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Hybrid Fuel Formulation
and Technology Development

Final Report
June 1995

Prepared for the
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PREFACE

This report documents the work done on NASA MSFC Contract NAS8-39944. The Contracting Officer Technical Representative was Roger J. Harwell, PT21. The work was conducted as a joint effort between McDonnell Douglas Aerospace-Huntsville and Marshall Space Flight Center, for which MSFC provided facilities and conducted motor firing tests, and for which MDA-HSV made fuel mixes, fabricated fuel grains, loaded and unloaded the labscale motor, analyzed data, and provided overall program management. Thiokol Corporation supported the effort in a subcontractor role, furnishing miscellaneous hardware for the 11-inch motor firing tests as well as assembling and disassembling the 11-inch motors.

MDA-HSV would like to express appreciation to NASA personnel as follows: to M. L. Semmel for coordinating use of M & P Laboratory facilities, to J. R. Cook and W. D. Cruit for coordinating use of Propulsion Laboratory facilities, to R. C. Cooper and C. H. Lee for conducting motor test firings and supplying results, and to J. T. Wiley for assisting with data acquisition during motor firings and for supplying results. MDA-HSV would also like to thank J. R. Ringgold of Thiokol Corporation for coordinating the Thiokol effort.

The MDA-HSV team consisted of K. P. Bruce, D. L. Dean, J. J. Pope, and E. M. Snell.

The ingredients in fuel formulations Approach 1 through Approach 4 were previously examined by MDA-HSV on IRAD, and MDA has retained patent rights to these formulations. Two patent disclosures have been filed based on a combination of the IRAD and the contracted efforts.

EXECUTIVE SUMMARY

ORIGINAL PAGE
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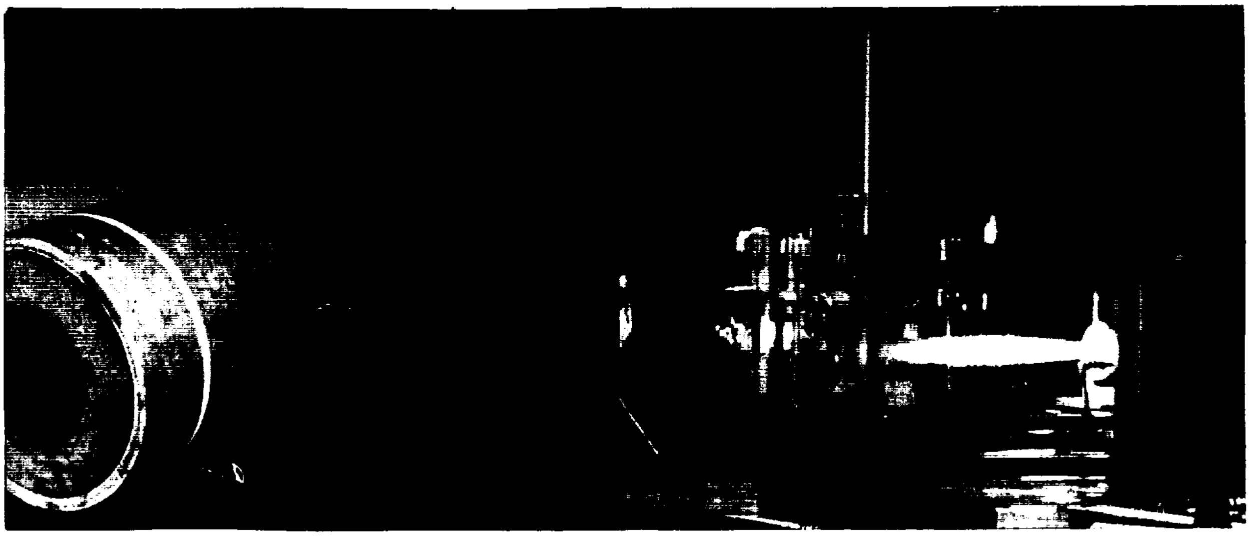

Fuel Grains Ready for Loading | First 11-Inch Motor Firing

McDonnell Douglas Aerospace is a provider of launch services furnishing access to space primarily via the Delta Launch System. In that role, MDA conducts IRAD programs to improve quality and reduce costs in order to increase the competitiveness of the US launch industry in the global economy. Hybrid rocket propulsion--derived from a solid fuel burned with a liquid or gaseous oxidizer--has the potential to be safer, more flexible, less expensive, and cleaner (compared to solids) as no energetic materials are involved, it can be throttled, stopped, and restarted, the fuel can be formulated from inexpensive materials already in volume production, and no HCl is formed during operation. In 1993 MDA recognized this potential and initiated an IRAD program to advance fuel technology.

Under the MDA IRAD program thirty-nine hybrid rocket motor test firings at the University of Arkansas at Little Rock during the '93-'94 academic year enabled MDA-HSV to demonstrate higher fuel performance via advanced, nitrogen containing, clean burning, environmentally friendly fuel formulations. This one year MSFC contract, valued at $244K, was to follow up on and extend the IRAD results.

The significance of this work was recognized by presentation of the AIAA Hermann Oberth Award for outstanding individual scientific achievement to David Dean, the project manager. Two patent disclosures have been submitted, as has AIAA paper No. 95-3080. Abstracts for additional papers have been submitted.

The primary objective of this program was to develop an improved hybrid fuel. The approach was to follow up on IRAD leads, obtain additional quantitative results in labscale motor firings, fine tune formulations, and then validate performance in a 2500 lbf scale, 11-inch diameter motor. The program was conducted at an accelerated pace with all objectives being met within nine months.

Seventy-five labscale motor firings were conducted during screening of thirty-five different candidate fuels. The tests showed that a combination of nitrogen containing additives gave the best combination of increased density and regression rate, reduced oxidizer requirement, smooth combustion, and minimal variation in axial regression rate, while achieving the desired exponent. In all cases, the cost of raw materials was approximately $1/lb. (See Appendix A.)

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The 11-inch motor was then fired twice to validate performance of the advanced fuel, using fuel segments weighing 70 lbs (4 in. port) and 78 lbs (3 in. port). It was fired at low and high oxidizer mass fluxes (0.155 and 0.546 lb/(sec sq in.), respectively) to demonstrate operation over a range of conditions. The calculated thrust in the second (three segment) test was just over 2500 lbf with a propellant flow of 11.0 lb/sec. The highlights were (1) good ignition followed by smooth operation (very minimal pressure oscillations) with a clean, smokeless flame which extinguished quickly on oxygen cut-off with no afterburning, (2) substantial reduction in amount of oxygen required for high efficiency combustion compared to straight hydrocarbons with successful tests at oxygen-to-fuel (O/F) ratios respectively of 1.5 and 1.75, (3) enhanced regression rates of 2.0 and 1.47 times that of the baseline MSFC Government/Industry Team formulation (CSD's UTF-29901) accompanied with a 15% increase in fuel density (meaning increases in fuel mass flow rates were 2.3X and 1.69X respectively), and (4) a more uniform axial regression rate with the aft grain losing only 16% more fuel than the head end grain in the three segment 11 inch motor test.

These results will enable design of an environmentally clean, higher performance, lower cost hybrid propulsion system since the higher density, higher regression rate, reduced pressure oscillation fuel will enable use of a smaller, lighter motor case (through a reduction in port volume and a lighter case designed for lower maximum pressure), and the lower oxidizer requirement will enable use of a smaller, lighter oxygen storage and delivery system. The lightening of the propulsion system hardware will reduce inert weight and ultimately cost.

In the second phase of the program, twenty fuel slabs were fabricated and shipped to Professor K. Kuo at the Pennsylvania State University for additional testing and characterization under a complementary MSFC hybrid propulsion contract.

RECOMMENDATION

Development of the fuel formulated here should be continued at an accelerated rate so that it will be available as a credible option for hybrid launch vehicle boosters, sounding rockets, and upper stages currently under consideration. The high performance and low cost will assist in making hybrid propulsion a competitive alternative to solid boosters. Test firings under a wider variety of conditions are needed to assist in definition of additional benefits. There is also a need for additional mix/cast process development to establish a process for volume production. Finally, the contributions of a number of fuel and motor operation parameters need to be better quantified as this short study was able to examine only the primary fuel formulation variables; the emphasis being on organic additives. Additional variables for optimization include heat transfer to the fuel surface via radiation, either from additives such as carbon black or aluminum, or from char generated during motor operation, as well as pressure effects, since radiation heat transfer and combustion efficiency are functions of pressure.

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Section 1

OBJECTIVE

The objective of this program was to develop an improved hybrid fuel with higher regression rate, a regression rate expression exponent close to 0.5, lower cost, and higher density. The approach was to formulate candidate fuels based on promising concepts, perform thermochemical analyses to select the most promising candidates, develop laboratory processes to fabricate fuel grains as needed, fabricate fuel grains and test in a small, labscale motors, select the best candidate, and then scale up and validate performance in a 2500 lbf scale, 11-inch diameter motor. This was to be performed in a short period in order that the results could be used on the rest of the program which consisted of testing in larger scale motors, that is, 11-inch and larger.

A second effort consisted of fabricating twenty fuel slabs for testing by Professor Ken Kuo and his group at the Pennsylvania State University on a complementary NASA MSFC contract.

Section 2

OVERVIEW

Introduction

MDA-HSV has participated in hybrid propulsion development at MSFC since 1991 when we designed tooling and equipment and oversaw its installation in MSFC Building 4767. This facility enables fabrication of hybrid fuel grains for both labscale and subscale (11-inch) motors on-site at MSFC. In 1993, MDA-HSV recognized the need to advance fuel technology for hybrid propulsion, to improve density, regression rate, and oxidizer-to-fuel ratios, while decreasing costs. During 1993, MDA-HSV initiated a fuel development IRAD program for this purpose, based on replacing the polymeric hydrocarbon filler in the baseline fuel, Chemical Systems Division of United Technologies formulation UTF-29901, which is used by the Government/Industry Team on the Joint IRAD Program at MSFC.

The new fuels exhibited dramatically improved performance--via increased density, increased regression rate, increased fuel mass flow, and reduced oxidizer-to-fuel (O/F) ratios, accompanied by reduced cost of raw materials. MDA-HSV conducted 39 hybrid rocket motor firings on IRAD to evaluate variations in improved hybrid rocket fuels during 1993 and 1994. The approach was based on using higher molecular weight, solid analogs of unsymmetrical dimethyl hydrazine (UDMH), a proven, high performance, liquid rocket fuel. Amines were used to replace a hydrocarbon filler in the fuel formulation currently baselined at MSFC. The improvements enable higher system performance via decreased inert case weight for fuel and oxidizer as well as decreased weight of oxidizer tankage and feed system.

Subsequent IRAD test series demonstrated processing of filler at up to 70% loading (baseline G/I Team formulation is 60%) and demonstrated the use of coadditives to tailor the exponent in the regression rate equation. An increase in the filler content further increases density, regression rate, and mass flow, as well as further lowering oxidizer requirements and raw materials cost. Ability to tailor the regression rate exponent enables greater design flexibility in optimizing the fuel for specific missions and/or different motor geometries and/or different oxidizers.

Summary of This Program

This fast paced MSFC program was initiated in June of 1994 to fine tune the use of amines, and to test some additional additives. A systematic scientific approach was pursued in which additives were chosen for their ability to affect a number of parameters relating to the hybrid rocket motor combustion process, especially heat of vaporization, activation energy of pyrolysis/vaporization, and radiative heat transfer.

A 55% increase in fuel mass flow rate was obtained from the selected formulation based on evaluation of over thirty different formulations in seventy five labscale motor firings. This was accompanied by a reduction in the optimum O/F ratio from 2.2 (representing the baseline G/I formulation) to 1.6 (calculated) or 1.5 (motor test conditions) along with a 15% increase in the fuel's density. The selected formulation burned especially cleanly and evenly. Fuel grains looked as clean after some firings as they had before being fired, the main difference being a larger bore.

Measured performance was further increased when the fuel was tested in the 11-inch motor. The fabrication process was scaled up in November 1994, and four fuel grains weighing over seventy pounds each were made for 11-inch motor testing. These were fired in mid January 1995 in different motor configurations. The first contained only one segment and was designed to examine a low oxidizer mass flux (OMF), namely 0.15 lb/(sec sq in.), in combination with a low O/F ratio. The test met all objectives, demonstrating high combustion efficiency (98 to 99%) at an O/F of 1.5, accompanied by a regression rate more than twice that of the baseline G/I team all hydrocarbon formulation, and smooth combustion with less than 10 psi pressure fluctuations compared to the chamber pressure which ranged between 600 and 920 psi. The plume showed Mach diamonds, a condition usually associated with complete combustion of the fuel. The absence of any visible smoke plus calculations showing high combustion efficiency were consistent with virtually complete combustion. The flame terminated quickly and cleanly when the oxygen flow was shut off. During the nitrogen purge after oxygen shut off, a small amount of white smoke could be seen.

The second 11-inch motor test conclusively validated higher performance. It was conducted a week after the first 11-inch motor test on a three segment, 10-foot long motor at a higher OMF of 0.55 lb/(sec sq in.). The total propellant flow rate was 11.0 lbs/sec with an O/F ratio of 1.75, developing over 2500 lbs of thrust. The fuel mass flow rate was 70% higher than the baseline G/I team all hydrocarbon formulation. It burned very smoothly with only 10 psi chamber pressure fluctuations compared to the chamber pressure which ranged between 430 and 480 psi. The regression rate was higher than the early labscale motor results, but was in agreement with labscale motor firing results on this particular mix. (Differences are attributed to changes in the binder.) The appearance of a smokeless, clean yellow flame was consistent with the calculated combustion efficiency of 95%. Oxygen cut off resulted in immediate cessation of the flame, followed by emergence of white smoke. There was no afterburning once the oxygen was shut off.

Examination of the fuel grains after the firing indicated very uniform surfaces, with no residual char. Weight losses in the three segments varied only 16%, with the head end segment losing the least. This is a significantly lower axial variation than that reported for the G/I team hydrocarbon based fuel which exhibited a segment weight loss variation on the order of 60% for firings at a similar OMF. The more even axial regression enables efficient operation over a wider range of OMF values and generates more uniform thrust throughout motor operation.

Ten labscale motor firings were conducted after the 11-inch motor tests to obtain additional data. The program total was 87 motor firings examining 35 different formulations. Several of these formulations exhibited significant increases in fuel performance. Each has different advantages.

Conclusions

The results show that the characteristics of a high performance fuel have been verified in 11-inch motor testing. The advanced fuel exhibits a 15% increase in density over an all hydrocarbon formulation accompanied by a 50% increase in regression rate (which when multiplied by the increase in density yields a 70% increase in fuel mass flow rate); has a significantly lower O/F ratio requirement at 1.5; has a significantly decreased axial regression rate variation making for more uniform propellant flow throughout motor operation; is very clean burning; extinguishes cleanly and quickly; and burns with a high combustion efficiency. These characteristics allow for increases in system performance via an increase in fuel mass fraction through decreased inert component weight.

Minimal pressure fluctuations will enable a case design with a minimal additional strength and weight to accommodate pressure oscillations about the mean. A reduced oxidizer requirement will enable a reduction in oxidizer tank weight, in pressurant weight or pump weight, in oxidizer delivery pipe size, and in the size and weight of associated valves. (There will have to be an increase in fuel weight to maintain the same total propellant mass.) The increase in regression rate will enable the fuel grain to have a thicker web and/or fewer ports. This will generally increase the average density of the motor and reduce the formation of pieces of fuel between ports at fuel burnout which can tear off in large chunks and cause either nozzle obstruction or other uneven conditions near the end of burn.

These tests have shown start up and shut down capability in addition to operating characteristics. The regression rate in the three segment motor was essentially the same as that in the labscale motor for the same mix. This is consistent with what has been reported previously for hybrid motors, namely that there are no major scaling factors, enabling meaningful design and analysis of large motors based on the data generated in this work. The higher regression rate appears to be due to a combination of lower heat of vaporization, formation of particulate char which can contribute to increased heat transfer to the surface via increased black body radiation, and lower energy of activation via replacement of polymer pyrolysis with simple vaporization, supporting the soundness of the basic approach. The results of this work have been disseminated in an AIAA paper.[1]

Recommendations

In order to continue development of the improved fuel formulation demonstrated here, additional work will be required in several areas as described below.

Additional 11-inch motor tests over a range of OMF values would enable better definition of the relationship between OMF and a number of associated parameters such as axial regression rates, absolute regression rates, and pressure. This would require a minimum of three to four 11-inch motor tests. By using an oxidizer flow of around 5.0 lb/sec, information can be obtained on lower OMF values and higher pressures (by using a smaller nozzle) while staying above an O/F of 1.45.

As a lower O/F ratio is one of the advantages of this fuel, a series of a minimum of three to five 11-inch motor tests would enable definition of performance at O/F ratios between 1.3 and 1.5. Good performance in this O/F range will provide additional system benefits.

Tests in the 24-inch motor would assist in definition of scale up factors and/or develop performance characteristics using liquid oxygen as opposed to gaseous oxygen as the oxidizer. Three to five 24-inch motor tests should establish baseline performance.

In order to develop a process to fabricate larger grains, it would be necessary to conduct some processing tests to define a continuous process. This would require acquisition of some miscellaneous hardware, equipment rental, assembly, testing, and would culminate in casting of grains for the 24-inch motor. This would be a three to six month effort and would demonstrate a process with a throughput rate of at least 100 lb/hr. A low cost facility could be constructed at MSFC.

Since some promising leads were identified, but the initial effort was too short to enable follow up, additional fuel tests could be conducted to further optimize the levels of carbon black and melamine. Varying levels of carbon black will generate data to assist in defining effects of radiation, since carbon black radiates. This is projected to be a moderate level activity extending about six months in order to analyze results of ongoing testing and to build on those tests.

In addition, routes to enhance the storage stability of the of the fuel need to be investigated. It is anticipated that surface coatings would considerably lengthen the storage life. These would need to be applied and weight loss examined over time.

Continuation of approximately one year of effort on this activity shows promise of generating a quantitative/comprehensive data base for use in a comprehensive trade study between this new fuel and the one currently baselined for use in hybrid propulsion systems.

Section 3

BACKGROUND ON HYBRID FUEL TECHNOLOGY

Hybrid propulsion is not a mature technology from either a system or a component aspect, and important technologies are being developed in response to recognition of shortfalls--as they are identified--in order to make the technology more cost effective and more reliable. A relatively little examined technology to date has been fuel formulation. System characteristics or hybrid rocket motor operating parameters that can be optimized or improved via special characteristics in the fuel include but are not limited to the following, which will be discussed in additional detail:

- density
- ballistic performance in terms of specific impulse
- minimizing the amount of oxidizer that must be used
- fuel regression rate
- uniformity of fuel regression rate axially down the length of the grain
- maintaining a reasonably constant oxidizer to fuel ratio throughout the burn
- combustion stability/pressure oscillations
- fuel mechanical properties

Density

Density is important because denser fuels can be carried in smaller, lighter weight structures, decreasing inert vehicle weight. Modern class 1.3 solid propellants are based on a combination of fuel (usually powdered aluminum, density 2.7 g/cc) and oxidizer (usually ammonium perchlorate, density 1.95 g/cc) held together by an elastomeric binder system. Net densities are around 1.84 g/cc. The binder system utilizes crosslinked hydroxyl terminated polybutadiene (HTPB) to hold the solid fillers. Crosslinked HTPB is used because 1) it is elastomeric after being crosslinked, 2) it is easily crosslinked with difunctional or multifunctional isocyanates and even highly loaded, yields products with good mechanical and aging properties, 3) it has been found to process well, and 4) it yields more energy than many alternatives on being burned. The cured HTPB binder system has a density of around 0.92 to 0.94 g/cc. Due to availability and experience, crosslinked HTPB is thus a logical choice of a binder for hybrid fuels.

The filler most widely used in current hybrid rocket fuel is a hydrocarbon (Escorez 5320) with a density of around 1.05 g/cc. The density of the hybrid fuel (filled HTPB) is about 1.0 g/cc. If the density of the filler and consequently the fuel can be increased, the size of the motor can be reduced (for a given mass of fuel), the weight of the inert structures can be reduced, and the fuel mass fraction of the system can be increased. As noted in the previous paragraph, solid class 1.3 propellants have densities of around 1.8 g/cc. Liquid propellant systems utilize liquid fuels with lower densities of around 0.7 g/cc (RP-1, kerosene) combined with liquid oxidizers with densities around 1.13 g/cc (cryogenic oxygen) to produce a weighted average density of around 1.0 g/cc. Hybrid fuels can be formulated with aluminum as a filler to increase the density. However, one goal of this program was a non-aluminized hybrid fuel which is safer to produce, safer to use, and combusts cleanly without producing smoke, while exhibiting a significantly higher density than 1.0 g/cc.

Ballistic Performance

It is important to maintain good ballistic performance in terms of specific impulse, since thrust is the product of mass flow through the nozzle and specific impulse. Specific impulse moves toward maximum when the molecular weight of the species produced during combustion is low and the heat of formation of the fuel is high. In selecting alternative fillers, heat of combustion was a consideration as was nitrogen content, since nitrogen has two advantages. The first is that it can be expelled as a relatively low molecular weight gas (N_2), molecular weight 28, compared to carbon monoxide (CO), also molecular weight 28, or carbon dioxide, (CO_2), molecular weight 44. The second is that the expelled nitrogen gas does not acquire any atoms from the oxidizer, thus reducing the oxidizer requirement. Simply put, the higher the nitrogen content, the lower the oxidizer requirement. However, this also decreases the total heat output, since formation of oxides such as water and carbon dioxide releases much more heat than does formation of nitrogen. Selecting the optimum combination is not simple, but requires systems analysis, since performance lost in utilizing a less than maximum specific impulse fuel will be offset by reductions in hardware weight enabled by the lower oxidizer requirement.

Oxidizer Requirements

One advantage of hybrid propulsion is that it has fewer moving parts, as only the oxidizer needs to be moved during operation. It follows that the less oxidizer that is required, the less inert weight required to store and move it as the tank can be smaller, the lines can be smaller, and the power requirement to move the oxidizer is smaller. In liquid engines, both the fuel and oxidizer are normally moved to the combustion chamber by turbopumps, expensive pieces of equipment. In order to decrease the cost and simplify the system, recent development work has concentrated on using pressure to move the oxidizer. This requires a gas at a higher pressure to push the oxidizer to the combustion chamber. This in turn requires a pressure tank for the oxidizer oxygen capable of withstanding approximately 1000 psi, if the motor is designed to operate around 500 psi. Thus a significant reduction in weight of oxidizer enables a significant weight savings in that pressure tank and associated system.

Regression Rate

Regression rate is a limiting factor in grain design. The goal is to burn through a fuel grain in a given amount of time. A low regression rate means that a thin grain will be required. This requires either a long single port grain or a multiport grain. One definite advantage of a higher regression rate fuel is that the motor will require less volume, since the thin grain (necessitated by a low regression rate) plus port(s) result in an increase in the overall volume, and a decrease in the net density. More volume means more inert weight and a lower fuel mass fraction. More ports also means more slivers between ports as the fuel is burned up. These represent pieces of unburned fuel which can potentially separate as large fragments and block the nozzle, or damage the nozzle as they are blown past, meaning that somehow this problem must either be overcome, or significant sliver must be left. If the approach is to leave slivers, a higher regression rate fuel will leave fewer slivers and consequently be more efficient. Thus an increase in the regression rate enables a higher net density fuel grain design, as well as more flexibility in grain design.

Axial Regression Rates and Oxygen to Fuel Ratios

Hybrid motors exhibit uneven regression in the axial direction. At the higher oxidizer mass fluxes where motors would most likely operate, the aft end regresses significantly faster than the head end. In one 11-inch, three segment motor firing on the Government/Industry Team JIRAD program, the aft end segment lost 79% more weight than the head end segment.[2] This leads to two concerns. The first is that if the aft end burns out sooner, it will need additional insulation to protect the case while the fuel further forward continues to burn. The second is that it is difficult to control the O/F ratio and predict the thrust when the regression rate is highly variable, as both the mass flow and the characteristic velocity will be changing during motor operation. At a constant oxygen flow, if extra fuel is initially lost per unit time, the O/F ratio will be decreased. If later on, less fuel is lost per unit time, especially after the aft end has burned out, the O/F ratio will be increased. Thus a more even axial regression performance will enable better control and reduce the need for additional insulation.

Combustion Stability

A major concern in hybrid motor operation is combustion stability. Combustion instability is characterized by pressure oscillations. Combustion stability is a complex aspect of rocket motor operation that is not completely understood. All rocket motors exhibit some pressure oscillations, whether they are solid, liquid, or hybrid. It is known that there are a number of factors which influence pressure oscillation, including motor geometry, fuel formulations, and flow rates. It was postulated by Netzer in 1972 that the driving mechanism for sub-acoustic pressure irregularities in hybrid rocket motors is some type of flow-combustion turbulence interaction along the surface of the fuel.[3] Studies conducted by Strand, *et al*, which were published in 1994 support the postulate.[4] Hybrid motor pressure traces obtained in the MSFC Government/Industry Team JIRAD program show pressure spikes on the order of 100 to 200 psi, and occasionally the chamber pressure shows a jump accompanied by a regression rate increase.[2] Thus there is a need to understand and be able to control these pressure spikes, in order to be able to design a minimum weight pressure vessel with an adequate margin of safety. It appears that there are contributions to pressure oscillations from both the motor geometry and from the fuel, and thus there is an opportunity to tailor the fuel for improved combustion stability.

Mechanical Properties

Fuel mechanical properties are very critical in solid propellants because cracks increase the surface area. Increased surface area during motor operation increases the volume of gas produced, which increases the chamber pressure. Since the rate of gas production rises with rising pressure, increased pressure increases the rate in a positive feedback loop which can rapidly lead to motor overpressurization. In contrast, the regression rate in hybrid motors utilizing organic fuels has been found to be essentially independent of pressure. Thus there is no positive feedback loop, and a much decreased operational sensitivity to cracks in the grain. Additional surface area from cracks does yield additional fuel during motor operation, and oxidation does increase chamber pressure. However, the oxidizer flow rate limits the total amount of gas molecules that can be produced per unit time, and as the O/F ratio decreases, the product ratio and heat output change. Experience to date indicates that overpressure conditions can be detected and the oxidizer flow terminated prior to onset of destructive overpressurization.

Mechanical properties are still important as any case-bonded solid fuel has a certain amount of induced strain due to thermal variations in storage conditions, and good strain capability is still needed to avoid tearing or cracking of the grain during storage. In addition, a multiport grain must avoid tearing as the ports burn together.

Section 4

SELECTION OF CANDIDATE FILLERS

In seeking denser fillers, it was noted that the incorporation of heteroatoms (nitrogen, oxygen, sulfur, or phosphorus, etc.) in an organic compound generally correlates with higher density than the corresponding hydrocarbon. Accordingly nitrogen compounds were most actively examined as an extension of hydrazine fuel technology, and a list of desirable attributes was compiled. In addition to high density, these included 1) a heat of formation close to zero or above zero, 2) commercially available and made in quantity to keep costs low, 3) non energetic to minimize hazard, and 4) a melting point well above 150°F. Based on known fuels, it was assumed that higher molecular weight analogs of unsymmetrical dimethylhydrazine (UDMH) would be advantageous, as it is a well characterized liquid fuel with high performance. The net chemical formula for UDMH is $C_2H_8N_2$. It has the same number of carbon and nitrogen atoms plus four times as many hydrogen atoms.

Specific Materials

A higher molecular weight homolog of UDMH would have fewer hydrogens. A compound of this type is hexamethylenetetramine, $C_6H_{12}N_4$, also known as hexamine. This material has the adamantane structure with the bridgehead positions occupied by nitrogen atoms. It is a white crystalline material, with a melting point variously reported as 265°C or 285-295°C, where it sublimes rather than simply melts. The molecular weight is 140.19, the heat of formation is +124.1 kJ/mol for the condensed form.[5] The number is positive as shown. The density has been measured as 1.33 g/cc,[6] although one manufacturer of a commercial grade indicates 1.27 g/cc. This compound is used in adhesive formulations and is made by several companies. It is sold in different particle sizes which can be used directly without requiring grinding. Cost quotes obtained in 1994 ranged from about $1.29/lb for small quantities, to about $0.50/lb in large quantities.

Hexamine has been examined as an ingredient of hybrid fuels in the past and was named in a German patent in 1964, and by the same company in a US patent application in 1965, which was finally issued on June 3, 1980 as US Patent 4,206,006 to Ratz, assigned to Dynamit Nobel Aktiengesellschaft, Federal Republic of Germany. This patent claims hexamine is a catalyst. Although regression rates are higher when this material is a part of the formulation, it is not a catalyst by the classical chemical definition. In keeping with the philosophy that the material is a catalyst, the Ratz patent claims loadings of less than or equal to 50% hexamine.

A review of substances with favorable heats of formation revealed dicyandiamide, $C_2H_4N_4$, heat of formation +8.49 kcal/100g, melting point 211°C, density 1.4 g/cc. This compound is also known as 1-cyanoguanidine. Cost is just over $1/lb. It is used as a curative for epoxies, and samples were obtained from two different manufacturers.

Another substance is acrylonitrile, C_3H_3N, heat of formation of +68.2 kcal/100g. Although acrylonitrile itself is a liquid, it polymerizes to a solid which has several commercial uses and is manufactured in quantity by several companies who use it as an intermediate in making (PAN) fibers. An inquiry suggested that it should be available for around $1/lb, although at this point in time all PAN is used internally as an intermediate and none is offered commercially. Consequently, a research sample was obtained from Aldrich Chemical.

Another commercially available, inexpensive amine is melamine, $C_3H_6N_6$, which costs around $0.60/lb. It is widely used in the plastics industry. Advantages include a density of 1.57 g/cc, and pyrolysis to cyanamide or dicyanamide, although it is also known to pyrolize to a char. Its heat of formation is -17.13 kcal/mol, or -13.595 kcal/100g. It is sold as a fine powder which can be used directly without requiring grinding.

The filler used in the NASA MSFC Government/Industry Team JIRAD formulation is Escorez 5320, made by Exxon. It is a saturated aliphatic hydrocarbon, apparently a fairly low molecular weight polymer of cyclopentadiene which has been hydrogenated. Cost is over $1/lb, with no discounts for quantity. The density listed by Exxon ranges between 1.0 and 1.05 g/cc. The heat of formation is -31.4 kcal/100g, for a formula of $C_{7.319}H_{11.059}$. It is listed as having a softening point of 122°C.

Exxon also offers another Escorez line, the 7000 series. These are aromatic hydrocarbons with slightly higher densities, averaging 1.05 g/cc, and presumably higher heats of formation. A sample of Escorez 7312 was obtained. The cost is significantly lower than the 5000 series. Both Escorez materials are sold as pellets which need to be ground for use as fillers in hybrid fuel.

These were the organic fillers selected for evaluation on the program: four nitrogen compounds and two hydrocarbons. Hexamine was chosen as an aliphatic amine with an ability to vaporize cleanly, with a favorable heat of formation and a low cost. Dicyanamide was acquired for its positive heat of formation and ready availability. Polyacrylonitrile was selected for its positive heat of formation and known exothermicity on pyrolysis. Melamine was picked as an aromatic amine that was inexpensive and dense. Escorez 5300 was chosen as an already widely used hybrid fuel filler, and Escorez 7312 was obtained as an alternative aromatic hydrocarbon with higher density and lower cost.

MDA-HSV IRAD Performed in 1993 and 1994

This effort builds on IRAD work conducted by McDonnell Douglas Aerospace-Huntsville during 1993 and 1994. During that time, samples of all of these materials were obtained, and most were made into fuel grains and tested in motor firings at the University of Arkansas at Little Rock. In this work, it was shown that 70% loadings of hexamine could be processed into fuel grains.

The MDA-HSV IRAD work showed that hexamine enhanced regression rates at loadings up to about 50% in crosslinked HTPB. The exponent in the basic regression rate expression for HTPB appeared to be unaffected by these low hexamine loadings. At higher loadings with hexamine as the only additive, the regression rate was found to decrease, and the regression rate expression exponent appeared to change. As a result, other additives were examined in combination with hexamine. The results were generally favorable. That is, fuel grains containing combinations of additives exhibited enhanced regression rates and exponents which could be tailored by using different ratios of the additives. In addition, inclusion of substantial loadings of hexamine decreased the amplitude of pressure oscillations during motor operation compared to unfilled, crosslinked HTPB. The IRAD program consisted of screening efforts and primarily identified promising leads.

Designations Assigned to Fillers

For simplification in tables the following will be used in this report:
A or additive A is hexamine
B or additive B is Escorez 5320
C or additive C is Escorez 7312
D or additive D is melamine
E or additive E is polyacrylonitrile
CB1 or additive CB1 is Elftex 12, a carbon black
CB2 or additive CB2 is Thermax N-991, also a carbon black

Nomenclature in This Report

The terms composition or formulation are used interchangeably when referring to fuels with different make-ups. Composition is an after-the-fact description; whereas formulation is derived from the word formula or a before-the-fact list of the ingredients to be mixed together. Formulating refers to the act of deciding which ingredients to include and how much of each to use. Composition can refer to the atomic make up as well as the ingredients. Another term--derived from the process of converting raw materials into fuel--is "mix." This word will also be used synonymously with formulation and composition. In this effort, the first formulation examined was called Mix A. All compositions examined are listed in Appendix A. As noted in Appendix A, Mixes A through F did not produce quality fuel grains, and thus are not referred to in motor test results. The primary reason was moisture in the raw materials which destroys curative, and the early mixes did not cure satisfactorily. As noted in the Processing Section, in order to produce quality fuel, it was necessary to dry the ingredients and to vacuum mix.

The different ingredients were selected for different reasons, and thus fell into groups based on the reason for their selection. These groups were designated approaches. Letter designation of mixes was made chronologically, while different approaches were investigated simultaneously. As a result, the only relationship indicated by the letter names is that mixes with letters further along in the alphabet were made later in time, and the letter designations within an approach will appear to be unrelated. However, the letter designation system evolved as the program progressed. Once all twenty six letters of the alphabet had all been used, they were simply doubled. Thus the twenty-seventh mix was designated AA. However, in some instances later mixes were related to earlier ones. Thus, instead of JJ, the designation was JX, because it was the same as formulation X. Similarly, once the MM formulation looked promising, binder variations were designated MW or MT. Additional mixes of the MM formulation investigated in the same time frame were assigned extra letters and include MMF, MMG, and MMH.

Section 5

BALLISTIC CONSIDERATIONS

Some obvious differences in comparing a solid hybrid fuel motor to a solid propellant motor is that the hybrid motor can be throttled, turned off, and restarted. In terms of an equation describing burning rate or surface regression rate, solid motors and hybrid motors are also significantly different. In hybrid motors, regression rate is a function of oxidizer mass flux, namely, $r = a(G_O)^n$, where G_O is the oxidizer mass flux, a is the preexponent, and n is the exponent. This makes comparison of regression rates for different fuels complex, since either or both a and/or n can be different, and different oxidizer mass fluxes will lead to different rates even with constant a and n values. By comparison, the equation for solid motors includes a pressure term with a positive exponent, making burning rates in solid motors sensitive to chamber pressure. There is no pressure term in the hybrid regression rate equation, and no regression rate pressure effects were observed in the testing in this program at pressures below 650 psi.

The term for hybrid fuel loss from the surface is regression rate, rather than burning rate which is used for solid propellants. The reason for the difference is that hybrid fuel does not burn at the surface during steady state operation. Instead, the heat generated during combustion of the vapors is transferred back to the surface causing a decomposition and release of low molecular weight gases. The continuous release of these gases effectively blows the oxidizer away from the surface and keeps combustion in the gaseous stream proceeding down the motor. It is known that HTPB pyrolysis also results in formation of some char,[6] and that formation of gases and char proceed simultaneously.

The literature indicates that regression rate is a function of heat transfer to the surface which has components of convection and radiation.[8] Radiative heat transfer during motor operation is facilitated via inclusion of carbon black. The MSFC Government/Industry Team baseline hybrid fuel (UTF cartridge-29901) contains 0.2% carbon black.

As the surface loss of fuel proceeds through reactions producing a) low molecular weight gases via pyrolysis reactions, b) char via pyrolysis reactions, and c) vaporization of some species without a reaction, it should be possible to affect the ballistics by changing the ingredients of the fuel and/or by changing the heat transferred to the surface. This was a consideration in selection of the candidate filler materials. The candidate fillers span a variety of types of materials from aliphatic to aromatic compounds; they range from those which vaporize without charring, to those which form high char yields. They range from those which absorb heat to vaporize, to those which pyrolize with release of heat. It was anticipated that some would be more effective than others in tailoring the regression rate expression exponent while maximizing the regression rate.

The pre-exponent and exponent for unfilled HTPB are respectively, 0.104 and 0.68.[8] However, in order to maintain a constant O/F ratio with a constant oxidizer input stream, it is desirable to have an exponent of close to 0.50. The MSFC Government/Industry Team baseline hybrid fuel has an exponent of 0.54,[2] achieved by using Escorez 5320 as a filler at the 60% level in crosslinked HTPB. The pre-exponent for this fuel is only 0.069, indicating that the lowering of the exponent was accompanied by a lowering of the pre-exponent.

Section 6

MOTOR FIRING TEST RESULTS

Labscale Motor

A total of 85 labscale motor firings were conducted on this program, 75 of them in order to make a selection on the fuel composition to scale up. The labscale motor was provided by MSFC. It has a 1.5" diameter interior. As configured for these tests, the combustion chamber is approximately 13.5 inches long, composed of a 10 inch long barrel plus head and aft ends which slide over the barrel and seal with O-rings. Four 2.5-inch long fuel grains cast in paper phenolic cartridges and laid end to end make up the fuel charge. These butt against the slightly smaller interior diameter head end piece which encloses a chamber about 2.5 inches long from injector to grain, with an igniter port about half way between the grain and the head end of the motor. The injector consists of a single hole about 3/16 inches in diameter centrally located in the head end through which the gaseous oxygen flows. The aft end of the grain assembly contains a ring with an interior diameter of about 1.0 inches and an exterior diameter about 2.25 inches. This seats into the aft segment of the motor, which consists of a mixing chamber about 1 inch long, with the approximately 2.25 inch diameter. Farthest aft is a piece of graphite, approximately 2 inches long. This can either be the nozzle, or it can hold a tungsten nozzle insert. It has about a one inch long section to serve as an exit cone. The entire assembly is held together by plates at the head and aft ends connected via two threaded rods. The fuel grains were cast with interior port diameters of either 0.826 inches or 0.625 inches.

Data Reduction for Labscale Motor

Each empty fuel cartridge was weighed prior to being filled. Each grain was weighed prior to a motor firing. After the motor firing the exterior surfaces were wiped clean (mostly to remove halocarbon grease) and the grains were reweighed. All weights were recorded on a spreadsheet. The spreadsheet calculated the density and weight loss for subsequent regression rate calculations.

The published relationship[8] between oxidizer mass flux and fuel regression rate for hybrid motors is

$$r = a(G_o)^n$$

where r is the fuel regression rate in inches per second, a is a pre-exponent dependent on the motor configuration and the units desired (in this work in./sec), G_o is the oxidizer mass flux in lb/(sec in.^{2}), and n is the exponent. The exponent for straight HTPB (probably cured with Desmodur N-100) is reported to be 0.68.[7,8]

Regression rate is calculated by a series of steps. First the weight loss is calculated using fuel grain weights from before and after firing. Then, using the density determined on the grain prior to firing, the volume of lost fuel is calculated. The next step is to calculate the final radius, assuming all weight lost is in a uniform shell. The regression rate then is calculated as the difference between initial and final radii divided by the action time. Since there is mass loss from the exposed ends of the grain, the assumption is not completely valid, and the numbers are not good for predictions or analysis. Better numbers can be obtained by using weight losses from only the center one or two grains. The regression rates, pre-exponents, and exponents in this report are all based on weight losses from the center grains only.

The oxidizer mass flux (OMF) or G_o in the above equation is calculated as the oxygen flow rate divided by the cross sectional area of the bore of the motor, which increases during the firing. The G_o used to reduce labscale motor data is an average, based on the average radius, which is calculated here as the sum of the initial radius and the final radius divided by two.

Motors were fired at two different conditions to obtain regression rates at two different oxidizer mass fluxes. The lower oxidizer mass flux was normally obtained by using the standard interior bore diameter of 0.826 in. and an oxidizer flow rate on the order of 0.08 to 0.09 lb/sec. The higher oxidizer mass flux was obtained by using an interior bore diameter of 0.625 in. and an oxidizer flow rate of 0.18 to 0.25 lb/sec. These two conditions combined with the series of operations described above provided a minimum of two sets of regression rates and oxidizer mass fluxes for each formulation. In some instances grains were refired, but under these circumstances it is difficult to assign an initial diameter which makes for greater uncertainty in the results. The exponent was extracted by taking the logarithms of both sides of the set of two equations, combining the two oxidizer mass flux conditions, and solving for n. Ballistic data for all labscale motor firings conducted can be found in Appendix B.

An alternative approach which was used to calculate the exponent and pre-exponent for the 11-inch motors and which is more accurate, is an iterative series of calculations which steps though small increments of time and recalculates the oxidizer mass flux each time. This approach is used in the spreadsheet calculations in Appendix C. This analysis method becomes more important in longer firings where the port size changes substantially. The labscale firings were nominally 3.5 sec for the low oxidizer flow rate tests and 2.6 sec for the high oxidizer flow rate tests.

Motor Firing Conditions

The nominal goal chamber pressures were 500±100 psi. Two standard nozzle insert sizes were used, 0.180" diameter for the low oxygen flow rate (around 0.08 to 0.09 lb/sec) tests, and 0.340" diameter for the high oxygen flow rate (around 0.18 to 0.25 lb/sec) tests. The observed results usually had chamber pressures close to 600 psi for the low oxidizer flow rate tests, and between 400 and 500 psi for the high oxidizer flow rate tests. Chamber pressure traces for all labscale motor firings are in Appendix B. The nozzles were reused unless the diameter had increased in size during the first firing. Generally the smaller diameter nozzles using the low flow rate could be used more times than the larger ones. This correlates with the O/F ratio which was usually around 2 for the low flow rate and above 3 for the high flow rate. It is hypothesized that the higher O/F ratio resulted in more rapid nozzle oxidation and erosion for the high flow rate tests.

Formulation Approach 0

Dicyandiamide was one of the candidate filler materials examined early in the program. One mix was made with this material and one set of grains was cast, designated I. The filler composition consisted of 55% hexamine and 15% dicyandiamide. The pot life was very short making casting difficult. The regression rate was 0.0412 in/sec at an oxidizer mass flux of 0.2835 lb/(sec sq in.). This is a significantly lower regression rate than obtained with Formulation H (which used the same binder system) described in Approach 2, and no further work was done with this additive.

Formulation Approach 1

This approach was examined early in the program due to the attractive lower cost of additive C, Escorez 7312, compared to additive B, Escorez 5320. Escorez 7312 is an aromatic hydrocarbon. Aromatic hydrocarbons are usually avoided in rocket fuels as they burn with low efficiency and produce soot, but it was felt that such a behavior might be beneficial in terms of tailoring the exponent. The approach here examined C as well as combinations of C and D to tailor the exponent with hexamine, A, as the primary filler. A total of five formulations were examined in at least two motor firings in order to determine the exponent. Only the last one contained carbon black (CB1). The first approach to binder formulation contained R45HT, antioxidant Cyanox 2246, surfactant, and Desmodur N-100 and is called "100". The second approach to binder formulation was used in the other four mixes and had the N-100 curative replaced by some Dow Voranol 230-660 and Desmodur W, and is designated "mxW." An overview can be obtained via examination of table 1.

Formulations G, M, and O examined fifteen percent of additive C with 55% hexamine utilizing slightly different binder systems as shown in table 1. There was some difference in the results, and in no case was the exponent lowered to the goal value of 0.50.

Table 1. Summary of Formulation Approach 1

Grain Designation	A	B	C	D	E	CB1	CB2	binder	dens g/cc	pre-exponent a	exponent n
G & M	55		15					100	1.07	0.086	0.54
O	55		15					mxW	1.06	0.124	0.71
P	55		10	5				mxW	1.10	0.109	0.60
Q	50		10	10				mxW	1.10	0.089	0.48
S	50		10	10		0.2		mxW	1.10	0.090	0.42

Ten percent C and five percent D combined with 55% hexamine, formulation P, produced an exponent of 0.60. Raising the D content to ten percent, and combining with ten percent C and 50 percent hexamine, formulation Q, further lowered the exponent to 0.48. This combination of organic additives was close to the goal, and it was subsequently combined with 0.2 percent CB1 carbon black, formulation S, to increase radiative heat transfer to the surface. This further lowered the exponent to 0.42.

The regression rate behavior of the formulations of Approach 1 are plotted in figure 1. It can be seen that all are well above the baseline G/I Team formulation, and that most are close to that of the advanced formulation later chosen for scale up. The general increase in regression rate is due to replacement of the Escorez in the G/I Team formulation with hexamine.

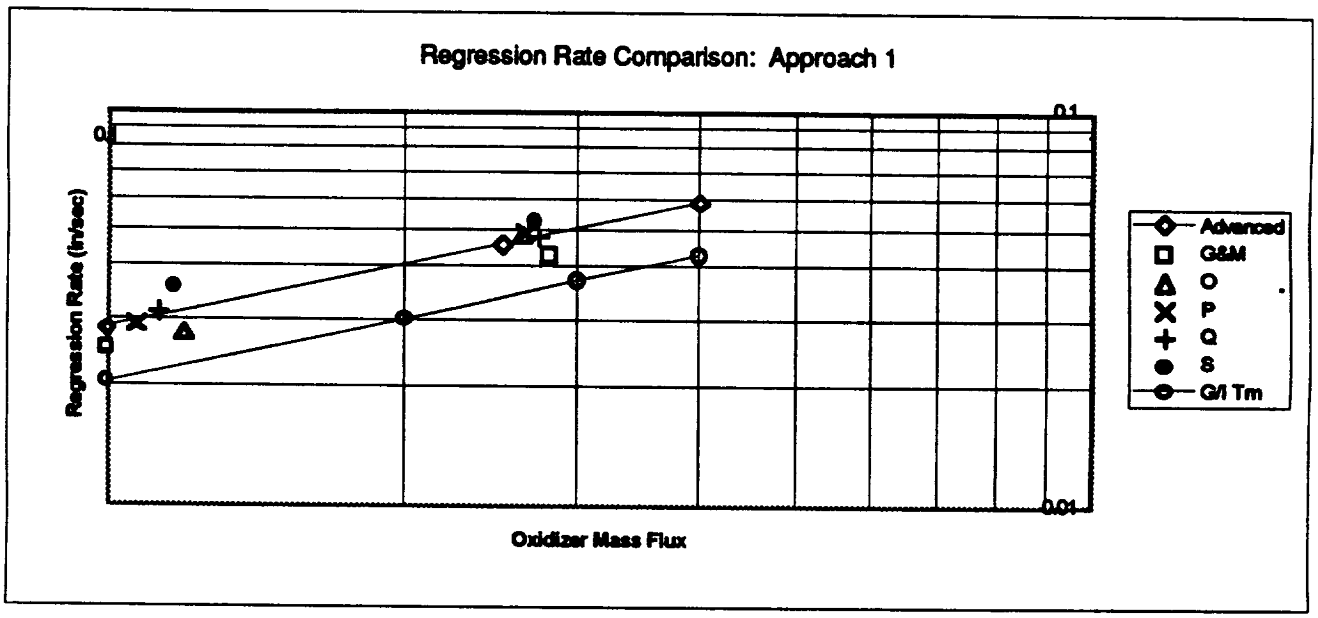

Figure 1. Regression performance of Approach 1 compared to the G/I Team baseline formulation and the advanced formulation from Approach 4.

Examination of the nozzle inserts after motor firings revealed black, sooty deposits. This undesirable result plus a low fuel density led to termination of this approach. However, the results demonstrated exponent tailoring and bracketing of the desired exponent value of 0.50, and indicated that aromatic ingredients can be very useful.

Formulation Approach 2

This approach emphasized the use of additive B or Escorez 5320, the main additive already most extensively utilized in hybrid fuels, in combination with hexamine. This made it closest to the experience base, since many grains have been made and fired using this material as the only filler. The largest number of motor firings were performed on this group. A total of 16 different formulations were examined, and several were fired more than twice in order to determine reproducibility and to obtain representative values. Results did not always appear to be reproducible, indicating that some parameters which were not controlled must play important roles. A summary can be found in table 2.

Table 2. Summary of Formulation Approach 2

Grain Designation	A	B	C	D	E	CB1	CB2	binder	dens g/cc	pre-exponent a	exponent n
H	55	15						100	1.07	0.129	0.70
T	50	5		15				mxW	1.13	0.098	0.56
BB	55	10		5			0.2	nW	1.09	0.091	0.50
V	50	5		15		0.2		nW	1.09	0.097	0.48
HV	50	5		15		0.2		nW	1.13	0.084	0.455
Y	50	5		15			0.2	nW	1.10	0.073	0.32
LL	50	7.5		12.5			0.2	nWg	1.14	0.106	0.52
NN	50	8.5		11.5			0.2	nWg	1.14	0.096	0.52
EE	50	10		10		0.2		nW	1.12	0.094	0.49
GG	50	10		10			0.2	nW	1.12	0.102	0.54
HH	50	10		10			0.2	nWg	1.13	0.090	0.47
W	45	10		15			0.2	nW	1.09	0.093	0.47
X	45	10		15		0.2		nW	1.10	0.096	0.48
JX	45	10		15		0.2		nW	1.13	0.115	0.55
IIa	40	15		15		0.2		nW	1.12	0.091	0.44
UU	8.7	49.8		1.3			0.2	nWg	0.99	0.124	0.59

One parameter varied in this group was the carbon black type and content. Two different types were examined as indicated in the section on selection of candidate fillers. Thermax (CB2) processed better than Elftex (CB1) and was ultimately used more frequently as well as for scale up. Sometimes when compared in the same formulation such as W and X, results were similar. Other times, such as in V, HV, and Y, or EE and GG, the results were quite different. There is currently no good explanation for the variance.

The goal was to obtain an exponent in the range of 0.50 to 0.53 in formulations containing carbon black, which was achieved by formulations BB, LL, and NN. The general approach was to use as much of additive A as possible to increase the density and regression rate while varying the content of additives B and D to tailor the exponent. Densities of up to 1.14 g/cc were obtained in this group. The goal exponent of 0.50 was clearly bracketed, with half of the formulations exhibiting an exponent below it. About half of the formulations were within +/-0.03 of the 0.50, indicating that the goal is definitely attainable. It should be possible to produce the desired exponent very accurately, since variations on the order of 1.0% of the exponent tailoring ingredients produce only slight variations in exponent.

It was during testing of this series that the final binder formulation was selected, and binder variations may have contributed to variations in ballistics to an extent greater than anticipated. Desmodur W reacts with moisture in the mix only very slowly to produce carbon dioxide gas. Some bubbles are formed after the polymer is significantly crosslinked, and then become trapped, leaving voids. As Desmodur N-100 reacts faster with water and releases bubbles before viscosity builds, it was formulated into the curative system to reduce void formation. The source of the moisture is the hexamine, which is polar and appears to hold a small amount of moisture despite attempts to dry it and keep it dry. The mixed curative is designated nW in table 2. Later glycerol was added for additional crosslinking in place of Voranol 230-660. This binder is designated nWg.

The last effort within this approach was to examine the effect of relatively small amounts of additives A and D in combination with additive B as the major component This was done in formulation UU. In this case a higher regression rate was achieved with the use of only a small amount of the amine additives, although the density of the fuel is relatively low at 1.01 g/cc. The higher exponent obtained in this one test can probably be reduced by formulating with a different ratio of the additives A and D. A processing advantage of lower amounts of additive A is a longer pot life.

One characteristic of motor performance of all these formulations (except UU) was a large variation in axial regression rate. That is, the weight losses from different segments within a given motor were significantly different. As a result, alternative formulations which had more uniform axial regression rates were examined in greater detail and ultimately selected for scale up. Formulation UU, which was examined late in the program after scaling up a denser composition from Approach 4, exhibits more uniform axial regression, comparable to the formulation scaled up.

The regression rate performance of several of the formulations with exponents close to 0.50 are plotted in figure 2. It can be seen that the rates are similar to that of the advanced formulation chosen for scale-up, and many are slightly higher. However, since the densities in this approach tend to be lower, the net result during motor firing is similar mass flows to those observed with the advanced formulation.

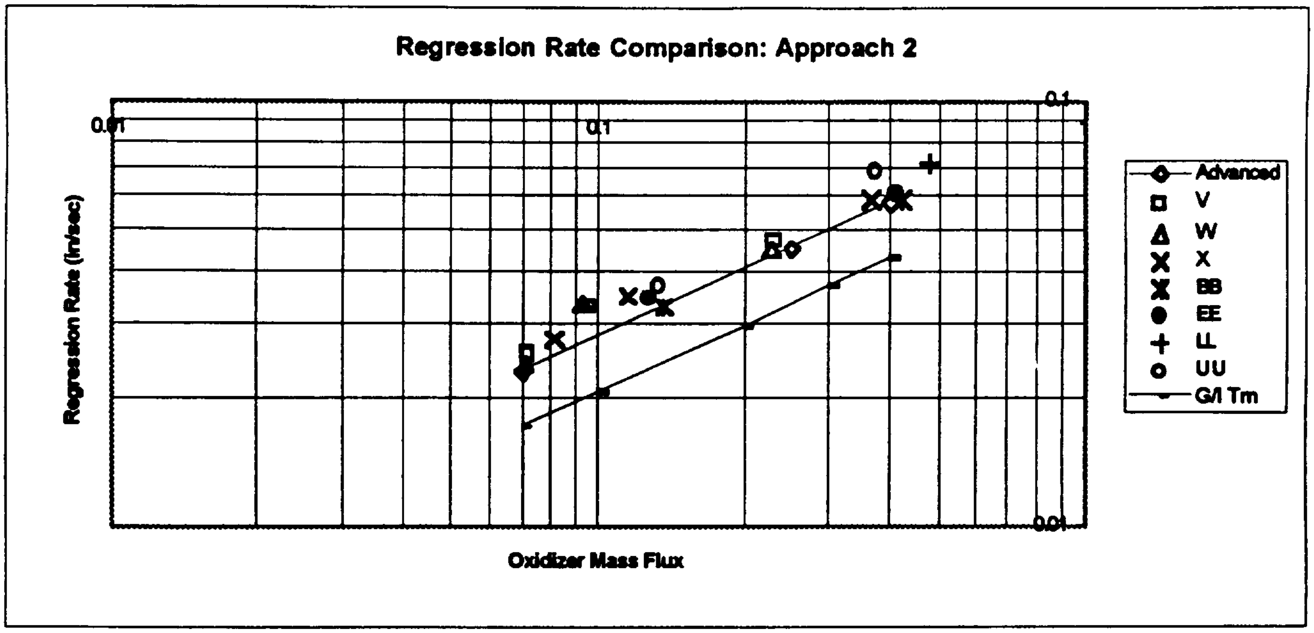

Figure 2. Regression performance of selected formulations in Approach 2 compared to scaled up formulation (Advanced) from Approach 4 and G/I Team formulation.

This approach performed nearly as well as Approach 4, which was ultimately selected for scale up. Less desirable characteristics of this approach included the need to grind the Escorez, the cost of the Escorez, the somewhat less uniform regression behavior, frequently observed as pocketing of the fuel surface after motor firing, and the lower density.

Formulation Approach 3

This approach emphasized the use of additive E or polyacrylonitrile, frequently referred to as PAN. This material was selected for examination as it is known to form a char via an exothermic reaction. Therefore, there should be more energy available at the fuel surface to assist in release of material from the surface, potentially boosting the regression rate. However, offsetting the favorable energy release is the fact that the char formed is physically tough, known for its strength in carbon fibers. If char were to stay on the surface and block either convective or radiative heat transfer to the surface, the effect on the regression rate would be negative.

The polyacrylonitrile was purchased from Aldrich Chemical. Their catalog does not provide any choice as to molecular weight; the density is listed as 1.18 g/cc. The first attempts to use this material during IRAD studies indicated that it is slightly soluble in HTPB and increased the viscosity significantly. It was concluded that only moderate loadings could be utilized and that the total solids content would be limited. A summary of activity within this approach can be found in table 3.

The first processible mix was designated K, and contained 52% additive A and 10% additive E. Motor testing produced an exponent of 0.55. However, the pre-exponent was the lowest in the program (for expressions with exponents around 0.5), indicating that a significant effect of this level of this additive was a reduction in the regression rate.

Table 3. Summary of Formulation Approach 3

Grain Designation	A	B	C	D	E	CB1	CB2	binder	dens g/cc	pre-exponent a	exponent n
K	52				10			100	1.04	0.084	0.55
U	50	17			3			nW	1.06	0.10	0.57
Z	50	10		9	1	0.2		nW	1.08	0.067	0.28
CC	55	14			1		0.2	nW	1.07	0.167	0.84
FF	55	10		4	1	0.2		nW	1.08	0.094	0.48

Subsequent mixes used much lower amounts of additive E. Formulation U contained a combination of only 3% E with 17% B and 50% A, bringing the total filler loading back up to the standard 70%. Motor firing results showed a lowering of the regression rate at the low OMF test condition which caused the exponent for this formulation to rise to 0.58. The next variation, formulation Z, examined the effect of combining 1% E with the basic GG formulation , (50% A, 10% B, and 10% D, which exhibited an exponent a little higher than 0.5), replacing 1% D with 1% E. This raised the regression rate at the low OMF test condition while having minimal effect at the higher oxidizer mass flux. Another factor was inclusion of carbon black in the Z formulation, whereas the previous two did not contain it.

The next iteration examined the effect of modifying formulation H (55% A and 15% B) with 1% E replacing 1% B. This raised the regression rate at the high OMF test condition while having no effect on the regression rate at the lower OMF test condition, opposite to the effect seen in formulation Z. The final formulation examined in this series was designated FF and is a variation of formulation BB (55% A, 10% B, and 5% D) in which 1% D is replaced with 1% E. This is similar to the relationship of formulations Z and EE, and the ballistic effect of the change was similar. That is, the low OMF regression rate was raised. However, in this instance, the high OMF regression rate was also raised a little. The regression rate results are tabulated in table 3 and shown graphically in figure 3.

This approach was discontinued in favor of Approach 4 for several reasons. These included 1) additive E is not offered commercially in quantity, 2) additive E does not process as well, 3) high loadings of additive E produced regression rate inhibition, and 4) ballistic effects of low loadings of additive E appeared somewhat inconsistent.

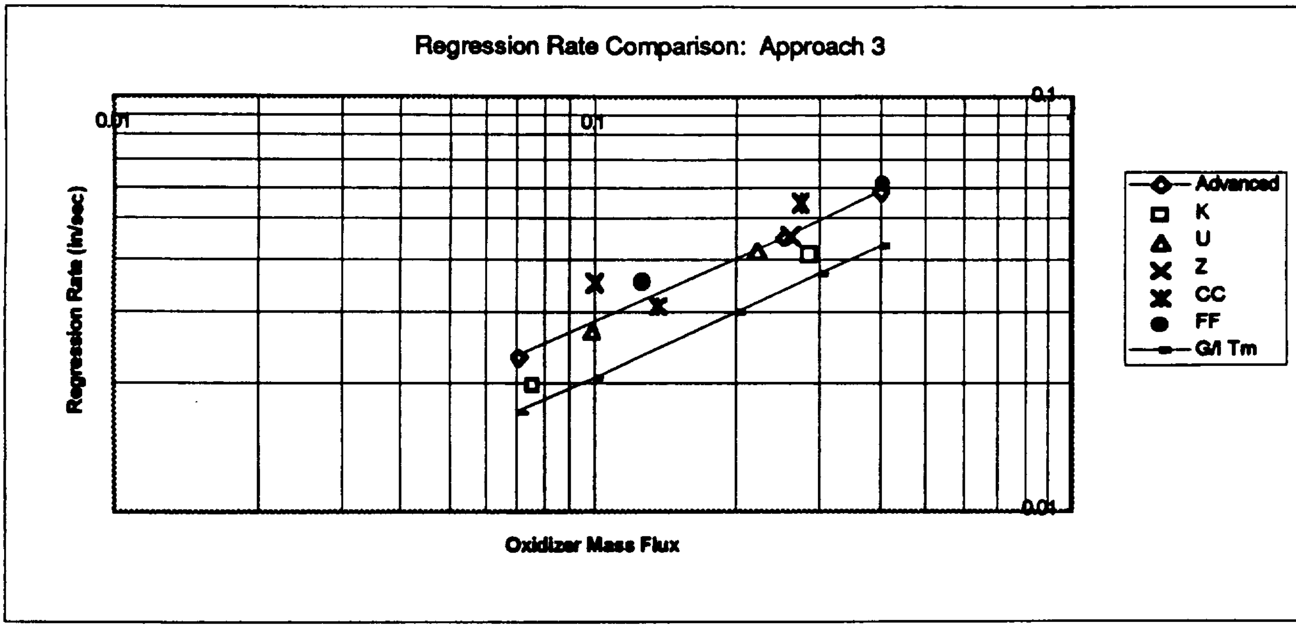

Figure 3. Regression performance of the fuel formulations in Approach 3 compared to scaled up formulation (Advanced) from Approach 4 as well as the G/I Team formulation.

Formulation Approach 4

This approach emphasized the use of two amines, additives A and D with no other additives except carbon black. It was initiated in the middle of the program when it was determined that additive D was the most effective at modifying the exponent. Since the density of additive D is relatively high, this increases the density of the fuel. Additive D is an aromatic amine. It is known to do more than one thing on being heated. Part of it vaporizes; another part forms a low molecular weight, weak char. The results of Approach 2 indicated that the desired exponent was obtained when the formulation contained around 10 to 15% D. Accordingly the first formulation examined here contained 55% A and 15% D and was designated AA. A summary of activity in this approach is shown in table 4.

Table 4. Summary of Formulation Approach 4

Grain Designation	A	B	C	D	E	CB1	CB2	binder	dens g/cc	pre-exponent a	exponent n
AA	55			15			0.2	nW	1.13	0.078	0.46
KK	60			10			0.2	nWg	1.14	0.087	0.509
MM	61			9			0.2	nWg	1.135	0.091	0.54
OO	62			8			0.2	nWg	1.13	0.089	0.55
IU	25			35			2.0	nWg	1.13	0.103	0.555
PP	60			–			0.2	nWg	1.06	0.107	0.58

Motor firings of formulation AA produced an exponent of 0.46, and it was concluded that 15% D did significantly reduce the exponent. The pre-exponent was also relatively low at 0.078, and approaches 2 and 3 looked more favorable at the time. However, one interesting characteristic of the fired grains was that there was no residual char on those fired at the higher OMF. The grains looked as clean after firing as before firing. This is in contrast to the results in the other approaches or that obtained with the G/I Team formulation where char was always visible on the surface of the grain after a motor firing. There was some char left on the grains of approach 4 when fired at the lower OMF. It was a weak, dry char that could be relatively easily scraped off. The surfaces of the fired grains were also smooth. This was in contrast to the grains containing Escorez which consistently exhibited pocketing of the surface.

The next composition evaluated in this series was formulation KK, which contained 60% additive A and 10% additive D. In this case the exponent calculated to be 0.509 with a pre-exponent of 0.0875, based on four motor firings. This looked very promising as this was basically the goal exponent. These grains also all exhibited smooth surfaces after firing. In order to obtain data on tailoring the exponent using this approach, formulations with only 1% difference in additive D content were examined. Formulation MM contained 9% additive D, and formulation OO contained 8% additive D. As can be seen in table 4, this caused a general increase in the exponent as anticipated. Formulation MM was subsequently chosen for scale up testing as its regression rate exponent most closely matched that of the G/I Team fuel formulation, and the fuel surface regressed very evenly.

By extrapolation of the series of AA through OO, it appears that the greater the additive D content, the lower regression rate, as both the exponent and pre-exponent are functions of the additive D content. The logical extension appeared to be a mix containing additive D only. However, quick attempts to do that with the nWg binder failed to cure. Formulation IU was a compromise, with more than twice as much additive D as any previous combination. It did cure in binder nWg. It was formulated to go in the head end of the 11-inch motor, as a 3/4 in. thick, thin web of fuel which correlated in previous G/I Team tests with reduced pressure oscillations compared to a bare silica phenolic head end insulator. The total solids was reduced to 60% to facilitate casting, as 70% was too stiff while 60% cast smoothly. The carbon black level was increased to increase the optical density of the fuel and to reduce radiation penetration into the fuel. It was labscale motor tested for ballistic properties only at the end of the program, after the 11-inch motor tests.

The head end insulator containing the thin web of formulation IU was used in two 11-inch motor firings. Each time it lost just a little weight and emerged in good condition. When formulation IU was tested in labscale motor firings, it was a surprise to learn that the regression parameters were very similar to those of the OO formulation, since it was anticipated that it would have a lower regression rate.

Formulation PP, containing only additive A at the 60% level, was tested to determine regression rate and exponent with no additive D. As expected, it exhibited a somewhat higher exponent than formulations containing additive D. Formulation N, containing 65% A and 5% D, was tested in one motor firing early in the program. It exhibited an anomalously low regression rate, which was probably due to variations in processing or binder. Representative results are shown in figure 4.

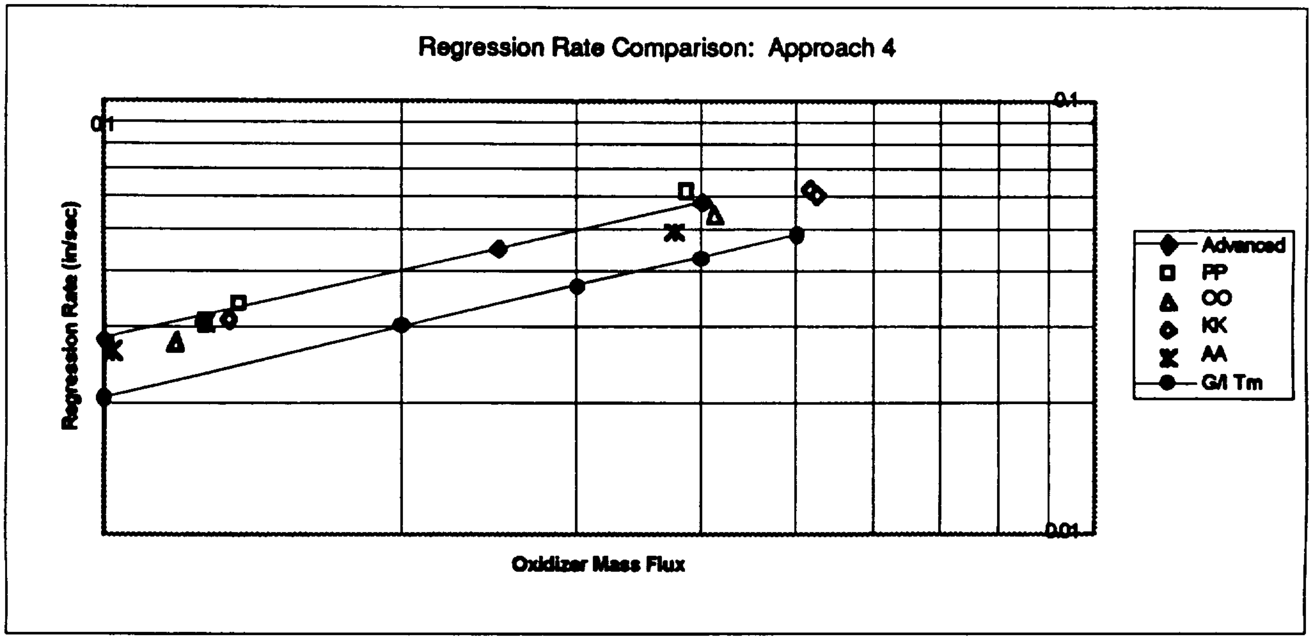

Figure 4. Regression performance of selected formulations in Approach 4 compared to the scaled up formulation (MM, called Advanced) from this group.

Combustion Stability

There are a number of factors which contribute to combustion stability. Injector location and geometry as well as motor chamber geometry are two that are well known. Motor chamber pressure traces during firing obtained in this study show that the fuel formulation can also affect both the frequency and amplitude of the pressure oscillations that occur during motor operation. Figure 5 shows the relatively low pressure oscillations observed during a low OMF firing of the formulation in this approach which exhibits an exponent of 0.5.

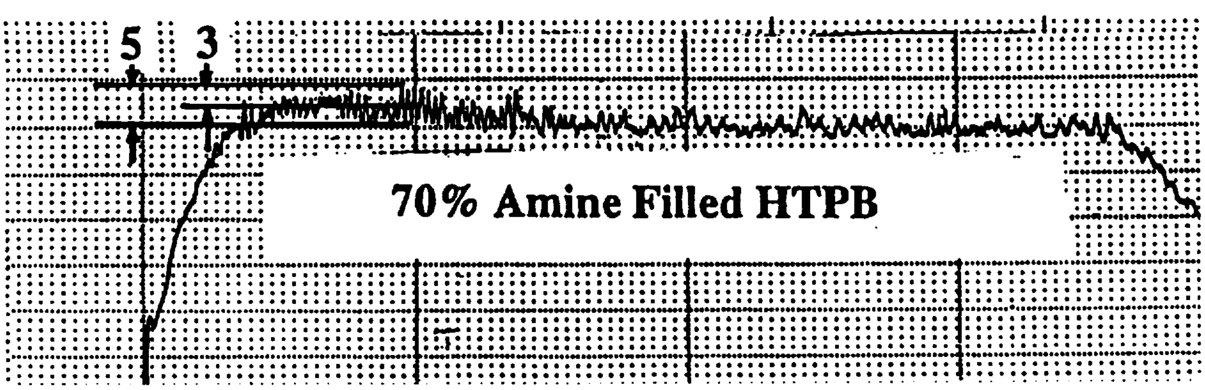

Figure 5. Motor Chamber Pressure Trace from the Advanced Fuel Formulation (KK, MSFC #49)

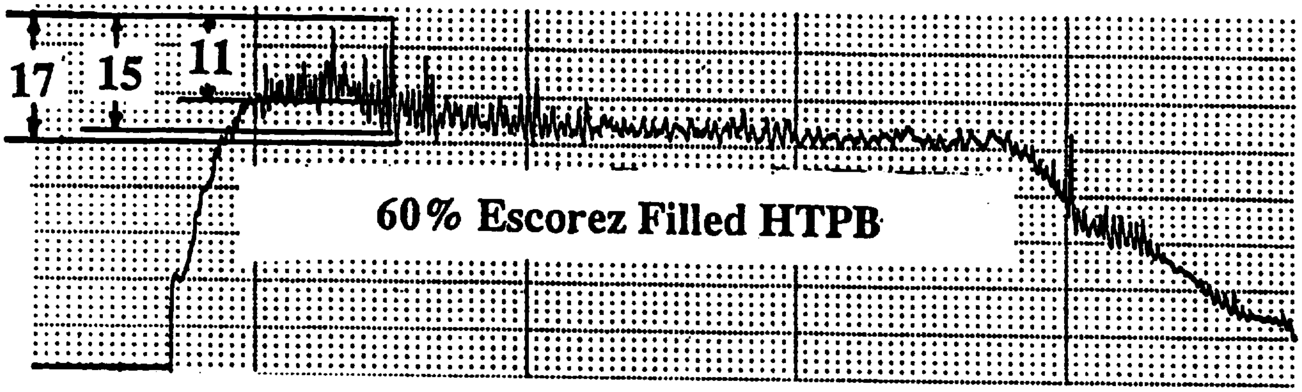

Figure 6. Motor Chamber Pressure Trace from the G/I Team Fuel Formulation (MSFC #50)

By comparison of figures 5 and 6 it can be seen that the pressure trace with the advanced fuel formulation is much smoother than that of the G/I Team fuel formulation. The numbers shown adjacent to the trace represent measurements of the size of the oscillations. Each measurement unit represents 14.74 psi. As a result, the peak-to-peak oscillation in the G/I Team formulation represents 250 psi, and the positive pressure spike represents 162 psi above the average chamber pressure. In contrast, the peak-to-peak variation in the advanced formulation represents only 74 psi, and the positive pressure spike is only 44 psi above the average chamber pressure. The net effect is that the pressure spike has been reduced 73%, enabling design of a lighter weight chamber, as the maximum pressure experienced by the chamber during motor operation is significantly lower. Labscale motor firings at higher OMF indicate that as the OMF goes up, the frequency of the oscillations tends to increase, while the amplititude stays about the same.

Chemical Composition and Heat of Formation for Scaled up Formulation

In order to perform accurate thermochemical analyses using NASA SP-273 to calculate specific impulse, characteristic velocity, and product distributions, it is important to have accurate input data.[8] As the compositions of the ingredients are well known and the cure reaction proceeds as an addition reaction, the initial composition is essentially the final composition, and can be easily calculated. Based on an MT composition (see Appendix A for exact composition), this works out to $C_{4.9762} H_{8.8549} N_{2.1819} O_{0.04969}$ for a 100 g fuel sample.

The heat of formation is the second critical value needed for input for the thermochemical analysis program. The heats of formation of HTPB prepolymer and crosslinked polymer binder system appear to be somewhat uncertain. MDA-HSV has the 1988 version of SPP which has an ingredients data base of some 342 chemical species.[9] These include CTPB (ID342) and HTPB (ID245). However, these appear to be prepolymer species and not cured species as they contain no nitrogen. Also, there appear to be some inconsistencies. The value listed for HTPB for heat of formation is negative and much lower than the heat of formation listed for CTPB which is positive at 11.7 kcal/100g. Inasmuch as carboxyl termination is more highly oxidized than hydroxyl termination, the relative energies appear to be reversed: the HTPB should be at a more positive heat of formation, not at a lower one. More significant is the omission of the curative and/or the heat of formation values for the cured binder, since the curative normally makes up on the order of 10% of the binder, and the cure reaction itself is somewhat exothermic.

To obtain data in this area, MDA-HSV made several bomb calorimetry runs on actual fuel formulations, burning them in high pressure oxygen atmospheres. In this case the heat released includes any effects of binder filler interactions. Some nitric acid was formed which was titrated, and its heat of formation was subtracted from the net heat released as part of the standard data reduction procedure. UAH made their bomb calorimeter available during a regularly scheduled lab. Using a bomb calorimeter, the average amount of heat released was 7855 cal/g of fuel, based on seven separate runs using different batches of fuel made on different days.

Using the relationship that the total heat available from complete combustion of carbon and hydrogen to carbon dioxide and water is equal to the heat of formation plus the heat of combustion, the heat of formation is equal to the total energy available less the heat of combustion. Then for 100g of fuel, heat of combustion is 4.9762 times 94.38 (heat of formation of carbon dioxide in kcal) plus 8.8549 times 34.19 (heat of formation of water divided by two to correspond to each hydrogen) less measured heat released or 785.5 kcal for 100 g. Since by convention these are both negative and the heat released is greater, the heat of formation of the fuel is a positive 13.1 kcal/100g. The contribution from the binder is 853 cal, or 2.843 kcal/100 g. Since one form of polybutadiene is listed as having a positive heat of formation of over 11 kcal, this value is possible and appears reasonable.

Eleven-Inch Motor

The supporting nozzles and silica phenolic insulation cylinders were made by Thiokol Corp., and the motors were loaded and unloaded by them as well. Thiokol also weighed the grains, took measurements on them, and reported the results.

The first 11-inch motor on this program contained only one segment with a three inch diameter port and utilized formulation RR, which had the standard filler ratio, but a slightly different binder system as shown in table 5. Later testing of small fuel grains in a labscale motor firing produced a regression rate of 0.0598 in/sec at an OMF of 0.4013 lb/(sec sq in.). Using an exponent of 0.54, this relationship requires a pre-exponent of 0.098.

Table 5. Compositions of 11-Inch Motor Fuel Grains

	R45M	R45 HT	anti-ox	sur-factant	gly-cerol	Des W	N-100	C Black	Hex-amine	Mel-amine
RR	27.39		0.28		0.11	1.97	0.26	0.2	61.0	9.0
MW		27.48	0.27			1.98	0.27	0.2	61.0	9.0
MT		27.31	0.28	0.28	0.10	1.79	0.24	0.2	61.0	9.0

The second 11-inch motor firing on this program consisted of three segments with four inch diameter ports. See Processing Section for rationale on selection of binder composition. The MW grain was placed in the center of this motor, flanked on both ends with MT grains. The MW formulation was later tested in a labscale motor firing and determined to exhibit a regression rate of 0.0469 in/sec at an OMF of 0.2347 lb/(sec sq in). Using an exponent of 0.54, this relationship requires a pre-exponent of 0.103. Data on both 11-inch motor firings are in Appendix C.

First firing, single grain, January 11, 1995

The fuel grain for the first 11-inch motor firing weighed 78.282 lbs prior to firing. The cartridge weighed about 17 lbs, leaving a net weight of 61 lbs for the fuel. The calculated density is 1.15 g/cc. Figure 7 is a picture of the firing.

Figure 7. First 11-Inch (Single Segment) Motor Test Firing

This motor was fired mid afternoon on a rainy day with a temperature approximately in the high fifties. The previous night had not been very cold, and the fuel grain temperature was probably in the fifties. The oxidizer mass flow for this firing averaged 1.06 lb/sec giving an initial OMF of 0.155 with flow initiated at 3.2 sec. Ignition occurred at 5.8 sec, and the pressure quickly rose to over 900 psi in 0.2 seconds as shown in figure 8. The higher than anticipated chamber pressure created an unchoked condition compared to the driving pressure of 1325 psi, and the chamber pressure then dropped to 883 psi at 6.4 sec. It subsequently rose back to 909 psi at 6.84 sec and then dropped as the nozzle eroded. The action time was 11.4 seconds. The flame had a purple hue and showed Mach diamonds, which is generally indicative of complete combustion of the fuel, and within the testing conducted on this program had previously been associated only with high O/F ratios. The grain burned out very evenly from end to end, and the pressure trace showed only very minimal pressure oscillations, on the order of 10 psi. Compared to the chamber pressure of 900 psi, this is about 1% pressure fluctuation.

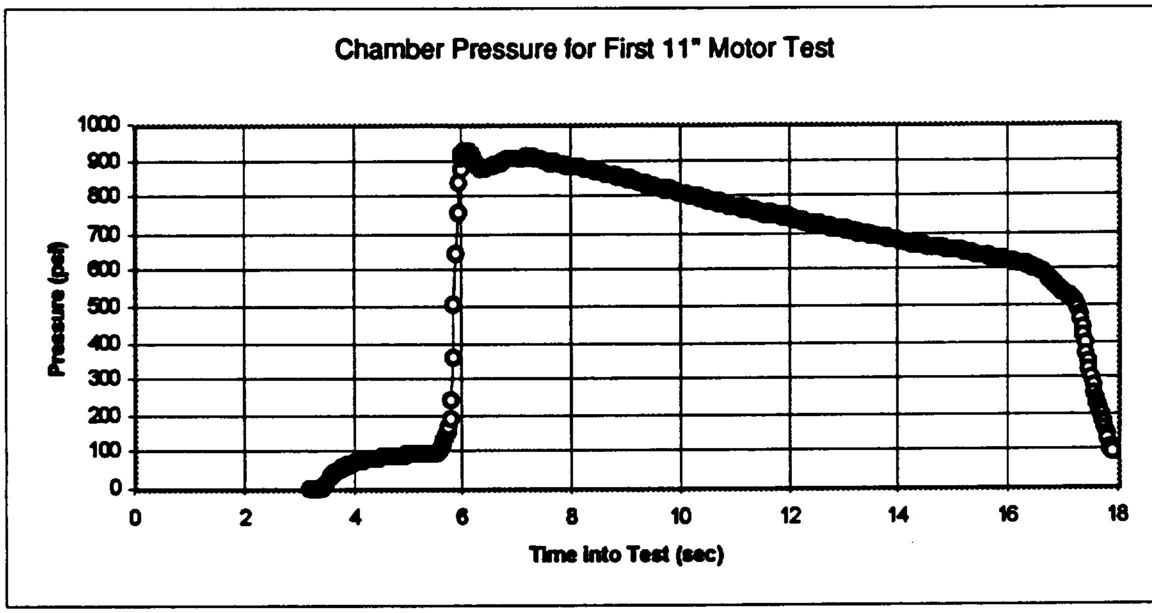

Figure 8. Chamber Pressure During First 11-Inch Motor Test

After firing the grain weighed 70.152 lbs. The net weight loss was 8.13 lbs. The head end insulator lost 0.215 lbs. Using the spreadsheet analysis (Appendix C), the initial regression rate was 0.54 in./sec., and the average regression rate was about 0.045 in/sec based on weight lost, density, and action time. This regression rate is consistent with the measured bore diameter after firing, which averaged around 3.93 in. Predicted average regression rate based on labscale firings and oxygen flow rate was about 0.035 in/sec. Actual regression rate was about 30% higher than predicted, and 100% higher than that of the Escorez based fuel. Calculated nozzle erosion was on the order of 7 mils/sec, in line with that seen at similar pressures on the MSFC G/I Team 11-inch motor testing. Combustion efficiency was approximately 99%, consistent with the high value reported by Thiokol on a G/I Team test at 770 psi.[2] Assuming an exponent of 0.53, the observed regression rate requires a pre-exponent of 0.144.

The binder for this formulation utilized R45M polymer and no surfactant, slight deviations from the lab scale formulations from which the baseline regression rate was derived. The labscale firing of this composition produced a slightly higher regression rate than the baseline MM compositions had, but was still well below the rate seen in this single segment motor.
The data for the labscale motor firings were reviewed, and it was noted that several positive deviations from calculated values have been obtained in this region of oxidizer mass flux, that is, around 0.1 to 0.15 lb/(sec sq in.). There may be something special at this OMF which causes a higher regression rate. Observations indicate more residual char on the fuel surface after a motor test, compared to the fact that there is none at high OMF.

Figure 9. Hybrid fuel extinguishment sequence at 1/3 second intervals

A desirable feature of a hybrid rocket fuel is that it extinguish cleanly and quickly after oxidizer shut off. The sequence of photographs shown in Figure 9 shows that the advanced fuel composition achieves this goal. One third of a second after a full size flame, there is no flame, and after two thirds of a second when the nitrogen purge has been turned on, there is only a little smoke.

Second firing, three grain configuration, January 18, 1995

This firing was performed about 2:30 in the afternoon. The air temperature was around 55° Fahrenheit. It had been much colder the previous night, and the grain had been exposed to the low temperature overnight. Consequently the grain temperature was probably in the forties. The oxygen flow rate was 7.0 lb/sec with an initial OMF of 0.546 lb/(sec sq in); the action time was 8.4 seconds. Ignition was smooth, and it burned fairly evenly with a much yellower flame than the previous firing, suggesting a lower combustion efficiency. It burned cleanly; no smoke could be seen during the burn as shown in figure 10. Mach diamonds were generally not visible,

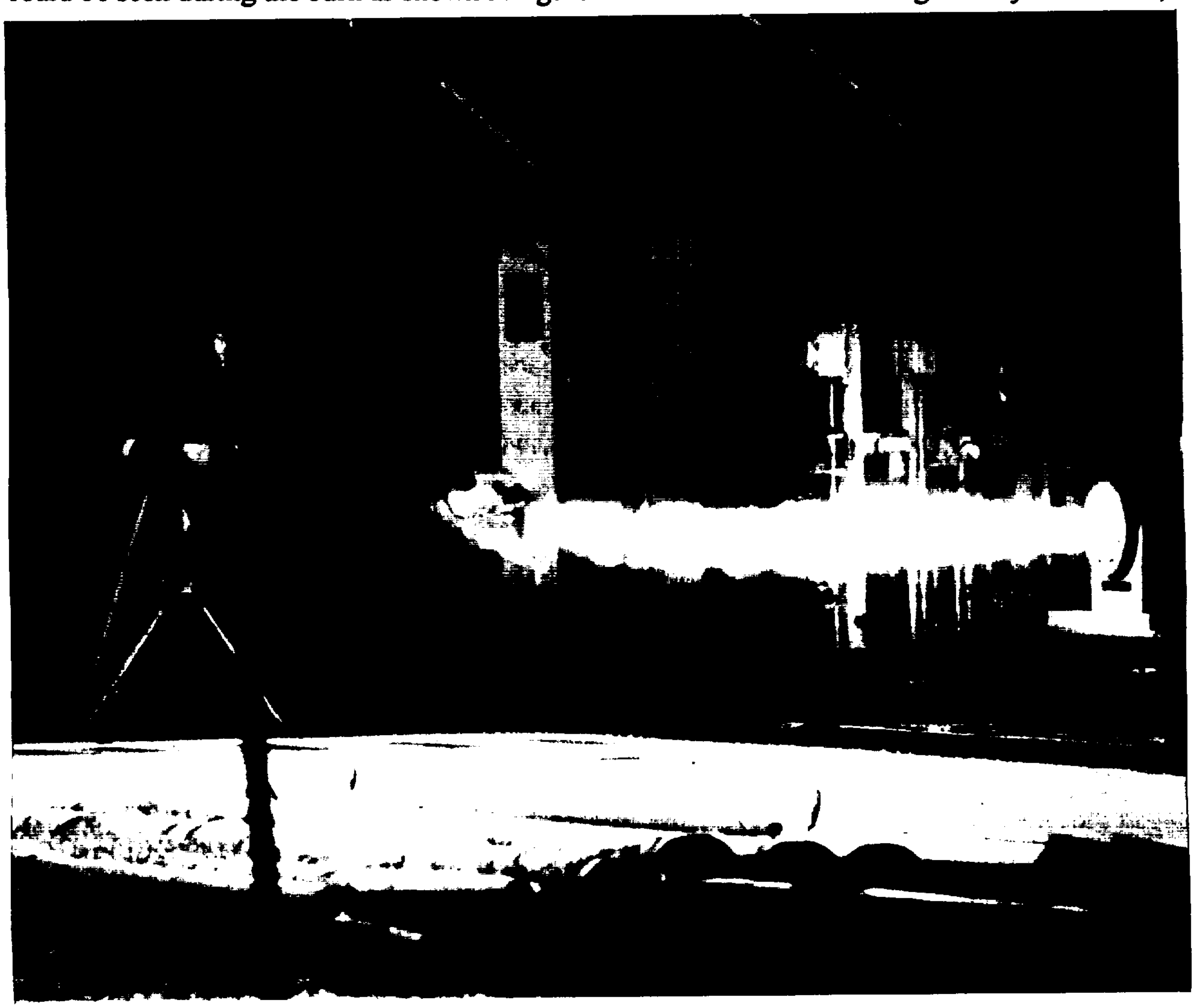

Figure 10. Second 11-Inch (Three Segment) motor Test Firing

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and the plume expanded to a much greater diameter than in the previous firing. This is due to a much larger nozzle diameter and a lower chamber pressure. As shown in figure 11, chamber pressure was initially about 480 and gradually dropped to 440 psi.

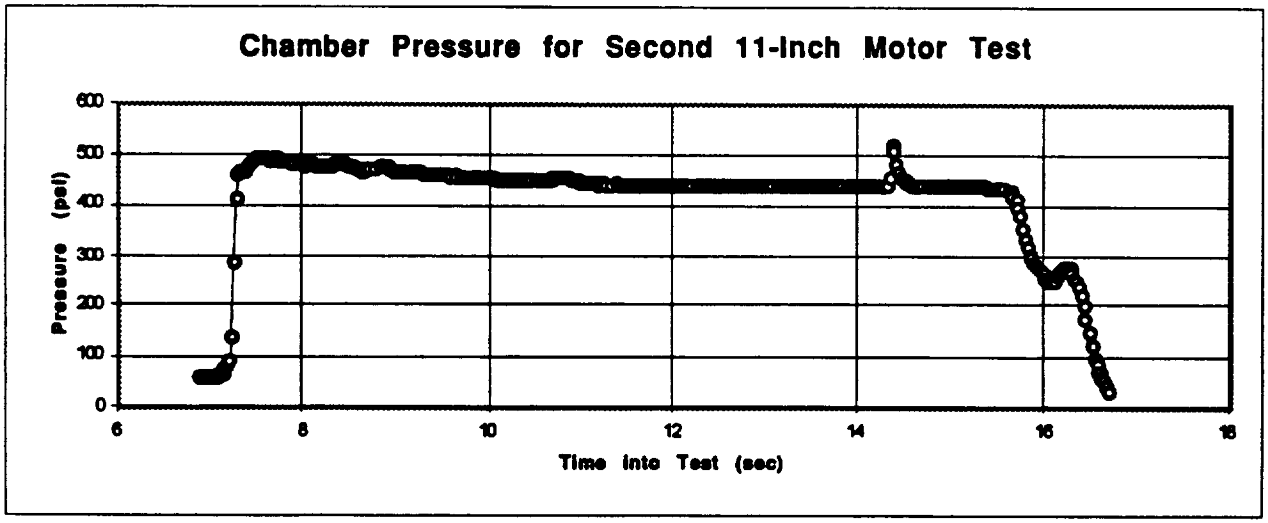

Figure 11. Chamber Pressure for Second 11-Inch Motor Test

There was a loud bang about seven seconds into the eight second firing, and a photograph showed that many glowing particles had been expelled. A spike can also be seen on the pressure trace, figure 11. Examination of the hardware after the firing indicated that the silica phenolic injector cover was lost during the firing, and the expelled fragments must have been due to disintegration of this cover. Fragments were recovered from the adjacent field after the firing. The nozzle also showed impact damage on the interior where it had been hit. Aside from the approximately 100 psi pressure spike which accompanied expulsion of the injector cover, the pressure trace was very smooth, with only 10 psi fluctuations.

According to this data reported by Thiokol which is shown in table 6, grains 3 and 4 lost very nearly the same weight, although the increase in bore diameter is different. The final weights were rechecked, and that of grain 4 is correct as measured, although the number for the larger bore would suggest a higher weight loss. Thiokol reported that the insides of all the fuel grains were smooth after firing. They were also free of char, although the head end insulator had lots of char on its surface after each firing.

Using the spreadsheet program to model the process in 0.1 sec intervals (Appendix C), the initial oxidizer mass flux is 0.546 lb/(sec sq in), and the initial regression rate is 0.076 in/sec with an O/F ratio of 1.75 (Appendix C). At 8.4 seconds (after ignition, essentially end of burn), the oxidizer mass flux is down to 0.34 lb/(sec sq inch), the regression rate is 0.059 in/sec, and the O/F is up to 1.77. To model this regression profile, the pre exponent must be 0.104 for an exponent of 0.53. The pre-exponent represents a 47% increase in regression rate over the basic Escorez based fuel.

Table 6. Eleven Inch Motor Grain Data from Thiokol.

Item	Wt. Before	Wt After	Wt loss	Dia Before	Dia After	Inc in radius
fwd grain, MDA #2	70.405 lbs	60.486 lbs	9.919 lbs	4.042 inches	5.04 inches	0.5025 inches
middle grain, MDA #3	70.400	58.984	11.416	4.035	5.163	0.564
aft grain, MDA #4	70.408	58.920	11.488	4.039	5.343	0.652
Totals or average	211.213	178.39	32.823	4.039	5.184	0.573
Insulator sleeve	10.050	9.188	0.862	6.428	6.715	0.1435

Combined with the increased density, the increased regression rate produces about a 70% increase in mass flow for the advanced fuel. To produce a chamber pressure from the spreadsheet program near 483 psi, a combustion efficiency of 0.95 is required. This is close to hybrid motor combustion efficiencies reported by Thiokol Corp. for the G/I Team testing.[1]

Section 7

MECHANICAL PROPERTIES

Mechanical properties are critical in solid propellants as cracks or large voids lead to burning of increased surface area during operation which in turn leads to higher pressures, and potentially to overpressurization. As a result, the criteria for acceptable mechanical properties is fairly well established as are routes to obtain them using HTPB binder systems. Although it is known that cracks are less critical in hybrid motors, it is still a good practice to make fuel with mechanical properties capable of withstanding thermal contraction and expansion during hot and/or cold storage. For these grains, especially the grains for the 11-inch motor which would be stored unheated in winter, the goal properties were stress of over 100 psi and strain of over 20%.

Mechanical properties were not optimized for the labscale grains. It was noted that the earliest grains were somewhat sticky, and the cure ratio was increased. Also, an additional cross linking material was added. After that, the labscale grains were crosslinked to stress levels well above 100 psi. They were never cooled significantly, and were never observed to crack.

When it was time to fabricate the grains for the 11-inch motor, more consideration was given to mechanical properties. As noted under Approach 4, new materials caused some initial difficulty in obtaining satisfactory processing parameters and mechanical properties, but these were over come as indicated in the Processing Section.

Mechanical Property Determinations

Cartons of fuel were cast (from the same mixes as went into the fuel grains tested in the 11-inch motor) and allowed to cure at room temperature for over a month. These were then cut into slabs on a guillotine at MICOM. Formulations cast in cartons included: RR (first 11-inch fuel grain), MTB (forward and aft grains in second 11-inch motor firing), MW (center grain in second 11-inch motor firing), and IU (insulation in the head end, used in both 11-inch motor firings). The slabs were then die cut using MICOM's die cutter into standard JANNAF dogbones, whose dimensions in the critical areas were measured.

The dogbones were pulled on the MSFC M&P Lab Instron, which automatically calculates stress based on the machine load and specimen dimensions which are input prior to each test. Strain was calculated as displacement divided by gage length, based on a gage length of 2.7 inches. The stress strain curves were plotted and lines drawn to determine the initial tangent modulus. Values for the initial tangent moduli were obtained via hand measurements from the plots. Data are shown in table 7.

Table 7. Advanced Fuel Mechanical Property Data

Mix Designation	Max Stress (psi)	Strain at Max Stress (%)	Initial Modulus (psi)
RR	169	32.0	710
MTB	95	31.8	446
MW	89	14.3	860
IU	141	52.1	296

Curative-to-polymer ratios (the most important contributor to mechanical properties with higher ratios producing higher stress capability) were selected on the basis of manual evaluation of small specimens cut from cure cups made from trial mixes. Normal testing machine mechanical property determinations were not made because equipment (guillotine, die cutters, and grips) was not readily available. Goal mechanical properties were: stress between 100 and 150 psi, strain greater than 20%, and modulus between 700 and 900. The results were obtained without any quantitative determination of mechanical properties prior to selection of a cure ratio, and demonstrate that a range of properties is readily attainable.

The RR mix was made with R45M prepolymer. It meets the stress and modulus goals with excellent strain. The modulus increases slightly after the initial value reported here. A disadvantage is the higher cost of the R45M prepolymer compared to R45HT. The significantly more expensive R45M prepolymer was used as an interim solution to a problem of how best to process the new lots of materials, including R45HT. (See Processing Section for discussion.) Since R45M costs over $4/lb compared to about $1.85 for R45HT, this increases the cost from about $0.99/lb to $1.65/lb. As keeping the raw materials cost low was a stated goal of this program, and since R45HT is used in a significant number of existing propellants and has been demonstrated to be an adequate alternative to R45M, it was used for the bulk of this program.

The MTB (MTB is simply a slight cure ratio variation of MT; MT is the new raw materials lot variation of MM with a much lower cure ratio) mix was made with R45HT prepolymer and includes surfactant. The modulus stays constant for a larger portion of the curve before it begins to decrease as shown in figure 12. The use of a higher cure ratio (more curative) would produce a higher stress and higher modulus. It was noted that the surface was somewhat sticky, although fuel grains made with this composition were machined with no trouble. Higher cure ratios were used in some of the later mixes for the fuel slabs.

The MW mix was made with R45HT prepolymer, but contained neither surfactant nor glycerol. Glycerol is a trifunctional additive which was used in most of the formulations to increase crosslinking. Leaving it out of formulation MW resulted in a greater number of voids in the carton, although the grain in the motor had the same weight and density as one of the grains made with the MTB formulation. The difference is probably due to the fact that the carton was cast after the motor when the mix was slightly more cured and did not flow as well to close voids. The voids in the carton specimens caused premature failures in the dogbones, resulting in low stress and low strain.

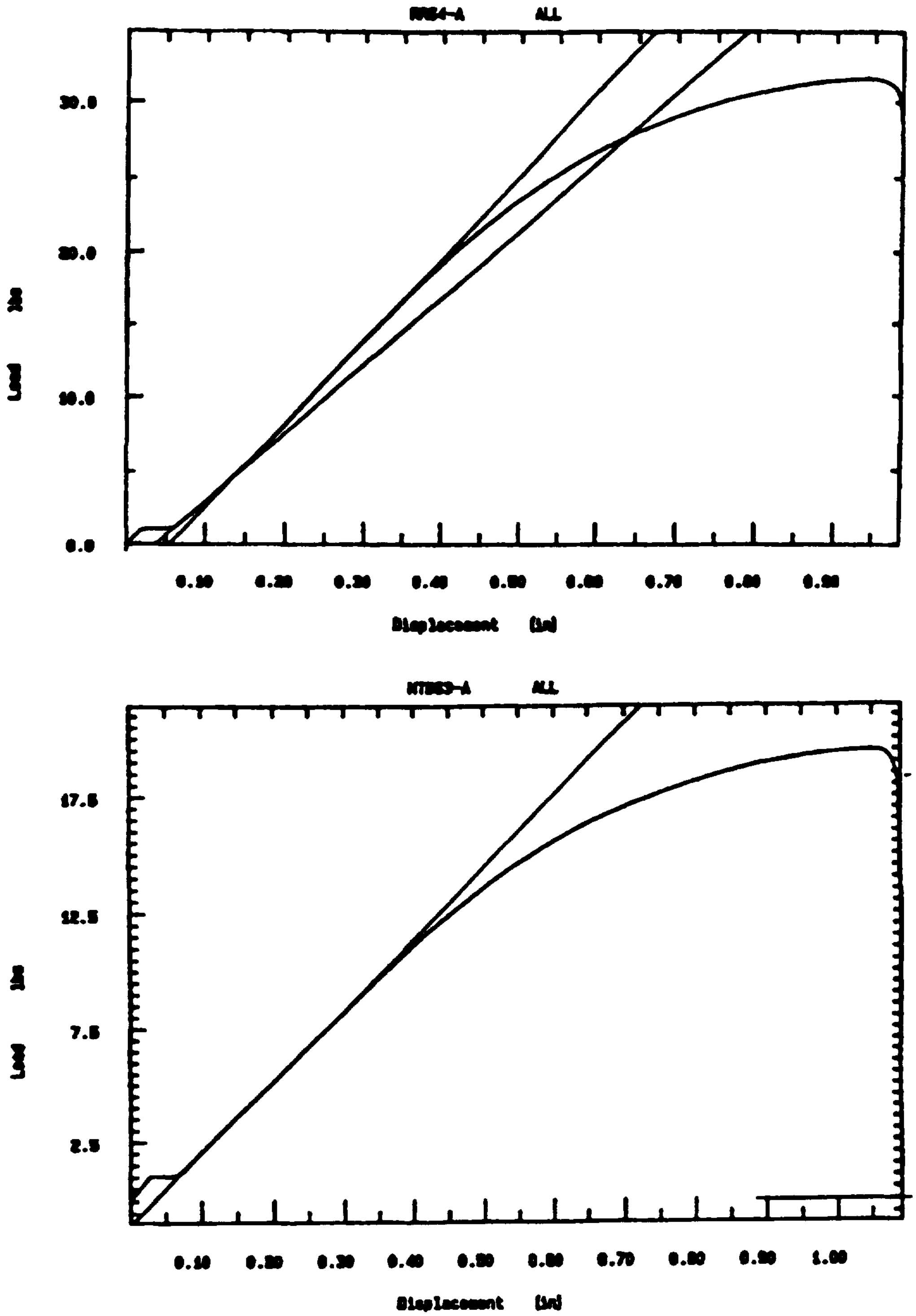

Figure 12. Stress-Strain Curves for Formulations RR and MTB

The IU mix used for the head end insulator was made with R45HT prepolymer and was only 60% filled, compared to the main fuel grain compositions which were 70% filled. It also contained more fine particle size filler. One result was a much higher ultimate strain capability. The shape of the initial portion of the stress strain curve was similar to that of Mix RR, namely starting with a lower modulus which increased with increasing strain. Perhaps the lower initial modulus is due in part to the absence of surfactant here also. The different particle size distribution could also be a factor.

The mechanical property test results indicate that the mechanical properties of this fuel are readily tailorable by varying the curative to polymer ratio and/or by using additional crosslinker (glycerol). In addition, the binder to filler interfaces appear well bonded as the stress strain curves gave no indication of dewetting (pulling of the binder away from the filler, where there is a break or knee in the curve). This means the fuel can absorb thermally induced strains without incurring damage.

As mentioned previously, the bulk of the labscale grains, with the exception of MW and RR formulations, generally were more highly crosslinked.

Section 8

PROCESSING

HTPB binder systems are processed at all the major propellant manufacturers in the country. One widely used propellant curative is IPDI because it reacts slowly and provides a long pot life. The standard procedure is to mix all the ingredients thoroughly, add the curative, mix it in, transport the mix bowl from the mixing building to the casting facility and cast. Casting of the entire contents of a "standard" size batch mix has been known to take up to 24 hours. A minimal pot life is on the order of six to eight hours.

The primary additive selected for this effort is hexamine. It is a tertiary amine, meaning that chemically it is a strong base. While it is a solid and is not soluble to any significant extent in the HTPB, it can still act as a catalyst for the cure reaction. As a result, the pot life of HTPB mixes containing hexamine was shorter than the classical six to eight hours, and was usually on the order of 10 to 15 minutes. This was enough time to cast 2 gallon (11 lb) mixes. However, the limited pot life requires development of a continuous mix process for large scale motors.

A major advantage of the hybrid fuel is that it is non energetic, and thus the mixing and casting can be done in areas which do no have to be remote, and can be close together. Based on readily available equipment in the chemical processing industry, a continuous mix procedure with a fairly short hold up time should be suitable for large scale production of this formulation.

Hybrid Fuel Mixing Procedure

Table 8. MTB Fuel Formulation, 5000g mix

Percent	Ingredient	Weight
27.32%	R45HT lot 408125	1366.05
0.27%	Cyanox 2246	13.65
0.27%	Surfynol 104	13.65
0.11%	glycerol	5.35
	above is premix; wt is	1398.70
0.24%	Desmodur N-100	11.95
1.79%	Desmodur W	89.35
30.00%	total binder	1500.00
60.80%	Hexamine	2890.00
9.00%	Melamine	450.00
0.20%	Thermax N-991	10.00
100.00%	total	5000.00

Figure 13. Additives pour easily

Figure 14. Fuel at end of mix

Mixes were made at 120°F. Polymer R45HT, Cyanox 2246, Surfynol 104, and glycerol were weighed into the bowl along with carbon black Thermax N-991. The bowl was heated via circulation of hot water, and these ingredients were vacuum mixed together for approximately 15 to 30 minutes. The curatives were weighed together into a weighing container and then transferred to the mix bowl. The binder containing carbon black was vacuum mixed for about 15 minutes at 120°F. The hexamine and melamine which had been stored under vacuum, were weighed, dry mixed together, and then added as shown in figure 13. All ingredients were mixed together for about 10 minutes and then the mix was cast. The mix ran easily off the blades as shown in figure 14, and cast readily as shown in figure 15.

Some typical viscosity curves are shown in figure 16. Significant variations in pot life were observed between different batches of hexamine and/or between different cure ratios. Formulations MT and MTB represent different lots of hexamine.

