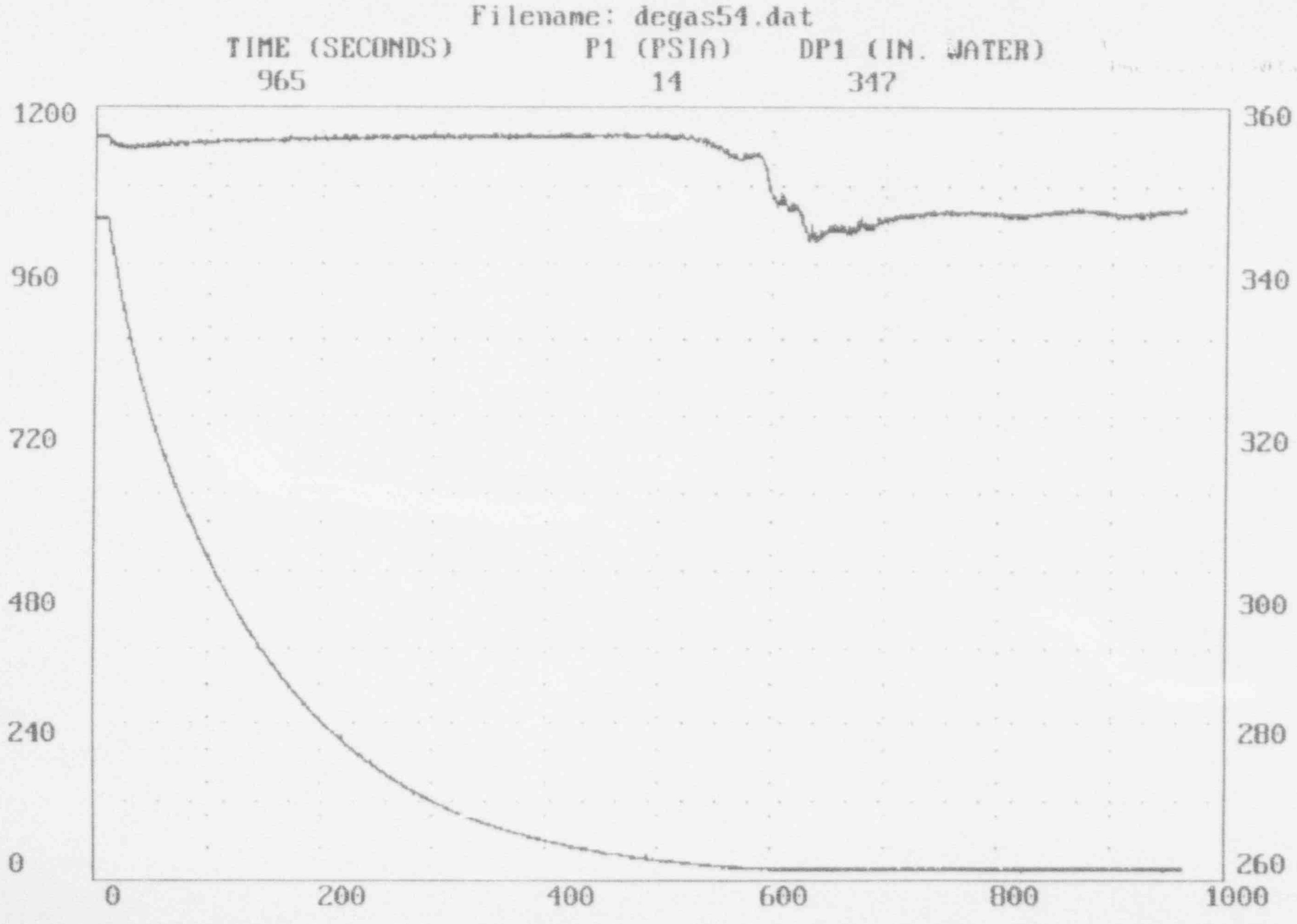


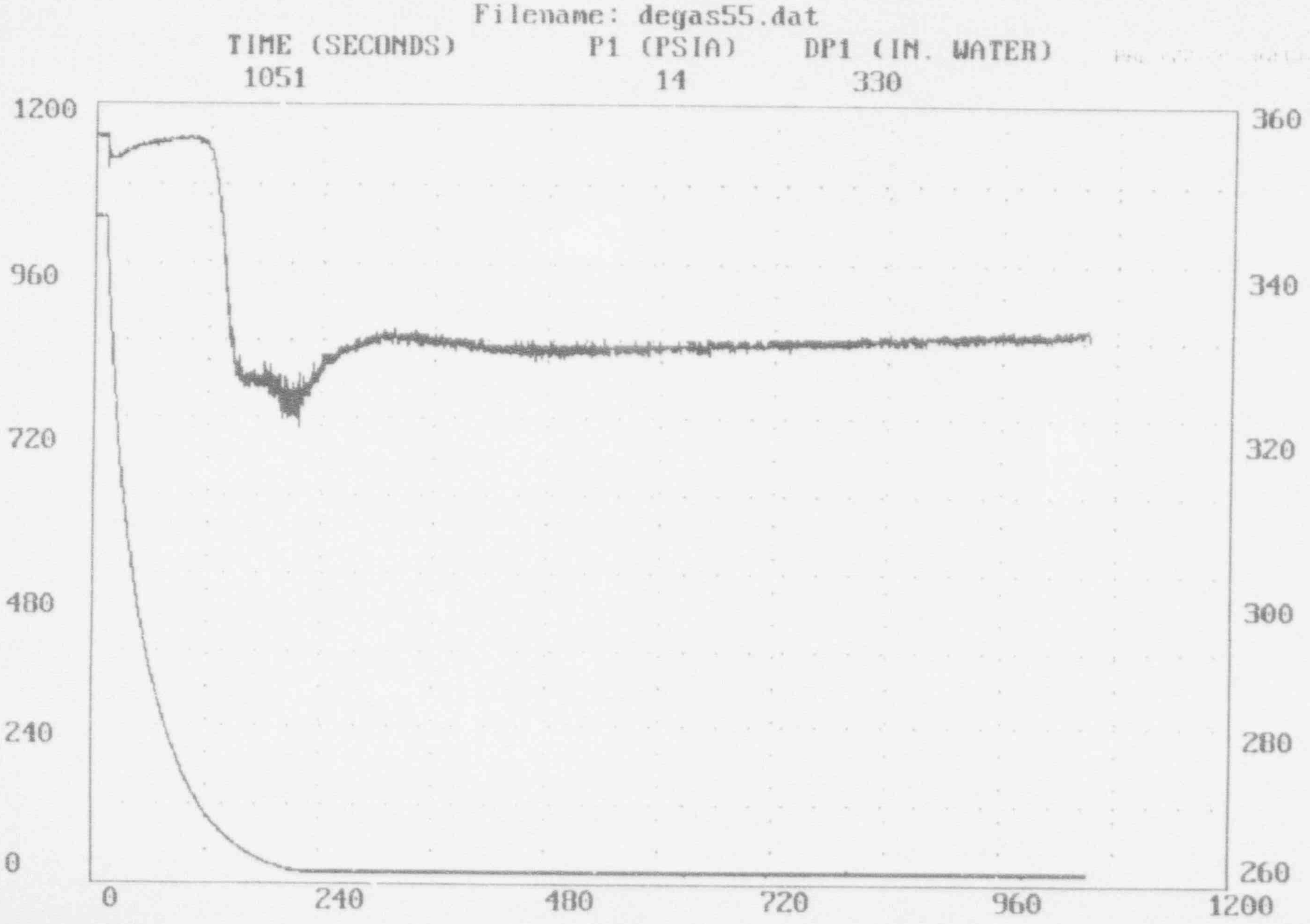


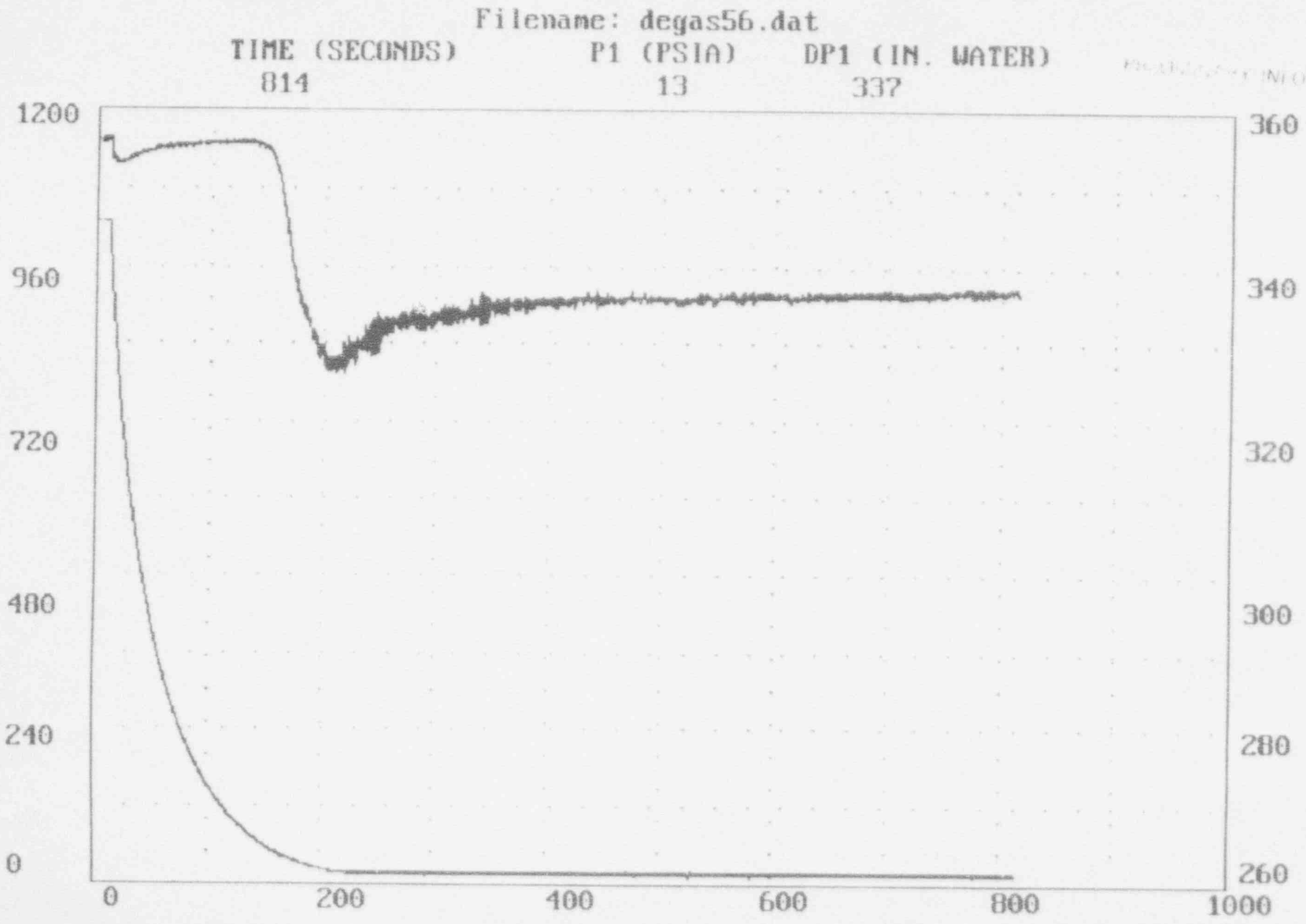



Filename: degas52.dat
TIME (SECONDS)
1295
P1 (PSIA)
14
DP1 (IN. WATER)
337
1200
960
720
480
240
0
360
340
320
300
280
260
0
280
560
840
1120
1400

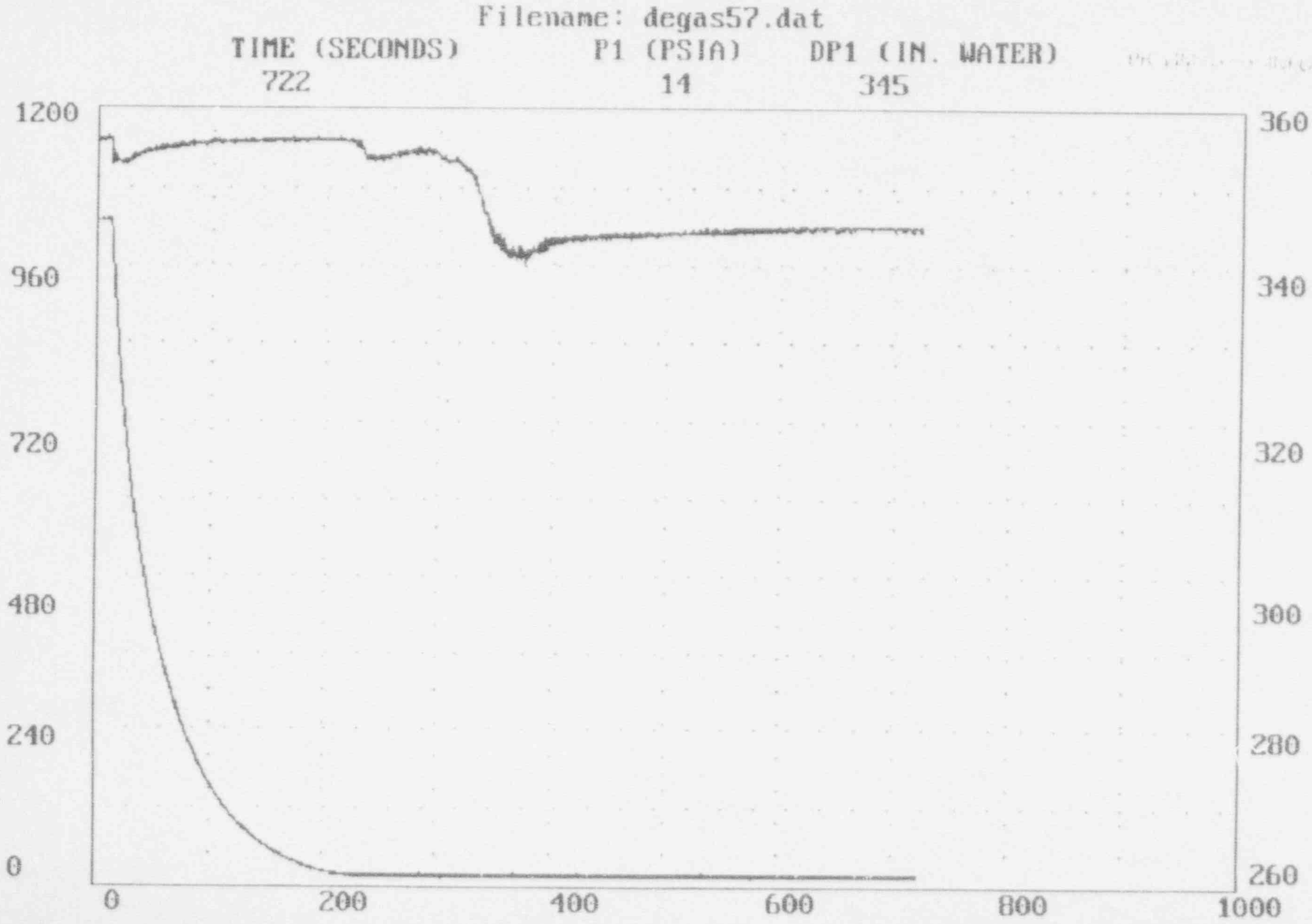

Filename: degas53.dat
TIME (SECONDS)
1145
P1 (PSIA)
14
DP1 (IN. WATER)
343
1200
960
720
480
240
0
0
240
480
720
960
1200
360
340
320
300
280
260

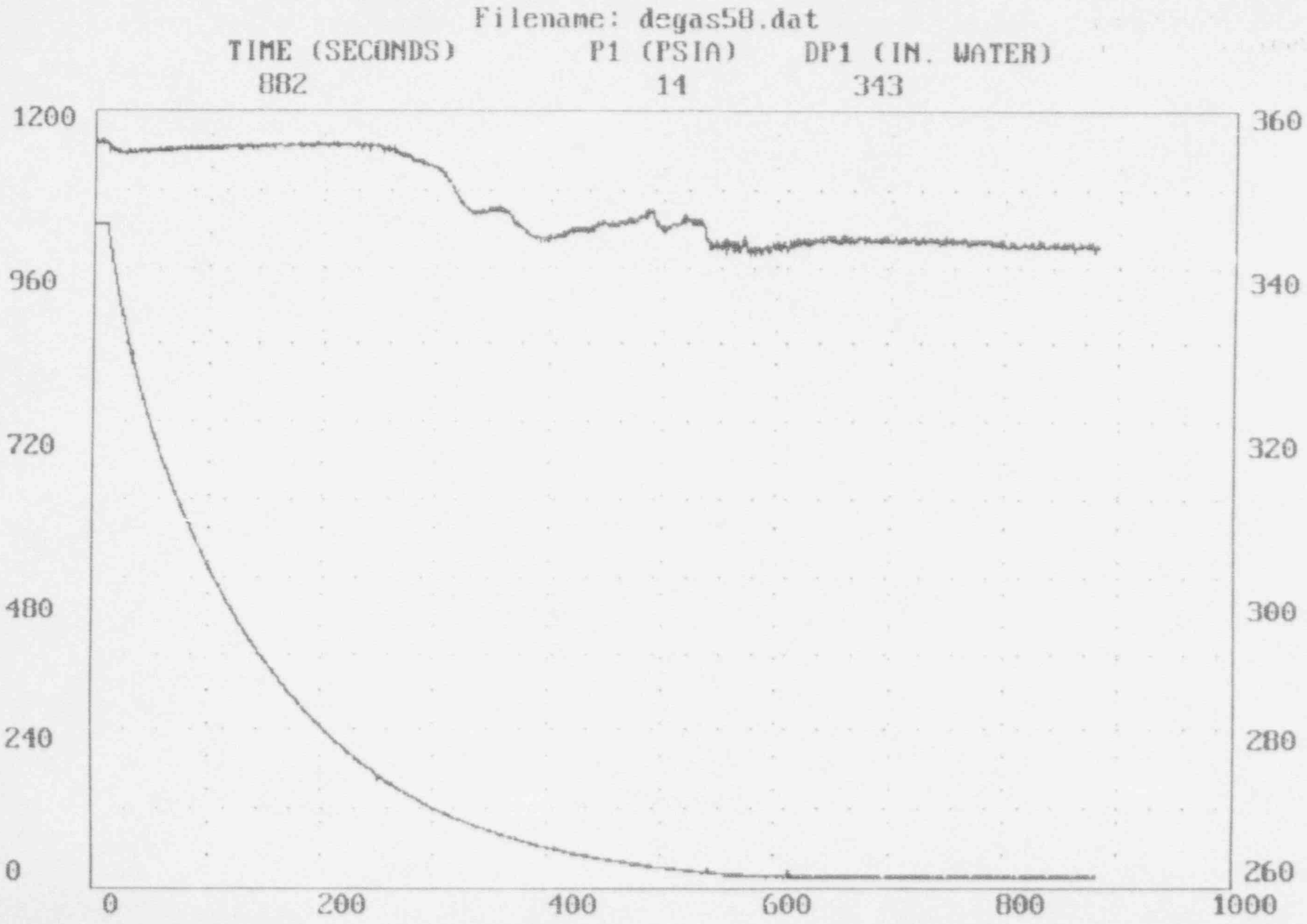

Filename: degas54.dat
TIME (SECONDS)
965
P1 (PSIA)
14
DP1 (IN. WATER)
347
1200
960
720
480
240
0
360
340
320
300
280
260
0
200
400
600
800
1000

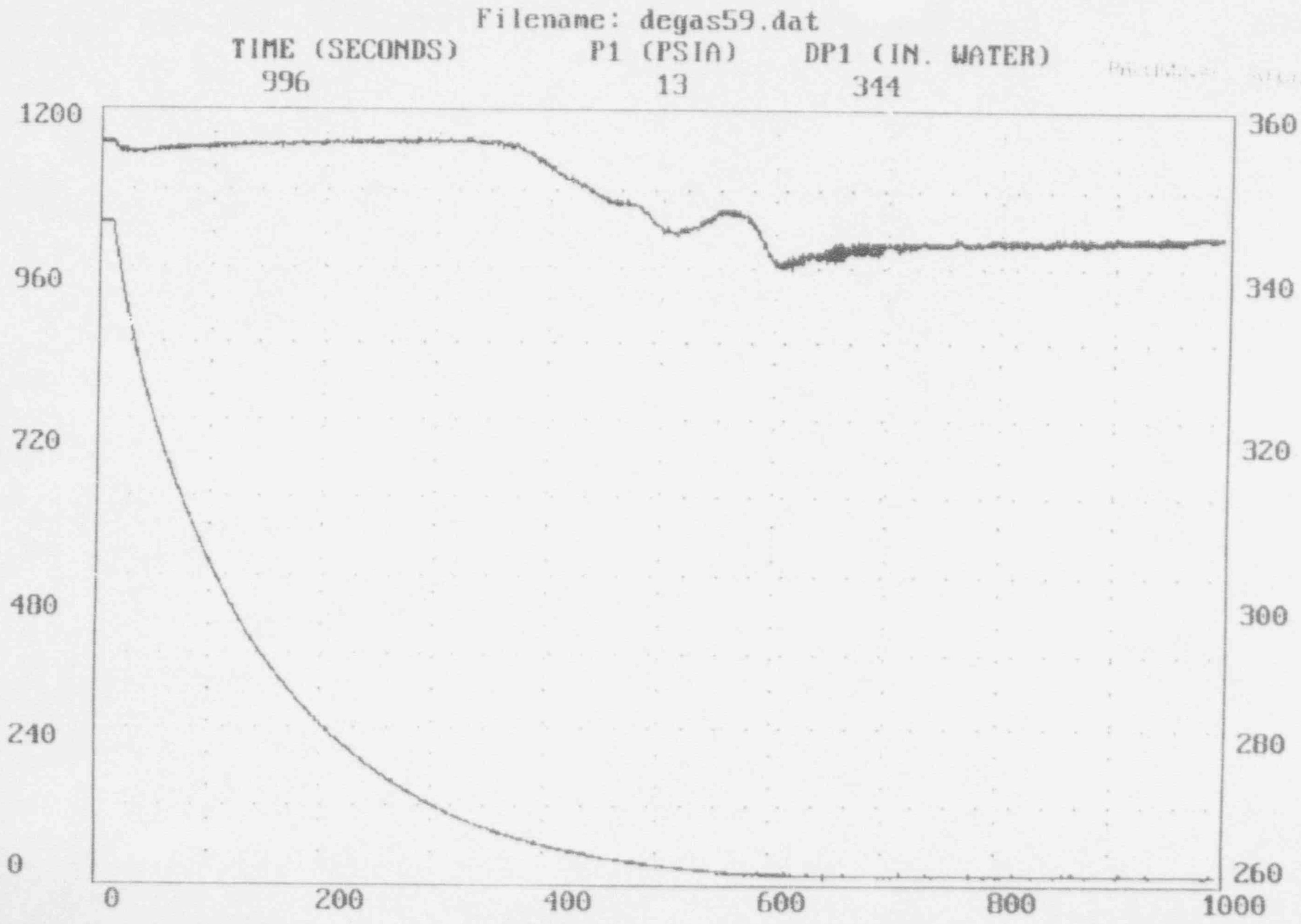

Filename: degas55.dat
TIME (SECONDS)
1051
P1 (PSIA)
14
DP1 (IN. WATER)
330
1200
960
720
480
240
0
360
340
320
300
280
260
0
240
480
720
960
1200



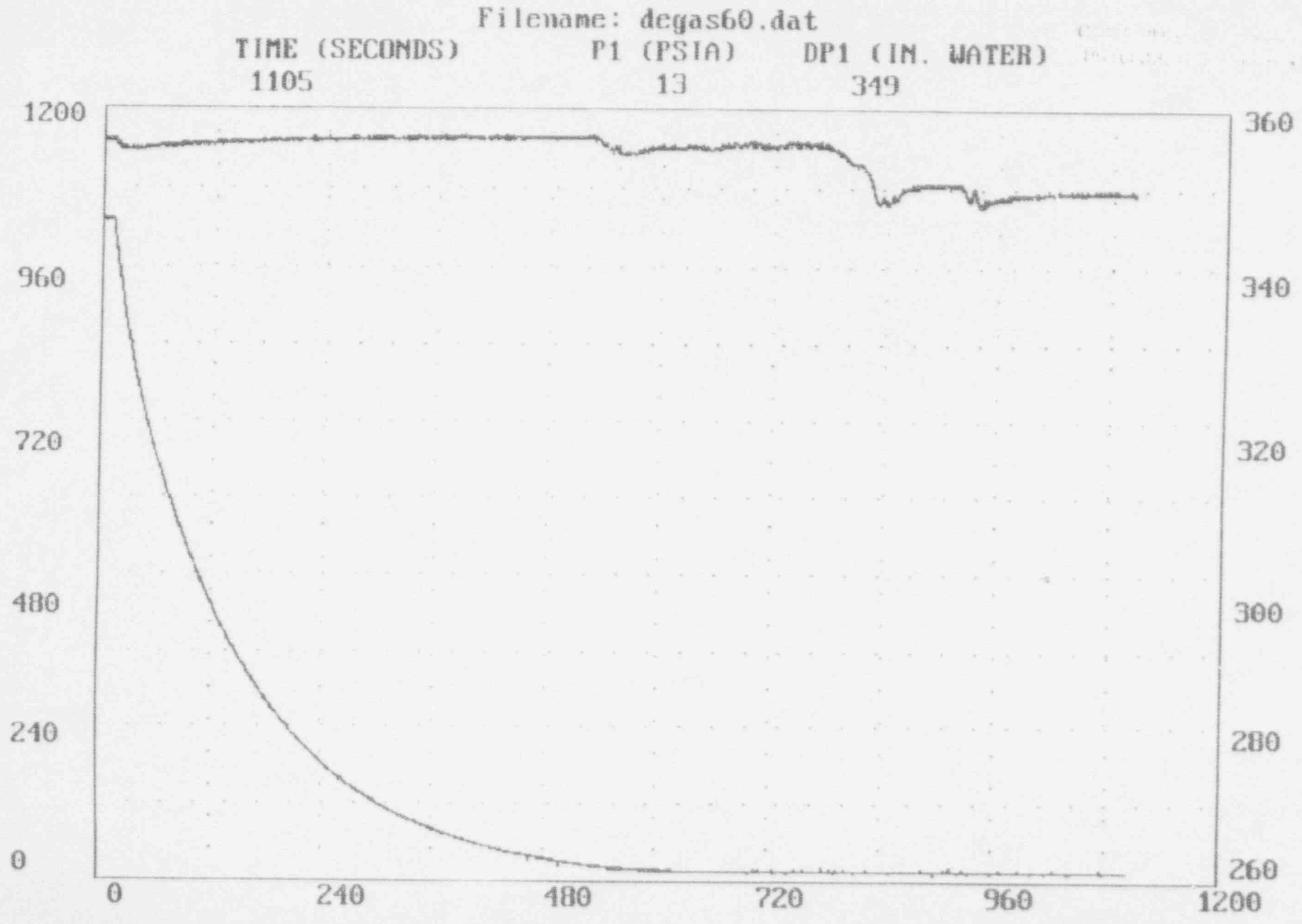
PRELIMINARY INFORMATION

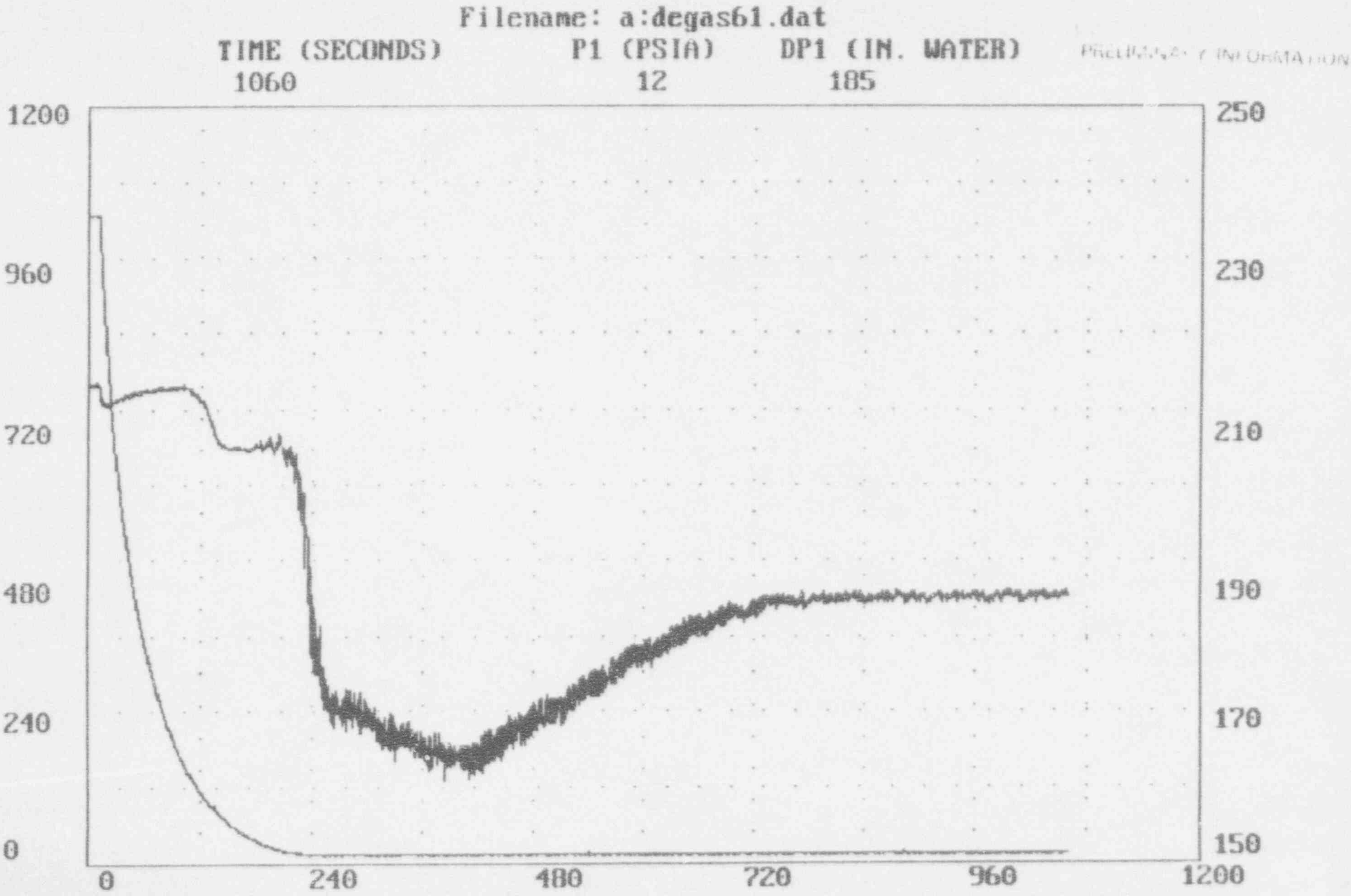

Filename: degas57.dat
TIME (SECONDS)
722
P1 (PSIA)
14
DP1 (IN. WATER)
345
1200
960
720
480
240
0
360
340
320
300
280
260
0
200
400
600
800
1000

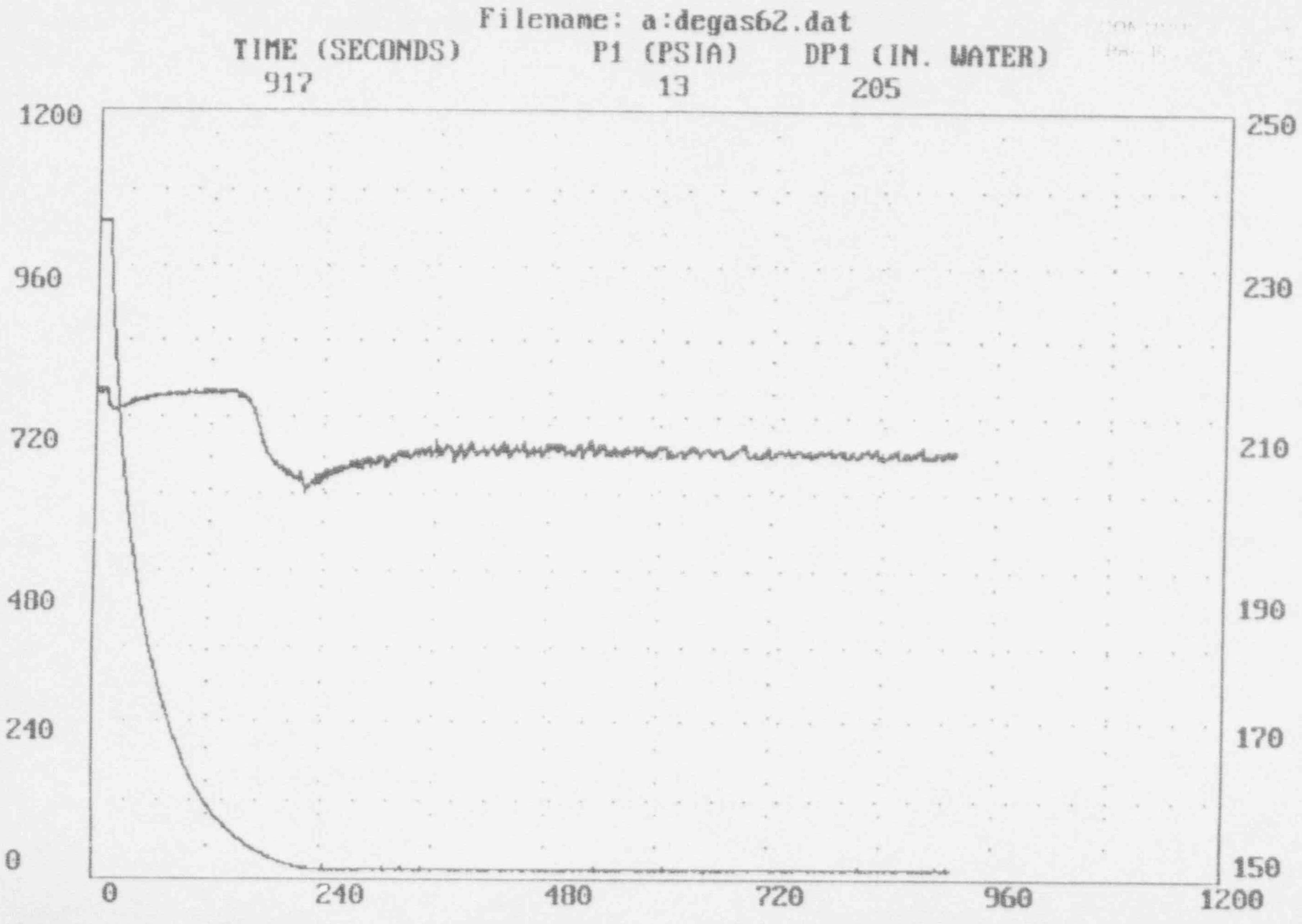

Filename: degas58.dat
TIME (SECONDS)
882
P1 (PSIA)
14
DP1 (IN. WATER)
343
1200
960
720
480
240
0
360
340
320
300
280
260
0
200
400
600
800
1000


Filename: degas59.dat
TIME (SECONDS) 996
P1 (PSIA) 13
DP1 (IN. WATER) 344
1200
960
720
480
240
0
360
340
320
300
280
260
0
200
400
600
800
1000

