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AIRBLAST CALCULATIONS FOR ADVANCED MISSILE SYSTEM (MX) SUPPORT

Charles E. Needham

Cydney Westmoreland

February 1976

Final Report

Distribution limited to US Government agencies only because test and evaluation of military systems is discussed in the report (Feb 76). Other requests for this document must be referred to AFWL (DYT), Kirtland AFB, NM, 87117.

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Air Force Systems Command

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This technical report has been reviewed and is approved for publication.

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A series of theoretical calculations of the air blast resulting from a 1 megaton (MT) detonation has been conducted. The calculations include the free air environment and propagation through a smooth tunnel with various inlet pressures. One calculation also included corrugated walls. The various results are compared.

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PREFACE

The calculations presented in this report compliment and supplement systems calculations initiated at TRW. Special appreciation is given to Mr. Allen Kuhl (TRW) for his cooperation and to Capt T. Tolman (AFWL/SA) for his guidance.

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ILLUSTRATIONS

TABLES

SECTION I

INTRODUCTION

Several questions have been raised regarding the propagation of air blast through tunnels with various input and surface conditions. A series of experiments was conducted to investigate this problem during the Pre Dice Throw 100 ton TNT event by TRW Systems. In addition TRW and the Air Force Weapons Laboratory (AFWL) have made several hydrodynamic calculations in support of the experiments and the underlying question of blast propagation in general.

The subsequent sections of this report include a summary of the AFWL calculations.

SECTION II

SMOOTH TUNNEL PROPAGATION

Four calculations have been completed for a smooth walled tunnel. In each case the input boundary conditions at the tunnel entrance were taken from the AFWL 1 KT Standard (ref. 1) scaled to 1 MT. The calculations were carried to a distance of 3.2 km, which corresponds to a free air overpressure of less than 10 psi. The inlet peak overpressure levels were 10^5, 10^4, 600, and 100 psi. Table 1 contains the initial conditions for each of the four calculations. All calculations were made with a one-dimensional, Eulerian, second order accurate, hydrodynamics code (DYTSAP). The zone size in the vicinity of the shock front was held constant at 2 meters. Figures 1 through 4 are plots of the peak overpressure versus distance from burst point for the four inlet pressure levels above.

The 1 KT standard used as boundary conditions is an analytic fit with discontinuous shocks. Hydrodynamic codes define the shock over a minimum of three zones, thus the shock front for these calculations is spread over approximately 6 meters (m). The effect of this interface between analytic and zone definition is an artificial drop in the peak overpressure immediately upon entering the hydro grid. As a check on this phenomenon, an additional calculation was made with 0.06 m zones (figure 5). The fine zone calculation exhibited the same drop in

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1. Needham, C. E., Air Force Weapons Laboratory (1 KT) Nuclear Blast Standard, AFWL-TR-73-55, Air Force Weapons Laboratory, Kirtland AFB, NM, April 1975.

Table 1

1-D INPUT PARAMETERS

Problem	13.0011	13.0012	13.0013	13.0014
Yield	1	1	1	1
Starting time (sec)	5.1×10^{-1}	9.3×10^{-2}	7.3×10^{-3}	1.0×10^{-3}
Distance of left mesh edge from burst center (M)	9.39×10^{2}	4.54×10^{2}	1.694×10^{2}	7.96×10^{1}
Initial peak pressure (Pascals)	6.8×10^{5} (Approx. 100 psi)	4.129×10^{6} (Approx. 600 psi)	6.8×10^{6} (Approx. 10^{4} psi)	6.5×10^{8} (10^{5} psi)
Number of cells	900	900	900	900
Width of cells (M)	2.	2.	2.	2.

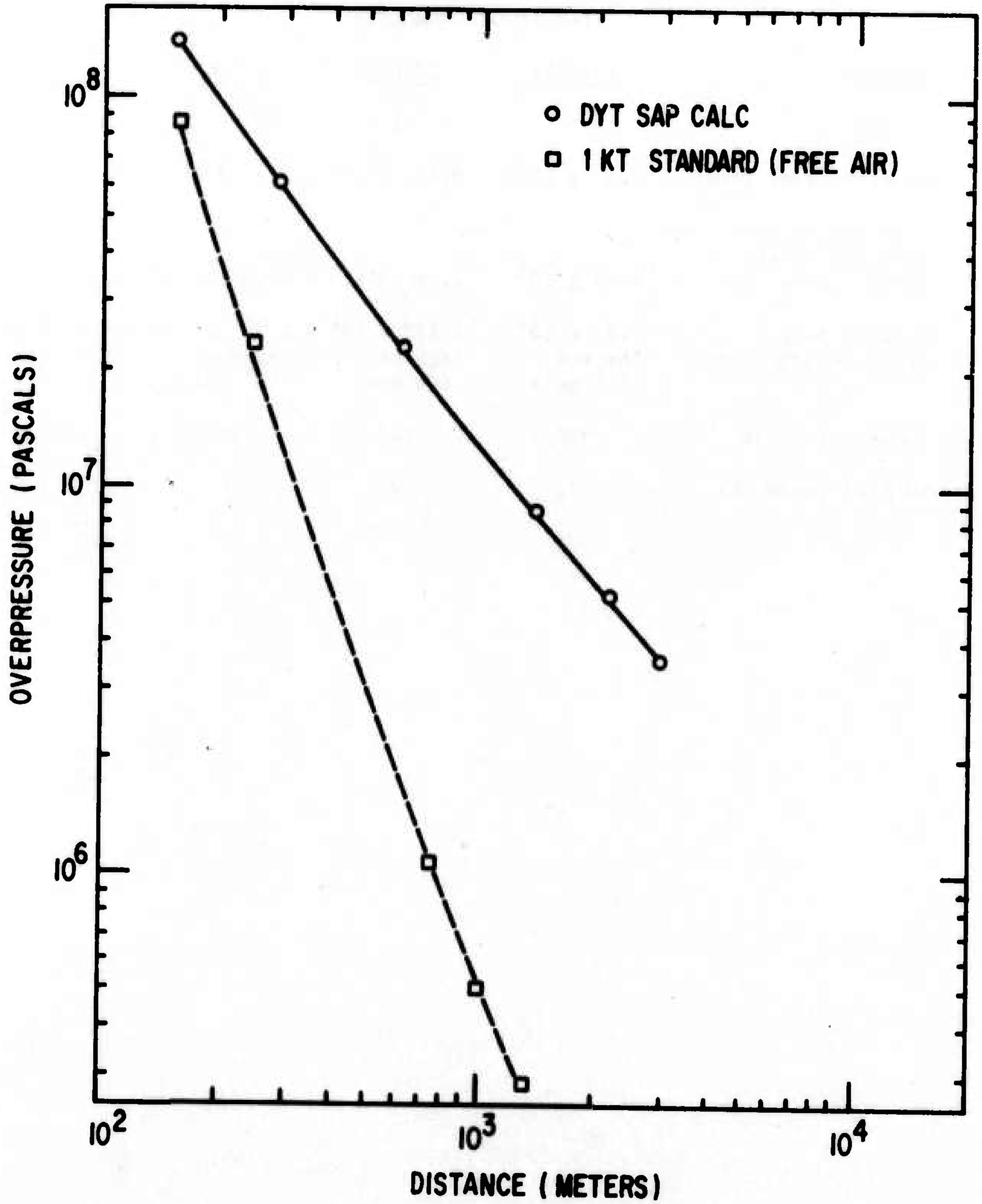


Figure 1. O.P. versus Distance - $P_o = 10^5$ psi

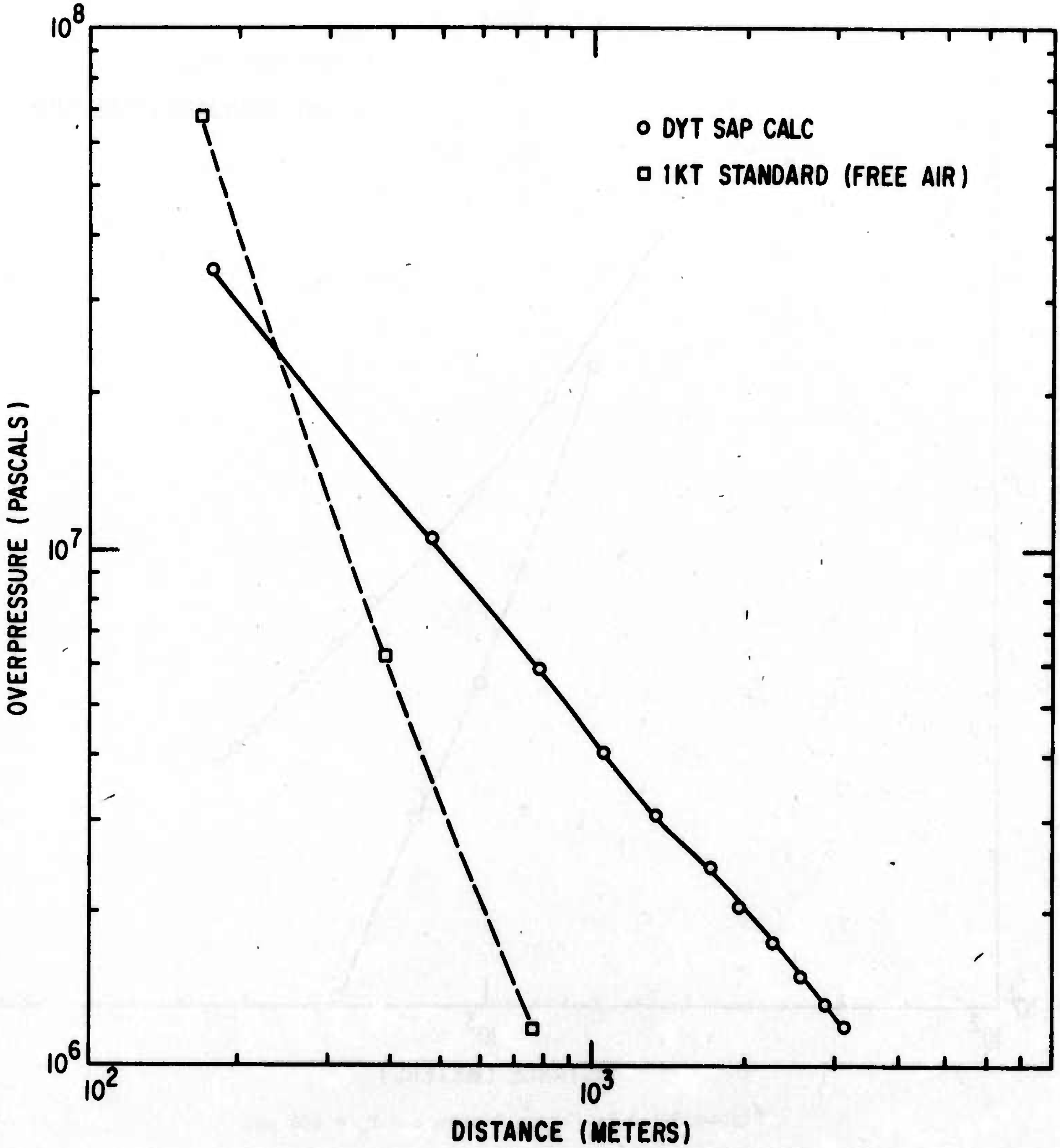


Figure 2. O.P. versus Distance - P_o = 10^4 psi

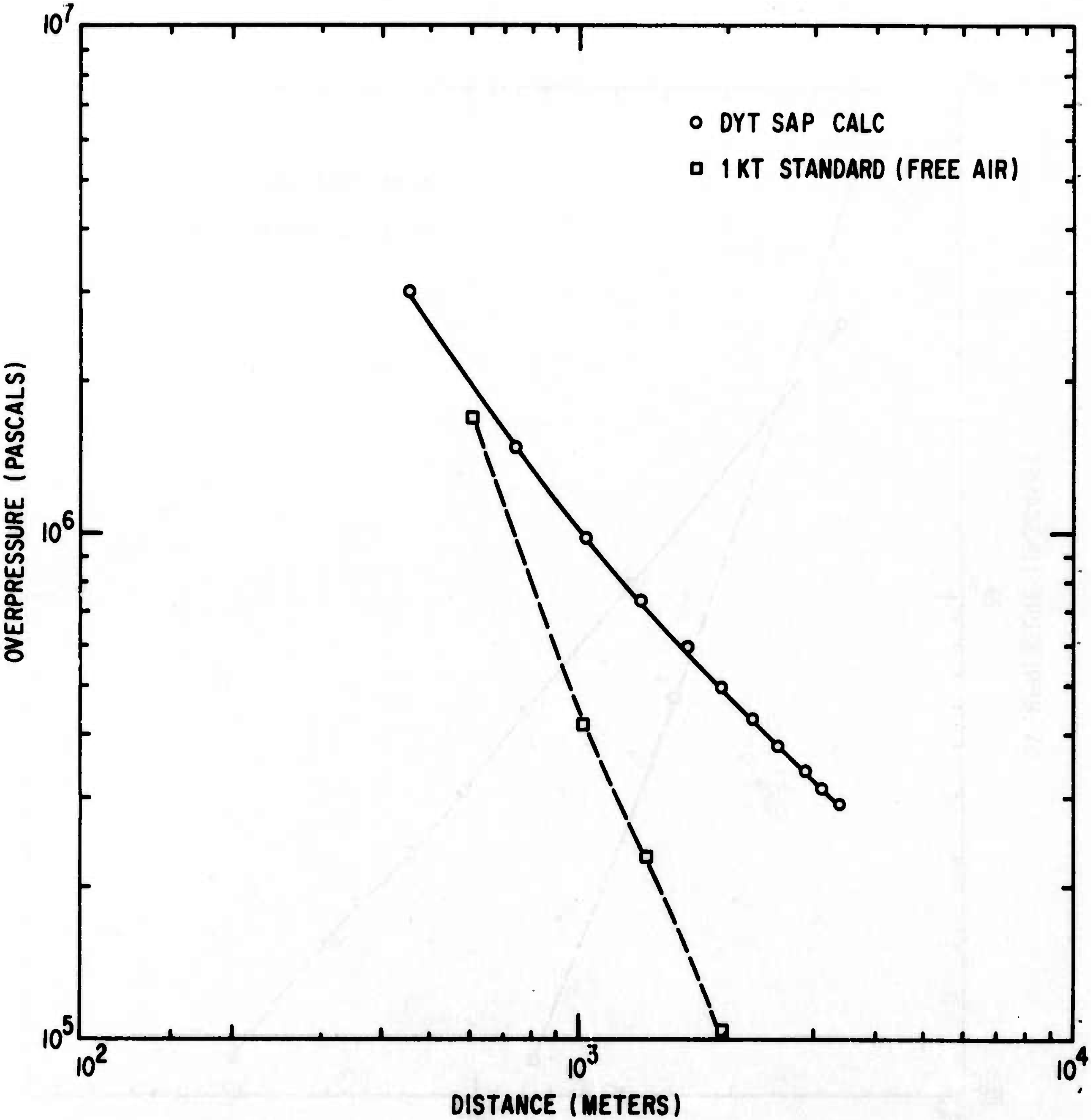


Figure 3. O.P. versus Distance - P_o = 600 psi

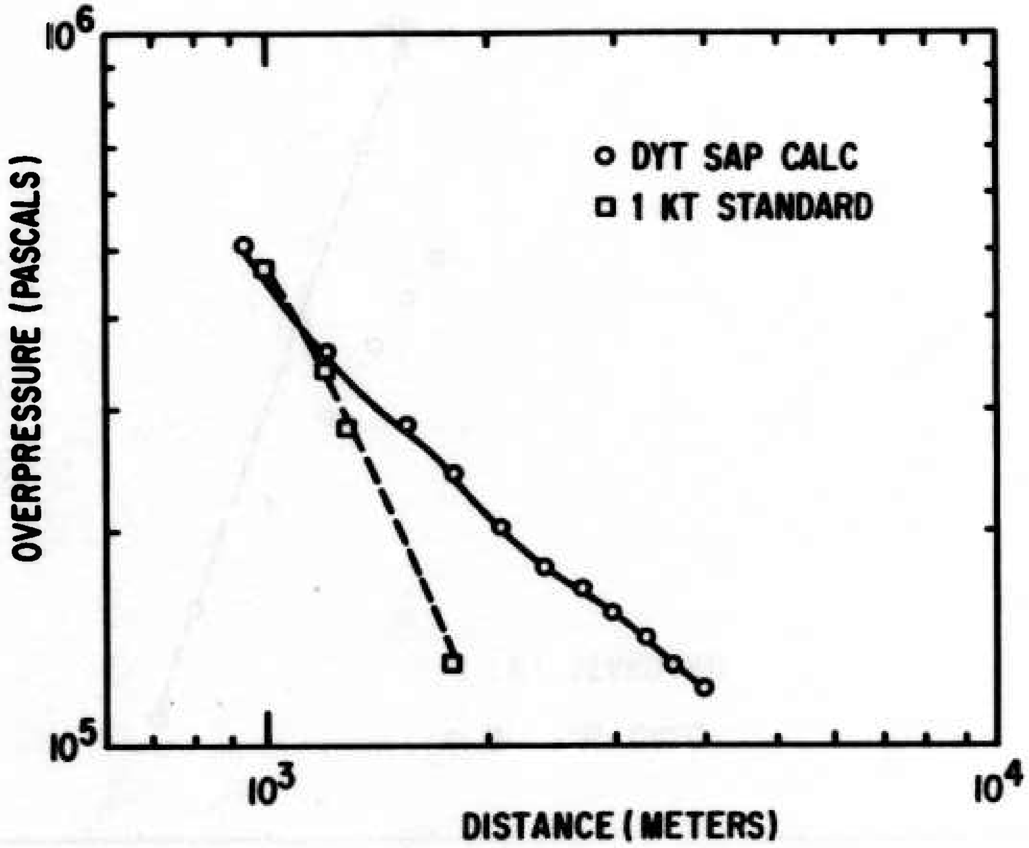


Figure 4. O.P. versus Distance - P_o = 100 psi

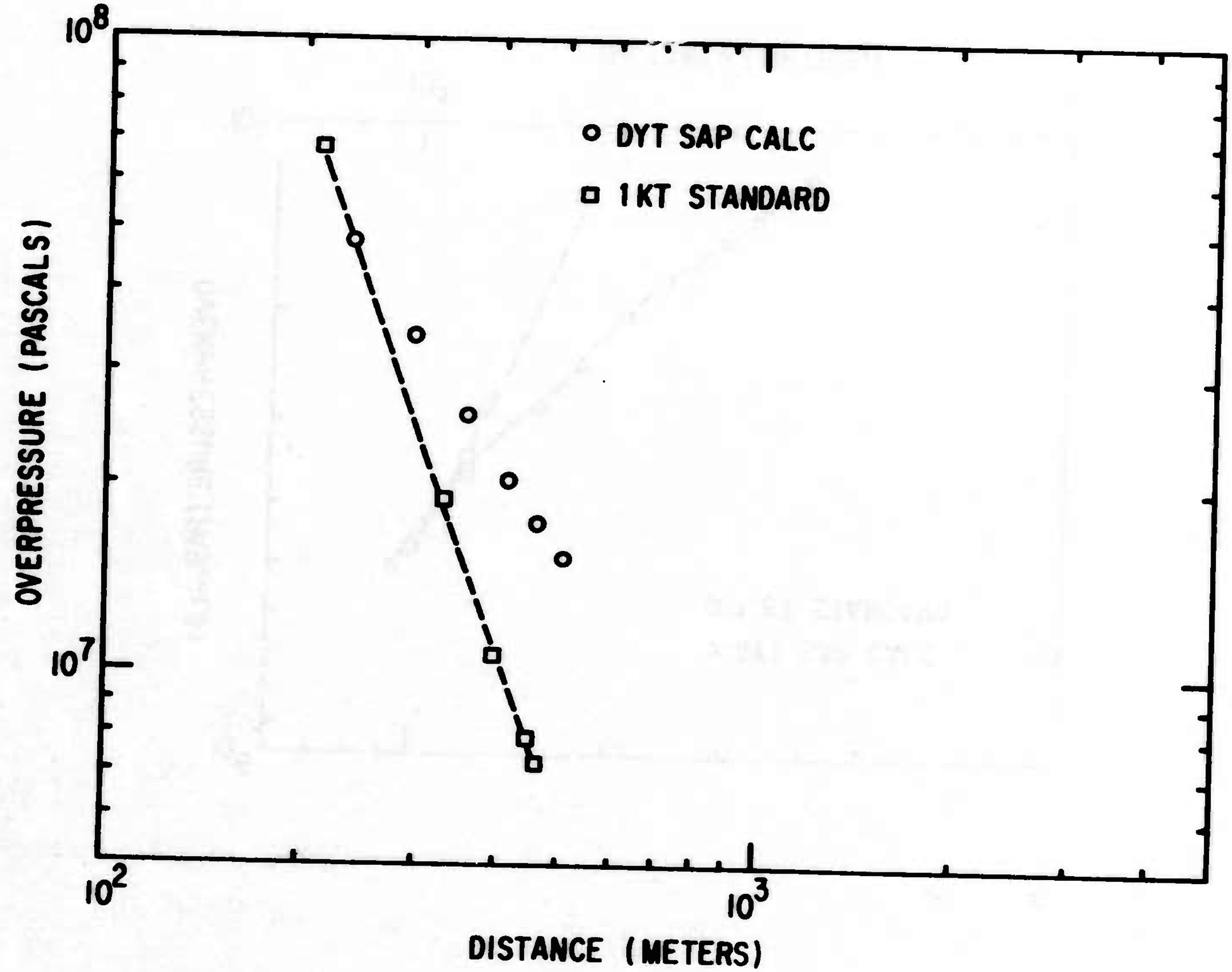


Figure 5. O.P. versus Distance - $\Delta R = 6$ cm

peak overpressure but only a small percentage of that of the 2 m zone calculation. As the two calculations progress, the overpressure distance curves merge, and by a distance of 500 m no significant differences can be found. The conclusion is that the correct amount of energy is entering the calculational mesh but takes a small amount of time (about 20 zones) to adjust to the new conditions.

Table 2 compares the various results with one another and with the free air case at 1 and 3 kilometers from the burst point.

Table 2

OVERPRESSURE FOR VARIOUS INLET CONDITIONS

P (Pascals)	P (Pascals) at R = 1 km	P (Pascals) at R = 3 km
6.8×10^8 (10^5 psi)	1.2×10^7	3.5×10^6
6.8×10^7 (10^4 psi)	4.3×10^6	1.2×10^6
4.13×10^6 (600 psi)	1.0×10^6	3.2×10^5
6.5×10^5 (100 psi)	4.9×10^5	1.5×10^5
Free air	4.8×10^5	6.0×10^4

The table shows that a factor of three increase in pressure results at a distance of 3 kilometers when the inlet pressure is increased from 10^4 to 10^5 psi. The pressure at 3 km for 10^4 inlet pressure is 20 times as great as that of free air at the same point. The overpressure impulse is more than 200 times that of free air. Similar comparisons can be made using table 1 for other inlet pressures. Plots of the pressure waveforms for these four problems are contained in Appendix A. A tabulation of inlet parameters for the 10^4 and 10^5 psi waveforms is given in Appendix B.

SECTION III

THE TWO-DIMENSIONAL CALCULATION

One calculation was made in two-dimensional cylindrical geometry to study the effects on air blast of corrugations on the inner surface of the tunnel wall. The calculational mesh was 28 radial by 800 axial zones for a total of 22,400. The radial zone dimensions were 6 cm near the outer edge of the tunnel with gradually increasing size to 15 cm at the center of the tunnel. The 800 axial zones were initially 12 cm, and the problem was rezoned such that the shock front always traveled through 12 cm zones. The tunnel had an outside diameter of 4.68 m. Attached to the wall were perfectly reflecting rings extending 0.24 m into the tunnel and 0.6 m of outer wall between rings or 2.04 m from center to center. At the tunnel entrance 10^4 psi input from a 2-MT free air burst was used as a boundary condition. The calculation has been run a distance of 180+ meters down the tunnel.

Waveform plots indicate multiple shock enhancement on the axis of symmetry. Overall decay of the shock front pressure appears to be matching that of the free air curve and is significantly more rapid than the 1-D (smooth walled) calculation. The enhancement of reflected shocks is a significant factor. A train of shock waves of gradually decreasing peak pressure follow the main shock at a nearly constant time interval between 1 and 1.5 ms. The impulse is at least as great as that of the 1-D calculations.

The inlet temperature, after shock passage, is in excess of 25,000°K. This high temperature gas is pulled into the tunnel behind the shock and is further shock heated to temperatures over 30,000°K.

Table 3 gives the maximum pressure reached at several points in the tunnel. In almost all cases the peak pressure reached is not the first shock but the second or third. Figure 6 is the pressure-distance curve inside the corrugated tunnel. Also included are curves from the free air case and the smooth tunnel calculation. Appendix C contains a number of plots of a small portion of the length of the tunnel during shock passage. The multiple shock enhancement is clearly shown.

Table 3

PEAK PRESSURES IN CORRUGATED TUBE

Range from burst (meter)	Peak pressure (dynes/cm^2)		
	Tunnel center	Between center and outer edge	Near outside edge
214.3	6.77E8	6.80E8	1.05E9
224	7.81E8	3.85E8	4.43E8
234	5.55E8	3.80E8	3.97E8
244	4.40E8	3.85E8	3.61E8
253	3.76E8	3.32E8	4.74E8
263	3.15E8	2.96E8	3.33E8
273	3.21E8	2.66E8	2.41E8
284	3.17E8	2.60E8	6.04E8
294	2.89E8	2.32E8	3.71E8
304	2.43E8	2.00E8	2.43E8
314	2.84E8	2.53E8	2.64E8
324	2.54E8	2.14E8	1.78E8
334	2.13E8	1.76E8	1.22E8
344	1.83E8	1.47E8	1.17E8
353	1.40E8	1.36E8	1.76E8
363	1.31E8	1.25E8	5.87E7

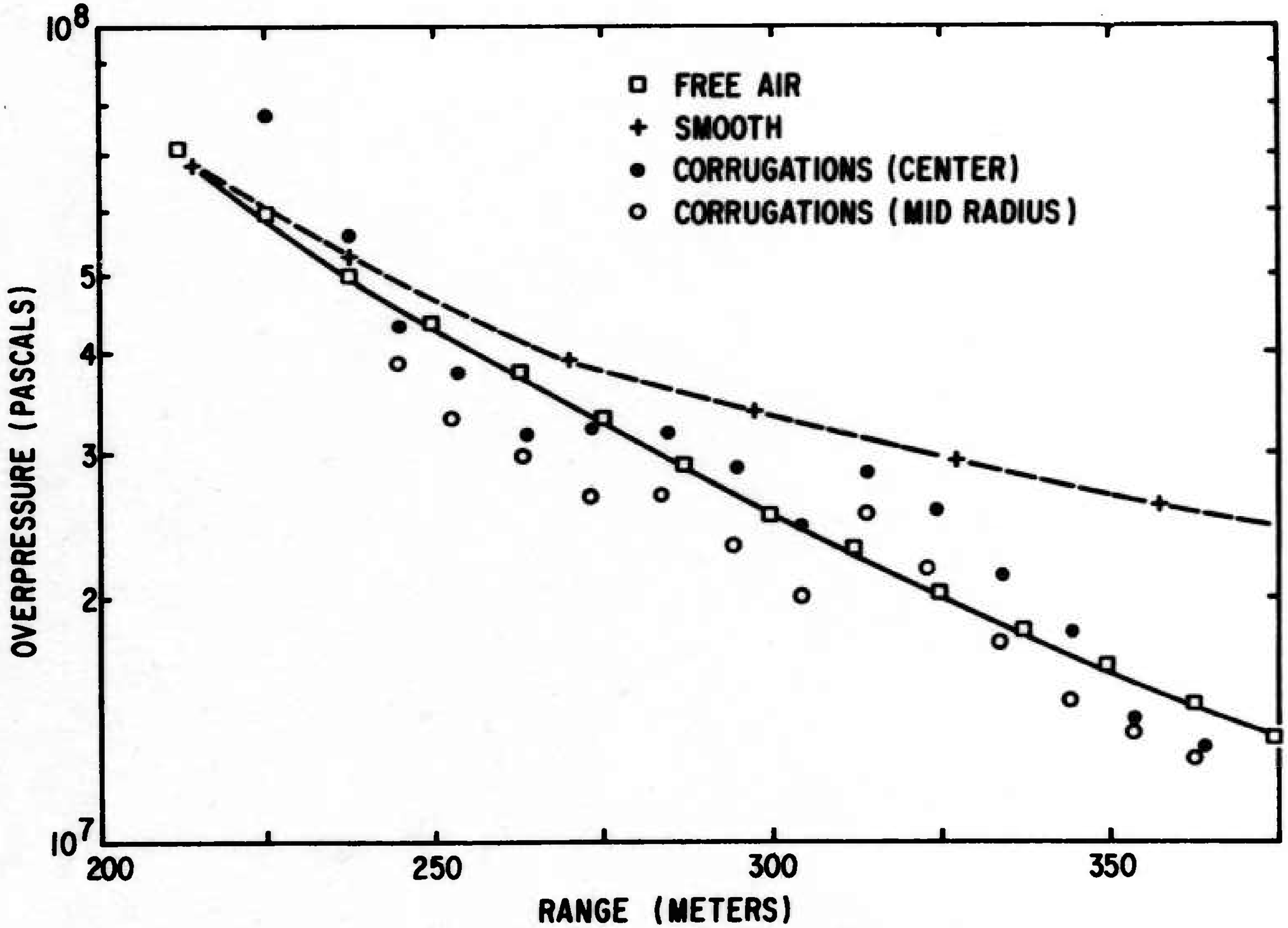
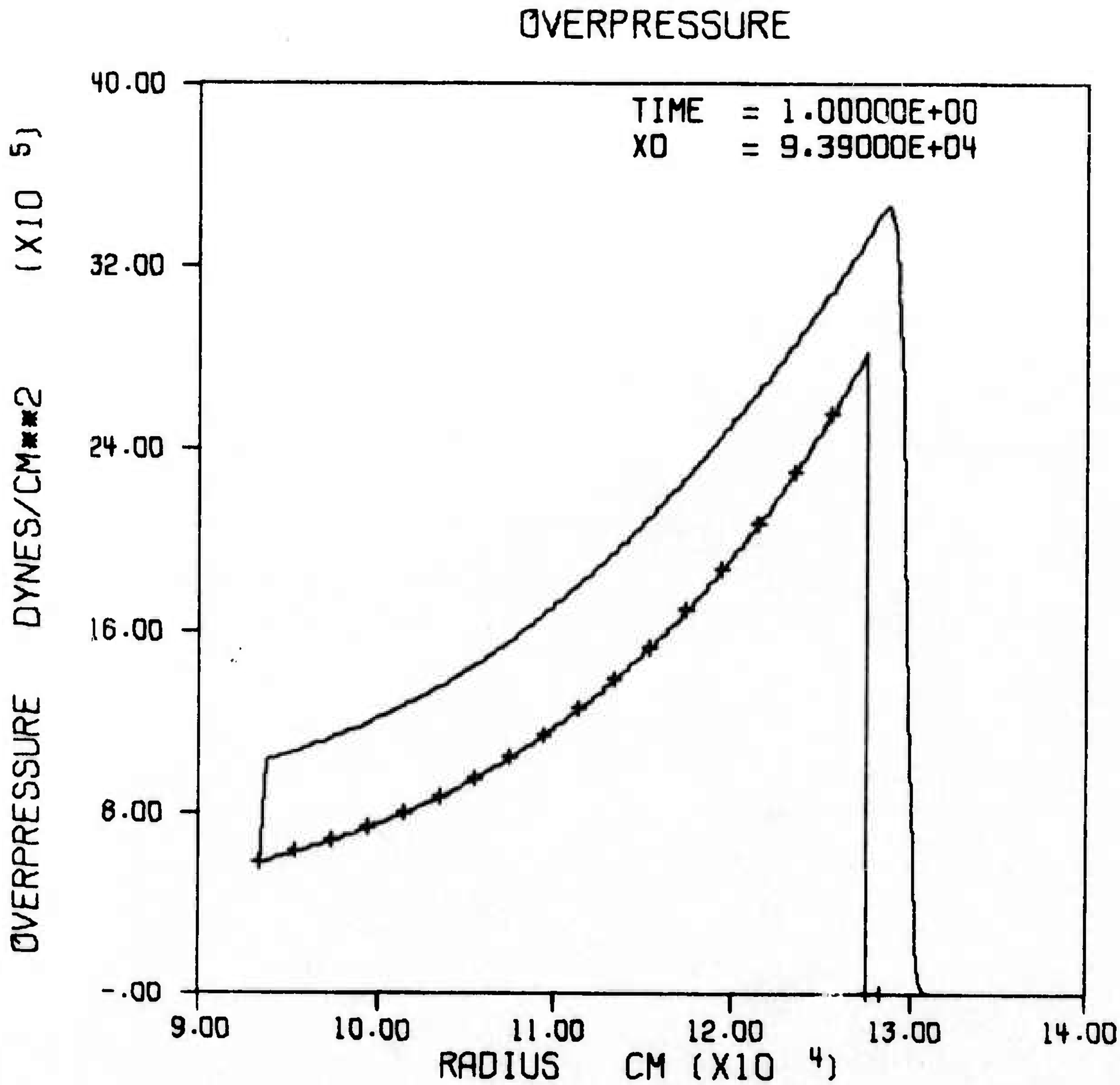


Figure 6. O.P. versus Distance - Corrugation Effects

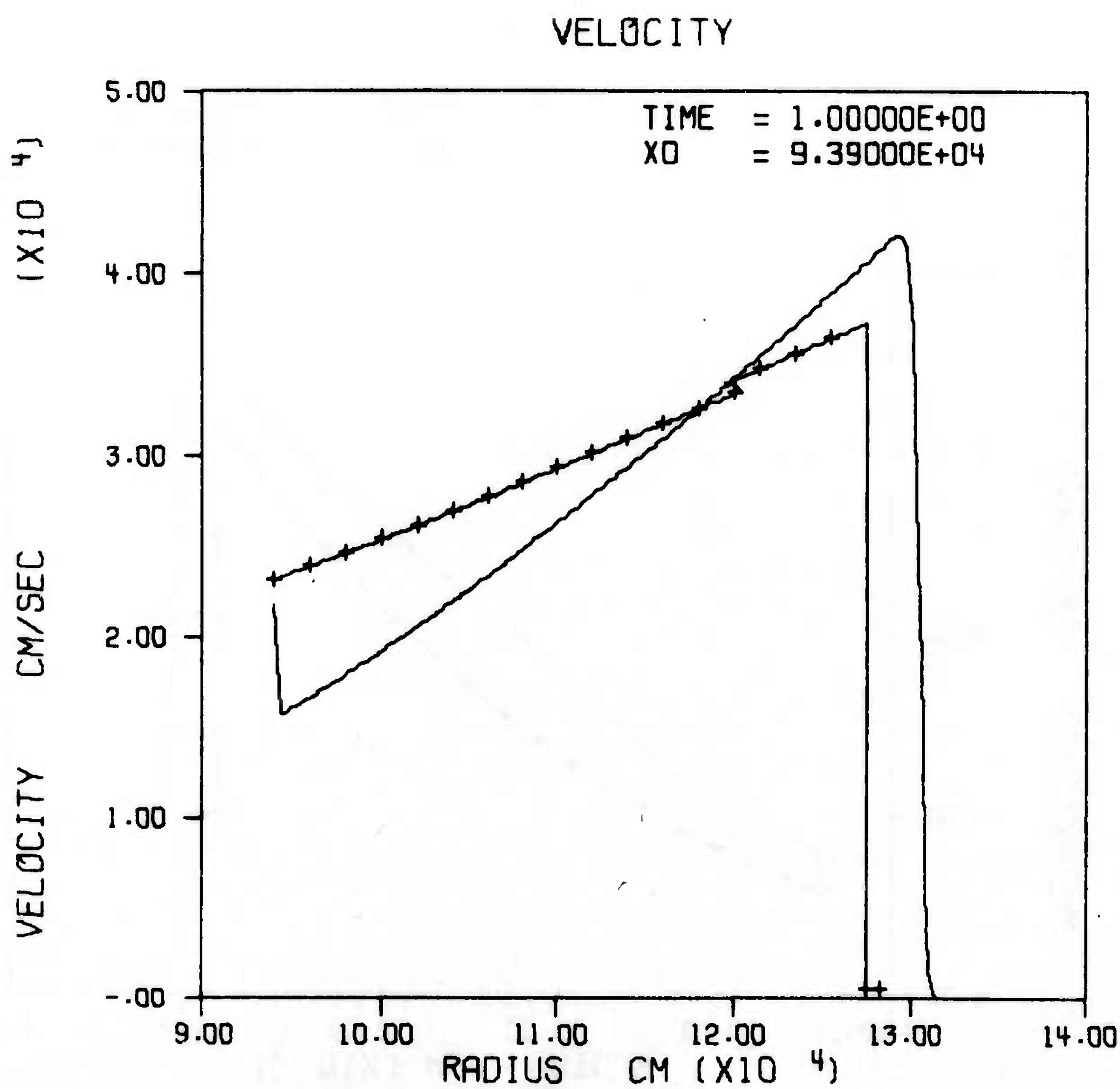
APPENDIX A

1-D WAVEFORM COMPARISONS

This appendix contains comparisons of overpressure waveforms inside the tunnel with free air waveforms at the corresponding times.



AFWL CALC OF 1 MT 1-D AND FREE AIR 100 PSI



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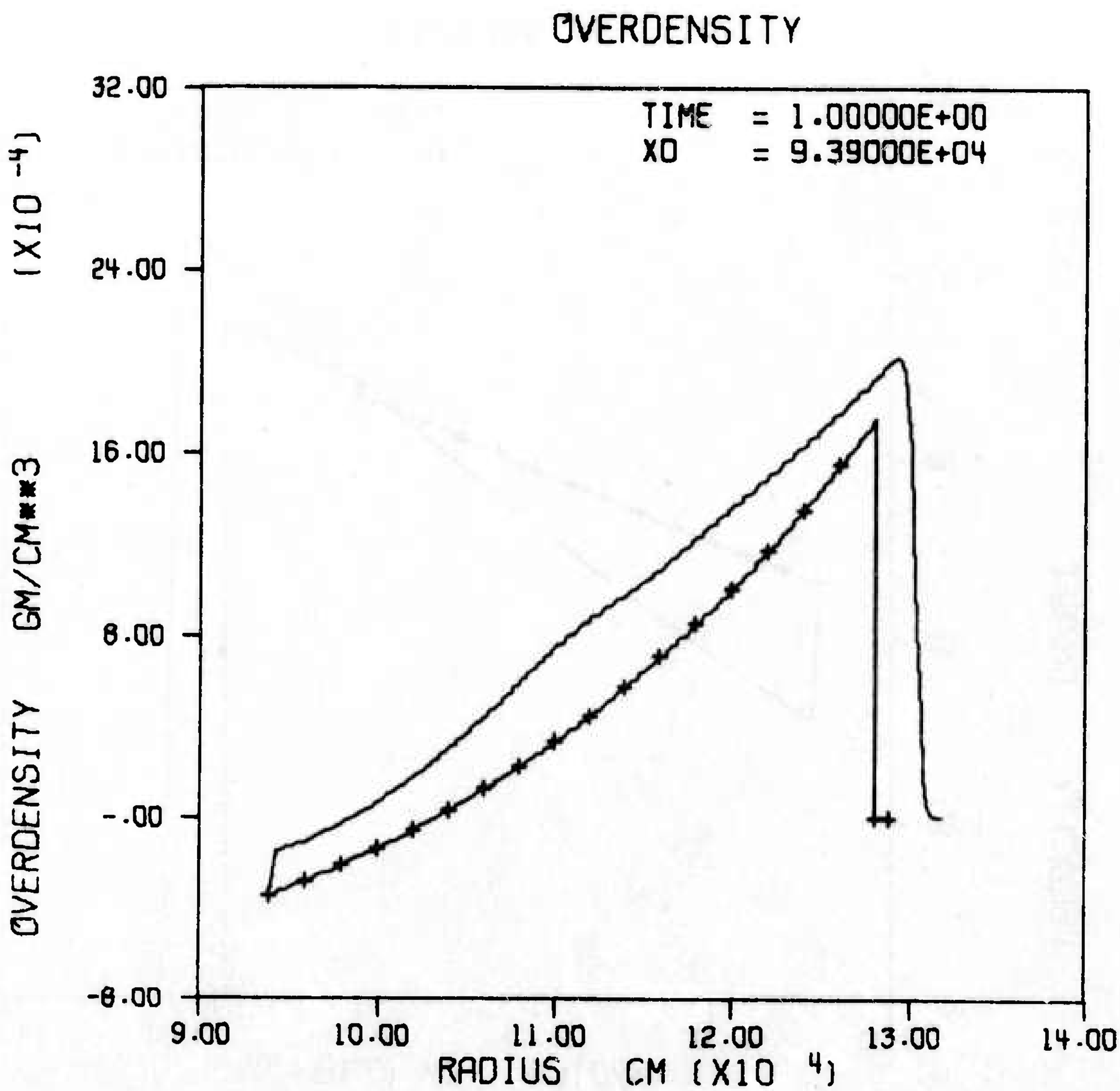

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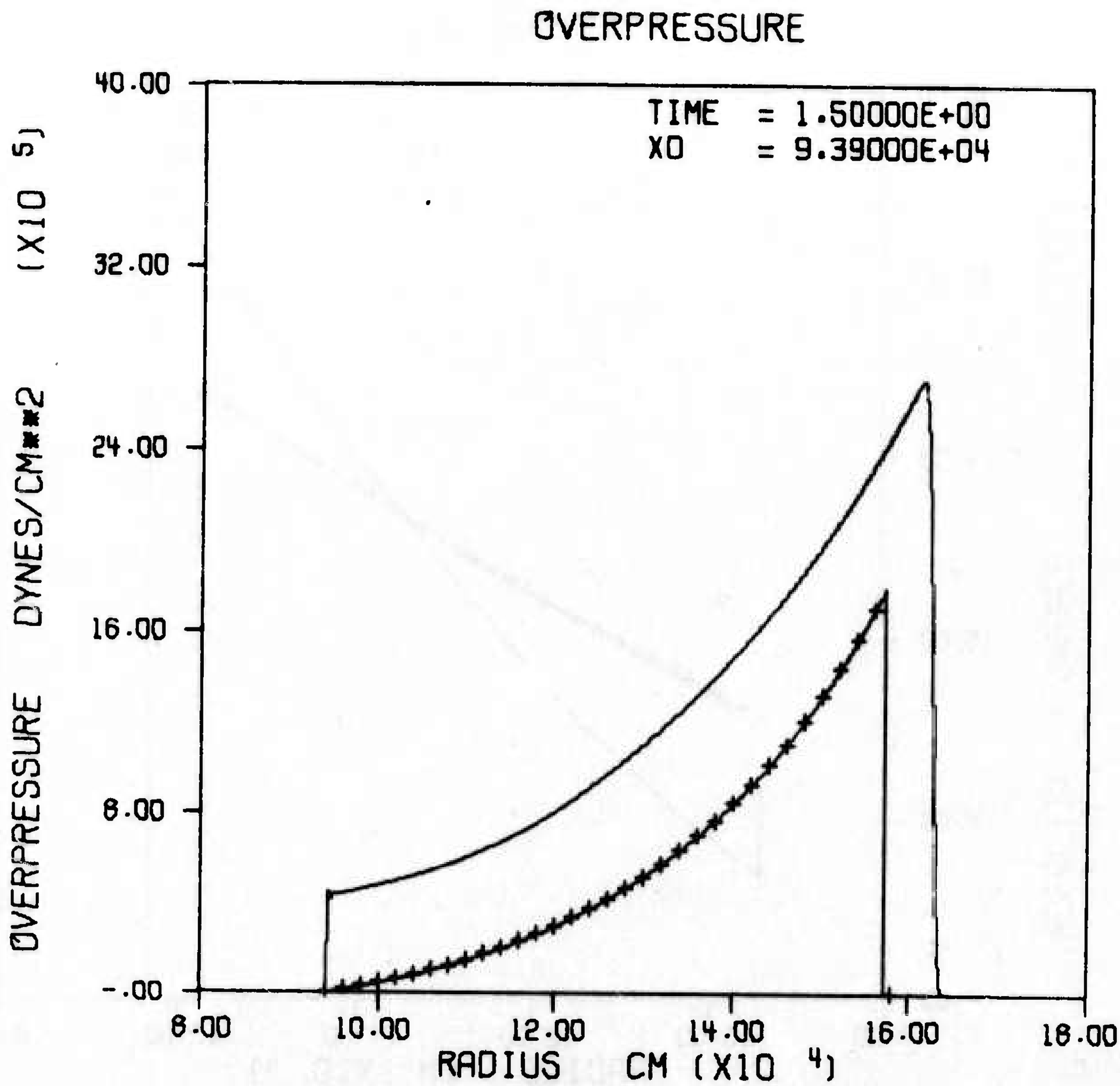

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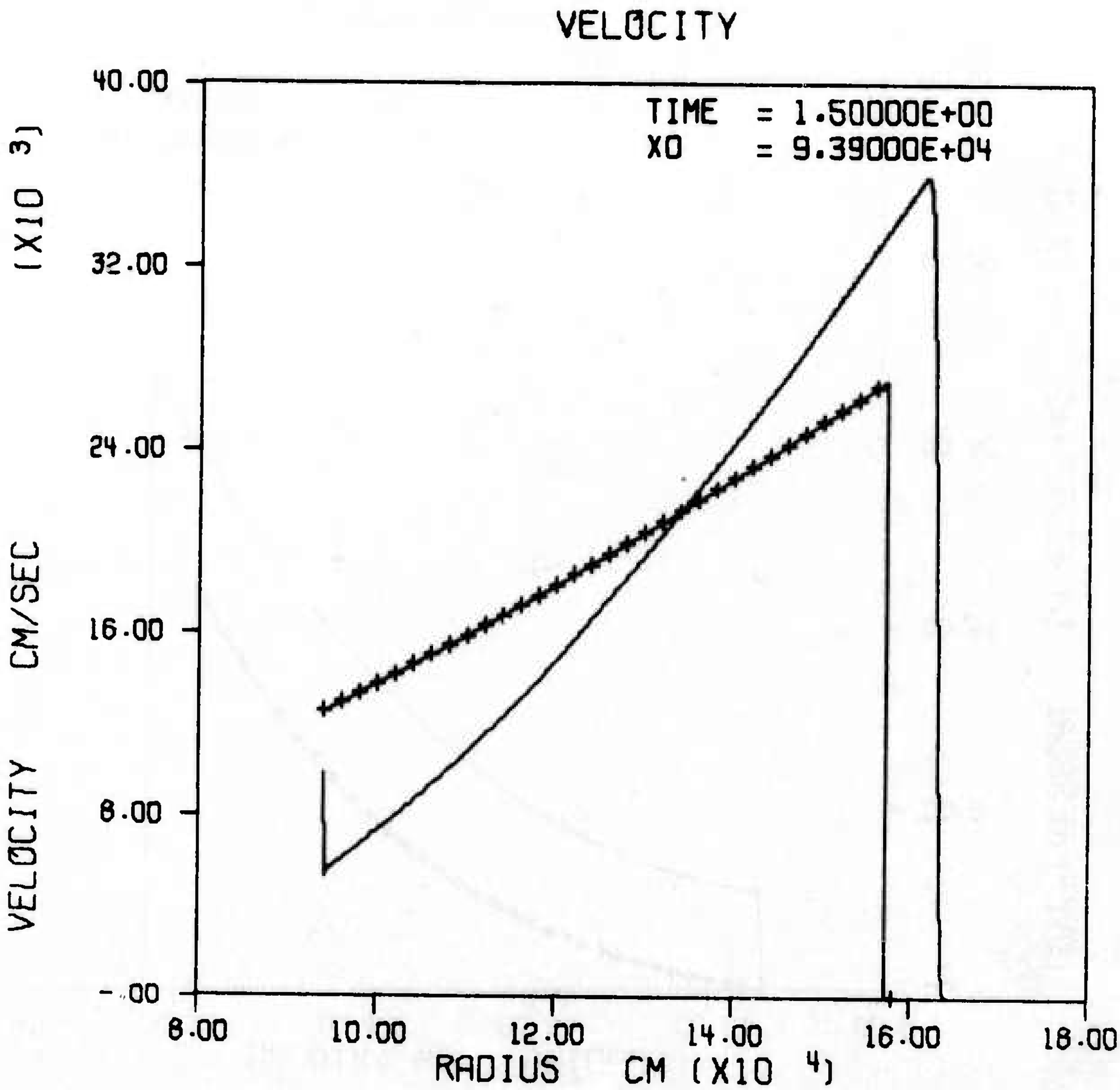

