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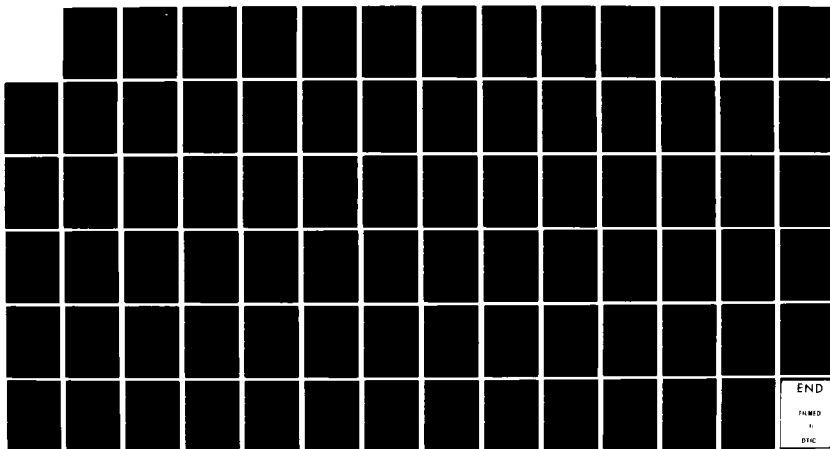
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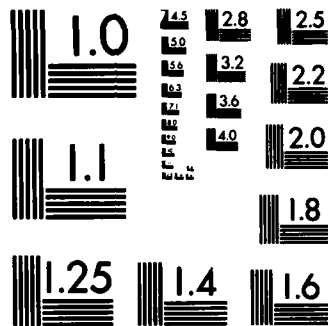
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**CATAPULT DYNAMICS
IN A HIGH ACCELERATION ENVIRONMENT**

**TECHNICAL NOTE
USAFA-TN-82-5**

Higgins, A.M.

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15 OCTOBER 1982

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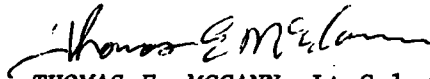
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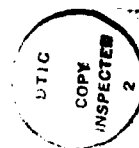
This Technical Note is approved for publication.



THOMAS E. MCCANN, Lt Colonel, USAF
Director of Research and Continuing Education

Foreword

This Technical Note is the final report covering the period 1 Oct 79 to 30 Sep 81 in response to AF Flight Dynamics Laboratory project order no. WAL 03019 which was administered by Mr. James M. Peters. Major A. M. Higgins was the Principal Investigator and was aided by staff and cadets at the Air Force Academy.



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CATAPULT DYNAMICS IN A HIGH ACCELERATION ENVIRONMENT

A.M. Higgins*

Abstract

This paper presents the results of a test program in which ejection catapults were test fired both in an environment of zero acceleration (catapult horizontal) and in a high acceleration environment. These test results showed a marked effect of G loading on the catapult dynamics. The catapult pressures, for example, were significantly higher. This paper also describes an attempt made to construct a computer model which would predict the catapult's dynamics under any G loading. A discussion of the model results is included, as is the computer model program.

I. Introduction

Modern fighter aircraft are using sustained high acceleration maneuvers as a useful combat technique. As a result, the trend toward increasing the sustained "G" loading capability of these aircraft promises to continue. One method used to enhance the aircraft's maneuverability and, consequently, its G loading, is the relaxation of the aircraft's stability margin. The F-16 fighter aircraft, for example, is the first modern aircraft with a negative stability margin (the only other was the Wright Flyer). Because of this negative stability margin the F-16 must be controlled by on-board computers and, consequently, damage to or failure of these computers could result in an uncontrollable aircraft, which would require emergency escape in a high acceleration environment.

The possibility of encountering these large impressed G fields during the escape event (up to 12 Gs) has a significant

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impact on emergency crew escape system design. Of particular interest is the effect of this imposed acceleration field on the performance of the ejection seat's catapult. Some analytical work has been done previously to predict the performance of the ejection catapult in a high G environment (Refs. 1 and 2) but no actual tests of an ejection catapult in a high acceleration field have been found. The results of the study reported in Ref. 1 were surprising. The study concluded, for example, that much higher internal catapult pressures would be encountered, and the ejection seat timing sequence would be markedly altered by the imposed acceleration field. The study also predicted much higher acceleration of the ejection seat and therefore higher loads on the ejectee.

It therefore became clear that more study and tests were required to fully understand the effects of imposed acceleration field on escape catapults. As a result, the Air Force Flight Dynamics Laboratory (AFFDL) and Air Force Aerospace Medical Research Laboratory (AMRL) initiated a joint test program in 1978 to determine these effects. The objective of this paper is to analyze these catapult test firing results and to report on the effort made to model the ejection catapult dynamics.

II Catapult Tests

A. Approach

It would seem that the simplest test approach would be to obtain a number of new escape catapults and then fire them in a

high G environment. However, to reduce the expense of the initial test program it was decided to obtain "outdated" catapults that had been removed from operational ejection seats. Because these catapults had been exposed to temperature cycling, vibration, and aging it was necessary to complete a series of tests to establish the repeatability of the catapult's performance prior to conducting tests of catapults in a high G environment. This was done with the experimental set-up shown in Figure 1. Essentially, the catapult had one end locked to the test track while the other end was free to move against a mass (payload) resting on the test track rails. This payload sled weighed 395 pounds. As one end of the catapult was locked to the track and was therefore unmoving, these tests were referred to as static or zero G tests. The tests were also used to establish an expected range of data, e.g., a baseline catapult pressure-time curve, and served as an instrumentation check-out prior to the high-G or dynamic tests.

The acceleration environment for the dynamic tests was generated by the test set-up shown in Figure 2. Both the payload and carrier sled were accelerated to a predetermined velocity, and then the brakes on the carrier sled were actuated. This resulted in a decelerating force being applied through the catapult to the payload. After the accelerometer on board the carrier sled sensed the preselected G level, the catapult was ignited and propelled the payload sled. The nominal G level for all the dynamic tests was selected to be 8 Gs (Ref. 3).

Thus the test approach was first to conduct static tests to establish data repeatability and a base-line data set. Then the dynamic tests were to be conducted and compared to the static data to determine any changes in catapult performance due to imposed acceleration field.

B. Test Apparatus

Three elements were needed to conduct these tests: (1) the test track facility which includes the payload and carrier sleds, (2) the escape system catapults, and (3) the various transducers used to sense the required data. The test track facility also includes a launch system, which propelled the catapult-sled system down the track for the dynamic tests, and appropriate electronics equipment to transmit, condition, and record the test data.

The Talley 2400 series catapult was used in these tests, and the data sensed and recorded are shown in Table 1. The specifications for each of these transducers and their installation are discussed more fully in Ref. 4.

C. Test Results

1. General

The data recorded during these tests were previously listed in Table 1. The primary parameter of interest throughout this analysis is the catapult pressure, since this is an indication of the energy released by the catapult and serves as

the driving force that produces the accelerations and displacements that follow. A sample data set for test 159 is included as Appendix A.

2. Static Tests

There were 24 catapult test firings during this test program. Twelve of these tests were static tests; Table 2 lists the identifying test numbers for both the static and dynamic tests.

The pressure curves for the static tests can be grouped into three sets. The first set (called Set No. 1) is composed of five tests (155, 157, 158, 159, 160); the results of these tests are used during the remaining analysis as "standard" catapult results. The rise in pressure is smooth without sharp drops or increases. Each pressure curve in this set is essentially identical with the others. Figure 3 shows this pressure relationship for two of the tests, nos. 159 and 160. The spike in pressure near the end of the catapult stroke (time of stroke is approximately 160 milliseconds) will be discussed shortly.

Set No. 2 is composed of three tests (161, 162, 165); each of the catapult pressure-time curves of this set is similar to the others but lower in amplitude and impulse than those of Set No. 1. The pressure spike is again evident in each of these tests. Figure 3 includes the pressure-time curve for test no. 161 to show the typical lower impulse of Set No. 2.

Set No. 3 is also composed of three tests (154, 156, 163) and these are similar in impulse to Set No. 2. The major difference between Set Nos. 2 and 3 is the delay in pressure onset. For Set No. 2 the sustained pressure rise starts at 20 milliseconds after the ignition signal. For Set No. 3 the sustained pressure rise starts at 40 milliseconds after the ignition signal. This pressure rise for Set No. 3 is rapid at first, and then assumes essentially the same track as the pressure curve in Set No. 2. Another difference is that two of the tests in Set No. 3 (154 and 156) do not exhibit the pressure spike at catapult separation (strip-off).

Test no. 164 is different from all of the other tests in that the pressure curve is very positive at the beginning and then goes to zero and then begins its steady rise.

If the accelerations of the first two sets of data are compared, it is obvious that, as expected, the lower pressures of Set No. 2 give rise to lower accelerations than in Set No. 1. Figure 4 is a plot of the catapult acceleration of test no. 165 (Set No. 2) versus test no. 158 (Set No. 1) and clearly shows this reduced acceleration for Set No. 2. It is also interesting to examine the acceleration curve for test no. 164 to see if the large pulse in pressure is reflected in the payload sled acceleration-time curve. Figure 5 shows that it is not. Thus it is hard to explain the pressure-time curve for test no. 164. As a result, the catapult pressure transducer was changed for the next test, test no. 165. In fact, three pressure transducers

were used during the tests. The first pressure transducer was used for tests 154 through 164, the second for tests 165 through 186, and the third for tests 196 through 198. It should also be mentioned that the transducer connection to the catapult chamber was changed after test no. 156. This was done to reduce the apparent lag in the catapult pressure response as compared with the force and acceleration response. The original configuration consisted of approximately seventeen inches of quarter-inch diameter tubing with two 90 degree bends and a 90 degree connector. This was changed to one inch of tubing with the 90 degree connector, thereby eliminating the lag. One other noteworthy change in pressure transducer instrumentation was made. The transducer pressure line was packed with silicon grease to protect the transducer from hot gases in test nos. 154 through 158. The use of this grease was discontinued until test no. 196 and then used again with the third transducer during test nos. 196 through 198.

In many of the static tests results a pressure spike appears at the time of catapult strip-off. These spikes are seen in each of the pressure-time plots in Figure 3. Upon closer examination it is clear that the beginning of the spike occurs just at the time of strip-off. It appears that this pressure increase occurs for the following reason. Prior to strip-off the catapult propellant is burning and therefore producing high pressure gas within the catapult tube, forcing the internal catapult tube (piston) out of the external tube (cylinder) as shown in Figure

6. At strip-off the internal tube pulls out of the "end-cap" leaving a hole in the end-cap. The end-cap motion relative to the external tube is stopped by mechanical interference. Hot gas then flows through the end-cap hole and into the rocket nozzle and ignites the rocket. The important point here, however, is that the rapid increase in volume that was occurring prior to strip-off ceases with the stopping of the end-cap. The catapult propellant is still burning, however, and the pressure in the catapult momentarily increases rapidly until the propellant is consumed and then drops rapidly with the gas flow out of the internal tube through the end-cap hole. If this analysis is correct the peak of the spike could be used as a measure of propellant burn-out. It is interesting to note that during the dynamic tests where more catapult propellant is needed due to the greater burn time, pressure spikes are observed only in test nos. 185 and 186. The behavior of the pressure curve in test no. 184 must be discounted as there was a break in the signal cable.

After this review of the static test data from the catapult firings and the pressure transducer modifications, data Set No. 1 was selected as the representative static test data for comparison with the dynamic test results. These five tests seem to be reproducible and representative of the Talley 2400 series catapult.

3. High-G Tests

Twelve high-G tests were conducted; these test numbers are listed in Table 2. The G level applied to the catapult in these tests was a nominal eight Gs but varied during each test and from test to test. This was necessitated by the difficult job of precisely braking the carrier sled. Figure 7 is a plot of the carrier sled acceleration in Gs for test no. 183 and shows that the deceleration varies between seven and nine Gs. A sample data set for the dynamic tests (again test no. 183) is listed in Appendix B. Because of the varying load on the catapult, little effort was made to correlate the high-G test results. A simple check of the output of the force transducers mounted at each end of the catapult was made. Figure 8 shows these values to be in very close agreement, as they should be.

4. Comparison of Static and High-G Tests

The first relationship investigated for this comparison was the effect of G loading on catapult pressure. Figure 9 compares the pressure-time curves of test no. 159 (static) with those of test no. 183 (high-G) where zero time is the onset of the catapult pressure rise. Notice that the maximum catapult pressure for the static test is 1499 psi (neglecting the pressure spike after catapult strip-off) versus 2202 psi for the high-G test. If we examine the catapult extension time from ignition to strip-off we find that for test no. 159 it takes 150 milliseconds to reach strip-off, while for test no. 183 it takes 195 milliseconds. However, the actual stroke time of the

catapult was 126 milliseconds for the dynamics test, no. 183, versus 134 milliseconds for the static test, no. 159. This is a typical comparison between the static and high-G tests and confirms the results of the earlier study (Ref. 1).

5. Conclusions

Although there was some significant variation in the static tests, a group of tests was selected as representative of the Talley 2400 series catapult and was used as "standard" data for computer modeling purposes.

Significantly higher catapult pressures were obtained during the high-G catapult tests, as expected (Ref. 1). Also, the time required for the catapult to reach separation was longer for the high-G tests than for the static tests.

III. Computer Model

A. Background

The computer model of an ejection catapult used in this study is a revised version of the model used in the 1975 catapult study (Ref. 1). Certain changes were made to the early program to improve or extend its capabilities and these changes will be discussed in the theory section of this report. The purpose of this program, however, remains the same: to provide a means of predicting escape catapult phenomena under any G loading at any initial propellant temperature.

B. Model Theory

The catapult computer model is composed of various governing equations. These are summarized below:

1. Energy Balance (First Law of Thermodynamics)

$$W_{\text{out of gas}} = mC_v \Delta T - Q_{\text{out of gas}} \quad (1)$$

2. Perfect Gas Relationship (Equation of State)

$$PV = mRT \quad (2)$$

3. Force Balance

$$EJM * ACCEL = (CADF - FRF - FPF) \quad (3)$$

4. Propellant Burn Rate Equation

$$r = \frac{dL}{dt} = kP^n \text{ (inches/time)} \quad (4)$$

5. Propellant Form Function

$$m = f(L) \quad (5)$$

Eqn. (1) states that the energy removed from the hot gas ($mC_v \Delta T$) goes to heat transfer (Q) or to work (piston motion or equivalently, payload motion). The perfect gas relationship, Eqn. (2), is standard and is used with an appropriate value of the gas constant R selected for the propellant gas. The force balance, Eqn. (3), merely states that the force of the catapult, $CADF$, minus the rail friction, FRF , and O-ring friction, FPF , equals the resultant force on the payload. In this expression, EJM is the ejected mass and thus $ACCEL$ is the resultant payload

acceleration. The propellant burn rate equation, Eqn. (4), relates the catapult internal pressure to the length of propellant burned. The variables k and n in Eqn. (4) are constants taken from Talley's propellant data sheet. Finally, the propellant form function, Eqn. (5), relates the length of propellant burned to the mass of propellant burned. This mass is the same as the mass, m , in Eqn. (1). These equations are combined in the program in one of two ways. The first technique requires the form functions to be known, and then the equations are structured to calculate the catapult temperature, pressure, acceleration, velocity, and displacement. A flow diagram for this technique is shown in Figure 10. The second technique uses known pressure data to calculate the form function for the catapult. A flow diagram for this technique is shown in Figure 11. Since the form function relates propellant mass burned (W) to propellant length consumed (WB), then if the length of propellant burned is known, i.e., the pressure-time curve is known, the amount of propellant can be determined.

The computer model is capable of using both techniques. In the present analysis the latter technique is used first in order to calculate the propellant form function using the known test data. This technique is used because the form function for the propellant at high pressures (high-G tests) is unknown.

C. Modeling Approach

The approach used in the modeling effort was to use the actual test data to create a "universal" form function for the Talley 2400 series catapult. With this form function known, any G loading could be prescribed along with other descriptive parameters such as seat weight, and the resulting output parameters, such as catapult pressures and seat/man accelerations, could be calculated with the computer model. A single form function does exist for tests in a one G environment; the present approach assumes that a single form function exists for all G loadings.

This approach requires, of course, a computer program that correctly generates a form function from the pressure data and that this form function can then be used to regenerate the pressure, acceleration, velocity, and displacement information of the original test. In short, the computer model must be mathematically accurate.

D. Data Manipulation

Rapid Analysis of computer program output requires the ability to quickly plot this output data either alone or with the experimental test results. This was accomplished through the following tests:

1. Statements were added to the computer program logic to cause the following output parameters to be stored in a separate data file: (1) pressure, (2) displacement, (3) acceleration, (4)

propellant burned (W), and (5) web burned (WB). Thus the pressure file would contain digitized values of pressure at two millisecond intervals throughout the catapult stroke. These files are identified by test number and can be easily called up for viewing or plotting at any time. For example, the computer-generated pressure data for test no. 159 are stored at P159.

2. A program was written to modify the experimental data taken from computer cards to make it compatible with the computer model output data. This program, DATA/MOD, changes the format of the data, eliminates the appropriate number of initial data points, selects the appropriate time step between data points, and stores the data. For example, it eliminates every other data point if data at two millisecond intervals are required. A copy of this program is included in Appendix C.

3. Various plotting routines have been created to plot recurring data formats. For example, the computer program GRAPH plots the computer model-generated payload sled acceleration versus the measured payload sled acceleration and stores the plotfile for future reference. The name of this plotfile for test no. 159 is PLOTFILE/GVSG/159 and to plot this data comparison at any time in the future one simply has to type the command PLOT and then PLOTFILE/GVSG/159. A copy of GRAPH is included in Appendix D.

E. Programming Changes

Numerous program changes were made during the model analysis period. A copy of the final version of the program is included in Appendix E. The input data required for the catapult program, NEWSET, are also listed there. Only the more important changes will be discussed here and these can be grouped under the following three headings: (1) removal of the igniter charge, CO, (2) modification of the calculation of rail friction, and (3) inclusion of imposed G field. The modification to permit output information to be sent to data files was a fourth major change, but this has been previously discussed.

1. Removal of Igniter Charge

Early in the evaluation of the technique used to create a form function from the experimental data, an attempt was made to compare the experimental pressure-time data used to calculate the form function to the pressure-time data resulting from the form function. These curves did not match. After some analysis it became clear that the amount of propellant needed to generate the pressure-time test data was being properly calculated. In the second phase of calculations, in which the form function was used to calculate the pressure-time curve, an extra amount of propellant, the igniter charge, was being added to the mass of propellant indicated by the form function. This extra propellant resulted in higher catapult pressures than those recorded during the actual test. When the igniter charge, CO,

was removed from the program logic, the pressures matched nicely, as shown in Figure 12 for test no. 183.

2. Rail Friction Modification

Later during this model analysis it was noticed that, although the experimental and calculated pressure-time curves matched for the static tests, the payload sled displacement (catapult displacement) did not. The displacement calculated by the computer model was significantly less. Examination of the computer model force balance [similar to Eqn. (3)] revealed that if the driving force, CADF, was calculated correctly (remember that the catapult pressure curve had been proven correct earlier and that the catapult end area was measured) and the ejected payload mass, EJM, was measured correctly, then the friction terms must be incorrect. Rail friction was previously calculated as 0.356 using the results of an actual track test (Ref. 5). Using the data from test no. 159 a value of O-ring friction was calculated as 0.008. These two values were inserted for K1 (changed from 0.2 to 0.008) and K2 (changed from 0.01 to 0.356) in the program logic. Also, the original logic, which attempted to incorporate the effect of sled movement (sled "rocking" on the track during translation along the track) on the rail friction term, was removed. With these new values and formulation, the new value of catapult displacement was determined by twice integrating the revised catapult acceleration predicted by the model. Figure 13 is a plot of the acceleration-time curves for

test no. 159 and compares the actual (test) catapult acceleration to the computer model's prediction. The fit is very good. The displacements were next compared and, as expected, the correlation was excellent.

A note of caution must be included here concerning the friction coefficients. These values change with test and track conditions, and in particular the O-ring friction value can be expected to change for the high-G tests due to pressure increases in the catapult. The changes in friction may be the cause of the variation in acceleration seen in Figure 14 (GVSG 159-161), since the O-ring friction coefficient was determined from test no. 159 data. Remember that the pressure curves correlate well for these two tests.

4. Inclusion of Imposed G Field Data

The G loading on the catapult is not constant, as previously discussed (Figure 7), and therefore the actual values of G loading, rather than a nominal or average value, should be input to the force balance in Eqn (3). Of course, Eqn. (3) must be modified to reflect this G-loading consideration. Representative G-loading data have been added to the program for various tests. These data can be called into the program as ZLF or program line 20820.

IV. Form Function Analysis

A. Calculations

The remaining task was to determine if a universal form function for the Talley 2400 series catapult exists. The approach was to use the actual data from the catapult tests to generate propellant form function curves (i.e., mass of propellant burned, W , plotted versus length of propellant burned, WB) and to compare them.

First, certain static tests were used to generate separate form function curves. A typical comparison of two separate form function curves for test nos. 159 and 160 is shown in Figure 15. The agreement is excellent, but it must be remembered that the results from these two tests were very similar, and good agreement would be expected. Indeed, the propellant burn rate depends only on the pressure, as shown by Eqn. (4), so that if the pressure-time curves for separate tests are the same, then burn rate and its integral, propellant length burned, must be the same.

Before the form function could be created for the High-G tests, an appropriate value of catapult acceleration had to be generated within or supplied to the catapult model. This acceleration would then be twice integrated to determine catapult stroke which is required to calculate the work term in the energy balance, Eqn. (1). It is also used to determine the latest value of catapult internal volume used in Eqn. (2). The standard technique for calculating this acceleration would be to formulate a new force balance for the high-G tests. This formulation would necessarily contain the friction forces discussed earlier and

would require a careful review prior to use. As this review could be time-consuming and require additional information on the friction factors, particularly O-ring friction, an alternate technique was used. Since the difference in payload sled acceleration and carrier sled acceleration is their relative acceleration or catapult stroking acceleration, then this difference could be used as input to the computer model to complete the high-G form function calculations. This was done by storing this relative acceleration (difference) in the test no. 183 G data file (shown in the computer program in Appendix E). This value of acceleration was then read into the computer program (line 21610). To check this technique, a plot of the resulting displacement of the catapult was compared to the actual catapult stroke data. This comparison is shown by Figure 16. The agreement is excellent.

With this program adjustment the form function could be calculated for the high-G tests. If we compare the resulting form function from a high-G test (test no. 183) to the one from test no. 159 (a static test), the Figure 17 results. The pressure-time curves for these two tests were previously shown in Figure 3. Unfortunately, the two form functions in Figure 17 are not the same. If we look more closely at each form function by plotting the propellant burned, W , versus time, as well as burn length, WB , for both tests, then Figures 18 and 19 result. Notice that Figure 19 shows that the web burned is about the same for test no. 159 as for test no. 183. This is surprising as the

pressure curves are significantly different after the 80 millisecond point. This suggests that the burn rate equation may not be as sensitive to pressure as it should be. Of greater concern, however, is the result shown in Figure 18. This result shows that more energy is expended (more propellant is burned) in the static test than in the high-G test. This, of course, is incorrect. Not only does the catapult do more work during the high-G tests, since the catapult pressure is higher, but also the burn time is increased, which allows more time for thermal energy transfer.