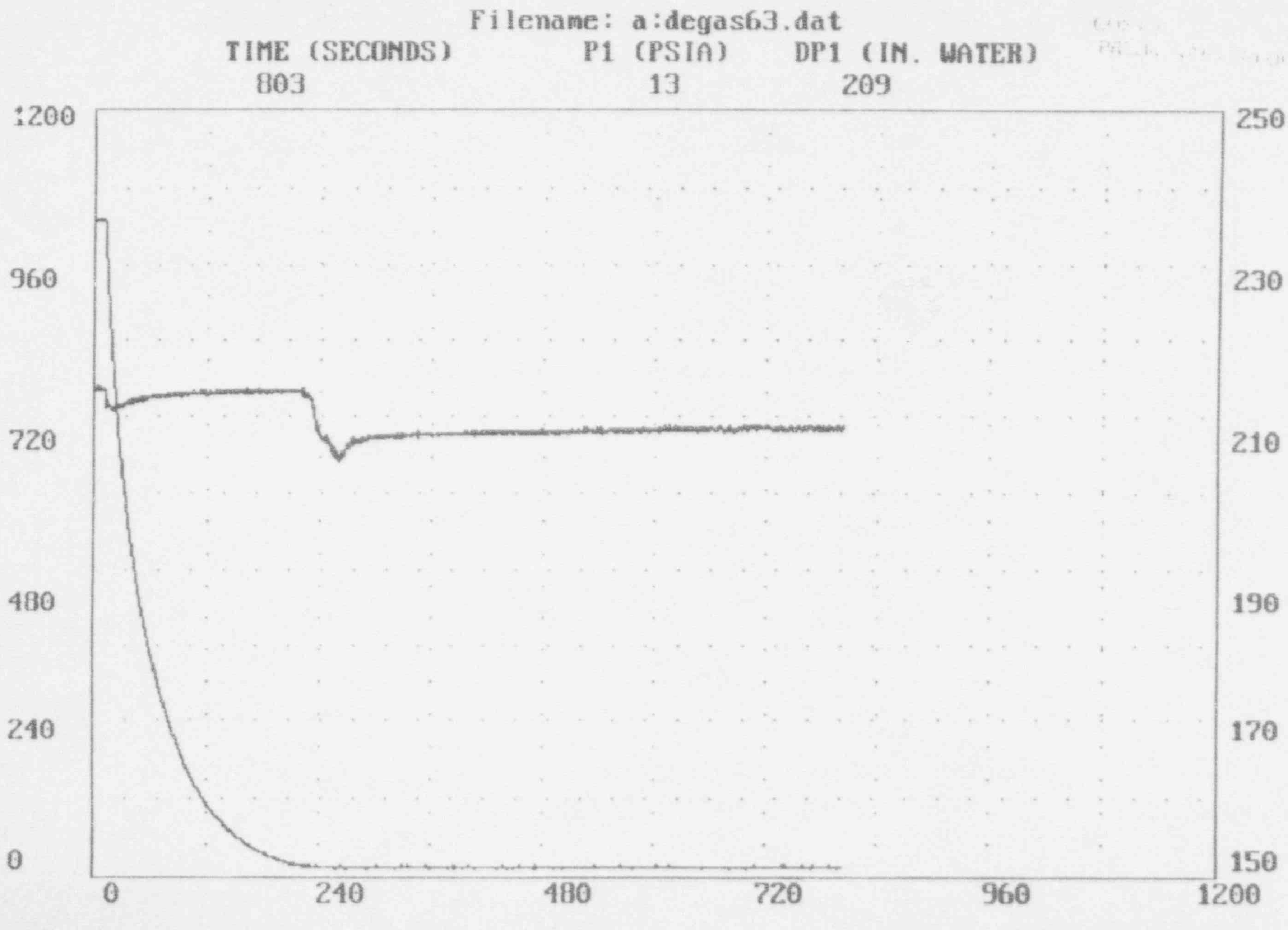
[illegible]

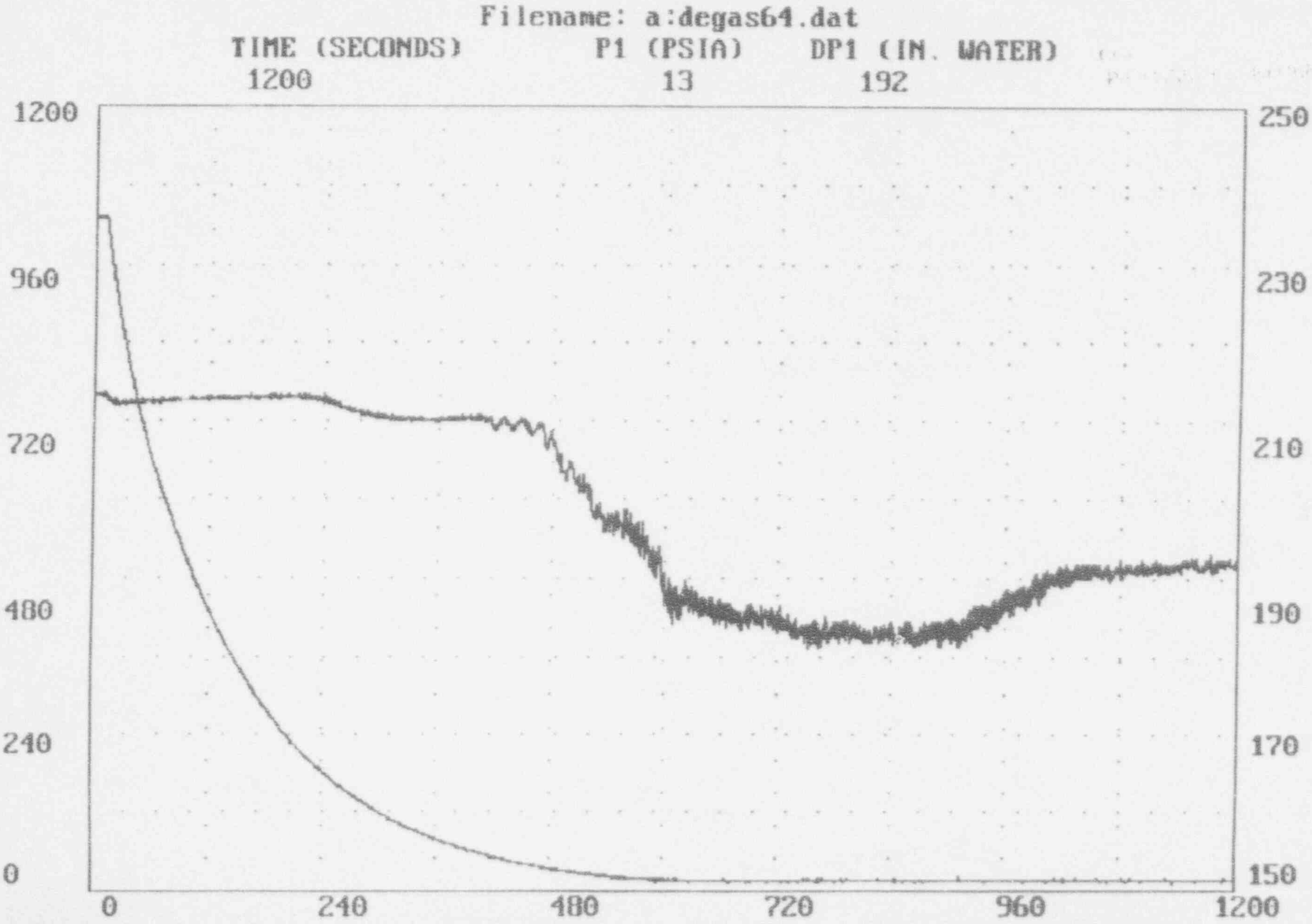

Filename: degas60.dat
TIME (SECONDS)
1105
P1 (PSIA)
13
DP1 (IN. WATER)
349
1200
960
720
480
240
0
360
340
320
300
280
260
0
240
480
720
960
1200

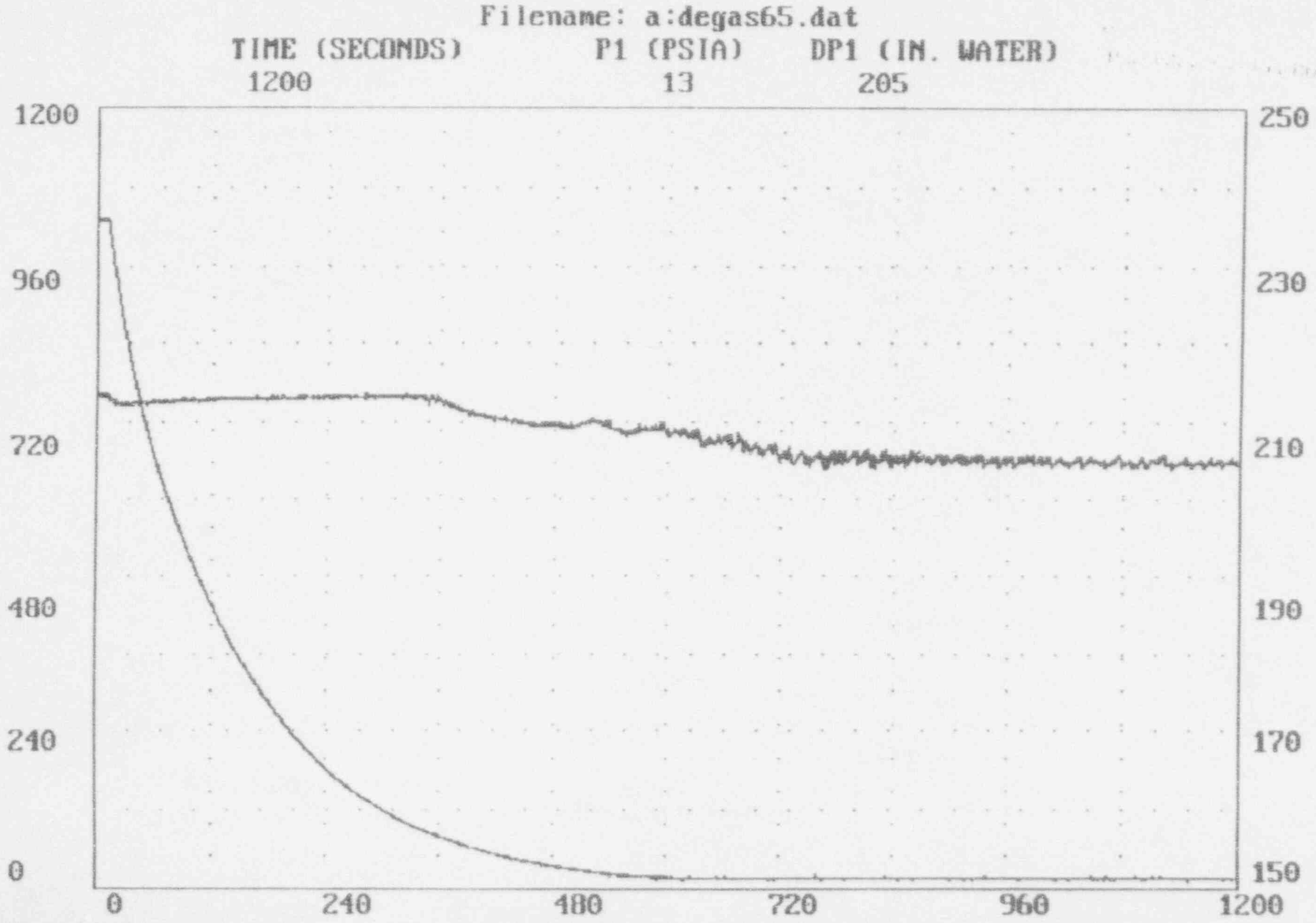

Filename: a:degas61.dat
TIME (SECONDS)
1060
P1 (PSIA)
12
DP1 (IN. WATER)
185
PRELIMINARY INFORMATION
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200

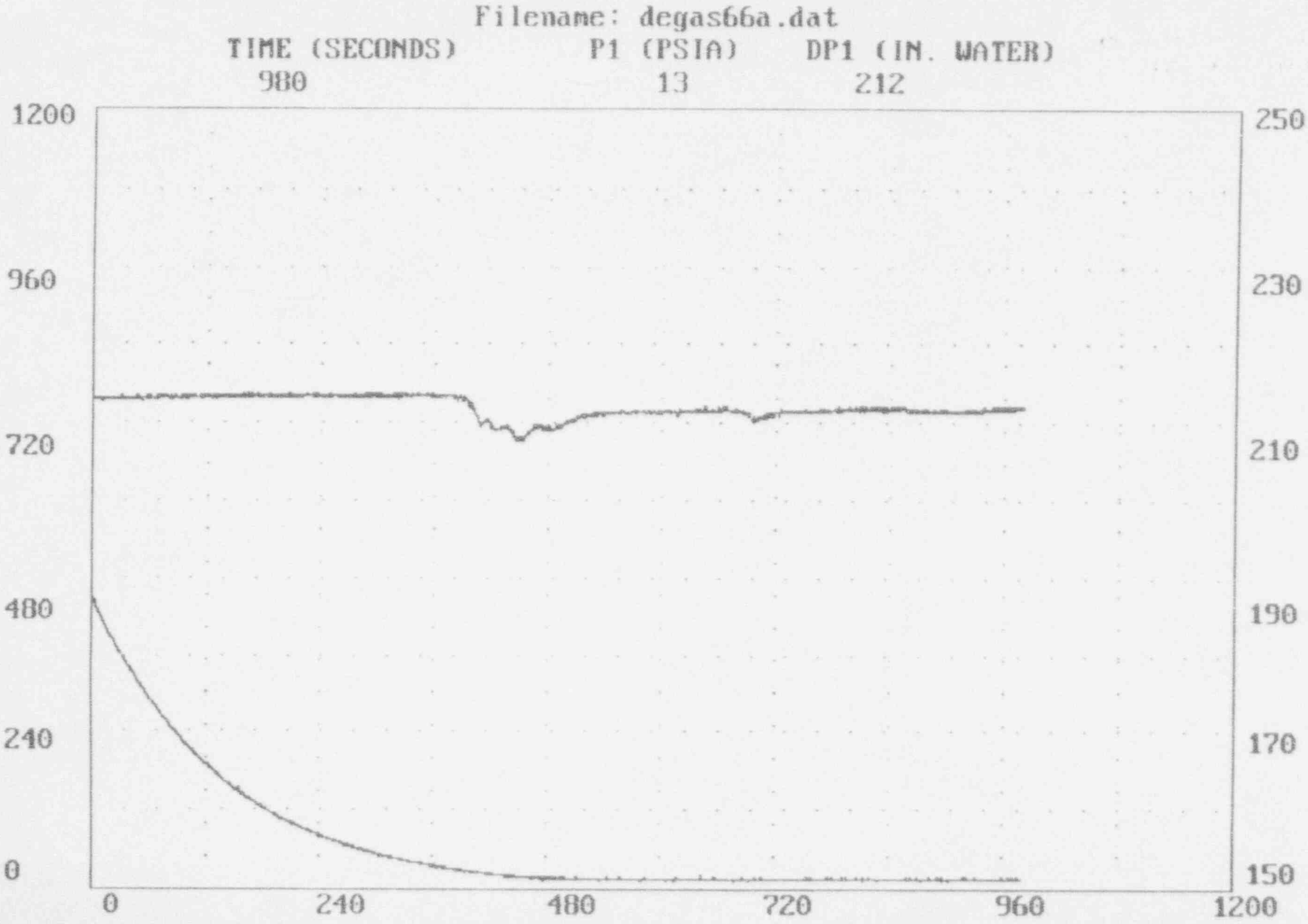


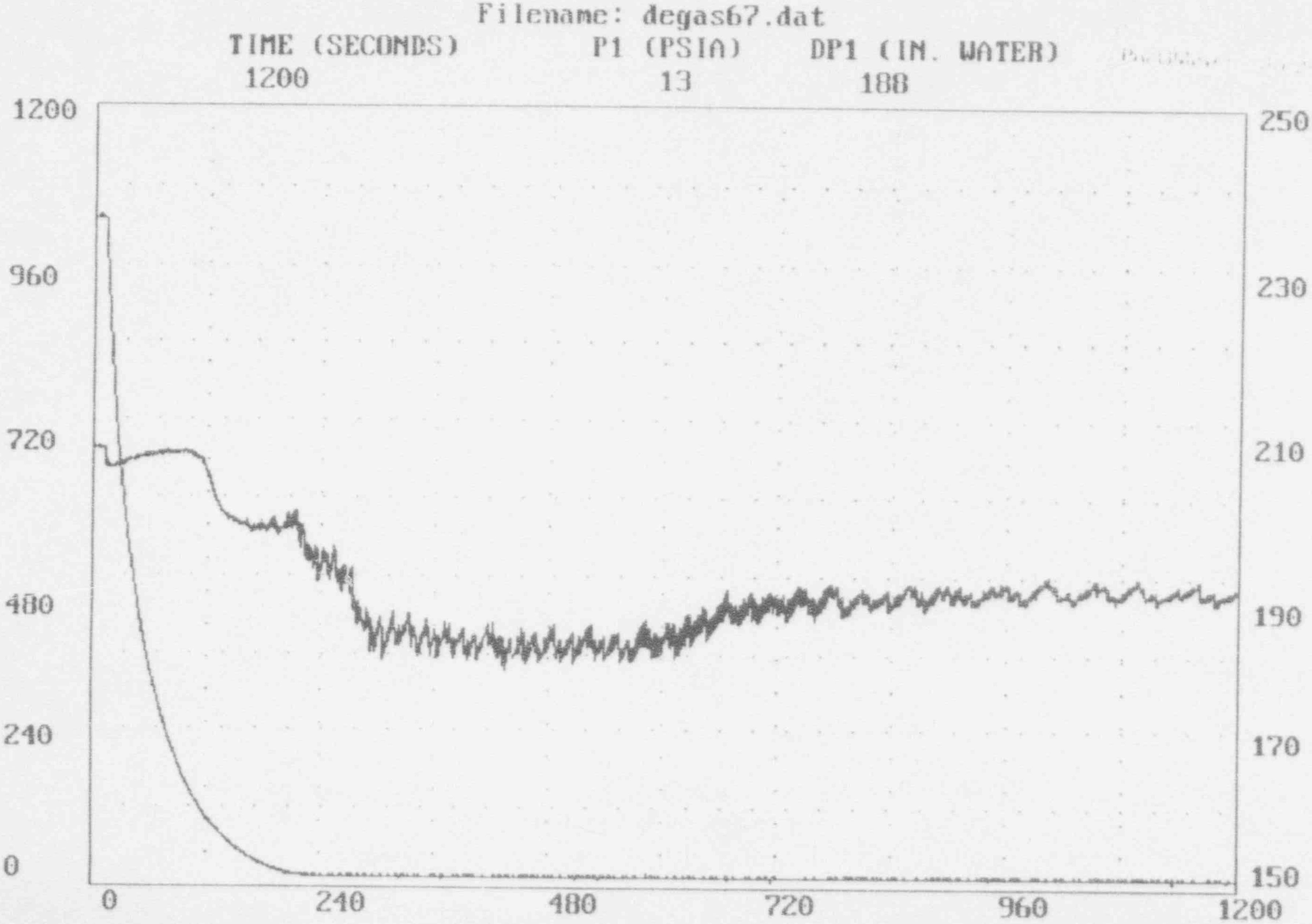
Filename: a:degas62.dat

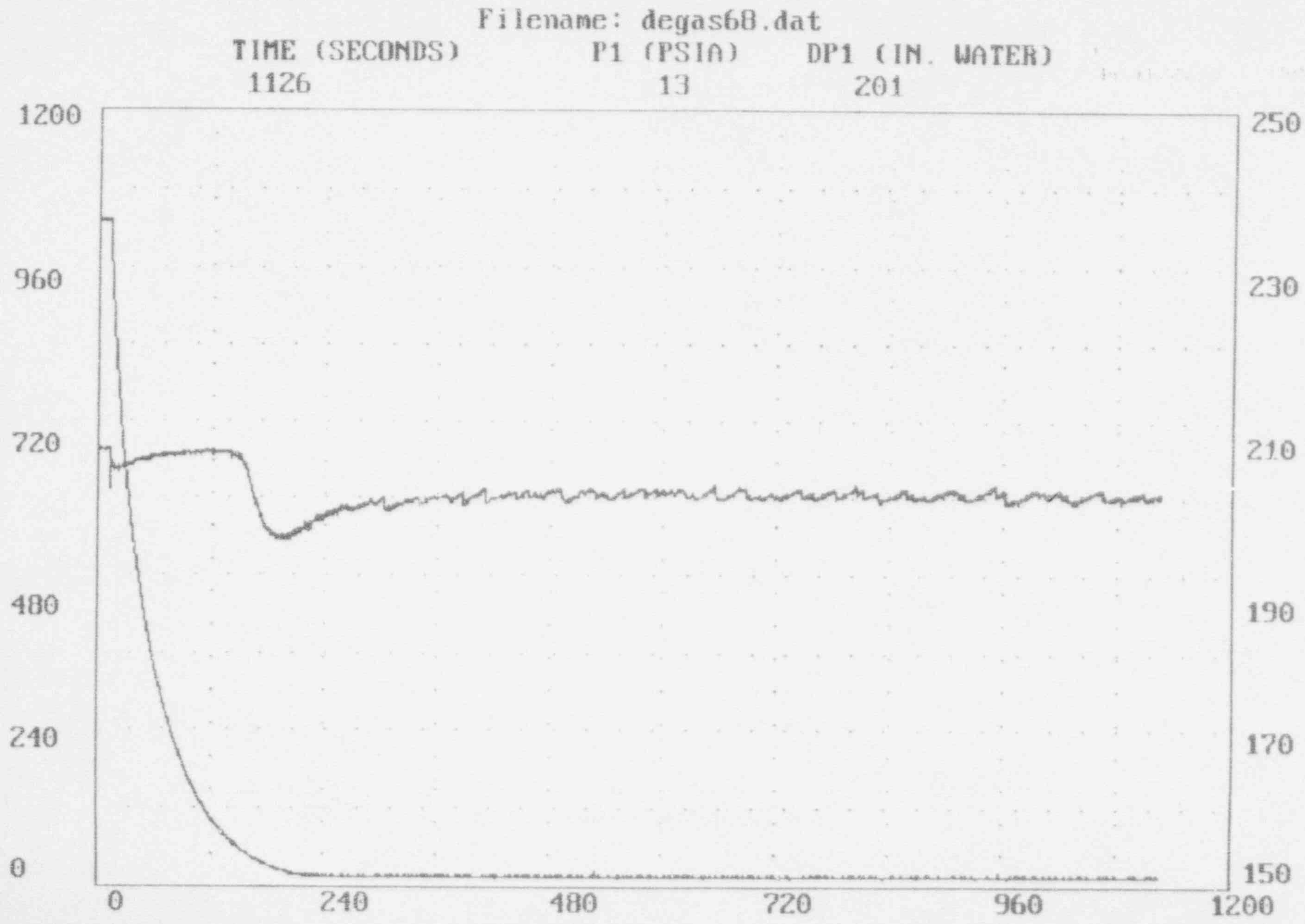

Filename: a:degas63.dat
TIME (SECONDS)
803
P1 (PSIA)
13
DP1 (IN. WATER)
209
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200

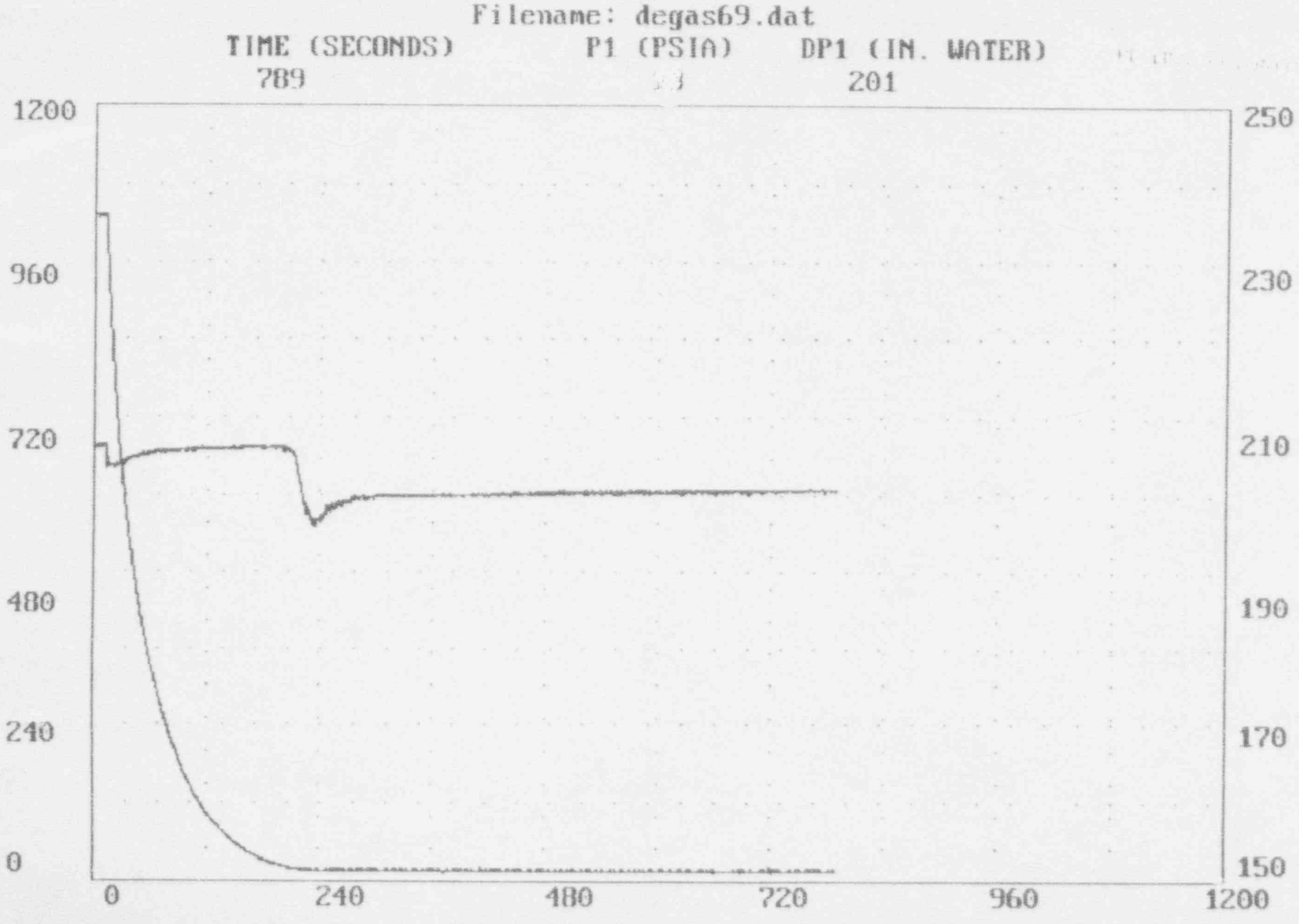

Filename: a:degas64.dat
TIME (SECONDS)
1200
P1 (PSIA)
13
DP1 (IN. WATER)
192
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200

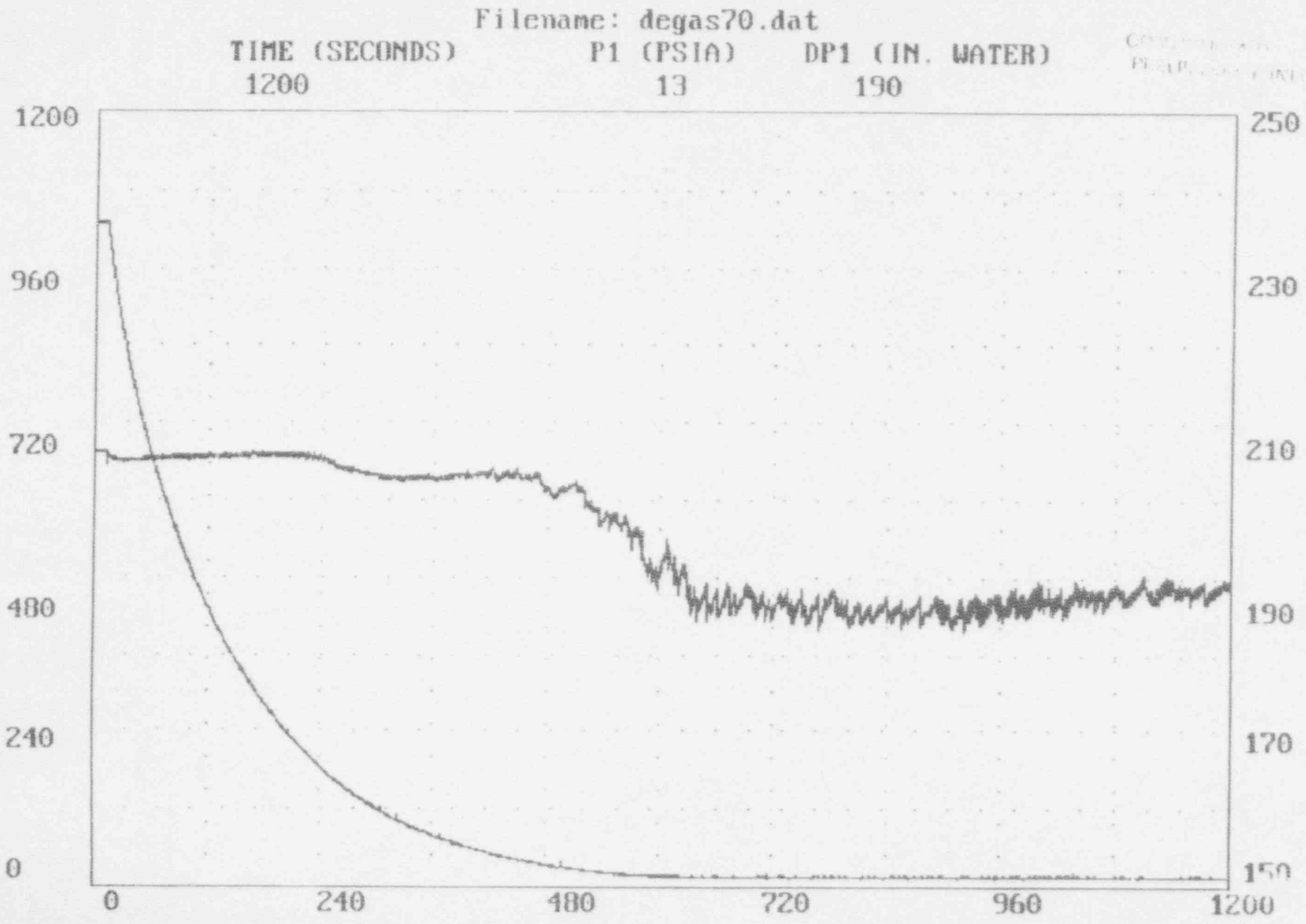

Filename: a:degas65.dat
TIME (SECONDS)
1200
P1 (PSIA)
13
DP1 (IN. WATER)
205
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200

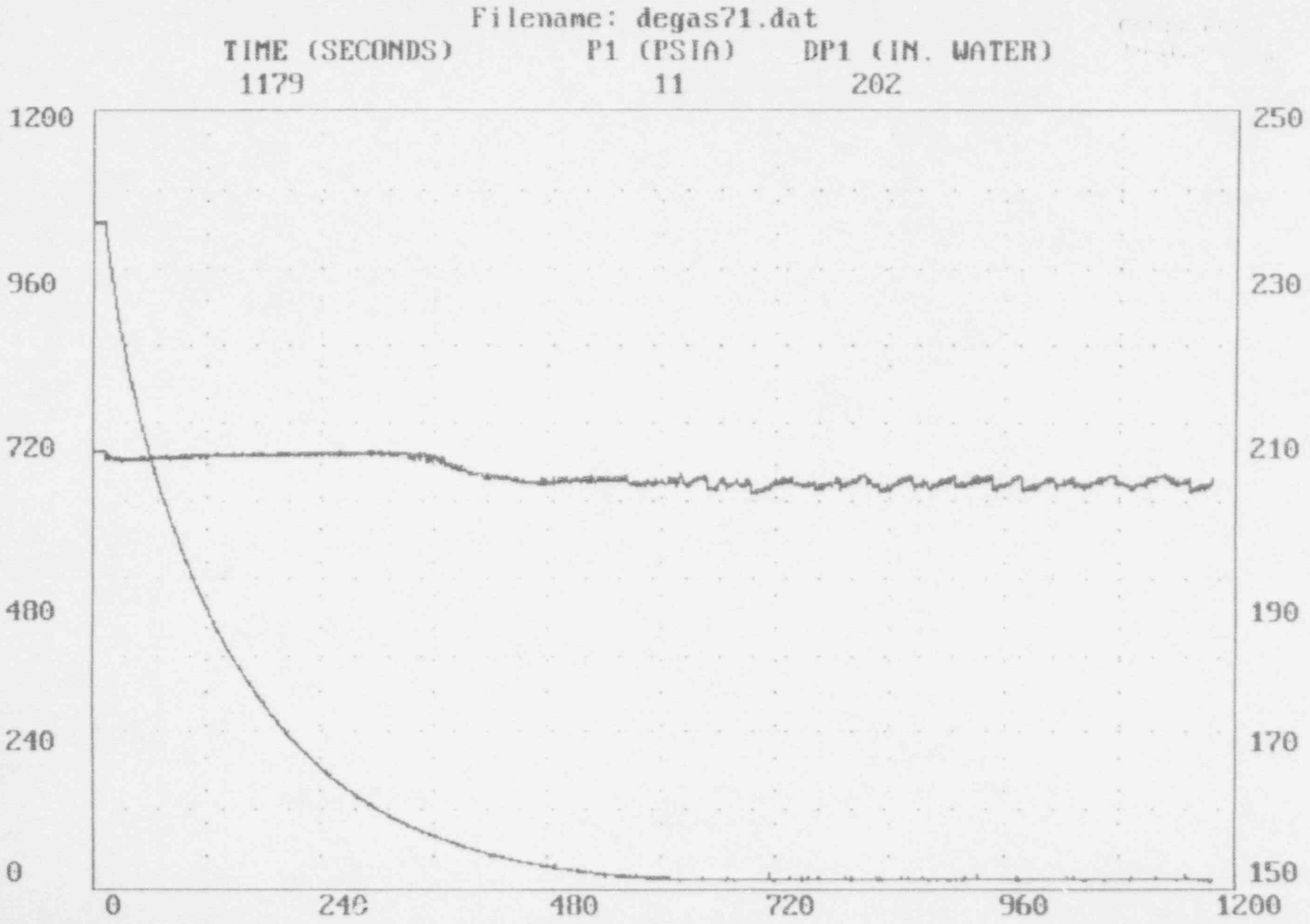

Filename: degas66a.dat
TIME (SECONDS)
980
P1 (PSIA)
13
DP1 (IN. WATER)
212
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200

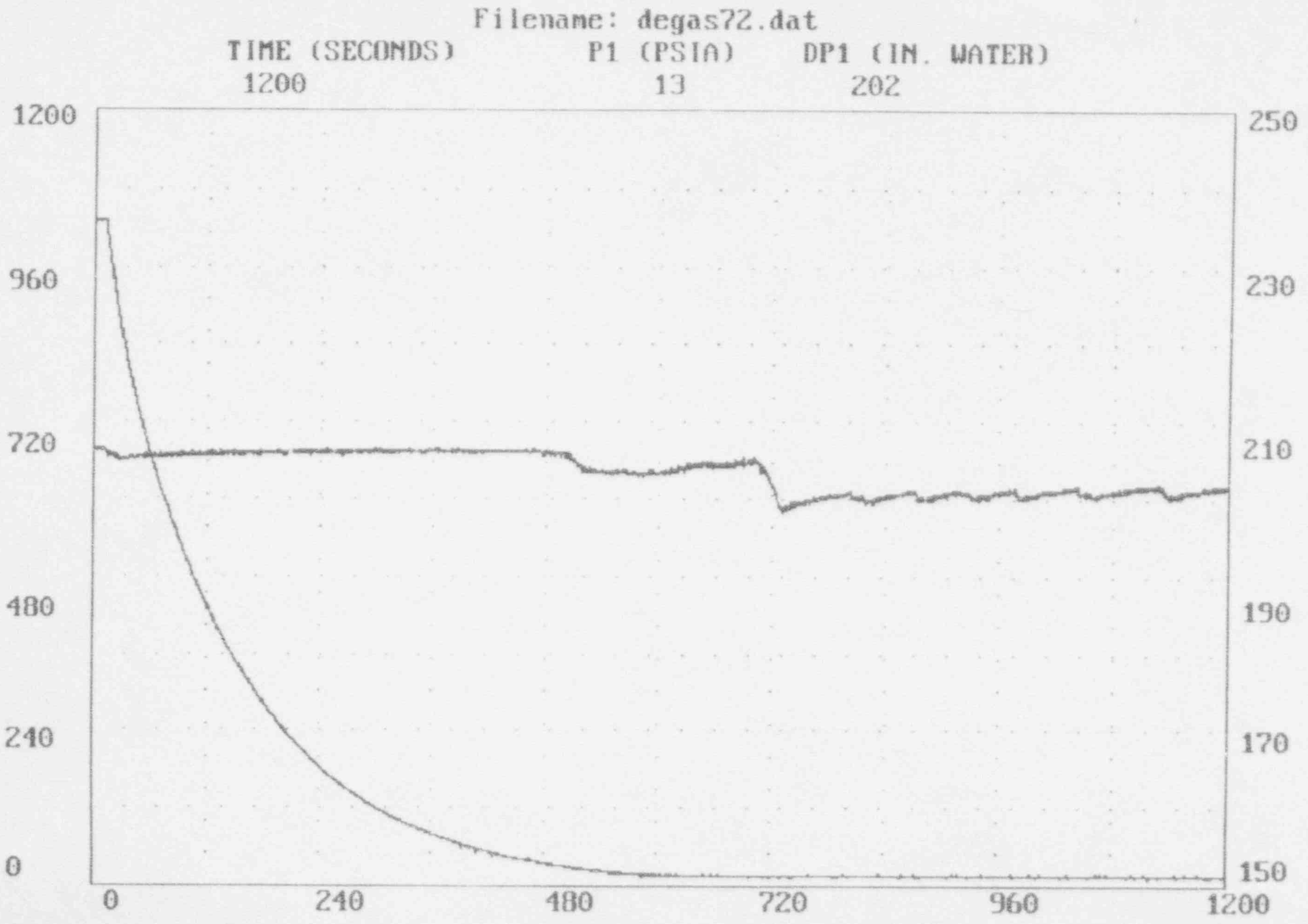

Filename: degas67.dat
TIME (SECONDS)
1200
P1 (PSIA)
13
DP1 (IN. WATER)
188
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200