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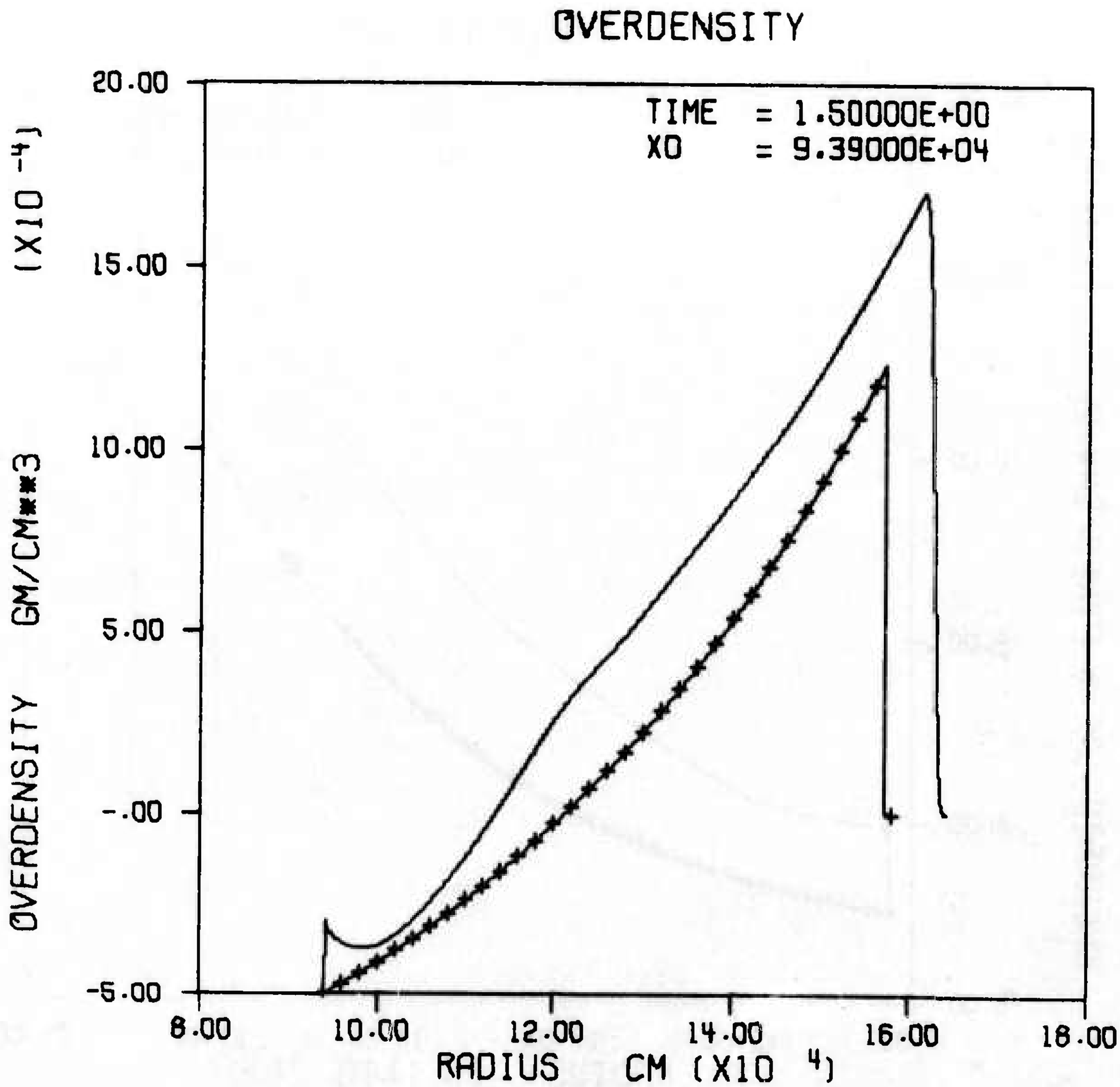

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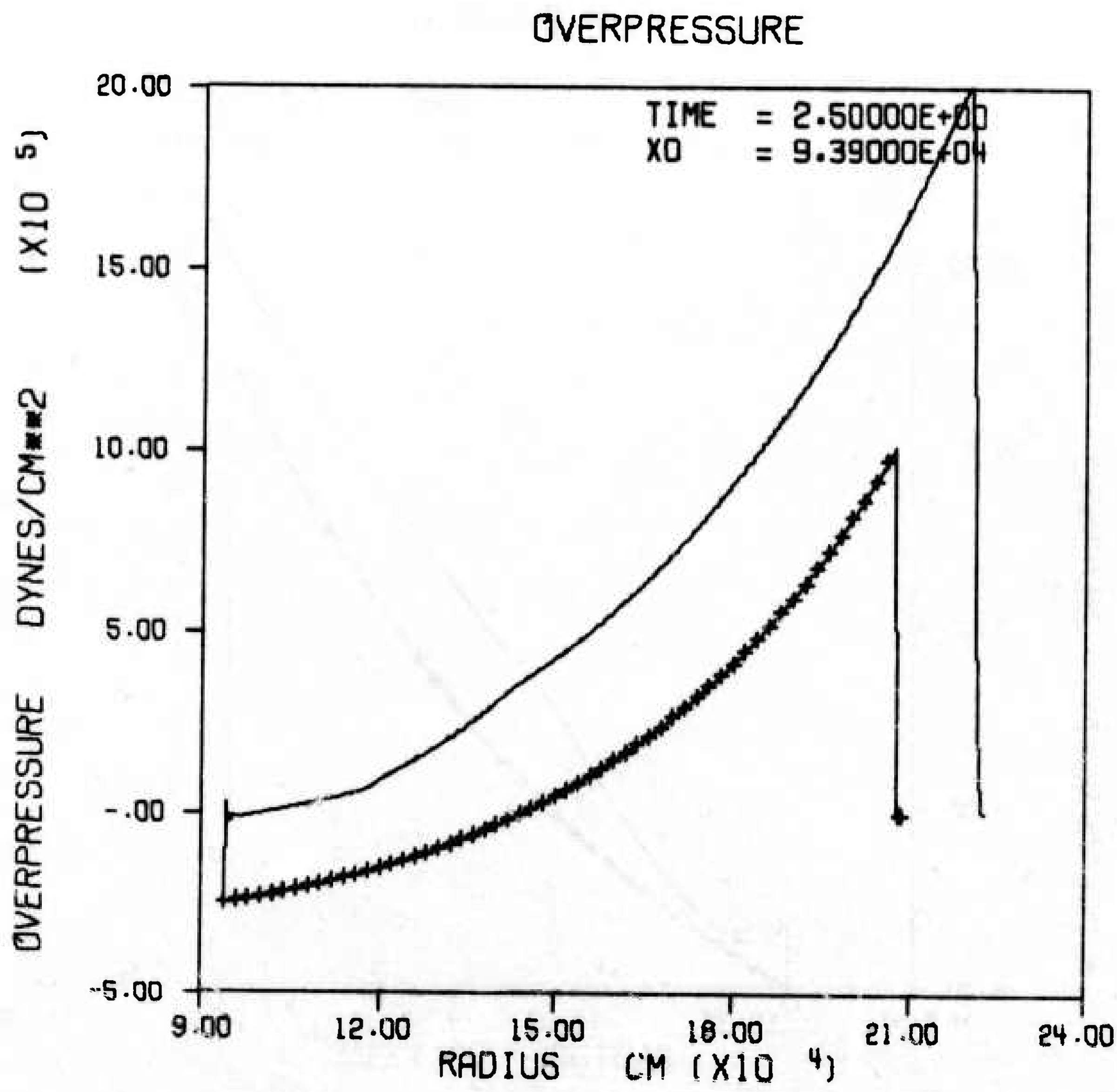

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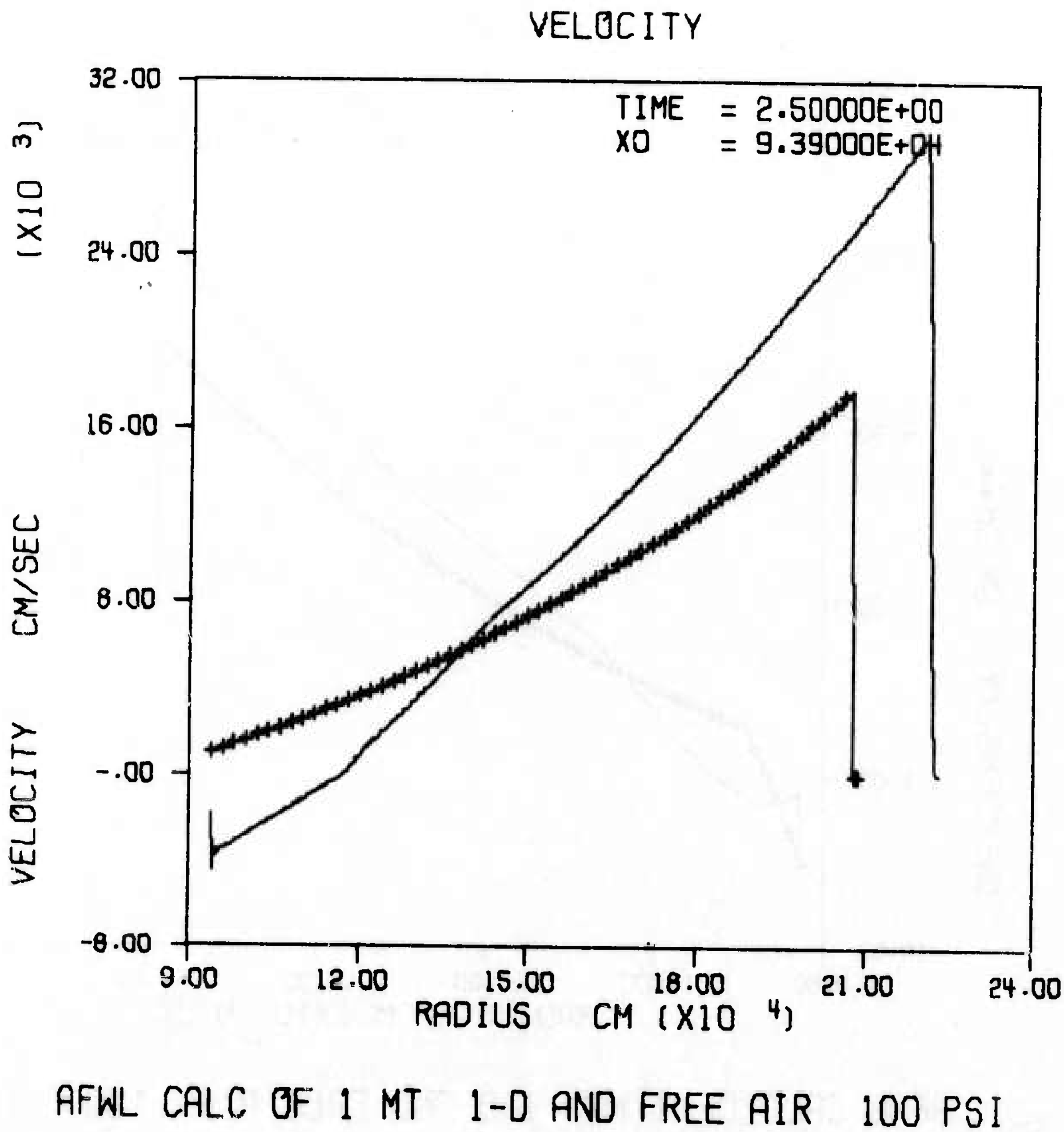

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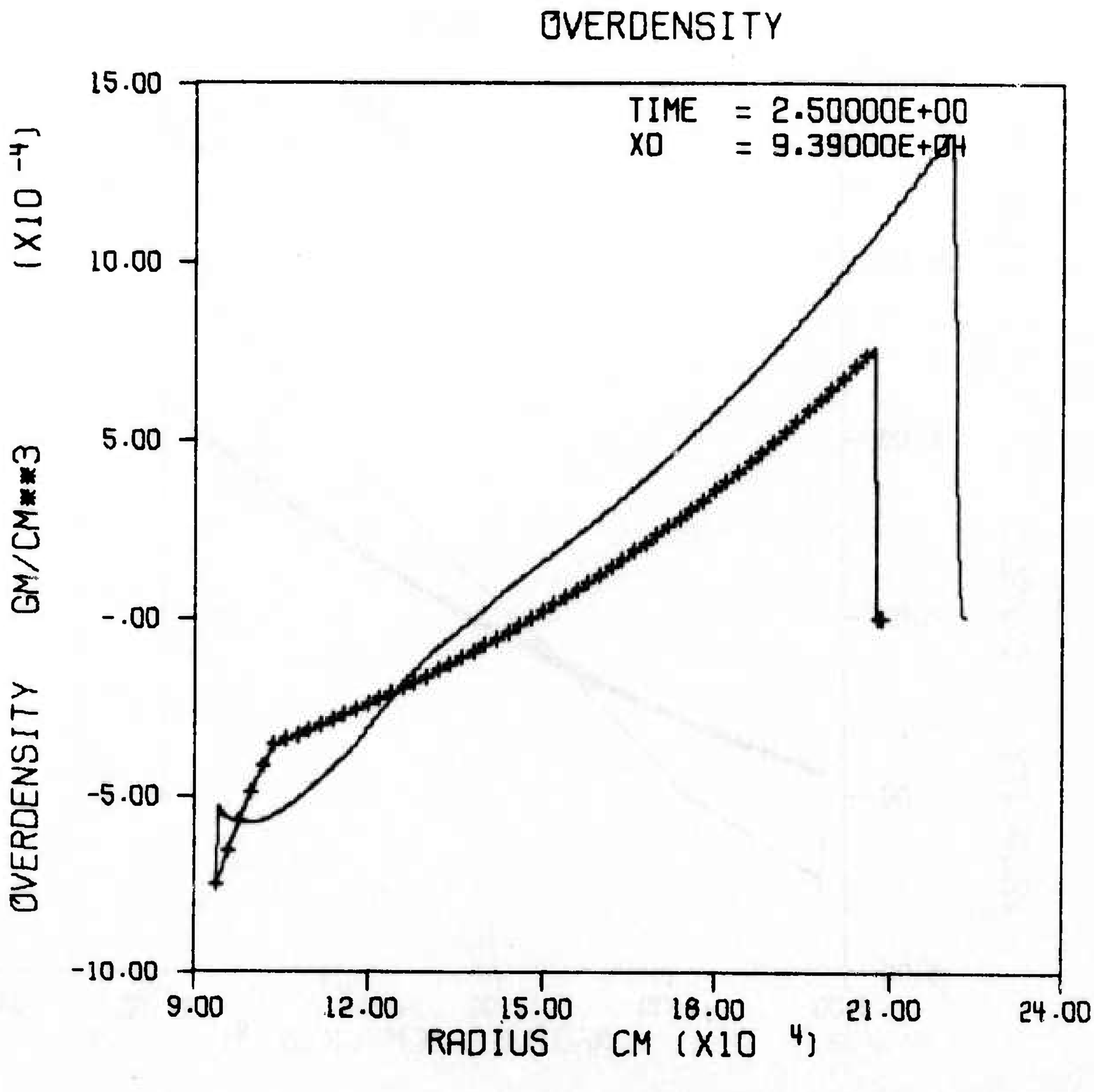

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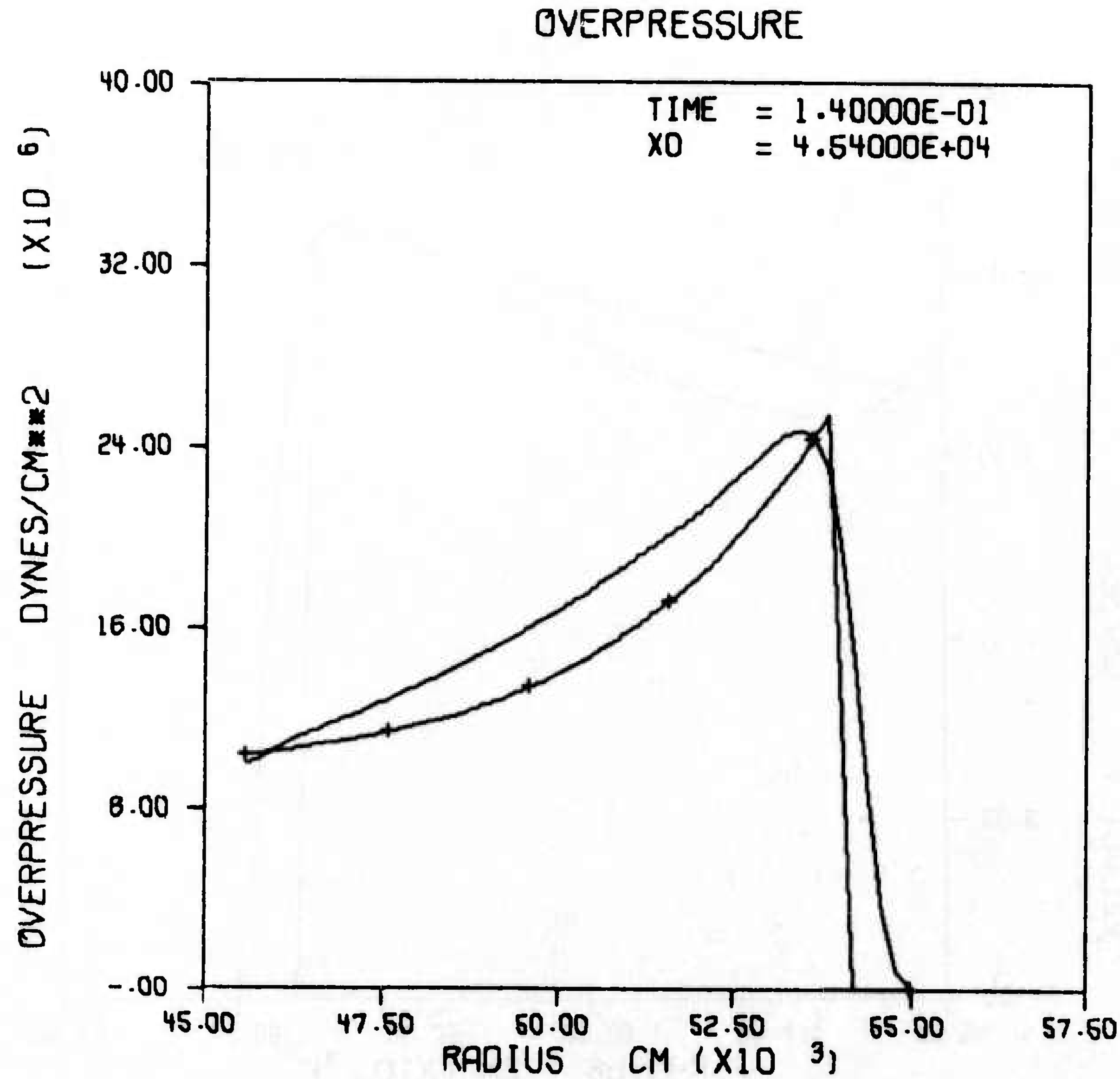

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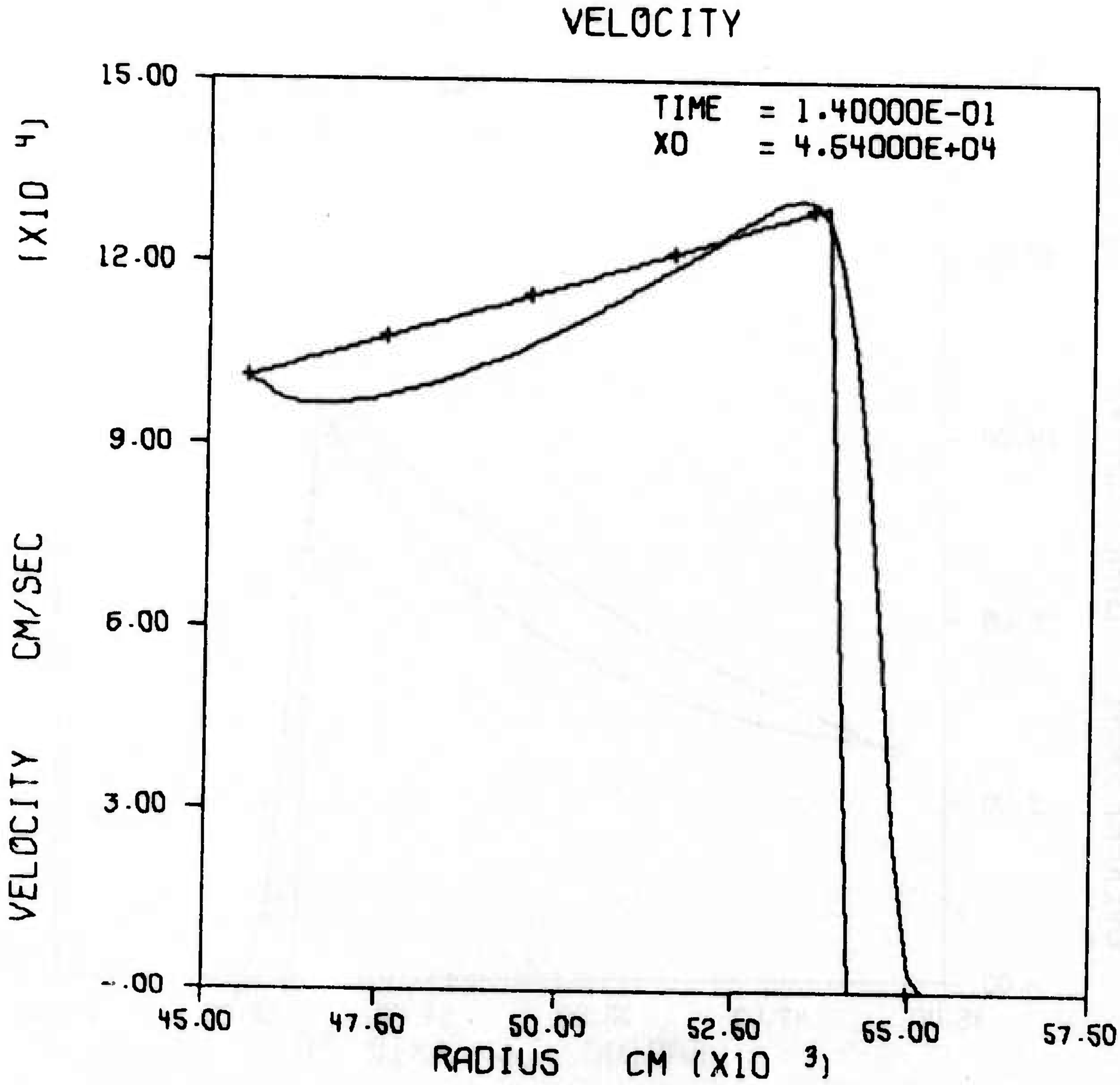

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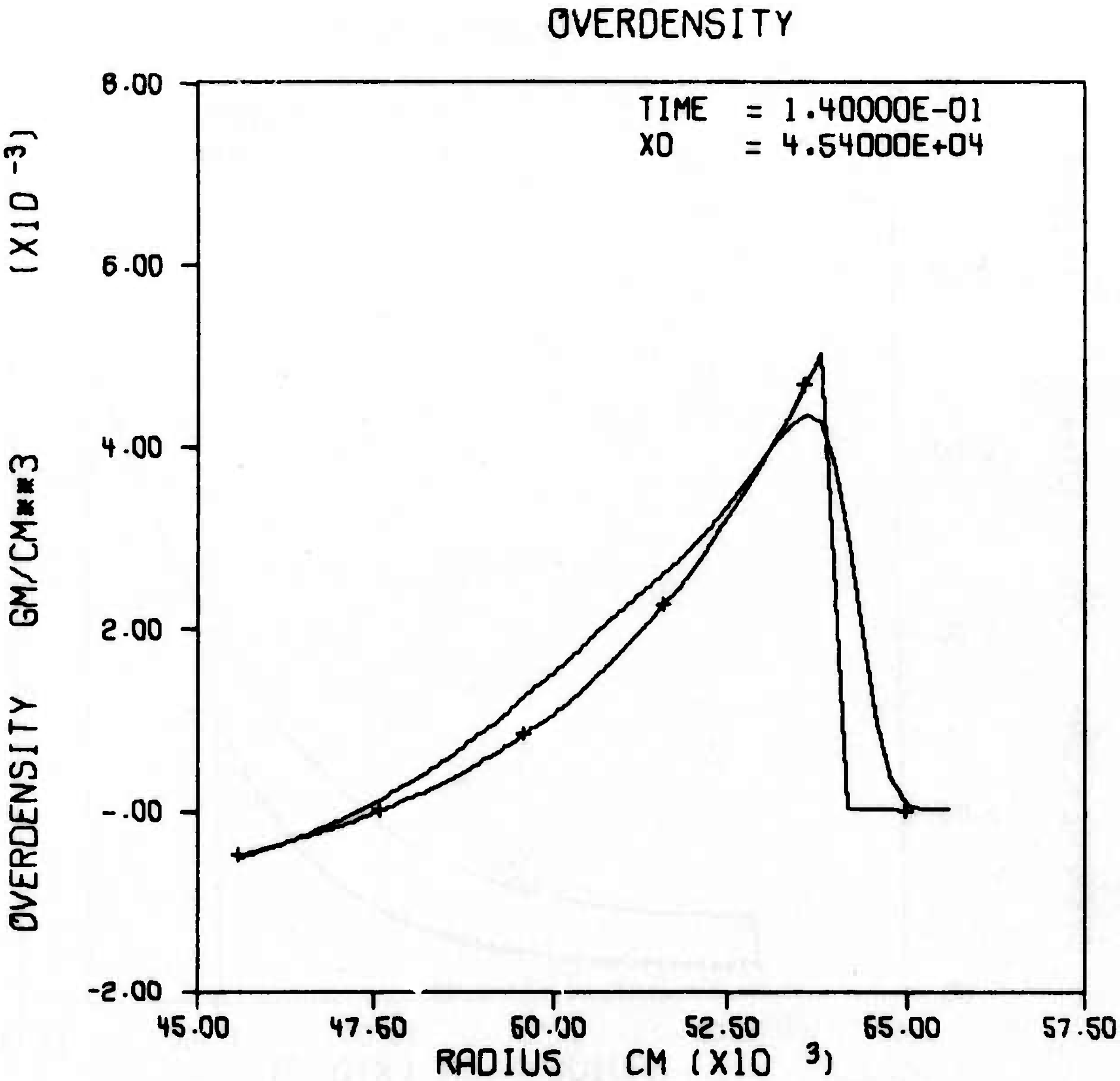

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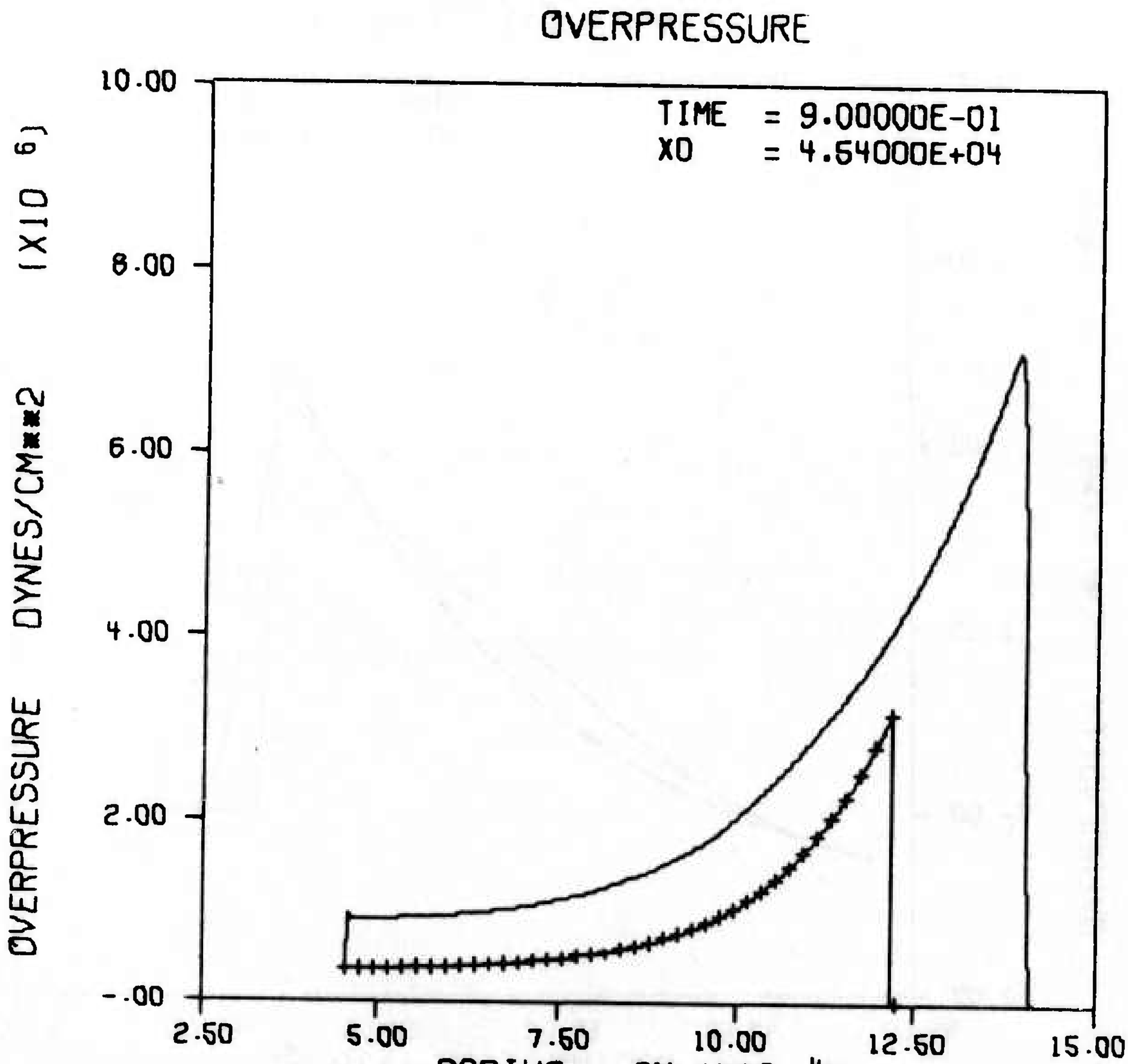

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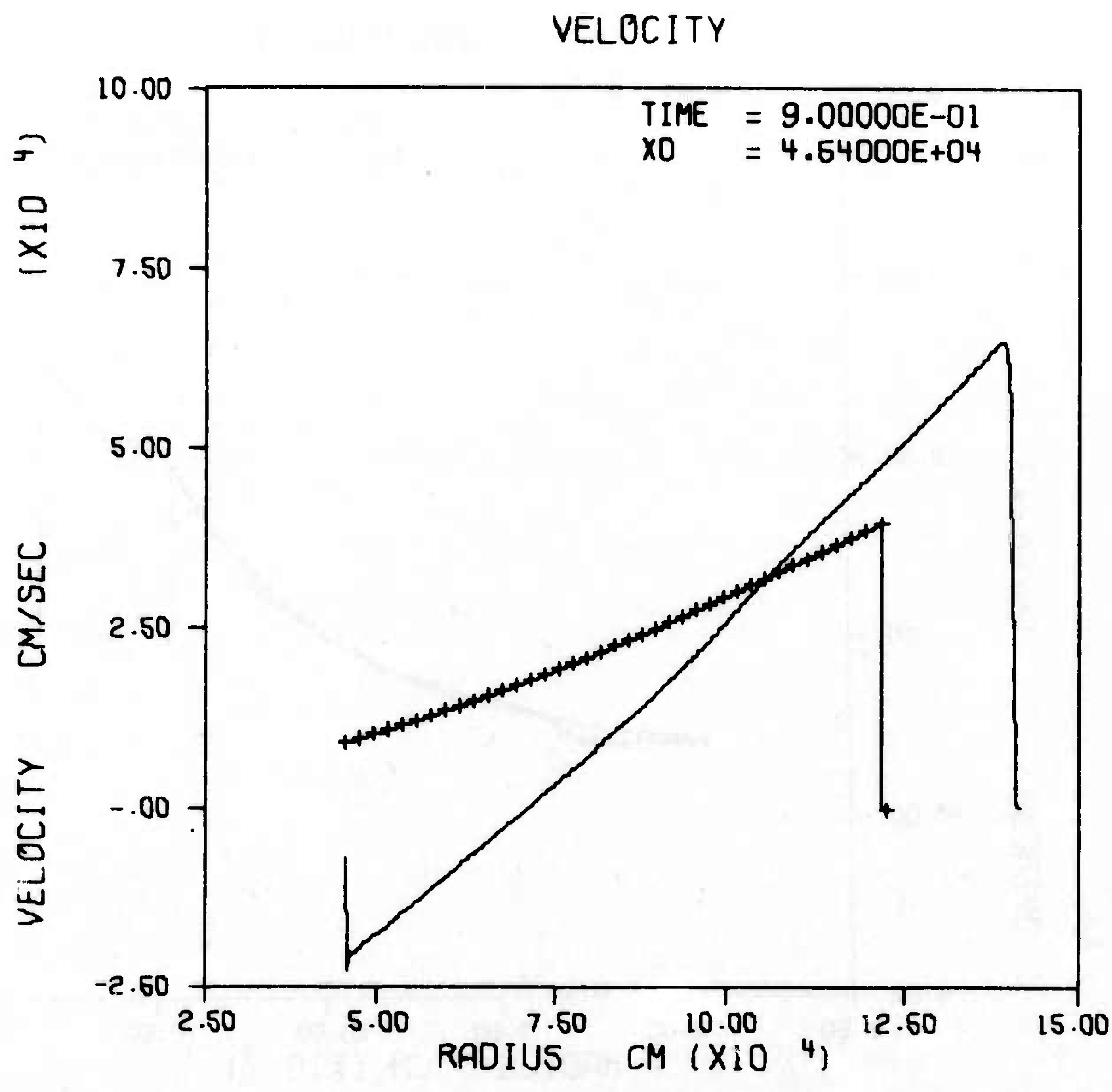

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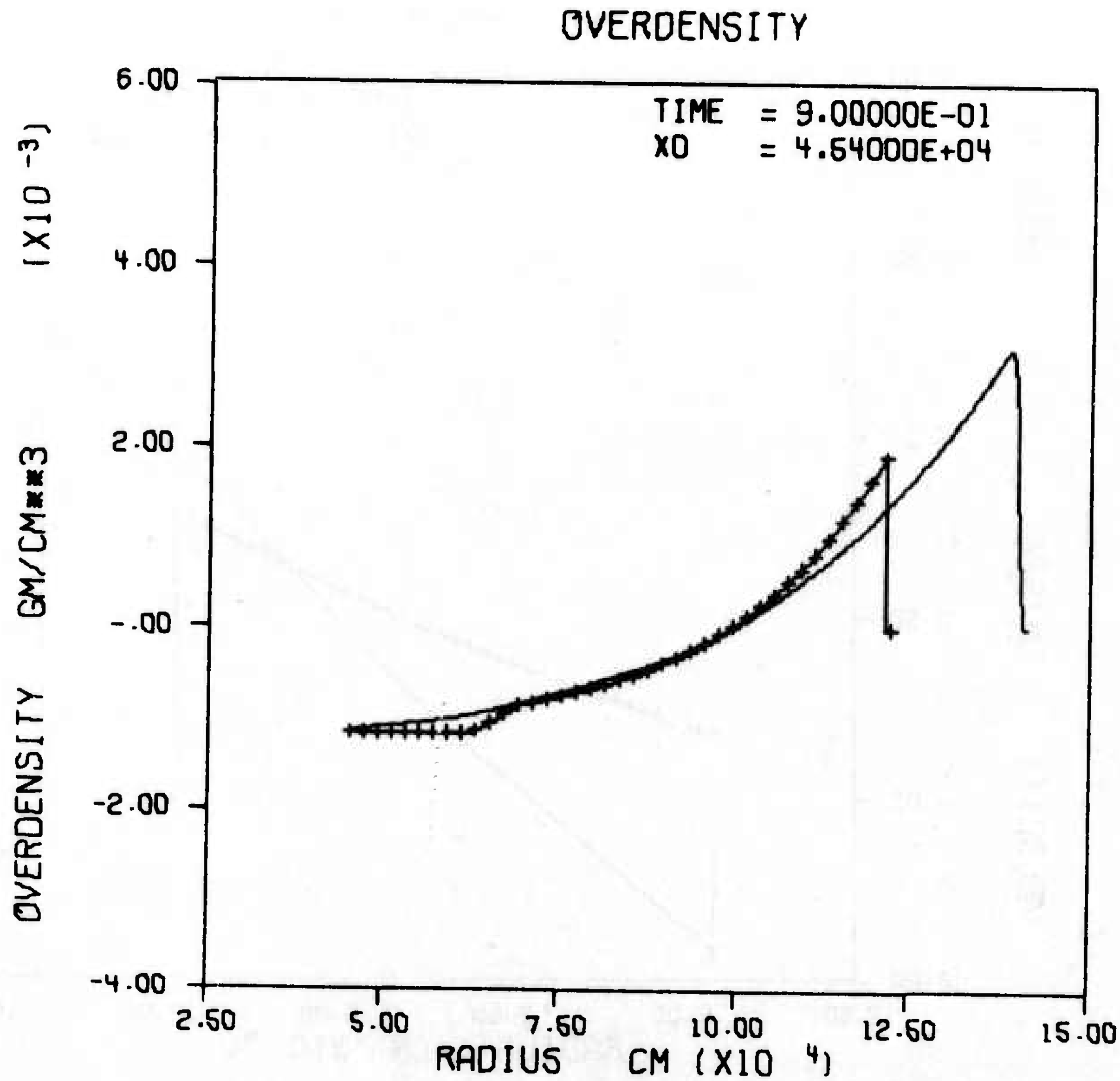

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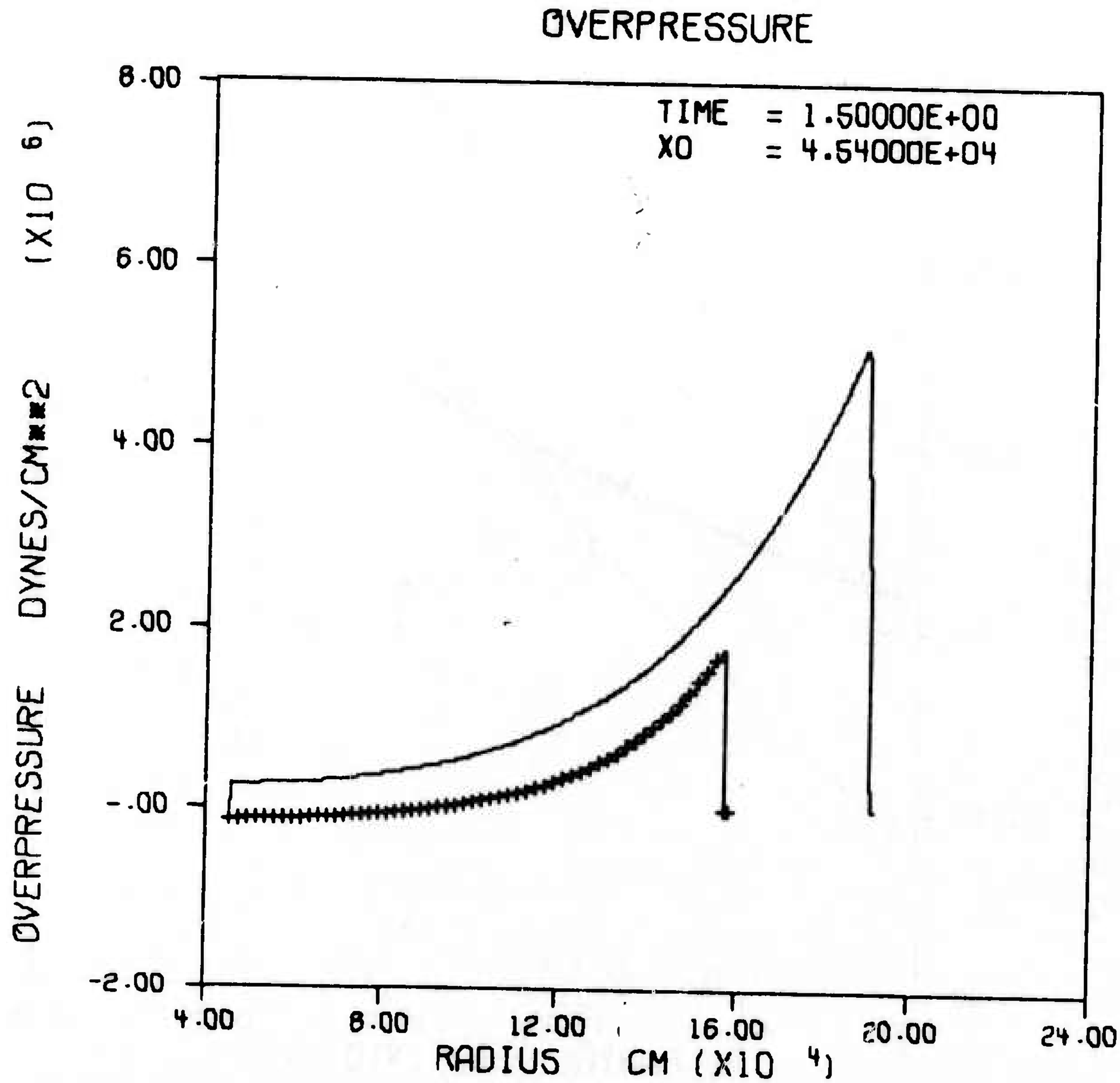

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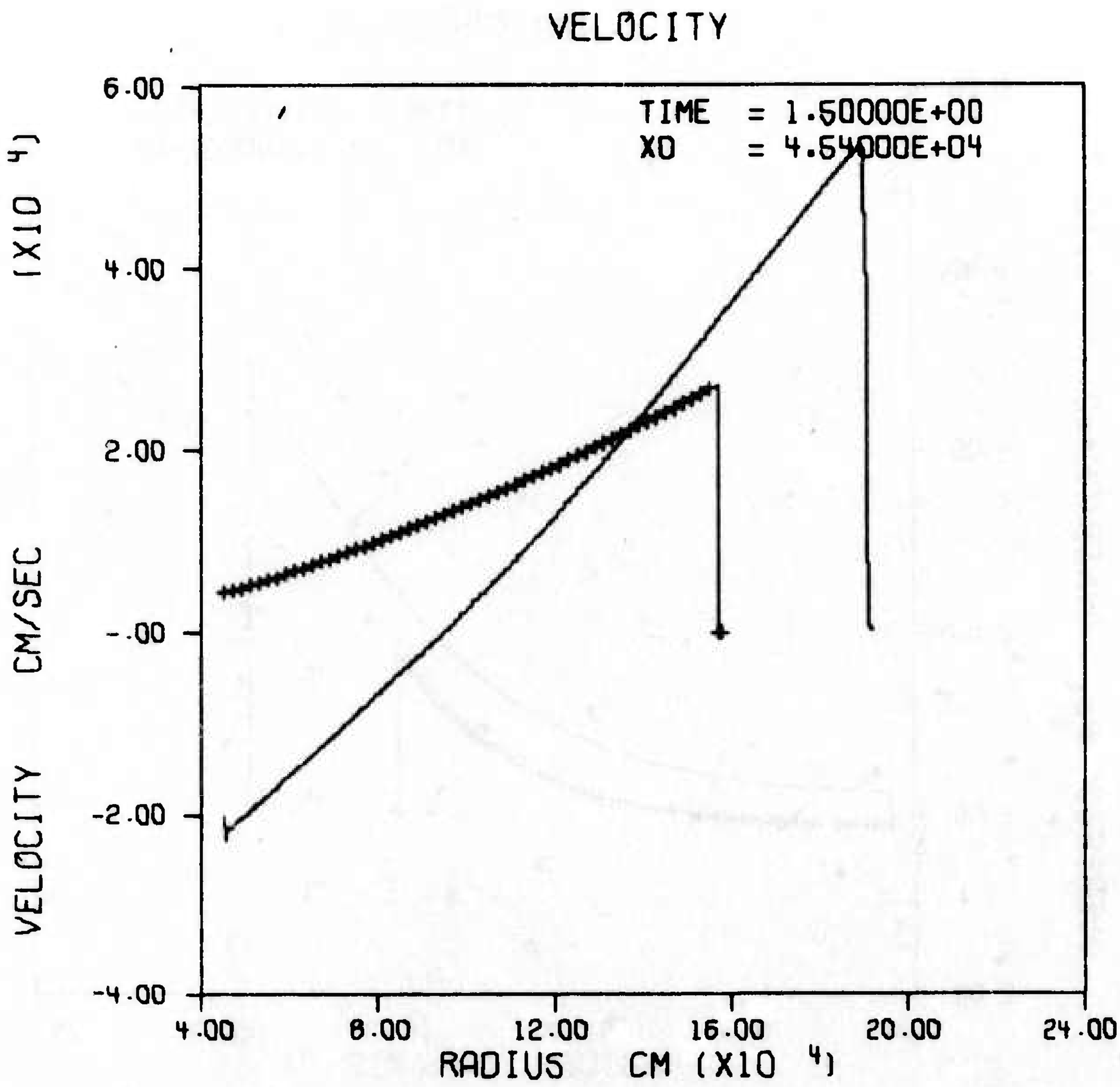

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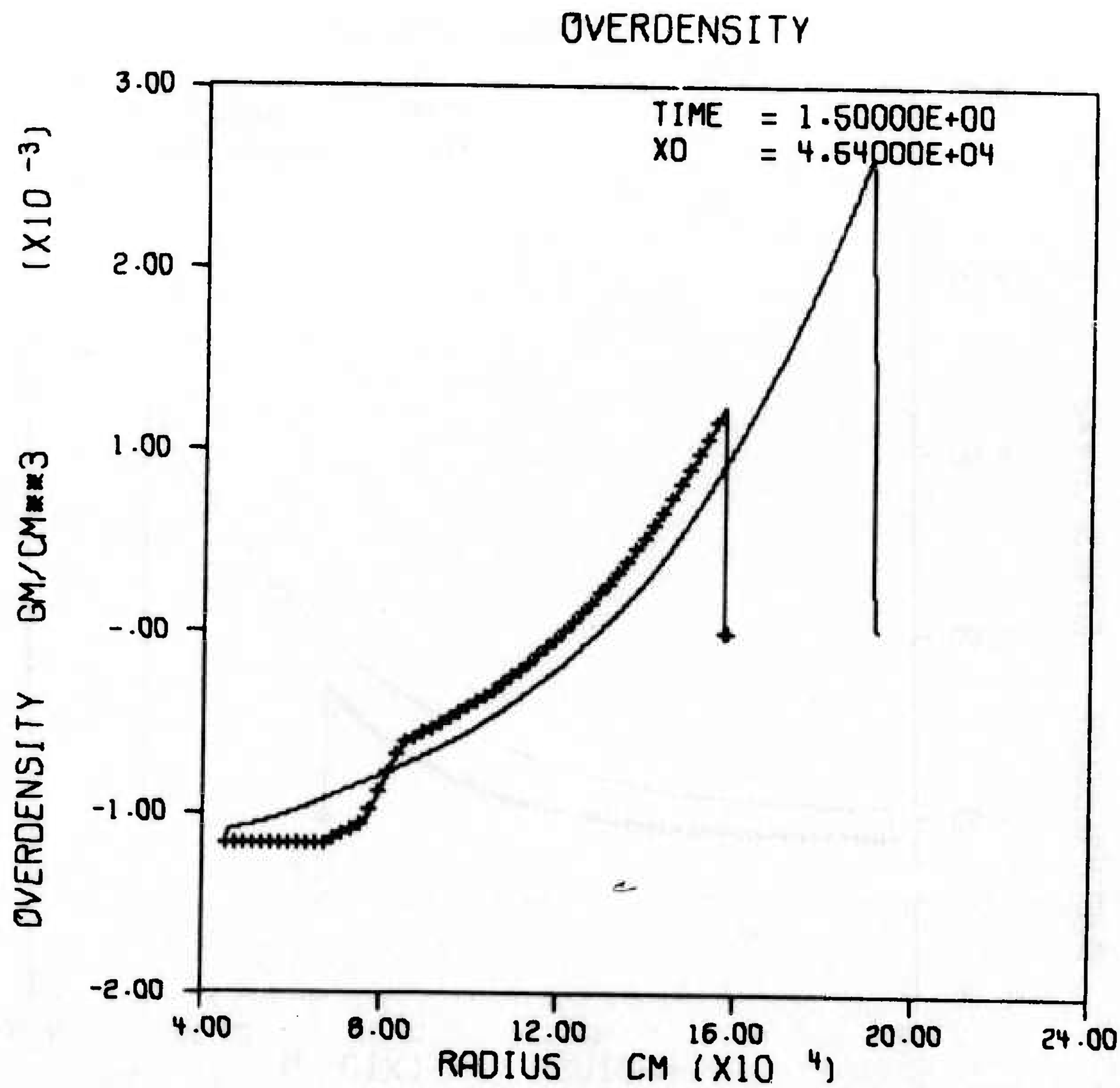

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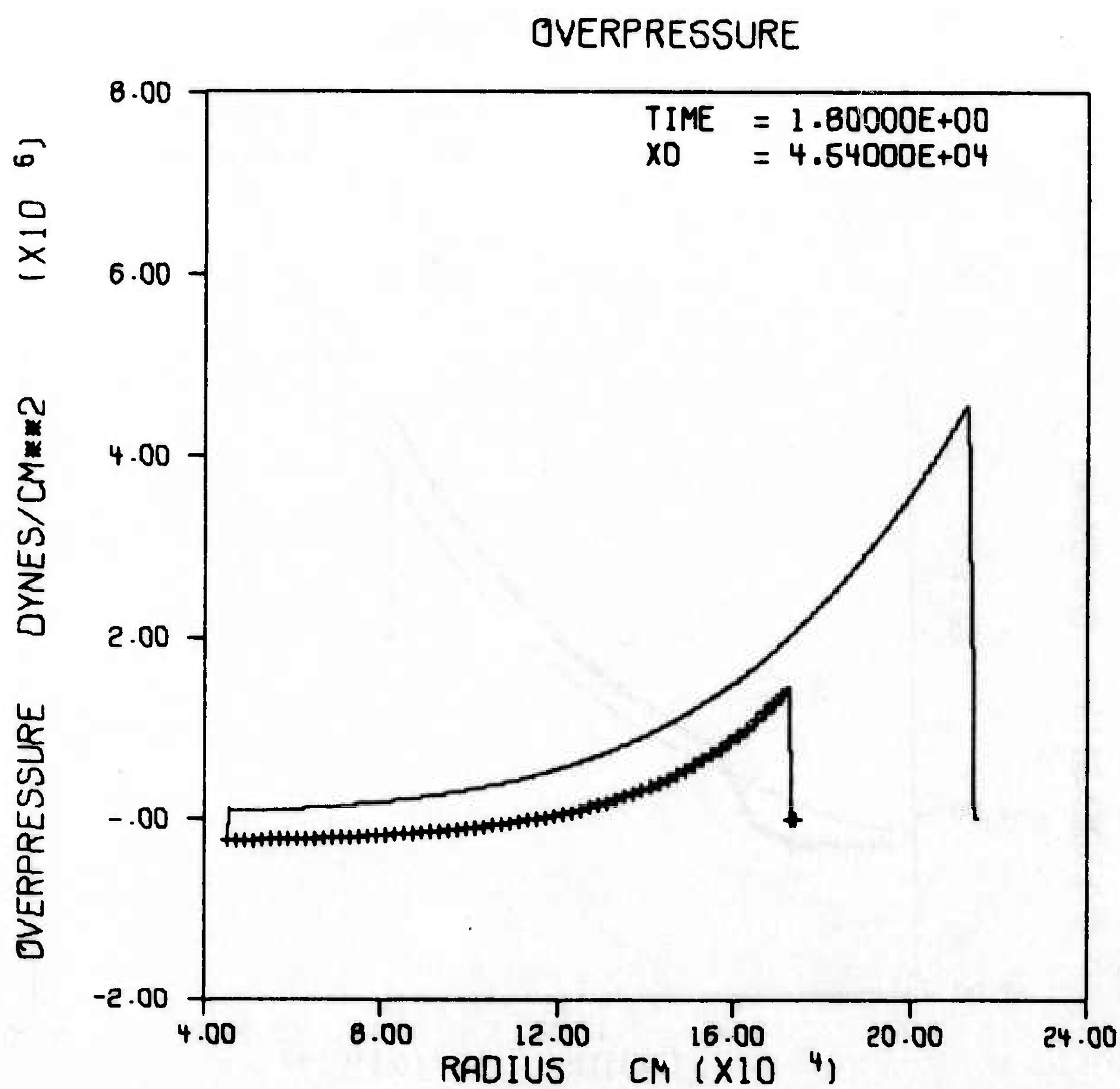