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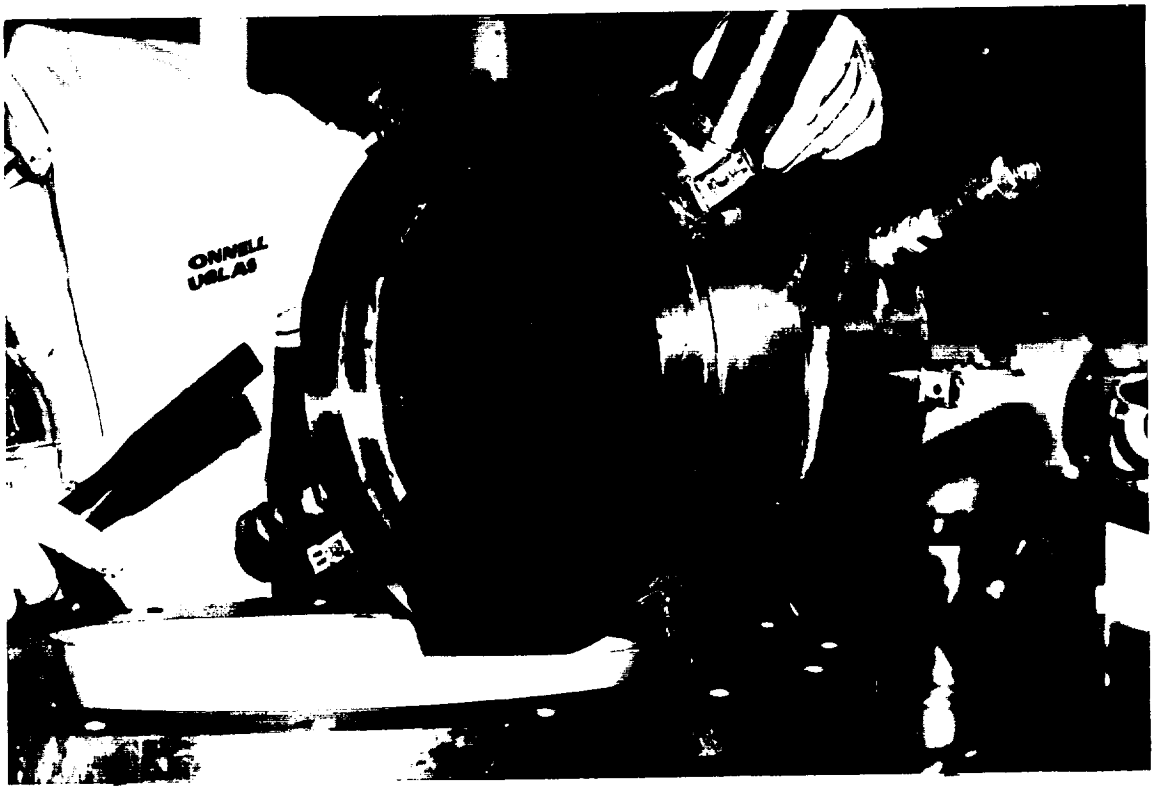

Figure 15. Casting Operation

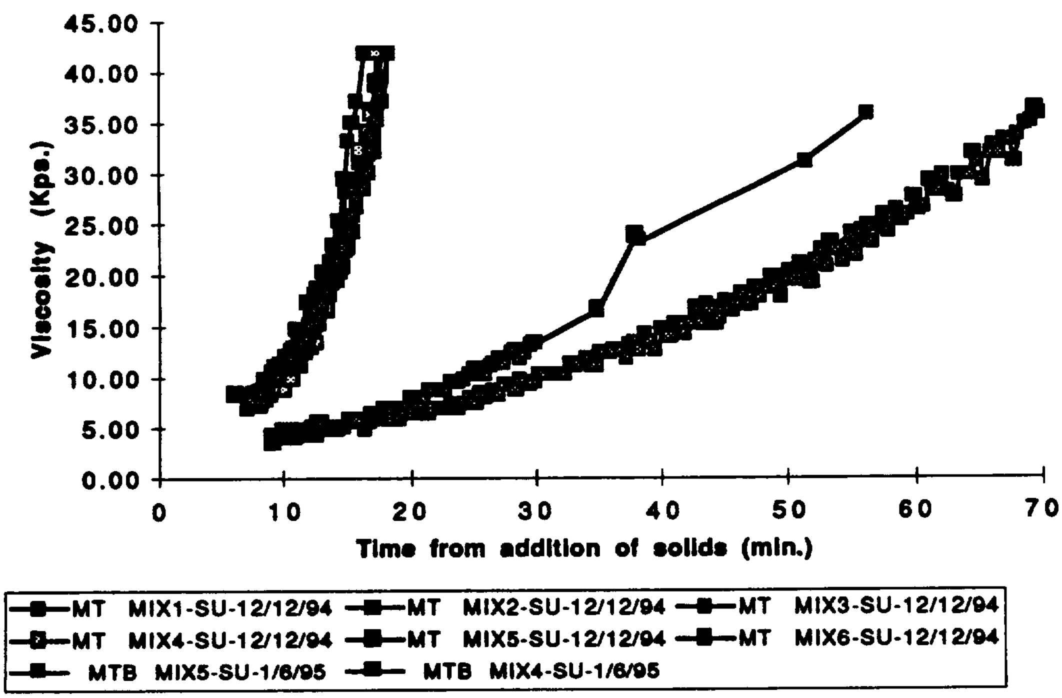

Figure 16. Representative Pot Life Curves for Advanced Fuel Formulation

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The fuel flows after casting as can be seen in figure 17 by the smooth surface of the curing fuel.

Figure 17. Hybrid fuel grain after casting

Scale Up Problems and Solutions

Formulation MM was chosen for scale-up. At time of scale-up, all new lots of materials were obtained in order to have sufficient quantities of the chosen materials for making the fuel grains for the 11-inch motor. The first mixes made with the standard recipes exhibited short pot lives. The cured fuel was very hard and exhibited very low strain capability. Clearly something was different, but since everything had changed, and most of the old materials were completely used up, it was difficult to determine what.

The approach to solving the problem was to replace some of the ingredients with available alternatives. It was determined that using a lot of R45M polymer increased pot life to an acceptable level. Also, it was found that by reducing the curative level, acceptable strain could be achieved. Seven two gallon mixes were made with R45M to fill a 37 in. long, 8 in. diameter cartridge with a 3 in. port. This single, 8 in. diameter grain was used in the first 11-inch motor firing on this program. The mechanical properties were stress of 169 psi, modulus of 710 psi, and strain of 32%. These are typical solid propellant properties.

Additional investigations on the materials revealed that a further reduction in cure ratio brought the pot life with R45HT into an acceptable range with acceptable strain in the cured fuel. In order to obtain these from the new lot of R45HT, it was determined that the cure ratio had to be lowered about 57% from that used in making most of the labscale motor fuel grains. Apparently the first lot of R45HT was the abnormal one, since other lots behave more like the second one used here. In the formulations with the original lot of R45HT, a trifunctional crosslinking agent was added to improve mechanical properties. The first 34 in. grain cast using the new R45HT utilized the standard binder ingredients with a lower cure ratio. This formulation was designated MT (a third letter, such as MTB, indicates a cure ratio variation). It contained the same fillers as the first 34 in. long grain. Subsequently it appeared that mixing could be simplified by removing the crosslinker and surfactant and raising the cure ratio. The binder portion of the second 34 in. grain made with the new R45HT contained neither surfactant nor trifunctional crosslinker although the filler portion remained the same. This formulation was designated MW. After removal of the mandrel, void formation was observed adjacent to the mandrel which had not happened with the MT formulation. Consequently, for the third grain in the set, the proven MT formulation was used to minimize void formation.

The mechanical properties of formulation MW were stress of 89 psi, modulus of 860 psi, and strain of 14%. The dogbones of formulation MW contained multiple small voids, unlike the other formulations tensile tested. The mechanical properties of formulation MT (which was not tested in a lab scale motor firing) were stress of 95 psi, modulus of 446 psi, and strain of 32%. This appears intuitively backwards, as the higher strain is obtained with a formulation containing a trifunctional crosslinker, but other differences include lower cure ratio as well as presence of surfactant in the higher strain formulation.

These fuel grains machined readily. The finished products are shown in Figure 18.

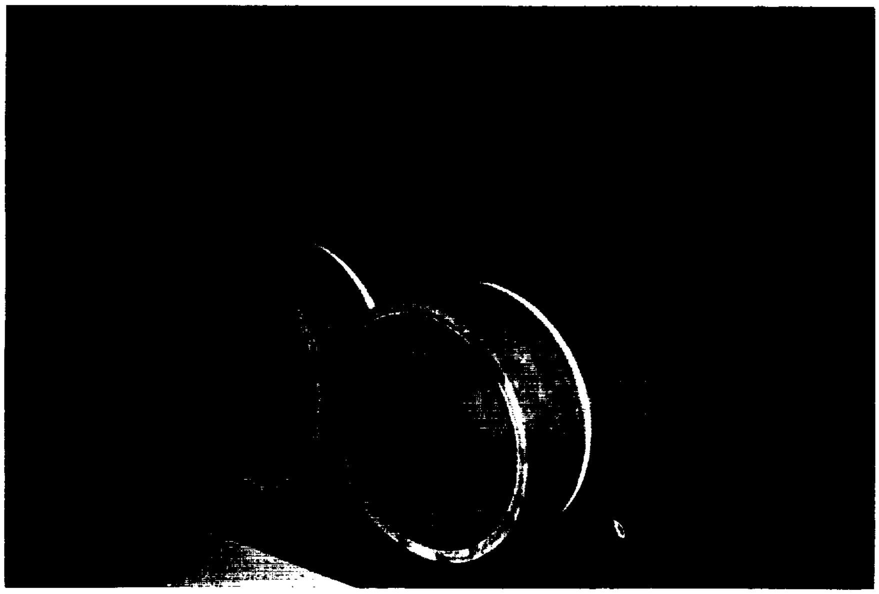

Figure 18. Hybrid fuel grains ready for placement in motor

Section 9

AGING

A detailed aging program is well beyond the scope of this program. However, hexamine does exhibit a small vapor pressure under ambient conditions, and fuel grains containing hexamine will exhibit some weight loss depending on the duration of storage, the temperature, and whether the grain is sealed or whether air is allowed to circulate freely over the surface. Based on some very rough measurements consisting of two data points taken about a month apart, it was estimated that a 61% hexamine content 34 in. fuel grain with a four inch diameter port, which was stored at ambient temperatures with the ends open, could lose on the order of 0.133% of its fuel weight per month. In all likelihood, weight losses could be reduced by sealing up a grain during storage, which is the normal storage condition. It is believed that other approaches could also be employed to reduce the vaporization rate, such as coating the surface of the grain with a reduced permeability coating.

Preliminary observations on small specimens of fuel aged open in a forced air oven indicated that the rate of vaporization of hexamine is higher at 150°F, and that this would be an unacceptable storage condition in the absence of something like a coating to reduce vaporization.

Section 10

THERMOCHEMICAL ANALYSES

The scaled up formulation from Approach 4 was analyzed using SPP.[10] The fuel composition is $C_{4.9762} H_{8.8549} N_{2.1819} O_{0.04969}$ for a 100 g fuel sample; the heats of formation (ΔH_f) used as input were those of the fillers plus that of HTPB, as these calculations were performed prior to experimental determination of the heat of formation. Different ΔH_f values cause the output values to vary slightly, but an 8 kcal difference in input for the fuel as a whole resulted in less than a 1% difference in calculated *Isp*. The HTPB ΔH_f used was -11.3 kcal/100g, which was chosen as a conservative value incorporating the effect of a saturated curative.

The main outputs of interest are specific impulse (*Isp*) and characteristic exhaust velocity (*C**) as functions of oxidizer-to-fuel ratio. Other input parameters which can be varied include oxidizer, chamber pressure, and expansion ratio. Results at one atmosphere will be different from those in vacuum with a higher expansion ratio. The only oxidizer considered on this program is oxygen. A chamber pressure of 500 psi was chosen as a reasonable compromise between high chamber pressure to obtain high *Isp* which requires higher motor case weight and oxidizer tank weight (assuming a pressurized system), compared to lower chamber pressures and vessel weights which produce lower *Isp*s. The primary emphasis of this program is a booster, but presumably a booster would fly from ground level to high altitude where the pressure is much lower. Accordingly, both sea level and vacuum results are reported in table 9. The vacuum *Isp* is based on an expansion ratio of 60. The performance of the Government/Industry Team formulation based on Escorez is shown for comparison in table 10.

Table 9. Characteristic Velocity (*C) and Specific Impulse (*Isp*) for Advanced Fuel Formulation from Approach 4 as a Function of Oxidizer-to-Fuel (O/F) Ratio**

O/F ratio	*C** in ft/sec	Sea Level *Isp* in sec	Vac *Isp* in sec
1	5415	247.3	307.3
1.2	5717	263.4	331.1
1.4	5841	272.5	346.5
1.6	5840	276.1	356.1
1.8	5782	275.2	360.1
1.9	5746	273.9	361.1
2.0	5708	272.3	360.4
2.4	5556	265.4	352.3
2.5	5521	263.7	350
2.8	5419	258.8	343.2
3.2	5298	252.8	334.3
3.6	5189	247.3	325.8
4.0	5091	242.3	317.5

Table 10. Characteristic Velocity (C^*) and Specific Impulse (Isp) for G/I Team Fuel Formulation as a Function of Oxidizer-to-Fuel (O/F) Ratio

O/F ratio	C^* in ft/sec	Sea Level *Isp* in sec	Vac *Isp* in sec
1.3	5241	238.6	294.3
1.6	5699	262.1	328.9
2	5888	276.2	353.2
2.2	5871	277.9	359.7
2.4	5824	277.1	363
2.5	5796	276.1	363.5
4	5380	256.9	341

These data are presented graphically in figures 19 and 20.

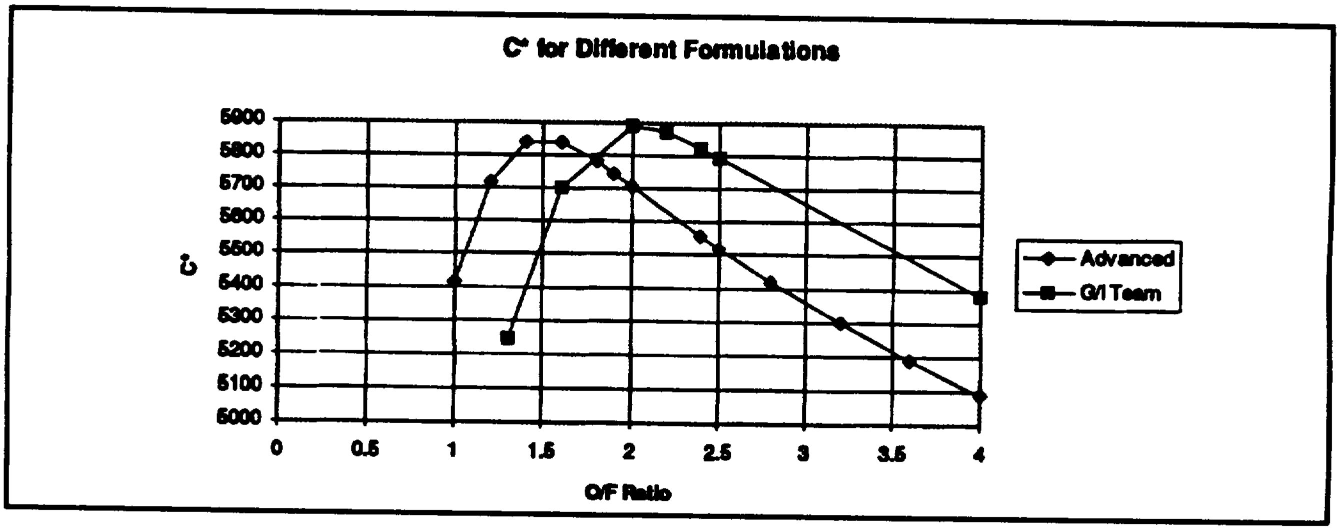

Figure 19. Characteristic Exhaust Velocity (C^*) for the Advanced Fuel Formulation and the G/I Team Formulation

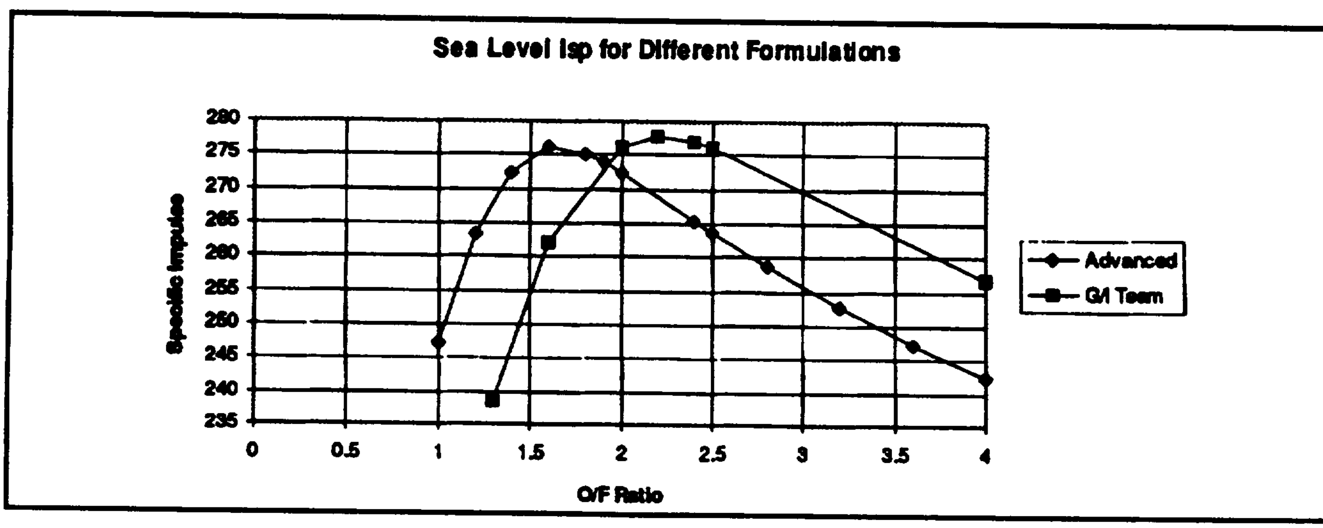

Figure 20. Sea Level Specific Impulse for the Advanced Fuel Formulation and the G/I Team Formulation

From figures 19 and 20 it can be seen that the values of *C** and *Isp* are similar for the advanced fuel formulation and for the G/I Team formulation, the biggest difference being that the maximum values for the advanced fuel occur at a much lower O/F ratio. The significance is that the improvements in density, regression rate, uniformity of regression rate, etc., have been achieved with almost no loss in *Isp*, with a simultaneous increase in the density *Isp* product.

Section 11

DISCUSSION

From the preceding it can be seen that as a result of changing the fuel composition, improvements have been made in fuel density, in tailorability of exponent in the regression rate expression, in the regression rate, in the uniformity of regression rate axially along the motor, in the amount of oxidizer required, and in combustion stability. At the same time, the ingredients cost less than those used in the G/I Team formulation. These items will each be discussed below in more detail.

Density

The improvement here is a result of using fillers with higher density. Aliphatic hydrocarbon fillers usually have densities close to 1.0 g/cc. In contrast, hexamine has a density of around 1.27 g/cc and melamine has a density of around 1.57 g/cc. By filling a binder with a density of 0.92 g/cc with 70 % of these materials, a density of 1.15 g/cc was obtained. This enables packing a given weight of fuel into a smaller container. In addition, when coupled with an increase in regression rate, it can be seen that the fuel mass flow is further increased since the mass flow is a product of regression rate and density.

The density of liquid oxygen is 1.135 g/cc. The G/I Team fuel with a density close to one was less dense than the oxidizer, and there was advantage from a density standpoint to use more oxidizer. Using the advanced fuel, however, the fuel density is greater than that of the oxidizer, and except for the need to have ports in the grain which increases the size of the combustion chamber, there is an advantage in increasing the amount of fuel relative to the amount of oxidizer.

Tailorability of the Exponent

With a regression rate expression exponent greater than 0.5, the O/F ratio tends to increase throughout the duration of the motor firing (at a constant oxidizer flow rate) because the rate of total fuel regression slowly decreases as the grain burns out. This is potentially accompanied by a decrease in thrust since the mass flow decreases, although it depends on the initial O/F ratio since if operating at an O/F ratio below maximum *Isp* initially, raising the ratio would also raise the *Isp*. The G/I Team formulation has an exponent of 0.53 to 0.54 and would exhibit such behavior. Although the advanced, scaled-up fuel formulation had a similar exponent by design, it is easy to change that exponent to exactly 0.5 by simply changing the ratio of the two amine additives. This is shown in the series AA to KK to MM to OO, which starts with an exponent below 0.5 and goes above it.

Even burnout, on which this analysis showing the increase in O/F at exponents above 0.5 is based, does not really exist. Therefore, it may be advantageous, based on actual motor firing results to aim for a slightly different exponent. This approach--varying the ratio of the two amine fillers --allows the fuel formulator and propulsion engineer to make those adjustments as needed.

It is not completely understood how melamine functions to alter the exponent. Melamine is sometimes sold as a "flame retardant" for some applications, probably due to its tendency to form a char. In fact, in the absence of a high flow rate of gas over the regressing surface, combustion tests on this fuel in ambient air show formation of a char layer which insulates the fuel beneath it and leads to self extinguishment. Observations of the surface of the fuel after a motor firing test show some residual, "dry" char at low oxidizer mass flux (<0.14 lb/(sec sq in.), and a clean surface at high oxidizer mass flux (>0.18 lb/(sec sq in.),. It is hypothesized that it is the char that in some way affects the exponent.

Regression Rate

Low regression rates drive a grain design to be either long and slender or to have multiple ports. As the regression rate is increased, the grain can either become shorter or contain fewer ports. Since the average density of the fuel is decreased by the number of ports, an increase in regression rate enables a decrease in the size and weight of the motor chamber and a resultant increase in system performance.

Correlations have been made to show that surface regression rate is a function of the heat delivered to the surface and is very strongly coupled to the oxidizer mass flux in hybrid motors.[7] Heat delivered by the gas is primarily via convection. However, radiation has also been reported to play a significant role, although its total contribution appears to be somewhat less than that of convection. Radiation can be either from the gases or particles suspended in the gas in the motor, and recent work has indicated that particulate radiation plays an important role.[3] Supporting evidence was obtained in tests here incorporating different loadings of carbon black into the fuel formulations. Carbon black loadings of 0.0, 0.2 and 2.0 percent were tested. While no systematic variation was performed within this program, the trend was an increasing regression rate with increasing carbon black content.

The increase in regression rate in the advanced fuel formulations is due primarily to replacing polymeric components--either crosslinked HTPB or Escorez-with molecular species which can be more easily vaporized. However, the chemical and physical processes that occur at the surface during combustion are complex. In the case of polymers or even some intermediate molecular weight materials, pyrolytic chemical reactions take place to produce low molecular weight gases as well as higher molecular weight chars. Pyrolysis reactions predominate in the binder and in polymeric fillers. There is no oxidation of the solid at the surface during steady state operation, since the rapid release of the gaseous molecules formed in the pyrolysis reaction effectively blows the oxidizer away from the surface.

As the fuel pyrolysis at the surface consists of chemical reactions, there are activation energies and alternative pathways leading to different products. Thus there are ways to influence rates and product distributions. Different fillers and even different curatives for the HTPB will have different reactions. Chen and Brill have shown that simply by changing the curative in crosslinked HTPB from TDI to DDI, the activation energy can be changed from 9.2 to 12.5 kcal/mole, and the regression rate can be changed from 0.14 to 0.20 mm/sec.[11]

Using hexamine as the sole filler was examined over a wide range of loadings. Some tests were run on MDA-HSV IRAD work, and some were conducted within this effort. At loadings of up to 50% hexamine in HTPB, the increase in regression rate appeared to be directly proportional to the hexamine loading. Fuel formulations with hexamine loadings above 50% appeared either to exhibit the same or lower regression rate, when hexamine was the only additive. However, when hexamine loadings above 50% were combined with other additives which produce char, the regression rate could be further increased. It is postulated that heat transfer from particulate radiation is responsible for the additional rate increase.

The mechanical integrity of char formed during motor operation appears to be significant. As noted in Formulation Approach 3, PAN was investigated as an additive which would produce char in an exothermic fashion. It was also known that the char would possess substantial mechanical strength. When a 10% loading of PAN was examined, the observed regression rate was significantly reduced, while the exponent was not.

There is some evidence to suggest that the degree of crosslinking of the HTPB binder also influences the regression rate. One test result on IRAD in which the binder contained significantly more glycerol for binder crosslinking exhibited a reduced regression rate. While the mechanical properties and crosslink density were not monitored for most of the labscale grains made and tested within this program there appear to be similar trends. The earliest grains made in this program were only lightly crosslinked and were very sticky. As noted in Formulation Approaches 1 and 2, the binder composition evolved during the program to something with more crosslinks and less surface tackiness. In fact, most of the labscale grains were fairly hard. When the MM series, using this hard, fairly highly crosslinked binder was tested in the labscale motor and the data was reduced, the pre-exponent obtained from a curve fitting routine was 0.093.

As noted under Approach 4, when this formulation was scaled up with new materials, the initial result gave a binder that was too hard, and the crosslink density was reduced by reducing the curative level. Mechanical property tests indicated that the stress level of fuel with the reduced curative level ranged from 89 psi (MW, center segment) to 95 psi (MTB, end segments). Firing of the second 11-inch motor containing these segments gave a regression rate which was consistent with a pre-exponent of 0.104. Firing of a labscale motor using grains made from the same mix gave a pre-exponent of 0.103, a very similar number. As the filler content was the same while the binder had changed, and as this is a significant change, the best explanation is the difference in the binder. Mix RR exhibited a higher stress of 169 psi. Labscale motor testing of this composition gave a regression rate consistent with a lower pre-exponent of 0.098.

Variation in Axial Regression Rate

All motor firings conducted on this program exhibited a variation in regression rate as a function of axial position. All labscale motor firings utilized four grains, and in every case these were individually weighed. This data is reported in Appendix B (pages 17-24). If the grains are numbered from one to four going from the head to the aft end, in general grain four lost the most weight, and the grain three lost the second most weight. There were two patterns in the head end grains. Sometimes the lowest weight loss was in head end, grain one, and sometimes it was in grain two. The results were fairly reproducible and were formulation dependent.

To enable a comparison to the existing data base, the G/I Team JIRAD data base on 11-inch motor tests was reviewed.[12] Weight losses were reported for each of three segments for eight tests over a range of OMF values. For analysis purposes, the weight loss in each segment was divided by the weight loss in the head end to generate weight loss ratios (dimensionless parameters) by segment within the motor. This data is plotted in figure 21. It can be seen that the aft end exhibits a higher regression rate when the OMF is greater than 0.385 lb/(sec sq in), and a lower regression rate when the OMF was equal to or less than 0.274 lb/(sec sq in). In the three tests where the OMF was above 0.6 lb/(sec sq in), the aft segment lost in excess of 60% **more** weight than did the head end segment. In contrast, at OMF below 0.20 lb/(sec sq in)., the aft end segment lost up to 43% **less** than did the head end segment.

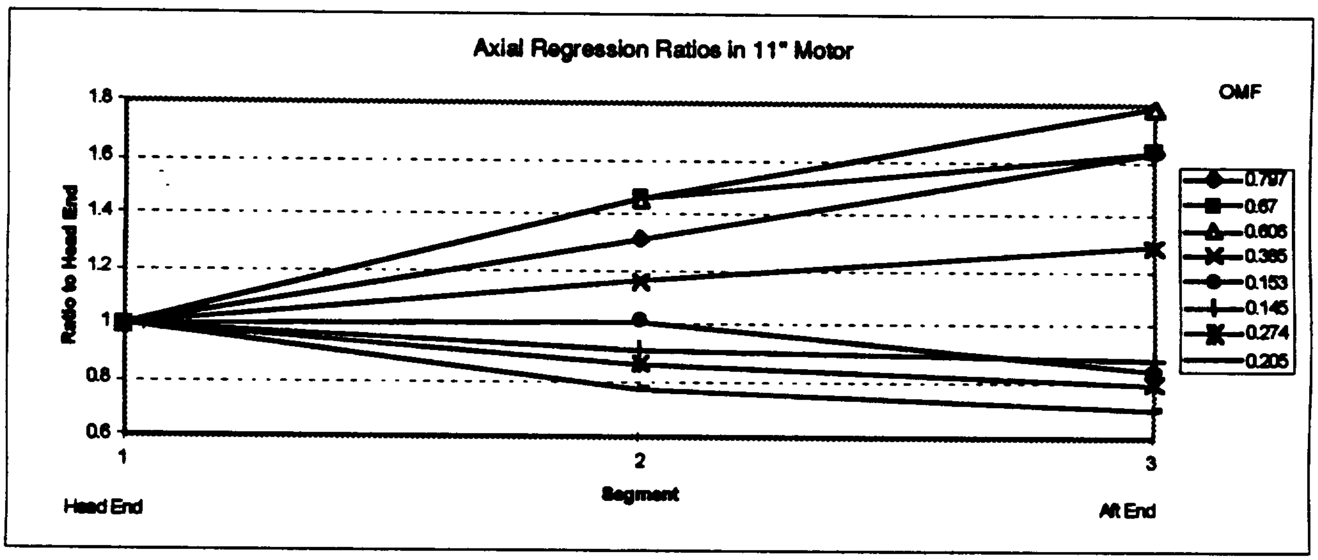

Figure 21. Variations in Axial Regression Rates Calculated as Segment Weight Loss Ratios for the G/I Team Formulation

The ratio of aft end weight loss compared to head end weight loss was then plotted as a function of OMF as shown in figure 22. It can be seen that the relationship appears linear to a first approximation with an intercept of 0.57 and a slope of 1.44. Using these relationships, weight losses representative of variation in axial regression rates at different OMF values can be more meaningfully compared. Of special interest is the OMF value at which the ratio is one, because this condition suggests a uniform axial regression rate. This analysis implies that a motor containing the G/I Team fuel operated at an OMF of 0.30 would exhibit uniform axial regression. A similar analysis based on the center segments instead of the aft end segments implies that uniform axial regression would be obtained at an OMF of 0.33.

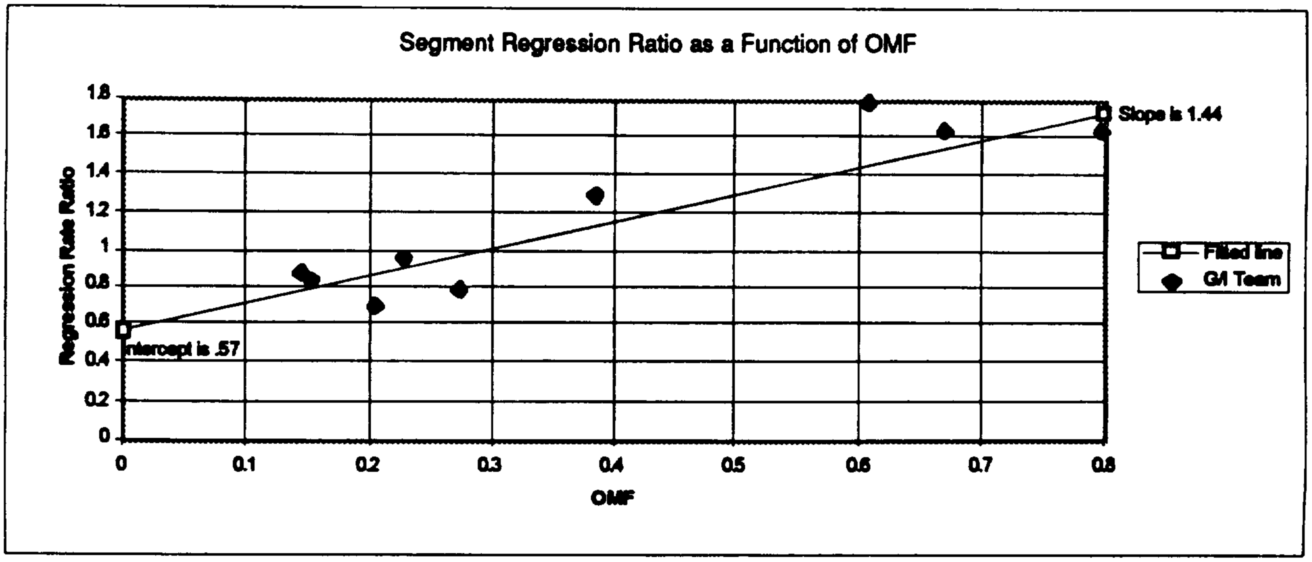

Figure 22. Regression Rate Ratios of Aft Segment to Head End Segment as a Function of OMF for the G/I Team Formulation in the 11-Inch Motor.

The similar ratio of weight loss in the aft end to that of the head end of the 11-inch motor was then calculated for the advanced fuel, resulting in a value of 1.16 at an OMF ratio of 0.546. This was then plotted for comparison to the G/I Team fuel and the line derived from it as shown in figure 23.

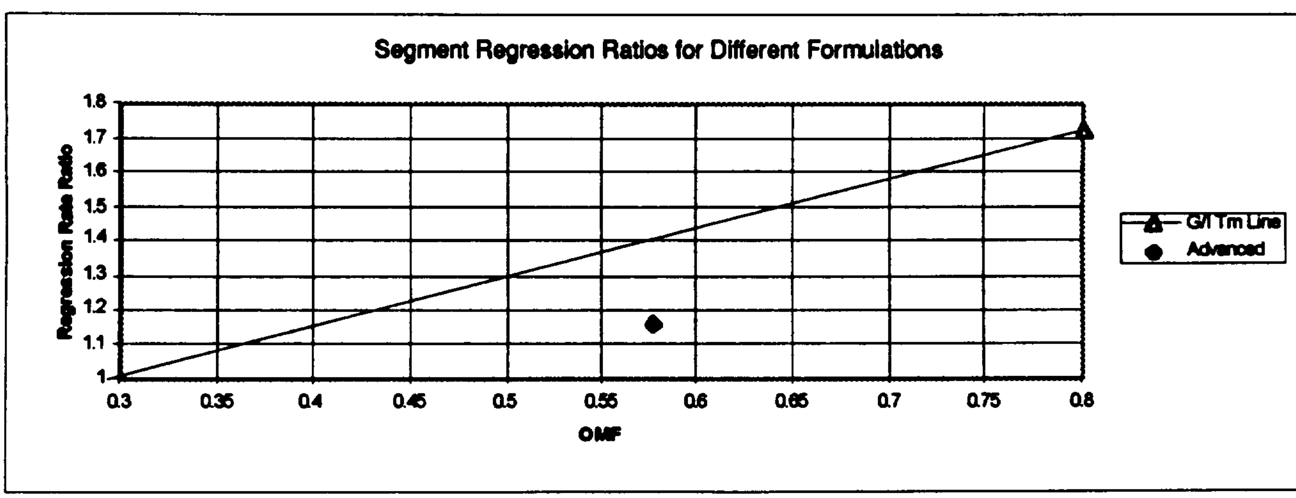

Figure 23. Regression Rate Ratios of Aft Segment to Head End Segment as a Function of OMF for the Advanced Formulation Compared to the G/I Team Formulation

From examination of figure 24 it can be seen that the axial variation in regression rate for the advanced formulation is much lower than that of the G/I Team formulation, as the point is well below the calculated line.

Since the variation in axial regression rate correlates with the OMF, it is postulated that when a higher regression rate is observed in the head end, it is at least partially due to a relatively long residence time there of oxygen, which becomes depleted due to formation of carbon monoxide and carbon dioxide as it moves down the bore, decreasing the downstream regression rate. Conversely, at high OMF more unreacted oxygen is able to penetrate toward the aft end of the grain where it can react to release heat. Transfer of this heat to the surface combined with the higher total mass flux in the aft end, contributes to a higher regression rate there.

The lower variation in axial regression rate observed with the advanced formulation is believed to be due to differences in activation energies of the alternative fillers. CFD models indicate an increasing temperature profile from the head end toward the aft end proceeding axially down the length of the grain.[13] The temperature increases toward the aft end of the grain. In general increasing the temperature increases the rate as Arrhenius theory predicts the rate to be proportional to $e^{-E_a/RT}$, where E_a is the activation energy for the reaction, R is the universal gas constant, and T is the temperature. For a given increase in temperature the rate will increase less for a smaller activation energy. The goal, in the approach to replace a polymeric filler with a monomeric one, is a reduction in the activation energy for "vaporization" from the surface. The reduction in variation of axial regression rate exhibited by the advanced fuel formulation is consistent with a net lower energy of activation for the "vaporization" process.

Amount of Oxidizer Required

The quantitative data for this topic was developed in the Thermochemical Analysis section. Since the amine fillers in the advanced fuel contain significant amounts of nitrogen, the nitrogen can be released during combustion as nitrogen gas. As nitrogen gas contains no oxygen, less oxygen is required for complete combustion of the basic fuel. It might appear that one effect would be significantly less heat evolved and a lower specific impulse, but the results of the thermochemical analysis show that there is only a very slight loss in Isp. This is because the primary filler, hexamine, has a favorable heat of formation, and because the average molecular weight is lower when nitrogen gas, molecular weight 28, is formed instead of carbon dioxide, molecular weight 44. The result is that a motor can be designed to operate at an O/F ratio of around 1.3 to 1.4 and still obtain high *Isp* and high thrust levels. This enables a smaller oxygen tank and a reduction in inert weight due to less pressurant, or a smaller pump, and smaller pipes.

Combustion Stability

The change in appearance of the pressure trace, in which an advanced formulation (Fig. 5) exhibited a reduction in both amplitude and frequency of pressure oscillations around the average chamber pressure compared to the G/I Team formulation (Fig. 6) suggests a net change in the overall mechanism of pyrolysis, decomposition, and vaporization.

It is known that the HTPB pyrolysis results in formation of some char.[7] During motor operation, the char is then torn from the surface in massive fragments compared to the smaller molecules which have formed and been vaporized. Once a piece of char flies off and becomes immersed in the oxygen rich gas stream, it is rapidly oxidized, producing a quick rise in the pressure. The pressure rise momentarily pushes the developing char more tightly into the surface and suppresses char release. Once the gas molecules formed from the combusted char exit the nozzle, the pressure drops, the newly formed char springs out and is torn off, and the cycle repeats.

The effect of replacing the HTPB with a filler which forms less char, decreases the amount of char that can be removed each cycle, thus decreasing the amplitude of the pressure spike. Since the action of tearing char off is probably due to an interaction between char and gas rushing over the surface, it is postulated that a certain minimum size of char must form prior to reaching a threshold of interaction with the gas passing over it. Due to a lower content of char forming material, it will take longer to form that minimum size and thus decrease the frequency of the pressure spikes. Consistent with this hypothesis is that the observed pressure oscillation frequency is higher at higher mass fluxes.

In the event that the char possesses high strength, it may stay in place for some time as the fuel surface recedes behind it. Once it sticks out a significant distance into the oxidizer rich gas stream, it may be oxidized in place. Should this occur, additional radiant energy will be transferred to the immediately adjacent fuel surface, and this adjacent fuel surface will exhibit an increased, localized regression rate. It is postulated that this is the cause of pocketing observed in the surface of fired fuel grains in formulations containing high loadings of polymeric hydrocarbon filler.

Costs

Raw Materials

One goal of this program was to lower costs. This has been accomplished for raw materials. All new formulations with estimated costs are listed in Appendix A. The G/I Team baseline formulation was probably established without regard for cost, since the curative is relatively expensive. The ingredients for that fuel cost about $2.25/lb. The crosslinked HTPB binder system for the advanced fuel developed here costs about $2.00/lb in 1994 dollars, when the price quotes were obtained. The most expensive component is the curative. At 30% of the fuel composition, the cost for the binder in the advanced fuel is on the order of $0.56 to 0.60/lb of fuel. The cost of the amine fillers is on the order of $0.55/lb. This would depend on volume. At 70% of the composition, the filler cost is about $0.39/lb of fuel. The total cost of the raw ingredients for the advanced fuel is then on the order of $1.00/lb.

Processing

All ingredients were used off the shelf, requiring no additional grinding. None are energetic and thus do not require special handling. Since the fillers wet easily in a relatively short time and do not cause a high shear condition requiring a high power mixer, the mix processing time is short and cost is minimal. The fairly short pot life would require a continuous mix and cast operation. There is a requirement for a vacuum for a part of the mix cycle as well as heating.

Section 12

FABRICATION OF SLAB BURNER SPECIMENS FOR THE PENNSYLVANIA STATE UNIVERSITY

Molds were provided by Penn State. The first ten slabs were cast from the end of the mold to minimize exposure of curing surfaces to moisture in the air during cure. It was learned that they had to be overcast and trimmed back. Starting with a net fill did not work due to cure shrinkage and degradation of surface fuel as a result of interaction with moisture in the air during cure.

The second ten slabs contained thermocouples, which were to be in a vertical position. To reduce mechanical loading on fragile thermocouples during casting, the second ten fuel slabs were cast via turning the mold "upside down" and removing the bottom, an action which positioned the thermocouples pointing straight up during casting. Professor Kuo had suggested this procedure. Fuel was poured on both sides of the fragile thermocouples and permitted to converge on the thermocouples simultaneously from opposite sides. It worked. All thermocouples tested positively to continuity checks after the slabs had cured. To minimize effect of moisture on curing fuel, these were overcast, and the excess trimmed back after the slab had cured. After trimming, some small voids were noted. Those on the lower edge of the slab were filled prior to shipment. A thermocoupled slab is shown in figure 24.

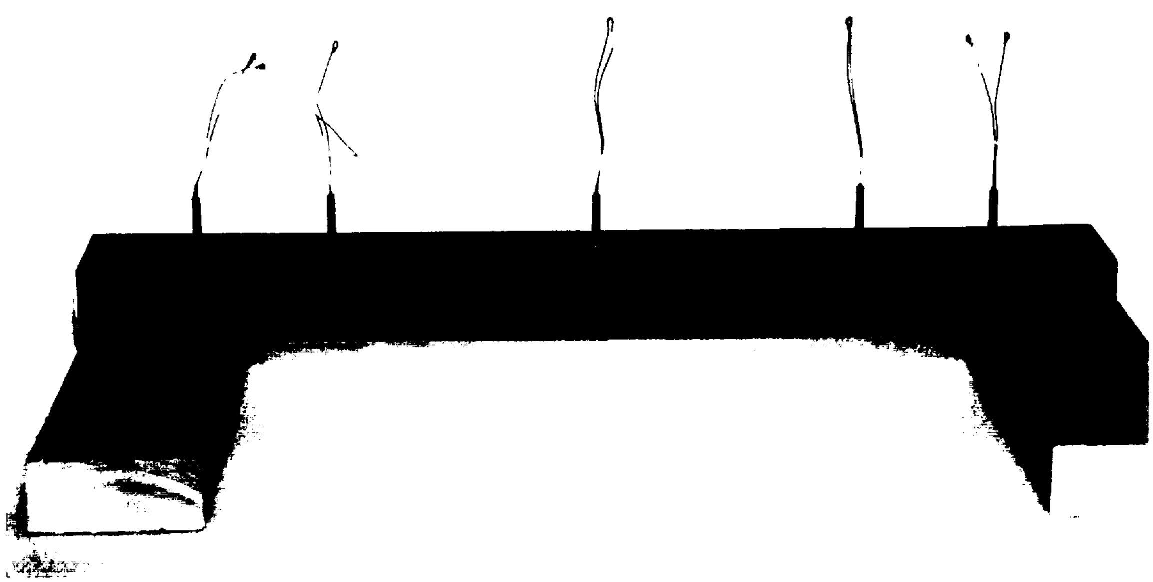

Figure 24. Thermocoupled Fuel Slab.

Section 13

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Appendix A

FORMULATIONS EXAMINED--
WITH COST OF RAW MATERIALS

FUEL FORMULATIONS EXAMINED

			PREMIX1	A		B		C		PREMIX2	D, E, & F	
MATERIAL	NAME	COST	%	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	%	CNTS/LB
PREPOLY	R45HT	$1.65	98.50%	25.59%	$0.42	29.86%	$0.49	35.83%	$0.59	98.00%	24.65%	$0.41
PREPOLY	230-660	$1.26		0.32%	$0.00	0.37%	$0.00	0.40%	$0.01			
Surfactant	Surfynol 104	$5.00	1.00%	0.26%	$0.01	0.30%	$0.02	0.36%	$0.02	1.00%	0.25%	$0.01
Crosslinker	glycerol	$1.25										
ANTI-OX	CYANOX 2246	$4.45	0.50%	0.13%	$0.01	0.15%	$0.01	0.18%	$0.01	1.00%	0.25%	$0.01
CURATIVE 1	PAPI 4027	$1.30										
CURATIVE 2	DES N-100	$4.20									4.85%	$0.20
CURATIVE 3	DES W	$3.85		3.70%	$0.14	4.31%	$0.17	5.22%	$0.20			
CURATIVE 4	DDI	$12.59										
BINDER FRACT				30.00%		35.00%		42.00%		100.00%	30.00%	
Binder cost					**$0.59**		**$0.69**		**$0.83**			**$0.63**
FILLER 1	Escorez 7312	$0.69										
FILLER 2	Dicyandiamide	$1.03										
FILLER 3	Hexamine	$0.48		55.00%	$0.26	55.00%	$0.26	50.00%	$0.24		55.00%	$0.26
FILLER 4	Escorez 5380	$1.00		15.00%	$0.15						15.00%	$0.15
FILLER 5	Melamine	$0.55										
FILLER 6	PAN	$1.00				10.00%	$0.10	8.00%	$0.08			
FILLER 7	THERMAX N991	$0.45										
FILLER 8	ELFTEX 12	$0.45										
Filler cost		Usually			**$0.41**		**$0.36**		**$0.32**			**$0.41**
SUM FRACT		ball park		100.00%		100.00%		100.00%		100.00%	100.00%	
TOTL CST/LB		for large			**$1.00**		**$1.05**		**$1.15**			**$1.05**
Date prepared		volume		6/22/94		6/22/94		6/22/94		6/22/94	D ON 6/27/1994	
						STIFF, NO FLOW		VISCOUS			D DID NOT CURE	
											E ON 7/1/94	
NONE OF THE MIXES (A THRU F) DESCRIBED ON THIS PAGE WERE MADE INTO QUALITY FUEL GRAINS											F ON 7/12/94	
AND NONE WERE TESTED IN MOTORS, ALTHOUGH MIXES OF SOME OF THE FORMULATIONS WERE											F CURED DURING	
LATER REMADE WITH NEW LETTER DESIGNATIONS AND MOTOR TESTED											CAST	

FUEL FORMULATIONS EXAMINED

		G, M		H, L		I		J		K	
MATERIAL	NAME	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB
PREPOLY	R45HT	24.65%	$0.41	24.65%	$0.41	24.65%	$0.41	34.50%	$0.57	31.22%	$0.52
PREPOLY	230-660										
Surfactant	Surfynol 104	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.35%	$0.02	0.32%	$0.02
Crosslinker	glycerol										
ANTI-OX	CYANOX 2246	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.35%	$0.02	0.32%	$0.01
CURATIVE 1	PAPI 4027										
CURATIVE 2	DES N-100	4.85%	$0.20	4.85%	$0.20	4.85%	$0.20	6.79%	$0.29	6.14%	$0.26
CURATIVE 3	DES W										
CURATIVE 4	DDI										
BINDER FRACT		30.00%		30.00%		30.00%		42.00%		38.00%	
Binder cost			**$0.63**		**$0.63**		**$0.63**		**$0.89**		**$0.80**
FILLER 1	Escorez 7312	15.00%	$0.10								
FILLER 2	Dicyandiamide					15.00%	$0.15				
FILLER 3	Hexamine	55.00%	$0.26	55.00%	$0.26	55.00%	$0.26	50.00%	$0.24	52.00%	$0.25
FILLER 4	Escorez 5380			15.00%	$0.15						
FILLER 4	Melamine										
FILLER 5	PAN							8.00%	$0.08	10.00%	$0.10
FILLER 6	THERMAX N991										
FILLER 7	ELFTEX 12										
Filler cost			**$0.37**		**$0.41**		**$0.42**		**$0.32**		**$0.35**
SUM FRACT		100.00%		100.00%		100.00%		100.00%		100.00%	
TOTL CST/LB			**$1.00**		**$1.05**		**$1.05**		**$1.21**		**$1.15**
Date mixed		7/12/94		7/13/94		7/13/94		7/13/94			
		M, 7/18		L, 7/18		Fired at only one oxidizer flow rate		Never fired			

FUEL FORMULATIONS EXAMINED

		N		O		P		Q		R	
MATERIAL	NAME	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB		CNTS/LB
PREPOLY	R45HT	25.02%	$0.41	25.02%	$0.41	25.02%	$0.41	25.02%	$0.41	42.20%	$0.70
PREPOLY	230-660	0.25%	$0.00	0.25%	$0.00	0.25%	$0.00	0.25%	$0.00	0.25%	$0.00
Surfactant	Surfynol 104	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01
Crosslinker	glycerol										
ANTI-OX	CYANOX 2246	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01
CURATIVE 1	PAPI 4027										
CURATIVE 2	DES N-100	0.97%	$0.04	0.97%	$0.04	0.97%	$0.04	0.97%	$0.04	1.62%	$0.07
CURATIVE 3	DES W	3.26%	$0.13	3.26%	$0.13	3.26%	$0.13	3.26%	$0.13	5.43%	$0.21
CURATIVE 4	DDI										
BINDER FRACT		30.00%		30.00%		30.00%		30.00%		50.00%	
Binder cost			**$0.61**		**$0.61**		**$0.61**		**$0.61**		**$1.00**
FILLER 1	Escorez 7312			15.00%	$0.10	10.00%	$0.07	10.00%	$0.07		
FILLER 2	Dicyandiamide										
FILLER 3	Hexamine	65.00%	$0.31	55.00%	$0.26	55.00%	$0.26	50.00%	$0.24	50.00%	$0.24
FILLER 4	Escorez 5380										
FILLER 5	Melamine	5.00%	$0.03			5.00%	$0.03	10.00%	$0.06		
FILLER 6	PAN										
FILLER 7	THERMAX N991										
FILLER 8	ELFTEX 12										
Filler cost			**$0.34**		**$0.37**		**$0.36**		**$0.36**		**$0.24**
SUM FRACT		100.00%		100.00%		100.00%		100.00%		100.00%	
TOTL CST/LB			**$0.95**		**$0.97**		**$0.97**		**$0.97**		**$1.24**
										too sticky to work	

FUEL FORMULATIONS EXAMINED

		S		T		U		V		W	
MATERIAL	NAME	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB
PREPOLY	R45HT	25.02%	$0.41	25.02%	$0.41	25.10%	$0.41	25.10%	$0.41	25.10%	$0.41
PREPOLY	230-660	0.25%	$0.00	0.25%	$0.00	0.28%	$0.00	0.28%	$0.00	0.28%	$0.00
Surfactant	Surfynol 104	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01
Crosslinker	glycerol										
ANTI-OX	CYANOX 2246	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01
CURATIVE 1	PAPI 4027										
CURATIVE 2	DES N-100	0.97%	$0.04	0.97%	$0.04	0.48%	$0.02	0.48%	$0.02	0.48%	$0.02
CURATIVE 3	DES W	3.26%	$0.13	3.26%	$0.13	3.63%	$0.14	3.63%	$0.14	3.63%	$0.14
CURATIVE 4	DDI										
BINDER FRACT		30.00%		30.00%		30.00%		30.00%		30.00%	
Binder cost			**$0.61**		**$0.61**		**$0.60**		**$0.60**		**$0.60**
FILLER 1	Escorez 7312	10.00%	$0.07								
FILLER 2	Dicyandiamide										
FILLER 3	Hexamine	49.80%	$0.24	55.00%	$0.26	50.00%	$0.24	49.80%	$0.24	44.80%	$0.22
FILLER 4	Escorez 5380					17.00%	$0.17	5.00%	$0.05	10.00%	$0.10
FILLER 5	Melamine	10.00%	$0.06	15.00%	$0.08			15.00%	$0.08	15.00%	$0.08
FILLER 6	PAN					3.00%	$0.03				
FILLER 7	THERMAX N991										
FILLER 8	ELFTEX 12	0.20%	$0.00					0.20%	$0.00	0.20%	$0.00
Filler cost			**$0.36**		**$0.35**		**$0.44**		**$0.37**		**$0.40**
SUM FRACT		100.00%		100.00%		100.00%		100.00%		100.00%	
TOTL CST/LB			**$0.97**		**$0.95**		**$1.04**		**$0.97**		**$1.00**

FUEL FORMULATIONS EXAMINED

		X		Y		Z		AA		BB	
MATERIAL	NAME	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB
PREPOLY	R45HT	25.10%	$0.41	25.10%	$0.41	25.10%	$0.41	25.10%	$0.41	25.10%	$0.41
PREPOLY	230-660	0.28%	$0.00	0.28%	$0.00	0.28%	$0.00	0.28%	$0.00	0.28%	$0.00
Surfactant	Surfynol 104	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01
Crosslinker	glycerol										
ANTI-OX	CYANOX 2246	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01
CURATIVE 1	PAPI 4027										
CURATIVE 2	DES N-100	0.48%	$0.02	0.48%	$0.02	0.48%	$0.02	0.48%	$0.02	0.48%	$0.02
CURATIVE 3	DES W	3.63%	$0.14	3.63%	$0.14	3.63%	$0.14	3.63%	$0.14	3.63%	$0.14
CURATIVE 4	DDI										
BINDER FRACT		30.00%		30.00%		30.00%		30.00%		30.00%	
Binder cost			**$0.60**		**$0.60**		**$0.60**		**$0.60**		**$0.60**
FILLER 1	Escorez 7312										
FILLER 2	Dicyandiamide										
FILLER 3	Hexamine	44.80%	$0.22	49.80%	$0.24	49.80%	$0.24	54.80%	$0.26	54.80%	$0.26
FILLER 4	Escorez 5380	10.00%	$0.10	5.00%	$0.05	10.00%	$0.10	15.00%	$0.15	10.00%	$0.10
FILLER 5	Melamine	15.00%	$0.08	15.00%	$0.08	9.00%	$0.05			5.00%	$0.03
FILLER 6	PAN					1.00%	$0.01				
FILLER 7	THERMAX N991			0.20%	$0.00			0.20%	$0.00	0.20%	$0.00
FILLER 8	ELFTEX 12	0.20%	$0.00			0.20%	$0.00				
Filler cost			**$0.40**		**$0.37**		**$0.40**		**$0.41**		**$0.39**
SUM FRACT		100.00%		100.00%		100.00%		100.00%		100.00%	
TOTL CST/LB			**$1.00**		**$0.97**		**$1.00**		**$1.02**		**$0.99**

FUEL FORMULATIONS EXAMINED

		CC		EE		FF		GG		HH	
MATERIAL	NAME	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB
PREPOLY	R45HT	25.10%	$0.41	25.10%	$0.41	25.10%	$0.41	25.10%	$0.41	25.26%	$0.42
PREPOLY	230-660	0.28%	$0.00	0.28%	$0.00	0.28%	$0.00	0.28%	$0.00		
Surfactant	Surfynol 104	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01
Crosslinker	glycerol									0.10%	$0.00
ANTI-OX	CYANOX 2246	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01
CURATIVE 1	PAPI 4027										
CURATIVE 2	DES N-100	0.48%	$0.02	0.48%	$0.02	0.48%	$0.02	0.48%	$0.02	0.49%	$0.02
CURATIVE 3	DES W	3.63%	$0.14	3.63%	$0.14	3.63%	$0.14	3.63%	$0.14	3.65%	$0.14
CURATIVE 4	DDI										
BINDER FRACT		30.00%		30.00%		30.00%		30.00%		30.00%	
Binder cost			**$0.60**		**$0.60**		**$0.60**		**$0.60**		**$0.60**
FILLER 1	Escorez 7312										
FILLER 2	Dicyandiamide										
FILLER 3	Hexamine	44.80%	$0.22	49.80%	$0.24	54.80%	$0.26	49.80%	$0.24	49.80%	$0.24
FILLER 4	Escorez 5380	10.00%	$0.10	10.00%	$0.10	10.00%	$0.10	10.00%	$0.10	10.00%	$0.10
FILLER 5	Melamine	15.00%	$0.08	10.00%	$0.06	4.00%	$0.02	10.00%	$0.06	10.00%	$0.06
FILLER 6	PAN					1.00%	$0.01				
FILLER 7	THERMAX N991							0.20%	$0.00	0.20%	$0.00
FILLER 8	ELFTEX 12	0.20%	$0.00	0.20%	$0.00	0.20%	$0.00				
Filler cost			**$0.40**		**$0.39**		**$0.40**		**$0.39**		**$0.39**
SUM FRACT		100.00%		100.00%		100.00%		100.00%		100.00%	
TOTL CST/LB			**$1.00**		**$1.00**		**$1.00**		**$1.00**		**$1.00**
				DD was not used as a name						Binder change to final formulation with glycerol	

FUEL FORMULATIONS EXAMINED

		IIa		JX		KK		LL		MM	
MATERIAL	NAME	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB
PREPOLY	R45HT	25.10%	$0.41	25.10%	$0.41	25.26%	$0.42	25.26%	$0.42	25.26%	$0.42
PREPOLY	230-660	0.28%	$0.00	0.28%	$0.00						
Surfactant	Surfynol 104	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01
Crosslinker	glycerol					0.10%	$0.00	0.10%	$0.00	0.10%	$0.00
ANTI-OX	CYANOX 2246	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01
CURATIVE 1	PAPI 4027										
CURATIVE 2	DES N-100	0.49%	$0.02	0.48%	$0.02	0.49%	$0.02	0.49%	$0.02	0.49%	$0.02
CURATIVE 3	DES W	3.63%	$0.14	3.63%	$0.14	3.65%	$0.14	3.65%	$0.14	3.65%	$0.14
CURATIVE 4	DDI										
BINDER FRACT		30.00%		30.00%		30.00%		30.00%		30.00%	
Binder cost			**$0.60**		**$0.60**		**$0.60**		**$0.60**		**$0.60**
FILLER 1	Escorez 7312										
FILLER 2	Dicyandiamide										
FILLER 3	Hexamine	39.80%	$0.19	44.80%	$0.22	59.80%	$0.29	49.80%	$0.24	60.80%	$0.29
FILLER 4	Escorez 5380	15.00%	$0.15	10.00%	$0.10			7.50%	$0.08		
FILLER 5	Melamine	15.00%	$0.08	15.00%	$0.08	10.00%	$0.06	12.50%	$0.07	9.00%	$0.05
FILLER 6	PAN										
FILLER 7	THERMAX N991					0.20%	$0.00	0.20%	$0.00	0.20%	$0.00
FILLER 8	ELFTEX 12	0.20%	$0.00	0.20%	$0.00						
Filler cost			**$0.42**		**$0.40**		**$0.34**		**$0.38**		**$0.34**
SUM FRACT		100.00%		100.00%		100.00%		100.00%		100.00%	
TOTL CST/LB			**$1.03**		**$1.00**		**$0.95**		**$0.99**		**$0.95**
				Same as X		nWg binder		nWg binder		nWg binder	

FUEL FORMULATIONS EXAMINED

		MMF		MMG		MMH		MT		MW	
MATERIAL	NAME	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB
PREPOLY	R45HT	25.26%	$0.42	25.26%	$0.42	25.26%	$0.42	27.31%	$0.45	27.48%	$0.45
PREPOLY	230-660										
Surfactant	Surfynol 104	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.28%	$0.01		
Crosslinker	glycerol	0.10%	$0.00	0.10%	$0.00	0.10%	$0.00	0.10%	$0.00		
ANTI-OX	CYANOX 2246	0.25%	$0.01	0.25%	$0.01	0.25%	$0.01	0.28%	$0.01	0.27%	$0.01
CURATIVE 1	PAPI 4027										
CURATIVE 2	DES N-100	0.49%	$0.02	0.49%	$0.02	0.49%	$0.02	0.24%	$0.01	0.27%	$0.01
CURATIVE 3	DES W	3.65%	$0.14	3.65%	$0.14	3.65%	$0.14	1.79%	$0.07	1.98%	$0.08
CURATIVE 4	DDI										
BINDER FRACT		30.00%		30.00%		30.00%		29.99%		30.00%	
Binder cost			**$0.60**		**$0.60**		**$0.60**		**$0.56**		**$0.55**
FILLER 1	Escorez 7312										
FILLER 2	Dicyandiamide										
FILLER 3	Hexamine	60.80%	$0.29	60.80%	$0.29	60.80%	$0.29	60.80%	$0.29	60.80%	$0.29
FILLER 4	Escorez 5380										
FILLER 5	Melamine	9.00%	$0.05	9.00%	$0.05	9.00%	$0.05	9.00%	$0.05	9.00%	$0.05
FILLER 6	PAN										
FILLER 7	THERMAX N991	0.20%	$0.00	0.20%	$0.00	0.20%	$0.00	0.20%	$0.00	0.20%	$0.00
FILLER 8	ELFTEX 12										
Filler cost			**$0.34**		**$0.34**		**$0.34**		**$0.34**		**$0.34**
SUM FRACT		100.00%		100.00%		100.00%		99.99%		100.00%	
TOTL CST/LB			**$0.95**		**$0.95**		**$0.95**		**$0.90**		**$0.90**
		nWg binder		nWg binder		nWg binder		Low cure ratio		No glycerol or surf	
								Scaled up	Used in second 11" motor	Scaled up	Used in second 11" motor

FUEL FORMULATIONS EXAMINED

		MTB		NN		OO		PP		RR	
MATERIAL	NAME	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB	%	CNTS/LB
PREPOLY	R45HT	27.27%	$0.45	25.26%	$0.42	25.26%	$0.42	36.51%	$0.60	27.39%	$1.05
PREPOLY	230-660										
Surfactant	Surfynol 104	0.27%	$0.01	0.25%	$0.01	0.25%	$0.01				
Crosslinker	glycerol	0.11%	$0.00	0.10%	$0.00	0.10%	$0.00	0.14%	$0.00	0.11%	$0.00
ANTI-OX	CYANOX 2246	0.27%	$0.01	0.25%	$0.01	0.25%	$0.01	0.37%	$0.02	0.28%	$0.01
CURATIVE 1	PAPI 4027										
CURATIVE 2	DES N-100	0.24%	$0.01	0.49%	$0.02	0.49%	$0.02	0.35%	$0.01	0.26%	$0.01
CURATIVE 3	DES W	1.97%	$0.08	3.65%	$0.14	3.65%	$0.14	2.64%	$0.10	1.97%	$0.08
CURATIVE 4	DDI										
BINDER FRACT		30.13%		30.00%		30.00%		40.01%		30.00%	
Binder cost			**$0.56**		**$0.60**		**$0.60**		**$0.74**		**$1.15**
FILLER 1	Escorez 7312										
FILLER 2	Dicyandiamide										
FILLER 3	Hexamine	60.69%	$0.29	49.80%	$0.24	61.80%	$0.30	59.80%	$0.29	60.80%	$0.29
FILLER 4	Escorez 5380			8.50%	$0.09						
FILLER 5	Melamine	8.98%	$0.05	11.50%	$0.06	8.00%	$0.04			9.00%	$0.05
FILLER 6	PAN										
FILLER 7	THERMAX N991	0.20%	$0.00	0.20%	$0.00	0.20%	$0.00	0.20%	$0.00	0.20%	$0.00
FILLER 8	ELFTEX 12										
Filler cost			**$0.34**		**$0.39**		**$0.34**		**$0.29**		**$0.34**
SUM FRACT		100.00%		100.00%		100.00%		100.01%		100.00%	
TOTL CST/LB			**$0.90**		**$0.99**		**$0.94**		**$1.02**		**$1.50**
		Slightly		nWg binder		nWg binder		Used R45M polymer		Low cure ratio	
		higher cure ratio	Used in slabs					Cost is for R45HT		Scaled up	Used in first 11" motor

FUEL FORMULATIONS EXAMINED

		IU		UU			G/I Team Baseline		
MATERIAL	NAME	%	CNTS/LB	%	CNTS/LB			%	CNTS/LB
PREPOLY	R45HT	36.42%	$0.60	36.42%	$0.60		R45 (assumed HT)	30.23%	$0.50
PREPOLY	230-660						Voranol 220-530	0.60%	$0.01
Surfactant	Surfynol 104	0.37%	$0.02	0.37%	$0.02				
Crosslinker	glycerol	0.14%	$0.00	0.14%	$0.00				
ANTI-OX	CYANOX 2246	0.37%	$0.02	0.37%	$0.02		Anti-oxidant	0.50%	$0.02
CURATIVE 1	PAPI 4027								
CURATIVE 2	DES N-100	0.32%	$0.01	0.32%	$0.01				
CURATIVE 3	DES W	2.38%	$0.09	2.38%	$0.09				
CURATIVE 4	DDI						DDI	8.47%	$1.07
BINDER FRACT		40.00%		40.00%				39.80%	
Binder cost			**$0.74**		**$0.74**				**$1.59**
FILLER 1	Escorez 7312								
FILLER 2	Dicyandiamide								
FILLER 3	Hexamine	25.00%	$0.12	8.70%	$0.04				
FILLER 4	Escorez 5380			49.80%	$0.50		Escorez 5320	60.00%	$0.60
FILLER 5	Melamine	33.00%	$0.18	1.30%	$0.01				
FILLER 6	PAN								
FILLER 7	THERMAX N991	2.00%	$0.01	0.20%	$0.00				
FILLER 8	ELFTEX 12						Elftex	0.20%	$0.00
Filler cost			**$0.31**		**$0.55**				**$0.60**
SUM FRACT		100.00%		100.00%				100.00%	
TOTL CST/LB			**$1.05**		**$1.29**				**$2.20**
		Used in head end							
		insulator in 11" motor							

Appendix B

LABSCALE MOTOR FIRINGS

Spreadsheet

Pressure Traces

SPREADSHEET TO RECORD DATA AND CALCULATE BALLISTICS ON LABSCALE MOTOR FIRINGS

The data are presented in spreadsheet form. Different fuel formulations go down the page; observed data and reduced (calculated) data for a given formulation go across the page.

PAGES 1-8: Left Side of Spreadsheet. Summary information to enable comparisons of critical values for different fuel compositions.

The first two columns of the spreadsheet contain information to identify a particular formulation and when it was tested in a motor firing. The first column is the day as month/day of the month followed by the test firing number for that day. The series begins in 1994. The second column identifies the MDA mix designation and an MSFC assigned number which for this program is P280-94 XX, where XX is the individual number shown in parentheses in column 2. Column 3 contains the calculated value for the oxidizer mass flux (OMF) for a test and column 4 contains the calculated regression rate. By using these values from a set of two firings of the same formulation the preexponent (a) and the exponent (n) are calculated and are shown in columns 5 and 6. The calculated oxidizer-to fuel (O/F) ratio is shown in column 7. The average measured density for the set of four fuel grains is shown in column 8. The calculated density, based on the densities of the components and no voids is shown in column 9. The initial weight for a set of four fuel grains is shown in column 10. The final weight (after the firing) of the set of four fuel grains is shown in column 11. The weight lost, namely the difference between initial and final weights, is shown in column 12. This could be used to calculate the average regression rate, but wasn't as indicated in the text. Instead the weight lost in the center two grains was used for that, and that is shown in column 13. The initial port radius, input as the diameter divided by two is shown in column 14. The final radius, calculated assuming loss of a uniform shell composed of the weight lost in column 13 combined with the density (from column 8) to give an increase in radius is shown in column 15.

In instances where there are more than two sets of data, the a and n values were extracted from a non-linear curve fit by the commercially available program EZFIT. When this was done, there is a notation and the results usually reported in the a and n columns.

Formulations MW and RR, used in the 11" motor tests, were tested only in single labscale motor firings. Thus it is not possible to calculate an exponent. In these cases a standard exponent was assumed and the preexponent calculated, which is shown with a note above it.

PAGES 9-16: Center of Spreadsheet.
This set repeats the identifiers from columns 1 and 2. Column 3 contains the oxidizer flow rate reported by MSFC, calculated from the driving pressure and the venturi used. Column 4 shows the average cross section which is calculated based on sum of the initial radius and the final radius divided by two, and then πr^2. Column 5 is the action time, or duration of firing which was obtained by examination of the pressure traces. It was taken as the time between reaching maximum initial pressure and the point where the pressure drops off dramatically when the

oxidizer is turned off. Column 7 is the sum of the weights of the empty fuel cartridges or cases. Subtracting this from the total weight and dividing by the volume allows calculation of the average density which is column 8 page 1. The last column on this page is a comment.

PAGES 17-24: Right Side of Spreadsheet.
The identifiers are once again shown in columns 1 and 2. The next group of numbers contain the individual weights of each grain before and after motor firing, which when subtracted give weight lost. The first set is the low flow condition, which is normally the second line within a single formulation on page 1. Going across the set, the first number represents the head end grain, the others follow in order toward the aft end. The top line is before firing, which in combination with the empty case weights enables calculation of the density. For the first few sets, individual empty cartridge, or case, weights were not reported. Starting with mix V, the individual empty cartridge weights were reported below the weight lost. From that point on, individual grain densities were calculated and are shown immediately below the empty cartridge weights. The number below the density is the ratio of the weight lost in that segment to that lost in the segment losing the least weight in that motor firing. In many cases this is preceded by the mix designation, as the set of numbers may have been imported into a chart and required an identifier. The segment with the least weight lost was always in either the head end position or the segment adjacent to it. Toward the right of the group are sums--of the weights before firing, of the weights after firing, and of the weight lost. Where individual densities are reported, the number in the "sum" column is the average density. The top number within a set in the Empty Case Weight column is the total of the four empty cartridge weights. The number below that is the weight lost in the center two segments. A density row number below that is the average density for the two center segments. Continuing to the right, similar data are shown for the high flow condition, normally the top line of a set on page 1. Occasionally a set of four grains was fired a second time. The additional data set is normally on the left.

CHAMBER PRESSURE TRACES

Chamber pressure traces for all motor firings are included, except one firing aborted due to failure of pressure transducer (#77). The action time was obtained manually from these traces, and each shows a hand-written notation regarding that value.

PRESSURE OSCILLATION TRACES

Pressure traces for motor firings P280-95-76 through 85 are included for reference. These were set up to examine only oscillations about the mean, and do not indicate absolute chamber pressure. The scale for the upper trace is 120 psi from baseline to top of scale, which means 24 psi per "different" dotted line, or 4.8 psi per single dotted line. The scale for the lower trace is twice that, namely 240 psi to the top. That was done in case any large oscillations went off scale on the top. These traces were taken during firing of formulations examined at the end of the program which exhibited only relatively small pressure oscillations. Firing 77 was not included because it experienced a pressure transducer failure and shut down prematurely.

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	OMF	regression rate in In./sec	a	n	O/F ratio	measured density in g/cc	calc dens (g/cc)	Initial wt (g)	final weight (g)	wt loss in g	wt loss for reg rate calc	Init port radius (inches)	fin port radius (inches)
			H											
7/26-1	H (01)	0.2695942	0.0513211			3.26	1.0748601	1.112	230.7	154.5	76.18	73.96	0.413	0.55157
7/27-2	(06)	0.0952117	0.0247243	0.1287516	0.7016761	2.22	1.07036	1.112	229.2	195.6	33.55	32.84	0.413	0.47976
			K											
7/26-2	K (02)	0.2835479	0.0415347			4.09	1.0394673	1.113	222.8	164.2	58.68	56.3	0.413	0.52514
8/2-1	(08)	0.0753361	0.0199289	0.0835002	0.5540567	2.17	1.0394673	1.113	172.3	140	32.31	31.792	0.52514	0.57895
			G&M											
		0.1	0.024847											
7/26-3	G (03)	0.2805698	0.0433739			3.73	1.0569813	1.1	227.5	163.1	64.4	60.1	0.413	0.53011
7/27-3	M (07)	0.095642	0.0242562	0.0861592	0.5400281	2.18	1.0706033	1.1	226.5	192.9	33.58	32.18	0.413	0.47849
7/26-4	I (04)	0.283482	0.0415751			3.91	1.131659	1.155	236.6	175.3	61.36		0.413	0.52525
7/27-1	O(05)	0.2437296	0.0685297	0.071236	0.314529	2.59	0.963999	1.1	210.5	115.6	94.88		0.413	0.60146
			O											
8/2-5	O(12)	0.2633031	0.0481908			3.23	1.0535758	1.1	224	150.7	73.31	68.9	0.413	0.54552
8/2-2	O(09)	0.1197871	0.0275411	0.1243548	0.710383	2.52	1.0577414	1.1	224.9	187.1	37.85	37.19	0.413	0.48874
			P											
8/2-6	P1(13)	0.2642088	0.0494056			3.12	1.0943201	1.1	230.5	155.6	74.91	72.1	0.413	0.5464
8/2-3	P2(10)	0.107042	0.0288322	0.1092307	0.5960845	2.04	1.0981513	1.1	232	189.9	42.12	40.58	0.413	0.49229
8/2-4	N(11)	0.2755821	0.0412326			3.82	1.1366456	1.15	234.9	172.6	62.33		0.413	0.52639

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	OMF	regression rate in in./sec	a	n	O/F ratio	measured density in g/cc	calc dens (g/cc)	Initial wt (g)	final weight (g)	wt loss in g	wt loss for reg rate calc	init port radius (inches)	fin port radius (inches)
			Q											
8/12-1	Q1(014)	0.273516	0.0478643			3.33	1.0999757	1.137	230.3	156.6	73.79	71.38	0.413	0.54463
8/12-4	Q2(017)	0.1126418	0.03131	0.0889962	0.478422	2.06	1.1006446		230.7	186.1	44.65	44.5	0.413	0.4991
			S											
8/12-2	S1(015)	0.2710395	0.0521714			3.08	1.0987594	1.138	229.5	150.5	79.01	77.04	0.413	0.55386
8/12-5	S2(018)	0.1165032	0.0358043	0.0933736	0.4458668	1.82	1.1002797		232.5	178.8	53.63	51.56	0.413	0.51146
8/12-3	T1(016)	0.2786724	0.0481193			3.25	1.1185843	1.161	234.8	159.5	75.31	71.52	0.413	0.54292
8/12-6	T2(019)	0.1148636	0.0305319	0.0927129	0.5132771	1.96	1.13847		236.7	189.1	47.55	44.78	0.413	0.49696
		3 points	EZFIT for T	0.09847	0.5573									
	2ND FIRING	0.2786724	0.0481193			3.25	1.1185843	1.161	234.8	159.5	75.31	71.52	0.413	0.54292
8/25-1	T2(020)	0.0731165	0.0220509	0.1013793	0.5832153	2.11	1.13847		189.1	121.1	68.01	65.12	0.49696	0.5984
			U											
8/25-2	U1(24)	0.218737	0.0424262			3.30	1.0636706		224.7	113.2	111.5	107.72	0.413	0.60604
8/25-5	U2(21)	0.0998393	0.0271759	0.1005804	0.5679323	2.28	1.0564948	1.104	223	157.6	65.38	64.98	0.413	0.53855
			V											
8/25-3	V1(025)	0.2283564	0.0471786			3.10	1.0846509		226.7	127.6	99.08	97.54	0.413	0.58992
8/25-6	V2(022)	0.0953963	0.0332453	0.0852998	0.4010096	1.79	1.0847117	1.16	227.8	144.2	83.6	82.2	0.413	0.56593
		0.0721178	0.0255496											
		3 points	EZFIT for V	0.09665	0.4811									
9/8-1	V(034)	0.0721178	0.0255496	0.1035233	0.5321166	2.14	1.088				63.62	62.44	0.56	0.65198
8/25-4	W2(026)	0.2249347	0.0456254			3.06	1.1066042		232.6	132	100.6	97.9	0.413	0.5841
8/25-7	W1(023)	0.0928242	0.0336044	0.0763969	0.3455066	1.72	1.0904281	1.15	229.6	144.7	84.92	85.96	0.413	0.56758
		3 points	EZFIT for W	0.093	0.471									
			W											
		0.0928242	0.0336044											
9/8-2	W(035)	0.070763	0.024196	0.1034133	0.5484574	2.11	1.094				66.09	62.66	0.567	0.65653
		0.2249347	0.0456254											

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	OMF	regression rate in in./sec	a	n	O/F ratio	measured density in g/cc	calc dens (g/cc)	initial wt (g)	final weight (g)	wt loss in g	wt loss for reg rate calc	init port radius (inches)	fin port radius (inches)
		0.3353142												
9/1-4	X(027)	0.3616818	0.0589703			3.12	1.1033204		233.6	123.6	110	105.96	0.3125	0.53364
9/1-1	X(030)	0.114669	0.0348644	0.0972191	0.4575264	1.90	1.1037968	1.15	275.7	186	89.78	88.54	0.413	0.57059
		3 points	EZFIT for X	0.096394	0.48128									
			X											
		0.114669	0.0348644											
9/1-4	X(027)	0.3616818	0.0589703			3.12	1.1033204		233.6	123.6	110	105.96	0.3125	0.53364
9/1-1	X(033)	0.0807406	0.027926	0.1735709	0.4984764	1.96	1.1098126	1.15	183.6	118.6	64.94	63.92	0.5	0.60193
	with one Y													
			Y											
9/1-5	Y(028)	0.2573816	0.0469284			3.26	1.1142998		278	174	104	100.1	0.413	0.58664
9/1-2	Y(031)	0.1489761	0.0393349	0.0727301	0.3228223	1.90	1.4197884	1.16	233.5	150.2	83.29	82.16	0.3125	0.49344
			Z											
9/1-6	Z(032)	0.2566992	0.0460429			3.50	1.0785089		227.7	128.1	99.52	97.42	0.413	0.58796
9/1-3	Z(029)	0.1008938	0.0355004	0.0672372	0.2784522	1.85	1.0433228		222.2	137.1	85.08	84.26	0.413	0.57275
			AA											
		0.1016715	0.0265517											
9/8-6	AA(039)	0.3760504	0.0496638			3.55	1.133432		280.9	191.4	89.48	85.12	0.3125	0.49377
9/8-3	AA(036)	0.1267664	0.0307049	0.0765372	0.4422141	2.25	1.1301995	1.172	236.8	171.1	65.67	61.92	0.413	0.52661
			EZFIT	0.0782	0.46289									
x														
10/13-1	AA(047)	0.1016715	0.0265517		0.4787426	2.35	1.1256704		186.3	127.5	58.74	55.14	0.4845	0.57478

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	OMF	regression rate in in./sec	a	n	O/F ratio	measured density in g/cc	calc dens (g/cc)	initial wt (g)	final weight (g)	wt loss in g	wt loss for reg rate calc	init port radius (inches)	fin port radius (inches)
			BB											
9/8-7	BB(040)	0.4185362	0.0588703			3.35	1.0922584		269.7	199.6	70.12	66.94	0.3125	0.46556
9/8-4	BB(0037)	0.136258	0.0334033	0.091392	0.5049675	2.47	1.0822793		226.8	161.3	65.44	65.52	0.413	0.53659
			CC											
9/8-8	CC(041)	0.2693352	0.0552589			3.02	1.0735223		227.9	150.2	77.75	76.52	0.413	0.55667
9/8-5	CC(038)	0.1373239	0.0313435	0.1667092	0.841762	2.57	1.0785697		228.2	165.7	62.52	60.74	0.413	0.52897
			EE											
9/15-1	EE(042)	0.4089103	0.0608468			3.24	1.0878698		271.3	199.6	71.76	69.72	0.3125	0.4707
9/15-4	EE(045)	0.1260196	0.034372	0.0939029	0.4852074	2.09	1.1357942	1.14	236.5	165.3	71.11	70.16	0.413	0.53846
			FF											
9/15-2	FF(043)	0.4059379	0.061241	0.1034207		3.14	1.1000493	1.13	271.5	196.6	74.82	71.62	0.3125	0.47356
9/15-5	FF(046)	0.1271977	0.0352721	0.0940146	0.4754367	2.29	1.0537582		221.2	154.2	66.93	67.54	0.413	0.54351
			GG											
9/15-3	GG(044)	0.3994873	0.0615757	0.1095958		3.07	1.1216469		278.9	203.8	75.13	73.14	0.3125	0.47383
10/14-1	GG(056)std	0.1271508	0.0346115	0.0977097	0.5032114	2.15	1.1078205		231.5	160.5	70.95	69.38	0.413	0.54106
			EZFIT	0.1019	0.5452									
10/13-2	GG(048)	0.0843275	0.0250655	0.1046325	0.5778138	1.90	1.1011311		231.3	183.5	47.81	47.14	0.413	0.50324

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	OMF	regression rate in in./sec	a	n	O/F ratio	measured density in g/cc	calc dens (g/cc)	initial wt (g)	final weight (g)	wt loss in g	wt loss for reg rate calc	init port radius (inches)	fin port radius (inches)
10/14-7	HH(062)	0.5156788	0.0676586	0.1047981		3.87	1.1357988		279.2	197.9	81.28	84.08	0.3125	0.4918
10/13-8	HH(054)	0.1291809	0.0353765	0.0922682	0.4684258	2.11	1.129713		236.7	162.7	74.02	73.1	0.413	0.54389
			EZFIT	0.0899	0.473									
11/4-4	HH(072)	0.4070623	0.0561493	0.0930837		3.23	1.1102071		277.6	216	61.52	57.88	0.3125	0.44614
11/4-1	HH(069)	0.1240585	0.0330482	0.0838435	0.4460878	2.17	1.1108003		233.8	170.5	63.32	62.24	0.413	0.52867
			HV											
10/14-8	HV(063)	0.5323339	0.0631111			3.86	1.1295365		279.1	198	81.18	76.7	0.3125	0.47911
10/13-9	HV(055)	0.1312093	0.0333696	0.0840813	0.455026	2.22	1.1288616	1.14	236.8	166.6	70.13	68.44	0.413	0.53647
			IIa											
10/14-3	IIA(058)	0.4881748	0.0665549			3.50	1.1097633		275	191.7	83.22	79.92	0.3125	0.48687
10/13-5	IIA(051)	0.127502	0.0370735	0.0909723	0.4358328	2.00	1.1215641	1.14	233.3	155.5	77.81	76.58	0.413	0.55017
			JX											
10/14-6	JX(061)	0.4878957	0.0770529			3.28	1.0633629		262.7	167.8	94.83	92.04	0.3125	0.51438
10/13-7	JX(053)	0.1279109	0.0366571	0.1147458	0.554902	2.13	1.0712722	1.15	226.7	153.6	73.1	71.94	0.413	0.54863
			KK											
10/14-5	KK(060)	0.5171122	0.0624544			3.74	1.1420118		281.6	198.8	82.89	77.84	0.3125	0.47988
10/13-3	KK(049)	0.1333651	0.0312133	0.0875294	0.5118123	2.36	1.1429701	1.14	235.2	170.1	65.09	63.08	0.413	0.52724
		0.5255736	0.0613195											
		0.1255818	0.0305904											

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	OMF	regression rate in in./sec	a	n	O/F ratio	measured density in g/cc	calc dens (g/cc)	initial wt (g)	final weight (g)	wt loss in g	wt loss for reg rate calc	init port radius (inches)	fin port radius (inches)
10/14-4	G/I Tm(059)	0.3578726	0.041395			4.93	0.9963504		207.8	149.1	58.62	51.46	0.413	0.52063
10/13-4	G/I Tm(050)	0.1408712	0.0250913	0.0718759	0.5369736	3.49	0.9963513		206.7	163.2	43.52	42.56	0.413	0.50333
			G/I Tm											
		0.3578726	0.041395											
		0.1408712	0.0250913											
			LL											
10/14-2	LL(057)	0.4762219	0.0719675			3.30	1.1418146		282.1	196.5	85.62	87.28	0.3125	0.49602
10/13-6	LL(052)	0.128273	0.03629	0.1060007	0.521964	2.03	1.1415106		238.1	161.4	76.72	76.06	0.413	0.54727
			KK											
10/28-1	KK(064)	0.5255736	0.0613195			3.86	1.1406312		280.3	202.6	77.7	73.68	0.3125	0.47193
10/28-4	KK(067)	0.1255818	0.0305904	0.0838128	0.4857821	2.27	1.1421795	1.14	237.3	172.9	64.37	62.36	0.413	0.52618
		0.5171122	EZFIT	0.08746	0.509									
		0.1333651	includes 2 points from previous KK set											
			MDA											
10/28-2	MM(065)	0.5445803	0.0663302			3.73	1.1354043		281.6	195.6	85.97	80.34	0.3125	0.48496
11/4-2	MMF(070)	0.1266931	0.0297893	0.0925972	0.5489427	2.33	1.1328144	1.14	237.4	179	58.34	55.94	0.413	0.51667
	MMF(073)	0.2715325	0.0439107											
	MMG(074)	0.4100621	0.055843											
	MMH(071)	0.1860631	0.0403559											
			MMF											
11/4-5	MMF(073)	0.2715325	0.0439107			3.38	1.1338482		237.1	177.4	59.66	57.2	0.413	0.51839
11/4-2	MMF(070)	0.1266931	0.0297893	0.0852603	0.5089859	2.33	1.1328144	1.14	237.4	179	58.34	55.94	0.413	0.51667
			EZFIT	0.091	0.541									
			MMGH											
11/4-6	MMG(074)	0.4100621	0.055843			3.19	1.1339744		281	218.4	62.67	59.12	0.3125	0.44541
11/4-3	MMH(071)	0.1860631	0.0403559	0.0805563	0.4110309	2.06	1.133432	1.14	281	215	65.98	63.4	0.3125	0.45375

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	OMF	regression rate in in./sec	a	n	O/F ratio	measured density in g/cc	calc dens (g/cc)	Initial wt (g)	final weight (g)	wt loss in g	wt loss for reg rate calc	init port radius (inches)	fin port radius (inches)
10/28-3	NN(066)	0.4901424	0.0661359			3.42	1.137426		279.8	195.6	84.27	80.04	0.3125	0.48445
10/28-5	NN(068)	0.1307357	0.0333828	0.0956411	0.5173369	2.21	1.1341523		236	164.4	71.55	69.6	0.413	0.53819
			OO											
11/4-7	OO(075)	0.4129762	0.0551109			3.29	1.1269231		279.8	218.2	61.6	58.46	0.3125	0.44477
2/17-10	OO(085)	0.1180829	0.0278012	0.0893613	0.5465397	2.48	1.13075	1.14	214	170	43.97	42.22	0.4579	0.53157
				assume										
				n is 0.54					lb	lb	g			
1/11-1	First 11"(044)	0.1102595	0.0455341	0.1497724		1.50	1.15		78.28	70.15	3688		1.4875	2.01114
1/18-1	2nd 11"(045)	0.4253716	0.0640958	0.1016938		1.79	1.15		211.2	178.4	14883		2.0195	2.5579
			IU											
2/17-6	IU(081)	0.3745238	0.0596477			3.03	1.1024162		274.4	204.7	69.66	69.72	0.3125	0.46758
2/17-1	IU(076)	0.1382818	0.0342994	0.1029106	0.5553465	2.30	1.1253953		236.5	172	64.57	64.06	0.413	0.52962
			PP											
2/17-7	PP(082)	0.3862296	0.0615961			2.90	1.0407791		262.5	186.3	76.16	67.76	0.3125	0.47265
2/17-3	PP(078)	0.1362518	0.0337674	0.106637	0.5769137	2.36	1.072683		227.8	163.5	64.31	61.92	0.413	0.53119
			UU											
2/17-9	UU(084)	0.3721374	0.0689015			2.97	0.9982249		254	179.1	74.93	73.9	0.3125	0.49164
2/17-4	UU(079)	0.1322387	0.0372556	0.1239801	0.5942816	2.36	0.9599854		208.6	144.7	63.83	61.68	0.413	0.54339

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	OMF	regression rate in in./sec	a	n	O/F ratio	measured density in g/cc	calc dens (g/cc)	Initial wt (g)	final weight (g)	wt loss in g	wt loss for reg rate calc	Init port radius (inches)	fin port radius (inches)
				calcd										
			RR/MW	assuming	n is									
2/17-5	RR(083)	0.4012871	0.0598109	0.0979298	0.54	3.06	1.1294379		280.6	206.7	73.88	70.554	0.3125	0.46801
2/17-8	MW(080)	0.2347031	0.0468915	0.1025685	0.54	2.81	1.13		233.7	167.5	66.11	63.184	0.413	0.53023

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	oxidizer flow rate in lb/sec	average cross sect in sq in.	length of firing (sec)	case wt in g	Comment
7/26-1	H (01)	0.197	0.7307278	2.7	53.9	Cured with N-100
7/27-2	(06)	0.0596	0.6259737	2.7	53.15	
7/26-2	K (02)	0.196	0.6912413	2.7	235.8	Formed a lot of char
8/2-1	(08)	0.0727	0.7911212	2.7	235.8	
7/26-3	G (03)	0.196	0.6985784	2.7	53.64	
7/27-3	M (07)	0.0597	0.6242027	2.7	50.46	
7/26-4	I (04)	0.196	0.6914019	2.7	50.54	Additive adversely impacts pot life
7/27-1	O(05)	0.197	0.8082727	2.75	51.95	Low density significantly increased the rate.
8/2-5	O(12)	0.19	0.7216018	2.75	50.72	
8/2-2	O(09)	0.0765	0.6386333	2.75	51.01	
8/2-6	P1(13)	0.191	0.722913	2.7	50.55	
8/2-3	P2(10)	0.0689	0.6436723	2.75	51.39	
8/2-4	N(11)	0.191	0.6930785	2.75	48.03	First hexamine/melamine combination examined. Appeared to exhibit lower regression rate.