B. Conclusions

It is not clear why the discrepancies mentioned above occur. At this point, it appears that the program logic still needs further refinement and that perhaps a single form function exists for the Talley 2400 series catapult regardless of the G loading. Further analysis of the thermal energy loss term, the burn rate coefficient and exponent, and calculated fuel consumption magnitude should be done. Also, the magnitude of the work term must be determined and compared for both the static and high-G tests. For example, does the program output show a larger value of work for the static or high-G tests? Although the present investigation ended before this analysis could be completed, this analysis is the next necessary step in the catapult model building process.

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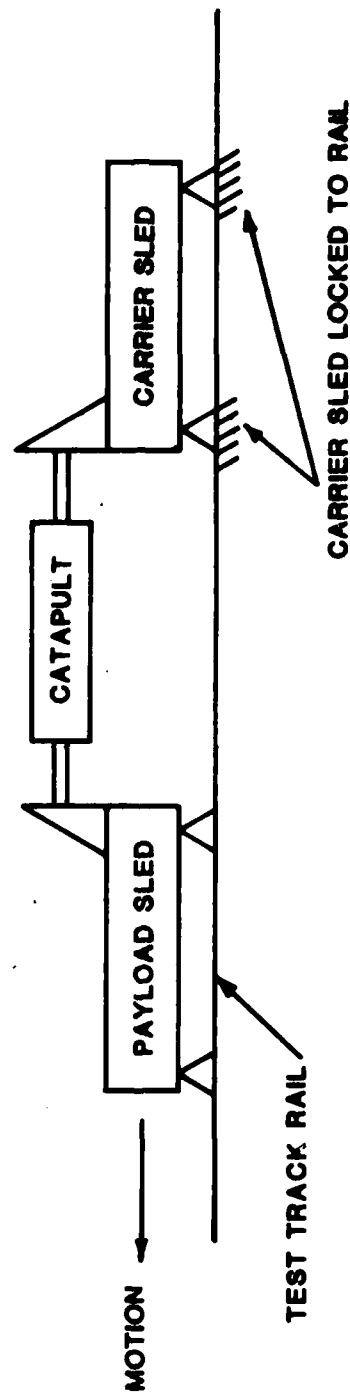


Figure 1. Schematic Diagram of Experimental Set-Up for Static Test of Ejection Catapult



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Table 1
PARAMETERS MEASURED DURING EJECTION CATAPULT TESTS*

PARAMETER	TEST SERIES
Payload sled x-axis acceleration	Static and High-G
Force applied to payload sled	"
Force applied to carrier sled	"
Internal gas pressure of catapult	"
Displacement of payload sled	"
Velocity of carrier sled	"
Carrier sled x-axis acceleration	High-G Tests Only
Carrier sled y-axis acceleration	"
Carrier sled z-axis acceleration	"

*Ref. 4

Table 2
IDENTIFYING TEST NUMBERS
OF CATAPULT FIRINGS

STATIC TESTS (12 tests)	HIGH-G TESTS (12 tests)
154	171
155	178
156	179
157	180
158	181
159	183
160	184
161	185
162	186
163	196
164	197
165	198

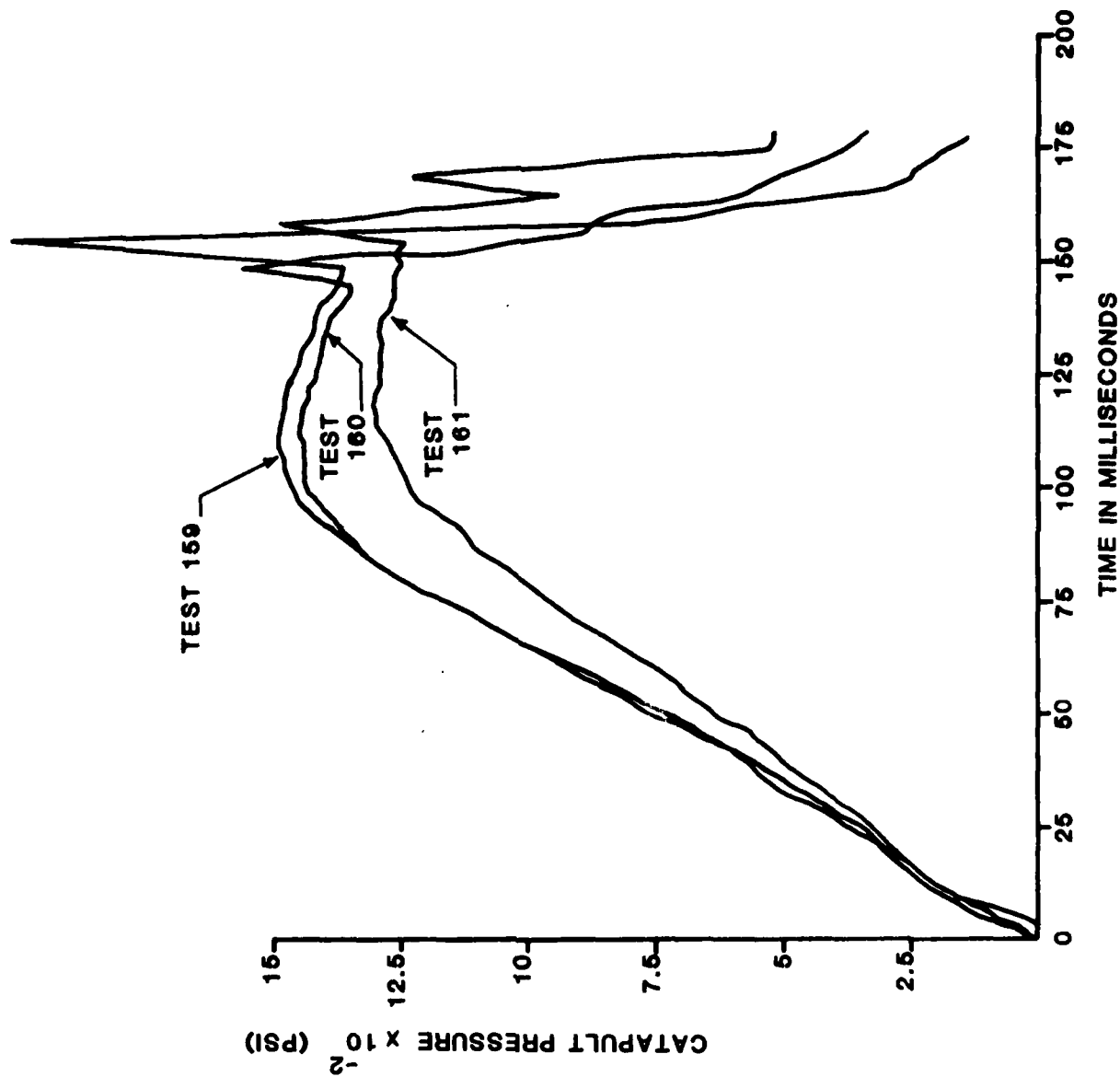


Figure 3. Catapult Pressure Test Data for Test Nos. 159, 160, and 161

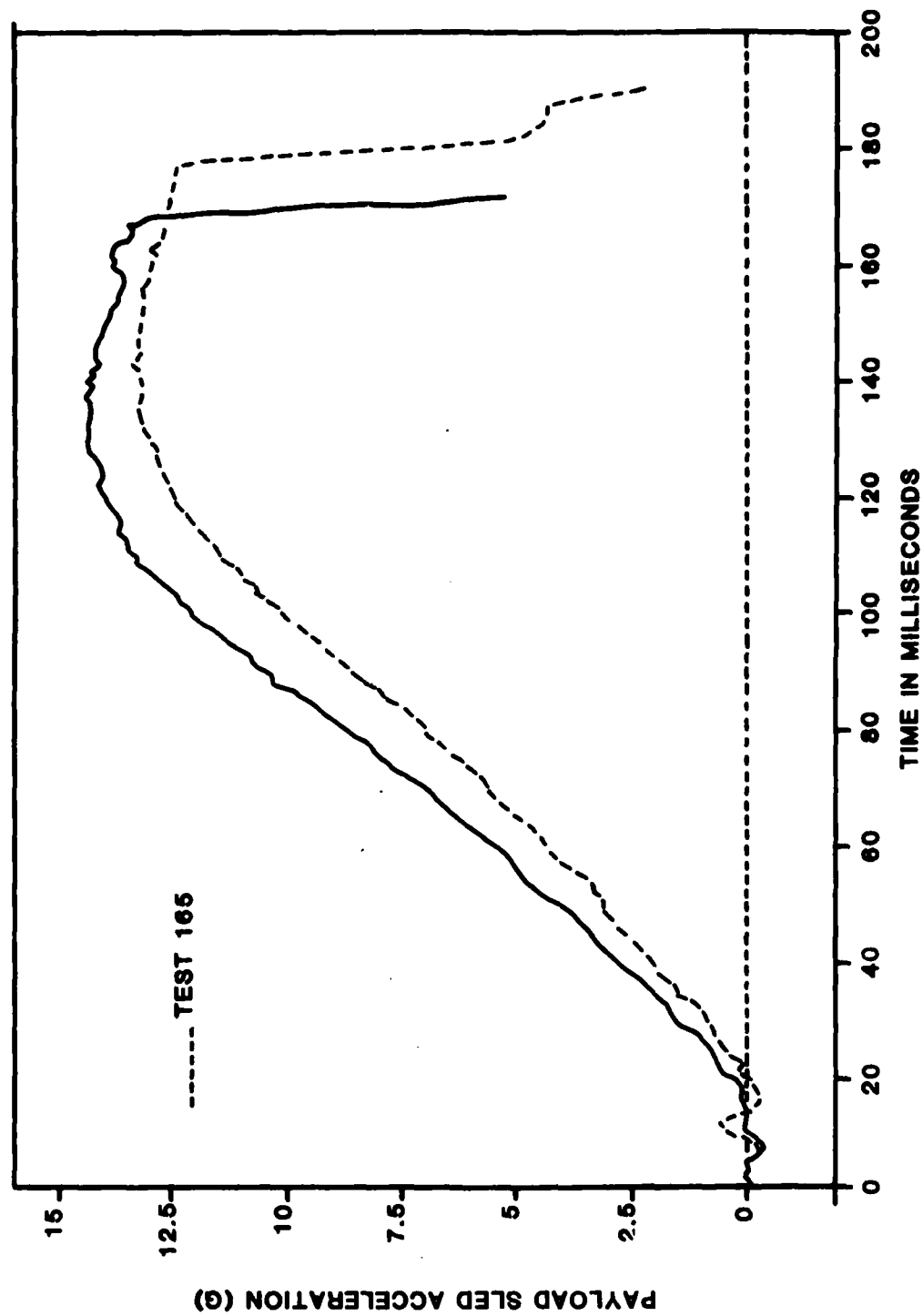


Figure 4. Catapult Acceleration Test Data for Test Nos. 158 and 165

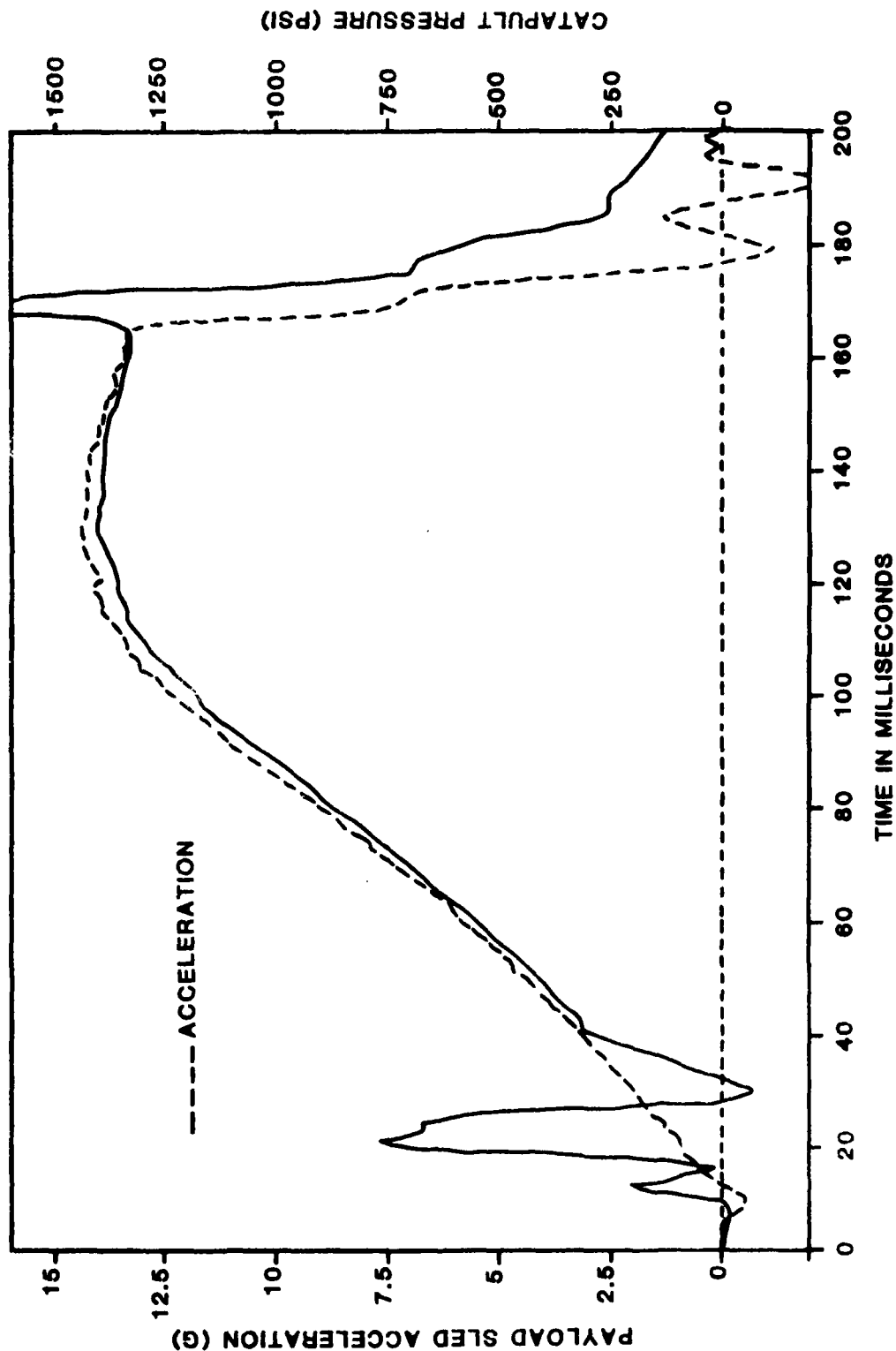


Figure 5. Acceleration of Payload Sled and Catapult Pressure versus Time for Test No. 164

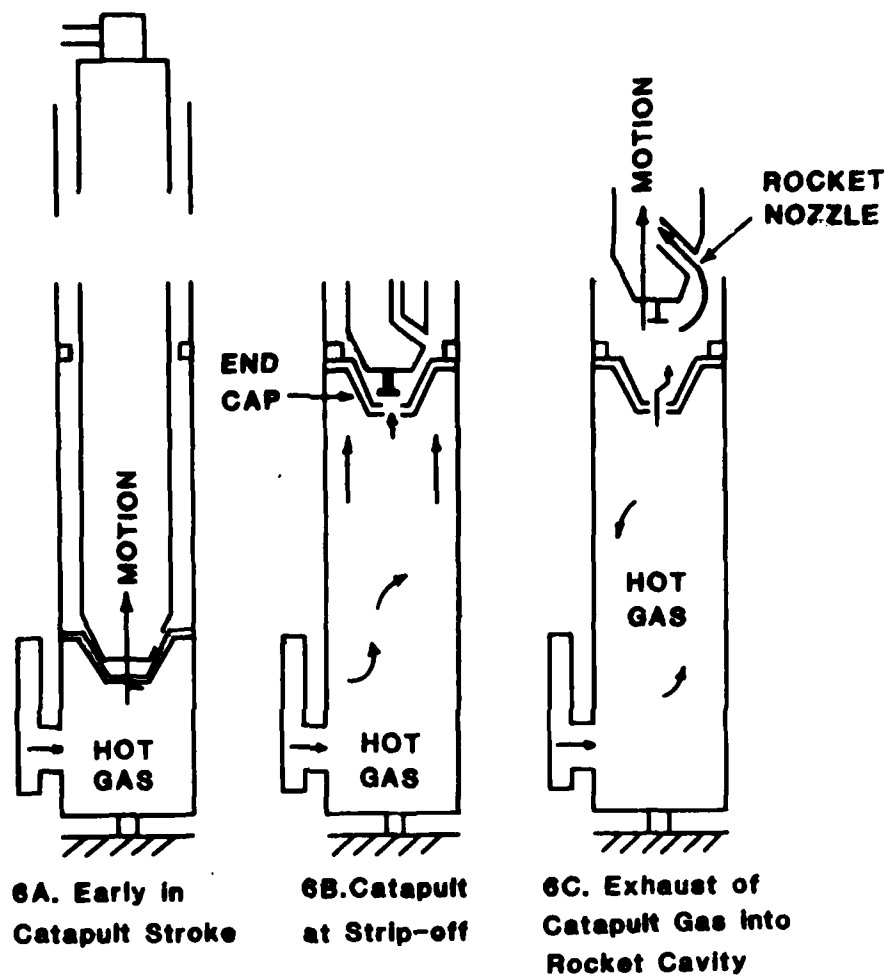


Figure 6. Separation of Internal Catapult Tube from Catapult End-Cap

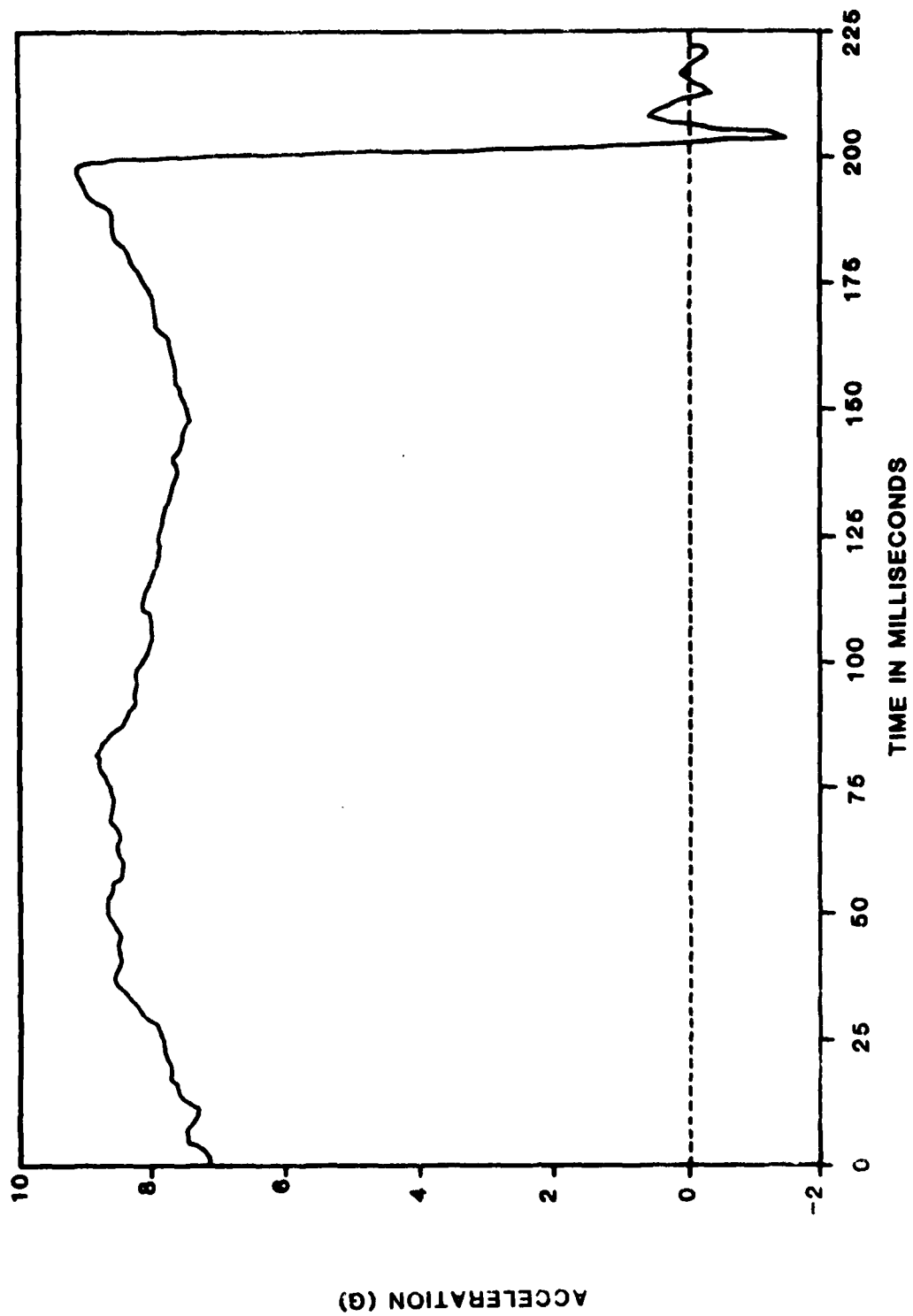
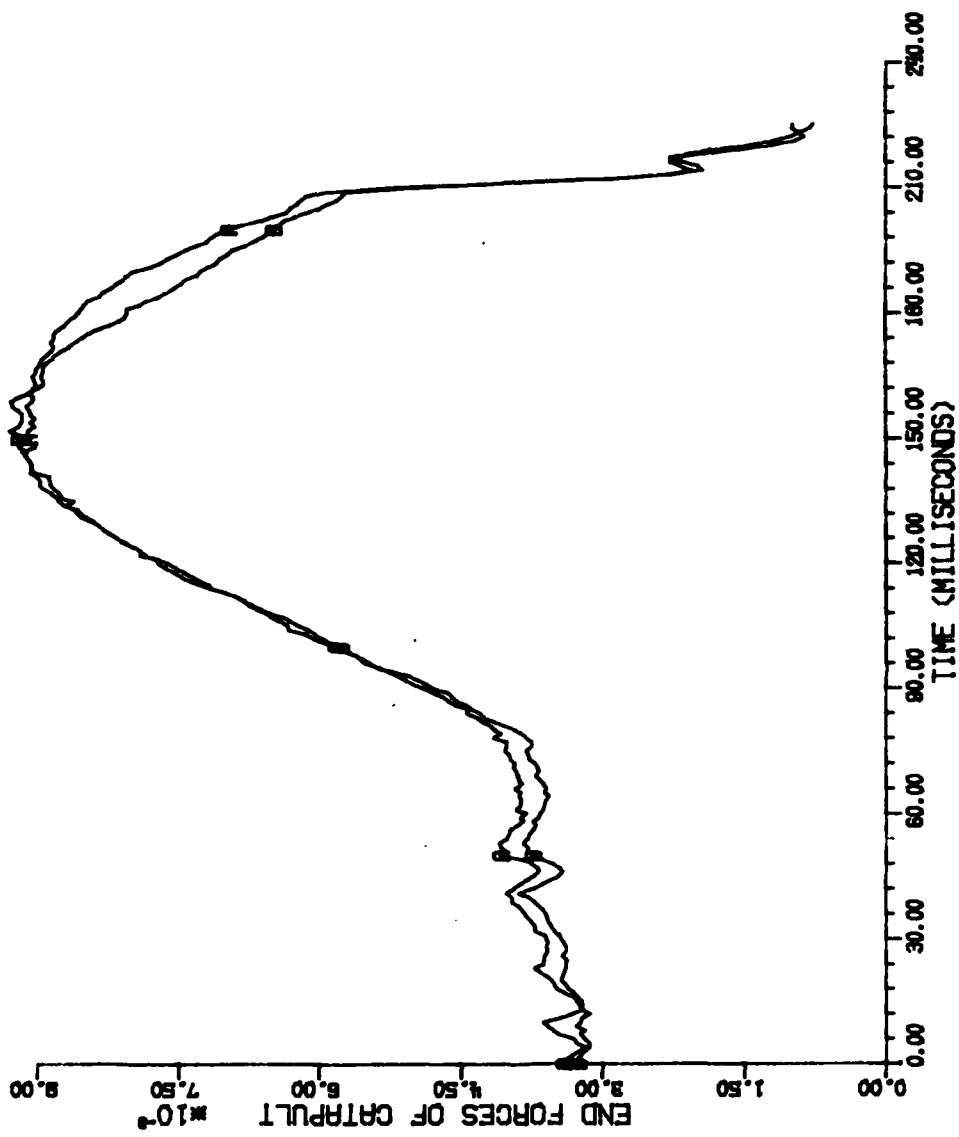