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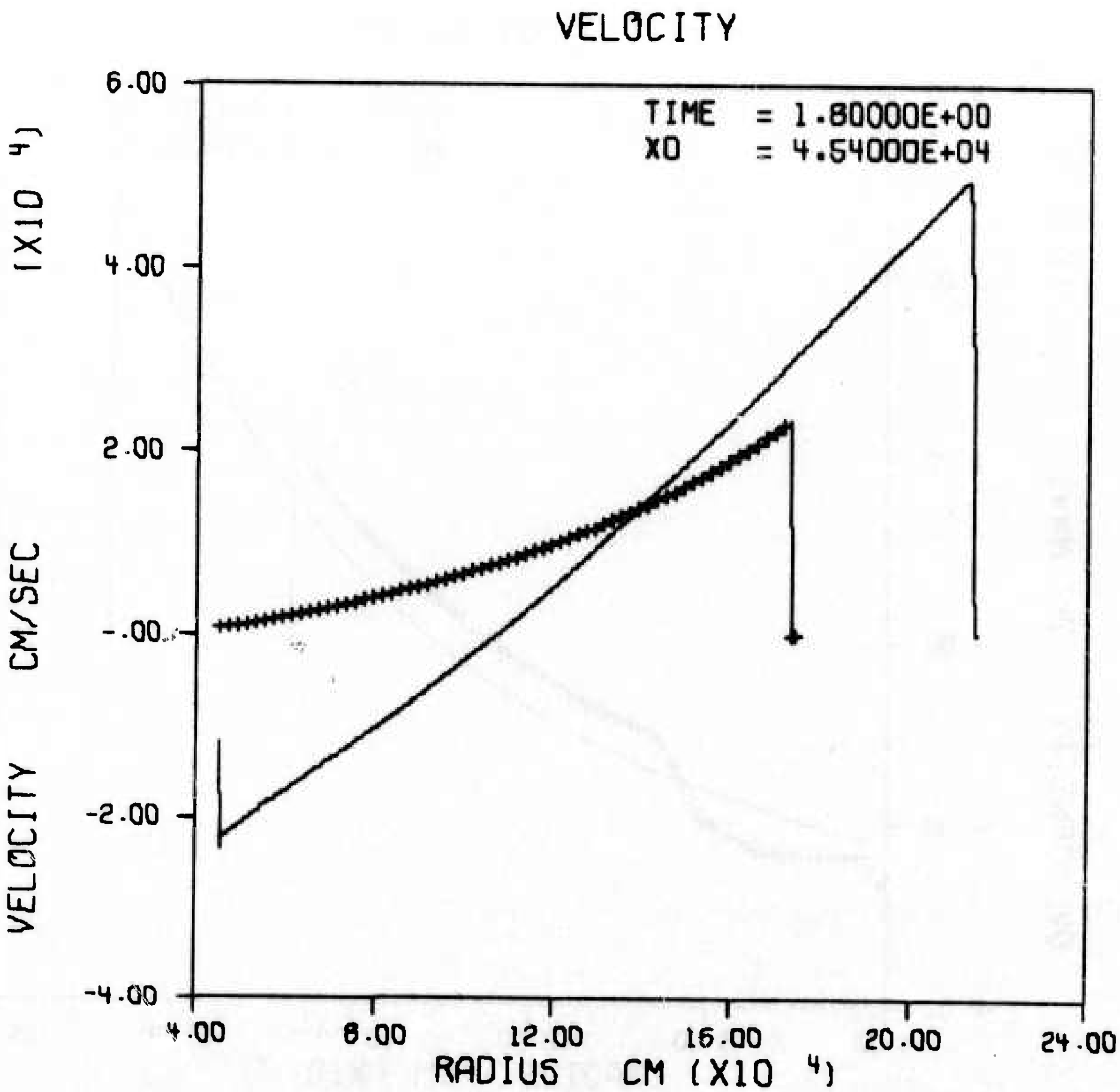

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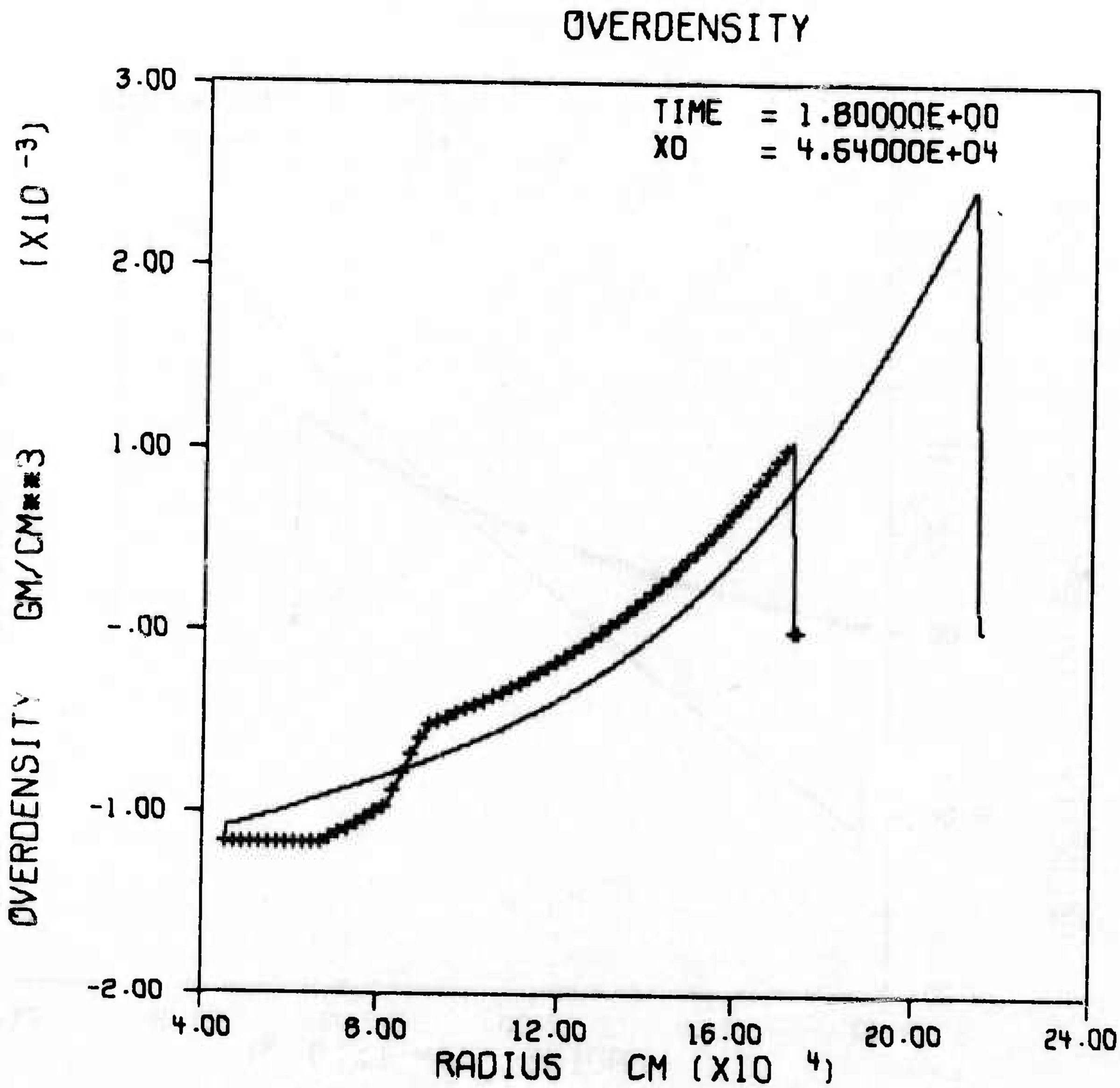

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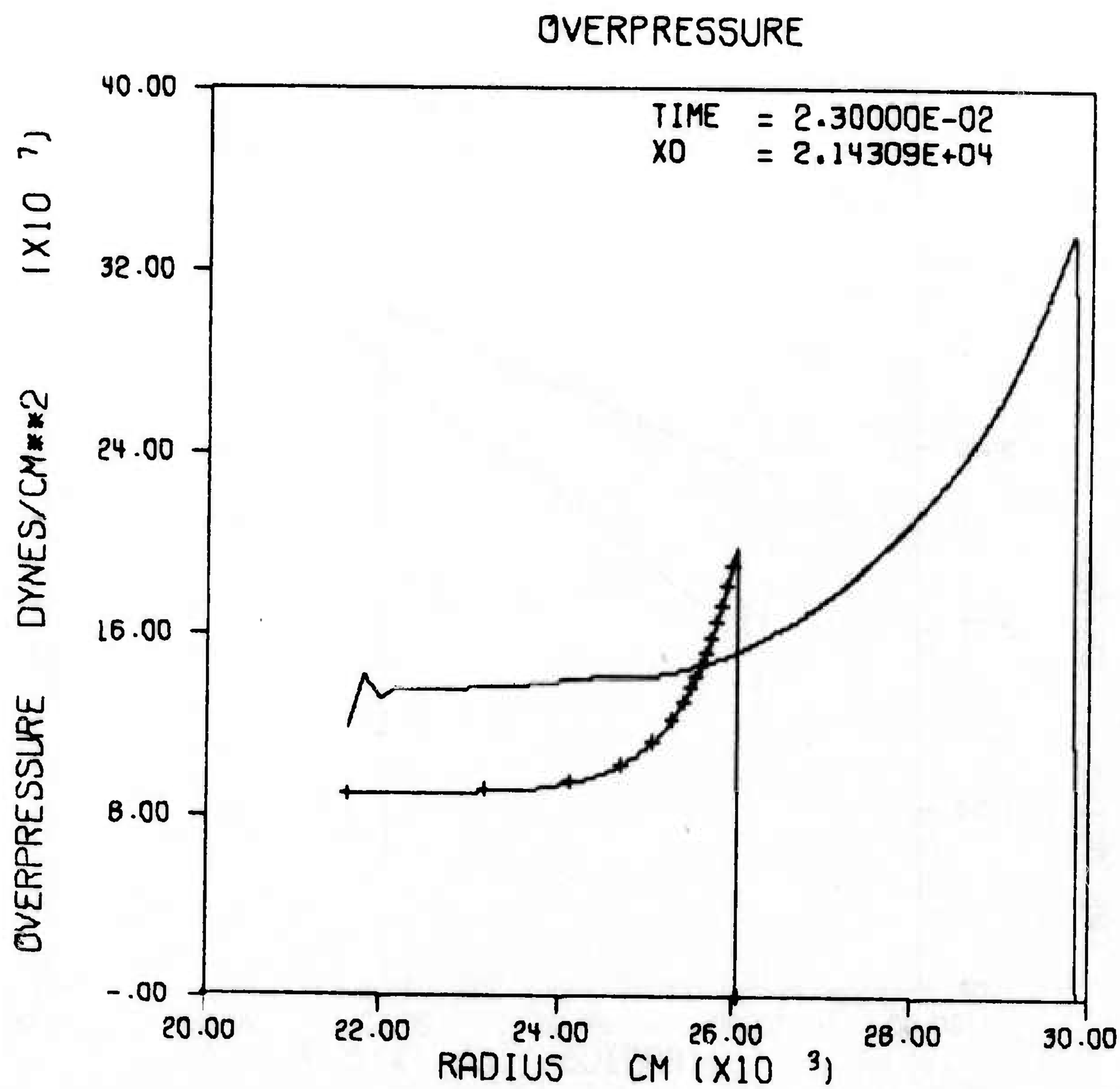

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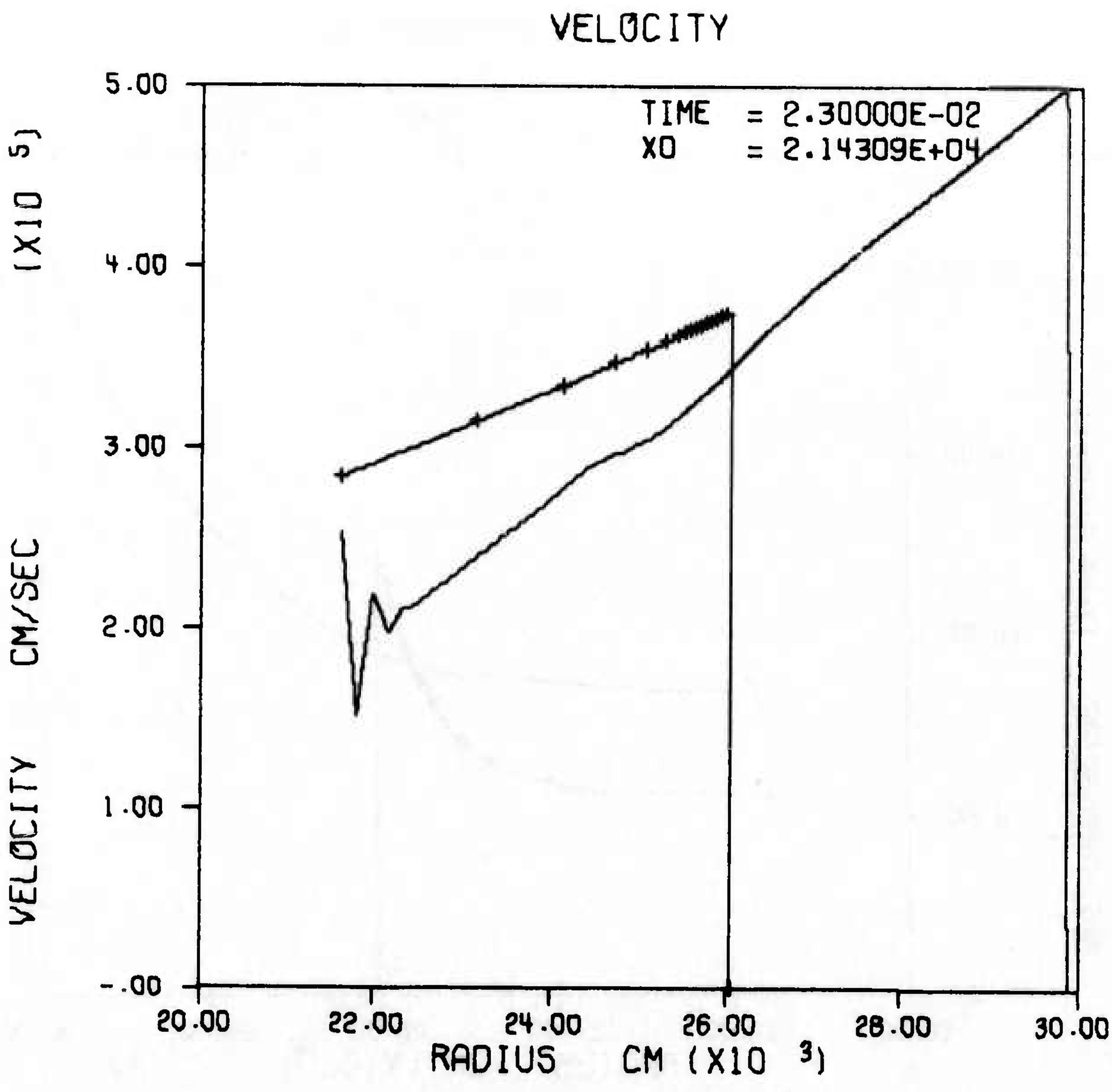

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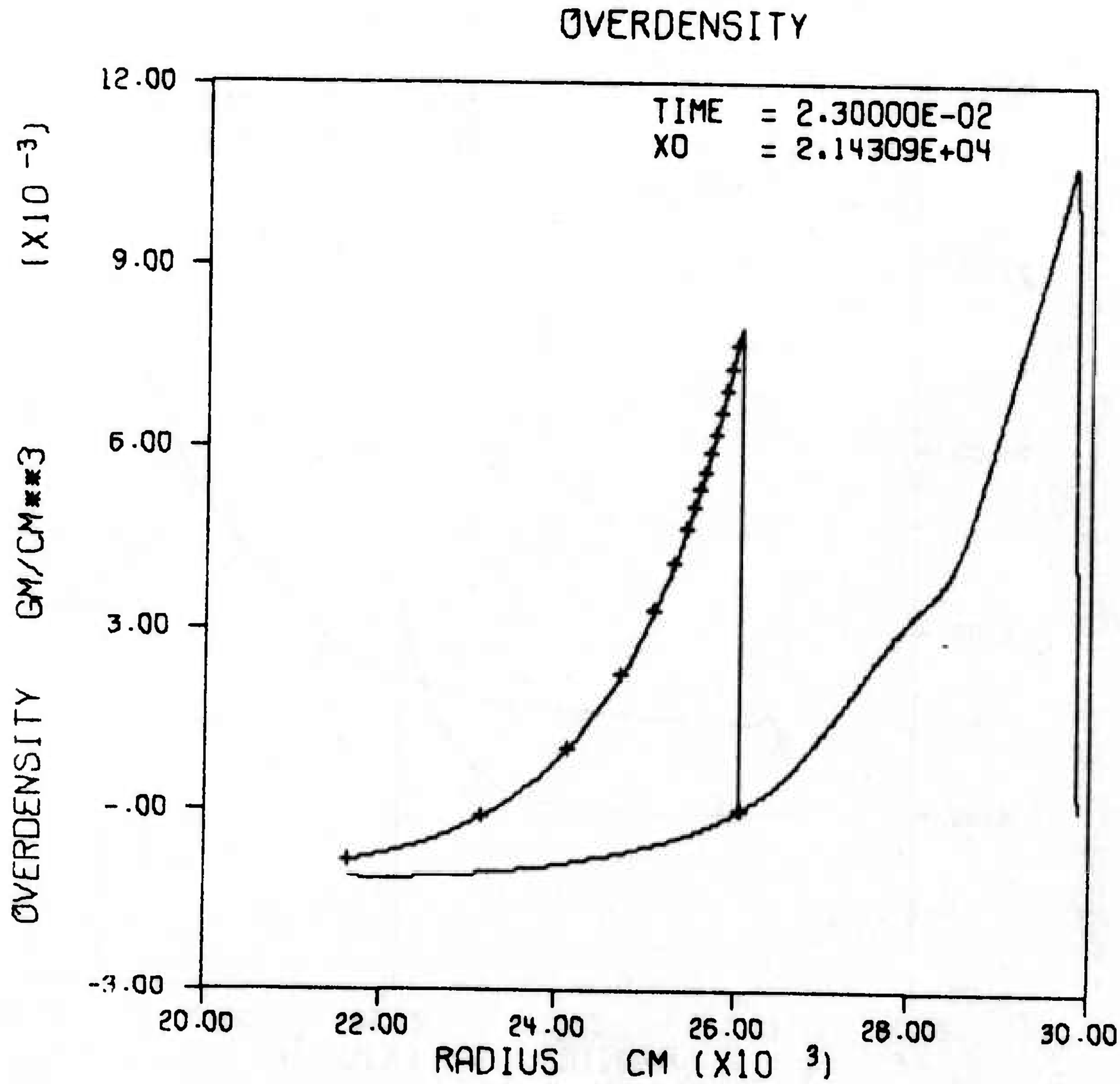

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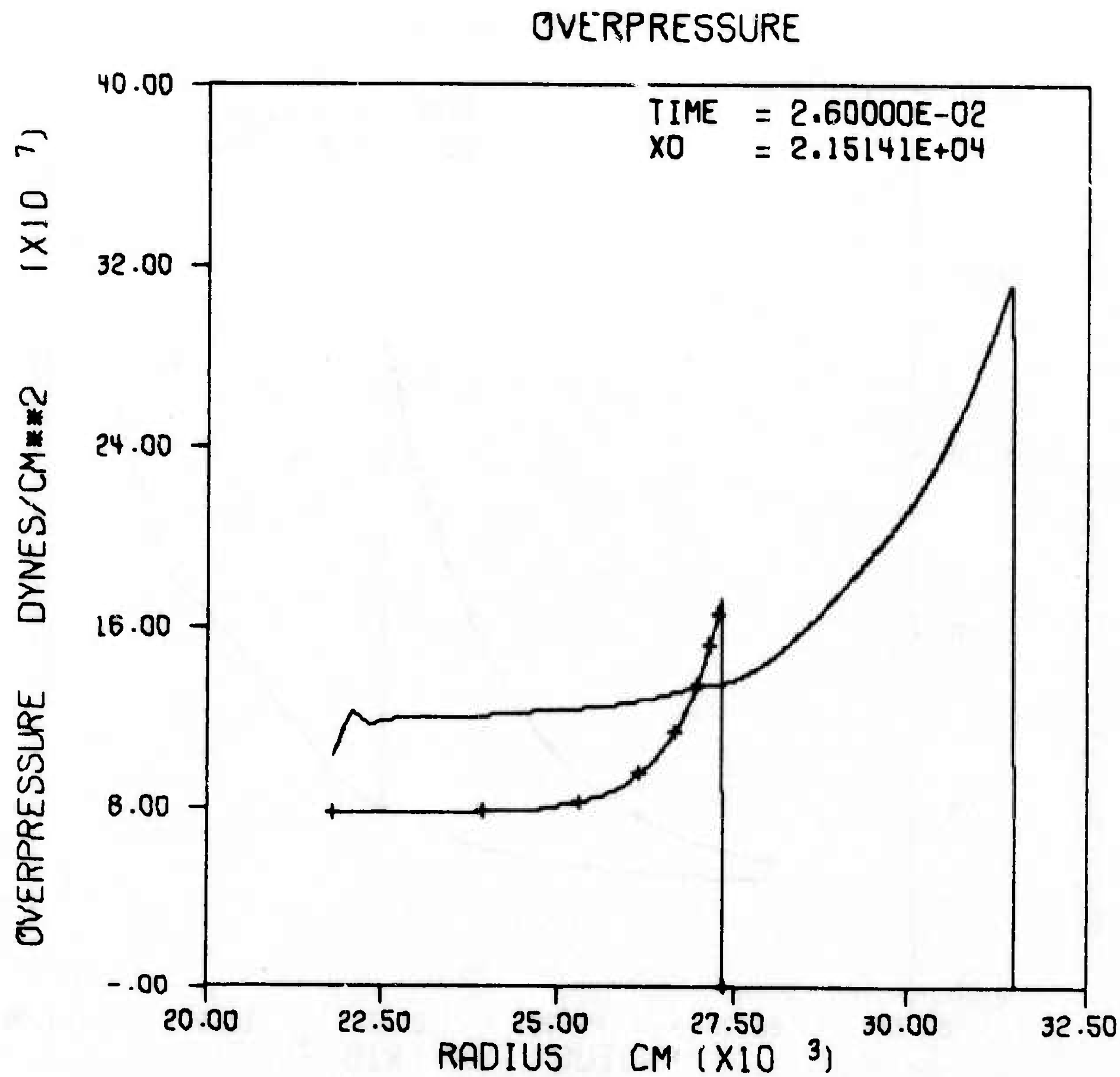

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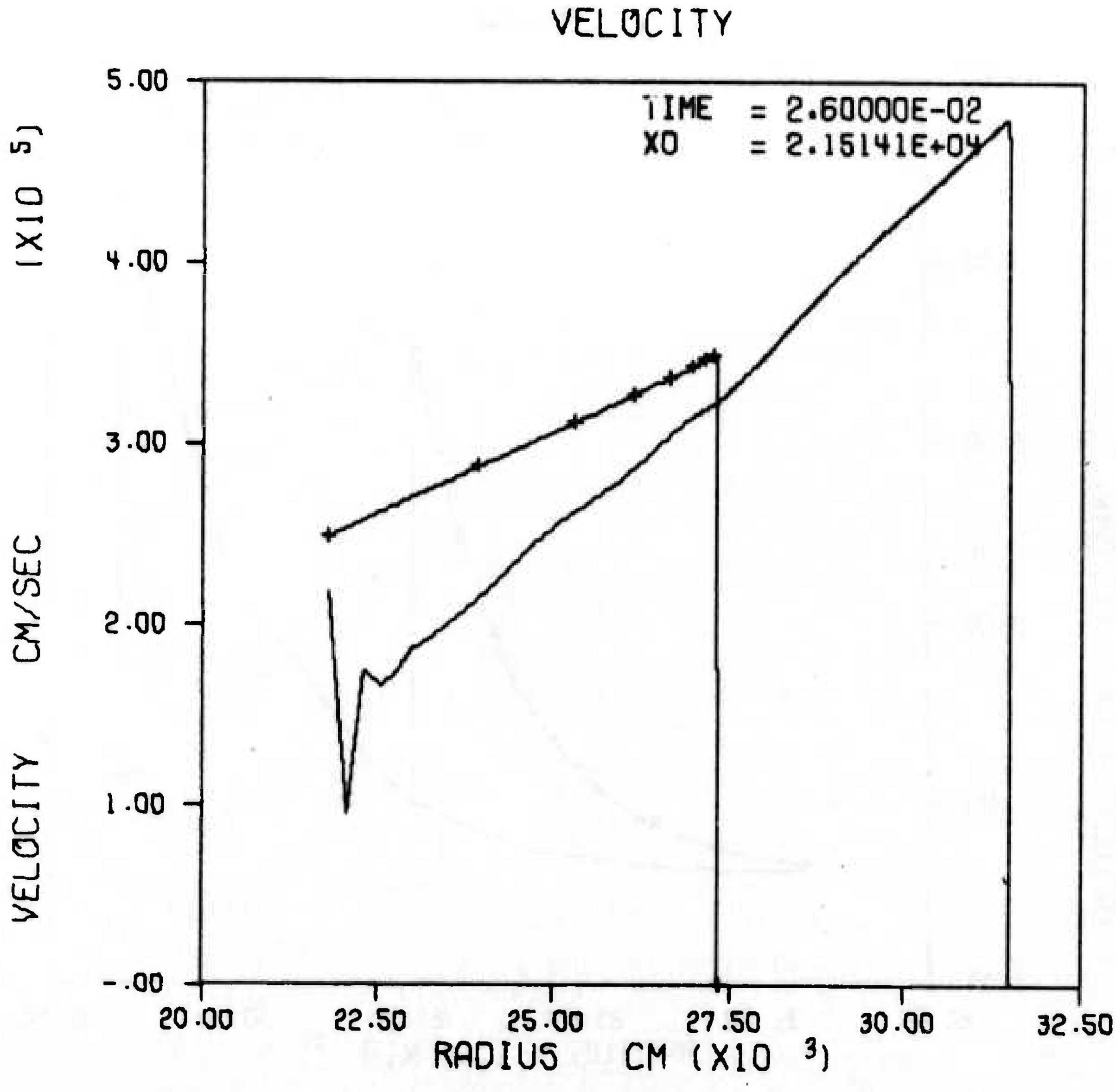

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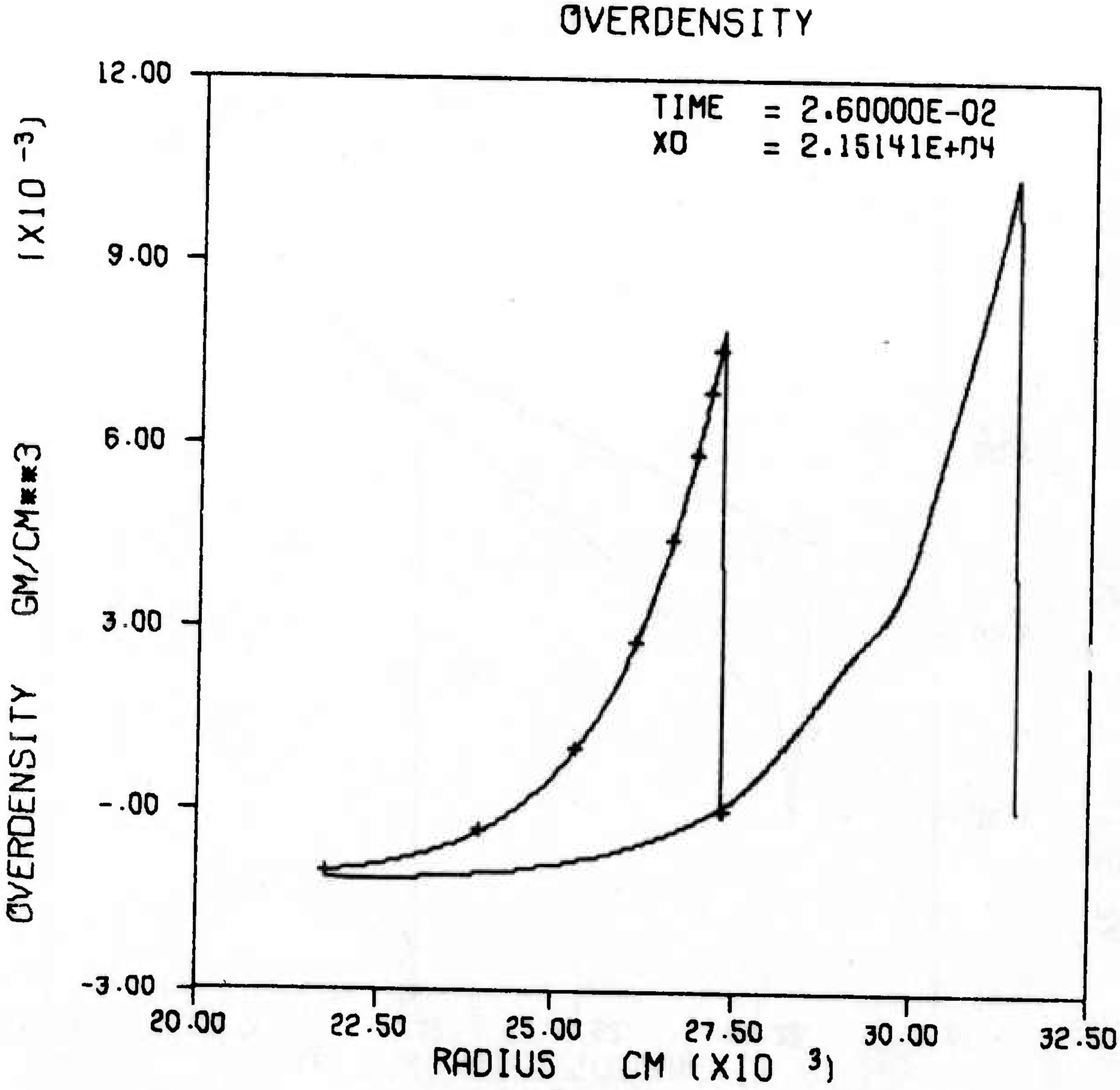

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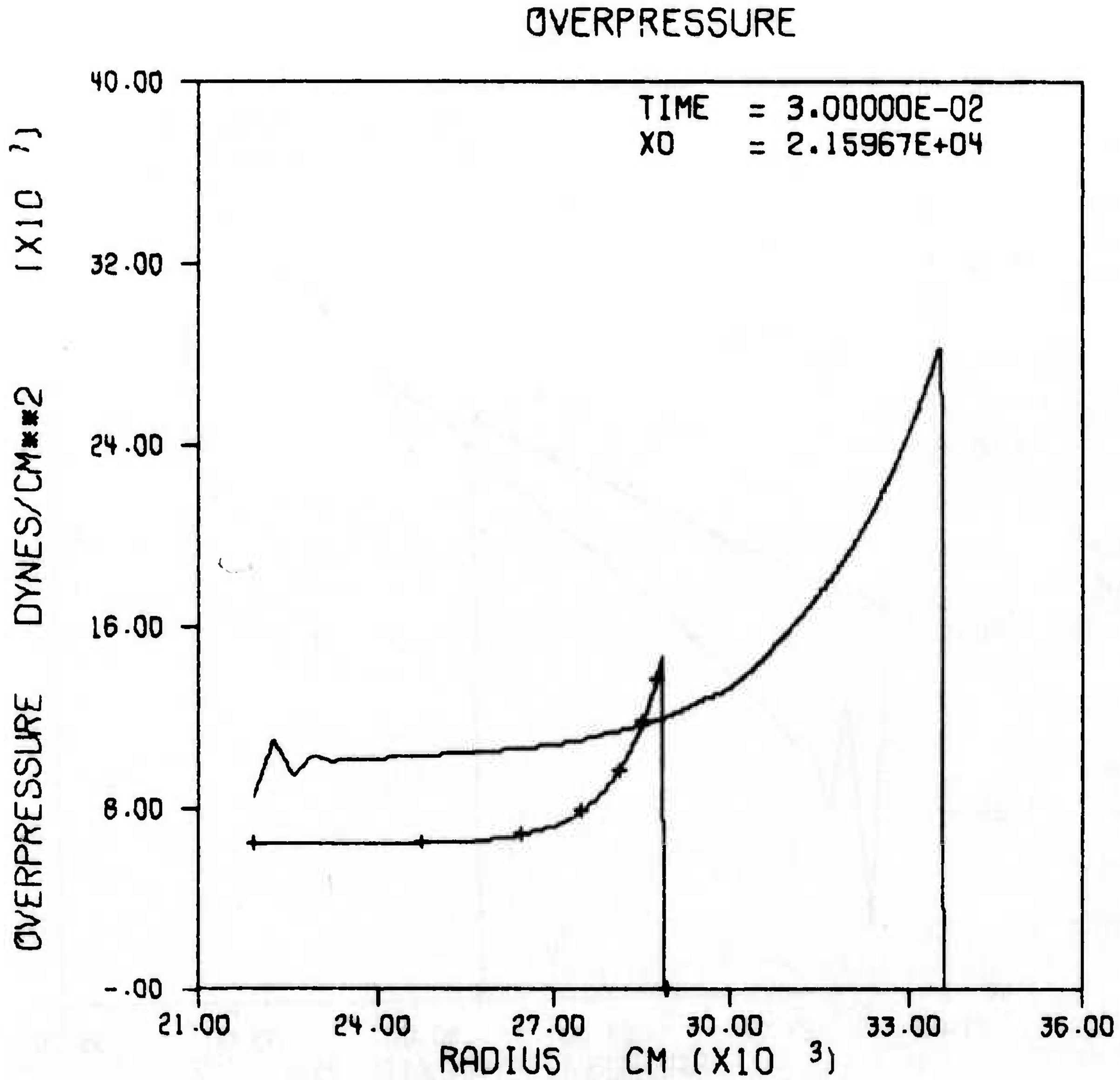

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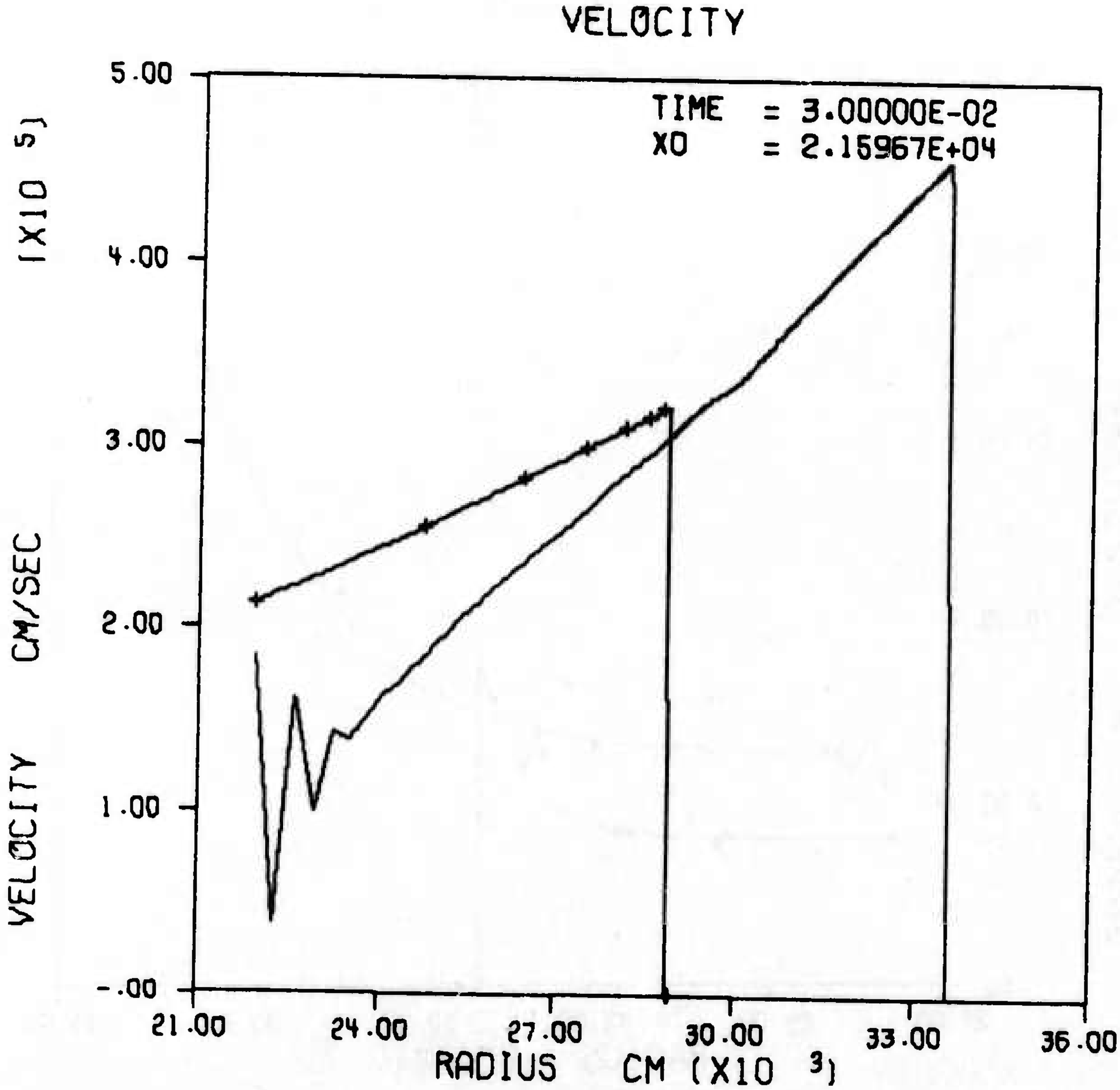

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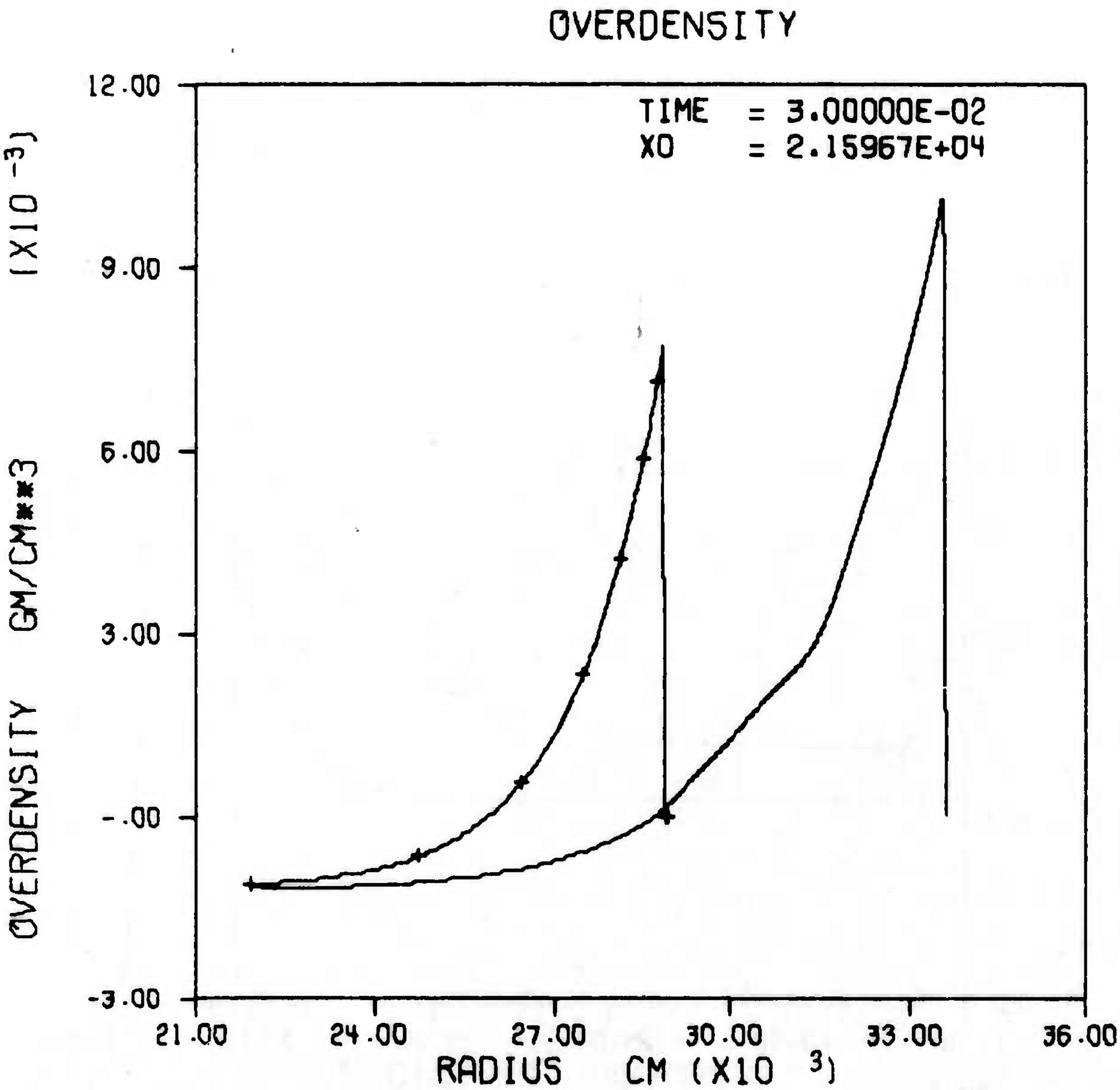

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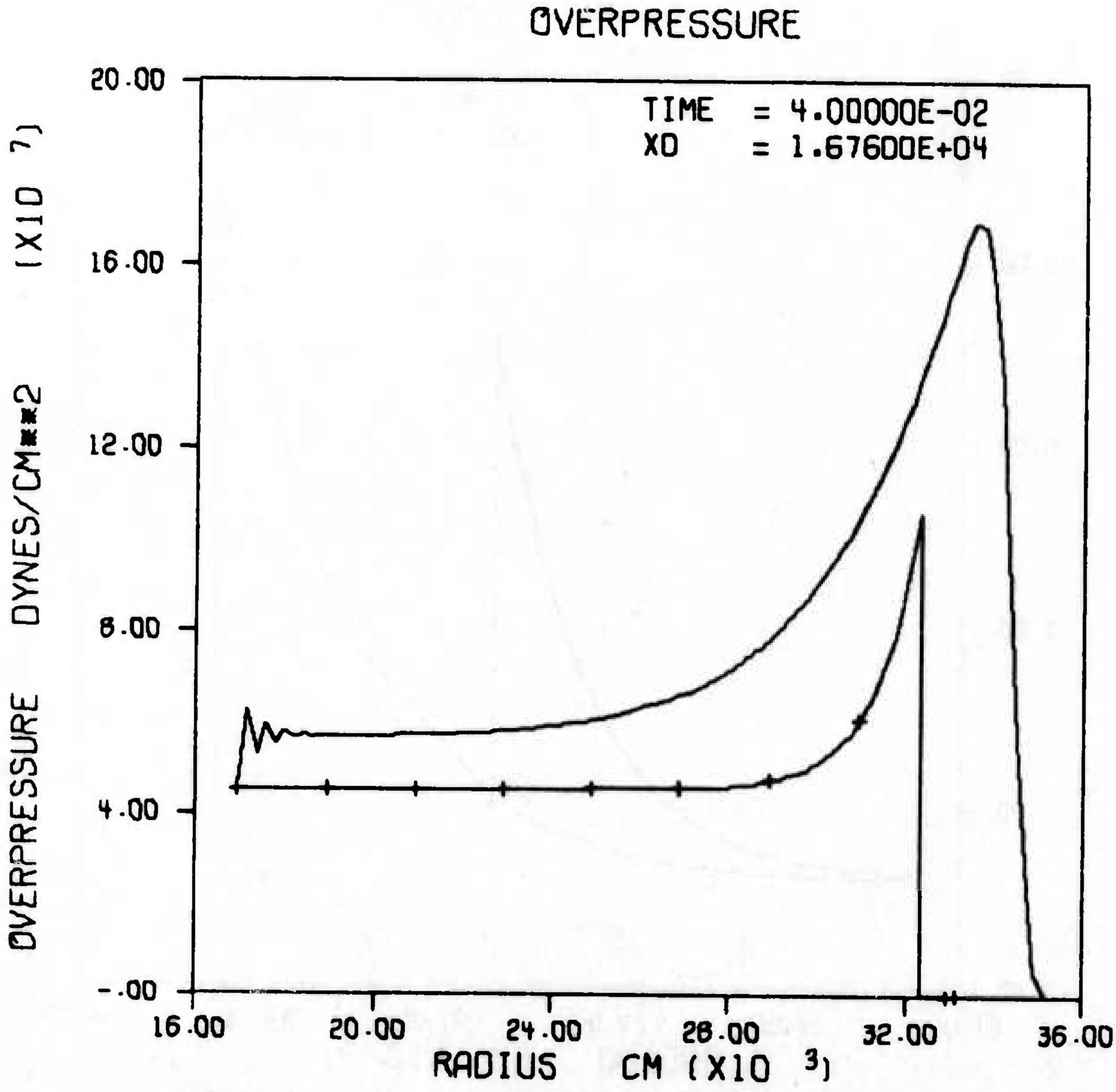

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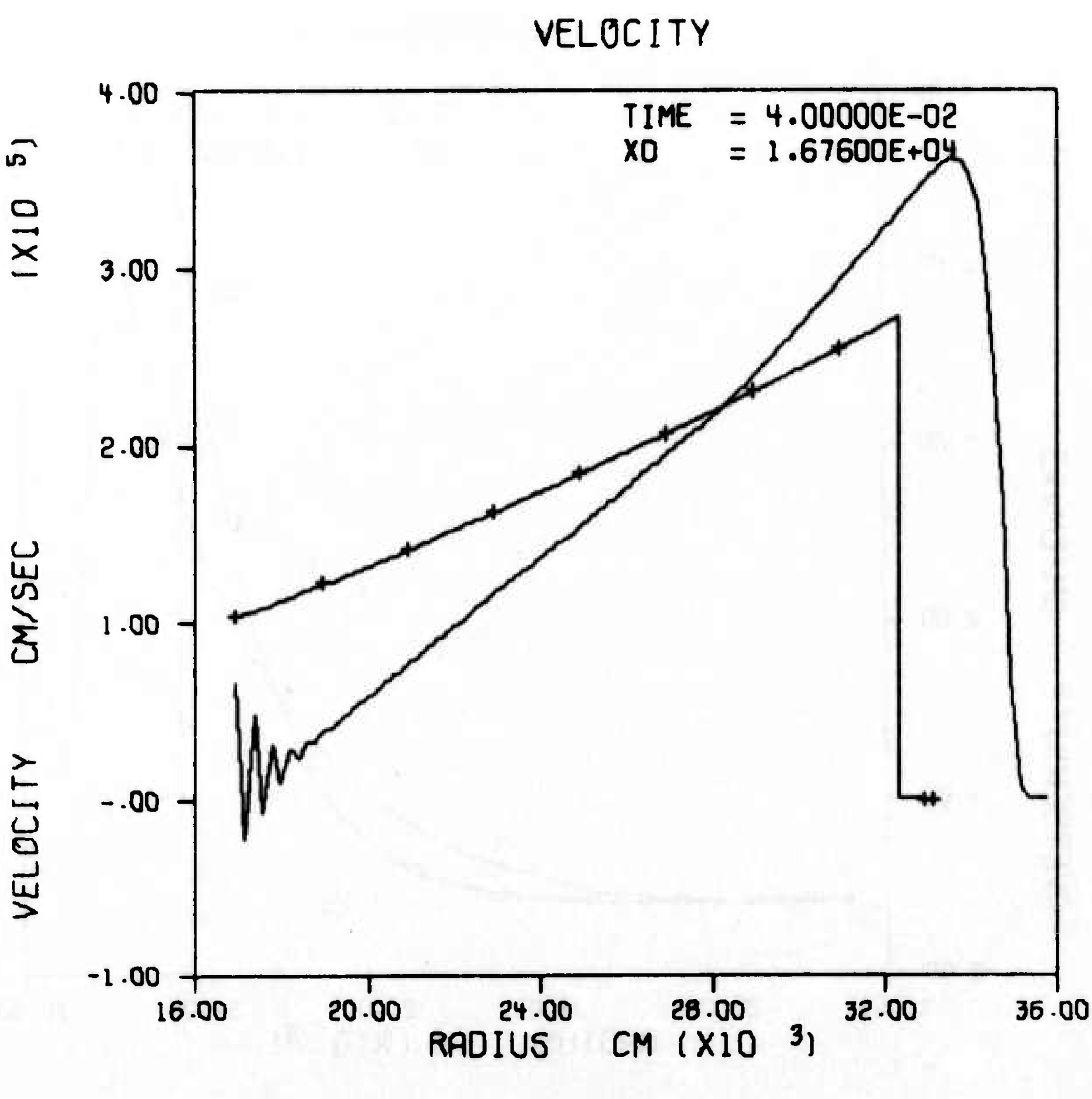