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	oxidizer flow rate in lb/sec	average cross sect in sq in.	length of firing (sec)	case wt in g	Comment
8/12-1	Q1(014)	0.197	0.7202503	2.75	49.46	
8/12-4	Q2(017)	0.0736	0.6533987	2.75	49.71	
8/12-2	S1(015)	0.199	0.7342103	2.7	48.85	
8/12-5	S2(018)	0.0782	0.6712261	2.75	51.53	
8/12-3	T1(016)	0.2	0.7176885	2.7	50.82	
8/12-6	T2(019)	0.0747	0.6503363	2.75	49.45	
	2ND FIRING	0.2	0.7176885	2.7	50.82	
8/25-1	T2(020)	0.0689	0.9423321	4.6	49.45	
8/25-2	U1(24)	0.1784	0.8155913	4.55	49.78	
8/25-5	U2(21)	0.071	0.7111426	4.62	49.24	
8/25-3	V1(025)	0.1804	0.7899933	3.75	48.31	
8/25-6	V2(022)	0.0718	0.7526494	4.6	49.4	
		0.0832	1.1536676	3.6		
8/25-4	W2(026)	0.181	0.7808439	3.75	50.61	
8/25-7	W1(023)	0.0701	0.7551914	4.6	50.3	
9/8-2	W(035)	0.0832	1.1757549	3.7		

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	oxidizer flow rate in lb/sec	average cross sect in sq in.	length of firing (sec)	case wt in g	Comment
9/1-4	X(027)	0.202	0.5623074	3.75	52.18	
9/1-1	X(030)	0.083	0.7598301	4.52	51.88	
9/1-4	X(027)	0.202	0.5623074	3.75	52.18	
9/1-1	X(033)	0.077	0.9536713	3.65	51.88	
9/1-5	Y(028)	0.202	0.7848269	3.7	52.02	
9/1-2	Y(031)	0.076	0.5101489	4.6	53.6	
9/1-6	Z(032)	0.202	0.7869133	3.8	50.3	
9/1-3	Z(029)	0.077	0.7631785	4.5	50.636	
9/8-6	AA(039)	0.192	0.5105698	3.65	51.04	
9/8-3	AA(036)	0.0879	0.6934012	3.7	50.93	
10/13-1	AA(047)	0.0896	0.8812699	3.4		

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	oxidizer flow rate in lb/sec	average cross sect in sq in.	length of firing (sec)	case wt in g	Comment
9/8-7	BB(040)	0.199	0.4754666	2.6	48.21	
9/8-4	BB(0037)	0.0965	0.7082151	3.7	48.81	
9/8-8	CC(041)	0.1989	0.7384849	2.6	51.37	
9/8-5	CC(038)	0.0957	0.6968926	3.7	50.85	
9/15-1	EE(042)	0.197	0.4817683	2.6	50.7	
9/15-4	EE(045)	0.0896	0.7110006	3.65	49.68	
9/15-2	FF(043)	0.197	0.4852959	2.63	48.36	
9/15-5	FF(046)	0.0914	0.7185667	3.7	47.87	
9/15-3	GG(044)	0.194	0.4856224	2.62	51.41	
10/14-1	GG(056)std	0.0909	0.714899	3.7	49.31	
10/13-2	GG(048)	0.0556	0.659334	3.6	50.19	

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	oxidizer flow rate in lb/sec	average cross sect in sq in.	length of firing (sec)	case wt in g	Comment
10/14-7	HH(062)	0.262	0.5080682	2.65	48.84	
10/13-8	HH(054)	0.0929	0.7191468	3.7	50.91	
11/4-4	HH(072)	0.184	0.4520192	2.38	52.41	
11/4-1	HH(069)	0.0864	0.6964454	3.5	51.15	
10/14-8	HV(063)	0.262	0.4921723	2.64	50.06	
10/13-9	HV(055)	0.0929	0.7080289	3.7	51.12	
10/14-3	IIA(058)	0.245	0.5018694	2.62	49.89	
10/13-5	IIA(051)	0.0929	0.7286159	3.7	48.86	
10/14-6	JX(061)	0.262	0.537	2.62	47.01	
10/13-7	JX(053)	0.0929	0.7262866	3.7	50.51	
10/14-5	KK(060)	0.255	0.4931232	2.68	50.04	
10/13-3	KK(049)	0.0926	0.6943348	3.66	47.22	

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	oxidizer flow rate in lb/sec	average cross sect in sq in.	length of firing (sec)	case wt in g	Comment
10/14-4	G/I Tm(059)	0.245	0.6846011	2.6	43.95	Made available courtesy of Thiokol Corp. Contains alternative anti-
10/13-4	G/I Tm(050)	0.0929	0.6594676	3.6	42.87	
10/14-2	LL(057)	0.2445	0.5134161	2.55	50.51	
10/13-6	LL(052)	0.0929	0.7242365	3.7	50.43	
10/28-1	KK(064)	0.254	0.4832815	2.6	48.96	
10/28-4	KK(067)	0.087	0.6927757	3.7	49.46	
10/28-2	MM(065)	0.272	0.4994672	2.6	51.34	MM. MF, MMG, MW, MT, AND MTB all have same amine filler content
11/4-2	MMF(070)	0.086	0.6788059	3.48	51.1	
	MMF(073)					
11/4-5	MMF(073)	0.185	0.6813181	2.4	50.61	
11/4-2	MMF(070)	0.086	0.6788059	3.48	51.1	
11/4-6	MMG(074)	0.185	0.4511512	2.38	51.07	
11/4-3	MMH(071)	0.0858	0.461134	3.5	51.1	

LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	oxidizer flow rate in lb/sec	average cross sect in sq in.	length of firing (sec)	case wt in g	Comment
10/28-3	NN(066)	0.2445	0.4988346	2.6	49.16	
10/28-5	NN(068)	0.0929	0.7105937	3.75	49.46	
11/4-7	OO(075)	0.186	0.4503891	2.4	51.27	
2/17-10	OO(085)	0.0908	0.7689513	2.65	51.1	
1/11-1	First 11"(044)	1.06	9.6136846	11.5		First 11" motor regression rate signficantly higher than labscale predicts
1/18-1	2nd 11"(045)	7	16.4562	8.4		Second 11" motor regression rate essentially same as labscale predicts
2/17-6	IU(081)	0.179	0.4779402	2.6	50.82	Used in head end insulator
2/17-1	IU(076)	0.0965	0.6978506	3.4	51.46	
2/17-7	PP(082)	0.187	0.484168	2.6	51.4	
2/17-3	PP(078)	0.0954	0.7001741	3.5	51.45	
2/17-9	UU(084)	0.189	0.507877	2.6	51.55	
2/17-4	UU(079)	0.095	0.718398	3.5	50.69	

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LABSCALE MOTOR FIRING DATA

Day-Run No. that day	ID: MDA (MSFC)	oxidizer flow rate in lb/sec	average cross sect in sq in.	length of firing (sec)	case wt in g	Comment
2/17-5	RR(083)	0.192	0.4784605	2.6	51.53	scaled up in first 11" motor
2/17-8	MW(080)	0.164	0.698755	2.5	51.65	scaled up in second 11" motor

LABSCALE MOTOR FIRING DATA

Day-Run No. that	ID: MDA (MSFC)	LOW FLOW	Weight losses by segment				sums	Empty Case Weight	HIGH FLOW	Weight losses by segment				sums	Empty Case Weight
7/26-1	H (01)	filled	57.94	58.43	56.54	57.74	230.65	53.9	filled	56.56	57.58	57.76	57.26	229.16	53.15
7/27-2	(06)	fired	40.07	41.18	36.81	36.41	154.47		fired	48.69	49.87	49.05	48	195.61	
		lost	17.87	17.25	19.73	21.33	76.18		lost	7.87	7.71	8.71	9.26	33.55	
			center segments		36.98	73.96				center segments		16.42	32.84		
7/26-2	K (02)	filled	42.08	41.4	44.056	44.77	172.306		filled	56.3	55.75	55.3	55.49	222.84	51.91
8/2-1	(08)	fired	34.26	34.05	35.51	36.18	140		fired	43.39	43.4	39.5	37.87	164.16	
		lost	7.82	7.35	8.546	8.59			lost	12.91	12.35	15.8	17.62	58.68	
			center segments		15.896	31.792				center segments		28.15	56.3		
7/26-3	G (03)	filled	55.23	56.18	58.1	57	226.51	50.46	filled	56.25	57.9	56.15	57.15	227.45	53.64
7/27-3	M (07)	fired	46.7	48.6	49.59	48.04	192.93		fired	41.75	44.26	39.74	37.3	163.05	
		lost	8.53	7.58	8.51	8.96	33.58		lost	14.5	13.64	16.41	19.85	64.4	
			center segments		16.09	32.18				center segments		30.05	60.1		
7/26-4	I (04)	filled	58.08	60.43	60	58.12	236.63	50.54	filled						
		fired	44.51	46.92	44.32	39.52	175.27		fired						
		lost	13.57	13.51	15.68	18.6	61.36		lost						
7/27-1	O(05)	filled	51.9	51.94	53.19	53.44	210.47	51.95	filled						
		fired	29.72	29.36	28.85	27.66	115.59		fired						
		lost	22.18	22.58	24.34	25.78	94.88		lost						
8/2-5	O(12)	filled	56.7	54.955	56.61	56.68	224.945	51.01	filled	55	56.78	56.09	56.1	223.97	50.72
8/2-2	O(09)	fired	47.73	46.39	46.58	46.4	187.1		fired	37.61	41.11	37.31	34.63	150.66	
		lost	8.97	8.565	10.03	10.28	37.845		lost	17.39	15.67	18.78	21.47	73.31	
			center segments		18.595	37.19				center segments		34.45	68.9		
8/2-6	P1(13)	filled	58.75	57.8	57.64	57.78	231.97	51.39	filled	56.29	57.37	58.48	58.36	230.5	50.55
8/2-3	P2(10)	fired	48.31	48.12	47.03	46.39	189.85		fired	38.59	39.68	40.12	37.2	155.59	
		lost	10.44	9.68	10.61	11.39	42.12		lost	17.7	17.69	18.36	21.16	74.91	
			center segments		20.29	40.58				center segments		36.05	72.1		
8/2-4	N(11)	filled							filled	58.48	59.13	59	58.33	234.94	48.03
		fired							fired	43.58	45.48	43.32	40.23	172.61	
		lost							lost	14.9	13.65	15.68	18.1	62.33	

LABSCALE MOTOR FIRING DATA

Day-Run No. that	ID: MDA (MSFC)	LOW FLOW	Weight losses by segment				sums	Empty Case Weight	HIGH FLOW	Weight losses by segment				sums	Empty Case Weight
8/12-1	Q1(014)	filled	56.74	57.12	59.09	57.75	230.7	49.71	filled	57.65	58.04	57.71	56.94	230.34	49.46
8/12-4	Q2(017)	fired	47.05	46.71	47.25	45.04	186.05		fired	39.4	40.92	39.14	37.09	156.55	
		lost	9.69	10.41	11.84	12.71	44.65		lost	18.25	17.12	18.57	19.85	73.59	
			center segments		22.25	44.5				center segments		35.69	71.38		
8/12-2	S1(015)	filled	57.51	57.35	58.92	58.68	232.46	51.53	filled	57.41	56.96	57.81	57.35	229.53	48.85
8/12-5	S2(018)	fired	45.14	45.65	44.84	43.2	178.83		fired	39.15	38.76	37.49	35.12	150.52	
		lost	12.37	11.7	14.08	15.48	53.63		lost	18.26	18.2	20.32	22.23	79.01	
			center segments		25.78	51.56				center segments		38.52	77.04		
8/12-3	T1(016)	filled	59.7	58.23	58.63	60.1	236.66	49.45	filled	57.65	59.44	58.94	58.73	234.76	50.82
8/12-6	T2(019)	fired	48.91	47.66	46.81	45.73	189.11		fired	38.76	42.55	40.07	38.07	159.45	
		lost	10.79	10.57	11.82	14.37	47.55		lost	18.89	16.89	18.87	20.66	75.31	
			center segments		22.39	44.78				center segments		35.76	71.52		
	2ND FIRING	filled	48.91	47.64	46.81	45.73	189.09	49.45	filled	57.65	59.44	58.94	58.73	234.76	50.82
8/25-1	T2(020)	fired	32.91	32.77	29.12	26.28	121.08		fired	38.76	42.55	40.07	38.07	159.45	
		lost	16	14.87	17.69	19.45	68.01		lost	18.89	16.89	18.87	20.66	75.31	
			center segments		32.56	65.12				center segments		35.76	71.52		
8/25-2	U1(24)	filled	55.03	55.87	56.1	55.97	222.97	49.24	filled	56.22	56.54	55.14	56.79	224.69	49.78
8/25-5	U2(21)	fired	39.66	40.67	38.81	38.45	157.59		fired	30.01	31	26.82	25.4	113.23	
		lost	15.37	15.2	17.29	17.52	65.38		lost	26.21	25.54	28.32	31.39	111.46	107.72
			center segments		32.49	64.98			cart. wt.	12.65	12.66	11.29	13.18	49.78	
									density	1.05984	1.06738	1.06665	1.06081	1.06367	
8/25-3	V1(025)	filled	56.15	57.66	56.64	57.32	227.77	49.4	filled	56.31	56.58	56.74	57.04	226.67	48.31
8/25-6	V2(022)	fired	37.22	38.34	34.86	33.75	144.17		fired	32.89	32.99	31.56	30.15	127.59	
		lost	18.93	19.32	21.78	23.57	83.6	82.2	lost	23.42	23.59	25.18	26.89	99.08	97.54
			12.06	13.21	11.91	12.22	49.4		order	12.55	11.7	12.04	12.02	48.31	
			1.07249	1.08125	1.08806	1.09706	1.08471	1.08465		1.06446	1.09171	1.08733	1.09511	1.08465	1.08952
		order	14.01	15.07	17.21	17.33	63.62	62.44							
8/25-4	W2(026)	filled	55.83	57.43	57.83	58.52	229.61	50.3	filled	57.64	58.35	58.61	57.98	232.58	50.61
8/25-7	W1(023)	fired	37.58	37.53	34.75	34.83	144.69		fired	34.39	35.28	32.73	29.57	131.97	
		lost	18.25	19.9	23.08	23.69	84.92	85.96	lost	23.25	23.07	25.88	28.41	100.61	97.9
		order	12.87	12.44	12.25	12.74	50.3		case	12.49	12.48	12.83	12.81	50.61	
			1.045	1.09438	1.10873	1.1136	1.09043	1.10156	density	1.09827	1.11579	1.1136	1.09876	1.1066	1.11469
										1.0078	1	1.1218	1.23147	1.09027	
		order	14.38	15.26	16.95	19.5	66.09	62.66							
								1.11117							

LABSCALE MOTOR FIRING DATA

Day-Run No. that	ID: MDA (MSFC)	LOW FLOW	Weight losses by segment				sums	Empty Case Weight	HIGH FLOW	Weight losses by segment				sums	Empty Case Weight
9/1-4	X(027)	filled	68.81	69.28	69.26	68.38	275.73	51.88	filled	58.86	58.28	57.62	58.85	233.61	52.18
9/1-1	X(030)	fired	48.87	45.61	48.66	42.81	185.95		fired	33.66	33.28	29.64	27	123.58	
		lost	19.94	23.67	20.6	25.57	89.78	88.54	lost	25.2	25	27.98	31.85	110.03	105.96
			13.41	13.13	12.9	12.44	51.88		case	13.45	13	12.46	13.27	52.18	
			1.0927	1.1075	1.11164	1.10335	1.1038	1.10957	density	1.1046	1.10144	1.09852	1.10873	1.10332	1.09998
		X	1	1.18706	1.0331	1.28235	1.12563		X	1.008	1	1.1192	1.274	1.1003	
9/1-4	X(027)	filled	46.5	42.81	45.61	48.66	183.58	51.88	filled	58.86	58.28	57.62	58.85	233.61	52.18
9/1-1	X(033)	fired	32.8	28.03	28.43	29.38	118.64		fired	33.66	33.28	29.64	27	123.58	
		lost	13.7	14.78	17.18	19.28	64.94	63.92	lost	25.2	25	27.98	31.85	110.03	105.96
		order	13.41	13.13	12.9	12.44	51.88		case	13.45	13	12.46	13.27	52.18	
			1.11677	1.10335	1.1075	1.11164	1.10981	1.10542	density	1.1046	1.10144	1.09852	1.10873	1.10332	1.09998
		X	1	1.07883	1.25401	1.4073	1.18504		X	1.008	1	1.1192	1.274	1.1003	
9/1-5	Y(028)	filled	57.71	57.88	59.1	58.78	233.47		filled	68.73	69.97	70.02	69.28	278	52.02
9/1-2	Y(031)	fired	39.24	39.1	36.8	35.04	150.18		fired	44.47	46.5	43.44	39.57	173.98	
		lost	18.47	18.78	22.3	23.74	83.29	82.16	lost	24.26	23.47	26.58	29.71	104.02	100.1
		order	13.2	13.3	13.7	13.4	53.6		case	12.79	13.35	13.05	12.83	52.02	
			1.0827	1.08441	1.10435	1.10387	1.09383	1.09438	density	1.10335	1.11677	1.12367	1.11341	1.1143	1.12022
			1	1.01678	1.20736	1.28533	1.12737		Y	1.03366	1	1.13251	1.26587	1.10801	
9/1-6	Z(032)	filled	54.77	55.12	54.97	57.34	222.2	50.636	filled	56.06	56.96	57.45	57.18	227.65	50.3
9/1-3	Z(029)	fired	36.36	35.52	32.44	32.8	137.12		fired	32.38	33.84	31.86	30.05	128.13	
		lost	18.41	19.6	22.53	24.54	85.08	84.26	lost	23.68	23.12	25.59	27.13	99.52	97.42
			12.31	12.676	11.96	13.69	50.636		case	12.13	12.59	12.98	12.6	50.3	
			1.03284	1.03245	1.04622	1.06179	1.04332	1.03933	density	1.0686	1.0793	1.08173	1.08441	1.07851	1.08052
		Z	1	1.06464	1.22379	1.33297	1.15535		Z	1.02422	1	1.10683	1.17344	1.07612	
9/8-6	AA(039)	filled	58.86	58.55	59.09	60.28	236.78	50.93	filled	70.31	70.36	69.61	70.62	280.9	51.04
9/8-3	AA(036)	fired	44.05	44.75	41.93	40.38	171.11		fired	49.16	50.34	47.07	44.85	191.42	
		lost	14.81	13.8	17.16	19.9	65.67	61.92	lost	21.15	20.02	22.54	25.77	89.48	85.12
			12.76	12.56	12.44	13.17	50.93		case	12.71	12.67	12.59	13.07	51.04	
			1.12138	1.11871	1.13476	1.14595	1.1302	1.12673	density	1.13609	1.13787	1.12465	1.13511	1.13343	1.13126
		AA	1.07319	1	1.24348	1.44203	1.18967		AA	1.05644	1	1.12587	1.28721	1.11738	
10/13-1	AA(047)	filled	47.03	44.84	44.05	50.35	186.27	51.09							
		fired	33.93	32.21	29.11	32.28	127.53								
		lost	13.1	12.63	14.94	18.07	58.74	55.14							
			12.59	13.07	12.76	12.67	51.09			1.03721	1	1.1829	1.43072	1.16271	
		den	1.1247	1.1187	1.12138	1.1379	1.12567	1.12004							

LABSCALE MOTOR FIRING DATA

Day-Run No. that	ID: MDA (MSFC)	LOW FLOW	Weight losses by segment				sums	Empty Case Weight	HIGH FLOW	Weight losses by segment				sums	Empty Case Weight
9/8-7	BB(040)	filled	56.27	56.4	57.1	57.01	226.78	48.81	filled	67.69	67.12	67.34	67.57	269.72	48.21
9/8-4	BB(0037)	fired	42.18	41.29	39.45	38.42	161.34		fired	51.84	52.02	48.97	46.77	199.6	
		lost	14.09	15.11	17.65	18.59	65.44	65.52	lost	15.85	15.1	18.37	20.8	70.12	66.94
		case	12.26	11.83	12.51	12.21	48.81		case	12.8	11.71	12.04	11.66	48.21	
		density	1.07054	1.08416	1.08465	1.08976	1.08228	1.08441	density	1.08264	1.0929	1.09073	1.10276	1.09226	1.09181
			1	1.07239	1.25266	1.31938	1.16111		BB	1.04967	1	1.21656	1.37748	1.16093	
9/8-8	CC(041)	filled	56.78	57.19	56.73	57.51	228.21	50.85	filled	57.48	56.52	57.41	56.49	227.9	51.37
9/8-5	CC(038)	fired	39.15	41.08	42.47	42.99	165.69		fired	39.89	38.25	37.42	34.59	150.15	
		lost	17.63	16.11	14.26	14.52	62.52	60.74	lost	17.59	18.27	19.99	21.9	77.75	76.52
			12.75	12.89	12.23	12.98	50.85		case	13.02	13.17	13.04	12.14	51.37	
			1.07103	1.0776	1.08246	1.08319	1.07857	1.08003	density	1.08149	1.05449	1.0793	1.07881	1.07352	1.06689
			1.23633	1.12973	1	1.01823	1.09607		CC	1	1.03866	1.13644	1.24503	1.10503	
9/15-1	EE(042)	filled	58.93	59.49	59.29	58.74	236.45	49.68	filled	67.27	67.88	68.27	67.9	271.32	50.7
9/15-4	EE(045)	fired	43.92	43.28	40.42	37.72	165.34		fired	52.28	51.5	49.79	45.99	199.56	
		lost	15.01	16.21	18.87	21.02	71.11	70.16	lost	14.99	16.38	18.48	21.91	71.76	69.72
			12.87	12.52	12.39	11.9	49.68		case	12.68	12.42	12.9	12.7	50.7	
			1.12041	1.14254	1.14084	1.13938	1.13579	1.14169	density	1.07673	1.09389	1.09211	1.08876	1.08787	1.093
			1	1.07995	1.25716	1.4004	1.18438		EE	1	1.09273	1.23282	1.46164	1.1968	
9/15-2	FF(043)	filled	55.61	55.44	55.09	55.01	221.15	47.87	filled	68.4	68.4	67.44	67.21	271.45	48.36
9/15-5	FF(046)	fired	41.19	39.98	36.78	36.27	154.22		fired	52.19	51.32	48.71	44.41	196.63	
		lost	14.42	15.46	18.31	18.74	66.93	67.54	lost	16.21	17.08	18.73	22.8	74.82	71.62
			12.38	12.55	11.57	11.37	47.87		order	12.69	12.67	11.75	11.25	48.36	
			1.05157	1.0433	1.05862	1.06154	1.05376	1.05096	FF	1.09882	1.09921	1.09842	1.10375	1.10005	1.09882
		FF	1	1.07212	1.26976	1.29958	1.16037		FF	1	1.05367	1.15546	1.40654	1.15392	
9/15-3	GG(044)	filled	58.01	58.24	57.33	57.9	231.48	49.31	filled	70.04	70.27	69.04	69.53	278.88	51.41
10/14-1	GG(056)st	fired	42.83	42.31	38.57	36.82	160.53		fired	53.81	53.29	49.45	47.2	203.75	
		lost	15.18	15.93	18.76	21.08	70.95	69.38	lost	16.23	16.98	19.59	22.33	75.13	73.14
		order	12.25	12.99	11.89	12.18	49.31		order	13.03	13.33	12.42	12.63	51.41	
			1.11311	1.10071	1.10533	1.11214	1.10782	1.10302		1.12446	1.12308	1.11677	1.12229	1.12165	1.11992
		GG	1	1.04941	1.23584	1.38867	1.16848		GG	1	1.04621	1.20702	1.37585	1.15727	
		filled	56.65	57.83	58.48	58.3	231.26	50.19	filled						
10/13-2	GG(048)	fired	46.3	46.99	45.75	44.41	183.45		fired						
		lost	10.35	10.84	12.73	13.89	47.81	47.14	lost						
		order	12.3	12.44	12.81	12.64	50.19								
			1.07881	1.10411	1.11092	1.11068	1.10113	1.10752							
			1	1.04734	1.22995	1.34203	1.15483								

Day-Run No. that	ID: MDA (MSFC)	LOW FLOW	Weight losses by segment				sums	Empty Case Weight	HIGH FLOW	Weight losses by segment				sums	Empty Case Weight
10/14-7	HH(062)	filled	58.64	58.69	59.33	60.02	236.68	50.91	filled	69.67	69.51	69.65	70.35	279.18	48.84
10/13-8	HH(054)	fired	43.32	41.94	39.53	37.87	162.66		fired	51.47	51.8	45.32	49.31	197.9	
		lost	15.32	16.75	19.8	22.15	74.02	73.1	lost	18.2	17.71	24.33	21.04	81.28	84.08
		order	12.94	12.05	12.76	13.16	50.91		??	12.11	12.05	12.27	12.41	48.84	
			1.11165	1.13452	1.13281	1.13987	1.12971	1.13367		1.13531	1.13333	1.13176	1.1428	1.1358	1.13254
		HH	1	1.09334	1.29243	1.44582	1.2079		HH	1.02767	1	1.3738	1.18803	1.14737	
11/4-4	HH(072)	filled	58.2	58.33	58.56	58.72	233.81	51.15	filled	69.49	69.73	69.07	69.27	277.56	52.41
11/4-1	HH(069)	fired	44.99	44.05	41.72	39.73	170.49		fired	54.87	56.23	53.63	51.31	216.04	
		lost	13.21	14.28	16.84	18.99	63.32	62.24	lost	14.62	13.5	15.44	17.96	61.52	57.88
		order	12.57	12.59	13.04	12.95	51.15		case	13.15	13.47	12.88	12.91	52.41	
			1.10995	1.11262	1.10727	1.11335	1.1108	1.10995	density	1.11124	1.10966	1.10828	1.11164	1.11021	1.10897
		HH	1	1.081	1.27479	1.43755	1.19833		HH	1.08296	1	1.1437	1.33037	1.13926	
10/14-8	HV(063)	filled	59.15	58.41	59.72	59.47	236.75	51.12	filled	69.85	69.4	70.25	69.63	279.13	50.06
10/13-9	HV(055)	fired	44.21	42.79	41.12	38.498	166.618		fired	51.13	51.49	49.81	45.52	197.95	
		lost	14.94	15.62	18.6	20.972	70.132	68.44	lost	18.72	17.91	20.44	24.11	81.18	76.7
		order	13.25	11.73	13.16	12.98	51.12		case	12.84	12.14	12.97	12.11	50.06	
			1.11652	1.13549	1.13257	1.13087	1.12886	1.13403	density	1.12446	1.12939	1.12978	1.13452	1.12954	1.12959
		HV	1	1.04552	1.24498	1.40375	1.17356		HV	1.04523	1	1.14126	1.34618	1.13317	
10/14-3	IIA(058)	filled	58.24	58.71	57.79	58.55	233.29	48.86	filled	68.17	68.98	68.27	69.53	274.95	49.89
10/13-5	IIA(051)	fired	41.84	41	37.21	35.43	155.48		fired	49.38	50.39	46.9	45.06	191.73	
		lost	16.4	17.71	20.58	23.12	77.81	76.58	lost	18.79	18.59	21.37	24.47	83.22	79.92
		order	12.9	12.53	11.4	12.03	48.86		case	13.06	12.79	11.53	12.51	49.89	
			1.10289	1.12333	1.12844	1.1316	1.12156	1.12588	density	1.08698	1.10828	1.11913	1.12465	1.10976	1.11371
			1	1.07988	1.25488	1.40976	1.18613		IIA	1.01076	1	1.14954	1.3163	1.11915	
10/14-6	JX(061)	filled	57.14	56.74	55.81	56.98	226.67	50.51	filled	65.89	65.82	65.28	65.67	262.66	47.01
10/13-7	JX(053)	fired	41.74	40.1	36.48	35.25	153.57		fired	45.41	44.92	40.16	37.34	167.83	
		lost	15.4	16.64	19.33	21.73	73.1	71.94	lost	20.48	20.9	25.12	28.33	94.83	92.04
		order	13.12	12.64	11.82	12.93	50.51		case	12.91	11.21	11.29	11.6	47.01	
			1.07079	1.07273	1.07006	1.07152	1.07127	1.07139	density	1.04497	1.07712	1.06489	1.06647	1.06336	1.07101
		JX	1	1.08052	1.25519	1.41104	1.18669		JX	0.9799	1	1.20191	1.3555	1.13433	
10/14-5	KK(060)	filled	59.58	59.25	57.93	58.41	235.17	47.22	filled	70.59	69.44	70.7	70.91	281.64	50.04
10/13-3	KK(049)	fired	45.06	44.59	41.05	39.38	170.08		fired	51.28	51.37	49.85	46.25	198.75	
		lost	14.52	14.66	16.88	19.03	65.09	63.08	lost	19.31	18.07	20.85	24.66	82.89	77.84
		order	12.26	12.27	11.12	11.57	47.22		case	12.9	11.89	12.65	12.6	50.04	
			1.15106	1.14279	1.13865	1.13938	1.14297	1.14072	density	1.13787	1.13511	1.14497	1.1501	1.14201	1.14004
		KK	1	1.00964	1.16253	1.31061	1.1207			1.06862	1	1.15385	1.36469	1.14679	

LABSCALE MOTOR FIRING DATA

Day-Run No. that	ID: MDA (MSFC)	LOW FLOW	Weight losses by segment				sums	Empty Case Weight	HIGH FLOW	Weight losses by segment				sums	Empty Case Weight
10/14-4	G/I	filled	51.72	51.77	51.83	51.39	206.71	42.87	filled	51.77	52.16	51.63	52.19	207.75	43.95
10/13-4	G/I	fired	41.15	41.57	40.75	39.72	163.19		fired	36.69	39.66	38.4	34.385	149.135	
		lost	10.57	10.2	11.08	11.67	43.52	42.56	lost	15.08	12.5	13.23	17.805	58.615	51.46
			10.69	10.73	10.75	10.7	42.87			10.7	11.2	10.80	11.25	43.95	
			0.99805	0.9983	0.99927	0.98978	0.99635	0.99878		0.99903	0.99635	0.99319	0.99586	0.99611	0.99477
		G/I Tm	1.03627	1	1.08627	1.14412	1.06667		G/I Tm at 0.358	1.2064	1	1.0584	1.4244	1.1723	
10/14-2	LL(057)	filled	60.05	59.38	58.85	59.86	238.14	50.43	filled	70.49	70.48	70.51	70.59	282.07	50.51
10/13-6	LL(052)	fired	44.02	41.73	38.47	37.2	161.42		fired	49.81	45.82	51.53	49.29	196.45	
		lost	16.03	17.65	20.38	22.66	76.72	76.06	lost	20.68	24.66	18.98	21.3	85.62	87.28
			13.28	12.21	11.81	13.13	50.43			12.59	12.51	12.62	12.79	50.51	
			1.13768	1.14741	1.14425	1.13671	1.14151	1.14583		1.14201	1.14339	1.14181	1.14004	1.14181	1.1426
		LL	1	1.10106	1.27137	1.4136	1.19651			1.08957	1.29926	1	1.12223	1.12777	
10/28-1	KK(064)	filled	58.81	59.48	59.37	59.62	237.28	49.46	filled	69.87	70.58	69.87	69.96	280.28	48.96
10/28-4	KK(067)	fired	44.68	45.13	42.54	40.56	172.91		fired	51.89	53.74	49.87	47.08	202.58	
		lost	14.13	14.35	16.83	19.06	64.37	62.36	lost	17.98	16.84	20	22.88	77.7	73.68
		order	12.58	12.54	12.62	11.72	49.46			12.64	12.47	11.94	11.91	48.96	
			1.12454	1.14181	1.13719	1.16517	1.14218	1.1395		1.1288	1.14615	1.1426	1.14497	1.14063	1.14438
			1	1.01557	1.19108	1.3489	1.13889		KK	1.0677	1	1.18765	1.35867	1.1535	
10/28-2	MM(065)	filled	59.13	58.88	59.15	60.22	237.38	51.1	filled	70.56	69.96	70.39	70.69	281.6	51.34
11/4-2	MMF(070)	fired	46.03	45.95	44.11	42.95	179.04		fired	50.1	51.25	48.93	45.35	195.63	
	MMF(073)	lost	13.1	12.93	15.04	17.27	58.34	55.94	lost	20.46	18.71	21.46	25.34	85.97	80.34
			12.62	12.7	12.63	13.15	51.1			12.87	12.35	12.94	13.18	51.34	
			1.13135	1.12333	1.1316	1.14498	1.13281	1.12746		1.13787	1.13629	1.13314	1.13432	1.1354	1.13471
		MM	1.01315	1	1.16319	1.33565	1.128			1.09353	1	1.14698	1.35436	1.14872	
11/4-5	MMF(073)	filled	59.13	58.88	59.15	60.22	237.38	51.1	filled	59.23	58.8	59.32	59.71	237.06	50.61
11/4-2	MMF(070)	fired	46.03	45.95	44.11	42.95	179.04		fired	45.08	45.23	44.29	42.8	177.4	
		lost	13.1	12.93	15.04	17.27	58.34	55.94	lost	14.15	13.57	15.03	16.91	59.66	57.2
			12.62	12.7	12.63	13.15	51.1			12.86	12.31	12.74	12.7	50.61	
			1.13135	1.12333	1.1316	1.14498	1.13281	1.12746		1.12795	1.13087	1.13306	1.14352	1.13385	1.13196
			1.01315	1	1.16319	1.33565	1.128		MM	1.04274	1	1.10759	1.24613	1.09912	
11/4-6	MMG(074)	filled	69.89	70.37	70.34	70.36	280.96	51.1	filled	69.75	70.2	70.89	70.2	281.04	51.07
11/4-3	MMH(071)	fired	54.71	55.54	53.47	51.26	214.98		fired	55.05	56.53	55	51.79	218.37	
		lost	15.18	14.83	16.87	19.1	65.98	63.4	lost	14.7	13.67	15.89	18.41	62.67	59.12
			12.62	12.7	12.63	13.15	51.1			12.71	12.77	12.72	12.87	51.07	
			1.12959	1.13748	1.13826	1.1284	1.13343	1.13787		1.12505	1.13274	1.14734	1.13077	1.13397	1.14004
			1.0236	1	1.13756	1.28793	1.11227		MM at 0.41	1.07535	1	1.1624	1.34674	1.14612	

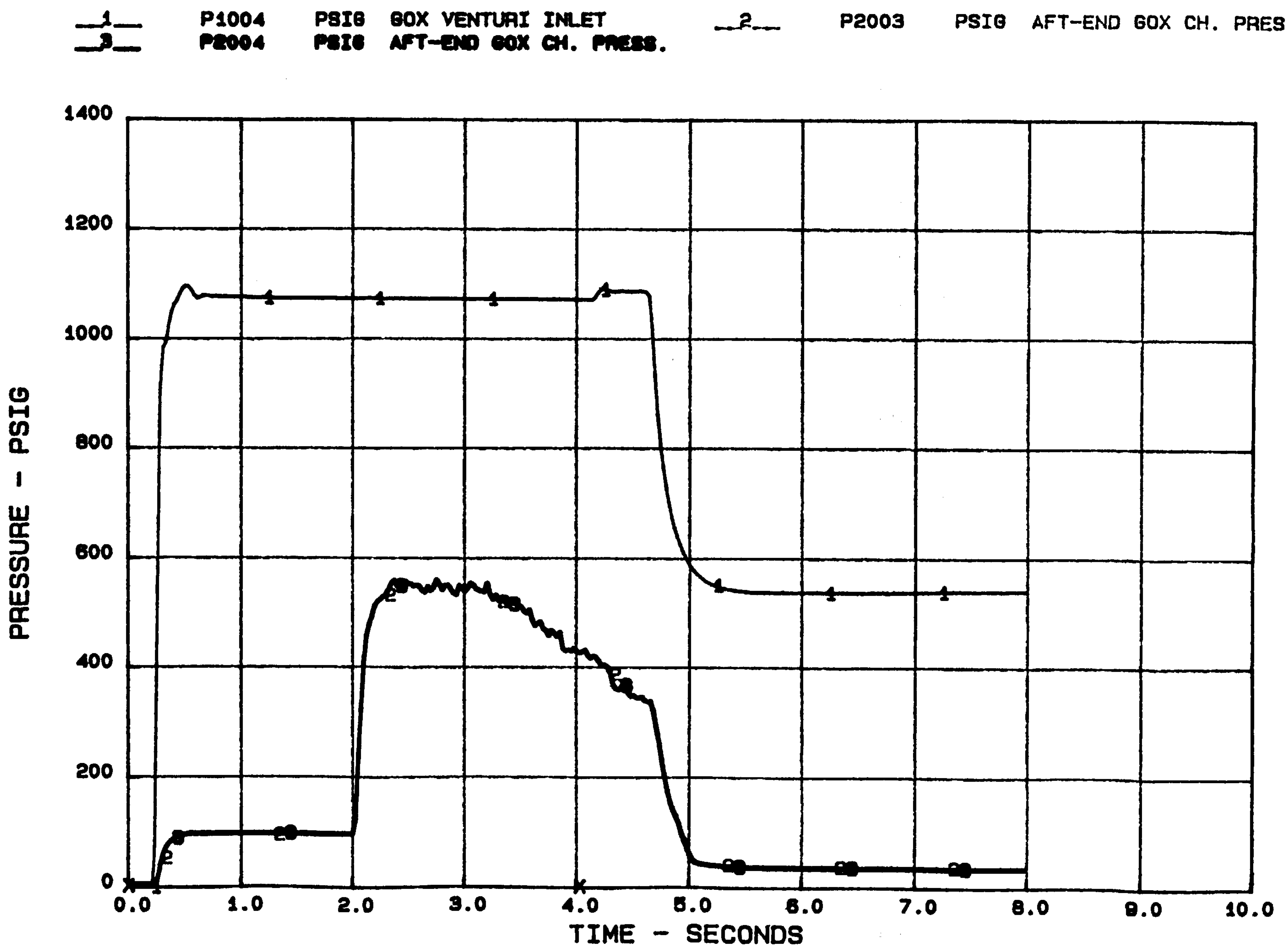
LABSCALE MOTOR FIRING DATA

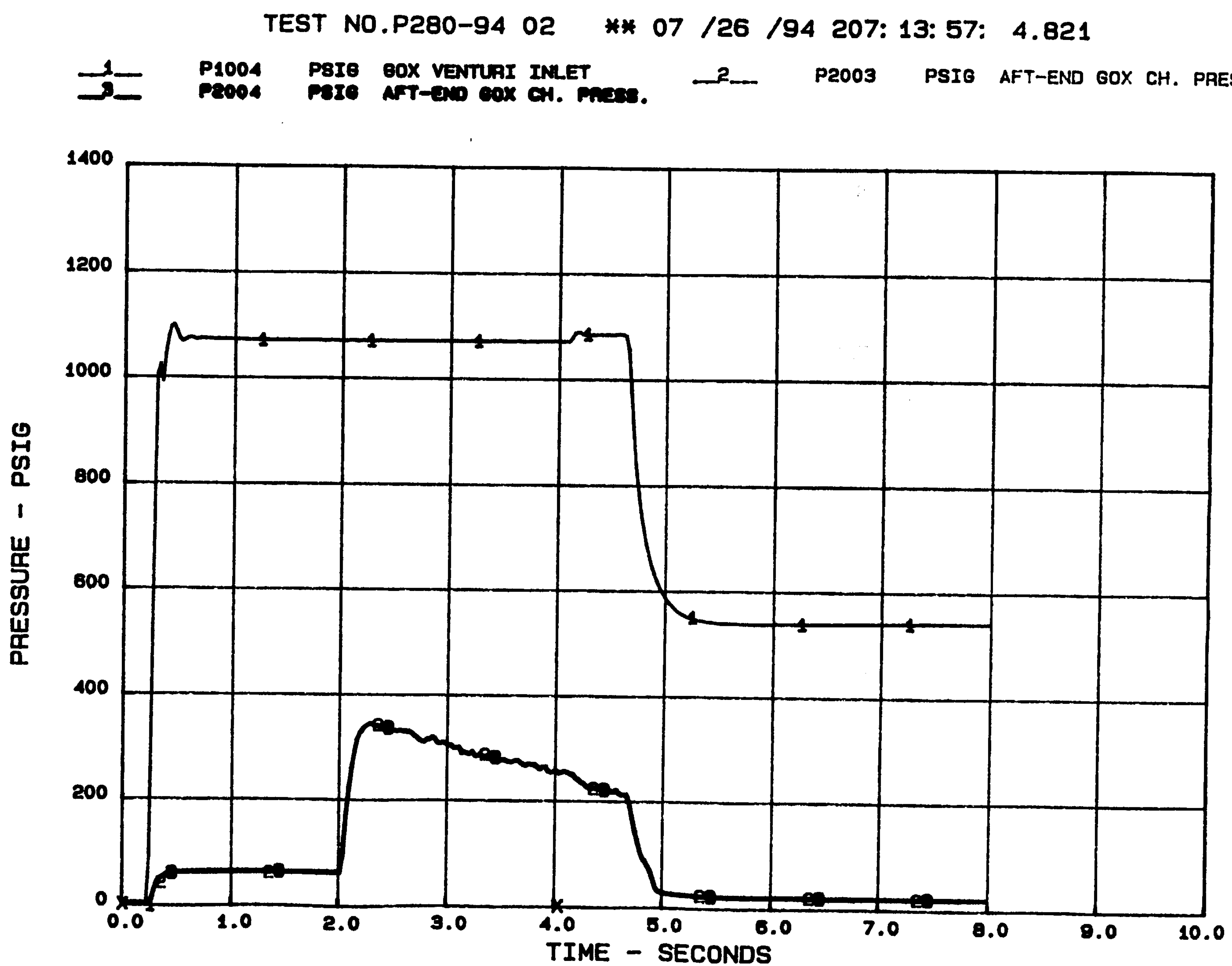
Day-Run No. that	ID: MDA (MSFC)	LOW FLOW	Weight losses by segment				sums	Empty Case Weight	HIGH FLOW	Weight losses by segment				sums	Empty Case Weight
10/28-3	NN(066)	filled	58.66	59.49	58.86	58.95	235.96	49.46	filled	70	69.2	69.6	71.03	279.83	49.16
10/28-5	NN(068)	fired	43.4	43.9	39.65	37.46	164.41		fired	50.84	50.74	48.04	45.94	195.56	
		lost	15.26	15.59	19.21	21.49	71.55	69.6	lost	19.16	18.46	21.56	25.09	84.27	80.04
		order	12.19	12.67	12.33	12.27	49.46			12.62	11.64	12.12	12.78	49.16	
			1.13038	1.1389	1.13184	1.13549	1.13415	1.13537		1.13176	1.13531	1.13373	1.14892	1.13743	1.13452
		NN	1	1.02163	1.25885	1.40826	1.17218		NN	1.03792	1	1.16793	1.35915	1.14125	
11/4-7	OO(075)	filled	53.87	54.28	53.32	52.52	213.99	51.1	filled	69.31	70.53	70.4	69.57	279.81	51.27
2/17-10	OO(085)	fired	43.77	44.48	42.01	39.76	170.02		fired	54.89	56.95	54.75	51.62	218.21	
		lost	10.1	9.8	11.31	12.76	43.97	42.22	lost	14.42	13.58	15.65	17.95	61.6	58.46
			12.62	12.7	12.63	13.15	51.1			12.73	13.06	12.91	12.57	51.27	
			1.139	1.121	1.129	1.134	1.13075	1.125		1.11598	1.13353	1.13393	1.12426	1.12692	1.13373
			1.03061	1	1.15408	1.30204	1.12168		OO	1.06186	1	1.15243	1.3218	1.13402	
1/11-1	First	filled	70.405	70.4	70.408		211.213		filled	78.282					
1/18-1	2nd	fired	60.486	58.984	58.92		178.39		fired	70.152					
		lost	9.919	11.416	11.488		32.823	34.248	lost	8.13					
					1.15818			1.15							
2/17-6	IU(081)	filled	59.66	59.63	59.11	58.12	236.52	51.46	filled	68.41	69.09	69.71	67.18	274.39	50.82
2/17-1	IU(076)	fired	45.59	44.48	42.23	39.65	171.95		fired	52.49	52.63	51.31	48.3	204.73	
		lost	14.07	15.15	16.88	18.47	64.57	64.06	lost	15.92	16.46	18.4	18.88	69.66	69.72
			13.22	12.71	12.96	12.57	51.46			12.7	12.72	12.57	12.83	50.82	
			1.12965	1.14133	1.1226	1.108	1.1254	1.13196		1.09882	1.11183	1.12702	1.07199	1.10242	1.11943
		IU	1	1.07676	1.19972	1.31272	1.1473		Weak Char	1	1.03392	1.15578	1.18593	1.09391	
2/17-7	PP(082)	filled	57.262	56.91	56.98	56.69	227.842	51.45	filled	64.51	66.17	66.26	65.53	262.47	51.4
2/17-3	PP(078)	fired	41.69	42.21	40.72	38.91	163.53		fired	42.23	49.47	49.08	45.53	186.31	
		lost	15.572	14.7	16.26	17.78	64.312	61.92	lost	22.28	16.7	17.18	20	76.16	67.76
			12.87	12.71	12.56	13.31	51.45			12.59	13.36	12.93	12.52	51.4	
			1.07983	1.07516	1.08052	1.05522	1.07268	1.07784		1.02406	1.04162	1.05187	1.04556	1.04078	1.04675
		PP	1.05932	1	1.10612	1.20952	1.09374		PP	1.33413	1	1.02874	1.1976	1.14012	
2/17-9	UU(084)	filled	51.91	51.75	52.65	52.24	208.55	50.69	filled	63.89	63.31	63.53	63.26	253.99	51.55
2/17-4	UU(079)	fired	35.96	37.11	36.45	35.2	144.72		fired	46.725	45.98	43.91	42.45	179.065	
		lost	15.95	14.64	16.2	17.04	63.83	61.68	lost	17.165	17.33	19.62	20.81	74.925	73.9
			12.67	12.55	12.86	12.61	50.69			12.82	12.91	12.89	12.93	51.55	
			0.95451	0.95354	0.96789	0.964	0.95999	0.96072		1.0073	0.99408	0.99882	0.9927	0.99822	0.99645

LABSCALE MOTOR FIRING DATA

Day-Run No. that	ID: MDA (MSFC)	LOW FLOW	Weight losses by segment				sums	Empty Case Weight	HIGH FLOW	Weight losses by segment				sums	Empty Case Weight
			1.08948	1	1.10656	1.16393	1.08999			1	1.00961	1.14302	1.21235	1.09125	
2/17-5	RR(083)	filled	58.863	58.558	58.562	57.67	233.653	51.65	filled	70.563	70.037	70.045	69.935	280.58	51.53
2/17-8	MW(080)	fired	42.029	43.41	42.118	39.984	167.541		fired	53.531	53.595	51.21	48.365	206.701	
		lost	16.834	15.148	16.444	17.686	66.112	63.184	lost	17.032	16.442	18.835	21.57	73.879	70.554
			12.82	13.04	12.82	12.97	51.65			12.93	12.57	13.02	13.01	51.53	
			1.12	1.10722	1.11267	1.08733	1.1068	1.10995		1.13675	1.13347	1.12475	1.12278	1.12944	1.12911
			1.1113	1	1.08556	1.16755	1.0911			1.03588	1	1.14554	1.31188	1.12333	

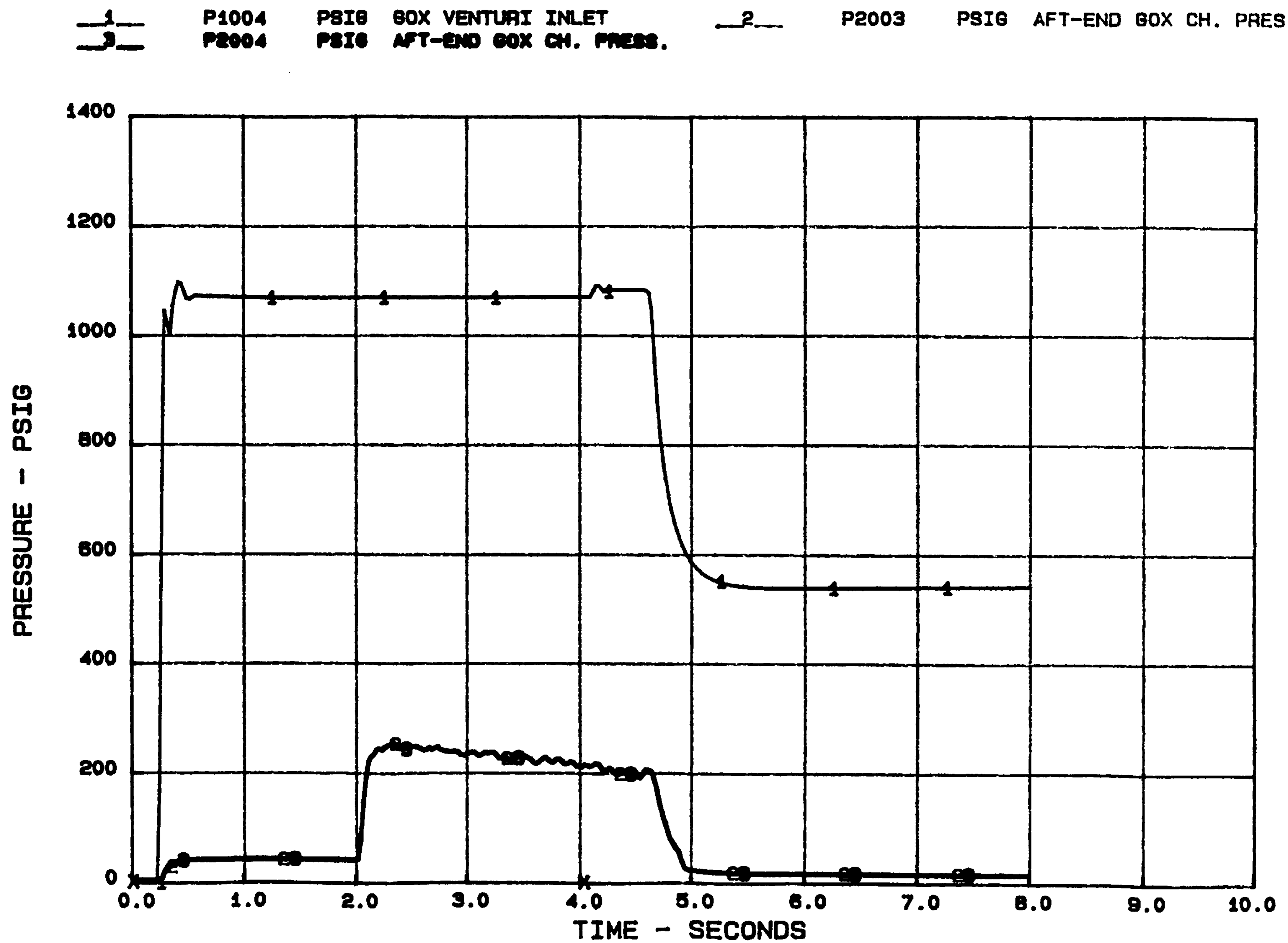
TEST NO.P280-94 01 ** 07 /26 /94 207: 13: 24: 37.604




TEST NO.P280-94 02 ** 07 /26 /94 207: 13: 57: 4.821
1 P1004 PSIG GOX VENTURI INLET
3 P2004 PSIG AFT-END GOX CH. PRESS.
2 P2003 PSIG AFT-END GOX CH. PRES
1400
1200
1000
800
600
400
200
0
PRESSURE - PSIG
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME - SECONDS

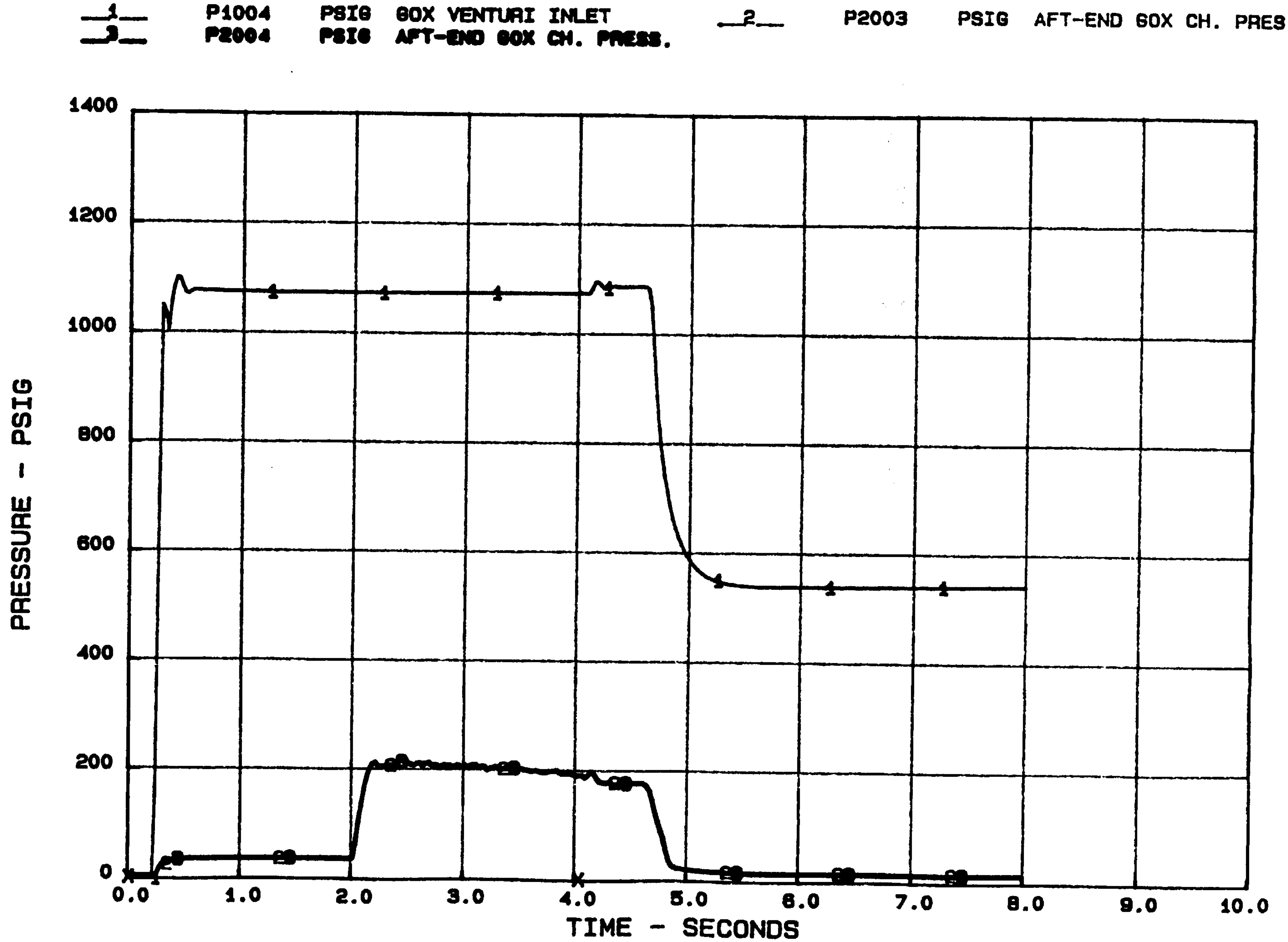
2.70

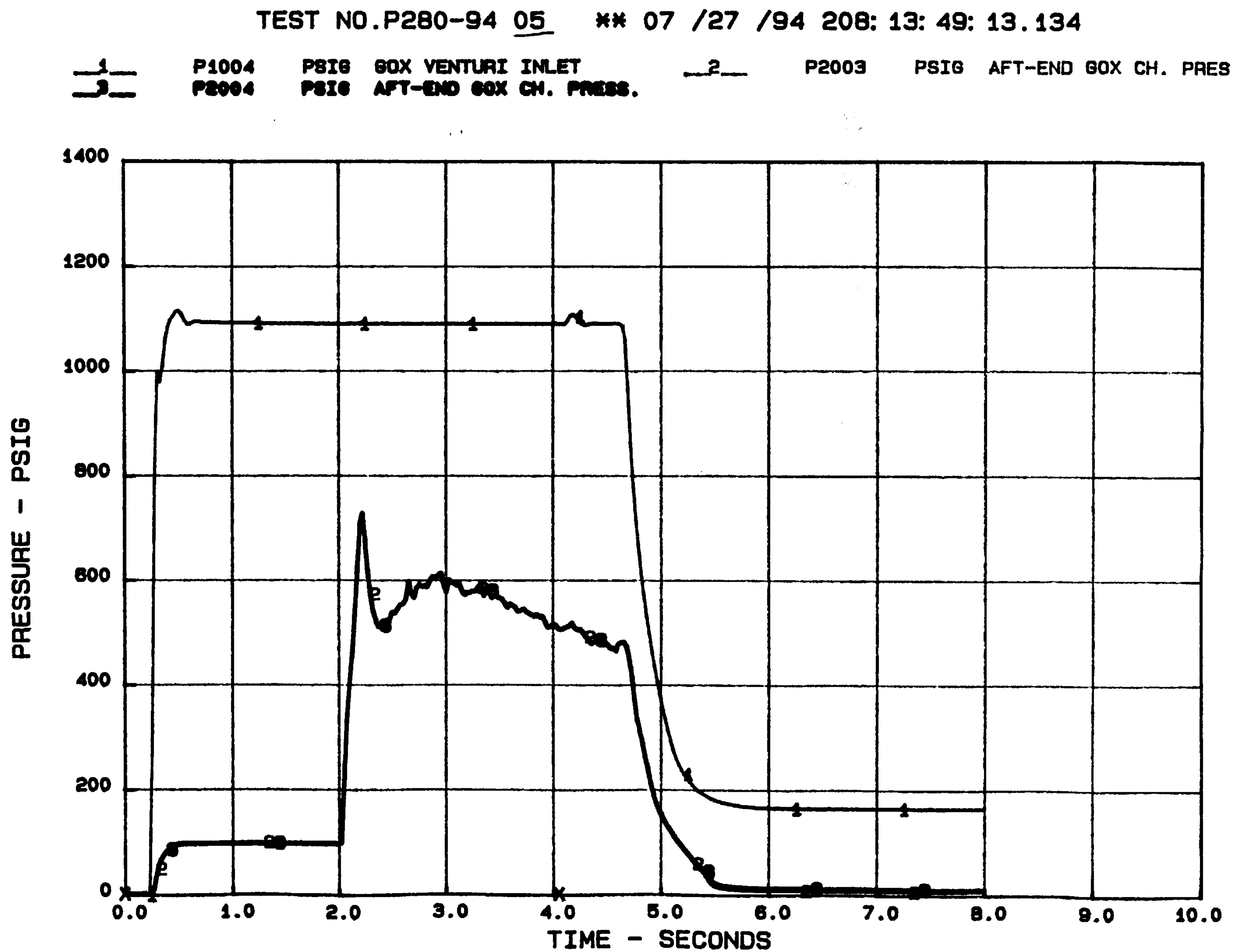
TEST NO.P280-94 03 ** 07 /26 /94 207: 14: 24: 17.190



2.70

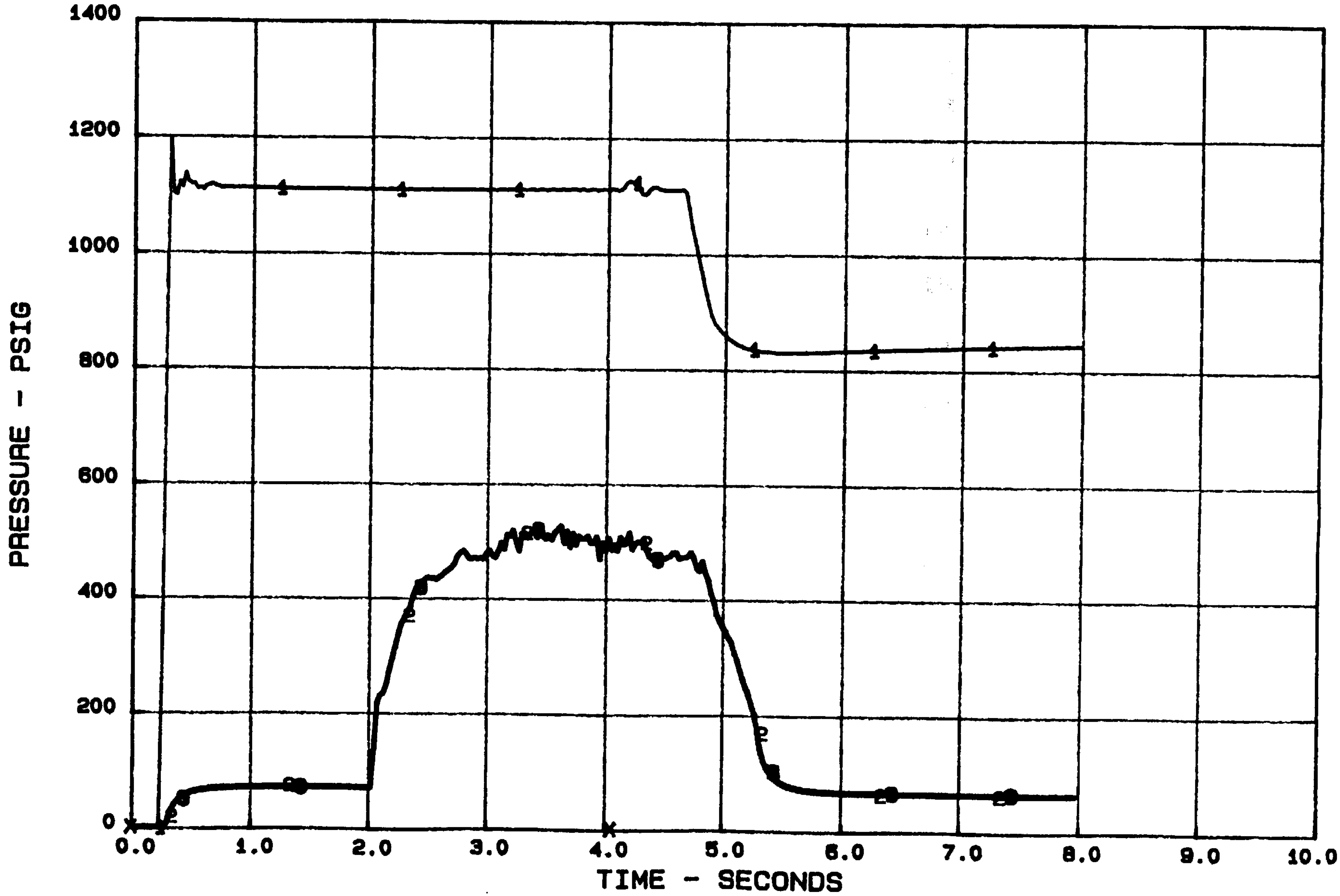
TEST NO.P280-94 04 ** 07 /26 /94 207: 14: 49: 16.234




TEST NO.P280-94 05 ** 07 /27 /94 208: 13: 49: 13.134
1 P1004 PSIG GOX VENTURI INLET
2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.
PRESSURE - PSIG
TIME - SECONDS
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

TEST NO.P280-94 06 ** 07 /27 /94 208: 14: 25: 3.802

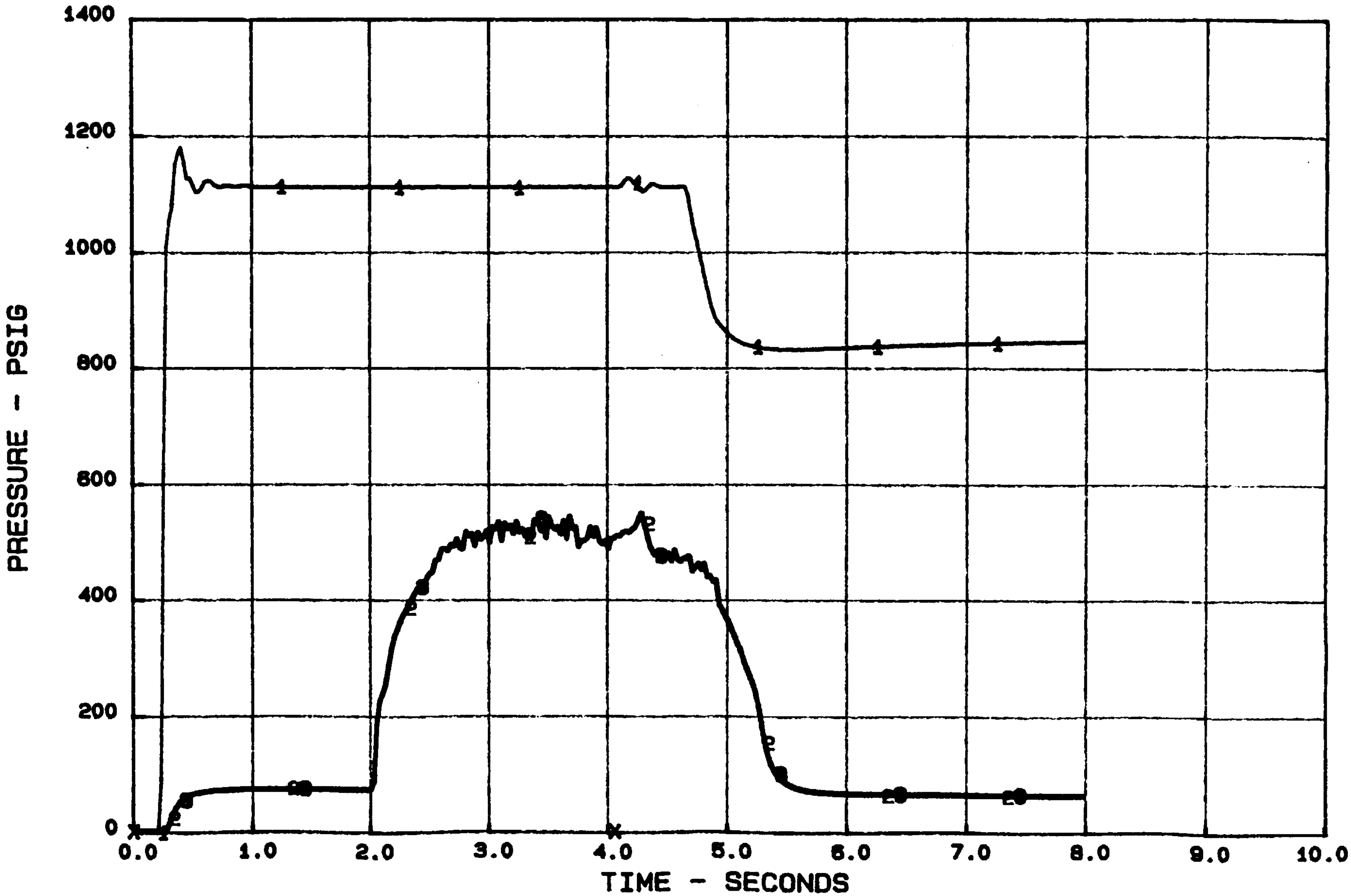
1	P1004	PSIG	GOX VENTURI INLET	2	P2003	PSIG	AFT-END GOX CH. PRES
3	P2004	PSIG	AFT-END GOX CH. PRESS.				



2.95

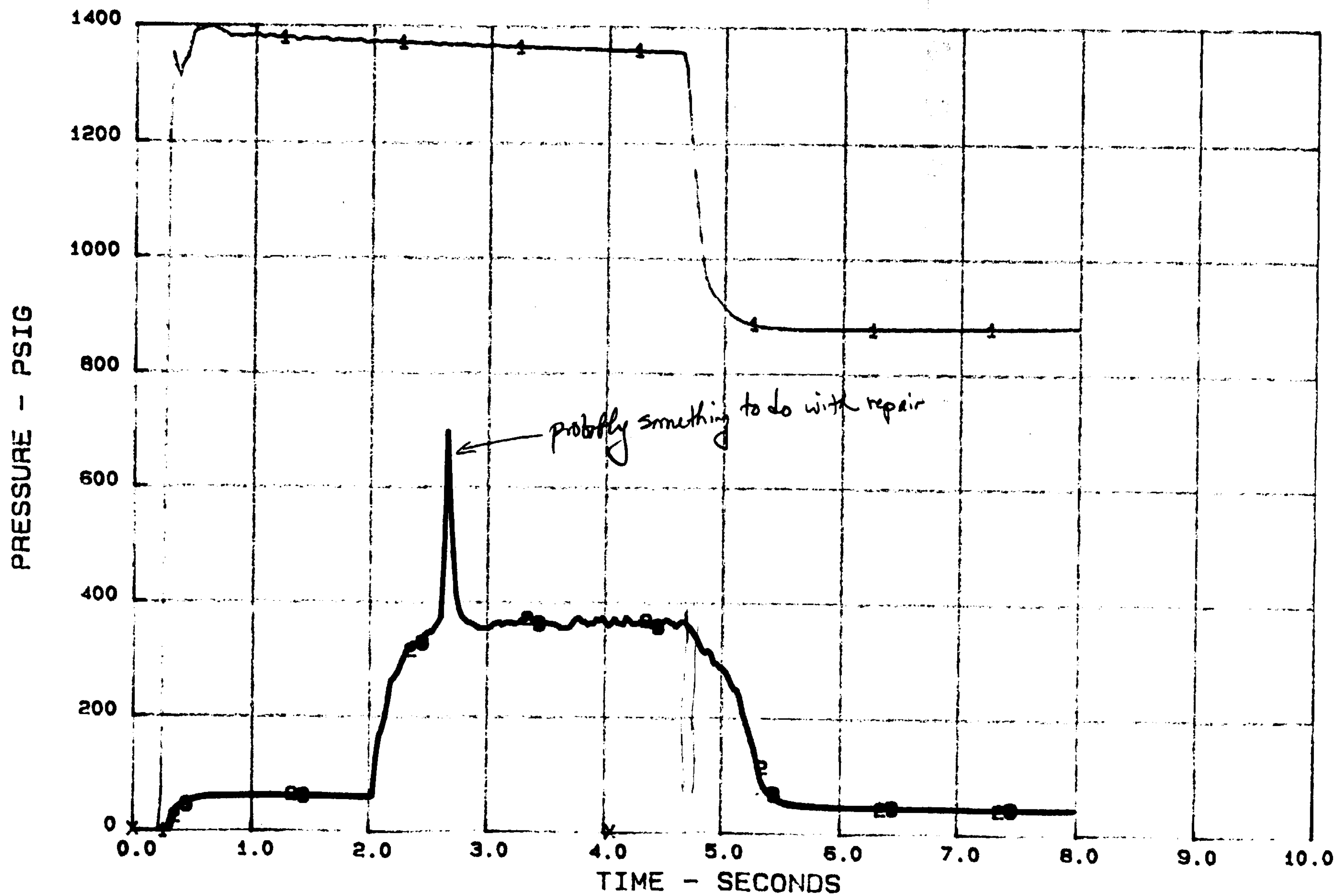
TEST NO.P280-94 07 ** 07 /27 /94 208: 14: 52: 9.770

1	P1004	PSIG	GOX VENTURI INLET	2	P2003	PSIG	AFT-END GOX CH. PRES
3	P2004	PSIG	AFT-END GOX CH. PRESS.				



TEST NO.P280-94 08 ** 08 / 2 /94 214: 10: 17: 5.237

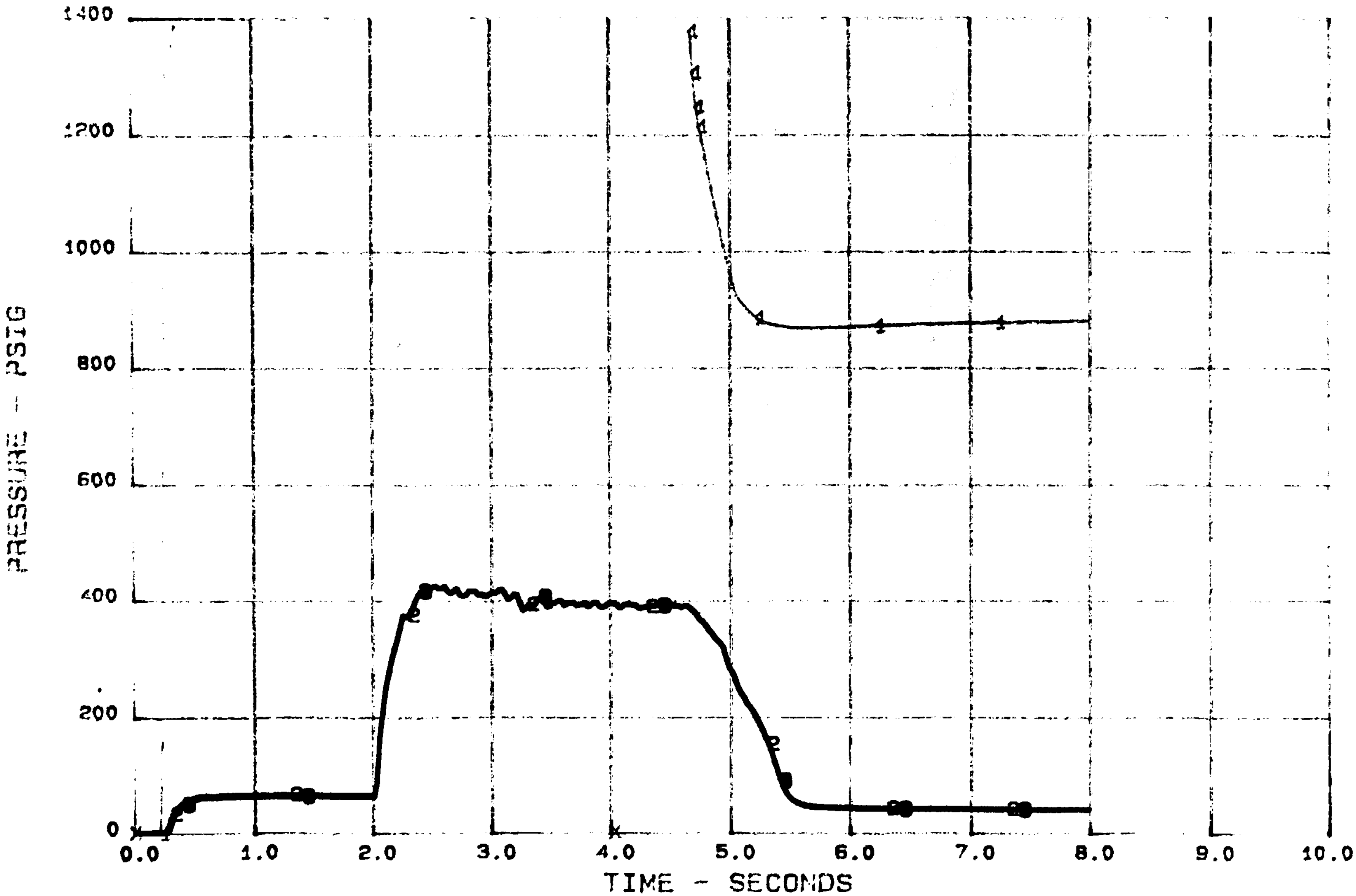
1	P1004	PSIG	GOX VENTURI INLET
2	P2003	PSIG	AFT-END GOX CH. PRES
3	P2004	PSIG	AFT-END GOX CH. PRESS.



Use 2.95 to in tail off

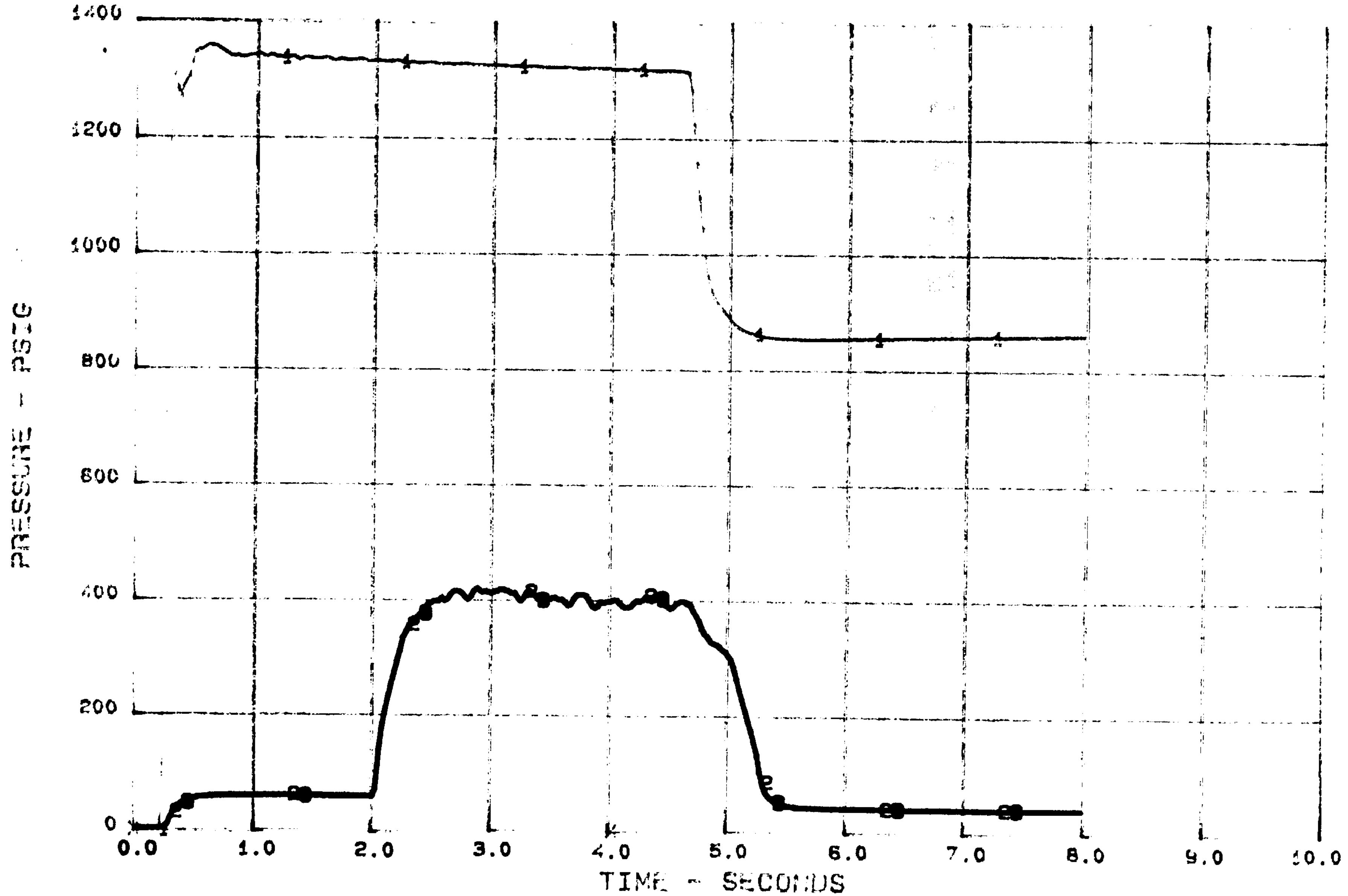
TEST NO.P280-94'09 ** 08 / 2 /94 214: 10: 44: 58.556

1	P1004	PSIG	GOX VENTURI INLET	2	P2003	PSIG	AFT-END GOX CH. PRES
3	P2004	PSIG	AFT-END GOX CH. PRESS.				



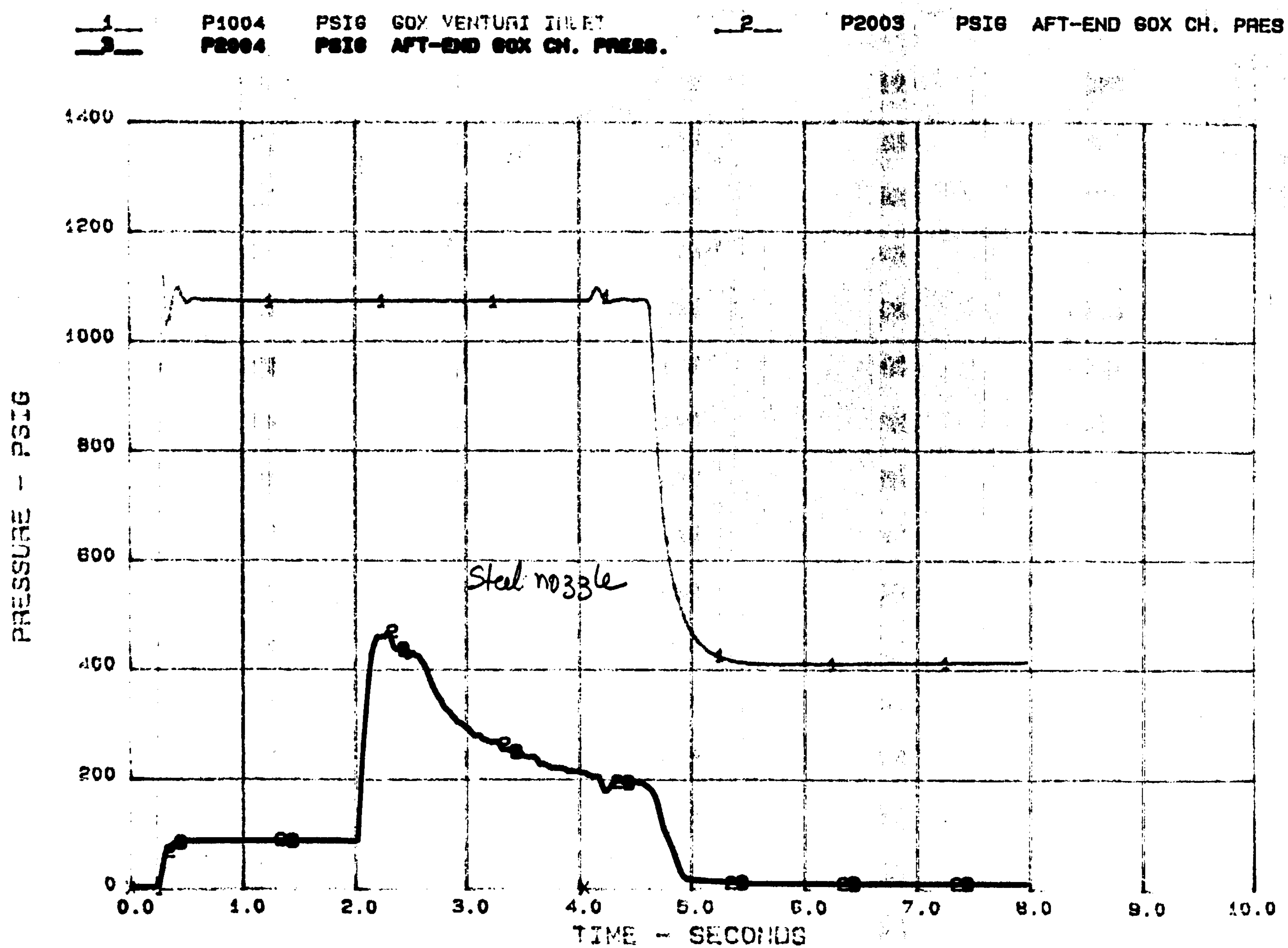
2.95 to include tail off

TEST NO.P280-94 10 ** 08 / 2 /94 214: 12: 52: 53.778

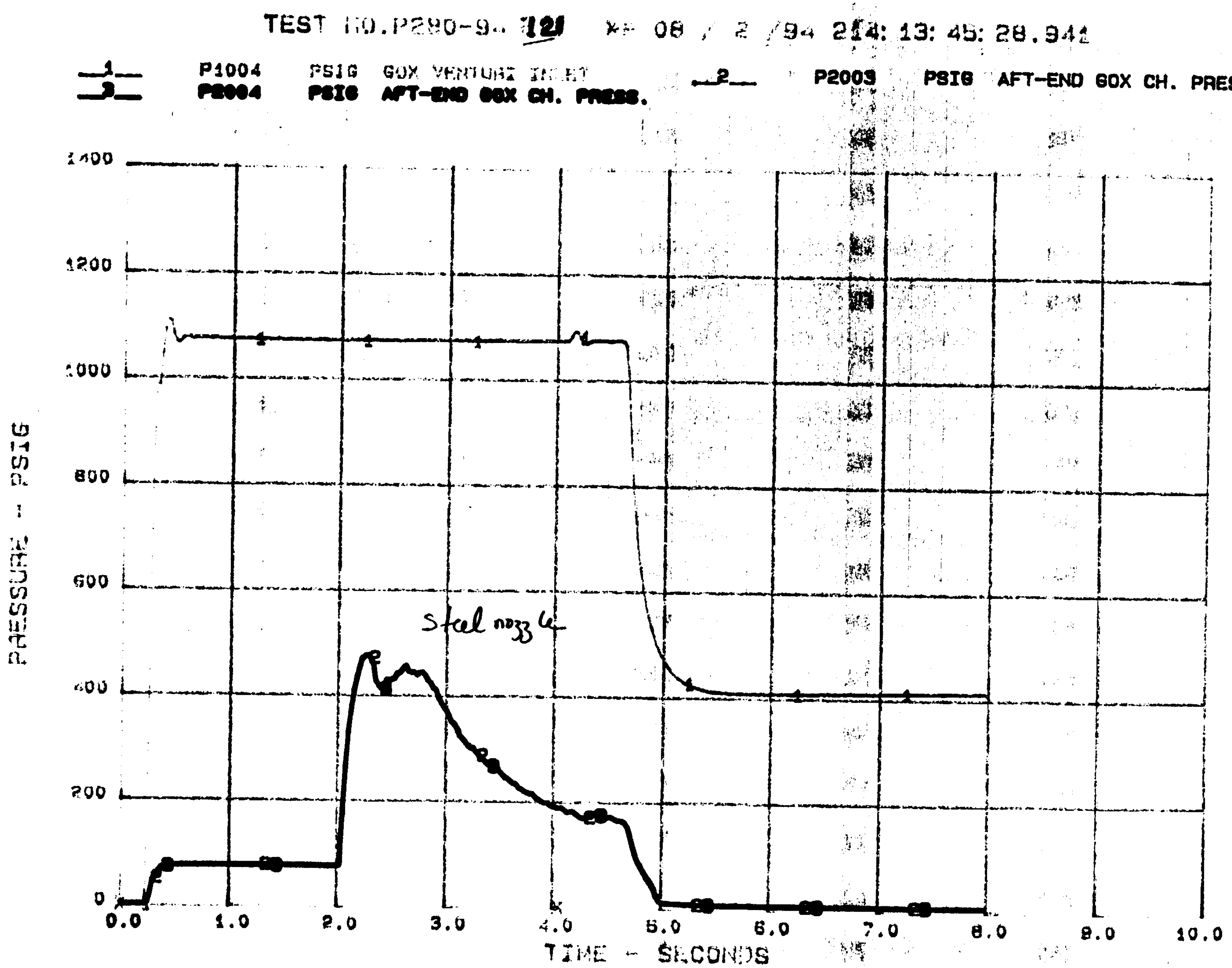


2.95 to mai iloff

TEST NO.P280-94 11 ** 08 / 2 /94 214: 13: 21: 26.721



2.75

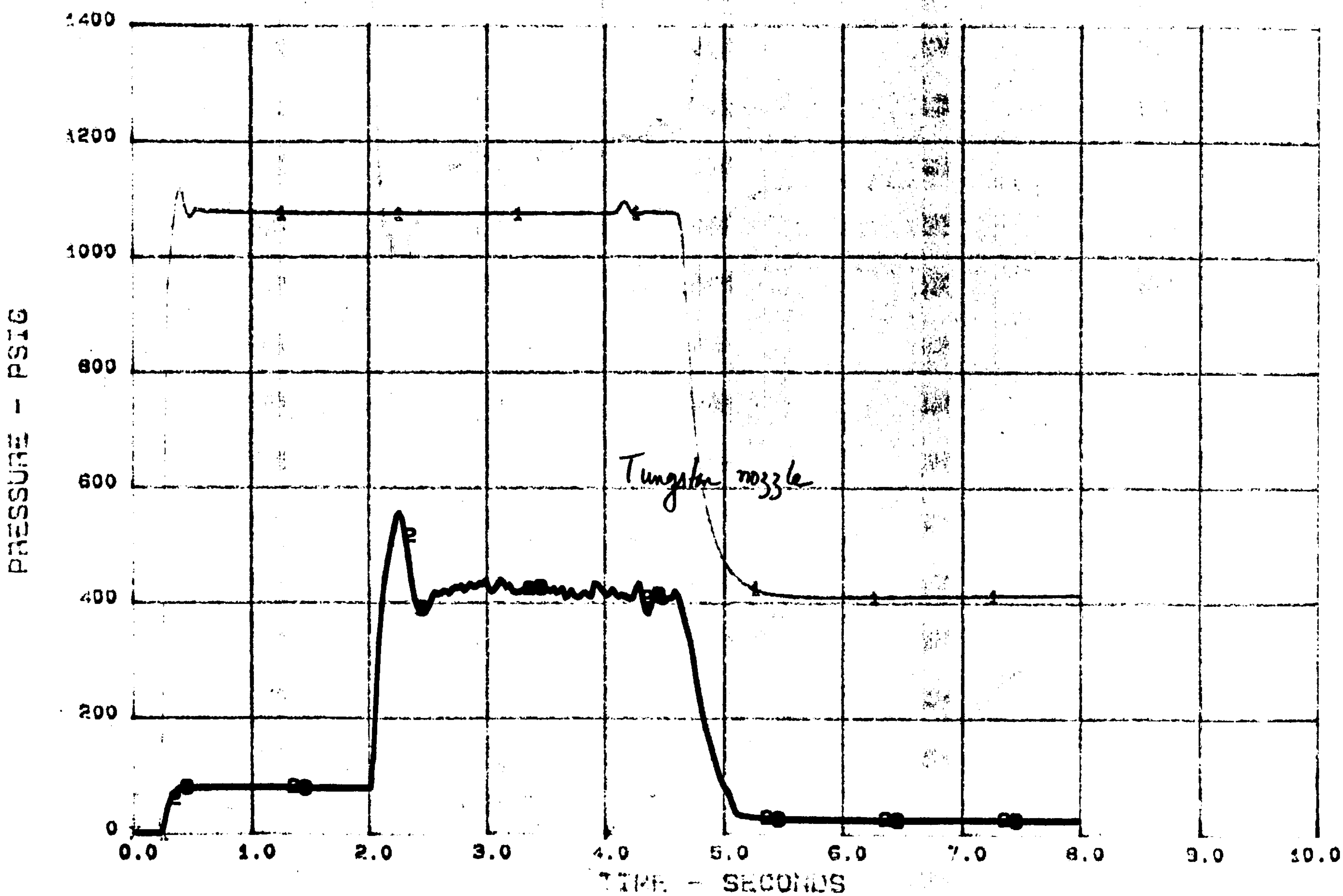


TEST NO.P280-94 12 08 / 2 /94 214: 13: 45: 28.941
1 P1004 PSIG GOX VENTURI INLET
3 P2004 PSIG AFT-END GOX CH. PRESS.
2 P2003 PSIG AFT-END GOX CH. PRES
PRESSURE - PSIG
0
200
400
600
800
1000
1200
1400
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME - SECONDS
Steel nozzle

2.75

TEST NO.P280-94 ** 08 / 2 /94 214: 14: 21: 17.584

1	P1004	PSIG	GOX VENTURI INLET	2	P2003	PSIG	AFT-END GOX CH. PRES
3	P2004	PSIG	AFT-END GOX CH. PRESS.				



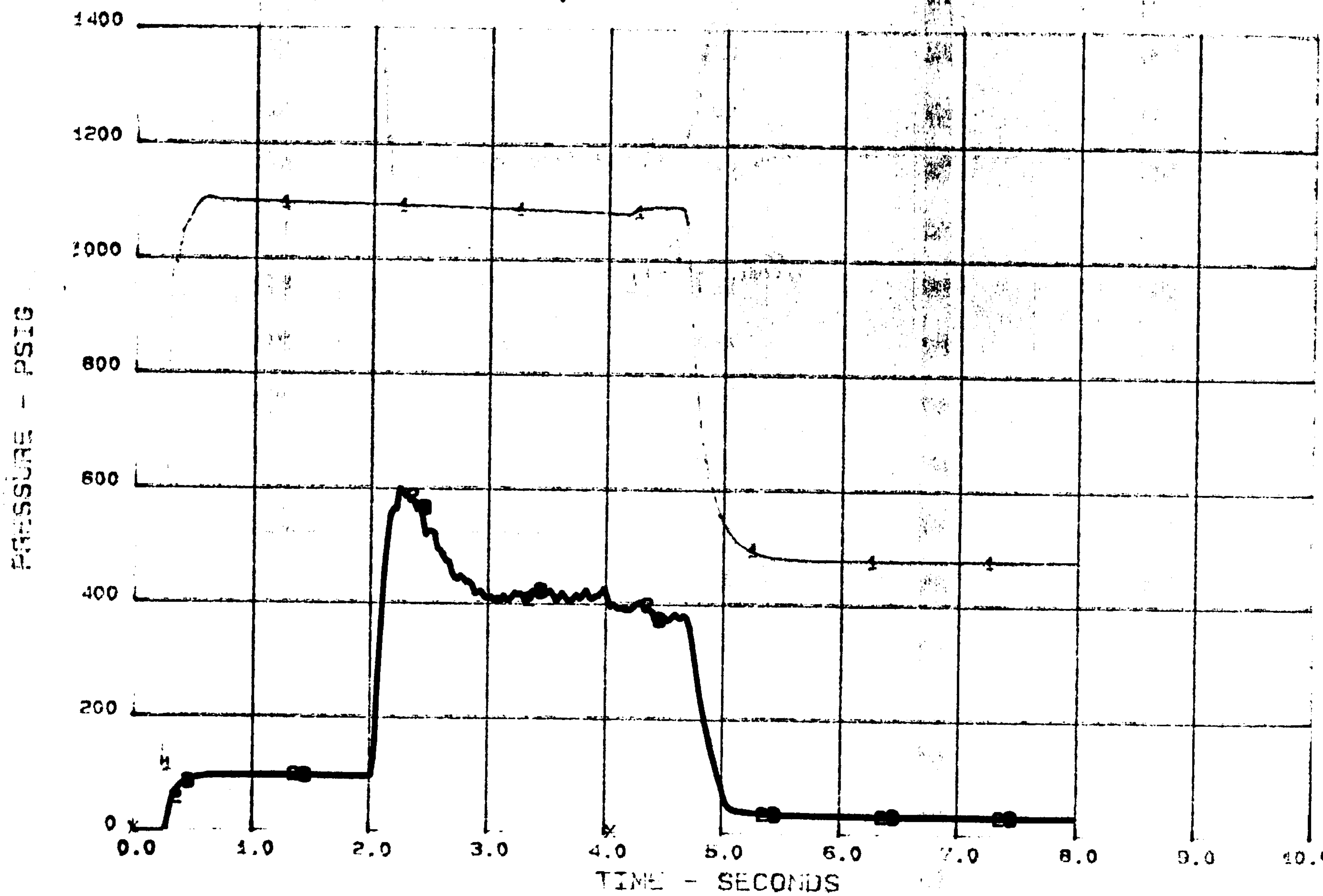
TEST I.D.P280-9_ **14** ** 08 /12 /94 224: 10: 4: 6.207

1 P1004 PSIG GOX VENTURI INLET

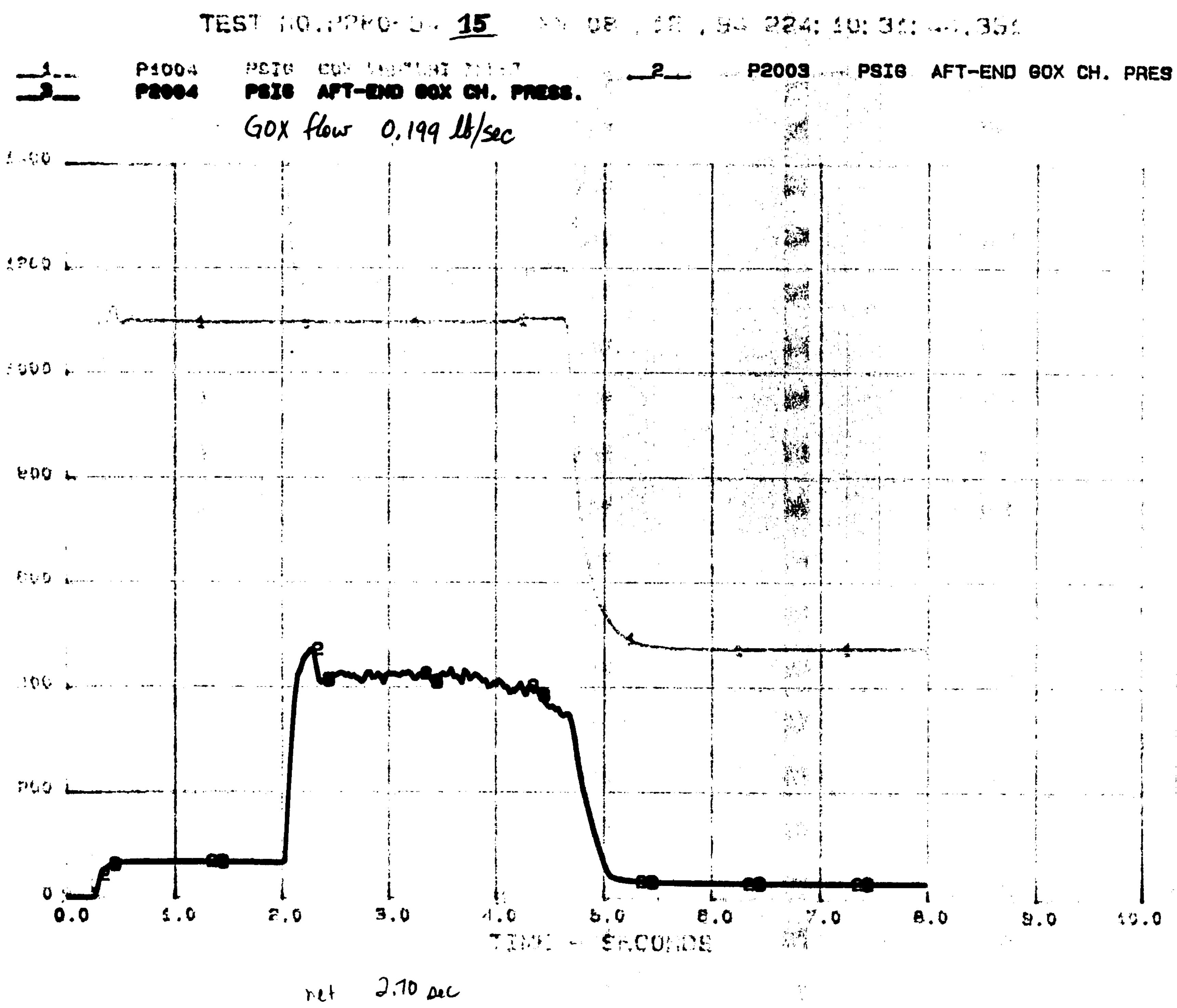
3 **P2004 PSIG AFT-END GOX CH. PRESS.**

2 **P2003 PSIG AFT-END GOX CH. PRES**

Gox flow 0.197 lb/sec



net 2.7

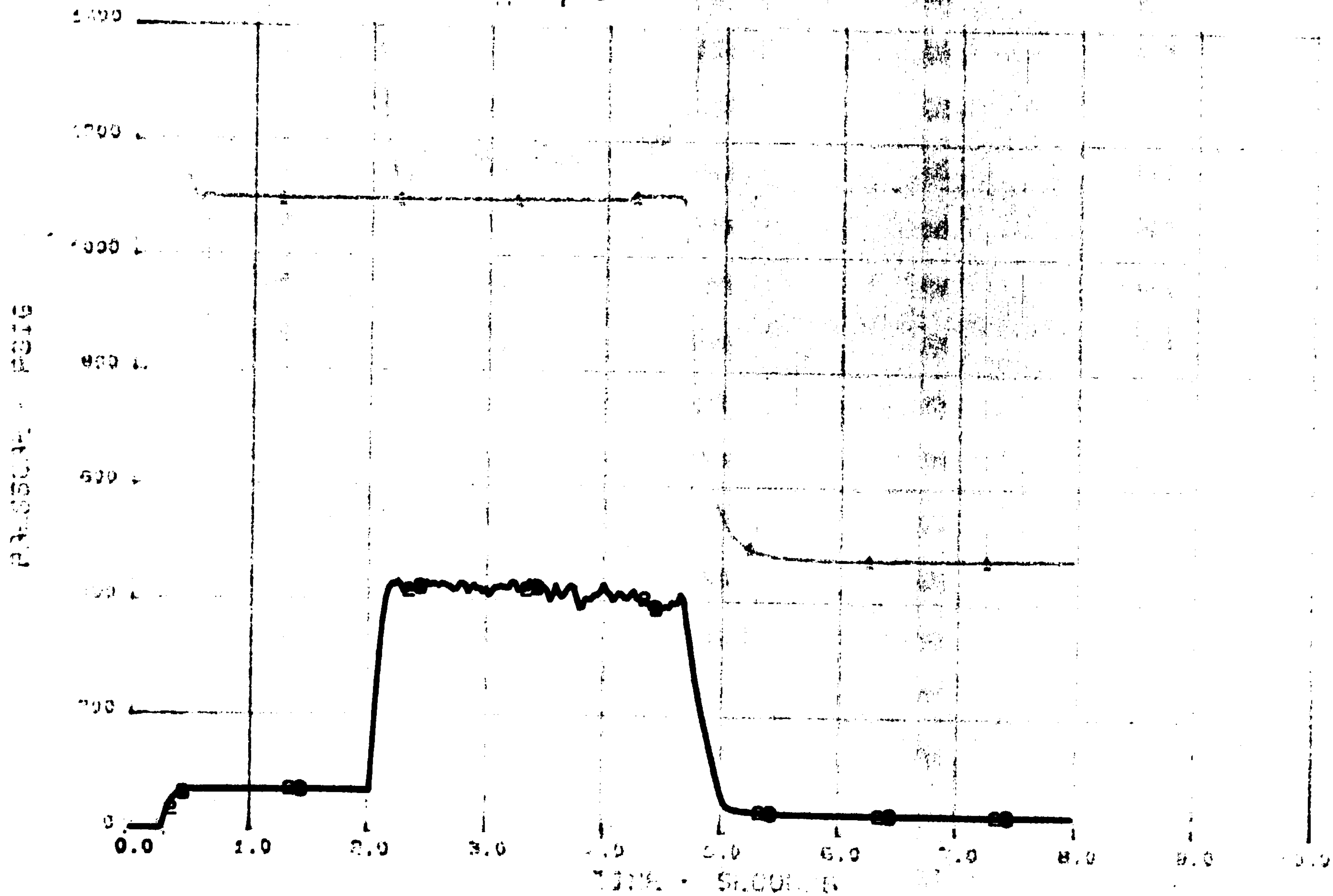


ORIGINAL PAGE IS
OF POOR QUALITY

TEST 1.0.1880-9 16 MAR 08 /12 /94 224: 10: 55: 0.320

1	P1004	PSIG	[illegible]
2	P2003	PSIG	AFT-END GOX CH. PRES
3	P2004	PSIG	AFT-END GOX CH. PRESS.

Gox flow 0.20 lb/sec

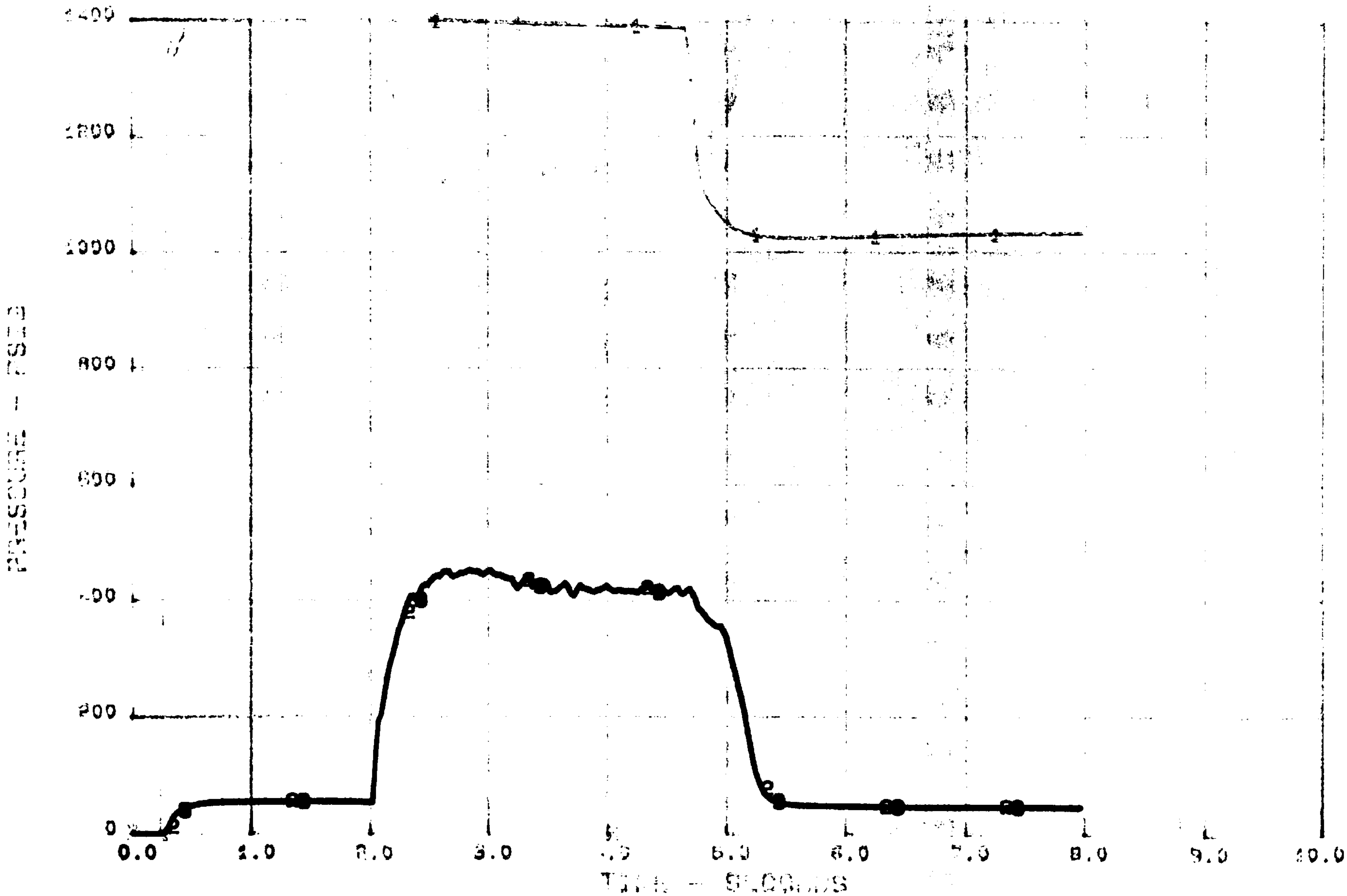


nt 2.70

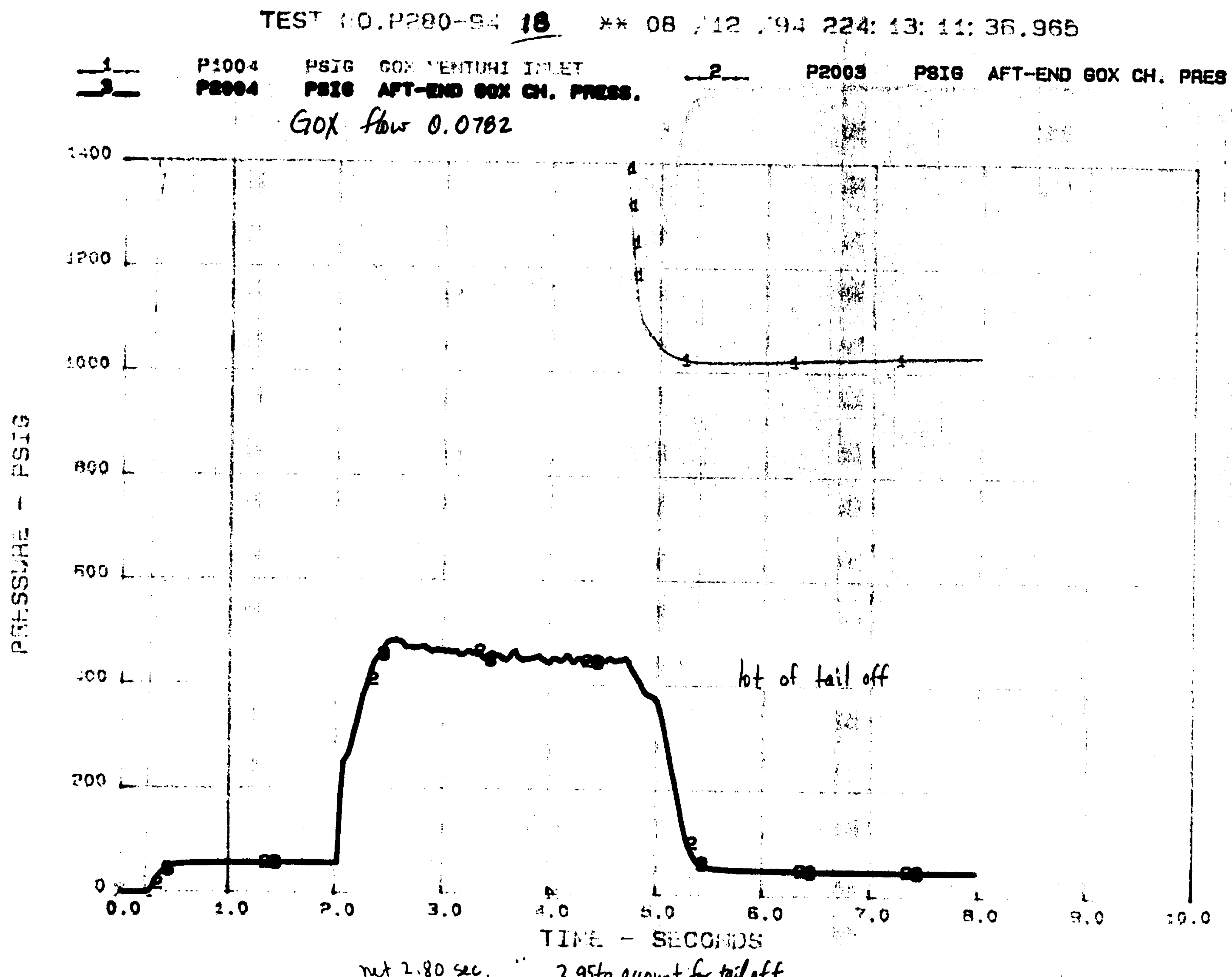
TEST NO.P080-0-17 08 /12 /94 224:12:49:36.5?0

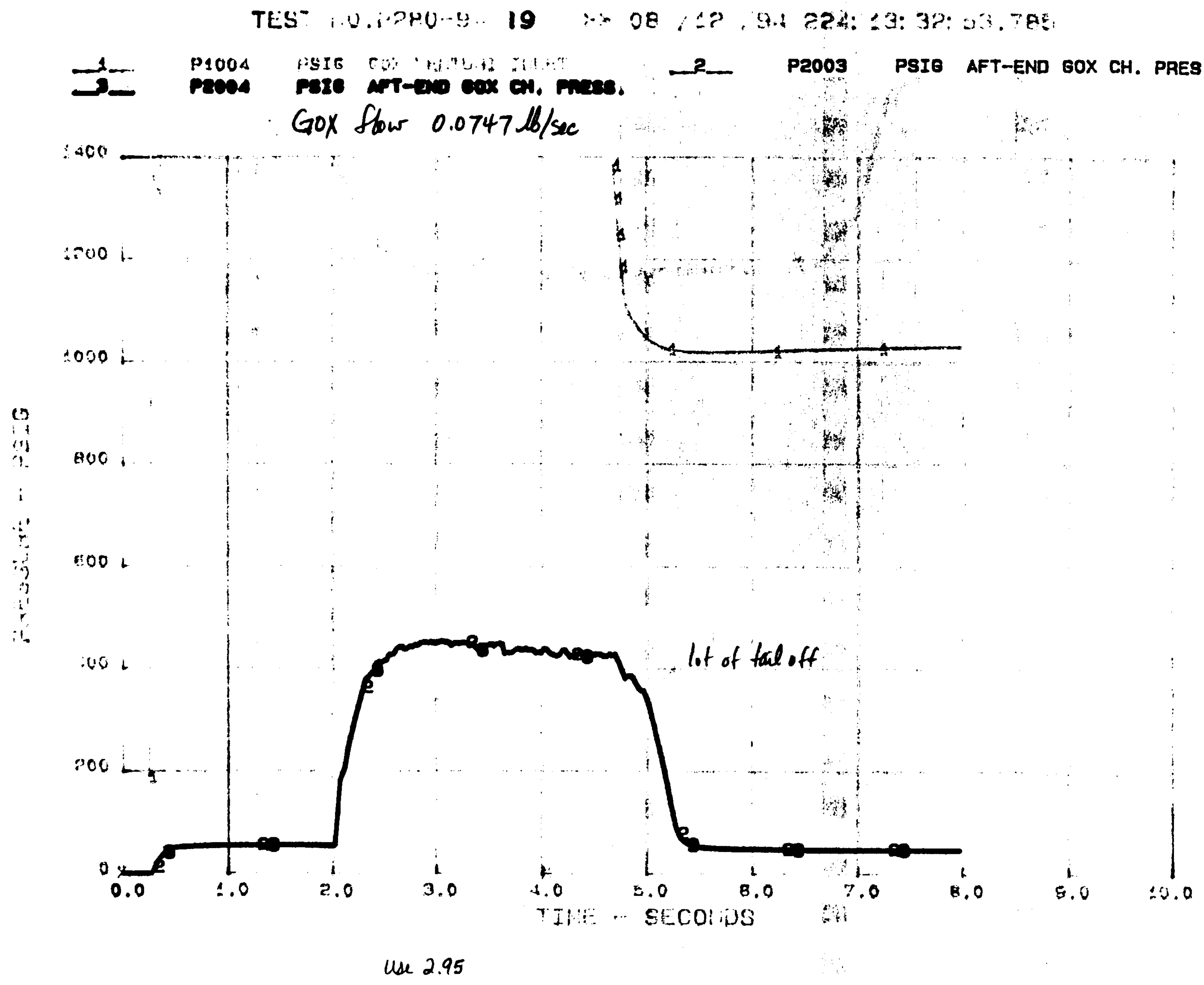
1	P1004	PSIG	GO. VENTURI ...
3	P2004	PSIG	AFT-END GOX CH. PRESS.
2	P2003	PSIG	AFT-END GOX CH. PRES

Gox flow 0.0736 lb/sec



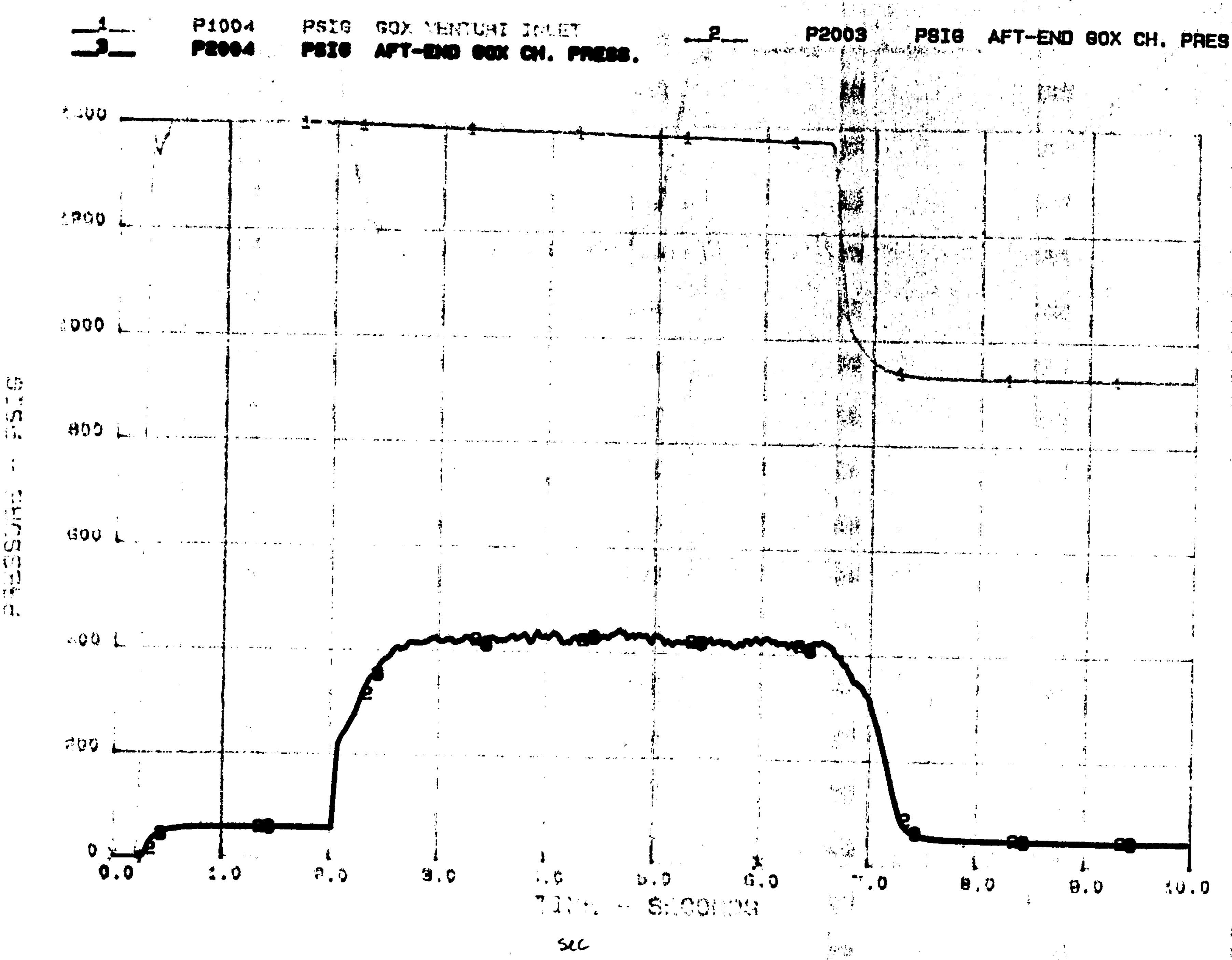
net 2.80 sec


TEST NO.P280-94 18 ** 08 /12 /94 224: 13: 11: 36.965
1 P1004 PSIG GOX VENTURI INLET
2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.
GOX flow 0.0782
1400
1200
1000
800
600
400
200
0
PRESSURE - PSIG
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME - SECONDS
lot of tail off
net 2.80 sec. " 2.95 to account for tail off



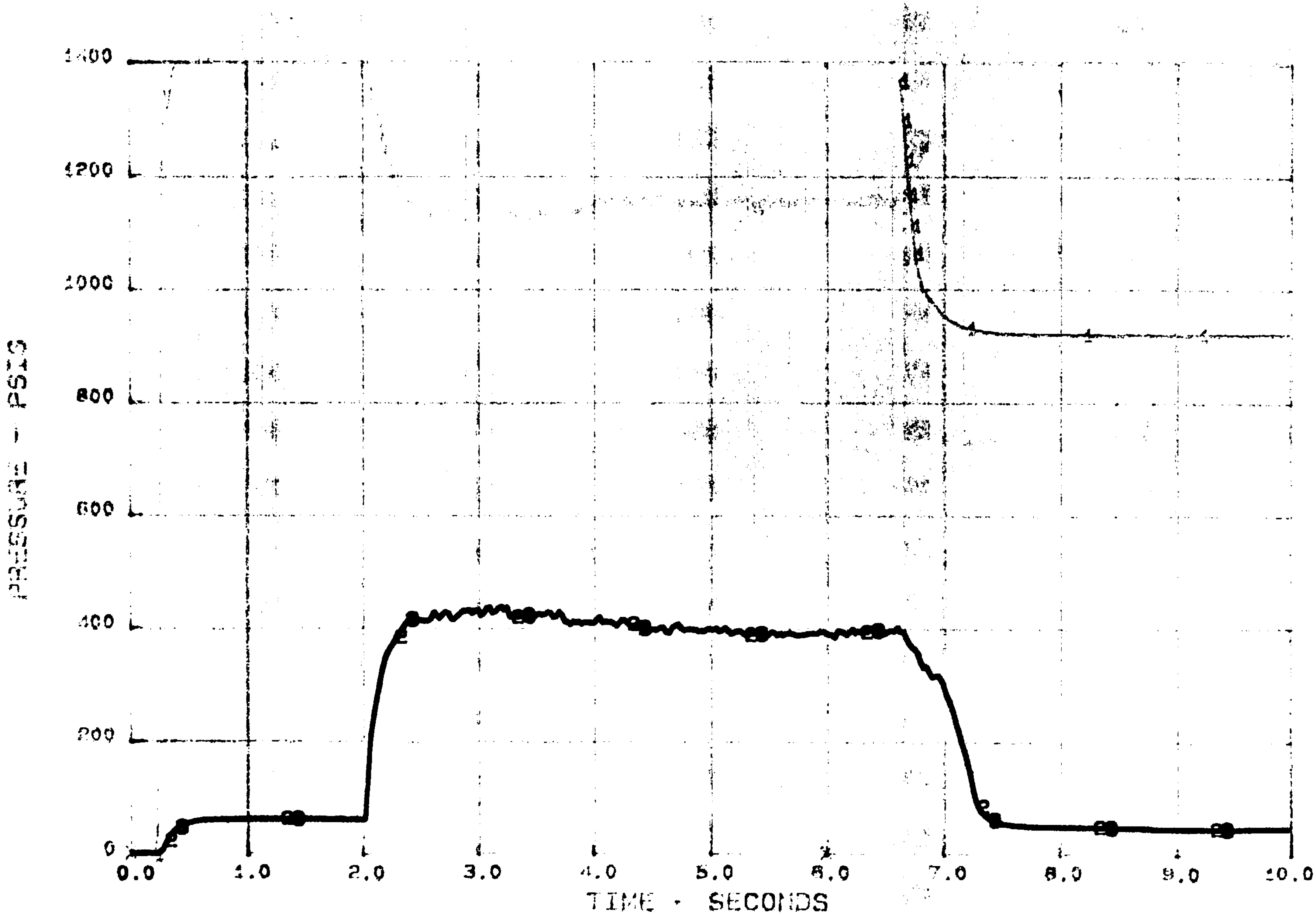
TEST 19 08 /12 /94 224: 13: 32: 53.785
1 P1004 PSIG
3 P2004 PSIG AFT-END GOX CH. PRESS.
2 P2003 PSIG AFT-END GOX CH. PRES
GOX flow 0.0747 lb/sec
1400
1000
800
600
200
0
0.0
2.0
3.0
4.0
8.0
7.0
8.0
9.0
TIME - SECONDS
lot of tail off
use 2.95

TEST NO.P280-94 20 ** 08 /25 /94 237: 10: 11: 13.259



TEST NO.P080-9- 21 ** 08 /25 /94 237: 10: 33: 25.803

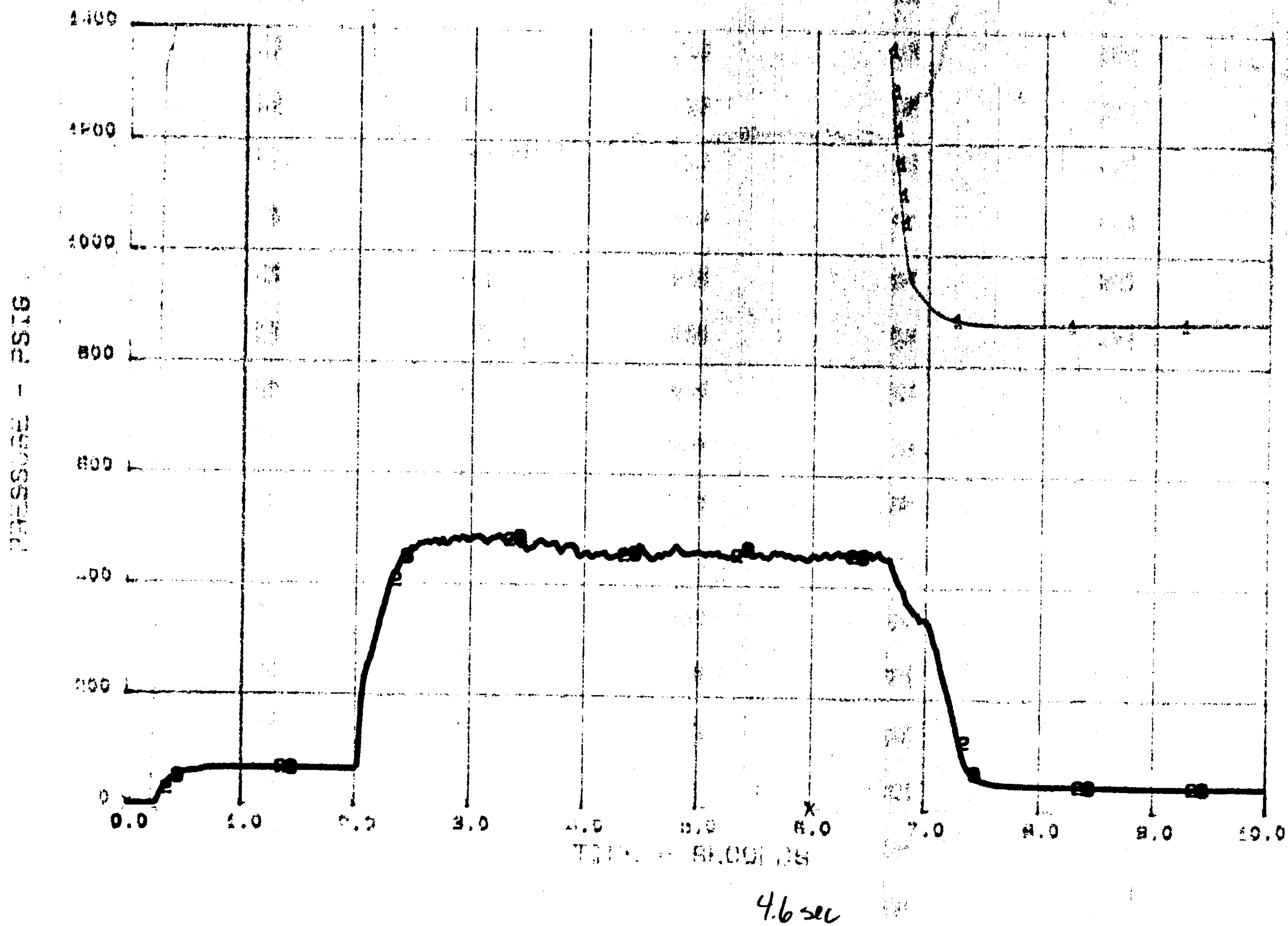
__1__ P1004 PSIG GOX VENTURI INLET __2__ P2003 PSIG AFT-END GOX CH. PRES
__3__ P2004 PSIG AFT-END GOX CH. PRESS.