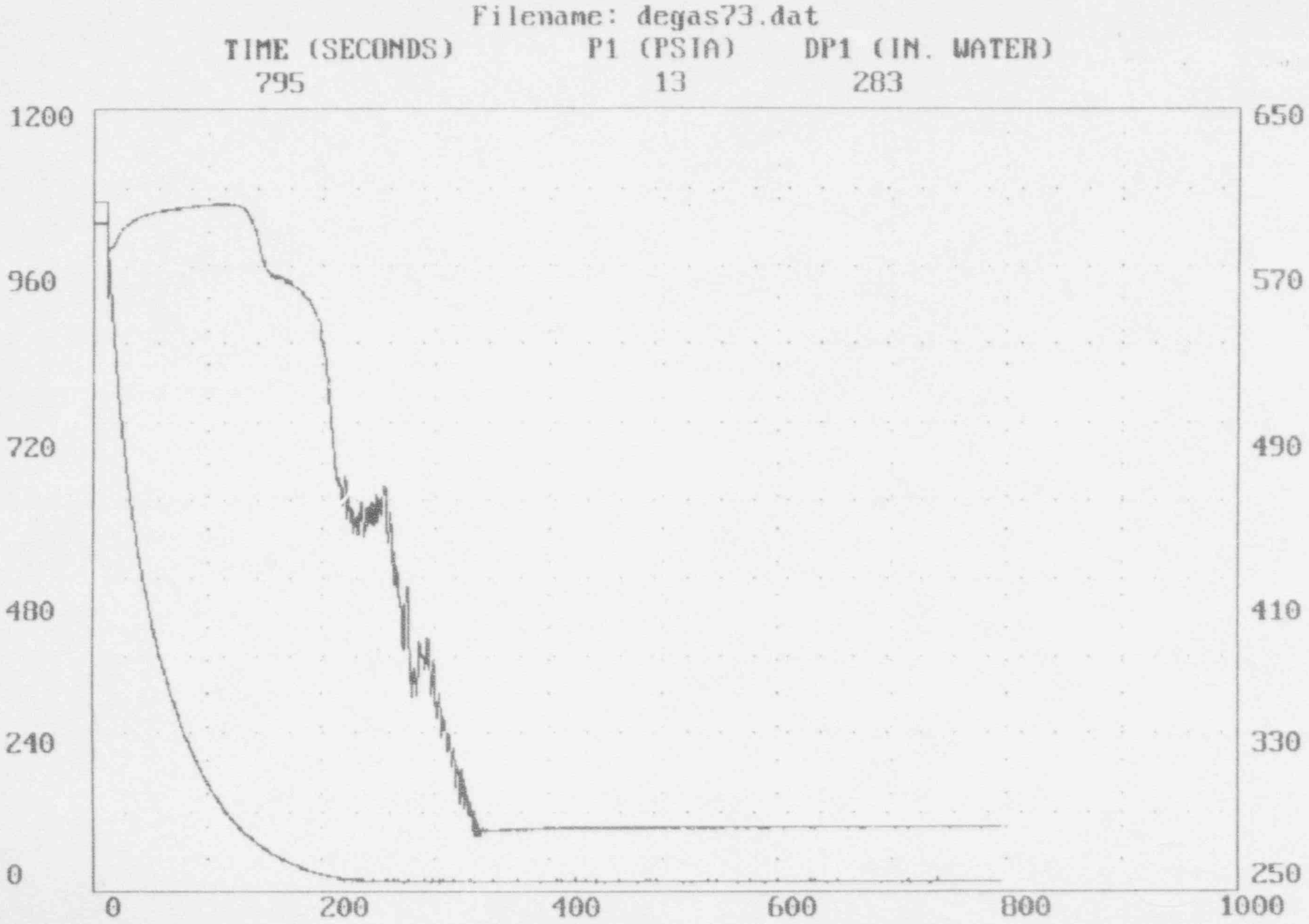

Filename: degas68.dat
TIME (SECONDS) 1126
P1 (PSIA) 13
DP1 (IN. WATER) 201
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200

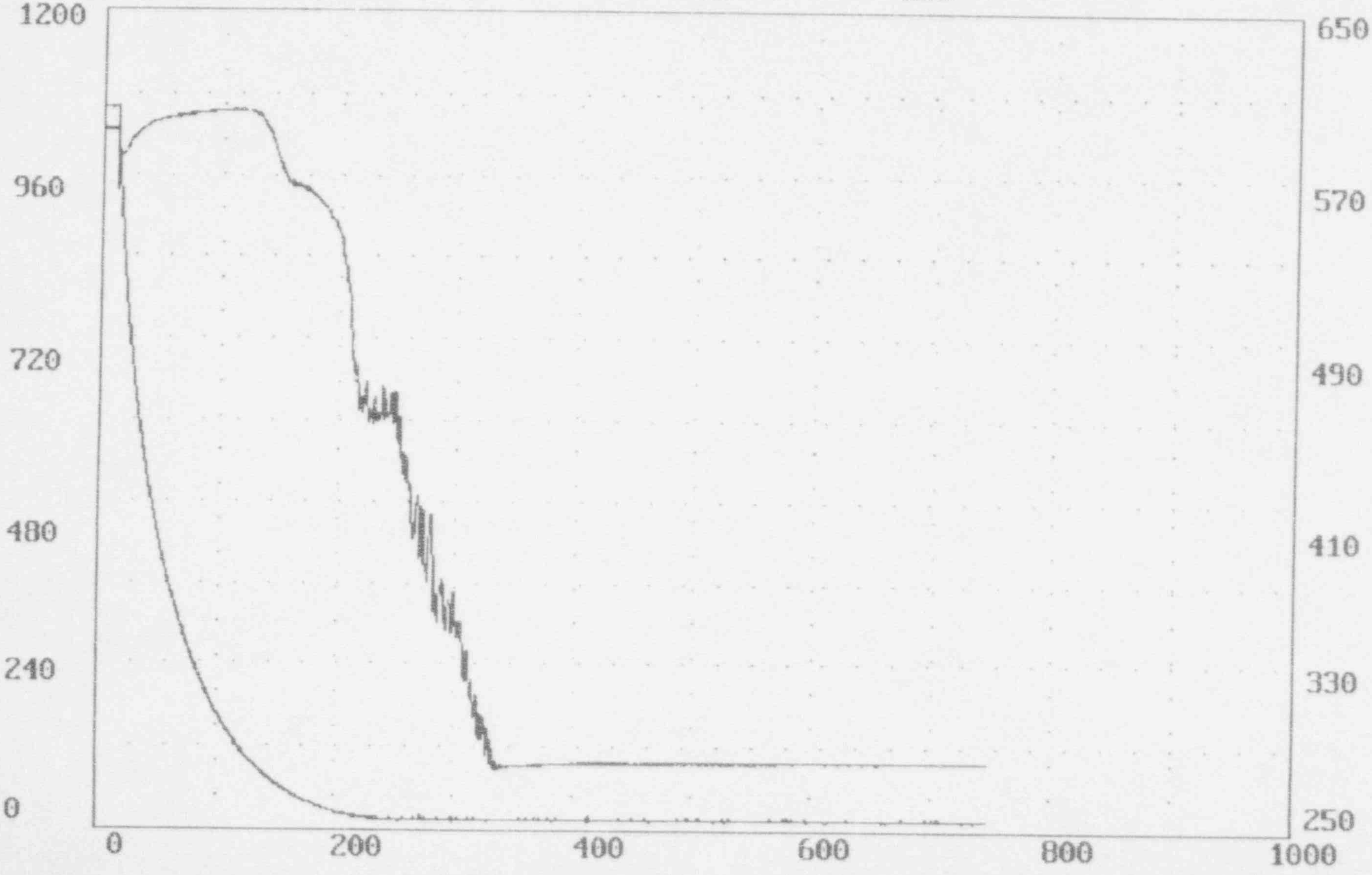

Filename: degas69.dat
TIME (SECONDS)
789
P1 (PSIA)
DP1 (IN. WATER)
201
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200


Filename: degas70.dat
TIME (SECONDS)
1200
P1 (PSIA)
13
DP1 (IN. WATER)
190
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200


Filename: degas71.dat
TIME (SECONDS)
P1 (PSIA)
DP1 (IN. WATER)
1179
11
202
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200


Filename: degas72.dat
TIME (SECONDS)
1200
P1 (PSIA)
13
DP1 (IN. WATER)
202
1200
960
720
480
240
0
250
230
210
190
170
150
0
240
480
720
960
1200


Filename: degas73.dat
TIME (SECONDS)
795
P1 (PSIA)
13
DP1 (IN. WATER)
283
1200
960
720
480
240
0
650
570
490
410
330
250
0
200
400
600
800
1000

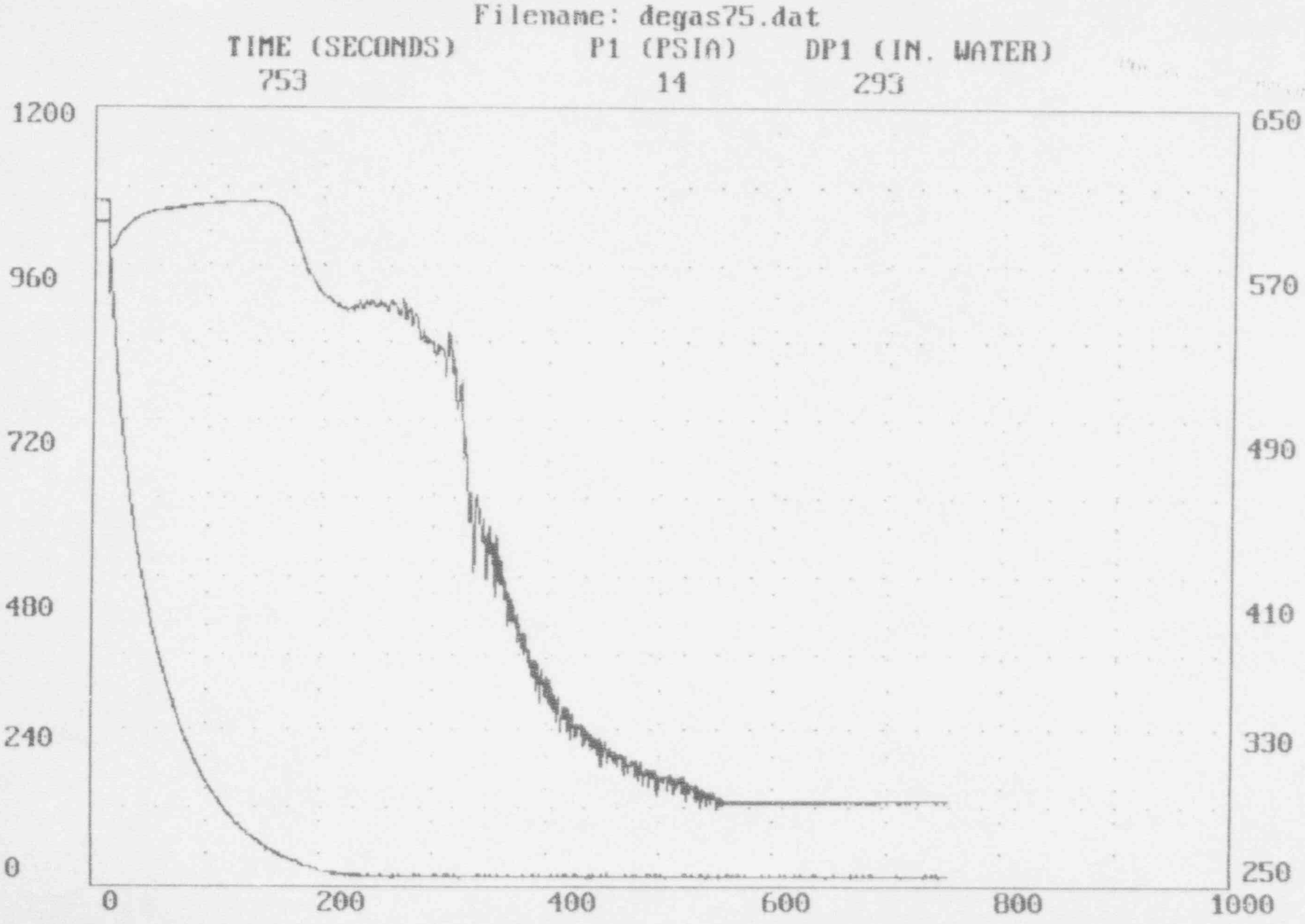


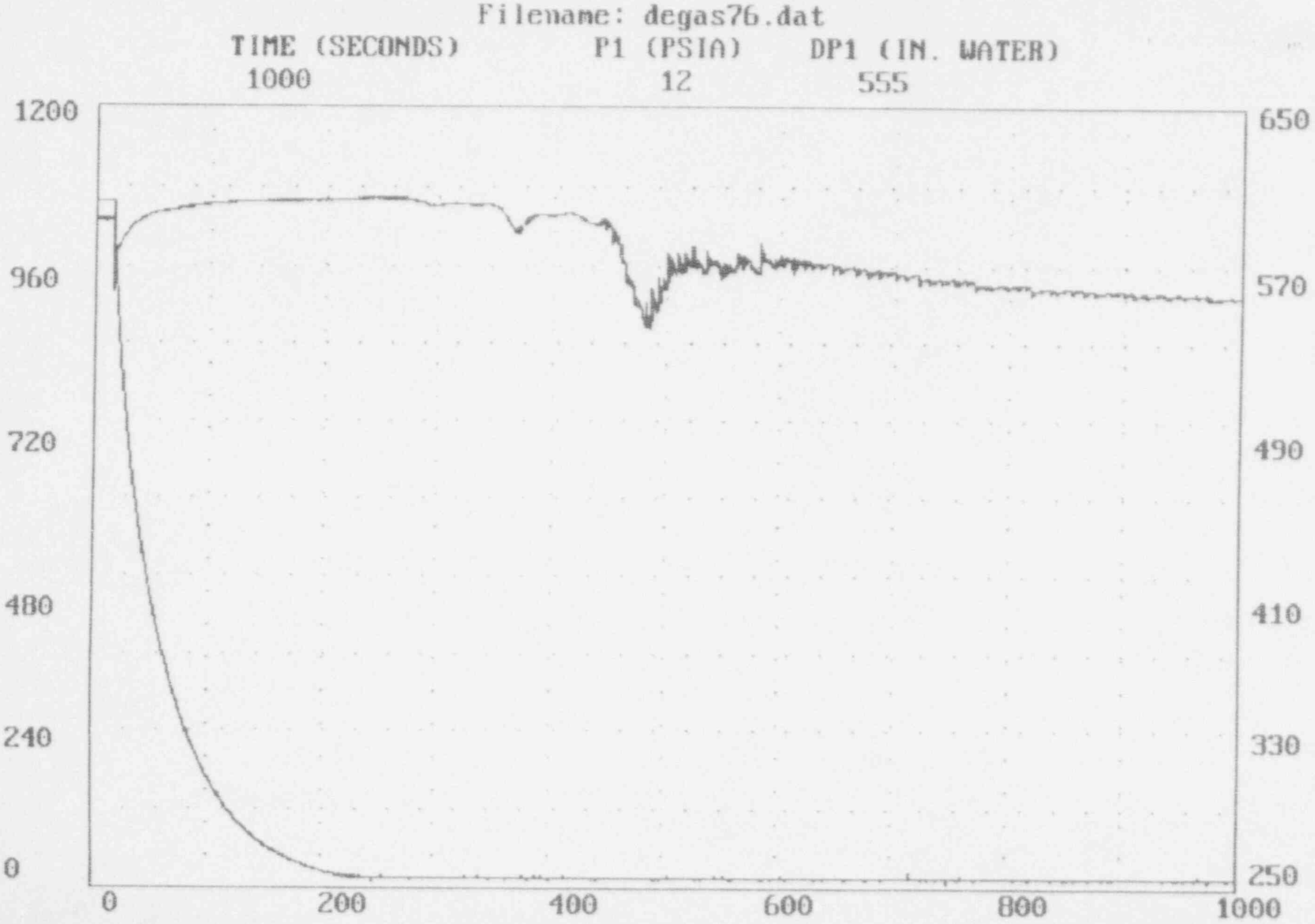
Filename: degas74.dat

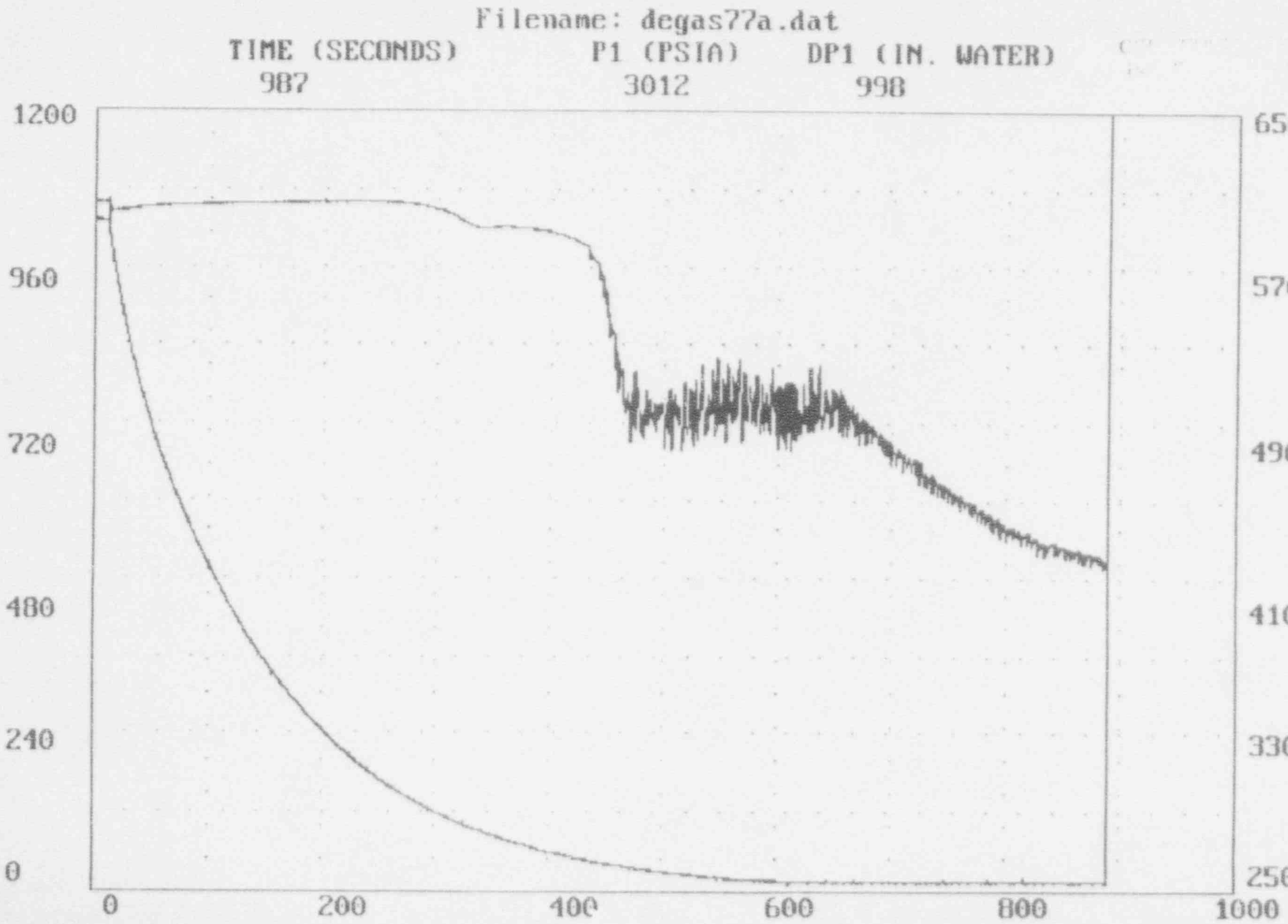
TIME (SECONDS) 747

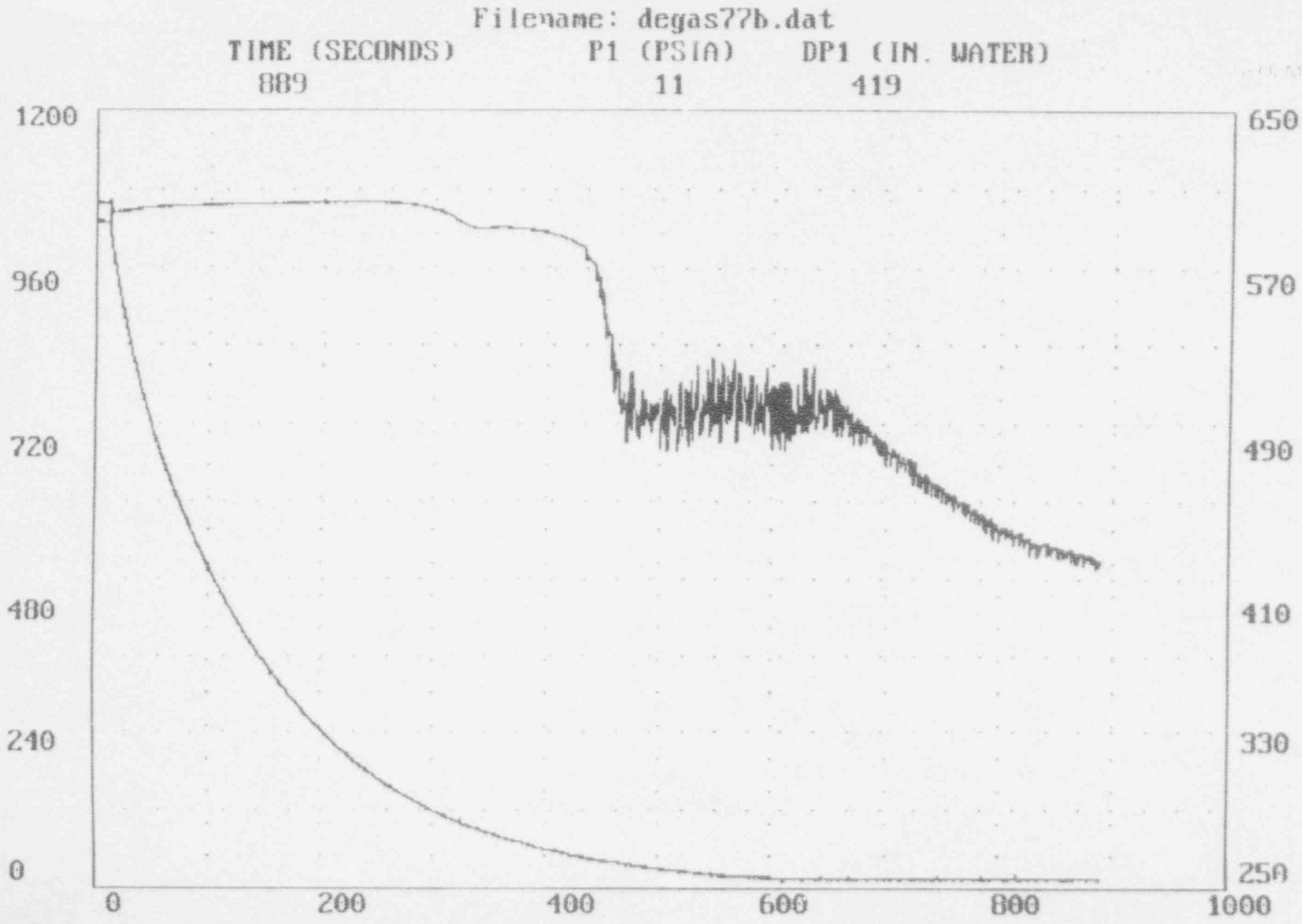
P1 (PSIA) 12

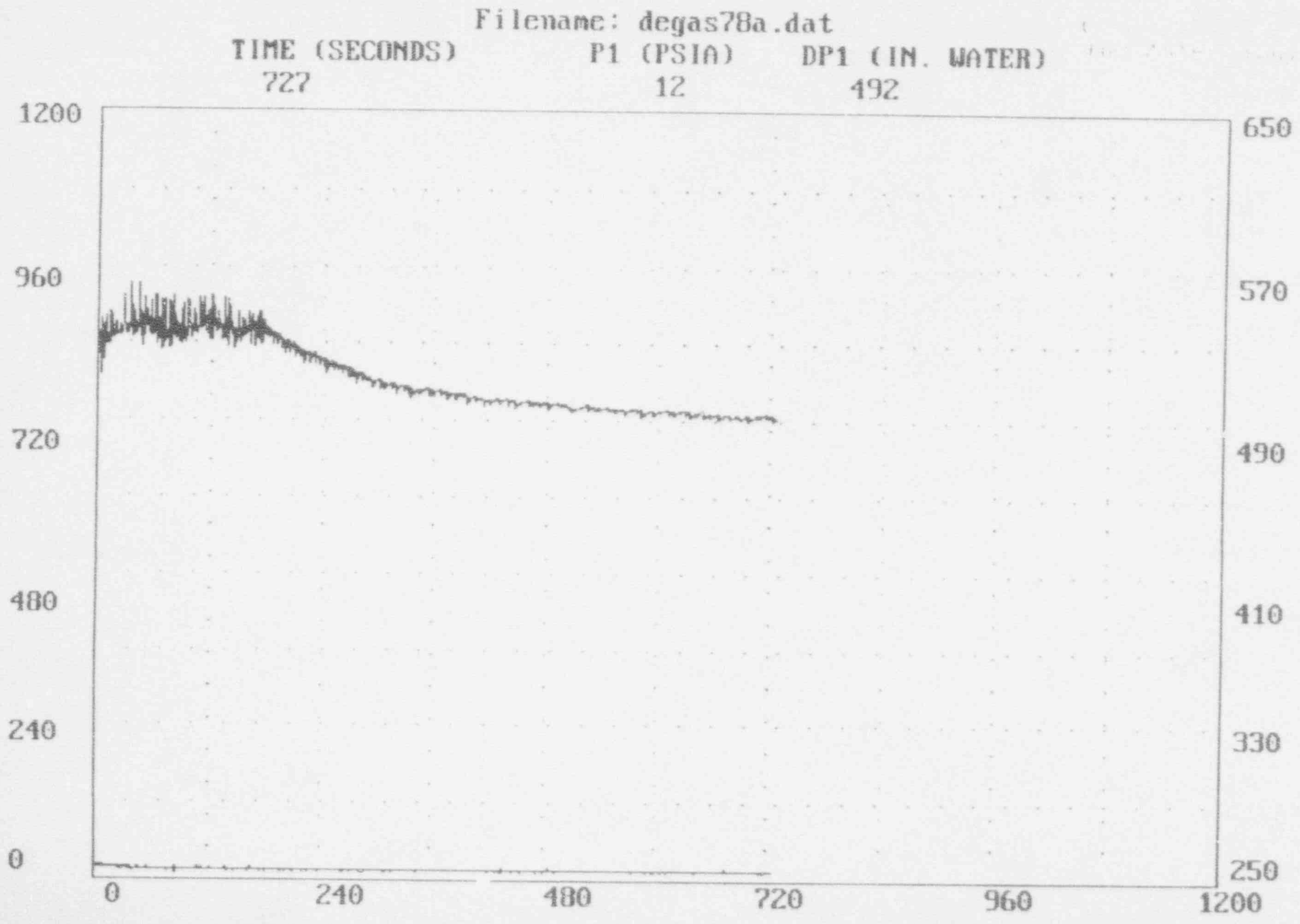
DP1 (IN. WATER) 283

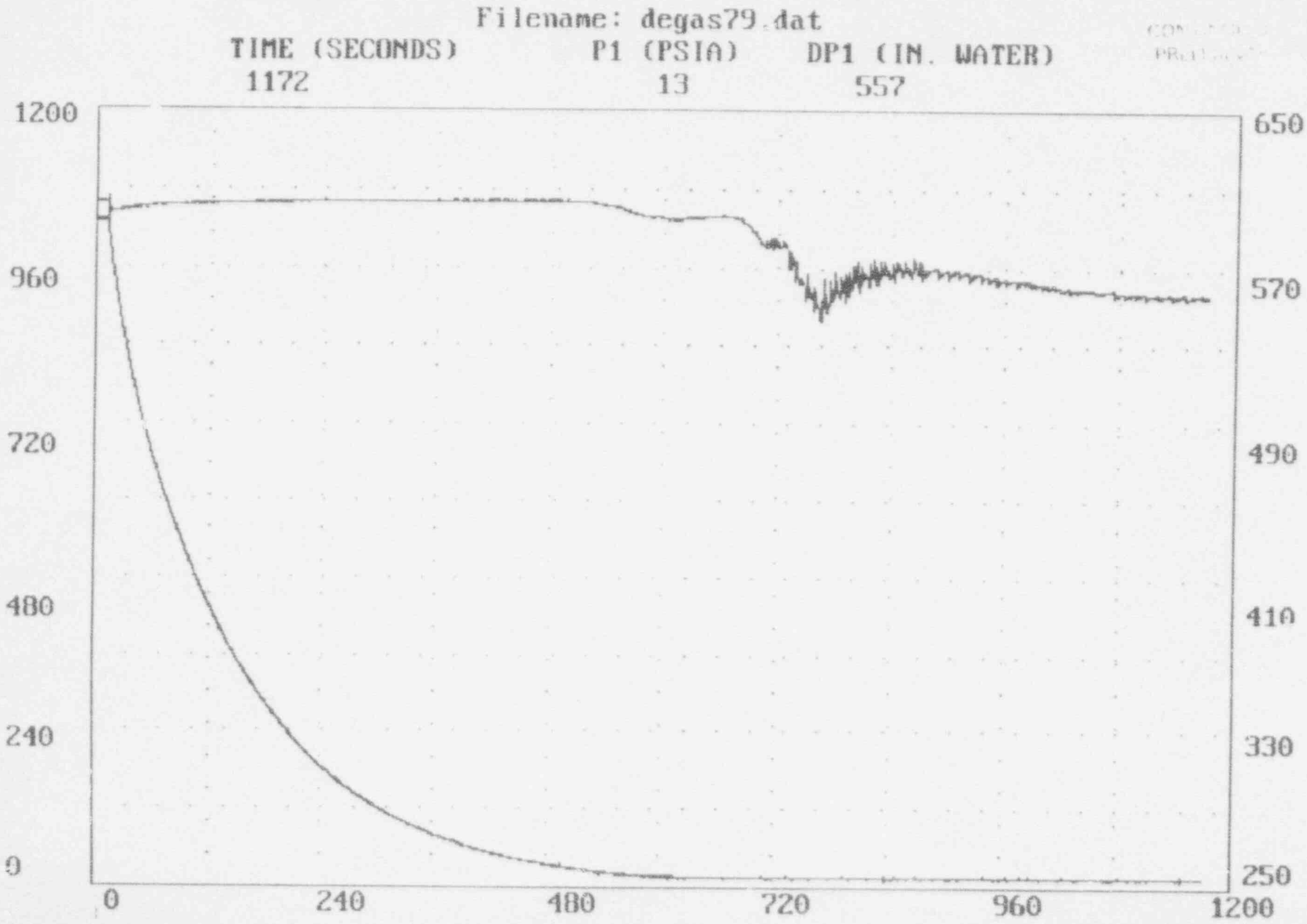

Filename: degas75.dat
TIME (SECONDS)
753
P1 (PSIA)
14
DP1 (IN. WATER)
293
1200
960
720
480
240
0
650
570
490
410
330
250
0
200
400
600
800
1000

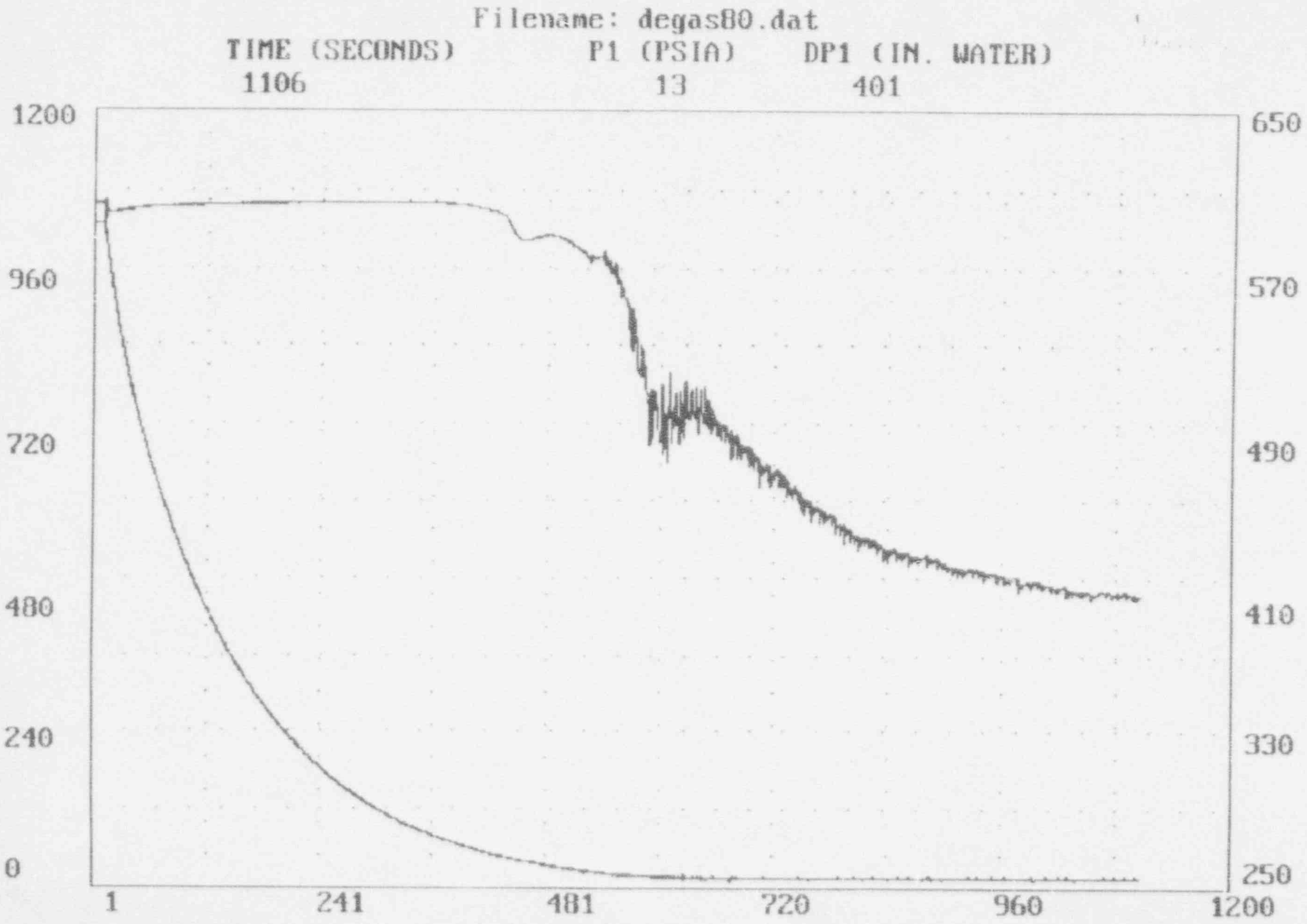

Filename: degas76.dat
TIME (SECONDS)
P1 (PSIA)
DP1 (IN. WATER)
1000
12
555
1200
960
720
480
240
0
650
570
490
410
330
250
0
200
400
600
800
1000