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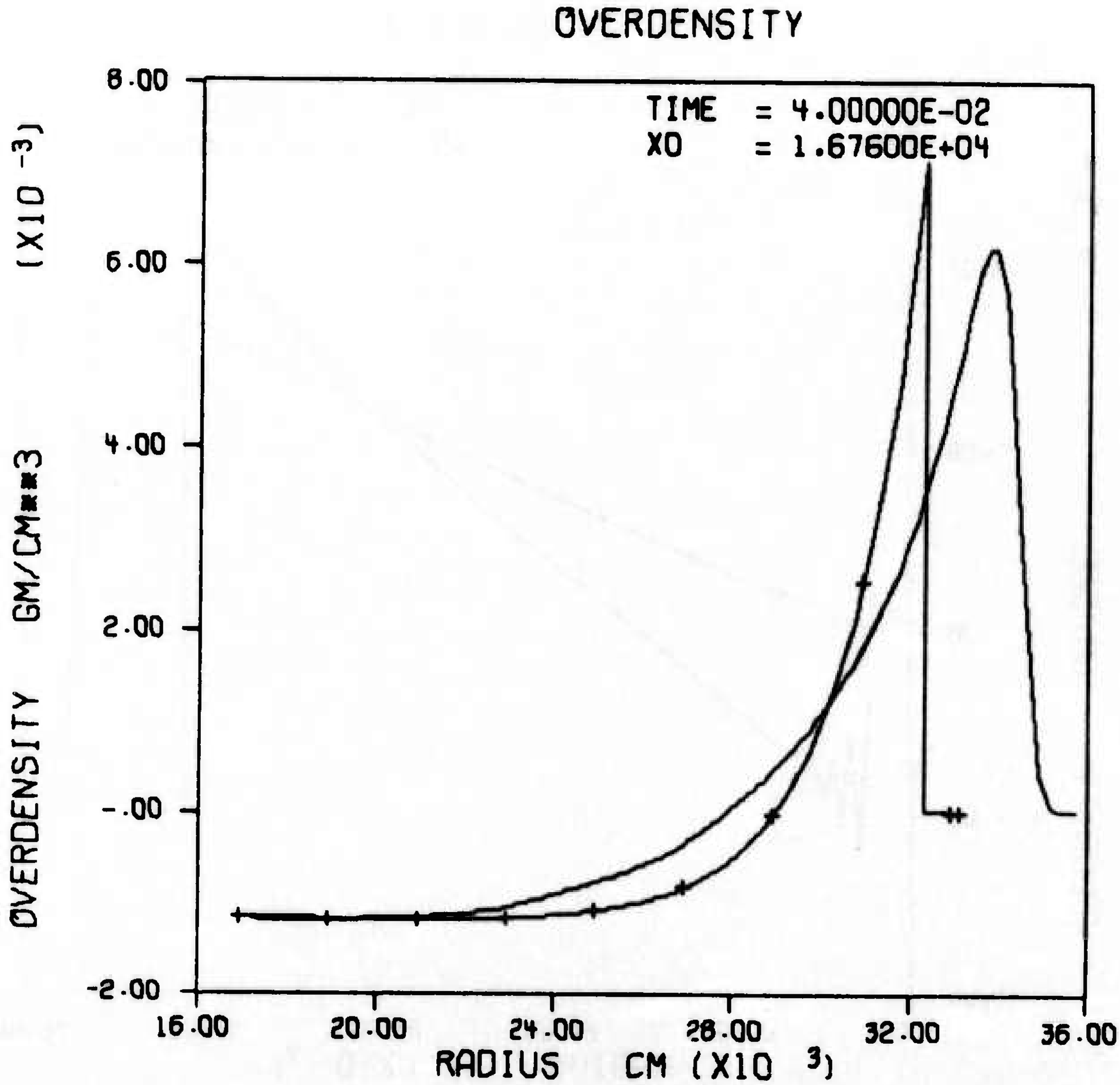

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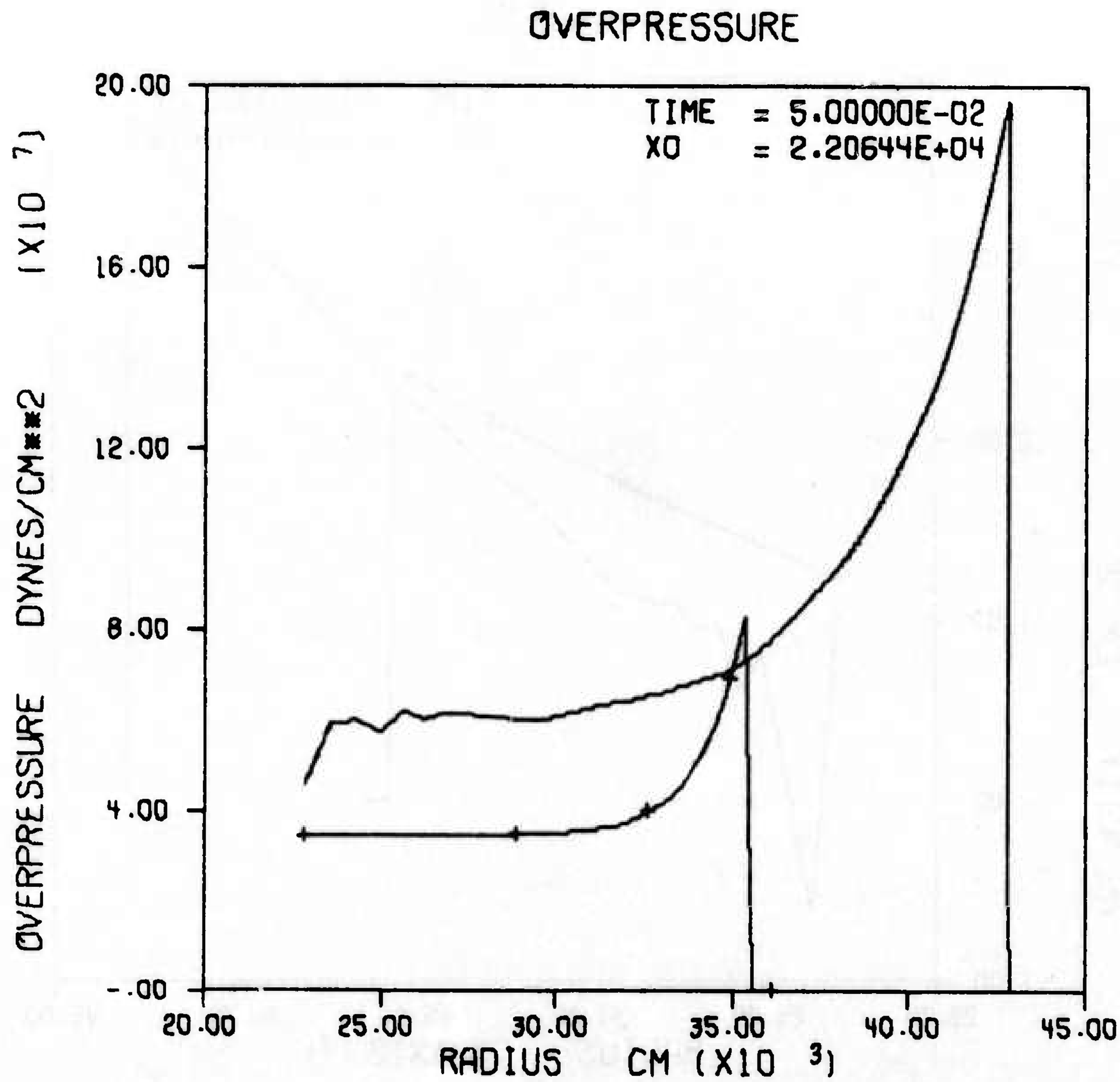

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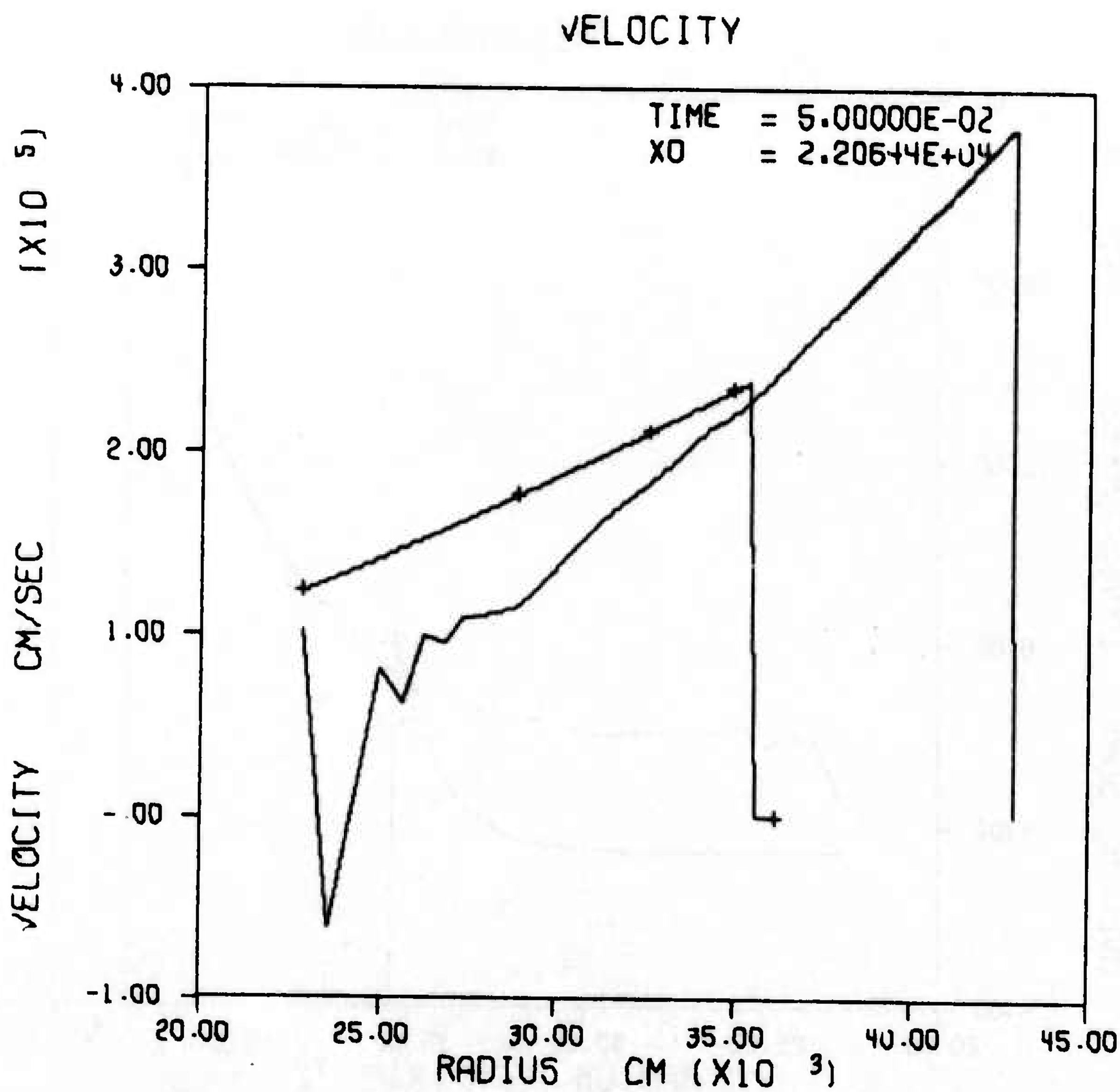

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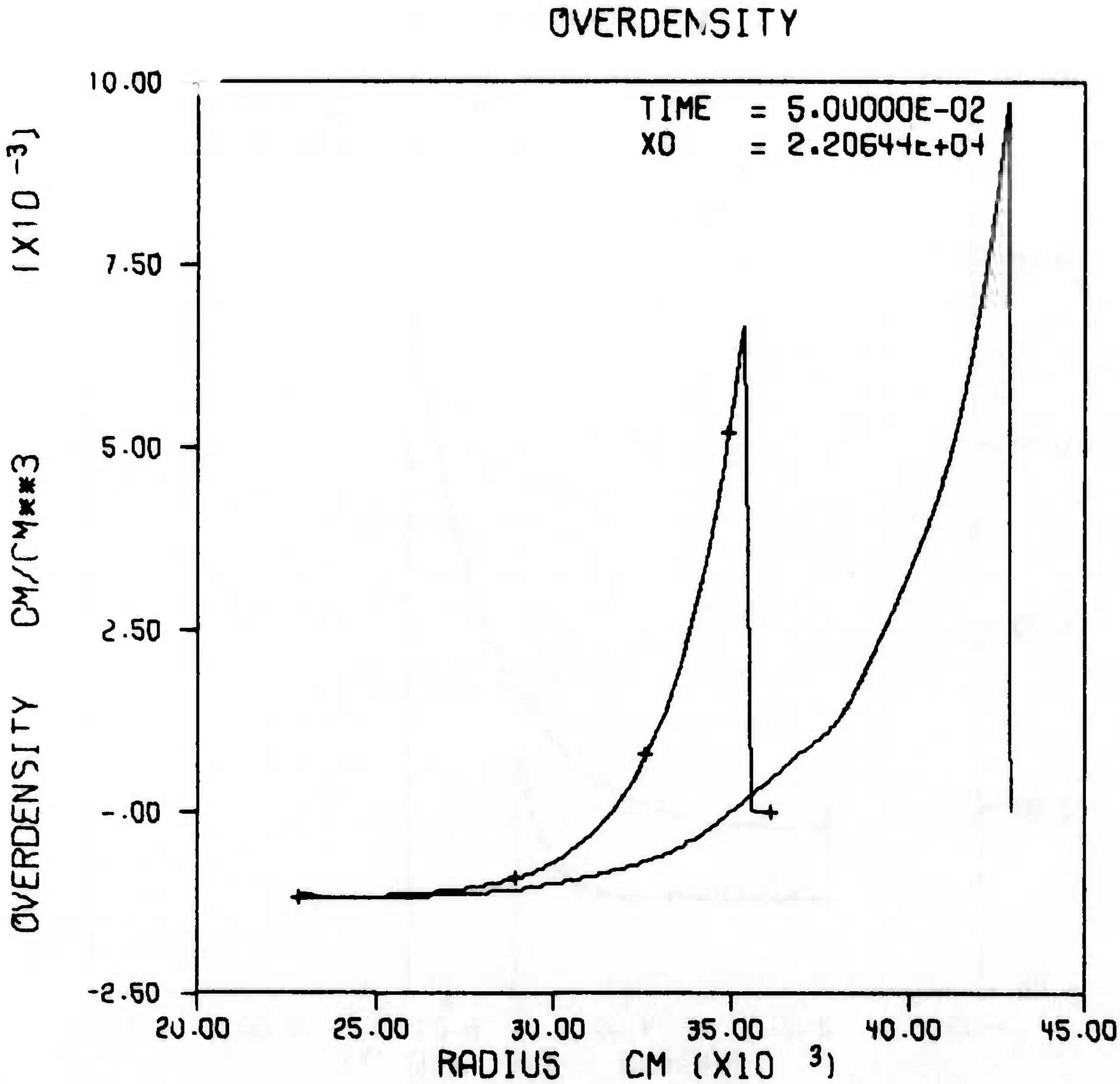

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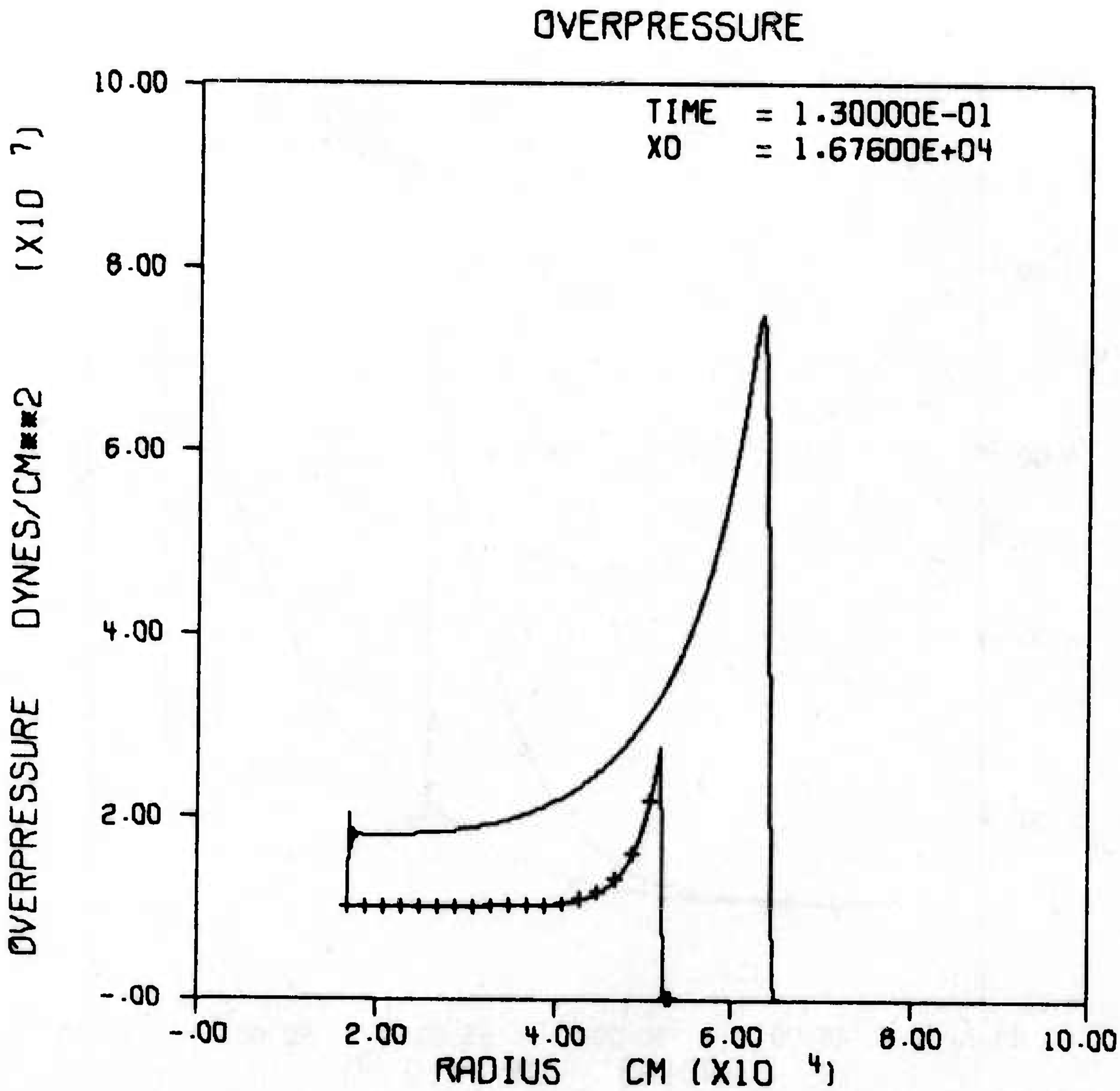

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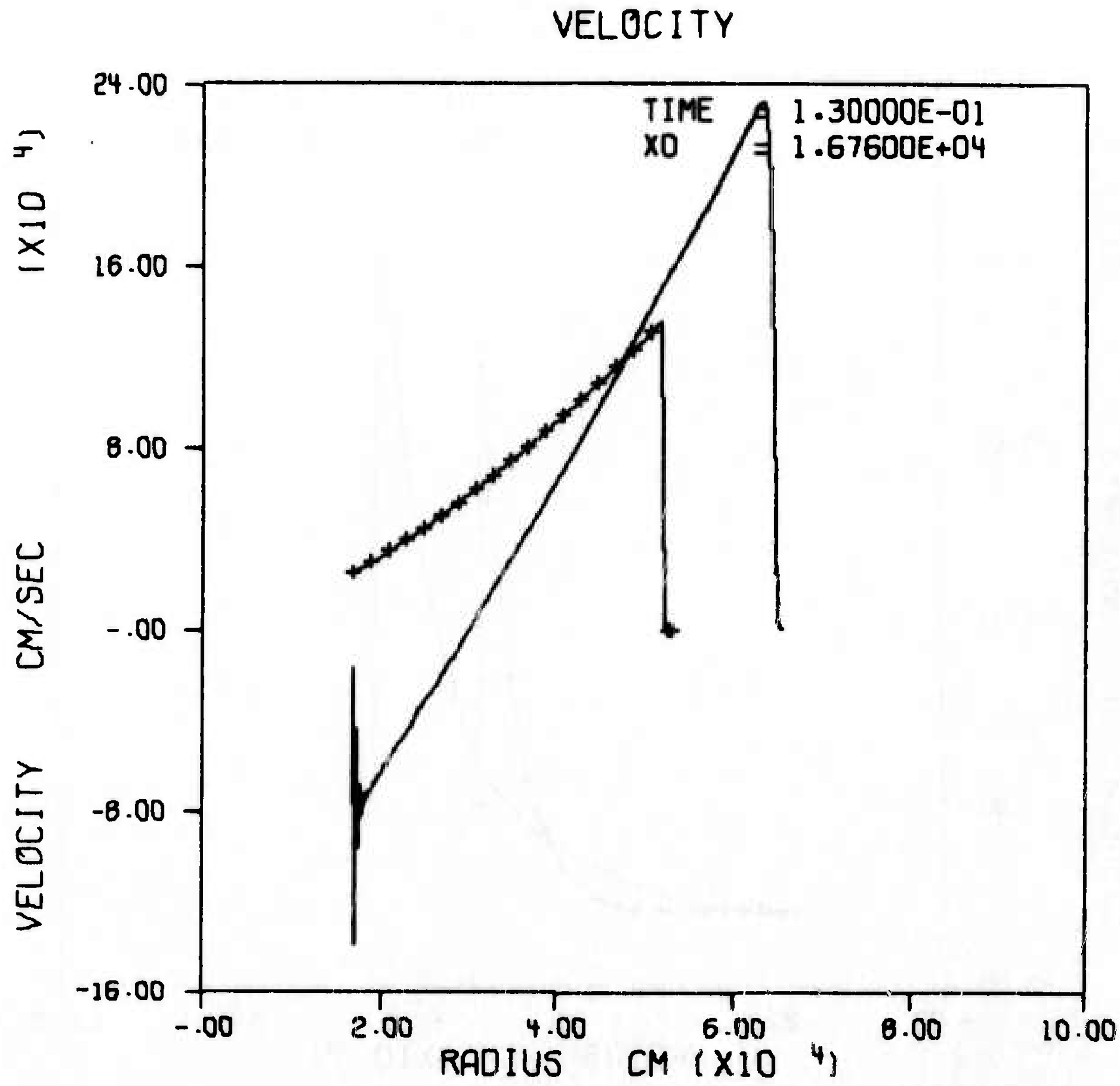

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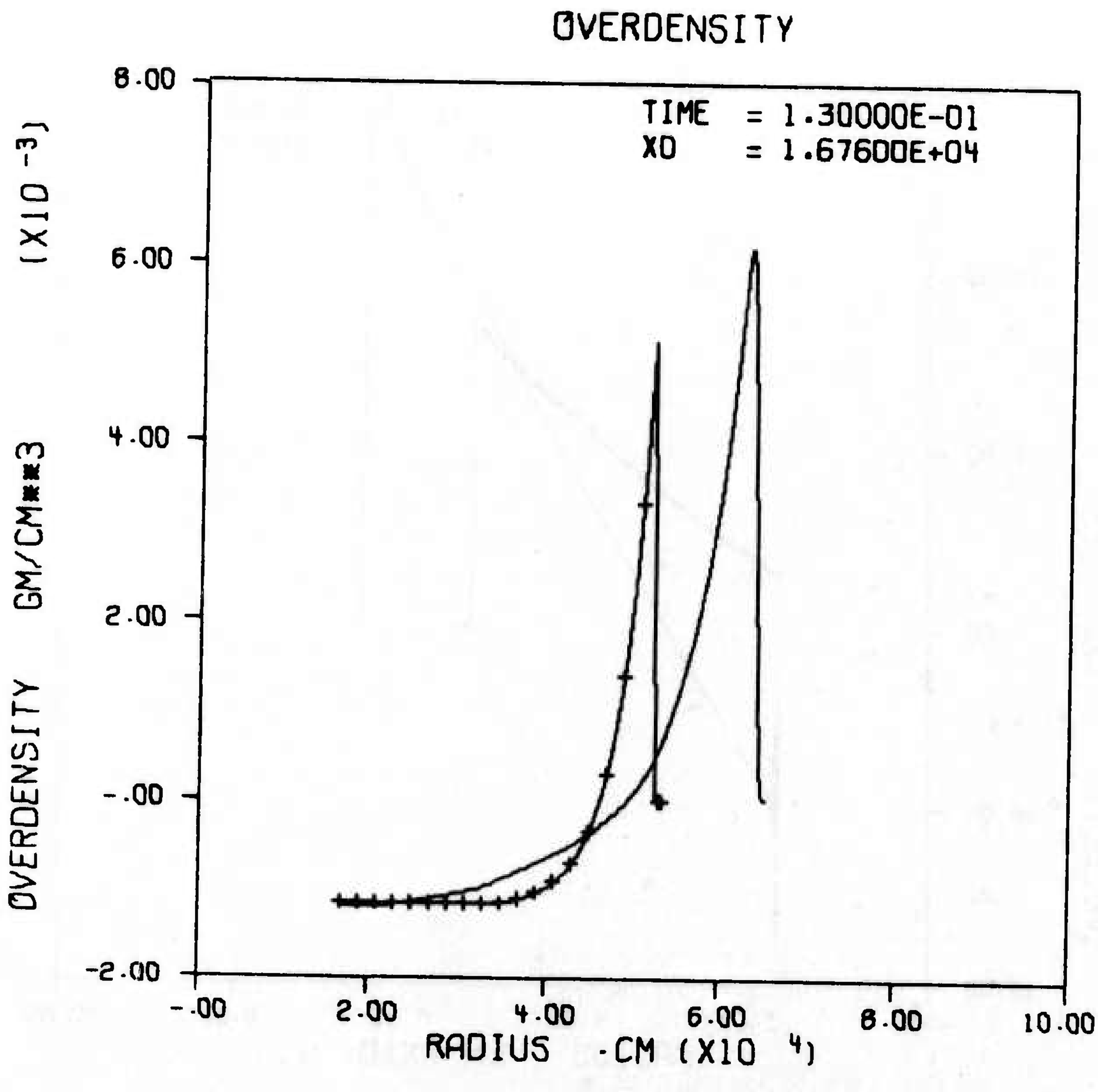

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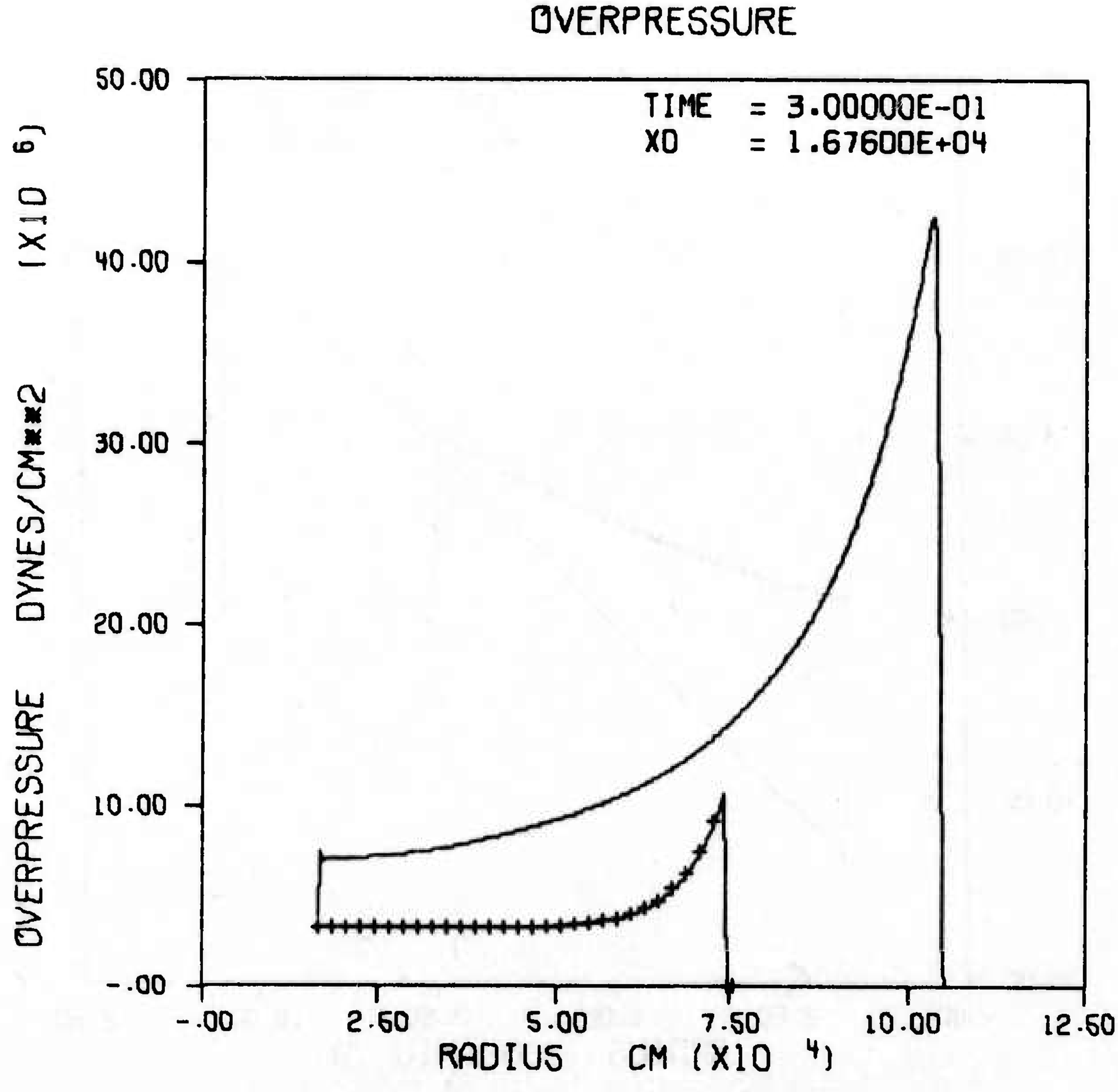

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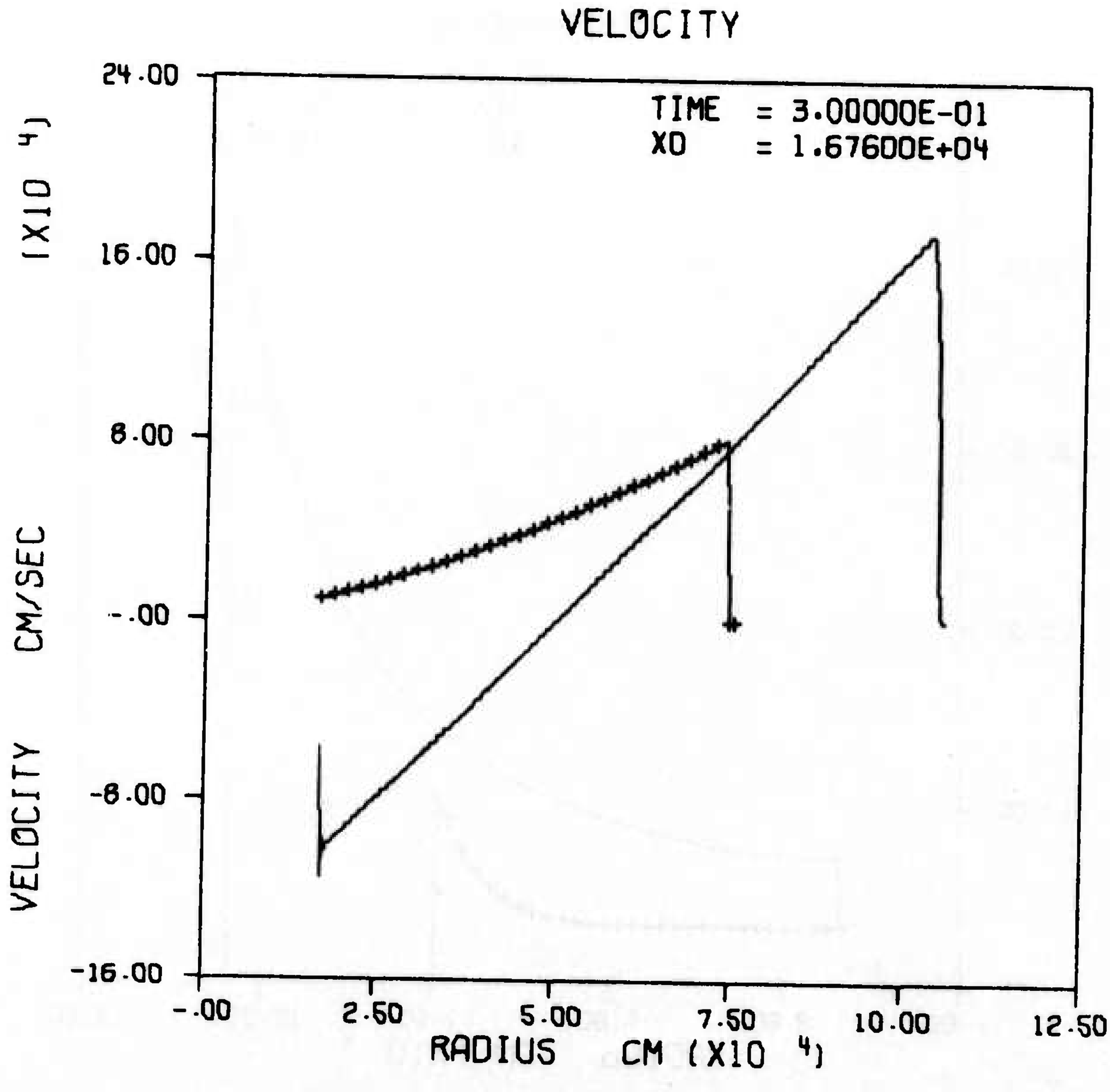

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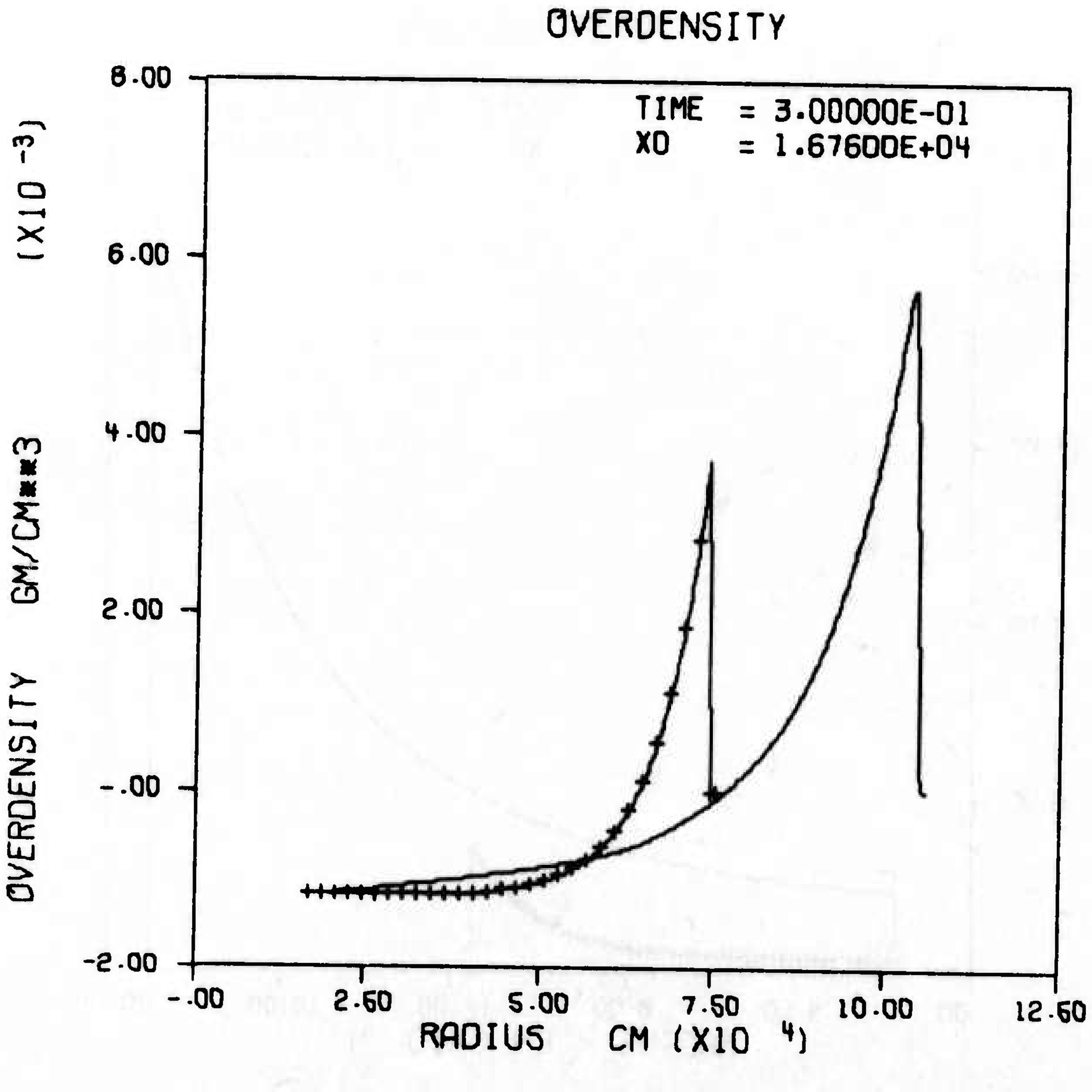

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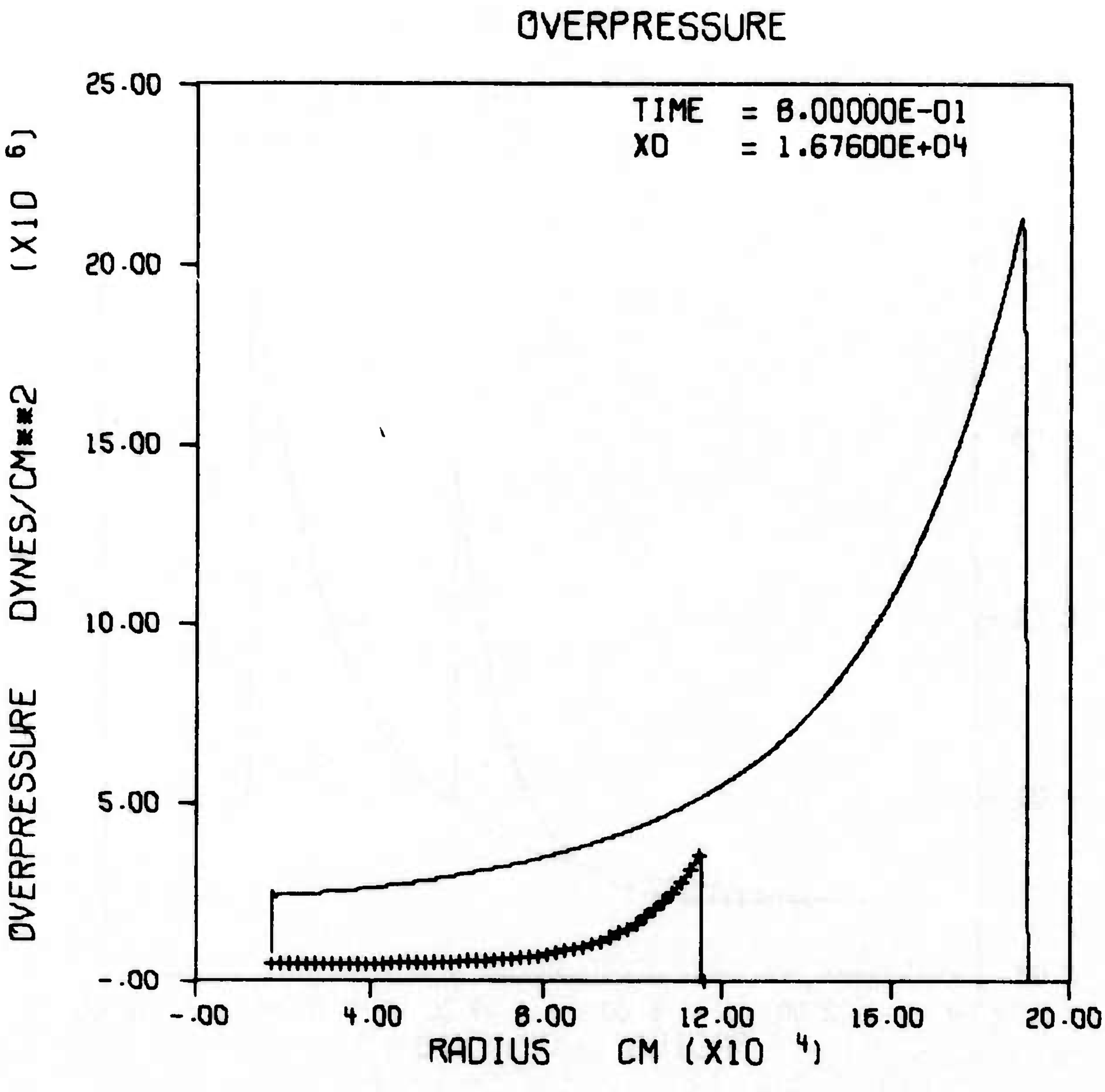

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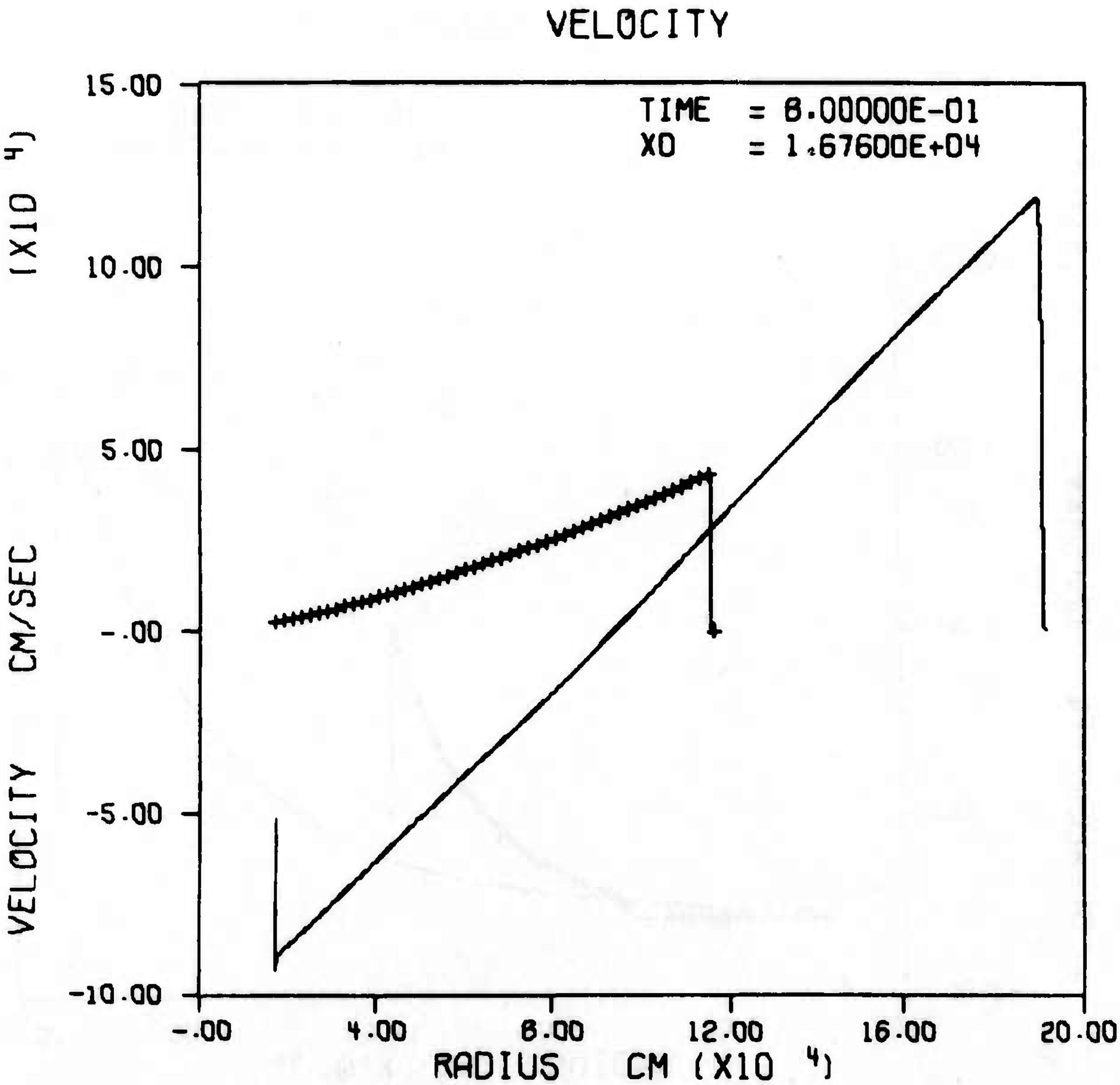

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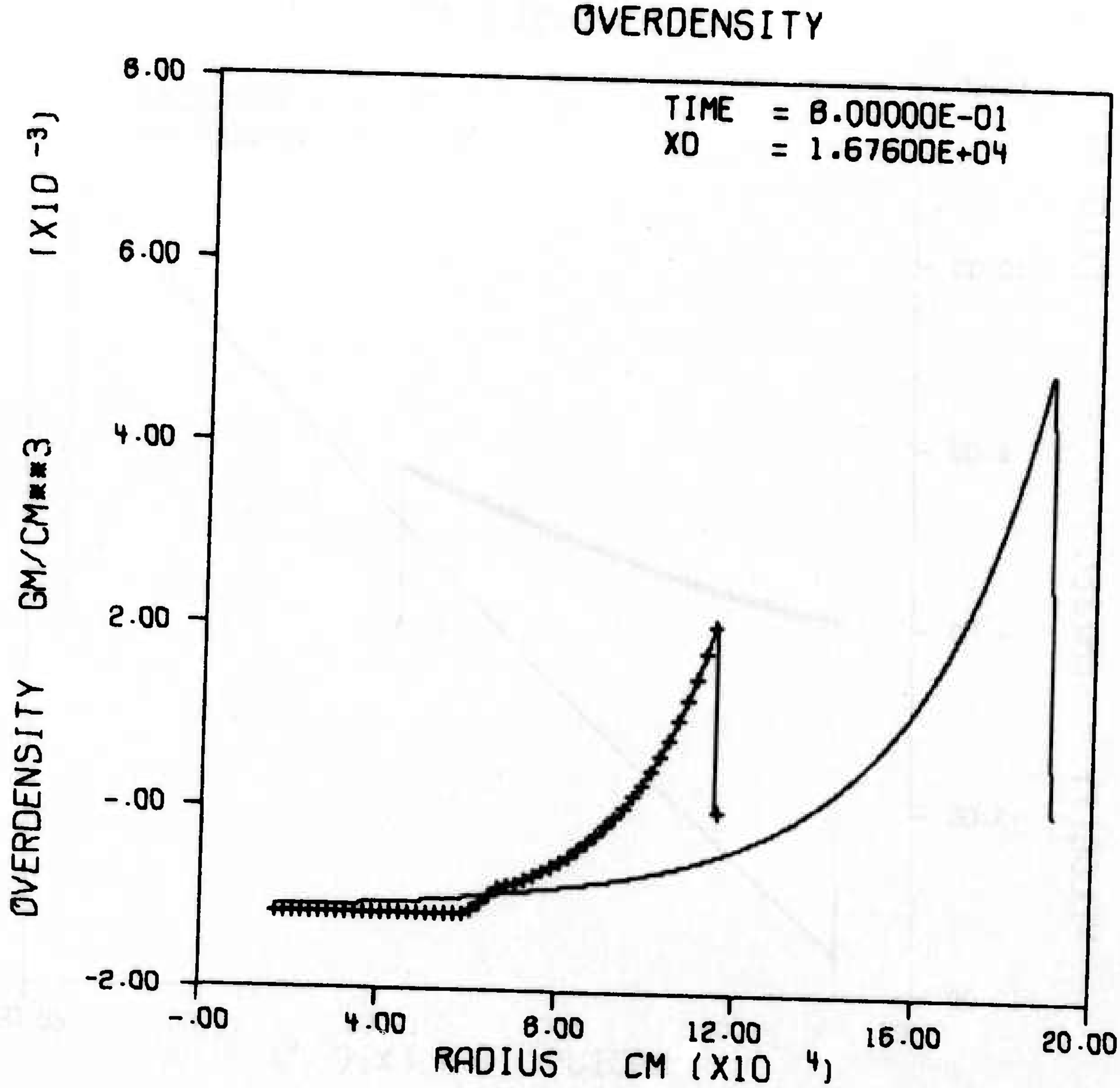
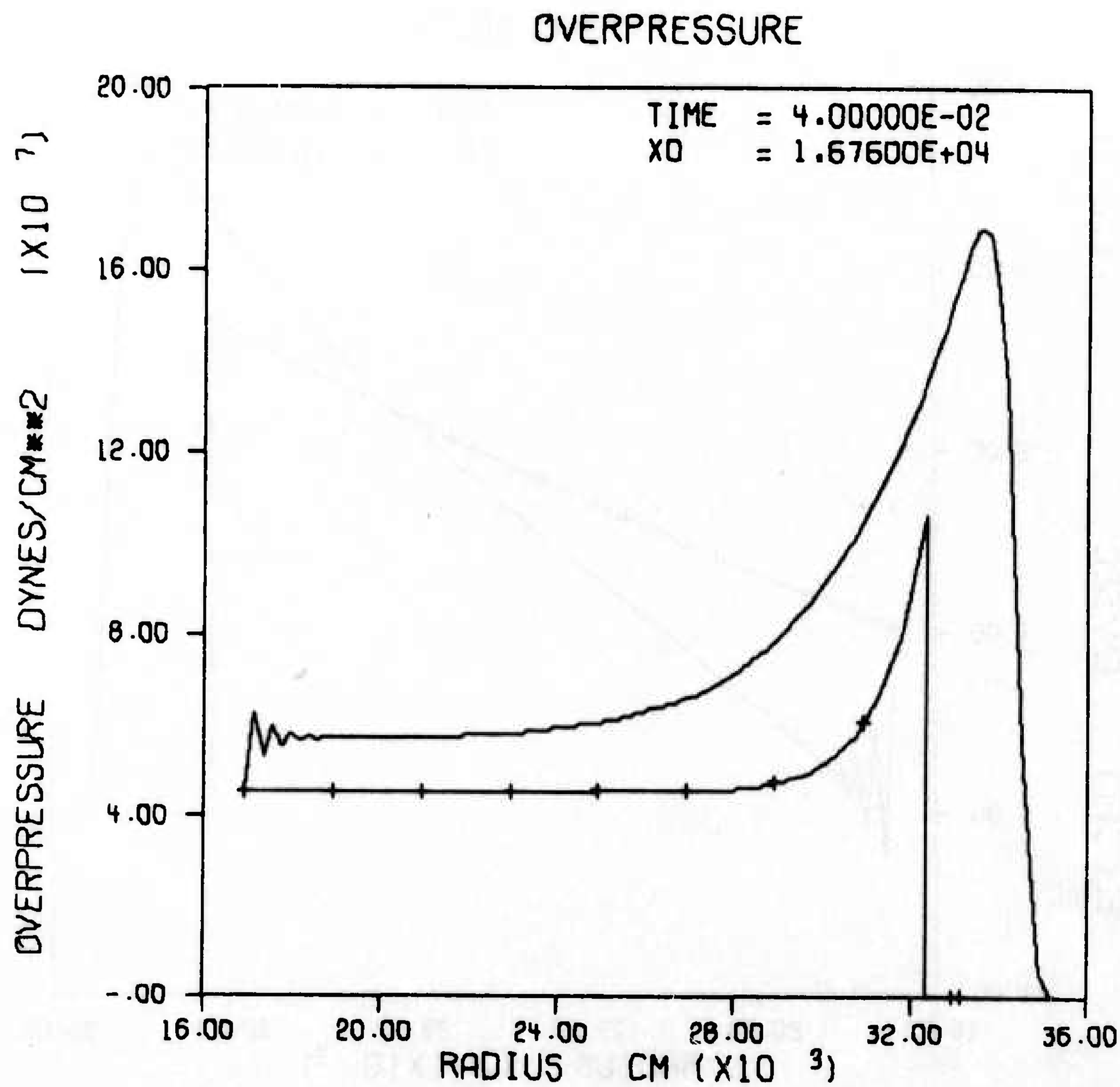
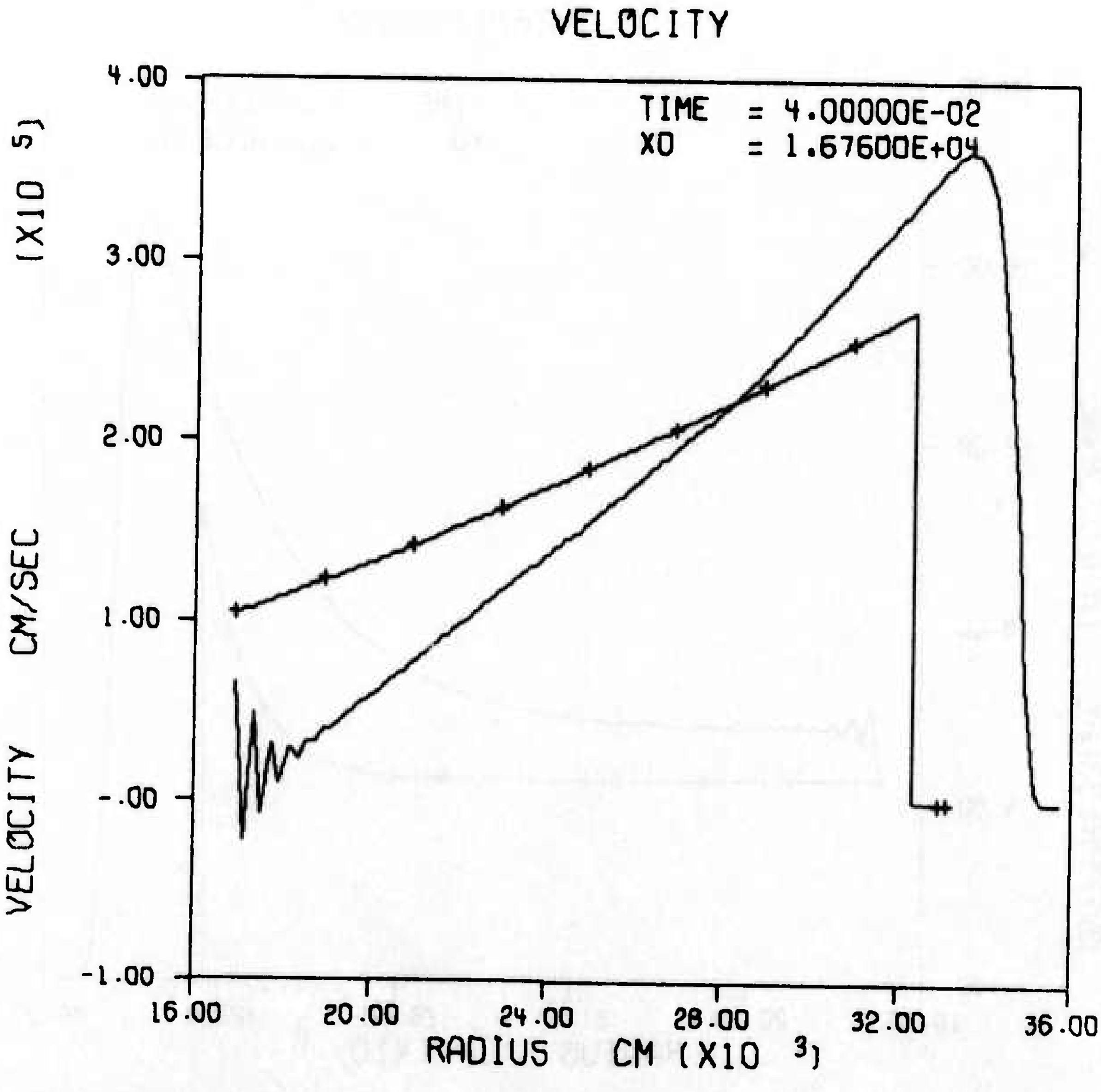


