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TECHNICAL REPORT TR-5364-2
REVISION 0

BOOK 1 OF 10

DONALD C. COOK NUCLEAR GENERATING PLANT

ANALYSIS OF PRESSURIZER SAFETY/RELIEF VALVES DISCHARGE PIPING SYSTEM PER NUREG-0737, II.D.1, UNIT 2

JUNE 10, 1983

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AMERICAN ELECTRIC POWER SERVICE CORPORATION
2 BROADWAY
NEW YORK, NEW YORK 10004

TECHNICAL REPORT TR-5364-2
REVISION 0

BOOK 1 OF 10

DONALD C. COOK NUCLEAR GENERATING STATION

ANALYSIS OF PRESSURIZER SAFETY/RELIEF VALVES DISCHARGE PIPING SYSTEM PER NUREG 0737, II. D.1, UNIT 2

JUNE 10, 1983

TELEDYNE ENGINEERING SERVICES

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WALTHAM, MASSACHUSETTS 02254
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Technical Report
TR-5364-2
Revision 0

TELEDYNE
ENGINEERING SERVICES

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1.0 INTRODUCTION

American Electric Power Service Corporation (AEP), purchase order number 02676-820-1N, authorized Teledyne Engineering Services (TES) to analyze the Pressurizer Safety/Relief Valve Discharge Piping per NRC NUREG-0737, Item II. D.1 for the Donald C. Cook Nuclear Power Plant, Unit #2.

This activity was performed in accordance with the TES Quality Assurance program which meets the requirements of 10CFR50, Appendix B, and ANSI N45.2.11 as interpreted by Regulatory Guide 1.64, Revision 2.

The scope of work for this effort is described in detail in Teledyne Engineering Services Technical Proposal PR-5653 (Reference 1), dated May 4, 1981 and modified as stated in AEP letter dated November 29, 1982, from Mr. Sam Ulan (AEP) to Mr. L. B. Semprucci (TES) and in AEP letter from Mr. Sam Ulan (AEP) to Mr. P. D. Harrison (TES) dated March 15, 1983 (References 2 and 3).

The majority of the analysis was performed after the receipt of AEP letters dated November 29, 1982 and March 15, 1983 (References 2 and 3), which were issued after more complete information was available from the EPRI data.

This analysis was performed using large digital computer programs supplemented with any necessary hand calculations. The RELAP5 MOD1 Cycle 14 computer program was used to do the thermal fluid transient analysis. The structural analysis, for all loading conditions, was done utilizing the TMRSAP computer program.

The size of the pressurizer safety/relief valve discharge piping system was so large that the computer models, for both RELAP and TMRSAP, strained the limits of the programs. This condition necessitated multiple RELAP runs in order to execute the thermal fluid transient analysis for the appropriate length of time. For the structural analysis it was necessary to expand the core of the TMRSAP program in order to avoid an overly conservative overlap analysis.

[illegible]

[illegible]

[illegible]

2.0 CONCLUSIONS

The analysis performed by TES on the Pressurizer Safety/Relief Valve Discharge Piping System indicates that all criteria of NRC NUREG-0737, Item II.D.1 is met for normal and upset (PORV discharge) conditions and is not met for the emergency (SV discharge) condition.

Evaluation of normal and upset conditions required structural analysis for deadweight, thermal, OBE seismic, and PORV transient shock loading conditions. Details of the various loadings considered are provided in Section 5.