Figure 7. Carrier Sled Acceleration for Test No. 183 in Gs



A BASE FORCED TEST 183
B PATLORD F TEST 183

Figure 8. Force Transducer Output at Opposite Ends of Catapult

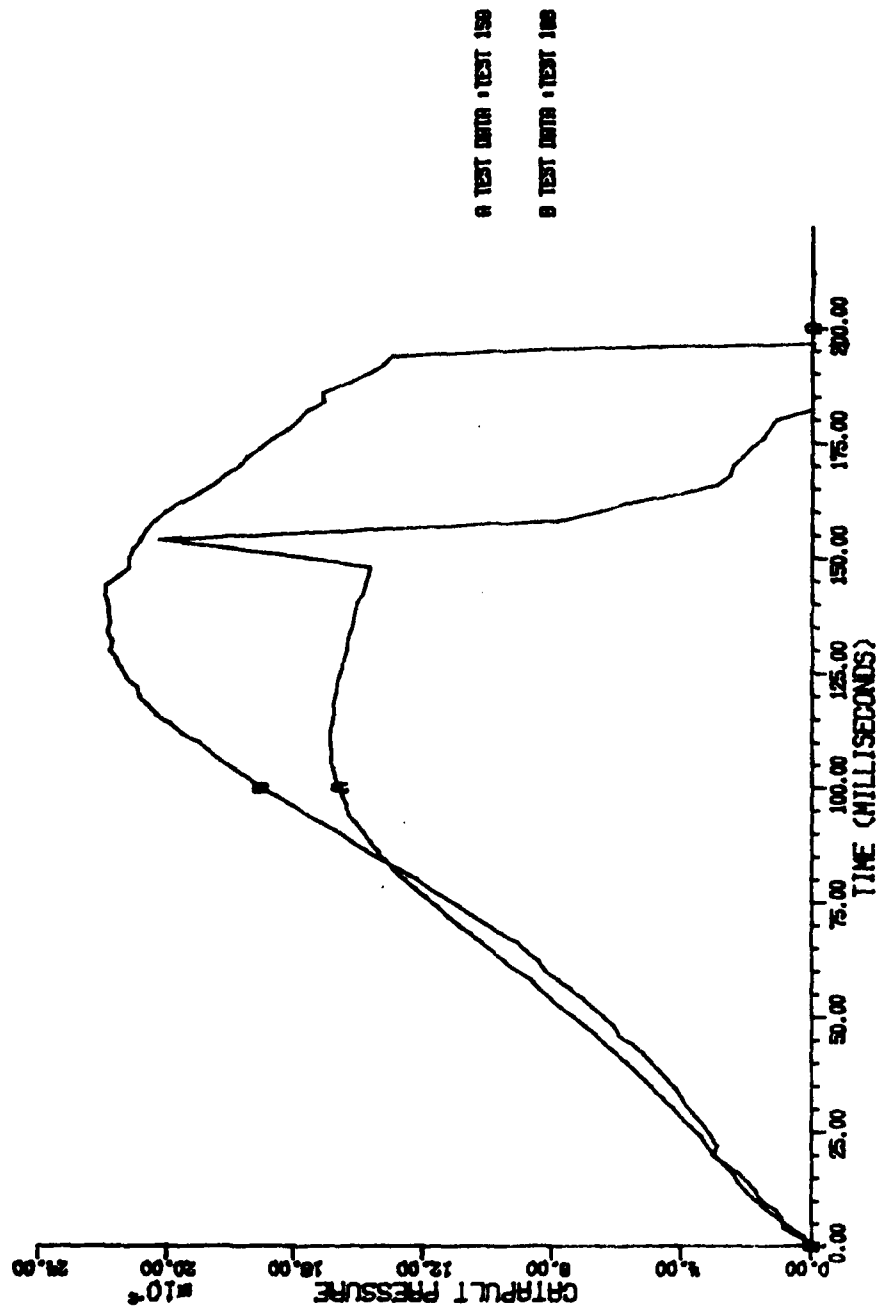


Figure 9. Pressure Comparison between Static Test (Test No. 159) and High-G Test (Test No. 183)

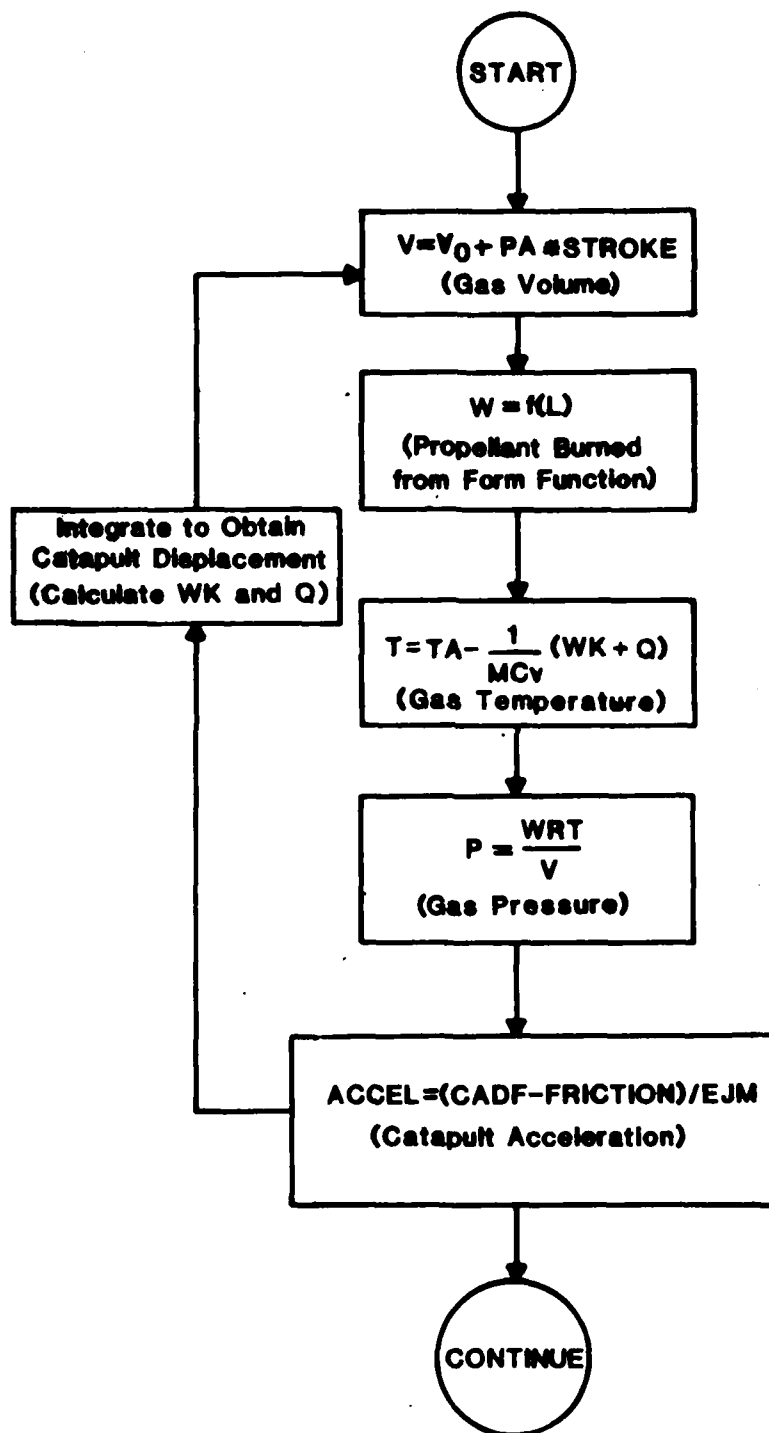


Figure 10. Logic Flow Diagram for a Known Propellant Form Function

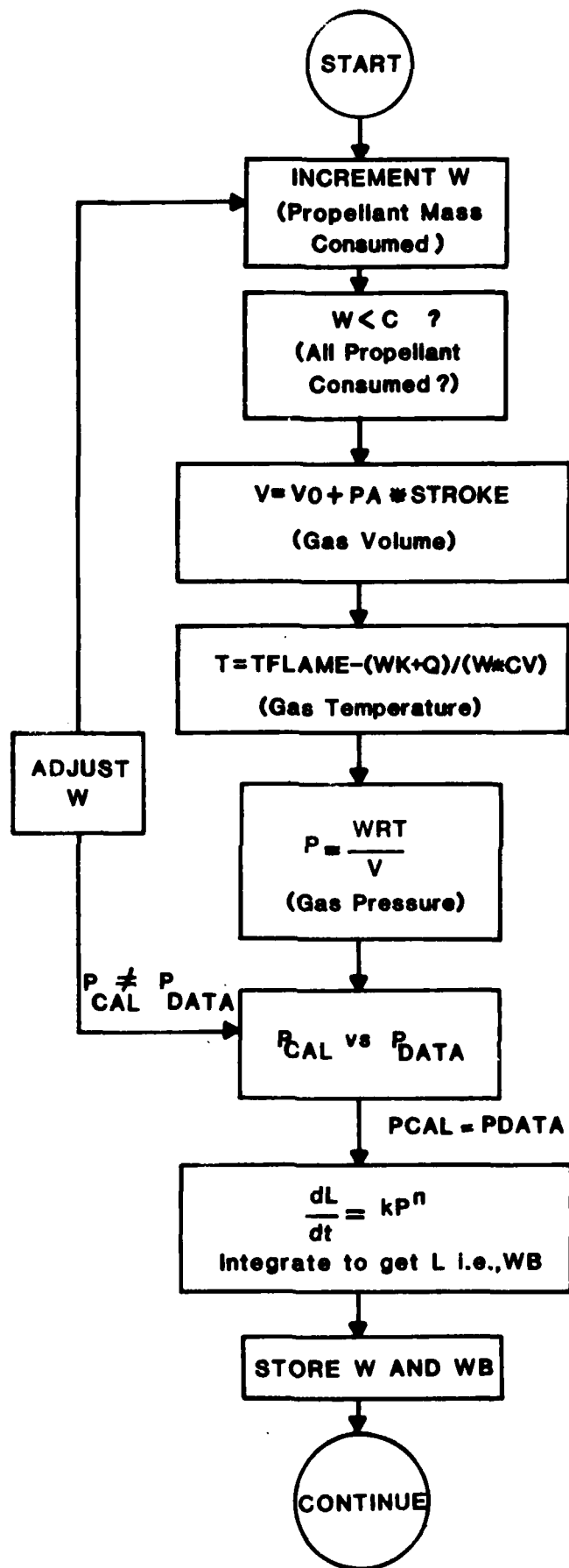
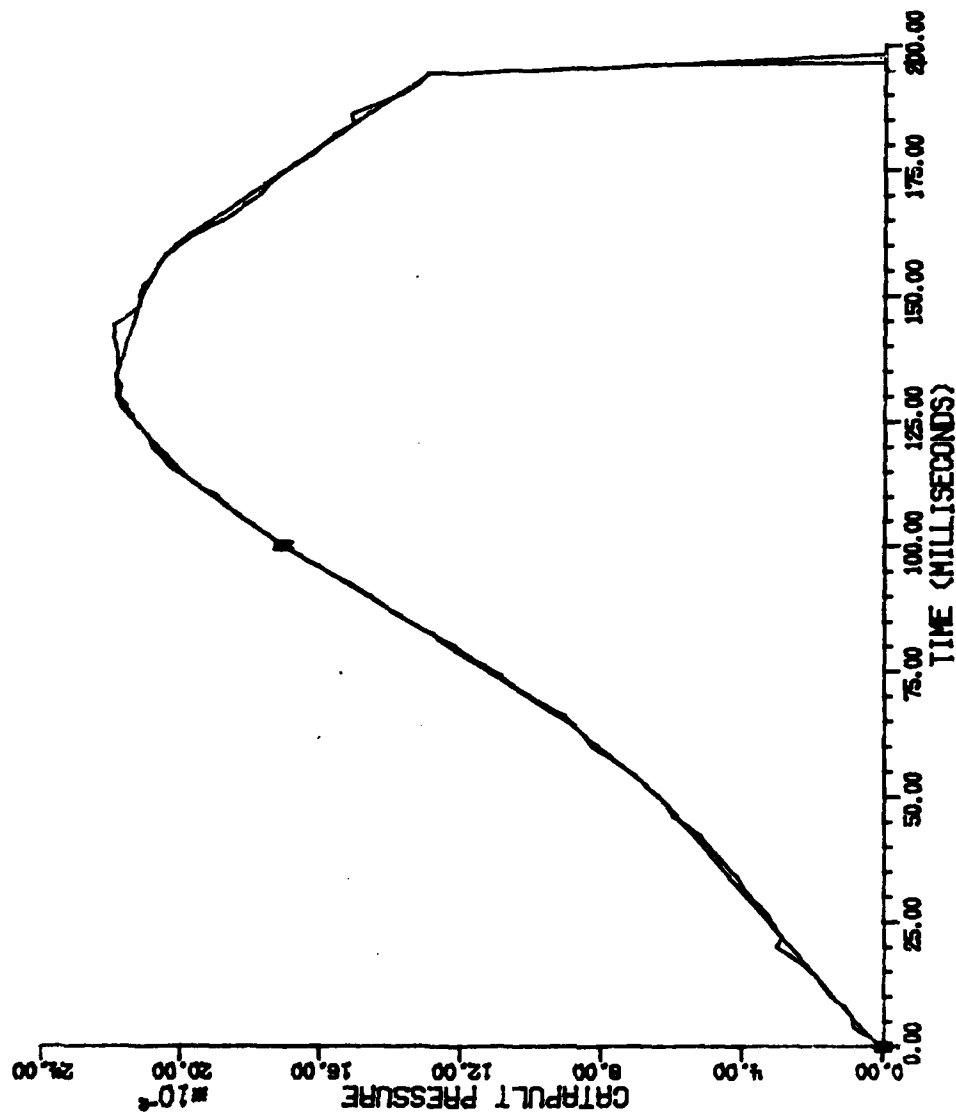


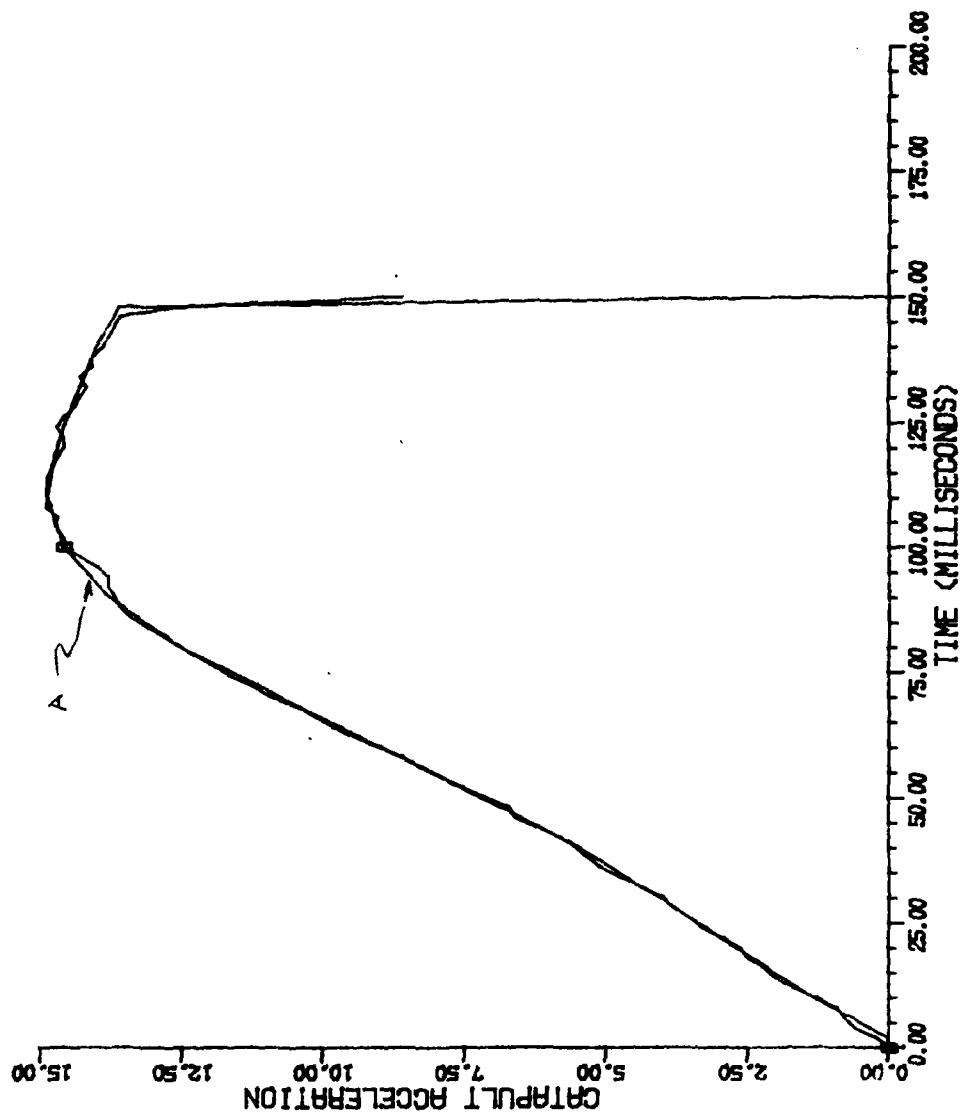
Figure 11. Logic Flow Diagram for Calculation of Propellant Form Function with Known Catapult Pressure



COMPUTER P-TEST 183

TEST DATA - TEST 183

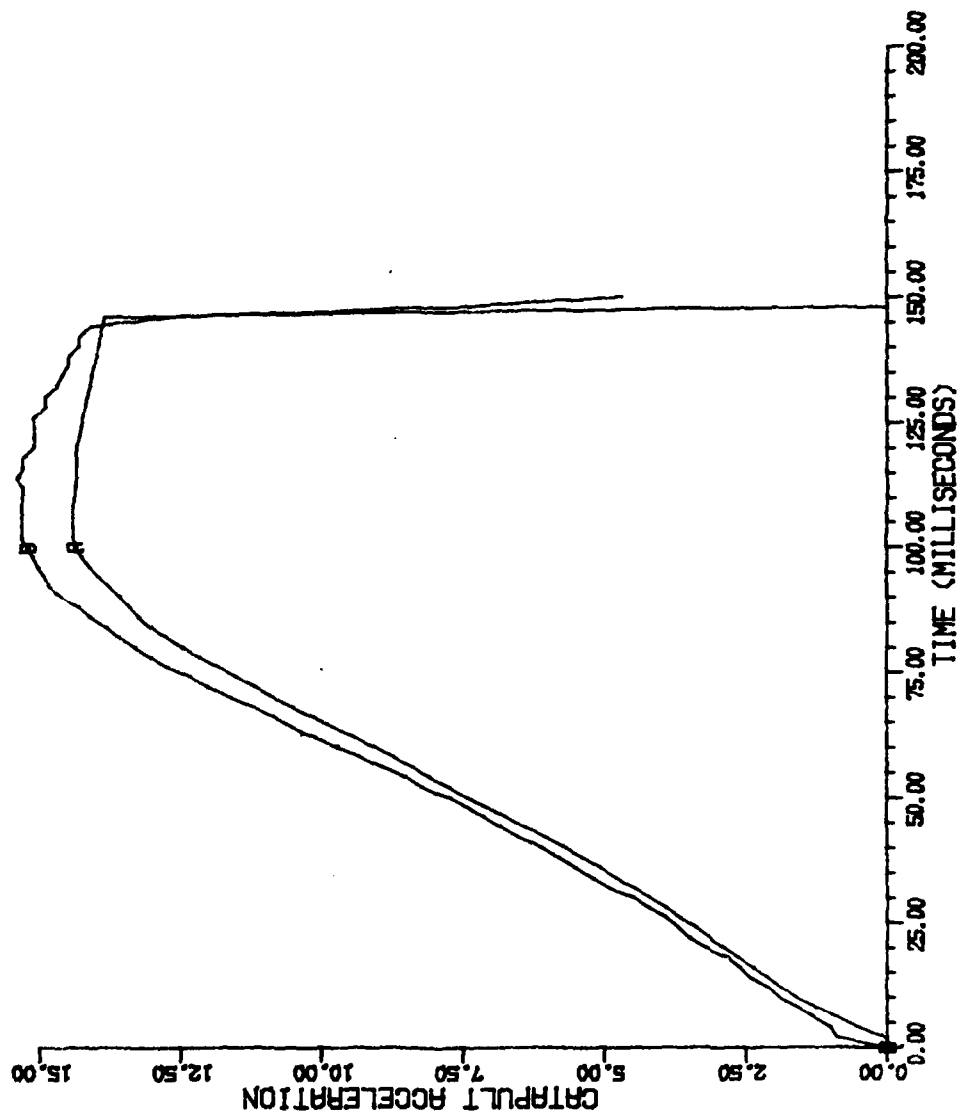
Figure 12. A Comparison of the Actual Catapult Pressure-Time Curve to the Pressure-Time Curve Generated by the Computer Model (Test No. 183)



A COMPUTER 0-TEST 159

B TEST DATA -TEST 159

Figure 13. A Comparison of the Actual Catapult Acceleration with the Acceleration Generated by the Computer Model (Test No. 159)



A COMPUTER O RESULTS
 B TEST DATA O VALUES

Figure 14. A Comparison of the Actual Catapult Acceleration with the Acceleration Generated by the Computer Model. Friction Coefficients Used Here Were Determined from Test No. 159 Data.