AFWL CALC OF 1 MT 1-D AND FREE AIR 1.E4 PSI



AFWL COMPARISON OF 1 MT FORCED AND FREE AIR WAVEFORMS 1.E5 PSI



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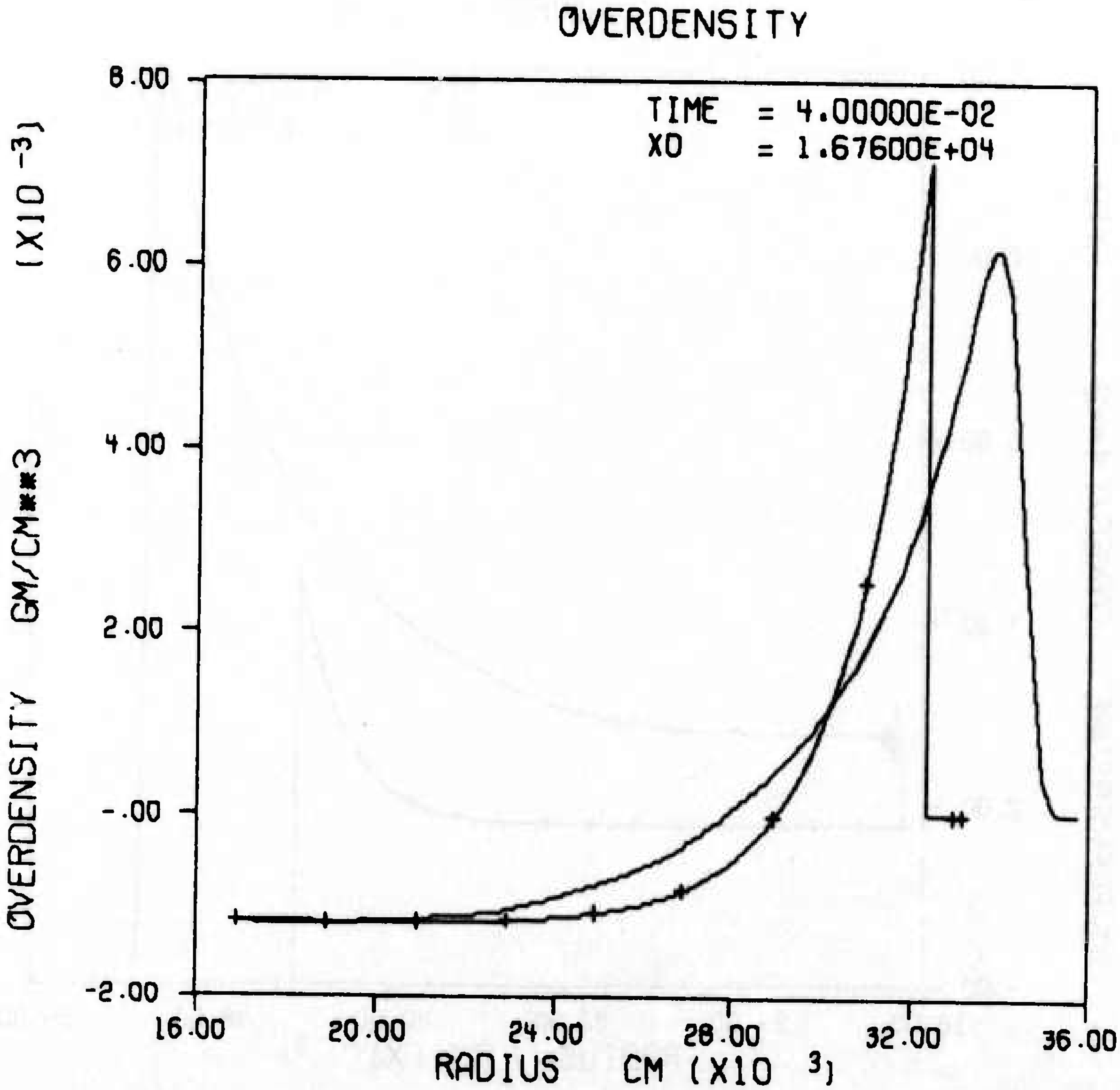

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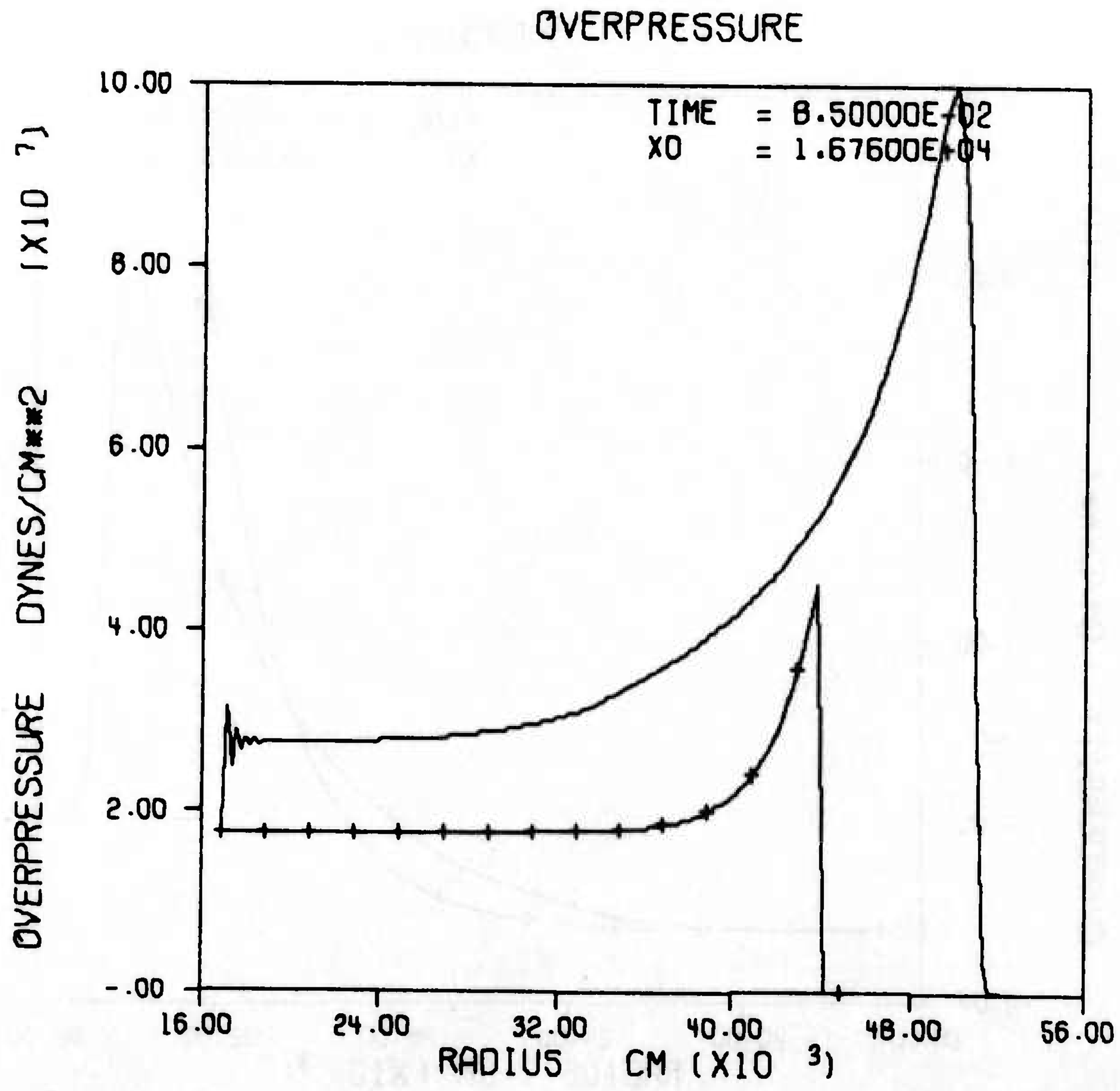
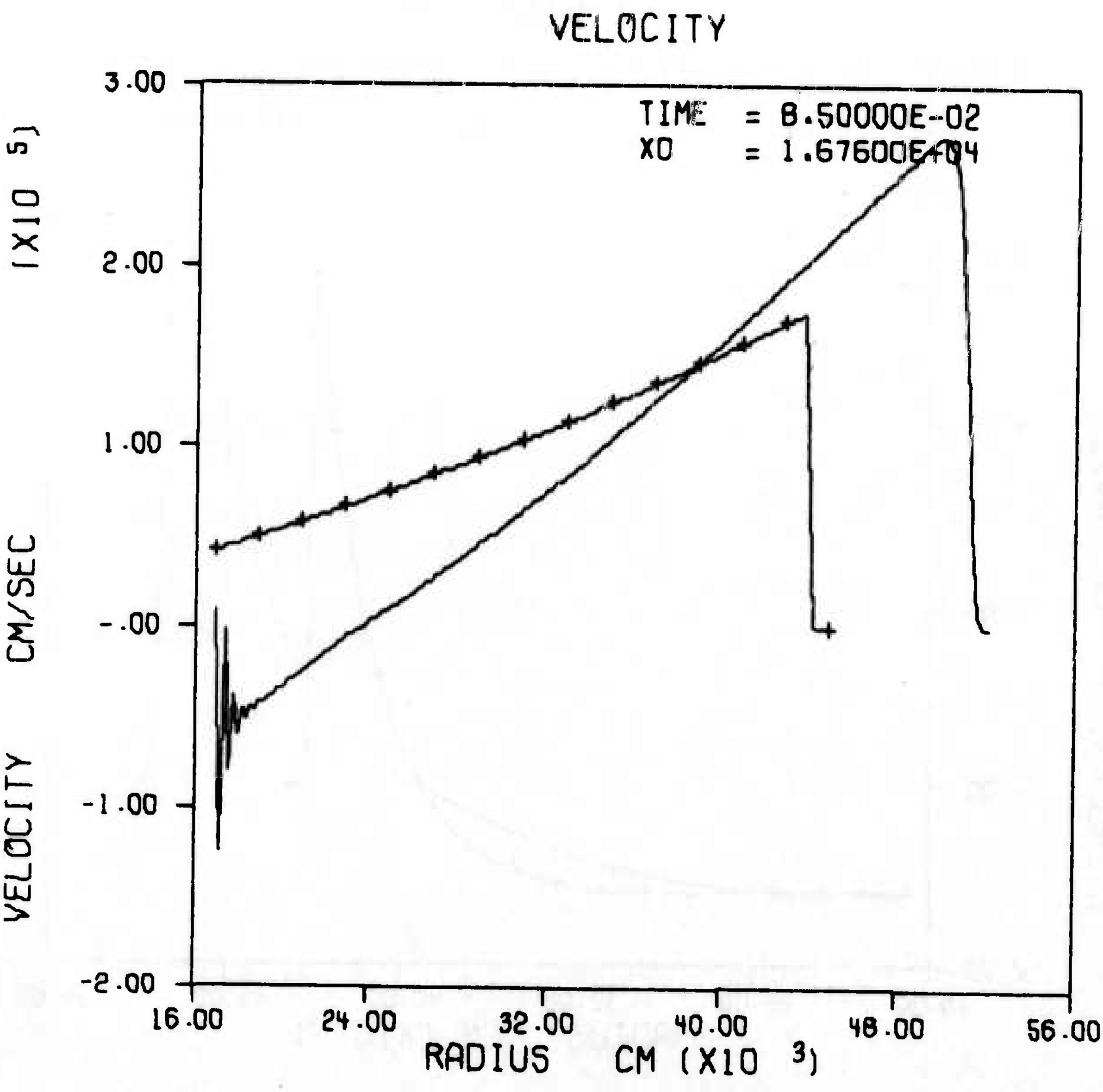
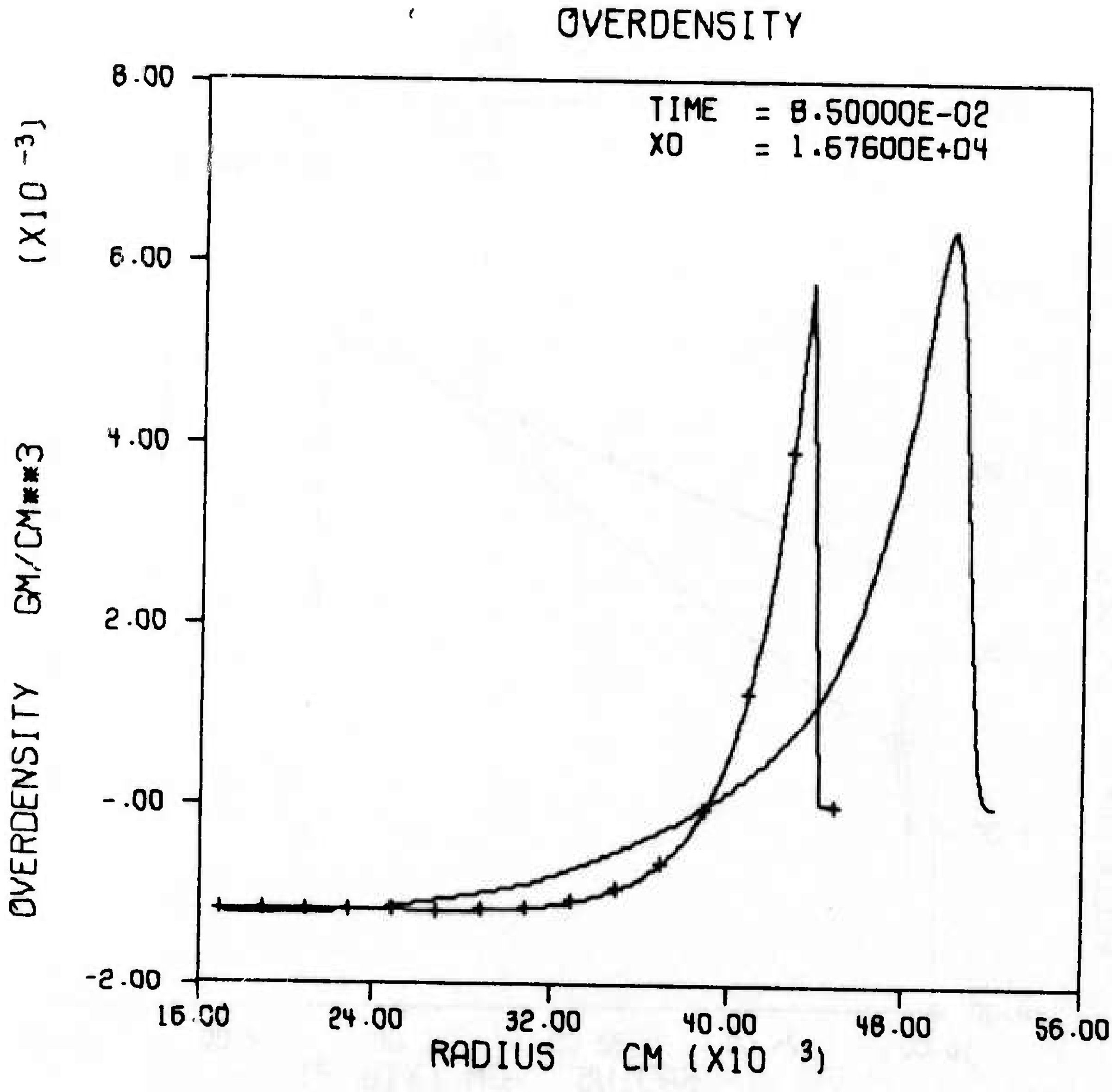


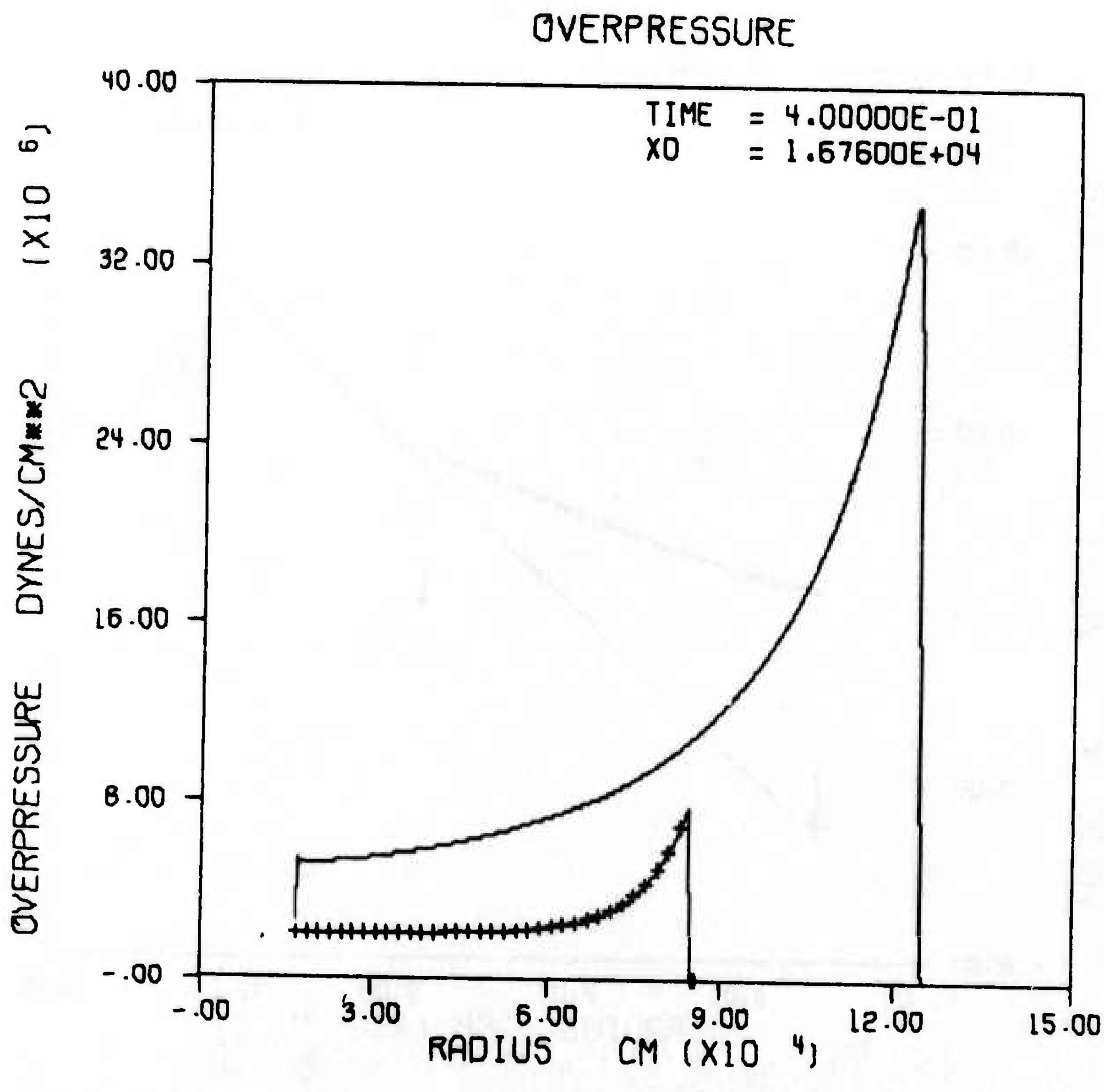
AFWL COMPARISON OF 1 MT FORCED AND FREE AIR WAVEFORMS 1.E5 PSI



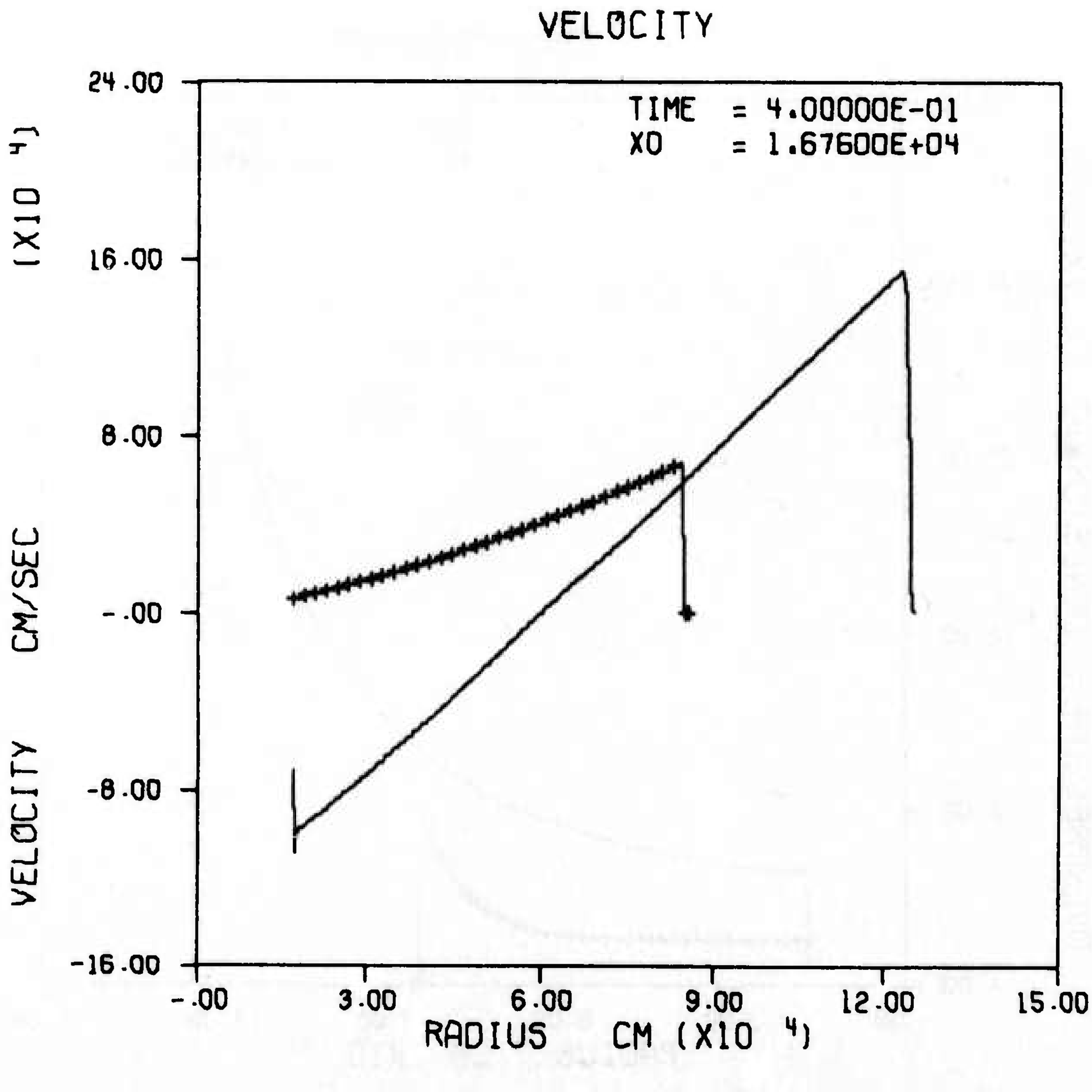
AFWL COMPARISON OF 1 MT FORCED AND FREE AIR WAVEFORMS 1.E5 PSI



AFWL COMPARISON OF 1 MT FORCED AND FREE AIR WAVEFORMS 1.E5 PSI



AFWL COMPARISON OF 1 MT FORCED AND FREE AIR WAVEFORMS 1.E5 PSI



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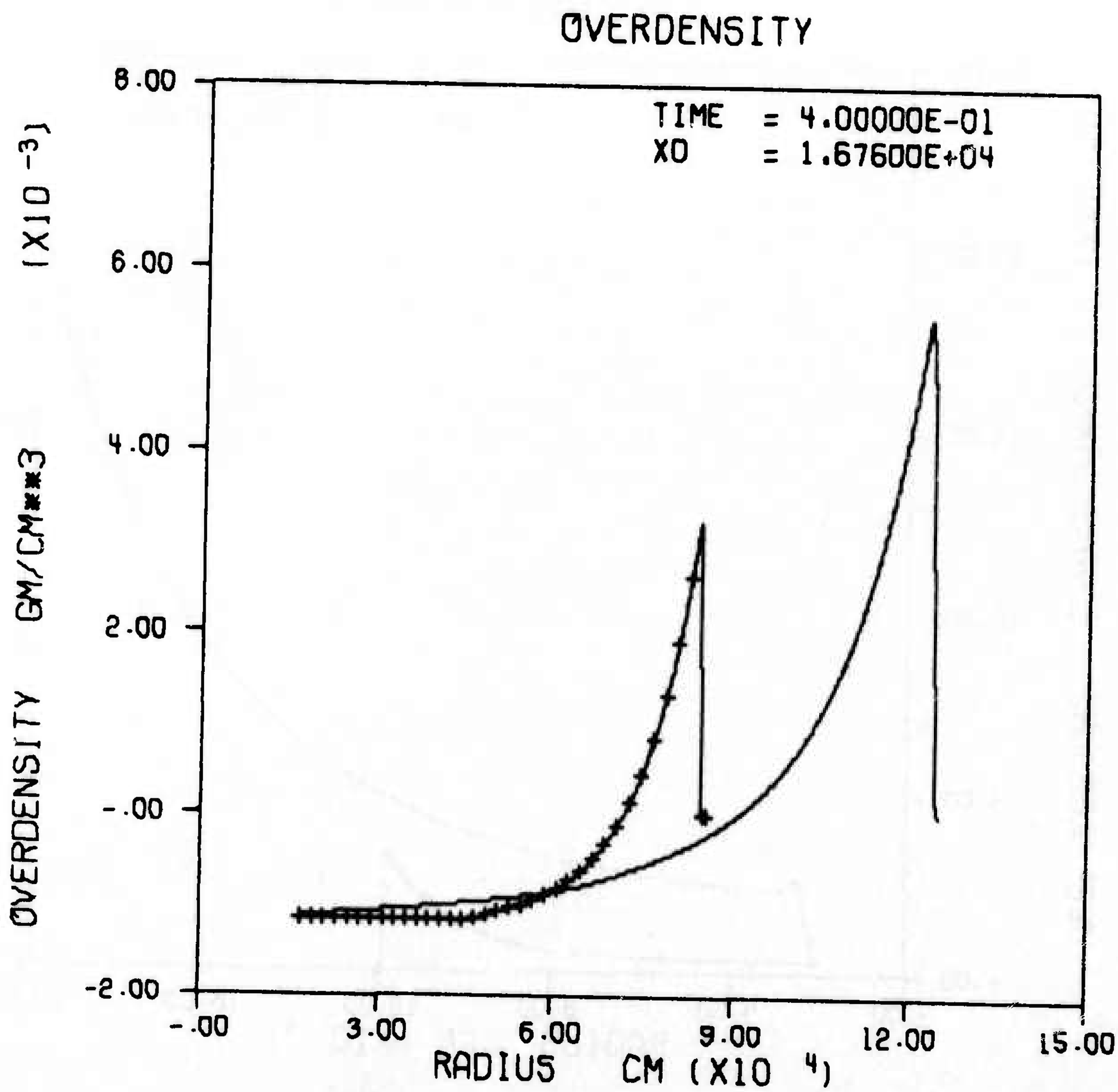
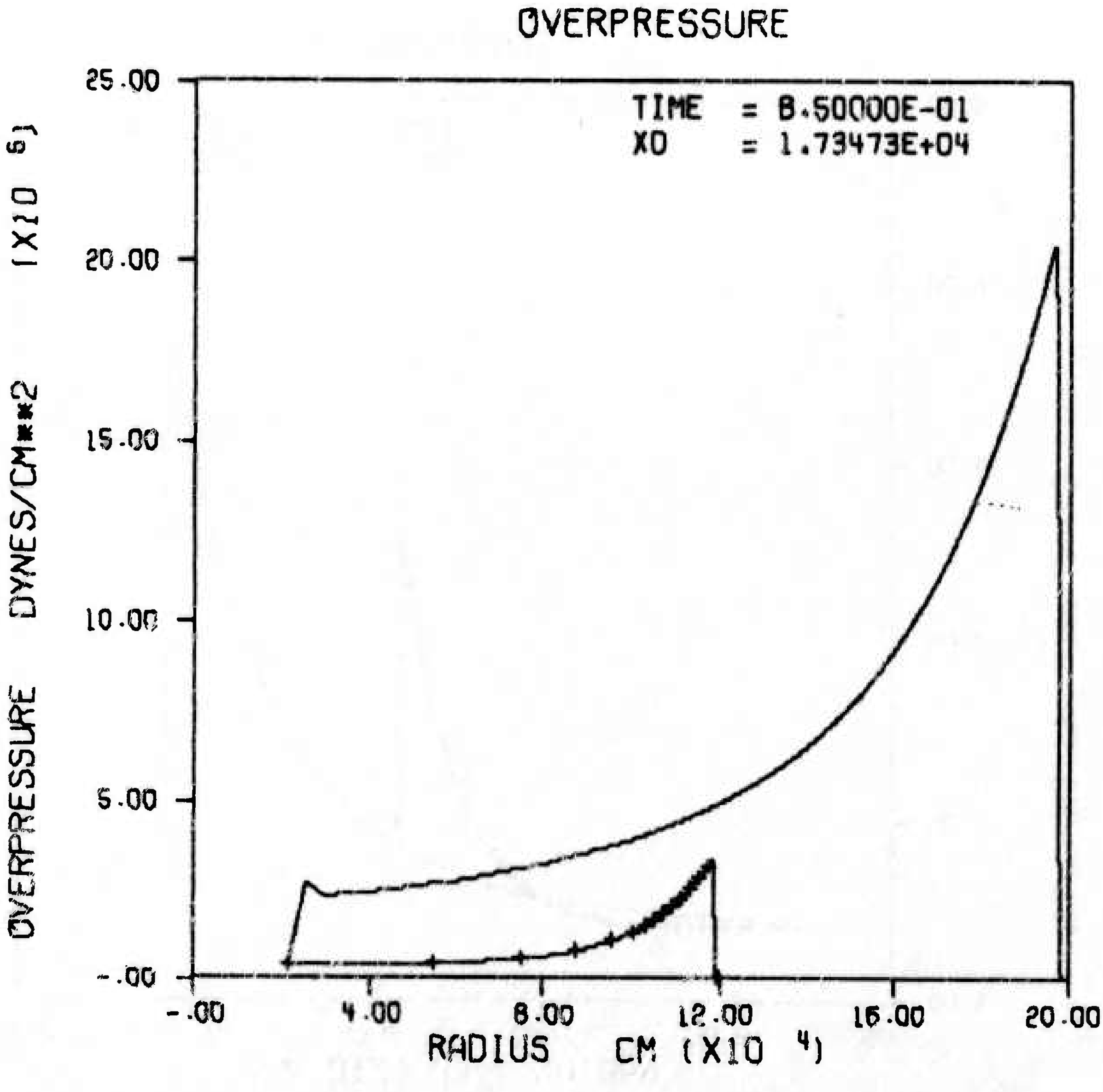
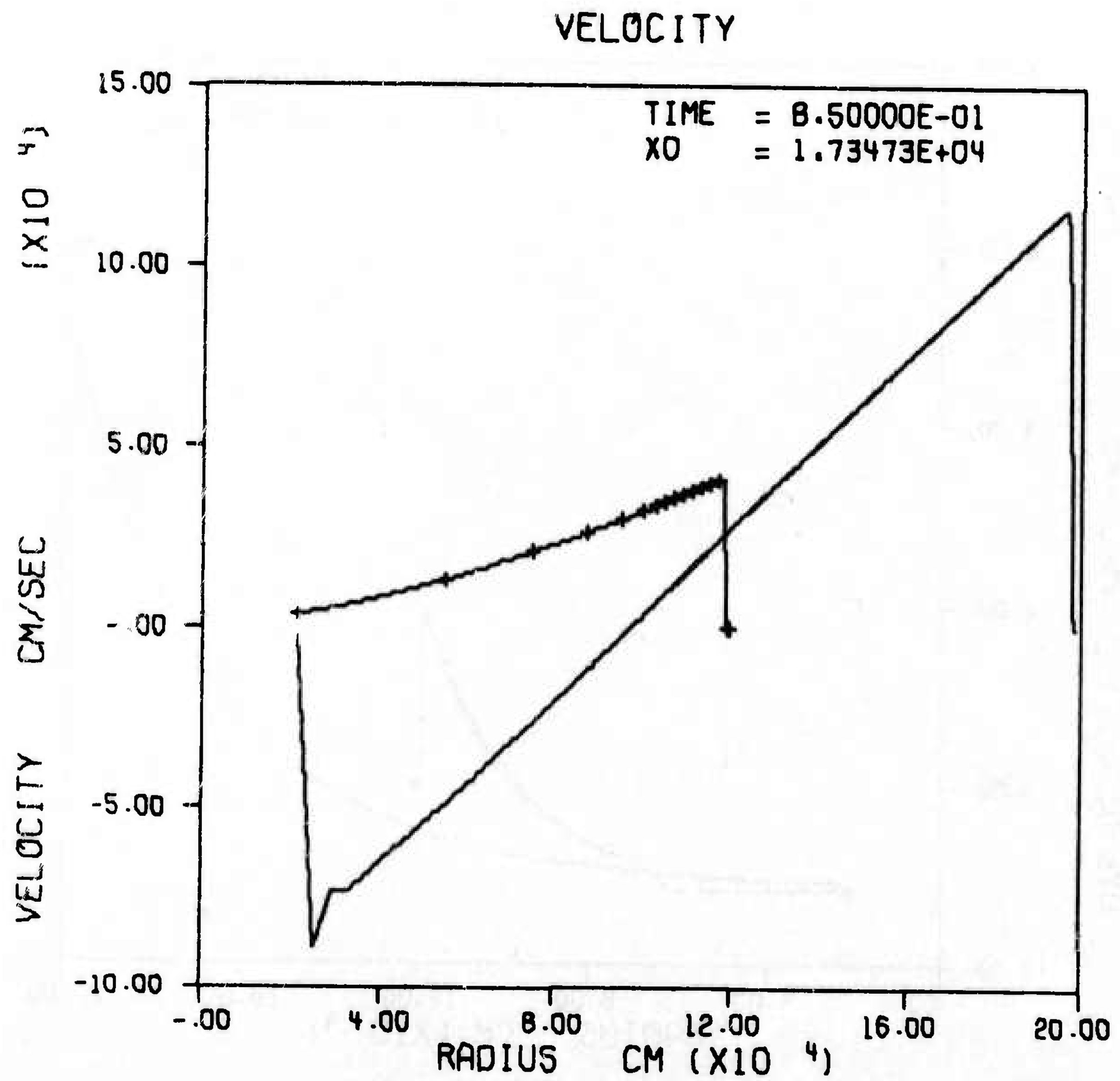


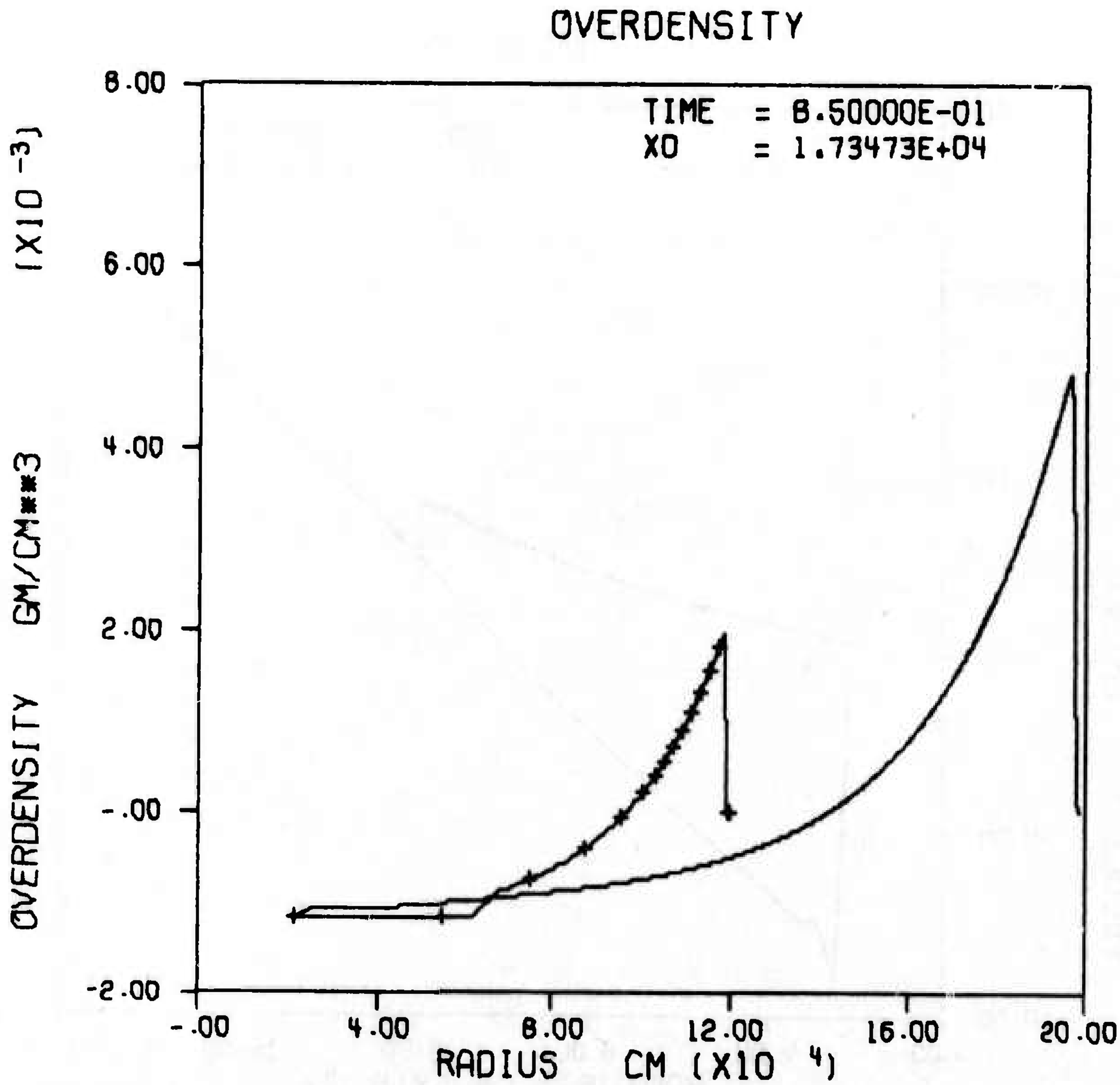
AFWL COMPARISON OF 1 MT FORCED AND FREE AIR WAVEFORMS 1.E5 PSI



AFWL COMPARISON OF 1 MT FORCED AND FREE AIR WAVEFORMS 1.E5 PSI



AFWL COMPARISON OF 1 MT FORCED AND FREE AIR WAVEFORMS 1.E5 PSI



AFWL COMPARISON OF 1 MT FORCED AND FREE AIR WAVEFORMS 1.E5 PSI

APPENDIX B

TABULATED INLET CONDITIONS

This appendix contains tabulated values of the inlet conditions for the 10^4 and 10^5 psi conditions. All units are CGS.

INPUT CONDITIONS FOR SMOOTH TUNNEL CALCULATIONS

YIELD = 1.000E+03 RADIUS = 7.360E+03

TIME	OVERPRESSURE	VELOCITY	OVERDENSITY	ENERGY DENSITY
1.000E-03	6.425E+09	2.147E+06	8.376E-03	2.914E+12
1.004E-03	5.798E+09	2.137E+06	8.183E-03	2.702E+12
1.008E-03	5.336E+09	2.128E+06	7.936E-03	2.555E+12
1.012E-03	4.992E+09	2.119E+06	7.813E-03	2.439E+12
1.018E-03	4.631E+09	2.105E+06	7.546E-03	2.363E+12
1.026E-03	4.331E+09	2.086E+06	7.206E-03	2.300E+12
1.038E-03	4.086E+09	2.060E+06	6.725E-03	2.301E+12
1.064E-03	3.853E+09	2.004E+06	5.794E-03	2.457E+12
1.112E-03	3.630E+09	1.908E+06	4.401E-03	2.888E+12
1.168E-03	3.418E+09	1.807E+06	3.180E-03	3.473E+12
1.226E-03	3.221E+09	1.712E+06	2.240E-03	4.222E+12
1.286E-03	3.039E+09	1.624E+06	1.512E-03	5.113E+12
1.350E-03	2.864E+09	1.539E+06	9.312E-04	6.118E+12
1.418E-03	2.697E+09	1.458E+06	4.699E-04	7.437E+12
1.488E-03	2.543E+09	1.382E+06	1.144E-04	9.005E+12
1.562E-03	2.397E+09	1.310E+06	-1.677E-04	1.091E+13
1.640E-03	2.259E+09	1.242E+06	-3.906E-04	1.303E+13
1.722E-03	2.128E+09	1.177E+06	-5.660E-04	1.578E+13
1.808E-03	2.005E+09	1.115E+06	-7.036E-04	1.909E+13
1.898E-03	1.890E+09	1.057E+06	-8.112E-04	2.267E+13
1.992E-03	1.781E+09	1.002E+06	-8.953E-04	2.724E+13
2.090E-03	1.680E+09	9.500E+05	-9.609E-04	3.258E+13
2.194E-03	1.583E+09	9.003E+05	-1.013E-03	3.823E+13
2.302E-03	1.493E+09	8.536E+05	-1.053E-03	4.521E+13
2.416E-03	1.408E+09	8.090E+05	-1.085E-03	5.225E+13
2.536E-03	1.327E+09	7.665E+05	-1.110E-03	6.084E+13
2.660E-03	1.252E+09	7.269E+05	-1.129E-03	6.882E+13
2.792E-03	1.180E+09	6.887E+05	-1.144E-03	7.835E+13
2.930E-03	1.112E+09	6.527E+05	-1.156E-03	8.653E+13
3.074E-03	1.049E+09	6.186E+05	-1.165E-03	9.581E+13
3.226E-03	9.890E+08	5.861E+05	-1.172E-03	1.028E+14
3.384E-03	9.329E+08	5.556E+05	-1.178E-03	1.087E+14
3.550E-03	8.799E+08	5.266E+05	-1.183E-03	1.154E+14
3.724E-03	8.300E+08	4.991E+05	-1.186E-03	1.187E+14

INPUT CONDITIONS FOR SMOOTH TUNNEL CALCULATIONS

YIELD = 1.000E+03 RADIUS = 1.596E+04

TIME	OVERPRESSURE	VELOCITY	OVERDENSITY	ENERGY DENSITY
7.300E-03	0.	0.	0.	2.043E+09
7.520E-03	6.782E+08	7.064E+05	9.436E-03	3.426E+11
7.560E-03	6.300E+08	7.022E+05	9.044E-03	3.333E+11
7.600E-03	5.887E+08	6.980E+05	8.669E-03	3.261E+11
7.640E-03	5.533E+08	6.939E+05	8.309E-03	3.180E+11
7.700E-03	5.091E+08	6.878E+05	7.797E-03	3.093E+11
7.760E-03	4.736E+08	6.819E+05	7.317E-03	3.039E+11
7.820E-03	4.447E+08	6.760E+05	6.866E-03	3.014E+11
7.900E-03	4.143E+08	6.683E+05	6.307E-03	3.069E+11
7.980E-03	3.906E+08	6.608E+05	5.791E-03	3.107E+11
8.080E-03	3.680E+08	6.516E+05	5.203E-03	3.194E+11
8.220E-03	3.449E+08	6.391E+05	4.474E-03	3.378E+11
8.400E-03	3.243E+08	6.237E+05	3.672E-03	3.697E+11
8.640E-03	3.055E+08	6.042E+05	2.799E-03	4.238E+11
8.960E-03	2.876E+08	5.799E+05	1.902E-03	4.964E+11
9.340E-03	2.713E+08	5.533E+05	1.125E-03	6.450E+11
9.780E-03	2.556E+08	5.252E+05	4.929E-04	8.692E+11
1.026E-02	2.408E+08	4.975E+05	2.051E-05	1.140E+12
1.076E-02	2.270E+08	4.714E+05	-3.152E-04	1.420E+12
1.130E-02	2.138E+08	4.458E+05	-5.619E-04	1.742E+12
1.186E-02	2.015E+08	4.219E+05	-7.359E-04	2.119E+12
1.244E-02	1.900E+08	3.995E+05	-8.593E-04	2.633E+12
1.306E-02	1.790E+08	3.779E+05	-9.500E-04	3.325E+12
1.370E-02	1.688E+08	3.577E+05	-1.015E-03	4.131E+12
1.438E-02	1.591E+08	3.384E+05	-1.062E-03	5.112E+12
1.510E-02	1.499E+08	3.199E+05	-1.097E-03	6.230E+12
1.584E-02	1.413E+08	3.027E+05	-1.122E-03	7.305E+12
1.662E-02	1.332E+08	2.864E+05	-1.141E-03	8.549E+12
1.744E-02	1.256E+08	2.709E+05	-1.154E-03	9.654E+12
1.830E-02	1.184E+08	2.562E+05	-1.165E-03	1.086E+13
1.920E-02	1.116E+08	2.424E+05	-1.173E-03	1.179E+13
2.014E-02	1.052E+08	2.293E+05	-1.179E-03	1.257E+13
2.112E-02	9.928E+07	2.171E+05	-1.183E-03	1.341E+13
2.216E-02	9.358E+07	2.054E+05	-1.187E-03	1.386E+13
2.324E-02	8.826E+07	1.945E+05	-1.190E-03	1.412E+13
2.438E-02	8.321E+07	1.840E+05	-1.192E-03	1.420E+13
2.558E-02	7.843E+07	1.741E+05	-1.193E-03	1.385E+13
2.682E-02	7.399E+07	1.649E+05	-1.191E-03	1.214E+13
2.812E-02	6.980E+07	1.561E+05	-1.188E-03	1.054E+13
2.950E-02	6.580E+07	1.476E+05	-1.184E-03	9.104E+12
3.094E-02	6.204E+07	1.396E+05	-1.180E-03	7.816E+12
3.244E-02	5.852E+07	1.321E+05	-1.177E-03	6.743E+12
3.402E-02	5.513E+07	1.250E+05	-1.175E-03	6.148E+12

APPENDIX C

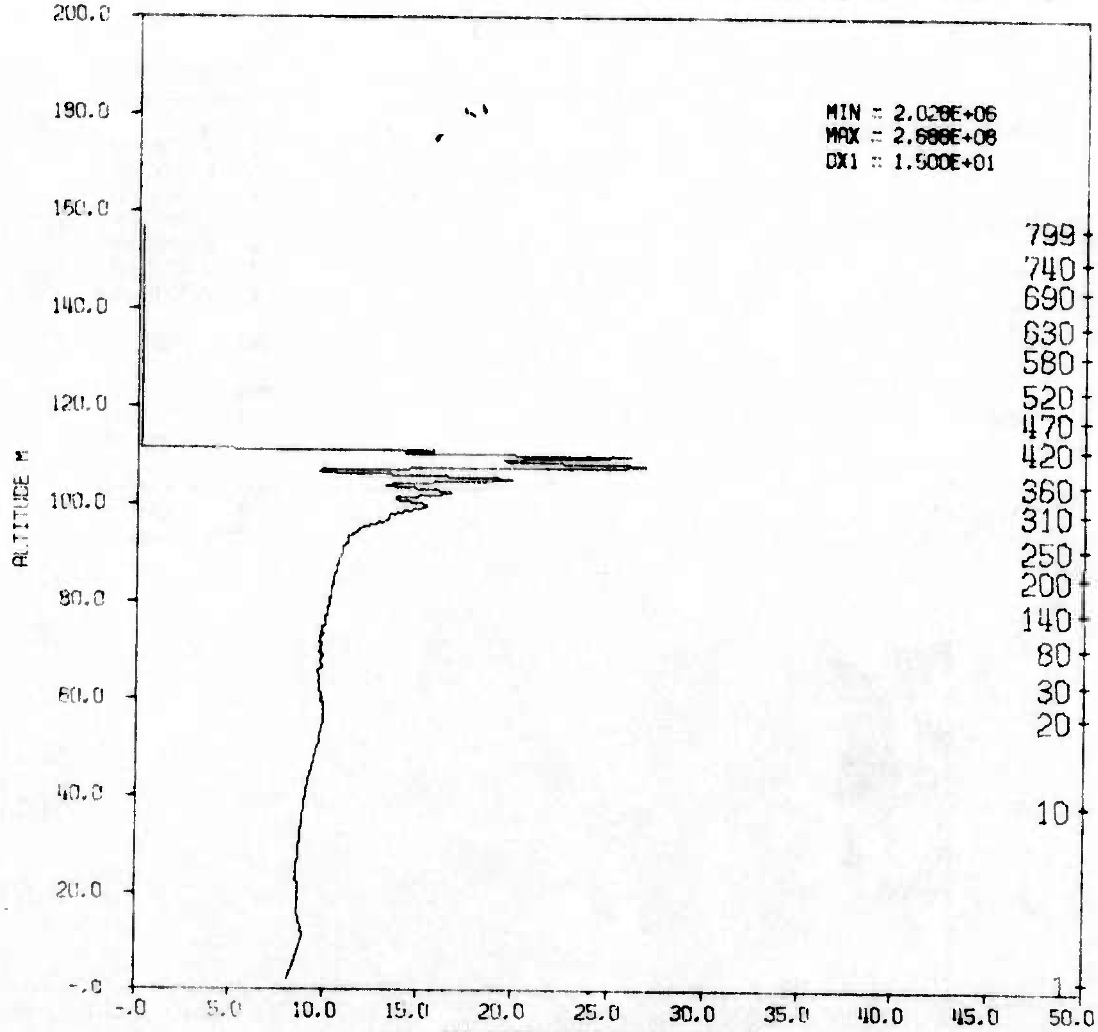
PLOTS OF THE 2-D CALCULATION

This appendix contains histograms, vectors, and contour plots of pertinent variables for the corrugated tunnel calculation. The shocks reflected from the corrugations, one shock for each corrugation, are clearly shown. The vortex formed between the corrugations can also be seen in the velocity vector plots and on the vorticity plots. The multiple shock fronts, so clearly seen on the pressure histograms, are not numerical instabilities. This is demonstrated by the fact that in the first eight shocks nearly 100 zones are used to resolve them. instabilities would be seen in essentially every other zone.