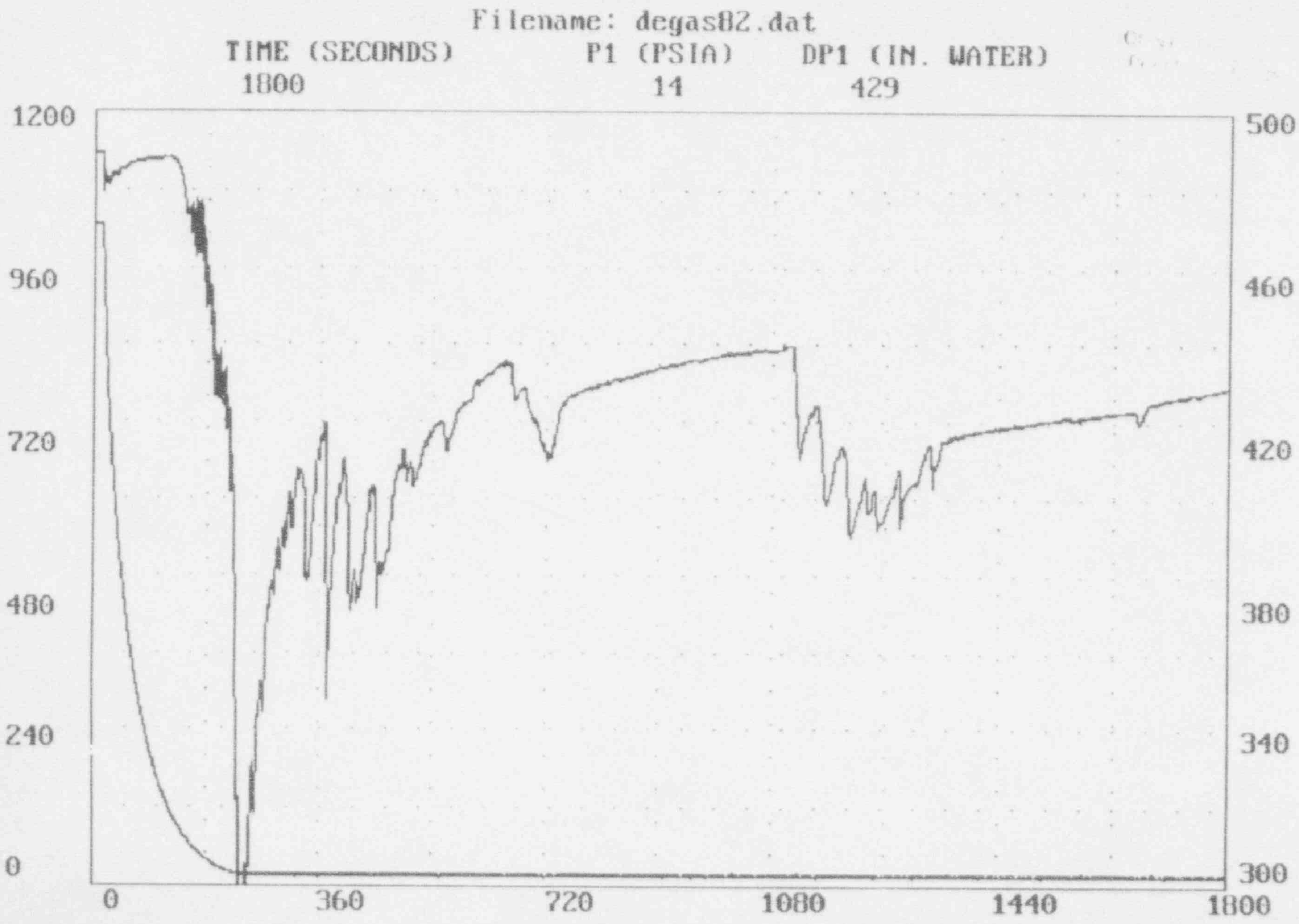

Filename: degas77a.dat
TIME (SECONDS)
987
P1 (PSIA)
3012
DP1 (IN. WATER)
998
1200
960
720
480
240
0
650
570
490
410
330
250
0
200
400
600
800
1000


Filename: degas77b.dat
TIME (SECONDS)
889
P1 (PSIA)
11
DP1 (IN. WATER)
419
1200
960
720
480
240
0
650
570
490
410
330
250
0
200
400
600
800
1000


Filename: degas78a.dat
TIME (SECONDS)
727
P1 (PSIA)
12
DP1 (IN. WATER)
492
1200
960
720
480
240
0
650
570
490
410
330
250
0
240
480
720
960
1200


Filename: degas79.dat
TIME (SECONDS)
1172
P1 (PSIA)
13
DP1 (IN. WATER)
557
1200
960
720
480
240
0
650
570
490
410
330
250
0
240
480
720
960
1200

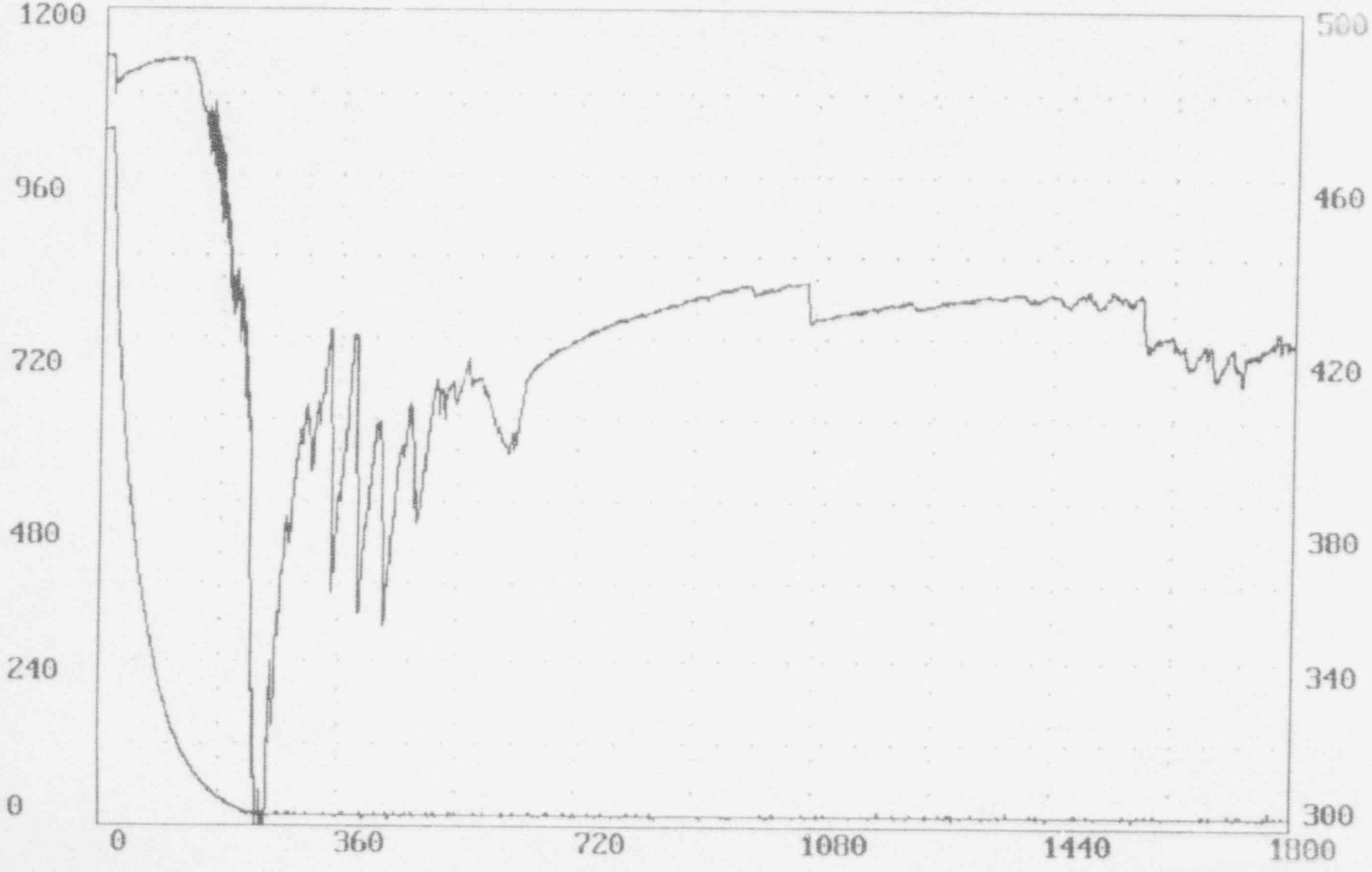

Filename: degas80.dat
TIME (SECONDS)
1106
P1 (PSIA)
13
DP1 (IN. WATER)
401
1200
960
720
480
240
0
650
570
490
410
330
250
1
241
481
720
960
1200

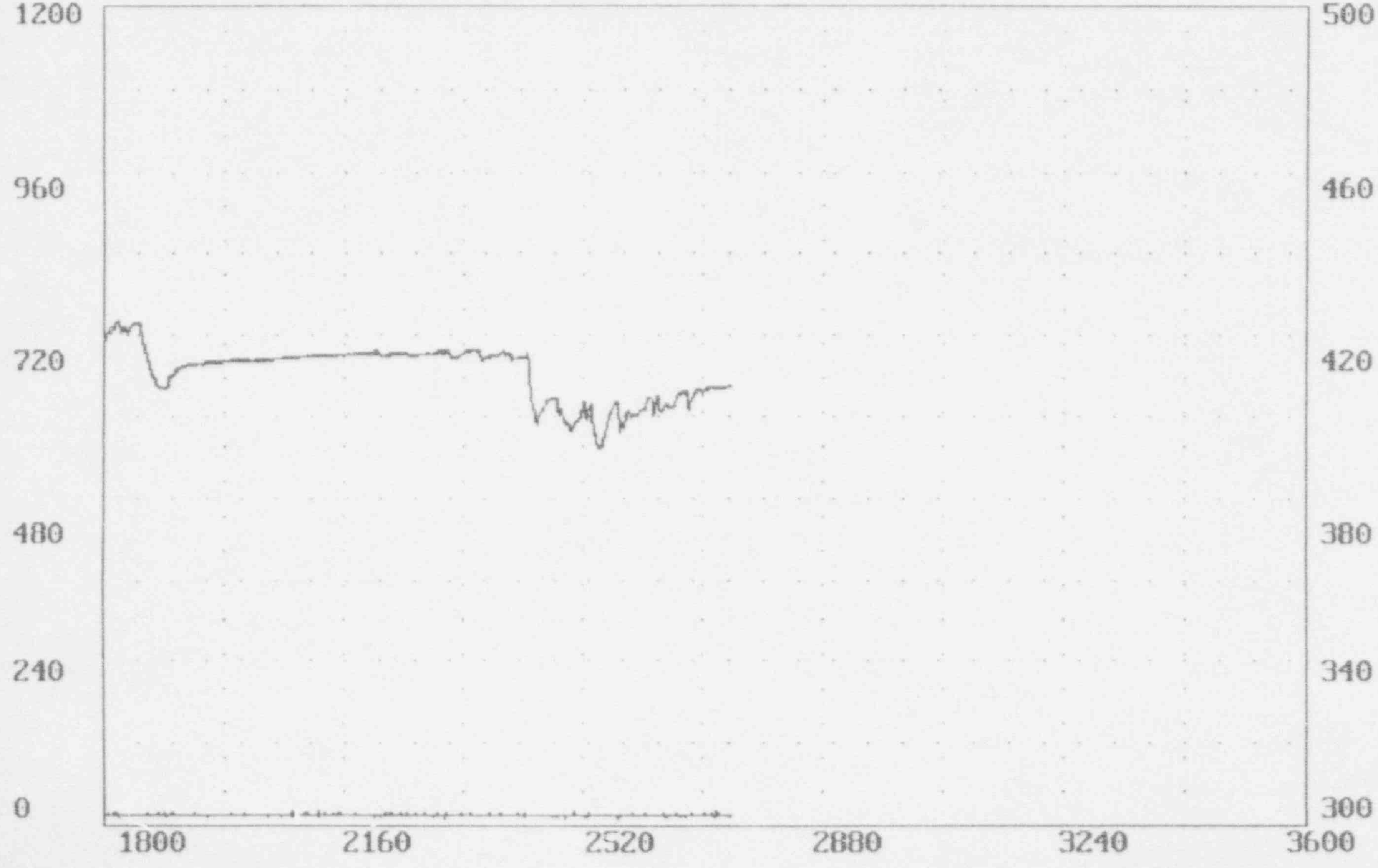

Filename: degas82.dat
TIME (SECONDS)
1800
P1 (PSIA)
14
DP1 (IN. WATER)
429
1200
960
720
480
240
0
500
460
420
380
340
300
0
360
720
1080
1440
1800

Filename: degas83.dat

TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

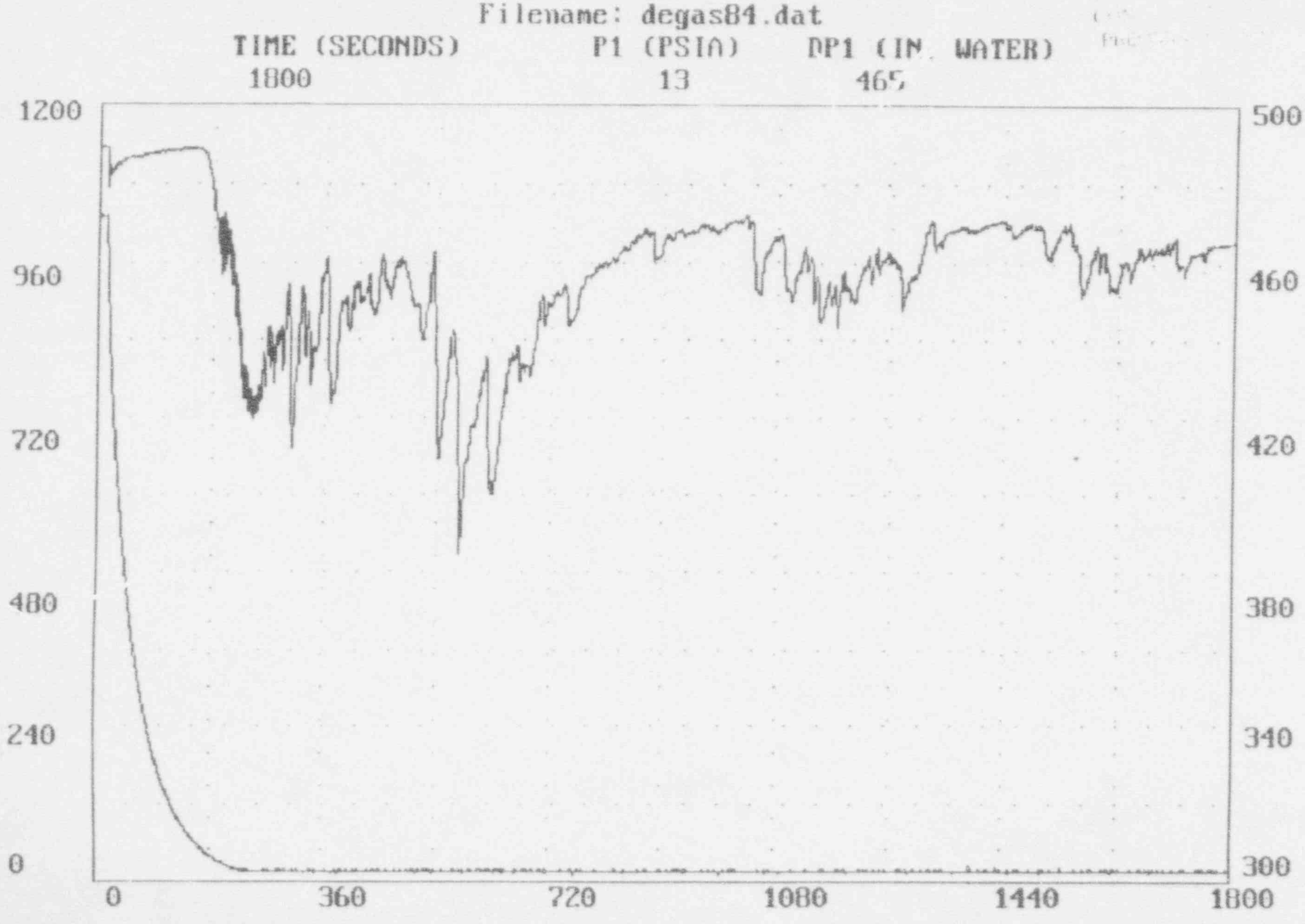
1800 13 420





Filename: degas83.dat

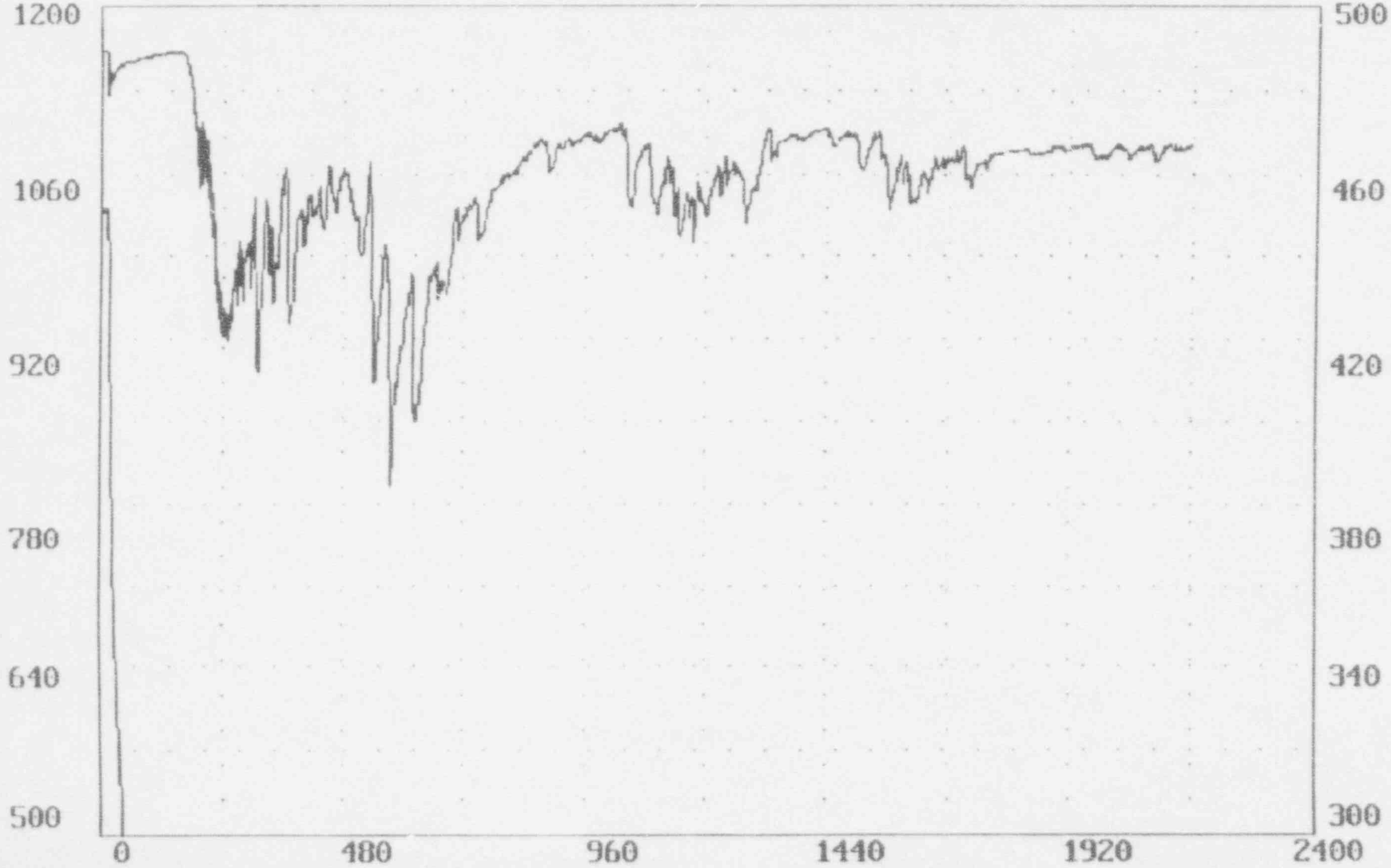
| TIME (SECONDS) | P1 (PSIA) | DP1 (IN. WATER) |
|---|---|---|
| 2742 | 13 | 407 |

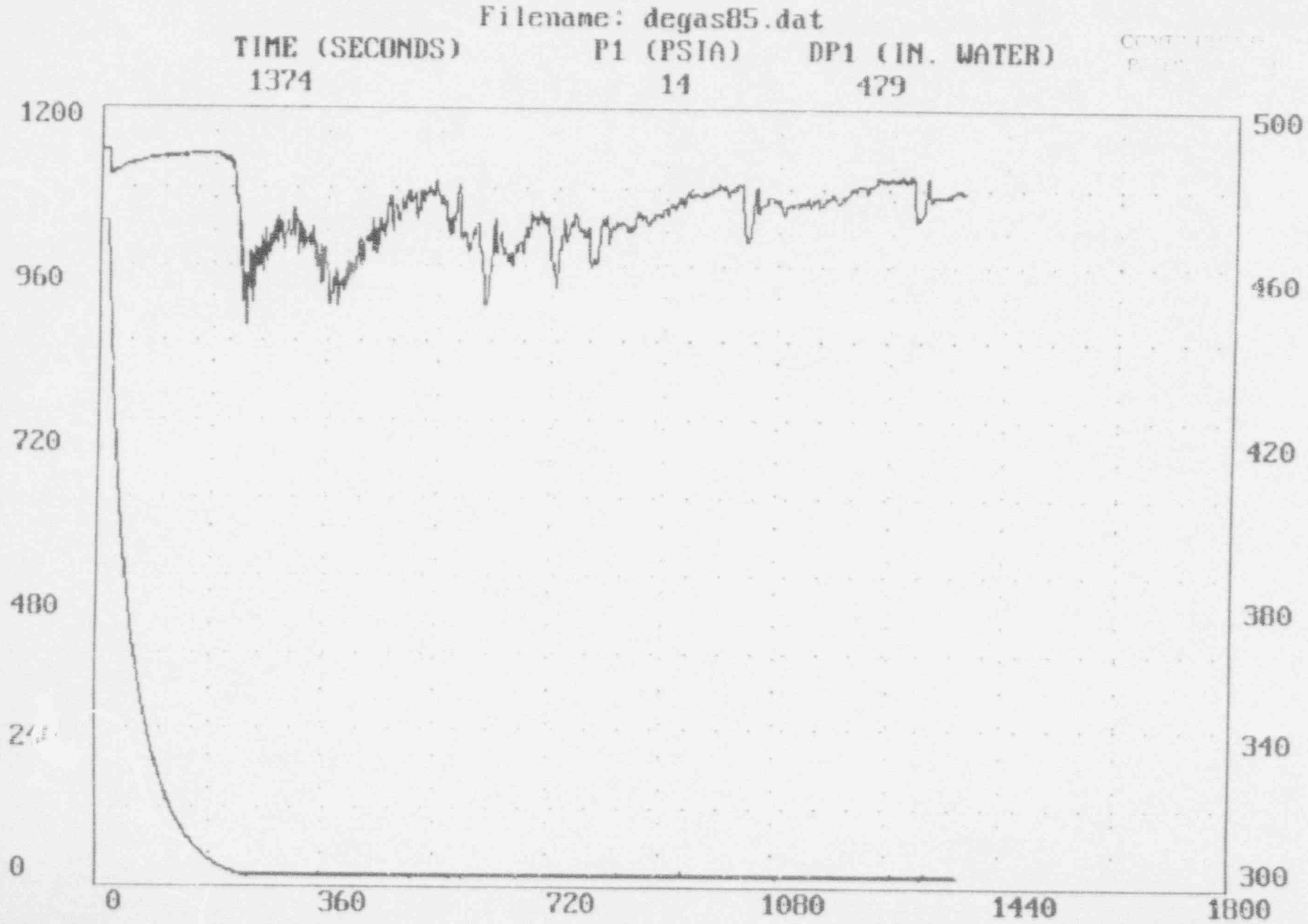

Filename: degas84.dat
TIME (SECONDS)
1800
P1 (PSIA)
13
DP1 (IN. WATER)
465
1200
960
720
480
240
0
500
460
420
380
340
300
0
360
720
1080
1440
1800

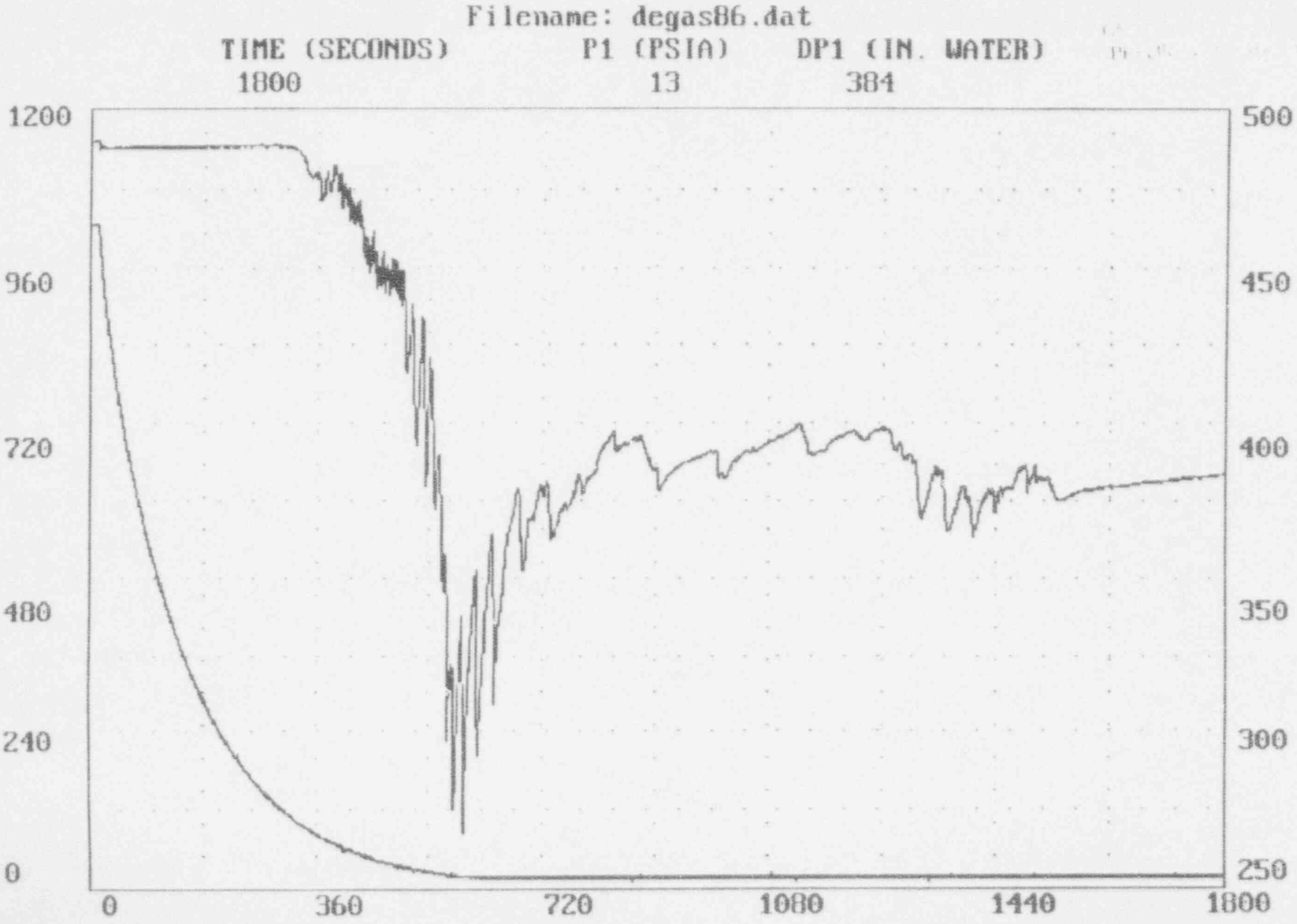
Filename: degas84.dat

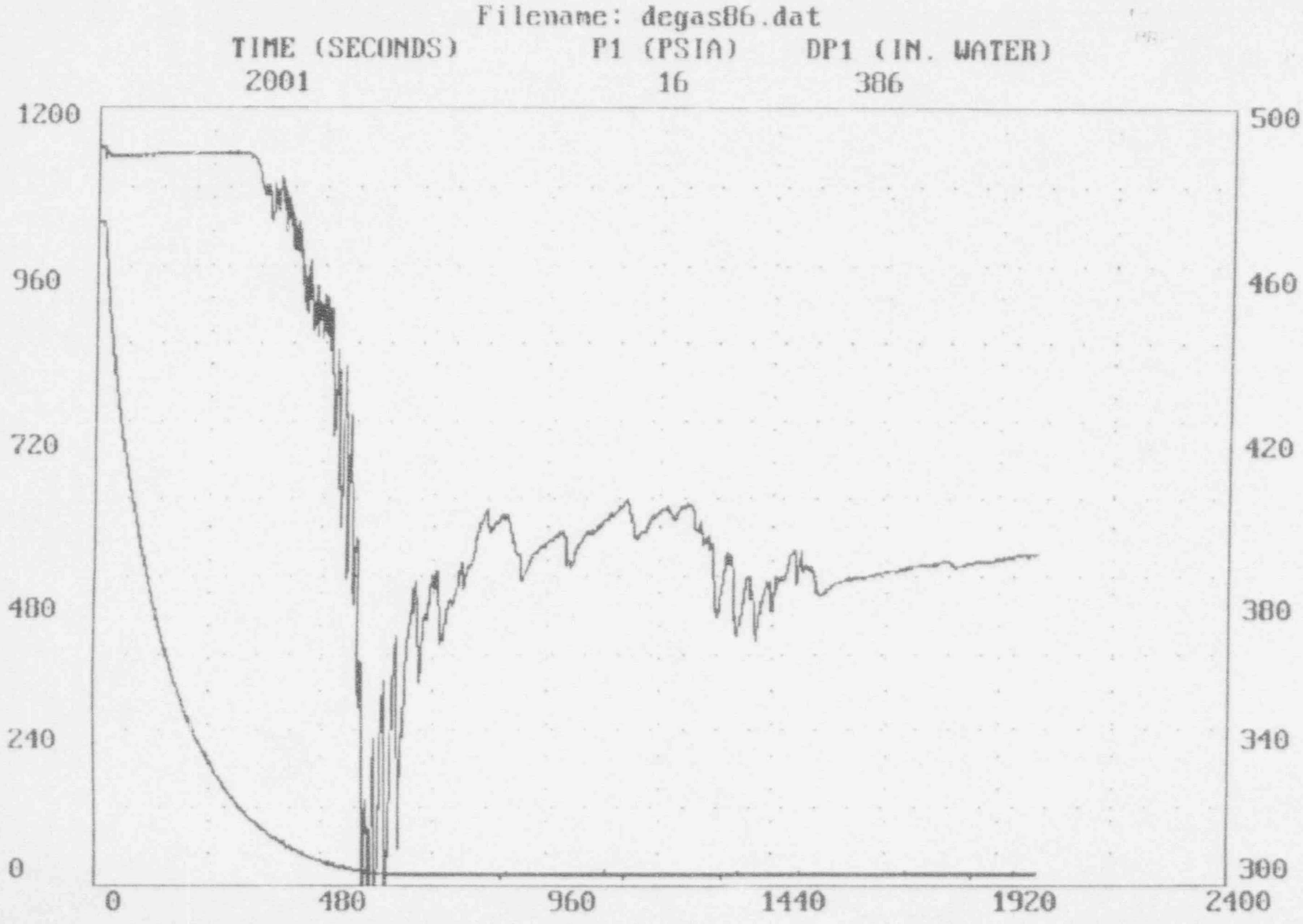
TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

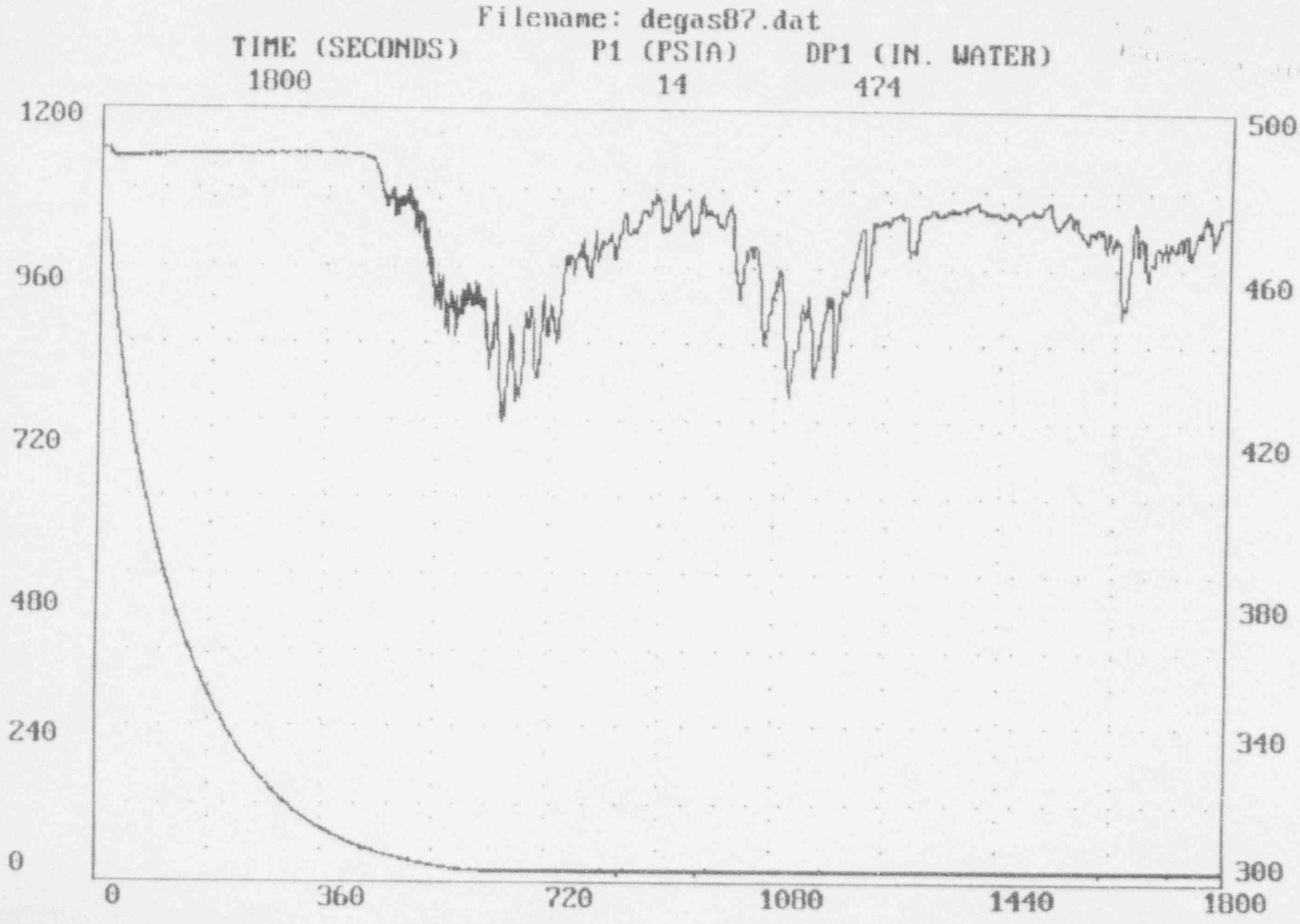
2157 13 467

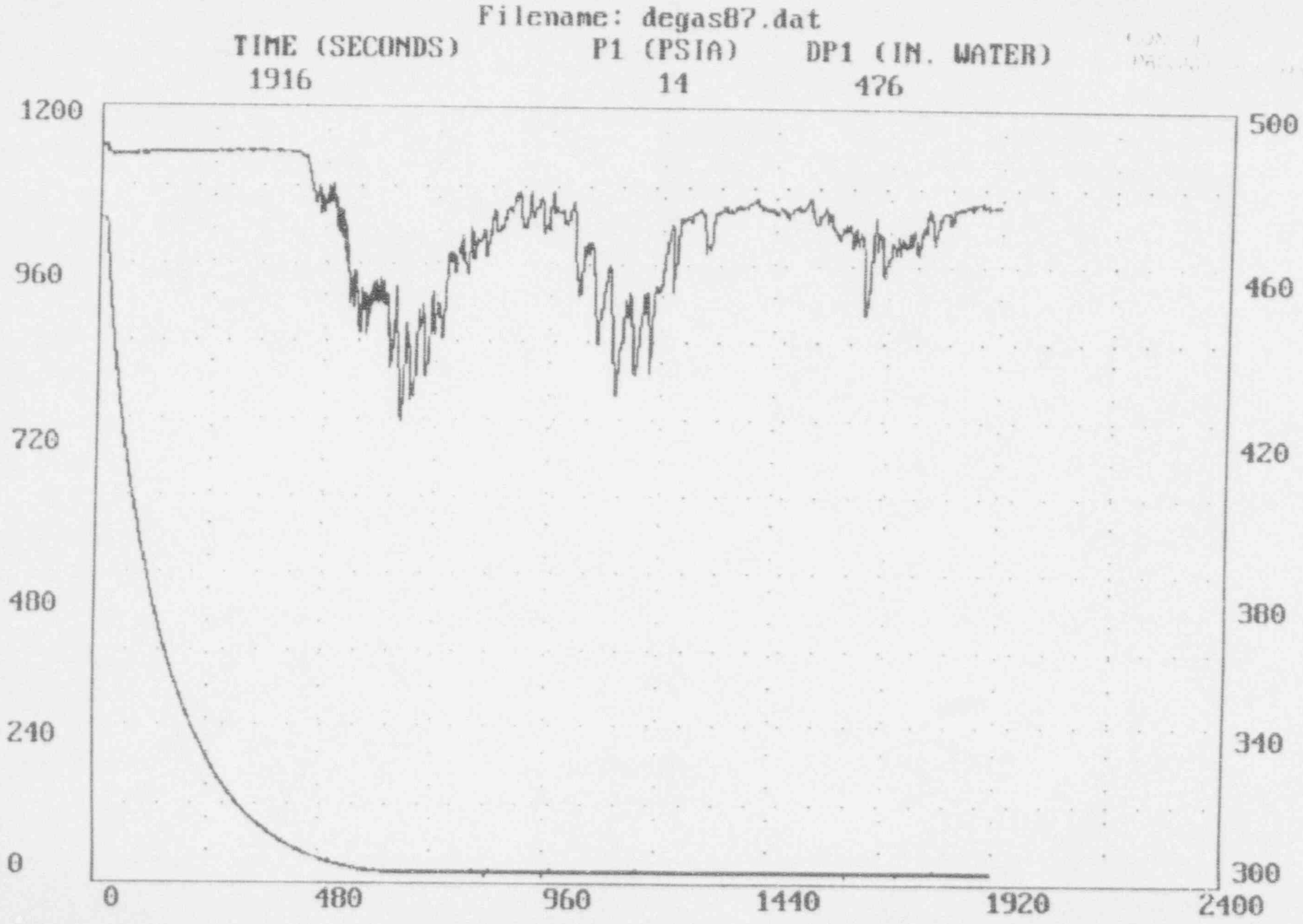


Filename: degas85.dat
TIME (SECONDS)
1374
P1 (PSIA)
14
DP1 (IN. WATER)
479
1200
960
720
480
24
0
500
460
420
380
340
300
0
360
720
1080
1440
1800