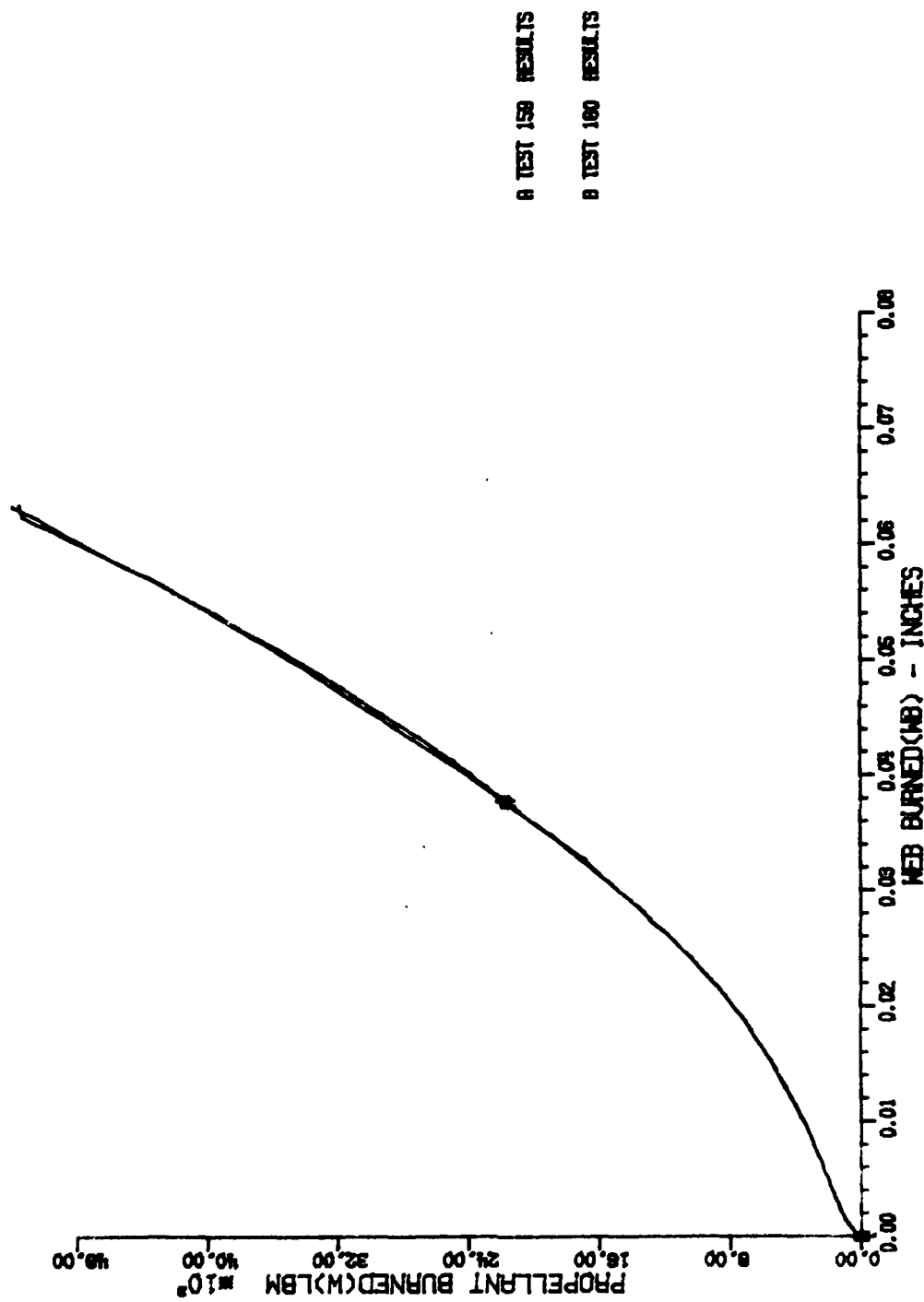
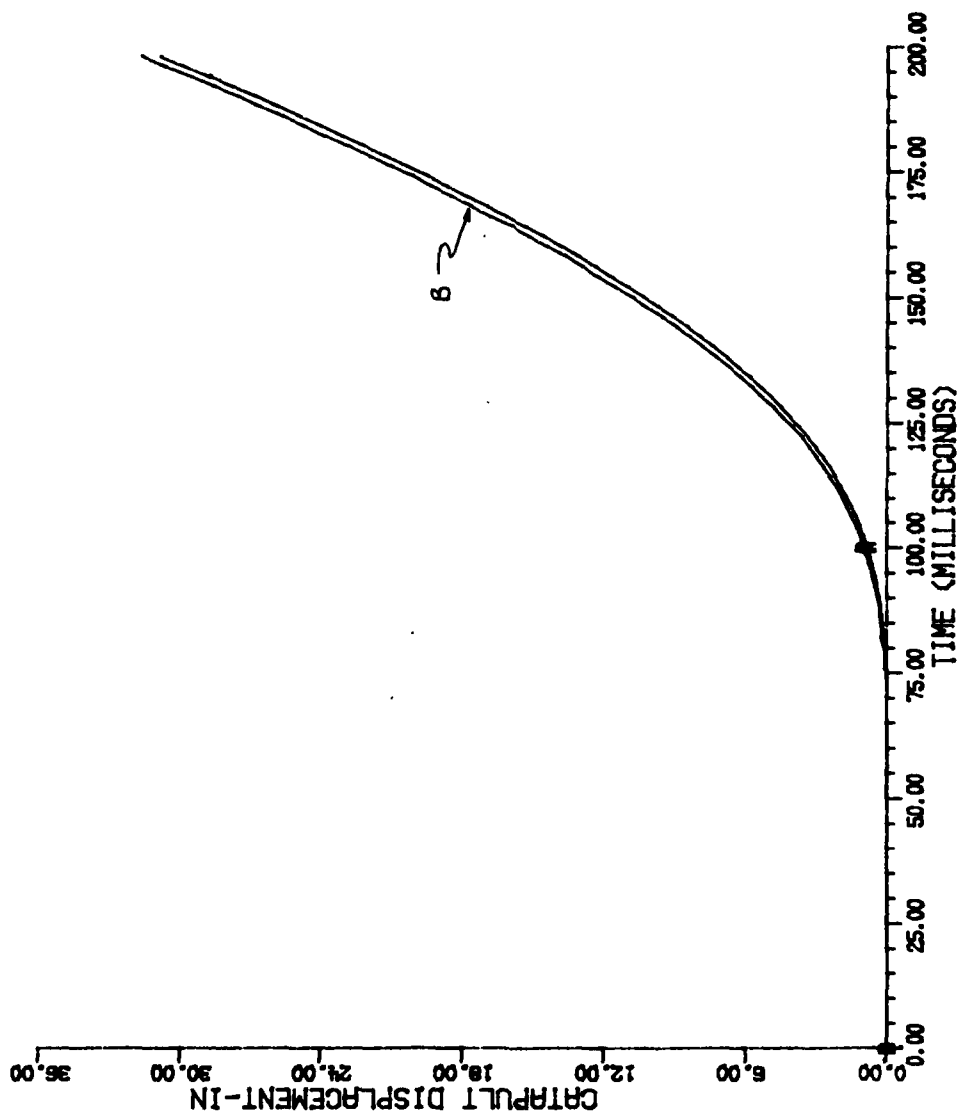


Figure 15. Form Function Comparison for Test Nos. 159 and 160



A COMPUTER D-TEST 183

B TEST DATA : TEST 183

Figure 16. Catapult Displacement versus Time for Test No. 183

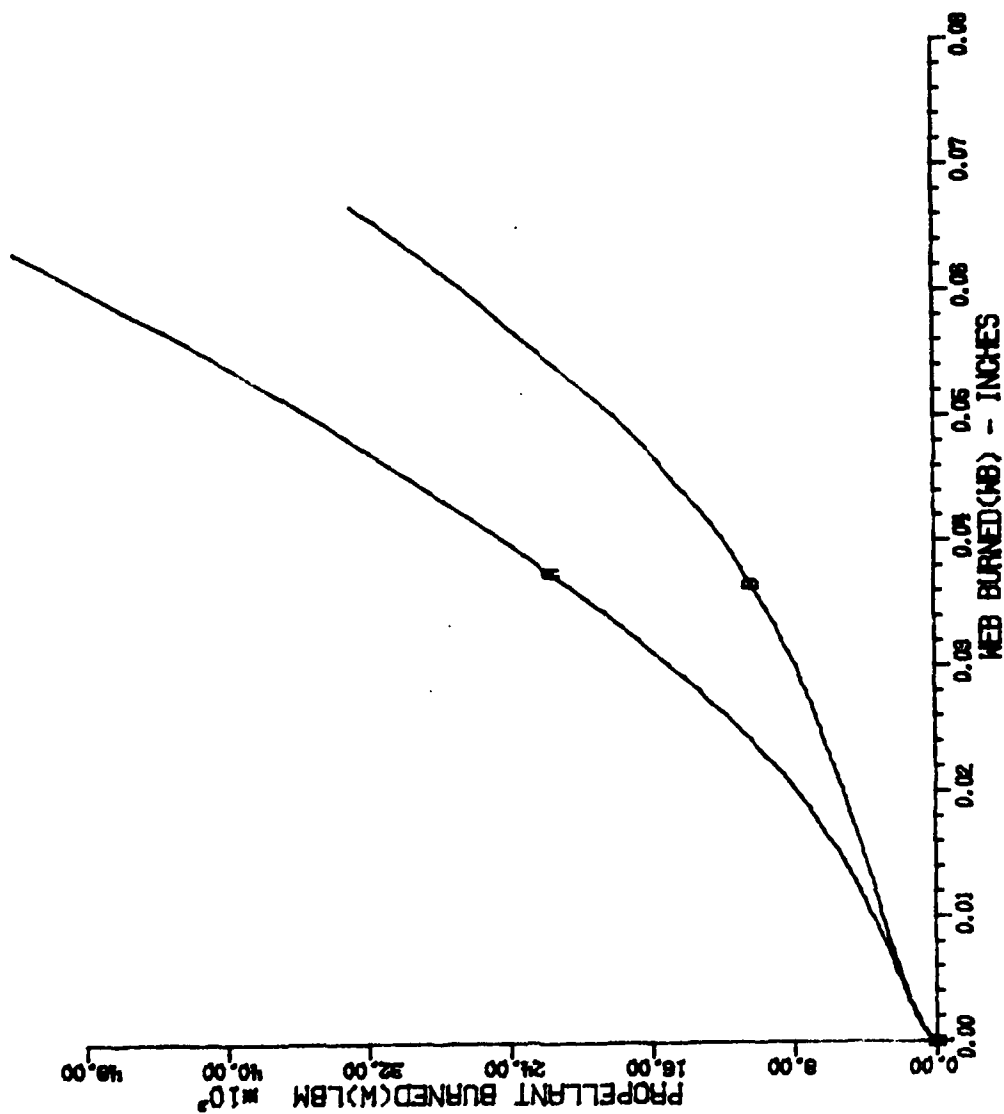
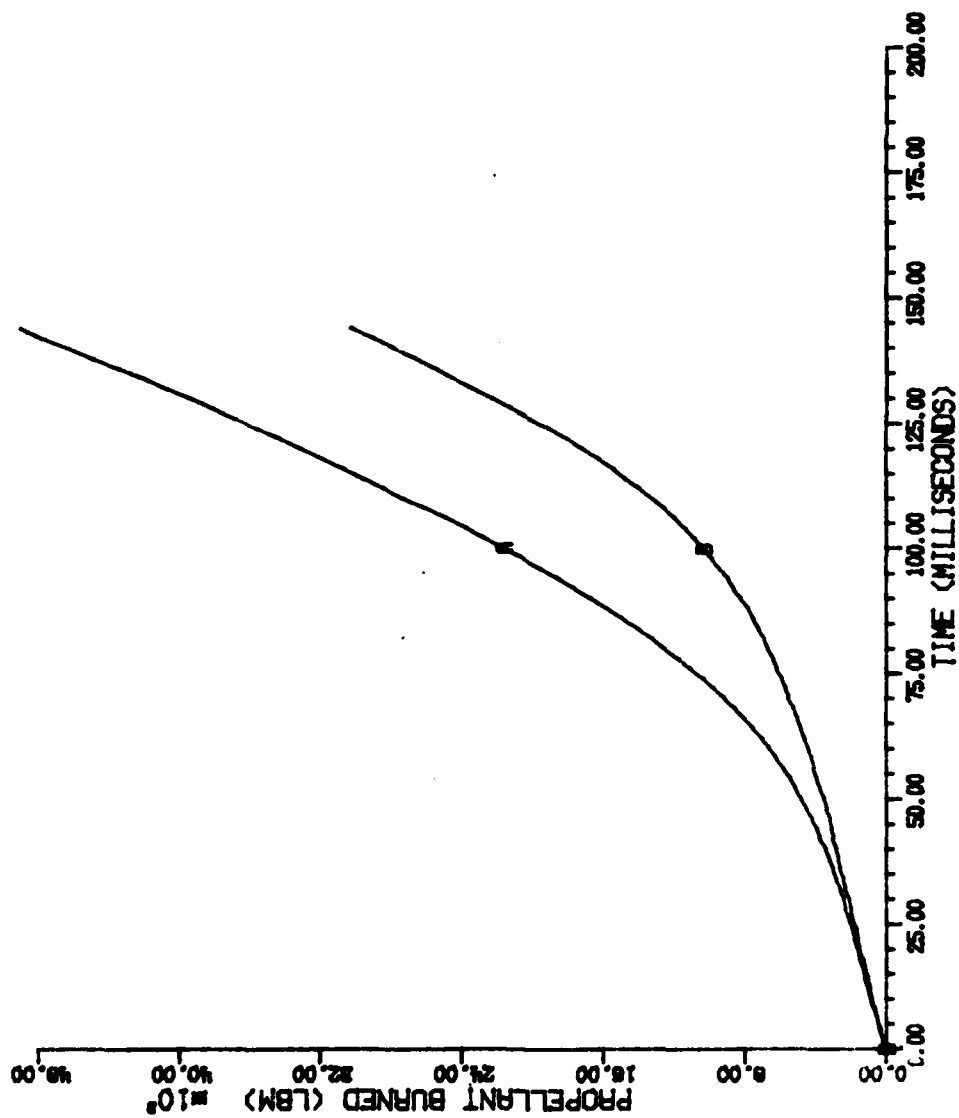


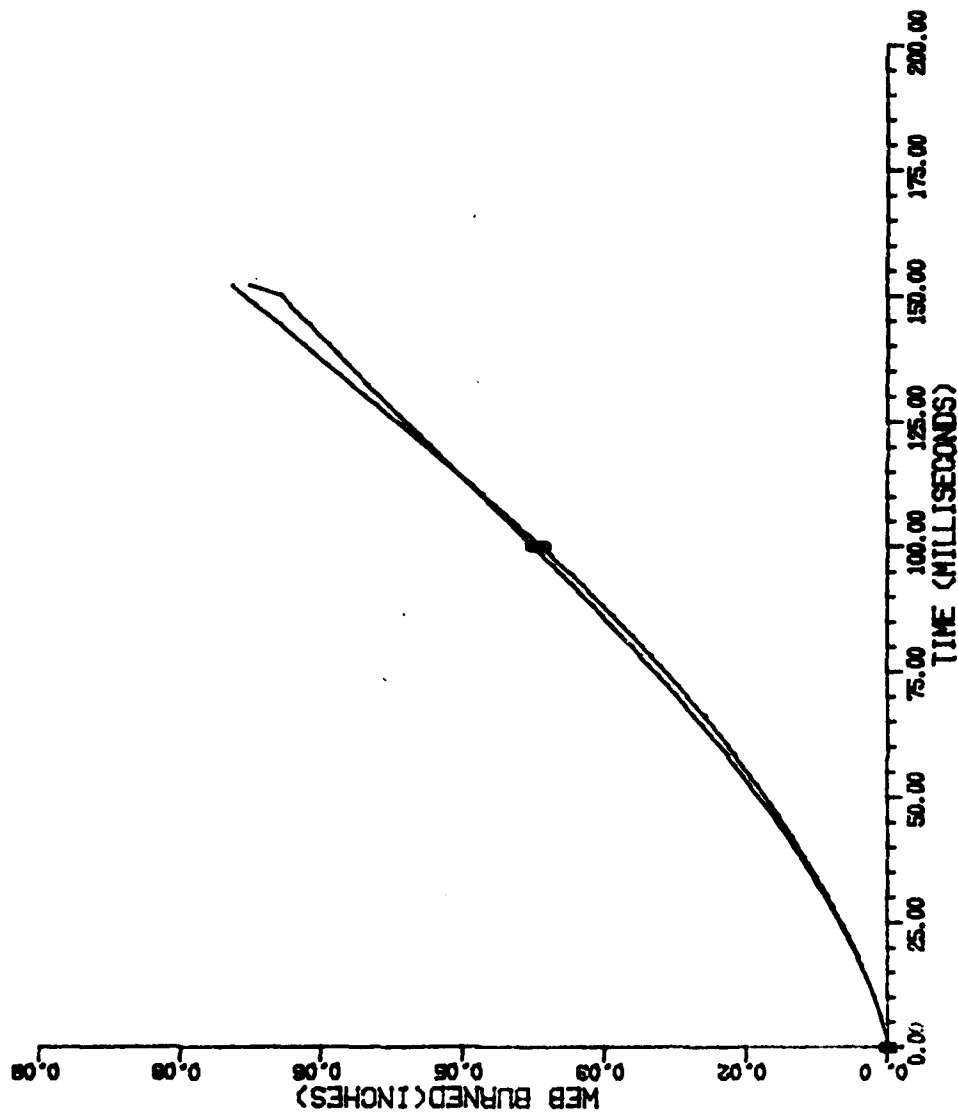
Figure 17. Form Function Comparison for Test Nos. 159 and 183



A COMP DATA : TEST 159

B COMP DATA : TEST 183

Figure 18. Calculated Value of Propellant Consumed versus Time for Test Nos. 159 and 183



8 COMP DATA : TEST 159

8 COMP DATA : TEST 183

Figure 19. Calculated Values of Web Burned versus Time for Test Nos. 159 and 183.

APPENDIX A

Digitized Data Set for Test 159

TEST: 159AAA PAYLOAD SLED DISP IN INCHESAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5
0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.1
1.1	1.2	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9
2.0	2.1	2.2	2.3	2.4	2.5	2.7	2.8	2.9	3.1
3.2	3.3	3.5	3.6	3.8	4.0	4.1	4.3	4.5	4.6
4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.5	6.7
6.9	7.2	7.4	7.7	7.9	8.2	8.5	8.7	9.0	9.3
9.6	9.9	10.2	10.5	10.8	11.1	11.4	11.8	12.1	12.4
12.8	13.1	13.5	13.9	14.2	14.6	15.0	15.4	15.8	16.2
16.6	17.0	17.4	17.8	18.3	18.7	19.1	19.6	20.0	20.5
20.9	21.4	21.9	22.3	22.8	23.3	23.8	24.3	24.8	25.3
25.8	26.4	26.9	27.4	28.0	28.5	29.0	29.6	30.1	30.7
31.3	31.8	32.4	33.0	33.5	34.1	34.7	35.3	35.8	36.4
37.0	37.6	38.2	38.7	39.3	39.9	40.5	41.0	41.6	42.2
42.8	43.4	43.9	44.5	45.1	45.7	46.3	46.8	47.4	48.0

48.6AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

TEST: 159AAA CATAPULT PRESSURE IN PSIAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

1.2	-0.5	1.2	1.2	-2.3	-0.5	4.7	20.4	27.4	8.2
-30.2	-49.4	-52.9	-42.4	-25.0	-14.5	-11.0	-11.0	-11.0	-7.5
6.4	22.2	44.9	62.3	85.0	99.0	116.4	135.6	149.6	165.3
181.0	198.5	214.2	222.9	233.4	240.4	256.1	268.3	284.0	294.5
310.2	318.9	322.4	338.1	353.8	367.8	378.3	395.7	414.9	423.7
441.1	453.3	470.8	483.0	493.5	510.9	524.9	540.6	556.3	566.8
584.3	598.2	619.2	634.9	659.3	662.8	683.8	697.7	716.9	730.9
751.8	771.0	792.0	802.5	823.4	839.1	858.3	865.3	889.8	910.7
929.9	947.3	966.5	980.5	998.0	1015.4	1034.6	1050.3	1071.3	1088.8
1106.2	1123.7	1139.4	1153.3	1174.3	1191.7	1209.2	1223.2	1249.3	1256.3
1279.0	1289.5	1300.0	1313.9	1327.9	1340.1	1354.1	1362.8	1385.5	1383.8
1401.2	1404.7	1416.9	1432.6	1434.4	1439.6	1453.6	1450.1	1464.1	1460.6
1465.8	1472.8	1478.0	1478.0	1478.0	1486.8	1490.2	1485.0	1499.0	1488.5
1492.0	1488.5	1486.8	1481.5	1483.3	1478.0	1478.0	1479.8	1479.8	1472.8
1472.8	1467.6	1465.8	1462.3	1458.8	1451.8	1453.6	1448.3	1446.6	1439.6
1434.4	1436.1	1429.2	1425.7	1422.2	1416.9	1416.9	1411.7	1404.7	1406.4
1396.0	1390.7	1389.0	1382.0	1378.5	1371.5	1366.3	1366.3	1429.2	1551.3
1635.1	1788.8	1977.3	2020.9	1797.5	1406.4	1022.4	786.8	690.7	659.3
624.4	566.8	483.0	401.0	338.1	291.0	261.3	252.6	247.4	243.9
229.9	212.4	193.2	186.3	161.8	151.3	144.4	132.1	118.2	109.4

100.7AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

TEST: 159AAA PAYLOAD FORCE IN LBSAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

-7.3	-22.0	-7.3	-22.0	-22.0	-14.6	-7.3	22.3	29.7	-96.1
-273.6	-362.5	-288.5	-192.3	-103.4	-29.5	-14.6	-22.0	-36.8	-44.3
29.7	88.9	140.7	229.5	318.3	355.3	421.9	473.7	562.5	569.9
666.1	688.3	769.7	828.9	873.3	932.5	984.3	1028.7	1102.7	1124.9
1213.7	1221.1	1302.5	1324.7	1376.5	1435.7	1472.7	1517.1	1620.7	1642.9
1702.1	1768.7	1835.3	1879.7	1938.9	1990.7	2049.9	2123.9	2168.3	2227.5
2286.7	2338.5	2382.9	2442.1	2486.5	2545.7	2619.7	2693.7	2738.1	2856.5
2923.1	2982.3	3034.1	3115.5	3167.3	3248.7	3293.1	3367.1	3433.7	3485.5
3552.1	3618.7	3707.5	3766.7	3833.3	3899.9	3944.3	4025.7	4092.3	4144.1
4225.5	4277.3	4343.9	4380.9	4469.7	4528.9	4588.1	4632.5	4691.7	4736.1
4795.3	4847.1	4913.7	4980.3	5002.5	5039.5	5113.5	5150.5	5209.7	5254.1
5283.7	5320.7	5350.3	5379.9	5416.9	5453.9	5439.1	5483.5	5505.7	5527.9
5535.3	5572.3	5564.9	5594.5	5601.9	5616.7	5616.7	5638.9	5631.5	5638.9
5631.5	5646.3	5638.9	5646.3	5638.9	5631.5	5638.9	5653.7	5631.5	5631.5
5646.3	5624.1	5609.3	5601.9	5579.7	5564.9	5550.1	5572.3	5527.9	5520.5
5498.3	5498.3	5490.9	5468.7	5431.7	5439.1	5394.7	5387.3	5372.5	5342.9
5328.1	5335.5	5276.3	5283.7	5254.1	5246.7	5187.5	4861.9	4218.1	3478.1
2974.9	2797.3	2738.1	2634.5	2353.3	1916.7	1302.5	725.3	370.1	222.1
214.7	273.9	236.9	177.7	51.9	-66.4	-118.3	-155.3	-110.8	-36.8
29.7	59.3	74.1	88.9	74.1	51.9	51.9	37.1	66.7	51.9