Based on preliminary SV thermal hydrodynamic transient analysis, excessive loads and stresses were anticipated. It was decided, for economic reasons, that a quarter model SV thermal transient analysis (RELAP5) should be performed to check the adequacy of the system for the emergency condition. In addition, due to the similarities of the Unit 1 and Unit 2 geometries, it was determined that the results of one unit could be considered applicable to the other unit. The quarter model consisted of the the Unit 2 geometry from the pressurizer, through valve SV-45C, and continuing down to the quench tank, therefore, the SV transient analysis considers only the effect of valve SV-45C opening. Although forcing functions were applied to the limited geometry described, the entire structural model was utilized for the analysis. The results of the quarter model analysis, which are considered to be realistic, indicate substantial failure of the entire quarter model geometry. Considering that TES is required to analyze for the simultaneous opening of all three SV valves (Reference 3), which is a more severe loading condition, it is evident that the quarter model analysis is sufficient to predict the failure, for the emergency condition, of both Units 1 and 2. This report, for Unit 2, contains the analysis and results for the quarter model SV thermal condition and the SV thermal transient shock condition.

Section 6 contains a summary of all node point stresses, support loads, valve acceleration calculations, pressurizer and quench tank nozzle loads, and moments on the end of each valve for all loading conditions. It should be noted that valves NRV-151, NRV-152, NRV-153, NMO-151, NMO-152, and NMO-153 are in excess of the vertical acceleration criteria of 2g for the PORV transient shock condition. Also, the acceleration of valves NMO-151, NMO-152 and NMO-153 exceeds the 3g horizontal criteria for the PORV transient shock condition. These values are considered acceptable per the approval given by AEP in their letter of May 26, 1983 from Mr. Sam Ulan of AEP to Mr. P. D. Harrison of TES (Reference 7). Valve SV-45C has acceleration values in the 12-30g range for the SV transient shock condition, which exceeds all criteria.

3.0 SYSTEM DESCRIPTION/DISCUSSION

The Pressurizer Safety/Relief Valve Discharge Piping consists of all of the piping from the pressurizer nozzles, down to the sparger in the quench tank. This information is depicted on TES drawing E-5761, Revision 2, generated from AEP drawings 2-GRC-22, sheets 1 and 2; 2-GRC-23, sheets 1, 2, and 3; 2-GRC-24, 2-GRC-25, 2-GRC-26 and 2-GRC-27.

The "Discharge" piping constitutes a very large system resulting in a large computer model. The size and geometrical complexity, which is due mainly to the sweeping curves around the pressurizer, complicates the modification effort in addition to causing longer run times.

Modification of this complex system, to attempt to secure satisfactory "Safety Valve Discharge" results, is limited to draining the SV loop seals. Heating the loop seals is not a viable "fix" because of the size of the loops. These long loops contain sufficient quantity of water such that on SV Discharge, the water seal does not "flash" completely enough to reduce the very high loads caused by the water slug. Modification to the support system is also a poor option because of the very limited space in the annulus around the pressurizer, which makes construction very difficult.

4.0 THERMAL FLUIDS ANALYSIS

4.1 Introduction

The thermodynamic fluid analysis determines the fluid forces which act on the pressurizer safety and relief valve discharge piping of the American Electric Power, Donald C. Cook Nuclear Power Plant, Unit 2. These forces are generated by the sudden opening of the pressurizer safety and relief valves during one or more of the pressurizer transients described in the AEP letter of November 29, 1982 to TES (Reference 2).

These fluid forces and the resulting loads and stresses on the piping system became of increased concern as a result of the incident at Three Mile Island. Following the Three Mile Island incident, the NRC issued NUREG 0578 and NUREG 0737, which required that each utility determine the effect of safety/relief valve operation upon the valve and the discharge piping. An elaborate program involving both testing and analysis was established under the general management of the Electric Power Research Institute (EPRI). The EPRI program included intensive testing of safety and relief valves as well as a full scale safety valve test facility, built at Combustion Engineering in Connecticut.

Simultaneously, an analytical program was initiated by Intermountain Technologies, Inc. to choose and test a computer program which would predict the fluid forces; RELAP5 MOD1 was chosen. RELAP5 MOD1 is the latest in the family of RELAP programs developed at the Idaho National Engineering Laboratory.