The tunnel is oriented along the axis of symmetry of the code. Thus, on the plots, altitude refers to distance along the length of the tunnel from the opening, not from the burst center. The numbers on the right and the top of the graphs are the zone numbers for the calculational grid.

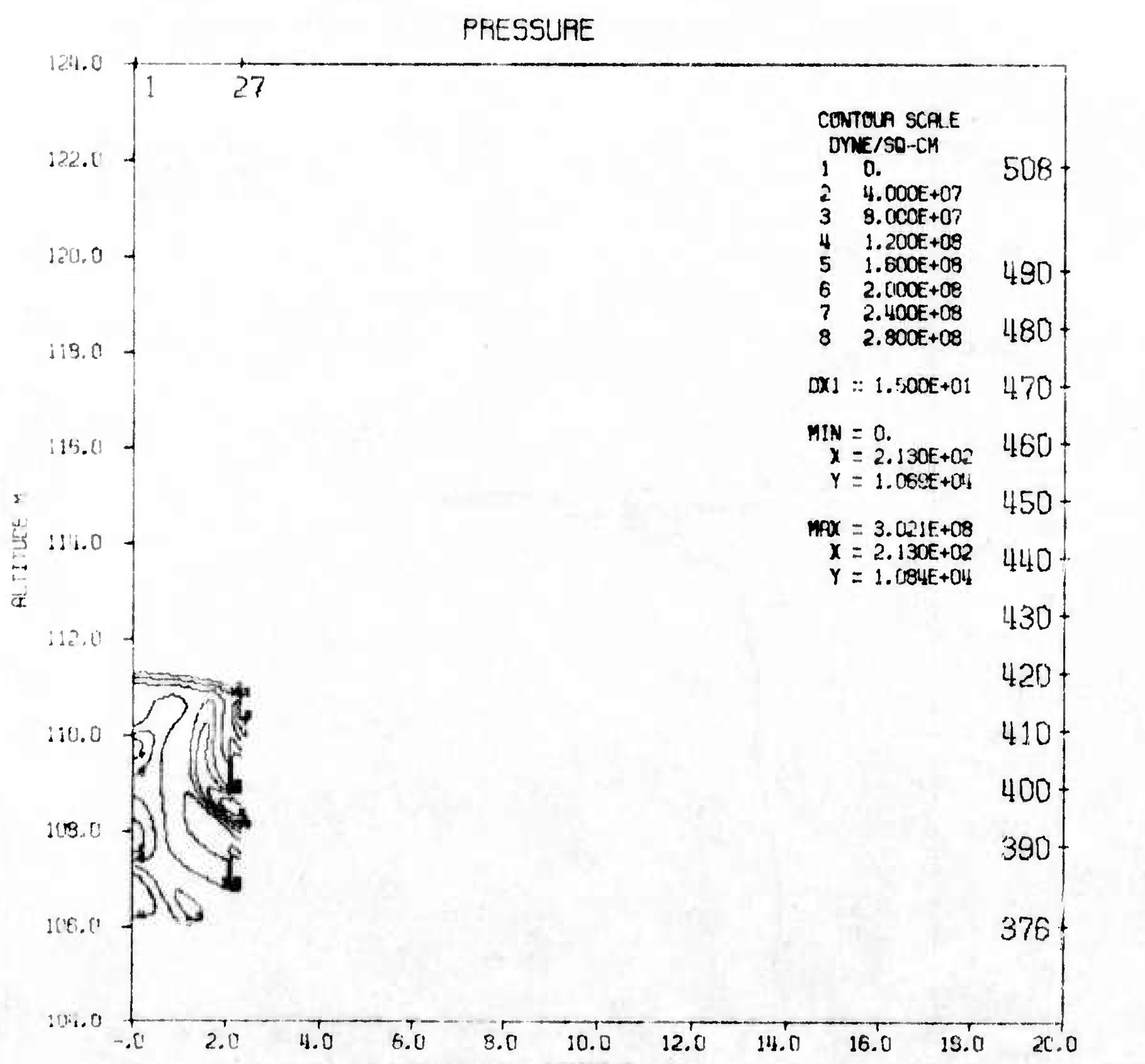
PRESSURE VERTICAL HISTOGRAM

VERTICAL CROSS SECTION AT RADIUS 7.50E-05 KM (I= 1)

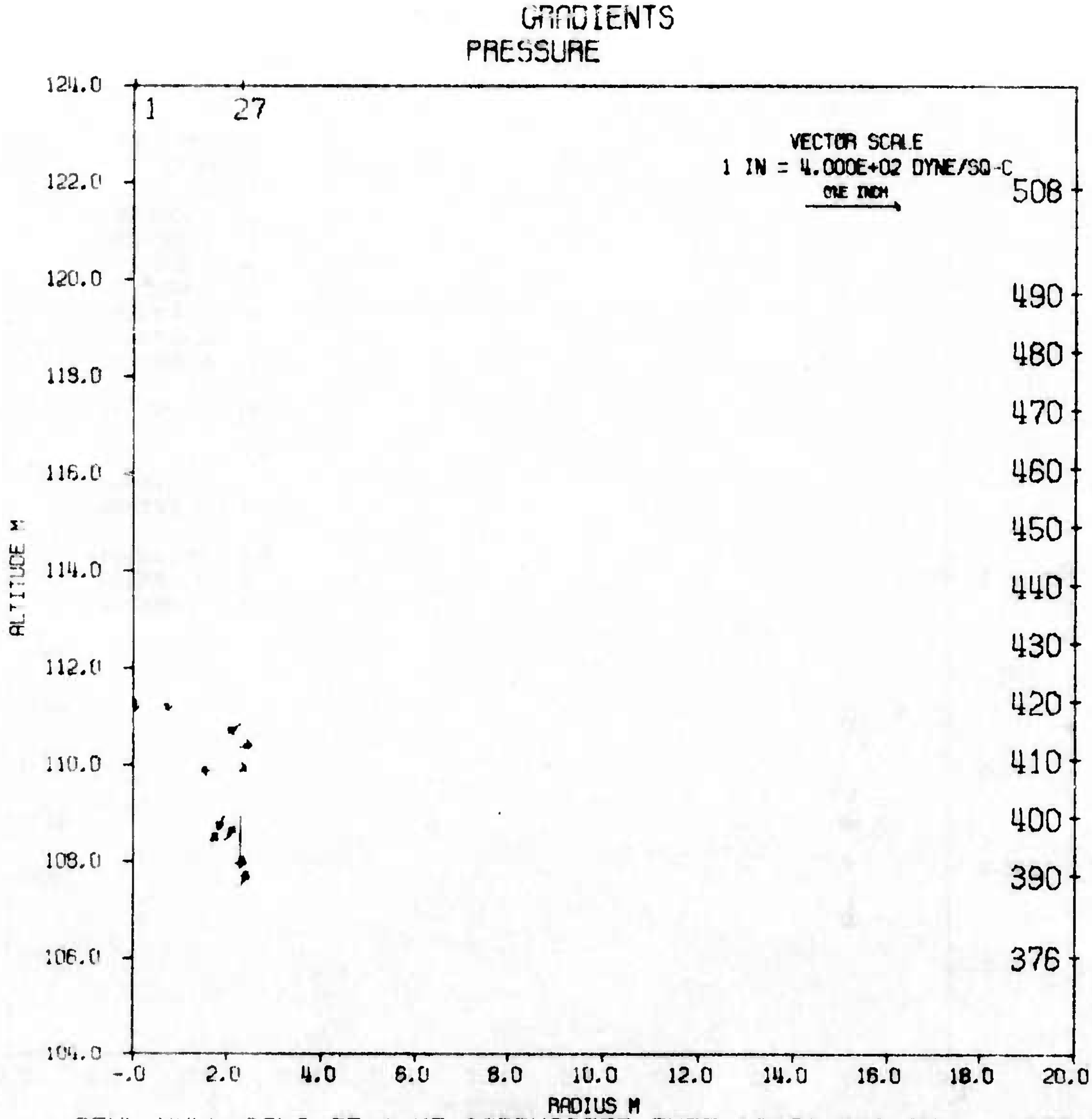


AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75

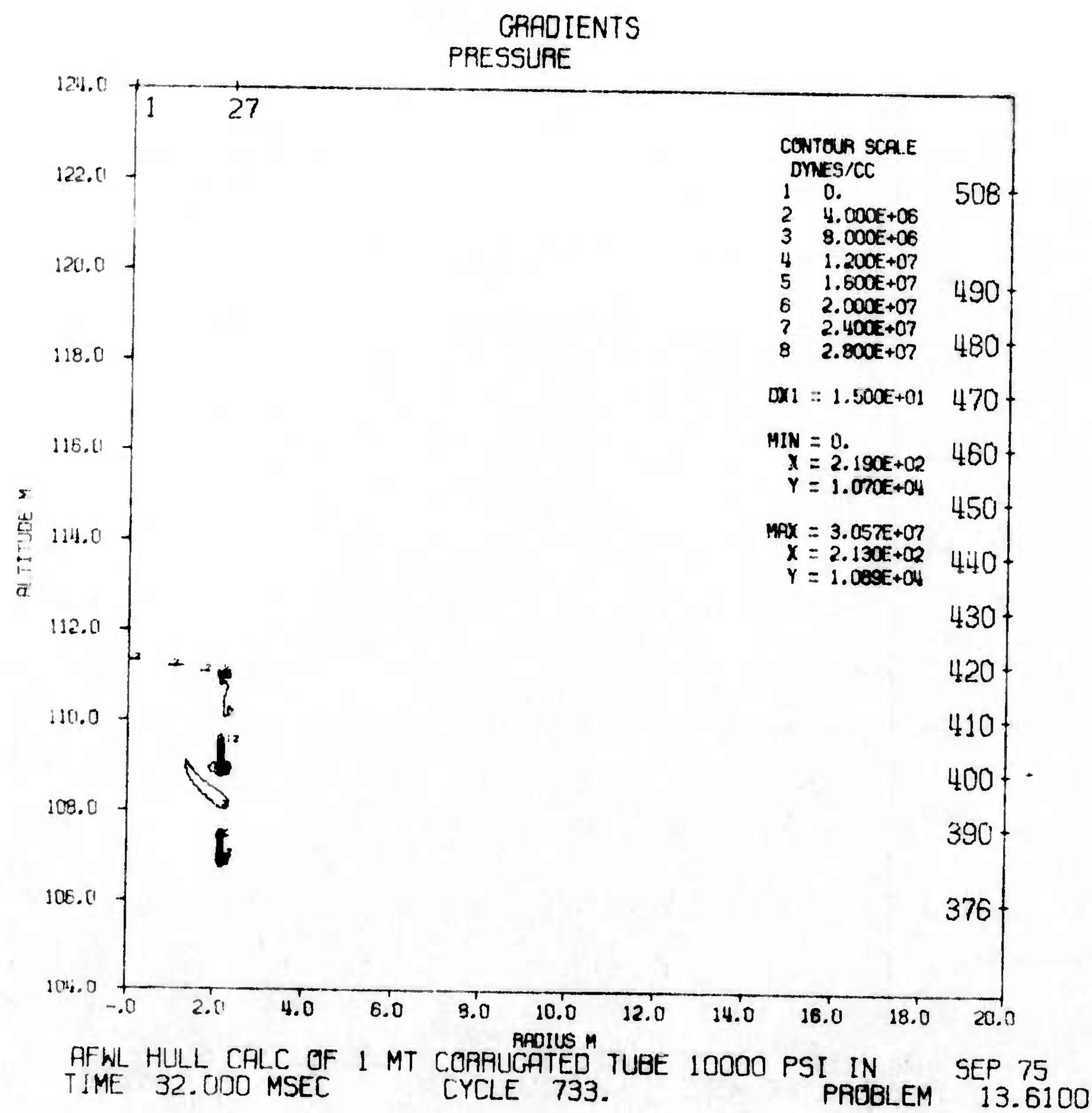
TIME 32.000 MSEC CYCLE 733. PROBLEM 13.6100

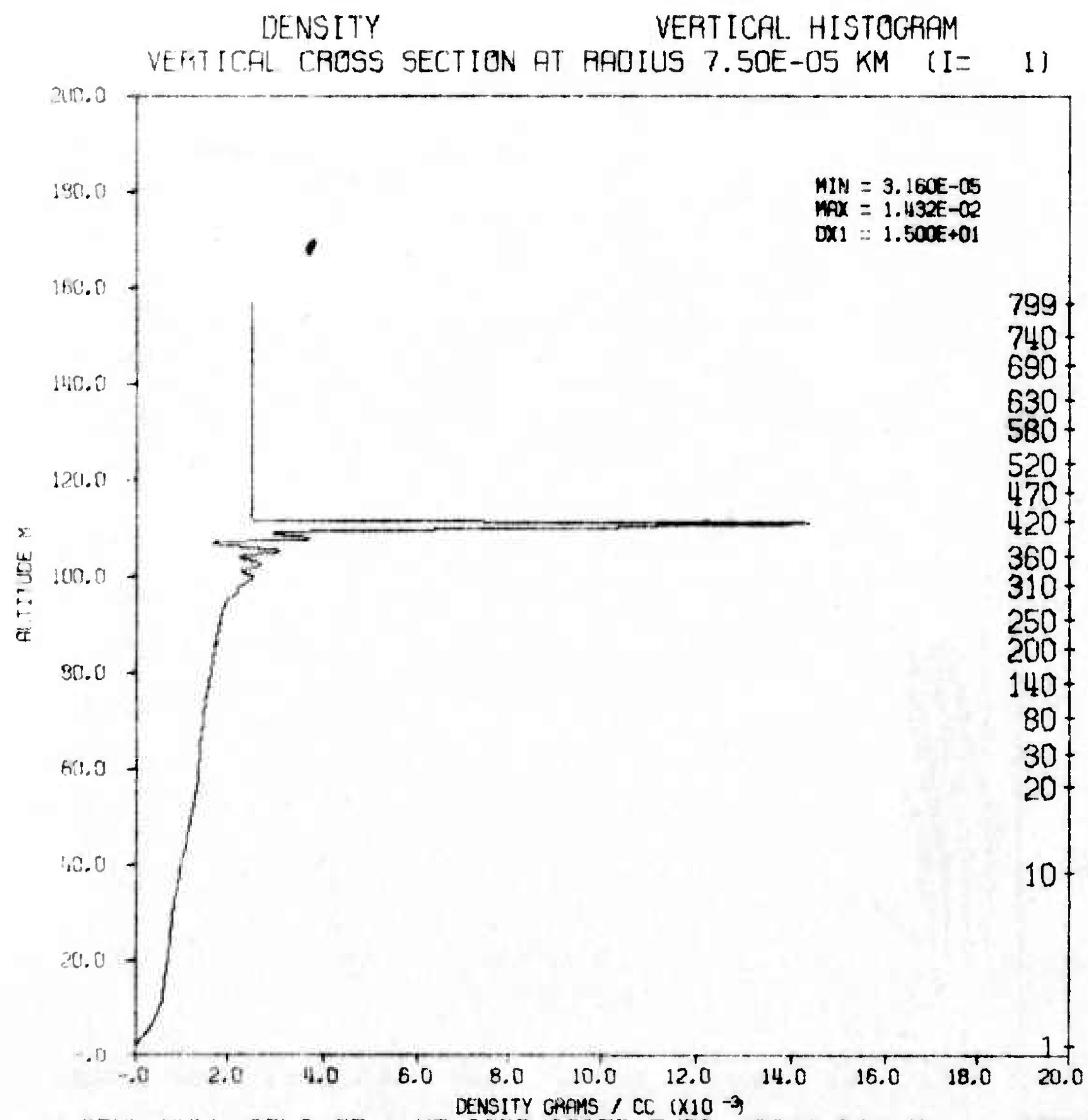


AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 32.000 MSEC CYCLE 733. PROBLEM 13.6100



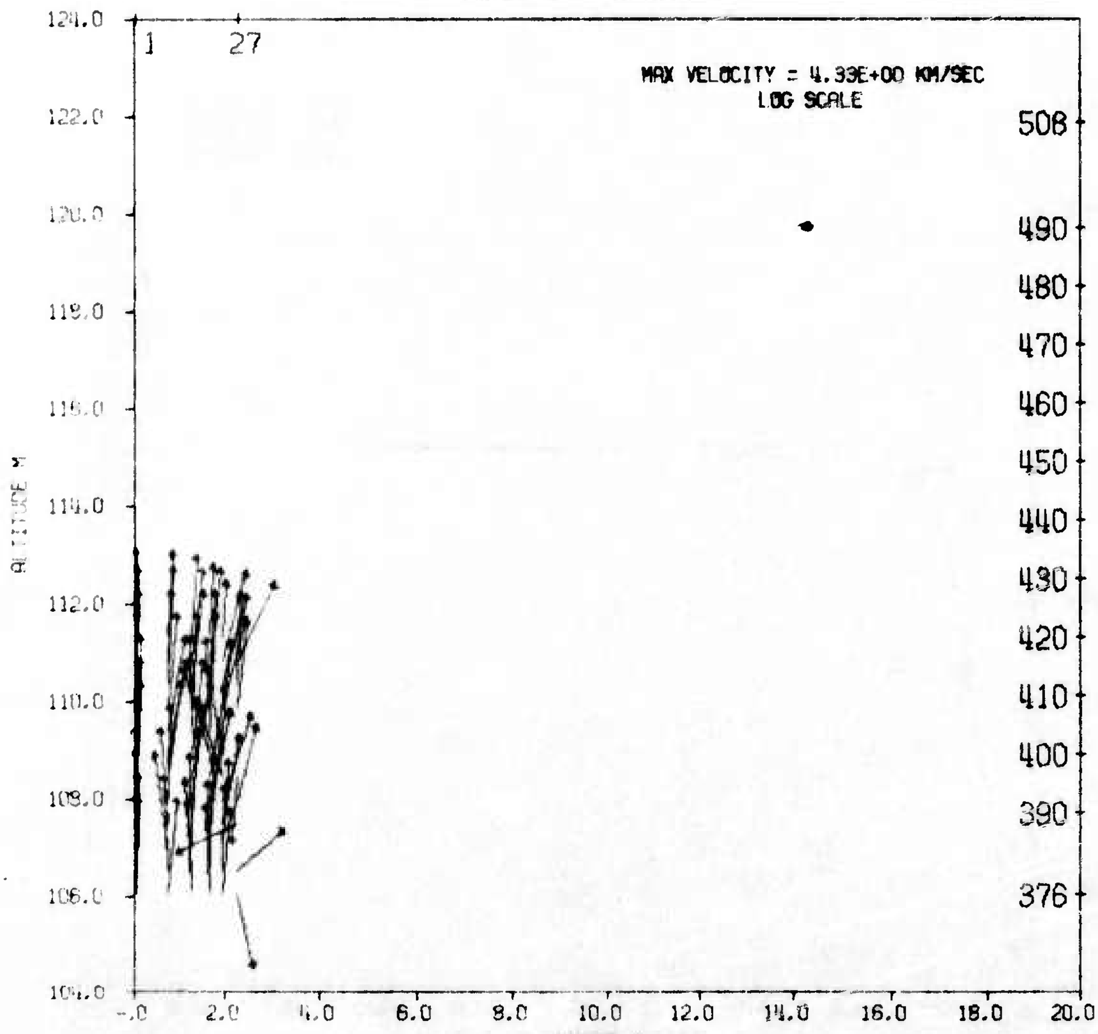
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 32.000 MSEC CYCLE 733. PROBLEM 13.6100


GRADIENTS
PRESSURE
CONTOUR SCALE
DYNES/CC
1 0.
2 4.000E+06
3 8.000E+06
4 1.200E+07
5 1.600E+07
6 2.000E+07
7 2.400E+07
8 2.800E+07
DX1 = 1.500E+01
MIN = 0.
X = 2.190E+02
Y = 1.070E+04
MAX = 3.057E+07
X = 2.130E+02
Y = 1.089E+04
ALTITUDE M
RADIUS M
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 32.000 MSEC CYCLE 733. PROBLEM 13.6100

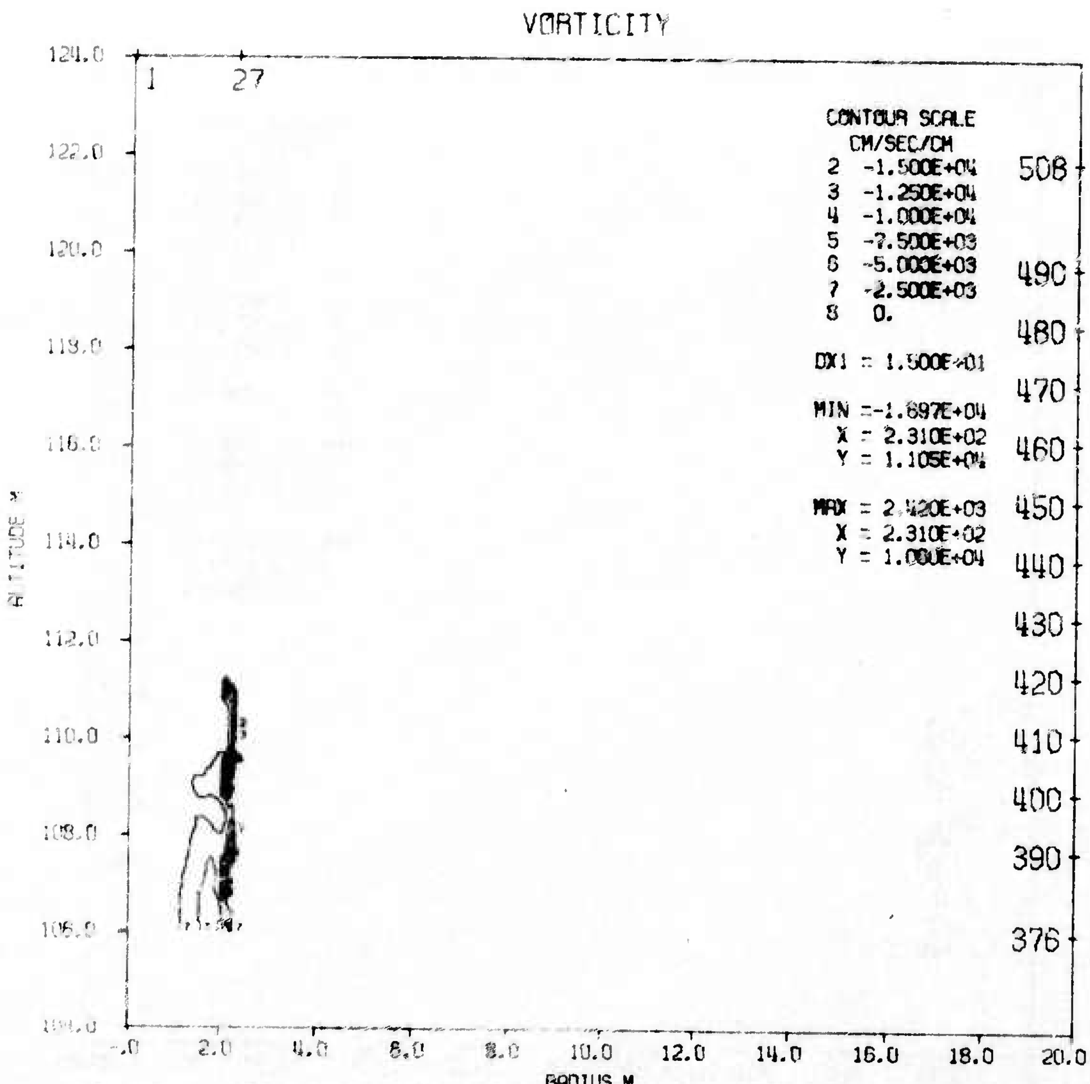


AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 32.000 MSEC CYCLE 733. PROBLEM 13.6100

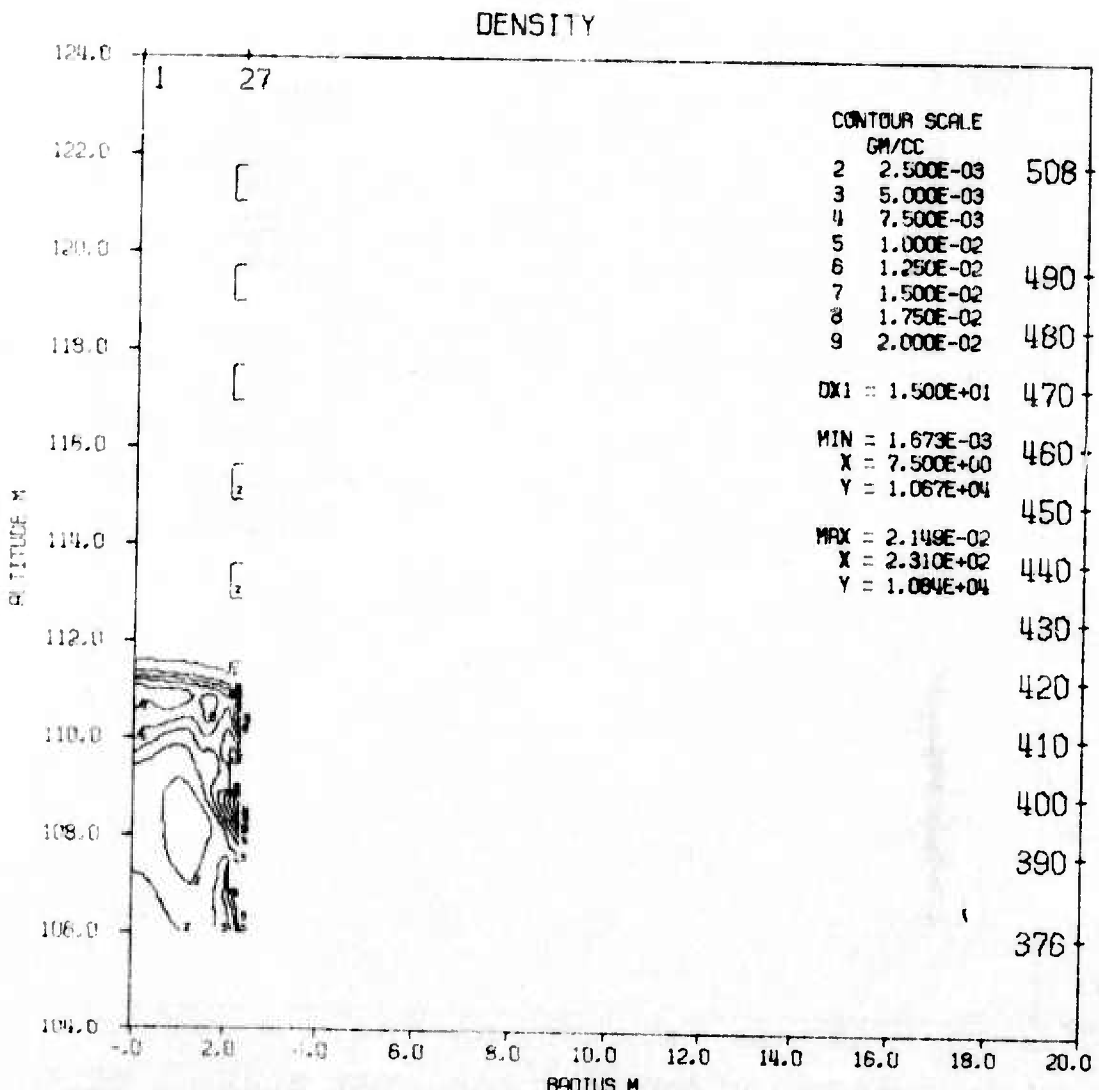
VECTOR VELOCITY



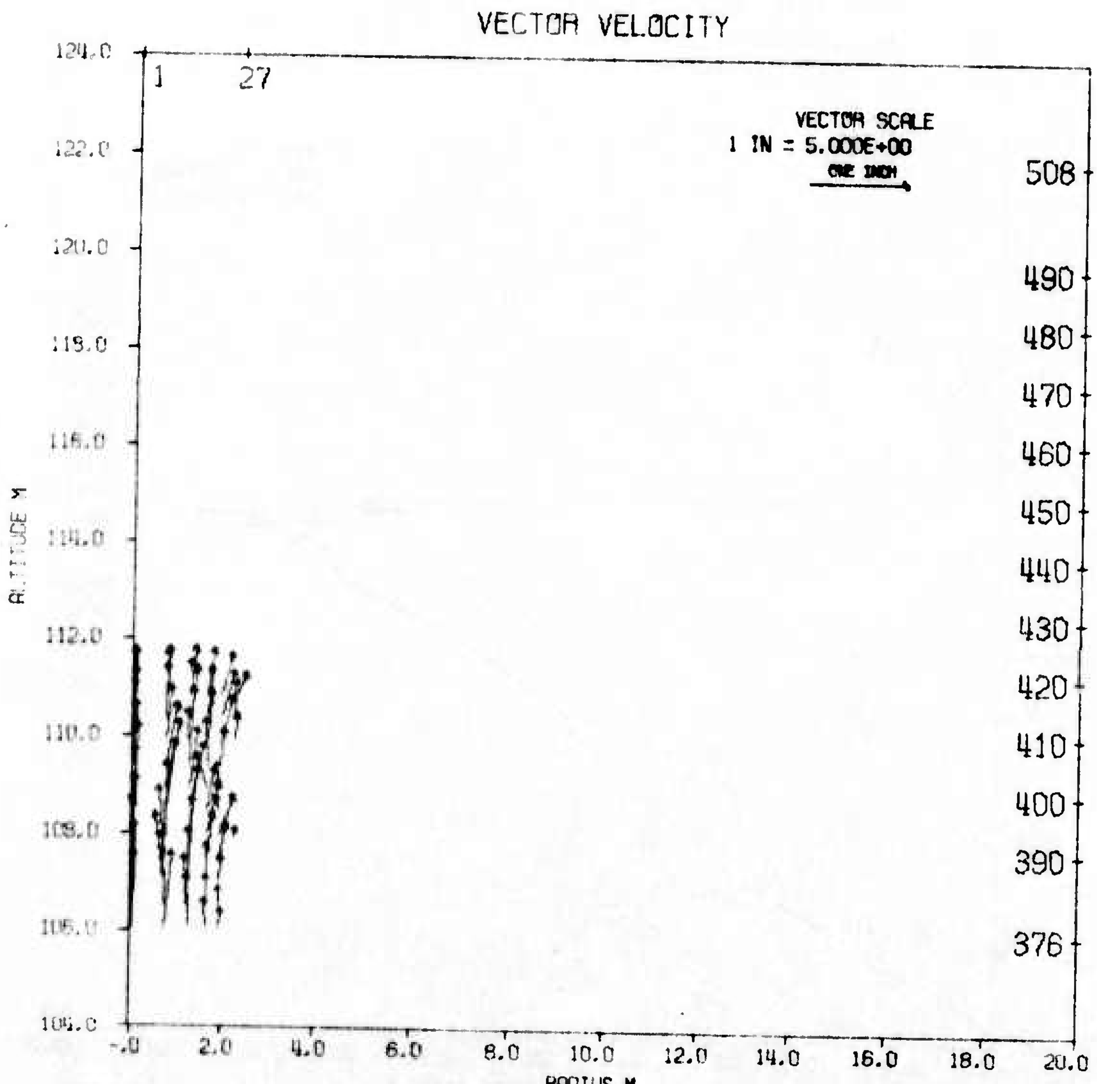
AFWL HULL CALC ØF 1 MT CØRRUGATED TUBE 10000 PSI IN SEP 75
TIME 32.000 MSEC CYCLE 733. PRØBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 32.000 MSEC CYCLE 733. PROBLEM 13.6100

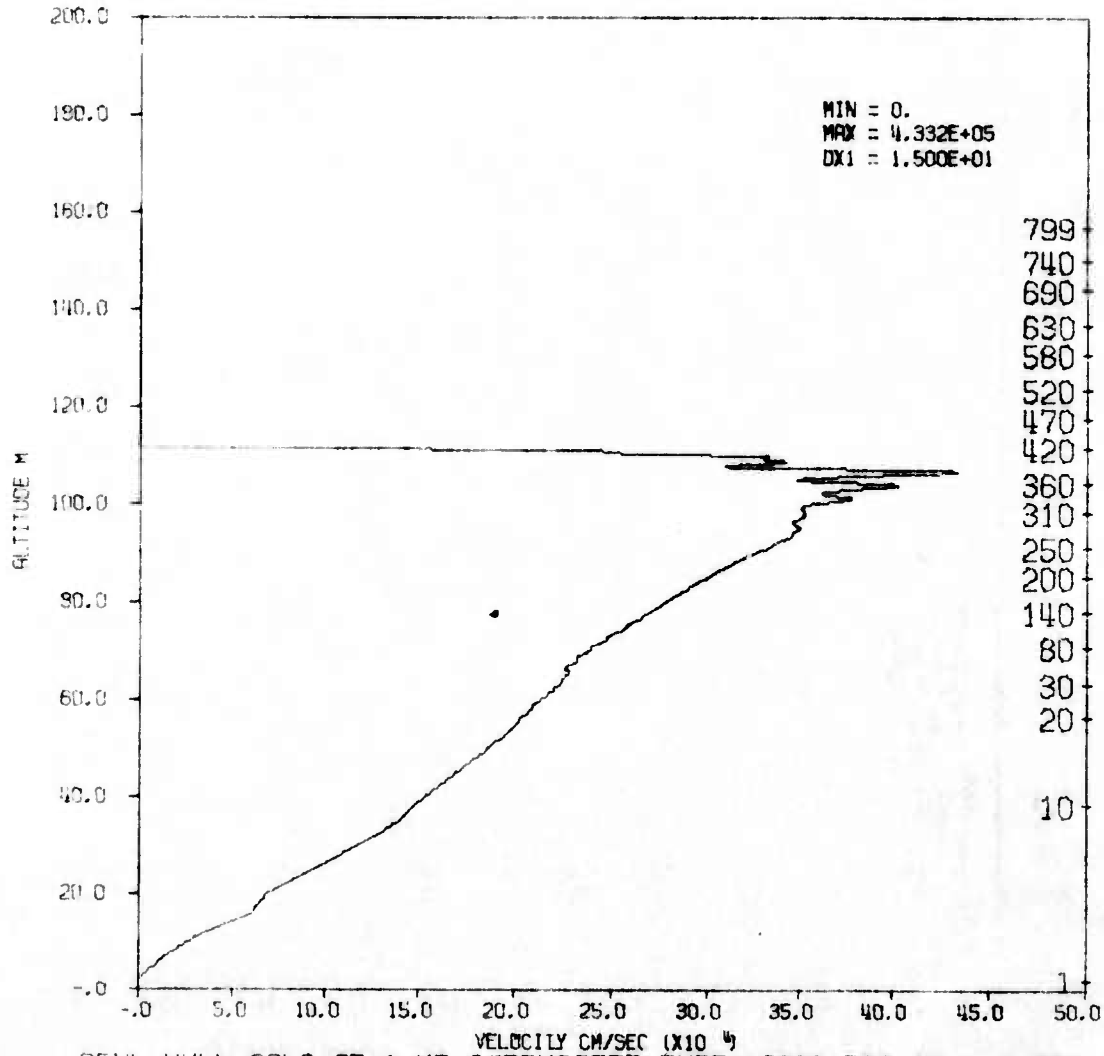


AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 32.000 MSEC CYCLE 733. PROBLEM 13.6100



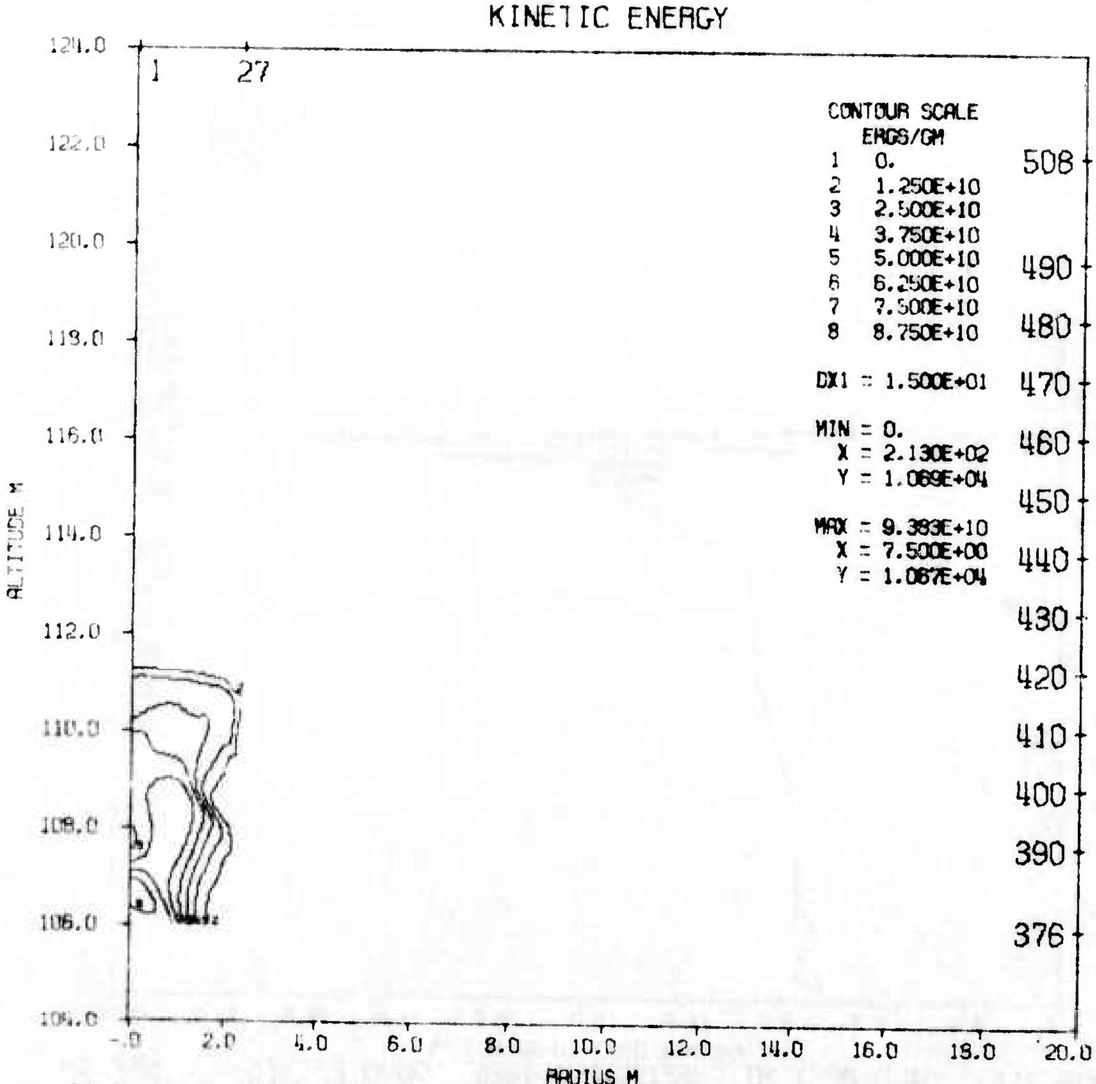
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 32.000 MSEC CYCLE 733. PROBLEM 13.6100

VERTICAL VELOCITY VERTICAL HISTOGRAM
VERTICAL CROSS SECTION AT RADIUS 7.50E-05 KM (I= 1)



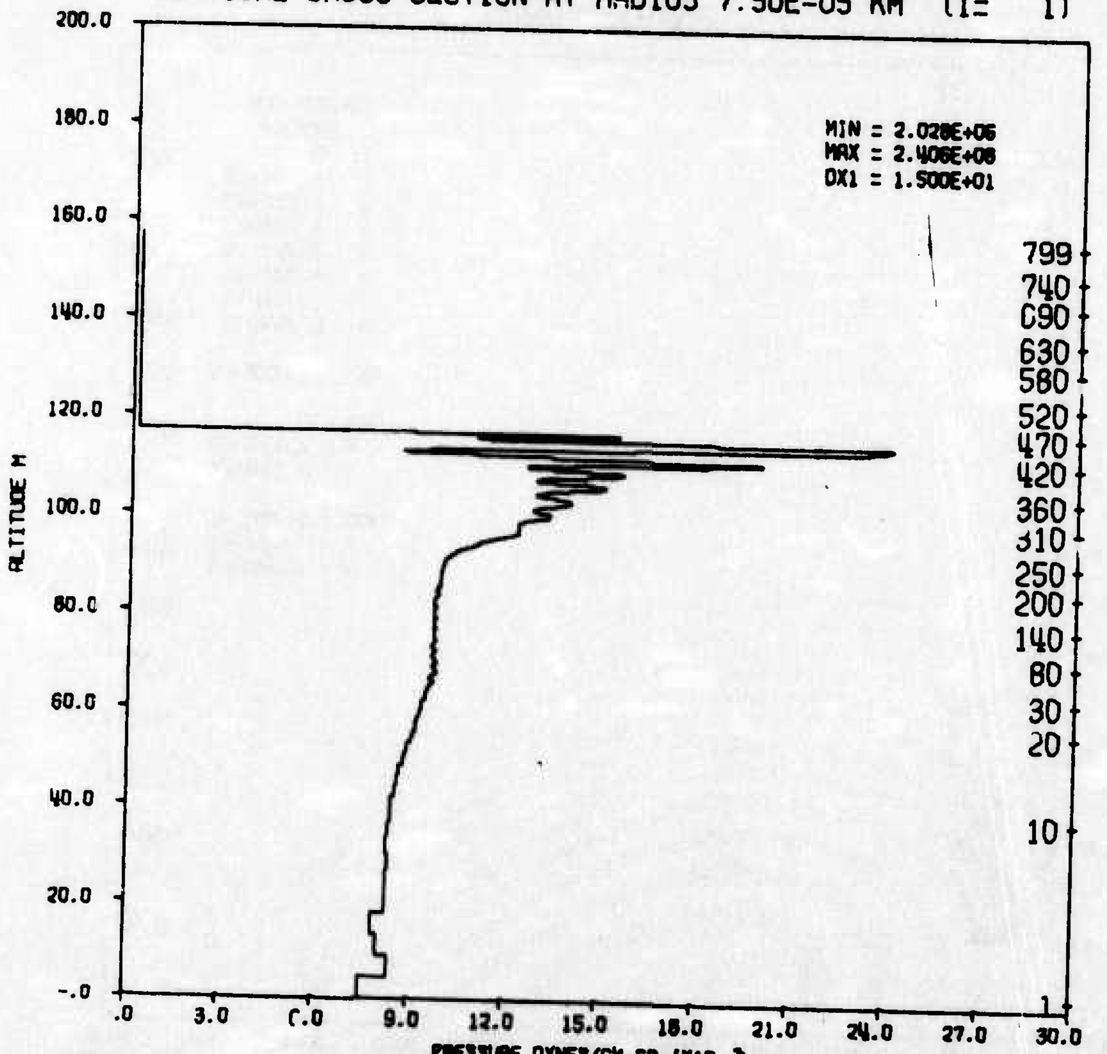
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 32.000 MSEC CYCLE 733. PROBLEM 13.6100

KINETIC ENERGY

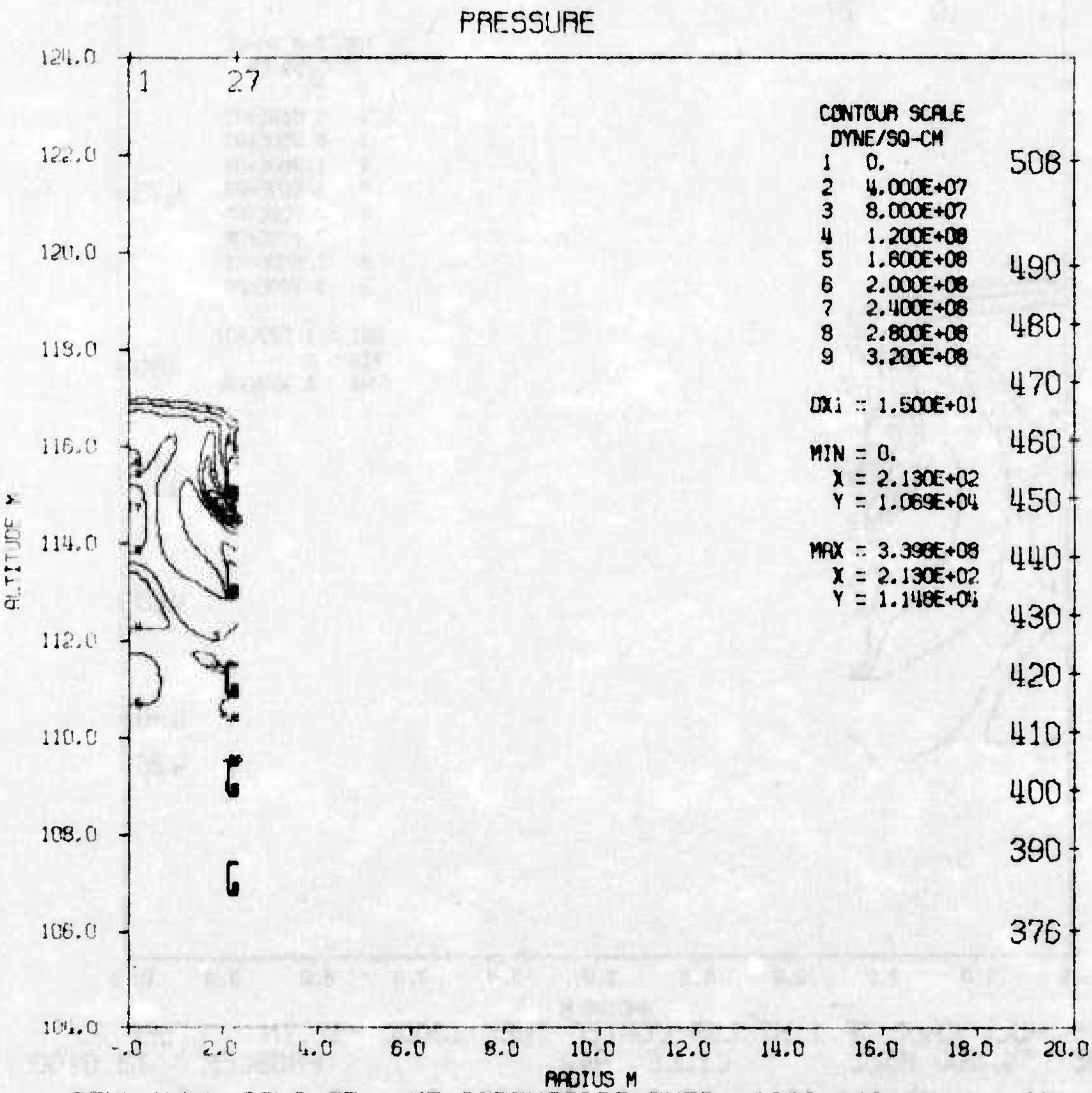


AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 32.000 MSEC CYCLE 733. PROBLEM 13.6100