66.7AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

TEST: 159AAA BASE FORCE IN LBSAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

-6.2	-35.6	-6.2	-6.2	-13.5	-28.3	1.2	30.6	67.4	-43.0
-197.6	-249.1	-227.0	-160.8	-28.3	30.6	45.3	38.0	23.3	15.9
52.7	104.2	185.2	280.9	339.8	428.1	479.6	531.2	575.3	604.8
663.7	715.2	774.1	847.7	891.8	958.1	958.1	1024.3	1075.9	1127.4
1178.9	1215.7	1259.9	1318.8	1362.9	1414.5	1451.3	1524.9	1561.7	1605.8
1657.4	1738.3	1775.1	1834.0	1873.8	1922.4	1988.6	2047.5	2099.0	2194.7
2216.8	2261.0	2327.2	2386.1	2422.9	2525.9	2577.5	2643.7	2680.5	2761.5
2813.0	2894.0	2975.0	3019.1	3085.4	3159.0	3217.9	3284.1	3343.0	3416.6
3482.9	3541.8	3600.6	3718.4	3762.6	3806.8	3865.6	3931.9	3990.8	4057.0
4115.9	4219.0	4241.0	4299.9	4351.5	4395.6	4491.3	4550.2	4579.6	4623.8
4668.0	4741.6	4778.4	4829.9	4888.8	4925.6	4991.9	5021.3	5087.5	5117.0
5146.4	5175.9	5205.3	5242.1	5264.2	5293.6	5293.6	5323.1	5323.1	5352.5
5382.0	5389.3	5411.4	5433.5	5448.2	5448.2	5448.2	5462.9	5477.7	5492.4
5492.4	5492.4	5470.3	5470.3	5485.0	5470.3	5492.4	5485.0	5485.0	5470.3
5470.3	5470.3	5492.4	5493.5	5448.2	5440.9	5433.5	5440.9	5418.8	5418.8
5411.4	5389.3	5374.6	5374.6	5374.6	5345.2	5359.9	5323.1	5323.1	5301.0
5308.4	5293.6	5293.6	5264.2	5271.6	5249.5	5264.2	4933.0	4307.3	3637.4
3122.2	2820.4	2746.8	2761.5	2636.4	2386.1	2032.8	1664.7	1326.1	1186.3
1017.0	766.7	560.6	295.6	148.4	30.6	52.7	74.8	170.5	236.7
280.9	317.7	303.0	273.5	266.2	244.1	214.6	214.6	199.9	192.6

163.1AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

TEST: 159AAA PAYLOAD SLED ACCEL IN GSAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	-0.3	-0.3
-0.3	-0.2	-0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
0.1	0.2	0.4	0.6	0.7	0.8	0.9	0.9	1.1	1.3
1.4	1.7	1.8	2.0	2.1	2.2	2.4	2.5	2.5	2.6
2.8	2.9	3.1	3.3	3.4	3.5	3.6	3.8	3.9	4.0
4.2	4.3	4.4	4.7	4.9	5.1	5.2	5.3	5.4	5.5
5.6	5.8	6.0	6.2	6.3	6.6	6.7	6.7	6.9	7.1
7.3	7.5	7.7	7.9	8.1	8.2	8.4	8.6	8.8	9.0
9.1	9.4	9.6	9.8	9.9	10.1	10.3	10.4	10.7	10.9
11.1	11.2	11.5	11.6	11.8	11.9	12.0	12.2	12.3	12.5
12.6	12.8	13.0	13.1	13.3	13.4	13.5	13.6	13.7	13.7
13.9	13.8	13.8	13.8	13.9	14.0	14.2	14.3	14.7	14.6
14.6	14.6	14.7	14.7	14.7	14.7	14.8	14.9	14.9	14.9
15.1	14.9	14.9	14.9	14.8	14.8	14.8	14.7	14.8	14.6
14.6	14.6	14.7	14.7	14.8	14.6	14.5	14.4	14.3	14.3
14.2	14.2	14.2	14.3	14.2	14.1	14.1	14.1	14.0	13.9
13.8	13.8	13.7	13.7	13.7	13.6	13.5	12.6	10.8	8.6
6.4	4.5	3.5	3.5	4.1	4.9	5.0	4.1	2.7	0.3
-2.1	-3.2	-2.8	-1.2	0.6	2.0	2.5	2.4	1.8	0.9
0.4	0.7	1.0	1.0	0.3	0.0	0.2	0.5	0.6	0.4
0.1									

0.1AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

TEST: 159AAA PAYLOAD SLED VEL IN FT/SECAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2
0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.9
0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8	1.9
2.1	2.2	2.3	2.5	2.7	2.8	3.0	3.1	3.3	3.5
3.7	3.9	4.1	4.3	4.4	4.7	4.9	5.1	5.3	5.5
5.8	6.0	6.3	6.5	6.8	7.0	7.3	7.6	7.8	8.1
8.4	8.7	9.0	9.4	9.7	10.0	10.3	10.6	11.0	11.3
11.7	12.1	12.4	12.8	13.2	13.5	13.9	14.3	14.7	15.1
15.5	15.9	16.3	16.8	17.2	17.6	18.0	18.5	18.9	19.4
19.8	20.3	20.7	21.1	21.6	22.0	22.5	23.0	23.4	23.9
24.4	24.8	25.3	25.8	26.3	26.7	27.2	27.7	28.1	28.6
29.1	29.6	30.1	30.6	31.0	31.5	32.0	32.5	32.9	33.4
33.9	34.4	34.8	35.3	35.8	36.3	36.7	37.2	37.7	38.1
38.6	39.0	39.5	40.0	40.4	40.9	41.3	41.8	42.2	42.7
43.1	43.6	44.0	44.5	44.9	45.3	45.8	46.2	46.6	46.9
47.1	47.3	47.4	47.5	47.7	47.8	48.0	48.1	48.2	48.3
48.3	48.2	48.1	48.0	48.0	48.0	48.1	48.2	48.3	48.3
48.3	48.3	48.4	48.4	48.4	48.4	48.4	48.4	48.5	48.5

48.5AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

APPENDIX B

Digitized Data Set for Test 183

TEST: 183 CATAPULT PRESSURE IN PSIAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

-30.1	-23.2	-23.2	-26.6	-19.8	-9.5	-9.5	42.0	52.3	55.8
31.7	-12.9	-43.8	-64.4	-57.5	-33.5	4.3	38.6	59.2	86.7
79.8	90.1	93.5	107.3	127.9	148.5	155.3	169.1	182.8	189.7
203.4	220.6	230.9	261.8	268.6	303.0	289.2	289.2	299.5	306.4
313.3	323.6	333.9	347.6	351.0	375.1	381.9	395.7	406.0	412.8
436.9	440.3	454.0	464.3	474.6	491.8	495.2	515.8	539.9	550.2
574.2	594.8	608.5	608.5	618.8	639.4	656.6	673.8	697.8	701.2
721.8	739.0	759.6	780.2	800.8	824.8	828.3	842.0	855.8	876.3
893.5	903.8	938.2	955.3	975.9	1003.4	1020.6	1048.0	1068.6	1085.8
1109.8	1130.4	1151.0	1178.5	1199.1	1216.3	1247.2	1271.2	1291.8	1322.7
1350.2	1374.2	1398.2	1418.8	1436.0	1456.6	1487.5	1504.7	1528.7	1559.6
1580.2	1604.2	1631.7	1652.3	1679.8	1707.3	1738.2	1745.0	1772.5	1789.7
1806.8	1834.3	1851.4	1868.6	1892.7	1896.1	1933.9	1954.5	1971.6	1988.8
2006.0	2033.4	2033.4	2057.5	2071.2	2084.9	2091.8	2091.8	2109.0	2126.1
2136.4	2139.9	2157.0	2157.0	2187.9	2181.1	2174.2	2174.2	2187.9	2187.9
2187.9	2181.1	2181.1	2184.5	2184.5	2187.9	2187.9	2194.8	2201.7	2194.8
2177.6	2153.6	2136.4	2119.3	2119.3	2119.3	2119.3	2109.0	2095.2	2084.9
2071.2	2067.8	2067.8	2043.7	2040.3	2006.0	1985.4	1961.3	1930.4	1906.4
1892.7	1854.9	1848.0	1820.6	1796.5	1775.9	1755.3	1751.9	1731.3	1714.1
1693.5	1672.9	1652.3	1624.8	1607.7	1590.5	1566.5	1563.0	1532.1	1508.1
1504.7	1511.5	1463.5	1439.4	1405.1	1370.8	1336.4	1326.1	1305.5	1295.2
1192.2	581.1	-675.6	-2217.2	-2745.9	-2745.9	-2745.9	-2745.9	-2745.9	-2745.9
-2745.9	-2745.9	-2745.9	-2745.9	-2745.9	-2745.9	-2745.9	-2745.9	-2745.9	-2745.9

TEST: 183 PAYLOAD FORCE IN LBSAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

3268.1	3268.1	3238.5	3208.9	3149.7	3149.7	3194.1	3238.5	3194.1	3282.9
3238.5	3223.7	3149.7	3223.7	3223.7	3223.7	3268.1	3312.5	3371.8	3401.4
3445.8	3431.0	3416.2	3401.4	3401.4	3386.6	3431.0	3401.4	3401.4	3416.2
3445.8	3475.4	3519.8	3549.4	3579.1	3593.9	3608.7	3638.3	3682.7	3727.1
3786.3	3890.0	3727.1	3653.1	3564.2	3475.4	3431.0	3460.6	3534.6	3653.1
3741.9	3801.1	3801.1	3845.6	3801.1	3786.3	3741.9	3712.3	3741.9	3682.7
3667.9	3638.3	3623.5	3608.7	3579.1	3623.5	3608.7	3638.3	3667.9	3712.3
3682.7	3697.5	3727.1	3786.3	3801.1	3816.0	3756.7	3756.7	3816.0	3860.4
3919.6	4038.1	4141.7	4260.2	4289.8	4378.6	4437.8	4541.5	4585.9	4630.3
4793.2	4867.2	4956.1	5044.9	5222.6	5355.9	5503.9	5563.1	5607.6	5696.4
5770.4	5874.1	5948.1	6037.0	6111.0	6214.6	6303.5	6377.5	6525.6	6629.2
6718.0	6821.7	6895.7	7014.2	7147.5	7177.1	7280.7	7354.7	7443.6	7532.4
7606.5	7710.1	7843.4	7902.6	7991.4	8065.5	8154.3	8228.3	8302.4	8346.8
8406.0	8480.0	8539.3	8568.9	8717.0	8761.4	8791.0	8850.2	8909.4	8968.7
8968.7	8998.3	9072.3	9072.3	9072.3	9087.1	9131.5	9116.7	9190.8	9161.2
9190.8	9176.0	9294.4	9205.6	9176.0	9176.0	9161.2	9205.6	9264.8	9279.6
9205.6	9087.1	9013.1	8939.0	8939.0	8953.8	8939.0	8939.0	8909.4	8835.4
8820.6	8731.8	8657.7	8598.5	8524.5	8465.2	8361.6	8257.9	8139.5	8065.5
8050.6	8050.6	7917.4	7843.4	7710.1	7636.1	7547.2	7473.2	7428.8	7310.3
7265.9	7191.9	7088.2	7058.6	6969.8	6925.4	6792.1	6703.3	6614.4	6555.2
6481.1	6421.9	6377.5	6259.0	6155.4	6007.3	5933.3	5814.9	5755.6	5711.2
4970.9	3934.4	2927.6	2305.7	2054.0	2172.4	2276.1	2187.2	1950.3	1565.3
1224.8	958.3	869.4	913.9	987.9	987.9	987.9	987.9	987.9	987.9

TEST: 183	PAYLOAD SLED VEL IN FPSAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA									
52.6	52.3	52.1	51.9	51.6	51.4	51.2	51.0	50.7	50.5	
50.3	50.1	49.8	49.6	49.4	49.1	48.9	48.6	48.4	48.1	
47.8	47.6	47.3	47.1	46.8	46.5	46.3	46.0	45.8	45.5	
45.3	45.0	44.7	44.5	44.2	43.9	43.6	43.4	43.1	42.8	
42.5	42.3	42.0	41.7	41.4	41.2	40.9	40.6	40.4	40.1	
39.8	39.5	39.2	38.9	38.7	38.4	38.1	37.8	37.5	37.3	
37.0	36.7	36.4	36.2	35.9	35.6	35.3	35.1	34.8	34.5	
34.2	34.0	33.7	33.4	33.1	32.8	32.5	32.3	32.0	31.7	
31.4	31.1	30.8	30.4	30.1	29.8	29.4	29.1	28.7	28.4	
28.0	27.6	27.2	26.8	26.4	26.0	25.6	25.1	24.7	24.3	
23.8	23.3	22.9	22.4	22.0	21.5	21.0	20.5	20.0	19.4	
18.9	18.4	17.8	17.3	16.7	16.2	15.6	15.0	14.4	13.8	
13.2	12.6	11.9	11.3	10.7	10.0	9.4	8.7	8.1	7.4	
6.7	6.0	5.3	4.6	3.9	3.2	2.5	1.8	1.1	0.4	
-0.3	-1.0	-1.7	-2.4	-3.1	-3.8	-4.5	-5.2	-5.9	-6.6	
-7.3	-8.1	-8.8	-9.5	-10.2	-10.9	-11.6	-12.3	-13.0	-13.7	
-14.4	-15.1	-15.8	-16.5	-17.2	-17.9	-18.6	-19.3	-19.9	-20.6	
-21.3	-22.0	-22.6	-23.3	-23.9	-24.6	-25.2	-25.9	-26.5	-27.1	
-27.7	-28.4	-29.0	-29.5	-30.1	-30.7	-31.3	-31.9	-32.4	-33.0	
-33.5	-34.1	-34.6	-35.2	-35.7	-36.2	-36.7	-37.2	-37.7	-38.2	
-38.6	-39.1	-39.6	-40.0	-40.5	-41.0	-41.4	-41.8	-42.3	-42.7	
-43.1	-43.4	-43.6	-43.7	-43.9	-44.0	-44.1	-44.3	-44.4	-44.5	
-44.6	-44.6	-44.6	-44.6	-44.5	-44.4	AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA				

TEST: 183	PAYLOAD SLED DISP IN INCHESAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA									
0.0	0.6	1.2	1.9	2.5	3.1	3.7	4.3	4.9	5.6	
6.2	6.8	7.4	8.0	8.6	9.1	9.7	10.3	10.9	11.5	
12.1	12.6	13.2	13.8	14.3	14.9	15.4	16.0	16.5	17.1	
17.6	18.2	18.7	19.3	19.8	20.3	20.9	21.4	21.9	22.4	
22.9	23.4	23.9	24.4	24.9	25.4	25.9	26.4	26.9	27.4	
27.9	28.3	28.8	29.3	29.7	30.2	30.7	31.1	31.6	32.0	
32.5	32.9	33.3	33.8	34.2	34.6	35.1	35.5	35.9	36.3	
36.7	37.2	37.5	38.0	38.3	38.8	39.1	39.5	39.9	40.3	
40.7	41.0	41.4	41.8	42.2	42.5	42.9	43.2	43.6	43.9	
44.3	44.6	44.9	45.2	45.5	45.9	46.2	46.5	46.8	47.1	
47.4	47.6	47.9	48.2	48.5	48.7	49.0	49.2	49.5	49.7	
49.9	50.2	50.4	50.6	50.8	51.0	51.2	51.4	51.5	51.7	
51.9	52.0	52.2	52.3	52.4	52.6	52.7	52.8	52.9	53.0	
53.1	53.2	53.2	53.3	53.3	53.4	53.4	53.4	53.5	53.5	
53.5	53.5	53.4	53.4	53.4	53.3	53.3	53.2	53.2	53.1	
53.0	52.9	52.8	52.7	52.6	52.5	52.3	52.2	52.0	51.9	
51.7	51.5	51.3	51.1	50.9	50.7	50.5	50.3	50.0	49.8	
49.5	49.3	49.0	48.7	48.5	48.2	47.9	47.6	47.3	46.9	
46.6	46.3	45.9	45.6	45.2	44.8	44.5	44.1	43.7	43.3	
42.0	42.5	42.1	41.7	41.3	40.8	40.4	39.9	39.5	39.0	
38.6	38.1	37.6	37.2	36.7	36.2	35.7	35.2	34.7	34.2	
33.7	33.2	32.6	32.1	31.6	31.0	30.5	30.0	29.5	28.9	
28.4	27.9	27.3	26.8	26.3	25.7	AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA				

TEST: 183	CARRIER SLED VEL IN FPSAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA								
52.6	52.4	52.1	51.9	51.7	51.4	51.2	50.9	50.7	50.5
50.2	50.0	49.8	49.5	49.3	49.0	48.8	48.5	48.3	48.0
47.8	47.5	47.3	47.0	46.8	46.5	46.3	46.0	45.8	45.5
45.3	45.0	44.7	44.5	44.2	43.9	43.6	43.4	43.1	42.8
42.5	42.3	42.0	41.7	41.5	41.2	40.9	40.6	40.4	40.1
39.8	39.5	39.2	39.0	38.7	38.4	38.1	37.9	37.6	37.3
37.0	36.8	36.5	36.2	36.0	35.7	35.4	35.1	34.8	34.6
34.3	34.0	33.8	33.5	33.2	32.9	32.6	32.4	32.1	31.8
31.5	31.2	30.9	30.7	30.4	30.1	29.8	29.6	29.3	29.0
28.8	28.5	28.2	28.0	27.7	27.4	27.2	26.9	26.6	26.4
26.1	25.9	25.6	25.3	25.1	24.8	24.6	24.3	24.0	23.8
23.5	23.3	23.0	22.7	22.5	22.2	22.0	21.7	21.5	21.2
20.9	20.7	20.4	20.2	19.9	19.7	19.4	19.2	18.9	18.7
18.4	18.2	17.9	17.7	17.4	17.2	16.9	16.7	16.4	16.2
15.9	15.7	15.4	15.2	15.0	14.7	14.5	14.2	14.0	13.8
13.5	13.3	13.0	12.8	12.6	12.3	12.1	11.8	11.6	11.3
11.1	10.8	10.6	10.3	10.1	9.8	9.6	9.3	9.1	8.8
8.6	8.3	8.0	7.8	7.5	7.3	7.0	6.7	6.5	6.2
5.9	5.7	5.4	5.1	4.8	4.6	4.3	4.0	3.7	3.5
3.2	2.9	2.6	2.3	2.0	1.8	1.5	1.2	0.9	0.6
0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA				

TEST: 183	CARRIER SLED DISP IN INCHESAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA								
0.0	0.6	1.2	1.9	2.5	3.1	3.7	4.3	4.9	5.6
6.2	6.8	7.4	8.0	8.6	9.1	9.7	10.3	10.9	11.5
12.1	12.6	13.2	13.8	14.3	14.9	15.4	16.0	16.5	17.1
17.6	18.2	18.7	19.3	19.8	20.3	20.8	21.4	21.9	22.4
22.9	23.4	23.9	24.4	24.9	25.4	25.9	26.4	26.9	27.4
27.9	28.3	28.8	29.3	29.7	30.2	30.6	31.1	31.6	32.0
32.5	32.9	33.3	33.8	34.2	34.6	35.1	35.5	35.9	36.3
36.7	37.2	37.6	38.0	38.4	38.8	39.2	39.5	39.9	40.3
40.7	41.1	41.4	41.8	42.2	42.5	42.9	43.3	43.6	44.0
44.3	44.7	45.0	45.3	45.7	46.0	46.3	46.6	47.0	47.3
47.6	47.9	48.2	48.5	48.8	49.1	49.4	49.7	50.0	50.3
50.6	50.9	51.1	51.4	51.7	52.0	52.2	52.5	52.7	53.0
53.2	53.5	53.7	54.0	54.2	54.5	54.7	54.9	55.2	55.4
55.6	55.8	56.0	56.2	56.5	56.7	56.9	57.1	57.3	57.5
57.7	57.9	58.0	58.2	58.4	58.6	58.8	58.9	59.1	59.3
59.4	59.6	59.8	59.9	60.1	60.2	60.3	60.5	60.6	60.8
60.9	61.0	61.2	61.3	61.4	61.5	61.7	61.8	61.9	62.0
62.1	62.2	62.3	62.4	62.5	62.6	62.7	62.7	62.8	62.9
63.0	63.0	63.1	63.2	63.2	63.3	63.3	63.4	63.4	63.5
63.5	63.5	63.6	63.6	63.6	63.7	63.7	63.7	63.7	63.7

TEST: 183	BASE FORCE IN LBSAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA									
3417.0	3387.4	3328.4	3269.3	3180.7	3284.1	3313.6	3476.1	3535.1	3594.2	
3638.5	3461.3	3328.4	3225.0	3254.5	3284.1	3313.6	3417.0	3490.8	3520.4	
3549.9	3594.2	3668.0	3727.1	3638.5	3638.5	3623.7	3594.2	3609.0	3594.2	
3609.0	3623.7	3727.1	3727.1	3756.6	3800.9	3830.5	3860.0	3889.6	3963.4	
3963.4	4022.5	3948.6	3889.6	3800.9	3741.9	3682.8	3697.6	3756.6	3845.3	
4081.5	4037.2	4081.5	4096.3	4022.5	3992.9	3978.2	3919.1	3845.3	3874.8	
3815.7	3919.1	3874.8	3874.8	3889.6	3874.8	3933.9	3860.0	3889.6	3904.3	
3919.1	3948.6	3933.9	3978.2	3992.9	4037.2	4022.5	4022.5	4155.4	4081.5	
4140.6	4184.9	4273.5	4332.6	4436.0	4421.2	4554.1	4627.9	4687.0	4790.4	
4893.8	5011.9	5085.8	5174.4	5263.0	5381.1	5454.9	5528.8	5617.4	5735.5	
5824.1	5912.8	6060.4	6134.3	6326.3	6341.0	6414.9	6503.5	6562.5	6665.9	
6754.5	6798.8	6887.4	7005.6	7138.5	7271.4	7374.8	7478.1	7552.0	7640.6	
7714.4	7729.2	7906.4	7906.4	7965.5	8098.4	8157.5	8246.1	8290.4	8349.4	
8423.3	8526.7	8571.0	8600.5	8689.1	8615.3	8748.2	8762.9	8807.3	8851.5	
8866.3	8866.3	9014.0	9058.3	9058.3	9087.8	9117.4	9161.7	9028.8	9058.3	
9087.8	9102.6	9102.6	9028.8	9073.1	9028.8	9073.1	9087.8	9117.4	9058.3	
9043.5	9087.8	9043.5	9014.0	9028.8	9043.5	9014.0	8999.2	8969.7	8954.9	
8895.8	8851.5	8822.0	8851.5	8822.0	8822.0	8777.7	8718.6	8674.3	8615.3	
8571.0	8526.7	8497.1	8452.8	8334.7	8305.1	8216.5	8142.7	8083.6	8054.1	
7995.0	7817.8	7699.7	7625.8	7522.4	7433.8	7330.5	7197.5	7153.3	7079.4	
6961.3	6828.4	6621.6	6503.5	6355.8	6311.5	6237.6	6193.3	6134.3	5912.8	
5203.9	4096.3	2959.2	2294.6	1940.2	1984.5	2146.9	2279.9	2073.1	1836.8	
1467.6	1201.8	1009.8	906.5	803.1	773.5	AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA				
63.7	63.7	63.7	63.7	63.7	63.7	63.7	63.7	63.7	63.7	
63.7	63.7	63.7	63.7	63.7	63.7	63.7	63.7	63.7	63.7	
63.7	63.7	63.7	63.7	63.7	63.7	63.7AAAAAAAAAAAAAAAAAAAAAAAAAAAA				