In this analysis, TES has used RELAP5 MOD1 version 2.11 as it is made available through Control Data Corp with a post-processor, REPIPE version 3.10, which calculates the fluid forces. This version of RELAP5 MOD1 is identified by the following computer job control language at Control Data Corporation:

```
BEGIN, RELAP5, R5M2, INPUT=INPUTFILE, SCM=377000B
```

The computer analysis procedure for the thermal analysis portion is included in Appendix A.

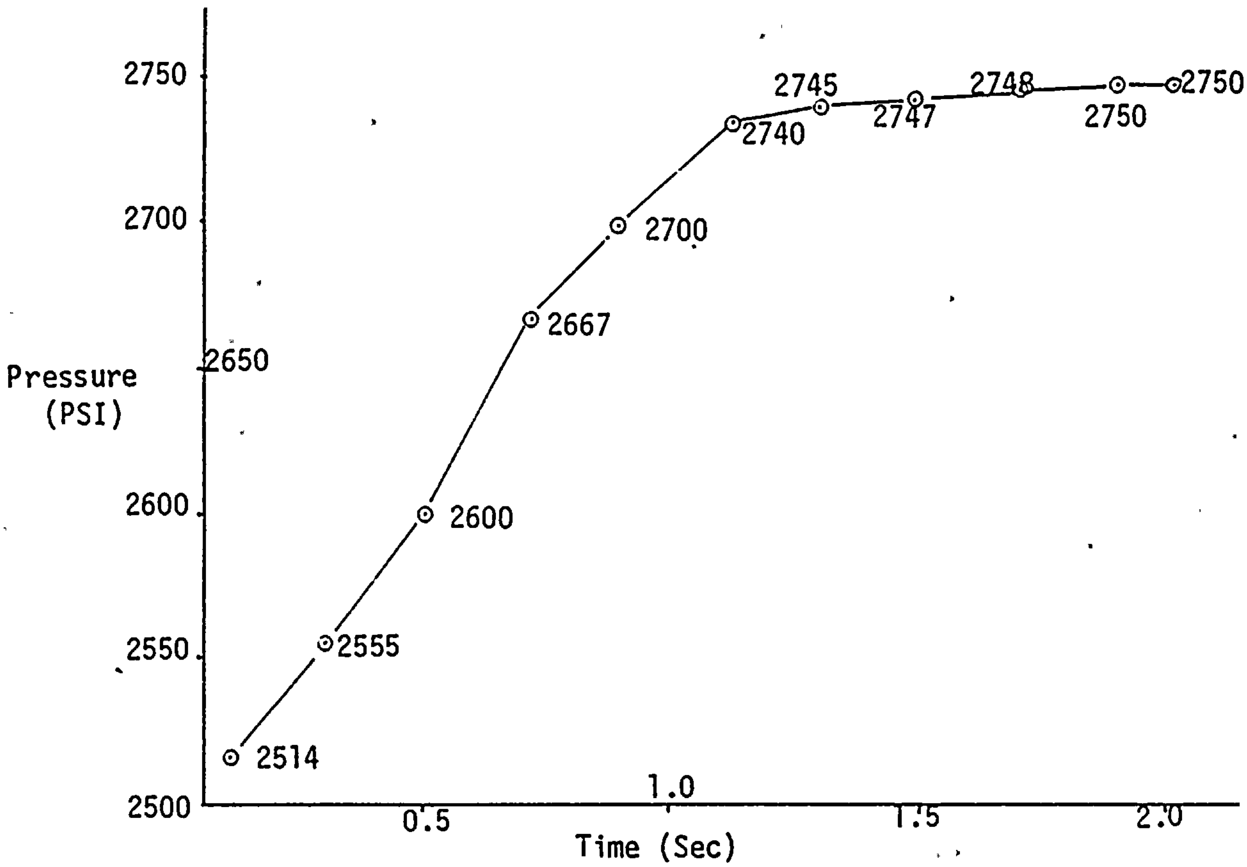
RELAP5 calculates hydrodynamic data for control volumes in each segment of pipe. REPIPE then takes this data and defines two force time histories for each segment, one set for inlet junction forces and the other for outlet junction forces. A TES generated program, SAP2SAP, adds these force time histories. Finally, one force time history for each segment of axial, unbalanced loads is analyzed structurally.