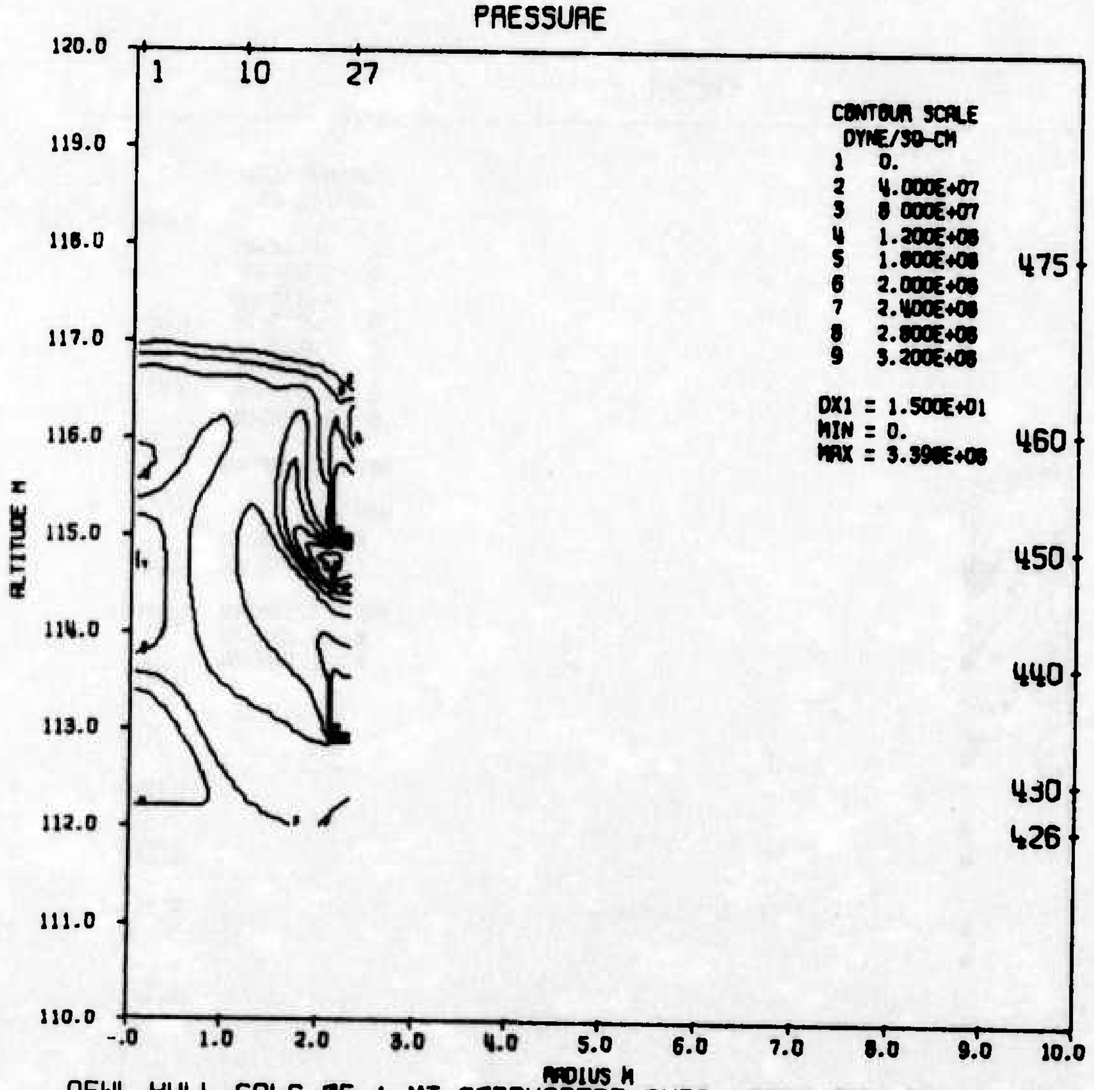
PRESSURE VERTICAL HISTOGRAM
VERTICAL CROSS SECTION AT RADIUS 7.50E-05 KM (I= 1)



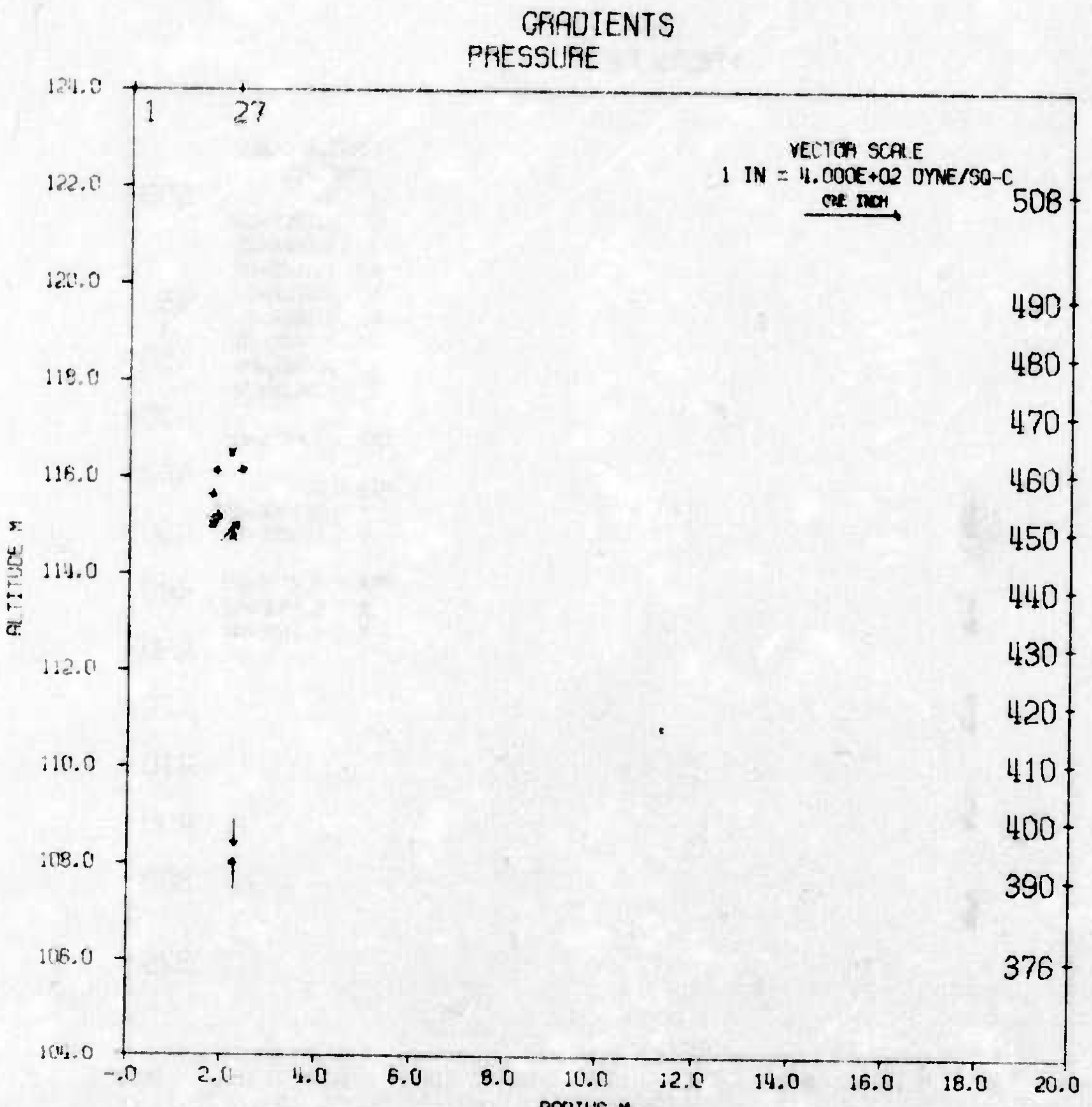
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSCC CYCLE 942. PROBLEM 13.6100



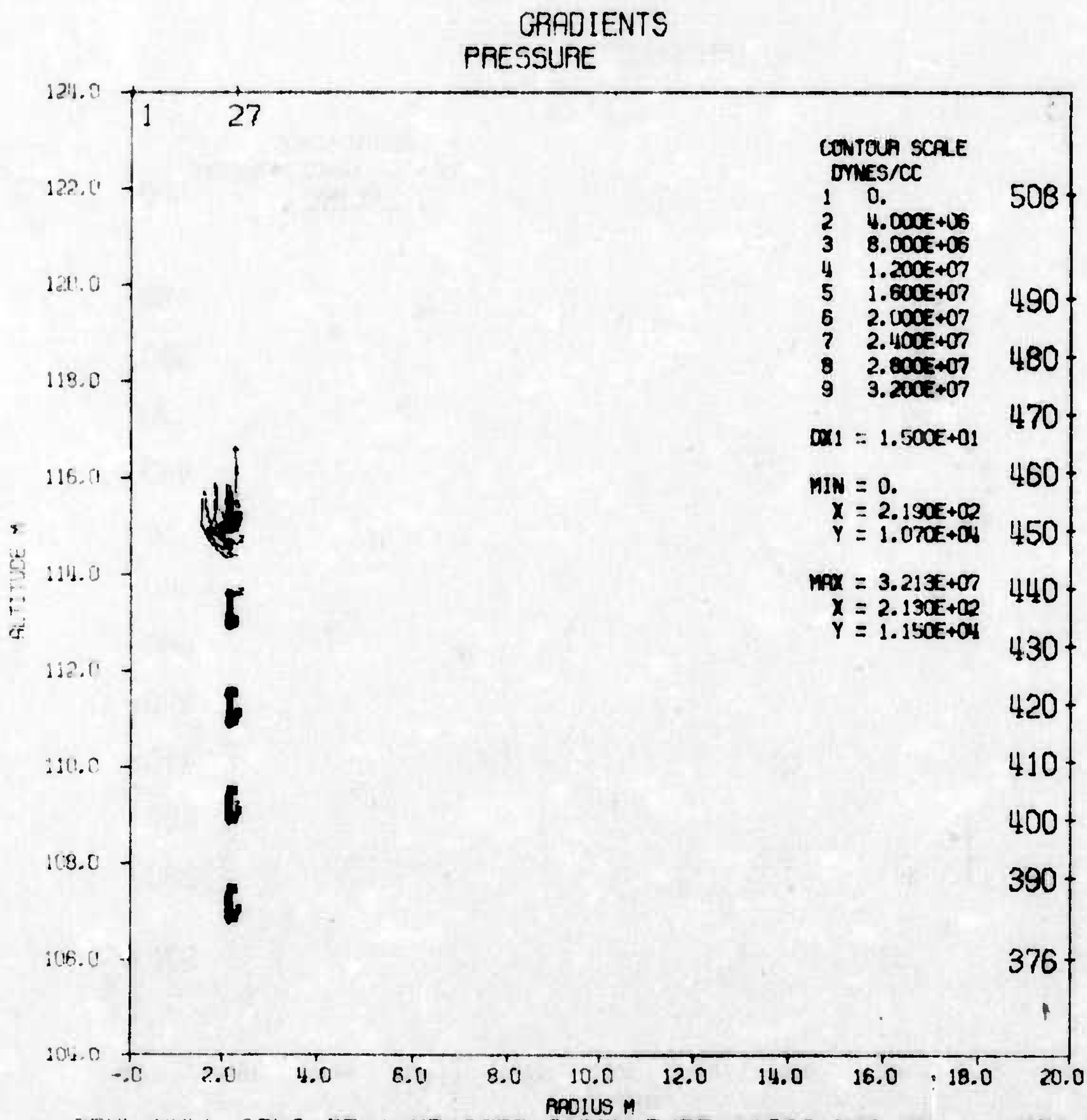
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100

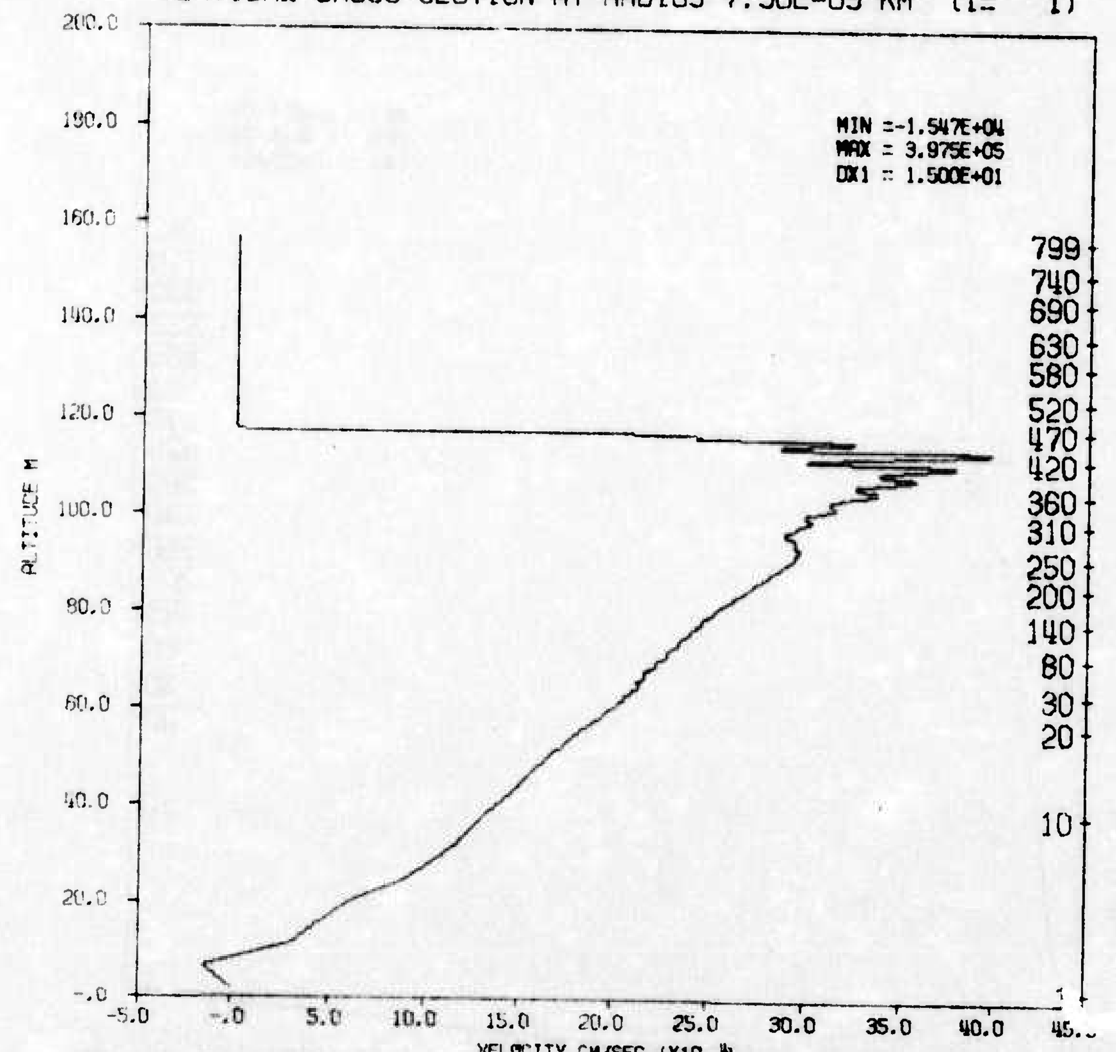


AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100

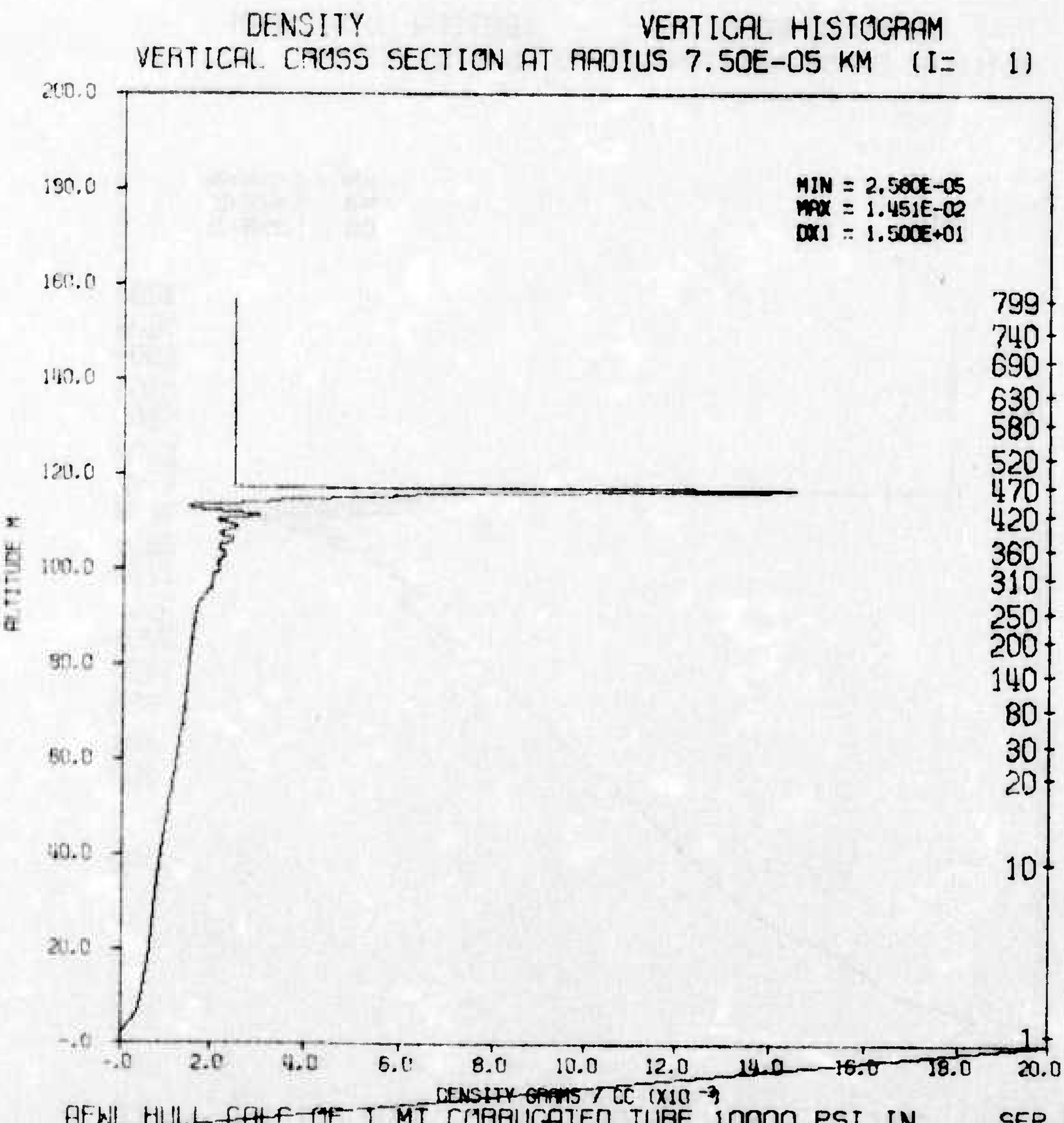


AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100

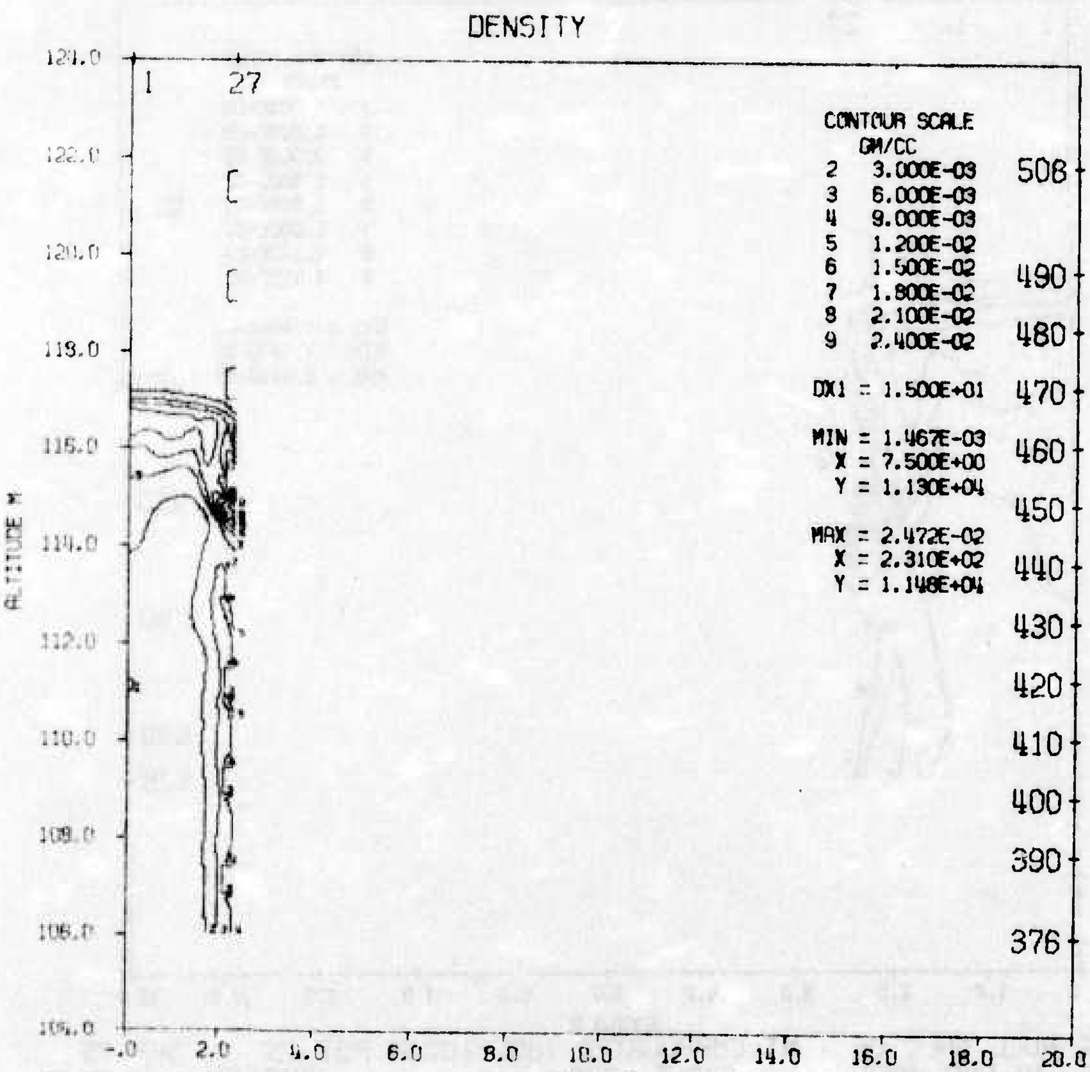
VERTICAL VELOCITY VERTICAL HISTOGRAM
VERTICAL CROSS SECTION AT RADIUS 7.50E-05 KM (I= 1)



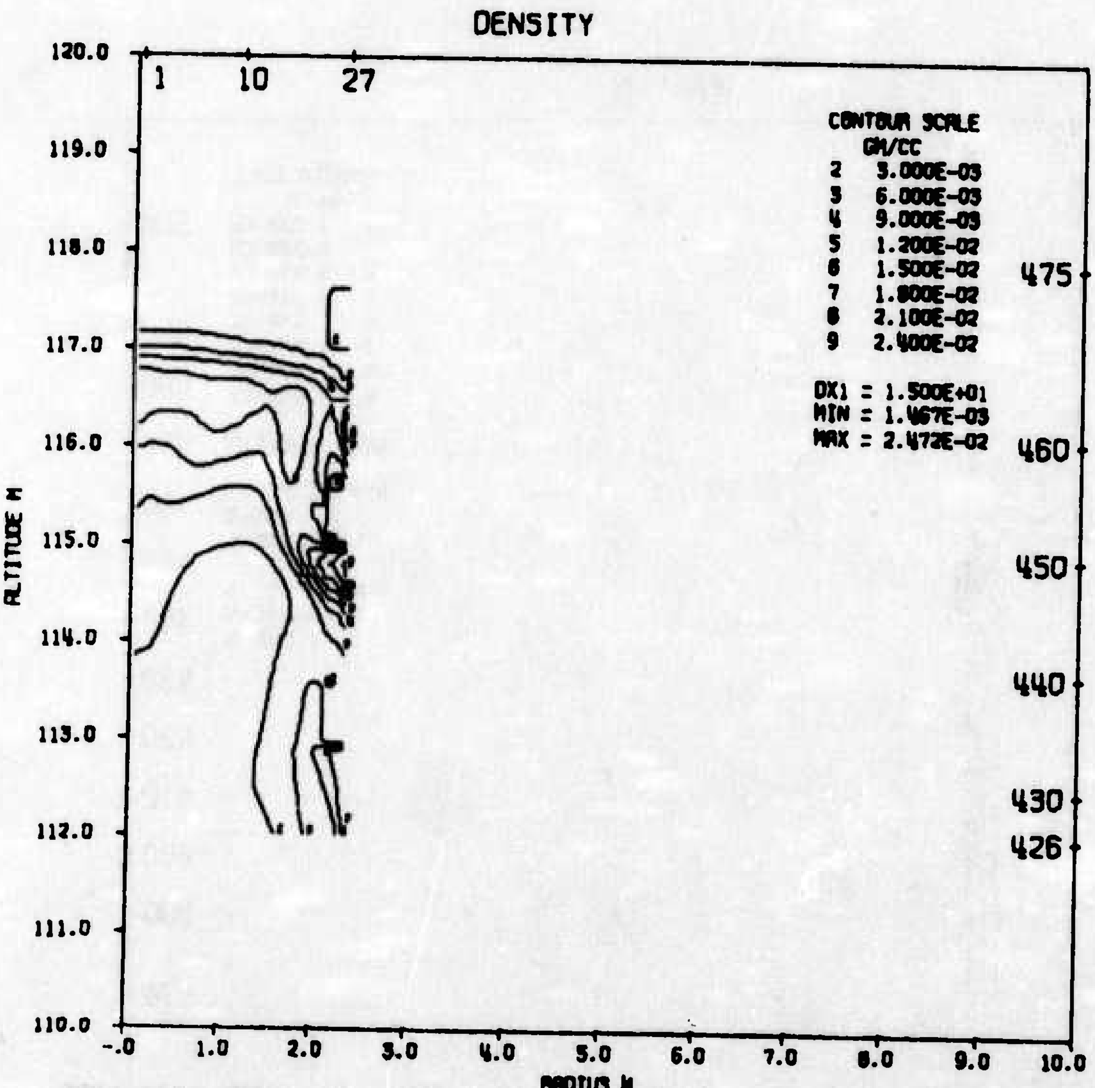
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100



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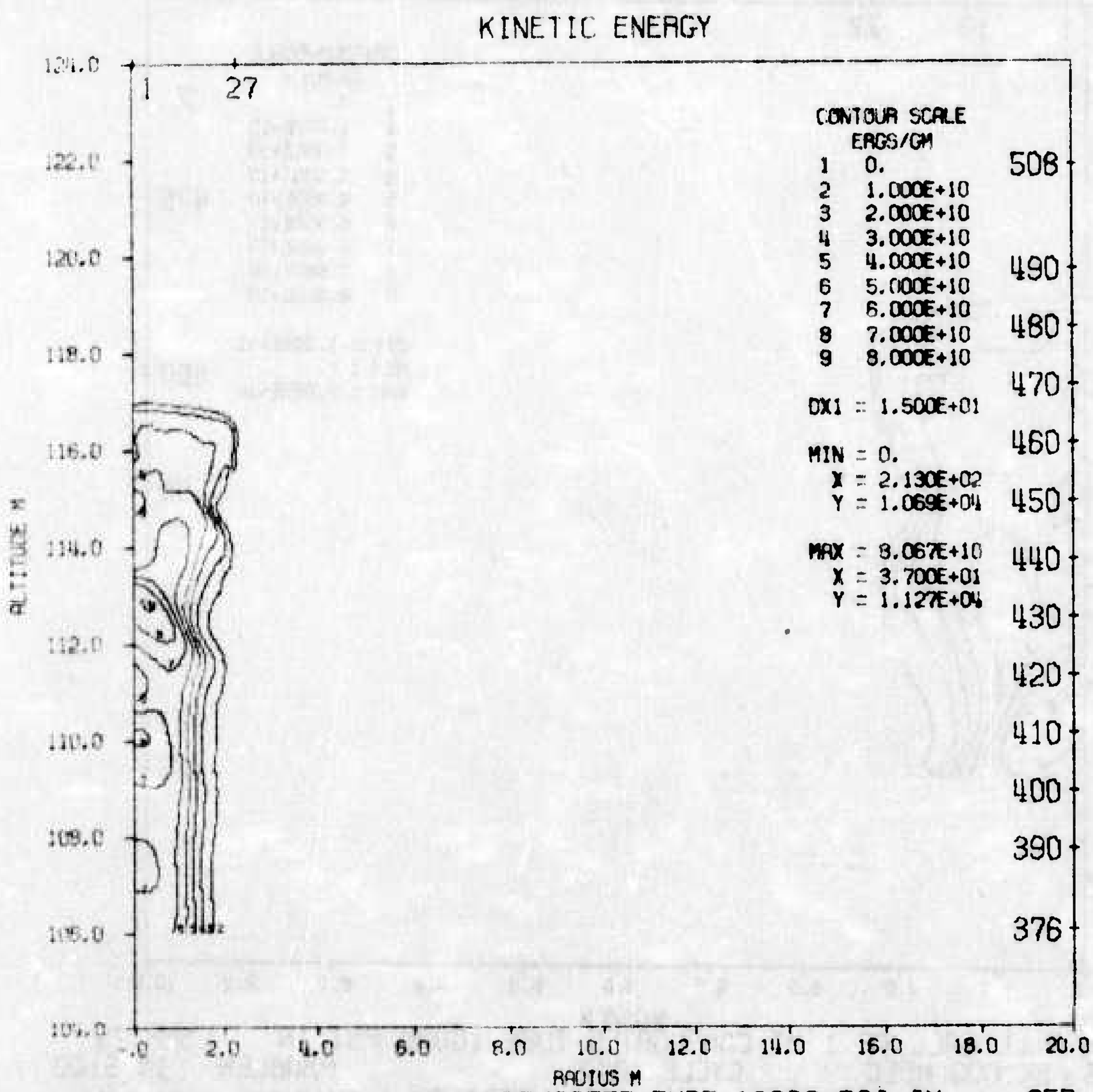
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100



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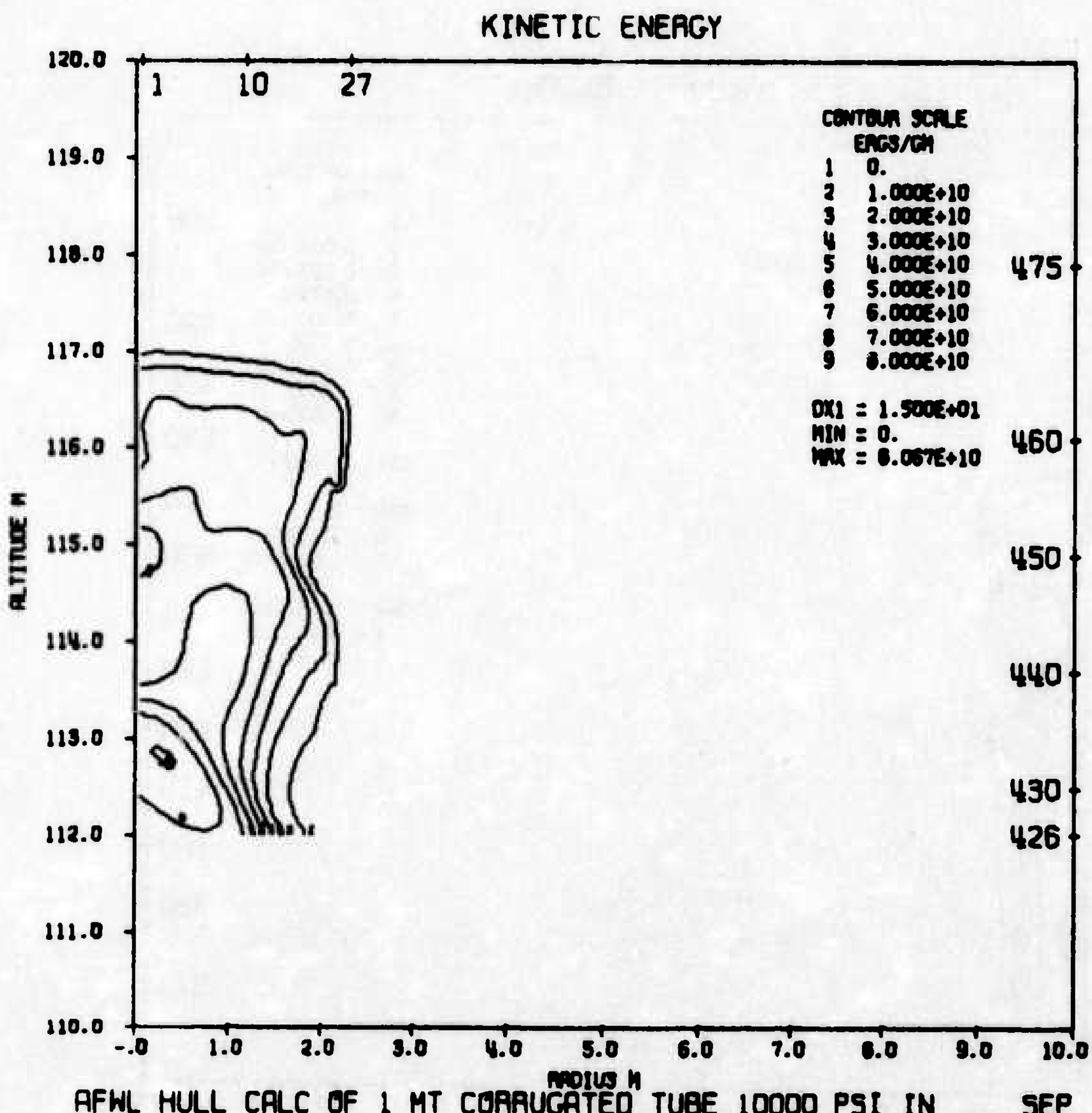
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100



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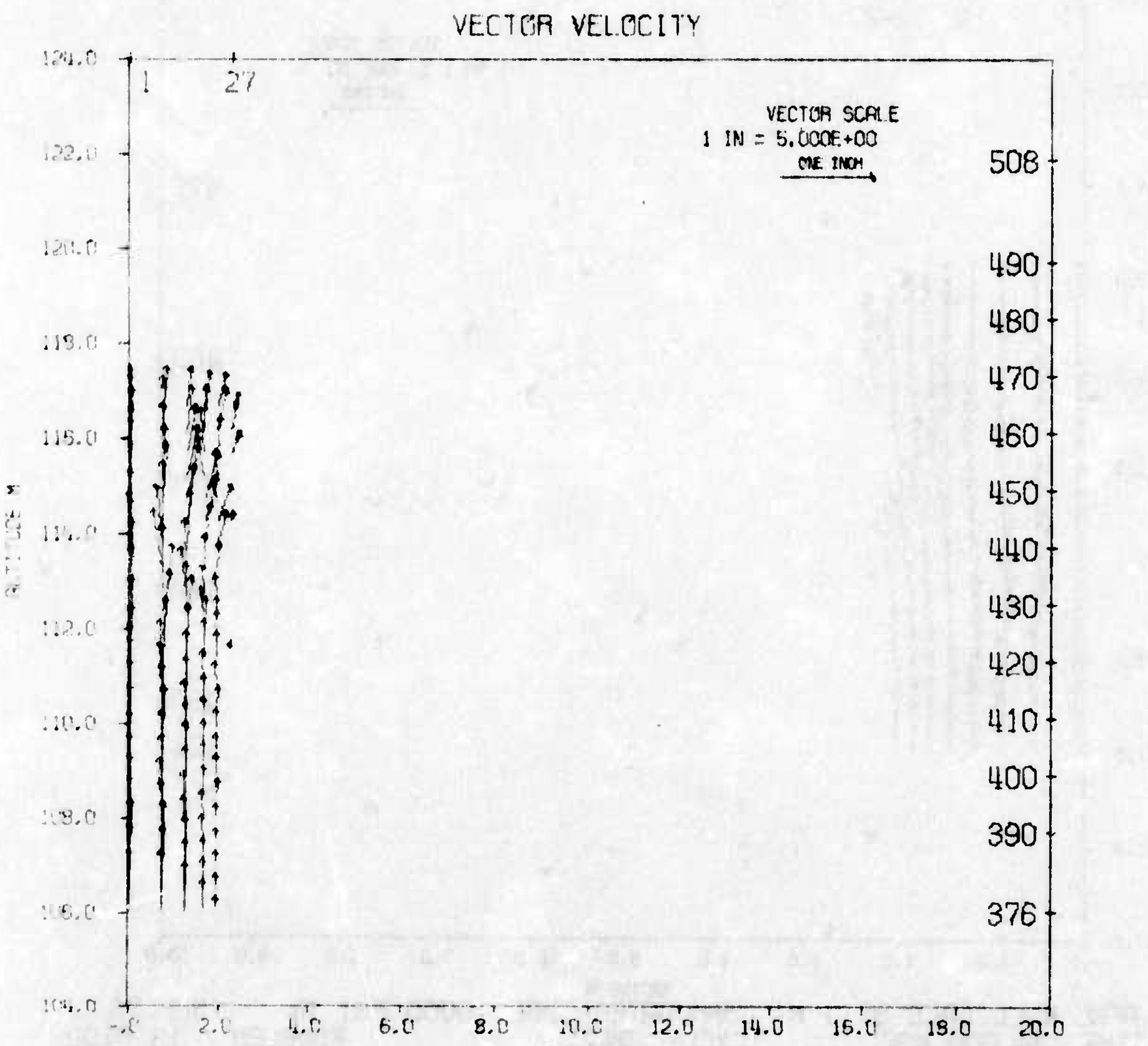
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100



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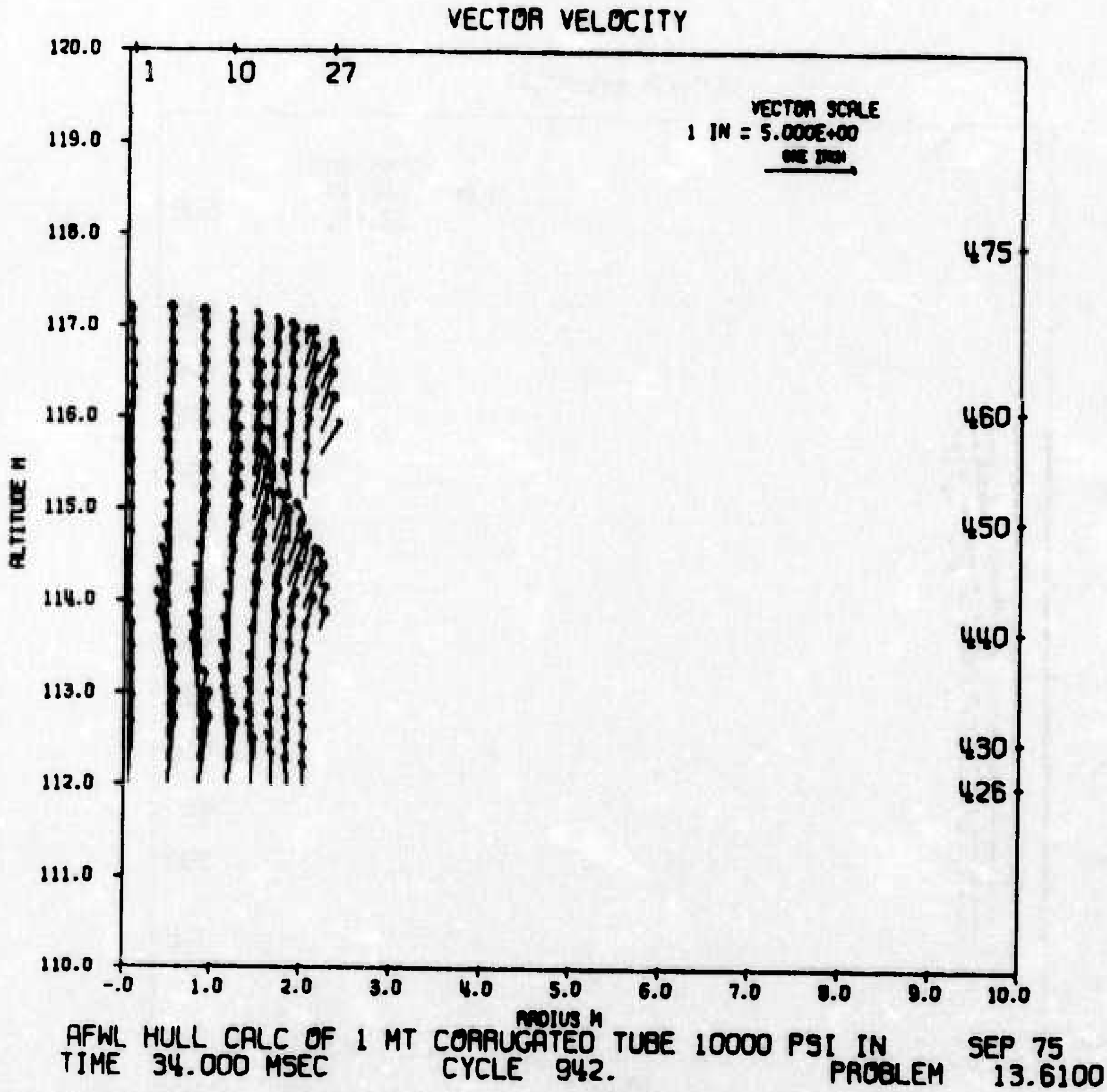
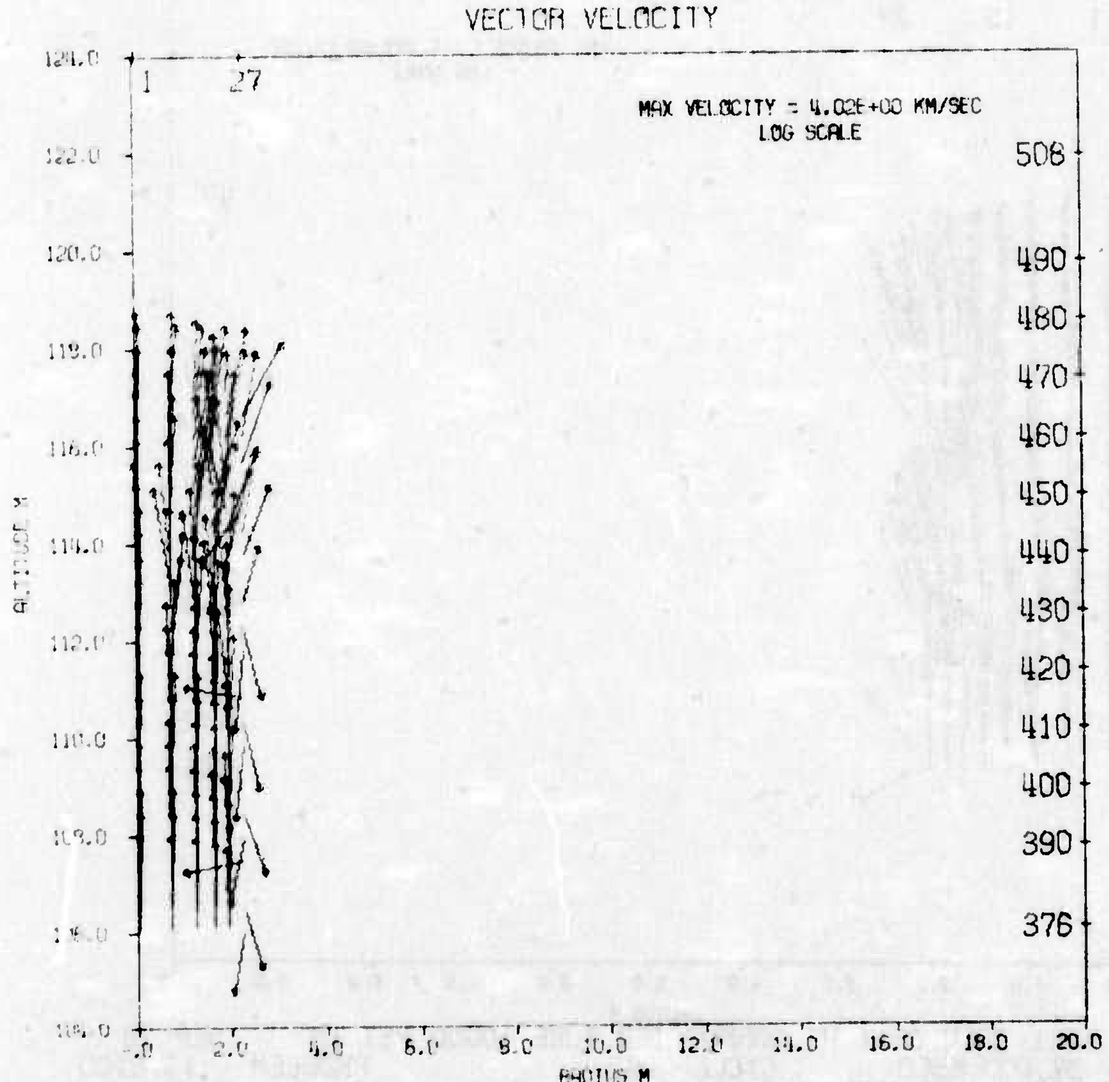
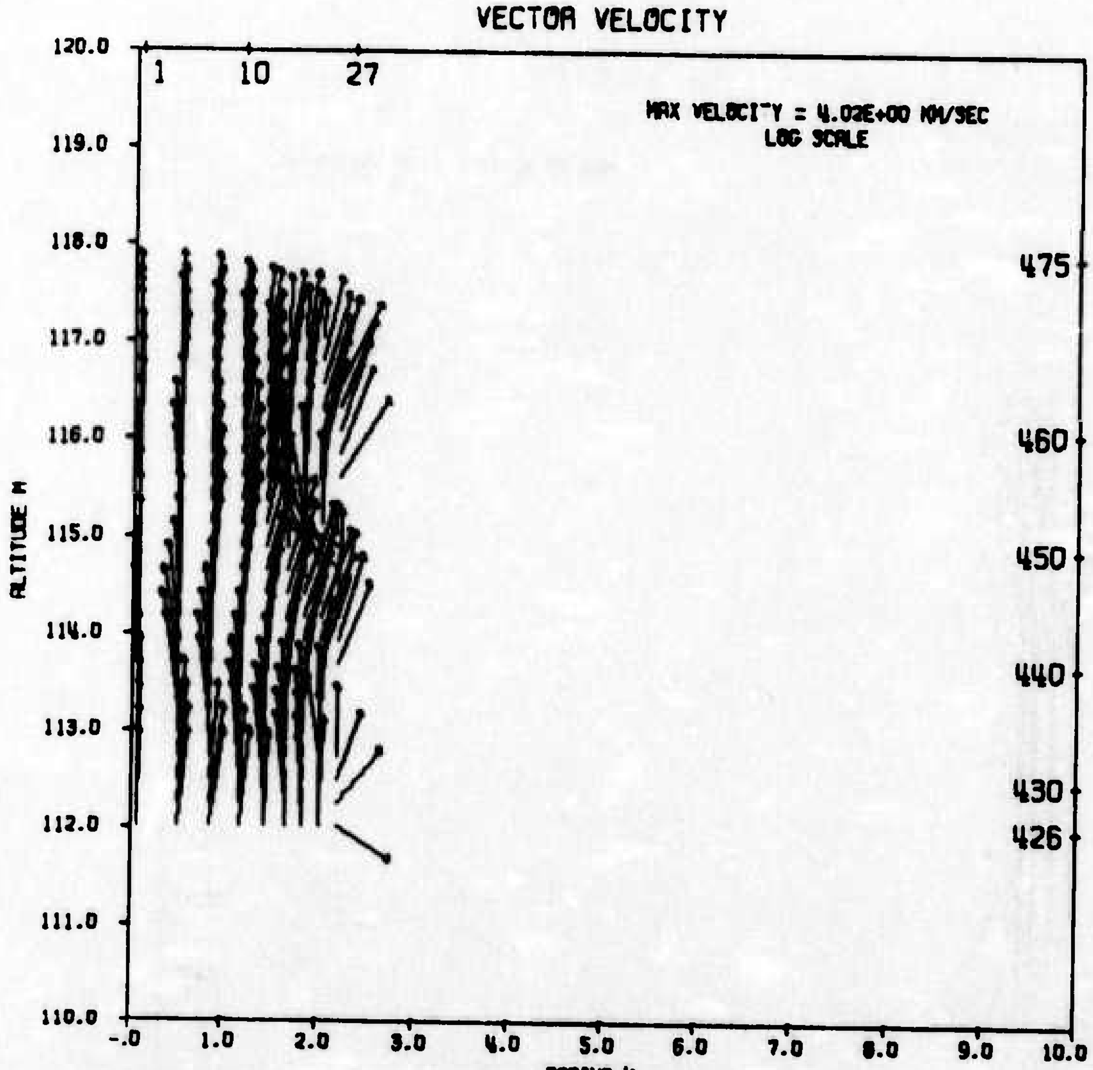
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100