TEST: 183	CATAPULT EXTENSION VEL IN FPSAAAAAAAAAAAAAAAAAAAAAAAAAAAA									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	
-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	
-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7	
0.8	0.9	1.0	1.1	1.3	1.4	1.6	1.8	1.9	2.1	
2.3	2.5	2.7	2.9	3.1	3.3	3.6	3.8	4.1	4.3	
4.6	4.9	5.2	5.4	5.8	6.1	6.4	6.7	7.0	7.4	
7.7	8.1	8.5	8.9	9.2	9.6	10.0	10.4	10.8	11.3	
11.7	12.1	12.6	13.0	13.5	13.9	14.4	14.9	15.3	15.8	
16.3	16.7	17.2	17.6	18.1	18.5	19.0	19.5	19.9	20.4	
20.9	21.3	21.8	22.3	22.7	23.2	23.6	24.1	24.6	25.0	
25.5	25.9	26.4	26.8	27.3	27.7	28.1	28.6	29.0	29.4	
29.8	30.3	30.7	31.1	31.5	31.8	32.2	32.6	33.0	33.3	
33.7	34.0	34.4	34.7	35.0	35.3	35.6	35.9	36.2	36.4	
36.7	37.0	37.2	37.5	37.7	37.9	38.2	38.4	38.5	38.7	
39.0	39.2	39.6	40.0	40.5	40.9	41.4	41.8	42.3	42.7	
43.0	43.4	43.6	43.7	43.9	44.0	44.1	44.3	44.4	44.5	
44.6	44.6	44.6	44.6	44.5	44.4	AAAAAAAAAAAAAAAAAAAAAAAAAAAA				

TEST: 183	CARRIER	SLED	ACCEL	IN	GS	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA
7.1	7.1	7.2	7.3	7.5	7.5	7.5	7.4	7.4	7.3											
7.3	7.3	7.4	7.5	7.6	7.6	7.6	7.7	7.7	7.7											
7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.9	7.9	8.1											
8.1	8.2	8.3	8.4	8.5	8.6	8.6	8.6	8.6	8.5											
8.5	8.5	8.5	8.4	8.4	8.5	8.5	8.6	8.6	8.6											
8.7	8.6	8.6	8.6	8.6	8.6	8.6	8.5	8.4	8.4											
8.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.6	8.6											
8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.7	8.7	8.8											
8.8	8.8	8.8	8.7	8.6	8.5	8.4	8.4	8.3	8.3											
8.3	8.3	8.2	8.3	8.3	8.3	8.2	8.2	8.2	8.1											
8.1	8.1	8.0	8.0	7.9	8.0	8.0	8.0	8.0	8.0											
8.1	8.1	8.1	8.1	8.1	8.1	8.0	7.9	7.9	7.9											
7.9	7.9	7.8	7.9	7.9	7.9	7.9	7.8	7.8	7.8											
7.7	7.7	7.7	7.7	7.7	7.7	7.6	7.6	7.6	7.6											
7.7	7.6	7.6	7.5	7.5	7.5	7.5	7.5	7.4	7.5											
7.5	7.5	7.5	7.6	7.6	7.6	7.6	7.7	7.7	7.7											
7.6	7.7	7.7	7.7	7.7	7.8	7.8	7.8	7.9	7.9											
7.9	8.0	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.3											
8.3	8.4	8.4	8.4	8.5	8.6	8.6	8.6	8.7	8.7											
8.8	8.8	8.9	9.0	9.0	9.1	9.1	9.1	9.1	8.8											
7.5	4.8	1.6	-0.6	-1.5	-1.2	-0.5	0.2	0.6	0.6											
0.5	0.2	-0.1	-0.3	-0.2	-0.1	-0.1	0.1	0.1	0.0											
-0.2	-0.3	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0											

TEST: 183	PAYLOAD	SLED	ACCEL	IN	GS	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA	AAAA
7.4	7.6	7.5	7.3	7.3	7.2	7.1	6.9	6.6	6.6											
6.8	7.2	7.4	7.6	7.7	7.8	7.7	7.7	7.8	7.9											
8.1	8.1	8.1	8.1	8.0	8.0	8.0	7.9	7.8	7.8											
8.0	8.3	8.4	8.6	8.7	8.6	8.5	8.4	8.3	8.5											
8.7	8.8	8.8	8.6	8.4	8.2	8.1	8.0	8.2	8.6											
9.1	9.3	9.2	8.9	8.8	8.8	8.7	8.5	8.4	8.4											
8.5	8.6	8.6	8.6	8.6	8.6	8.5	8.5	8.4	8.6											
8.6	8.6	8.6	8.6	8.8	8.9	9.1	9.1	9.1	9.2											
9.4	9.6	9.7	9.9	10.4	10.5	10.9	11.1	11.2	11.4											
11.8	12.1	12.4	12.5	12.7	13.0	13.3	13.4	13.6	13.8											
14.0	14.2	14.3	14.5	14.9	15.2	15.5	15.7	15.9	16.2											
16.5	16.7	16.9	17.1	17.5	17.8	18.0	18.3	18.4	18.8											
19.1	19.4	19.6	19.6	19.8	20.1	20.4	20.6	20.8	21.0											
21.4	21.5	21.5	21.6	21.8	21.9	22.0	22.1	22.2	22.3											
22.3	22.0	21.6	21.5	21.5	21.7	21.8	21.8	21.9	21.9											
22.1	22.1	22.0	21.9	21.9	21.9	21.8	21.8	21.7	21.7											
21.8	21.7	21.6	21.6	21.5	21.5	21.3	21.1	21.0	21.0											
21.1	20.9	20.7	20.4	20.2	20.0	19.9	19.7	19.5	19.4											
19.2	19.0	18.6	18.1	17.8	17.7	17.8	17.6	17.4	17.2											
17.1	17.0	16.7	16.4	16.1	15.9	15.7	15.3	14.9	14.7											
14.7	14.7	14.6	14.4	14.1	14.0	13.8	13.6	13.1	12.6											
10.7	8.2	5.6	4.2	3.7	4.0	4.2	3.9	3.6	3.0											
2.0	0.6	-0.6	-1.7	-2.8	-3.2	-3.2	-3.2	-3.2	-3.2											

54

APPENDIX C

Program Listing of "DATA/MOD"

```

160
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000

$RESET FREE
$SET 0=N
FILE 6(TITLE="DDI183",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420)
FILE 7(TITLE="GPI183",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420)
FILE 8(TITLE="DDATA183",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,
-PROTECTION=SAVE)
DIMENSION Y(250),X(250),Z(250)
FILE 6 IS DISPLACEMENT DATA FROM ACTUAL TEST (TEST 183)
N=226
READ(6,100)(X(J),J=1,N)
READ(7,100)(Y(J),J=1,N)
100 FORMAT(10F8.2)
C WRITE OUT THE RESULTS IN THE NEW FORMAT. THE NEW DATA TABLE
C WILL ALSO BE SHIFTED IN TIME IF REQUIRED. START DATA STRING AT
C 16TH ELEMENT. MAKE THIS NEW FIRST TERM ZERO AND ELIMINATE EVERY
C SECOND TERM.
X(16) = 0.0
WRITE(8,101)(X(J),J=16,N,2)
101 FORMAT(8F10.4)
STOP
END

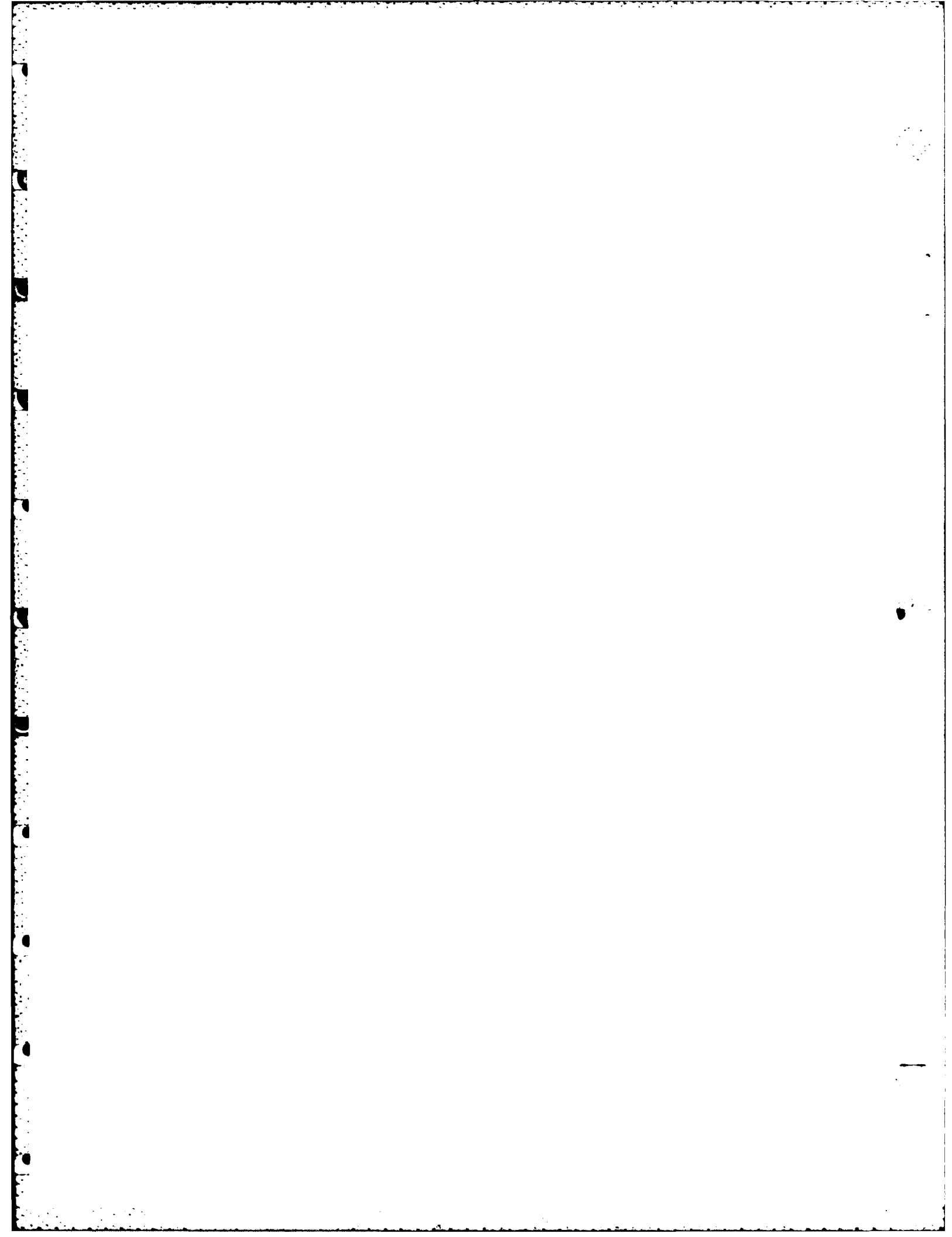
```

APPENDIX D

Program Listing of "GRAPH"

[illegible]

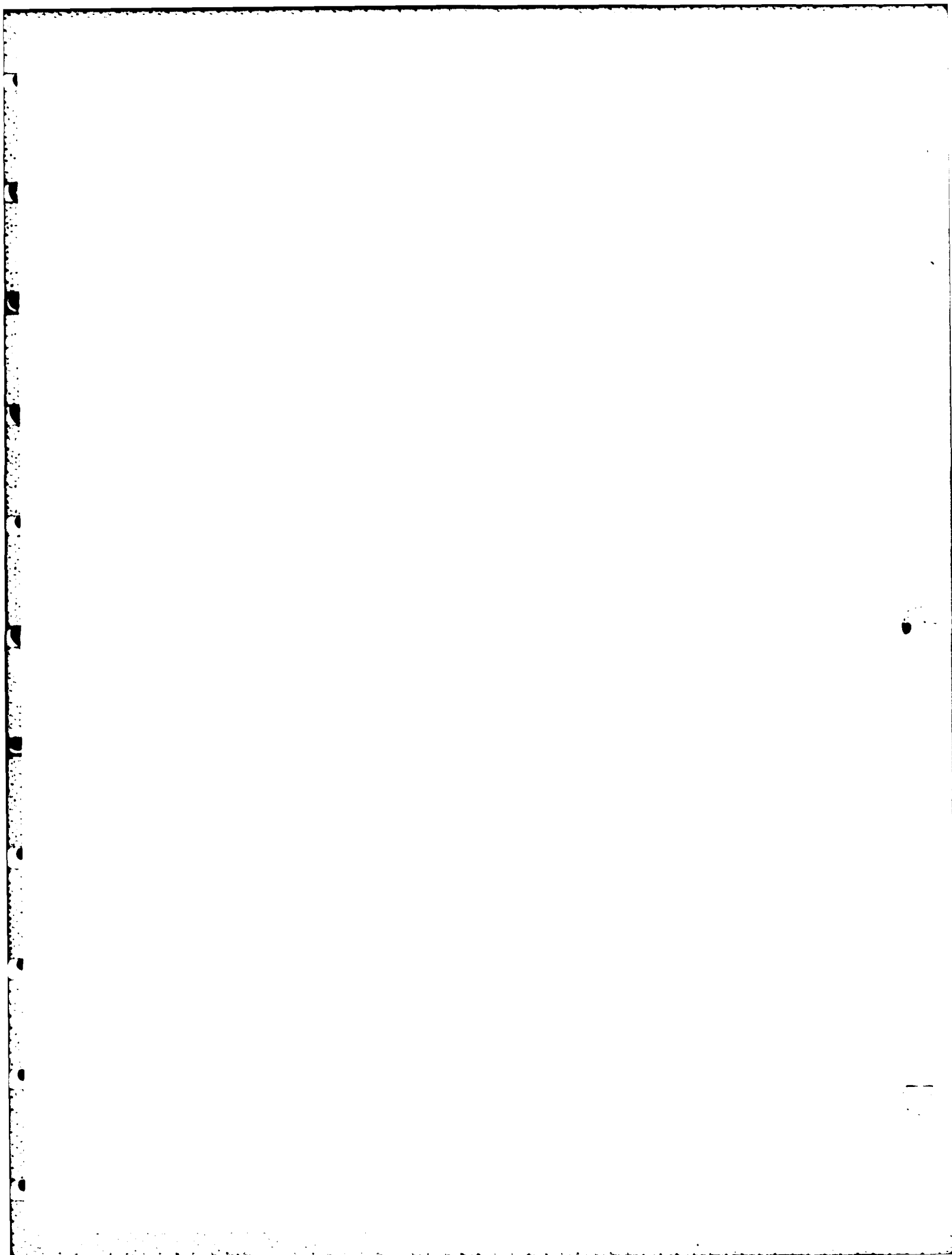
[illegible]



APPENDIX E

Program Listing of (DYNMO)

**Catapult Model with Data Set
(NEWSET)**



DYNAMO (07/22/81)

7:12 PM TUESDAY, OCTOBER 5, 1982

```

100 $RESET FREE
150 $SET OWN
200 C$SET LIST
300 FILE 5(TITLE="NEWSET",KIND=DISK,FILETYPE=7)
400 FILE 6(KIND=PRINTER,MAXRECSIZE=60)
410 FILE 7(TITLE="PRESS",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,
411 PROTECTION=SAVE)
420 FILE 8(TITLE="GACCZ",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,
421 PROTECTION=SAVE)
430 FILE 9(TITLE="DISP",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,
431 PROTECTION=SAVE)
440 FILE 10(TITLE="WB",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,
441 PROTECTION=SAVE)
450 FILE 11(TITLE="W",KIND=DISK,MAXRECSIZE=14,BLOCKSIZE=420,
451 PROTECTION=SAVE)
500 C PROGRAM CATAPULT
600
700 C
800 DIMENSION OUT(100),OUTMAX(100),OUTMIN(100),WDW(250),CA(4),
805 WORK(18),GLF(220),GACCZ(200),DISP(200)
810 COMMON /GDATA/ GDT(3,220)
810 COMMON /OUTDAT/ TIME,CASE,GEEZ,VELC,STROKE,HT,VOL,DRI,BRP,BW,BA,
900 W,TEMP,PRESS,EK,EP,FE,HE,CADF,THA,FRF,GRK,RPLRT,TLF,
900 RFE,BB,WKDOT,WRK,HP
1000 COMMON /CATDAT/ PL(250),WB(250),WG(250),CTCC(250),CT1(250),
1000 RK1(250),PRI(250),NPTS,PSI(250)
1100 COMMON /TESTDT/ P(30,3,3),TIMEP(30,3,3),DAT(25,3)
1200 COMMON /INTG/ SUM(10),PSUM(10),RATE(10),SAVE(10)
1300
1400 EQUIVALENCE (RATE(1),ACCB),(SUM(1),VELB),
1400 (RATE(2),VELBB),(SUM(2),DISTB),
1500 (RATE(3),ACCZ),(SUM(3),VELZ),
1500 (RATE(4),VELZZ),(SUM(4),DISTZ),
1600 (RATE(5),PBR),(SUM(5),WB),
1600 (RATE(6),EFDOT),(SUM(6),EF),
1700 (RATE(7),ELDOT),(SUM(7),EL),
1700 (RATE(8),WKDOT),(SUM(8),WK),
1800 (RATE(9),EPDOT),(SUM(9),EP),
1800 (RATE(10),EKDOT),(SUM(10),EK),
1900 EQUIVALENCE (OUT(1),TIME)
2000
2100 REAL K1,K2,K3,K4,K41
2200 NAMELIST /NEWSET/ DT,CO,TEST,C,PA,EJW,STROFF,VO,B,PXP,RM,K1,
2300 K3,RHOP,RHO,OMEGA,THETA,ZLF,NPRT,TFLAME,CV,PLOCK,
2400 CTMP,MODE,IDIAG,CSD,RLRD,K2,DPLMT,NOUT,IFPLT,K4,
2500 IFPRT,MODEL,TIGN,RK,ICOND,ISTOP
2600
2700 C *****
2800 C *****
2900 C *****
3000 C *****
3100 C *****
3200 C *****
3300 C *****
3310 C *****
3400 C *****
3500 C *****
3600 C *****
3700 C *****
3800 C *****
3900 C *****
4000 C *****
4100 C *****

```

4200	C***	BA	BURNING AREA (IN**2)	00004200
4300	C***	BB	AN ALTERNATE VARIABLE NAME FOR B	00004300
4400	C***	BBB	A LOCATION IN WHICH TO SAVE AN ORIGINAL B DURING ANY CASE	00004400
4500	C***	BRP	PRINTOUT VARIABLE NAME FOR BURN RATE	00004500
4600	C***	BW	PRINTOUT VARIABLE NAME FOR PROPELLANT CONSUMED	00004600
4700	C***	C	TOTAL AVAILABLE PROPELLANT (SLUGS)	00004700
4800	C***	CA	UNDEFINED	00004800
4810	C***	CADF	NET FORCE EXECUTED BY THE CATAPULT (LBS)	00004810
4820	C***	CASE	CASE NUMBER IDENTIFIER	00004820
4830	C***	C6D	PERPENDICULAR DISTANCE BETWEEN THE CG OF THE PROPELLED	00004830
4840	C***		MASS AND THE AXIS OF THE GUIDE RAILS (FT)	00004840
4850	C***	CLF	COMPUTED LOAD FACTOR PARALLEL TO RAIL AXIS (NON DIM)	00004850
4860	C***	CTCC	AN ALTERNATE ARRAY NAME FOR TIME	00004860
4870	C***	CTEMP	TEMPERATURE CONDITION OF THE PROPELLANT AT THE BEGINNING	00004870
4880	C***		OF THE CASE (DEGREE F)	00004880
4890	C***	CTH	COSINE OF THE ANGLE BETWEEN THE G FIELD AND THE RAILS(ND)	00004890
4900	C***	CTMP	INPUT VERSION OF CTEMP (DEGREE F)	00004900
4910	C***	CT1	AN ALTERNATE ARRAY NAME FOR PROPELLANT CONSUMED(W)(SLUGS)	00004910
4920	C***	CV	SPECIFIC HEAT OF THE PROPELLANT (FT-LBS/SLUGS K)	00004920
4930	C***	CO	IGNITER PROPELLANT (SLUGS)	00004930
4940	C***	DAT	AN ALTERNATE ARRAY NAME FOR MANY VARIABLES	00004940
4950	C***	DGR	CONSTANT TO CONVERT DEGREES TO RADIAN	00004950
4960	C***	DISTB	SLUMP DISPLACEMENT OF MAN DURING LOADING THE DISPLACEMENT	00004960
4970	C***		TERM IN THE EQUATION (FT)	00004970
4980	C***	DISTZ	THE INTEGRATED PAYLOAD DISPLACEMENT ALONG THE RAILS (FT)	00004980
4990	C***		(CURRENT INTERACTION)	00004990
5000	C***	DPLMT	CONVERGENCE ERROR LIMIT ON PRESSURE WHEN PRESSURE COM-	00005000
5010	C***		PARISONS ARE BEING MADE DURING A PRESSURE COMPARISON RUN.	00005010
5020	C***		(PSI)	00005020
5030	C***	DRI (ND)	DELTA TIME STEP FOR INTEGRATION	00005030
5040	C***	DT	O RING FRICTIONAL ENERGY DISSIPATED (FT-LBS)	00005040
5050	C***	EF	O RING FRICTIONAL ENERGY RATE (FT-LBS/SEC)	00005050
5060	C***	EFDOT	PAYLOAD MASS (SLUGS)	00005060
5070	C***	EJM	PAYLOAD WEIGHT (LBS)	00005070
5080	C***	EJW	KINETIC ENERGY OF PAYLOAD (FT-LBS)	00005080
5090	C***	EK	HEAT ENERGY LOST OVERBOARD (FT-LBS)	00005090
5100	C***	EL	HEAT ENERGY LOSS RATE (FT-LBS/SEC)	00005100
5110	C***	ELDGT	POTENTIAL ENERGY (FT-LBS)	00005110
5120	C***	EP	POTENTIAL ENERGY RATE (FT-LBS/SEC)	00005120
5130	C***	EPDOT	PRINTOUT VARIABLE NAME FOR EF	00005130
5140	C***	FE	VOLUME RATE THAT CURRENT PROPELLANT CONSUMPTION RATE	00005140
5150	C***	FILDOT	COULD SUPPORT AT THE CURRENT PRESSURE (IN**3/SEC)	00005150
5160	C***		SLIDER BLOCK FRICTION LOAD (LBS)	00005160
5170	C***	FRF	ROLLER TO RAIL LOAD (LBS)	00005170
5180	C***	FRLR	ACCZ/32.174	00005180
5190	C***	G	PRINTOUT VARIABLE NAME FOR EL	00005190
5200	C***	GEEZ	HORSEPOWER OUTPUT OF CATAPULT	00005200
5210	C***	HE	HEIGHT OR DISTANCE TRAVELLED THROUGH THE G FIELD	00005210
5220	C***	HP	INTEGER INDEX USED SEVERAL PLACES	00005220
5230	C***	HT	INTEGER FLAG INDICATING TEMPERATURE CONDITION.	00005230
5240	C***	I	1=COLD 2=ROOM 3=HOT	00005240
5250	C***	ICOND	INTEGER FLAG THAT DUMPS ALL VARIABLES FROM CADS EACH TIME	00005250
5260	C***		THRU TO AID IN DIAGNOSIS FOR DEBUGGING PURPOSES	00005260
5270	C***	IDIAG	FLAG INDICATING THE FIRST TIME THRU THE CODE. ONLY ONCE	00005270
5280	C***		PER CASE	00005280
5290	C***	IFIRST	FLAG TO REQUEST PLOTTING 0=NO PLOTTING REQUIRED	00005290
5300	C***		INTEGRATION ITERATION COUNTER: 1-4	00005300
5310	C***	IFPLT	FLAG SELECTING OUTPUT VS NO OUTPUT	00005310
5320	C***	INT	FLAG INDICATING THAT THE PROPELLANT HAS APPARENTLY SNUFF-	00005320
5330	C***	IPRT	OUT. (CODE MAY NOT BE CORRECT)	00005330
5340	C***	ISNUFF	PROGRAM STOP QUE ISTOPQ=0 CONTIN	00005340
5350	C***		PROPORTIONALITY CONSTANT BETWEEN C	00005350
5360	C***	ISTOPQ	1=STOPQ=1 END	00005360
5370	C***	K1	MULTIPLY PRESSURE AND	00005370