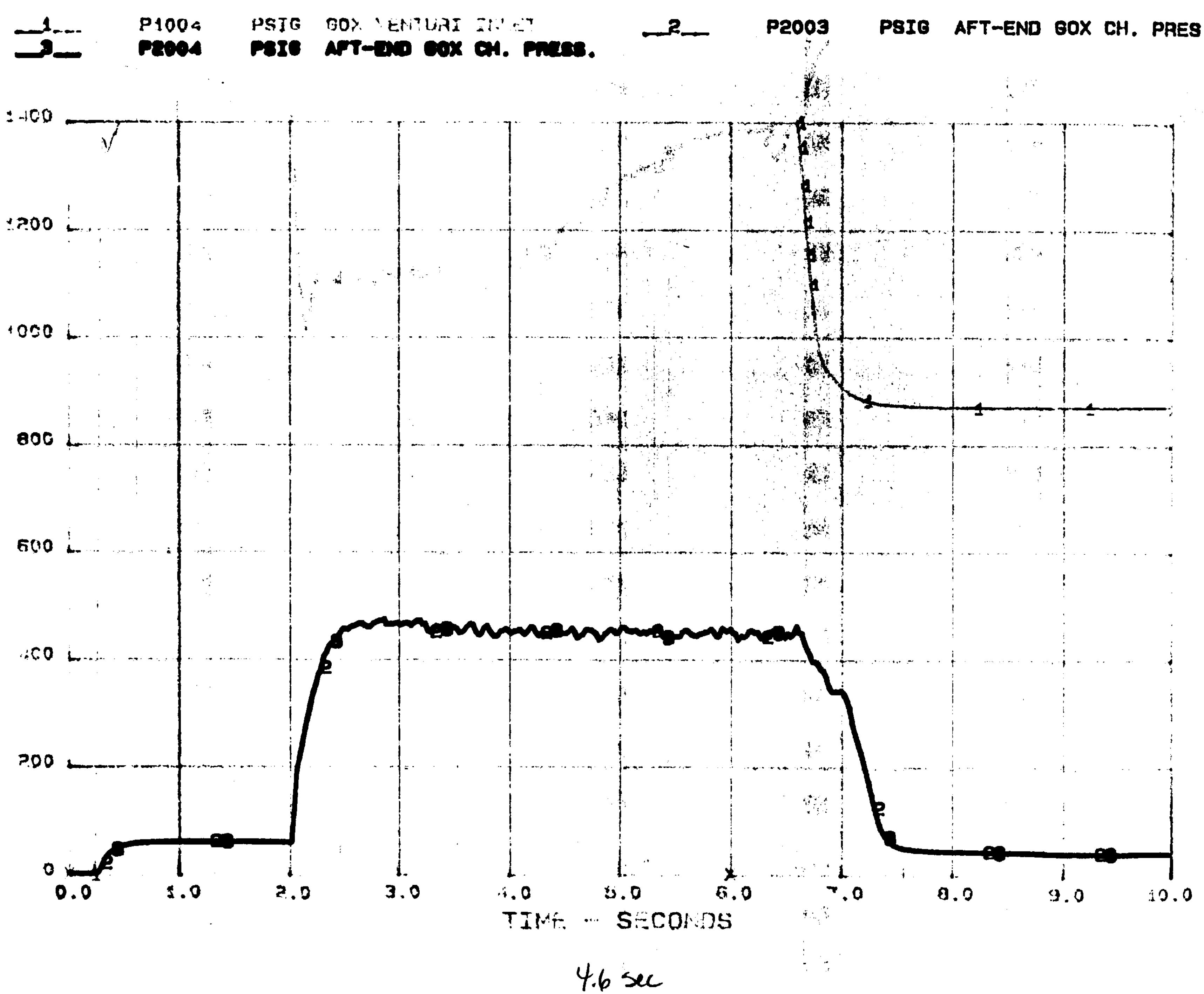
4.62 sec

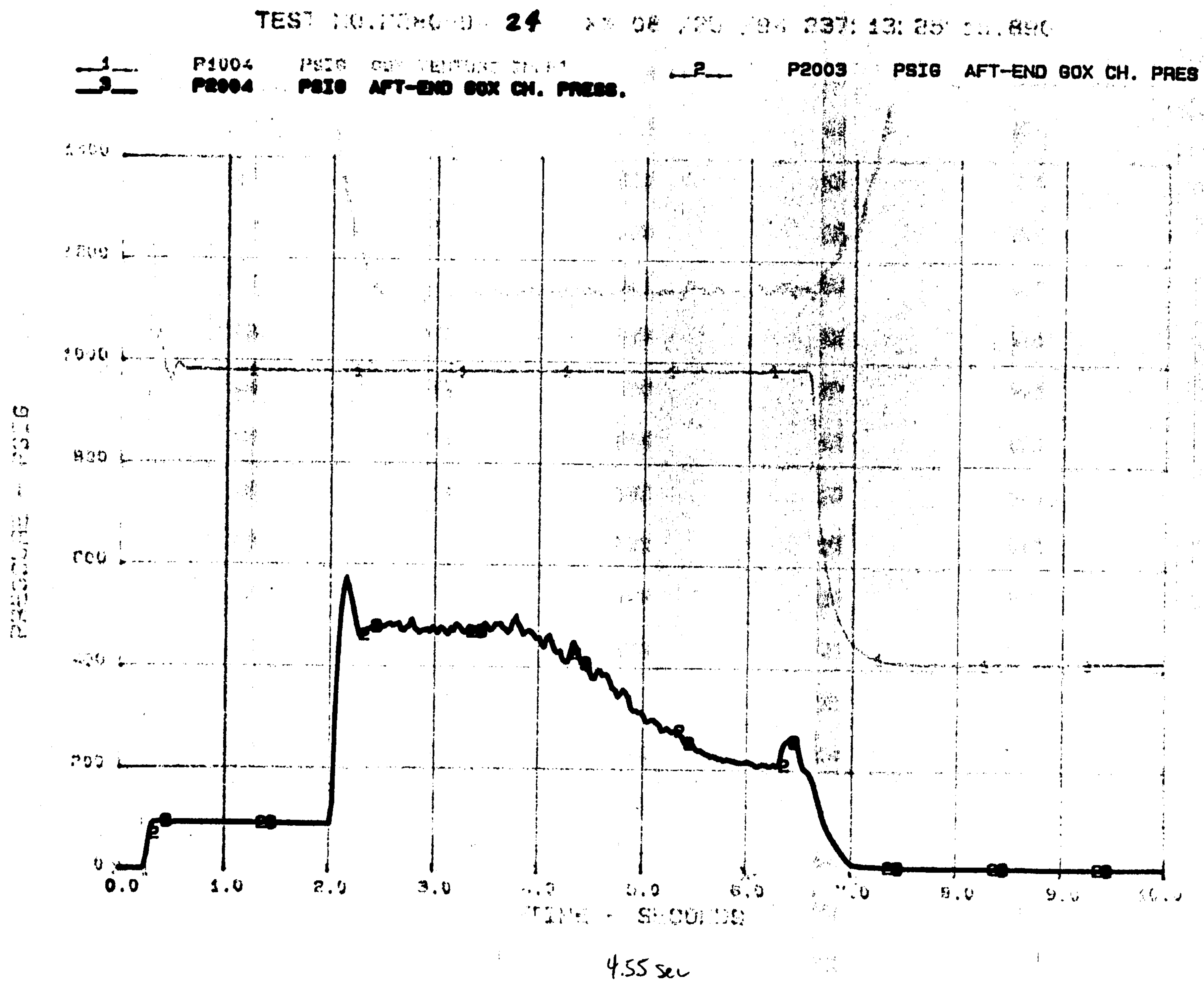
TEST NO.P280-94 22 [illegible] 08 /25 /94 237: 12: 30: 59.375

1	P1004	PSIG	GOX VENTURI INLET	2	P2003	PSIG AFT-END GOX CH. PRES
3	P2004	PSIG	AFT-END GOX CH. PRESS.			



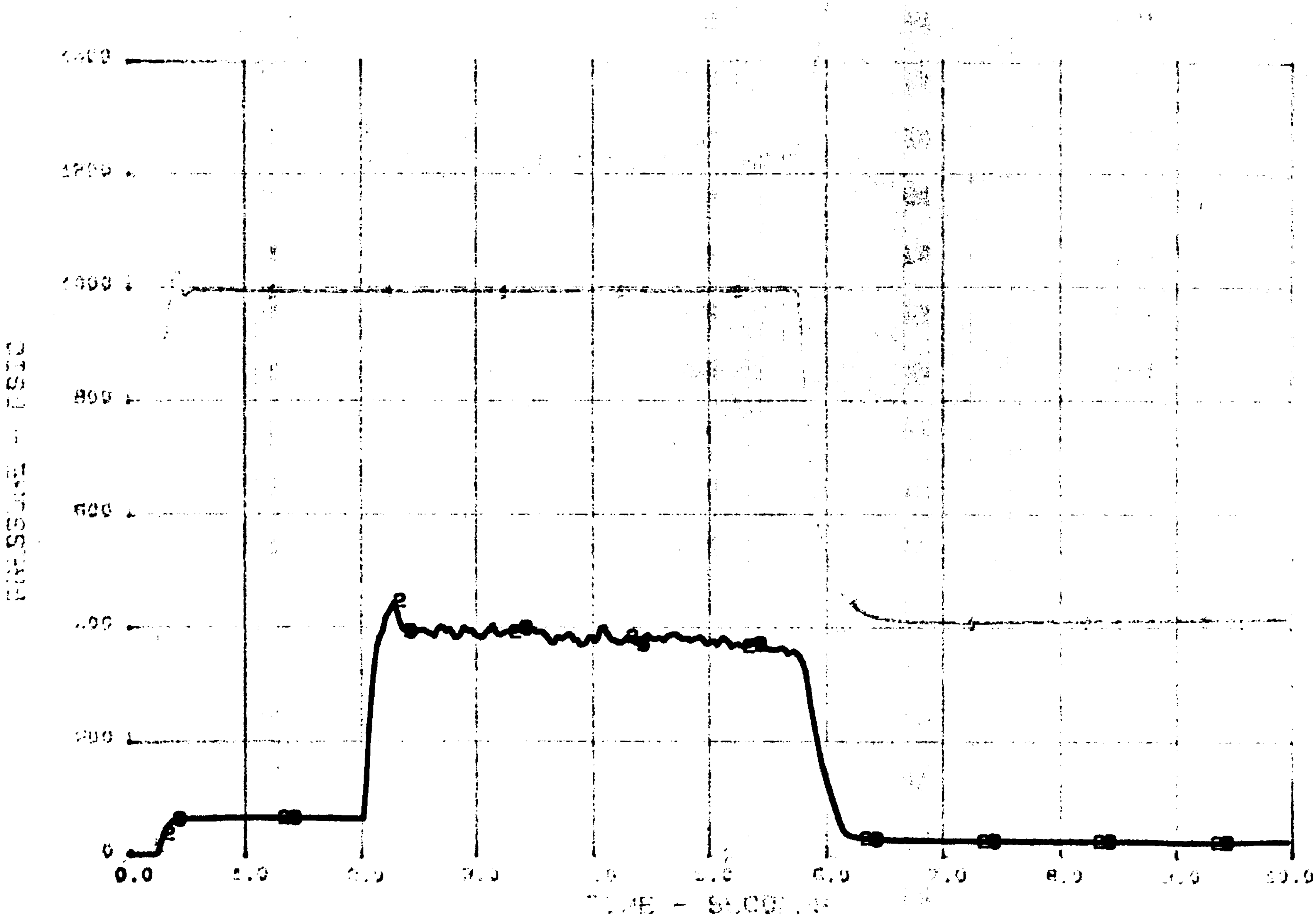
TEST NO.P280-94 23 ** 08 /25 /94 237: 12: 55: 43.194



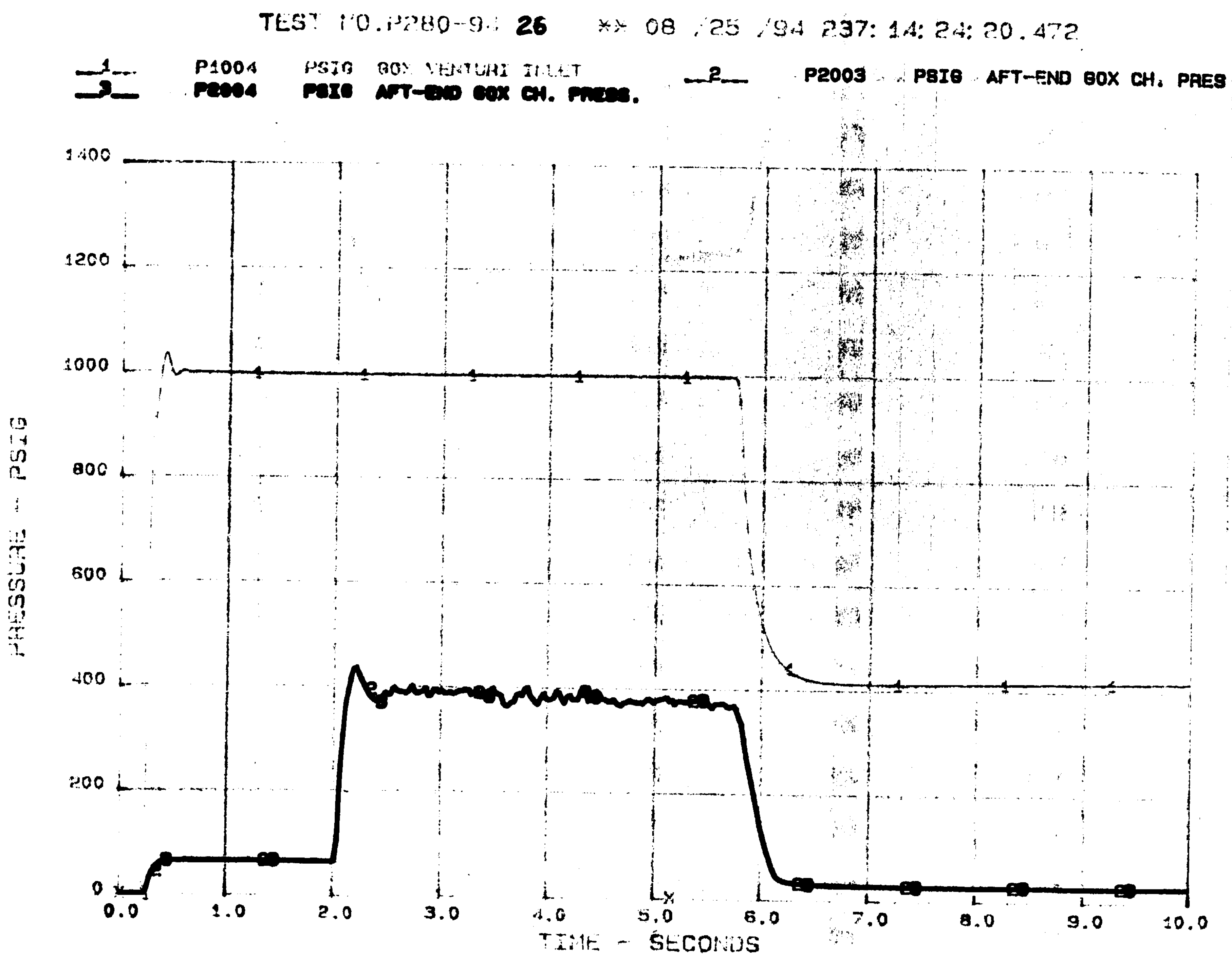

TEST NO. 24
1 P1004 PSIG
2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.
PRESSURE - PSIG
0
200
400
600
800
1000
1200
1400
0.0
1.0
2.0
3.0
5.0
6.0
8.0
9.0
TIME - SECONDS
4.55 sec

TEST [illegible] 25 [illegible] 94 237: 13: 59: [illegible].078

1 P2004 PSIG [illegible] 2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.



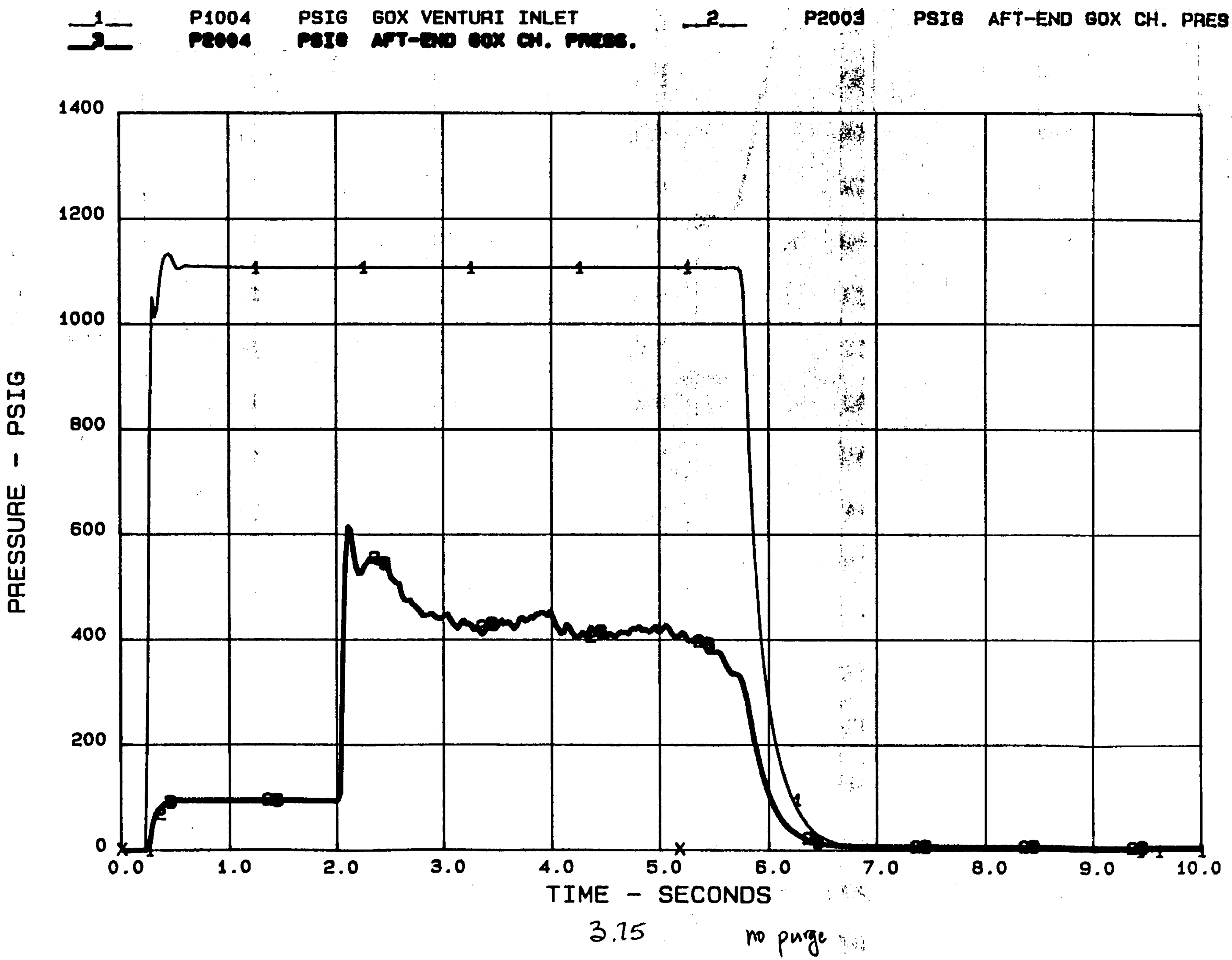
3.15 sec

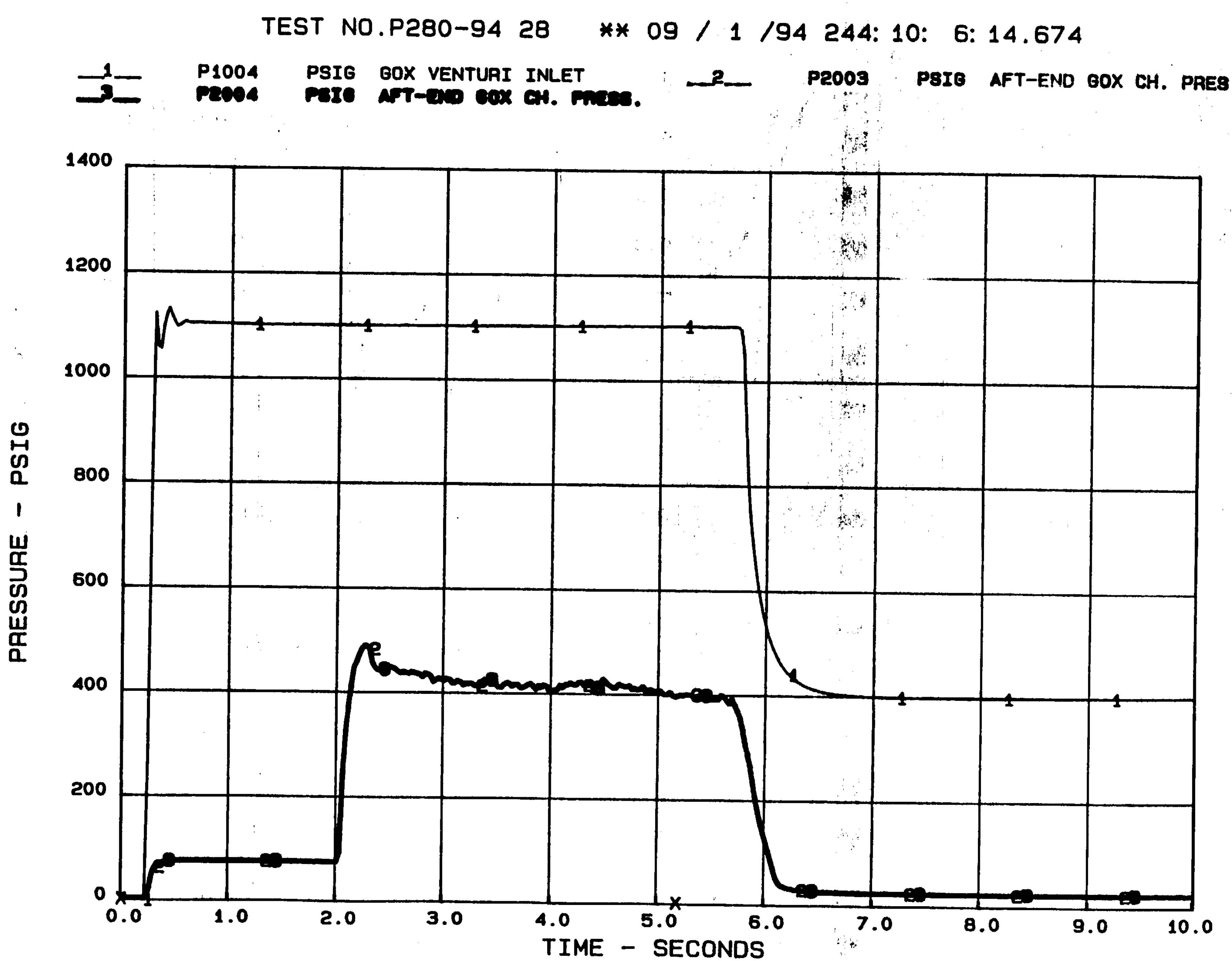


TEST NO.P280-94 26 ** 08 /25 /94 237: 14: 24: 20.472
1 P1004 PSIG GOX VENTURI INLET
2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.
PRESSURE - PSIG
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME - SECONDS

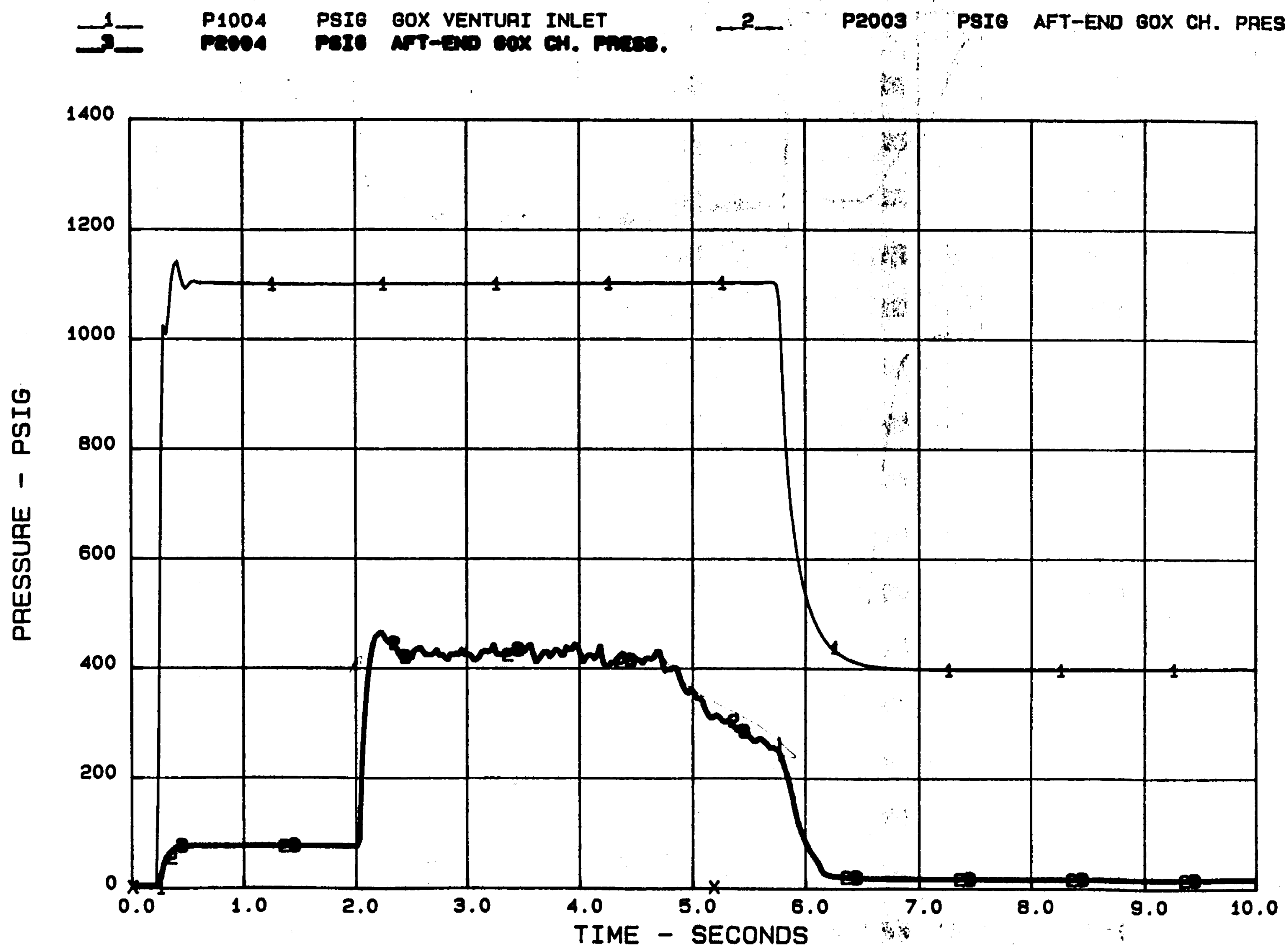
3.75

TEST NO.P280-94 27 ** 09 / 1 /94 244: 9: 42: 21.956

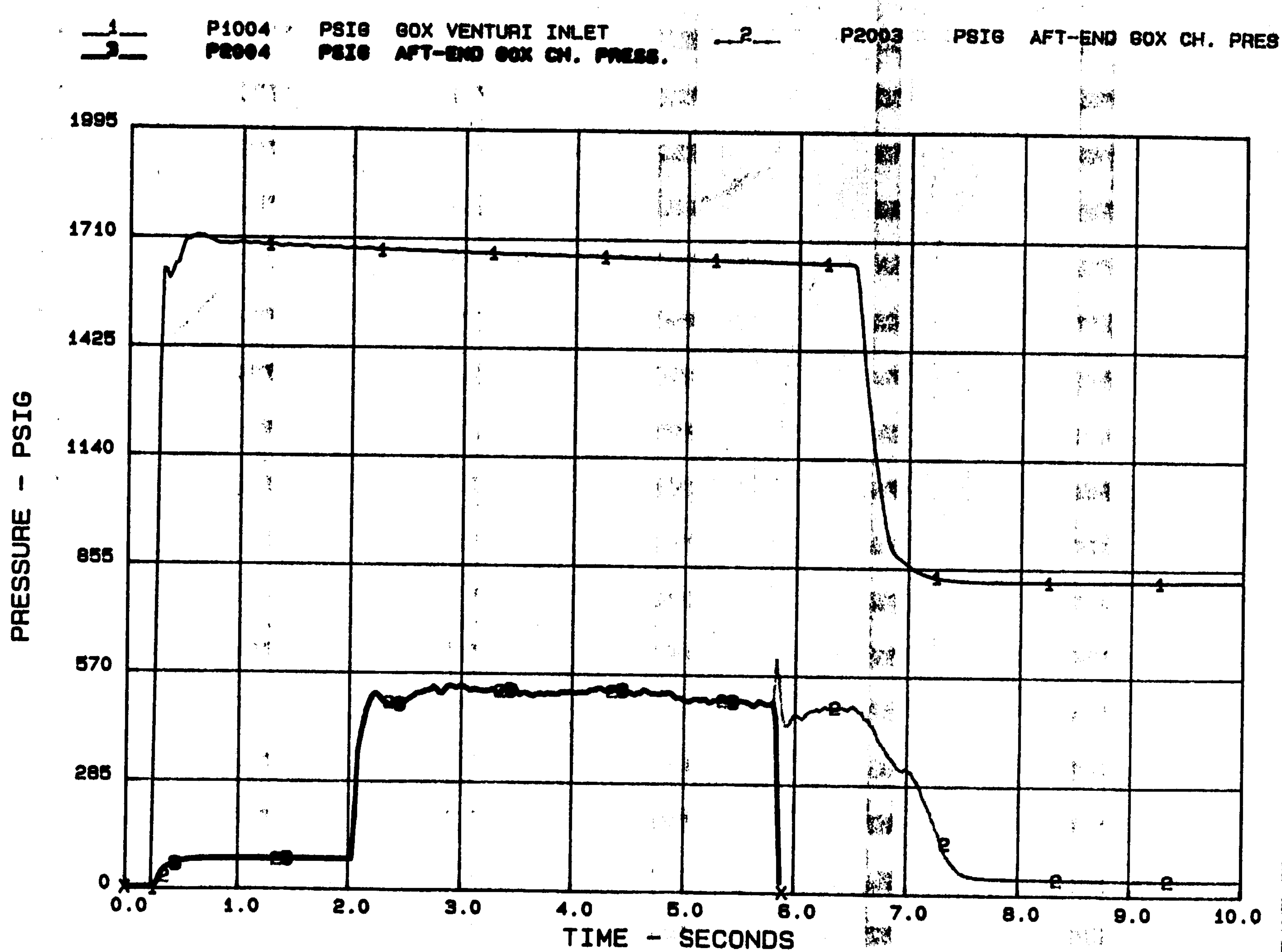



TEST NO.P280-94 28 ** 09 / 1 /94 244: 10: 6: 14.674
1 P1004 PSIG GOX VENTURI INLET
3 P2004 PSIG AFT-END GOX CH. PRESS.
2 P2003 PSIG AFT-END GOX CH. PRES
PRESSURE - PSIG
1400
1200
1000
800
600
400
200
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME - SECONDS

TEST NO.P280-94 29 ** 09 / 1 /94 244: 10: 29: 41.993

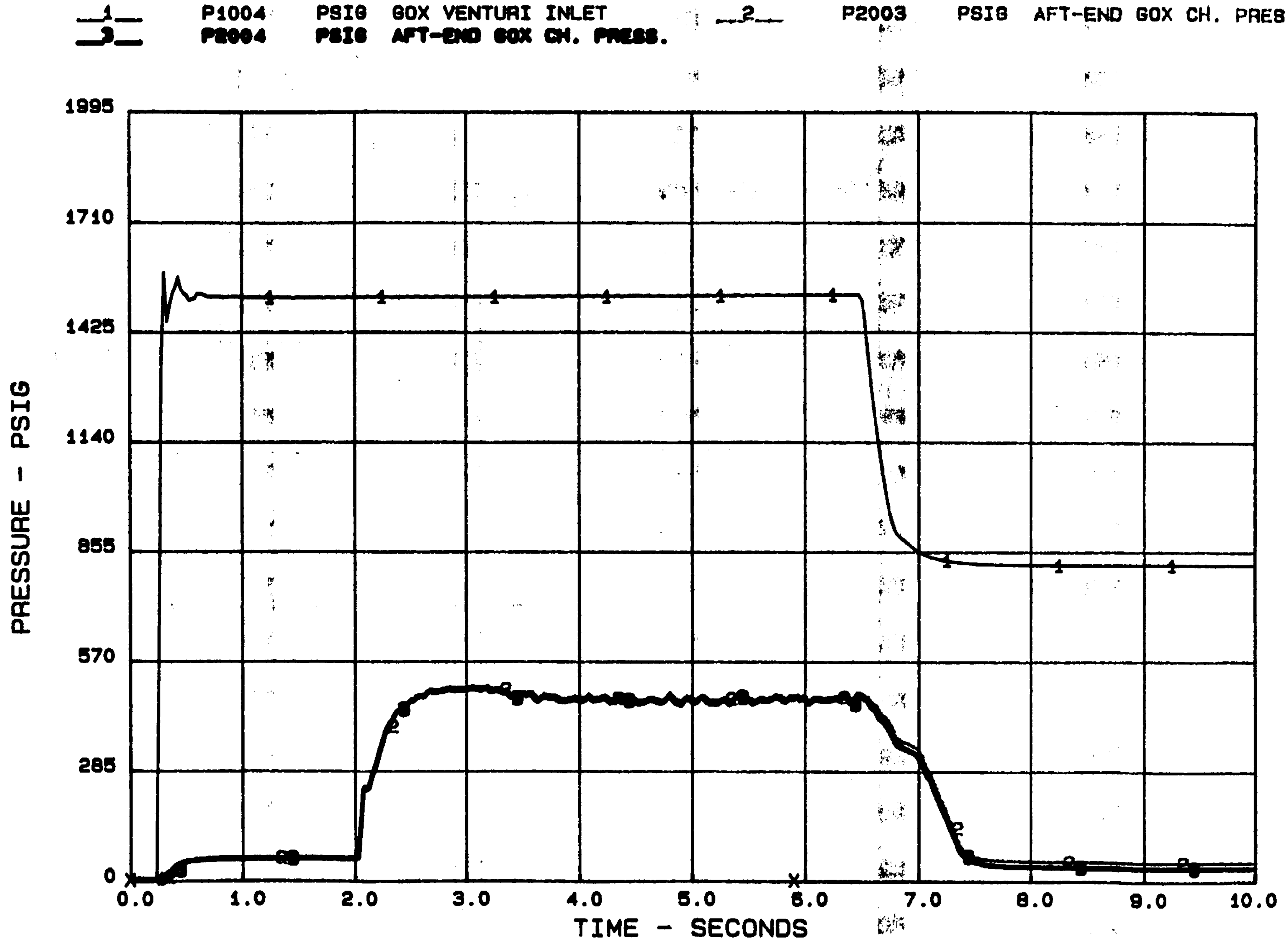


TEST NO.P280-94 30 ** 09 / 1 /94 244: 12: 57: 24.076



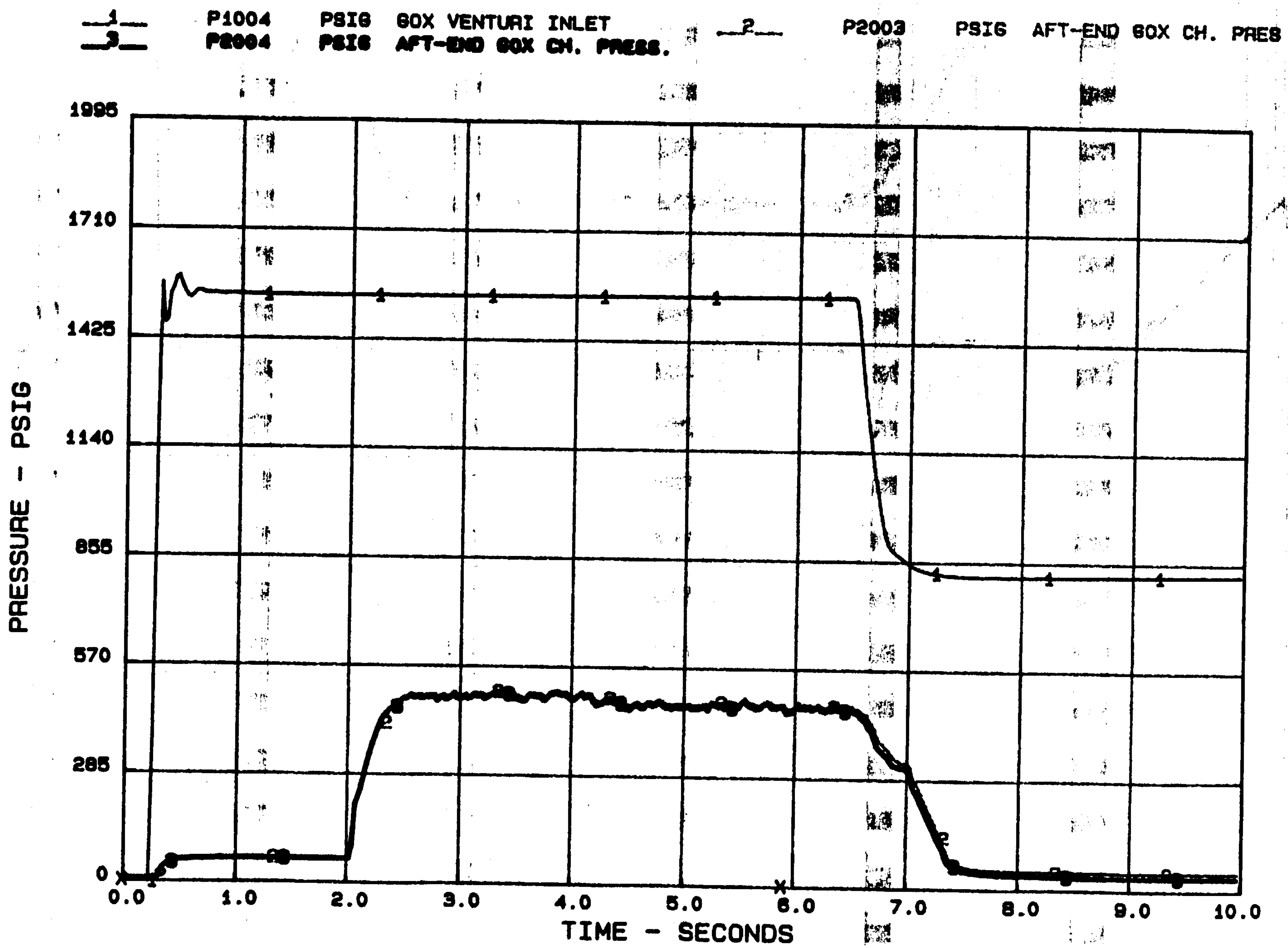
4.52 1

TEST NO.P280-94 31 ** 09 / 1 /94 244: 13: 32: 47.576



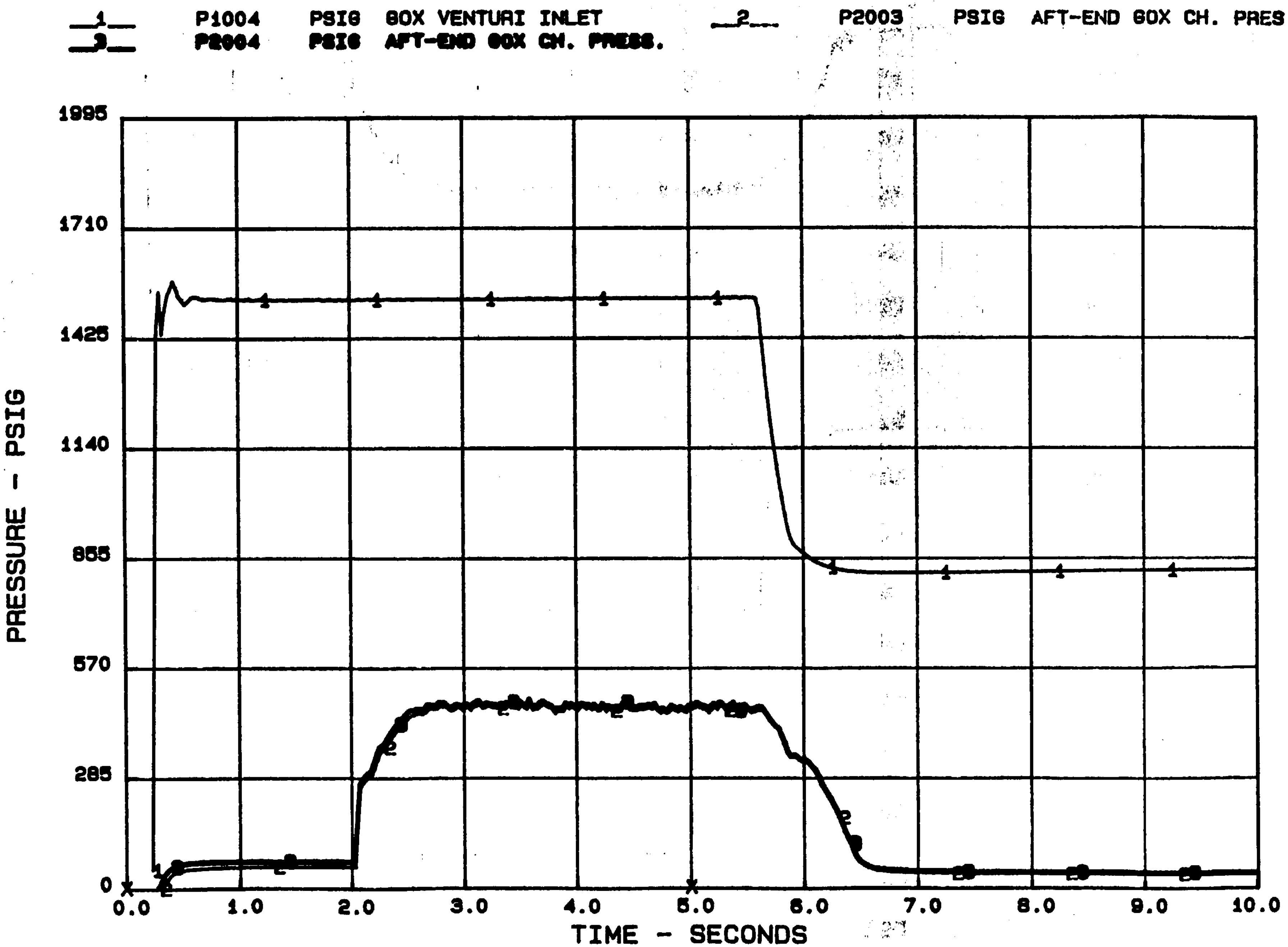
4.60

TEST NO.P280-94 32 **09 / 1 /94 244: 13: 55: 39.870



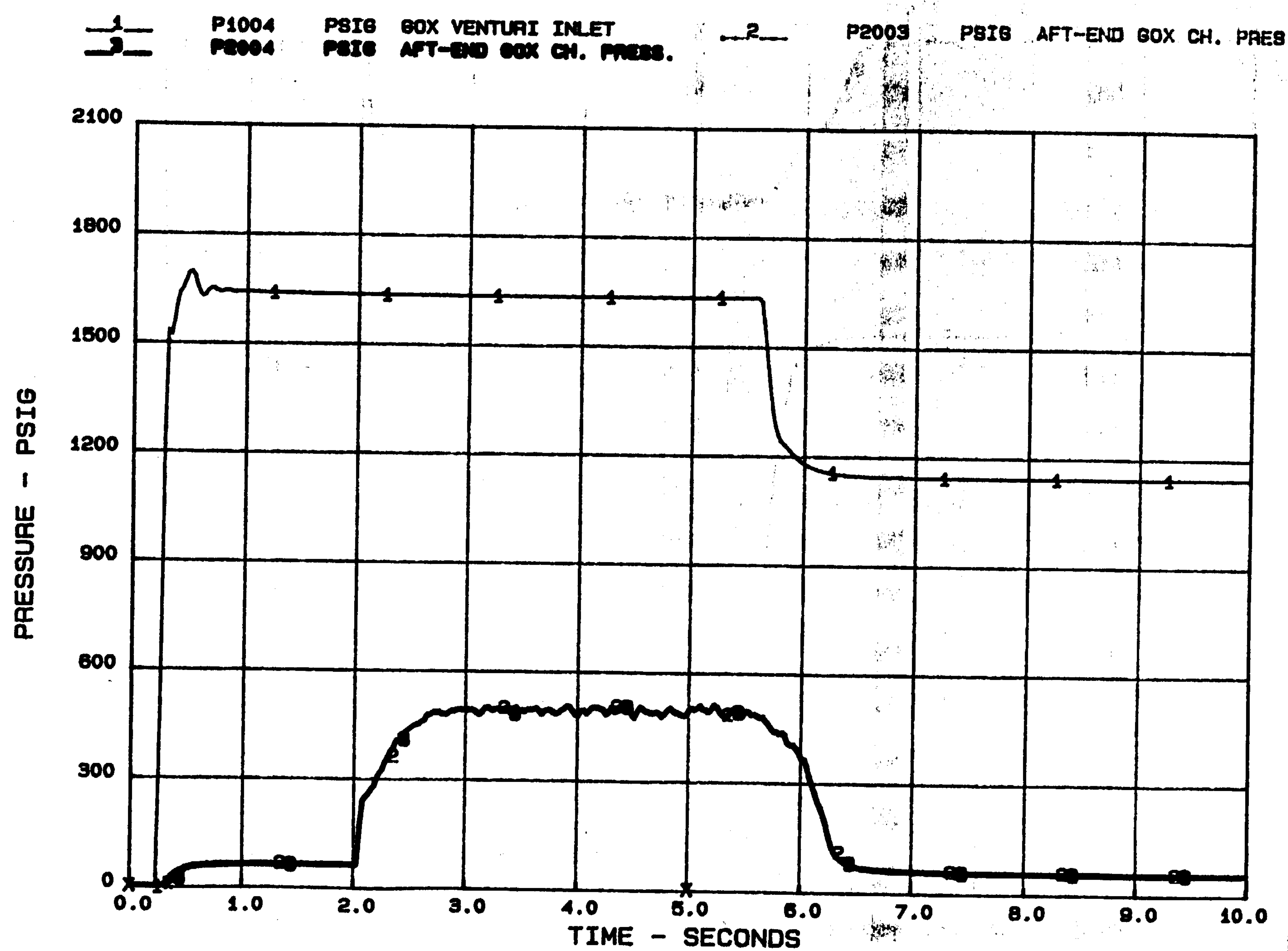
4.50

TEST NO.P280-94 33 ** 09 / 1 /94 244: 14: 25: 27.513

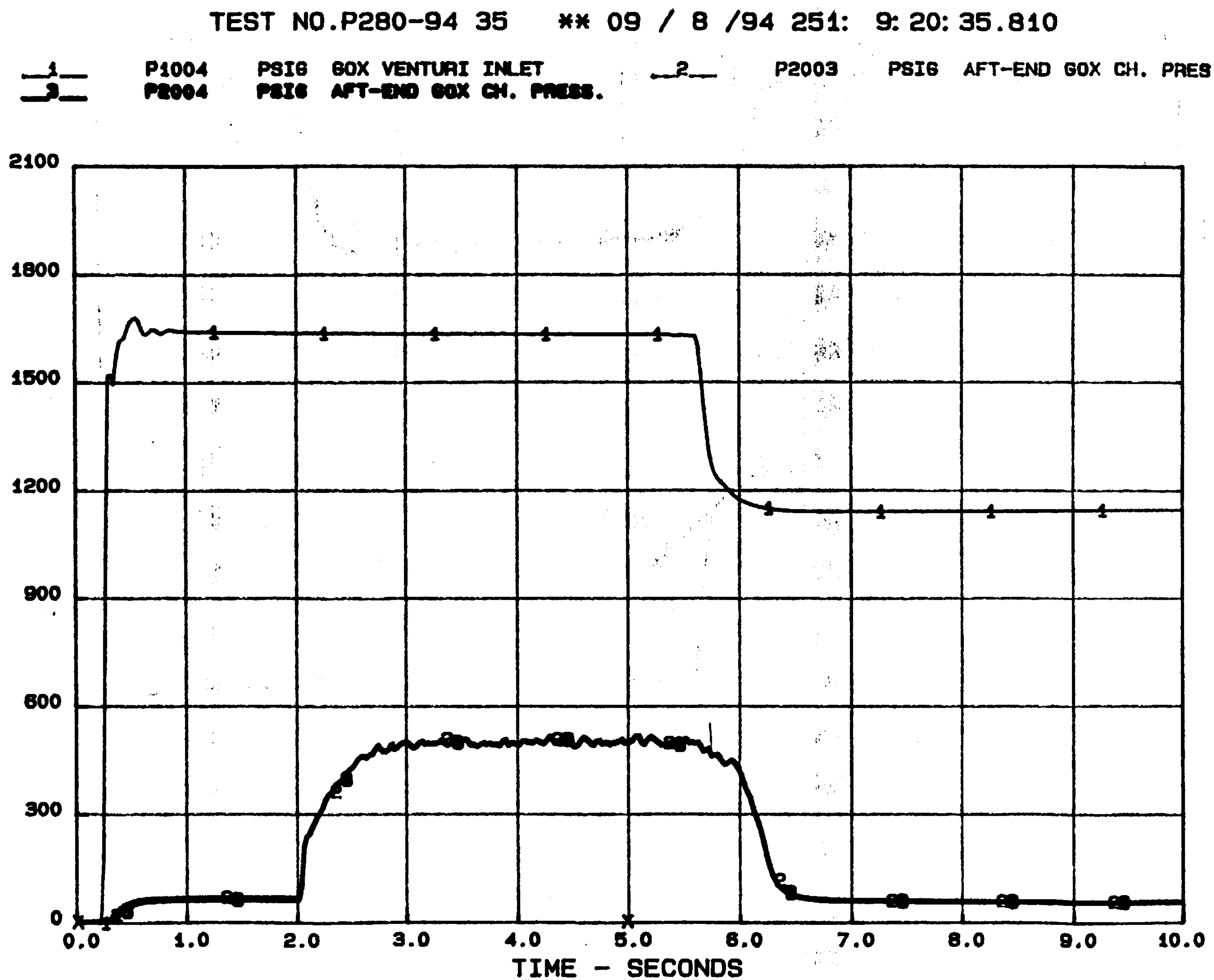


3.65

TEST NO.P280-94 34 ** 09 / 8 /94 251: 9: 4:55.789



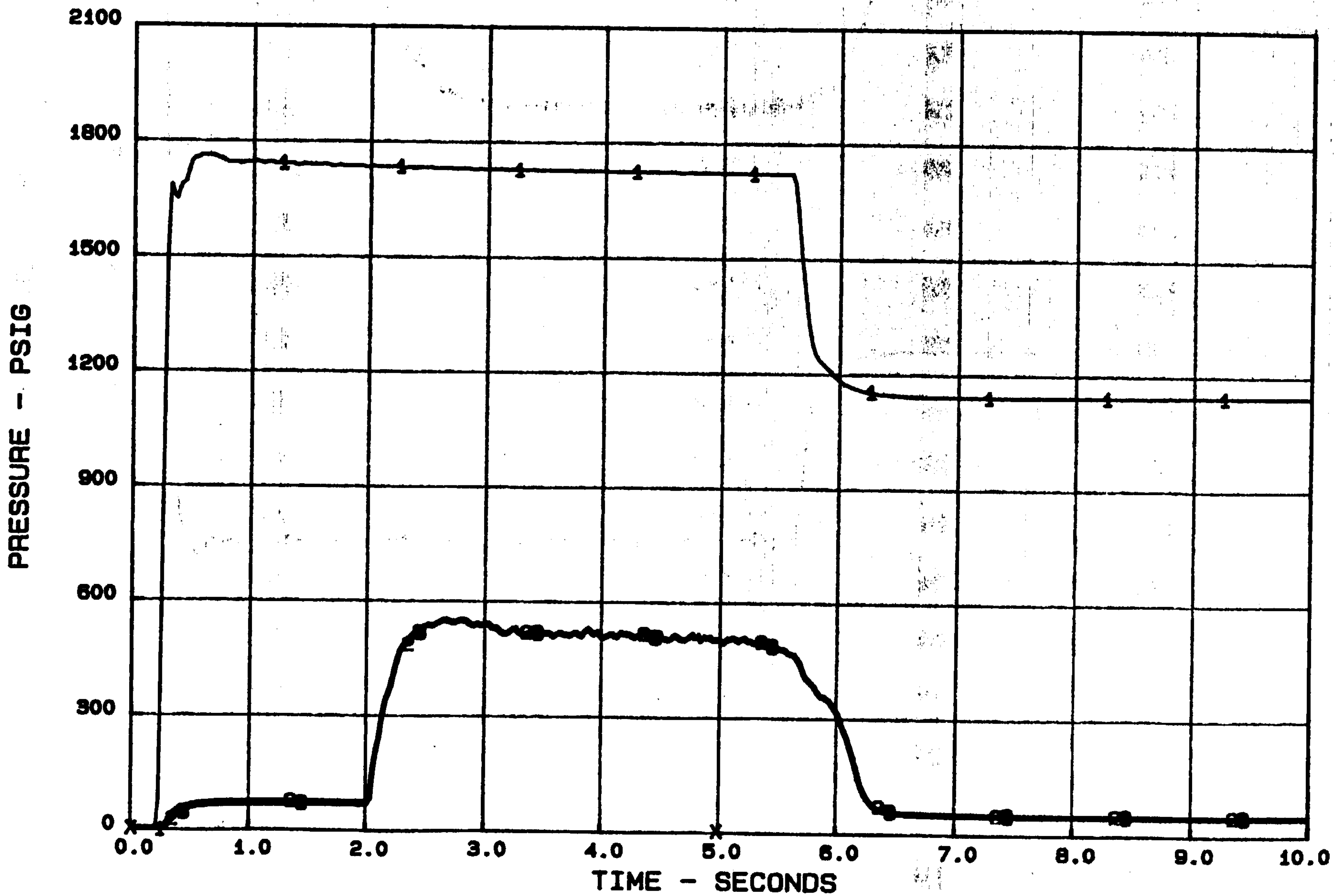
3.6

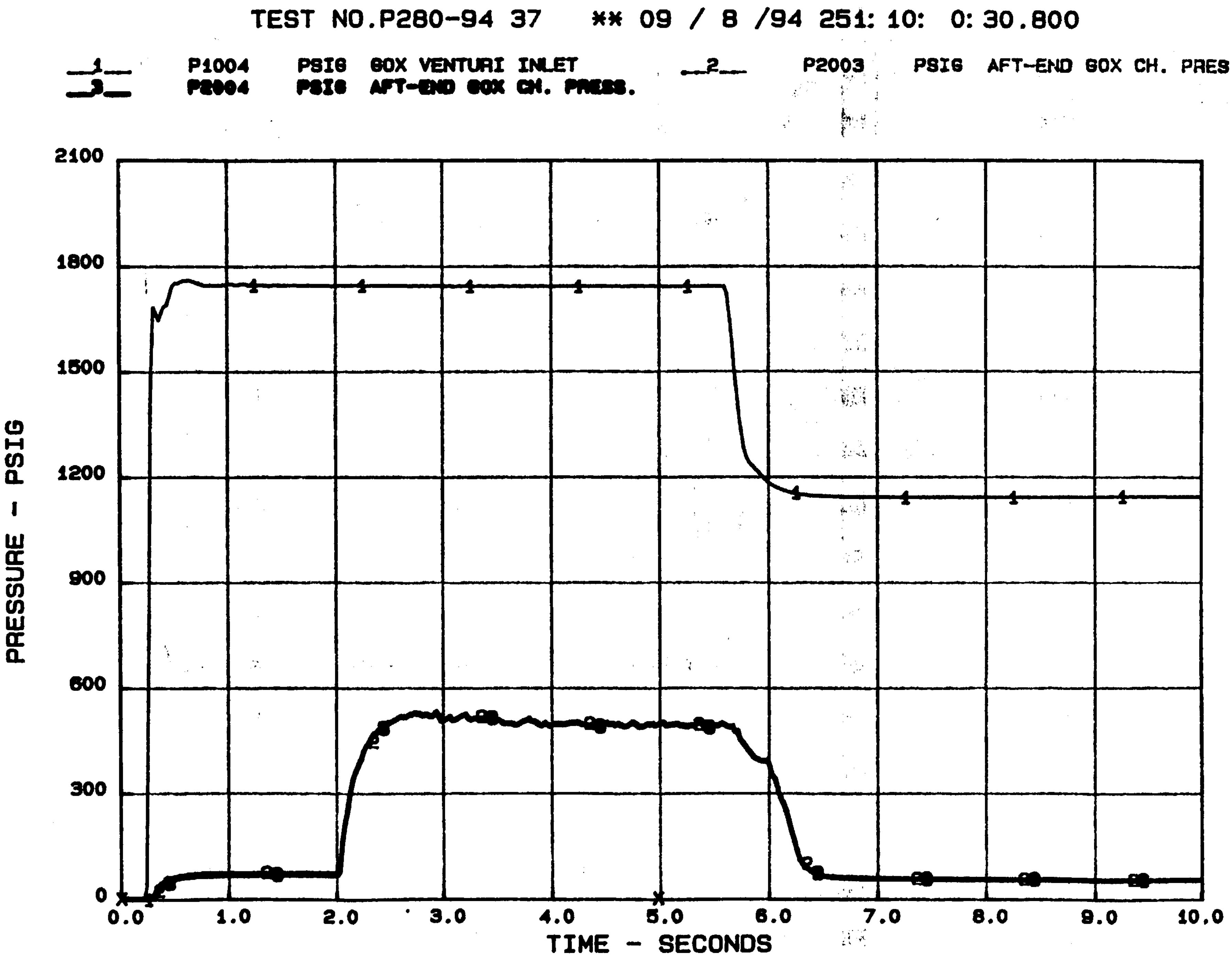

TEST NO.P280-94 35 ** 09 / 8 /94 251: 9: 20: 35.810
1 P1004 PSIG GOX VENTURI INLET
2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.
PRESSURE - PSIG
2100
1800
1500
1200
900
600
300
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME - SECONDS

3.1

TEST NO.P280-94 36 ** 09 / 8 /94 251: 9: 38: 50.330

1	P1004	PSIG	GOX VENTURI INLET	2	P2003	PSIG	AFT-END GOX CH. PRES
3	P3004	PSIG	AFT-END GOX CH. PRESS.				



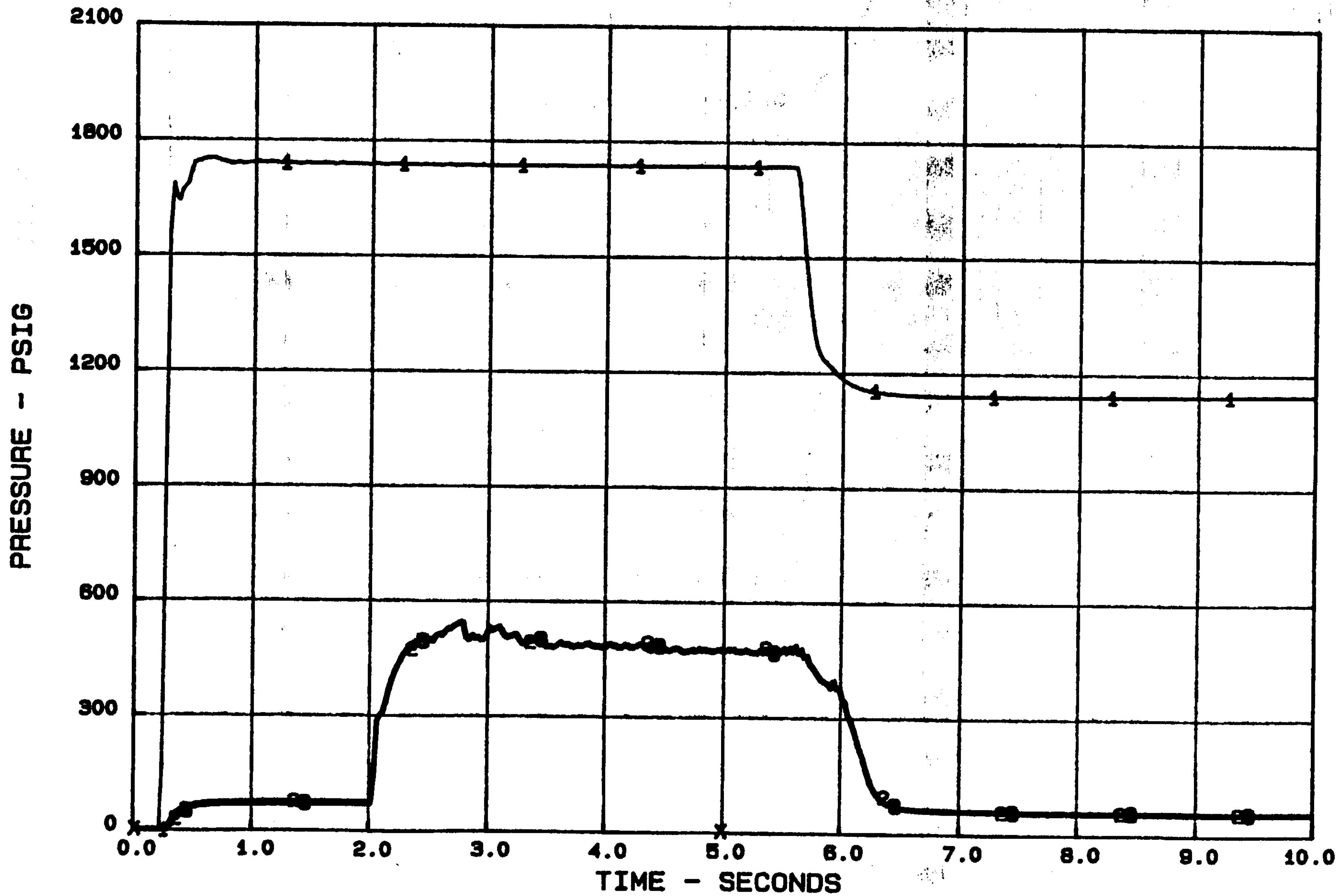

TEST NO.P280-94 37 ** 09 / 8 /94 251: 10: 0: 30.800
1 P1004 PSIG GOX VENTURI INLET
2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.
2100
1800
1500
1200
900
600
300
0
PRESSURE - PSIG
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME - SECONDS

3.1

TEST NO.P280-94 38 ** 09 / 8 /94 251: 10: 31: 21.018

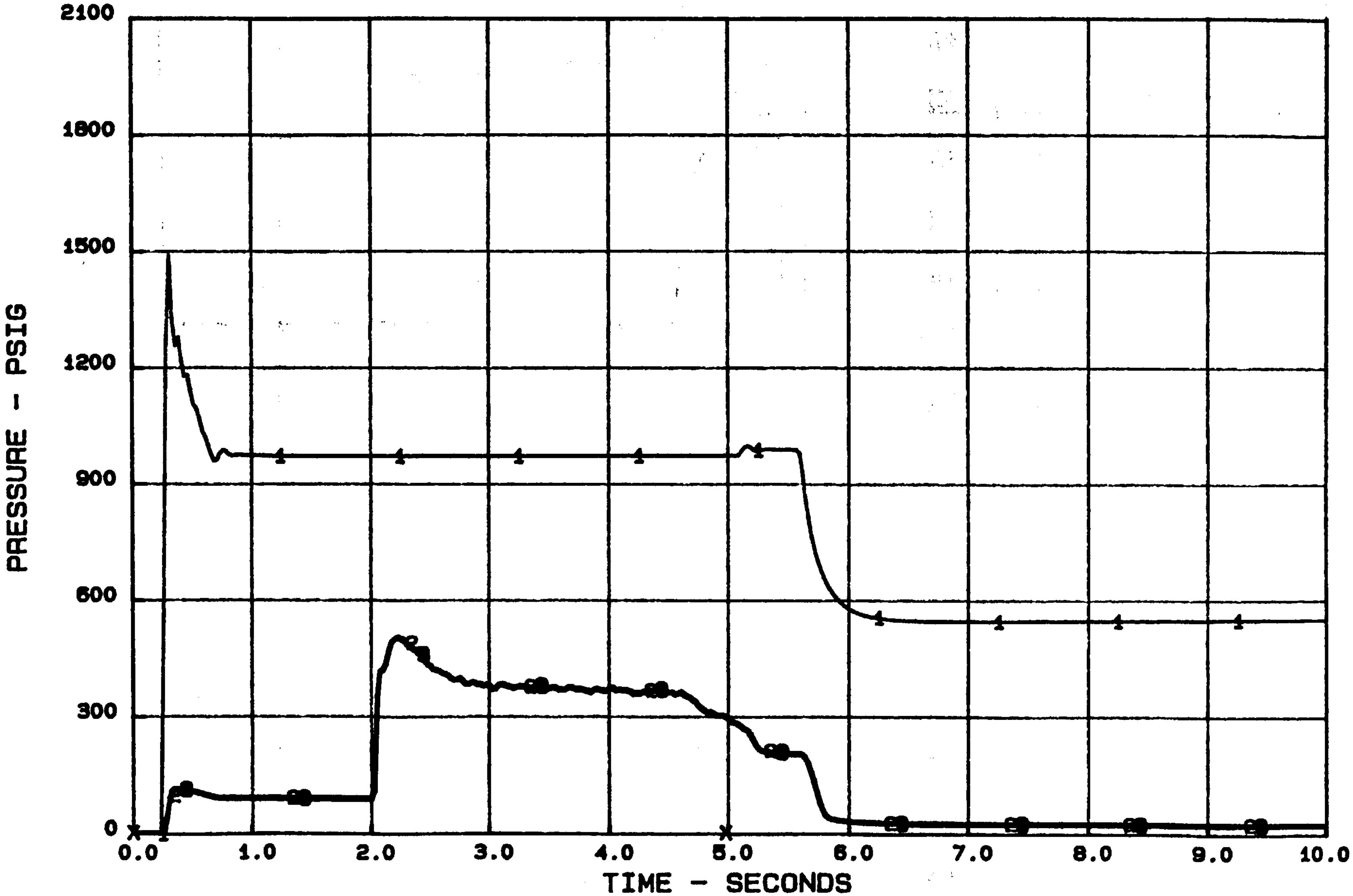
1 P1004 PSIG GOX VENTURI INLET 2 P2003 PSIG AFT-END GOX CH. PRES

3 P2004 PSIG AFT-END GOX CH. PRESS.



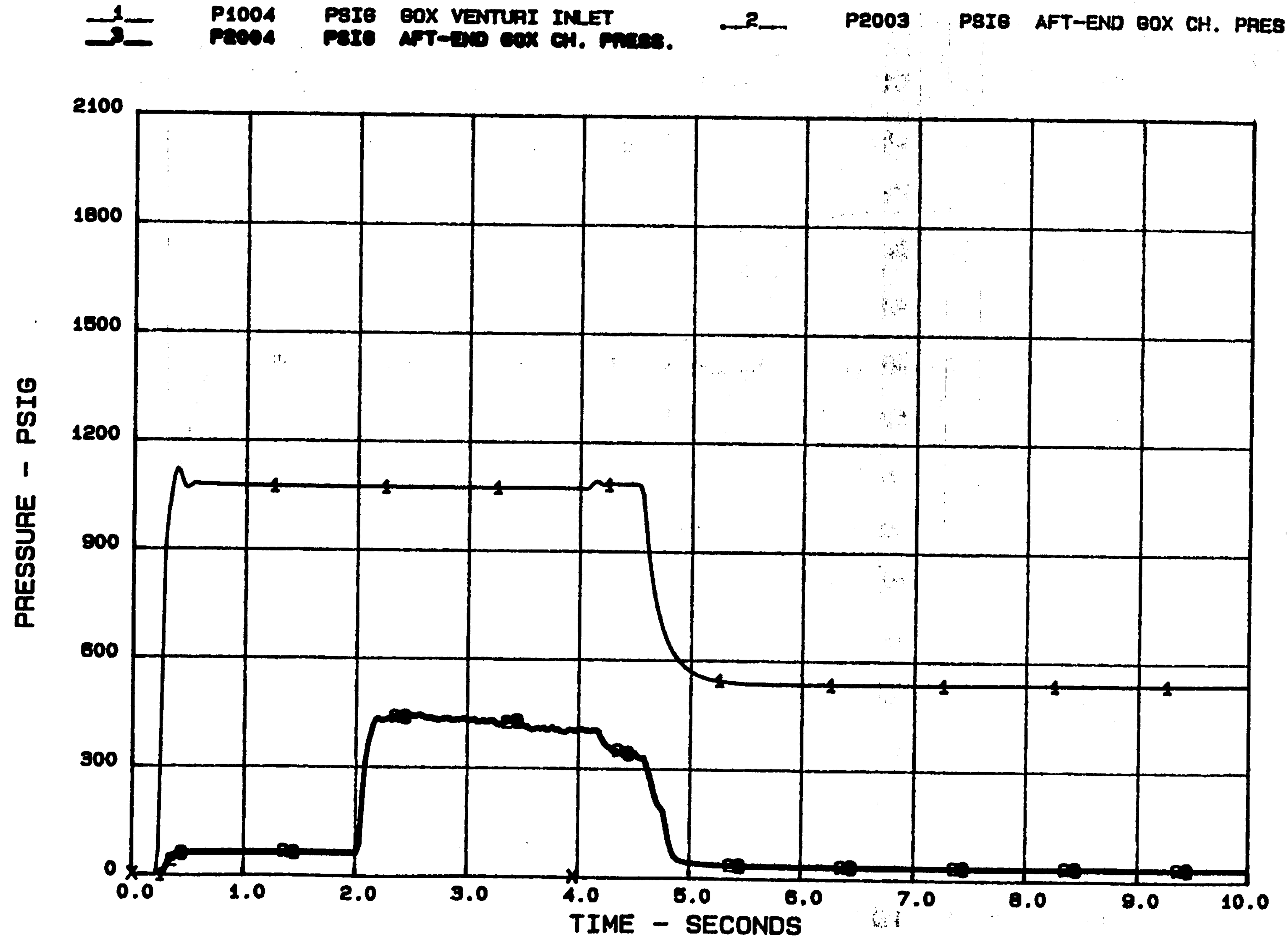
TEST NO.P280-94 39 ** 09 / 8 /94 251: 10: 54: 12.237

1 P1004 PSIG GOX VENTURI INLET 2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.



3.65

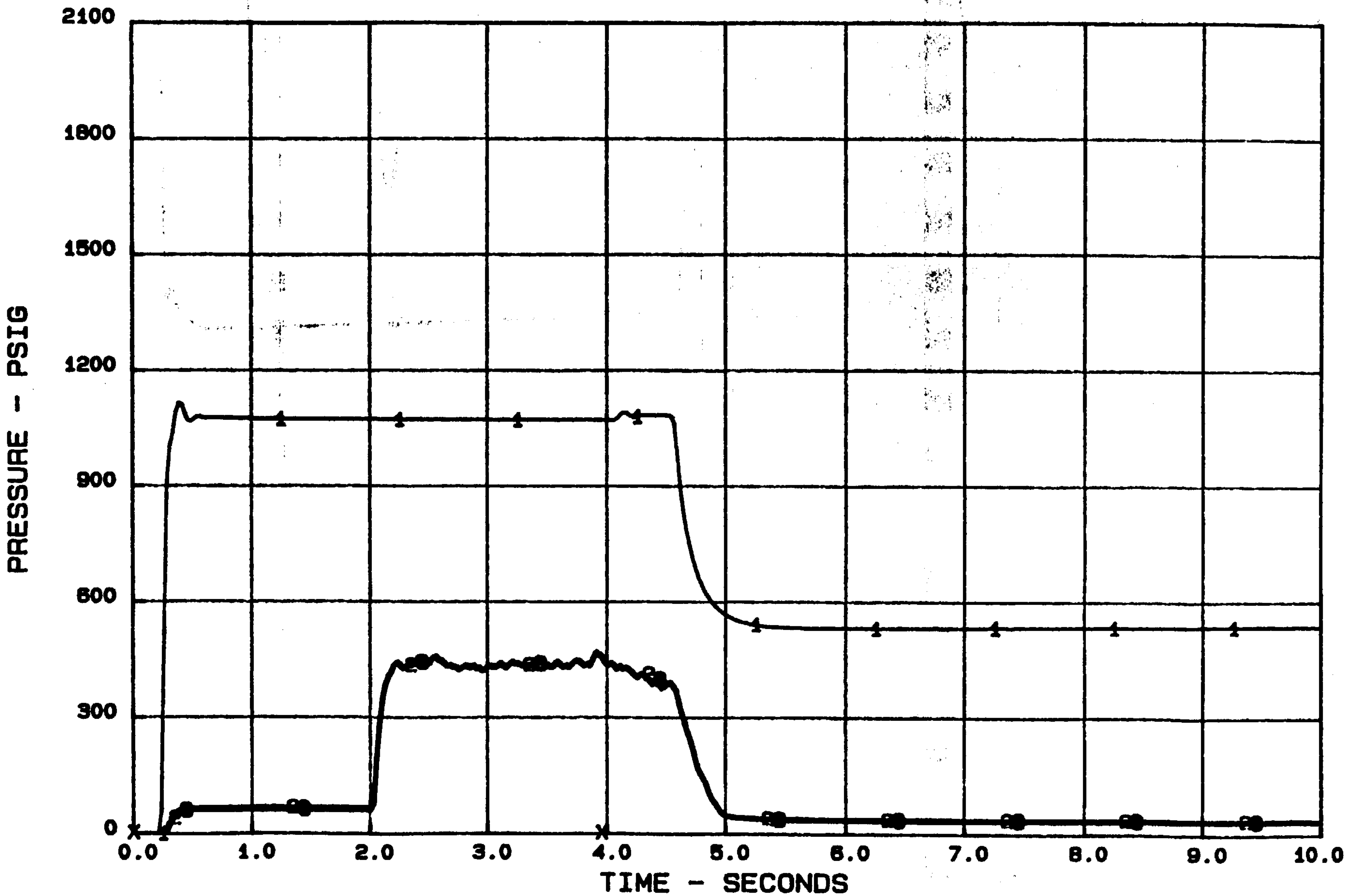
TEST NO.P280-94 40 ** 09 / 8 /94 251: 12: 49: 39.284



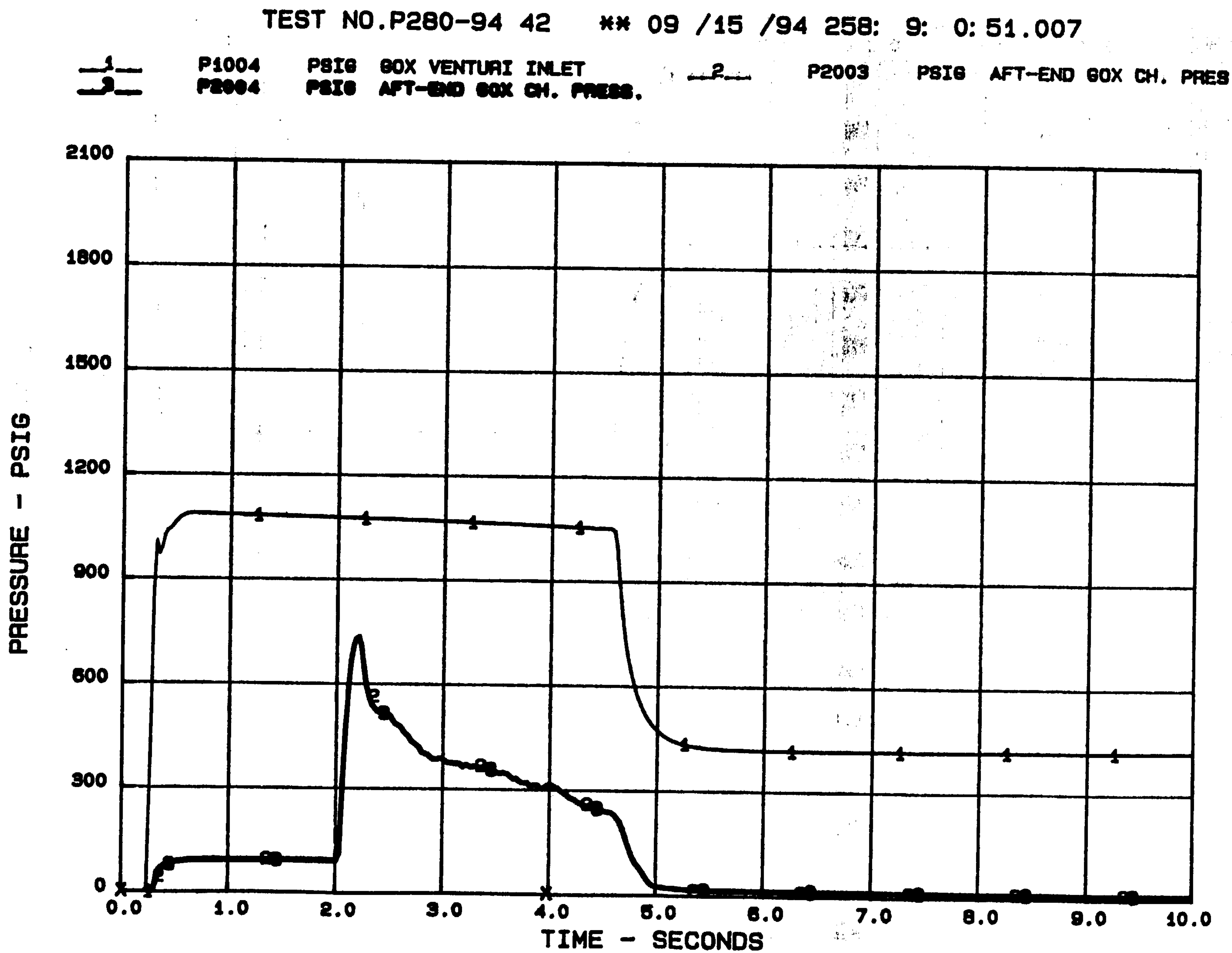
2.6

TEST NO.P280-94 41 ** 09 / 8 /94 251: 13: 8: 13.930

__1__ P1004 PSIG GOX VENTURI INLET __2__ P2003 PSIG AFT-END GOX CH. PRES
__3__ P2004 PSIG AFT-END GOX CH. PRESS.



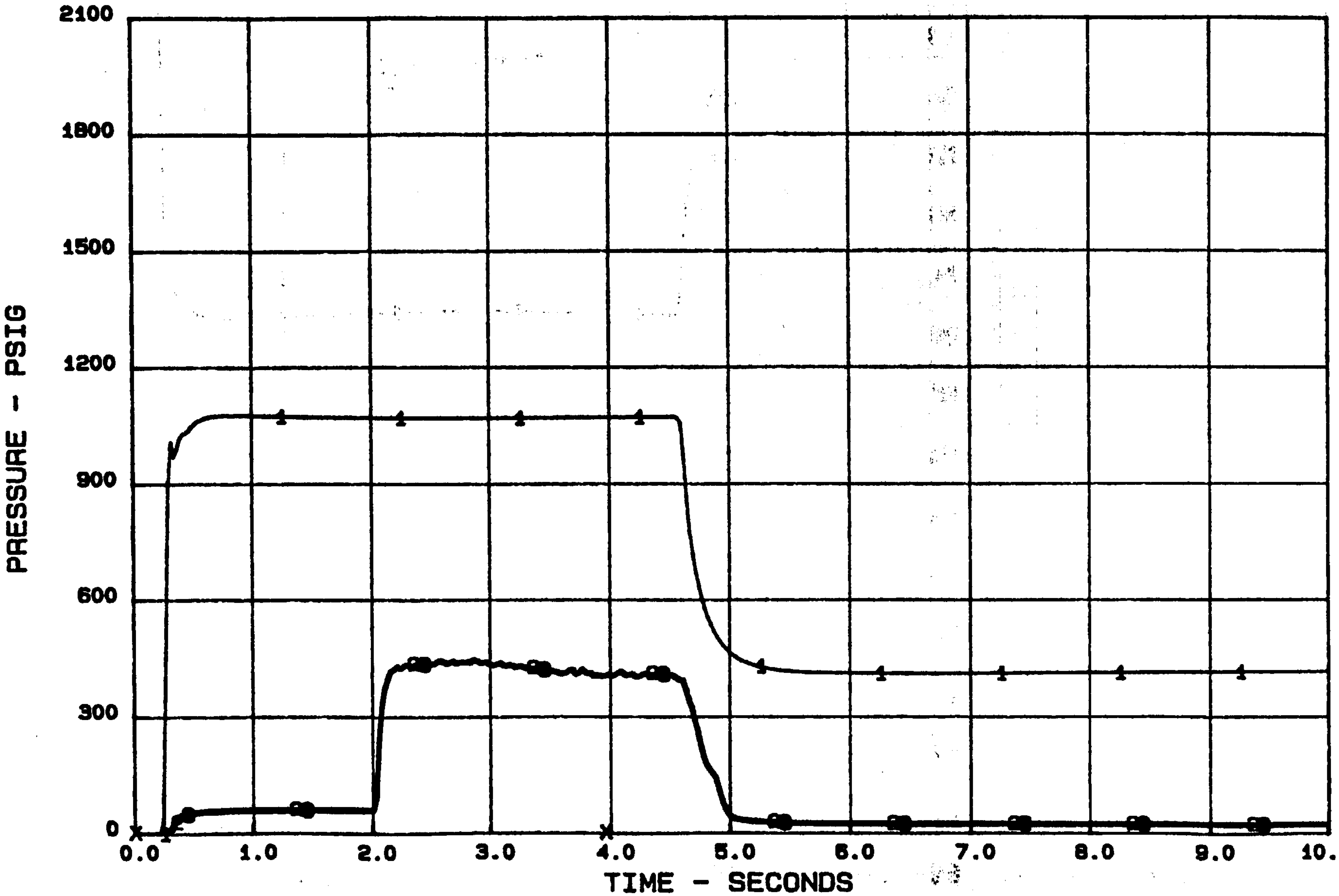
2.6


TEST NO.P280-94 42 ** 09 /15 /94 258: 9: 0: 51.007
1 P1004 PSIG GOX VENTURI INLET
3 P2004 PSIG AFT-END GOX CH. PRESS.
2 P2003 PSIG AFT-END GOX CH. PRES
PRESSURE - PSIG
2100
1800
1500
1200
900
600
300
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME - SECONDS

2.6

TEST NO.P280-94 43 ** 09 /15 /94 258: 9: 21: 7.428

__1__	P1004	PSIG	GOX VENTURI INLET	__2__	P2003	PSIG	AFT-END GOX CH. PRES
__3__	P2004	PSIG	AFT-END GOX CH. PRESS.				



2.63

TEST NO.P280-94 44 ** 09 /15 /94 258: 9: 42: 27.897

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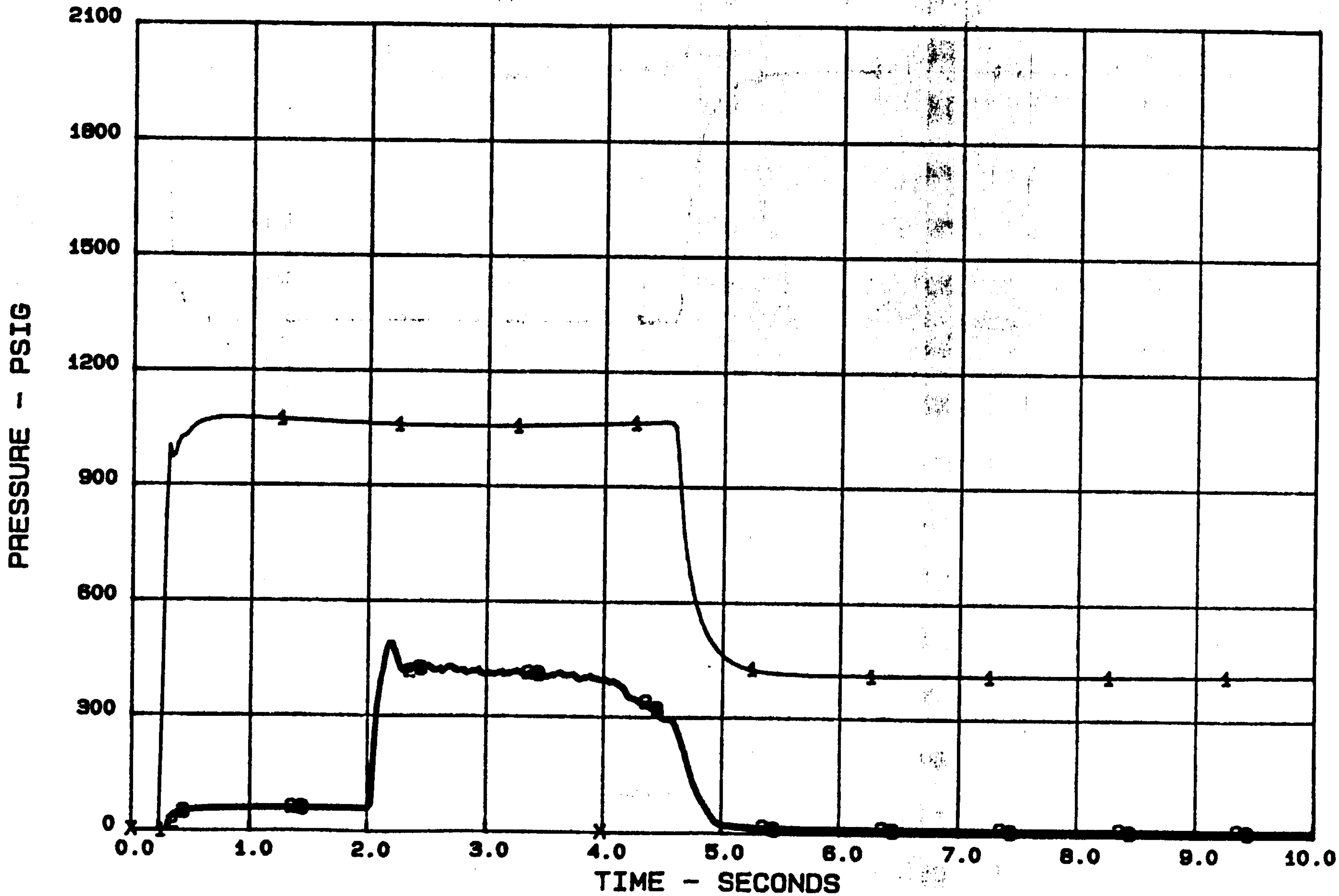
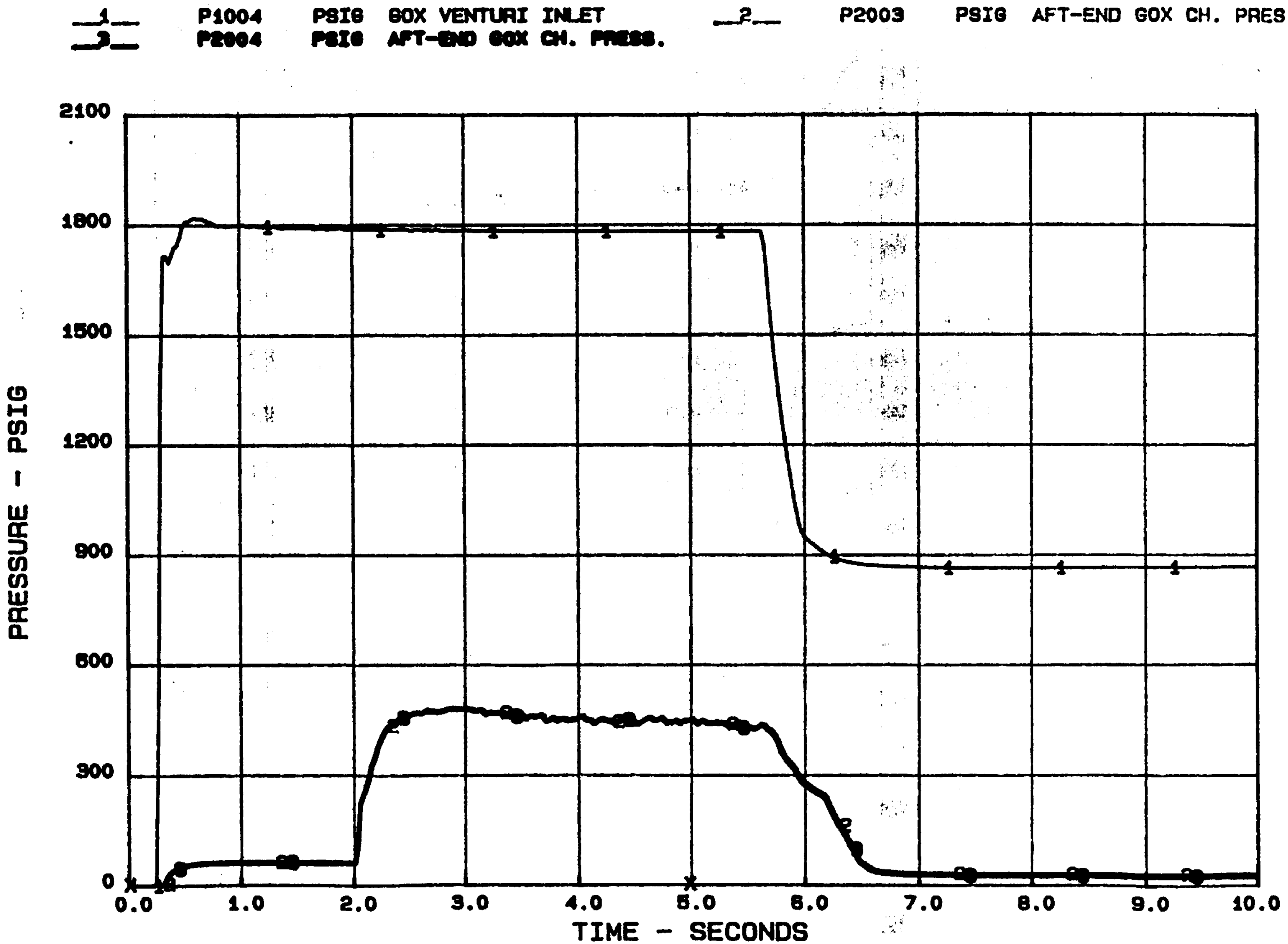
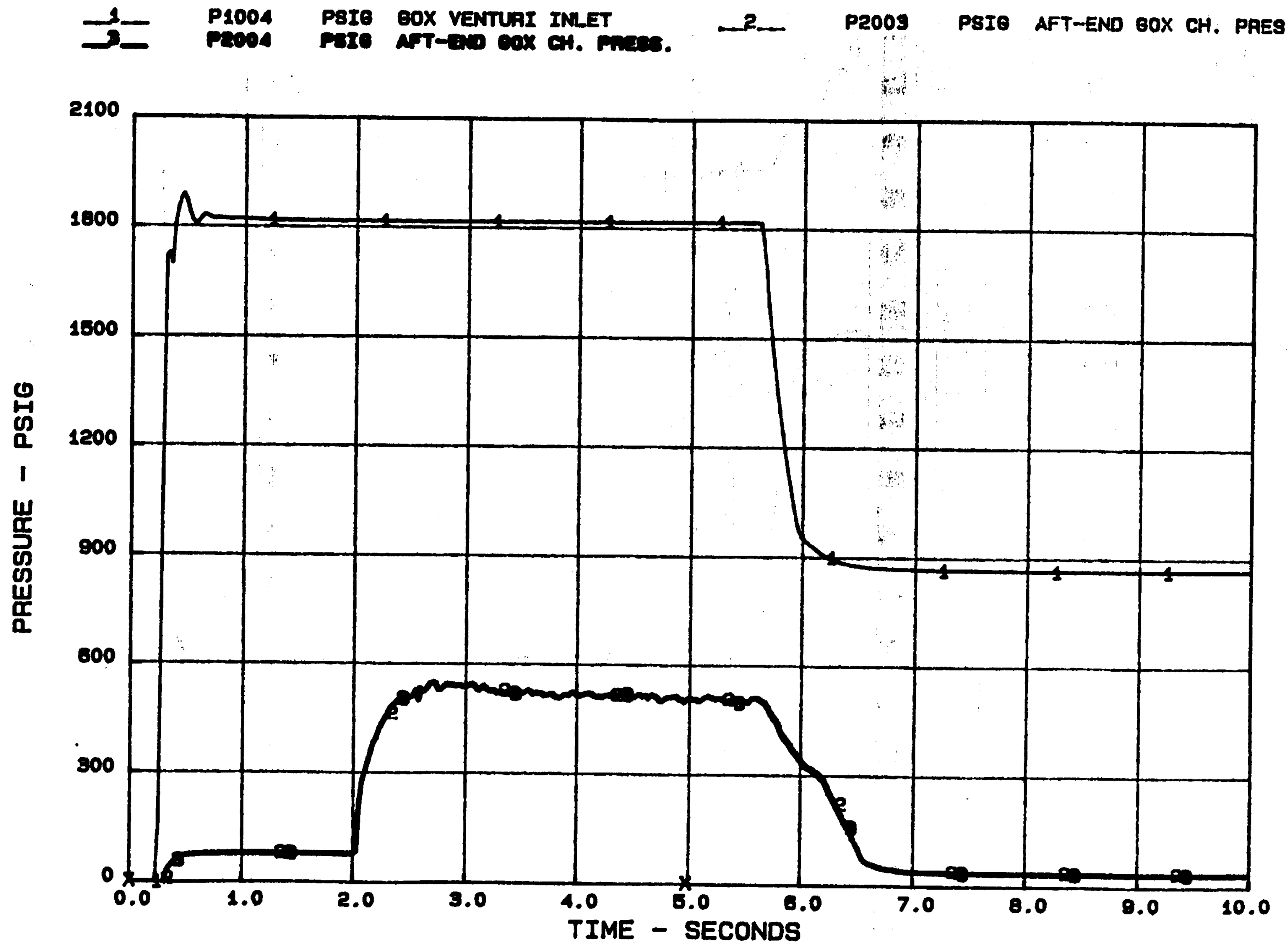
__3__ P2004 PSIG AFT-END GOX CH. PRESS.