Filename: degas86.dat
TIME (SECONDS)
1800
P1 (PSIA)
13
DP1 (IN. WATER)
384
1200
960
720
480
240
0
500
450
400
350
300
250
0
360
720
1080
1440
1800


Filename: degas86.dat
TIME (SECONDS)
2001
P1 (PSIA)
16
DP1 (IN. WATER)
386
1200
960
720
480
240
0
500
460
420
380
340
300
0
480
960
1440
1920
2400


Filename: degas87.dat
TIME (SECONDS)
1800
P1 (PSIA)
14
DP1 (IN. WATER)
474
1200
960
720
480
240
0
500
460
420
380
340
300
0
360
720
1080
1440
1800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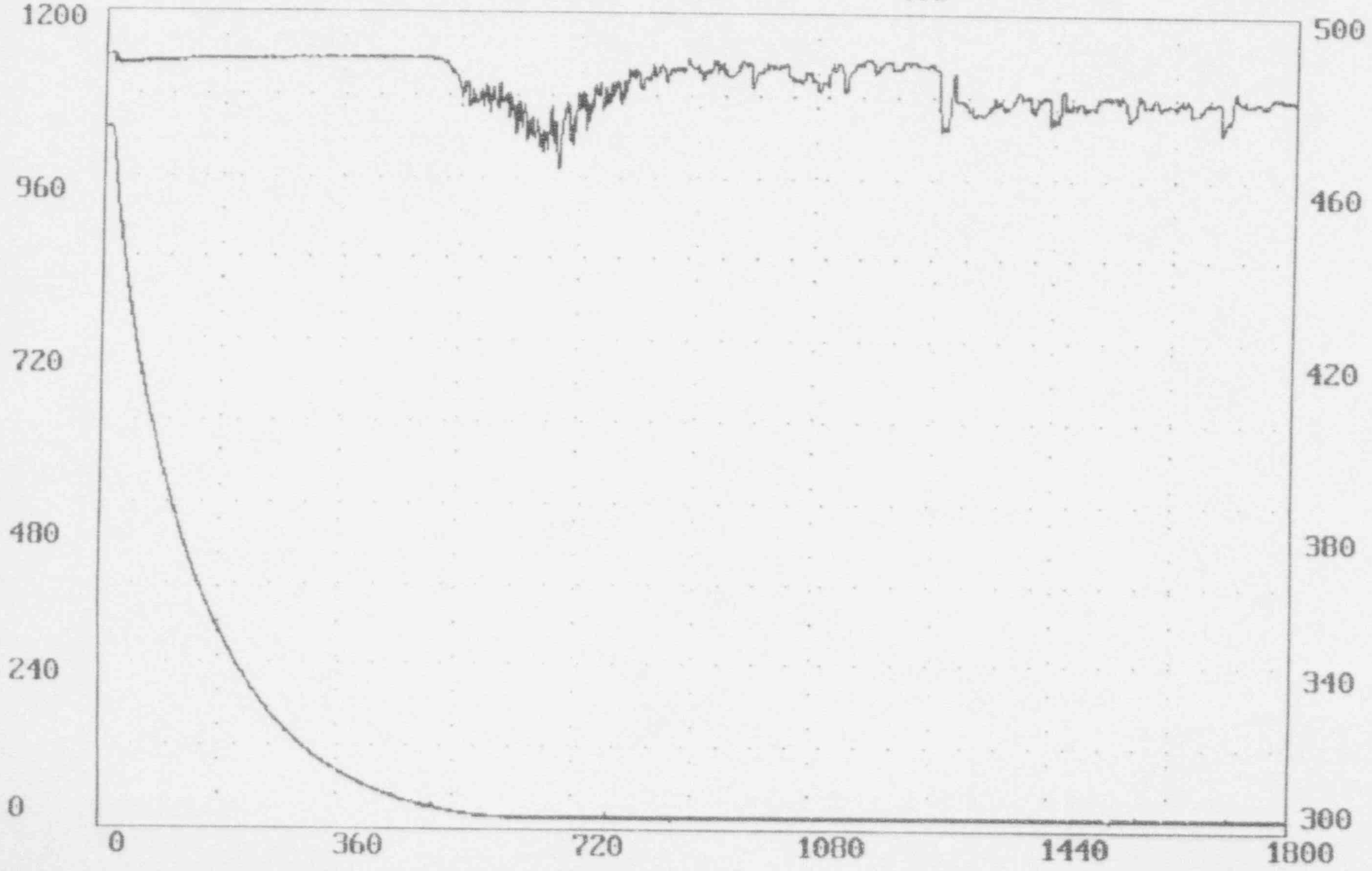
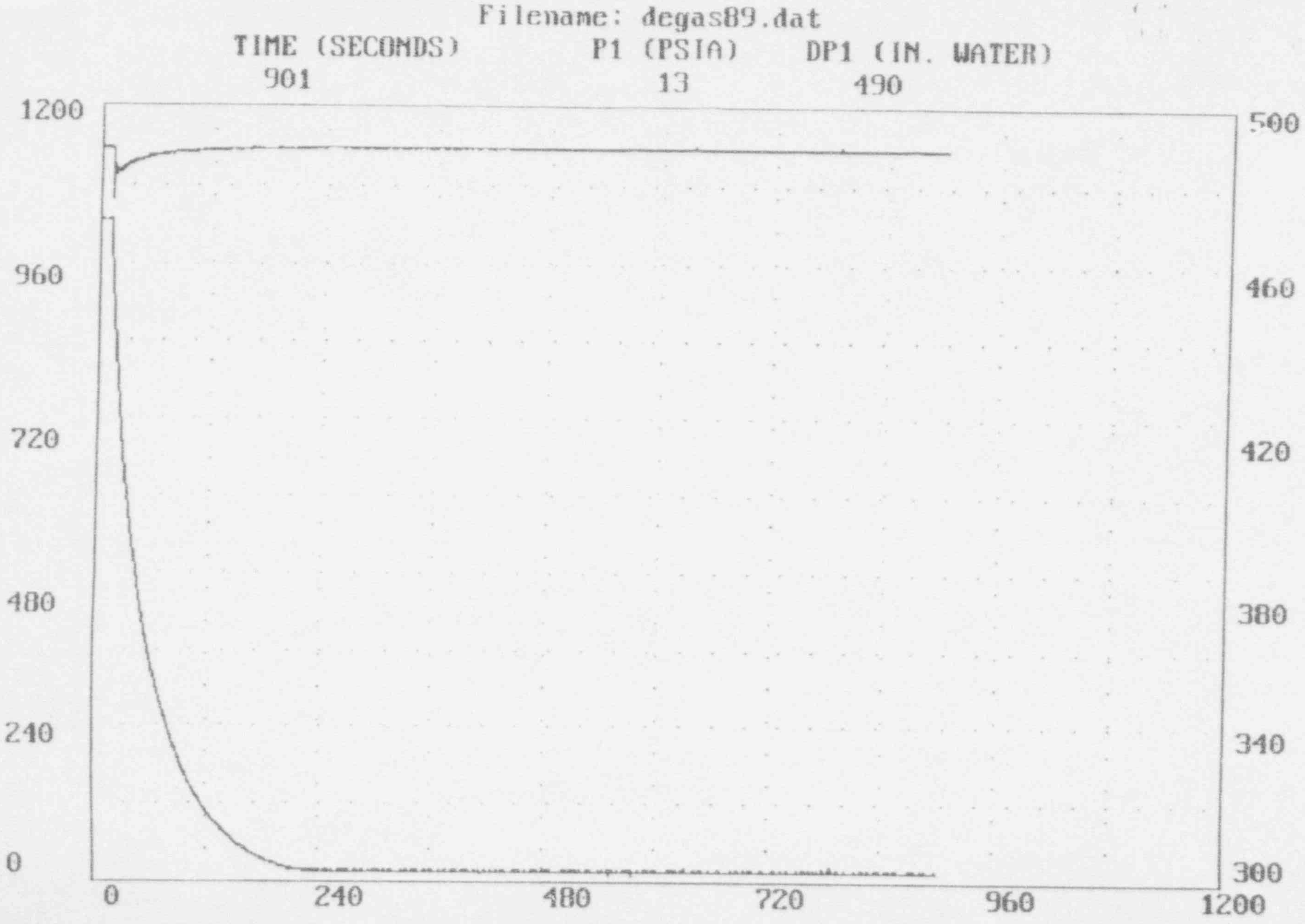
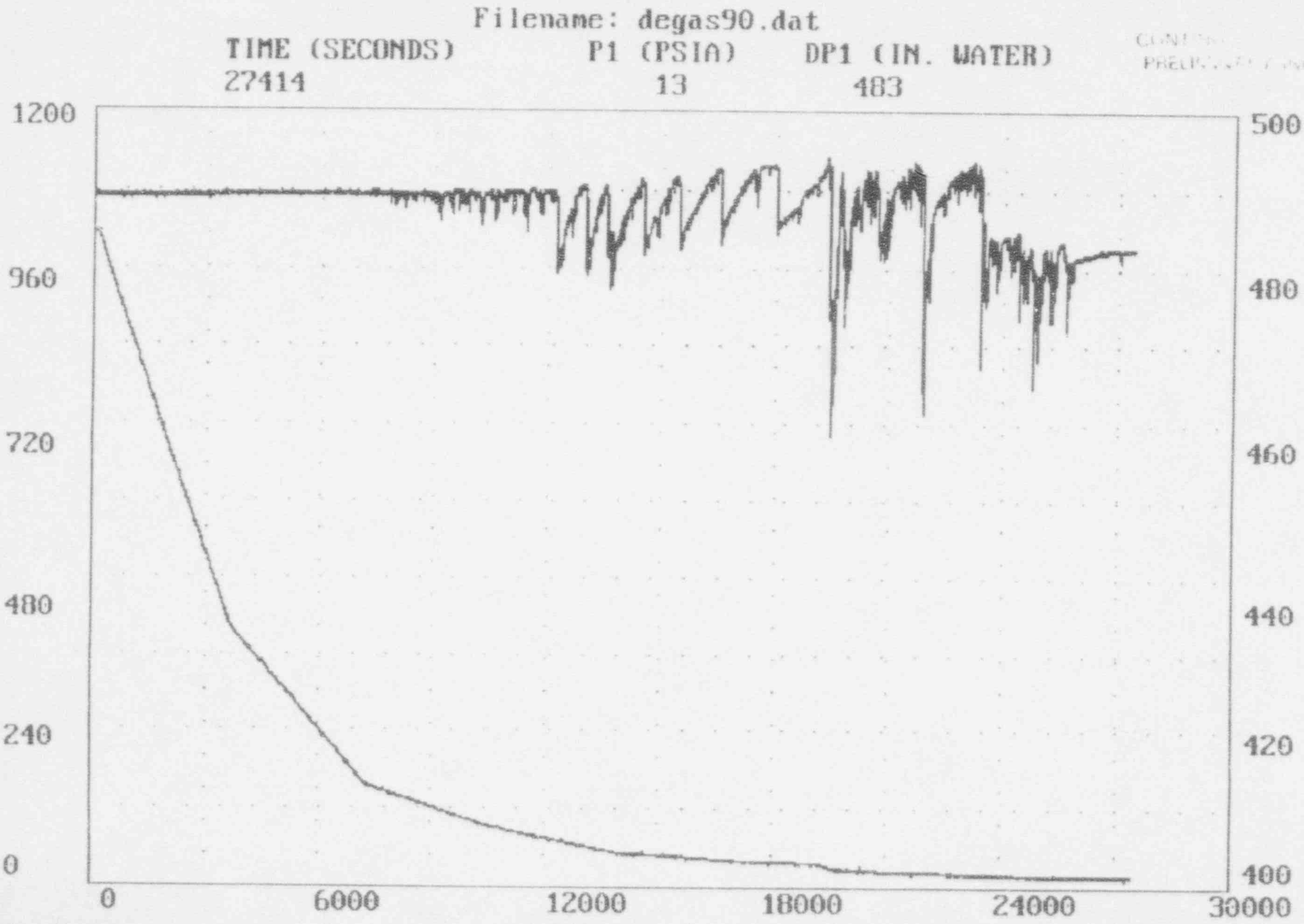
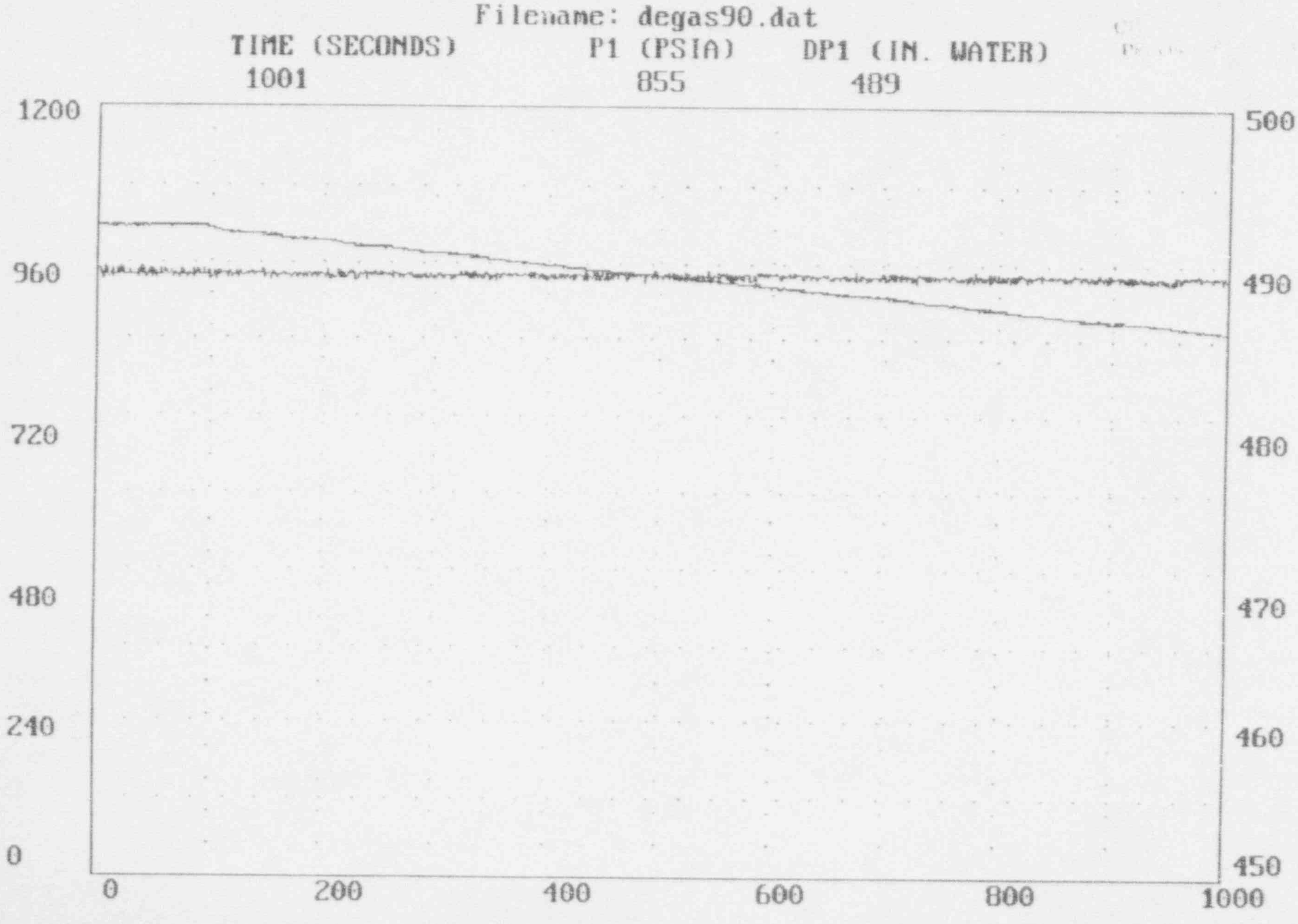
TIME (SECONDS)
1916
P1 (PSIA)
14
DP1 (IN. WATER)
476
1200
960
720
480
240
0
500
460
420
380
340
300
0
480
960
1440
1920
2400

Filename: degas88.dat




Filename: degas89.dat
TIME (SECONDS)
901
P1 (PSIA)
13
DP1 (IN. WATER)
490
1200
960
720
480
240
0
0
240
480
720
960
1200
500
460
420
380
340
300

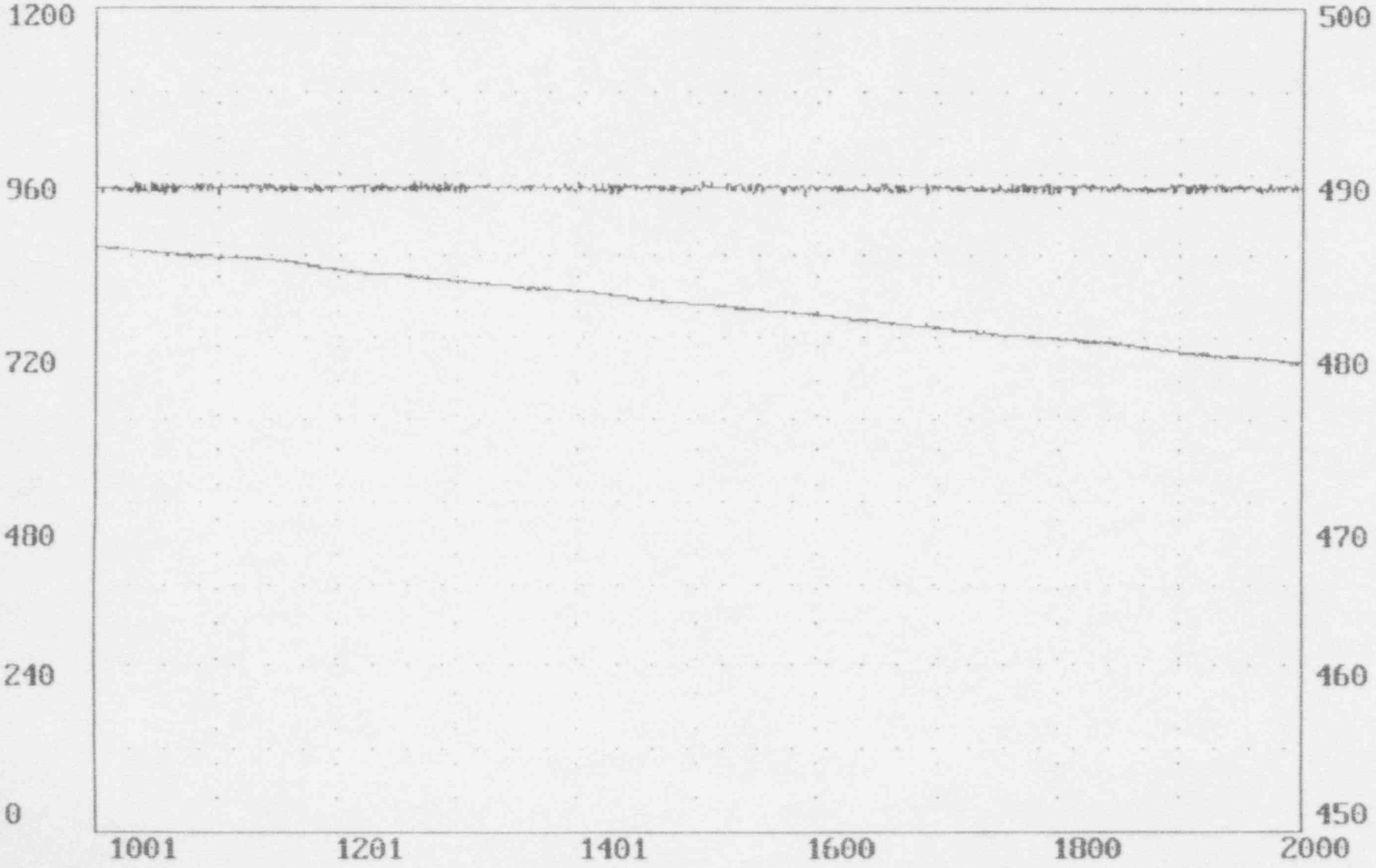

Filename: degas90.dat
TIME (SECONDS)
27414
P1 (PSIA)
13
DP1 (IN. WATER)
483
1200
960
720
480
240
0
500
480
460
440
420
400
0
6000
12000
18000
24000
30000

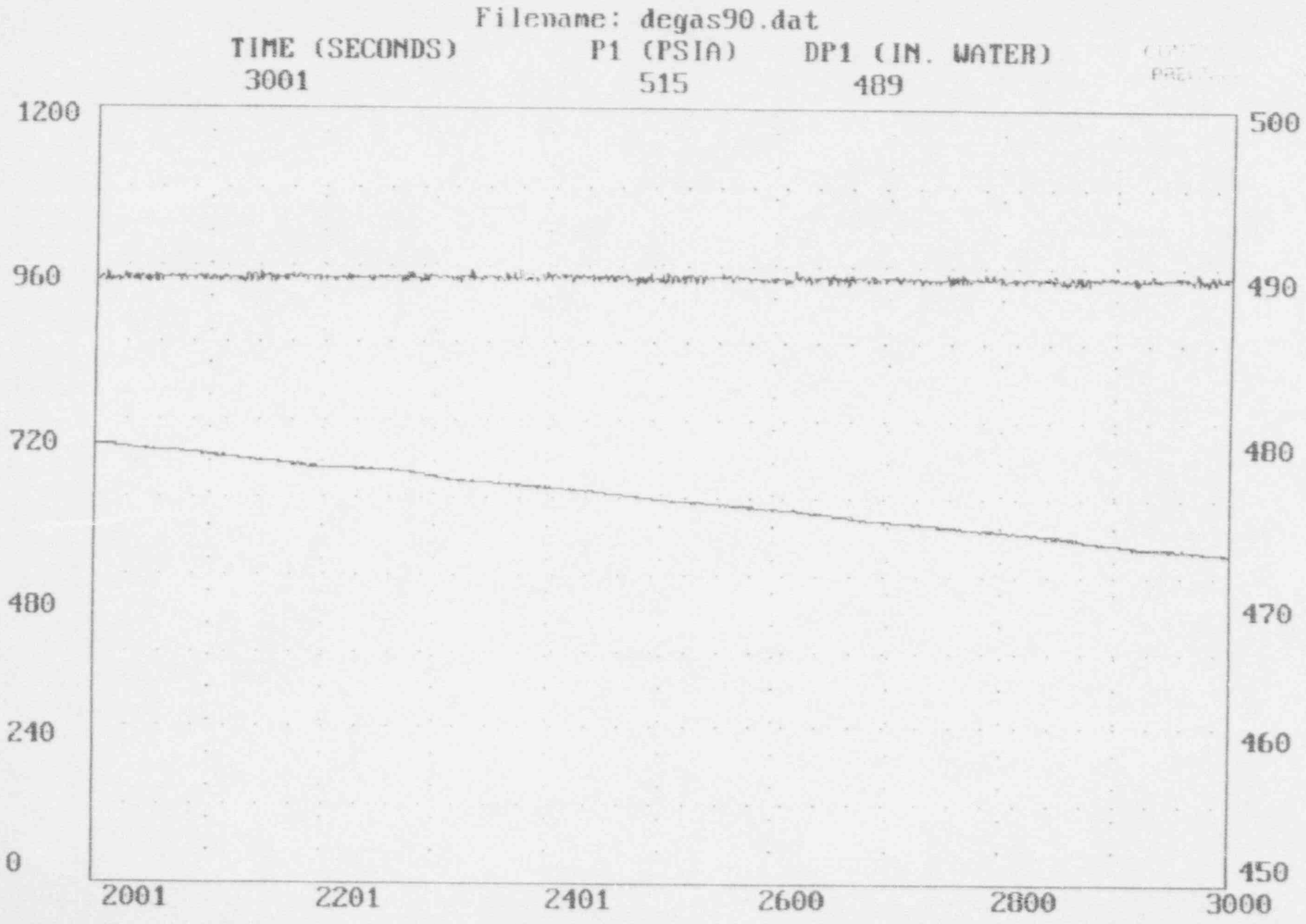

Filename: degas90.dat
TIME (SECONDS)
1001
P1 (PSIA)
855
DP1 (IN. WATER)
489
1200
960
720
480
240
0
0
200
400
600
800
1000
500
490
480
470
460
450

Filename: degas90.dat

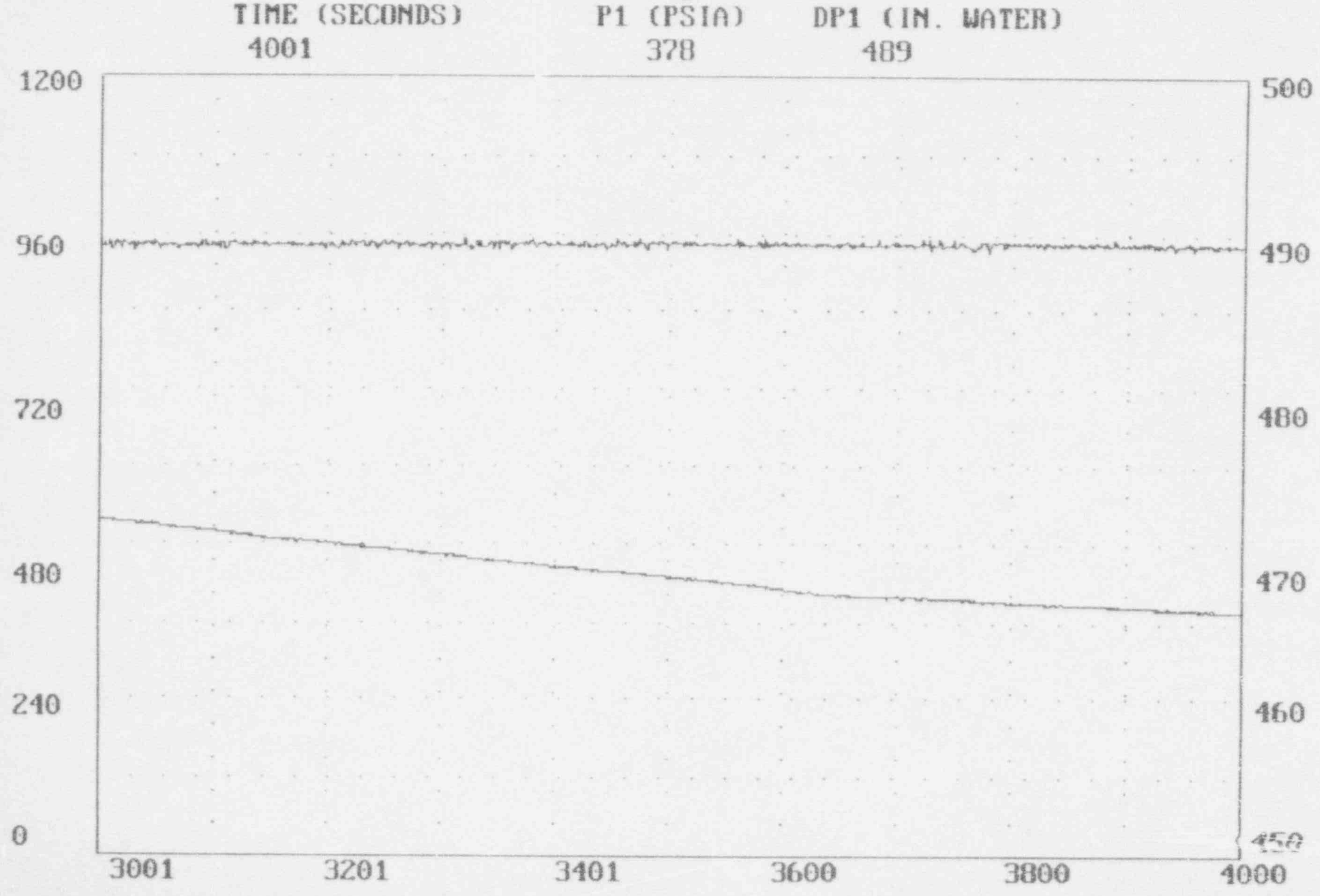
TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