5370	C***	K2	INTERNAL FRICTION FORCE (LBS/PSI)	00005370
5380	C***		PROPORTIONALITY CONSTANT BETWEEN FORCE ON SLIDER BLOCK	00005380
5390	C***		AND FRICTION IN RAILS. (ND)	00005390
5400	C***	K3	PROPORTIONALITY CONSTANT BETWEEN: (SPACE AVERAGE GAS	00005400
5410	C***		TEMPERATURE (TEMP)-CATAPULT CONDITION TEMPERATURE(CTEMP)	00005410
5420	C***		AS WELL AS THERMAL BOUNDARY AREA (FT LBS/IN**2-K)	00005420
5430	C***	K4	NO LONGER USED	00005430
5440	C***	K41	NO LONGER USED	00005440
5450	C***	MODE	INTEGER FLAG INDICATING WHETHER OR NOT THIS CASE IS	00005450
5460	C***		DEVELOPING A PROPELLANT CONSUMPTION CURVE BY EVALUATING	00005460
5470	C***		A PRESSURE CURVE, OR IT'S RUNNING FROM A PREVIOUSLY	00005470
5480	C***		DEVELOPED CONSUMPTION CURVE. 0-RUNNING NON 0-DEVELOPING	00005480
5490	C***	MODEL	INTEGER SERVING AS A SUBSCRIPT TO THE DAT ARRAY TO SELECT	00005490
5500	C***		GIVEN DATA FROM THE TESTDAT BLOCK.	00005500
5510	C***	NCASE	AN INTEGER CASE COUNTER FOR MULTICASE RUNS	00005510
5520	C***	NOUT	NUMBER OF OUTPUT VARIABLES	00005520
5530	C***	NPRT	PRINT EACH NPRT-TH TIME. (PRINTING INTERVAL)	00005530
5540	C***	NPT	NUMBER OF POINTS IN THE OUTPUT ARRAYS TO BE PLOTTED	00005540
5550	C***	NPTS	NUMBER OF POINTS ON THE CURVE TO BE INTERPOLATED	00005550
5560	C***	NPTW	NUMBER OF VALUES OF PROPELLANT CURVE SLOPES USED IN	00005560
5570	C***		COMPUTATION OF AVERAGE SLOPE	00005570
5580	C***	NV	NUMBER OF VARIABLES INTEGRATED	00005580
5590	C***	OMEGA	NATURAL FREQUENCY OF MAN USED IN DRI INJURY MODEL	00005590
5600	C***	OMGASQ	OMEGA SQUARED	00005600
5610	C***	OUT	THE OUTPUT ARRAY NAME	00005610
5620	C***	OUTMAX	ARRAY NAMES FOR THE MAXIMUM AND MINIMUM VALUES OF THE	00005620
5630	C***		OUTPUT	00005630
5640	C***	OUTMIN	SEE LINE ABOVE	00005640
5650	C***	P	ARRAY NAME FOR PRESSURES IN TEST DATA/TESTDAT/	00005650
5660	C***	PA	PISTON AREA (IN*IN)	00005660
5670	C***	PBR	PROPELLANT LINEAR BURN RATE (IN/SEC)	00005670
5680	C***	PC	PISTON CIRCUMFERENCE (IN)	00005680
5690	C***	PDC	PISTON DIAMETER (IN)	00005690
5700	C***	PDISTZ	INTEGRATED DISPLACEMENT OF PAYLOAD (PREVIOUS INTEGRATION)	00005700
5710	C***		(FT)	00005710
5720	C***	PDOT	NO LONGER USED	00005720
5730	C***	PE	OUTPUT VARIABLE NAME FOR POTENTIAL ENERGY EP	00005730
5740	C***	PIE	3.14159	00005740
5750	C***	PL	ALTERNATE ARRAY NAME FOR PROPELLANT WEB BURNED	00005750
5760	C***	PLOCK	CATAPULT UNLOCK PRESSURE (PSI)	00005760
5770	C***	PP	CATAPULT PRESSURE (PREVIOUS ITERATION) (PSI)	00005770
5780	C***	PRESS	CATAPULT PRESSURE (CURRENT ITERATION) (PSI)	00005780
5790	C***	PR1	ALTERNATE ARRAY NAME FOR PBR	00005790
5800	C***	PS1	ALTERNATE ARRAY NAME FOR PRESS	00005800
5810	C***	PSUM	INTEGRATION ARRAY NAME FOR THE ALL PREVIOUSLY INTEGRATED	00005810
5820	C***		VALUES OF THE INTEGRATED VARIABLE	00005820
5830	C***	PW	PROPELLANT CONSUMED (SLUGS) PREVIOUS ITERATION....	00005830
5840	C***	PXP	BURN RATE EXPONENT ON PRESSURE	00005840
5850	C***	RATE	ARRAY NAME FOR ALL INTEGRATABLES	00005850
5860	C***	RPLRT	REPLACEMENT RATIO FILDOT/VOLDOT	00005860
5870	C***	RFE	RAIL FRICTION ENERGY (FT-LBS)	00005870
5880	C***	RHO	DAMPING COEFFICIENT IN DRI INJURY MODEL (ND)	00005880
5890	C***	RHOP	DENSITY OF PROPELLANT (SLUGS/IN**3)	00005890
5900	C***	RK	AN ARBITRARY MULTIPLIER ON THE CONVERGENCE STEP SIZE IN	00005900
5910	C***	RK1	ALTERNATE ARRAY NAME FOR BURN RATE PRESSURE COEFFICIENT	00005910
5920	C***	RLRD	DISTANCE BETWEEN ROLLERS/SLIDER BLOCKS (FT)	00005920
5930	C***	RM	GAS CONSTANT (144. * FT-LBS/SLUG-K)	00005930
5940	C***	RMOM	MOMENT GENERATED BY ROLLER/SLIDER BLOCKS (FT-LBS)	00005940
5950	C***	ROZMGA	2. *RHO*OMEGA	00005950
5960	C***	RPLRT	ALTERNATE VARIABLE NAME FOR REPLRT	00005960
5970	C***	RTEMP	NO LONGER USED	00005970
5980	C***	SAVE	AN ARRAY USED BY THE INTEGRATOR	00005980
5985	C***	STRDT	DX/DT OF CATAPULT. THE SAME AS VELZ.	00005985
5990	C***	STRFL	FLAG NOTING THE OCCURRENCE OF CATAPULT STRIPOFF	00005990

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6000 C*** STRIPT TIME AT STRIPOFF (SECONDS)
6010 C*** STROKE CATAPULT PISTON TRAVEL (IN)
6020 C*** SUM AN ARRAY USED BY THE INTEGER
6030 C*** TOWDWB SUMMATION OF SLOPES OF PROPELLANT CONSUMPTION CURVE. (FOR
6040 C*** TEST AVERAGE SLOPE COMPUTATION)
6050 C*** DYNAMIC TEST NO: 1(171),2(183),3(180)
6052 C*** TEST=0 : G LEVEL IS CONSTANT
6055 C*** ITEST INTEGER FORM OF TEST
6060 C*** TFLAME ADIABATIC FLAME TEMPERATURE (K)
6070 C*** THA EXPOSED AREA TO CATAPULT CASES (IN**2)
6080 C*** STROFF LENGTH OF STROKE AT CATAPULT STRIPOFF (IN)
6090 C*** THETA ANGLE OF RAILS IN G FIELD (DEG)
6100 C*** TIG PROPELLANT IGNITION TEMPERATURE (K)
6110 C*** TIGN INPUT VERSION OF TIG (F)
6120 C*** TIME CURRENT TIME (SECS)
6130 C*** TIMEP ARRAY NAME FOR TIME: PRESSURE TIME CURVE OF TEST DATA (S)
6140 C*** TLF G FIELD LOAD FACTOR COMPONENT PARALLEL TO RAILS
6150 C*** TLO INITIAL VOLUME/PISTON AREA (IN)
6160 C*** VELB MAN DEFLECTION VELOCITY IN DRI MODEL (FT/SEC)
6170 C*** VELBB SAME AS VELB
6180 C*** VELC CATAPULT VELOCITY (FT/SEC) OUTPUT NAME
6190 C*** VELZ WORKING VERSION OF VELC
6200 C*** VELZZ SAME AS VELZ
6210 C*** VOL CURRENT CATAPULT VOLUME (IN**3)
6220 C*** VOLDOT RATE OF INCREASE OF VOL (IN**3/SEC)
6230 C*** VO
6240 C*** W PROPELLANT CONSUMED (SLUGS)
6250 C*** WB PROPELLANT WEB CONSUMED (IN)
6260 C*** WBG ALTERNATE ARRAY NAME FOR WB
6270 C*** WDOT PROPELLANT CONSUMPTION RATE (SLUGS/SEC)
6280 C*** WDW NOT USED
6290 C*** WG ALTERNATE ARRAY NAME FOR W
6300 C*** WK WORK DONE BY CATAPULT (FT-LBS)
6310 C*** WKDOT RATE OF DOING WORK BY CATAPULT (FT-LBS/SEC)
6320 C*** ZLF G FIELD LOAD FACTOR
6400
6500 C*****
6600
6700
6800
6900
7000 1 NCASE = 0
7100 IPRT = 0
7200 READ (5,NEVSET)
7300 IF (ISTOPQ.EQ.1) GO TO 6
7400
7500 C INITIALIZE.....
7600
7700 IF (MODE.EQ.0)
7800 NCASE = NCASE + 1
7900 TIME = 0.0
8000 NV = 8
8100 INT = 0
8200 NPT = 1
8300 DO 3 I=1,40
8400 SUM(I) = 0.0
8500 DGR = 0.017453292
8600 CASE = NCASE
8700 CTEMP = (CTMP-32.)*.55555 + 273.0
8800 TIG = (TIGN-32.)*.55555+273.
8900 PP = 0.0
9000 VOL = VO
9100 DRI = 0.0
9200 WB = 0.000001
9300 W = 0.000001
9400 RA = 0.0
9500
9600
9700
9800
9900
1000
1010
1020
1030
1040
1050
1060
1070
1080
1090
1100
1110
1120
1130
1140
1150
1160
1170

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11800
11900
12000
12100
12200
12300
12400
12500
12600
12700
12800
12900
13000
13010
13015
13020
13030
13040
13050
13055
13060
13070
13090
13100
13200
13300
13400
13500
13600
13700
13800
13900
14000
14100
14200
14300
14400
14500
14600
14700
14800
14900
15000
15100
15200
15300
15400
15500
15600
15700
15800
15900
16000
16100
16200
16300
16400
16500
16600
16700
16800
16900
17000
17100

PW = 0.0
PRESS = 14.7
G = 32.174
R02MGA = RH0*2.0*OMEGA
OMGASQ = OMEGA*OMEGA
DO 20 I=1, NOUT
OUTMAX(I) = -1.0E50
OUTMIN(I) = 1.0E50
EJM = EJM/G
STROKE = 0.0
STRIPT = 0.0
STRFL = 0.0
CTH = COS (THETA*DGR)

20
C
ITEST = TEST
IF (TEST.NE.0.0) ZLF = GDT(ITEST,1)
WRITE(6,16) TEST,ITEST,ZLF
16 FORMAT(1H0,10X,"TEST = ",F10.4,5X,"ITEST = ",14,5X,"ZLF = ",
F10.5)
IF (ITEST.EQ.0.0) GO TO 18
WRITE(6,17) (GDT(ITEST,J),J=1,220)
17 FORMAT(1H0,10X,"***** G DATA *****",/,22(10F6.1/))
C
18 CLF = ZLF*CTH
CASE = NCASE
PIE = 3.14159
TLO = VO/PA
FRF = 0.0
PDC = SQRT ((4.0/PIE)*PA)
PC = PIE*PDC
THA = PC*TLO + 2.0*PA
GEEZ = 0.0
EK = 0.0
EP = 0.0
AFACT = 4.0/RHOP/PIE
WRK = 0.0
WRKDOT = 0.0
HP = 0.0
TEMP = CTEMP
VELC = 0.0
BRP = 0.0
BW = 0.0
FE = 0.0
HE = 0.0
ISNUFF = 0
IFIRST = 0
NPTW = 0
TDWDWB = 0.000001
RFE = 0.0
PDISTZ = 0.0
TLF = CLF
RTEMP = TFLAME - TIG
BBB = B

C
WRITE (6,13) NCASE,
DT,CO,A1,A2,A3,C,PA,EJM,STROFF,VO,B,PXP,RM,K1,K3,
RHOP,RHO,OMEGA,THETA,ZLF,TFLAME,CV,PLOCK,CTMP,CGD,
RLRD,K2,DPLMT,TIGN,
NPRT,MODE,NOUT,IFPLT,MODEL,ICOND
13 FORMAT (1H1,"INPUT DATA, CASE ",14,/,
" DT,CO,A1,A2,A3,C",/," PA,EJM,STROFF,VO,B,PXP",/," RM,K1,
" K3,RHOP,RHO,OMEGA",/," THETA,ZLF,TFLAME,CV,PLOCK,CTMP",/
" CGD,RLRD,K2,DPLMT,TIGN",/

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17200      " NPRT,MODE,NOUT,(FPLT,MODEL,COND)//,4(6F14.6/),
17300      5F14.6,/618//)
17400
17500      IF (IFPLT.NE.O) WRITE (6,12) NPT,OUT,NCASE
17600      RK1(NPT) = 0.0
17700      PL (NPT) = 0.0
17800      CT1(NPT) = 0.0
17900      NPT = NPT + 1
18000
18100      IF (IFPRT.EQ.O) GO TO 4
18200
18300      WRITE (6,14)
18400      FORMAT (1H0," OUTPUT",//,8X,"TIME",66X,"CASE"/9X,"GZ"/12X,"VZ",10X,
18500      "STROKE"/10X,"HT",11X,"VOL",12X,"DRI"/8X,"PBR",12X,"WB",12X,"BA",
18600      "13X,"W",11X,"TEMP"/10X,"PRESS"/9X,"EK",12X,"EP",12X,"EF",12X,"EL",
18700      "11X,"FORCE",9X,"TAREA"/8X,"FRF",12X,"RK",10X,"RPLRT",10X,"TLF",
18800      "11X,"RFE",12X,"BB"/7X,"WDOT",11X,"WRK",12X,"HP",//)
18900
19000      WRITE (6,12) (OUT(I),I=1,NOUT)
19100
19200      4 CALL INTGRT (TIME,DT,SUM,PSUM,RATE,SAVE,NV,INT)
19300
19400      CALL CAD (TIME,CADF,PRESS,PBR,WB,W,STRFL,STROKE,TEMP,TFLAME,CV,
19500      B,PXP,C,CO,A1,A2,A3,RM,VO,PA,K1,K3,PLOCK,STROFF,EJM,
19600      VELZ,HT,CLF,VOL,THA,ELDOT,WKDOT,WK,EL,MODE,INT,STRIPT,
19700      EFDOT,EF,CTEMP,IDIAG,DPLMT,RK,ISNUFF,MODEL,BB,DT,COND,
19800      EPDOT,EP,EKDOT,EK,ACCZ)
19900
20000      WRITE(6,53)
20100      53 FORMAT("OUT OF CAD INTO THE MAIN PROGRAM")
20200      PBACC = K4*((TIG-CTEMP)*(FDDOT*VOL+VOLDOT*PRESS-RM*WDOT*TEMP))/
20300      (RHOP*TEMP*TEMP*RM*W)*(-1.0)
20400
20500      COMPUTE DISTANCE TRAVELLED THROUGH THE G FIELD AND CATAPULT STROKE...
20600      HT = DISTZ*CTH
20700      STROKE = DISTZ*12.0
20800
20900      COMPUTE FRICTION FORCE IN RAILS.....
21000
21100      ITEST = TEST
21200      ITIME = TIME * 1000.
21300      IF(ITIME.EQ.O) ITIME = 1
21400      IF(ITEST.NE.O.O) ZLF = GDT(ITEST,ITIME)
21500
21600      CLF = ZLF*CTH
21700      TLF = CLF + ACCZ/G
21800      RMOM1 = EJM*TLF*CGD
21900      FRLR = RMOM/RLRD
22000      FRF = K2*FRLR*2.0
22100      FRF = K2*EJM
22200
22300      SUM THE EXTERNAL FORCES ON THE EJECTED MASS.....
22400
22500      FPF = PA*PRESS*K1
22600      ACCZ = (CADF-FRF-FPF)/EJM - CLF*G
22700      ACCZ = CLF * G
22800
22900      COMPUTE THERMAL AREA.....
23000
23100      THA = PC*(TLO + STROKE) + 2.0*PA
23200
23300      DON'T LET THE EJECTED MASS FALL.....
23400

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22300 C
22400 C IF (ZLF*G*CTH.GT.CADF/EJM.AND.DISTZ .LE.O.O) GO TO 8
22410 IF (ACCB.LT.O.O) ACCZ = O.O
22500 C
22600 C SPINE DEFLECTION ACCELERATION.....
22700 C
22800 C ACCB = ACCZ - RM2MGA*VELB - OMGASQ*DISTB
22900 GEEB = ACCB/G
23000 C
23100 C GO TO 9
23200 C
23300 C 8 CONTINUE
23400 VELZ = O.O
23500 DISTZ = O.O
23510 ACCZ = O.O
23600 C
23700 C CALCULATE NEW RATES FOR INTEGRATION.....
23800 C
23900 C 9 VELBB = VELB
24000 VELZZ = VELZ
24100 IF (IFIRST.EQ.1.OR.ISNUFF.EQ.O) GO TO 400
24200 WRITE (6,401)
24300 FORMAT (85X," SNUFFED OUT ????"")
24400 IFIRST = 1
24500 CONTINUE
24600 C
24700 C GO TO (4,4,4,10), INT
24800 C
24900 C 10 DRI = OMGASQ*DISTB/G
25000 GEEZ = ACCZ/G
25100 VELC = VELZ
25200 BRP = PBR
25300 BW = WB
25400 FE = EF
25500 HE = EL
25600 HP = WKDOT/550.
25700 WKDOT = WKDOT
25800 WRK = WK
26000 C
26100 C COMPUTE FRICTIONAL ENERGY LOST IN RAIL FRICTION.....
26200 C
26300 C RFE = RFE + FRF*(DISTZ - PDISTZ)
26400 PDISTZ = DISTZ
26500 ORK = K41
26600 WKDOT = (W-PW)/DT
26700 IF (MODE.NE.O.O) GO TO 607
26800 PW = W
26900 IF (WKDOT.LT.O.O) WRITE (6,605)
27000 FORMAT (1H," WKDOT.LT.O.O")
27100 IF (PBR.GT.O.O) BA = WKDOT/PBR/RHOP
27200 IF (BA.LT.O.O) BA = O.O
27300 IF (BA.GT.O.O) WKDOT = WKDOT/BA/RHOP
27400 VOLDOT = PA*VELZ*12.O
27500 IF (VOLDOT.EQ.O.O) VOLDOT = O.O0001
27600 FILDOT = O.O
27700 IF (PRESS.GT.O.O) FILDOT = RM*TEMP/PRESS*BA*RHOP*PBR
27800 REPLAT = FILDOT/VOLDOT
27900 RPLRT = REPLAT
28000 PDOT = (PRESS - PP)/DT
28100 PP = PRESS
28200 IF (TIME.LT.O.1.OR.ICOND.NE.2) GO TO 607
28300 IF (PBR.GT.O.O) TDWDWB = TDWDWB + WKDOT/PBR
28400 NPTW = NPTW + 1
28500 CONTINUE
28600 C 607