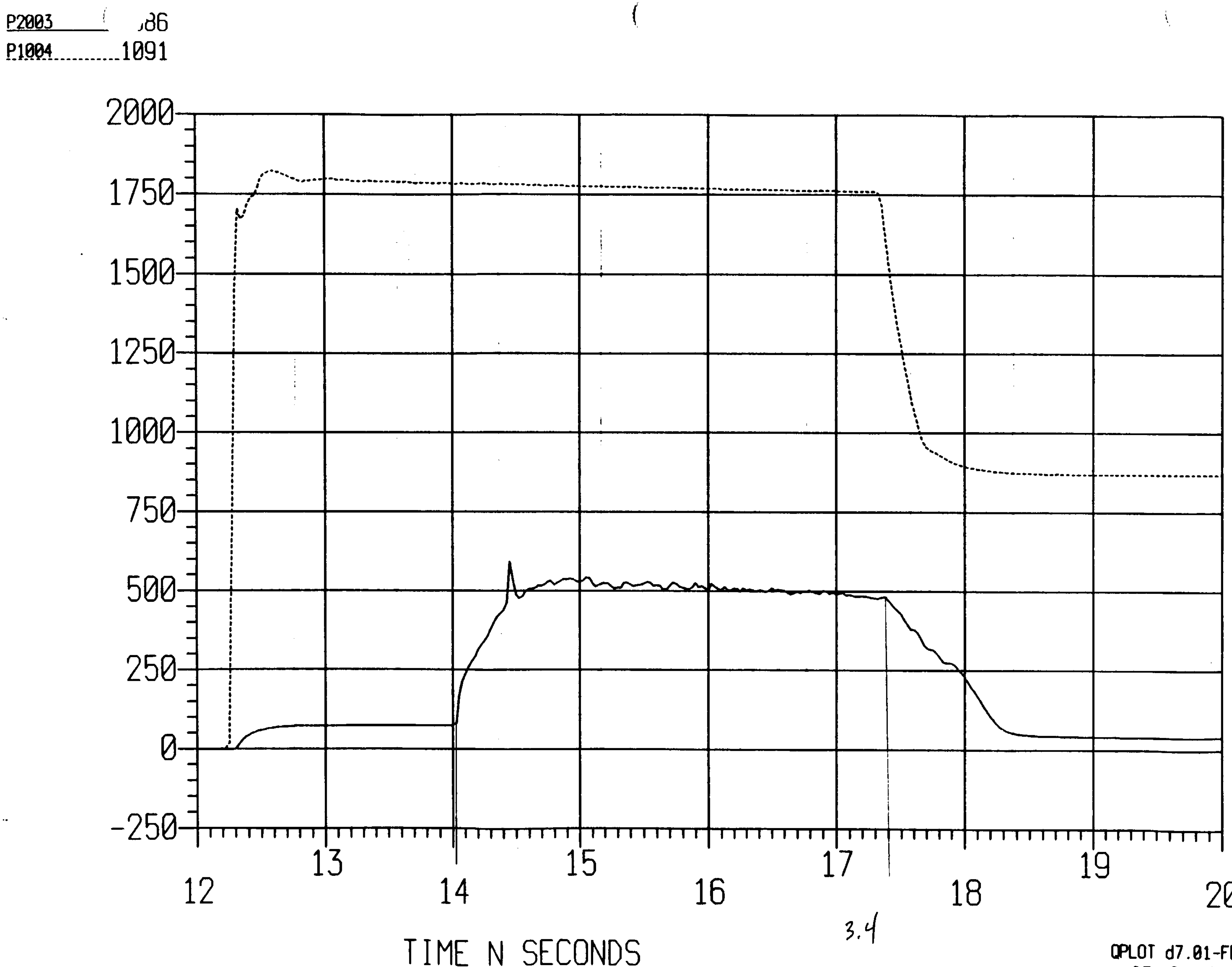
TEST NO.P280-94 45 ** 09 /15 /94 258: 10: 7: 18.317



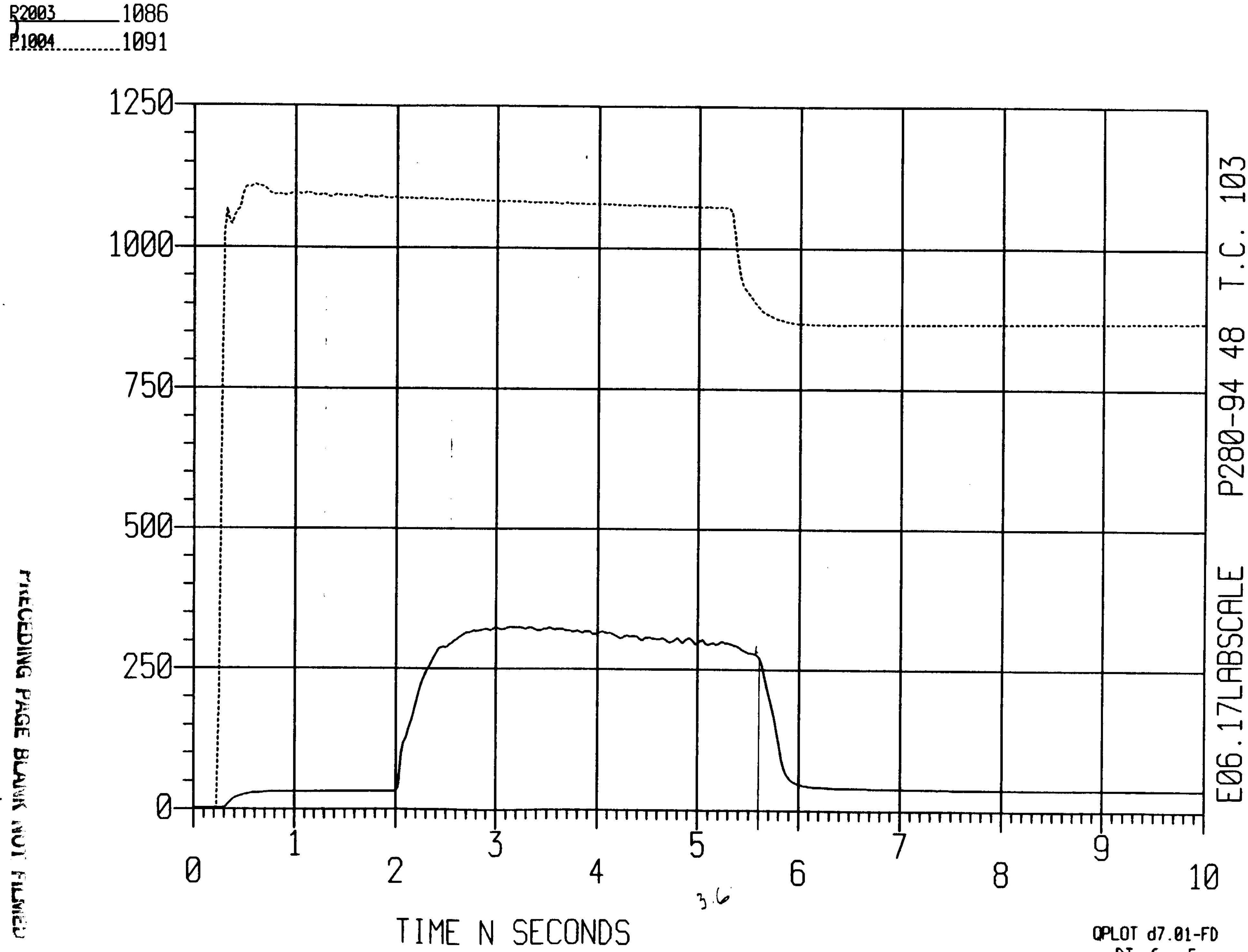
TEST NO.P280-94 46 ** 09 /15 /94 258: 10: 28: 59.436

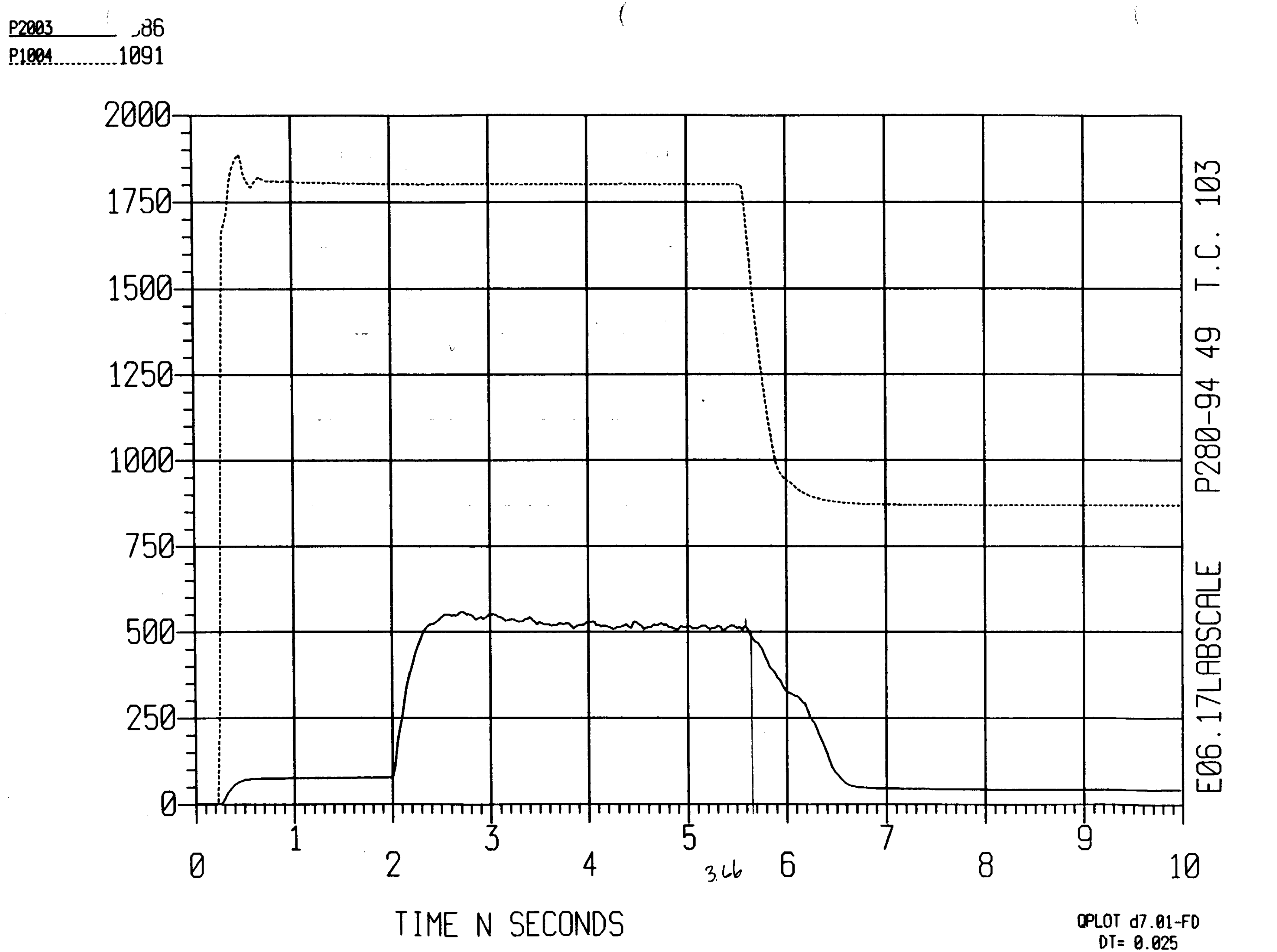


3.7



P2003 ,86
P1004 1091
2000
1750
1500
1250
1000
750
500
250
0
-250
12
13
14
15
16
17
18
19
20
TIME N SECONDS
3.4
P280-94 47 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 0.025


P2003 1086
P1004 1091
1250
1000
750
500
250
0
0
1
2
3
4
5
6
7
8
9
10
TIME N SECONDS
3.6
P280-94 48 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD



P2003 386
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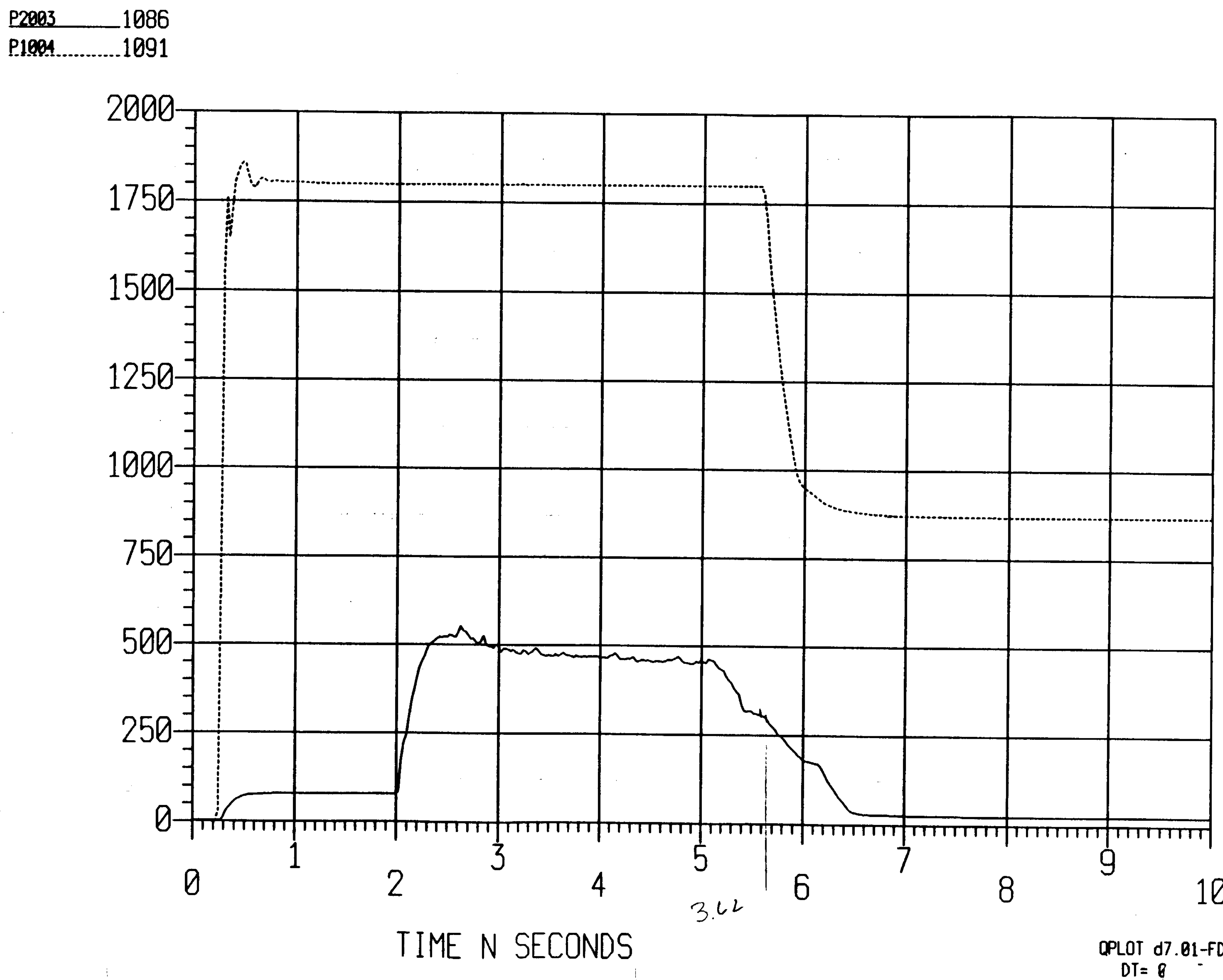
1750
1500
1250
1000
750
500
250
0
0
1
2
3
4
5
6
7
8
9
10
3.66
TIME N SECONDS
P280-94 49 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 0.025



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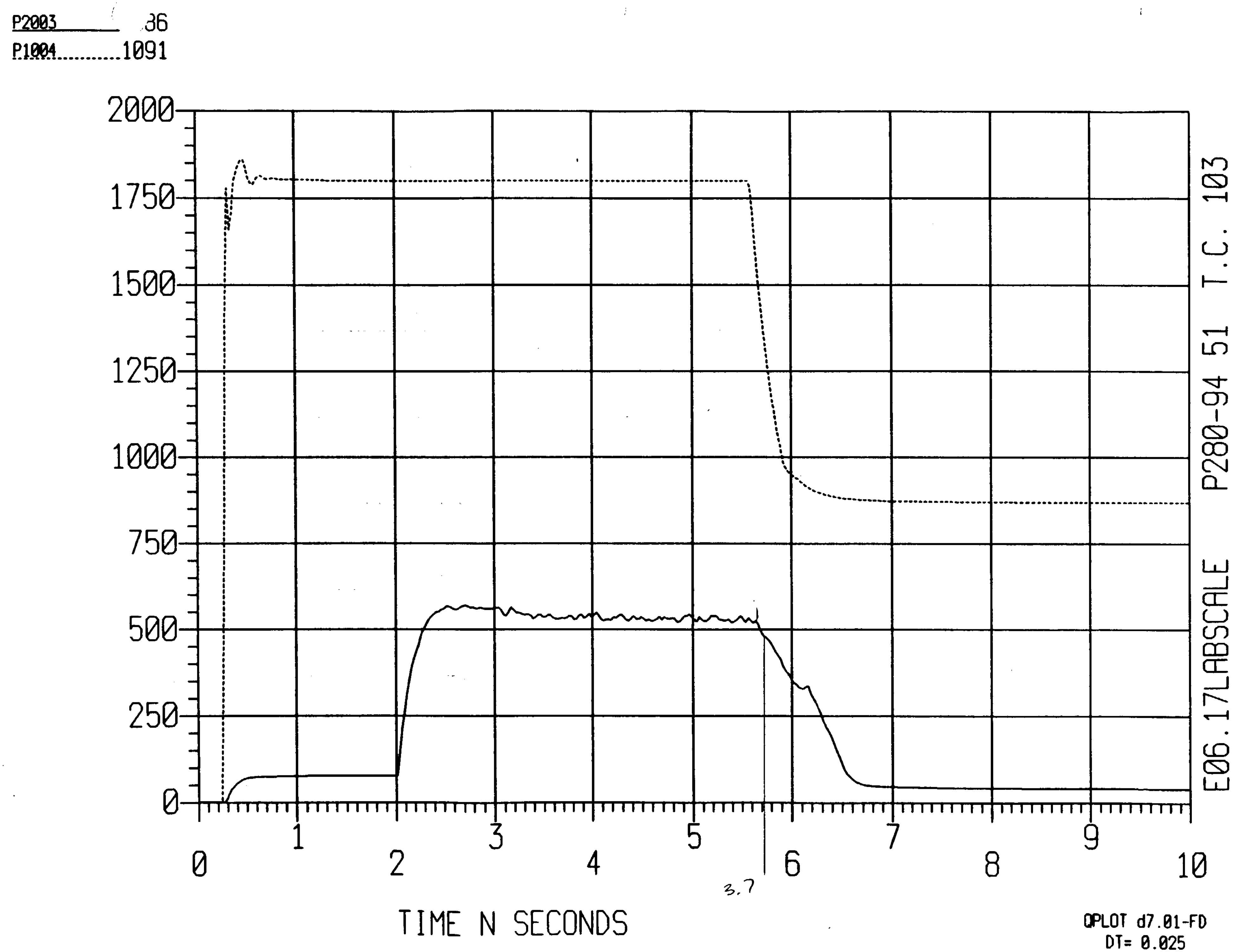
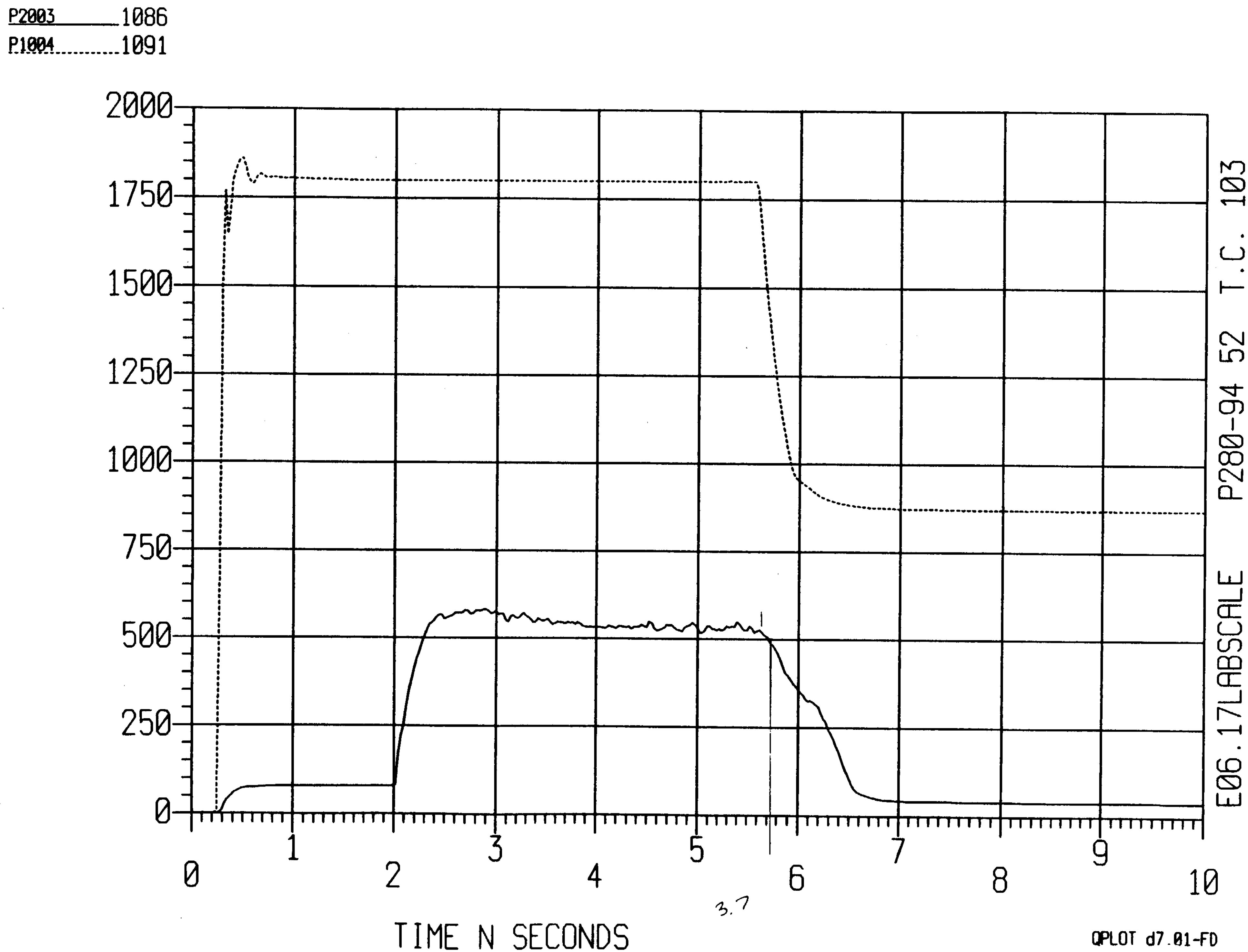
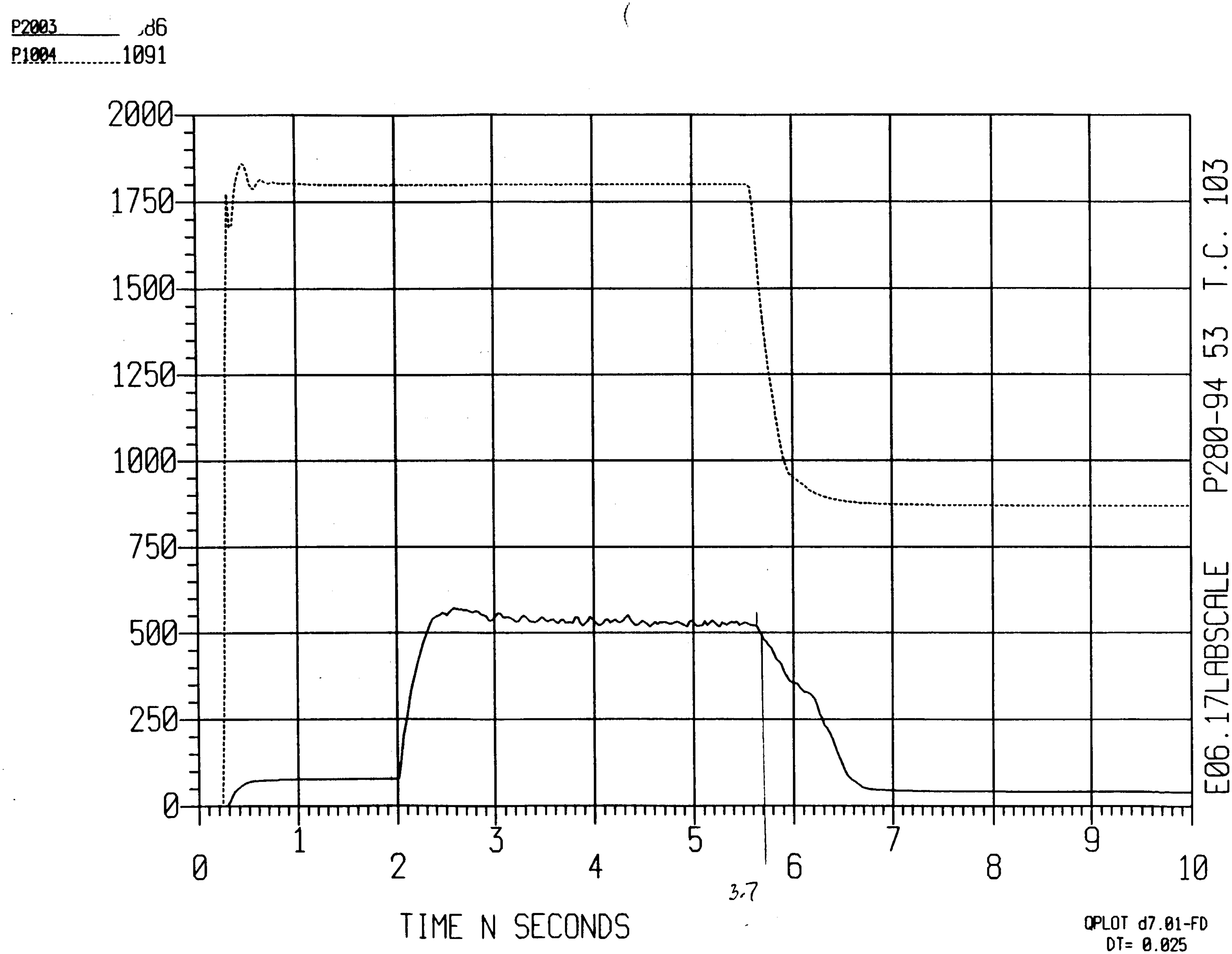
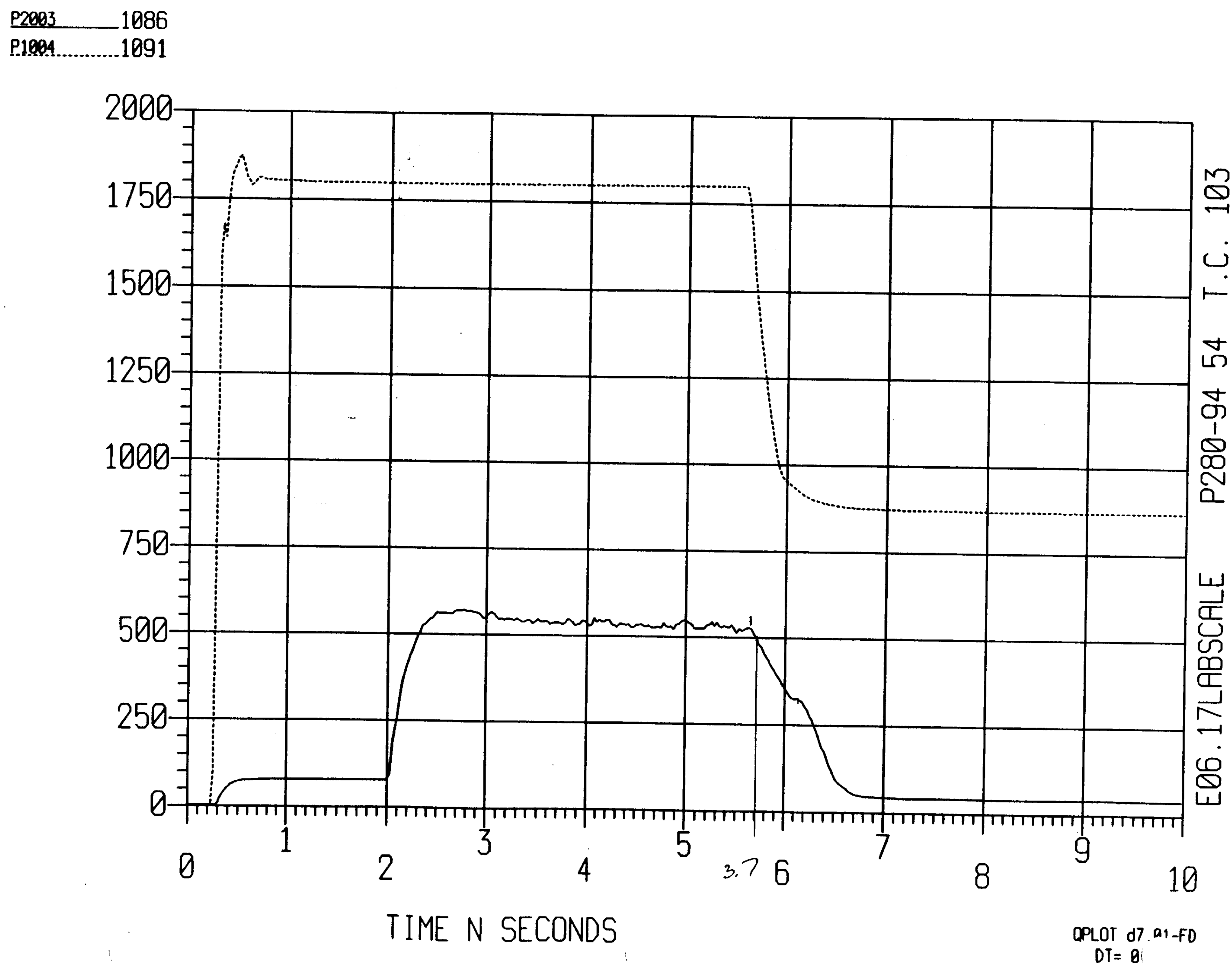
P1004 1091
2000
1750
1500
1250
1000
750
500
250
0
0
1
2
3
4
5
6
7
8
9
10
3.62
TIME N SECONDS
P280-94 50 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 0


P2003 36
P1004 1091
2000
1750
1500
1250
1000
750
500
250
0
0 1 2 3 4 5 6 7 8 9 10
3.7
TIME N SECONDS
P280-94 51 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 0.025

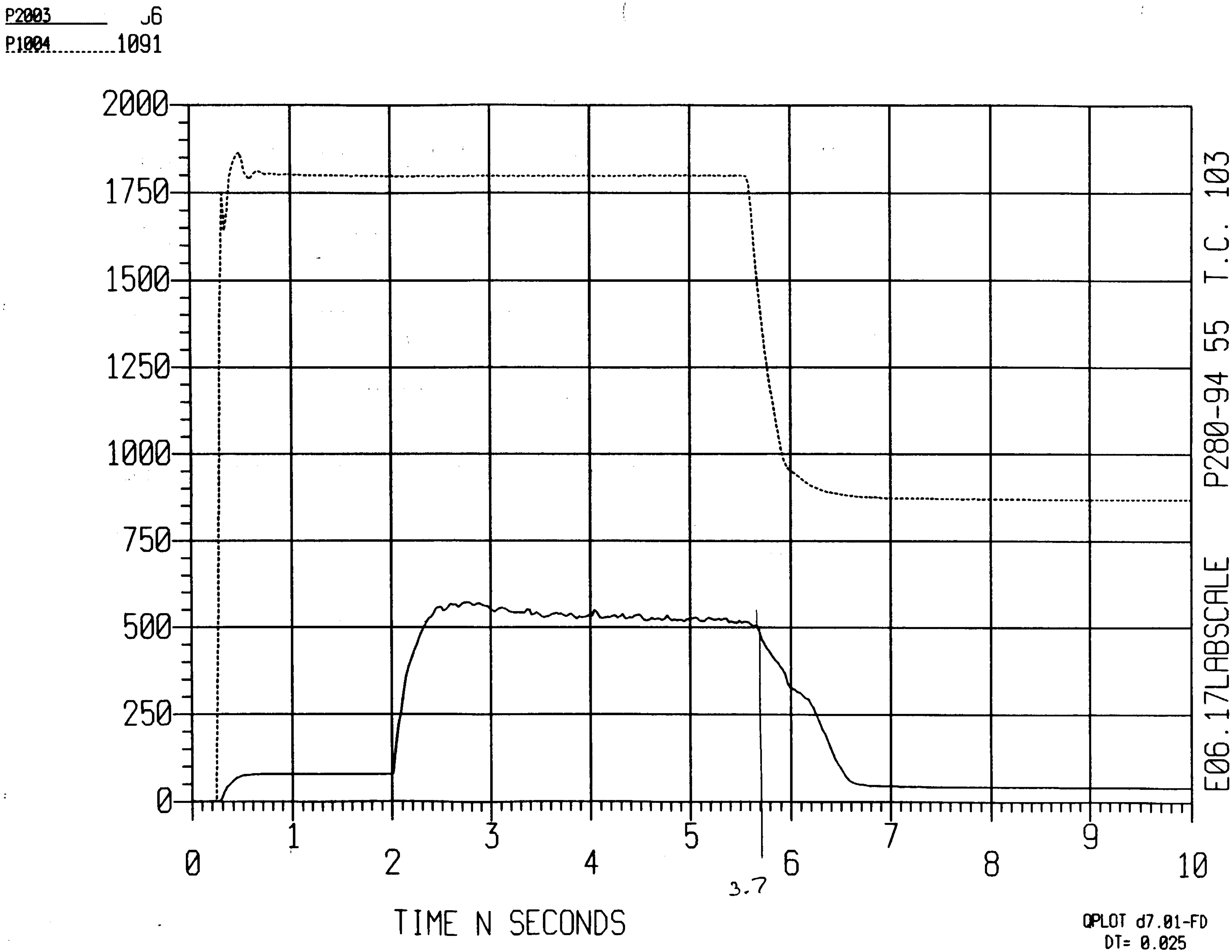

P2003 1086
P1004 1091
2000
1750
1500
1250
1000
750
500
250
0
0
1
2
3
4
5
6
7
8
9
10
TIME N SECONDS
3.7
P280-94 52 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 6



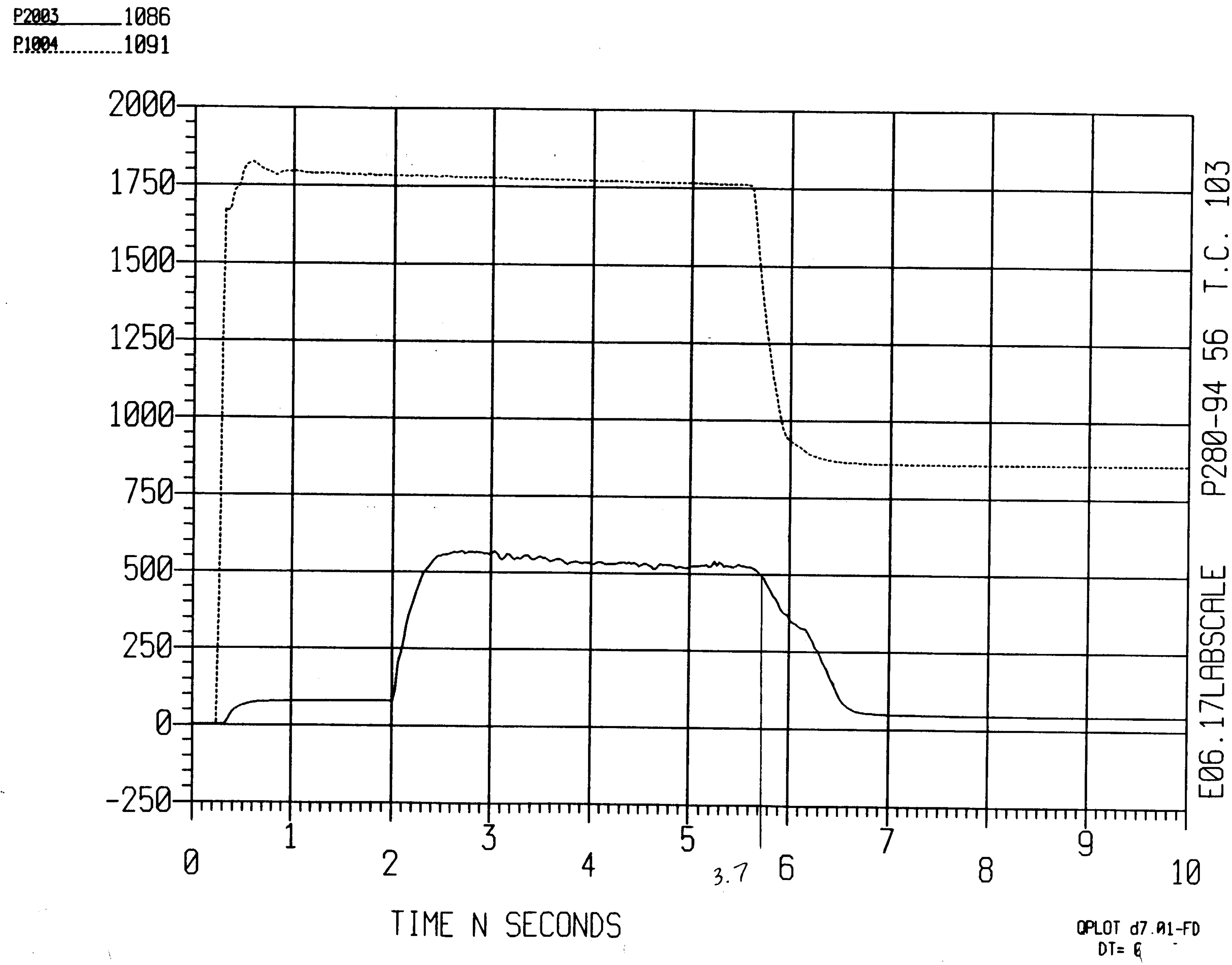
P2003 _86
P1004 1091
2000
1750
1500
1250
1000
750
500
250
0
0
1
2
3
4
5
6
7
8
9
10
3.7
TIME N SECONDS
P280-94 53 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 0.025



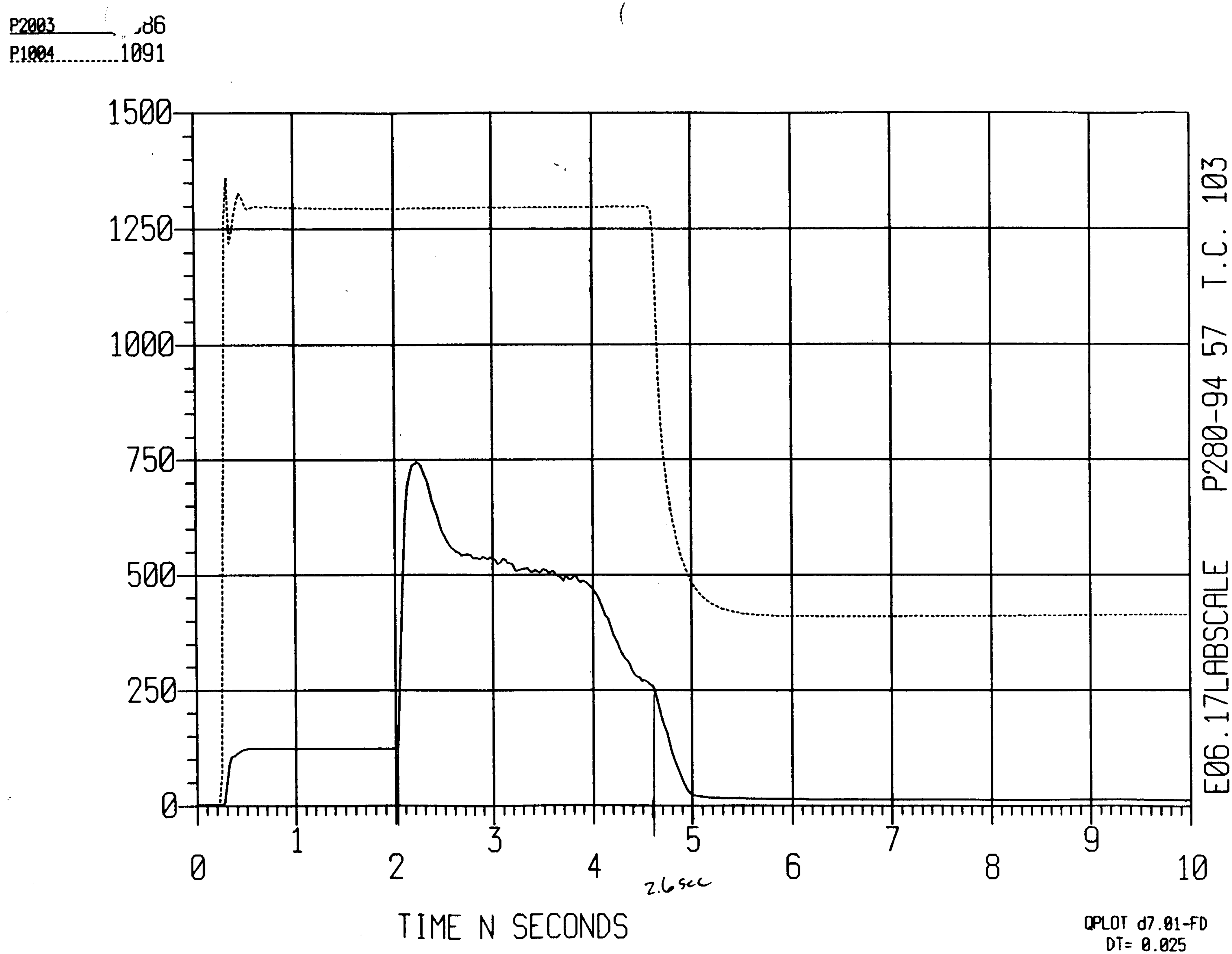
P2003 1086
P1004 1091
2000
1750
1500
1250
1000
750
500
250
0
0
1
2
3
4
5
3.7
6
7
8
9
10
TIME N SECONDS
E06.17LABSCALE P280-94 54 T.C. 103
QPLOT d7.01-FD
DT= 0



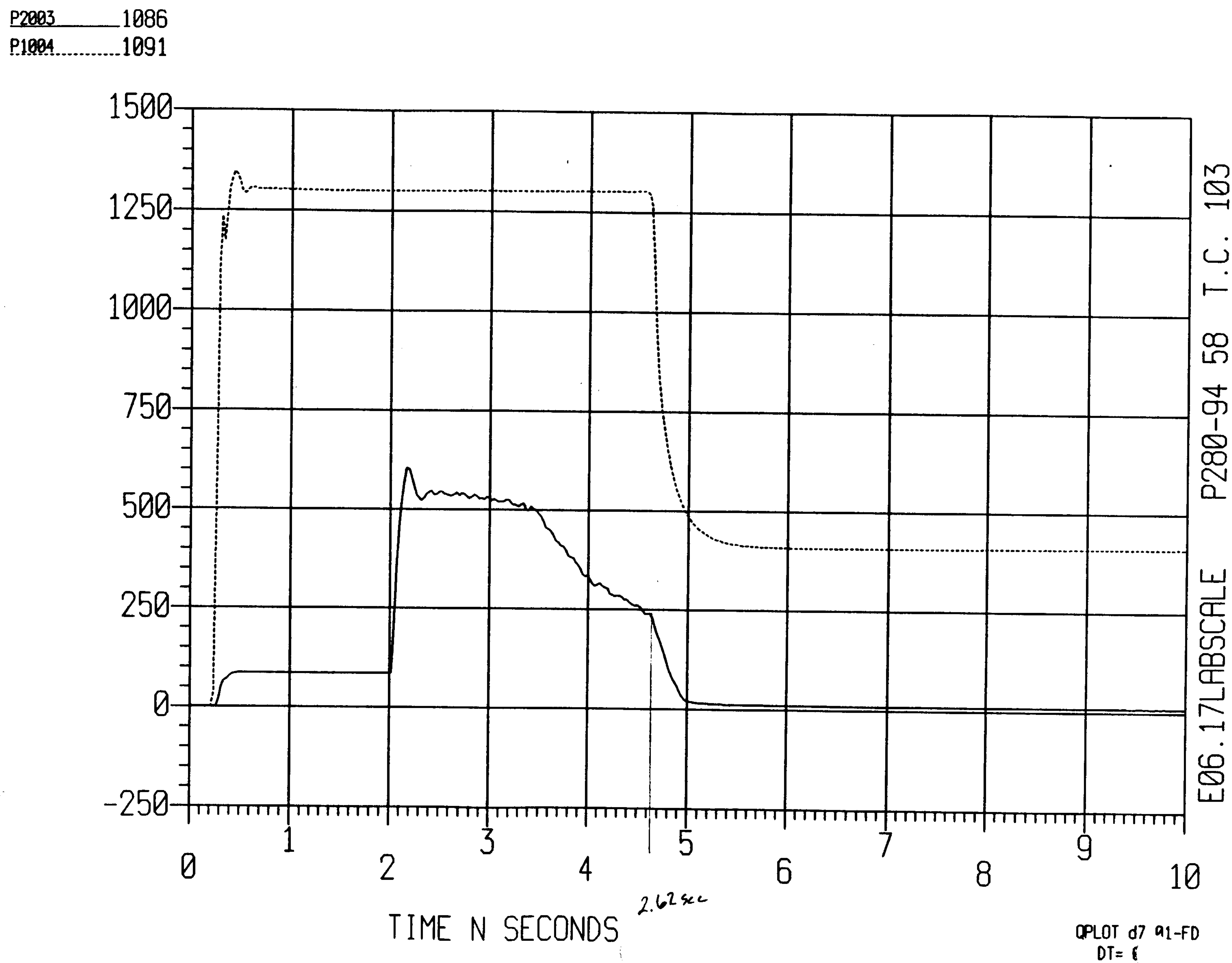
P2003 J6
P1004 1091
2000
1750
1500
1250
1000
750
500
250
0
0 1 2 3 4 5 6 7 8 9 10
3.7
TIME N SECONDS
P280-94 55 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 0.025



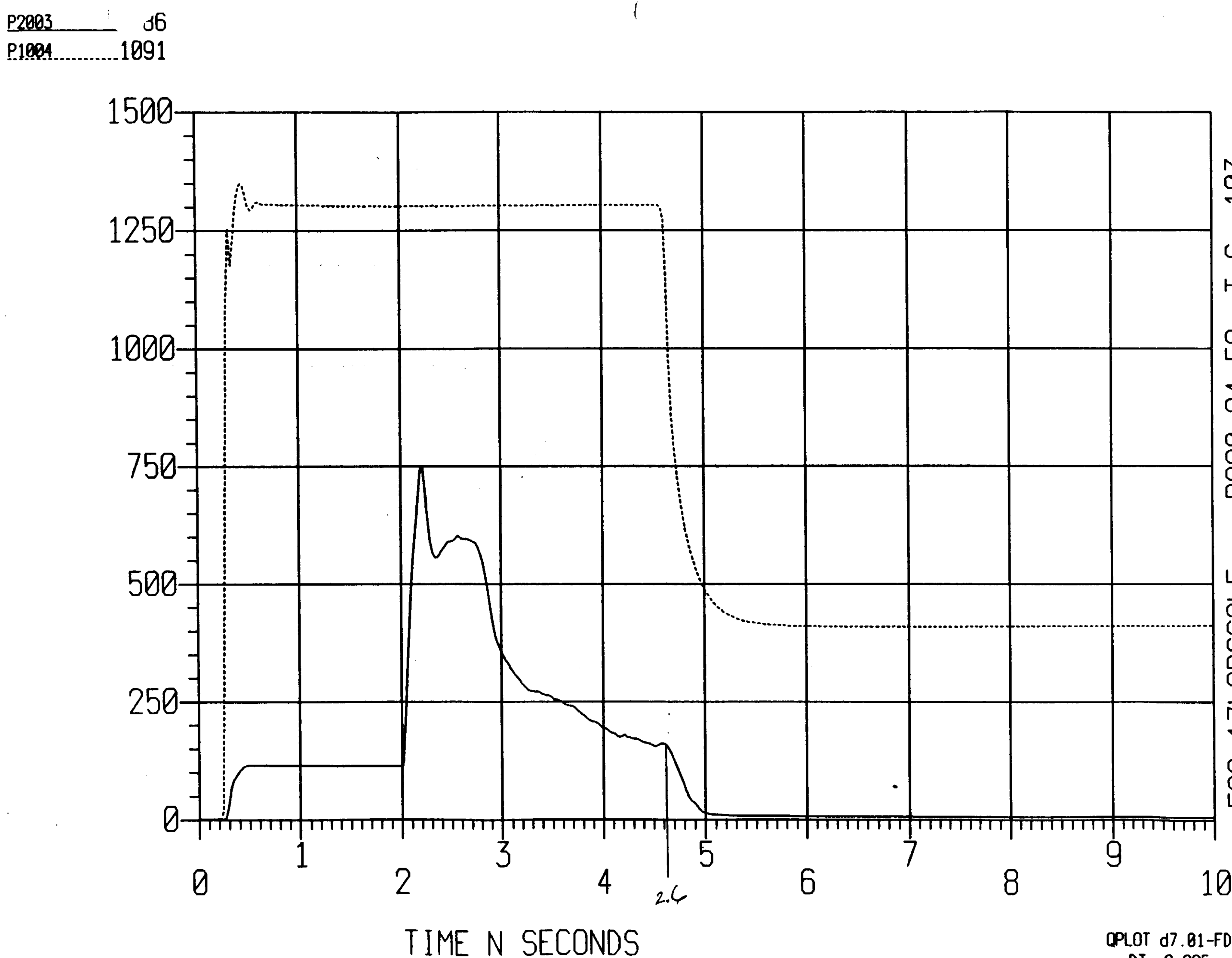
P2003 1086
P1004 1091
2000
1750
1500
1250
1000
750
500
250
0
-250
0
1
2
3
4
5
3.7
6
7
8
9
10
TIME N SECONDS
P280-94 56 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 6

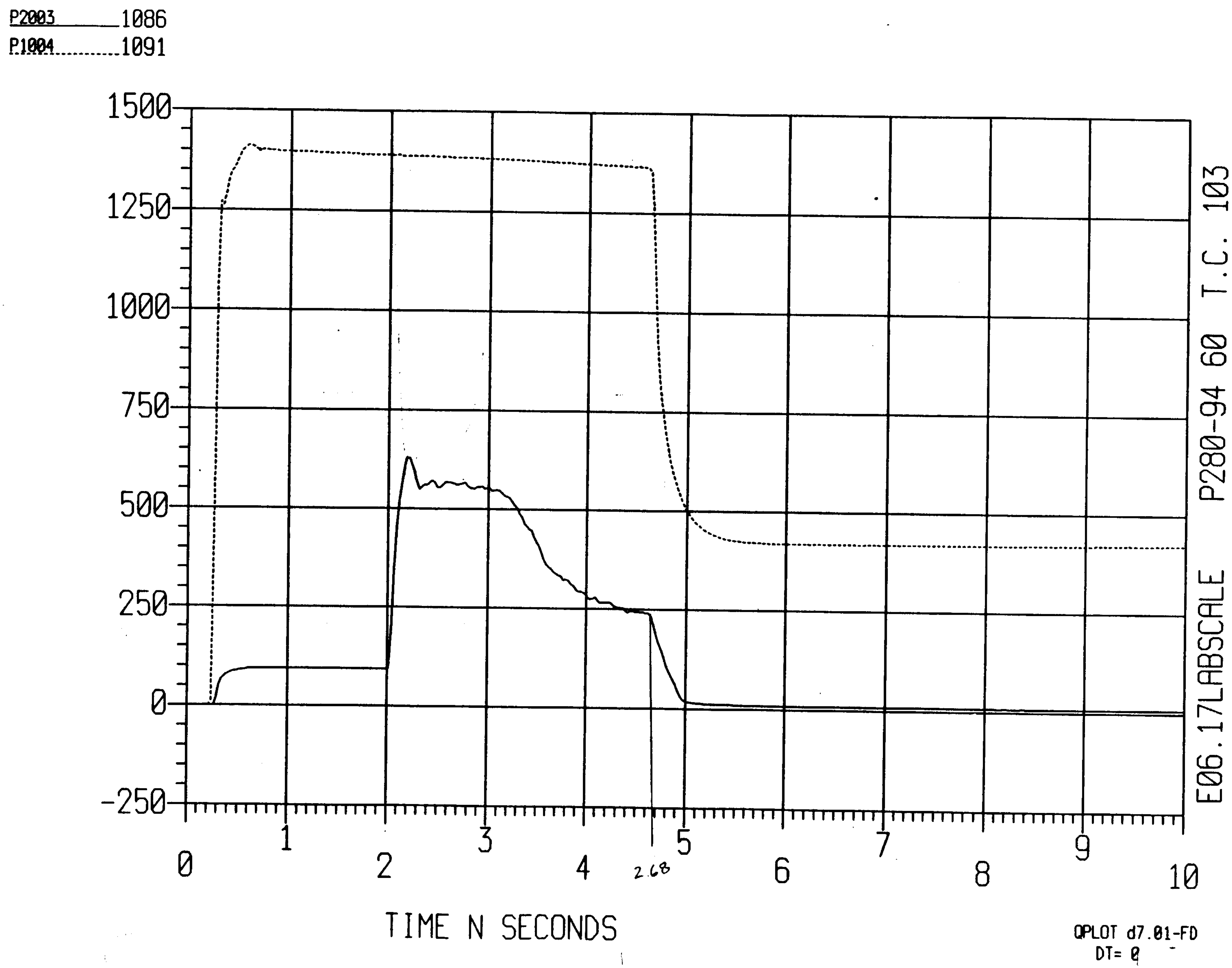


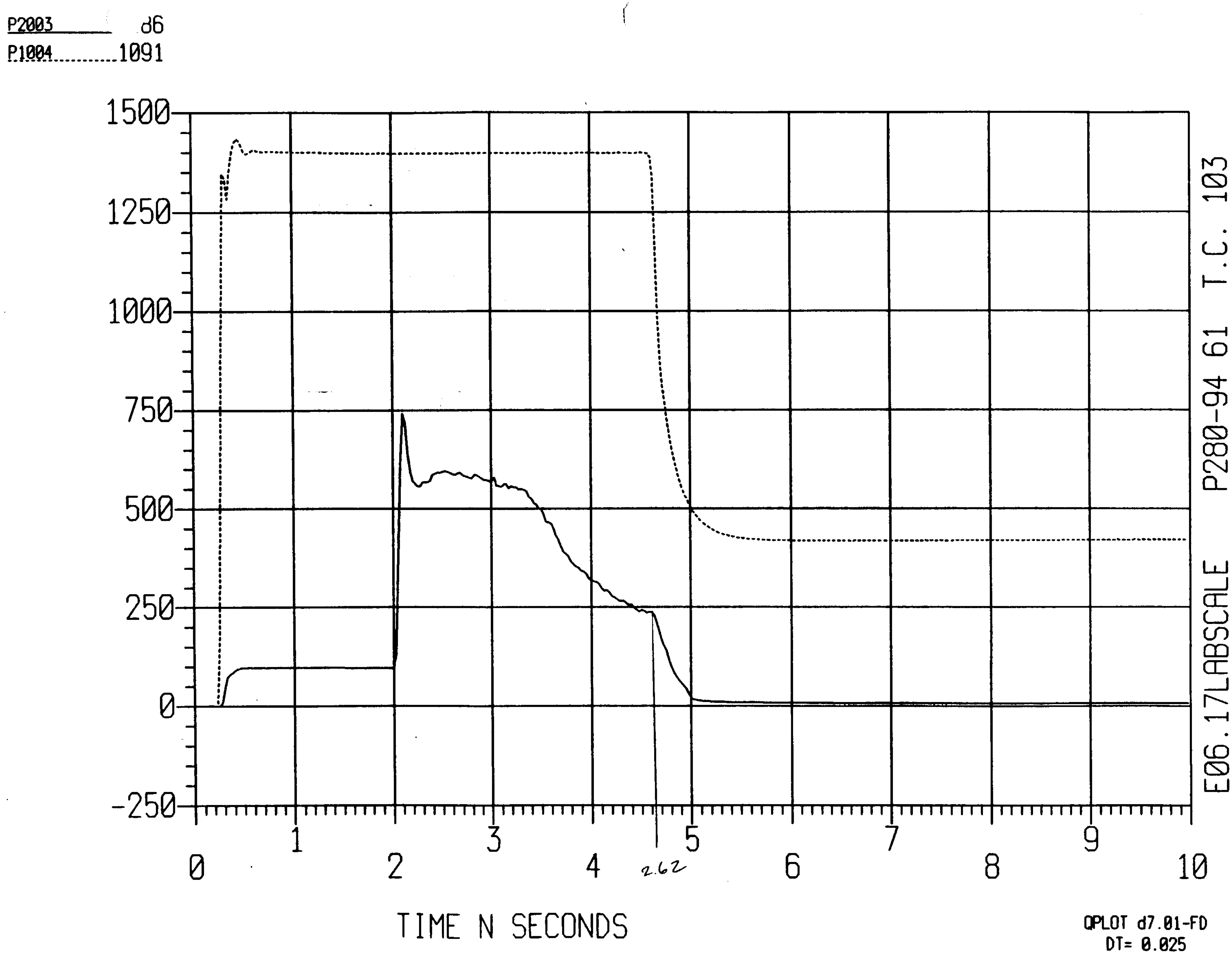
P2003 ...86
P1004 1091
1500
1250
1000
750
500
250
0
0
1
2
3
4
5
6
7
8
9
10
2.6sec
TIME N SECONDS
P280-94 57 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 0.025



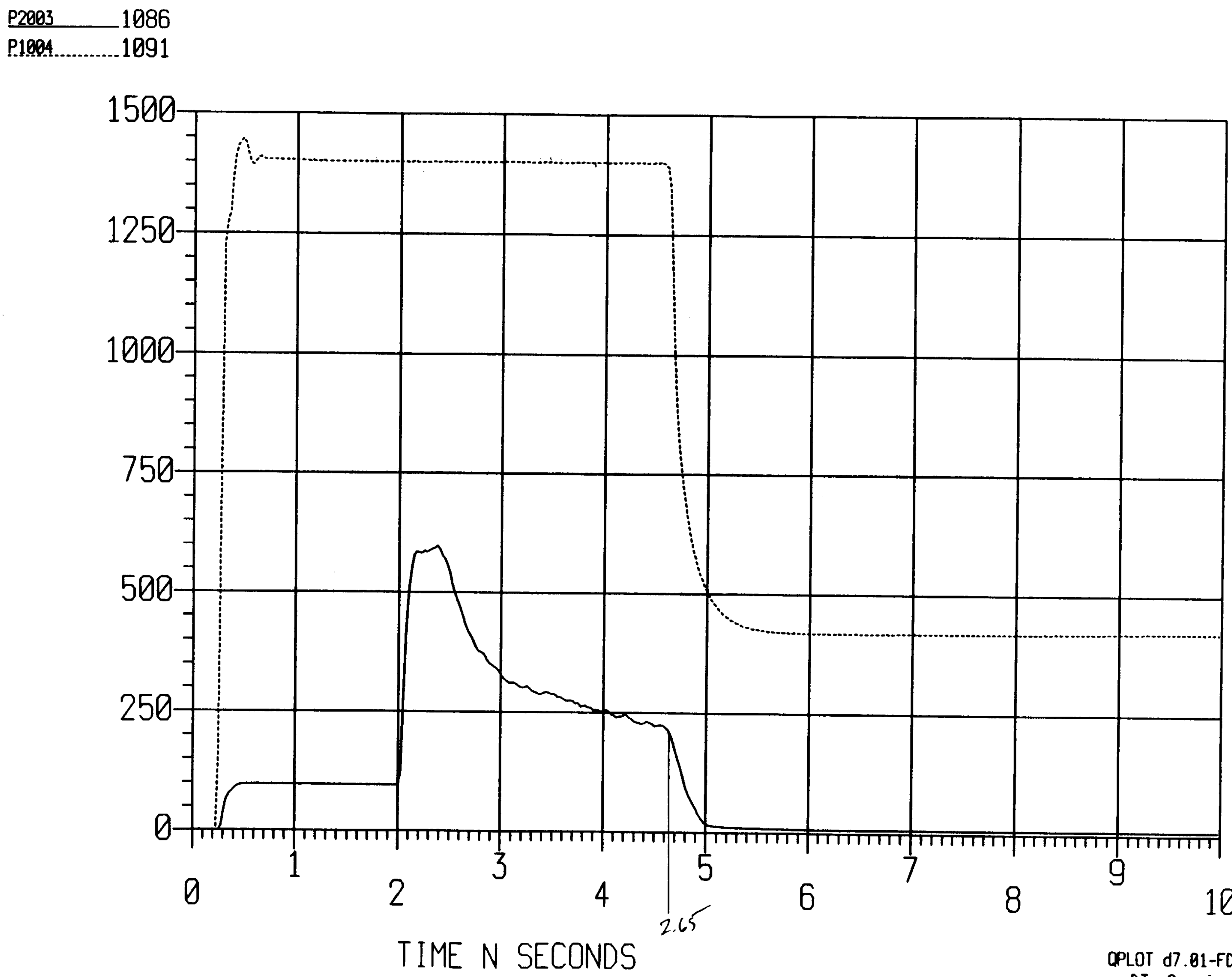
P2003 1086
P1004 1091
1500
1250
1000
750
500
250
0
-250
0
1
2
3
4
5
6
7
8
9
10
TIME N SECONDS
2.62 sec
P280-94 58 T.C. 103
E06.17LABSCALE
QPLOT d7 91-FD
DT= 6


P2003 d6
P1004 1091
1500
1250
1000
750
500
250
0
0
1
2
3
4
5
6
7
8
9
10
2.6
TIME N SECONDS
E06.17LABSCALE P280-94 59 T.C. 103
QPLOT d7.01-FD
DT= 0.025

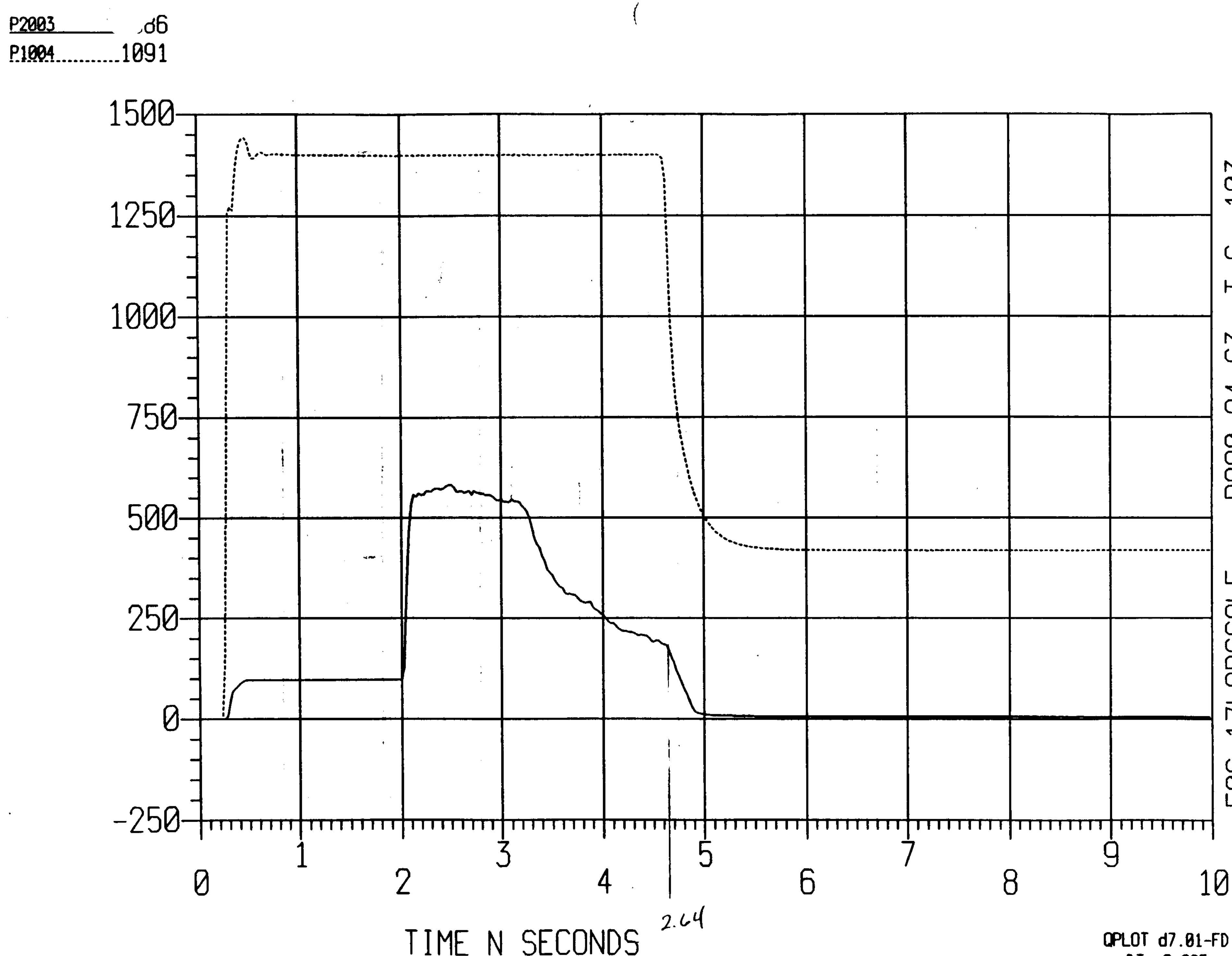

P2003 1086
P1004 1091
1500
1250
1000
750
500
250
0
-250
0
1
2
3
4
2.68
5
6
7
8
9
10
TIME N SECONDS
E06.17LABSCALE P280-94 60 T.C. 103
QPLOT d7.01-FD
DT= 0



P2003 d6
P1004 1091
1500
1250
1000
750
500
250
0
-250
0
1
2
3
4
5
6
7
8
9
10
2.62
TIME N SECONDS
E06.17LABSCALE P280-94 61 T.C. 103
QPLOT d7.01-FD
DT= 0.025

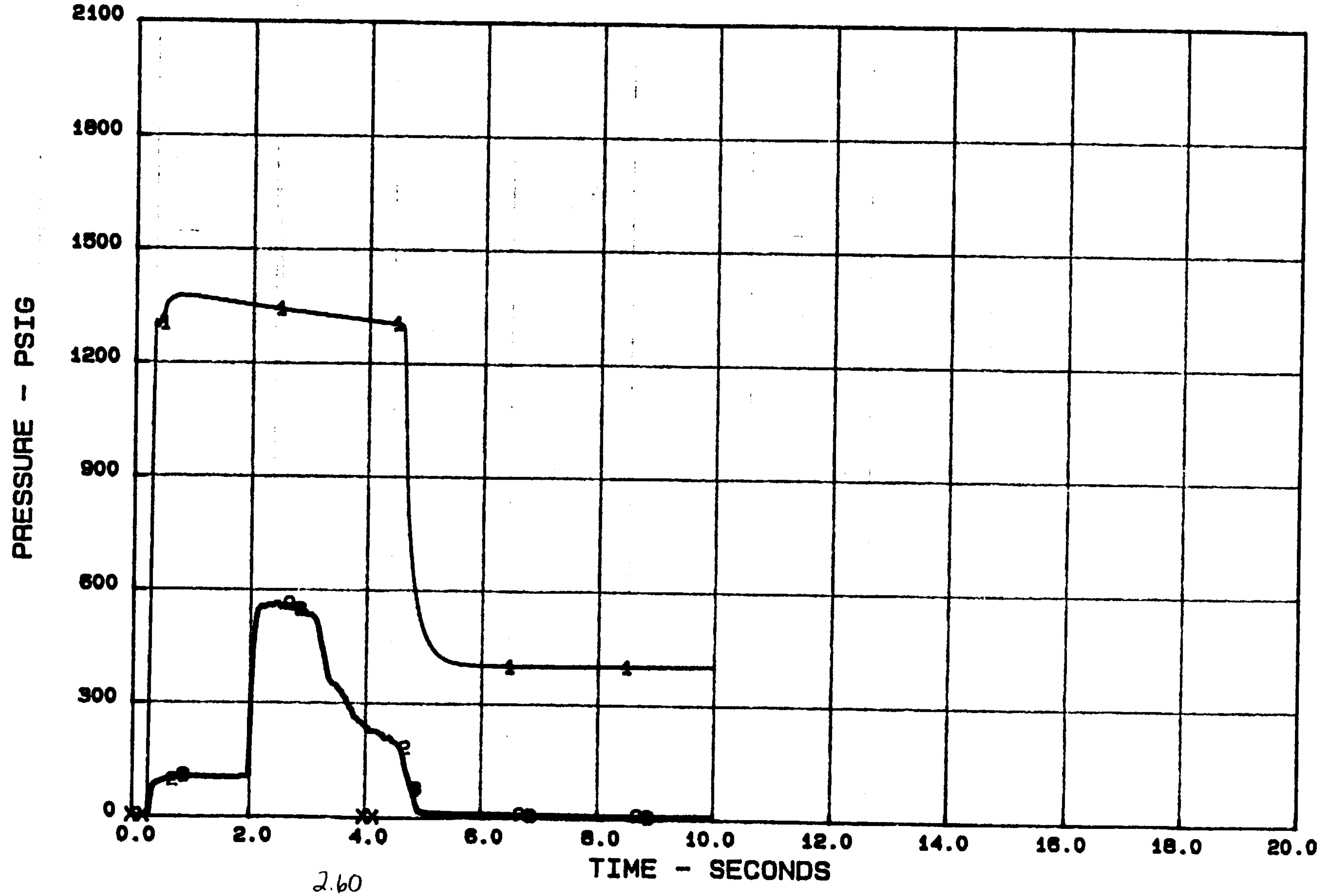


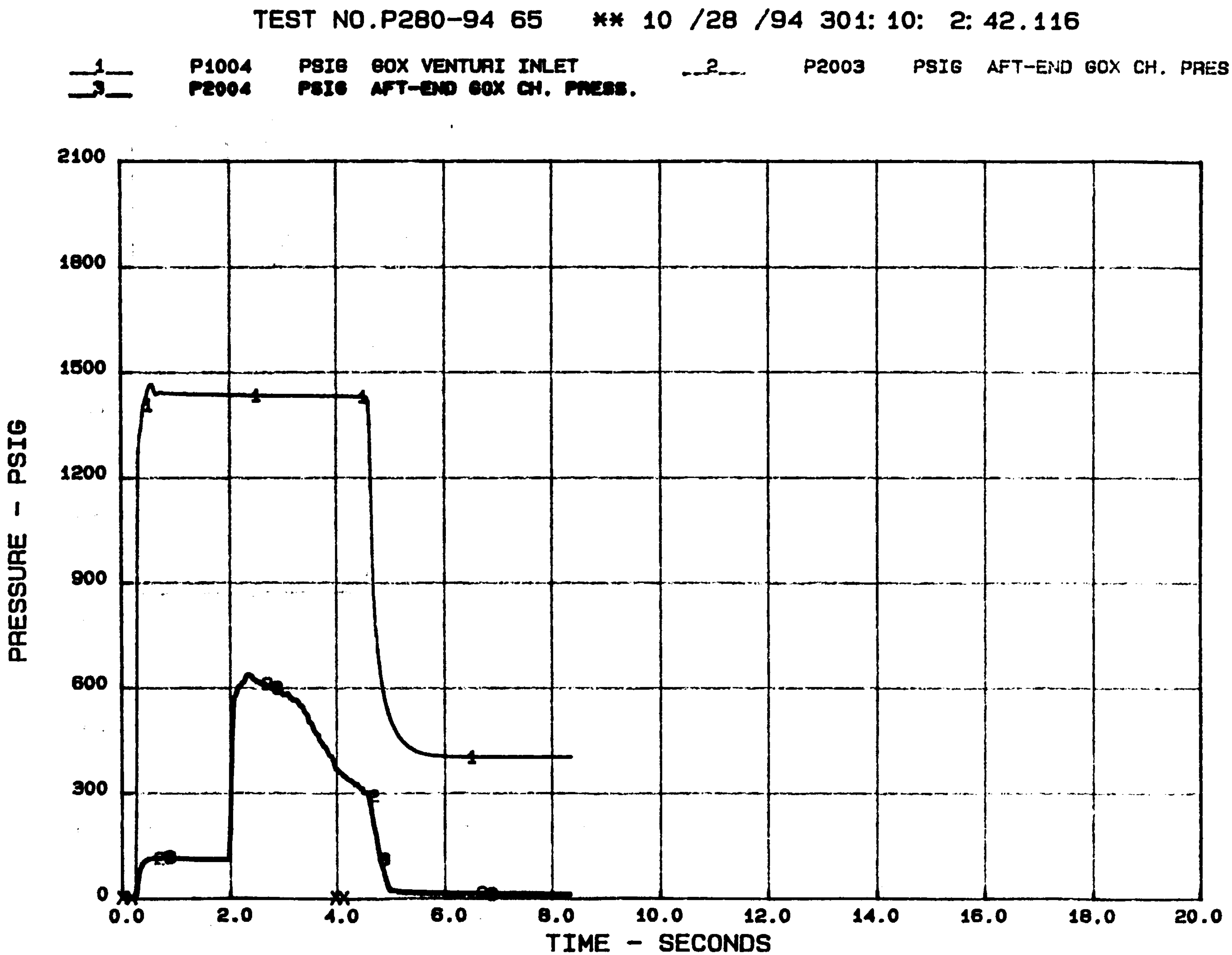
P2003 1086
P1004 1091
1500
1250
1000
750
500
250
0
0
1
2
3
4
5
6
7
8
9
10
2.65
TIME N SECONDS
P280-94 62 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 0


P2003 ,d6
P1004 1091
1500
1250
1000
750
500
250
0
-250
0
1
2
3
4
5
6
7
8
9
10
TIME N SECONDS
2.64
E06.17LABSCALE P280-94 63 T.C. 103
QPLOT d7.01-FD
DT= 0.025

TEST NO.P280-94 64 ** 10 /28 /94 301: 9: 42: 51.820

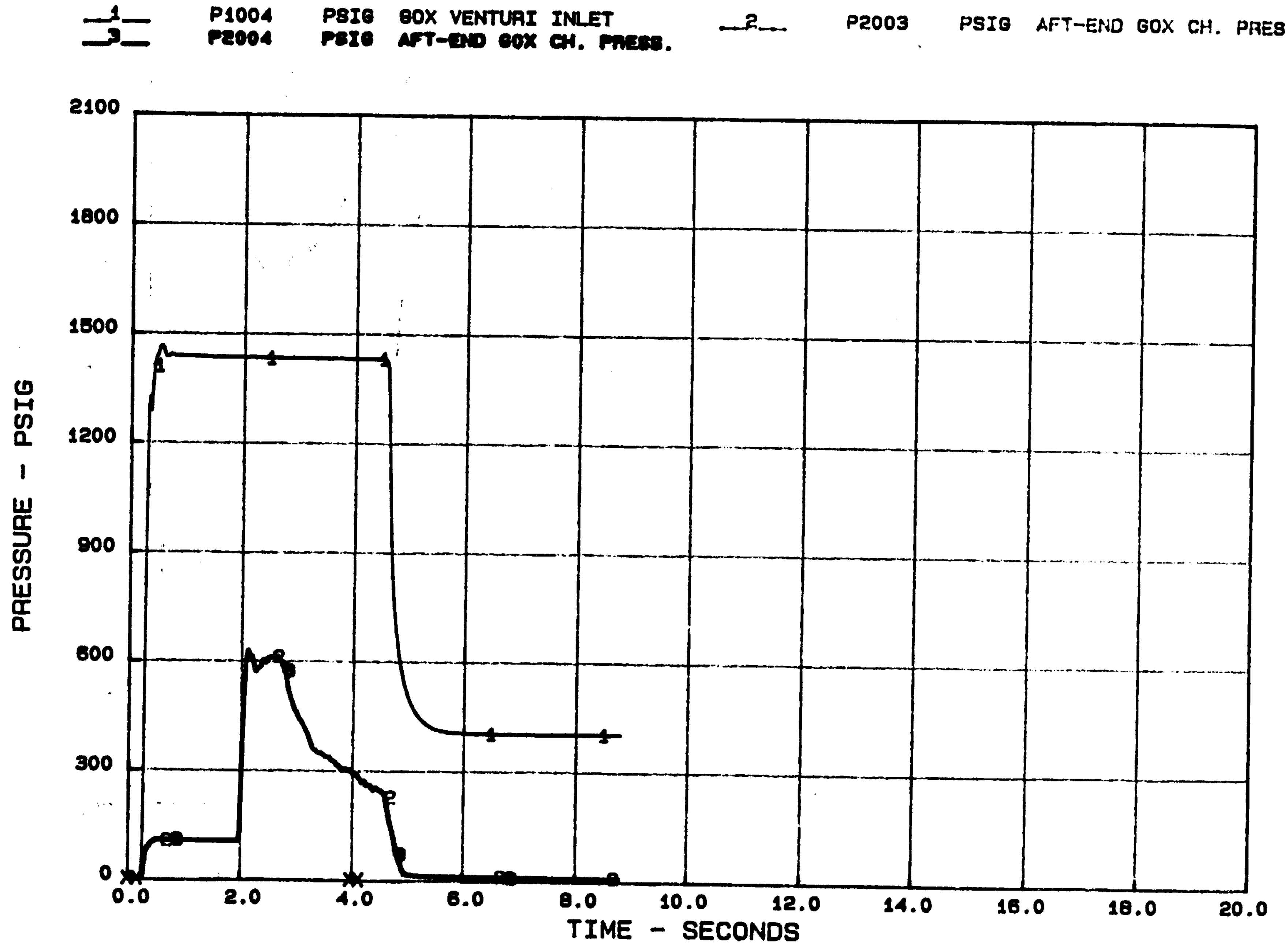
1	P1004	PSIG	GOX VENTURI INLET
2	P2003	PSIG	AFT-END GOX CH. PRES
3	P2004	PSIG	AFT-END GOX CH. PRESS.




TEST NO.P280-94 65 ** 10 /28 /94 301: 10: 2: 42.116
1 P1004 PSIG GOX VENTURI INLET
2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.
PRESSURE - PSIG
2100
1800
1500
1200
900
600
300
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
TIME - SECONDS

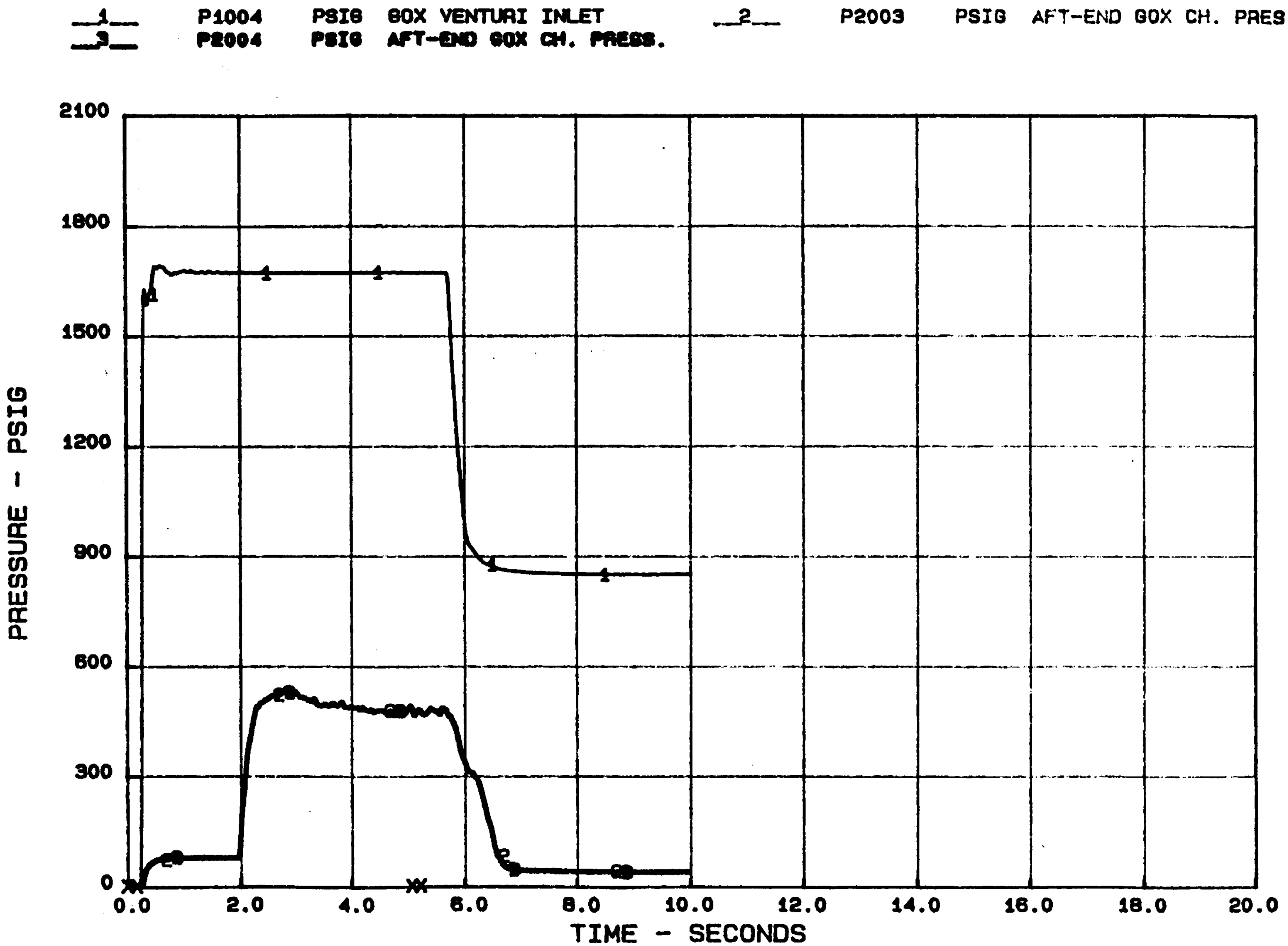
2.6

TEST NO.P280-94 66 ** 10 /28 /94 301: 10: 21: 36.936



2.6

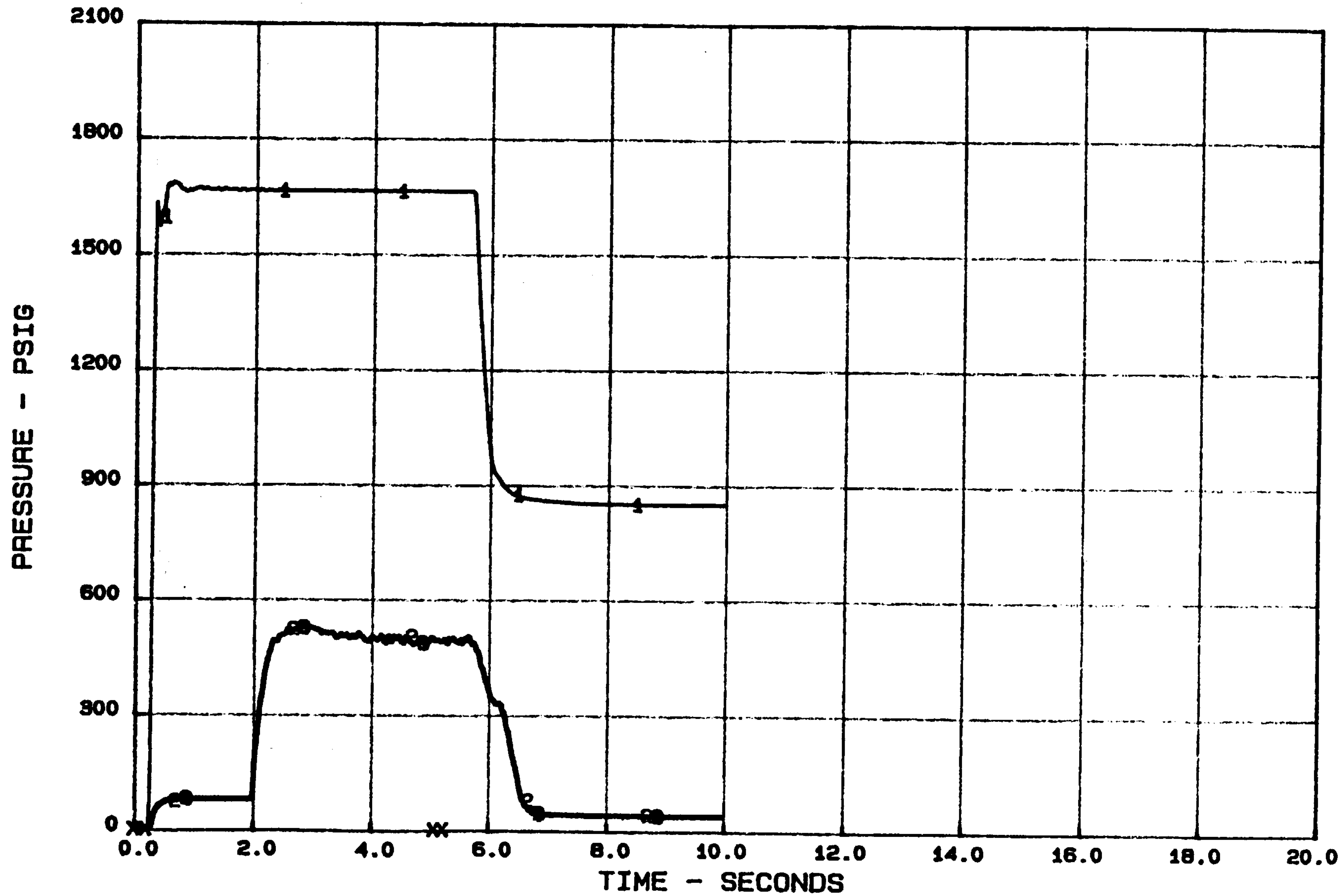
TEST NO.P280-94 67 ** 10 /28 /94 301: 10: 43: 35.406



3.7

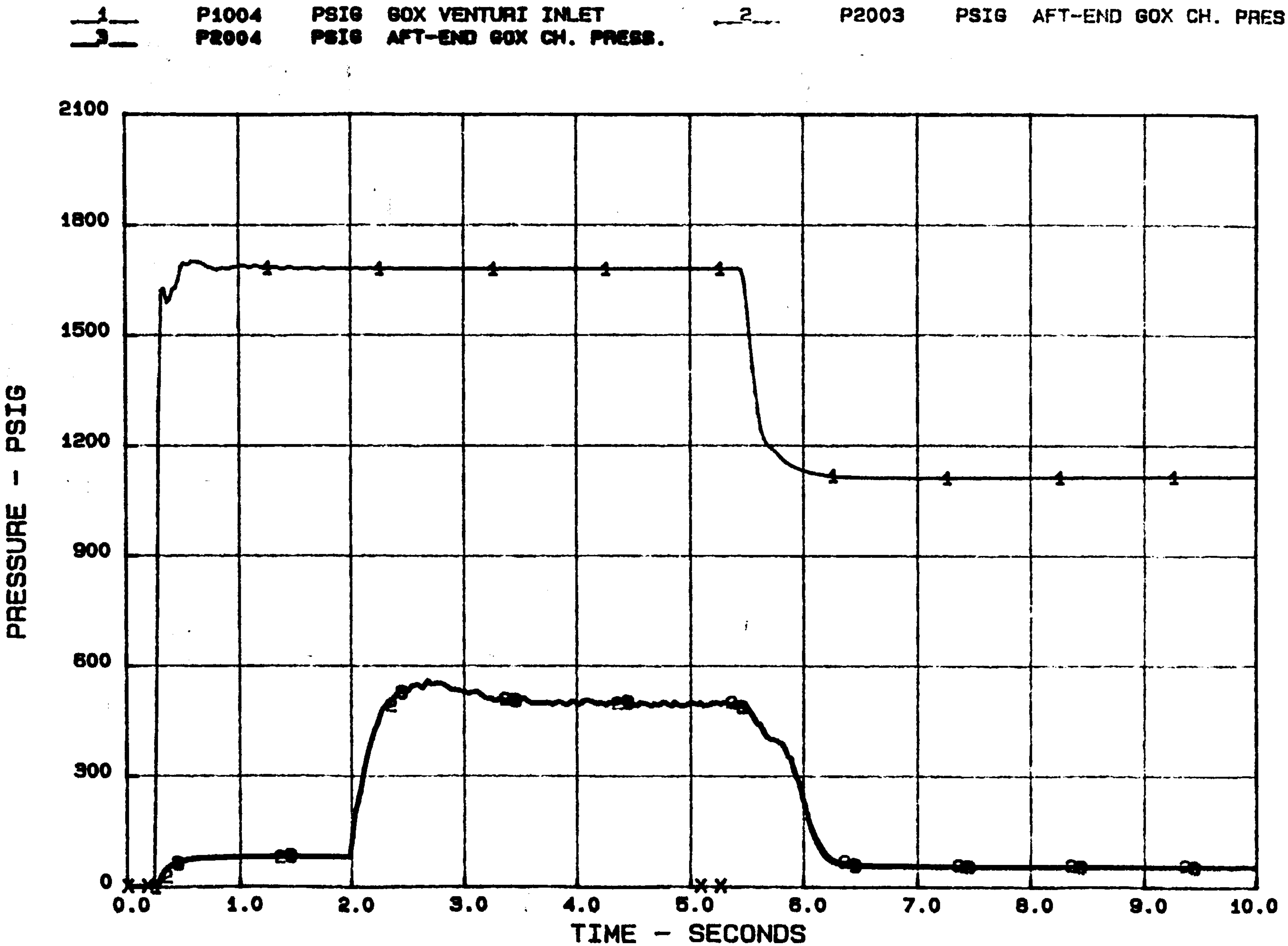
TEST NO.P280-94 68 ** 10 /28 /94 301: 10: 56: 19.954

1	P1004	PSIG	GOX VENTURI INLET	2	P2003	PSIG	AFT-END GOX CH. PRES
3	P2004	PSIG	AFT-END GOX CH. PRESS.				



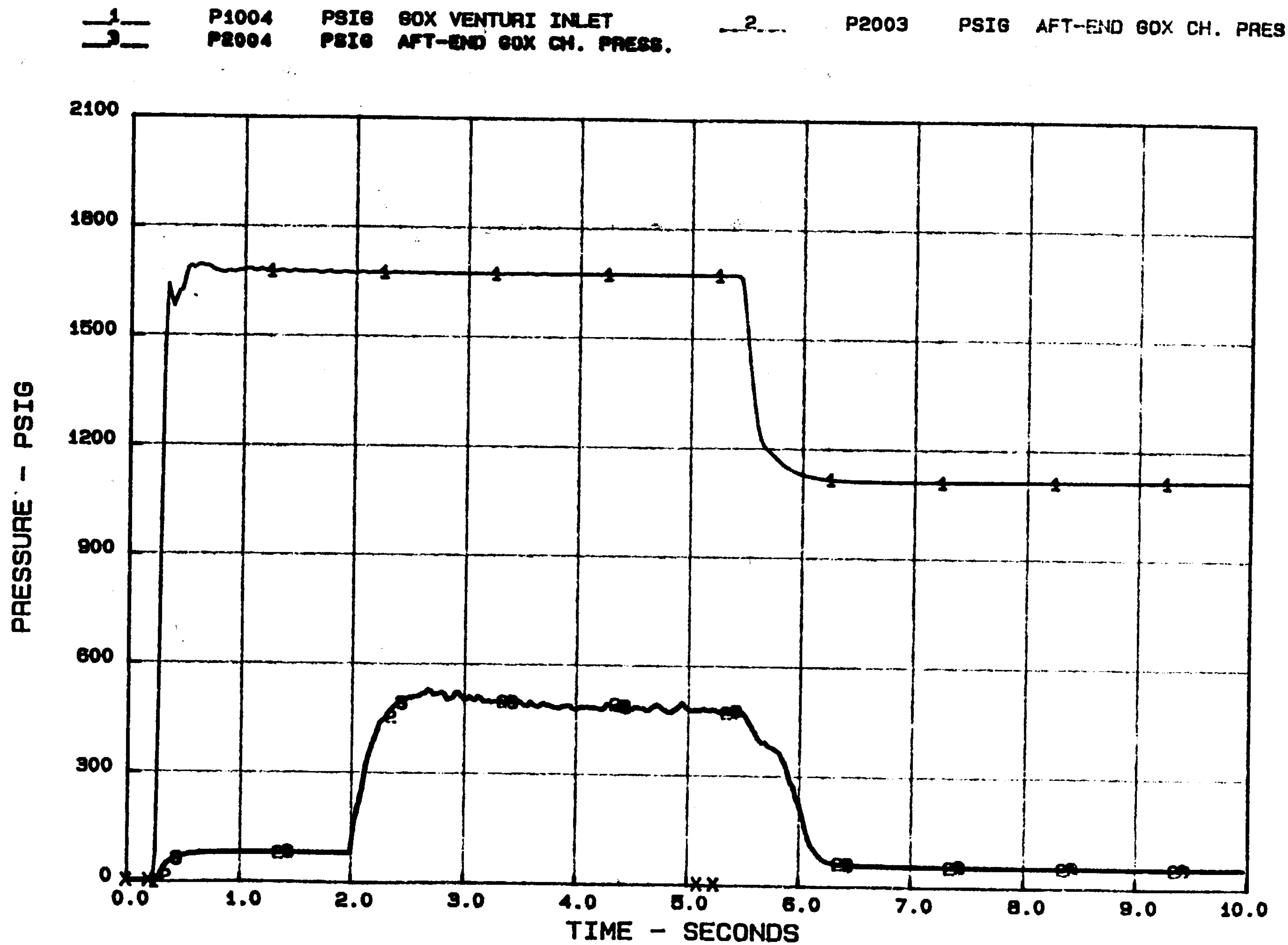
3.75

TEST NO.P280-94 69   ** 11 / 4 /94 308: 9: 24: 29.919

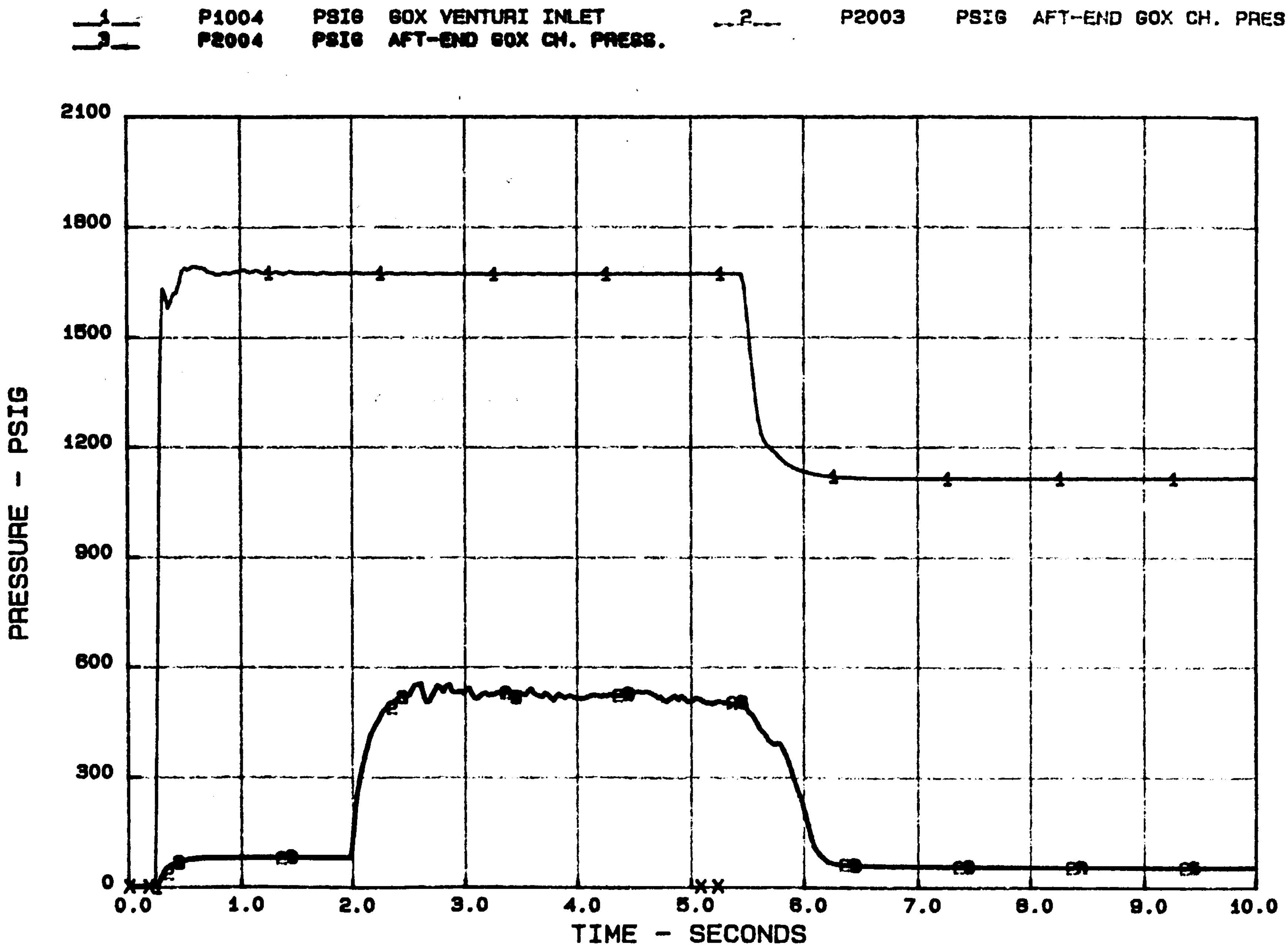


3.5

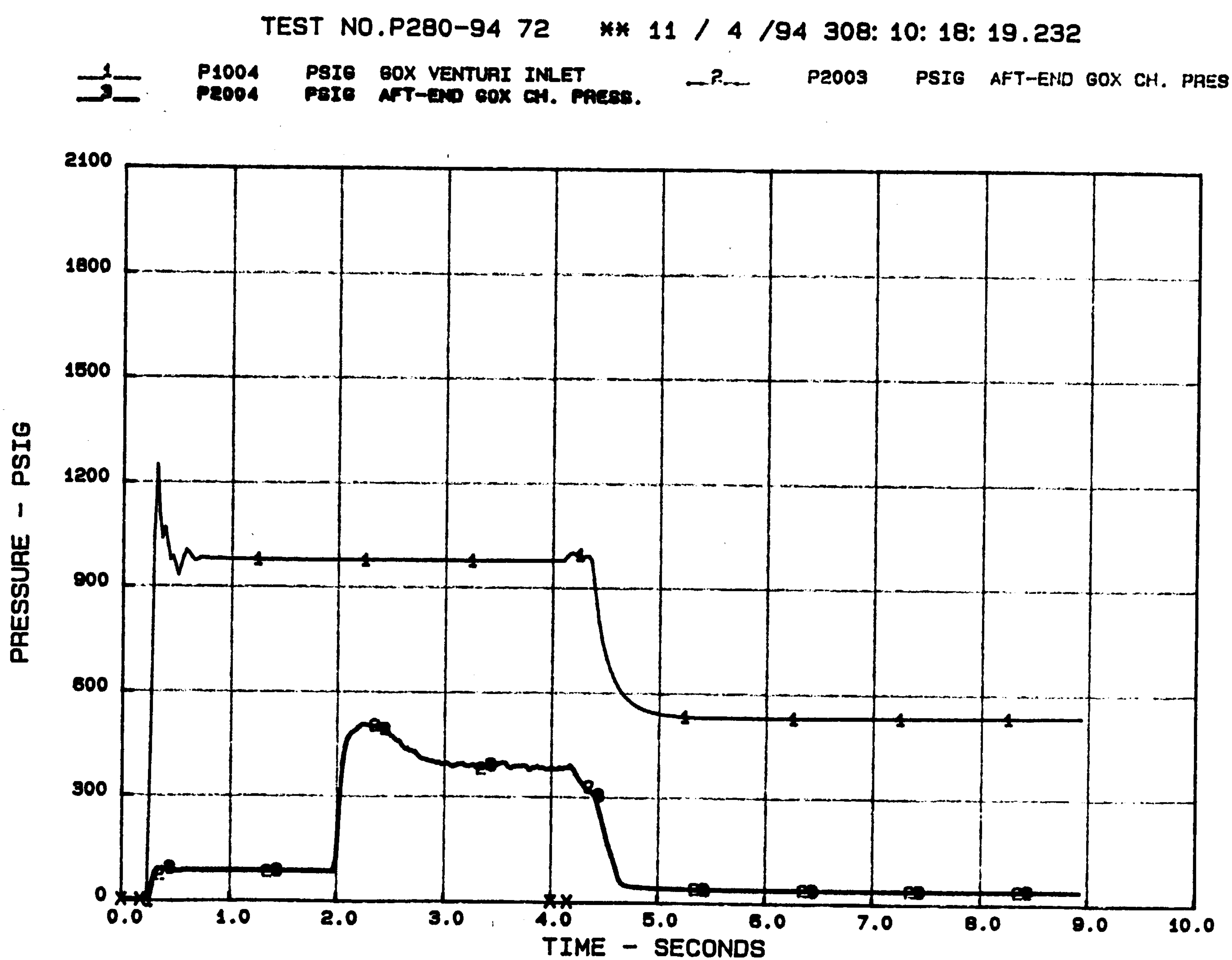
TEST NO.P280-94 70 ** 11 / 4 /94 308: 9: 45: 46.390



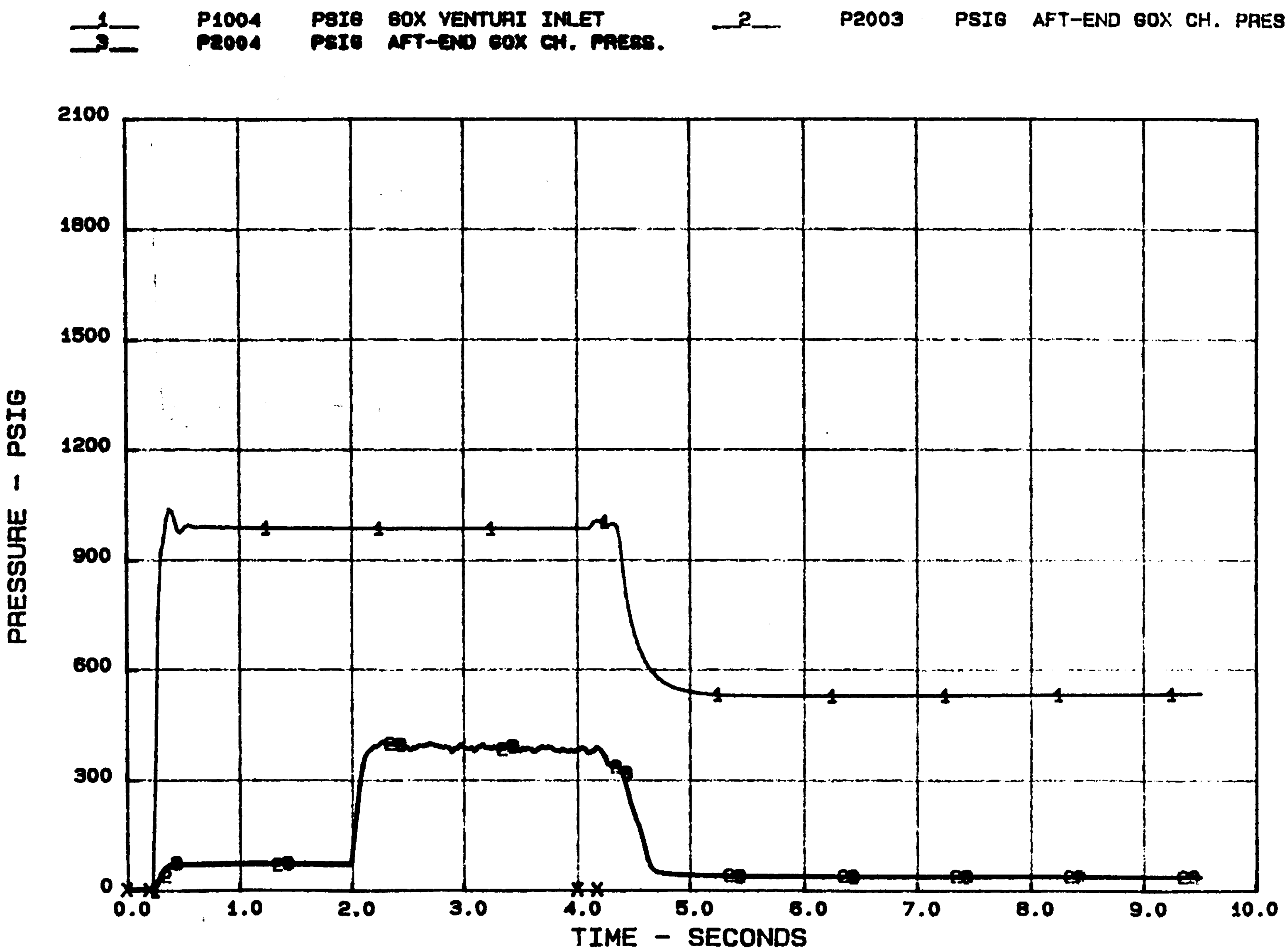
TEST NO.P280-94 71 ** 11 / 4 /94 308: 10: 1: 14.036