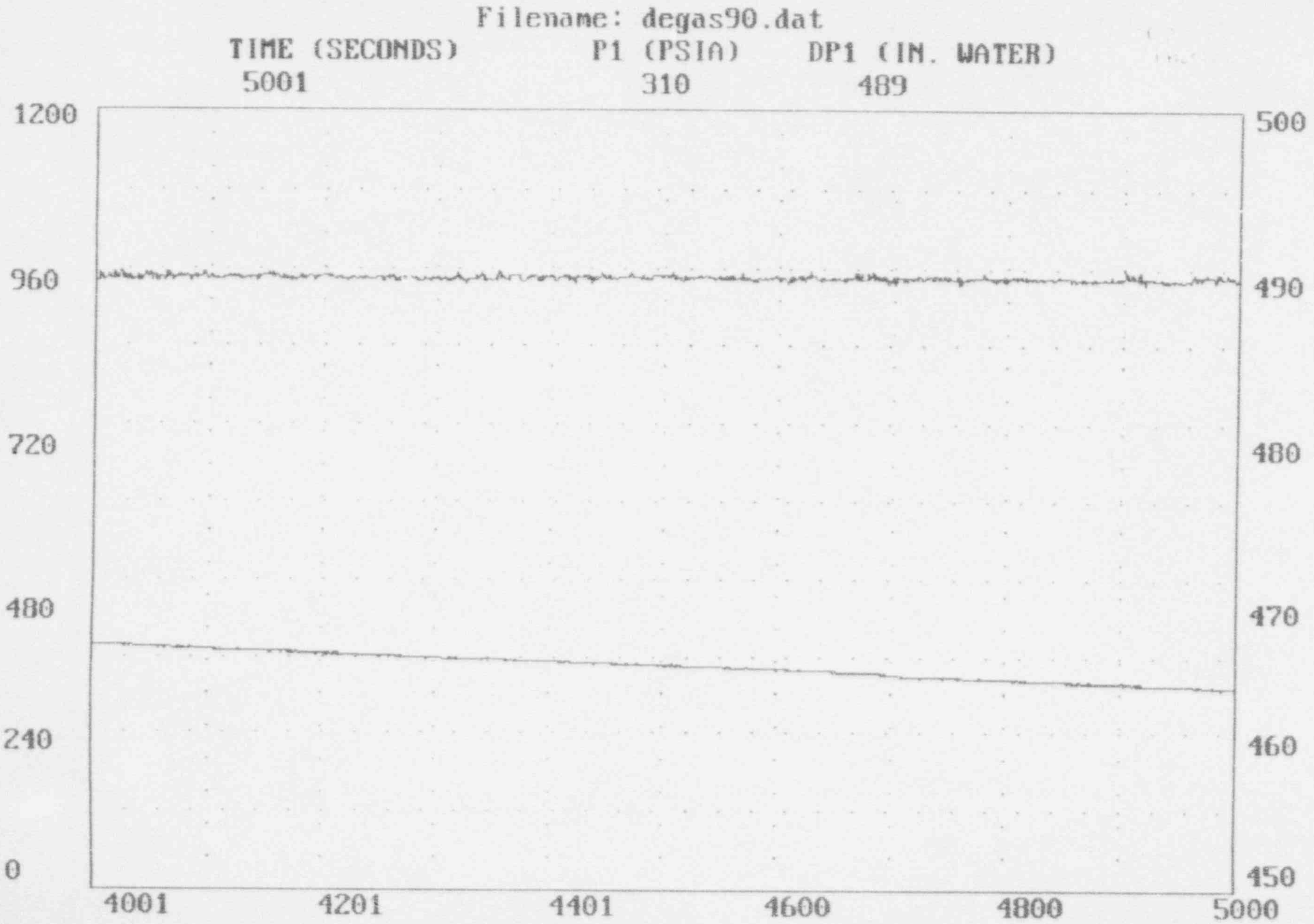
2001 685 489

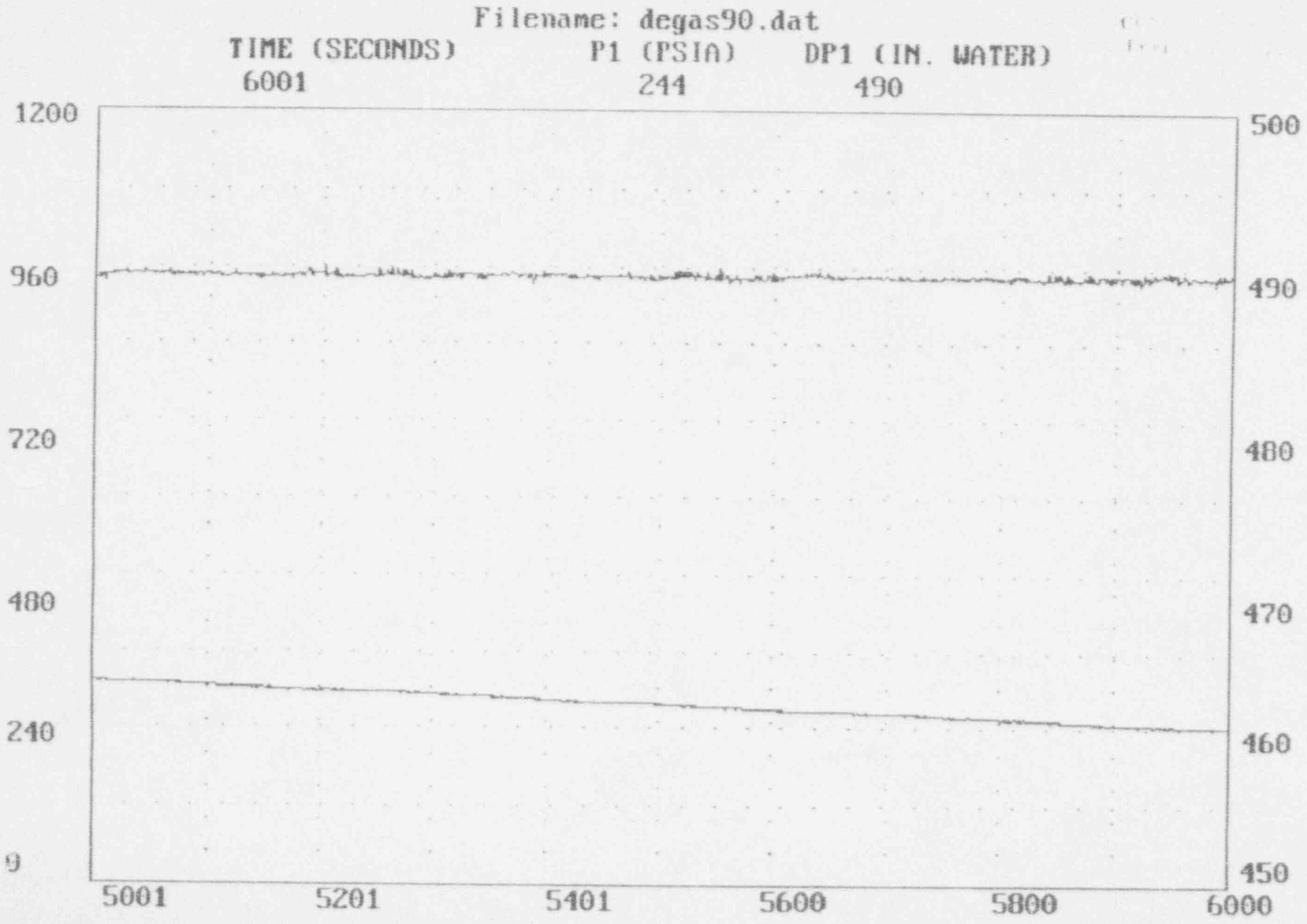


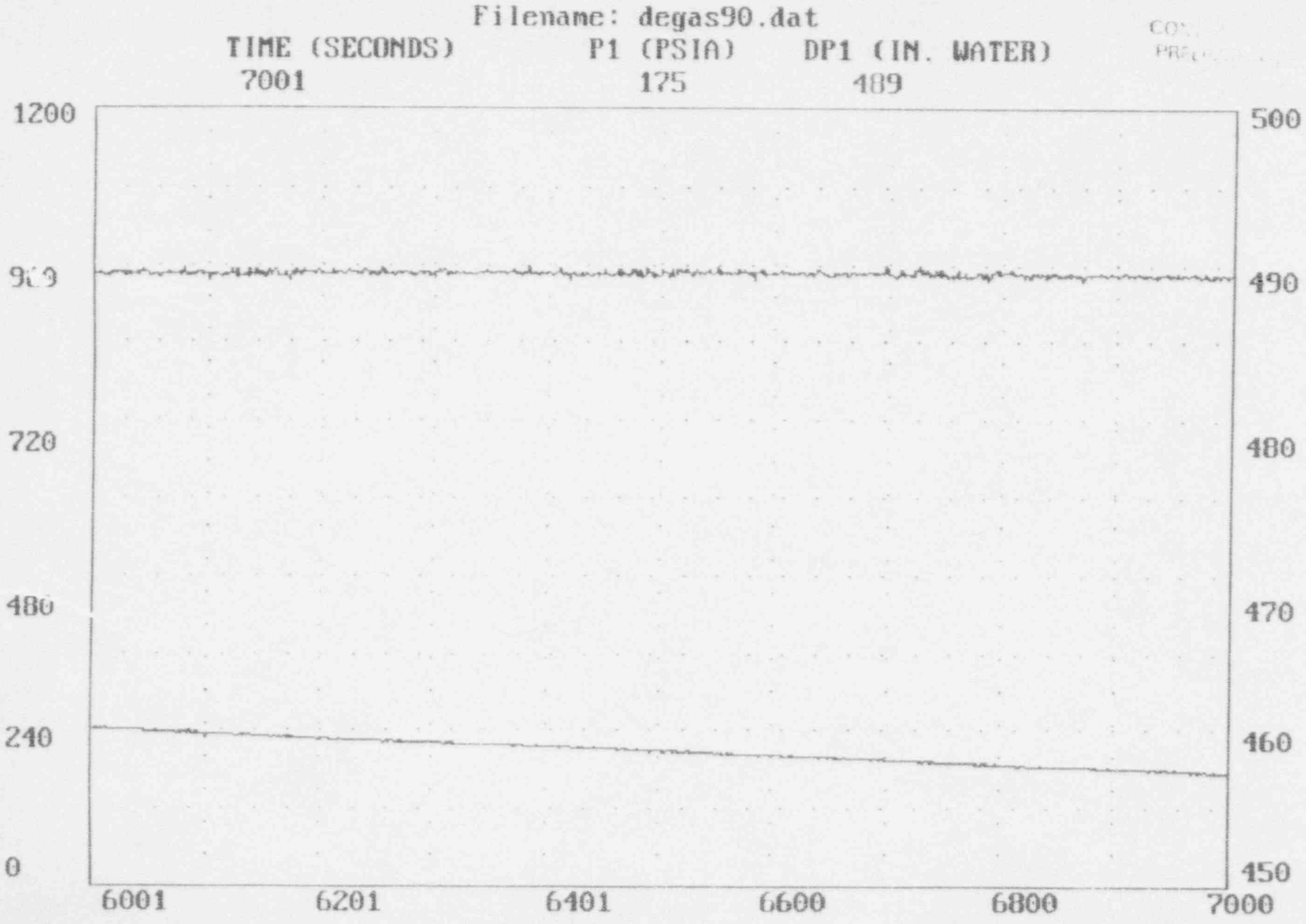

Filename: degas90.dat
TIME (SECONDS)
3001
P1 (PSIA)
515
DP1 (IN. WATER)
489
1200
960
720
480
240
0
500
490
480
470
460
450
2001
2201
2401
2600
2800
3000

Filename: degas90.dat



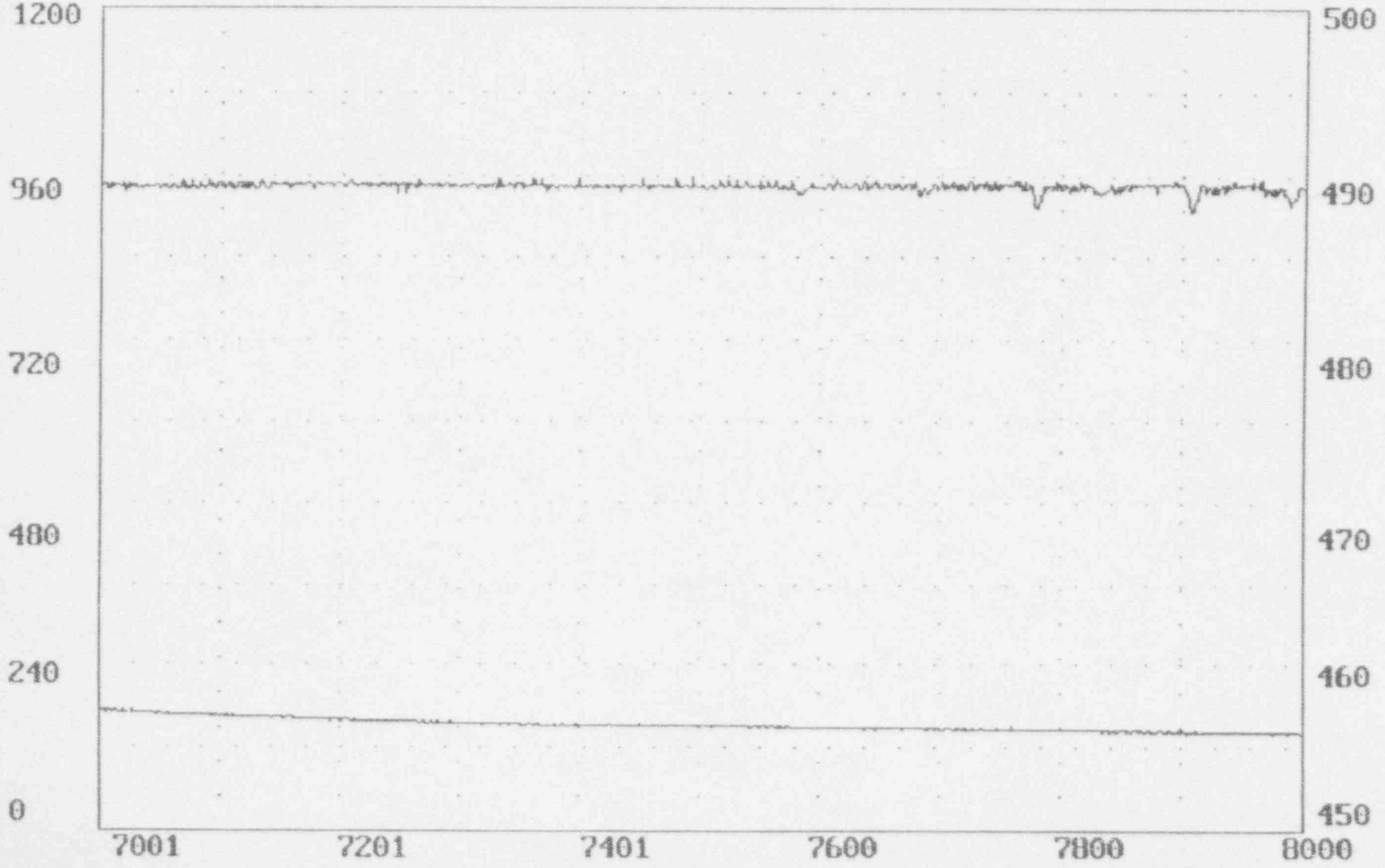

Filename: degas90.dat
TIME (SECONDS)
5001
P1 (PSIA)
310
DP1 (IN. WATER)
489
1200
960
720
480
240
0
500
490
480
470
460
450
4001
4201
4401
4600
4800
5000


Filename: degas90.dat
TIME (SECONDS)
6001
P1 (PSIA)
244
DP1 (IN. WATER)
490
1200
960
720
480
240
0
500
490
480
470
460
450
5001
5201
5401
5600
5800
6000


Filename: degas90.dat
TIME (SECONDS)
7001
P1 (PSIA)
175
DP1 (IN. WATER)
489
1200
960
720
480
240
0
500
490
480
470
460
450
6001
6201
6401
6600
6800
7000

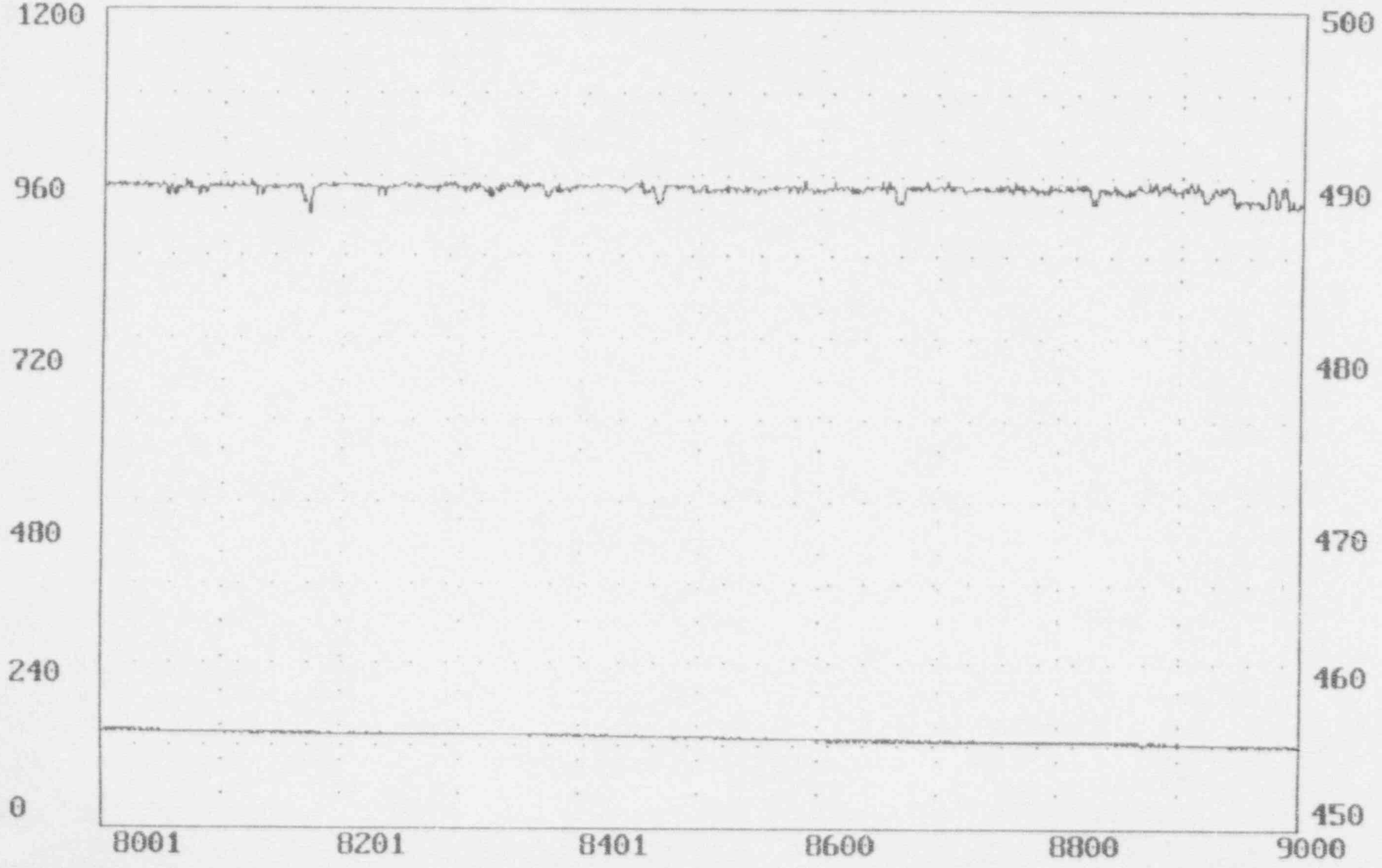
Filename: degas90.dat

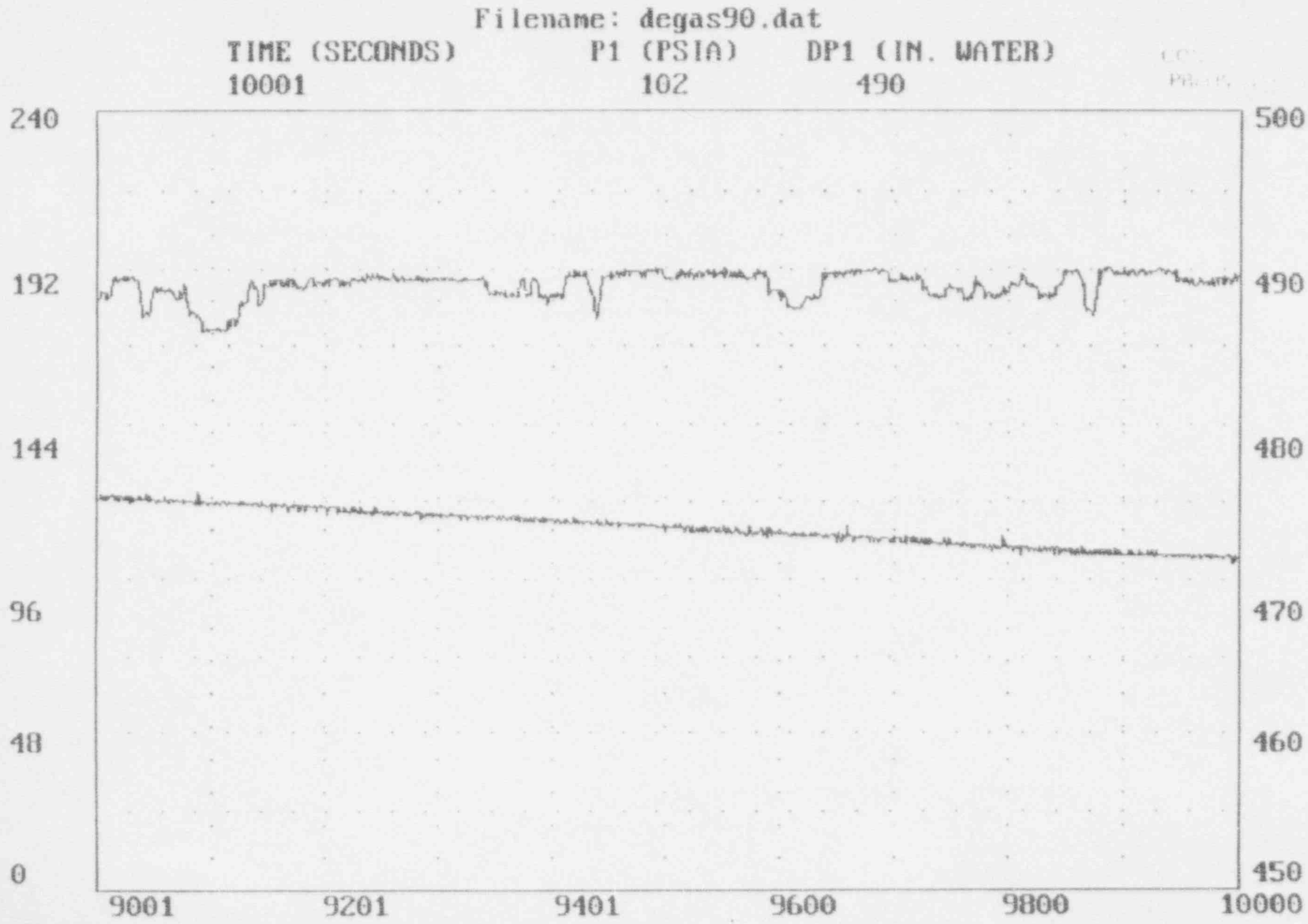
TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)
8001 140 489

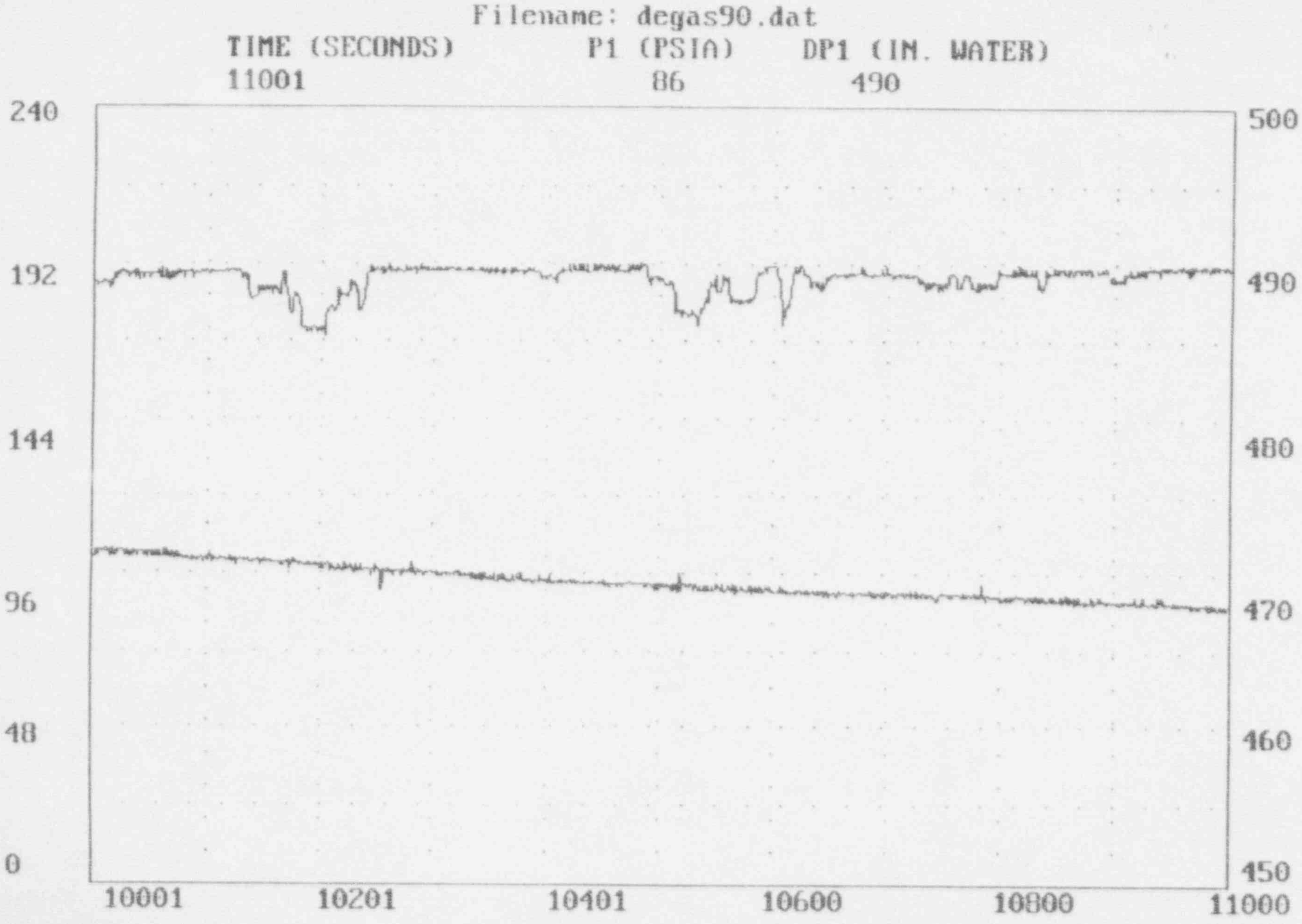


Filename: degas90.dat

TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)
9001 120 488

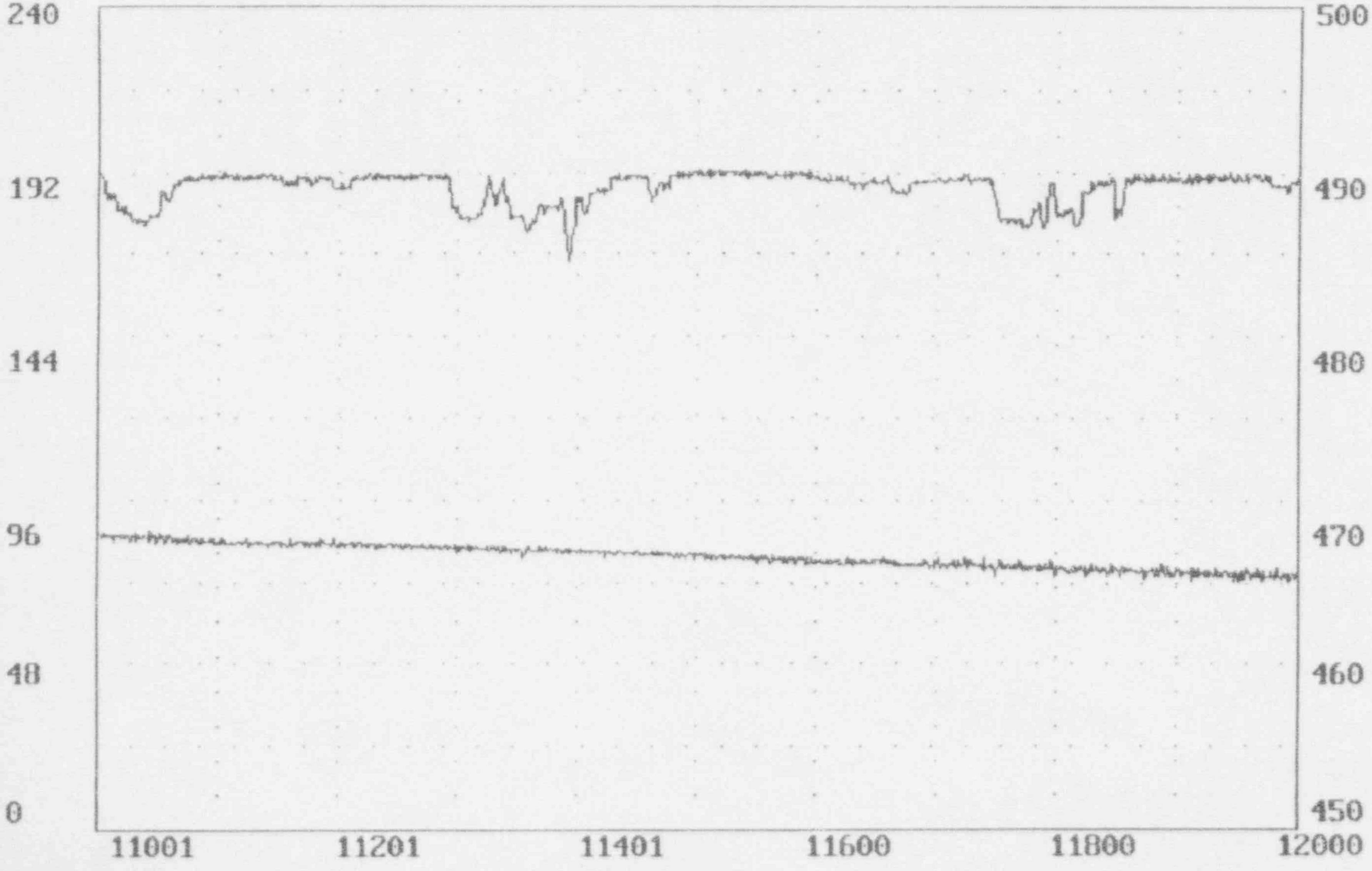


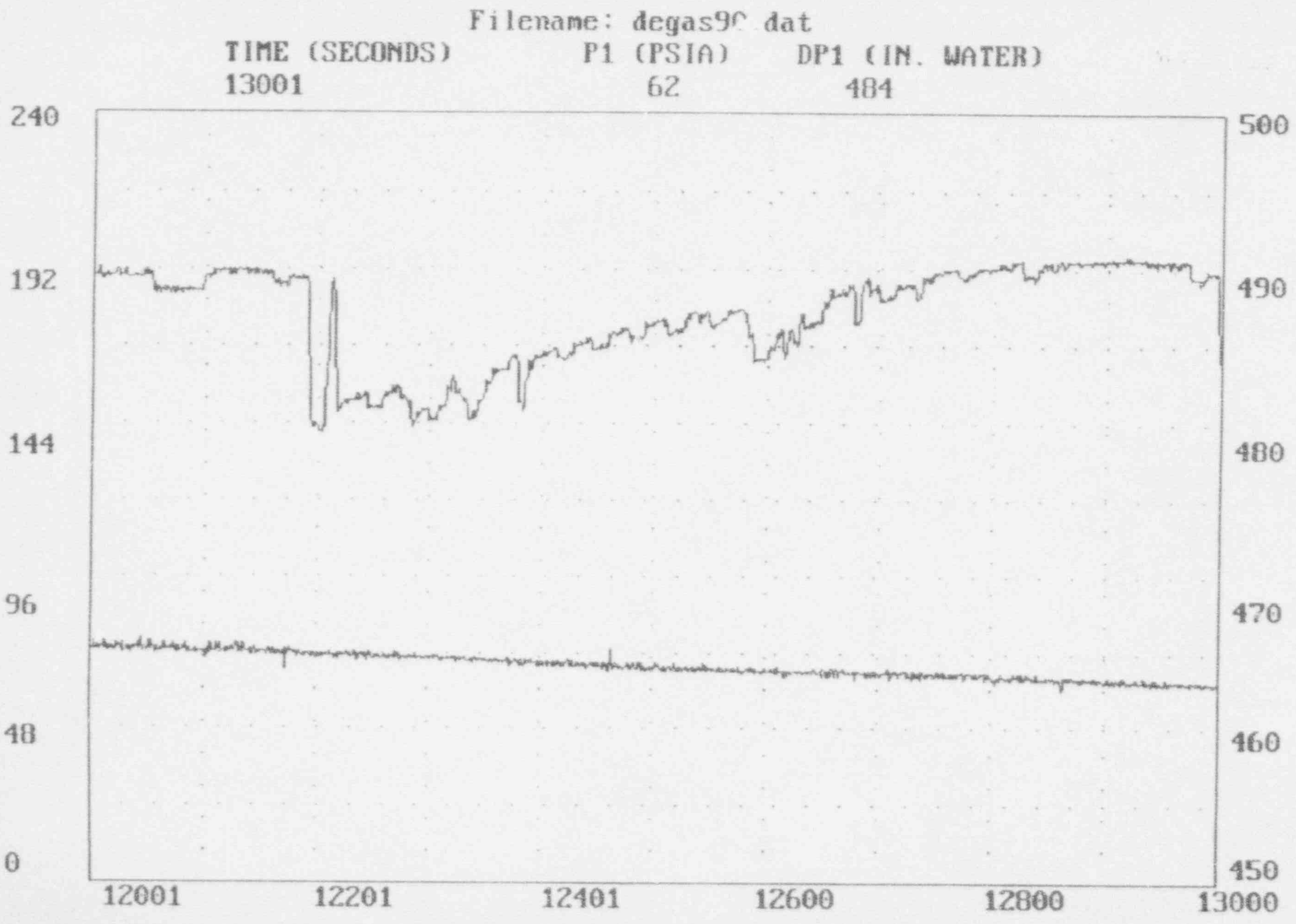

Filename: degas90.dat
TIME (SECONDS)
10001
P1 (PSIA)
102
DP1 (IN. WATER)
490
240
192
144
96
48
0
500
490
480
470
460
450
9001
9201
9401
9600
9800
10000

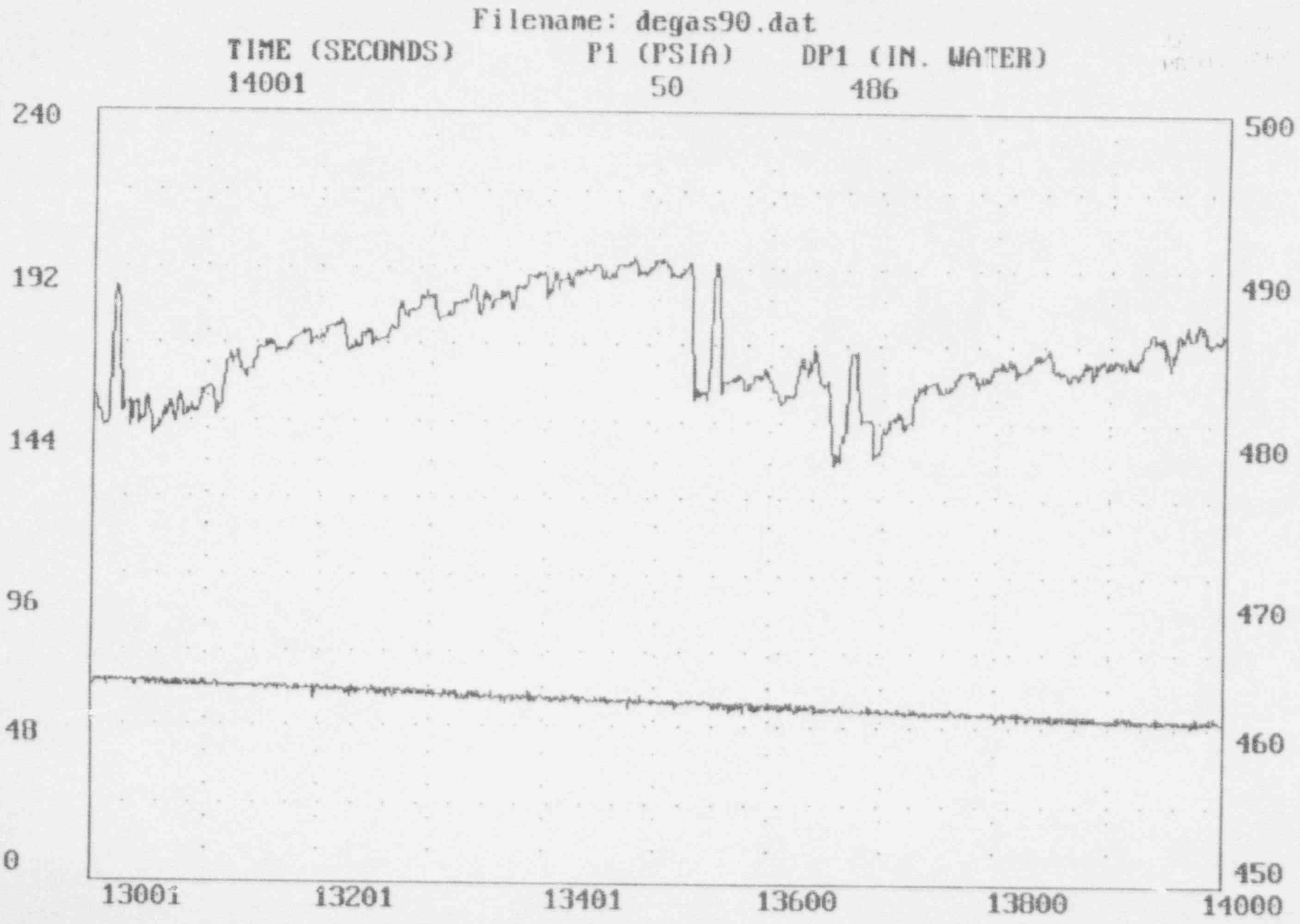

Filename: degas90.dat
TIME (SECONDS)
11001
P1 (PSIA)
86
DP1 (IN. WATER)
490
240
192
144
96
48
0
500
490
480
470
460
450
10001
10201
10401
10600
10800
11000

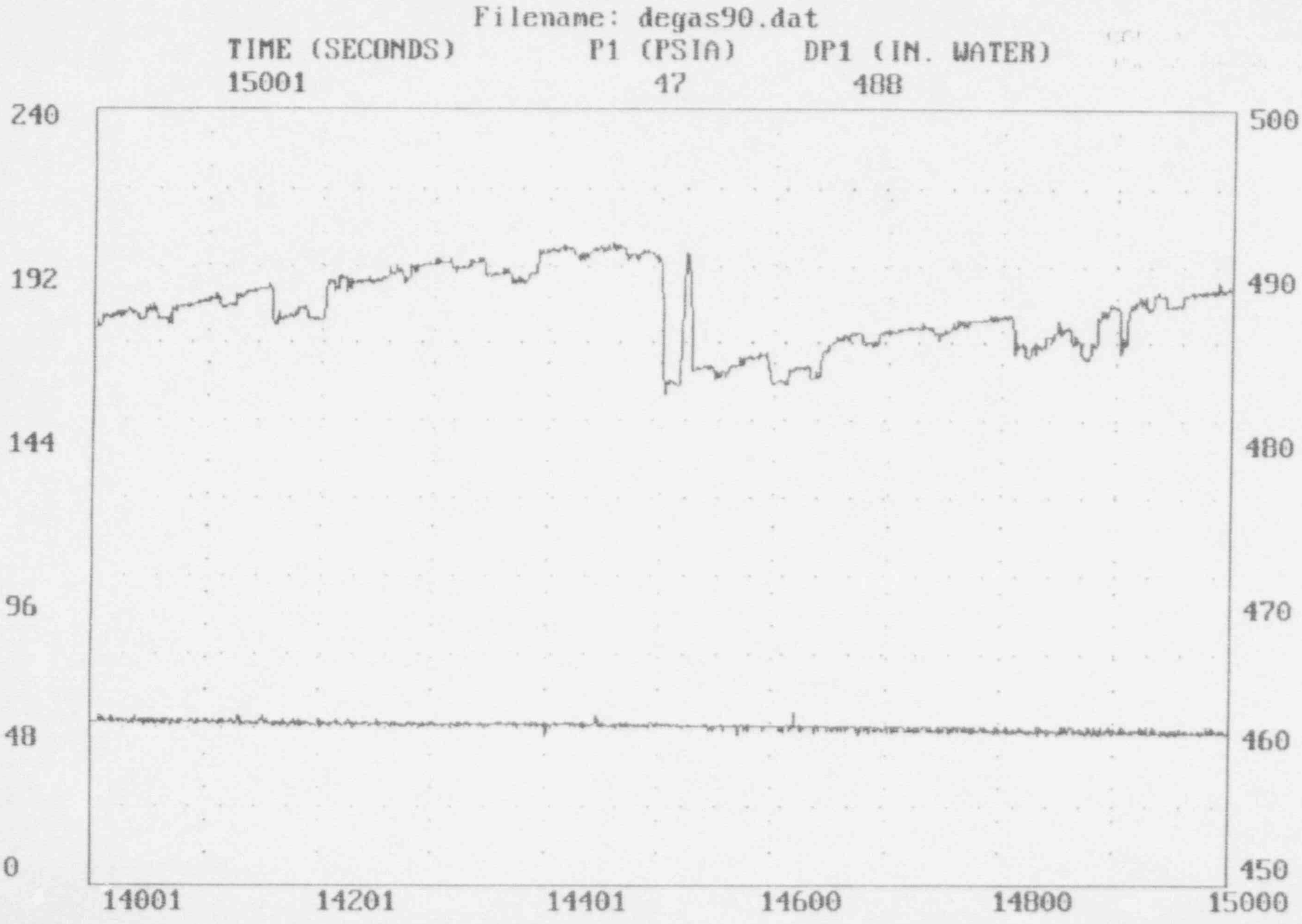
Filename: degas90.dat

TIME (SECONDS)    P1 (PSIA)    DP1 (IN. WATER)
12001    75    490




Filename: degas9c.dat
TIME (SECONDS)
13001
P1 (PSIA)
62
DP1 (IN. WATER)
484
240
192
144
96
48
0
500
490
480
470
460
450
12001
12201
12401
12600
12800
13000