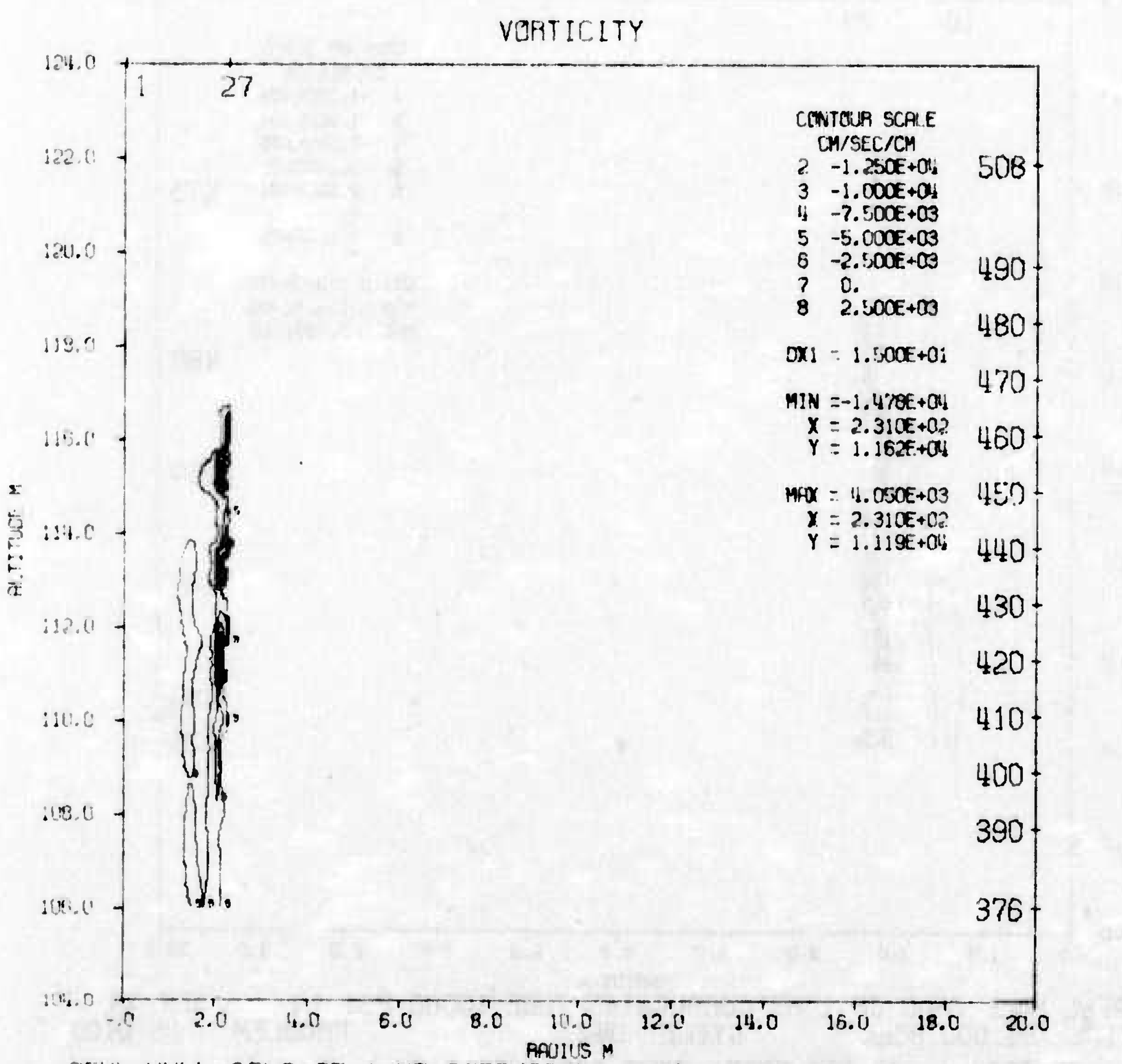
VECTOR VELOCITY
120.0
119.0
118.0
117.0
116.0
115.0
114.0
113.0
112.0
111.0
110.0
ALTITUDE M
1
10
27
VECTOR SCALE
1 IN = 5.000E+00
475
460
450
440
430
426
-.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
RADIUS M
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN
SEP 75
TIME 34.000 MSEC
CYCLE 942.
PROBLEM 13.6100



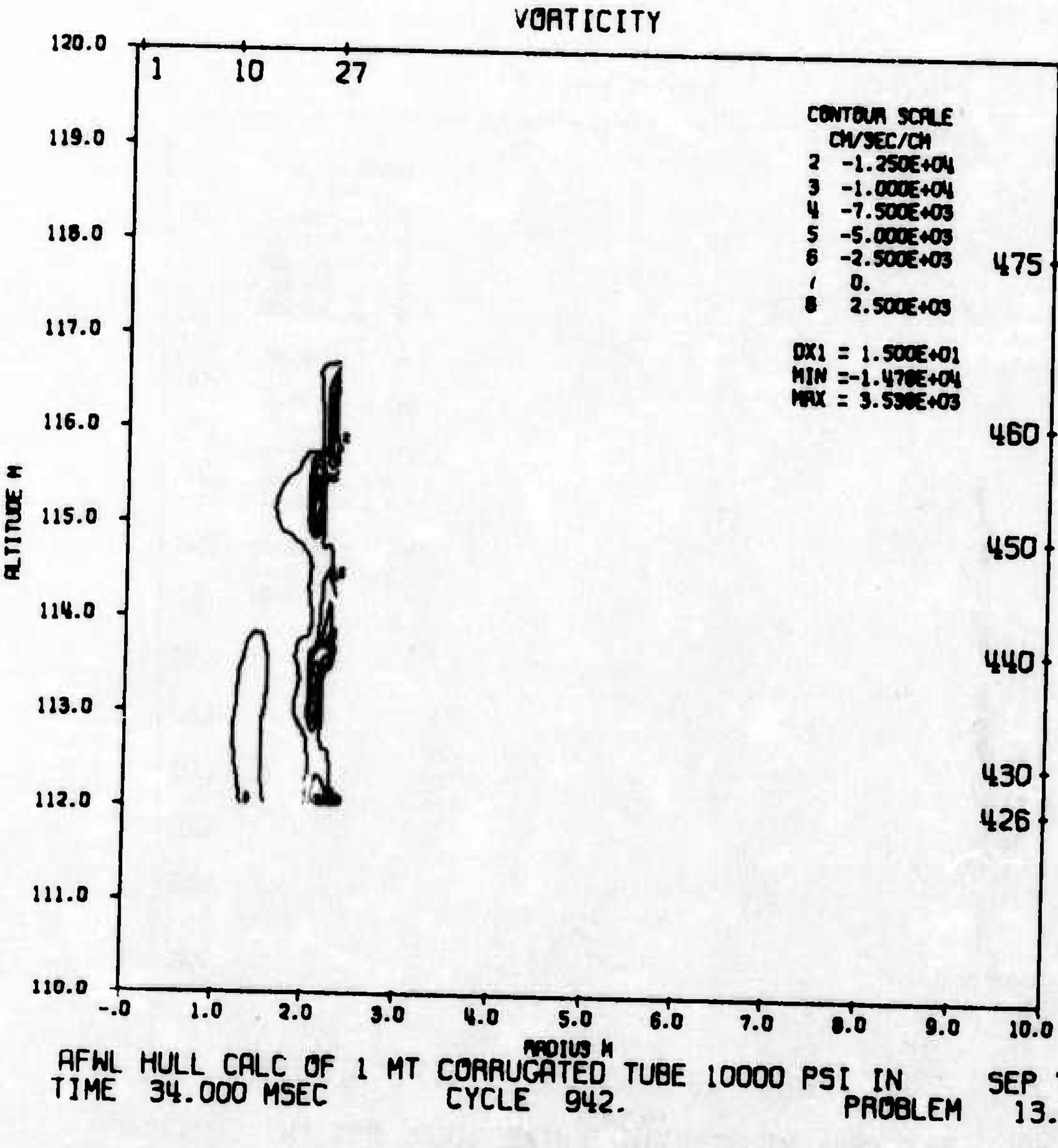
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100

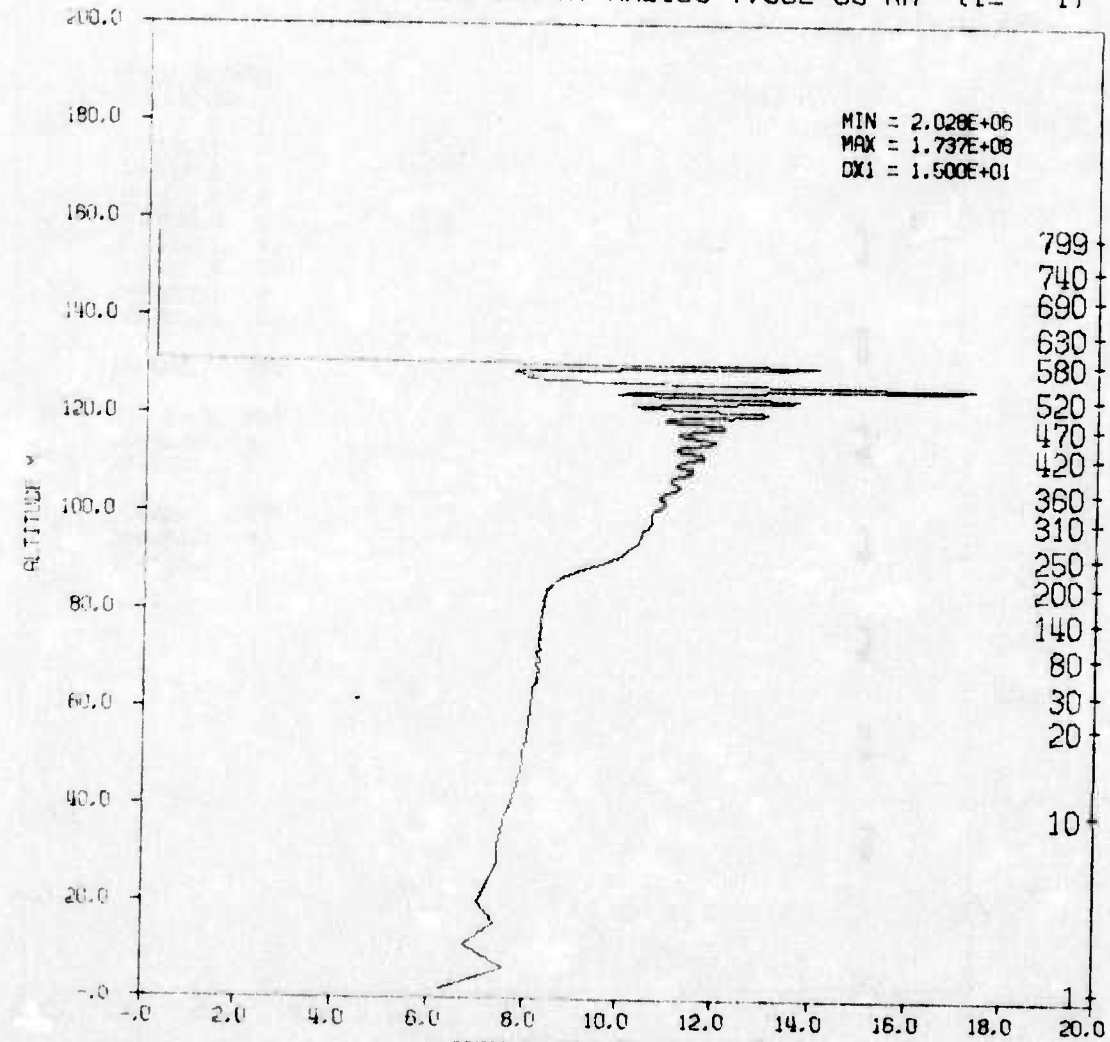


AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100

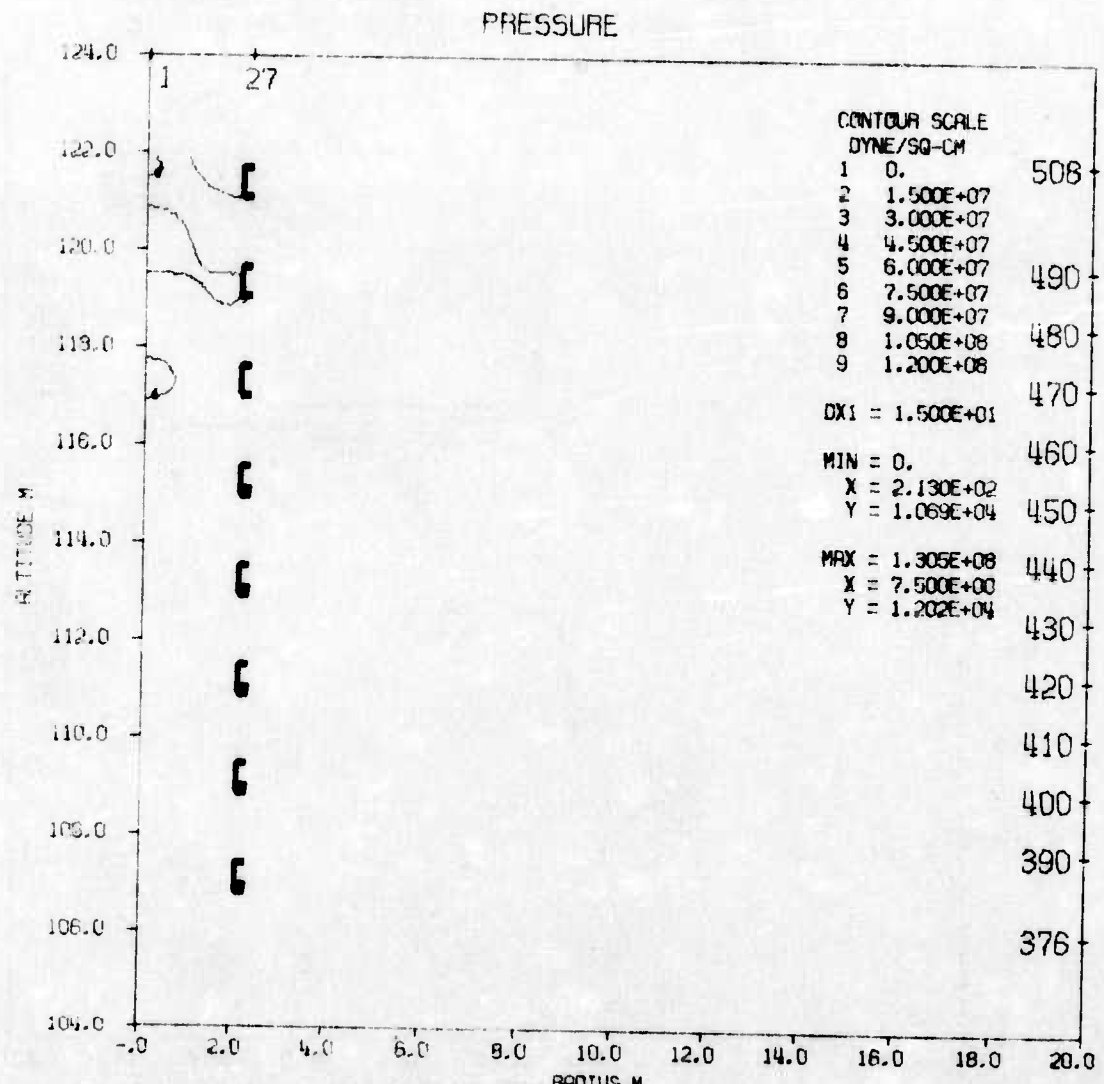


AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 34.000 MSEC CYCLE 942. PROBLEM 13.6100

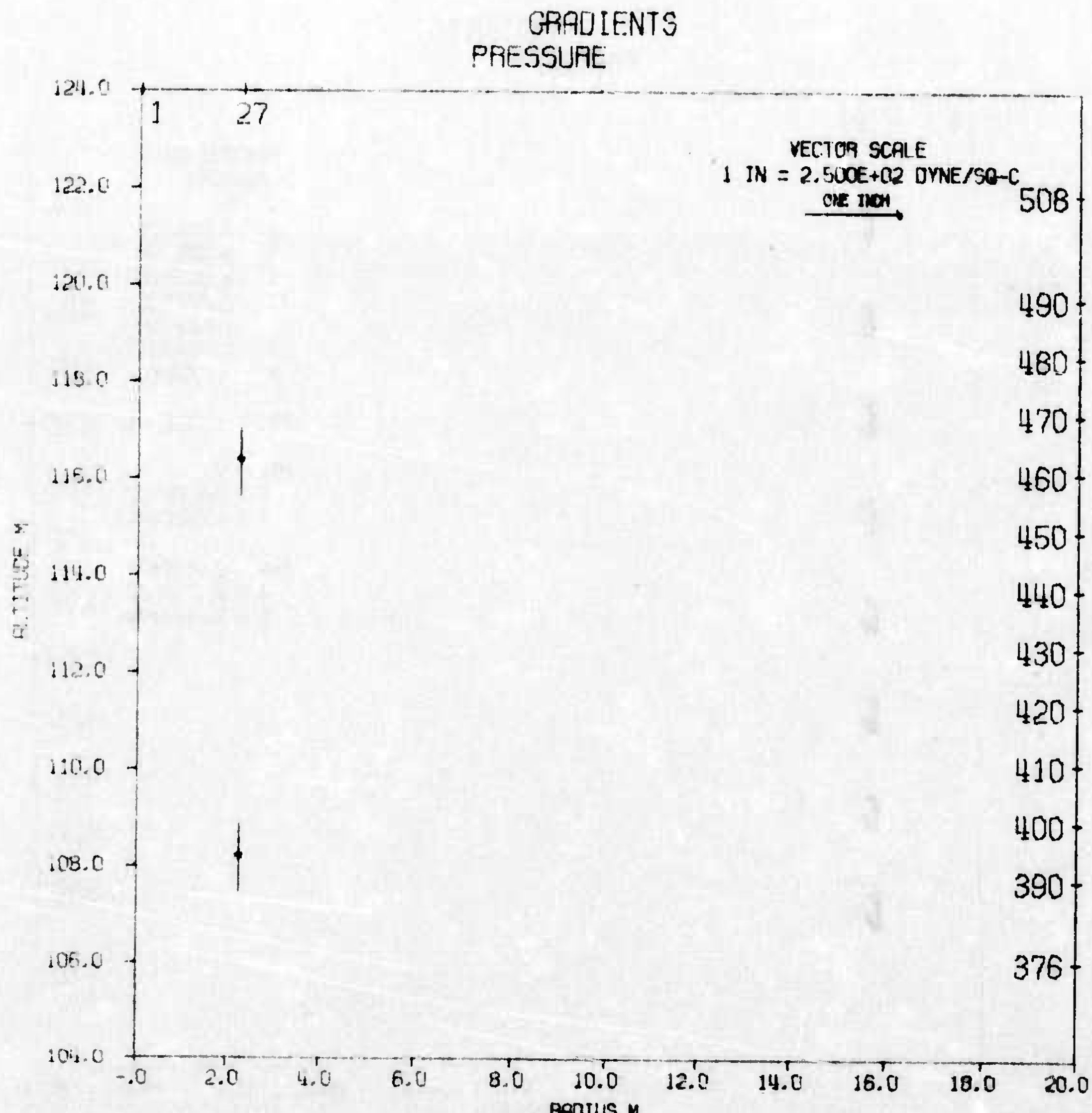
PRESSURE VERTICAL HISTOGRAM
VERTICAL CROSS SECTION AT RADIUS 7.50E-05 KM (I= 1)



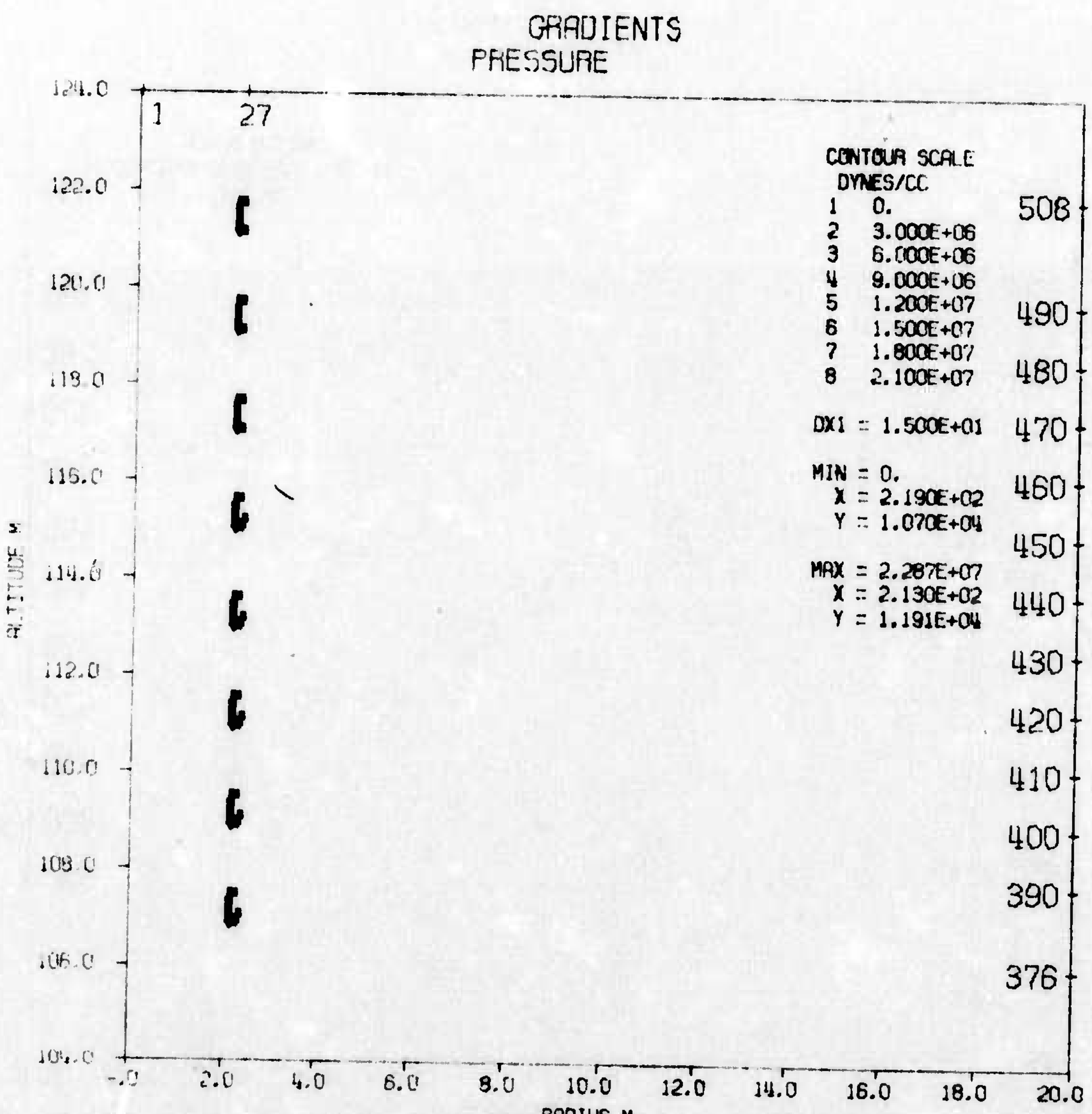
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 38.249 MSEC CYCLE 1474. PROBLEM 13.6100



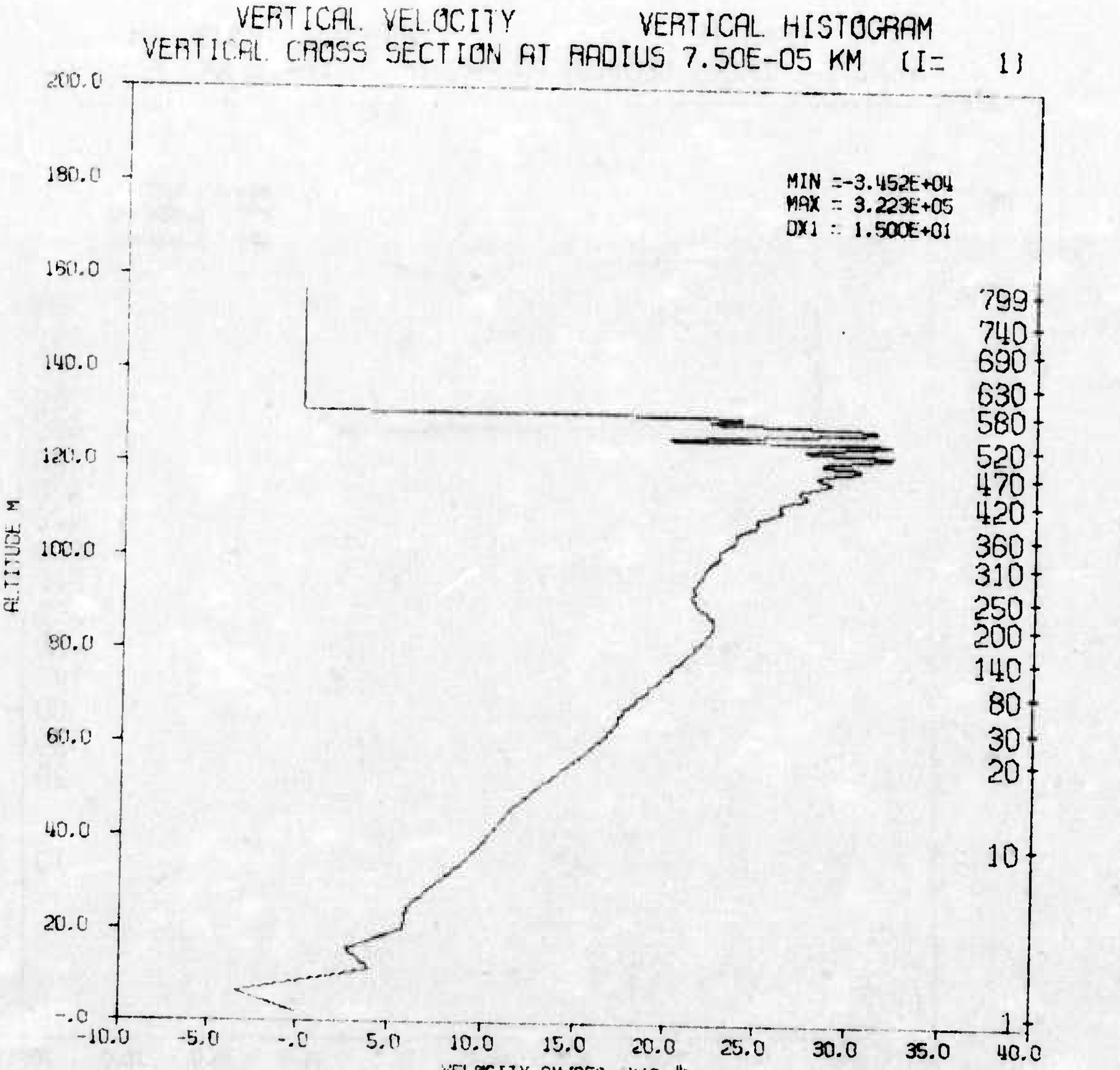
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 39.249 MSEC CYCLE 1474. PROBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 39.249 MSEC CYCLE 1474. PROBLEM 13.6100



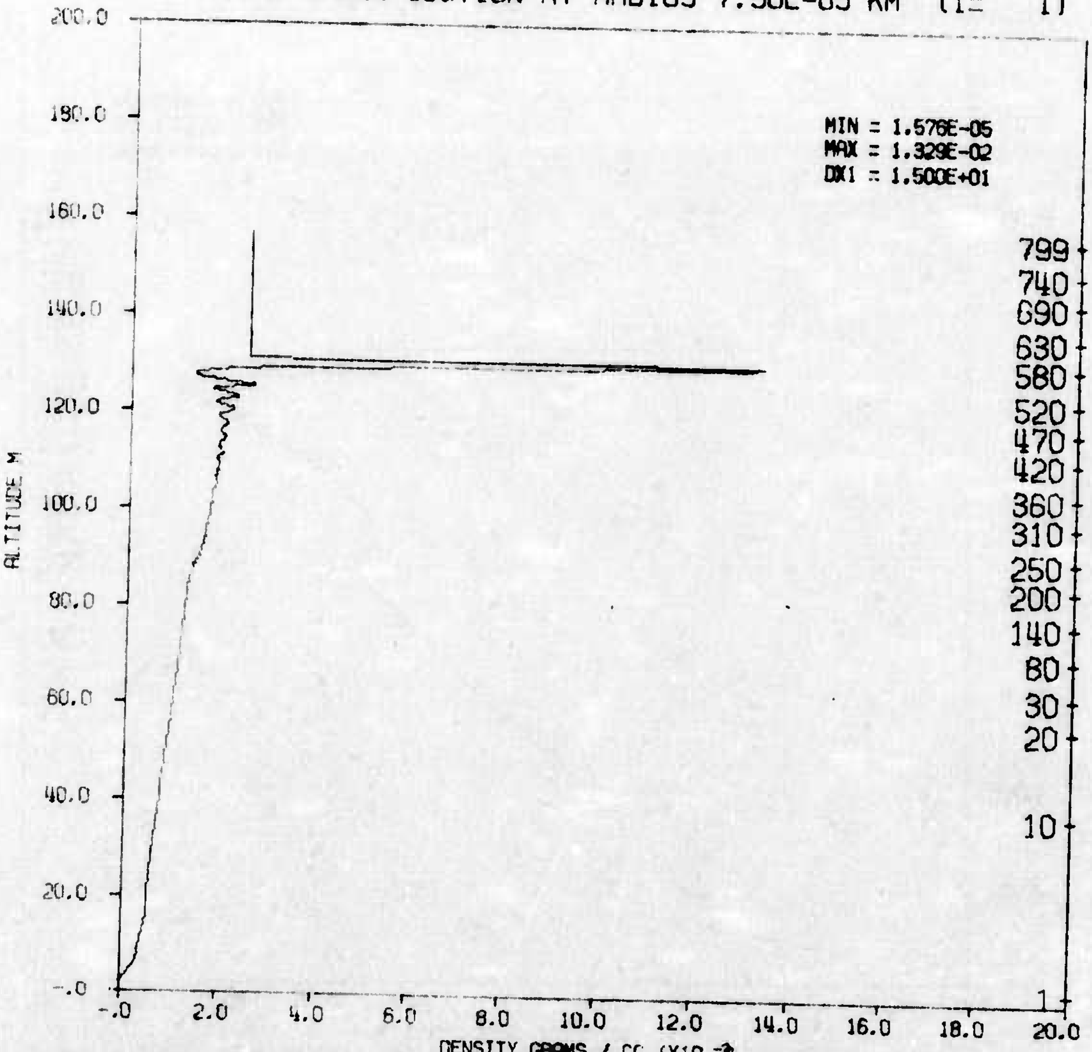
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 39.249 MSEC CYCLE 1474. PROBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 39.249 MSEC CYCLE 1474. PROBLEM 13.6100

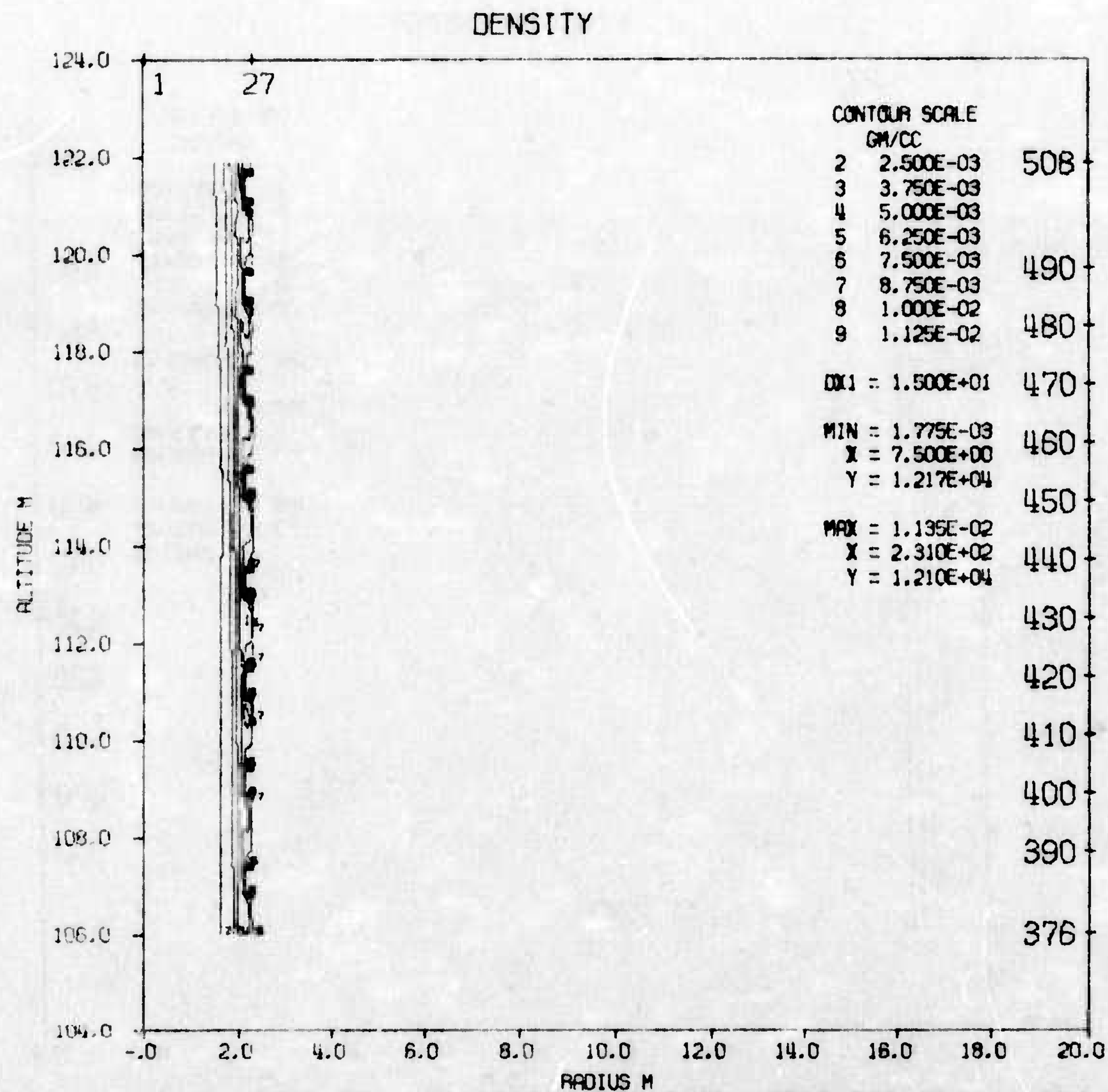
DENSITY VERTICAL HISTOGRAM

VERTICAL CROSS SECTION AT RADIUS 7.50E-05 KM (I= 1)

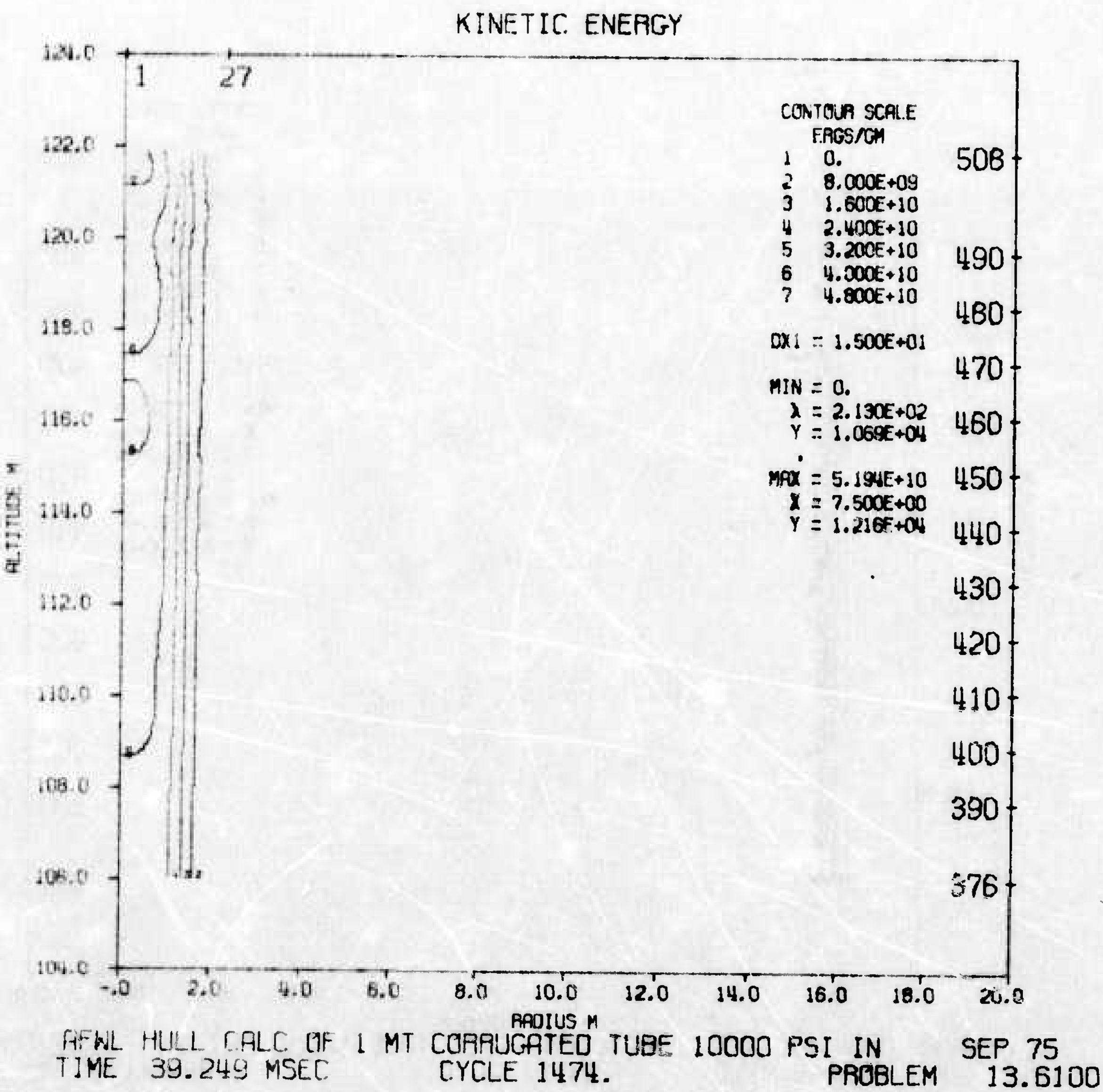


AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75

TIME 39.249 MSEC CYCLE 1474. PROBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 39.249 MSEC CYCLE 1474. PROBLEM 13.6100


KINETIC ENERGY
CONTOUR SCALE
ERGS/CM
1 0.
2 8.000E+09
3 1.600E+10
4 2.400E+10
5 3.200E+10
6 4.000E+10
7 4.800E+10
DX1 = 1.500E+01
MIN = 0.
X = 2.130E+02
Y = 1.069E+04
MAX = 5.194E+10
X = 7.500E+00
Y = 1.216E+04
ALTITUDE M
RADIUS M
124.0
122.0
120.0
118.0
116.0
114.0
112.0
110.0
108.0
106.0
104.0
-.0
2.0
4.0
6.0
8.0
10.0
12.0
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16.0
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20.0
1
27
508
490
480
470
460
450
440
430
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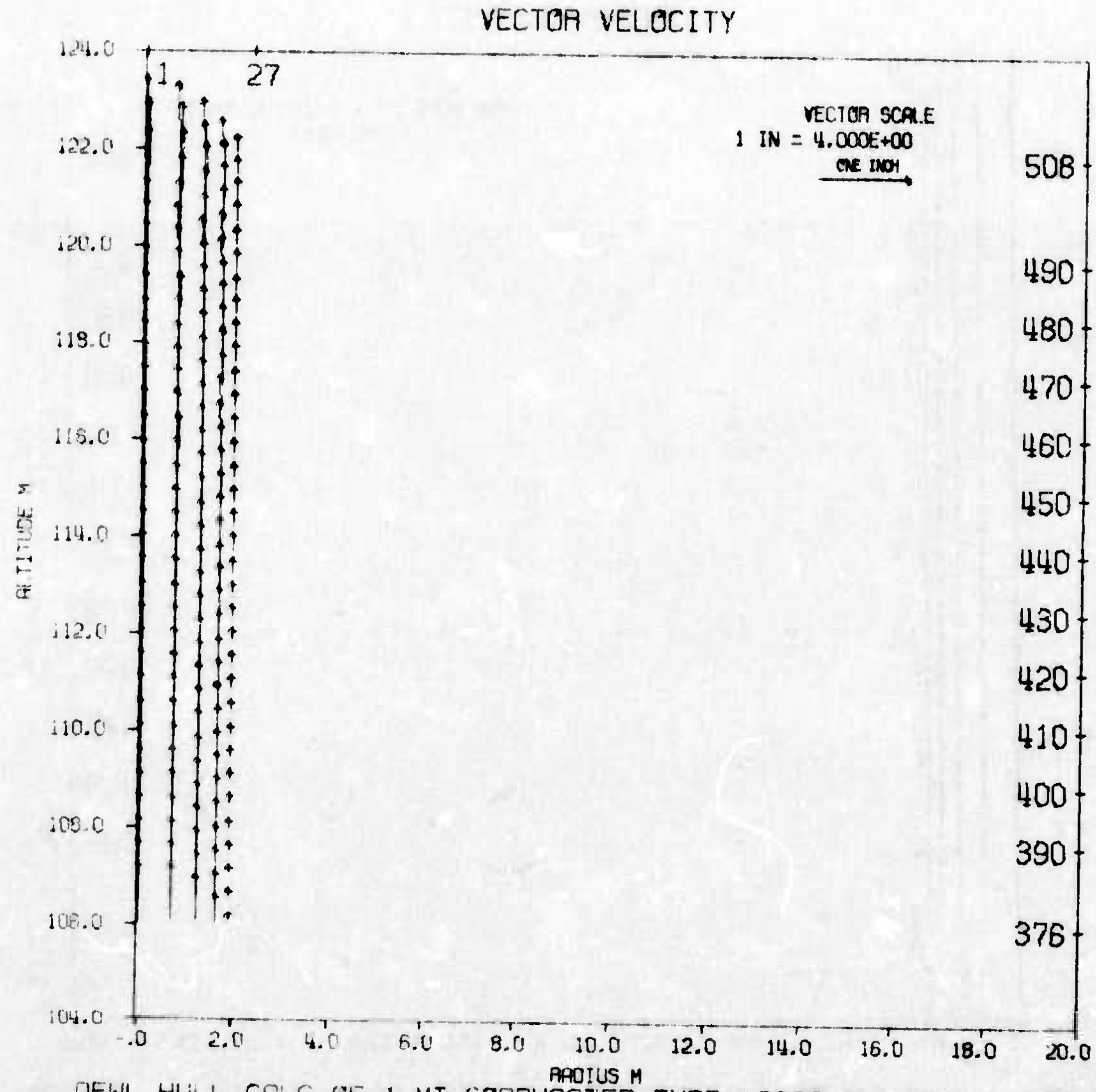
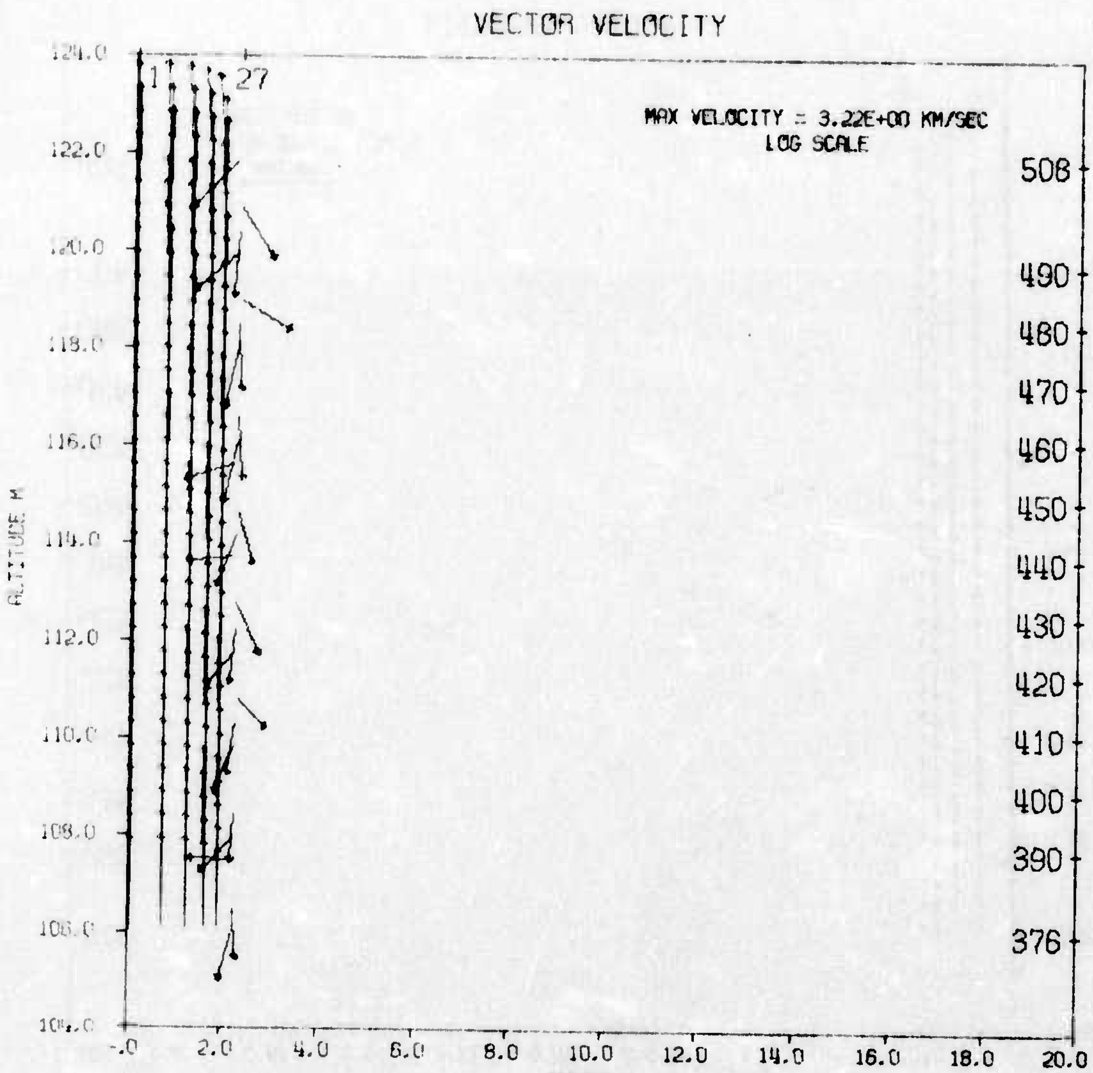
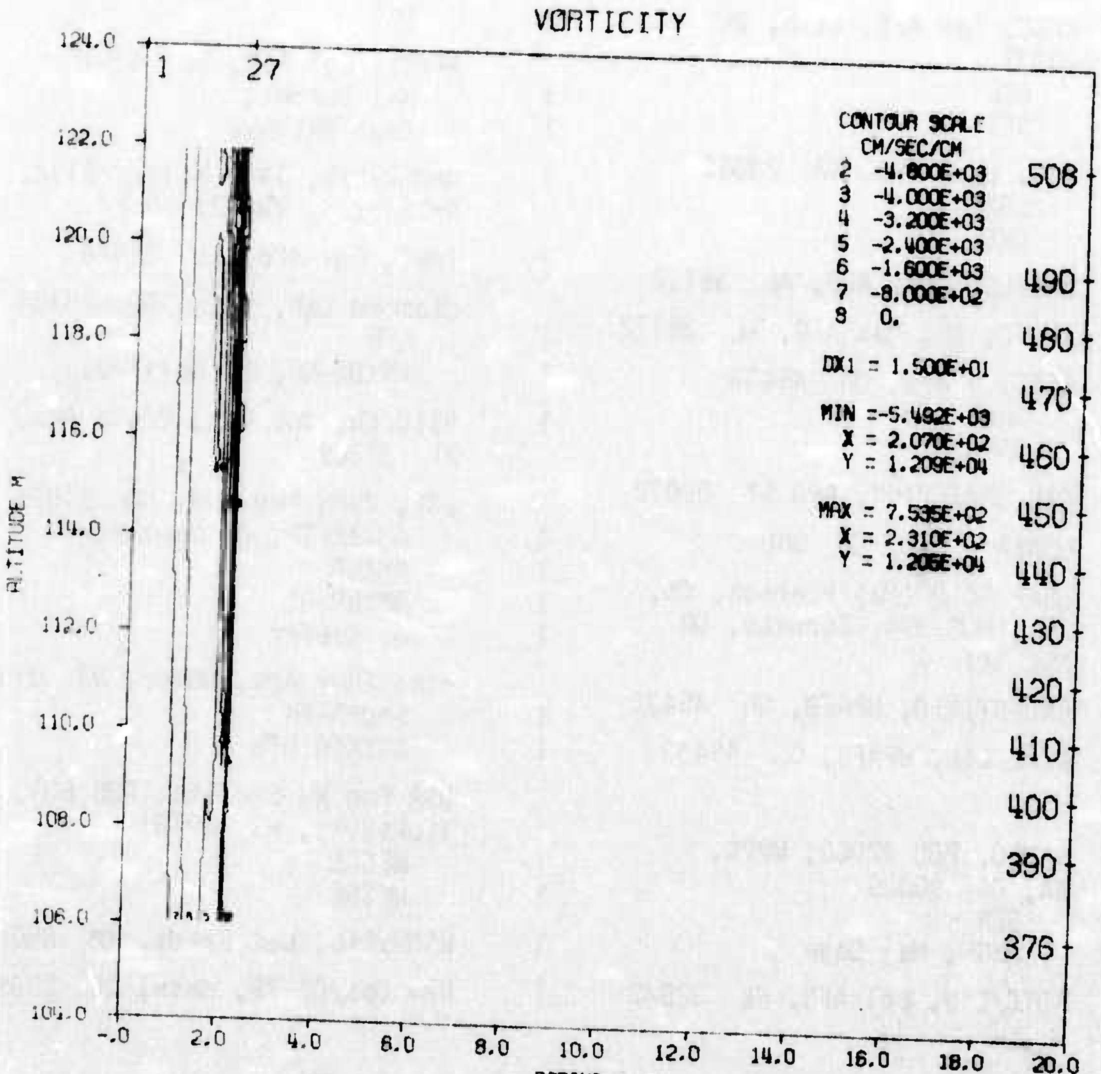
376
AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 39.249 MSEC CYCLE 1474. PROBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 39.249 MSEC CYCLE 1474. PROBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 39.249 MSEC CYCLE 1474. PROBLEM 13.6100



AFWL HULL CALC OF 1 MT CORRUGATED TUBE 10000 PSI IN SEP 75
TIME 39.249 MSEC CYCLE 1474. PROBLEM 13.6100

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1	SMUPA-TN
1	STINFO Ofc
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1	WESRL
1	WESSS
1	WSMR/Lib, Wht Sands, NM 88002
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1	DIA/Mr. Castlebury, Wash, DC 20305
	Sandia Lab, Kirt AFB, NM 87115
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1	Nat War Col/Lib, Ft McNair, Wash, DC 20315
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1	USAEC/AMSEL-RD, Ft Monmouth, NJ 07703
	USNCEL, Pt Hueneme, CA 93041
1	Code L31
1	CEC Ofcr
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1	IITRI, 10 W. 35, Chicago, IL 60616
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1	RAC/Lib, McLean, VA 22101

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