3.5

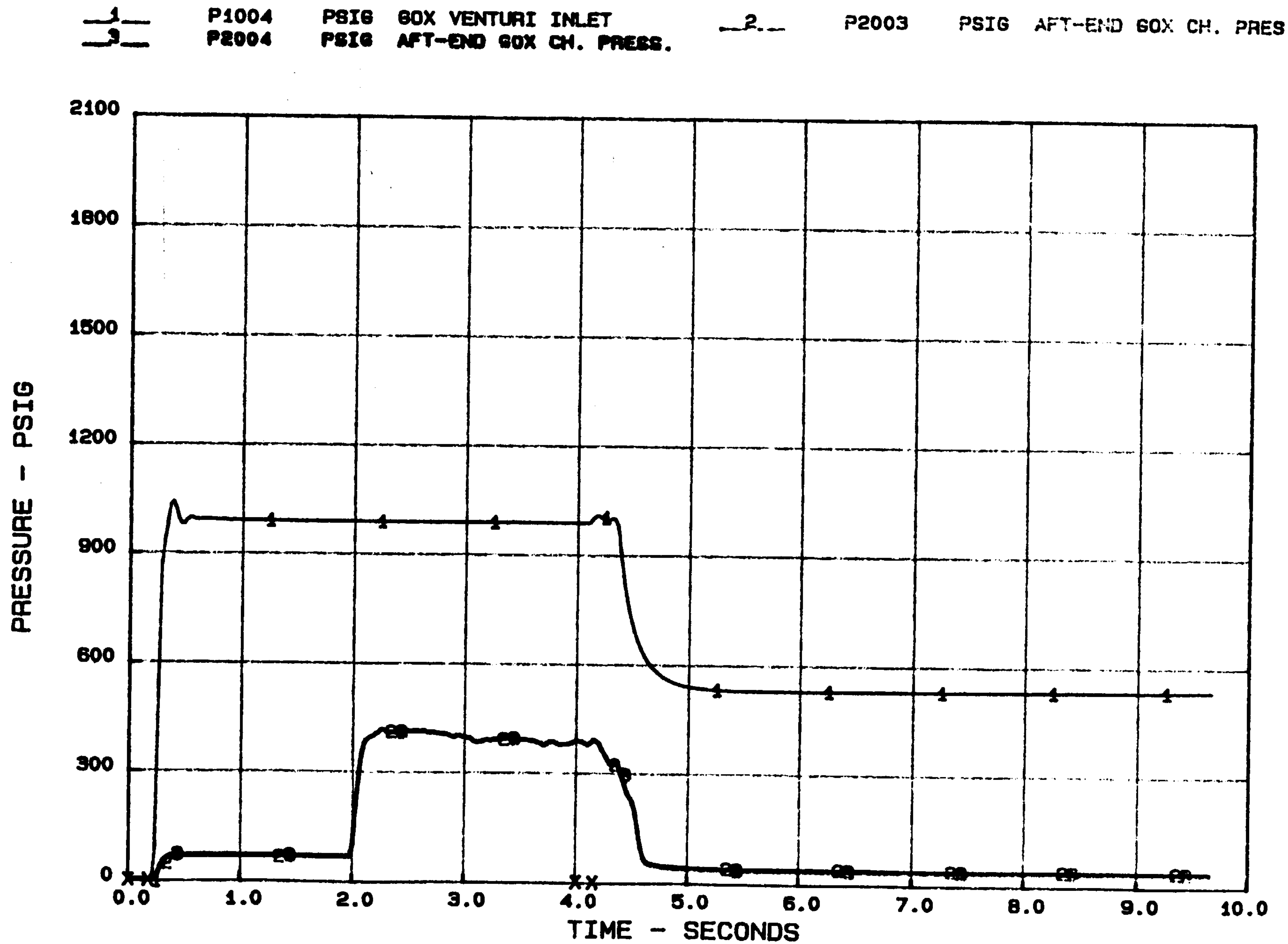

TEST NO.P280-94 72 ** 11 / 4 /94 308: 10: 18: 19.232
1 P1004 PSIG GOX VENTURI INLET
2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.
PRESSURE - PSIG
2100
1800
1500
1200
900
600
300
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME - SECONDS

TEST NO.P280-94 73 ** 11 / 4 /94 308: 10: 31: 59.255

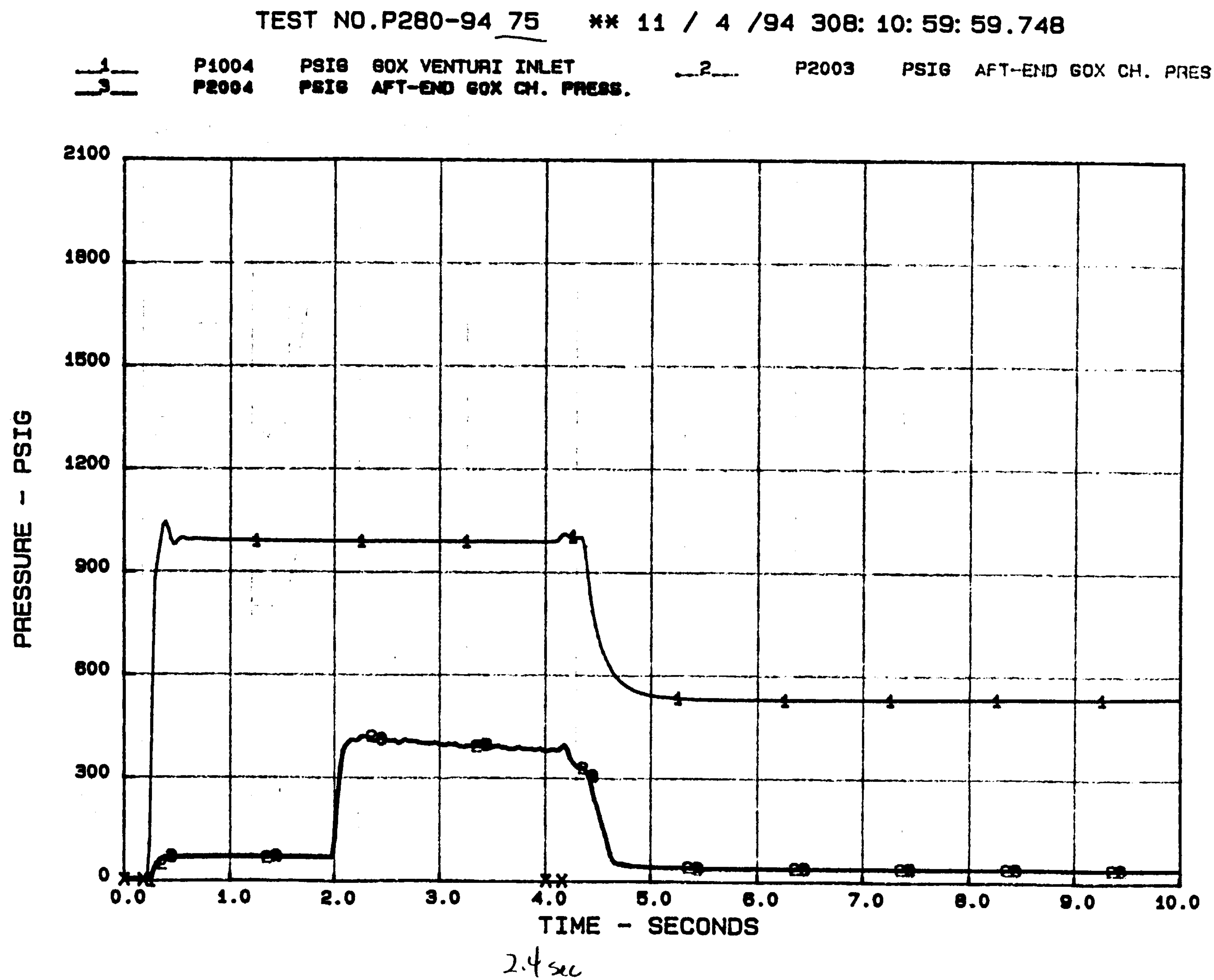


240

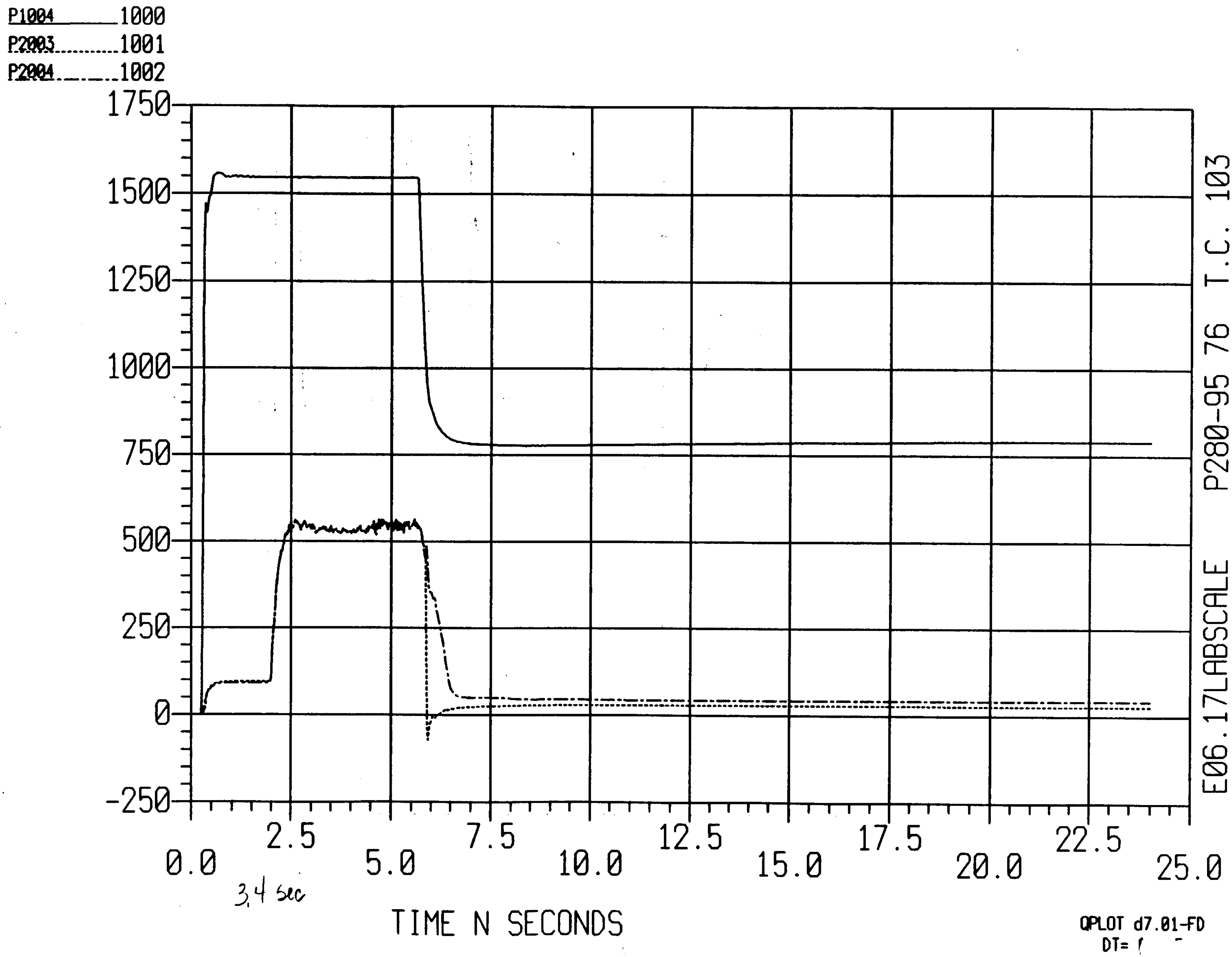
TEST NO.P280-94 74 ** 11 / 4 /94 308: 10: 45: 58.426

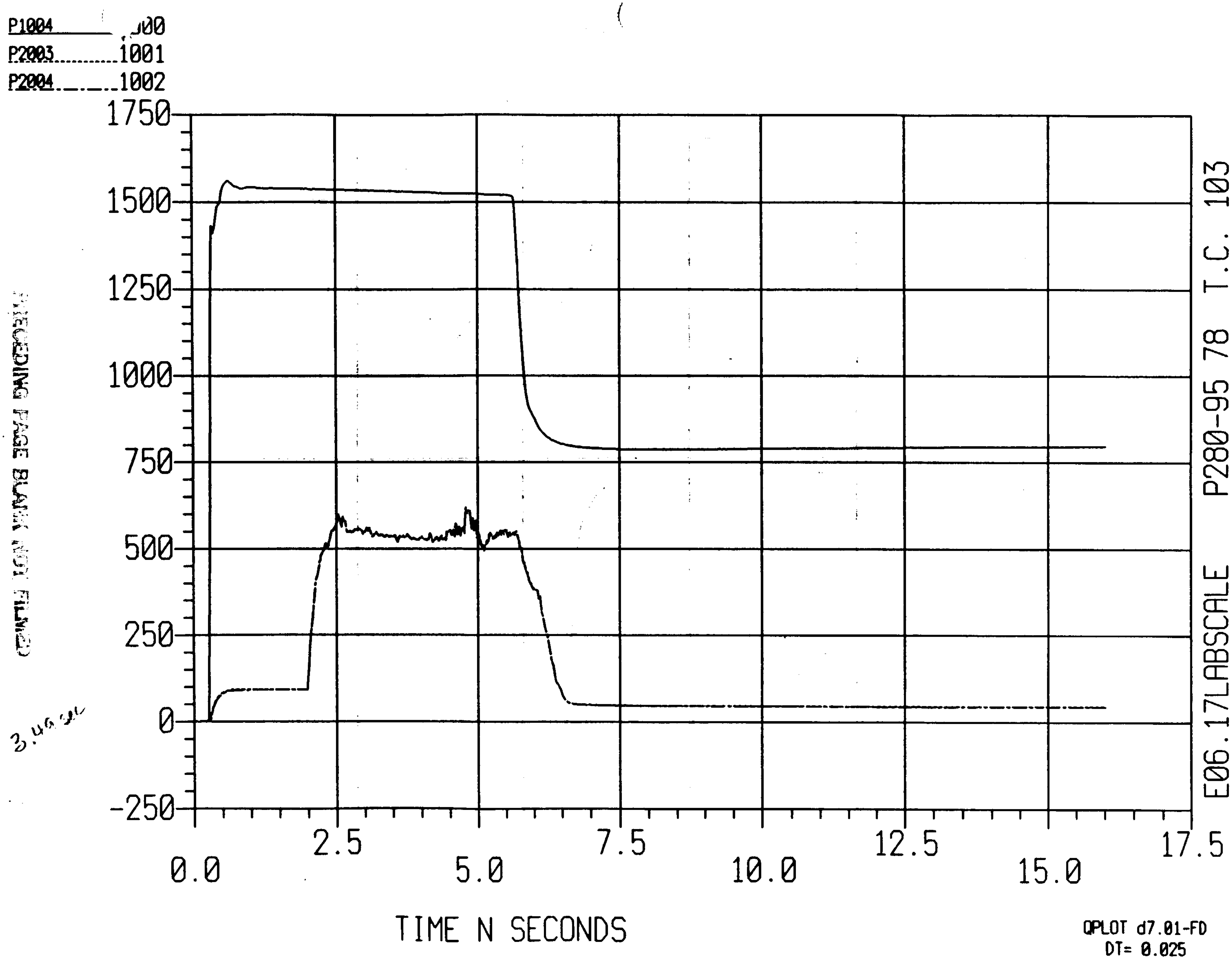


2.38



TEST NO.P280-94 75 ** 11 / 4 /94 308: 10: 59: 59.748
1 P1004 PSIG GOX VENTURI INLET
2 P2003 PSIG AFT-END GOX CH. PRES
3 P2004 PSIG AFT-END GOX CH. PRESS.
PRESSURE - PSIG
2100
1800
1500
1200
900
600
300
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
TIME - SECONDS
2.4 sec


P1004 1000
P2003 1001
P2004 1002
1750
1500
1250
1000
750
500
250
0
-250
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
3.4 sec
TIME N SECONDS
P280-95 76 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT=



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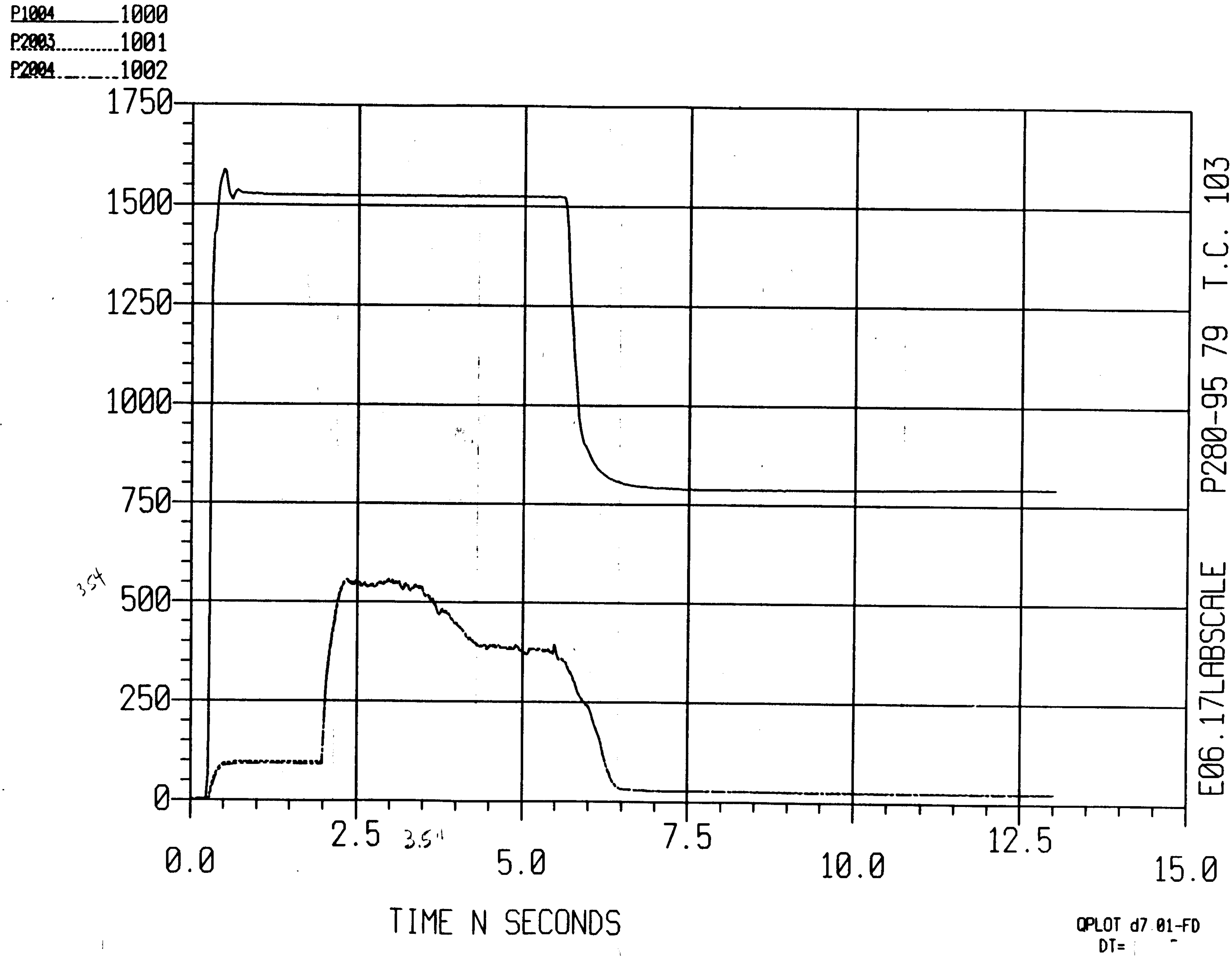
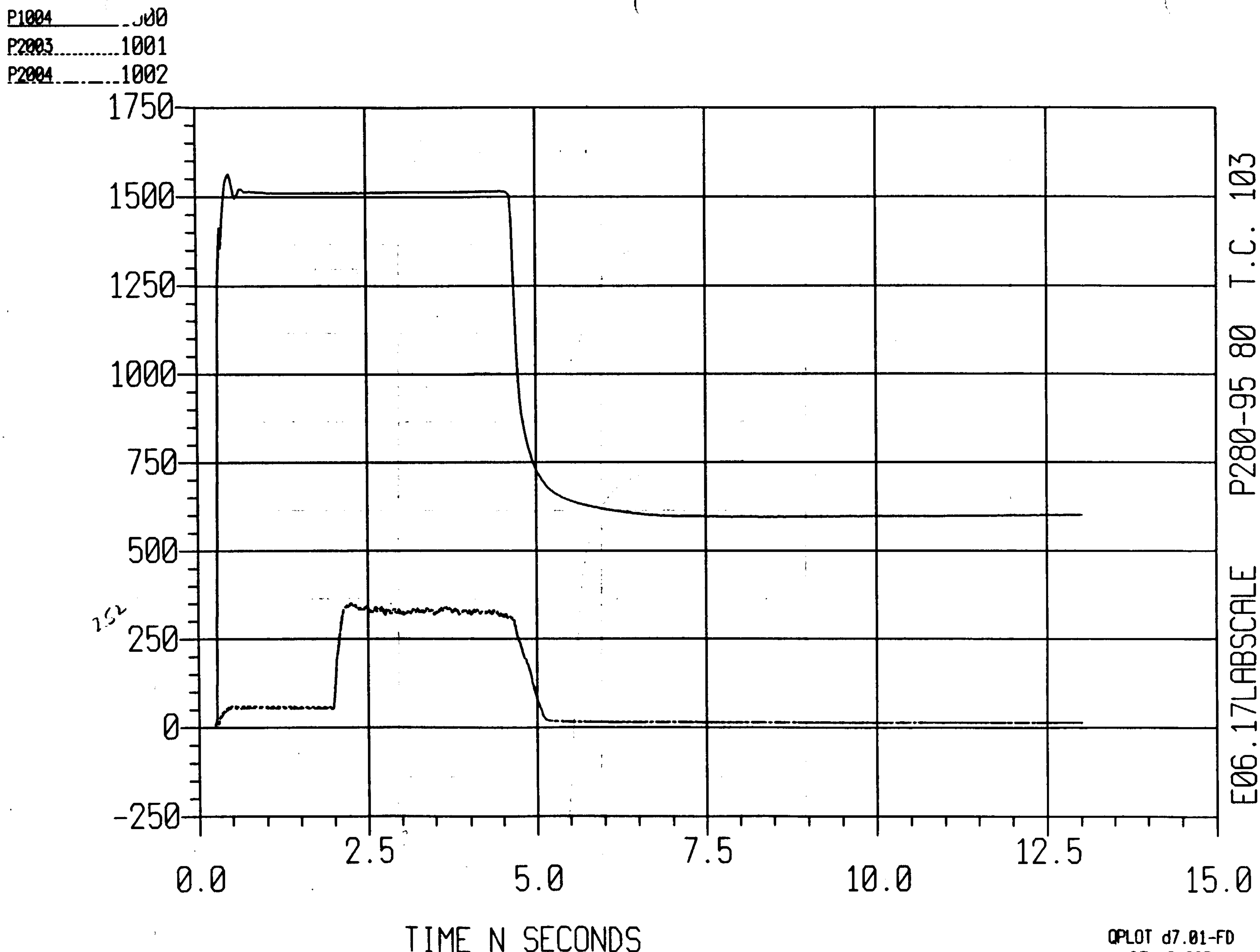
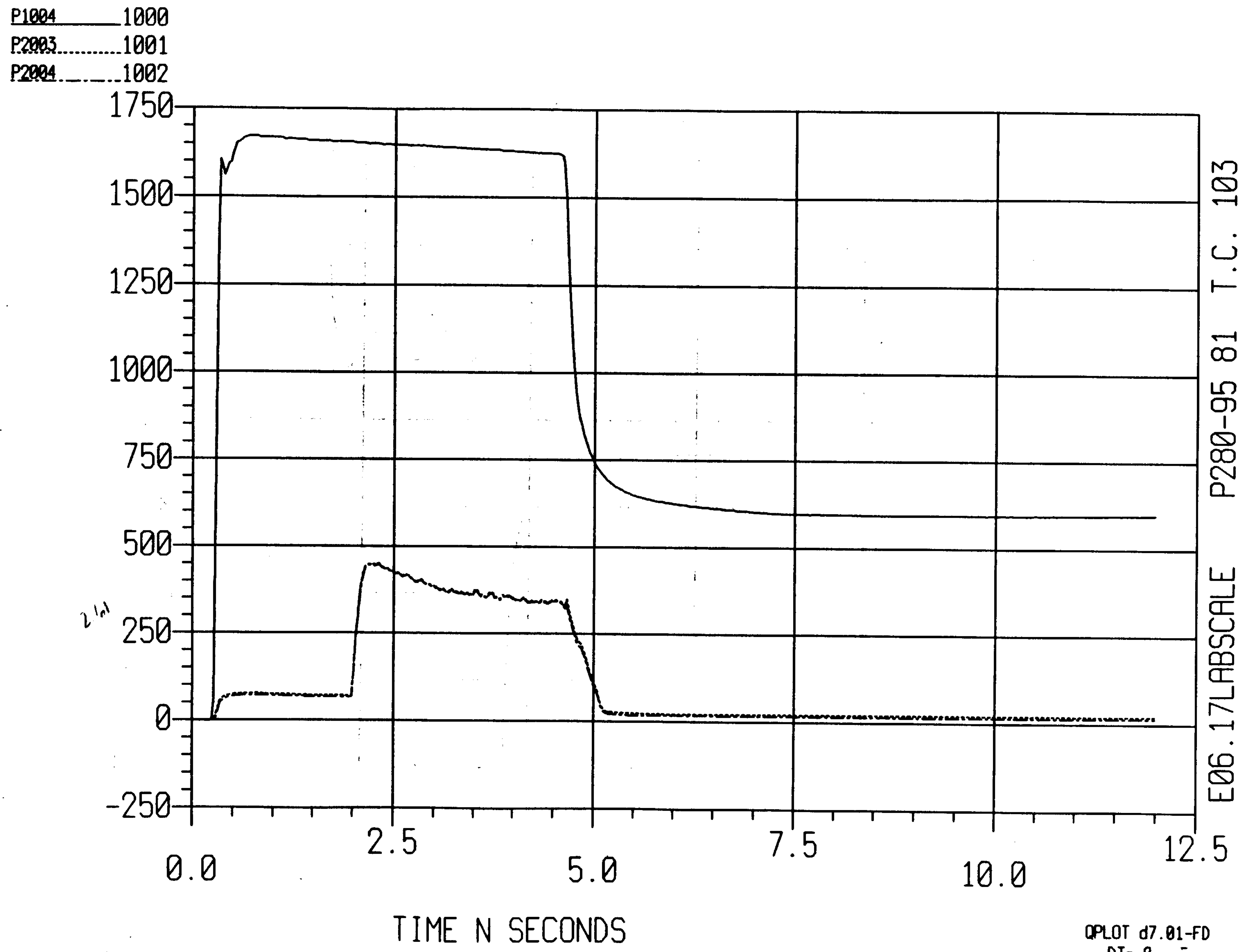

P1004 1000
P2003 1001
P2004 1002
1750
1500
1250
1000
750
500
250
0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
TIME N SECONDS
P280-95 79 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT=



P1004 .000
P2003 1001
P2004 1002
1750
1500
1250
1000
750
500
250
0
-250
0.0
2.5
5.0
7.5
10.0
12.5
15.0
TIME N SECONDS
P280-95 80 T.C. 103
E06.17LABSCALE
QPLOT d7.01-FD
DT= 0.025



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1250
1000
750
500
250
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-250
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2.5
5.0
7.5
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TIME N SECONDS
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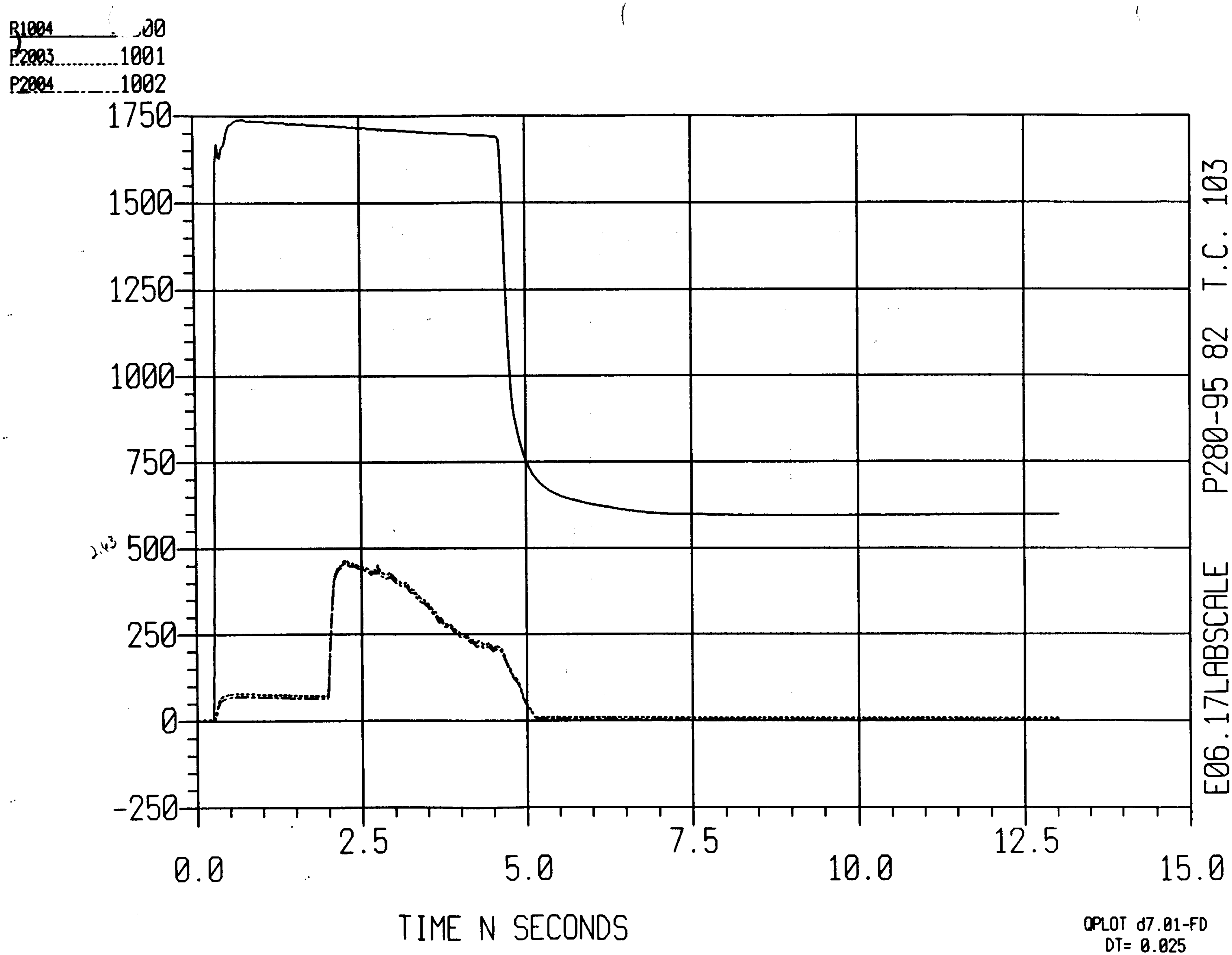

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5.0
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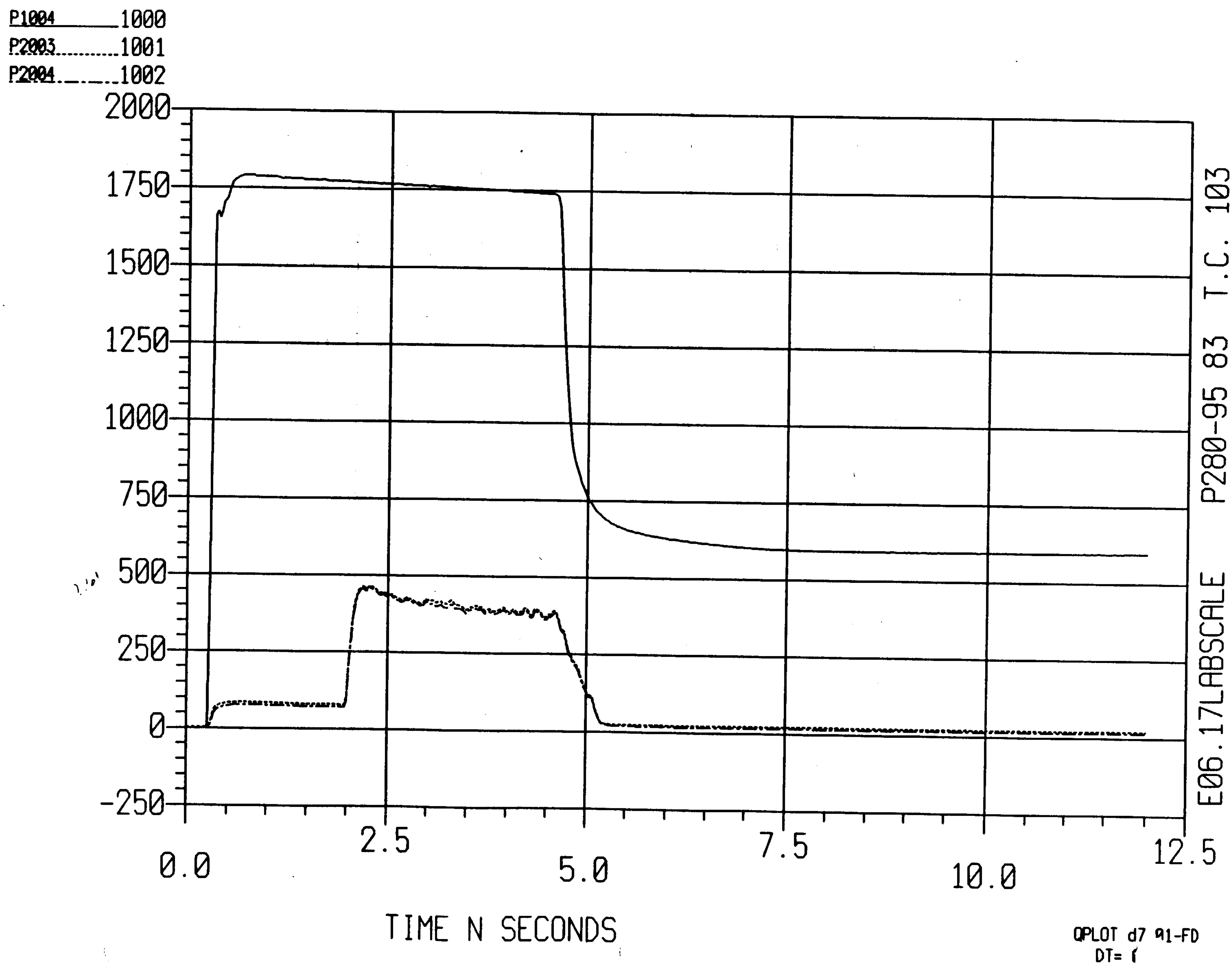
DT= 0.025



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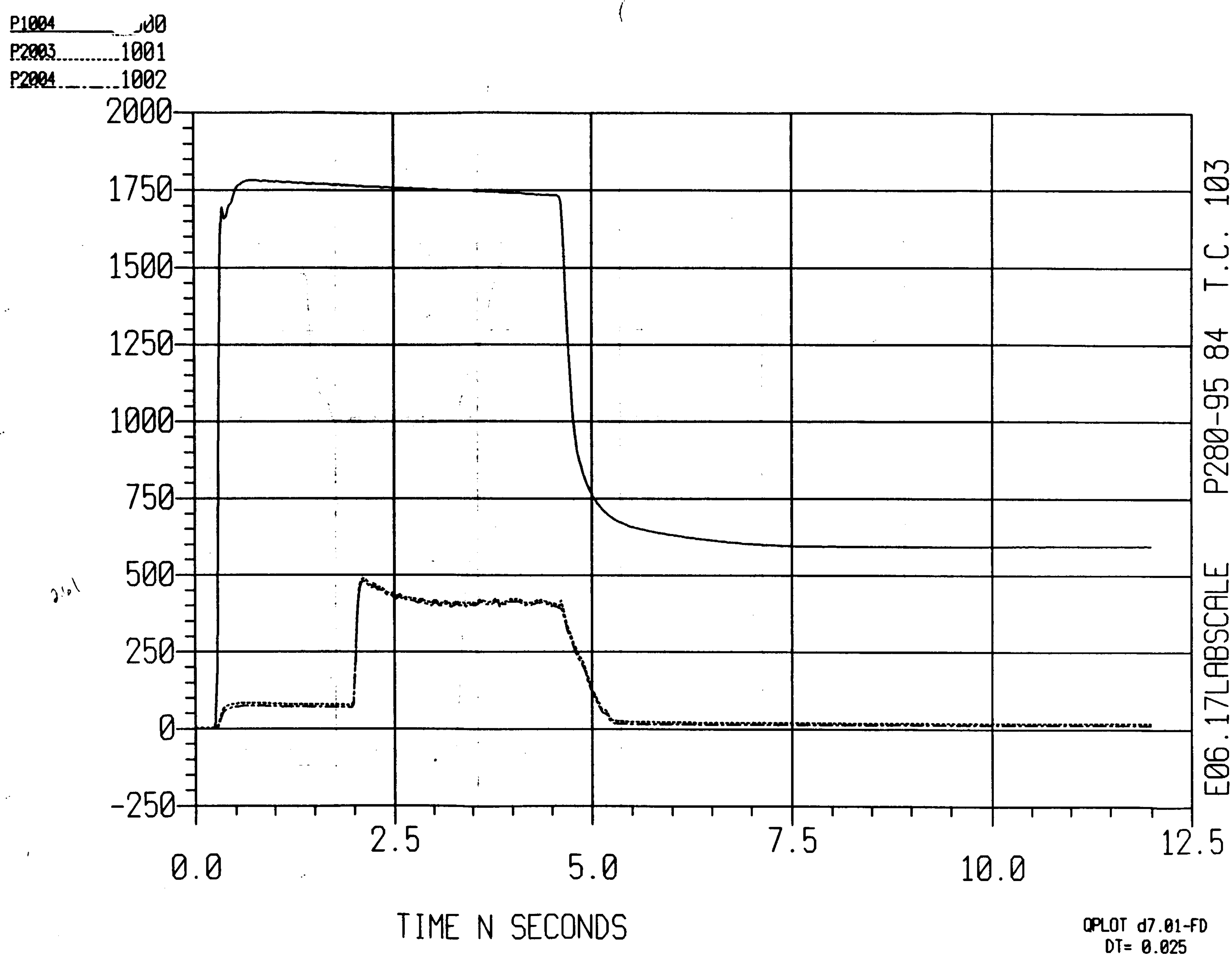
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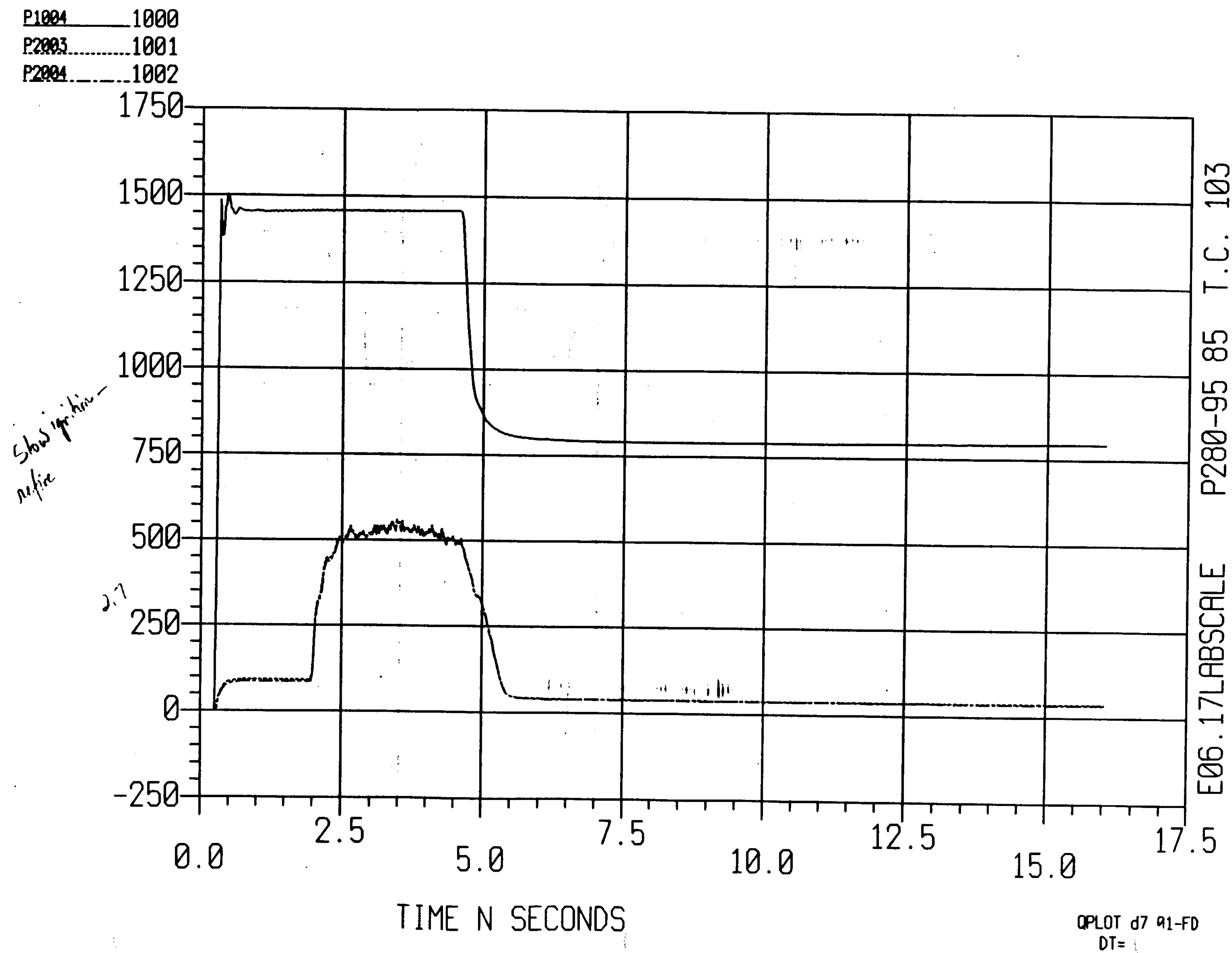

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10.0
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TIME N SECONDS
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DT=

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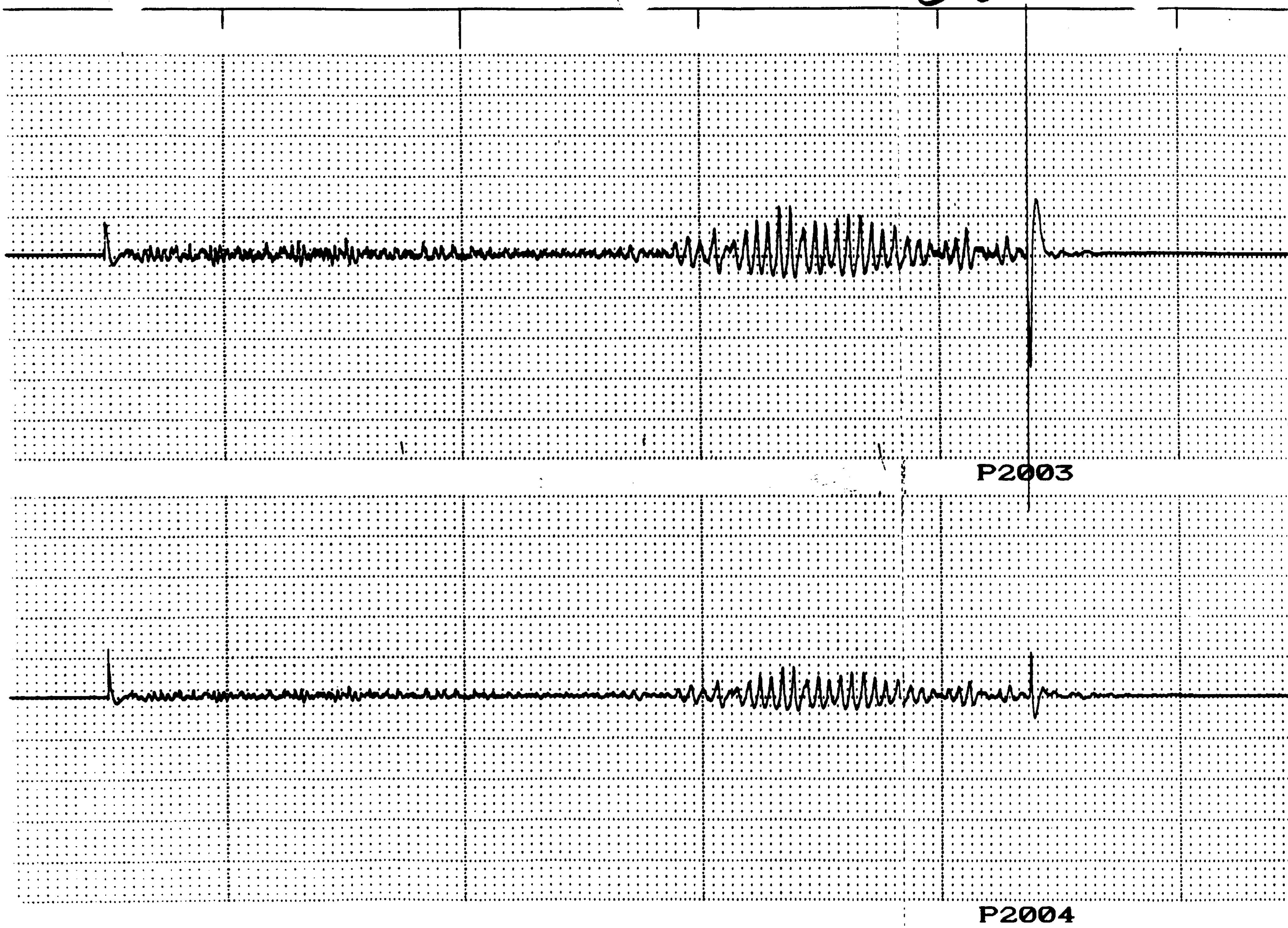

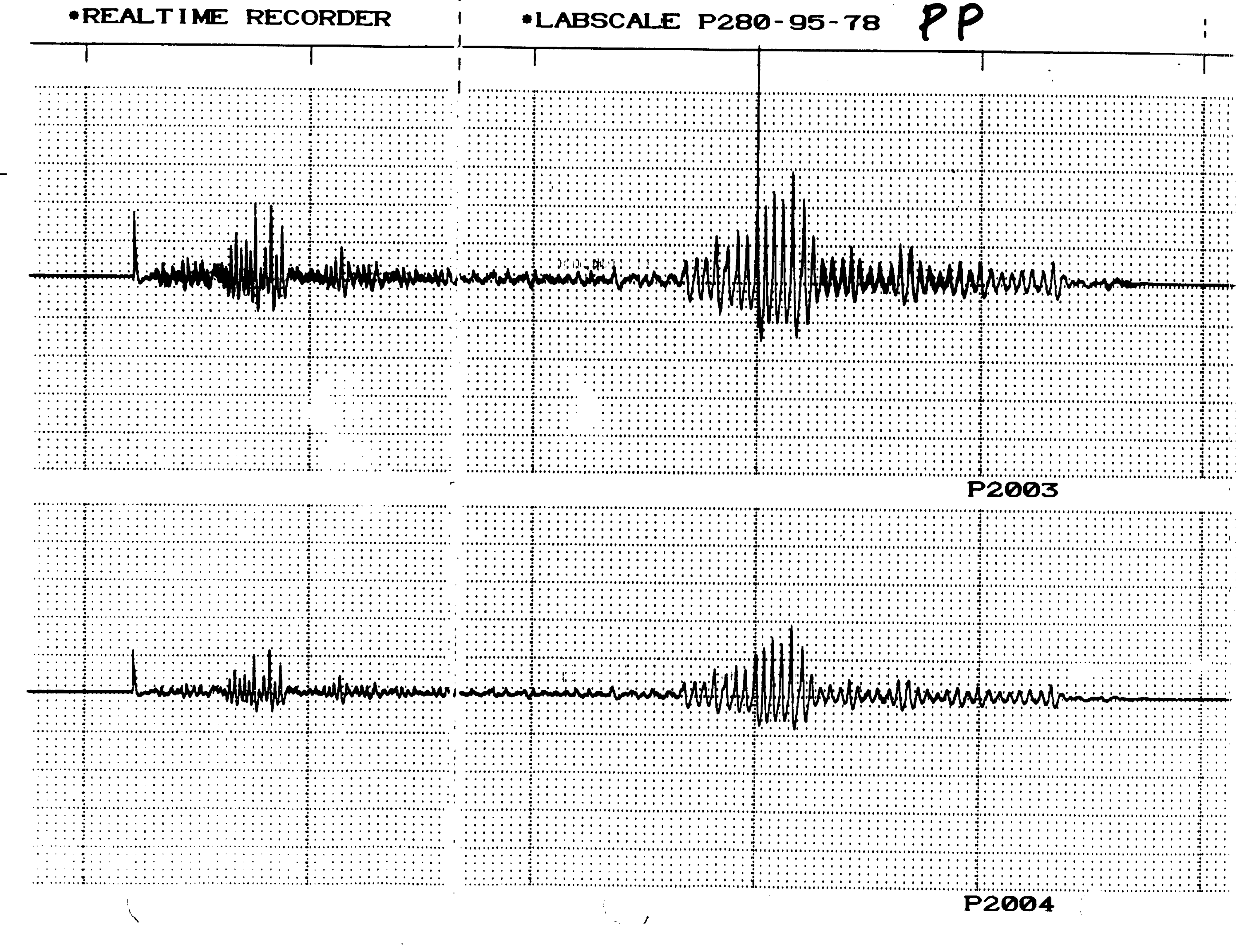

*REALTIME RECORDER
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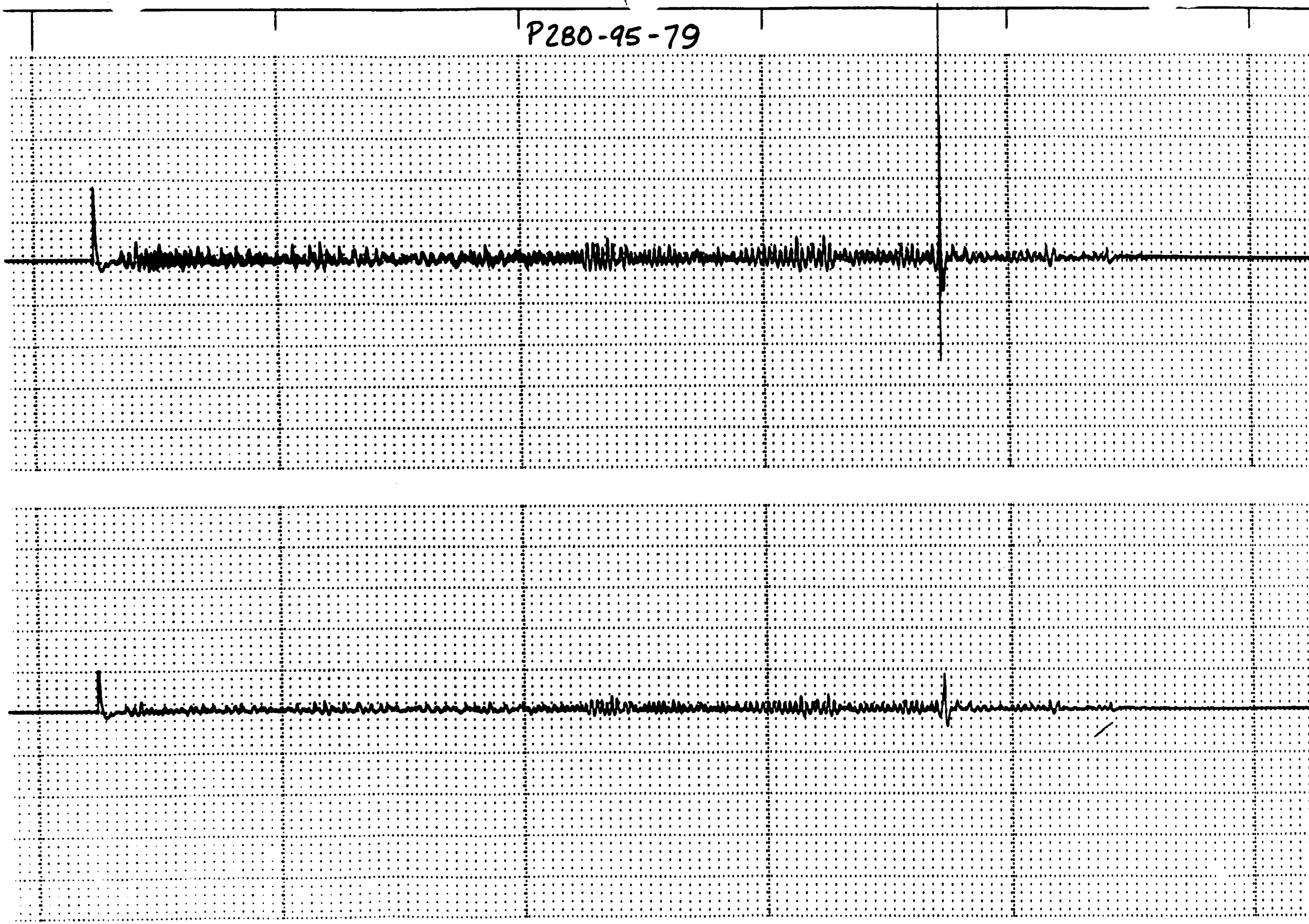
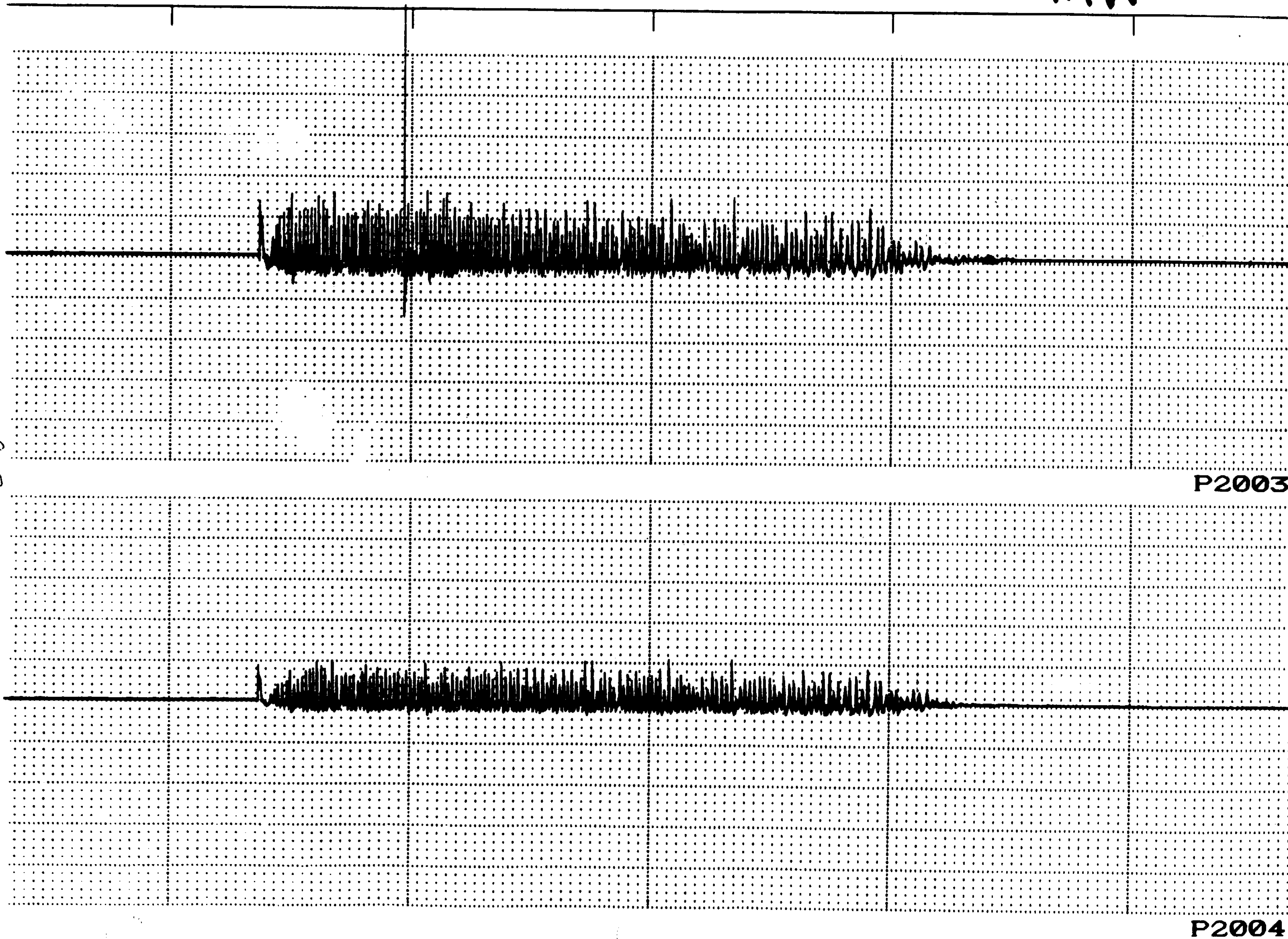
PP
P2003
P2004

5 MM/S TIME SCALE: 40.00 MS/MM "U *REALTIME RECORDER *LAB

P280-95-79

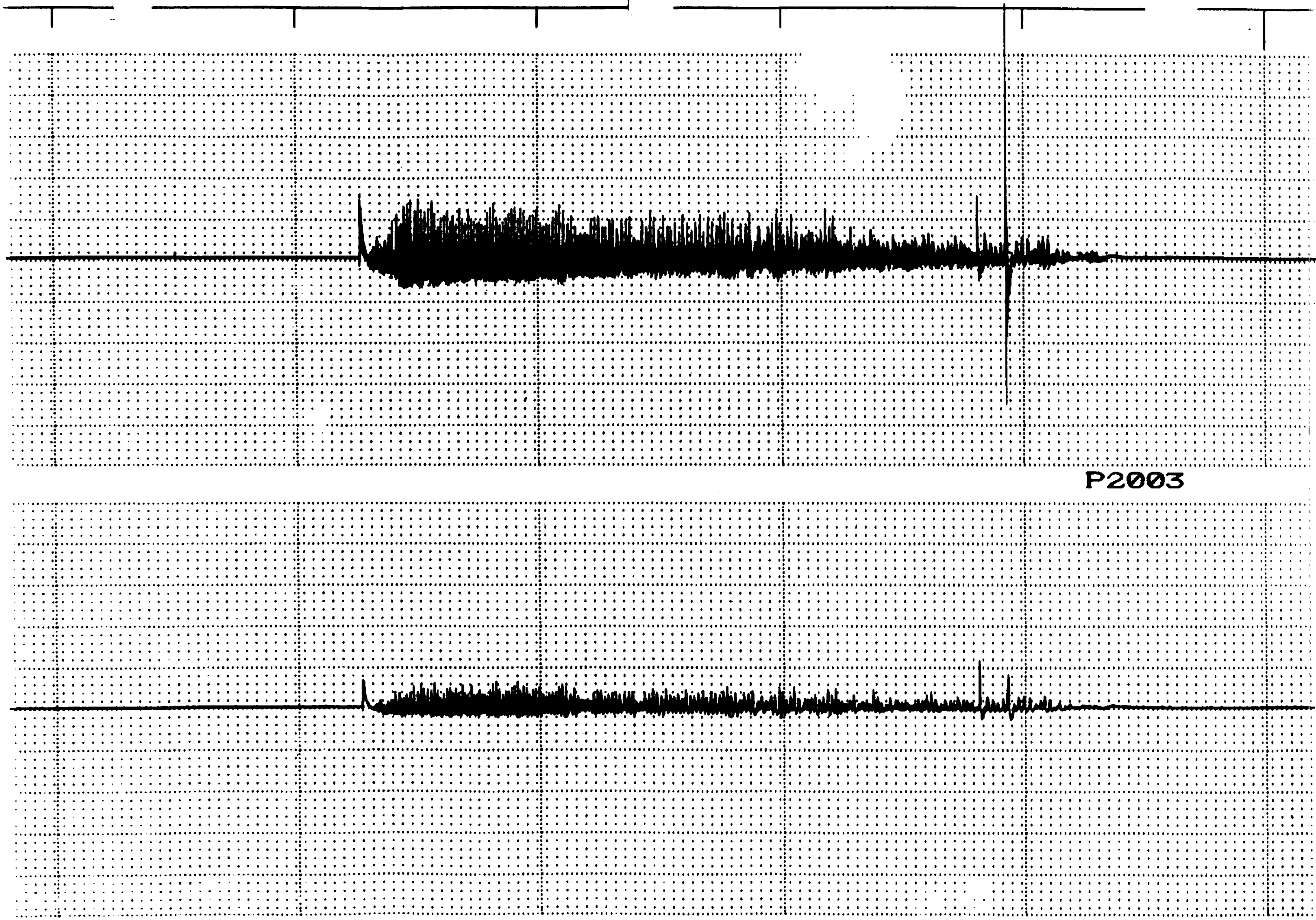


1M *REALTIME RECORDER *LABSCALE P280-95-80 MW

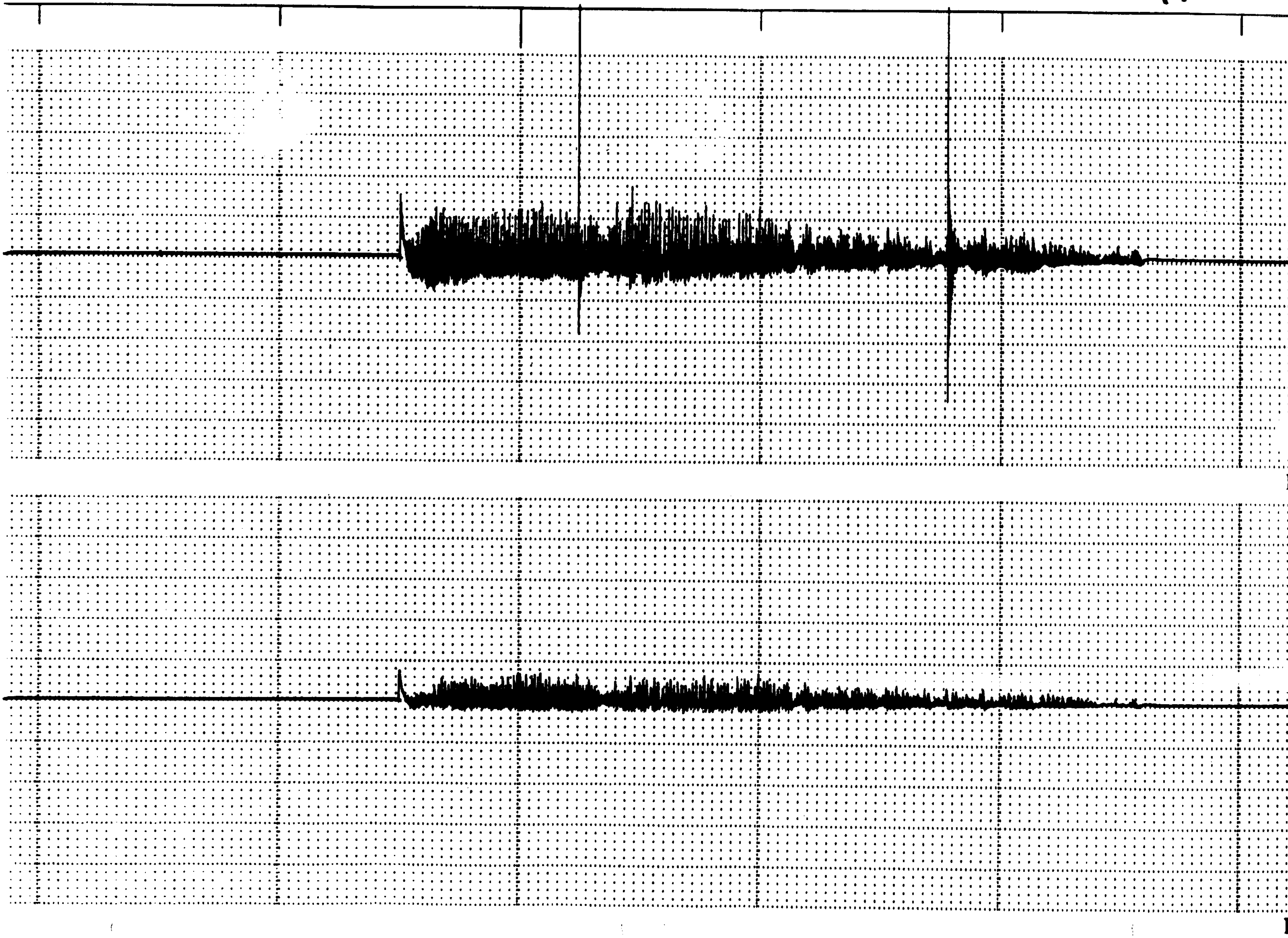


C-3

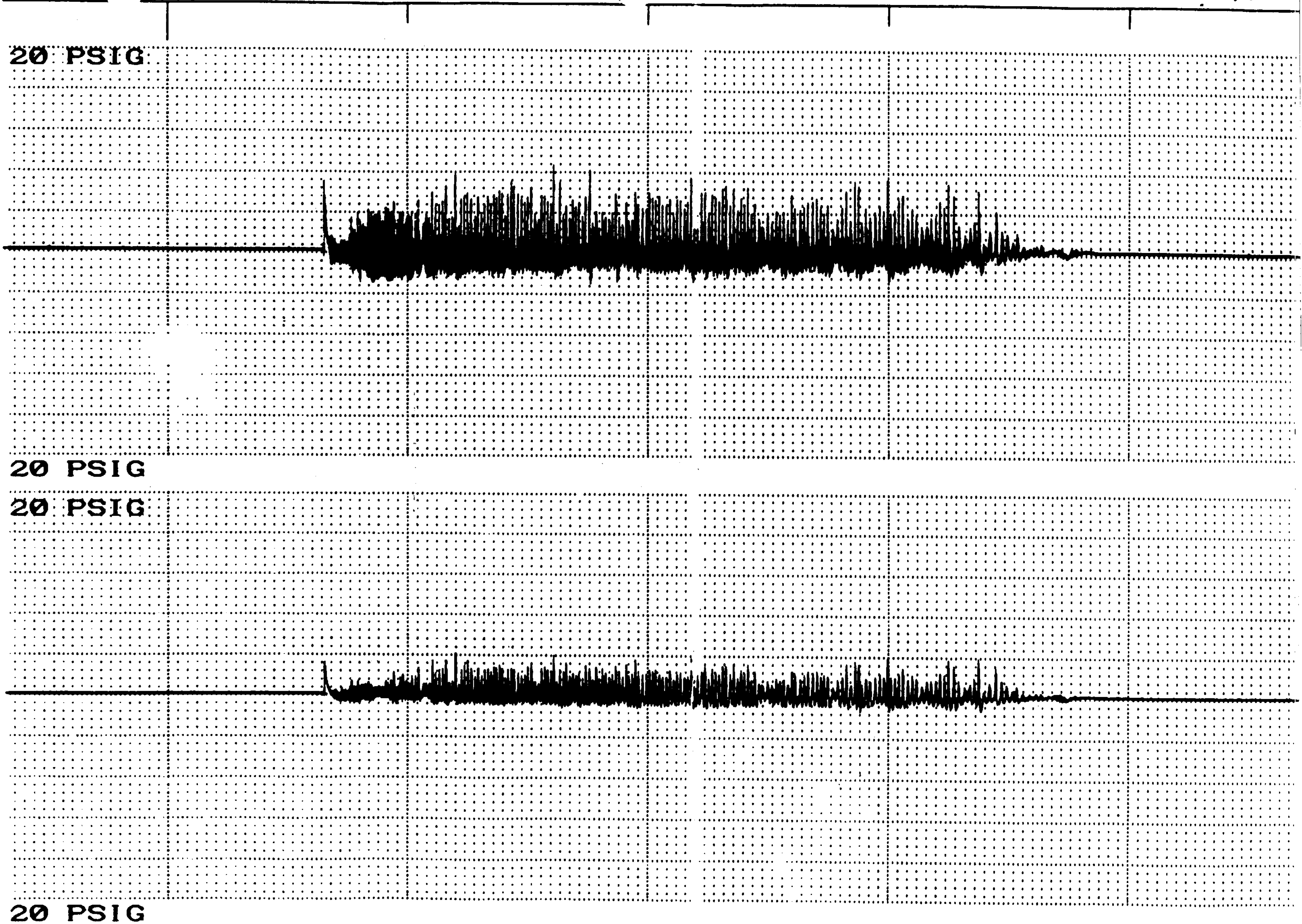
•REAL TIME RECORDER •LABSCALE P280-95-81 IU



MS/MM •REALTIME RECORDER •LABSCALE P280-95-82 PP



83 ?R *SPD: 25 MM/S *TIME ' ALE: 40.00 MS/MM * \LTIME



ⓂM *REALTIME RECORDER *LABSCALE P280-95-84 uu

RDER *LABSCALE P280-95-85

Appendix C

ELEVEN INCH MOTOR FIRINGS

A. First Eleven Inch Motor Firing

- **Spreadsheet to calculate ballistics**
- **MSFC data on pressures, temperatures, and igniter current**

B. Second Eleven Inch Motor Firing

- **Spreadsheet to calculate ballistics**
- **MSFC data on pressures, temperatures, and igniter current**

A. First Eleven-Inch Motor Firing

SPREADSHEET TO CALCULATE BALLISTICS

A spreadsheet was used to calculate the weight loss and pressure obtained in incremental steps of 0.1 sec. Input parameters are listed in bold and include regression expression parameters as well as motor characteristics and oxygen flow rate. Some of the output values are summarized at the top left in order to make it easy to determine the effect of changing input parameters which produce reasonable outputs. This spreadsheet was provided by Derek Straub of MSFC as an aid in calculating pressures and sizing nozzles assuming a ball park estimate of the regression performance of the fuel. It is just as useful to calculate the ballistic parameters, using the chamber pressure, oxidizer flow rate, and nozzle size as inputs. It was donated as a working tool, not as flawless software. Some minor errors were noted and corrected. Others may have remained undetected.

The spreadsheet requires characteristic exhaust velocities which were calculated as noted in the Thermochemical Analysis Section where they were reported in table 9, and are entered in the spreadsheet at the far right. Values for O/F ratios above 4.0 were merely estimated. As noted in the results section, the unchoked condition for the oxygen flow led to some flow variations in the first 11-inch motor firing. These are noted as different values in this spreadsheet in the column containing the oxidizer mass flow.

Actual chamber pressure is compared with calculated chamber pressure on an embedded chart in the middle of the spreadsheet printout.

MSFC DATA

Tabulation of the data from MSFC is essentially self explanatory. The time in the left hand column was when MSFC started a timing sequence. Nothing significant happened until about 3.1 seconds along that sequence, and consequently the output was truncated to reduce it to reasonable size by limiting data points to the time period during oxidizer flow, ignition, and significant chamber pressures. An embedded chart at the end of the MSFC data compares observed chamber pressure with calculated chamber pressure from the first spreadsheet.

B. Second Eleven-Inch Motor Firing

The data is reported and analyzed the same way as for the first 11-inch motor firing.

FIRST 11-INCH MOTOR FIRING

Inputs		Gox flow =	1.0600		port dia=	2.975	Total	impulse=	5077.367	lb sec				Erosion
					Density=	1.150	Total fuel	used =	8.0005	lb				Rate(in/.1s)
Init rdot	0.054	pre exp =	0.144		Port Length	=	34.000	Pc final=	523.68	psi				7.70E-04
Avg rdot	0.045	exp =	0.530	Init OMF=	0.155			Final dia=	4.008	inch	total			Nozzl dia
Burn Time	Do	Mdot Ox	Mdot Ox	Flux/Port	Rdot	D final	MdotF	MdotF	O/F	Rdot	Mdot T	Flux	C*	D5
(sec)	in	lb/.1s	lb/sec	lb/.1s/in^2	in/.1s	in	lb/.1s	lb/s		in/sec	lb/.1 sec	total		
0.000	2.975	0.1080	1.080	0.016	0.0054	2.986	0.0709	0.7094	1.53	0.054	0.179	0.026	5841.000	0.650
0.100	2.986	0.1036	1.036	0.015	0.0052	2.996	0.0694	0.6937	1.50	0.052	0.173	0.025	5841.000	0.652
0.200	2.996	0.0984	0.984	0.014	0.0051	3.006	0.0675	0.6749	1.47	0.051	0.166	0.024	5841.000	0.653
0.300	3.006	0.0987	0.987	0.014	0.0051	3.016	0.0676	0.6758	1.47	0.051	0.166	0.023	5841.000	0.655
0.400	3.016	0.1008	1.008	0.014	0.0051	3.027	0.0683	0.6833	1.49	0.051	0.169	0.024	5841.000	0.656
0.500	3.027	0.1025	1.025	0.014	0.0051	3.037	0.0689	0.6892	1.50	0.051	0.171	0.024	5841.000	0.658
0.600	3.037	0.1025	1.025	0.014	0.0051	3.047	0.0689	0.6891	1.50	0.051	0.171	0.024	5841.000	0.659
0.700	3.047	0.1025	1.025	0.014	0.0051	3.057	0.0689	0.6889	1.50	0.051	0.171	0.024	5841.000	0.661
0.800	3.057	0.1021	1.021	0.014	0.0051	3.067	0.0687	0.6873	1.50	0.051	0.171	0.023	5841.000	0.662
0.900	3.067	0.1020	1.020	0.014	0.0050	3.078	0.0687	0.6868	1.50	0.050	0.171	0.023	5841.000	0.664
1.000	3.078	0.1013	1.013	0.014	0.0050	3.088	0.0684	0.6842	1.49	0.050	0.170	0.023	5841.000	0.665
1.100	3.088	0.1016	1.016	0.014	0.0050	3.098	0.0685	0.6851	1.49	0.050	0.170	0.023	5841.000	0.667
1.200	3.098	0.1016	1.016	0.013	0.0050	3.107	0.0685	0.6850	1.49	0.050	0.170	0.023	5841.000	0.668
1.300	3.107	0.1015	1.015	0.013	0.0050	3.117	0.0684	0.6845	1.49	0.050	0.170	0.022	5841.000	0.670
1.400	3.117	0.1017	1.017	0.013	0.0049	3.127	0.0685	0.6851	1.49	0.049	0.170	0.022	5841.000	0.672
1.500	3.127	0.1016	1.016	0.013	0.0049	3.137	0.0685	0.6846	1.49	0.049	0.170	0.022	5841.000	0.673
1.600	3.137	0.1021	1.021	0.013	0.0049	3.147	0.0686	0.6862	1.50	0.049	0.171	0.022	5841.000	0.675
1.700	3.147	0.1025	1.025	0.013	0.0049	3.157	0.0688	0.6875	1.50	0.049	0.171	0.022	5841.000	0.676
1.800	3.157	0.1028	1.028	0.013	0.0049	3.167	0.0688	0.6884	1.50	0.049	0.172	0.022	5841.000	0.678
1.900	3.167	0.1031	1.031	0.013	0.0049	3.176	0.0689	0.6894	1.51	0.049	0.172	0.022	5841.000	0.679
2.000	3.176	0.1034	1.034	0.013	0.0049	3.186	0.0690	0.6903	1.51	0.049	0.172	0.022	5841.000	0.681
2.100	3.186	0.1037	1.037	0.013	0.0049	3.196	0.0691	0.6912	1.51	0.049	0.173	0.022	5841.000	0.682
2.200	3.196	0.1040	1.040	0.013	0.0049	3.206	0.0692	0.6921	1.51	0.049	0.173	0.022	5841.000	0.684
2.300	3.206	0.1043	1.043	0.013	0.0049	3.216	0.0693	0.6931	1.51	0.049	0.174	0.022	5841.000	0.685
2.400	3.216	0.1041	1.041	0.013	0.0048	3.225	0.0692	0.6922	1.51	0.048	0.173	0.021	5841.000	0.687
2.500	3.225	0.1041	1.041	0.013	0.0048	3.235	0.0692	0.6921	1.51	0.048	0.173	0.021	5841.000	0.689
2.600	3.235	0.1044	1.044	0.013	0.0048	3.245	0.0693	0.6930	1.52	0.048	0.174	0.021	5841.000	0.690
2.700	3.245	0.1047	1.047	0.013	0.0048	3.254	0.0694	0.6940	1.52	0.048	0.174	0.021	5841.000	0.692
2.800	3.254	0.1047	1.047	0.013	0.0048	3.264	0.0694	0.6938	1.52	0.048	0.174	0.021	5841.000	0.693
2.900	3.264	0.1050	1.050	0.013	0.0048	3.273	0.0695	0.6948	1.52	0.048	0.174	0.021	5841.000	0.695

Inputs		Gox flow =	1.0600		port dia=	2.975	Total	impulse=	5077.367	lb sec				Erosion
					Density=	1.150	Total fuel	used =	8.0005	lb				Rate(in/.1s)
Init rdot	0.054	pre exp =	0.144		Port Length	=	34.000	Pc final=	523.68	psi				
Avg rdot	0.045	exp =	0.530	Init OMF=	0.155			Final dia=	4.008	inch				7.70E-04
Burn Time	Do	Mdot Ox	Mdot Ox	Flux/Port	Rdot	D final	MdotF	MdotF	O/F	Rdot	total Mdot T	Flux	C*	Nozzl dia D5
(sec)	in	lb/.1s	lb/sec	lb/.1s/in^2	in/.1s	in	lb/.1s	lb/s		in/sec	lb/.1 sec	total		
3.000	3.273	0.1053	1.053	0.013	0.0048	3.283	0.0696	0.6957	1.52	0.048	0.175	0.021	5841.000	0.696
3.100	3.283	0.1054	1.054	0.012	0.0048	3.292	0.0696	0.6959	1.52	0.048	0.175	0.021	5841.000	0.698
3.200	3.292	0.1055	1.055	0.012	0.0048	3.302	0.0696	0.6961	1.53	0.048	0.175	0.021	5841.000	0.699
3.300	3.302	0.1058	1.058	0.012	0.0048	3.311	0.0697	0.6970	1.53	0.048	0.176	0.020	5841.000	0.701
3.400	3.311	0.1061	1.061	0.012	0.0047	3.321	0.0698	0.6980	1.53	0.047	0.176	0.020	5841.000	0.702
3.500	3.321	0.1060	1.060	0.012	0.0047	3.330	0.0697	0.6975	1.53	0.047	0.176	0.020	5841.000	0.704
3.600	3.330	0.1063	1.063	0.012	0.0047	3.340	0.0698	0.6984	1.53	0.047	0.176	0.020	5841.000	0.705
3.700	3.340	0.1064	1.064	0.012	0.0047	3.349	0.0699	0.6986	1.53	0.047	0.176	0.020	5841.000	0.707
3.800	3.349	0.1066	1.066	0.012	0.0047	3.359	0.0699	0.6992	1.53	0.047	0.177	0.020	5841.000	0.709
3.900	3.359	0.1068	1.068	0.012	0.0047	3.368	0.0700	0.6998	1.54	0.047	0.177	0.020	5841.000	0.710
4.000	3.368	0.1068	1.068	0.012	0.0047	3.377	0.0700	0.6997	1.54	0.047	0.177	0.020	5841.000	0.712
4.100	3.377	0.1071	1.071	0.012	0.0047	3.387	0.0701	0.7006	1.54	0.047	0.177	0.020	5841.000	0.713
4.200	3.387	0.1072	1.072	0.012	0.0047	3.396	0.0701	0.7008	1.54	0.047	0.177	0.020	5841.000	0.715
4.300	3.396	0.1073	1.073	0.012	0.0046	3.405	0.0701	0.7010	1.54	0.046	0.177	0.020	5841.000	0.716
4.400	3.405	0.1074	1.074	0.012	0.0046	3.415	0.0701	0.7013	1.54	0.046	0.178	0.019	5841.000	0.718
4.500	3.415	0.1075	1.075	0.012	0.0046	3.424	0.0701	0.7015	1.54	0.046	0.178	0.019	5841.000	0.719
4.600	3.424	0.1077	1.077	0.012	0.0046	3.433	0.0702	0.7021	1.54	0.046	0.178	0.019	5841.000	0.721
4.700	3.433	0.1079	1.079	0.012	0.0046	3.442	0.0703	0.7026	1.55	0.046	0.178	0.019	5841.000	0.722
4.800	3.442	0.1079	1.079	0.012	0.0046	3.452	0.0703	0.7025	1.55	0.046	0.178	0.019	5841.000	0.724
4.900	3.452	0.1080	1.080	0.012	0.0046	3.461	0.0703	0.7027	1.55	0.046	0.178	0.019	5841.000	0.725
5.000	3.461	0.1081	1.081	0.011	0.0046	3.470	0.0703	0.7030	1.55	0.046	0.178	0.019	5841.000	0.727
5.100	3.470	0.1083	1.083	0.011	0.0046	3.479	0.0704	0.7035	1.55	0.046	0.179	0.019	5841.000	0.729
5.200	3.479	0.1082	1.082	0.011	0.0046	3.488	0.0703	0.7031	1.55	0.046	0.179	0.019	5841.000	0.730
5.300	3.488	0.1083	1.083	0.011	0.0045	3.497	0.0703	0.7033	1.55	0.045	0.179	0.019	5841.000	0.732
5.400	3.497	0.1084	1.084	0.011	0.0045	3.506	0.0704	0.7035	1.55	0.045	0.179	0.019	5841.000	0.733
5.500	3.506	0.1084	1.084	0.011	0.0045	3.515	0.0703	0.7034	1.55	0.045	0.179	0.019	5841.000	0.735
5.600	3.515	0.1086	1.086	0.011	0.0045	3.524	0.0704	0.7040	1.55	0.045	0.179	0.018	5841.000	0.736
5.700	3.524	0.1087	1.087	0.011	0.0045	3.533	0.0704	0.7042	1.55	0.045	0.179	0.018	5841.000	0.738
5.800	3.533	0.1087	1.087	0.011	0.0045	3.542	0.0704	0.7041	1.55	0.045	0.179	0.018	5841.000	0.739
5.900	3.542	0.1086	1.086	0.011	0.0045	3.551	0.0704	0.7037	1.55	0.045	0.179	0.018	5841.000	0.741

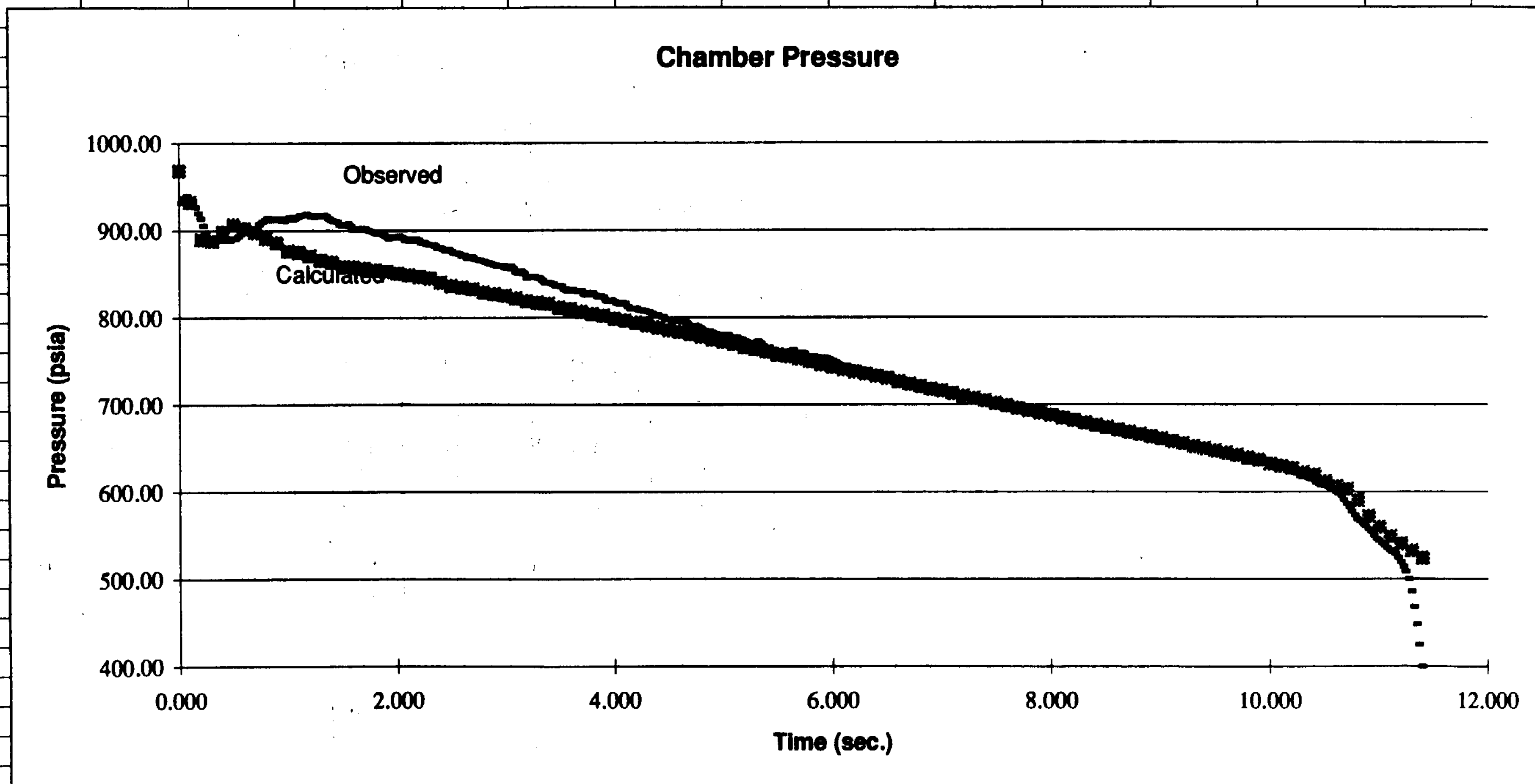
FIRST 11-INCH MOTOR FIRING

Inputs		Gox flow =	1.0600		port dia=	2.975	Total	impulse=	5077.367	lb sec				Erosion
					Density=	1.150	Total fuel	used =	8.0005	lb				Rate(in/.1s)
Init rdot	0.054	pre exp =	0.144		Port Length	=	34.000	Pc final=	523.68	psi				7.70E-04
Avg rdot	0.045	exp =	0.530	Init OMF=	0.155			Final dia=	4.008	inch	total			Nozzl dia
Burn Time	Do	Mdot Ox	Mdot Ox	Flux/Port	Rdot	D final	MdotF	MdotF	O/F	Rdot	Mdot T	Flux	C*	D5
(sec)	in	lb/.1s	lb/sec	lb/.1s/in^2	in/.1s	in	lb/.1s	lb/s		in/sec	lb/.1 sec	total		
6.000	3.551	0.1087	1.087	0.011	0.0045	3.560	0.0704	0.7039	1.55	0.045	0.179	0.018	5841.000	0.742
6.100	3.560	0.1087	1.087	0.011	0.0045	3.569	0.0704	0.7038	1.55	0.045	0.179	0.018	5841.000	0.744
6.200	3.569	0.1088	1.088	0.011	0.0044	3.578	0.0704	0.7040	1.56	0.044	0.179	0.018	5841.000	0.745
6.300	3.578	0.1089	1.089	0.011	0.0044	3.587	0.0704	0.7043	1.56	0.044	0.179	0.018	5841.000	0.747
6.400	3.587	0.1090	1.090	0.011	0.0044	3.596	0.0704	0.7045	1.56	0.044	0.179	0.018	5841.000	0.749
6.500	3.596	0.1091	1.091	0.011	0.0044	3.605	0.0705	0.7047	1.56	0.044	0.180	0.018	5841.000	0.750
6.600	3.605	0.1090	1.090	0.011	0.0044	3.613	0.0704	0.7043	1.56	0.044	0.179	0.018	5841.000	0.752
6.700	3.613	0.1090	1.090	0.011	0.0044	3.622	0.0704	0.7042	1.56	0.044	0.179	0.017	5841.000	0.753
6.800	3.622	0.1091	1.091	0.011	0.0044	3.631	0.0704	0.7044	1.56	0.044	0.180	0.017	5841.000	0.755
6.900	3.631	0.1091	1.091	0.011	0.0044	3.640	0.0704	0.7043	1.56	0.044	0.180	0.017	5841.000	0.756
7.000	3.640	0.1092	1.092	0.010	0.0044	3.648	0.0705	0.7045	1.56	0.044	0.180	0.017	5841.000	0.758
7.100	3.648	0.1092	1.092	0.010	0.0043	3.657	0.0704	0.7044	1.56	0.043	0.180	0.017	5841.000	0.759
7.200	3.657	0.1092	1.092	0.010	0.0043	3.666	0.0704	0.7043	1.56	0.043	0.180	0.017	5841.000	0.761
7.300	3.666	0.1093	1.093	0.010	0.0043	3.674	0.0705	0.7046	1.56	0.043	0.180	0.017	5841.000	0.762
7.400	3.674	0.1093	1.093	0.010	0.0043	3.683	0.0704	0.7045	1.56	0.043	0.180	0.017	5841.000	0.764
7.500	3.683	0.1093	1.093	0.010	0.0043	3.692	0.0704	0.7044	1.56	0.043	0.180	0.017	5841.000	0.765
7.600	3.692	0.1093	1.093	0.010	0.0043	3.700	0.0704	0.7043	1.56	0.043	0.180	0.017	5841.000	0.767
7.700	3.700	0.1093	1.093	0.010	0.0043	3.709	0.0704	0.7041	1.56	0.043	0.180	0.017	5841.000	0.769
7.800	3.709	0.1093	1.093	0.010	0.0043	3.717	0.0704	0.7040	1.56	0.043	0.180	0.017	5841.000	0.770
7.900	3.717	0.1093	1.093	0.010	0.0043	3.726	0.0704	0.7039	1.56	0.043	0.180	0.017	5841.000	0.772
8.000	3.726	0.1093	1.093	0.010	0.0043	3.734	0.0704	0.7038	1.56	0.043	0.180	0.016	5841.000	0.773
8.100	3.734	0.1093	1.093	0.010	0.0042	3.743	0.0704	0.7037	1.56	0.042	0.180	0.016	5841.000	0.775
8.200	3.743	0.1093	1.093	0.010	0.0042	3.751	0.0704	0.7036	1.56	0.042	0.180	0.016	5841.000	0.776
8.300	3.751	0.1093	1.093	0.010	0.0042	3.760	0.0704	0.7035	1.56	0.042	0.180	0.016	5841.000	0.778
8.400	3.760	0.1093	1.093	0.010	0.0042	3.768	0.0703	0.7034	1.56	0.042	0.180	0.016	5841.000	0.779
8.500	3.768	0.1093	1.093	0.010	0.0042	3.777	0.0703	0.7033	1.56	0.042	0.180	0.016	5841.000	0.781
8.600	3.777	0.1093	1.093	0.010	0.0042	3.785	0.0703	0.7033	1.56	0.042	0.180	0.016	5841.000	0.782
8.700	3.785	0.1093	1.093	0.010	0.0042	3.793	0.0703	0.7032	1.56	0.042	0.180	0.016	5841.000	0.784
8.800	3.793	0.1093	1.093	0.010	0.0042	3.802	0.0703	0.7031	1.56	0.042	0.180	0.016	5841.000	0.786
8.900	3.802	0.1093	1.093	0.010	0.0042	3.810	0.0703	0.7030	1.56	0.042	0.180	0.016	5841.000	0.787

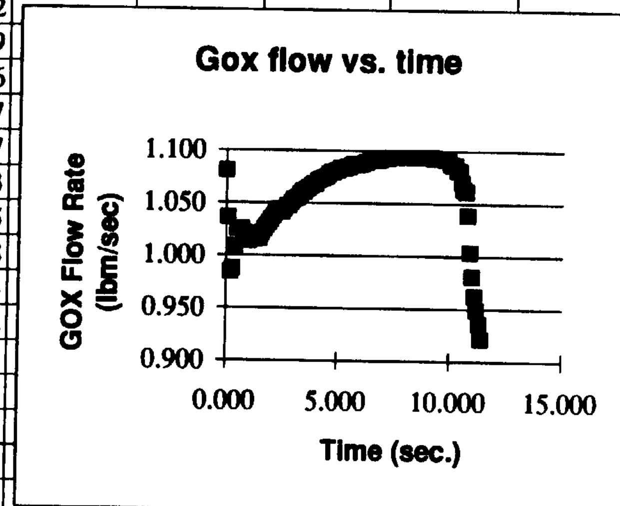
Inputs		Gox flow =	1.0600		port dia=	2.975	Total	impulse=	5077.367	lb sec				Erosion
					Density=	1.150	Total fuel	used =	8.0005	lb				Rate(in/.1s)
Init rdot	0.054	pre exp =	0.144		Port Length	=	34.000	Pc final=	523.68	psi				7.70E-04
Avg rdot	0.045	exp =	0.530	Init OMF=	0.155			Final dia=	4.008	inch	total			Nozzl dia
Burn Time	Do	Mdot Ox	Mdot Ox	Flux/Port	Rdot	D final	MdotF	MdotF	O/F	Rdot	Mdot T	Flux	C*	D5
(sec)	in	lb/.1s	lb/sec	lb/.1s/in^2	in/.1s	in	lb/.1s	lb/s		in/sec	lb/.1 sec	total		
9.000	3.810	0.1093	1.093	0.010	0.0042	3.818	0.0703	0.7029	1.57	0.042	0.180	0.016	5841.000	0.789
9.100	3.818	0.1093	1.093	0.010	0.0041	3.827	0.0703	0.7028	1.57	0.041	0.180	0.016	5841.000	0.790
9.200	3.827	0.1093	1.093	0.010	0.0041	3.835	0.0703	0.7027	1.57	0.041	0.180	0.016	5841.000	0.792
9.300	3.835	0.1092	1.092	0.009	0.0041	3.843	0.0702	0.7022	1.57	0.041	0.179	0.016	5841.000	0.793
9.400	3.843	0.1092	1.092	0.009	0.0041	3.851	0.0702	0.7021	1.57	0.041	0.179	0.015	5841.000	0.795
9.500	3.851	0.1092	1.092	0.009	0.0041	3.860	0.0702	0.7021	1.57	0.041	0.179	0.015	5841.000	0.796
9.600	3.860	0.1092	1.092	0.009	0.0041	3.868	0.0702	0.7020	1.57	0.041	0.179	0.015	5841.000	0.798
9.700	3.868	0.1092	1.092	0.009	0.0041	3.876	0.0702	0.7019	1.57	0.041	0.179	0.015	5841.000	0.799
9.800	3.876	0.1091	1.091	0.009	0.0041	3.884	0.0701	0.7014	1.57	0.041	0.179	0.015	5841.000	0.801
9.900	3.884	0.1091	1.091	0.009	0.0041	3.892	0.0701	0.7013	1.57	0.041	0.179	0.015	5841.000	0.802
10.000	3.892	0.1087	1.087	0.009	0.0041	3.900	0.0700	0.6999	1.56	0.041	0.179	0.015	5841.000	0.804
10.100	3.900	0.1086	1.086	0.009	0.0040	3.908	0.0699	0.6995	1.56	0.040	0.179	0.015	5841.000	0.806
10.200	3.908	0.1086	1.086	0.009	0.0040	3.917	0.0699	0.6994	1.56	0.040	0.179	0.015	5841.000	0.807
10.300	3.917	0.1081	1.081	0.009	0.0040	3.925	0.0698	0.6976	1.56	0.040	0.178	0.015	5841.000	0.809
10.400	3.925	0.1080	1.080	0.009	0.0040	3.933	0.0697	0.6971	1.56	0.040	0.178	0.015	5841.000	0.810
10.500	3.933	0.1070	1.070	0.009	0.0040	3.941	0.0694	0.6936	1.55	0.040	0.176	0.015	5841.000	0.812
10.600	3.941	0.1063	1.063	0.009	0.0040	3.948	0.0691	0.6911	1.55	0.040	0.175	0.014	5841.000	0.813
10.700	3.948	0.1061	1.061	0.009	0.0039	3.956	0.0690	0.6903	1.55	0.039	0.175	0.014	5841.000	0.815
10.800	3.956	0.1038	1.038	0.008	0.0039	3.964	0.0682	0.6823	1.53	0.039	0.172	0.014	5841.000	0.816
10.900	3.964	0.1003	1.003	0.008	0.0038	3.972	0.0670	0.6699	1.51	0.038	0.167	0.014	5841.000	0.818
11.000	3.972	0.0980	0.980	0.008	0.0038	3.979	0.0662	0.6616	1.49	0.038	0.164	0.013	5841.000	0.819
11.100	3.979	0.0962	0.962	0.008	0.0037	3.987	0.0655	0.6551	1.48	0.037	0.162	0.013	5841.000	0.821
11.200	3.987	0.0948	0.948	0.008	0.0037	3.994	0.0650	0.6499	1.47	0.037	0.160	0.013	5841.000	0.822
11.300	3.994	0.0935	0.935	0.007	0.0036	4.001	0.0645	0.6451	1.46	0.036	0.158	0.013	5841.000	0.824
11.400	4.001	0.0921	0.921	0.007	0.0036	4.008	0.0640	0.6399	1.45	0.036	0.156	0.012	5841.000	0.826
					0.5167	0.0453	8.0005							
					totl radius	avg reg	total							
					increase	rate	fuel							
							consumed							

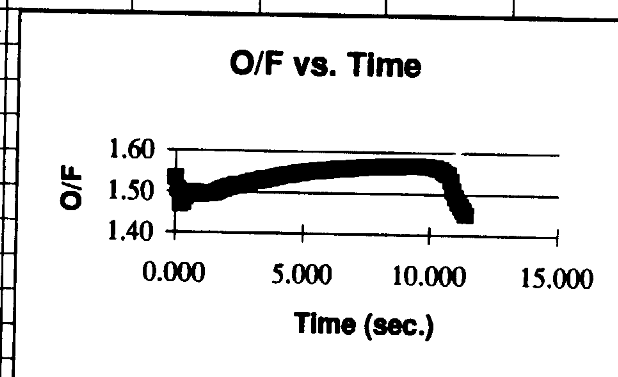
FIRST 11-INCH MOTOR FIRING

Inputs		Gox flow =	1.0600		port dia=	2.975	Total	impulse=	5077.367	lb sec				Erosion
					Density=	1.150	Total fuel	used =	8.0005	lb				Rate(in/.1s)
Init rdot	0.054	pre exp =	0.144		Port Length	=	34.000	Pc final=	523.68	psi				7.70E-04
Avg rdot	0.045	exp =	0.530	Init OMF=	0.155			Final dia=	4.008	inch	total			Nozzl dia
Burn Time	Do	Mdot Ox	Mdot Ox	Flux/Port	Rdot	D final	MdotF	MdotF	O/F	Rdot	Mdot T	Flux	C*	D5
(sec)	in	lb/.1s	lb/sec	lb/.1s/in^2	in/.1s	in	lb/.1s	lb/s		in/sec	lb/.1 sec	total		



		Ae/A* =	10.000				
	Calc	De =	2.055				
	Chamber	Ambient Pressure=		14.700			
	Press					impulse	total
A5	Eff	Epsilon	Cf	Thrust	ISP	.95Eff	Mdot T
	0.990				Theor.		lb/sec
0.332	968.42	10.000	1.495	480	268.506	456.434	1.789372
0.333	931.71	9.953	1.490	463	267.502	439.568	1.729719
0.335	889.34	9.906	1.483	442	266.234	419.562	1.65886
0.337	887.26	9.859	1.483	443	266.241	420.571	1.662807
0.338	898.21	9.813	1.485	451	266.672	428.460	1.691257
0.340	906.14	9.767	1.487	458	266.999	434.806	1.714203
0.341	901.83	9.722	1.486	458	266.933	434.661	1.714055
0.343	897.56	9.676	1.486	457	266.867	434.517	1.713908
0.345	890.48	9.631	1.485	456	266.712	432.851	1.708334
0.346	885.58	9.587	1.485	455	266.624	432.328	1.706832
0.348	876.50	9.542	1.483	452	266.403	429.528	1.697184
0.349	874.48	9.498	1.483	453	266.406	430.528	1.701118
0.351	870.38	9.455	1.483	453	266.340	430.386	1.700978
0.353	865.63	9.411	1.483	452	266.252	429.865	1.699481
0.354	862.97	9.368	1.483	453	266.233	430.487	1.702058
0.356	858.27	9.325	1.482	453	266.149	429.973	1.700563
0.357	857.70	9.283	1.482	454	266.197	431.732	1.707213
0.359	856.44	9.241	1.482	456	266.222	433.111	1.712502
0.361	854.51	9.199	1.482	457	266.224	434.109	1.716434
0.362	852.59	9.157	1.482	458	266.227	435.107	1.720364
0.364	850.67	9.116	1.483	459	266.233	436.111	1.724294
0.366	848.76	9.075	1.483	460	266.234	437.105	1.728222
0.367	846.87	9.034	1.483	461	266.234	438.099	1.732149
0.369	844.98	8.993	1.483	462	266.235	439.094	1.736074
0.371	839.82	8.953	1.482	461	266.127	438.197	1.733236
0.372	836.00	8.913	1.482	461	266.066	438.064	1.733105
0.374	834.16	8.873	1.482	462	266.066	439.057	1.737032
0.376	832.32	8.834	1.482	463	266.066	440.049	1.740958
0.377	828.57	8.794	1.481	463	266.001	439.909	1.740828
0.379	826.76	8.756	1.481	464	266.002	440.902	1.744754

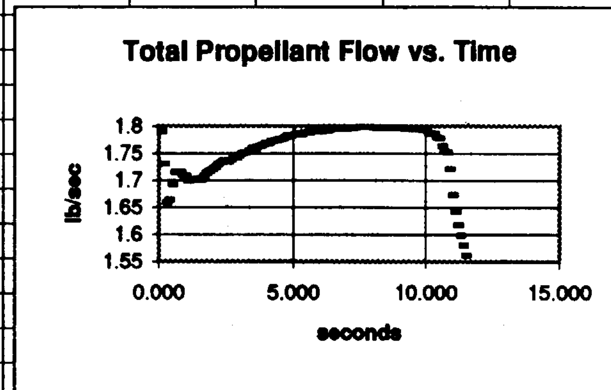




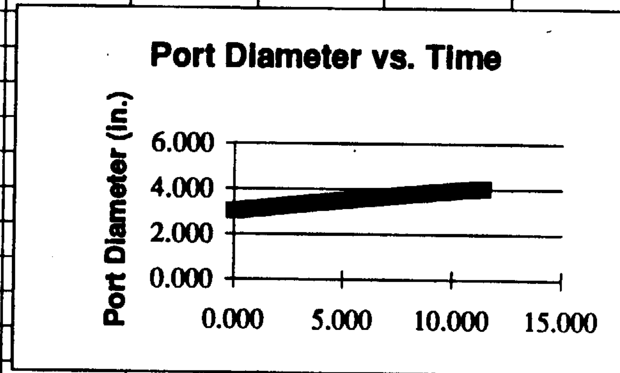
O/F	C*
1.000	5415.000
1.200	5717.000
1.400	5841.000
1.600	5840.000
1.800	5782.000
1.900	5746.000
2.000	5708.000
2.100	5670.000
2.300	5591.000
2.400	5556.000
2.500	5521.000
3.000	5390.000
3.200	5298.000
3.600	5189.000
4.000	5091.000
4.500	5000.000
5.000	4900.000
5.500	4800.000
6.000	4700.000
6.500	4600.000
7.000	4500.000