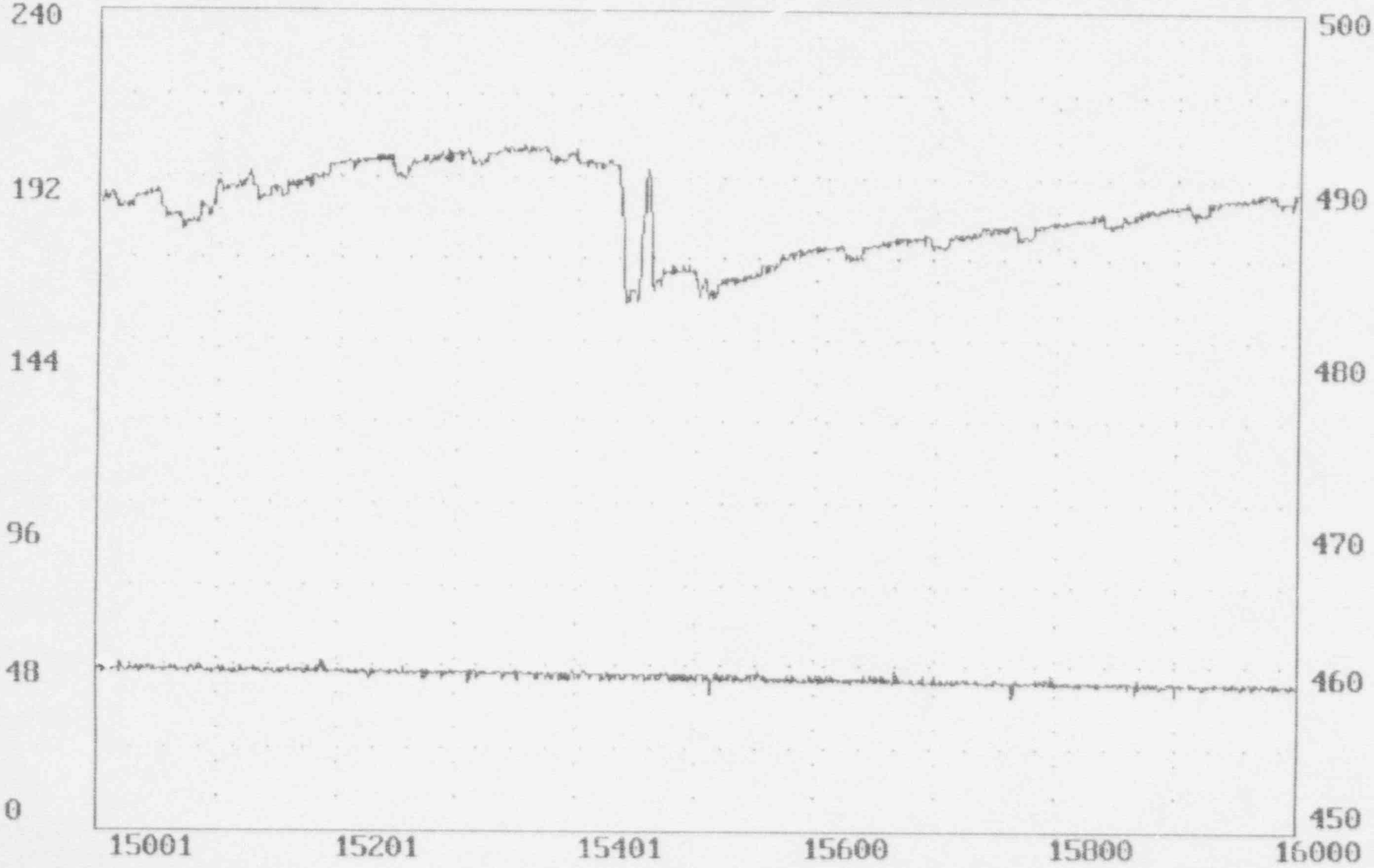

Filename: degas90.dat
TIME (SECONDS)
14001
P1 (PSIA)
50
DP1 (IN. WATER)
486
240
192
144
96
48
0
500
490
480
470
460
450
13001
13201
13401
13600
13800
14000


Filename: degas90.dat
TIME (SECONDS)
15001
P1 (PSIA)
47
DP1 (IN. WATER)
488
240
192
144
96
48
0
500
490
480
470
460
450
14001
14201
14401
14600
14800
15000

Filename: degas90.dat

TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

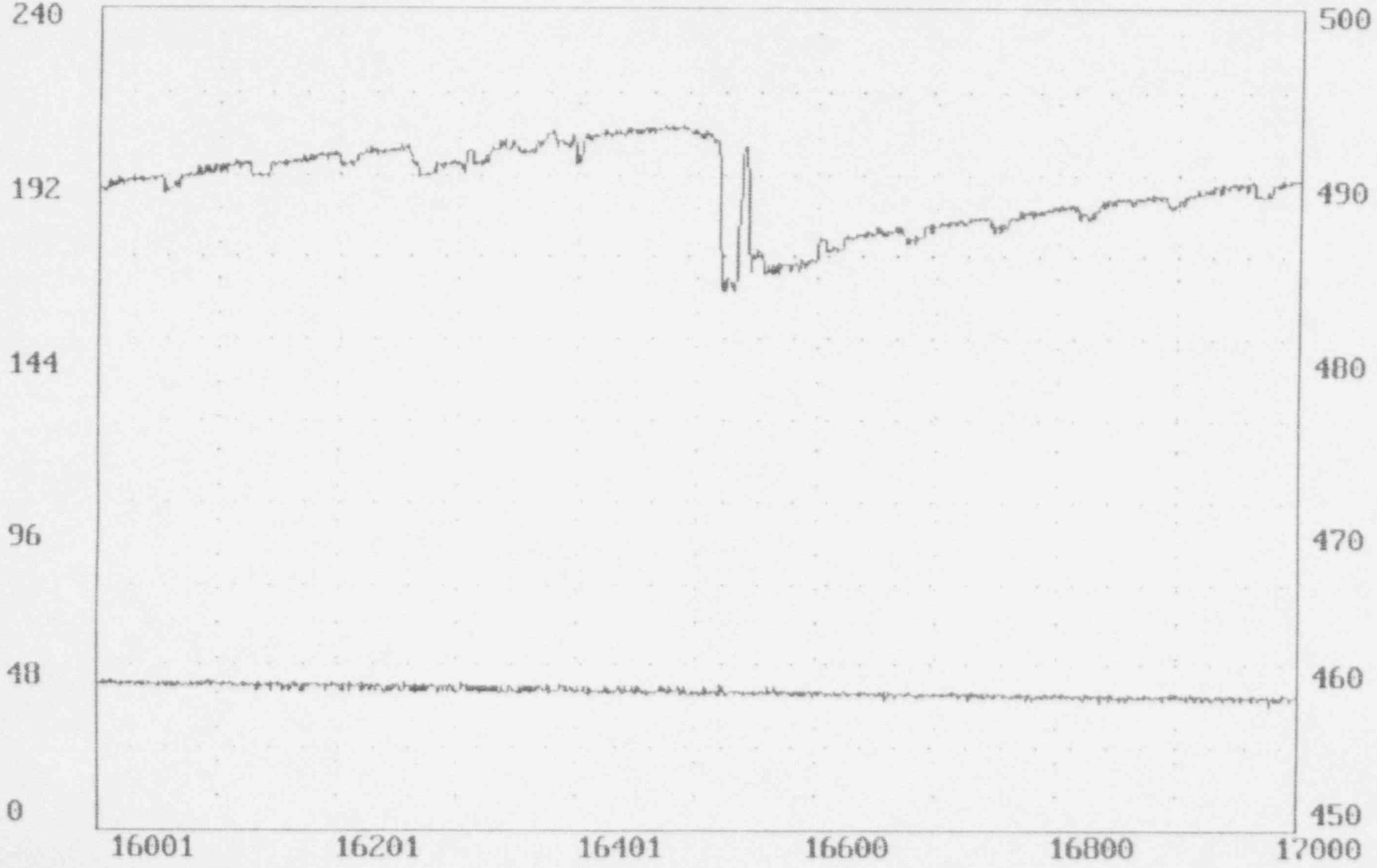
16001 43 489

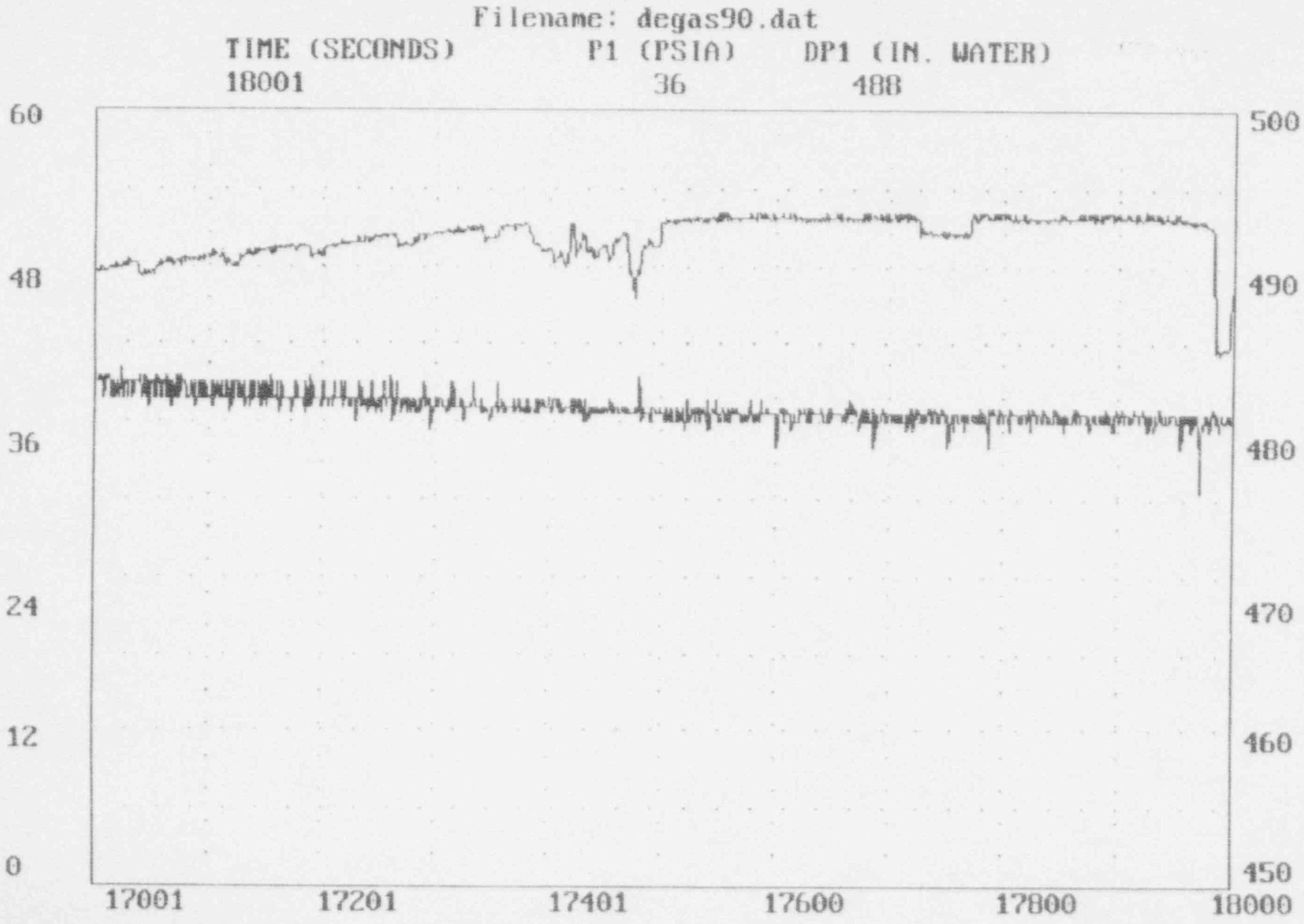


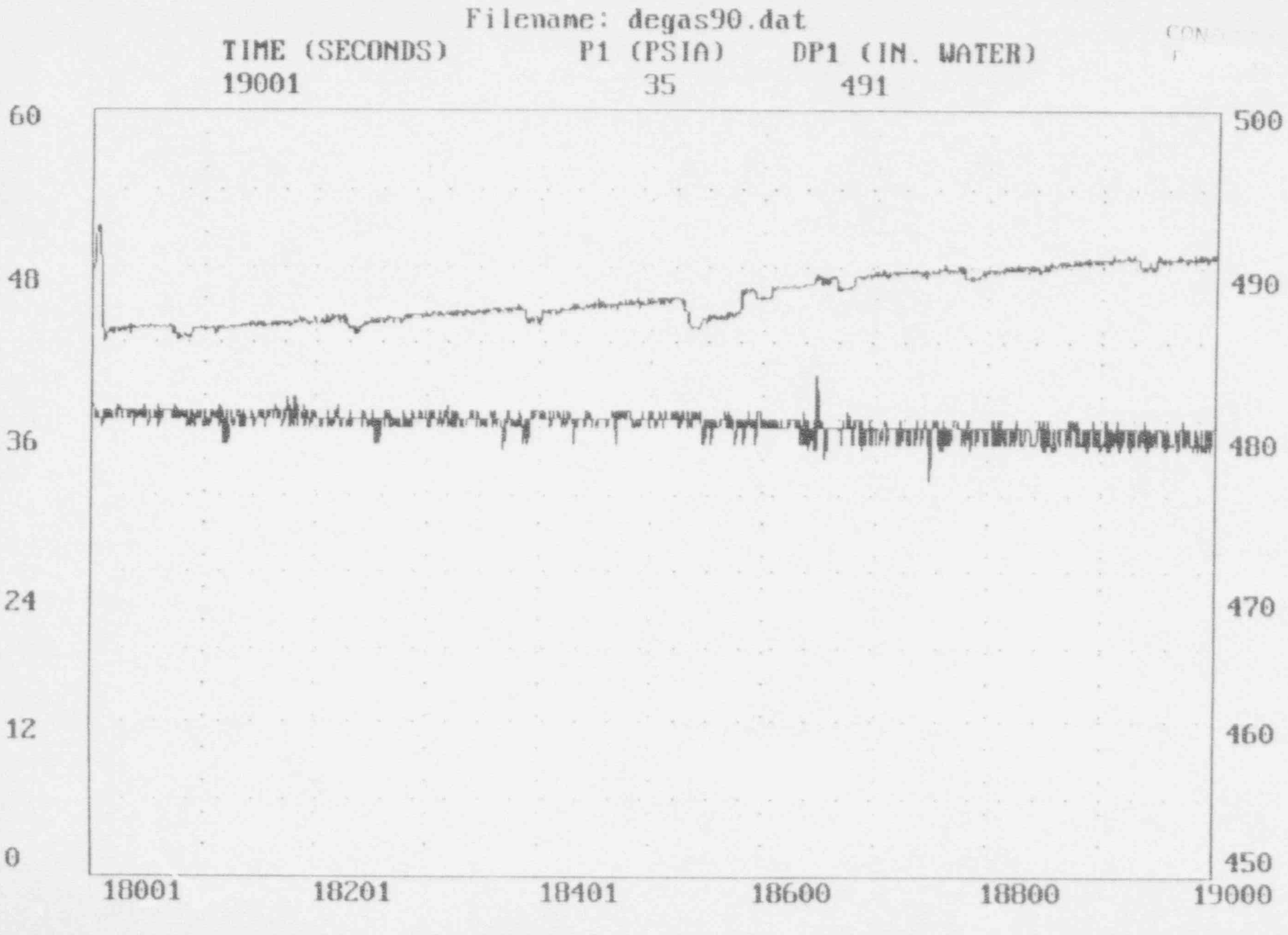
Filename: degas90.dat

TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

17001 40 490



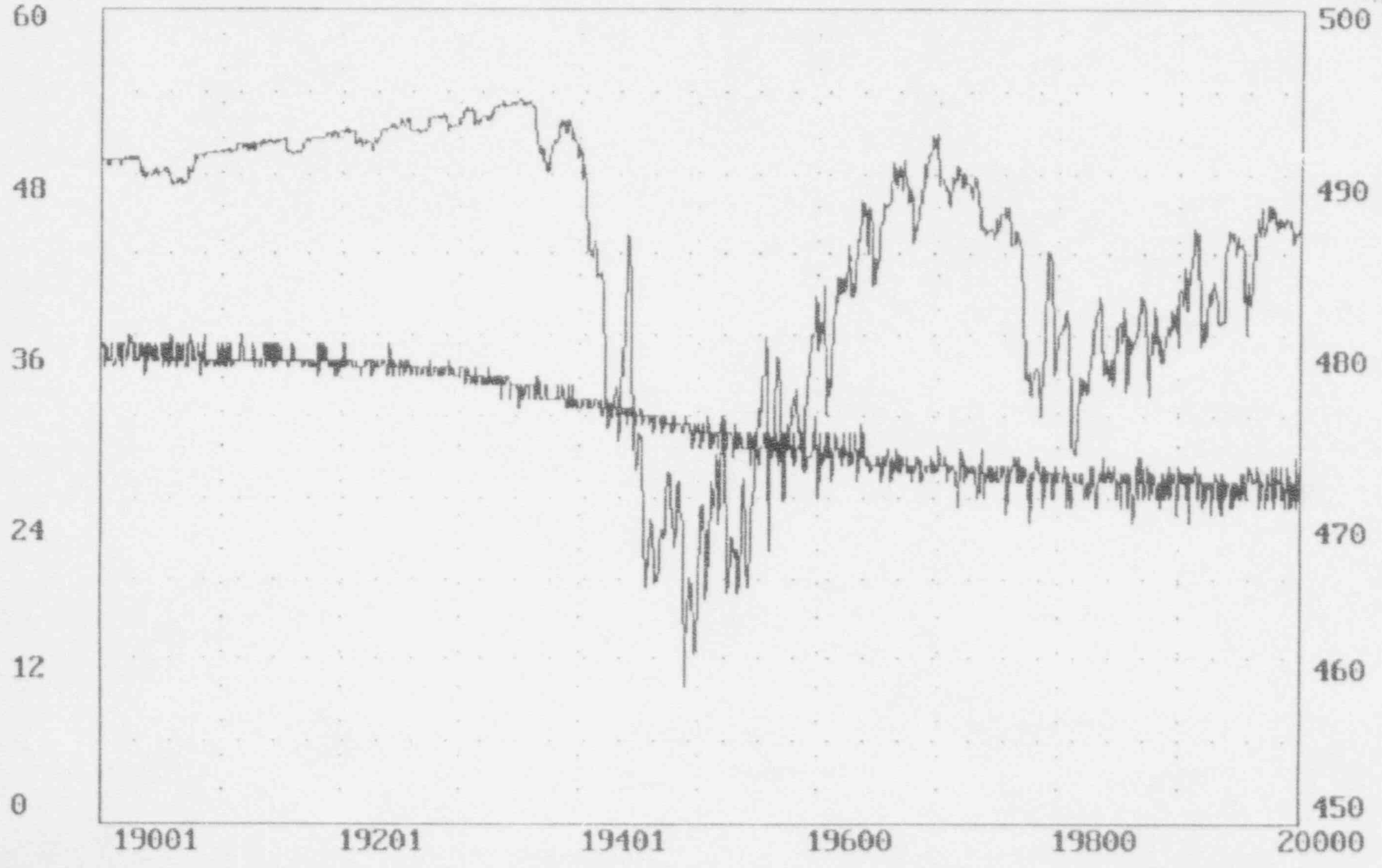


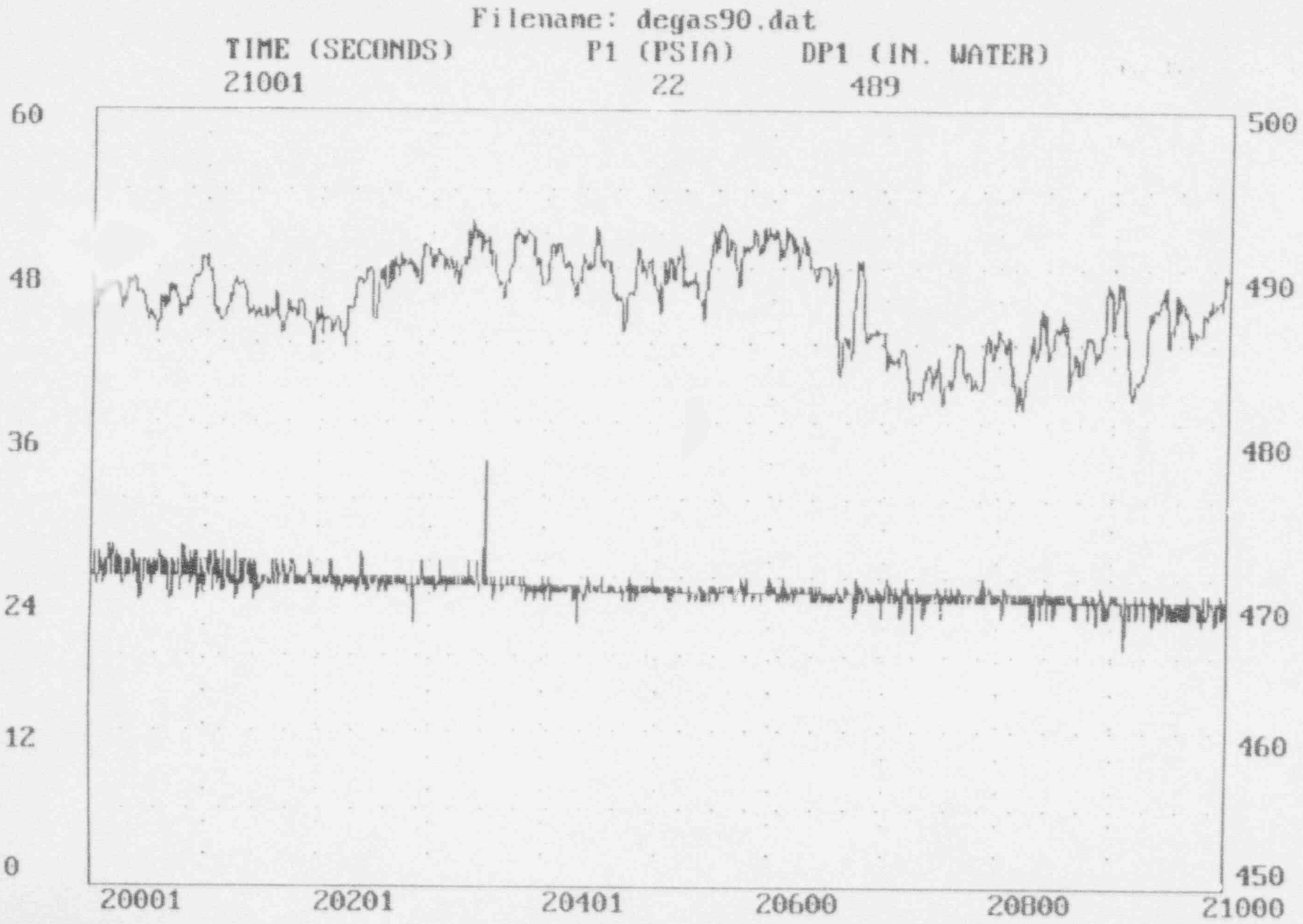

Filename: degas90.dat
TIME (SECONDS)
19001
P1 (PSIA)
35
DP1 (IN. WATER)
491
60
48
36
24
12
0
500
490
480
470
460
450
18001
18201
18401
18600
18800
19000

Filename: degas90.dat

TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

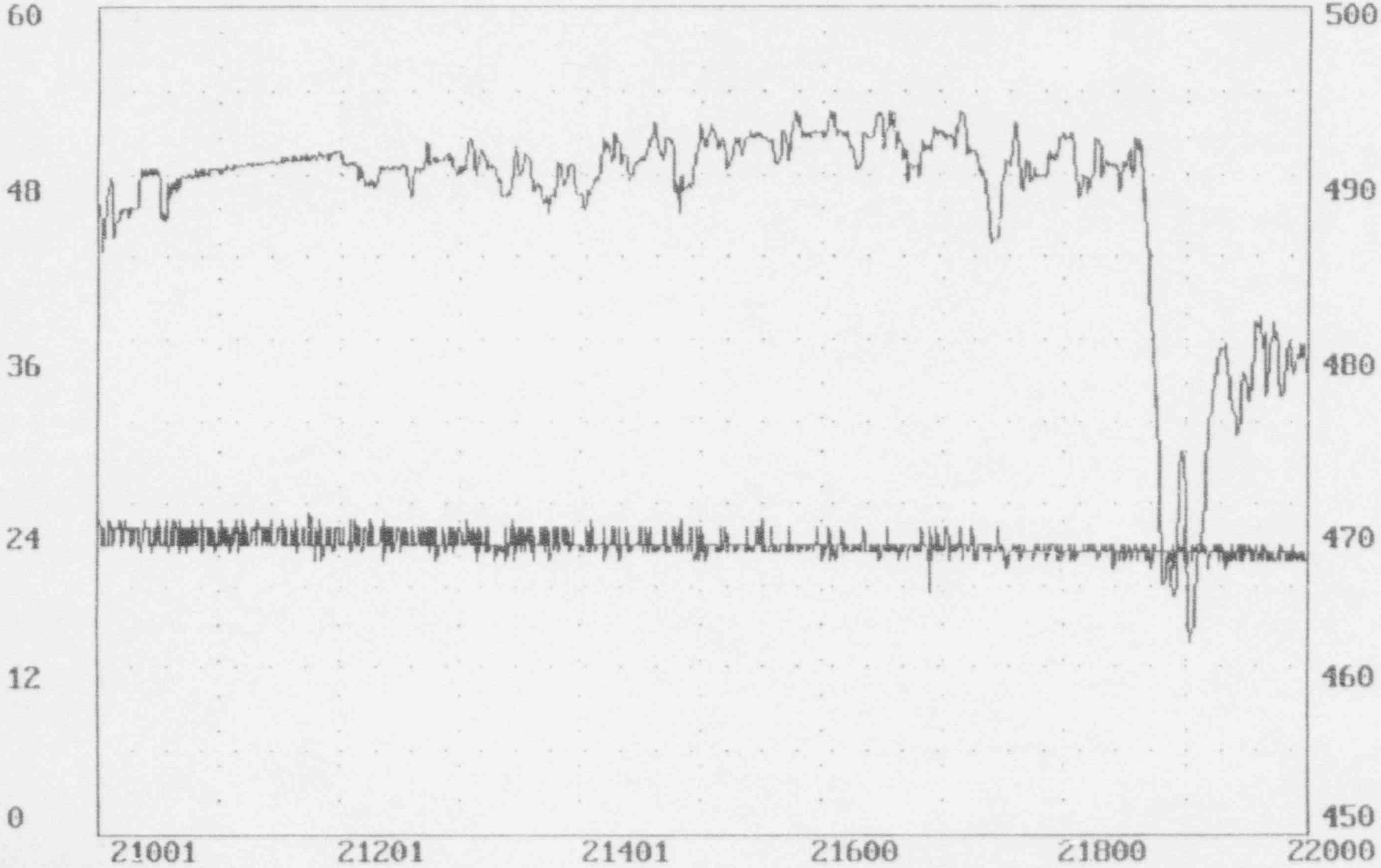
20001 26 487

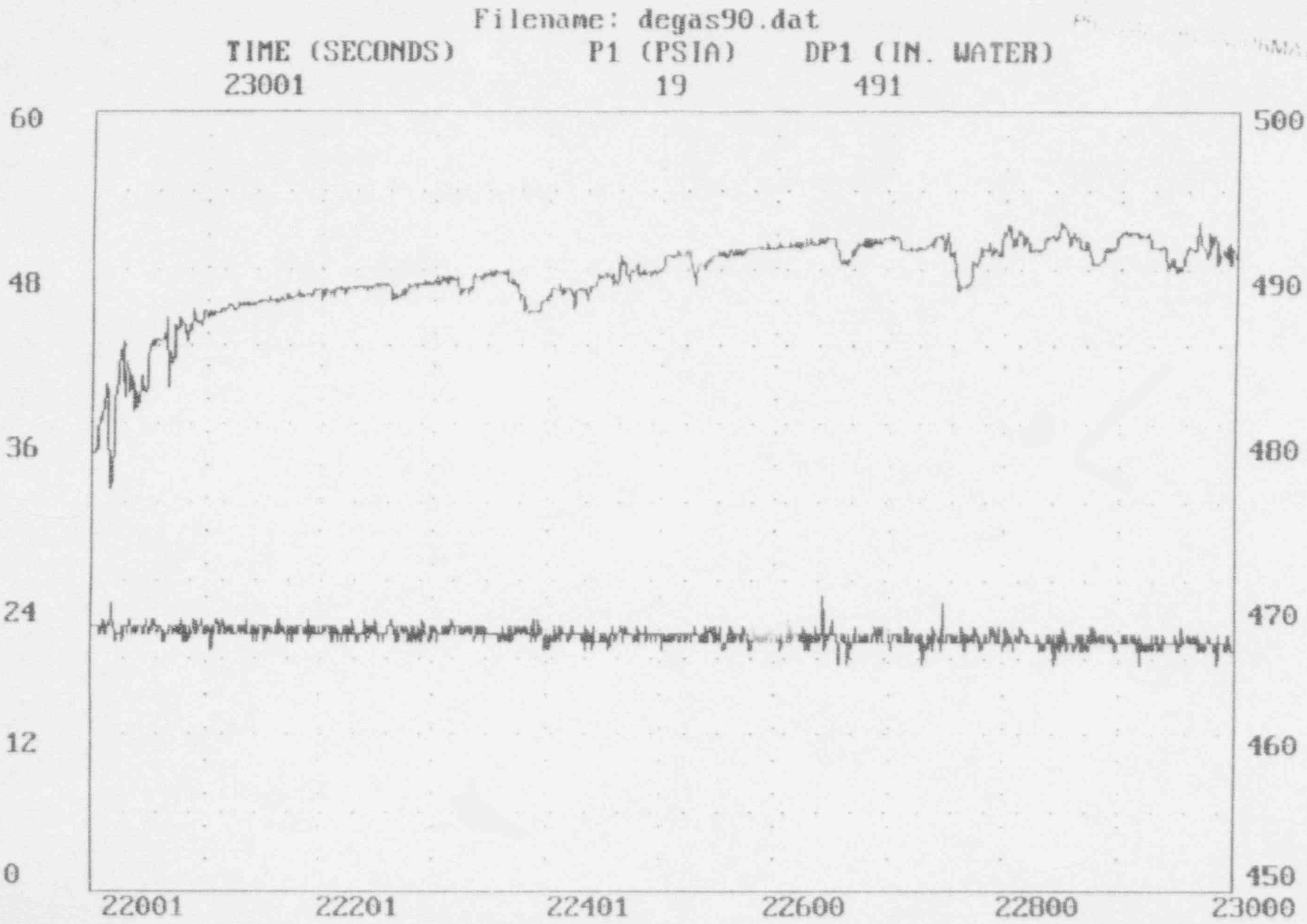


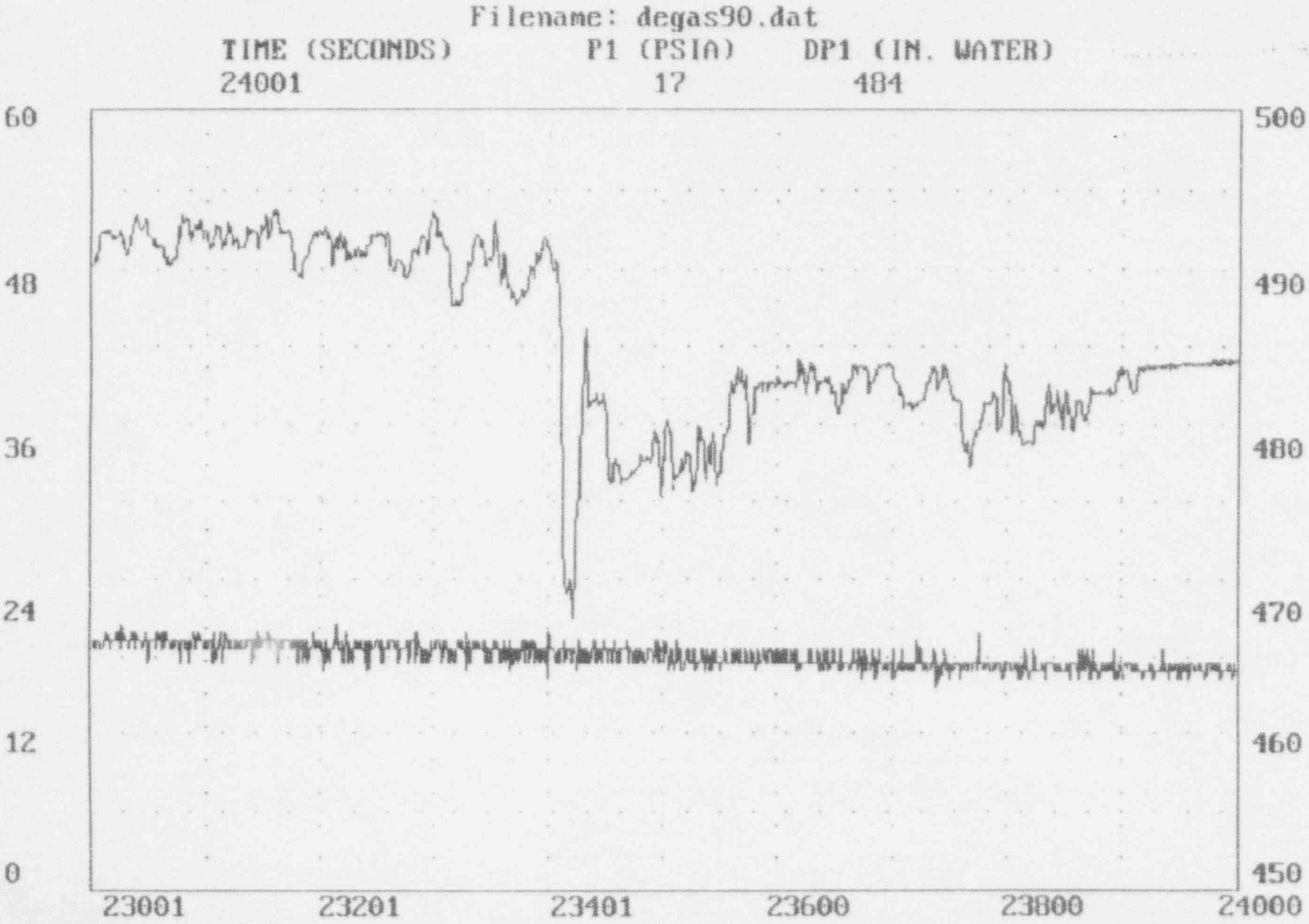

Filename: degas90.dat
TIME (SECONDS)
21001
P1 (PSIA)
22
DP1 (IN. WATER)
489
60
48
36
24
12
0
500
490
480
470
460
450
20001
20201
20401
20600
20800
21000