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28700 C COMPUTE K41.....
28800 C
28900 C K41 = PBR*RHOP*CV*DTEMP/RTMP
29000 C
29100 C IPRT = IPRT + 1
29200 C IF (IPRT.EQ.NPRT) GO TO 11
29300 C GO TO 4
29400 C
29500 C 11 IF (IPRT.EQ.0) GO TO 44
29600 C IF (STROKE.GT.STROFF)
29700 C WRITE (6,1000)
29800 C
29900 C 1000 FORMAT (1H0,6X,6("STRIP OFF " ))
30000 C WRITE (6,12) (OUT(I), I=1, NOUT)
30100 C
30200 C 12 FORMAT (1H0/, F14.6, 56X, F14.6/(6F14.6))
30300 C 44 CONTINUE
30400 C DO 21 I=1, NOUT
30500 C OUTMAX(I) = AMAX1 (OUT(I), OUTMAX(I))
30600 C OUTMIN(I) = AMIN1 (OUT(I), OUTMIN(I))
30700 C IF (IFPLT.NE.0) WRITE (6,12) NPT, OUT, NCASE
30800 C IPRT = 0
30900 C CTCC(NPT) = TIME
31000 C PL(NPT) = WB
31100 C CT1(NPT) = W
31200 C PSI(NPT) = PRESS
31300 C PR1(NPT) = PBR
31400 C RK1(NPT) = BB
31500 C GLF(NPT) = ZLF
31600 C GACC2(NPT)=GEEZ
31700 C DISP(NPT)=STROKE
31800 C
31900 C IF (STRFL.EQ.1.0) GO TO 7
32000 C NPT = NPT + 1
32100 C GO TO 4
32200 C
32300 C 7 CONTINUE
32400 C IF (IFPLT.NE.0) WRITE (11) NOUT, NCASE, NPT, OUTMAX, OUTMIN
32500 C IF (MODE.EQ.0) GO TO 602
32600 C ADWDWB = TDWDWB/(FLOAT(NPTW)+0.000001)
32700 C IF (ICOND.NE.2) GO TO 701
32800 C PL(NPT+1) = (C-W)/ADI/DWB + WB
32900 C CT1(NPT+1) = C
33000 C CONTINUE
33100 C RK1(NPT+1) = BB
33200 C PSI(NPT+1) = PRESS
33300 C PR1(NPT+1) = PBR
33400 C NPTS = NPT + 1
33500 C IF (MODE.NE.0.AND.(COND.EQ.2)) GO TO 707
33600 C GO TO 700
33700 C
33800 C 707 DO 909 I=1,NPTS
33900 C IF (CT1(I).LE.0.0) CT1(I) = 0.0
34000 C WBG(I) = PL(I)
34100 C WGI(I) = CT1(I)
34200 C
34300 C 909 CONTINUE
34400 C IF (NCASE.EQ.0) GO TO 600
34500 C
34600 C C**= WRITE PRESSURE, ACCELERATION, AND DISPLACEMENT DATA TO DISK FILE
34700 C
34800 C WRITE(7,150) (PSI(I), I=1,NPTS)
34900 C WRITE(8,150) (GACC2(I), I=1,NPTS)
35000 C WRITE(9,150) (DISP(I), I=1,NPTS)
35100 C WRITE(10,150) (PL(I), I=1,NPTS)
35200 C

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34054 WRITE(1,150) (CT1(I)*32.174, I=1,NPTS)
34060 FORMAT(6F10.4)
C
600 WRITE (6,601) (CTCC(I),CT1(I),PL(I),RK1(I),PSI(I),PR1(I),GLF(I),
34100 I=1,NPTS)
601 FORMAT(1H0/////" WEB BURNED VS PROPELLANT CONSUMED...."//7X"TIME"
34200 7X,"PROPELLANT",8X,"WEB",13X,"B",12X,"PRESS",9X,"PBR",
34300 9X,"GFIELD",//,(7F14.7))
C
C
602 CONTINUE
B = BBB
GO TO 1
6 WRITE (6,15)
15 FORMAT (2(1H0,/),60X,"END OF JOB")
STOP "END OF JOB"
END
SUBROUTINE CAD (TIME,CADF,PRESS,PBR,WB,W,STRFL,STROKE,TEMP,
TFLAME,CV,B,PXP,C,CO,A1,A2,A3,RM,VO,PA,K1,K3,
PLOCK,STROFF,EJM,STRKDT,HT,CLF,VOL,THA,ELDOT,
WKDOT,WK,EL,MODE,INT,STRIPT,EFDOT,EF,CTEMP,IDIAG,
DPLMT,RK,ISNUFF,MODEL,BB,DT,ICOND,
EPDOT,EP,EKDOT,EK,ACCZ)
C
C SUBROUTINE FOR COMPUTING PERFORMANCE OF A CLOSED TELESCOPING TUBE,
C ACTING AGAINST A LOAD IN ANY G ENVIRONMENT AND USING A BURNING
C PROPELLANT AS A SOURCE OF ENERGY.....
C
COMMON /CATDAT/ PL(250), WBG(250), W0(250), CTCC(250), CT1(250),
RK1(250),PR1(250),NPTS,PSI(250)
C
REAL K1,K3
C
C HAS CATAPULT REACHED STROFF.....
C
IF (STROKE - STROFF) 1,1,10
C
C COMPUTE PROPELLANT CONSUMED.....
C
1 IF (MODE.NE.0)
.W = W + 0.000001
C
IF (MODE.EQ.0)
.W = FINTRP (WB,WG,WBG,NPTS)
C
C HAS ALL THE PROPELLANT BURNED.....
C
IF (W -C) 3,3,2
C
AAAAALLLLL BURRRRRRRRRNNNNNNNNNNEDDD.....
C
2 W = C
C
C COMPUTE INTERNAL VOLUME.....
C
3 VOL = VO + PA*STROKE
C
C DONT LET VOLUME DECREASE BELOW INITIAL VALUE.....
C
IF (VOL) 4,4,5
C
4 VOL = VO
C
41300

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41400 C COMPUTE THE ENERGY TERMS.....
41500 C
41600 IF (INT.EQ.1) PW = W
41700 IC = 0
41800 5 CONTINUE
41900 C
42000 C WORK PORTION.....(WK).....COMING FROM INTEGRATOR.....
42100 C
42200 C FRICTIONAL ENERGY PORTION....EF..... COMING FROM INTEGRATOR ROUTINE..
42300 C
42400 C HEAT ENERGY LOST PORTION.....EL.....COMING FROM INTEGRATOR ROUTINE...
42410 C
42420 C POTENTIAL ENERGY PORTION.....EP.....COMING FROM INTEGRATOR ROUTINE...
42430 C
42440 C KINETIC ENERGY PORTION.....EK.....COMING FROM INTEGRATOR ROUTINE....
42500 C
42600 C COMPUTE SPACE AVERAGE GAS TEMP
42700 C
42800 TEMP = TFLAME - (WK + EL)/(W*CV)
42900 C
43000 C COMPUTE CHAMBER PRESSURE USING EQUATION OF STATE.....
43100 C
43200 PRESS = RM*TEMP*W/VOL
43300 C
43400 C IF WE ARE TRYING TO FIT TEST DATA, CALL FITTER.....
43500 C
43600 C WRITE(6,13) INT, PRESS
43610 C 13 FORMAT(10X,"INT=",13,3X,"PRESSURE=",F12.5)
43700 IF (INT.NE.4) GO TO 50
43800 IF (MODE.EQ.0) GO TO 50
43900 IF (ICOND.EQ.2) GO TO 60
44000 C
44100 CALL FITTER (TIME,PRESS,W,IC,ICOND,DPLMT,RK,MODEL,&10,&5,&40)
44200 C
44300 C 40 IF (INT.NE.4) GO TO 50
44400 C
44500 C
44600 W=W-CO
44700 WB = FINTRP (W,WBG,WG,NPTS)
44800 BB = ((WB-PWB)/DT)/ABS(PRESS)**PXP
44900 B = BB
45000 PWB = WB
45100 GO TO 50
45200 C
45300 60 CONTINUE
45310 C WRITE(6,14)
45320 C 14 FORMAT(3X,"*****GOING INTO FITTER*****")
45400 CALL FITTER (TIME,PRESS,W,IC,ICOND,DPLMT,RK,MODEL,&10,&5,&50)
45500 C
45600 50 CONTINUE
45610 C WRITE(6,15)
45620 C 15 FORMAT("PRESSURE FIT HAS BEEN MADE")
45700 C
45800 C COMPUTE INTERNAL FRICTIONAL ENERGY RATE.....(POWER).....
45900 C
46000 EFDOT = ABS(K1*PRESS*STRKDT)
46100 C
46200 C COMPUTE HEAT LOSS RATE.....
46300 C
46400 ELDOT = ABS (K3*(TEMP - CTEMP)*THA)
46500 C
46600 C COMPUTE WORK RATE.....
46700 C
46800 WKDOT = ABS (CADF * STRKDT)
46900 C
47000 C

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46900 C
46910 C COMPUTE POTENTIAL ENERGY RATE.....
46920 C
46930 C EPDOT = EJM*STRKDT*CLF*32.2
46940 C
46950 C COMPUTE POTENTIAL ENERGY RATE.....
46960 C
46970 C EKDOT = EJM*0.5*ACCZ**2.0
46980 C
46990 C PBR = 0.0
47000 C IF (W -C) 6,7,7
47100 C
47200 C 6 PBR = B*ABS(PRESS)**PXP
47300 C IF (INT.EQ.4 .AND. PW.EQ.W) PBR = 0.0
47400 C IF (PBR.GE.0.0) GO TO 20
47500 C PBR = 0.0
47600 C JSNUFF = 1
47700 C 20 CONTINUE
47800 C
47900 C C HAS PRESSURE UNLOCKED PISTON YET.....
48000 C
48100 C 7 IF (PRESS-PLOCK) 8,9,9
48200 C
48300 C C STILL LOCKED.....CATAPULT FORCE IS ZERO.....
48400 C
48500 C 8 CADF = 0.0
48600 C GO TO 11
48700 C
48800 C C UNLOCKED....HIT 'EM UP AND MOVE 'EM OUT.....
48900 C
49000 C 9 CADF = PA*PRESS
49100 C STRPL = 0.0
49200 C GO TO 11
49300 C
49400 C C STRIPOFF HAS OCCURRED.....MARK THE EVENT.....
49500 C
49600 C 10 STRFL = 1.0
49700 C STRIPT = TIME
49800 C PRESS = 0.0
49900 C PBR = 0.0
50000 C CADF = 0.0
50100 C IF (IDIAG.NE.0)
50200 C .WRITE (6,12)
50300 C TIME,CADF,PRESS,PBR,WB,W,STRFL,STROKE,TEMP,
50400 C TFLAME,CV,B,PXP,C,A0,A1,A2,A3,RM,VO,PA,K1,K3,
50500 C PLOCK,STROFF,EJM,STRKDT,HT,CLF,VOL,THA,
50600 C EK,EP,EL,MODE,INT,STRIPT,EFDOT,EF,CTEMP
50700 C 12 FORMAT (1H0,(5F14.7))
50800 C RETURN
50900 C END
51000 C SUBROUTINE FITTER (TIME,PRESS,W,IC,ICOND,DPLMT,RK,MODEL,*,*,*)
51100 C
51200 C COMMON /TESTDT/ PP(30,3,3),T(30,3,3),DAT(25,3)
51300 C
51400 C IF (IC.EQ.0)
51500 C .P = FINTRP (TIME,PP(1,ICOND,MODEL),T(1,ICOND,MODEL),30)
51600 C IF (TIME.GT.T(3,ICOND,MODEL).AND.P.EQ.0.0) GO TO 10
51700 C
51710 C STATEMENT 10: STRIPOFF HAS OCCURRED
51720 C
51730 C DP = P - PRESS
51800 C IF (P.GT.0.0) PRATIO = DP/P
51900 C IF (ABS(PRATIO).GT.1.0.AND.PRESS.GT.0) PRATIO = DP/PRESS
52000 C IF (P.LE.0.0.AND.PRESS.LT.0.0) PRATIO = 0.0
52100 C

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52200 C
52220 C
52230 C 5
52240 C
52300 C
52400 C
52500 C
52510 C
52520 C 6
52600 C
52700 C
52800 C
52900 C
53000 C
53100 C
53200 C
53300 C
53400 C
53500 C
53600 C
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56800 C
56900 C
57000 C
57100 C
57200 C
57300 C
57310 C
57320 C 10
57400 C
57500 C
57600 C
57700 C
57800 C

WRITE(6,5) DP,DPLMT,P,PRESS
FORMAT(5X,"DP=",F12.5,3X,"DPLMT=",F12.5,3X,"P=",F12.5,3X,
"PRESS=",F12.5)
IF (DP) 30,50,30
IF (ABS (DP)) LE.DPLMT) GO TO 50
W = W + RK*PRATIO*W
WRITE(6,6) W
FORMAT(5X,"W=",F12.5)
IF (TIME GE. 0.155 .AND. TIME LE. 0.157)
WRITE (6,100) TIME,PRESS,P,DP,PRATIO,W,RK,IC
IF (IC GT.100)
WRITE (6,100) TIME,PRESS,P,DP,PRATIO,W,RK,IC
FORMAT (7F14.7,110)
IF (P.EQ.0.0) GO TO 50
IC = IC + 1
RETURN 2
IF (IC GT.300) STOP "IC STOP"
RETURN 3
IC = 0
RETURN 1
END
SUBROUTINE INTGRT (TIME,DELTIM,STATE,PSTATE,RATE,SAVE,NV,INT)
DIMENSION RATE(NV),STATE(NV),PSTATE(NV),SAVE(NV)
DATA HALF/.5/
IF (INT.EQ.4) INT = 0
INT=INT+1
IF (INT.LT.1.OR.INT.GT.4) GO TO 80
DO 50 I=1,NV
DELTARATE(I)=DELTIM
GO TO(10,20,30,40),INT
10 SAVE(I) = DELTA
DELTARATE(I)=DELTARATE(I)*HALF
PSTATE(I) = STATE(I)
GO TO 50
20 SAVE(I) = (DELTARATE(I) + SAVE(I)
DELTARATE(I)=DELTARATE(I)*HALF
GO TO 50
30 SAVE(I) = (DELTARATE(I) + SAVE(I)
GO TO 50
40 DELTA = (SAVE(I) + DELTA)/6.
50 STATE(I) = PSTATE(I) + DELTA
GO TO(60,70,80,70),INT
60 TIME=TIME+(DELTIM*HALF)
70 CONTINUE
80 WRITE (6,90)
90 FORMAT (1H0,128HILLEGAL VALUE FOR INTEGRATION COUNTER, IT MUST BE
INITIALIZED TO A VALUE OF 0 AT THE BEGINNING OF EACH NEW INTEGRATI
ON CASE.....)
STOP
END
FUNCTION FINTRP (ARG,ORD,ABSC,NPTS)
DIMENSION ABSC(NPTS),ORD(NPTS)
CALL RATIO (NPTS,ARG,ABSC,RATX,I)
FINTRP = ORD(I) - RATX * (ORD(I) - ORD(I-1))
WRITE(6,10) FINTRP
C 10 FORMAT(1H0,"FINTRP =",F12.5)
RETURN
END
SUBROUTINE RATIO (NV,GV,TV,RAT,NC)
DIMENSION TV(1)

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00057900 IF (NV.EQ.1) GO TO 120
00058000 IF (GV - TV(1)) 120,120,150
00058100 NC = 1
00058200 RAT = 0.
00058300 GO TO 220
00058400 DO 170 NCNT=2,NV
00058500 NC = NCNT
00058600 IF (GV - TV(NC)) 200,130,170
00058700 CONTINUE
00058800 GO TO 130
00058900 RAT = (TV(NC) - GV)/(TV(NC) - TV(NC-1))
00058910 WRITE (6,5)RAT,TV(NC),GV,TV(NC-1),NC
00058920 C 5 FORMAT(1H0,"RAT=",F12.5,3X,"TV(NC)=" ,F12.5,3X,"GV=",3X,F12.5,
00058930 "TV(NC-1)=" ,3X,F12.5,"NC=" ,15)
00059000 RETURN
00059100 END
00059200 BLOCK DATA
00059300 COMMON /TESTDT/ P(30,3,3),T(30,3,3),DAT(25,3)
00059400
00059500 C DAT WORD DEF'S.... CO,A1,A2,A3,C,B,PXP,RM,RHOP,CV,TFLAME,PA,STRIPOFF,
00059600 VO,K1,K2,K3,POCK,EJW,CGD,RLRD
00059700 C
00059800 C
00059900 C PRESSURE VS TIME CURVES FOR SEVERAL EJECTION CATAPULT FIRINGS AT COLD
00060000 ROOM AND HOT TEMPERATURES .....(-65 F, 70 F, 165 F)
00060100 C
00060200 C CKU5/A.....
00060300 C
00060400 DATA (((P(I,J,K),I=1,20),J=1,3),K=1,1) /
00060500 .0.,450.,900.,1750.,2150.,2375.,3150.,3750.,4150.,4370.,4750.,4700.,
00060600 .4650.,4100.,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
00060700 .5450.,5450.,5250.,4000.,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
00060800 .0.0,0.0,225.,2250.,2800.,3750.,6000.,7500.,6850.,5990.,0.0,0.0,0.0,0.0,
00060900 .0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
00061000 .0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
00061100 DATA (((T(I,J,K),I=1,20),J=1,3),K=1,1) /
00061200 .0.0,01.,02.,03.,035.,04.,06.,08.,1.,12.,14.,16.,168.,179.,179.,
00061300 .180.,181.,182.,183.,184.,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
00061400 .171.,172.,173.,174.,175.,176.,177.,178.,179.,180.,181.,0.0,0.0,0.0,
00061500 .03.,04.,06.,10.,132.,145.,156.,156.,157.,158.,159.,160.,161.,162.,
00061600 .163.,164.,165.,166/
00061700 C
00061800 DATA ((DAT(I,J),I=1,23),J=1,1) /
00061900 .0.0002.,2.1930318,14.8387570,-47.0218638,0.00385,0.0335,0.41,
00062000 .42084.,0.0019581,17567.,3480.,0.7854,33.996,19.5,0.05,0.01,0.3,
00062100 .10.,333.96.,935,0.75,500.,0.000001/
00062200 C TALLY 2400..... PRESSURE/TIME DATA FROM TEST 183
00062300 C
00062400 DATA (((P(I,J,K),I=1,20),J=1,3),K=2,2) /
00062500 .0.0,140.,250.,355.,475.,605.,740.,880.,1015.,1120.,1200.,
00062600 .1240.,1255.,1245.,1220.,1185.,1145.,1145.,0.0,0.0,0.0,
00062700 .0.0,4.3,38.6,128.,618.8,
00062800 .876.3,1323.,1680.,1790.,1893.,1988.8,2187.9,2187.9,2119.3,
00062900 .2085.,2040.,1508.1,1295.2,581.1,0.0,
00063000 .0.0,405.,605.,
00063100 .825.,1070.,1310.,1670.,1725.,1725.,1685.,1630.,1565.,1530.,0.0,
00063200 .0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
00063300 C DATA (((T(I,J,K),I=1,20),J=1,3),K=2,2) /
00063400 .0.0,.008,02.,03.,04.,05.,06.,07.,08.,09.,10.,11.,12.,13,
00063500 .14.,15.,16.,161.,165.,17,
00063600 .0.0,001.,002.,009.,049.,064.,084.,099.,104.,109.,114.,129.,134,
00063700 .0.0,001.,002.,009.,049.,064.,084.,099.,104.,109.,114.,129.,134,

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69900
70000
70100
70200
70300
70310
70400
70500
70600
70700
70800
70900
71000
71100
71200
71300
71400
71500
71600
71700
71800
71900
72000
72100
72200
72300
72400
72500
72600
72700
72800
72900
73000
73100
73200

11.9, 11.8, 11.5, 11.3, 11.1, 10.9, 10.6, 10.2, 9.7, 9.3,
9.1, 9.2, 9.0, 8.7, 8.5, 8.3, 8.2, 7.8, 7.4, 7.1,
6.8, 6.6, 6.2, 5.8, 5.9, 7.2, 9.9, 13.0, 15.0, 15.6,
15.2, 14.3, 13.4, 12.5, 12.0, 10.2, 8.0, 5.7, 4.5, 3.9,
4.1, 4.3, 3.6, 3.5, 3.0, 2.2, 0.9, -0.4, -1.7, -2.8,
-3.2, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0/
TEST 180..... I = 3
DATA((GDT(I, J), I=3,3), J=1,220)/
8.1, 8.2, 8.1, 8.1, 8.1, 8.1, 8.1, 8.3, 8.4, 8.4,
8.4, 8.4, 8.4, 8.4, 8.4, 8.4, 8.4, 8.7, 8.7, 8.7,
8.5, 8.5, 8.6, 8.6, 8.6, 8.6, 8.6, 8.6, 8.6, 8.6,
8.9, 9.0, 9.0, 9.0, 9.0, 9.0, 9.0, 9.0, 9.0, 9.0,
9.0, 9.0, 8.9, 8.9, 8.9, 8.9, 8.9, 8.9, 8.9, 8.9,
9.2, 9.1, 9.1, 9.2, 9.2, 9.2, 9.2, 9.3, 9.3, 9.3,
9.1, 9.1, 9.1, 9.1, 9.1, 9.1, 9.1, 9.1, 9.1, 9.1,
8.6, 8.6, 8.6, 8.6, 8.6, 8.6, 8.6, 8.6, 8.6, 8.6,
8.5, 8.4, 8.4, 8.4, 8.4, 8.4, 8.4, 8.4, 8.4, 8.4,
8.3, 8.3, 8.4, 8.4, 8.3, 8.3, 8.3, 8.3, 8.3, 8.4,
8.4, 8.4, 8.5, 8.5, 8.5, 8.5, 8.5, 8.4, 8.3, 8.3,
8.5, 8.5, 8.4, 8.4, 8.4, 8.4, 8.5, 8.5, 8.6, 8.6,
8.3, 8.5, 8.4, 8.4, 8.9, 8.9, 8.9, 9.1, 9.1, 9.2,
9.3, 9.4, 9.4, 9.5, 9.5, 9.5, 9.6, 9.6, 9.6, 9.7,
9.8, 9.8, 9.9, 9.9, 9.9, 10.0, 10.0, 10.1, 10.1, 10.1,
10.2, 10.1, 10.2, 10.2, 10.2, 9.9, 8.9, 6.4, 2.8, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0/
END

00069900
00070000
00070100
00070200
00070300
00070310
00070400
00070500
00070600
00070700
00070800
00070900
00071000
00071100
00071200
00071300
00071400
00071500
00071600
00071700
00071800
00071900
00072000
00072100
00072200
00072300
00072400
00072500
00072600
00072700
00072800
00072900
00073000
00073100
00073200

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100      &NEWSET
200          C = 0.0044,
300          CO = 0.000069,
400          TEST = 2. ,
500          B = 0.0189 ,
600          PXP = 0.46 ,
700          RM = 40526.0 ,
800          RHOP = 0.0019581,
900          CV = 16082.0 ,
1000      TFLAME = 3876.0 ,
1100          PA = 4.076 ,
1200      STROFF = 32.48 ,
1300          VO = 20.28 ,
1400          K1 = 0.008 ,
1500          K2 = .356 ,
1600          K3 = 0.3 ,
1700      PLOCK = 44.82 ,
1800          EJW = 395.00 ,
1900          CGD = 0.935 ,
2000      RLRD = 0.75 ,
2100          RHO = 0.224 ,
2200          ZLF = 0.0 ,
2300      THETA = 0.0 ,
2400      DPLMT = 1.0 ,
2500      IFPRT = 1 ,
2600          DT = 0.001 ,
2700      OMEGA = 52.9 ,
2800      NPRT = 2 ,
2900      IFPLT = 0 ,
3000      MODEL = 2 ,
3100      MGDE = 2 ,
3200      TIGN = 500. ,
3300      CIMP = 70. ,
3400          K4 = 0.25 ,
3500          RK = 0.5 ,
3600      ICOND = 2 ,
3700      IDIAG = 0 ,
3800      NOUT = 29 ,
3900      ISTGPQ = 0 ,
4000          &END
4100      &NEWSET
4200          MODE = 0 ,
4300          &END
4400      &NEWSET
4500          ISTGPQ = 1 ,
4600          &END

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