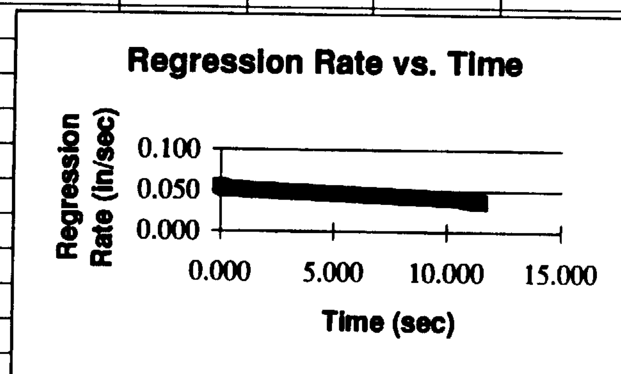
FIRST 11-INCH MOTOR FIRING

		Ae/A* =	10.000				
	Calc	De =	2.055				
	Chamber	Ambient Pressure=		14.700			
	Press					impulse	total
A5	Eff	Epsilon	Cf	Thrust	ISP	.95Eff	Mdot T
	0.990				Theor.		lb/sec
0.381	824.96	8.717	1.481	465	266.006	441.901	1.748678
0.382	821.89	8.678	1.481	465	265.962	442.136	1.7499
0.384	818.85	8.640	1.481	466	265.918	442.372	1.751123
0.386	817.08	8.602	1.481	467	265.917	443.362	1.755047
0.387	815.32	8.565	1.481	468	265.917	444.352	1.758969
0.389	811.08	8.527	1.480	467	265.835	443.844	1.757494
0.391	809.34	8.490	1.480	468	265.833	444.831	1.761416
0.393	806.38	8.453	1.480	468	265.789	445.066	1.76264
0.394	804.05	8.416	1.480	469	265.766	445.677	1.765213
0.396	801.73	8.380	1.480	470	265.744	446.289	1.767785
0.398	798.21	8.344	1.479	470	265.685	446.159	1.767663
0.399	796.53	8.308	1.479	471	265.682	447.143	1.771583
0.401	793.65	8.272	1.479	471	265.637	447.377	1.772808
0.403	790.79	8.236	1.479	471	265.593	447.612	1.774034
0.405	787.94	8.201	1.479	471	265.549	447.848	1.77526
0.406	785.11	8.166	1.478	472	265.511	448.094	1.776487
0.408	782.89	8.131	1.478	472	265.487	448.701	1.77906
0.410	780.69	8.096	1.478	473	265.463	449.309	1.781633
0.412	777.32	8.062	1.478	473	265.398	449.169	1.781514
0.413	774.55	8.028	1.478	473	265.354	449.404	1.782742
0.415	771.81	7.994	1.477	473	265.310	449.640	1.783971
0.417	769.66	7.960	1.477	474	265.291	450.257	1.786544
0.419	765.79	7.927	1.477	473	265.205	449.743	1.785083
0.420	763.09	7.893	1.477	474	265.160	449.977	1.786313
0.422	760.41	7.860	1.476	474	265.116	450.211	1.787543
0.424	757.18	7.827	1.476	474	265.052	450.073	1.787429
0.426	755.10	7.794	1.476	474	265.034	450.691	1.790004
0.427	752.47	7.762	1.476	475	264.989	450.924	1.791234
0.429	749.29	7.730	1.475	475	264.923	450.784	1.791122
0.431	745.57	7.698	1.475	474	264.838	450.272	1.789666



		Ae/A* =	10.000				
	Calc	De =	2.055				
	Chamber	Ambient Pressure=		14.700			
	Press					impulse	total
A5	Eff	Epsilon	Cf	Thrust	ISP	.95Eff	Mdot T
	0.990				Theor.		lb/sec
0.433	742.99	7.666	1.474	474	264.793	450.507	1.790899
0.435	739.87	7.634	1.474	474	264.729	450.370	1.790788
0.436	737.33	7.602	1.474	474	264.690	450.614	1.792022
0.438	734.80	7.571	1.474	475	264.645	450.847	1.793256
0.440	732.28	7.540	1.473	475	264.600	451.081	1.79449
0.442	729.78	7.509	1.473	475	264.556	451.315	1.795724
0.444	726.20	7.478	1.473	475	264.471	450.806	1.794273
0.446	723.19	7.448	1.472	474	264.413	450.680	1.794166
0.447	720.74	7.417	1.472	475	264.367	450.913	1.795402
0.449	717.77	7.387	1.472	474	264.302	450.775	1.795295
0.451	715.34	7.357	1.471	475	264.257	451.009	1.796532
0.453	712.40	7.327	1.471	475	264.192	450.872	1.796427
0.455	709.48	7.298	1.471	474	264.128	450.736	1.796322
0.457	707.11	7.268	1.471	475	264.090	450.981	1.79756
0.458	704.22	7.239	1.470	475	264.024	450.843	1.797456
0.460	701.35	7.210	1.470	474	263.959	450.705	1.797353
0.462	698.49	7.181	1.469	474	263.894	450.569	1.79725
0.464	695.66	7.152	1.469	474	263.829	450.433	1.797148
0.466	692.84	7.124	1.469	474	263.765	450.298	1.797046
0.468	690.04	7.095	1.468	474	263.706	450.172	1.796945
0.470	687.25	7.067	1.468	474	263.640	450.035	1.796845
0.471	684.48	7.039	1.468	474	263.575	449.898	1.796745
0.473	681.73	7.011	1.467	473	263.510	449.762	1.796645
0.475	679.00	6.983	1.467	473	263.446	449.627	1.796546
0.477	676.28	6.956	1.467	473	263.381	449.493	1.796447
0.479	673.58	6.928	1.466	473	263.323	449.368	1.796349
0.481	670.89	6.901	1.466	473	263.257	449.232	1.796251
0.483	668.23	6.874	1.466	473	263.192	449.096	1.796154
0.485	665.57	6.847	1.465	473	263.127	448.961	1.796058
0.487	662.93	6.820	1.465	472	263.062	448.827	1.795961





		Ae/A* =	10.000				
	Calc	De =	2.055				
	Chamber	Ambient Pressure=		14.700			
	Press					impulse	total
A5	Eff	Epsilon	Cf	Thrust	ISP	.95Eff	Mdot T
	0.990				Theor.		lb/sec
0.488	660.31	6.794	1.464	472	262.998	448.694	1.795866
0.490	657.71	6.767	1.464	472	262.939	448.570	1.79577
0.492	655.12	6.741	1.464	472	262.874	448.434	1.795675
0.494	652.05	6.715	1.463	472	262.788	447.930	1.79424
0.496	649.49	6.689	1.463	471	262.723	447.796	1.794146
0.498	646.95	6.663	1.463	471	262.659	447.663	1.794052
0.500	644.42	6.637	1.462	471	262.595	447.530	1.793959
0.502	641.91	6.612	1.462	471	262.536	447.407	1.793867
0.504	638.93	6.586	1.461	470	262.450	446.903	1.792434
0.506	636.45	6.561	1.461	470	262.385	446.769	1.792342
0.508	632.08	6.536	1.460	469	262.238	445.160	1.786886
0.510	629.16	6.511	1.460	468	262.153	444.659	1.785454
0.512	626.73	6.486	1.459	468	262.089	444.528	1.785364
0.514	621.97	6.462	1.459	466	261.927	442.562	1.778564
0.515	619.11	6.437	1.458	465	261.841	442.060	1.777133
0.517	612.07	6.413	1.457	461	261.567	438.237	1.763613
0.519	606.47	6.388	1.455	458	261.353	435.522	1.754116
0.521	603.22	6.364	1.455	458	261.246	434.654	1.75134
0.523	590.29	6.340	1.452	448	260.680	426.020	1.720275
0.525	571.87	6.316	1.447	435	259.820	412.919	1.672891
0.527	559.07	6.293	1.443	426	259.201	404.233	1.641618
0.529	548.65	6.269	1.440	418	258.685	397.396	1.617067
0.531	540.12	6.246	1.438	413	258.260	392.044	1.597917
0.533	532.11	6.222	1.436	407	257.853	387.061	1.580101
0.535	523.68	6.199	1.433	402	257.410	381.698	1.560887
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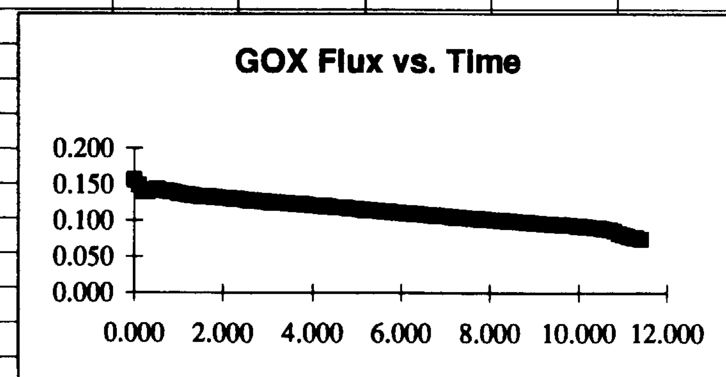


	4890.000
0.100	4882.000
0.150	4874.000
0.200	4866.000

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
3.184	1203.727	0.123	-0.613	1379.485	2428.259	1.475	-2.78	-0.249	-0.731	-0.748	1382.89	0	55.37	57.052
3.211	1203.727	0.854	-0.368	1380.296	2428.259	1.229	-2.75	-0.373	-0.731	-0.623	1382.89	0	55.479	57.107
3.235	1203.727	5.24	-0.49	1379.485	2428.259	1.229	-2.73	-0.373	-0.812	-0.623	1382.89	0	55.262	56.998
3.258	1203.727	21.323	-0.49	1379.485	2428.259	1.475	-2.7	-0.497	-0.812	-0.499	1382.89	0	55.425	57.107
3.286	1203.727	63.479	-0.245	1379.485	2428.259	1.721	-2.68	-0.373	-0.812	-0.623	1382.89	0	55.37	57.052
3.309	1203.727	151.813	-0.368	1379.485	2428.259	1.475	-2.65	-0.249	-0.812	-0.623	1382.89	0	55.425	57.107
3.336	1203.232	333.841	-0.613	1379.485	2428.259	1.229	-2.63	-0.497	-0.812	-0.748	1382.89	0	55.479	57.052
3.36	1202.241	735.912	-0.858	1379.485	2428.259	1.229	-2.6	0.248	-0.65	-0.748	1382.89	0	55.588	57.107
3.383	1198.278	1039.292	-0.368	1379.485	2428.259	1.229	-2.58	1.986	-0.812	-0.499	1381.84	0.001	55.642	57.052
3.411	1189.856	1103.624	1.225	1379.485	2428.259	2.212	-2.55	5.339	-0.812	0.249	1381.84	0	55.967	57.161
3.434	1173.012	1098.75	3.676	1379.485	2428.259	4.671	-2.53	10.306	-0.731	1.495	1382.89	0	56.781	57.378
3.461	1146.755	1127.017	7.106	1379.485	2421.278	9.833	-2.5	16.266	-0.731	2.991	1382.89	0	57.324	57.757
3.485	1108.113	1163.569	11.762	1379.485	2399.338	15.733	-2.48	22.475	-0.569	5.608	1382.89	0	58.137	58.245
3.508	1054.608	1179.164	17.276	1379.485	2371.415	20.404	-2.45	28.931	-0.731	8.225	1382.89	0	58.516	58.895
3.536	1034.296	1182.088	23.035	1379.485	2349.474	24.583	-2.43	34.271	-0.65	11.466	1382.89	0	59.058	59.491
3.559	1052.131	1177.702	28.671	1379.485	2350.472	29.253	-2.4	39.362	-0.731	14.831	1382.89	0.001	59.166	60.141
3.586	1070.461	1166.98	33.695	1379.485	2358.45	33.433	-2.38	43.708	-0.65	18.694	1381.84	0.001	59.708	60.79
3.61	1103.158	1152.36	38.473	1379.485	2362.438	37.857	-2.35	47.557	-0.569	22.433	1382.89	0	59.708	61.494
3.633	1145.764	1130.916	42.761	1379.485	2378.395	41.299	-2.33	51.034	-0.812	26.67	1381.84	0	60.249	62.143
3.661	1169.048	1099.238	46.07	1379.485	2395.349	44.495	-2.3	53.89	-0.731	30.534	1381.84	0	60.357	62.683
3.684	1177.966	1069.021	49.133	1379.485	2401.333	47.199	-2.28	56.373	-0.65	35.02	1381.84	0	60.682	63.17
3.711	1178.461	1069.996	51.461	1379.485	2395.349	49.411	-2.25	58.484	-0.65	39.008	1382.89	0	60.79	63.656
3.735	1172.021	1084.129	53.421	1379.485	2385.376	51.132	-2.23	60.471	-0.65	42.872	1382.89	0	60.899	63.765
3.758	1162.608	1103.136	55.382	1378.673	2373.409	53.099	-2.2	62.582	-0.65	46.361	1381.84	0	60.953	64.089
3.786	1151.709	1137.739	57.587	1379.485	2362.438	55.311	-2.18	64.817	-0.65	49.851	1381.84	0	61.169	64.089
3.809	1134.369	1163.569	59.67	1379.485	2347.48	57.278	-2.15	67.052	-0.731	53.091	1382.89	0	61.115	64.251
3.836	1112.571	1176.24	61.998	1379.485	2326.537	59.736	-2.13	69.411	-0.731	56.207	1382.89	0.001	61.169	64.305
3.86	1101.672	1180.626	63.713	1379.485	2298.612	61.457	-2.1	71.522	-0.731	58.824	1381.84	0	61.169	64.197
3.883	1108.608	1179.652	65.919	1379.485	2276.672	63.424	-2.08	73.26	-0.812	61.441	1382.89	0	61.169	64.251
3.911	1119.507	1174.778	67.634	1380.296	2265.702	65.144	-2.05	75.123	-0.65	63.684	1382.89	0.001	61.169	64.143
3.934	1140.81	1168.93	69.227	1379.485	2260.716	66.619	-2.03	76.489	-0.731	66.052	1382.89	0	61.169	64.089
3.961	1165.085	1159.67	70.452	1379.485	2271.686	68.094	-2	77.73	-0.65	67.797	1381.84	0	61.223	64.089

MSFC DATA ON FIRST 11-INCH MOTOR FIRING

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
3.985	1180.938	1146.511	71.678	1379.485	2284.651	69.323	-1.98	78.972	-0.65	69.542	1382.89	0	61.223	63.981
4.008	1189.856	1135.302	72.903	1379.485	2293.626	70.307	-1.95	79.841	-0.65	70.788	1382.89	0	61.277	63.927
4.036	1192.333	1137.251	73.393	1379.485	2296.618	71.044	-1.93	80.462	-0.65	71.661	1382.89	0	61.115	63.765
4.059	1190.351	1146.511	74.251	1379.485	2294.623	71.782	-1.9	81.58	-0.65	72.408	1381.84	0.001	61.223	63.71
4.086	1187.874	1161.132	74.986	1379.485	2288.64	72.765	-1.88	82.325	-0.731	73.53	1382.89	0	61.169	63.44
4.11	1183.415	1181.114	75.966	1379.485	2277.669	73.502	-1.85	83.318	-0.65	74.278	1382.89	0	61.277	63.44
4.133	1175.984	1196.222	76.946	1379.485	2265.702	74.486	-1.83	84.436	-0.65	75.275	1382.89	0	61.169	63.224
4.161	1167.562	1205.482	77.926	1379.485	2247.751	75.469	-1.8	85.305	-0.731	76.147	1381.84	0	61.223	63.008
4.184	1166.076	1210.355	79.152	1379.485	2226.808	76.207	-1.78	86.547	-0.65	77.394	1382.89	0	61.115	62.9
4.211	1172.021	1210.355	80.009	1380.296	2210.851	77.436	-1.75	87.416	-0.812	78.266	1382.89	0	61.277	62.846
4.235	1180.443	1209.868	80.867	1379.485	2202.874	78.419	-1.73	88.285	-0.65	79.138	1382.89	0	61.061	62.683
4.258	1194.314	1208.406	81.725	1379.485	2201.876	78.911	-1.7	88.906	-0.812	79.886	1381.84	0	61.223	62.683
4.286	1208.186	1205.482	82.46	1380.296	2210.851	79.894	-1.68	89.775	-0.731	80.883	1382.89	0	61.061	62.467
4.309	1218.094	1201.583	83.072	1379.485	2219.828	80.631	-1.65	90.272	-0.731	81.506	1382.89	0	61.331	62.413
4.336	1224.534	1200.121	83.562	1379.485	2228.803	81.123	-1.63	90.893	-0.812	81.88	1382.89	0	61.169	62.305
4.36	1226.516	1204.507	84.175	1379.485	2234.787	81.615	-1.6	91.141	-0.731	82.254	1382.89	0	61.277	62.197
4.383	1227.011	1211.33	84.543	1379.485	2238.776	82.106	-1.58	91.886	-0.812	82.753	1382.89	0	61.277	62.089
4.411	1226.516	1221.077	85.155	1379.485	2239.773	82.598	-1.55	92.258	-0.731	83.5	1382.89	0	61.277	61.981
4.434	1225.525	1232.286	85.523	1379.485	2239.773	83.09	-1.53	93.252	-0.812	83.999	1382.89	0	61.385	61.818
4.461	1223.048	1241.546	86.136	1379.485	2238.776	83.582	-1.5	93.873	-0.812	84.497	1382.89	0	61.385	61.764
4.485	1220.571	1247.395	86.626	1380.296	2235.783	84.319	-1.48	94.493	-0.812	85.12	1382.89	0	61.385	61.656
4.508	1223.048	1250.806	87.361	1380.296	2232.793	84.811	-1.45	94.99	-0.731	85.494	1382.89	0	61.385	61.44
4.536	1227.507	1251.293	87.973	1379.485	2231.794	85.794	-1.43	95.487	-0.731	86.242	1382.89	0	61.44	61.385
4.559	1233.947	1251.781	88.709	1379.485	2233.79	86.04	-1.4	96.108	-0.893	86.865	1381.84	0.001	61.548	61.331
4.586	1242.369	1251.781	89.199	1379.485	2240.771	86.777	-1.38	96.356	-0.731	87.364	1381.84	0	61.548	61.277
4.61	1249.305	1251.293	89.689	1379.485	2251.74	86.777	-1.35	97.101	-0.731	87.738	1382.89	0	61.602	61.277
4.633	1254.755	1249.831	90.179	1379.485	2264.705	87.269	-1.33	97.474	-0.812	88.236	1382.89	0	61.71	61.115
4.661	1258.718	1251.293	90.424	1379.485	2274.679	88.006	-1.3	97.722	-0.731	88.735	1382.89	0	61.872	60.953
4.684	1259.709	1254.705	90.914	1379.485	2281.659	88.006	-1.28	98.219	-0.65	88.984	1382.89	0	61.764	60.953
4.711	1260.204	1259.091	91.159	1380.296	2285.648	88.744	-1.25	98.467	-0.569	89.233	1382.89	0	61.926	60.899
4.735	1260.7	1265.427	91.404	1380.296	2287.643	88.99	-1.23	99.088	-0.731	89.732	1382.89	0	61.981	60.79
4.758	1260.204	1271.275	91.772	1379.485	2289.637	88.99	-1.2	99.212	-0.487	89.981	1382.89	0	62.089	60.682

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
4.786	1259.709	1275.661	92.262	1379.485	2290.634	89.358	-1.18	99.709	-0.569	90.604	1382.89	0.001	62.089	60.682
4.809	1259.709	1279.073	92.629	1379.485	2291.632	89.973	-1.15	100.081	-0.487	90.853	1382.89	0	62.197	60.52
4.836	1262.186	1280.535	93.119	1379.485	2292.629	90.465	-1.13	100.578	-0.65	91.103	1382.89	0	62.251	60.466
4.86	1265.158	1281.51	93.61	1379.485	2294.623	90.71	-1.1	100.95	-0.65	91.601	1382.89	0.001	62.413	60.411
4.883	1269.617	1282.484	93.855	1380.296	2299.611	91.079	-1.08	101.199	-0.569	91.85	1382.89	0	62.521	60.357
4.911	1274.076	1282.484	94.1	1380.296	2304.597	91.448	-1.05	101.447	-0.65	92.224	1382.89	0	62.467	60.249
4.934	1278.039	1281.997	94.345	1380.296	2311.577	91.694	-1.03	101.695	-0.65	92.473	1381.84	0	62.683	60.195
4.961	1281.011	1282.484	94.59	1379.485	2316.564	92.063	-1	102.068	-0.812	92.473	1382.89	0.001	62.738	60.141
4.985	1282.993	1283.459	94.957	1379.485	2319.555	92.308	-0.98	102.192	-0.65	93.097	1382.89	0	62.954	60.141
5.008	1283.489	1286.383	95.08	1379.485	2322.548	92.431	-0.95	102.565	-0.65	93.097	1382.89	0.001	63.008	60.032
5.036	1284.479	1289.307	95.447	1379.485	2324.542	92.8	-0.93	102.689	-0.731	93.346	1382.89	0	63.062	59.978
5.059	1284.975	1293.206	95.57	1379.485	2325.54	92.923	-0.9	102.813	-0.731	93.595	1382.89	0	63.17	59.978
5.086	1284.479	1296.13	96.06	1379.485	2325.54	93.046	-0.88	103.185	-0.731	93.969	1382.89	0	63.224	59.816
5.11	1284.975	1299.054	96.06	1380.296	2326.537	93.415	-0.85	103.31	-0.731	94.218	1382.89	0	63.278	59.762
5.133	1285.47	1301.004	96.305	1379.485	2326.537	93.66	-0.83	103.806	-0.731	94.468	1382.89	0	63.44	59.762
5.161	1286.957	1301.979	96.795	1379.485	2328.531	93.783	-0.8	104.055	-0.812	94.468	1382.89	0	63.602	59.708
5.184	1289.433	1302.466	96.795	1379.485	2329.529	94.275	-0.78	104.179	-0.812	94.966	1381.84	0	63.602	59.653
5.211	1292.406	1303.441	97.285	1380.296	2332.52	94.275	-0.75	104.551	-0.731	95.215	1382.89	0	63.765	59.653
5.235	1295.378	1303.928	97.408	1379.485	2335.512	94.644	-0.73	104.427	-0.65	95.34	1381.84	0	63.819	59.599
5.258	1297.36	1303.928	97.408	1379.485	2338.504	94.767	-0.7	104.924	-0.812	95.464	1382.89	0	63.927	59.491
5.286	1298.846	1303.928	97.53	1379.485	2340.498	95.012	-0.68	104.924	-0.812	95.589	1382.89	0	63.981	59.437
5.309	1300.333	1305.39	97.775	1379.485	2342.494	95.258	-0.65	105.172	-0.812	95.838	1382.89	0	64.143	59.383
5.336	1301.323	1307.34	97.898	1380.296	2343.49	95.258	-0.63	105.296	-0.812	95.714	1382.89	0	64.143	59.329
5.36	1301.819	1309.776	98.143	1379.485	2344.488	95.504	-0.6	105.296	-0.731	96.337	1382.89	0	64.359	59.383
5.383	1302.314	1311.726	98.266	1379.485	2345.484	95.381	-0.58	105.669	-0.812	96.088	1381.84	0	64.413	59.329
5.411	1302.314	1314.163	98.388	1380.296	2346.483	95.75	-0.55	105.917	-0.812	96.337	1381.84	0	64.521	59.166
5.434	1302.81	1315.625	98.511	1379.485	2347.48	95.996	-0.53	106.165	-0.65	96.711	1382.89	0	64.629	59.22
5.461	1303.801	1317.087	98.878	1379.485	2347.48	95.873	-0.5	106.414	-0.731	96.711	1382.89	0.001	64.683	59.274
5.485	1304.791	1317.574	98.878	1379.485	2348.477	96.365	-0.48	106.29	-0.812	96.96	1381.84	0	64.737	59.058
5.508	1306.278	1318.062	99.001	1380.296	2349.474	96.119	-0.45	106.538	-0.812	97.085	1382.89	0.001	64.845	59.166
5.536	1308.259	1318.549	100.103	1380.296	2351.469	96.487	-0.43	106.414	-0.731	97.085	1382.89	4.608	64.953	59.166
5.559	1310.241	1319.523	458.981	1380.296	2353.463	97.102	-0.4	107.283	-0.731	349.331	1382.89	9.53	65.007	71.047

MSFC DATA ON FIRST 11-INCH MOTOR FIRING

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
5.586	1311.727	1319.523	835.135	1379.485	2354.461	102.387	-0.38	112.622	-0.731	1036.527	1381.84	10.24	65.061	101.317
5.61	1313.213	1320.011	906.2	1379.485	2356.455	111.237	-0.35	121.19	-0.812	1314.196	1382.89	10.2	65.277	110.116
5.633	1313.213	1320.986	886.106	1380.296	2357.452	120.087	-0.33	130.006	-0.812	1336.131	1382.89	10.04	65.331	100.943
5.661	1313.709	1322.448	872.873	1379.485	2358.45	128.691	-0.3	138.45	-0.65	1317.686	1382.89	10.03	65.331	90.15
5.684	1314.699	1323.91	870.912	1379.485	2357.452	136.803	-0.28	146.397	-0.569	1312.202	1381.84	10.04	65.439	81.633
5.711	1315.195	1324.885	871.893	1379.485	2359.448	145.899	-0.25	155.337	-0.569	1313.698	1382.89	10.04	65.493	75.781
5.735	1314.699	1325.372	871.893	1379.485	2359.448	156.346	-0.23	165.767	-0.569	1313.698	1382.89	10.04	65.655	71.747
5.758	1314.699	1326.346	871.893	1379.485	2359.448	170.359	-0.2	179.55	-0.325	1322.173	1382.89	10.04	65.601	68.622
5.786	1315.195	1327.321	871.403	1380.296	2359.448	191.254	-0.18	200.411	-0.406	1331.644	1382.89	10.04	65.763	66.68
5.809	1316.186	1328.296	871.403	1379.485	2360.444	244.476	-0.15	253.804	-0.163	1333.638	1382.89	10.04	65.817	65.439
5.836	1317.672	1329.271	871.893	1380.296	2362.438	359.277	-0.13	368.786	0.487	1328.653	1382.89	10.04	65.925	64.467
5.86	1319.654	1329.758	871.893	1379.485	2363.437	504.438	-0.1	513.569	0.974	1323.668	1382.89	10.04	65.979	63.602
5.883	1320.149	1330.245	871.893	1379.485	2364.434	647.51	-0.08	656.365	1.868	1320.677	1382.89	10.04	66.033	62.683
5.911	1320.645	1330.245	873.363	1379.485	2366.427	760.591	-0.05	768.864	2.599	1317.686	1382.89	10.04	66.141	61.926
5.934	1321.635	1330.245	876.794	1380.296	2366.427	834.585	-0.03	843.118	3.005	1316.19	1382.89	10.04	66.141	61.223
5.961	1322.626	1331.22	884.635	1380.296	2366.427	877.113	-0.07	885.833	8.203	1315.193	1382.89	10.04	66.249	60.79
5.985	1323.617	1332.682	903.259	1379.485	2367.426	902.925	-0.05	910.667	13.157	1315.692	1382.89	10.04	66.357	60.52
6.008	1324.112	1333.657	918.942	1379.485	2368.423	919.15	-0.03	924.574	15.837	1316.19	1382.89	10.04	66.357	60.303
6.036	1324.112	1334.144	926.784	1379.485	2368.423	923.821	0	931.031	15.837	1319.181	1382.89	10.04	66.465	60.195
6.059	1324.112	1335.119	932.666	1379.485	2369.42	927.508	0.023	936.494	15.187	1324.167	1382.89	10.04	66.572	60.249
6.086	1324.112	1335.606	934.626	1380.296	2369.42	929.229	0.05	938.978	15.674	1326.659	1382.89	10.04	66.572	60.357
6.11	1324.608	1336.094	931.685	1380.296	2369.42	925.541	0.074	935.004	16.162	1328.155	1382.89	10.04	66.734	60.411
6.133	1325.103	1337.068	928.745	1380.296	2370.417	923.083	0.097	932.521	16.893	1329.152	1382.89	10.04	66.68	60.466
6.161	1326.094	1337.556	923.354	1380.296	2370.417	917.429	0.125	926.561	16.811	1331.146	1381.84	10.04	66.734	60.466
6.184	1327.085	1338.043	916.002	1380.296	2371.415	910.3	0.148	919.607	16.974	1331.644	1382.89	10.04	66.842	60.249
6.211	1327.58	1338.531	909.631	1379.485	2372.412	904.4	0.175	913.15	17.055	1331.146	1382.89	10.04	66.896	60.141
6.235	1328.076	1338.043	901.789	1380.296	2372.412	896.042	0.199	905.203	17.542	1330.149	1381.84	10.04	66.896	60.195
6.258	1329.066	1338.531	894.437	1379.485	2373.409	888.421	0.222	897.753	17.867	1328.155	1382.89	10.04	67.004	59.924
6.286	1329.066	1339.018	887.576	1379.485	2373.409	882.276	0.25	891.296	18.436	1326.161	1382.89	10.04	66.95	59.653
6.309	1330.057	1339.992	883.165	1380.296	2374.406	876.13	0.273	885.336	18.842	1309.211	1381.84	5.643	67.004	59.383
6.336	1330.553	1340.967	883.165	1380.296	2374.406	874.901	0.3	883.846	19.329	1212.002	1373.46	0.587	67.058	56.944
6.36	1330.553	1340.967	937.076	1379.485	2374.406	879.08	0.324	888.316	19.735	1099.339	1367.17	-0.407	67.058	51.512

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
6.383	1330.553	1341.455	1031.176	1378.673	2375.404	882.03	0.347	891.296	20.141	1074.912	1370.32	-0.168	67.112	45.625
6.411	1330.553	1341.942	1109.102	1379.485	2375.404	878.343	0.375	887.323	20.628	1118.781	1370.32	-0.003	67.22	43.549
6.434	1331.048	1342.917	1150.761	1378.673	2375.404	878.588	0.398	887.819	20.791	1162.65	1370.32	0.018	67.274	45.625
6.461	1332.039	1343.404	1177.227	1378.673	2376.401	879.817	0.425	888.813	21.278	1193.557	1372.41	0.007	67.166	51.131
6.485	1332.534	1343.891	1203.692	1378.673	2377.398	879.08	0.449	888.316	22.253	1220.477	1371.36	0.002	67.328	61.71
6.508	1332.534	1343.891	1228.197	1377.862	2377.398	880.801	0.472	889.806	23.227	1245.402	1371.36	0.001	67.328	72.985
6.536	1333.03	1344.379	1251.722	1378.673	2378.395	881.047	0.5	890.303	24.121	1268.334	1372.41	0.001	67.274	79.863
6.559	1334.021	1344.379	1273.777	1378.673	2378.395	883.997	0.523	892.786	24.933	1290.268	1372.41	0.001	67.436	82.438
6.586	1334.021	1344.866	1293.381	1378.673	2379.394	886.455	0.55	895.766	25.826	1310.208	1372.41	0.001	67.544	82.599
6.61	1334.516	1344.866	1311.515	1377.862	2379.394	888.913	0.574	897.753	26.313	1328.653	1372.41	0.001	67.382	81.526
6.633	1334.516	1345.841	1329.158	1377.862	2380.39	890.388	0.597	899.243	26.395	1345.603	1372.41	0.001	67.544	80.024
6.661	1335.011	1346.328	1344.842	1377.862	2380.39	890.634	0.625	899.243	26.557	1361.056	1373.46	0.001	67.544	78.36
6.684	1335.507	1346.328	1359.545	1377.862	2380.39	893.092	0.648	902.223	26.719	1375.015	1373.46	0.001	67.49	76.748
6.711	1335.507	1346.328	1371.797	1377.051	2380.39	892.109	0.675	900.733	26.801	1387.478	1373.46	0.001	67.544	75.297
6.735	1336.002	1347.303	1383.56	1377.862	2381.387	893.83	0.699	902.72	26.882	1398.943	1373.46	0.001	67.651	73.953
6.758	1336.002	1347.303	1394.342	1377.862	2381.387	897.763	0.722	906.693	27.207	1409.412	1373.46	0.001	67.597	72.877
6.786	1336.002	1347.79	1403.654	1377.051	2381.387	900.467	0.75	909.673	142.613	1418.884	1373.46	0.001	67.597	71.801
6.809	1336.498	1347.79	1411.496	1377.051	2381.387	902.679	0.773	911.163	499.876	1427.358	1373.46	0.001	67.651	70.885
6.836	1336.993	1348.278	1419.337	1377.051	2382.384	905.138	0.8	913.647	793.386	1434.337	1374.51	0.001	67.705	70.077
6.86	1337.489	1348.278	1425.219	1377.051	2382.384	903.663	0.824	912.654	894.742	1440.818	1374.51	0.001	67.813	69.323
6.883	1337.489	1348.765	1430.61	1377.051	2383.381	902.188	0.847	911.163	905.137	1446.8	1374.51	0.001	67.813	68.622
6.911	1337.489	1348.765	1436.001	1376.239	2383.381	902.679	0.875	911.163	885.971	1451.287	1373.46	0.001	67.651	68.029
6.934	1337.984	1349.252	1440.412	1377.051	2383.381	904.154	0.898	913.15	847.962	1455.773	1374.51	0.001	67.759	67.49
6.961	1338.479	1349.252	1444.823	1377.051	2384.38	904.646	0.925	913.15	835.293	1459.263	1374.51	0.001	67.813	66.95
6.985	1338.479	1349.74	1448.743	1377.051	2384.38	902.188	0.949	910.667	834.968	1462.752	1374.51	0.001	67.813	66.465
7.008	1338.479	1349.74	1450.214	1376.239	2383.381	903.908	0.972	912.654	832.369	1465.245	1374.51	0.001	67.813	65.925
7.036	1338.975	1350.227	1453.645	1376.239	2384.38	906.367	1	914.64	845.039	1467.738	1373.46	0.001	67.813	65.655
7.059	1338.975	1350.227	1455.605	1376.239	2384.38	902.925	1.023	911.66	846.338	1469.732	1374.51	0.001	67.759	65.223
7.086	1338.975	1350.227	1456.095	1376.239	2384.38	904.154	1.05	913.15	837.242	1471.227	1374.51	0.001	67.813	65.007
7.11	1339.47	1350.714	1457.565	1376.239	2385.376	906.613	1.074	915.137	836.267	1472.224	1374.51	0.001	67.705	64.629
7.133	1339.47	1351.202	1459.526	1376.239	2386.374	907.35	1.097	916.13	834.968	1474.218	1374.51	0.001	67.867	64.413
7.161	1339.47	1351.202	1460.506	1375.428	2385.376	908.088	1.125	916.627	822.623	1475.215	1374.51	0.001	67.867	64.143

MSFC DATA ON FIRST 11-INCH MOTOR FIRING

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
7.184	1339.966	1351.202	1460.996	1375.428	2385.376	909.317	1.148	918.117	813.527	1476.212	1374.51	0.001	67.867	63.873
7.211	1339.966	1351.202	1462.957	1375.428	2385.376	908.825	1.175	917.124	806.38	1476.212	1374.51	0.001	67.759	63.71
7.235	1339.966	1351.202	1463.447	1375.428	2386.374	907.104	1.199	915.634	798.259	1477.708	1374.51	0.001	67.921	63.494
7.258	1340.461	1351.689	1464.427	1375.428	2386.374	906.613	1.222	915.137	790.137	1478.206	1374.51	0.001	67.813	63.332
7.286	1340.461	1351.689	1464.427	1375.428	2386.374	907.842	1.25	916.13	781.691	1479.203	1374.51	0	67.921	63.224
7.309	1340.956	1352.177	1464.427	1374.616	2387.37	908.333	1.273	916.627	770.971	1479.203	1374.51	0.001	67.813	63.116
7.336	1340.956	1352.177	1464.917	1374.616	2387.37	908.088	1.3	917.124	764.473	1479.702	1374.51	0.001	67.867	62.954
7.36	1340.956	1352.664	1465.897	1374.616	2387.37	907.35	1.324	915.634	764.149	1480.2	1374.51	0.001	67.867	62.846
7.383	1340.956	1352.664	1465.407	1373.805	2387.37	905.138	1.347	913.15	753.753	1480.2	1374.51	0.001	67.813	62.683
7.411	1340.956	1352.664	1465.897	1373.805	2387.37	902.679	1.375	911.163	747.256	1480.2	1374.51	0.001	67.813	62.629
7.434	1340.956	1352.664	1466.387	1374.616	2388.369	901.942	1.398	910.17	747.256	1480.699	1374.51	0	67.921	62.521
7.461	1341.452	1352.664	1466.877	1374.616	2388.369	901.45	1.425	909.673	753.104	1481.197	1374.51	0	67.921	62.413
7.485	1341.452	1352.664	1467.857	1373.805	2388.369	898.254	1.449	906.197	757.976	1481.197	1374.51	0	67.813	62.413
7.508	1341.452	1353.151	1466.387	1373.805	2388.369	896.288	1.472	904.707	760.25	1481.197	1374.51	0.001	67.759	62.197
7.536	1341.452	1353.151	1466.877	1374.616	2388.369	897.025	1.5	905.203	760.9	1481.696	1374.51	0	67.759	62.197
7.559	1341.452	1353.151	1468.348	1373.805	2388.369	898.5	1.523	906.693	763.499	1481.696	1375.56	0	67.759	62.143
7.586	1341.452	1353.151	1467.857	1373.805	2388.369	896.042	1.55	904.21	762.199	1481.696	1374.51	0.001	67.813	62.143
7.61	1341.947	1353.638	1467.367	1374.616	2389.366	891.863	1.574	899.74	757.327	1481.696	1374.51	0.001	67.813	61.981
7.633	1341.947	1353.638	1467.367	1374.616	2389.366	892.846	1.597	901.23	757.652	1481.696	1374.51	0	67.813	62.035
7.661	1341.947	1353.638	1467.857	1373.805	2389.366	891.617	1.625	899.74	758.626	1482.194	1374.51	0.001	67.759	61.981
7.684	1341.947	1354.126	1467.857	1373.805	2389.366	893.584	1.648	901.726	762.524	1482.194	1374.51	0.001	67.759	61.981
7.711	1341.947	1354.126	1468.838	1373.805	2389.366	893.83	1.675	901.726	763.824	1482.194	1375.56	0	67.759	61.872
7.735	1341.947	1353.638	1468.838	1373.805	2389.366	891.617	1.699	899.74	761.225	1482.194	1374.51	0	67.813	61.926
7.758	1341.947	1354.126	1467.857	1373.805	2389.366	890.88	1.722	898.746	757.652	1482.194	1375.56	0.001	67.759	61.872
7.786	1342.443	1354.126	1468.348	1373.805	2390.363	890.634	1.75	898.25	753.428	1482.194	1374.51	0	67.705	61.764
7.809	1342.443	1354.126	1468.838	1373.805	2389.366	887.93	1.773	896.263	749.205	1482.194	1374.51	0.001	67.651	61.71
7.836	1342.443	1354.126	1468.838	1373.805	2389.366	887.684	1.8	895.766	747.581	1482.693	1374.51	0	67.597	61.656
7.86	1342.443	1354.126	1467.857	1373.805	2390.363	888.176	1.824	896.263	746.931	1482.693	1374.51	0	67.705	61.71
7.883	1342.443	1354.126	1468.348	1373.805	2390.363	886.455	1.847	894.276	743.358	1482.693	1374.51	0	67.597	61.71
7.911	1342.443	1354.126	1469.328	1373.805	2390.363	884.734	1.875	892.29	738.485	1482.693	1374.51	0	67.759	61.656
7.934	1342.443	1353.638	1469.818	1372.994	2390.363	882.03	1.898	889.806	731.988	1482.693	1374.51	0.001	67.651	61.548
7.961	1342.938	1354.126	1468.838	1373.805	2390.363	883.751	1.925	891.296	731.013	1482.693	1374.51	0	67.651	61.71

MSFC DATA ON FIRS[illegible]1-INCH MOTOR FIRING

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
7.985	1342.443	1354.126	1468.838	1373.805	2390.363	883.997	1.949	891.793	725.166	1482.693	1374.51	0	67.597	61.548
8.008	1342.938	1354.126	1469.328	1373.805	2390.363	884.488	1.972	892.786	716.07	1482.693	1374.51	0	67.597	61.548
8.036	1341.947	1354.126	1468.348	1372.994	2390.363	885.471	2	893.283	710.547	1482.194	1374.51	0.001	67.49	61.548
8.059	1342.443	1354.126	1468.838	1373.805	2390.363	883.505	2.023	891.296	670.914	1482.693	1374.51	0.001	67.544	61.44
8.086	1342.443	1354.126	1469.328	1373.805	2391.36	880.063	2.05	887.819	553.153	1482.693	1374.51	0.001	67.544	61.548
8.11	1342.443	1354.613	1469.818	1373.805	2391.36	881.047	2.074	889.309	492.404	1482.693	1374.51	0	67.544	61.494
8.133	1342.443	1354.126	1469.818	1372.994	2391.36	879.817	2.097	887.323	512.708	1482.693	1374.51	0.001	67.382	61.44
8.161	1342.443	1354.613	1469.818	1373.805	2391.36	879.326	2.125	887.323	526.515	1482.693	1374.51	0	67.49	61.44
8.184	1342.938	1354.126	1469.328	1372.994	2391.36	881.292	2.148	889.309	522.454	1482.693	1374.51	0	67.382	61.494
8.211	1342.938	1354.126	1468.838	1373.805	2391.36	880.063	2.175	887.819	518.231	1482.693	1374.51	0	67.49	61.385
8.235	1342.443	1354.126	1469.818	1372.994	2391.36	876.867	2.199	884.839	508.81	1482.693	1374.51	0.001	67.328	61.44
8.258	1342.443	1354.613	1469.818	1373.805	2391.36	877.359	2.222	885.336	487.694	1482.693	1374.51	0	67.382	61.385
8.286	1342.443	1354.613	1469.328	1373.805	2391.36	876.13	2.25	883.846	477.461	1482.693	1374.51	0.001	67.274	61.44
8.309	1342.443	1354.126	1469.818	1373.805	2391.36	875.393	2.273	883.349	487.531	1483.191	1374.51	0	67.22	61.385
8.336	1342.443	1354.126	1469.818	1372.994	2391.36	875.147	2.3	882.853	488.993	1482.693	1374.51	0	67.274	61.385
8.36	1342.443	1354.613	1469.328	1373.805	2391.36	874.409	2.324	881.859	474.375	1483.191	1374.51	0.001	67.328	61.385
8.383	1342.443	1354.613	1468.838	1373.805	2391.36	871.705	2.347	879.376	460.243	1482.693	1374.51	0	67.274	61.331
8.411	1342.443	1354.613	1469.818	1372.994	2391.36	871.705	2.375	879.376	443.838	1482.693	1374.51	0	67.22	61.277
8.434	1342.443	1354.613	1469.818	1372.994	2392.358	870.722	2.398	878.382	431.168	1482.693	1374.51	0	67.112	61.331
8.461	1342.443	1354.613	1470.308	1373.805	2392.358	868.755	2.425	876.396	413.139	1482.693	1374.51	0	67.274	61.277
8.485	1342.443	1354.613	1469.328	1372.994	2391.36	869.493	2.449	877.389	404.855	1482.693	1374.51	0	67.166	61.223
8.508	1342.443	1354.613	1469.328	1373.805	2392.358	868.018	2.472	875.402	409.89	1483.191	1374.51	0	67.112	61.223
8.536	1342.443	1354.126	1470.308	1372.994	2392.358	866.297	2.5	873.912	406.479	1482.693	1374.51	0	67.058	61.277
8.559	1342.443	1354.126	1470.798	1372.994	2392.358	865.805	2.523	873.416	413.139	1483.191	1374.51	0	67.004	61.277
8.586	1342.443	1354.126	1469.818	1372.994	2392.358	864.822	2.55	872.422	423.209	1482.693	1374.51	0.001	67.112	61.223
8.61	1342.443	1354.126	1469.818	1372.994	2392.358	862.364	2.574	869.939	422.397	1483.191	1374.51	0.001	66.95	61.277
8.633	1342.443	1354.126	1469.328	1372.994	2392.358	863.101	2.597	870.932	423.697	1482.693	1374.51	0.001	66.95	61.223
8.661	1342.443	1354.613	1469.818	1372.994	2392.358	860.151	2.625	867.455	425.483	1482.693	1374.51	0	66.95	61.277
8.684	1342.443	1354.126	1470.798	1372.994	2392.358	860.643	2.648	867.952	430.356	1482.693	1374.51	0.001	66.95	61.115
8.711	1341.947	1354.126	1470.798	1372.994	2392.358	860.889	2.675	868.449	429.057	1483.191	1374.51	0	66.896	61.277
8.735	1341.947	1354.126	1469.818	1372.994	2392.358	858.922	2.699	866.462	423.047	1483.191	1374.51	0	66.842	61.115
8.758	1341.947	1354.126	1470.308	1372.994	2392.358	858.185	2.722	865.469	420.286	1483.191	1374.51	0	66.788	61.169

MSFC DATA ON FIRST 11-INCH MOTOR FIRING

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
8.786	1342.443	1354.126	1470.308	1372.994	2392.358	856.956	2.75	864.972	415.738	1483.191	1374.51	0	66.68	61.169
8.809	1341.947	1354.126	1469.818	1372.994	2392.358	856.956	2.773	864.475	411.677	1483.191	1374.51	0	66.68	61.169
8.836	1341.947	1354.126	1469.328	1372.994	2392.358	855.48	2.8	862.985	411.677	1483.191	1374.51	0	66.734	61.223
8.86	1341.947	1354.126	1469.818	1372.994	2392.358	854.743	2.824	861.992	415.413	1483.191	1374.51	0	66.734	61.277
8.883	1341.947	1354.126	1469.818	1372.994	2392.358	853.514	2.847	860.999	417.524	1483.191	1374.51	0	66.626	61.115
8.911	1342.443	1354.126	1470.308	1372.994	2392.358	852.285	2.875	860.005	409.403	1483.191	1374.51	0	66.626	61.115
8.934	1341.947	1354.126	1469.818	1372.994	2392.358	851.301	2.898	858.515	407.129	1483.191	1374.51	0	66.572	61.169
8.961	1341.947	1354.126	1470.308	1372.182	2393.355	851.793	2.925	859.012	407.616	1483.191	1374.51	0	66.572	61.115
8.985	1341.947	1353.638	1469.818	1372.994	2393.355	852.039	2.949	859.509	401.931	1483.191	1374.51	0	66.572	61.061
9.008	1341.947	1354.126	1470.308	1372.994	2392.358	849.826	2.972	857.025	398.033	1483.191	1374.51	0	66.465	61.169
9.036	1341.452	1353.638	1470.798	1372.994	2392.358	848.597	3	856.032	398.195	1483.191	1374.51	0	66.465	61.115
9.059	1341.452	1354.126	1470.308	1372.994	2392.358	850.81	3.023	858.515	401.606	1483.191	1374.51	0.001	66.411	61.007
9.086	1341.452	1353.638	1470.798	1372.994	2393.355	847.86	3.05	855.535	399.495	1483.191	1374.51	0.001	66.518	61.115
9.11	1341.452	1353.638	1470.798	1372.994	2393.355	844.172	3.074	851.562	397.221	1483.191	1374.51	0	66.357	61.061
9.133	1341.452	1353.638	1470.798	1372.994	2393.355	843.189	3.097	850.568	394.947	1483.191	1374.51	0	66.411	61.061
9.161	1341.452	1353.638	1470.308	1372.994	2393.355	845.647	3.125	852.555	394.947	1483.191	1374.51	0	66.303	61.061
9.184	1341.452	1353.638	1470.798	1372.994	2393.355	842.698	3.148	850.072	398.683	1483.69	1374.51	0.001	66.249	61.061
9.211	1341.452	1353.638	1470.798	1372.994	2393.355	837.781	3.175	845.105	396.246	1483.69	1374.51	0	66.249	61.007
9.235	1341.452	1353.151	1470.308	1372.994	2393.355	838.272	3.199	845.601	396.896	1483.191	1374.51	0	66.249	61.061
9.258	1341.452	1353.638	1470.308	1372.994	2393.355	839.01	3.222	846.098	401.119	1483.191	1374.51	0	66.195	61.061
9.286	1341.452	1353.151	1469.818	1372.994	2393.355	838.764	3.25	846.098	400.957	1483.191	1374.51	0	66.195	61.061
9.309	1341.452	1353.151	1470.798	1372.994	2393.355	838.027	3.273	845.105	404.53	1483.69	1374.51	0.001	66.141	61.061
9.336	1340.956	1353.151	1470.798	1372.182	2393.355	837.289	3.3	844.608	412.164	1483.191	1374.51	0	66.087	61.061
9.36	1340.956	1353.151	1470.798	1372.182	2393.355	834.585	3.324	841.628	413.789	1483.191	1374.51	0.001	66.033	61.061
9.383	1340.956	1353.151	1471.288	1372.994	2393.355	831.881	3.347	839.145	406.804	1483.191	1375.56	0	65.979	61.061
9.411	1340.956	1353.151	1470.308	1372.994	2393.355	832.127	3.375	839.641	399.17	1483.191	1375.56	0	66.033	61.007
9.434	1340.956	1352.664	1470.798	1372.182	2393.355	831.389	3.398	838.648	399.982	1483.191	1374.51	0	65.925	61.007
9.461	1340.956	1352.664	1469.818	1372.182	2393.355	830.406	3.425	837.654	408.916	1483.69	1374.51	0	65.979	61.115
9.485	1340.956	1352.664	1470.308	1372.994	2393.355	828.439	3.449	835.668	427.92	1483.191	1374.51	0	65.871	61.007
9.508	1340.956	1352.664	1470.798	1372.994	2393.355	828.439	3.472	835.668	443.676	1483.69	1374.51	0	65.925	61.061
9.536	1340.461	1352.177	1470.798	1372.182	2393.355	828.194	3.5	835.171	443.676	1483.191	1374.51	0	65.871	60.953
9.559	1340.461	1352.177	1470.308	1372.994	2393.355	824.506	3.523	831.694	442.864	1483.69	1374.51	0	65.817	61.007

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
9.586	1340.461	1352.177	1469.818	1372.182	2393.355	823.031	3.55	830.204	437.828	1483.69	1374.51	0	65.763	61.115
9.61	1340.461	1352.664	1469.818	1372.994	2393.355	824.014	3.574	831.198	431.818	1483.69	1374.51	0	65.817	60.953
9.633	1340.461	1352.664	1470.308	1372.182	2394.352	824.26	3.597	831.198	433.605	1483.69	1374.51	0	65.709	61.007
9.661	1340.461	1352.177	1469.818	1372.182	2393.355	823.031	3.625	830.204	431.818	1483.191	1374.51	0	65.655	61.061
9.684	1340.461	1352.177	1470.308	1372.182	2393.355	822.048	3.648	829.211	436.204	1483.69	1374.51	0	65.655	61.007
9.711	1340.461	1352.664	1470.308	1372.182	2393.355	823.031	3.675	830.204	437.503	1483.191	1374.51	0.001	65.601	60.953
9.735	1339.966	1352.177	1470.308	1372.182	2393.355	819.098	3.699	826.231	436.529	1483.191	1374.51	0	65.601	61.007
9.758	1339.966	1352.177	1470.798	1372.182	2393.355	818.115	3.722	825.237	433.28	1483.191	1374.51	0	65.547	61.007
9.786	1339.966	1352.177	1470.798	1372.182	2394.352	820.081	3.75	827.224	428.407	1483.69	1374.51	0	65.547	61.061
9.809	1339.966	1352.177	1470.798	1372.182	2393.355	820.081	3.773	827.224	433.93	1483.69	1374.51	0.001	65.547	60.953
9.836	1339.966	1352.177	1470.308	1372.182	2393.355	817.869	3.8	824.989	438.803	1483.69	1374.51	0	65.493	61.061
9.86	1339.966	1351.689	1469.818	1372.182	2393.355	815.902	3.824	823.002	434.255	1483.191	1374.51	0	65.439	60.953
9.883	1339.966	1351.689	1470.798	1372.182	2393.355	816.148	3.847	823.499	431.656	1483.69	1374.51	0	65.439	60.953
9.911	1339.966	1351.689	1471.288	1372.182	2393.355	815.165	3.875	822.257	429.869	1483.69	1374.51	0	65.331	60.953
9.934	1339.966	1351.689	1470.308	1372.182	2393.355	811.477	3.898	819.029	425.971	1483.69	1374.51	0	65.331	60.899
9.961	1339.47	1351.689	1470.308	1372.182	2393.355	810.986	3.925	817.787	420.448	1483.191	1374.51	0.001	65.169	60.953
9.985	1339.47	1351.689	1470.798	1372.182	2393.355	811.723	3.949	819.277	421.423	1483.69	1374.51	0	65.331	60.844
10.01	1339.47	1351.689	1470.798	1372.182	2393.355	810.248	3.972	817.539	424.346	1483.191	1374.51	0	65.169	60.899
10.04	1339.47	1351.689	1470.798	1372.182	2394.352	808.527	4	815.552	429.219	1483.191	1374.51	0.001	65.169	60.899
10.06	1339.47	1351.202	1470.308	1372.182	2393.355	808.036	4.023	814.807	430.519	1483.191	1374.51	0	65.169	60.899
10.09	1339.47	1351.202	1470.308	1372.182	2394.352	809.511	4.05	816.297	432.468	1483.69	1374.51	0	65.115	61.007
10.11	1339.47	1351.202	1470.798	1372.182	2393.355	808.773	4.074	815.801	434.742	1483.69	1374.51	0	65.061	60.953
10.13	1338.975	1351.202	1470.308	1372.182	2393.355	804.84	4.097	812.075	428.082	1483.69	1374.51	0	65.169	60.899
10.16	1338.975	1350.714	1470.798	1372.182	2393.355	802.382	4.125	809.095	422.397	1483.69	1374.51	0	64.899	60.953
10.18	1338.975	1350.714	1469.818	1372.182	2393.355	802.136	4.148	809.095	420.936	1483.191	1374.51	0	64.953	60.844
10.21	1338.975	1350.714	1470.798	1372.182	2393.355	802.873	4.175	809.84	422.073	1483.69	1374.51	0	65.007	60.899
10.24	1338.975	1350.714	1470.308	1372.182	2393.355	801.398	4.199	808.35	430.519	1483.69	1374.51	0	64.953	60.899
10.26	1338.975	1350.714	1469.818	1372.182	2393.355	800.415	4.222	807.357	445.3	1483.69	1374.51	0	64.953	60.899
10.29	1338.975	1350.714	1469.818	1372.182	2394.352	799.432	4.25	806.612	449.848	1483.69	1374.51	0	64.845	60.899
10.31	1338.479	1350.714	1469.818	1372.182	2393.355	799.677	4.273	806.364	439.29	1483.69	1374.51	0	64.845	60.844
10.34	1338.479	1350.714	1470.798	1372.182	2393.355	799.186	4.3	805.867	436.691	1483.69	1374.51	0	64.791	60.844
10.36	1338.479	1350.714	1470.308	1372.182	2394.352	796.973	4.324	803.88	431.656	1483.69	1374.51	0	64.791	60.899

MSFC DATA ON FIRST 11-INCH MOTOR FIRING

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
10.38	1338.479	1350.227	1470.798	1372.182	2393.355	795.007	4.347	801.893	427.433	1483.69	1374.51	0	64.791	60.953
10.41	1338.479	1350.227	1470.798	1372.182	2394.352	795.253	4.375	802.142	424.022	1483.69	1374.51	0	64.737	60.844
10.43	1337.984	1350.714	1469.818	1372.182	2393.355	793.778	4.398	800.403	424.184	1483.69	1374.51	0	64.737	60.844
10.46	1338.479	1350.227	1470.308	1372.182	2393.355	793.286	4.425	800.155	429.544	1483.69	1374.51	0	64.629	60.899
10.49	1337.984	1350.227	1470.308	1372.182	2393.355	790.582	4.449	797.672	430.031	1483.69	1374.51	0	64.629	61.007
10.51	1337.984	1350.227	1470.798	1371.371	2394.352	789.844	4.472	796.927	425.646	1483.69	1374.51	0	64.629	60.844
10.54	1337.984	1350.227	1470.308	1372.182	2394.352	789.599	4.5	796.678	419.961	1483.69	1374.51	0	64.575	60.899
10.56	1337.984	1349.74	1470.308	1371.371	2393.355	788.369	4.523	795.188	423.047	1483.69	1374.51	0	64.521	60.79
10.59	1337.489	1349.74	1470.798	1371.371	2393.355	787.878	4.55	794.691	421.423	1483.69	1374.51	0.001	64.575	60.953
10.61	1337.984	1349.74	1470.308	1371.371	2394.352	788.369	4.574	795.437	420.773	1483.191	1374.51	0.001	64.521	60.899
10.63	1337.489	1349.252	1471.288	1372.182	2394.352	787.632	4.597	794.443	419.961	1483.69	1374.51	0	64.467	60.899
10.66	1337.489	1349.74	1471.288	1371.371	2394.352	787.878	4.625	794.691	422.56	1483.69	1374.51	0	64.413	60.953
10.68	1337.489	1349.252	1470.798	1372.182	2393.355	785.665	4.648	792.705	424.671	1483.69	1374.51	0.001	64.359	60.899
10.71	1337.489	1349.74	1469.818	1371.371	2394.352	782.961	4.675	789.725	428.895	1483.69	1374.51	0	64.359	60.79
10.74	1337.489	1349.252	1470.308	1372.182	2393.355	782.715	4.699	789.725	431.818	1483.69	1374.51	0	64.305	60.899
10.76	1337.489	1349.252	1470.308	1371.371	2393.355	783.207	4.722	789.973	431.656	1483.69	1374.51	0	64.251	60.953
10.79	1336.993	1349.252	1470.308	1372.182	2393.355	781.978	4.75	788.731	431.656	1483.69	1374.51	0	64.305	60.844
10.81	1336.993	1349.252	1470.308	1371.371	2393.355	780.503	4.773	786.993	429.869	1483.69	1374.51	0	64.251	60.899
10.84	1336.993	1349.252	1470.798	1371.371	2393.355	777.799	4.8	784.509	432.63	1483.69	1374.51	0	64.305	60.844
10.86	1336.993	1349.252	1470.798	1371.371	2393.355	777.062	4.824	784.013	434.905	1483.69	1374.51	0	64.251	60.844
10.88	1336.993	1348.765	1471.288	1371.371	2393.355	776.816	4.847	783.516	435.067	1483.69	1374.51	0.001	64.143	60.844
10.91	1336.993	1348.765	1470.798	1372.182	2393.355	775.586	4.875	782.274	432.63	1483.69	1374.51	0	64.197	60.844
10.93	1336.498	1348.765	1470.308	1371.371	2393.355	773.62	4.898	780.536	431.656	1483.69	1374.51	0	64.197	60.844
10.96	1336.498	1348.765	1470.798	1371.371	2393.355	773.374	4.925	780.039	433.443	1483.69	1374.51	0	64.035	60.844
10.99	1336.002	1348.278	1470.798	1371.371	2393.355	771.407	4.949	778.052	431.168	1483.69	1374.51	0	64.089	60.79
11.01	1336.498	1348.278	1470.308	1371.371	2393.355	773.128	4.972	780.039	429.382	1483.69	1374.51	0	63.981	60.736
11.04	1336.498	1348.765	1470.798	1371.371	2393.355	773.374	5	779.791	432.63	1483.69	1374.51	0	63.981	60.844
11.06	1336.498	1348.278	1470.308	1371.371	2393.355	772.636	5.023	779.294	436.204	1484.188	1374.51	0.001	63.981	60.79
11.09	1336.002	1347.79	1470.308	1371.371	2393.355	769.932	5.05	776.811	440.265	1483.69	1374.51	0	63.981	60.736
11.11	1336.002	1348.278	1470.798	1371.371	2393.355	767.966	5.074	774.824	444.813	1483.69	1374.51	0	63.981	60.899
11.13	1336.002	1347.79	1470.798	1371.371	2394.352	769.932	5.097	776.563	449.848	1483.69	1374.51	0	63.927	60.844
11.16	1336.002	1347.79	1470.798	1371.371	2393.355	768.458	5.125	775.073	452.772	1483.69	1374.51	0	63.873	60.79

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
11.18	1335.507	1348.278	1469.818	1371.371	2393.355	767.72	5.148	774.576	452.934	1483.69	1374.51	0	63.873	60.844
11.21	1336.002	1348.278	1470.798	1371.371	2393.355	765.508	5.175	772.341	454.071	1484.188	1374.51	0	63.873	60.844
11.24	1335.507	1347.79	1471.288	1371.371	2393.355	764.278	5.199	771.099	458.294	1483.69	1374.51	0	63.873	60.899
11.26	1335.507	1347.79	1471.288	1371.371	2393.355	764.278	5.222	770.851	462.355	1483.69	1374.51	0	63.765	60.844
11.29	1335.507	1347.79	1470.308	1371.371	2393.355	762.803	5.25	769.857	467.39	1483.69	1374.51	0.001	63.765	60.899
11.31	1335.507	1347.79	1471.778	1371.371	2393.355	763.541	5.273	770.354	477.948	1483.69	1374.51	0	63.656	60.899
11.34	1335.507	1347.303	1471.288	1371.371	2393.355	764.77	5.3	771.596	487.044	1483.69	1374.51	0	63.765	60.79
11.36	1335.507	1347.303	1471.288	1371.371	2393.355	762.558	5.324	769.112	495.49	1484.188	1374.51	0	63.71	60.953
11.38	1335.011	1347.303	1471.778	1371.371	2393.355	759.854	5.347	766.38	504.099	1483.69	1374.51	0	63.602	60.844
11.41	1335.011	1347.303	1470.798	1371.371	2393.355	758.378	5.375	765.139	508.81	1484.188	1374.51	0	63.602	60.899
11.43	1335.011	1347.303	1470.308	1371.371	2393.355	758.133	5.398	764.89	513.845	1484.188	1374.51	0	63.548	60.844
11.46	1335.011	1347.303	1470.308	1371.371	2393.355	756.412	5.425	762.656	524.565	1483.69	1374.51	0.001	63.602	60.899
11.49	1335.011	1346.816	1470.308	1370.56	2393.355	755.92	5.449	762.656	537.397	1483.69	1374.51	0	63.548	60.844
11.51	1335.011	1346.816	1471.288	1371.371	2393.355	753.462	5.472	760.42	547.143	1484.188	1374.51	0.001	63.494	60.844
11.54	1335.011	1346.816	1471.778	1371.371	2393.355	753.216	5.5	759.924	555.589	1484.188	1374.51	0	63.602	60.953
11.56	1334.516	1346.816	1470.308	1371.371	2393.355	752.479	5.523	759.179	562.574	1483.69	1374.51	0	63.494	60.844
11.59	1334.516	1346.328	1470.798	1371.371	2393.355	751.987	5.55	758.682	570.533	1483.191	1374.51	0	63.44	60.844
11.61	1334.516	1346.816	1470.798	1371.371	2393.355	753.462	5.574	759.924	581.253	1484.188	1374.51	0	63.44	60.953
11.63	1334.516	1346.816	1470.798	1371.371	2393.355	753.708	5.597	760.42	590.999	1483.69	1374.51	0	63.494	60.79
11.66	1334.516	1346.328	1470.798	1371.371	2393.355	755.429	5.625	761.91	602.369	1483.69	1374.51	0	63.44	60.736
11.68	1334.021	1346.328	1469.818	1370.56	2393.355	752.479	5.648	758.93	606.917	1483.69	1374.51	0.001	63.386	60.844
11.71	1334.021	1346.328	1470.798	1371.371	2393.355	752.479	5.675	759.179	614.389	1484.188	1374.51	0	63.332	60.844
11.74	1334.021	1346.328	1470.798	1371.371	2393.355	752.479	5.699	759.179	621.536	1484.188	1374.51	0	63.332	60.79
11.76	1334.021	1346.328	1470.798	1371.371	2393.355	751.495	5.722	758.185	630.307	1483.69	1374.51	0	63.332	60.79
11.79	1334.021	1345.841	1471.778	1370.56	2393.355	748.545	5.75	754.957	627.708	1483.191	1374.51	0	63.332	60.844
11.81	1334.516	1345.841	1471.288	1370.56	2393.355	747.316	5.773	753.715	593.923	1483.69	1374.51	0	63.224	60.844
11.84	1333.525	1345.841	1470.308	1371.371	2393.355	747.562	5.8	753.715	585.476	1484.188	1374.51	0	63.278	60.899
11.86	1334.021	1345.841	1470.798	1371.371	2393.355	747.808	5.824	754.46	598.471	1484.188	1374.51	0	63.278	60.899
11.88	1333.525	1345.841	1471.288	1371.371	2393.355	746.087	5.847	752.473	612.44	1483.69	1374.51	0	63.062	60.79
11.91	1333.525	1345.354	1470.798	1371.371	2393.355	746.087	5.875	752.473	622.51	1483.69	1374.51	0	63.224	60.899
11.93	1333.525	1345.841	1470.798	1370.56	2393.355	747.071	5.898	753.467	630.307	1484.188	1374.51	0	63.17	60.844
11.96	1333.525	1345.354	1470.798	1371.371	2393.355	746.333	5.925	752.722	636.154	1483.69	1374.51	0	63.17	60.79

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
11.99	1333.03	1345.354	1471.288	1370.56	2393.355	744.612	5.949	751.48	643.626	1484.188	1374.51	0	63.116	60.79
12.01	1333.525	1345.354	1471.288	1371.371	2393.355	743.629	5.972	749.742	653.047	1484.188	1374.51	0	63.062	60.844
12.04	1333.03	1345.354	1470.798	1370.56	2393.355	741.662	6	748.251	660.519	1484.188	1374.51	0	63.062	60.844
12.06	1333.03	1345.354	1470.798	1371.371	2392.358	740.064	6.023	746.265	666.041	1484.188	1374.51	0.001	63.116	60.79
12.09	1333.03	1344.866	1470.308	1370.56	2393.355	737.36	6.05	743.781	669.615	1483.69	1374.51	0	63.008	60.736
12.11	1333.03	1344.866	1471.288	1370.56	2393.355	736.623	6.074	743.036	672.539	1484.188	1374.51	0	62.954	60.899
12.13	1333.03	1344.866	1471.778	1370.56	2393.355	736.5	6.097	743.036	671.239	1484.188	1374.51	0	62.954	60.79
12.16	1332.534	1344.866	1472.268	1370.56	2393.355	736.254	6.125	742.54	672.214	1484.188	1374.51	0.001	62.954	61.007
12.18	1332.534	1344.866	1471.778	1370.56	2393.355	733.427	6.148	739.808	674.163	1484.188	1374.51	0	62.9	60.899
12.21	1332.534	1344.379	1471.288	1371.371	2393.355	731.706	6.175	738.07	676.437	1484.188	1374.51	0	62.954	60.899
12.24	1332.534	1344.379	1470.798	1370.56	2392.358	731.829	6.199	738.07	678.711	1484.188	1374.51	0	62.954	60.79
12.26	1332.534	1344.866	1470.308	1370.56	2392.358	732.567	6.222	739.063	682.609	1484.188	1374.51	0	62.9	60.844
12.29	1332.534	1344.379	1470.798	1370.56	2392.358	729.617	6.25	736.083	683.584	1484.188	1374.51	0	62.9	60.899
12.31	1332.039	1344.379	1471.288	1370.56	2393.355	726.79	6.273	733.351	682.609	1484.188	1375.56	0	62.846	61.007
12.34	1332.039	1344.379	1471.288	1370.56	2393.355	727.527	6.3	733.848	683.908	1484.188	1374.51	0	62.792	60.899
12.36	1332.039	1344.379	1471.778	1370.56	2392.358	728.142	6.324	734.344	686.832	1484.188	1374.51	0	62.846	60.899
12.38	1332.039	1344.379	1470.798	1370.56	2392.358	725.438	6.347	731.861	687.157	1484.188	1374.51	0	62.792	60.844
12.41	1332.039	1343.891	1469.818	1370.56	2392.358	726.298	6.375	732.854	689.431	1484.188	1374.51	0	62.792	60.899
12.43	1331.543	1343.891	1470.798	1370.56	2393.355	726.79	6.398	733.351	693.979	1484.188	1374.51	0.001	62.792	60.844
12.46	1332.039	1344.379	1470.798	1370.56	2393.355	724.946	6.425	731.365	689.106	1484.188	1374.51	0	62.683	60.844
12.49	1332.039	1343.891	1470.308	1370.56	2393.355	726.421	6.449	732.854	684.233	1484.188	1374.51	0.001	62.738	60.844
12.51	1331.543	1343.404	1470.308	1370.56	2392.358	724.946	6.472	731.365	685.858	1484.188	1374.51	0	62.629	60.899
12.54	1331.543	1343.404	1470.798	1370.56	2393.355	724.577	6.5	730.868	689.106	1484.188	1374.51	0	62.629	60.899
12.56	1331.048	1343.404	1470.798	1370.56	2392.358	723.594	6.523	729.626	691.055	1484.687	1374.51	0	62.629	60.899
12.59	1331.048	1343.404	1470.308	1370.56	2393.355	722.979	6.55	729.378	692.355	1484.188	1375.56	0.001	62.683	60.844
12.61	1331.048	1343.404	1470.308	1370.56	2392.358	722.242	6.574	728.633	693.654	1484.188	1374.51	0	62.629	60.844
12.63	1331.048	1343.404	1470.308	1370.56	2392.358	721.75	6.597	727.888	693.33	1484.188	1374.51	0	62.683	60.899
12.66	1331.048	1343.404	1470.798	1370.56	2392.358	721.873	6.625	727.888	695.279	1484.188	1374.51	0	62.575	60.899
12.68	1331.048	1343.404	1470.798	1369.749	2392.358	720.644	6.648	726.894	696.903	1484.188	1374.51	0	62.629	60.953
12.71	1330.553	1342.917	1471.288	1369.749	2392.358	719.292	6.675	725.653	697.228	1484.188	1374.51	0.001	62.521	60.899
12.74	1331.048	1342.917	1470.798	1370.56	2392.358	717.694	6.699	724.163	696.903	1483.69	1374.51	0.001	62.575	60.844
12.76	1330.553	1343.404	1470.798	1370.56	2392.358	716.834	6.722	722.921	696.578	1483.69	1374.51	0	62.521	60.844

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
12.79	1330.553	1342.917	1470.798	1369.749	2392.358	716.219	6.75	722.424	696.253	1484.188	1374.51	0	62.521	60.953
12.81	1330.553	1342.917	1470.798	1370.56	2392.358	714.007	6.773	720.189	693.005	1484.188	1374.51	0	62.413	60.844
12.84	1330.553	1342.917	1470.798	1370.56	2392.358	714.867	6.8	721.182	693.005	1484.188	1374.51	0.001	62.413	60.844
12.86	1330.553	1342.917	1471.778	1370.56	2392.358	712.778	6.824	719.196	692.03	1484.188	1374.51	0.001	62.521	60.844
12.88	1330.553	1342.429	1471.288	1370.56	2392.358	711.917	6.847	718.202	691.705	1484.188	1374.51	0	62.575	60.899
12.91	1330.553	1342.429	1471.288	1370.56	2392.358	712.778	6.875	718.947	692.355	1484.188	1374.51	0.001	62.359	60.899
12.93	1330.057	1342.917	1469.818	1370.56	2392.358	712.532	6.898	718.699	692.03	1484.188	1374.51	0	62.359	60.899
12.96	1330.057	1342.917	1470.308	1370.56	2392.358	711.302	6.925	717.954	690.731	1483.69	1374.51	0	62.413	60.79
12.99	1330.057	1342.429	1470.798	1369.749	2392.358	710.811	6.949	716.961	689.756	1484.188	1374.51	0	62.359	60.899
13.01	1329.562	1342.429	1470.308	1369.749	2391.36	711.302	6.972	717.706	690.406	1484.188	1374.51	0	62.413	60.844
13.04	1330.057	1341.942	1470.798	1370.56	2392.358	709.582	7	715.719	689.756	1484.687	1374.51	0	62.305	60.79
13.06	1330.057	1342.429	1470.798	1370.56	2392.358	707.861	7.023	713.98	687.807	1484.188	1374.51	0	62.251	60.899
13.09	1329.562	1341.942	1471.778	1370.56	2392.358	704.911	7.05	711	685.208	1484.188	1374.51	0	62.359	60.899
13.11	1329.562	1341.942	1470.798	1369.749	2391.36	706.14	7.074	711.994	684.883	1483.69	1374.51	0	62.305	60.899
13.13	1329.562	1341.942	1470.798	1370.56	2392.358	705.157	7.097	711.249	683.259	1484.188	1374.51	0	62.251	60.899
13.16	1329.562	1341.942	1470.798	1370.56	2392.358	704.788	7.125	710.752	682.609	1483.69	1374.51	0.001	62.251	60.844
13.18	1329.066	1341.455	1472.268	1370.56	2392.358	703.559	7.148	709.51	681.959	1483.69	1374.51	0	62.251	60.953
13.21	1329.562	1341.942	1472.268	1369.749	2392.358	702.822	7.175	708.765	680.985	1484.188	1374.51	0.001	62.197	60.844
13.24	1329.066	1341.942	1471.288	1369.749	2392.358	702.453	7.199	708.517	680.335	1484.188	1374.51	0	62.197	60.899
13.26	1329.066	1341.455	1471.288	1369.749	2391.36	701.592	7.222	707.524	680.66	1484.188	1374.51	0	62.251	60.899
13.29	1329.066	1341.455	1470.798	1369.749	2392.358	701.715	7.25	707.772	680.985	1484.188	1374.51	0	62.251	60.953
13.31	1329.066	1341.455	1470.798	1369.749	2392.358	701.346	7.273	707.524	680.985	1484.188	1374.51	0	62.089	60.844
13.34	1329.066	1341.455	1470.798	1369.749	2392.358	699.994	7.3	706.034	679.685	1484.188	1374.51	0	62.143	60.953
13.36	1329.066	1340.967	1471.288	1369.749	2392.358	699.38	7.324	705.537	679.036	1484.188	1374.51	0	62.143	60.899
13.38	1328.571	1340.967	1471.778	1369.749	2392.358	697.659	7.347	703.799	677.736	1484.188	1374.51	0	62.143	60.899
13.41	1328.571	1340.967	1471.778	1369.749	2391.36	696.553	7.375	702.557	676.437	1484.188	1374.51	0	62.089	60.953
13.43	1329.066	1340.967	1471.778	1369.749	2392.358	696.922	7.398	703.053	673.838	1484.188	1374.51	0	62.197	60.899
13.46	1329.066	1340.967	1470.798	1369.749	2392.358	696.553	7.425	702.557	672.539	1484.188	1374.51	0	62.035	60.844
13.49	1328.571	1340.48	1470.308	1369.749	2391.36	694.955	7.449	701.067	670.589	1484.188	1374.51	0	62.089	60.79
13.51	1328.571	1340.967	1470.308	1369.749	2392.358	693.48	7.472	699.577	669.94	1484.188	1374.51	0	62.089	60.844
13.54	1328.571	1340.48	1471.288	1369.749	2391.36	692.988	7.5	699.08	669.29	1483.69	1374.51	0	61.981	60.953
13.56	1328.076	1340.48	1471.288	1369.749	2391.36	692.988	7.523	699.328	669.94	1484.188	1374.51	0	61.981	60.899

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
Sys-tem Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvan-ometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
13.59	1328.076	1340.48	1471.778	1369.749	2391.36	692.865	7.55	698.832	669.94	1483.69	1374.51	0	62.089	60.953
13.61	1328.076	1340.48	1471.288	1369.749	2391.36	692.742	7.574	698.832	670.264	1484.188	1374.51	0	62.035	60.953
13.63	1328.076	1339.992	1471.288	1369.749	2391.36	692.742	7.597	698.583	670.589	1484.188	1374.51	0.001	62.035	60.844
13.66	1328.076	1340.48	1471.778	1369.749	2391.36	692.374	7.625	698.583	671.239	1484.188	1374.51	0	62.035	60.953
13.68	1328.076	1339.992	1471.288	1369.749	2391.36	691.882	7.648	697.838	671.239	1484.188	1374.51	0	62.035	60.953
13.71	1327.58	1339.992	1471.778	1369.749	2391.36	690.653	7.675	696.597	670.914	1484.188	1374.51	0	62.035	60.953
13.74	1327.58	1339.992	1471.778	1369.749	2391.36	689.547	7.699	695.603	669.615	1484.188	1374.51	0	62.035	60.953
13.76	1327.58	1339.992	1471.778	1370.56	2391.36	689.055	7.722	695.107	669.29	1484.188	1374.51	0	61.981	61.007
13.79	1327.085	1339.992	1472.268	1368.937	2391.36	687.334	7.75	693.616	667.99	1484.188	1374.51	0	61.981	61.061
13.81	1327.58	1339.992	1470.798	1369.749	2391.36	686.351	7.773	692.375	666.691	1484.188	1374.51	0	61.926	61.061
13.84	1327.085	1339.505	1470.308	1368.937	2391.36	685.368	7.8	691.133	665.392	1484.188	1374.51	0	61.926	61.061
13.86	1327.085	1339.505	1471.288	1369.749	2391.36	685.982	7.824	692.126	665.717	1484.188	1374.51	0	61.926	60.899
13.88	1327.085	1339.505	1471.288	1369.749	2391.36	684.753	7.847	690.885	665.067	1484.188	1374.51	0	61.818	60.953
13.91	1327.085	1339.505	1471.288	1369.749	2391.36	684.261	7.875	690.14	663.118	1484.188	1374.51	0	61.872	61.007
13.93	1327.085	1339.018	1470.798	1368.937	2391.36	683.278	7.898	689.395	661.168	1484.188	1374.51	0	61.872	60.953
13.96	1327.085	1339.505	1471.288	1369.749	2391.36	683.77	7.925	689.643	660.844	1484.188	1374.51	0.001	61.872	61.007
13.99	1327.085	1339.505	1470.308	1368.937	2391.36	683.893	7.949	689.891	661.168	1484.687	1374.51	0	61.818	61.007
14.01	1327.085	1339.018	1471.288	1369.749	2391.36	679.345	7.972	685.173	656.945	1484.188	1374.51	0	61.872	60.953
14.04	1326.589	1339.018	1471.288	1368.937	2391.36	677.87	8	683.683	652.397	1484.188	1374.51	0	61.764	60.953
14.06	1326.589	1339.018	1471.288	1369.749	2391.36	676.764	8.023	682.938	650.773	1484.188	1374.51	0	61.818	61.007
14.09	1326.589	1338.531	1471.288	1369.749	2391.36	677.378	8.05	683.683	650.773	1484.188	1374.51	0.001	61.818	61.061
14.11	1326.589	1339.018	1470.798	1369.749	2391.36	677.01	8.074	682.938	651.098	1484.188	1374.51	0	61.764	60.953
14.13	1326.589	1338.531	1470.798	1368.937	2391.36	674.183	8.097	679.958	649.149	1483.69	1374.51	0.001	61.71	60.953
14.16	1326.589	1338.531	1471.288	1369.749	2391.36	673.691	8.125	679.461	648.174	1484.188	1374.51	0	61.71	61.007
14.18	1326.589	1338.531	1470.798	1369.749	2391.36	674.428	8.148	680.455	649.149	1484.188	1374.51	0.001	61.818	60.953
14.21	1326.589	1338.531	1470.798	1368.937	2391.36	673.445	8.175	679.213	648.499	1484.188	1374.51	0	61.71	61.061
14.24	1326.094	1338.531	1470.798	1368.937	2391.36	672.093	8.199	677.971	647.524	1483.69	1374.51	0	61.764	60.953
14.26	1326.094	1338.531	1471.288	1369.749	2391.36	671.847	8.222	677.971	643.626	1484.188	1374.51	0	61.764	61.007
14.29	1326.094	1338.531	1471.288	1369.749	2391.36	671.11	8.25	676.978	640.053	1484.188	1374.51	0	61.71	61.007
14.31	1326.094	1338.531	1470.308	1368.937	2391.36	670.372	8.273	676.233	639.078	1484.188	1374.51	0	61.764	61.007
14.34	1325.599	1338.043	1470.798	1369.749	2391.36	672.462	8.3	678.219	640.702	1484.188	1374.51	0	61.656	61.007
14.36	1326.094	1338.043	1470.798	1368.937	2391.36	670.741	8.324	676.481	641.352	1484.188	1374.51	0	61.764	60.899

MSFC DATA ON FIRST 11-INCH MOTOR FIRING

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
14.38	1325.599	1338.043	1471.288	1369.749	2391.36	670.495	8.347	676.481	642.002	1484.188	1374.51	0	61.71	60.953
14.41	1325.599	1338.043	1471.288	1368.937	2391.36	668.283	8.375	674.246	641.027	1484.188	1374.51	0	61.656	61.007
14.43	1325.599	1337.556	1471.288	1368.937	2391.36	666.931	8.398	673.004	640.053	1484.188	1374.51	0	61.548	60.953
14.46	1325.599	1338.043	1471.288	1369.749	2391.36	666.931	8.425	673.004	640.053	1484.188	1374.51	0	61.602	61.007
14.49	1325.103	1337.556	1471.288	1368.937	2390.363	666.193	8.449	672.011	639.403	1484.188	1374.51	0.001	61.548	61.061
14.51	1325.599	1337.556	1471.288	1369.749	2391.36	664.349	8.472	670.272	637.454	1484.188	1374.51	0	61.656	60.953
14.54	1325.103	1337.556	1470.798	1368.937	2390.363	663.612	8.5	669.528	635.505	1484.188	1374.51	0	61.548	61.061
14.56	1325.103	1337.556	1469.328	1368.937	2391.36	663.735	8.523	669.776	634.855	1480.2	1374.51	0	61.656	61.061
14.59	1325.103	1337.556	1446.783	1369.749	2391.36	664.472	8.55	670.272	634.855	1458.764	1374.51	0	61.602	60.574
14.61	1325.103	1337.556	1426.689	1368.937	2390.363	663.735	8.574	670.024	634.53	1455.773	1373.46	0	61.602	59.87
14.63	1325.103	1337.556	1395.813	1368.937	2390.363	663.243	8.597	669.031	633.231	1470.729	1373.46	0	61.548	59.924
14.66	1325.103	1337.068	1356.114	1368.937	2391.36	663.981	8.625	669.776	633.555	1480.699	1375.56	0	61.548	60.303
14.68	1325.103	1337.556	1319.846	1368.937	2391.36	662.997	8.648	668.782	633.231	1489.672	1375.56	0	61.548	61.007
14.71	1324.608	1337.068	1287.5	1368.937	2390.363	661.154	8.675	667.292	631.931	1476.711	1375.56	0.001	61.548	61.44
14.74	1324.608	1337.068	1257.604	1368.937	2391.36	660.17	8.699	666.299	630.307	1445.304	1377.65	0	61.602	60.844
14.76	1324.608	1337.068	1229.177	1368.937	2391.36	661.277	8.722	667.292	629.982	1413.4	1378.7	0	61.548	59.545
14.79	1324.608	1337.068	1201.732	1368.937	2391.36	661.768	8.75	667.789	630.957	1384.486	1379.75	0.001	61.494	58.082
14.81	1324.608	1336.581	1176.246	1368.937	2391.36	661.154	8.773	667.044	630.632	1358.065	1379.75	0.001	61.548	56.402
14.84	1324.608	1336.581	1151.251	1368.937	2390.363	659.187	8.8	665.057	628.683	1332.143	1379.75	0	61.44	54.936
14.86	1324.608	1336.581	1126.256	1368.937	2390.363	657.343	8.824	663.071	626.084	1308.214	1380.79	0	61.494	53.741
14.88	1324.608	1336.581	1103.711	1368.937	2390.363	657.835	8.847	663.319	625.109	1284.784	1380.79	0	61.548	52.872
14.91	1324.608	1336.581	1082.147	1368.937	2390.363	657.22	8.875	663.071	624.459	1262.85	1380.79	0	61.548	52.111
14.93	1324.112	1336.581	1060.582	1368.937	2390.363	655.008	8.898	661.084	622.51	1241.414	1380.79	0	61.494	51.512
14.96	1324.112	1336.094	1039.018	1368.937	2390.363	654.885	8.925	660.835	621.211	1220.975	1380.79	0.001	61.44	51.022
14.99	1324.112	1336.581	1019.414	1368.937	2390.363	652.918	8.949	658.6	619.587	1200.536	1380.79	0	61.44	50.696
15.01	1324.112	1336.581	998.339	1369.749	2390.363	653.041	8.972	658.849	619.911	1181.593	1380.79	0	61.494	50.369
15.04	1323.617	1336.094	976.775	1368.937	2390.363	652.673	9	658.6	619.262	1162.65	1380.79	0	61.548	49.988
15.06	1324.112	1336.581	960.111	1368.937	2390.363	651.443	9.023	657.11	617.637	1144.703	1380.79	0	61.44	49.716
15.09	1323.617	1336.094	941.977	1369.749	2390.363	652.058	9.05	657.855	617.313	1127.255	1380.79	0	61.44	49.443
15.11	1323.617	1336.094	924.334	1368.937	2390.363	654.025	9.074	659.594	619.262	1109.807	1380.79	0	61.44	49.28
15.13	1323.617	1336.094	905.71	1368.937	2390.363	653.164	9.097	658.849	620.561	1093.356	1380.79	0	61.494	49.171
15.16	1323.617	1335.606	888.556	1368.937	2390.363	650.952	9.125	656.614	616.338	1076.906	1380.79	0.001	61.385	49.117

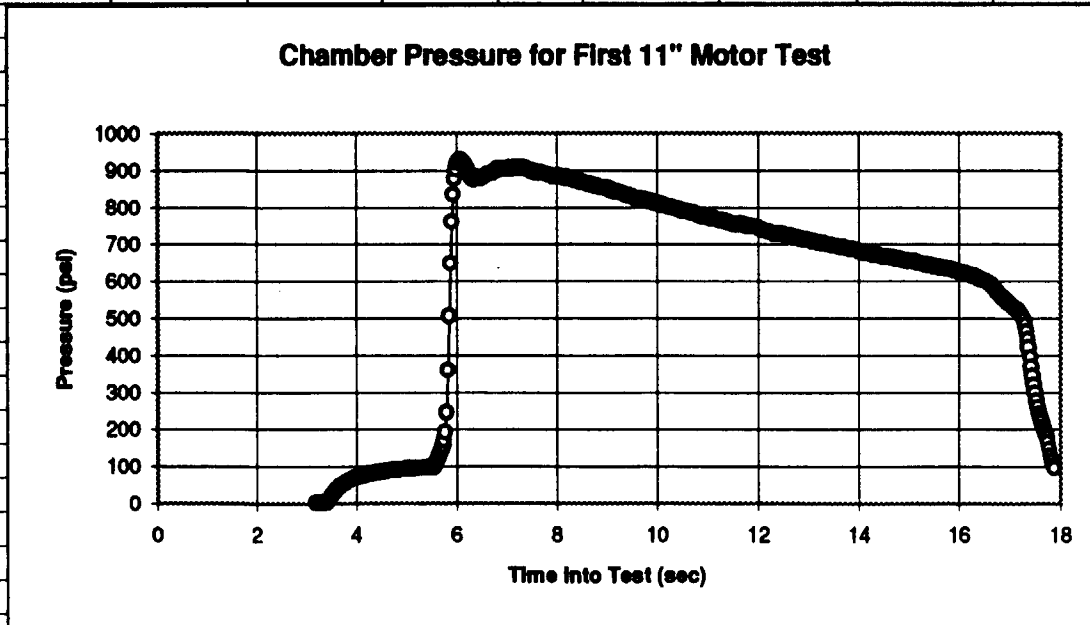
	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
15.18	1323.617	1335.606	871.893	1368.937	2390.363	648.371	9.148	654.379	610.815	1061.951	1381.84		61.385	
15.21	1323.122	1335.606	855.229	1368.937	2390.363	647.019	9.175	652.889	607.892	1046.995	1381.84	0	61.277	49.062
15.24	1323.122	1335.606	838.076	1368.937	2390.363	647.264	9.199	653.137	605.942	1033.037	1380.79	0	61.331	48.899
15.26	1323.122	1335.606	822.882	1368.937	2390.363	647.019	9.222	652.64	604.643	1019.079	1381.84	0	61.385	48.79
15.29	1323.122	1335.606	806.464	1368.937	2390.363	645.667	9.25	651.647	603.993	1005.619	1381.84	0	61.331	48.681
15.31	1323.122	1335.606	791.761	1368.937	2390.363	644.314	9.273	650.405	603.019	992.159	1381.84	0	61.385	48.517
15.34	1323.122	1335.119	776.078	1368.937	2390.363	645.052	9.3	650.902	601.719	979.198	1381.84	0	61.385	48.299
15.36	1322.626	1335.119	761.129	1368.937	2389.366	644.192	9.324	650.157	600.745	966.735	1381.84	0.001	61.385	48.081
15.38	1322.626	1335.119	749.122	1368.937	2390.363	643.085	9.347	648.915	600.745	954.272	1381.84	0.001	61.331	47.917
15.41	1322.626	1335.119	736.624	1372.182	2390.363	642.84	9.375	648.667	601.07	941.81	1379.75	0	61.331	47.917
15.43	1322.626	1335.119	724.862	1389.221	2390.363	642.84	9.398	648.418	599.445	929.347	1374.51	0	61.331	47.754
15.46	1322.626	1334.632	713.834	1411.938	2389.366	642.102	9.425	647.673	597.171	917.881	1371.36	0	61.331	47.59
15.49	1322.626	1335.119	702.807	1432.222	2389.366	641.488	9.449	647.177	594.248	906.415	1374.51	0	61.331	47.536
15.51	1322.131	1335.119	692.515	1446.015	2390.363	639.889	9.472	645.687	591.324	894.95	1374.51	0	61.385	47.427
15.54	1322.626	1334.632	684.183	1458.185	2390.363	639.644	9.5	645.438	588.725	883.484	1374.51	0	61.385	47.372
15.56	1322.131	1334.632	675.852	1467.921	2389.366	637.431	9.523	643.203	587.426	872.018	1375.56	0.001	61.223	47.372
15.59	1322.131	1334.632	668.255	1476.034	2390.363	636.94	9.55	642.707	587.101	861.55	1375.56	0	61.277	47.263
15.61	1322.131	1334.632	661.394	1482.525	2390.363	636.817	9.574	642.707	587.426	850.582	1375.56	0	61.277	47.263
15.63	1322.131	1334.144	656.002	1488.205	2389.366	636.079	9.597	641.713	587.101	840.114	1376.6	0	61.331	47.317
15.66	1322.131	1334.144	651.101	1492.261	2389.366	634.358	9.625	640.223	585.152	829.645	1376.6	0	61.223	47.317
15.68	1322.131	1334.144	647.671	1495.507	2389.366	635.096	9.648	640.968	582.228	819.176	1377.65	0	61.223	47.208
15.71	1322.131	1334.632	645.22	1497.941	2389.366	635.465	9.675	641.465	579.142	809.206	1377.65	0	61.277	47.263
15.74	1322.131	1334.144	643.505	1499.563	2389.366	634.358	9.699	640.223	577.68	799.236	1377.65	0	61.385	47.427
15.76	1322.131	1333.657	641.79	1500.375	2389.366	633.252	9.722	638.733	573.944	789.266	1377.65	0	61.277	47.481
15.79	1322.131	1334.144	640.564	1501.186	2389.366	633.006	9.75	638.733	569.558	779.794	1378.7	0	61.223	47.699
15.81	1322.131	1332.195	638.849	1501.186	2390.363	630.917	9.773	636.995	569.396	770.322	1378.7	0	61.331	47.863
15.84	1321.635	1329.758	637.624	1501.186	2389.366	630.917	9.8	636.746	569.071	760.851	1378.7	0	61.277	48.136
15.86	1321.635	1329.271	637.378	1501.186	2389.366	631.163	9.824	636.746	557.539	751.379	1378.7	0.001	61.223	48.081
15.88	1321.635	1328.783	637.134	1501.997	2389.366	630.671	9.847	636.498	545.356	742.904	1379.75	0	61.223	48.081
15.91	1321.14	1329.271	635.908	1501.997	2389.366	628.458	9.875	634.263	539.022	733.931	1379.75	0.001	61.277	48.245
15.93	1319.158	1329.271	634.193	1501.997	2389.366	626.615	9.898	632.525	536.098	724.958	1379.75	0	61.277	48.245
15.96	1317.672	1328.783	632.968	1501.186	2388.369	626.738	9.925	632.525	533.824	715.985	1378.7	0	61.169	48.354
														48.517

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
15.99	1315.69	1328.296	632.723	1501.997	2388.369	626.369	9.949	632.028	533.499	708.009	1379.75	0.001	61.223	48.408
16.01	1314.204	1328.783	631.742	1501.997	2388.369	625.754	9.972	631.531	530.9	700.032	1379.75	0	61.169	48.463
16.04	1314.204	1328.296	630.272	1501.997	2387.37	623.296	10	629.048	527.976	692.056	1379.75	0	61.169	48.517
16.06	1314.204	1328.296	628.802	1501.997	2387.37	621.944	10.02	627.558	524.728	684.08	1378.7	0	61.169	48.626
16.09	1315.195	1326.834	627.822	1502.809	2387.37	621.207	10.05	626.564	522.129	676.852	1379.75	0	61.169	48.626
16.11	1316.186	1325.372	627.086	1501.997	2388.369	621.33	10.07	627.061	520.017	669.623	1379.75	0	61.169	48.681
16.13	1318.167	1322.935	626.841	1502.809	2388.369	620.838	10.1	626.813	518.88	662.893	1379.75	0	61.169	48.79
16.16	1322.626	1321.473	625.861	1502.809	2388.369	619.978	10.13	625.571	518.393	656.163	1378.7	0	61.169	48.899
16.18	1335.507	1320.986	624.146	1502.809	2393.355	617.765	10.15	623.336	516.119	650.181	1377.65	0	61.223	48.953
16.21	1354.828	1320.498	622.676	1502.809	2405.323	616.413	10.18	622.094	514.008	644.199	1274.46	0.001	61.115	49.008
16.24	1371.177	1320.011	621.45	1501.997	2418.287	615.921	10.2	621.846	512.058	638.716	1255.6	0.001	61.115	49.008
16.26	1382.571	1319.523	620.715	1501.997	2421.278	614.938	10.22	620.853	511.246	633.481	1302.74	0	61.169	49.117
16.29	1390.498	1318.062	620.225	1501.186	2414.298	614.569	10.25	620.108	510.434	629.493	1343.6	0	61.115	49.171
16.31	1395.947	1315.625	619.49	1501.186	2408.313	614.078	10.27	619.611	507.023	625.505	1372.41	0	61.061	49.28
16.34	1399.91	1307.34	618.02	1501.186	2408.313	611.496	10.3	616.879	502.962	621.766	1360.89	0	61.007	49.443
16.36	1403.874	1301.979	616.059	1500.375	2413.301	609.53	10.32	614.892	498.414	618.277	1354.6	0	61.061	49.498
16.38	1405.36	1300.029	614.589	1500.375	2413.301	608.055	10.35	613.651	495.49	615.535	1354.6	0	61.007	49.661
16.41	1407.342	1299.054	613.118	1499.563	2409.312	607.195	10.38	612.906	494.029	613.042	1355.13	0	61.007	49.716
16.43	1408.828	1297.592	611.648	1499.563	2405.323	604.613	10.4	609.926	491.755	610.55	1356.17	0	60.899	49.934
16.46	1409.819	1296.13	609.443	1498.752	2409.312	601.786	10.43	607.442	488.506	607.808	1356.17	0	60.899	49.988
16.49	1410.314	1295.156	608.218	1498.752	2412.302	602.401	10.45	607.939	485.258	605.814	1356.17	0	60.899	50.206
16.51	1410.81	1294.668	607.237	1497.941	2411.306	601.663	10.47	607.194	483.796	604.319	1356.17	0	60.953	50.369
16.54	1411.8	1293.206	606.012	1497.941	2406.32	600.311	10.5	605.704	482.009	602.823	1356.17	0	60.899	50.424
16.56	1411.8	1291.257	604.297	1497.129	2406.32	598.222	10.52	603.965	479.573	601.078	1356.7	0	60.844	50.75
16.59	1411.8	1287.358	602.581	1497.941	2410.309	595.886	10.55	601.234	475.674	599.333	1356.7	0	60.79	50.914
16.61	1411.8	1278.585	600.621	1496.318	2411.306	593.92	10.57	599.495	472.101	596.841	1356.7	0	60.844	51.022
16.63	1412.296	1266.401	598.66	1496.318	2409.312	591.953	10.6	597.509	468.202	595.096	1355.65	0	60.736	51.186
16.66	1412.296	1254.218	596.455	1496.318	2406.32	589.372	10.63	595.025	464.304	592.604	1354.6	0	60.79	51.295
16.68	1412.296	1243.496	593.024	1495.507	2407.316	584.947	10.65	590.307	460.893	589.862	1353.56	0	60.682	51.295
16.71	1412.296	1233.749	589.348	1495.507	2411.306	580.154	10.68	585.34	458.457	586.621	1352.51	0.001	60.574	51.295
16.74	1412.296	1224.489	585.673	1494.695	2410.309	576.835	10.7	582.111	455.858	583.132	1351.46	0.001	60.574	51.295
16.76	1412.296	1217.178	581.997	1494.695	2407.316	571.918	10.72	577.145	450.985	579.393	1348.84	0	60.52	51.24

MSFC DATA ON FIRST 11-INCH MOTOR FIRING

	P3000	P3002	P3005	P3006	P3007	P3009		P3010	P3011	P5004	P6004	SP000	T2009	T6012
System Time	GOX trailer supply P below reg	GOX Venturi 2" System	GH2 ignition venturi P	GH2 Venturi Feed P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi Press	N2 press	Spark detect galvanometer	GOX venturi 2" inlet Temp	GOX pilot ignition system T
16.79	1412.296	1208.406	577.586	1493.884	2406.32	567.002	10.75	572.426	444.65	575.654	1345.17	0.001	60.52	51.24
16.81	1411.8	1201.095	573.665	1493.884	2409.312	562.823	10.77	568.204	438.803	571.666	1344.13	0	60.466	51.131
16.84	1412.296	1193.785	569.744	1493.884	2411.306	560.61	10.8	565.721	434.417	568.177	1342.03	0	60.466	51.24
16.86	1411.8	1187.449	566.314	1493.073	2409.312	557.292	10.82	562.492	431.818	564.687	1339.94	0	60.411	51.131
16.88	1411.8	1180.626	563.128	1492.261	2407.316	554.464	10.85	559.761	427.92	561.447	1337.32	0	60.303	51.077
16.91	1411.8	1175.265	559.942	1492.261	2407.316	551.76	10.88	556.781	424.509	557.957	1334.7	0	60.195	51.077
16.93	1411.8	1169.417	557.002	1492.261	2410.309	548.688	10.9	553.801	420.123	554.966	1331.56	0	60.249	51.022
16.96	1411.8	1164.056	553.816	1492.261	2410.309	544.631	10.93	549.579	412.489	551.227	1328.41	0	60.141	50.968
16.99	1411.305	1158.695	549.65	1491.45	2407.316	540.329	10.95	545.605	406.642	547.738	1324.74	0	59.978	51.022
17.01	1411.8	1153.334	546.709	1491.45	2407.316	538.24	10.97	543.618	401.606	544.747	1321.6	0	60.032	50.968
17.04	1411.8	1148.461	543.524	1490.638	2408.313	535.658	11	540.638	401.444	541.755	1317.41	0	59.924	50.968
17.06	1411.305	1143.587	540.828	1490.638	2410.309	532.463	11.02	537.907	403.393	539.014	1313.22	0	59.924	51.022
17.09	1410.81	1138.714	537.888	1489.827	2409.312	529.759	11.05	534.927	403.556	535.524	1308.51	0	59.762	51.077
17.11	1411.305	1134.327	535.682	1489.827	2407.316	527.177	11.07	532.443	403.231	532.782	1303.27	0	59.762	50.914
17.13	1411.305	1129.941	532.987	1489.827	2407.316	524.965	11.1	529.96	401.931	530.04	1298.55	0.001	59.653	50.968
17.16	1411.305	1125.068	530.291	1489.016	2409.312	522.875	11.13	527.973	398.683	527.548	1293.84	0.001	59.599	50.968
17.18	1410.81	1120.194	527.105	1489.016	2410.309	518.697	11.15	523.503	392.348	524.557	1288.08	0	59.329	51.077
17.21	1411.305	1115.808	523.92	1488.205	2408.313	513.534	11.18	518.784	388.287	521.067	1282.32	0	59.329	51.022
17.24	1410.81	1110.934	519.509	1488.205	2407.316	508.617	11.2	513.818	385.851	517.328	1276.55	0	59.274	50.914
17.26	1410.81	1106.061	514.853	1488.205	2408.313	502.595	11.22	507.857	381.14	513.34	1270.27	0	59.22	50.968
17.29	1410.81	1101.187	509.952	1487.393	2409.312	494.974	11.25	499.662	374.481	508.854	1264.51	0	58.895	50.805
17.31	1410.81	1095.826	503.09	1487.393	2409.312	480.47	11.27	485.258	364.897	503.869	1258.22	0	58.949	50.75
17.34	1410.81	1090.952	495.004	1487.393	2408.313	462.648	11.3	467.378	350.766	497.886	1251.41	0	58.841	50.696
17.36	1410.81	1085.592	486.182	1487.393	2408.313	442.613	11.32	447.262	332.087	491.655	1245.12	0.001	58.678	50.533
17.38	1410.81	1079.743	476.87	1486.582	2408.313	420.365	11.35	424.663	313.245	485.175	1238.84	0	58.57	50.315
17.41	1410.314	1074.87	467.313	1486.582	2410.309	395.045	11.38	399.332	294.728	478.943	1232.55	0	58.462	50.151
17.43	1410.314	1069.021	458.491	1485.771	2409.312	368.25	11.4	372.511	275.399	472.961	1226.27	0	58.353	49.988
17.46	1410.81	1063.66	448.689	1485.771	2408.313	342.561	11.43	346.932	253.958	466.979	1220.5	0	58.191	49.77
17.49	1410.314	1057.812	439.867	1484.959	2407.316	320.313	11.45	324.333	232.924	460.997	1214.22	0	58.028	49.661
17.51	1410.314	1052.938	431.535	1484.959	2409.312	299.418	11.47	303.348	214.001	455.264	1208.46	0	57.974	49.552
17.54	1410.314	1047.09	422.958	1484.959	2409.312	278.892	11.5	282.86	194.996	449.531	1202.69	0	57.811	49.498
17.56	1410.314	1041.729	414.872	1484.148	2408.313	259.348	11.52	263.365	177.779	444.048	1196.93	0	57.703	49.443