Filename: degas90.dat

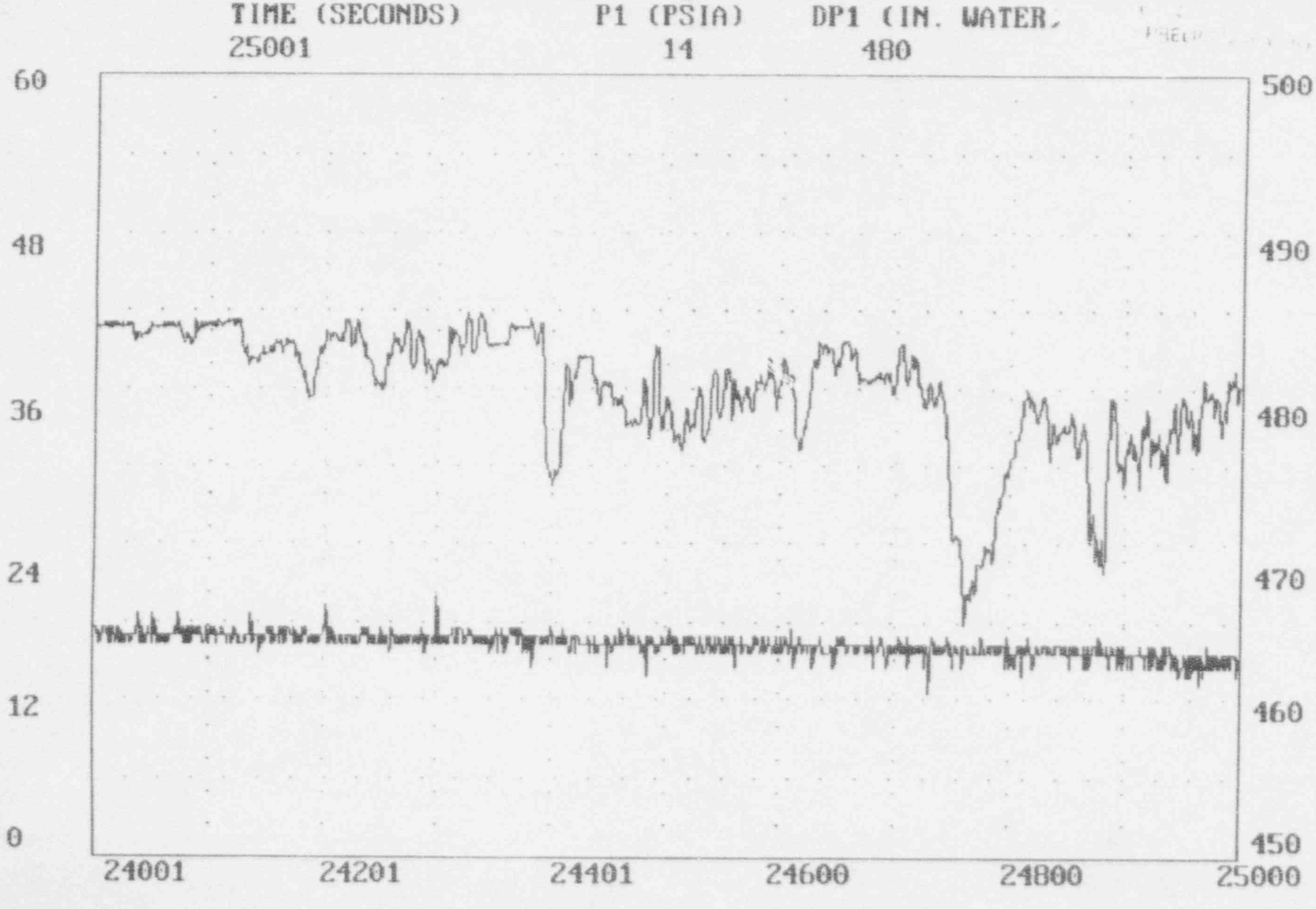
```
TIME (SECONDS)          P1 (PSIA)    DP1 (IN. WATER)
22001                   20           478
```




Filename: degas90.dat
TIME (SECONDS)
P1 (PSIA)
DP1 (IN. WATER)
23001
19
491
60
48
36
24
12
0
500
490
480
470
460
450
22001
22201
22401
22600
22800
23000


Filename: degas90.dat
TIME (SECONDS)
P1 (PSIA)
DP1 (IN. WATER)
24001
17
484
60
48
36
24
12
0
500
490
480
470
460
450
23001
23201
23401
23600
23800
24000

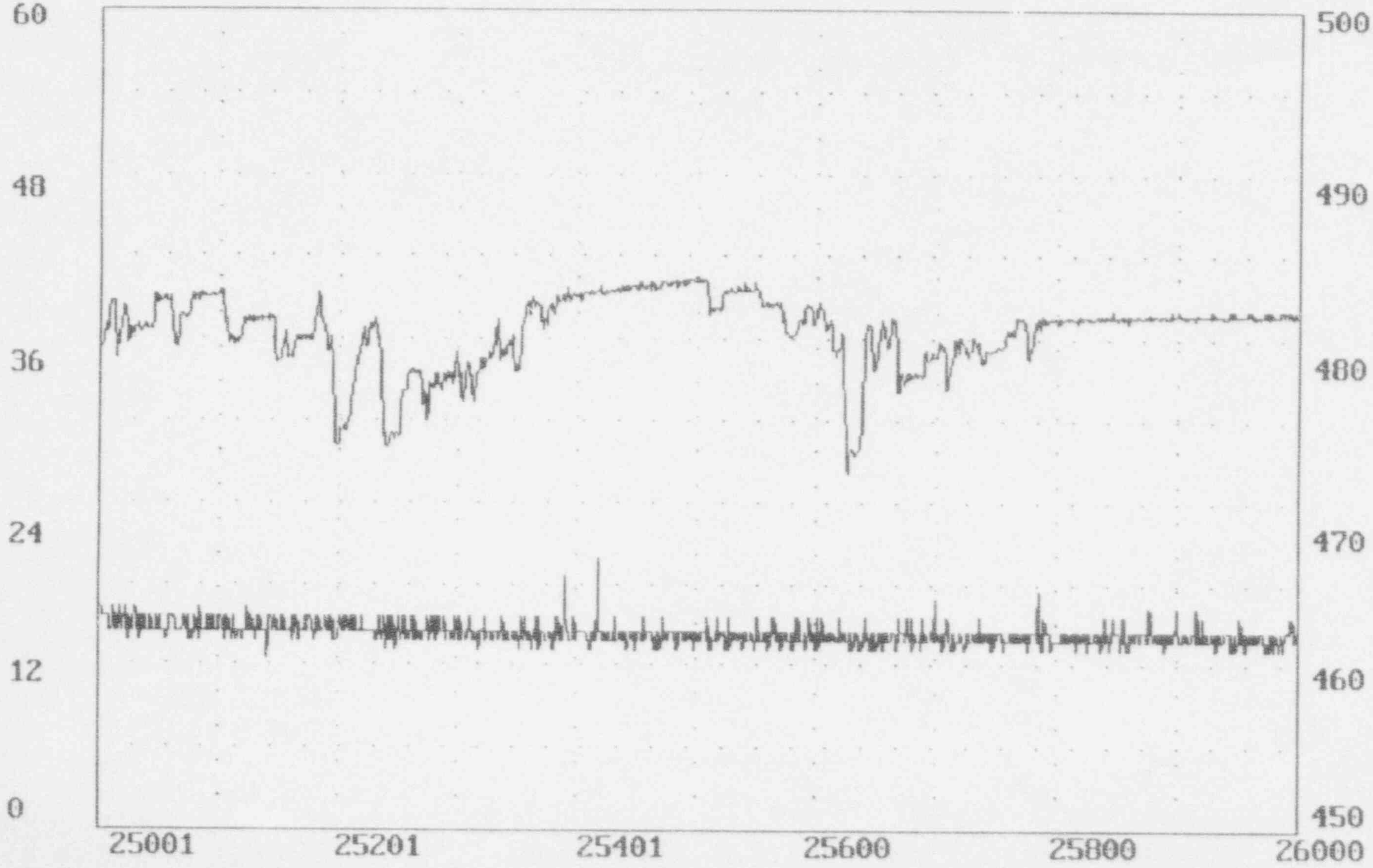
Filename: degas90.dat

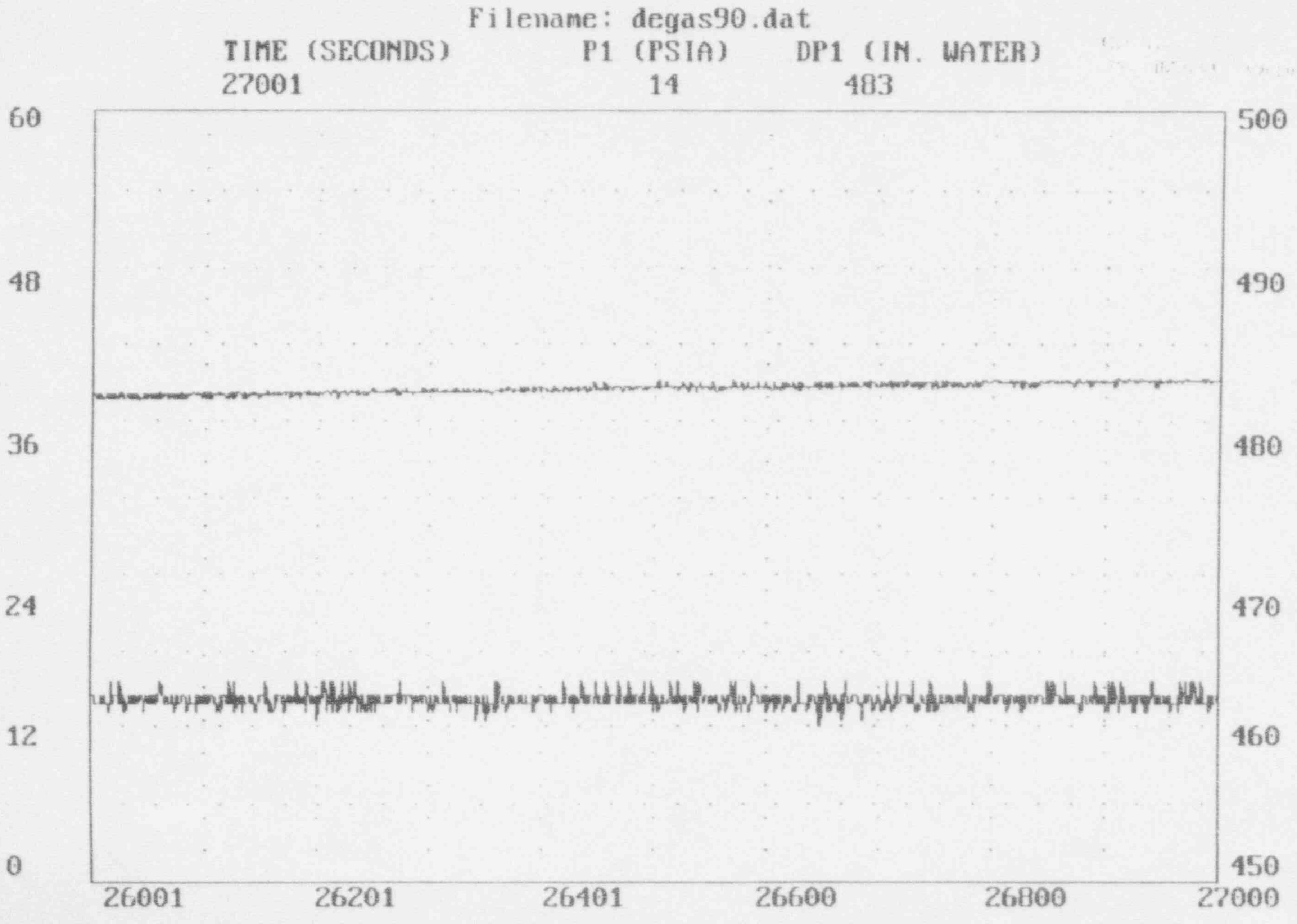


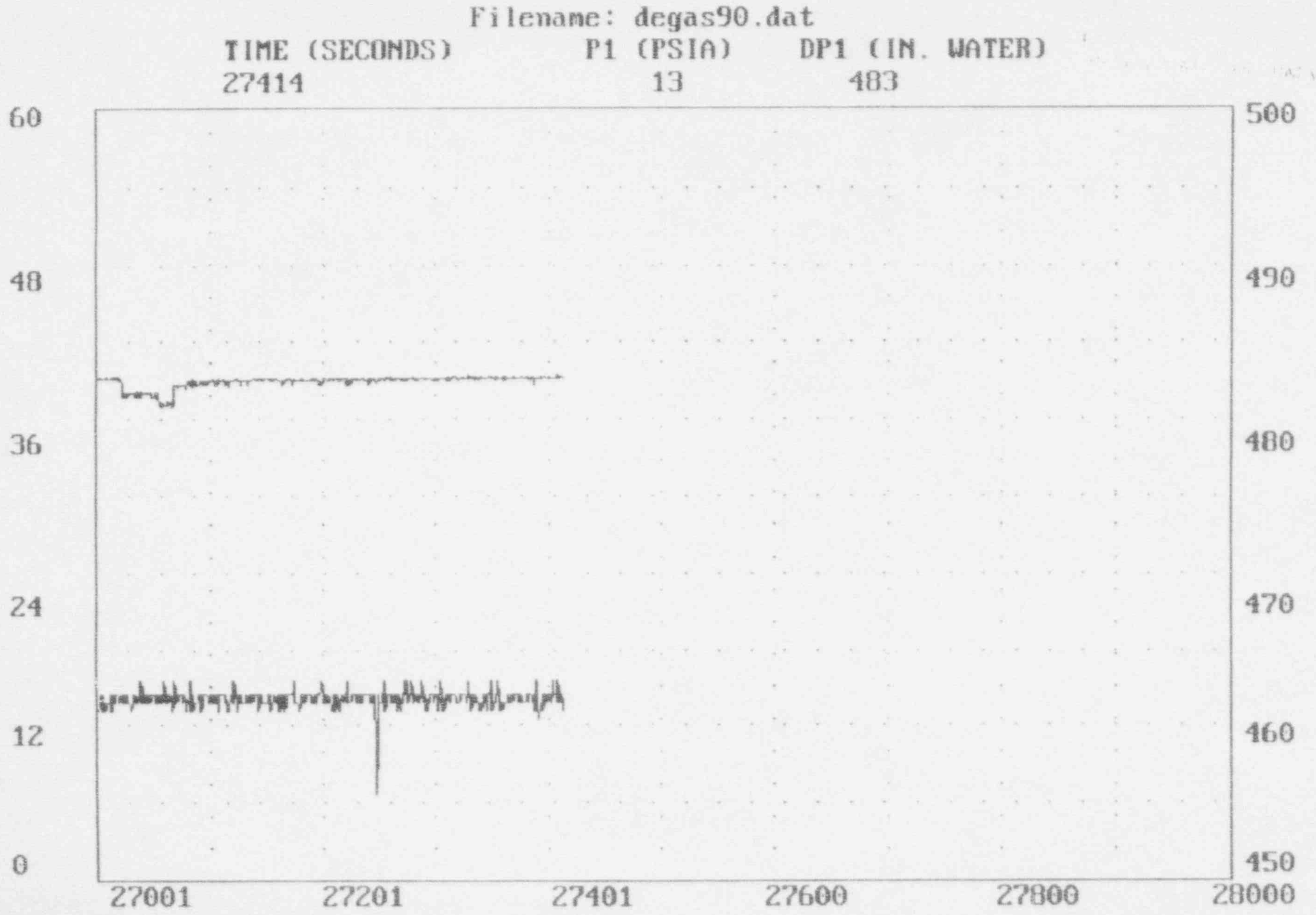
Filename: degas90.dat

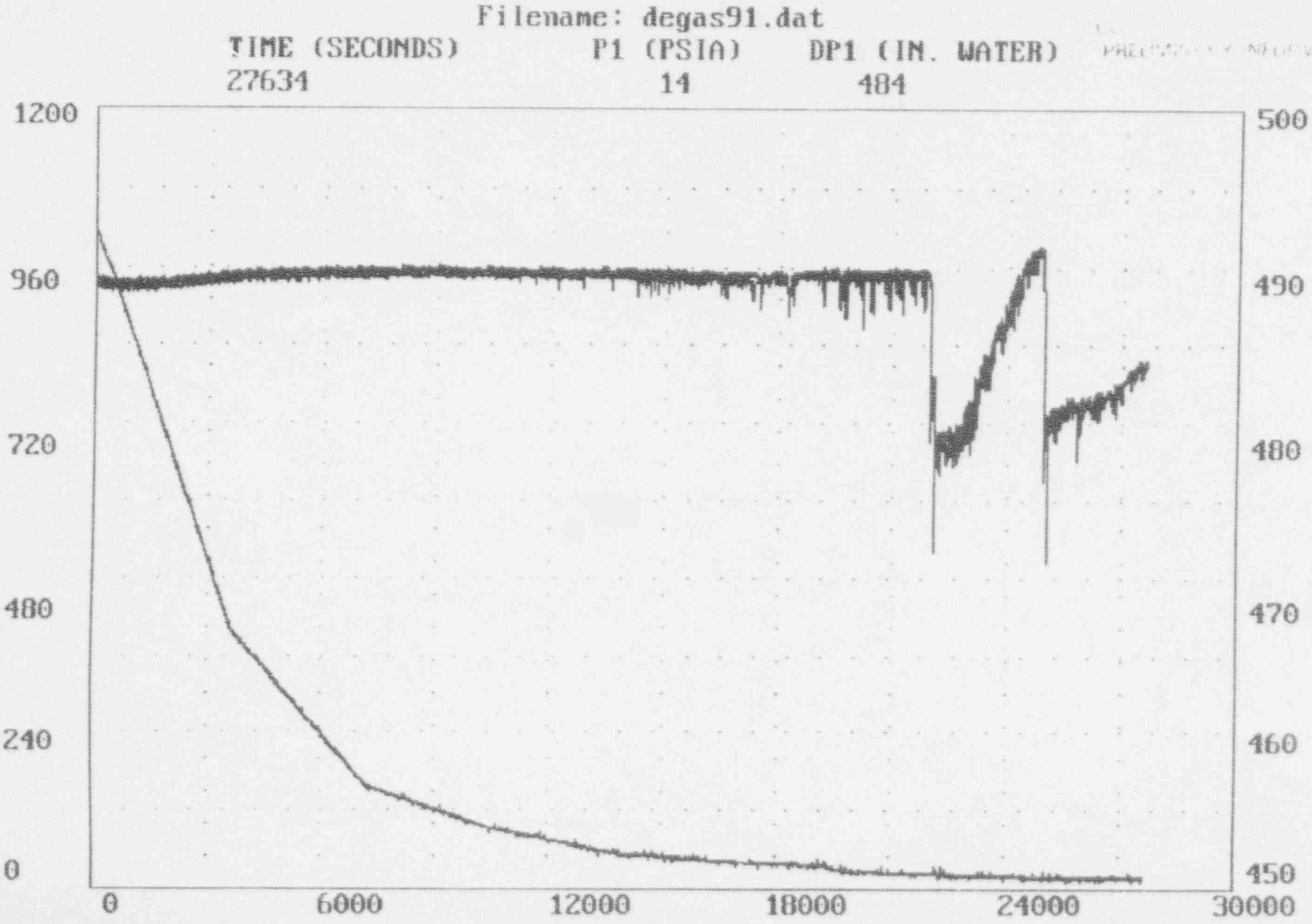
TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

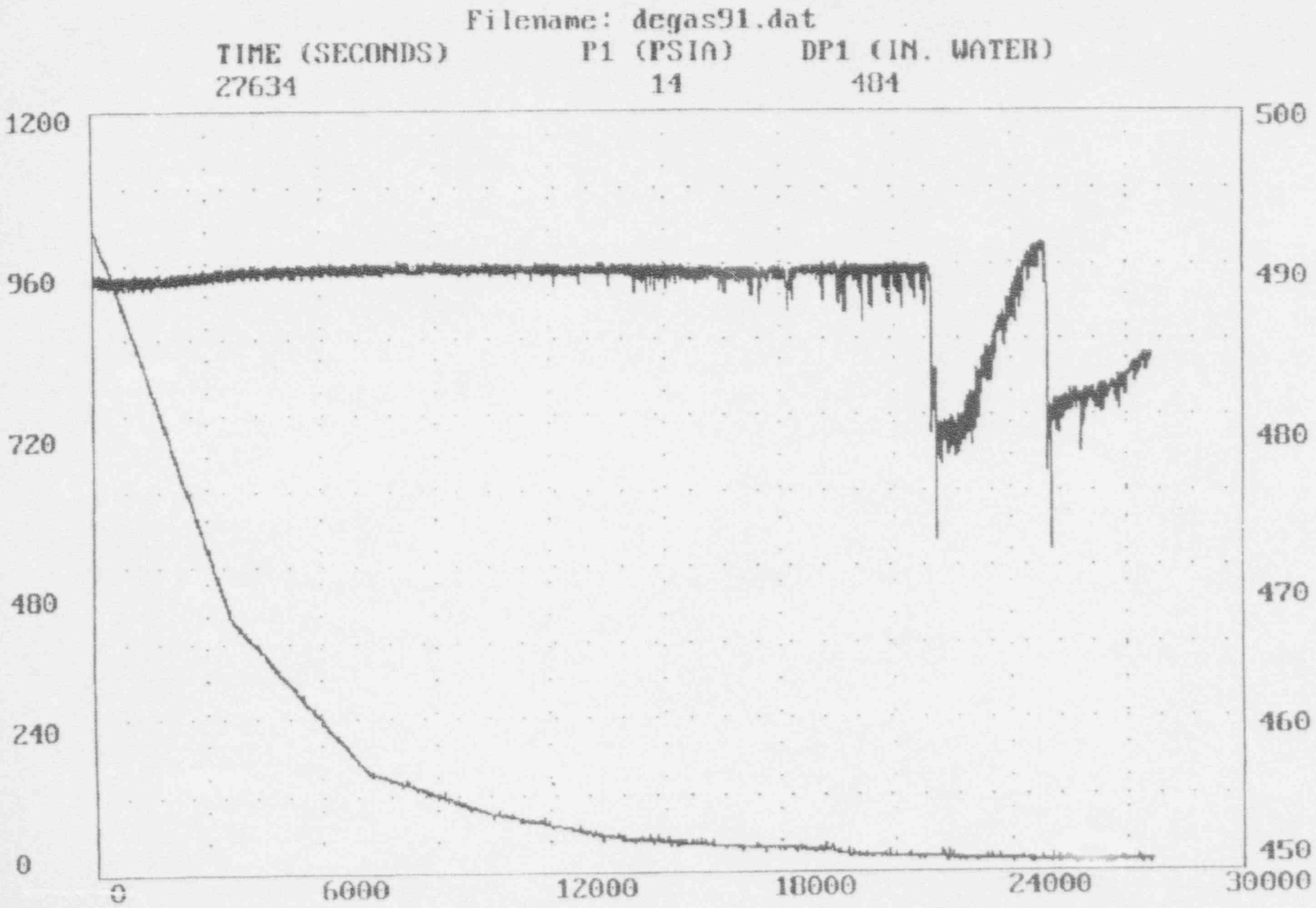
26001 14 481




Filename: degas90.dat
TIME (SECONDS)
27001
P1 (PSIA)
14
DP1 (IN. WATER)
483
60
48
36
24
12
0
500
490
480
470
460
450
26001
26201
26401
26600
26800
27000


Filename: degas90.dat
TIME (SECONDS)
27414
P1 (PSIA)
13
DP1 (IN. WATER)
483
60
48
36
24
12
0
500
490
480
470
460
450
27001
27201
27401
27600
27800
28000


Filename: degas91.dat
TIME (SECONDS)
27634
P1 (PSIA)
14
DP1 (IN. WATER)
484
1200
960
720
480
240
0
500
490
480
470
460
450
0
6000
12000
18000
24000
30000

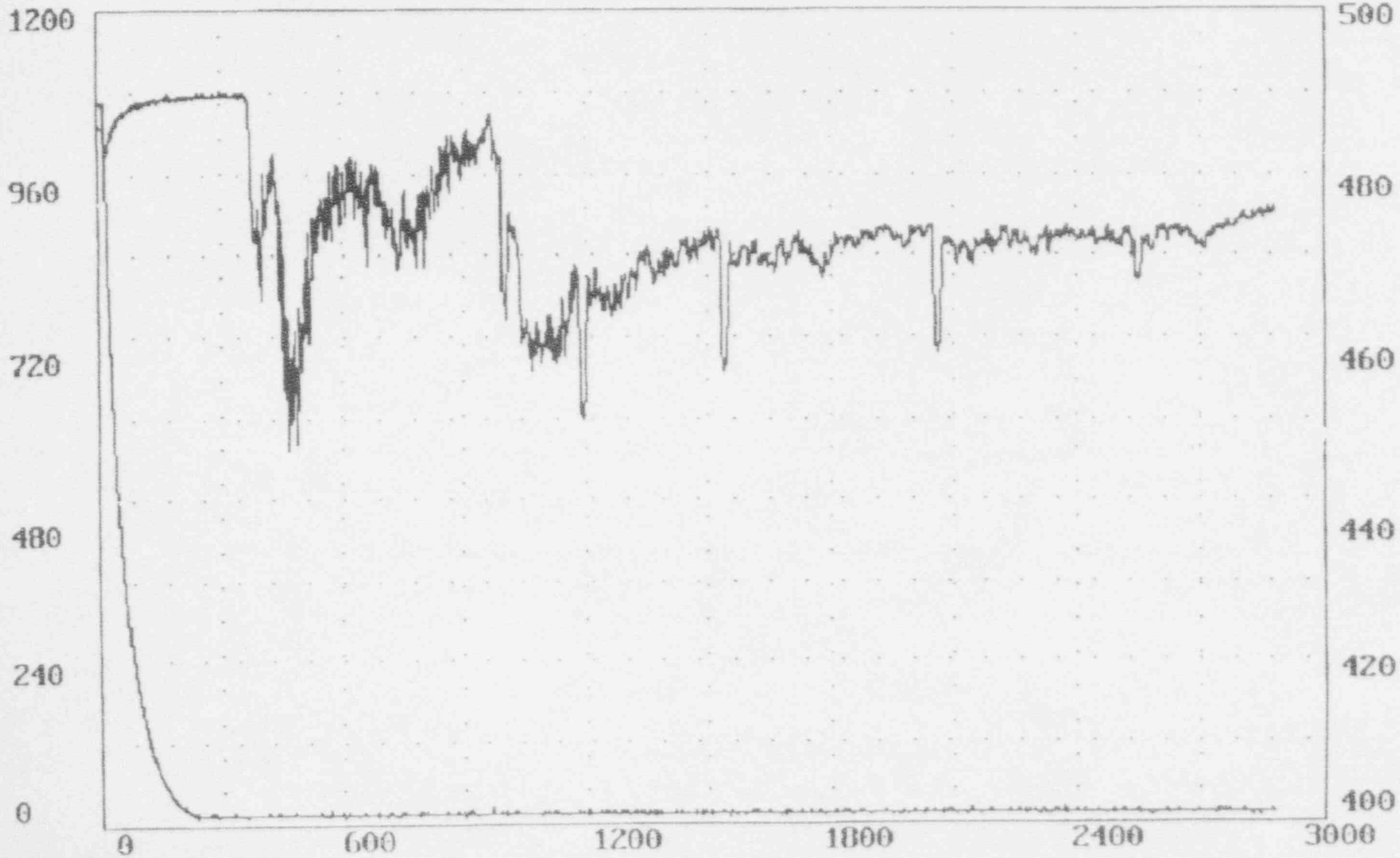


CONTINUUM DYNAMICS, INC.
PRELIMINARY INFORMATION

Filename: degas92.dat

TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)

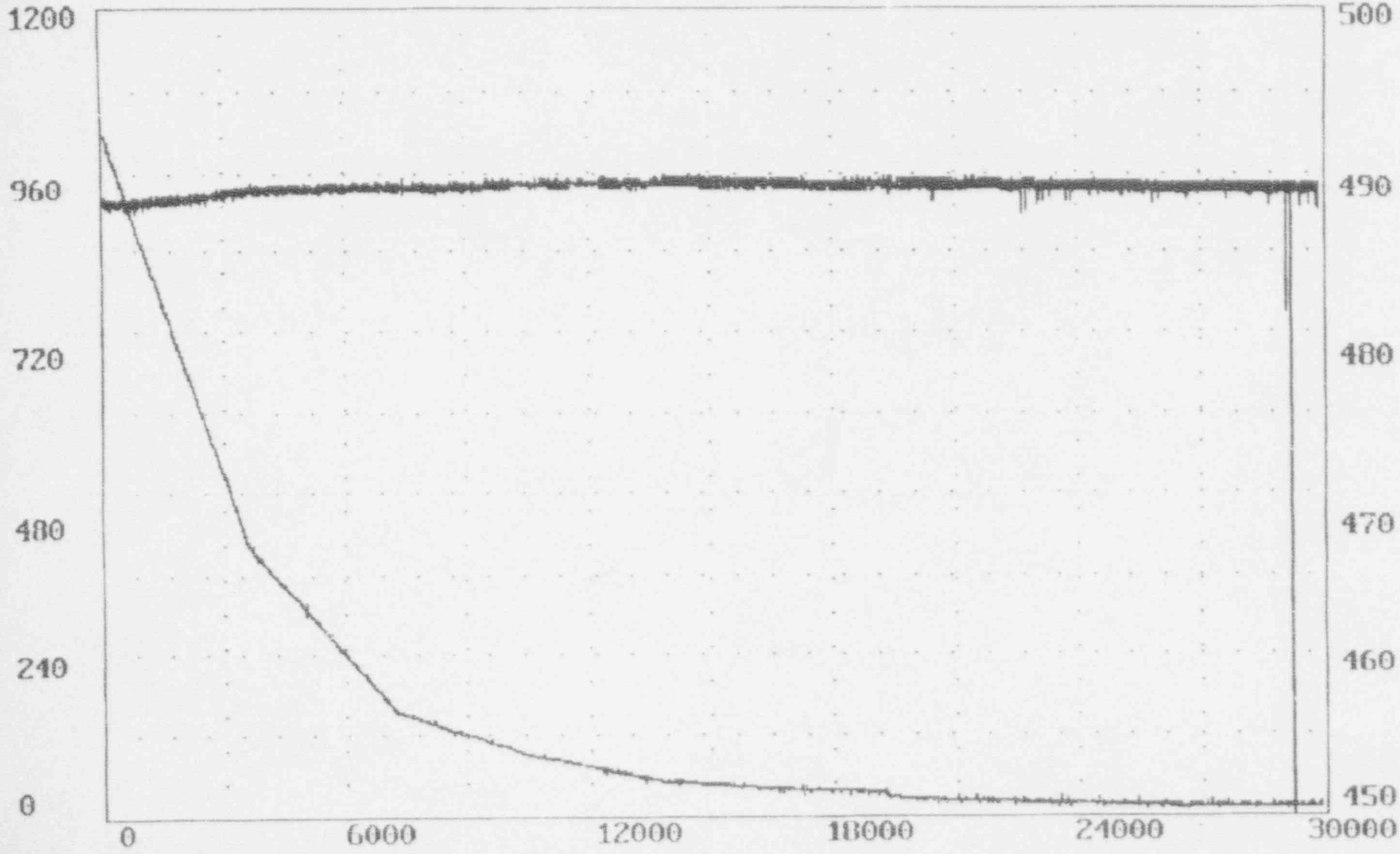
2887 13 475



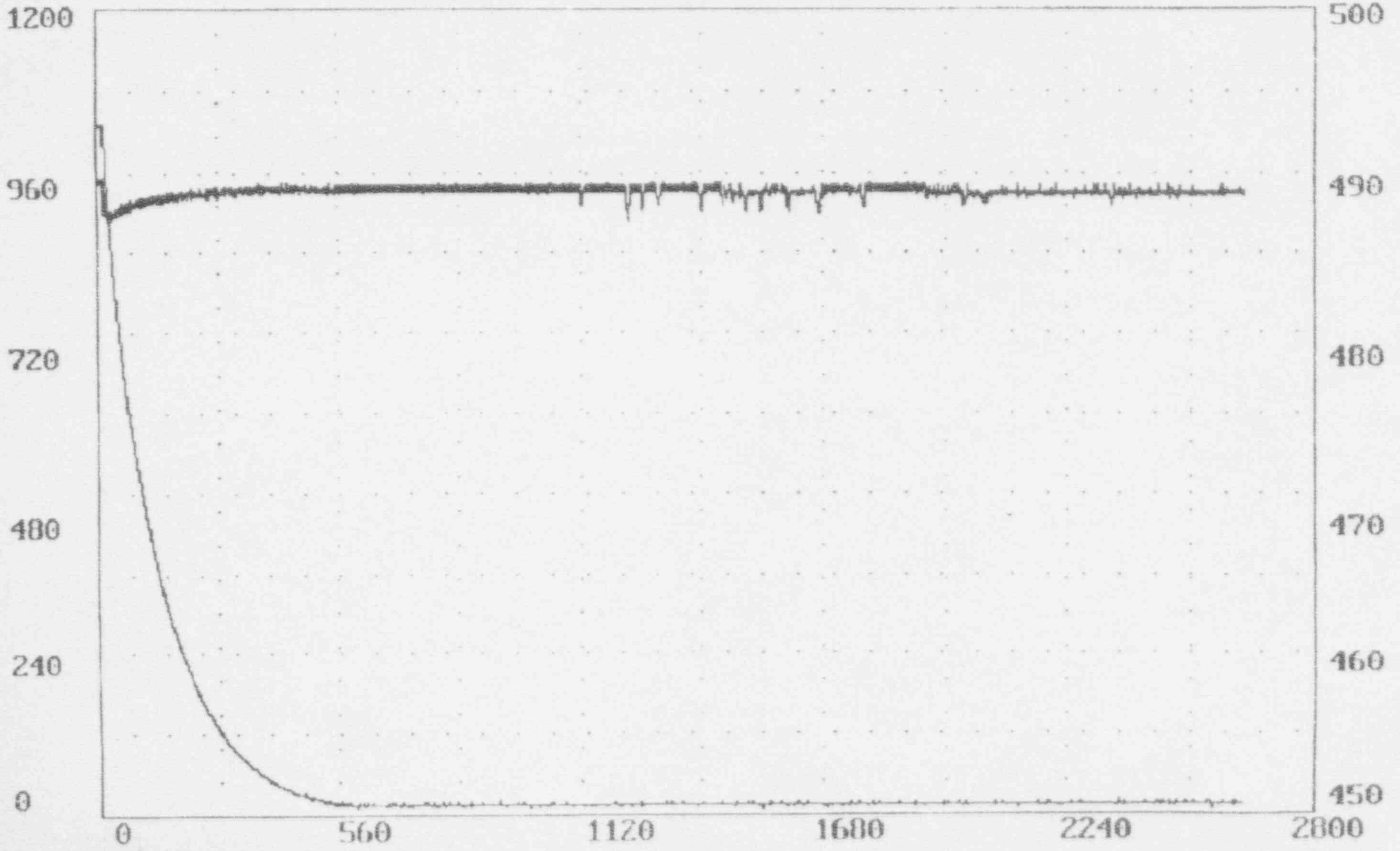
CONTINUUM DYNAMICS, INC.
PRELIMINARY INFORMATION

Filename: DEGAS93.DAT

TIME (SECONDS) P1 (PSIA) DP1 (IN. WATER)
29902 13 489



CONTINUUM DYNAMICS, INC.
PRELIMINARY INFORMATION


Filename: degas94.dat

| TIME (SECONDS) | P1 (PSIA) | DP1 (IN. WATER) |
|---|---|---|
| 2642 | 13 | 488 |

CONTINUUM DYNAMICS, INC.
PRELIMINARY INFORMATION