Sys-tem Time	P3000 GOX trailer supply P below reg	P3002 GOX Venturi 2" System	P3005 GH2 ignition venturi P	P3006 GH2 Venturi Feed P	P3007 GOX Trailer supply P	P3009 Motor fwd closure 135 deg	Adj time	P3010 Aft "mixing" chamber 120 deg	P3011 Motor, behind grain plane 135	P5004 GOX ignition venturi Press	P6004 N2 press	SP000 Spark detect galvan-ometer	T2009 GOX venturi 2" inlet Temp	T6012 GOX pilot ignition system T
17.59	1410.314	1036.368	407.03	1484.959	2408.313	243.001	11.55	246.851	162.998	438.564	1191.17	0.001	57.54	49.443
17.61	1410.314	1031.007	399.434	1484.148	2409.312	229.972	11.57	234.061	147.892	433.33	1185.93	0	57.324	49.443
17.63	1410.314	1025.646	391.837	1483.336	2410.309	219.524	11.6	223.134	133.273	428.095	1180.69	0	57.324	49.335
17.66	1409.819	1020.286	384.24	1483.336	2409.312	208.093	11.63	211.835	121.497	422.861	1175.46	0	57.161	49.389
17.68	1409.819	1014.925	377.134	1483.336	2408.313	196.416	11.65	200.038	113.376	417.876	1169.69	0	56.998	49.552
17.71	1409.819	1010.051	370.272	1483.336	2408.313	186.583	11.68	190.105	107.772	412.641	1164.46	0	56.89	49.607
17.74	1409.819	1005.177	362.921	1482.525	2409.312	177.733	11.7	181.04	102.249	407.906	1159.74	0	56.727	49.607
17.76	1409.819	1000.304	356.305	1482.525	2410.309	164.95	11.72	168.375	96.97	402.671	1153.98	0	56.673	49.607
17.79	1409.819	995.43	349.443	1481.714	2408.313	147.62	11.75	150.867	91.366	397.686	1149.26	0	56.51	49.607
17.81	1409.819	990.557	343.072	1481.714	2408.313	129.305	11.77	132.614	84.301	393.199	1144.55	0	56.347	49.607
17.84	1409.323	986.17	336.456	1481.714	2408.313	113.695	11.8	116.844	76.342	388.464	1139.84	0	56.239	49.607
17.86	1409.819	981.297	330.084	1480.902	2409.312	102.387	11.82	105.42	70.413	383.479	1135.12	0	56.13	49.552
17.88	1409.323	976.423	323.958	1480.902	2409.312	95.627	11.85	98.964	69.601	378.743	1130.41	0	55.913	49.552



SECOND 11-INCH MOTOR FIRING

Inputs		**Gox flow =**	7.0000		**port dia=**	4.039	Total	impulse=	20463.96	lb sec				Erosion
					Density=	1.150	Total fuel	used =	34.1576	lb				Rate(in/.1s)
Init rdot	0.075	**pre exp =**	0.104		**Port Length**	=	102.000	Pc final=	425.90	psi				7.70E-04
Avg rdot	0.066	**exp =**	0.530	Init OMF=	0.546			Final dia=	5.156	inch	total			Nozzl dia
Burn Time	Do	Mdot Ox	Mdot Ox	Flux/Port	Rdot	D final	MdotF	MdotF	O/F	Rdot	Mdot T	Flux	C*	D5
(sec)	in	lb/.1s	lb/sec	lb/.1s/in^2	in/.1s	in	lb/.1s	lb/s		in/sec	lb/.1 sec	total		
0.000	4.039	0.7000	7.000	0.055	0.0075	4.054	0.4052	4.0519	1.74	0.075	1.105	0.086	5840.000	2.250
0.100	4.054	0.7000	7.000	0.054	0.0075	4.069	0.4051	4.0509	1.74	0.075	1.105	0.086	5840.000	2.252
0.200	4.069	0.7000	7.000	0.054	0.0075	4.084	0.4050	4.0500	1.74	0.075	1.105	0.085	5840.000	2.253
0.300	4.084	0.7000	7.000	0.053	0.0074	4.099	0.4049	4.0490	1.74	0.074	1.105	0.084	5840.000	2.255
0.400	4.099	0.7000	7.000	0.053	0.0074	4.114	0.4048	4.0481	1.74	0.074	1.105	0.084	5840.000	2.256
0.500	4.114	0.7000	7.000	0.053	0.0074	4.128	0.4047	4.0472	1.74	0.074	1.105	0.083	5840.000	2.258
0.600	4.128	0.7000	7.000	0.052	0.0074	4.143	0.4046	4.0462	1.74	0.074	1.105	0.083	5840.000	2.259
0.700	4.143	0.7000	7.000	0.052	0.0073	4.158	0.4045	4.0453	1.74	0.073	1.105	0.082	5840.000	2.261
0.800	4.158	0.7000	7.000	0.052	0.0073	4.172	0.4044	4.0444	1.74	0.073	1.104	0.081	5840.000	2.262
0.900	4.172	0.7000	7.000	0.051	0.0073	4.187	0.4044	4.0435	1.74	0.073	1.104	0.081	5840.000	2.264
1.000	4.187	0.7000	7.000	0.051	0.0072	4.201	0.4043	4.0426	1.74	0.072	1.104	0.080	5840.000	2.265
1.100	4.201	0.7000	7.000	0.050	0.0072	4.216	0.4042	4.0417	1.74	0.072	1.104	0.080	5840.000	2.267
1.200	4.216	0.7000	7.000	0.050	0.0072	4.230	0.4041	4.0408	1.74	0.072	1.104	0.079	5840.000	2.268
1.300	4.230	0.7000	7.000	0.050	0.0072	4.245	0.4040	4.0400	1.74	0.072	1.104	0.079	5840.000	2.270
1.400	4.245	0.7000	7.000	0.049	0.0071	4.259	0.4039	4.0391	1.74	0.071	1.104	0.078	5840.000	2.272
1.500	4.259	0.7000	7.000	0.049	0.0071	4.273	0.4038	4.0382	1.74	0.071	1.104	0.077	5840.000	2.273
1.600	4.273	0.7000	7.000	0.049	0.0071	4.287	0.4037	4.0374	1.74	0.071	1.104	0.077	5840.000	2.275
1.700	4.287	0.7000	7.000	0.048	0.0071	4.301	0.4037	4.0365	1.74	0.071	1.104	0.076	5840.000	2.276
1.800	4.301	0.7000	7.000	0.048	0.0070	4.316	0.4036	4.0357	1.74	0.070	1.104	0.076	5840.000	2.278
1.900	4.316	0.7000	7.000	0.048	0.0070	4.330	0.4035	4.0349	1.74	0.070	1.103	0.075	5840.000	2.279
2.000	4.330	0.7000	7.000	0.048	0.0070	4.344	0.4034	4.0340	1.75	0.070	1.103	0.075	5840.000	2.281
2.100	4.344	0.7000	7.000	0.047	0.0070	4.357	0.4033	4.0332	1.75	0.070	1.103	0.074	5840.000	2.282
2.200	4.357	0.7000	7.000	0.047	0.0069	4.371	0.4032	4.0324	1.75	0.069	1.103	0.074	5840.000	2.284
2.300	4.371	0.7000	7.000	0.047	0.0069	4.385	0.4032	4.0316	1.75	0.069	1.103	0.074	5840.000	2.285
2.400	4.385	0.7000	7.000	0.046	0.0069	4.399	0.4031	4.0308	1.75	0.069	1.103	0.073	5840.000	2.287
2.500	4.399	0.7000	7.000	0.046	0.0069	4.413	0.4030	4.0300	1.75	0.069	1.103	0.073	5840.000	2.289
2.600	4.413	0.7000	7.000	0.046	0.0069	4.426	0.4029	4.0292	1.75	0.069	1.103	0.072	5840.000	2.290
2.700	4.426	0.7000	7.000	0.045	0.0068	4.440	0.4028	4.0284	1.75	0.068	1.103	0.072	5840.000	2.292
2.800	4.440	0.7000	7.000	0.045	0.0068	4.454	0.4028	4.0276	1.75	0.068	1.103	0.071	5840.000	2.293
2.900	4.454	0.7000	7.000	0.045	0.0068	4.467	0.4027	4.0268	1.75	0.068	1.103	0.071	5840.000	2.295

SECOND 11-INCH MOTOR FIRING

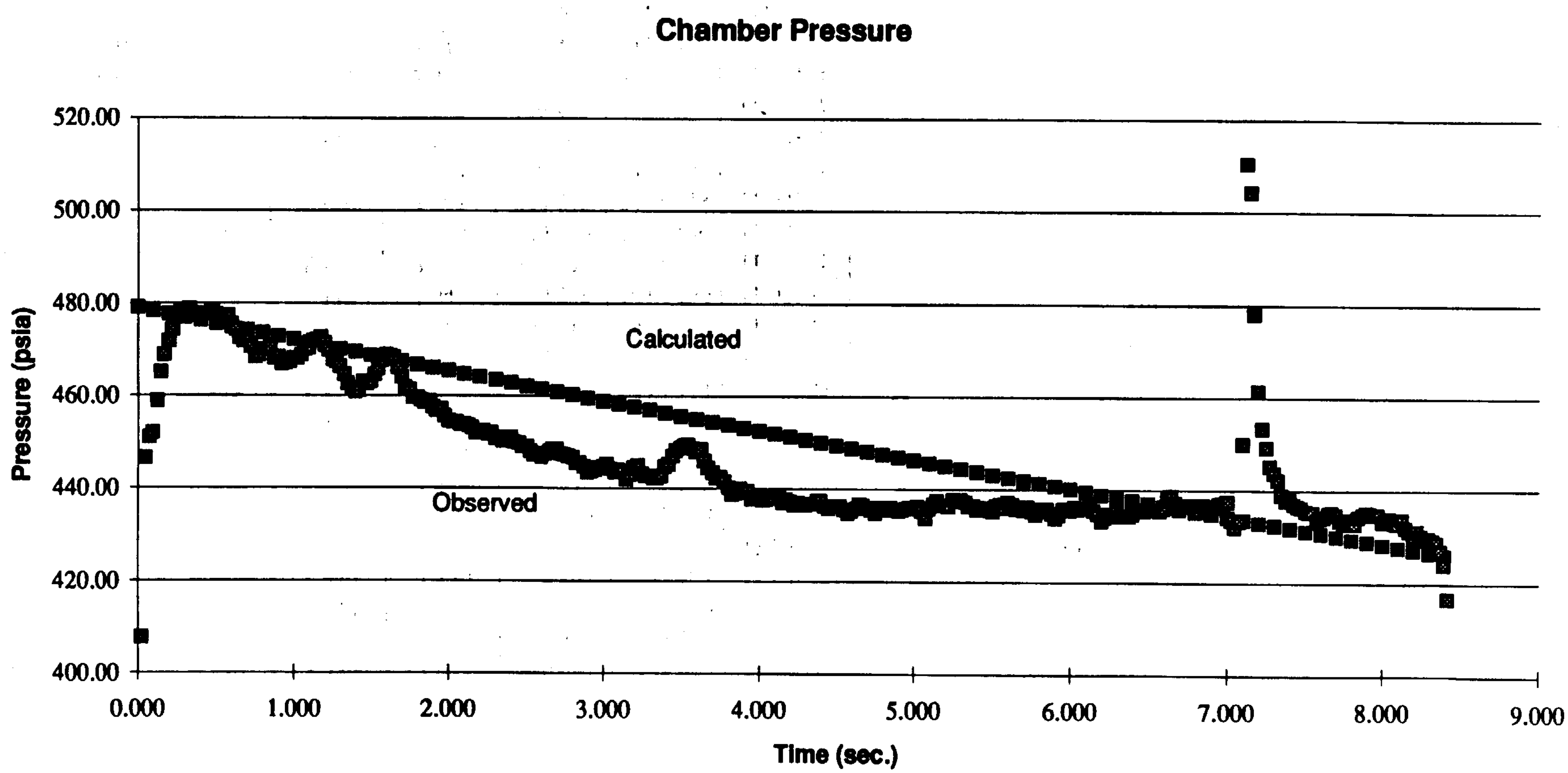
Inputs		Gox flow =	7.0000		port dia=	4.039	Total	impulse=	20463.96	lb sec				Erosion
					Density=	1.150	Total fuel	used =	34.1576	lb				Rate(in/.1s)
Init rdot	0.075	pre exp =	0.104		Port Length	=	102.000	Pc final=	425.90	psi				7.70E-04
Avg rdot	0.066	exp =	0.530	Init OMF=	0.546			Final dia=	5.156	inch	total			Nozzl dia
Burn Time	Do	Mdot Ox	Mdot Ox	Flux/Port	Rdot	D final	MdotF	MdotF	O/F	Rdot	Mdot T	Flux	C*	D5
(sec)	in	lb/.1s	lb/sec	lb/.1s/in^2	in/.1s	in	lb/.1s	lb/s		in/sec	lb/.1 sec	total		
3.000	4.467	0.7000	7.000	0.045	0.0068	4.481	0.4026	4.0261	1.75	0.068	1.103	0.070	5840.000	2.296
3.100	4.481	0.7000	7.000	0.044	0.0067	4.494	0.4025	4.0253	1.75	0.067	1.103	0.070	5840.000	2.298
3.200	4.494	0.7000	7.000	0.044	0.0067	4.508	0.4025	4.0245	1.75	0.067	1.102	0.069	5840.000	2.299
3.300	4.508	0.7000	7.000	0.044	0.0067	4.521	0.4024	4.0238	1.75	0.067	1.102	0.069	5840.000	2.301
3.400	4.521	0.7000	7.000	0.044	0.0067	4.535	0.4023	4.0230	1.75	0.067	1.102	0.069	5840.000	2.302
3.500	4.535	0.7000	7.000	0.043	0.0067	4.548	0.4022	4.0223	1.75	0.067	1.102	0.068	5840.000	2.304
3.600	4.548	0.7000	7.000	0.043	0.0066	4.561	0.4022	4.0215	1.75	0.066	1.102	0.068	5840.000	2.305
3.700	4.561	0.7000	7.000	0.043	0.0066	4.574	0.4021	4.0208	1.75	0.066	1.102	0.067	5840.000	2.307
3.800	4.574	0.7000	7.000	0.043	0.0066	4.588	0.4020	4.0201	1.75	0.066	1.102	0.067	5840.000	2.309
3.900	4.588	0.7000	7.000	0.042	0.0066	4.601	0.4019	4.0193	1.75	0.066	1.102	0.067	5840.000	2.310
4.000	4.601	0.7000	7.000	0.042	0.0066	4.614	0.4019	4.0186	1.75	0.066	1.102	0.066	5840.000	2.312
4.100	4.614	0.7000	7.000	0.042	0.0065	4.627	0.4018	4.0179	1.75	0.065	1.102	0.066	5840.000	2.313
4.200	4.627	0.7000	7.000	0.042	0.0065	4.640	0.4017	4.0172	1.75	0.065	1.102	0.066	5840.000	2.315
4.300	4.640	0.7000	7.000	0.041	0.0065	4.653	0.4016	4.0165	1.75	0.065	1.102	0.065	5840.000	2.316
4.400	4.653	0.7000	7.000	0.041	0.0065	4.666	0.4016	4.0157	1.75	0.065	1.102	0.065	5840.000	2.318
4.500	4.666	0.7000	7.000	0.041	0.0065	4.679	0.4015	4.0150	1.75	0.065	1.102	0.064	5840.000	2.319
4.600	4.679	0.7000	7.000	0.041	0.0064	4.692	0.4014	4.0143	1.75	0.064	1.101	0.064	5840.000	2.321
4.700	4.692	0.7000	7.000	0.040	0.0064	4.705	0.4014	4.0137	1.75	0.064	1.101	0.064	5840.000	2.322
4.800	4.705	0.7000	7.000	0.040	0.0064	4.717	0.4013	4.0130	1.75	0.064	1.101	0.063	5840.000	2.324
4.900	4.717	0.7000	7.000	0.040	0.0064	4.730	0.4012	4.0123	1.75	0.064	1.101	0.063	5840.000	2.325
5.000	4.730	0.7000	7.000	0.040	0.0064	4.743	0.4012	4.0116	1.75	0.064	1.101	0.063	5840.000	2.327
5.100	4.743	0.7000	7.000	0.040	0.0063	4.756	0.4011	4.0109	1.76	0.063	1.101	0.062	5840.000	2.329
5.200	4.756	0.7000	7.000	0.039	0.0063	4.768	0.4010	4.0102	1.76	0.063	1.101	0.062	5840.000	2.330
5.300	4.768	0.7000	7.000	0.039	0.0063	4.781	0.4010	4.0096	1.76	0.063	1.101	0.062	5840.000	2.332
5.400	4.781	0.7000	7.000	0.039	0.0063	4.793	0.4009	4.0089	1.76	0.063	1.101	0.061	5840.000	2.333
5.500	4.793	0.7000	7.000	0.039	0.0063	4.806	0.4008	4.0083	1.76	0.063	1.101	0.061	5840.000	2.335
5.600	4.806	0.7000	7.000	0.039	0.0063	4.818	0.4008	4.0076	1.76	0.063	1.101	0.061	5840.000	2.336
5.700	4.818	0.7000	7.000	0.038	0.0062	4.831	0.4007	4.0069	1.76	0.062	1.101	0.060	5840.000	2.338
5.800	4.831	0.7000	7.000	0.038	0.0062	4.843	0.4006	4.0063	1.76	0.062	1.101	0.060	5840.000	2.339
5.900	4.843	0.7000	7.000	0.038	0.0062	4.856	0.4006	4.0056	1.76	0.062	1.101	0.060	5840.000	2.341

Inputs		Gox flow =	7.0000		port dia=	4.039	Total	impulse=	20463.96	lb sec				Erosion
					Density=	1.150	Total fuel	used =	34.1576	lb				Rate(in/.1s)
Init rdot	0.075	pre exp =	0.104		Port Length	=	102.000	Pc final=	425.90	psi				7.70E-04
Avg rdot	0.066	exp =	0.530	Init OMF=	0.546			Final dia=	5.156	inch	total			Nozzl dia
Burn Time	Do	Mdot Ox	Mdot Ox	Flux/Port	Rdot	D final	MdotF	MdotF	O/F	Rdot	Mdot T	Flux	C*	D5
(sec)	in	lb/.1s	lb/sec	lb/.1s/in^2	in/.1s	in	lb/.1s	lb/s		in/sec	lb/.1 sec	total		
6.000	4.856	0.7000	7.000	0.038	0.0062	4.868	0.4005	4.0050	1.76	0.062	1.101	0.059	5840.000	2.342
6.100	4.868	0.7000	7.000	0.038	0.0062	4.881	0.4004	4.0044	1.76	0.062	1.100	0.059	5840.000	2.344
6.200	4.881	0.7000	7.000	0.037	0.0062	4.893	0.4004	4.0037	1.76	0.062	1.100	0.059	5840.000	2.345
6.300	4.893	0.7000	7.000	0.037	0.0061	4.905	0.4003	4.0031	1.76	0.061	1.100	0.059	5840.000	2.347
6.400	4.905	0.7000	7.000	0.037	0.0061	4.917	0.4002	4.0025	1.76	0.061	1.100	0.058	5840.000	2.349
6.500	4.917	0.7000	7.000	0.037	0.0061	4.930	0.4002	4.0018	1.76	0.061	1.100	0.058	5840.000	2.350
6.600	4.930	0.7000	7.000	0.037	0.0061	4.942	0.4001	4.0012	1.76	0.061	1.100	0.058	5840.000	2.352
6.700	4.942	0.7000	7.000	0.036	0.0061	4.954	0.4001	4.0006	1.76	0.061	1.100	0.057	5840.000	2.353
6.800	4.954	0.7000	7.000	0.036	0.0061	4.966	0.4000	4.0000	1.76	0.061	1.100	0.057	5840.000	2.355
6.900	4.966	0.7000	7.000	0.036	0.0060	4.978	0.3999	3.9994	1.76	0.060	1.100	0.057	5840.000	2.356
7.000	4.978	0.7000	7.000	0.036	0.0060	4.990	0.3999	3.9988	1.76	0.060	1.100	0.057	5840.000	2.358
7.100	4.990	0.7000	7.000	0.036	0.0060	5.002	0.3998	3.9982	1.76	0.060	1.100	0.056	5840.000	2.359
7.200	5.002	0.7000	7.000	0.036	0.0060	5.014	0.3998	3.9976	1.76	0.060	1.100	0.056	5840.000	2.361
7.300	5.014	0.7000	7.000	0.035	0.0060	5.026	0.3997	3.9970	1.76	0.060	1.100	0.056	5840.000	2.362
7.400	5.026	0.7000	7.000	0.035	0.0060	5.038	0.3996	3.9964	1.76	0.060	1.100	0.055	5840.000	2.364
7.500	5.038	0.7000	7.000	0.035	0.0060	5.050	0.3996	3.9958	1.76	0.060	1.100	0.055	5840.000	2.365
7.600	5.050	0.7000	7.000	0.035	0.0059	5.062	0.3995	3.9952	1.76	0.059	1.100	0.055	5840.000	2.367
7.700	5.062	0.7000	7.000	0.035	0.0059	5.074	0.3995	3.9946	1.76	0.059	1.099	0.055	5840.000	2.369
7.800	5.074	0.7000	7.000	0.035	0.0059	5.086	0.3994	3.9940	1.76	0.059	1.099	0.054	5840.000	2.370
7.900	5.086	0.7000	7.000	0.034	0.0059	5.097	0.3993	3.9934	1.76	0.059	1.099	0.054	5840.000	2.372
8.000	5.097	0.7000	7.000	0.034	0.0059	5.109	0.3993	3.9929	1.76	0.059	1.099	0.054	5840.000	2.373
8.100	5.109	0.7000	7.000	0.034	0.0059	5.121	0.3992	3.9923	1.76	0.059	1.099	0.054	5840.000	2.375
8.200	5.121	0.7000	7.000	0.034	0.0059	5.133	0.3992	3.9917	1.76	0.059	1.099	0.053	5840.000	2.376
8.300	5.133	0.7000	7.000	0.034	0.0058	5.144	0.3991	3.9912	1.76	0.058	1.099	0.053	5840.000	2.378
8.400	5.144	0.7000	7.000	0.034	0.0058	5.156	0.3991	3.9906	1.76	0.058	1.099	0.053	5840.000	2.379
8.500	5.156	0.7000	7.000	0.034	0.0058	5.168	0.3990	3.9900	1.76	0.058	1.099	0.053	5840.000	2.381
8.600	5.168	0.7000	7.000	0.033	0.0058	5.179	0.3989	3.9895	1.76	0.058	1.099	0.052	5840.000	2.382
8.700	5.179	0.7000	7.000	0.033	0.0058	5.191	0.3989	3.9889	1.76	0.058	1.099	0.052	5840.000	2.384
8.800	5.191	0.7000	7.000	0.033	0.0058	5.202	0.3988	3.9884	1.77	0.058	1.099	0.052	5840.000	2.386
8.900	5.202	0.7000	7.000	0.033	0.0058	5.214	0.3988	3.9878	1.77	0.058	1.099	0.052	5840.000	2.387

Inputs		Gox flow =	7.0000		port dia=	4.039	Total	impulse=	20463.96	lb sec				Erosion
					Density=	1.150	Total fuel	used =	34.1576	lb				Rate(in/.1s)
Init rdot	0.075	pre exp =	0.104		Port Length	=	102.000	Pc final=	425.90	psi				7.70E-04
Avg rdot	0.066	exp =	0.530	Init OMF=	0.546			Final dia=	5.156	inch	total			Nozzl dia
Burn Time	Do	Mdot Ox	Mdot Ox	Flux/Port	Rdot	D final	MdotF	MdotF	O/F	Rdot	Mdot T	Flux	C*	D5
(sec)	in	lb/.1s	lb/sec	lb/.1s/in^2	in/.1s	in	lb/.1s	lb/s		in/sec	lb/.1 sec	total		
9.000	5.214	0.7000	7.000	0.033	0.0057	5.225	0.3987	3.9873	1.77	0.057	1.099	0.051	5840.000	2.389
9.100	5.225	0.7000	7.000	0.033	0.0057	5.237	0.3987	3.9867	1.77	0.057	1.099	0.051	5840.000	2.390
9.200	5.237	0.7000	7.000	0.032	0.0057	5.248	0.3986	3.9862	1.77	0.057	1.099	0.051	5840.000	2.392
9.300	5.248	0.7000	7.000	0.032	0.0057	5.260	0.3986	3.9856	1.77	0.057	1.099	0.051	5840.000	2.393
9.400	5.260	0.7000	7.000	0.032	0.0057	5.271	0.3985	3.9851	1.77	0.057	1.099	0.051	5840.000	2.395
9.500	5.271	0.7000	7.000	0.032	0.0057	5.282	0.3985	3.9846	1.77	0.057	1.099	0.051	5840.000	2.396
9.600	5.282	0.7000	7.000	0.032	0.0057	5.294	0.3984	3.9840	1.77	0.057	1.098	0.050	5840.000	2.398
9.700	5.294	0.7000	7.000	0.032	0.0057	5.305	0.3983	3.9835	1.77	0.057	1.098	0.050	5840.000	2.399
9.800	5.305	0.7000	7.000	0.032	0.0056	5.316	0.3983	3.9830	1.77	0.056	1.098	0.050	5840.000	2.401
9.900	5.316	0.7000	7.000	0.032	0.0056	5.327	0.3982	3.9824	1.77	0.056	1.098	0.050	5840.000	2.402
10.000	5.327	0.7000	7.000	0.031	0.0056	5.339	0.3982	3.9819	1.77	0.056	1.098	0.049	5840.000	2.404
10.100	5.339	0.7000	7.000	0.031	0.0056	5.350	0.3981	3.9814	1.77	0.056	1.098	0.049	5840.000	2.406
10.200	5.350	0.7000	7.000	0.031	0.0056	5.361	0.3981	3.9809	1.77	0.056	1.098	0.049	5840.000	2.407
10.300	5.361	0.7000	7.000	0.031	0.0056	5.372	0.3980	3.9804	1.77	0.056	1.098	0.049	5840.000	2.409
10.400	5.372	0.7000	7.000	0.031	0.0056	5.383	0.3980	3.9798	1.77	0.056	1.098	0.048	5840.000	2.410
10.500	5.383	0.7000	7.000	0.031	0.0056	5.394	0.3979	3.9793	1.77	0.056	1.098	0.048	5840.000	2.412
10.600	5.394	0.7000	7.000	0.031	0.0055	5.406	0.3979	3.9788	1.77	0.055	1.098	0.048	5840.000	2.413
10.700	5.406	0.7000	7.000	0.031	0.0055	5.417	0.3978	3.9783	1.77	0.055	1.098	0.048	5840.000	2.415
10.800	5.417	0.7000	7.000	0.030	0.0055	5.428	0.3978	3.9778	1.77	0.055	1.098	0.048	5840.000	2.416
10.900	5.428	0.7000	7.000	0.030	0.0055	5.439	0.3977	3.9773	1.77	0.055	1.098	0.047	5840.000	2.418
11.000	5.439	0.7000	7.000	0.030	0.0055	5.450	0.3977	3.9768	1.77	0.055	1.098	0.047	5840.000	2.419
11.100	5.450	0.7000	7.000	0.030	0.0055	5.461	0.3976	3.9763	1.77	0.055	1.098	0.047	5840.000	2.421
11.200	5.461	0.7000	7.000	0.030	0.0055	5.472	0.3976	3.9758	1.77	0.055	1.098	0.047	5840.000	2.422
11.300	5.472	0.7000	7.000	0.030	0.0055	5.482	0.3975	3.9753	1.77	0.055	1.098	0.047	5840.000	2.424
11.400	5.482	0.7000	7.000	0.030	0.0054	5.493	0.3975	3.9748	1.77	0.054	1.097	0.046	5840.000	2.426
					0.5585	0.0665	34.1576							
				For 8.4 sec	totl radius	avg reg	total							
					increase	rate	fuel							
							consumed							

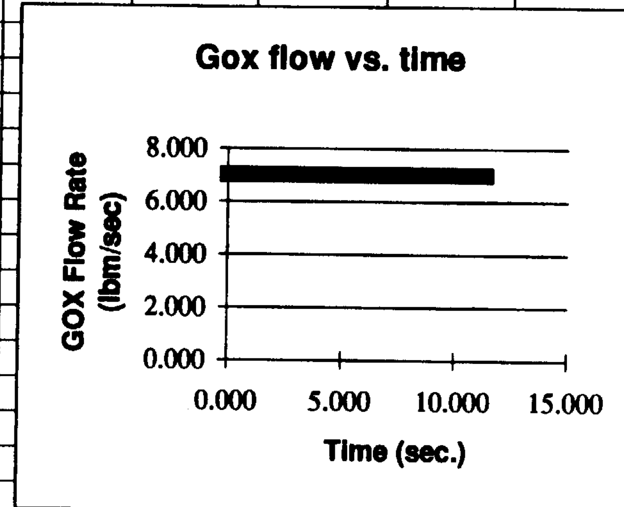
SECOND 11-INCH MOTOR FIRING

Inputs		Gox flow =	7.0000		port dia=	4.039	Total	impulse=	20463.96	lb sec				Erosion
					Density=	1.150	Total fuel	used =	34.1576	lb				Rate(in/.1s)
Init rdot	0.075	pre exp =	0.104		Port Length	=	102.000	Pc final=	425.90	psi				7.70E-04
Avg rdot	0.066	exp =	0.530	Init OMF=	0.546			Final dia=	5.156	inch	total			Nozzl dia
Burn Time	Do	Mdot Ox	Mdot Ox	Flux/Port	Rdot	D final	MdotF	MdotF	O/F	Rdot	Mdot T	Flux	C*	D5
(sec)	in	lb/.1s	lb/sec	lb/.1s/in^2	in/.1s	in	lb/.1s	lb/s		in/sec	lb/.1 sec	total		



SECOND 11-INCH MOTOR FIRING

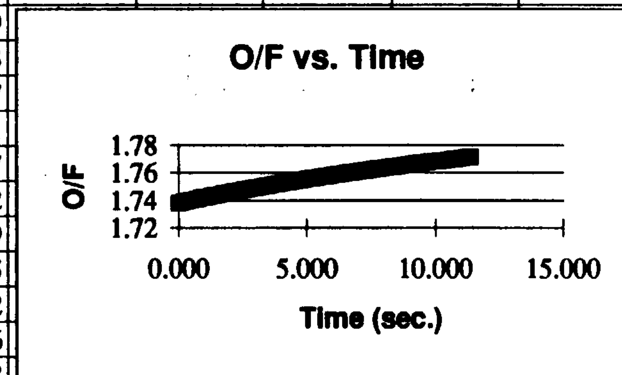
		Ae/A* =	10.000				
	Calc	De =	7.115				
	Chamber	Ambient Pressure=		14.700			
	Press					impulse	total
A5	Eff	Epsilon	Cf	Thrust	ISP	.95Eff	Mdot T
	0.950				Theor.		lb/sec
3.976	478.93	10.000	1.340	2,552	230.883	2424.108	11.05189
3.981	478.24	9.986	1.340	2,551	230.861	2423.663	11.05093
3.987	477.54	9.973	1.340	2,551	230.838	2423.220	11.04998
3.992	476.85	9.959	1.340	2,550	230.816	2422.779	11.04903
3.998	476.16	9.945	1.340	2,550	230.794	2422.341	11.04809
4.003	475.47	9.932	1.339	2,549	230.772	2421.906	11.04716
4.009	474.78	9.918	1.339	2,549	230.750	2421.473	11.04624
4.014	474.09	9.905	1.339	2,548	230.728	2421.042	11.04532
4.020	473.41	9.891	1.339	2,548	230.706	2420.613	11.04441
4.025	472.73	9.878	1.339	2,548	230.684	2420.187	11.04351
4.031	472.05	9.865	1.339	2,547	230.663	2419.764	11.04262
4.036	471.37	9.851	1.339	2,547	230.641	2419.342	11.04173
4.042	470.69	9.838	1.338	2,546	230.619	2418.923	11.04085
4.047	470.02	9.824	1.338	2,546	230.598	2418.506	11.03997
4.053	469.34	9.811	1.338	2,545	230.577	2418.091	11.03911
4.058	468.67	9.798	1.338	2,545	230.560	2417.729	11.03825
4.064	468.00	9.785	1.338	2,545	230.538	2417.313	11.03739
4.069	467.33	9.771	1.338	2,544	230.516	2416.898	11.03654
4.075	466.66	9.758	1.338	2,544	230.495	2416.485	11.0357
4.080	466.00	9.745	1.338	2,543	230.473	2416.075	11.03487
4.086	465.33	9.732	1.338	2,543	230.451	2415.666	11.03404
4.091	464.67	9.719	1.337	2,542	230.430	2415.260	11.03321
4.097	464.01	9.706	1.337	2,542	230.408	2414.855	11.0324
4.102	463.35	9.692	1.337	2,542	230.387	2414.453	11.03158
4.108	462.69	9.679	1.337	2,541	230.365	2414.052	11.03078
4.113	462.04	9.666	1.337	2,541	230.344	2413.654	11.02998
4.119	461.38	9.653	1.337	2,540	230.323	2413.257	11.02918
4.124	460.73	9.640	1.337	2,540	230.301	2412.862	11.02839
4.130	460.08	9.627	1.337	2,539	230.280	2412.469	11.02761
4.135	459.43	9.615	1.336	2,539	230.259	2412.078	11.02683

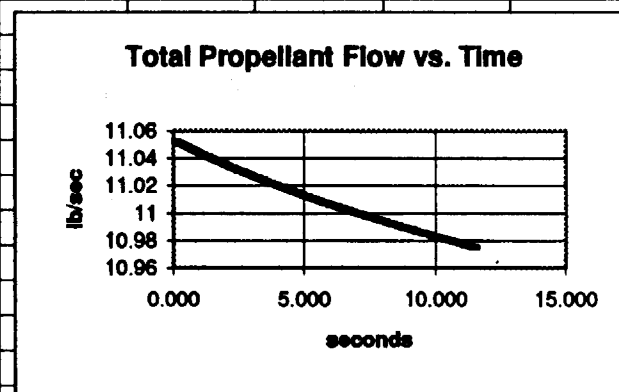


O/F	C*
1.000	5415.000
1.200	5717.000
1.400	5841.000
1.600	5840.000
1.800	5782.000
1.900	5746.000
2.000	5708.000
2.100	5670.000
2.300	5591.000
2.400	5556.000
2.500	5521.000
3.000	5390.000
3.200	5298.000
3.600	5189.000
4.000	5091.000
4.500	5000.000
5.000	4900.000
5.500	4800.000
6.000	4700.000
6.500	4600.000
7.000	4500.000

SECOND 11-INCH MOTOR FIRING

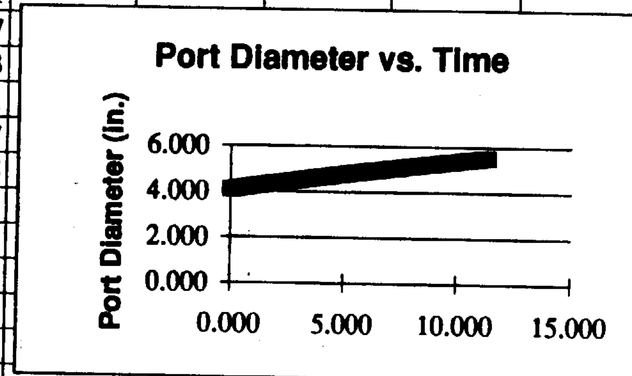
		Ae/A* =	10.000				
	Calc	De =	7.115				
	Chamber	Ambient Pressure=		14.700			
	Press					impulse	total
A5	Eff	Epsilon	Cf	Thrust	ISP	.95Eff	Mdot T
	0.950				Theor.		lb/sec
4.141	458.78	9.602	1.336	2,539	230.238	2411.688	11.02606
4.146	458.13	9.589	1.336	2,538	230.217	2411.301	11.02529
4.152	457.49	9.576	1.336	2,538	230.201	2410.965	11.02453
4.158	456.84	9.563	1.336	2,537	230.180	2410.575	11.02377
4.163	456.20	9.550	1.336	2,537	230.158	2410.186	11.02301
4.169	455.56	9.538	1.336	2,537	230.137	2409.799	11.02227
4.174	454.92	9.525	1.336	2,536	230.116	2409.414	11.02152
4.180	454.28	9.512	1.335	2,536	230.095	2409.031	11.02079
4.185	453.65	9.499	1.335	2,535	230.073	2408.649	11.02005
4.191	453.01	9.487	1.335	2,535	230.052	2408.269	11.01932
4.197	452.38	9.474	1.335	2,535	230.031	2407.891	11.0186
4.202	451.75	9.462	1.335	2,534	230.010	2407.514	11.01788
4.208	451.12	9.449	1.335	2,534	229.989	2407.139	11.01716
4.213	450.49	9.436	1.335	2,533	229.968	2406.765	11.01645
4.219	449.86	9.424	1.335	2,533	229.948	2406.393	11.01575
4.225	449.24	9.411	1.334	2,533	229.927	2406.022	11.01504
4.230	448.61	9.399	1.334	2,532	229.906	2405.653	11.01435
4.236	447.99	9.386	1.334	2,532	229.886	2405.286	11.01365
4.241	447.37	9.374	1.334	2,531	229.865	2404.920	11.01296
4.247	446.75	9.362	1.334	2,531	229.849	2404.607	11.01228
4.253	446.13	9.349	1.334	2,531	229.828	2404.237	11.0116
4.258	445.51	9.337	1.334	2,530	229.807	2403.870	11.01092
4.264	444.90	9.324	1.334	2,530	229.786	2403.503	11.01025
4.270	444.28	9.312	1.334	2,530	229.765	2403.139	11.00958
4.275	443.67	9.300	1.333	2,529	229.744	2402.775	11.00892
4.281	443.06	9.288	1.333	2,529	229.724	2402.413	11.00825
4.287	442.45	9.275	1.333	2,528	229.703	2402.053	11.0076
4.292	441.84	9.263	1.333	2,528	229.682	2401.694	11.00694
4.298	441.23	9.251	1.333	2,528	229.662	2401.336	11.00629
4.304	440.62	9.239	1.333	2,527	229.641	2400.980	11.00565

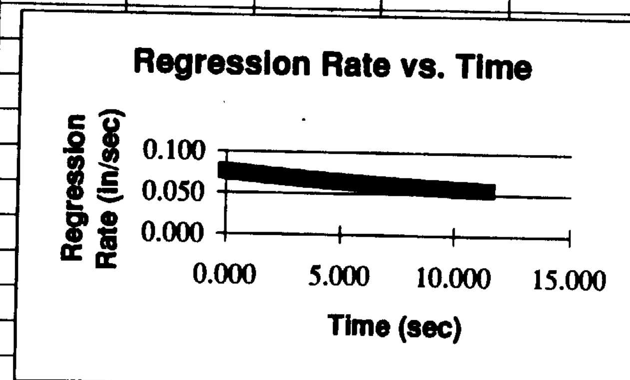




SECOND 11-INCH MOTOR FIRING

		Ae/A* =	10.000				
	Calc	De =	7.115				
	Chamber	Ambient Pressure=		14.700			
	Press					impulse	total
A5	Eff	Epsilon	Cf	Thrust	ISP	.95Eff	Mdot T
	0.950				Theor.		lb/sec
4.309	440.02	9.227	1.333	2,527	229.620	2400.625	11.00501
4.315	439.42	9.215	1.333	2,527	229.600	2400.271	11.00437
4.321	438.81	9.202	1.332	2,526	229.579	2399.919	11.00373
4.326	438.21	9.190	1.332	2,526	229.559	2399.568	11.0031
4.332	437.61	9.178	1.332	2,525	229.539	2399.218	11.00247
4.338	437.02	9.166	1.332	2,525	229.518	2398.870	11.00185
4.343	436.42	9.154	1.332	2,525	229.503	2398.576	11.00123
4.349	435.82	9.142	1.332	2,524	229.482	2398.224	11.00061
4.355	435.23	9.130	1.332	2,524	229.462	2397.873	10.99999
4.360	434.64	9.118	1.332	2,524	229.441	2397.524	10.99938
4.366	434.04	9.106	1.332	2,523	229.420	2397.176	10.99877
4.372	433.45	9.095	1.331	2,523	229.400	2396.829	10.99817
4.377	432.86	9.083	1.331	2,523	229.379	2396.483	10.99757
4.383	432.28	9.071	1.331	2,522	229.359	2396.139	10.99697
4.389	431.69	9.059	1.331	2,522	229.338	2395.796	10.99638
4.395	431.11	9.047	1.331	2,522	229.318	2395.454	10.99578
4.400	430.52	9.036	1.331	2,521	229.298	2395.113	10.99519
4.406	429.94	9.024	1.331	2,521	229.277	2394.773	10.99461
4.412	429.36	9.012	1.331	2,520	229.257	2394.435	10.99403
4.418	428.78	9.000	1.330	2,520	229.237	2394.098	10.99345
4.423	428.20	8.989	1.330	2,520	229.217	2393.761	10.99287
4.429	427.62	8.977	1.330	2,519	229.197	2393.427	10.9923
4.435	427.05	8.965	1.330	2,519	229.177	2393.093	10.99172
4.441	426.47	8.954	1.330	2,519	229.157	2392.760	10.99116
4.446	425.90	8.942	1.330	2,518	229.141	2392.479	10.99059
4.452	425.32	8.931	1.330	2,518	229.121	2392.143	10.99003
4.458	424.75	8.919	1.330	2,518	229.100	2391.807	10.98947
4.464	424.18	8.908	1.330	2,517	229.080	2391.473	10.98891
4.469	423.61	8.896	1.329	2,517	229.060	2391.139	10.98836
4.475	423.05	8.885	1.329	2,517	229.039	2390.807	10.98781





		Ae/A* =	10.000											
	Calc	De =	7.115											
	Chamber	Ambient Pressure=		14.700										
	Press					impulse	total							
A5	Eff	Epsilon	Cf	Thrust	ISP	.95Eff	Mdot T							
	0.950				Theor.		lb/sec							
4.481	422.48	8.873	1.329	2,516	229.019	2390.476	10.98726							
4.487	421.91	8.862	1.329	2,516	228.999	2390.146	10.98671							
4.492	421.35	8.850	1.329	2,516	228.979	2389.817	10.98617							
4.498	420.79	8.839	1.329	2,515	228.958	2389.489	10.98563							
4.504	420.23	8.828	1.329	2,515	228.938	2389.163	10.98509							
4.510	419.67	8.816	1.329	2,515	228.918	2388.837	10.98455							
4.516	419.11	8.805	1.329	2,514	228.898	2388.512	10.98402							
4.521	418.55	8.794	1.328	2,514	228.878	2388.188	10.98349							
4.527	417.99	8.782	1.328	2,514	228.858	2387.866	10.98296							
4.533	417.44	8.771	1.328	2,513	228.839	2387.544	10.98243							
4.539	416.88	8.760	1.328	2,513	228.819	2387.224	10.98191							
4.545	416.33	8.749	1.328	2,513	228.804	2386.960	10.98139							
4.550	415.78	8.737	1.328	2,512	228.784	2386.635	10.98087							
4.556	415.22	8.726	1.328	2,512	228.764	2386.311	10.98035							
4.562	414.67	8.715	1.328	2,512	228.743	2385.988	10.97984							
4.568	414.13	8.704	1.327	2,511	228.723	2385.667	10.97933							
4.574	413.58	8.693	1.327	2,511	228.703	2385.346	10.97882							
4.580	413.03	8.682	1.327	2,511	228.683	2385.026	10.97831							
4.585	412.49	8.671	1.327	2,510	228.663	2384.707	10.97781							
4.591	411.94	8.660	1.327	2,510	228.643	2384.389	10.97731							
4.597	411.40	8.649	1.327	2,510	228.623	2384.072	10.97681							
4.603	410.86	8.638	1.327	2,509	228.603	2383.756	10.97631							
4.609	410.32	8.627	1.327	2,509	228.583	2383.441	10.97581							
4.615	409.78	8.616	1.327	2,509	228.563	2383.127	10.97532							
4.621	409.24	8.605	1.326	2,508	228.543	2382.814	10.97483							
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														4890.000
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													0.150	4874.000
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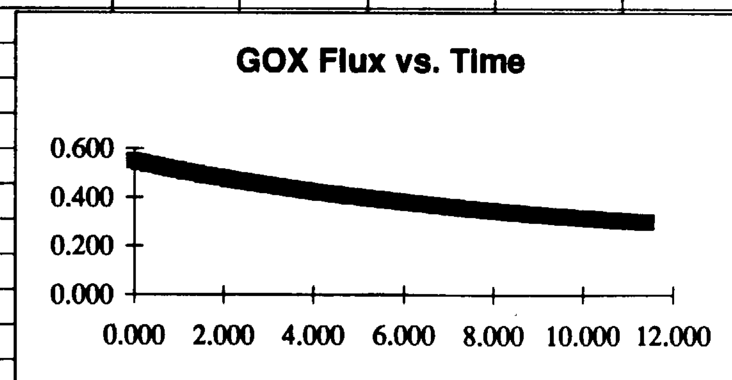


SECOND 11-INCH MOTOR FIRING

		Ae/A* =	10.000											
	Calc	De =	7.115											
	Chamber	Ambient Pressure=		14.700										
	Press					impulse	total							
A5	Eff	Epsilon	Cf	Thrust	ISP	.95Eff	Mdot T							
	0.950				Theor.		lb/sec							
													0.250	4858.000
													0.300	4851.000
													0.350	4843.000
													0.400	4835.000
													0.450	4827.000
													0.500	4820.000
													0.550	4812.000
													0.600	4805.000
													0.650	4797.000
													0.700	4790.000
													0.750	4782.000
													6.250	4746.000
													6.500	4710.000
													6.750	4675.000
													7.000	4641.000
													7.250	4607.000
													7.500	4573.000

MSFC DATA ON SECC 11-INCH MOTOR FIRING

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
6.906	1035.688	969.17	953.62	42.992	1222.605	53.802	-0.352	65.7	8.328	43.5	1367.39	0	54.393
6.93	1033.707	967.679	951.671	42.87	1220.612	53.678	-0.328	65.452	8.452	43.5	1367.39	0	54.393
6.957	1032.221	966.189	950.208	42.747	1219.615	53.678	-0.301	65.452	8.576	43.375	1367.39	0.271	54.339
6.98	1030.24	964.202	948.259	79.003	1218.12	53.429	-0.278	65.079	8.452	50.729	1367.39	6.675	54.393
7.008	1028.259	962.215	946.309	508.44	1216.127	54.176	-0.25	65.825	8.576	393.991	1367.39	10.102	54.285
7.031	1026.773	960.228	944.36	736.02	1214.632	55.671	-0.227	67.936	8.328	875.605	1367.39	10.238	54.393
7.055	1024.792	958.241	942.41	753.65	1213.137	56.916	-0.203	69.55	8.452	1006.229	1367.39	10.13	54.285
7.082	1022.811	956.751	939.973	734.06	1211.642	58.037	-0.176	70.544	8.452	999.748	1367.39	10.028	54.285
7.105	1021.325	955.26	938.998	726.95	1211.144	60.03	-0.153	72.655	8.576	984.791	1367.39	10.025	54.339
7.133	1019.344	952.777	937.536	726.71	1209.15	63.641	-0.125	76.63	8.452	977.313	1367.39	10.035	54.122
7.156	1017.859	951.286	935.586	727.2	1207.157	69.495	-0.102	83.088	8.701	974.82	1367.39	10.04	54.339
7.18	1016.373	949.299	933.149	727.2	1206.659	77.59	-0.078	91.782	8.701	973.324	1367.39	10.04	54.339
7.207	1013.897	947.809	931.687	727.2	1205.164	89.92	-0.051	104.078	8.825	980.304	1367.39	10.04	54.23
7.23	1011.916	946.319	930.712	727.2	1204.167	132.639	-0.028	144.069	9.073	985.788	1367.39	10.038	54.23
7.258	1010.43	944.829	928.762	727.2	1201.177	285.33	0	288.387	11.062	979.307	1367.39	10.04	54.339
7.281	1008.449	943.338	927.3	727.44	1200.679	415.104	0.023	407.617	17.898	966.843	1367.39	10.04	54.067
7.305	1006.963	941.848	925.838	727.2	1200.181	457.698	0.047	446.367	25.728	959.364	1367.39	10.04	54.176
7.332	1005.478	939.861	924.376	727.2	1199.184	461.186	0.074	450.838	32.315	958.866	1367.39	10.04	54.23
7.355	1004.487	938.371	922.913	726.95	1197.689	461.684	0.097	451.832	40.021	957.868	1366.342	10.038	53.959
7.383	1003.001	936.88	921.451	726.95	1196.194	468.409	0.125	458.787	50.461	956.373	1367.39	10.04	54.122
7.406	1001.02	935.887	919.989	727.2	1194.201	474.636	0.148	464.997	63.511	953.88	1367.39	10.04	53.959
7.43	999.535	933.9	918.527	727.44	1193.204	478.373	0.172	468.723	79.668	950.39	1367.39	10.04	54.067
7.457	998.049	932.41	916.577	727.2	1193.204	481.362	0.199	471.703	101.045	948.396	1367.39	10.04	54.122
7.48	996.068	930.423	915.602	726.95	1191.211	483.853	0.222	474.188	129.134	950.889	1367.39	10.04	53.904
7.508	995.077	929.429	914.14	727.2	1188.72	487.091	0.25	477.417	161.324	955.376	1367.39	10.04	54.122
7.531	993.592	927.939	912.678	727.44	1187.225	487.589	0.273	477.913	194.508	955.874	1367.39	10.04	53.904
7.555	992.106	926.448	910.728	727.44	1186.726	487.34	0.297	477.665	220.111	953.381	1367.39	10.04	54.067
7.582	991.115	924.958	909.753	727.2	1185.73	487.838	0.324	478.658	234.404	949.393	1367.39	10.038	54.067
7.605	989.629	923.468	909.266	727.2	1183.737	487.091	0.347	477.665	245.342	947.399	1367.39	10.04	54.067
7.633	988.144	922.475	906.829	726.95	1181.743	486.842	0.375	477.417	257.521	945.404	1367.39	10.04	54.176
7.656	986.658	921.481	905.367	726.95	1181.743	486.593	0.398	477.168	265.352	943.909	1367.39	10.04	53.959
7.68	985.667	919.494	904.879	726.71	1181.245	487.34	0.422	477.665	266.097	941.416	1367.39	10.04	53.85

MSFC DATA ON SECOND 11-INCH MOTOR FIRING

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
7.707	984.182	918.004	902.93	726.71	1180.248	486.842	0.449	477.665	247.082	937.427	1367.39	10.038	53.959
7.73	982.696	917.01	901.467	726.95	1179.252	487.091	0.472	477.913	226.45	933.937	1367.39	9.635	54.013
7.758	981.706	915.52	900.493	709.07	1178.255	486.593	0.5	477.417	221.603	901.032	1365.293	3.151	54.067
7.781	980.22	914.527	899.518	728.67	1177.259	485.845	0.523	476.671	226.201	874.608	1353.765	-0.106	54.393
7.805	979.229	913.533	898.055	908.97	1176.262	485.098	0.547	475.926	234.901	981.8	1348.525	-0.347	54.285
7.832	977.743	912.043	897.081	1056.4	1174.767	486.344	0.574	477.168	247.082	1081.014	1353.765	-0.083	54.285
7.855	976.753	911.049	895.618	1116.7	1174.269	484.351	0.597	475.429	261.996	1133.862	1352.718	0.014	54.339
7.883	975.763	909.062	894.156	1144.6	1173.272	482.856	0.625	474.188	277.283	1164.275	1353.765	0.014	54.556
7.906	974.277	908.069	893.181	1169.6	1172.275	481.113	0.648	472.449	285.61	1191.197	1354.813	0.004	54.393
7.93	972.296	907.075	891.719	1196.6	1171.279	480.116	0.672	471.703	290.209	1217.621	1353.765	0.001	54.393
7.957	972.296	906.082	891.232	1222	1169.784	480.365	0.699	471.703	296.672	1243.048	1354.813	0.001	54.339
7.98	971.305	904.591	889.77	1244.6	1168.787	478.871	0.722	470.461	310.84	1266.48	1355.861	0.001	54.339
8.008	969.324	903.598	889.282	1266.6	1167.791	476.629	0.75	468.226	328.738	1287.42	1355.861	0.001	54.393
8.031	967.839	902.604	887.82	1287.2	1167.791	477.376	0.773	468.723	343.403	1307.861	1354.813	0.001	54.502
8.055	967.343	901.611	886.845	1305.3	1167.292	477.875	0.797	469.965	355.335	1326.308	1355.861	0.001	54.447
8.082	966.848	900.121	885.383	1323.5	1165.797	478.373	0.824	469.965	365.029	1343.26	1355.861	0.001	54.393
8.105	965.362	899.127	883.921	1339.1	1163.804	478.871	0.847	470.461	375.718	1358.715	1355.861	0.001	54.447
8.133	964.372	897.637	883.433	1353.3	1162.808	476.38	0.875	467.978	388.395	1373.173	1355.861	0.001	54.447
8.156	962.886	896.643	881.971	1365.1	1162.309	476.38	0.898	468.226	399.332	1385.637	1355.861	0.001	54.502
8.18	961.4	895.65	880.509	1376.4	1161.313	474.885	0.922	466.736	411.512	1398.102	1355.861	0.001	54.61
8.207	960.41	895.153	880.509	1388.6	1161.313	475.135	0.949	466.984	422.201	1408.073	1355.861	0.001	54.447
8.23	959.419	894.159	880.021	1398.9	1160.316	475.384	0.972	467.232	431.895	1418.044	1355.861	0.001	54.447
8.258	958.924	893.166	879.046	1407.7	1160.316	475.882	1	467.978	440.098	1426.52	1356.909	0.001	54.556
8.281	957.934	892.172	877.584	1415.6	1157.824	476.131	1.023	467.978	448.052	1433.998	1356.909	0.001	54.556
8.305	956.943	891.179	876.122	1421.9	1156.828	476.878	1.047	468.723	455.012	1440.978	1356.909	0.001	54.556
8.332	955.457	889.689	875.147	1427.3	1155.831	478.124	1.074	469.965	462.221	1446.961	1356.909	0.001	54.556
8.355	954.467	889.192	874.66	1433.2	1155.333	478.124	1.097	470.213	467.938	1451.947	1356.909	0.001	54.665
8.383	953.476	888.198	873.685	1437.6	1154.336	479.618	1.125	471.703	472.412	1456.434	1356.909	0	54.665
8.406	952.981	887.205	872.71	1441.5	1153.838	480.116	1.148	471.952	475.147	1460.921	1356.909	0.001	54.556
8.43	951.991	886.211	871.735	1445.9	1153.34	480.365	1.172	472.449	477.384	1464.411	1356.909	0.001	54.665
8.457	951	885.218	871.248	1448.9	1152.343	479.12	1.199	471.207	478.875	1466.904	1357.958	0.001	54.665
8.48	950.01	884.224	869.786	1451.8	1152.343	477.625	1.222	469.716	478.875	1469.895	1356.909	0.001	54.665

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
8.508	949.019	883.231	868.811	1452.8	1150.35	475.384	1.25	467.729	477.384	1472.388	1356.909	0.001	54.719
8.531	948.524	882.237	867.836	1455.3	1149.353	475.135	1.273	467.232	477.135	1473.884	1356.909	0.001	54.665
8.555	947.038	881.741	867.349	1456.2	1149.851	473.889	1.297	466.239	476.389	1475.878	1356.909	0.001	54.665
8.582	946.543	880.747	865.886	1456.7	1148.855	471.896	1.324	464.5	474.65	1477.374	1356.909	0	54.773
8.605	945.057	879.754	865.399	1458.7	1147.858	470.153	1.347	462.513	473.158	1478.371	1356.909	0.001	54.828
8.633	944.562	878.76	864.424	1463.1	1147.36	468.907	1.375	461.519	472.164	1479.368	1356.909	0	54.828
8.656	943.571	878.263	863.937	1464.1	1146.862	467.911	1.398	460.774	471.169	1480.365	1356.909	0	54.773
8.68	943.076	877.767	863.449	1463.6	1145.865	468.16	1.422	461.022	471.169	1481.362	1356.909	0.001	54.773
8.707	942.581	876.773	862.962	1465.1	1144.868	470.402	1.449	463.01	472.909	1481.861	1357.958	0	54.828
8.73	941.59	875.78	861.012	1464.6	1144.37	470.402	1.472	462.513	472.909	1482.359	1356.909	0	54.773
8.758	940.6	874.786	860.525	1466.5	1143.872	470.402	1.5	463.01	473.158	1483.356	1357.958	0.001	54.882
8.781	940.105	874.289	860.038	1466.5	1142.875	471.896	1.523	464.5	474.152	1483.855	1356.909	0	54.773
8.805	939.114	873.296	859.55	1466	1141.878	472.893	1.547	465.742	475.395	1484.354	1356.909	0.001	54.828
8.832	938.124	872.799	858.088	1466.5	1140.882	474.636	1.574	467.481	477.135	1483.855	1356.909	0	54.882
8.855	937.628	872.302	857.6	1467.5	1141.38	475.882	1.597	468.723	478.378	1484.354	1356.909	0	54.882
8.883	936.638	870.812	857.113	1468.5	1141.38	475.882	1.625	468.474	478.627	1484.852	1356.909	0	54.882
8.906	936.143	870.315	856.138	1469	1139.885	475.135	1.648	468.226	478.378	1484.852	1356.909	0	54.936
8.93	935.152	869.322	855.651	1468.5	1139.885	472.893	1.672	465.99	476.141	1485.351	1356.909	0	54.936
8.957	934.657	868.825	854.676	1467	1138.888	470.9	1.699	464.003	473.904	1485.351	1356.909	0	54.828
8.98	934.162	867.831	853.701	1469	1138.888	468.409	1.722	461.768	471.915	1485.351	1356.909	0	54.936
9.008	933.171	867.335	853.701	1470.4	1137.892	467.662	1.75	461.271	471.169	1485.849	1356.909	0	54.991
9.031	932.676	866.341	852.239	1470.4	1137.394	466.167	1.773	459.532	469.429	1485.849	1357.958	0	54.936
9.059	931.686	865.844	851.751	1469.5	1136.895	465.918	1.801	459.532	469.181	1485.849	1356.909	0	54.991
9.082	930.695	864.851	850.777	1469.5	1134.902	465.42	1.824	459.035	468.932	1485.849	1356.909	0	55.099
9.105	930.695	864.354	850.777	1470	1134.902	464.673	1.847	458.539	467.938	1486.348	1356.909	0	55.045
9.133	929.704	863.857	849.802	1470	1135.4	465.171	1.875	458.787	467.938	1486.348	1356.909	0	55.099
9.156	928.714	863.361	849.802	1470.4	1133.906	463.677	1.898	457.545	466.944	1486.348	1356.909	0	55.099
9.18	928.219	862.367	848.34	1470.4	1133.407	462.929	1.922	456.8	465.701	1485.849	1356.909	0	55.045
9.207	927.724	861.87	847.852	1469.5	1133.906	463.178	1.949	457.048	466.447	1486.348	1357.958	0	55.153
9.23	927.228	860.877	847.365	1469.5	1131.912	461.684	1.972	455.558	465.204	1486.348	1357.958	0	55.208
9.258	926.238	860.38	846.39	1470	1131.912	460.438	2	454.564	463.464	1486.348	1357.958	0.001	55.153
9.281	925.742	859.386	846.39	1470	1130.417	460.438	2.023	454.316	463.464	1486.846	1356.909	0	55.099

MSFC DATA ON SECOND 11-INCH MOTOR FIRING

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow-meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
9.305	925.247	859.386	845.415	1469.5	1130.916	459.94	2.047	454.316	462.967	1486.846	1356.909	0	55.262
9.332	924.257	858.393	844.928	1470	1129.919	459.691	2.074	453.819	462.967	1486.846	1356.909	0	55.208
9.355	922.771	857.896	843.953	1470.4	1128.922	459.691	2.097	453.819	462.469	1486.846	1356.909	0	55.262
9.383	922.276	857.4	843.466	1470.4	1127.926	459.691	2.125	453.571	462.718	1487.345	1355.861	0	55.262
9.406	921.781	856.903	842.978	1470	1127.926	458.695	2.148	453.074	461.972	1486.348	1356.909	0	55.208
9.43	921.781	855.909	842.491	1470.4	1127.427	458.197	2.172	451.832	461.227	1486.846	1356.909	0.001	55.262
9.457	921.285	855.909	842.491	1470.9	1127.427	458.197	2.199	452.329	461.475	1486.846	1356.909	0	55.262
9.48	920.79	855.413	841.516	1470	1126.431	458.197	2.222	452.329	461.227	1486.846	1356.909	0	55.262
9.508	919.304	854.419	840.541	1470	1125.932	457.449	2.25	451.583	460.481	1486.846	1356.909	0	55.316
9.531	919.304	853.426	840.054	1470.4	1126.431	457.449	2.273	451.832	460.232	1486.846	1356.909	0	55.316
9.555	918.809	853.426	840.054	1470.9	1125.434	456.204	2.297	450.59	458.99	1486.846	1356.909	0	55.316
9.582	918.809	852.929	839.079	1470.9	1124.936	456.453	2.324	450.838	459.238	1486.348	1356.909	0.001	55.37
9.605	918.314	851.935	838.591	1469.5	1124.438	455.457	2.347	450.093	458.741	1486.348	1356.909	0	55.262
9.633	917.818	851.935	837.616	1469	1123.441	455.706	2.375	450.093	458.244	1486.348	1356.909	0	55.316
9.656	917.323	850.942	837.129	1469	1123.441	456.453	2.398	450.838	459.238	1486.846	1356.909	0	55.37
9.68	916.333	850.942	837.616	1470	1123.939	454.958	2.422	449.845	457.995	1486.846	1356.909	0	55.37
9.707	915.838	849.948	836.642	1470.4	1123.441	454.958	2.449	449.596	458.244	1486.846	1356.909	0	55.479
9.73	915.342	849.948	836.154	1471.4	1122.444	453.962	2.472	448.851	457.001	1486.846	1356.909	0	55.425
9.758	914.847	848.955	835.667	1470.9	1120.949	454.211	2.5	448.851	457.25	1486.846	1356.909	0	55.425
9.781	914.352	848.458	834.692	1470	1120.949	453.215	2.523	447.857	456.504	1486.846	1356.909	0.001	55.425
9.805	913.361	847.961	834.692	1470.4	1120.949	451.969	2.547	447.112	455.012	1486.846	1356.909	0	55.425
9.832	912.866	847.464	833.717	1470.4	1120.949	452.717	2.574	447.361	455.758	1486.846	1356.909	0	55.425
9.855	912.371	846.968	833.23	1470.4	1120.451	452.219	2.597	446.615	455.012	1486.846	1356.909	0	55.37
9.883	912.371	845.974	832.742	1470.9	1120.451	452.219	2.625	447.361	455.261	1487.345	1356.909	0	55.425
9.906	911.38	845.974	832.255	1470.4	1118.956	453.215	2.648	447.857	455.51	1487.345	1356.909	0.001	55.479
9.93	910.885	845.478	832.255	1469.5	1118.458	453.713	2.672	448.354	456.255	1487.345	1356.909	0	55.533
9.957	910.885	844.981	831.28	1470.4	1118.956	453.464	2.699	448.354	456.255	1486.846	1357.958	0	55.425
9.98	910.39	844.484	830.793	1470.9	1117.959	452.468	2.722	447.361	455.261	1486.846	1356.909	0	55.533
10.008	909.895	844.484	831.28	1470.9	1116.963	451.969	2.75	447.112	455.261	1487.345	1356.909	0	55.479
10.031	909.399	843.987	830.305	1470.9	1116.963	451.72	2.773	446.864	454.764	1487.844	1356.909	0	55.533
10.059	909.399	843.49	829.818	1470.4	1116.963	451.471	2.801	446.615	454.018	1487.345	1357.958	0.001	55.479
10.082	908.409	842.994	829.331	1469.5	1116.963	450.475	2.824	445.374	453.024	1486.846	1356.909	0	55.533

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
10.105	907.914	842.497	828.356	1471.4	1117.461	450.226	2.847	445.374	453.272	1487.345	1356.909	0.001	55.533
10.133	907.418	842	828.356	1471.4	1115.966	449.479	2.875	444.628	452.029	1486.846	1356.909	0	55.588
10.156	906.428	842	827.868	1470.4	1115.468	448.233	2.898	443.386	451.532	1487.345	1356.909	0	55.588
10.18	906.428	841.007	827.868	1470.9	1114.97	448.233	2.922	443.635	451.035	1486.846	1357.958	0	55.533
10.207	905.437	840.51	826.894	1470.9	1114.471	448.731	2.949	443.883	451.284	1487.844	1356.909	0	55.588
10.23	905.932	840.51	826.894	1470.9	1113.973	448.98	2.972	444.38	451.532	1487.345	1357.958	0	55.588
10.258	905.437	840.013	826.406	1471.9	1113.973	449.229	3	444.628	451.781	1486.846	1356.909	0	55.642
10.281	904.942	839.516	825.919	1471.9	1113.475	450.226	3.023	445.125	452.527	1487.345	1356.909	0	55.533
10.305	904.447	839.02	825.919	1471.9	1112.478	448.98	3.047	444.132	451.532	1487.345	1356.909	0	55.588
10.332	903.952	838.523	825.919	1471.9	1112.478	447.984	3.074	443.386	450.538	1486.846	1356.909	0	55.588
10.355	903.456	838.523	824.944	1471.9	1113.973	448.233	3.097	443.883	451.035	1486.846	1356.909	0	55.642
10.383	902.961	838.026	824.457	1470.9	1111.98	448.482	3.125	443.635	451.284	1486.846	1356.909	0	55.696
10.406	902.961	837.529	823.969	1470.9	1110.983	446.739	3.148	441.896	449.792	1486.846	1356.909	0	55.642
10.43	901.97	837.033	823.482	1471.9	1110.485	447.486	3.172	442.889	449.792	1486.846	1356.909	0	55.642
10.457	901.97	837.033	823.482	1471.9	1109.987	449.479	3.199	444.38	451.532	1486.846	1356.909	0	55.75
10.48	901.475	836.536	823.482	1470.4	1109.987	449.479	3.222	444.877	451.781	1487.345	1356.909	0	55.642
10.508	901.475	836.039	822.507	1470.9	1110.485	447.984	3.25	443.138	450.538	1487.345	1356.909	0	55.696
10.531	901.475	835.542	822.507	1471.4	1109.488	446.988	3.273	442.641	449.792	1487.345	1356.909	0	55.75
10.555	901.475	835.542	822.019	1471.4	1110.485	447.486	3.297	442.641	449.792	1487.345	1356.909	0	55.75
10.582	900.485	834.549	821.532	1472.4	1109.987	446.739	3.324	442.144	449.544	1486.846	1356.909	0	55.642
10.605	899.99	834.549	821.045	1472.4	1108.99	447.237	3.347	442.144	449.295	1487.345	1356.909	0	55.696
10.633	899.99	834.052	821.045	1471.9	1108.492	447.486	3.375	442.641	449.544	1486.846	1356.909	0	55.75
10.656	899.494	833.555	820.07	1471.9	1108.99	449.479	3.398	444.628	451.284	1486.846	1356.909	0	55.696
10.68	898.504	833.555	820.07	1471.9	1107.495	449.728	3.422	445.125	451.781	1487.345	1356.909	0	55.75
10.707	898.009	833.059	820.07	1471.4	1107.495	451.72	3.449	446.864	453.521	1486.846	1356.909	0	55.805
10.73	898.009	833.059	819.582	1471.4	1107.495	452.966	3.472	448.106	454.764	1487.345	1356.909	0	55.75
10.758	898.504	832.562	819.582	1471.4	1106.498	453.464	3.5	448.603	455.261	1486.846	1356.909	0	55.805
10.781	898.009	832.562	819.095	1471.4	1106	453.962	3.523	449.099	456.007	1486.846	1356.909	0	55.75
10.805	897.513	832.065	819.095	1471.9	1105.502	453.962	3.547	449.348	456.255	1487.345	1356.909	0	55.75
10.832	897.018	831.568	818.608	1472.4	1105.502	452.966	3.574	448.603	455.261	1487.345	1356.909	0	55.75
10.855	896.523	831.072	818.12	1472.4	1106	452.468	3.597	447.857	455.012	1487.345	1356.909	0	55.805
10.883	896.028	831.072	817.633	1471.4	1105.502	452.717	3.625	448.354	455.012	1487.345	1356.909	0	55.75

MSFC DATA ON SECOND 11-INCH MOTOR FIRING

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow-meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
10.906	896.028	830.575	817.145	1470.4	1106	450.475	3.648	445.87	452.775	1487.345	1356.909	0	55.805
10.93	895.532	830.078	817.145	1470	1104.505	448.731	3.672	444.38	451.284	1487.345	1356.909	0	55.859
10.957	895.532	830.078	816.658	1471.4	1103.509	447.735	3.699	443.386	450.538	1487.345	1356.909	0	55.805
10.98	895.037	829.581	816.658	1471.4	1104.505	446.49	3.722	442.144	449.295	1487.345	1356.909	0	55.859
11.008	894.542	829.084	816.17	1471.9	1104.505	446.739	3.75	442.393	449.295	1487.345	1356.909	0	55.859
11.031	895.037	828.588	815.683	1471.9	1102.512	445.493	3.773	441.399	448.301	1487.345	1356.909	0	55.859
11.059	894.542	828.588	815.196	1471.9	1103.01	444.248	3.801	440.157	447.058	1486.846	1356.909	0	55.913
11.082	894.047	828.091	815.196	1470.9	1103.509	442.753	3.824	438.667	445.318	1487.345	1356.909	0	55.805
11.105	893.552	828.091	814.708	1470.4	1104.007	443.251	3.847	438.915	445.318	1486.846	1356.909	0	55.805
11.133	893.056	827.594	814.708	1471.4	1103.01	444.248	3.875	439.909	446.312	1487.345	1356.909	0	55.859
11.156	893.552	827.594	814.708	1471.9	1102.013	443.75	3.898	439.164	445.567	1487.345	1356.909	0	55.859
11.18	892.066	827.594	814.221	1472.4	1101.515	443.75	3.922	439.412	446.064	1486.846	1356.909	0	55.859
11.207	892.066	827.097	814.221	1472.4	1101.515	441.508	3.949	437.673	444.075	1486.846	1356.909	0	55.913
11.23	891.075	826.104	813.733	1470	1101.515	442.255	3.972	438.17	444.572	1487.345	1356.909	0	55.859
11.258	891.075	826.601	813.246	1470.4	1102.013	442.255	4	438.17	444.324	1486.846	1356.909	0	55.967
11.281	891.57	826.104	813.246	1472.4	1101.017	441.259	4.023	437.425	443.826	1486.846	1356.909	0	55.967
11.305	891.075	826.104	813.246	1472.9	1100.519	441.757	4.047	437.673	444.075	1487.345	1356.909	0	55.967
11.332	891.075	825.607	813.246	1471.9	1100.519	442.006	4.074	437.922	443.826	1486.846	1356.909	0	55.913
11.355	891.075	825.607	812.759	1471.9	1100.519	442.006	4.097	437.922	444.075	1487.345	1356.909	0	55.967
11.383	890.58	825.11	812.271	1470.9	1100.519	442.504	4.125	438.17	444.324	1487.345	1356.909	0	55.913
11.406	890.084	825.11	812.271	1471.9	1099.522	440.511	4.148	436.928	443.081	1487.345	1356.909	0	55.913
11.43	890.084	824.614	811.784	1471.4	1100.02	441.757	4.172	437.673	443.578	1487.345	1356.909	0	55.967
11.457	889.094	824.117	811.296	1472.4	1100.02	441.01	4.199	437.177	443.329	1487.345	1356.909	0	55.913
11.48	888.599	824.117	810.809	1471.9	1100.519	440.013	4.222	436.431	442.335	1487.345	1356.909	0	55.913
11.508	888.599	824.117	811.296	1471.9	1099.024	440.511	4.25	436.928	443.081	1487.345	1356.909	0	55.913
11.531	888.599	823.62	810.809	1472.4	1099.024	440.76	4.273	436.68	442.832	1487.345	1356.909	0	55.967
11.555	888.599	823.123	810.322	1470.4	1098.027	440.013	4.297	436.431	442.086	1486.846	1356.909	0	55.967
11.582	888.599	822.627	810.322	1471.9	1098.525	440.511	4.324	436.68	442.335	1486.846	1356.909	0	56.022
11.605	888.599	822.627	809.834	1472.4	1098.027	440.511	4.347	436.68	442.584	1487.345	1356.909	0	55.967
11.633	888.104	822.627	809.347	1472.4	1097.031	441.259	4.375	437.425	443.081	1486.846	1356.909	0	55.967
11.656	888.104	822.627	809.347	1472.4	1097.031	441.259	4.398	437.425	443.578	1486.846	1356.909	0	56.022
11.68	887.113	822.13	809.347	1471.4	1097.031	439.515	4.422	436.183	442.335	1486.846	1356.909	0	55.913

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow-meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
11.707	887.113	822.13	809.347	1470	1097.529	439.266	4.449	435.686	441.341	1486.846	1356.909	0	55.913
11.73	886.618	821.633	808.859	1469	1097.529	439.764	4.472	436.183	441.589	1486.846	1355.861	0	55.967
11.758	886.123	821.633	808.859	1470	1096.532	440.262	4.5	436.183	442.086	1486.846	1356.909	0	55.967
11.781	886.123	821.136	808.372	1470	1095.535	439.515	4.523	436.183	441.838	1486.846	1355.861	0	56.022
11.805	886.123	821.136	808.372	1470	1096.034	438.519	4.547	435.438	441.092	1486.846	1356.909	0	56.022
11.832	885.627	820.64	808.372	1470	1096.532	438.27	4.574	434.692	440.346	1486.846	1356.909	0	56.022
11.855	885.627	820.64	807.397	1471.4	1096.034	438.768	4.597	435.189	440.595	1486.846	1356.909	0	56.076
11.883	885.627	820.64	807.885	1471.9	1095.037	439.266	4.625	435.686	441.092	1486.846	1356.909	0	56.076
11.906	885.132	820.143	807.397	1470	1095.037	440.013	4.648	436.68	441.838	1486.846	1355.861	0	55.967
11.93	885.132	819.646	807.397	1470.4	1095.535	439.515	4.672	436.431	441.838	1486.846	1356.909	0	56.076
11.957	885.132	819.646	807.397	1471.4	1094.041	439.266	4.699	435.935	441.341	1486.846	1356.909	0	55.913
11.98	884.637	819.149	806.91	1471.9	1093.542	438.768	4.722	435.438	440.844	1486.846	1356.909	0	56.076
12.008	884.142	819.149	806.422	1471.9	1095.037	438.021	4.75	434.692	440.098	1487.345	1356.909	0	56.076
12.031	883.646	819.149	806.422	1471.9	1094.539	439.515	4.773	435.935	441.092	1487.345	1356.909	0	56.076
12.059	884.142	819.149	805.935	1470.9	1093.542	439.017	4.801	435.438	441.341	1487.345	1356.909	0	55.967
12.082	883.646	818.653	805.935	1470	1094.041	438.768	4.824	435.438	440.844	1486.846	1356.909	0	55.967
12.105	883.646	818.156	805.448	1470.4	1094.539	439.266	4.847	435.935	441.341	1486.846	1356.909	0	56.022
12.133	883.646	817.659	804.96	1470.9	1094.041	438.768	4.875	435.438	440.844	1486.846	1355.861	0	56.022
12.156	883.151	817.659	804.96	1471.9	1092.546	438.519	4.898	435.189	440.595	1486.846	1356.909	0	56.022
12.18	883.151	817.659	804.96	1470.4	1093.542	439.017	4.922	435.438	440.595	1486.846	1355.861	0	56.022
12.207	883.151	818.156	805.448	1470.4	1093.542	438.768	4.949	435.686	440.844	1486.846	1356.909	0	56.076
12.23	883.151	817.659	805.448	1470.4	1092.047	439.017	4.972	435.935	440.595	1486.846	1356.909	0	56.076
12.258	882.656	817.162	804.473	1471.9	1092.546	439.266	5	435.686	441.092	1486.846	1356.909	0	56.022
12.281	882.656	817.162	804.473	1472.4	1093.044	439.515	5.023	436.183	441.838	1486.846	1356.909	0	56.13
12.305	882.161	816.666	804.473	1471.4	1092.546	438.519	5.047	435.189	440.346	1486.846	1355.861	0	55.967
12.332	881.666	817.162	804.473	1471.9	1092.047	436.775	5.074	433.699	439.104	1486.846	1356.909	0	56.076
12.355	881.666	816.666	803.985	1471.4	1092.546	439.017	5.097	435.686	440.346	1486.348	1355.861	0	56.022
12.383	881.17	816.169	803.498	1471.9	1092.047	439.764	5.125	436.68	441.341	1486.846	1355.861	0	56.022
12.406	881.17	816.169	803.498	1471.4	1091.051	440.511	5.148	437.425	442.086	1486.846	1356.909	0	56.022
12.43	881.17	816.169	803.498	1470.9	1090.552	439.515	5.172	436.431	441.838	1486.846	1356.909	0	56.076
12.457	880.675	816.169	803.498	1471.4	1091.051	439.266	5.199	436.431	441.092	1486.846	1356.909	0	56.13
12.48	880.675	816.169	803.498	1470.9	1090.054	439.017	5.222	436.183	440.844	1486.846	1356.909	0	56.076

MSFC DATA ON SECOND 11-INCH MOTOR FIRING

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
12.508	880.18	815.672	803.498	1470.9	1090.054	441.01	5.25	437.673	442.335	1486.348	1355.861	0	56.022
12.531	880.18	815.672	803.01	1471.4	1090.054	440.262	5.273	437.425	442.335	1486.846	1356.909	0	56.076
12.555	880.18	815.175	802.523	1471.4	1090.054	440.511	5.297	437.673	442.086	1486.846	1355.861	0	56.022
12.582	880.18	814.678	802.523	1471.4	1089.556	440.262	5.324	437.177	441.838	1486.846	1355.861	0	56.022
12.605	879.684	814.678	802.035	1472.4	1089.556	439.017	5.347	436.183	441.092	1486.348	1355.861	0	56.022
12.633	878.694	814.678	802.035	1471.4	1089.057	439.266	5.375	436.431	441.341	1486.846	1355.861	0	56.13
12.656	878.694	814.678	802.035	1470.4	1088.559	438.27	5.398	435.438	440.346	1487.345	1356.909	0	56.13
12.68	879.189	814.182	801.548	1470	1089.057	438.519	5.422	435.438	440.098	1486.846	1355.861	0	56.076
12.707	878.694	813.685	801.548	1470.4	1088.559	439.017	5.449	435.935	440.844	1486.348	1355.861	0	56.13
12.73	879.189	814.182	801.548	1470	1088.559	438.519	5.472	435.686	440.346	1486.846	1355.861	0	56.13
12.758	878.198	813.685	801.548	1471.4	1089.556	438.519	5.5	435.189	440.098	1486.846	1355.861	0	56.076
12.781	877.703	813.685	800.573	1471.9	1089.057	439.515	5.523	436.431	440.844	1486.846	1355.861	0	56.022
12.805	878.198	813.188	800.573	1471.9	1089.057	439.764	5.547	436.68	441.092	1486.846	1355.861	0	56.022
12.832	878.198	812.692	800.573	1470.9	1088.061	438.768	5.574	435.935	440.346	1486.846	1355.861	0	56.076
12.855	878.198	813.685	800.573	1471.4	1088.559	440.262	5.597	437.177	441.589	1486.846	1355.861	0	56.13
12.883	878.198	813.188	801.061	1471.9	1088.061	439.764	5.625	436.68	441.589	1486.846	1355.861	0	55.967
12.906	877.703	812.692	800.573	1470.9	1088.061	439.017	5.648	435.686	440.595	1486.846	1355.861	0	56.13
12.93	877.208	812.692	799.598	1470.4	1087.563	438.768	5.672	435.686	440.595	1486.846	1355.861	0	55.967
12.957	877.208	812.692	800.086	1470.4	1087.563	438.27	5.699	435.438	440.346	1486.846	1355.861	0	56.076
12.98	876.713	812.195	800.086	1470.9	1087.563	439.515	5.722	436.183	440.595	1486.846	1355.861	0	56.022
13.008	877.208	812.195	799.598	1472.4	1087.563	438.27	5.75	435.189	439.849	1486.846	1355.861	0	56.076
13.031	876.713	812.195	799.598	1472.4	1087.064	437.273	5.773	434.444	439.352	1486.846	1355.861	0	56.022
13.059	876.218	811.698	799.111	1472.4	1086.566	438.519	5.801	435.686	440.098	1486.846	1355.861	0	56.022
13.082	876.713	811.698	799.111	1470	1086.068	438.021	5.824	435.189	439.601	1486.846	1355.861	0	55.967
13.105	876.218	811.698	799.111	1470.9	1086.068	438.519	5.847	435.686	440.346	1486.846	1355.861	0	56.076
13.133	876.713	811.201	799.111	1471.9	1086.566	437.522	5.875	434.692	439.104	1486.846	1355.861	0	56.076
13.156	876.218	811.201	798.624	1470.9	1086.566	436.277	5.898	433.699	438.358	1486.348	1355.861	0	56.076
13.18	875.227	810.705	799.111	1470.9	1085.569	437.273	5.922	434.444	438.855	1486.846	1355.861	0	56.076
13.207	875.227	810.953	798.624	1470.4	1086.566	438.519	5.949	435.686	439.849	1486.846	1355.861	0	56.13
13.23	875.722	810.705	798.624	1470	1086.566	438.519	5.972	435.438	440.098	1486.348	1355.861	0	56.022
13.258	875.227	810.705	798.624	1471.9	1085.569	438.27	6	435.438	439.601	1486.846	1355.861	0	56.022
13.281	875.227	810.456	798.136	1471.9	1085.569	438.768	6.023	436.183	440.098	1486.846	1356.909	0	56.022

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow-meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
13.305	875.227	810.705	798.624	1472.4	1085.071	438.768	6.047	435.686	440.098	1486.846	1355.861	0	56.076
13.332	874.732	810.456	797.649	1470.9	1084.074	438.768	6.074	435.935	440.346	1486.846	1355.861	0	56.022
13.355	874.732	810.208	797.649	1471.4	1084.074	438.768	6.097	435.935	440.595	1486.846	1355.861	0	56.076
13.383	874.732	809.959	797.649	1470.9	1084.573	439.266	6.125	436.431	440.595	1486.348	1355.861	0	56.022
13.406	874.732	809.959	797.649	1470.9	1084.074	438.021	6.148	435.438	439.849	1486.846	1355.861	0	56.022
13.43	874.732	809.959	797.161	1469.5	1084.573	437.522	6.172	434.692	439.352	1486.846	1356.909	0	56.022
13.457	874.237	809.711	797.161	1467	1084.573	435.779	6.199	433.202	437.612	1486.846	1356.909	0	55.967
13.48	874.237	809.711	797.161	1469.5	1084.573	436.526	6.222	433.947	438.109	1486.846	1355.861	0	56.076
13.508	873.741	809.463	796.674	1470.9	1084.573	437.522	6.25	434.692	438.855	1486.846	1355.861	0	56.13
13.531	873.741	809.214	796.674	1470.9	1084.074	436.775	6.273	434.196	438.606	1486.846	1356.909	0	56.076
13.555	873.246	809.214	796.918	1470.4	1085.071	438.021	6.297	435.189	439.352	1486.846	1355.861	0	56.076
13.582	873.246	809.214	796.674	1470.4	1084.573	436.775	6.324	434.196	438.606	1486.846	1356.909	0	55.967
13.605	873.246	809.214	796.674	1471.4	1083.576	436.775	6.347	434.196	438.358	1486.348	1355.861	0	56.022
13.633	873.246	809.214	796.43	1470.9	1083.078	436.526	6.375	434.196	438.358	1486.846	1355.861	0	56.13
13.656	873.246	808.966	796.43	1470.9	1082.579	437.024	6.398	434.692	438.855	1486.846	1355.861	0	56.022
13.68	872.751	808.718	796.187	1470.9	1082.579	438.021	6.422	435.438	439.352	1487.345	1355.861	0	55.967
13.707	872.751	808.469	795.943	1470.4	1082.579	438.519	6.449	435.686	439.849	1486.846	1355.861	0	56.076
13.73	872.751	808.469	795.943	1471.4	1082.081	438.27	6.472	435.438	439.601	1486.846	1356.909	0	56.022
13.758	872.751	808.718	795.699	1470.4	1081.583	438.519	6.5	435.686	439.601	1486.846	1355.861	0	55.967
13.781	872.751	808.221	795.699	1471.4	1082.081	438.519	6.523	435.686	439.601	1486.846	1355.861	0	56.076
13.805	872.751	807.972	795.943	1470.4	1082.579	438.27	6.547	435.686	440.098	1486.846	1355.861	0	56.076
13.832	872.256	807.972	795.699	1470	1083.576	437.771	6.574	435.438	439.104	1486.348	1355.861	0	56.022
13.855	872.256	807.972	795.456	1470	1083.576	438.27	6.597	435.935	439.601	1486.846	1356.909	0	55.967
13.883	871.76	807.724	795.212	1471.4	1082.081	440.262	6.625	437.922	441.341	1486.846	1355.861	0	55.967
13.906	871.76	807.972	795.943	1471.4	1082.579	441.01	6.648	438.667	442.086	1486.846	1355.861	0	56.022
13.93	872.256	807.476	795.699	1470.4	1082.081	439.764	6.672	437.177	441.092	1486.846	1355.861	0	56.022
13.957	871.76	807.227	794.968	1470.9	1082.579	438.021	6.699	435.686	440.098	1486.348	1355.861	0	56.022
13.98	871.76	807.227	794.724	1470.9	1080.586	438.768	6.722	436.68	439.849	1486.348	1355.861	0	55.967
14.008	870.77	806.979	794.481	1471.9	1080.088	438.768	6.75	436.431	440.346	1486.846	1355.861	0	56.022
14.031	870.77	806.73	794.481	1470.4	1080.586	439.266	6.773	436.68	440.346	1486.846	1355.861	0.001	55.913
14.059	870.77	806.979	794.724	1468	1080.088	438.519	6.801	436.183	440.346	1486.348	1355.861	0.001	55.967
14.082	870.77	806.73	794.481	1470.4	1080.586	438.021	6.824	435.438	439.352	1486.846	1355.861	0	55.967

MSFC DATA ON SECOND 11-INCH MOTOR FIRING

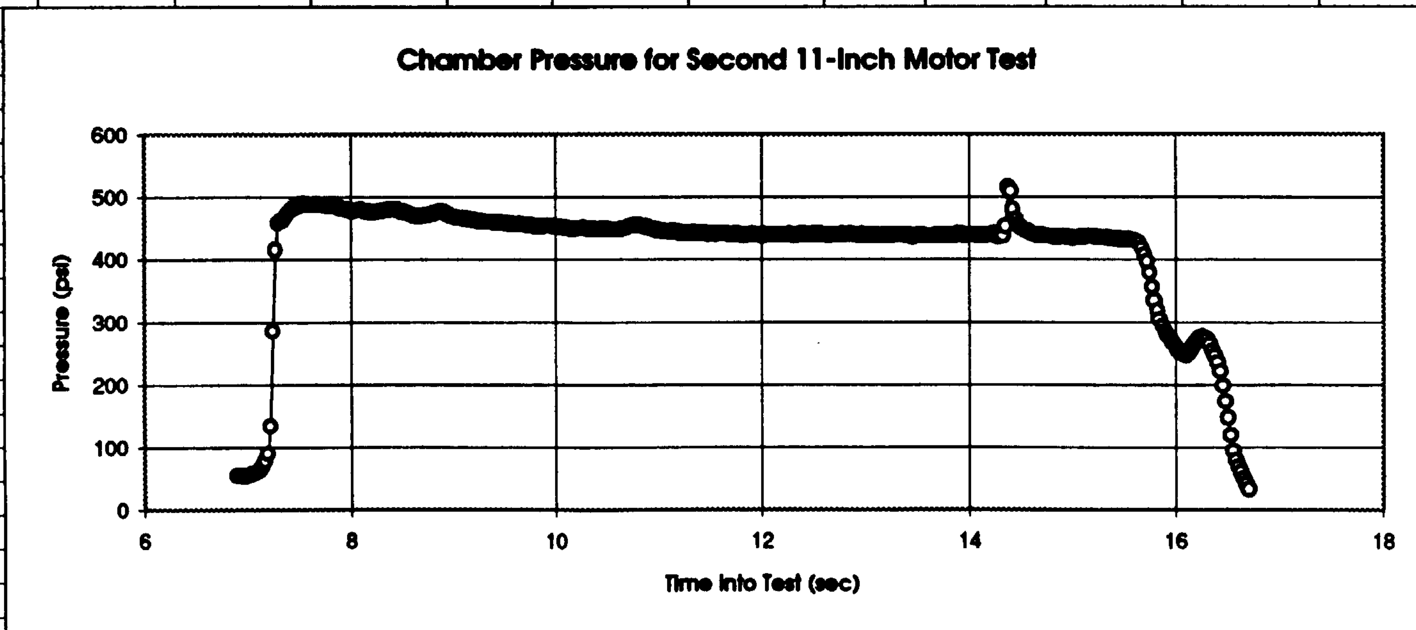
	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
14.105	870.77	806.979	794.481	1465.1	1080.088	439.017	6.847	436.68	440.098	1478.869	1355.861	0	55.967
14.133	870.77	806.979	794.237	1442.5	1079.59	437.771	6.875	435.438	439.104	1462.417	1354.813	0	55.913
14.156	870.77	806.482	793.993	1433.2	1080.088	438.021	6.898	435.686	439.352	1457.929	1353.765	0	55.967
14.18	870.275	806.234	793.506	1408.2	1080.088	438.768	6.922	436.431	439.849	1472.388	1354.813	0	55.913
14.207	871.265	806.234	793.75	1368	1081.084	439.017	6.949	436.928	440.098	1483.855	1356.909	0	55.967
14.23	870.275	806.234	793.75	1328.8	1080.586	439.764	6.972	437.177	441.092	1494.823	1356.909	0	55.913
14.258	870.77	805.985	793.75	1292.6	1079.59	439.764	7	437.425	441.341	1500.308	1356.909	0	55.913
14.281	870.77	805.985	793.75	1258.8	1079.091	436.028	7.023	433.45	438.606	1503.798	1356.909	0	55.859
14.305	870.275	805.985	793.75	1227.9	1080.088	436.526	7.047	431.96	436.866	1506.29	1357.958	0	55.913
14.332	870.275	805.737	793.019	1197.5	1079.59	437.024	7.074	433.202	436.369	1506.789	1357.958	0	55.859
14.355	869.284	805.737	793.262	1169.6	1078.593	452.219	7.097	449.845	445.069	1503.798	1357.958	0	55.859
14.383	869.78	805.24	793.262	1142.2	1078.593	514.74	7.125	510.453	478.875	1481.861	1359.006	0	55.913
14.406	869.78	804.992	793.019	1116.7	1078.593	508.263	7.148	504.243	491.055	1449.952	1360.054	0	55.75
14.43	869.78	805.489	793.019	1092.2	1079.59	479.867	7.172	477.913	480.864	1419.54	1361.101	0	55.859
14.457	869.284	805.489	792.775	1068.7	1079.091	462.68	7.199	461.271	467.689	1392.119	1361.101	0	55.913
14.48	869.284	805.24	793.262	1045.2	1077.596	454.709	7.222	453.322	459.238	1366.194	1362.149	0	55.805
14.508	869.284	804.992	793.262	1023.6	1077.596	450.724	7.25	449.099	453.77	1340.767	1361.101	0	55.859
14.531	868.789	804.992	792.287	1001.1	1077.596	446.739	7.273	445.125	449.047	1317.334	1362.149	0	55.913
14.555	869.284	804.992	792.044	978.54	1077.098	444.995	7.297	443.635	446.809	1294.899	1362.149	0	55.859
14.582	868.789	804.495	792.044	959.43	1077.098	443.999	7.324	442.144	445.318	1272.962	1362.149	0	55.75
14.605	868.294	804.743	792.531	940.81	1077.596	440.511	7.347	438.915	442.335	1252.022	1362.149	0	55.805
14.633	868.294	804.495	792.287	922.2	1077.098	439.266	7.375	437.673	440.595	1231.581	1362.149	0	55.642
14.656	868.789	804.743	792.287	903.09	1078.095	439.266	7.398	437.922	440.844	1212.137	1362.149	0	55.75
14.68	868.789	804.247	792.044	884.96	1079.091	438.021	7.422	436.928	439.601	1193.191	1362.149	0	55.859
14.707	868.789	804.247	791.8	866.83	1076.6	437.771	7.449	436.431	439.104	1175.243	1362.149	0	55.75
14.73	868.294	803.998	791.556	850.17	1076.6	437.522	7.472	436.183	439.104	1157.793	1362.149	0.001	55.75
14.758	868.294	803.998	791.313	833.76	1077.098	437.024	7.5	435.438	438.606	1140.344	1363.197	0	55.75
14.781	868.294	803.75	791.556	817.35	1078.095	436.775	7.523	435.189	438.109	1123.891	1363.197	0	55.859
14.805	868.294	803.75	791.8	801.67	1077.596	436.775	7.547	435.189	438.109	1106.939	1363.197	0	55.696
14.832	868.294	803.75	791.8	785.5	1077.098	434.533	7.574	433.202	436.121	1091.484	1363.197	0	55.75
14.855	867.798	803.75	791.8	769.33	1077.098	435.281	7.597	433.947	436.369	1075.53	1362.149	0	55.805
14.883	867.303	803.253	790.825	753.65	1076.6	435.53	7.625	434.196	436.866	1060.573	1363.197	0	55.859

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow-meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
14.906	867.303	803.502	790.825	739.2	1077.098	436.277	7.648	434.941	437.612	1045.616	1363.197	0	55.805
14.93	867.798	803.502	791.313	724.75	1077.098	436.526	7.672	435.189	437.861	1031.158	1363.197	0	55.805
14.957	867.303	803.502	791.313	708.58	1077.596	436.028	7.699	434.692	437.364	1017.198	1362.149	0	55.696
14.98	867.798	803.75	791.313	692.9	1076.6	434.782	7.722	433.45	436.121	1002.74	1356.909	0	55.75
15.008	868.294	803.253	791.069	678.69	1076.6	434.035	7.75	432.705	435.624	989.278	1353.765	0	55.75
15.031	868.789	803.005	790.825	664.49	1077.098	434.782	7.773	433.699	436.121	975.817	1355.861	0	55.805
15.059	869.284	803.005	790.582	651.5	1077.596	434.284	7.801	432.954	435.872	962.854	1356.909	0	55.75
15.082	869.78	802.757	790.582	639.5	1078.095	434.284	7.824	432.705	435.375	949.393	1355.861	0	55.696
15.105	870.77	802.508	790.338	626.76	1077.596	435.779	7.847	434.196	436.618	936.929	1357.958	0	55.696
15.133	870.77	802.508	789.606	613.53	1077.596	436.028	7.875	434.692	437.364	923.966	1357.958	0	55.696
15.156	871.265	802.26	790.094	600.79	1077.596	436.775	7.898	435.189	437.861	912	1357.958	0	55.805
15.18	871.76	802.011	789.606	588.79	1078.593	436.277	7.922	434.941	437.364	900.035	1357.958	0	55.75
15.207	872.751	801.763	788.875	577.28	1078.593	436.277	7.949	434.692	437.364	888.069	1359.006	0	55.696
15.23	873.246	802.011	789.363	565.52	1079.091	436.028	7.972	434.692	437.612	876.104	1359.006	0	55.75
15.258	873.741	801.763	789.363	554.25	1080.088	434.284	8	433.202	436.121	864.637	1360.054	0	55.642
15.281	873.741	801.515	789.119	543.71	1080.088	434.533	8.023	433.45	436.369	853.668	1360.054	0	55.75
15.305	874.732	801.018	788.388	532.69	1079.59	435.031	8.047	433.947	436.121	842.201	1360.054	0	55.642
15.332	876.218	799.776	787.413	522.16	1081.084	434.284	8.074	432.954	435.872	831.233	1360.054	0	55.696
15.355	880.18	799.031	786.438	512.6	1082.579	433.786	8.097	432.705	435.126	820.264	1360.054	0	55.588
15.383	885.132	798.286	785.951	503.05	1085.071	434.782	8.125	433.699	436.121	809.795	1360.054	0	55.642
15.406	889.094	798.286	785.707	493.5	1088.061	433.039	8.148	431.96	434.629	799.325	1361.101	0	55.642
15.43	896.028	797.541	784.976	485.17	1090.552	432.292	8.172	431.215	433.884	788.855	1361.101	0	55.588
15.457	906.428	797.044	784.976	477.33	1096.532	431.295	8.199	430.221	432.889	778.884	1361.101	0	55.588
15.48	921.781	795.802	783.758	469.73	1104.505	432.042	8.222	431.215	433.635	768.912	1361.101	0	55.533
15.508	947.533	794.312	782.052	463.12	1116.465	431.046	8.25	430.221	432.641	758.442	1361.101	0	55.642
15.531	1009.439	793.318	780.346	456.75	1144.37	430.548	8.273	429.476	431.895	749.468	1361.101	0	55.533
15.555	1103.537	791.58	778.884	451.85	1207.157	431.046	8.297	429.725	432.889	740.992	1361.101	0	55.479
15.582	1196.148	788.599	775.959	446.95	1279.911	430.548	8.324	429.228	431.895	732.018	1361.101	0	55.479
15.605	1275.388	784.873	772.303	443.28	1349.674	430.05	8.347	428.731	431.398	723.044	1361.101	0	55.479
15.633	1345.713	776.925	765.723	440.34	1414.953	428.057	8.375	426.992	429.658	714.569	1361.101	0	55.37
15.656	1411.086	756.807	749.152	437.64	1475.747	425.317	8.398	424.011	427.669	706.093	1361.101	0	55.425
15.68	1473.488	719.55	709.427	434.46	1535.544	417.595	8.422	416.56	420.958	695.872	1361.101	0	55.37

MSFC DATA ON SECOND 11-INCH MOTOR FIRING

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow-meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
15.707	1530.936	693.47	681.401	429.8	1594.843	407.881	8.449	406.624	412.258	689.391	1361.101	0	55.425
15.73	1584.918	687.261	675.552	422.7	1653.145	395.925	8.472	394.701	401.321	681.414	1361.101	0	55.262
15.758	1635.928	691.235	679.939	415.35	1709.952	378.987	8.5	377.313	387.152	673.188	1361.101	0	55.208
15.781	1685.453	692.477	680.914	406.53	1768.753	355.822	8.523	353.964	368.012	665.211	1362.149	0	54.936
15.805	1733.989	689.993	678.233	397.96	1829.548	333.653	8.547	332.353	347.629	657.732	1361.101	0	54.773
15.832	1779.552	686.764	674.578	388.89	1889.344	316.715	8.574	315.462	329.11	650.004	1362.149	0	54.502
15.855	1824.123	684.032	672.141	380.56	1950.139	303.762	8.597	302.67	313.948	642.277	1362.149	0	54.23
15.883	1868.696	679.313	667.266	372.97	2007.943	293.176	8.625	291.989	301.27	634.3	1362.149	0	54.013
15.906	1915.249	673.352	660.686	365.13	2067.739	285.33	8.648	284.165	291.452	627.07	1362.149	0	53.687
15.93	1959.822	665.9	653.375	357.78	2126.54	278.231	8.672	277.209	283.125	619.592	1362.149	0	53.47
15.957	1995.479	655.22	643.871	350.43	2185.341	271.381	8.699	270.379	275.792	612.612	1362.149	0	53.198
15.98	2023.212	638.579	627.542	343.33	2235.173	265.776	8.722	264.666	269.204	605.134	1362.149	0	52.872
16.008	2041.042	623.676	611.458	336.47	2273.043	260.172	8.75	259.201	263.487	597.904	1362.149	0	52.6
16.031	2051.937	617.715	603.659	329.61	2298.955	254.816	8.773	253.736	258.019	591.174	1362.149	0	52.219
16.055	2054.909	617.715	603.903	322.63	2314.901	250.208	8.797	249.389	252.923	583.945	1360.054	0	51.947
16.082	2050.947	616.721	603.172	316.14	2312.909	247.344	8.824	246.16	249.319	577.463	1258.396	0.001	51.567
16.105	2045.004	613.989	600.004	309.77	2288.989	245.476	8.847	244.67	247.082	570.483	1239.532	0	51.131
16.133	2039.061	610.76	595.373	303.64	2270.054	249.585	8.875	248.768	249.443	563.753	1284.596	0	50.914
16.156	2034.109	607.78	591.23	297.64	2278.026	256.062	8.898	255.351	254.539	557.022	1301.888	0	50.478
16.18	2031.137	603.557	586.6	292.62	2295.966	263.285	8.922	262.181	260.753	550.79	1299.268	0	50.097
16.207	2028.166	598.59	580.507	288.82	2297.96	268.765	8.949	267.895	265.724	544.059	1291.409	0.001	49.77
16.23	2025.193	592.629	572.465	286.86	2284.006	273.249	8.972	272.366	270.447	537.578	1288.789	0	49.389
16.258	2022.223	586.171	564.179	285.51	2277.031	275.491	9	274.353	274.052	531.595	1287.741	0	49.117
16.281	2019.252	577.726	551.994	283.8	2286	274.37	9.023	273.483	274.176	525.363	1286.693	0	48.626
16.305	2017.271	569.033	538.346	282.21	2293.972	271.381	9.047	270.503	272.56	519.38	1285.121	0	48.408
16.332	2014.298	563.32	524.942	278.78	2290.983	263.659	9.074	262.678	266.719	513.148	1281.977	0	47.863
16.355	2012.317	562.823	508.127	274.37	2283.009	253.945	9.097	253.364	258.143	507.166	1278.832	0	47.645
16.383	2010.336	566.052	480.101	268.86	2282.014	245.351	9.125	244.545	249.319	501.183	1274.116	0	47.154
16.406	2008.355	575.242	421.124	263.47	2287.994	235.263	9.148	234.485	240.246	495.449	1268.876	0	46.772
16.43	2006.374	585.674	328.76	257.71	2291.98	220.069	9.172	219.209	228.687	489.466	1262.065	0	46.444
16.457	2004.393	586.668	253.333	251.83	2287.994	197.9	9.199	197.102	212.779	484.231	1255.253	0	46.008
16.48	2002.412	582.694	209.831	246.2	2284.006	172.742	9.222	173.132	193.887	478.498	1248.44	0	45.462

	P3000	P3001	P3002	P3005	P3007	P3009		P3010	P3011	P5004	P6004	SP0001	T2009
T1428-1927 Time	GOX trailer supply P below reg	GOX Flow-meter 4 inlet P	GOX Venturi 2" System P	GH2 ignition venturi P	GOX Trailer supply P	Motor fwd closure 135 deg	Adj time	Aft "mixing" chamber 120 deg	Motor, behind grain plane 135	GOX ignition venturi P	N2 press	Spark detection galvan-ometer	GOX venturi 2" inlet Temp
16.508	2000.431	576.733	183.511	241.17	2286	146.339	9.25	147.919	174.126	472.764	1240.581	0	44.806
16.531	1998.451	571.268	161.212	236.03	2288.989	118.565	9.273	121.217	153.245	467.53	1232.197	0	44.15
16.555	1996.47	566.549	140.863	231.01	2289.986	93.781	9.297	97.495	132.987	461.796	1221.716	0	43.275
16.582	1995.479	561.83	124.291	226.11	2286.997	78.587	9.324	82.094	115.338	456.561	1211.236	0	42.509
16.605	1993.498	556.366	112.105	221.45	2286	68.748	9.347	71.165	100.672	451.575	1200.756	0	41.743
16.633	1992.508	552.888	102.114	216.8	2286.997	59.033	9.375	60.981	87.622	446.091	1189.752	0	40.921
16.656	1990.527	552.392	95.412	212.39	2289.986	49.942	9.398	51.542	76.561	441.105	1178.224	0	40.154
16.68	1988.546	557.856	90.659	207.86	2287.994	40.601	9.422	42.351	66.121	435.871	1167.744	0	39.331
16.707	1987.555	576.733	85.907	203.33	2286.997	32.132	9.449	33.781	57.048	430.885	1157.264	0	38.563



MARSHALL SPACE FLIGHT

HUNTSVILLE AL

RETURN ... CHANGES

544-4... 30000...