4.2 RELAP Model

4.2.1 The D.C. Cook pressurizer was modeled as a single time dependent volume with the following transient conditions as specified by the American Electric Power, November 29, 1982 letter to Mr. L.B. Semprucci, pages 1-7 (Reference 2):

Safety Valves

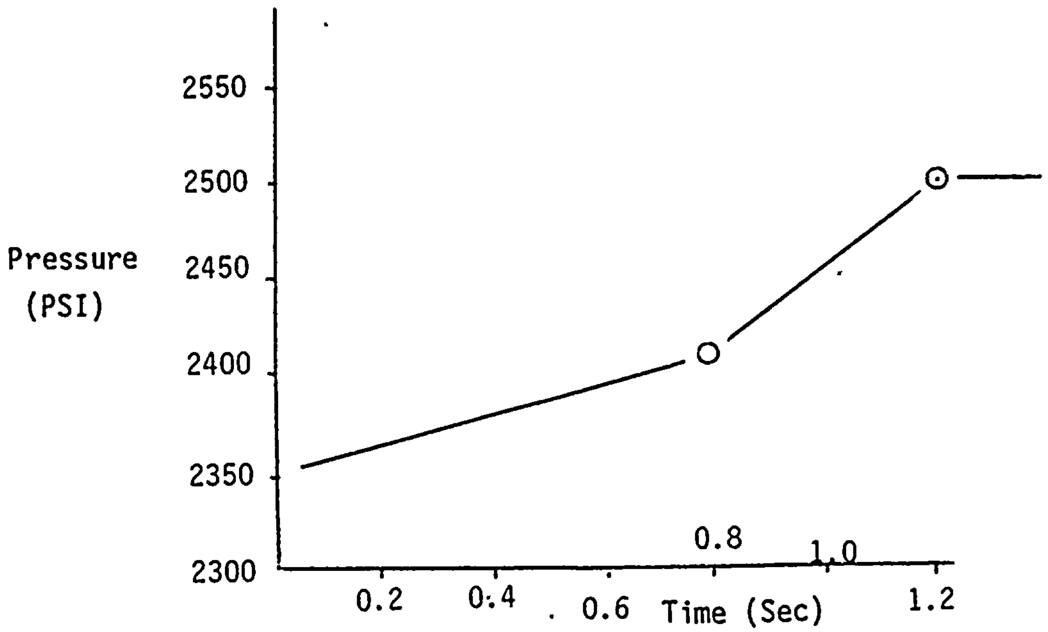
Pressure Time History (in the pressurizer)



The safety valve pressure boundary conditions were used in analyzing the quarter model cold loop seal case.

PORV

Pressure Time History (in the pressurizer)



Using the above pressure boundary conditions, two cases were analyzed. Case 1 is a steam discharge preceded by a condensate loop seal and Case 2 is a 400°F subcooled water discharge. It was determined in the Unit 1 PORV as-built analysis (Reference TES report TR-5364-1, Section 4.5.2) that Case 2 was the controlling case and, therefore, the Case 1 analysis is not repeated in this report.

4.2.2 Safety valves and power operated relief valves were modeled as RELAP junctions using the following information:

Type	Manufacturer	Orifice Area	Opening Time
SV	Crosby HB-BP-86 (Ref. 13)	0.022 Ft^2	0.010 Sec.
PORV	Masoneilan NO-38-20721 (Ref. 14)	0.00806 Ft^2	1.0 Sec.

TELEDYNE ENGINEERING SERVICES

BY EAT DATE 1-12-83	DONALD C. COOK NUCLEAR GEN. STATION UNITS 1 & 2 QUENCH TANK	SHEET NO. 1 OF 6
CHKD. BY CHM DATE 3-11-83		PROJ. NO. 5364

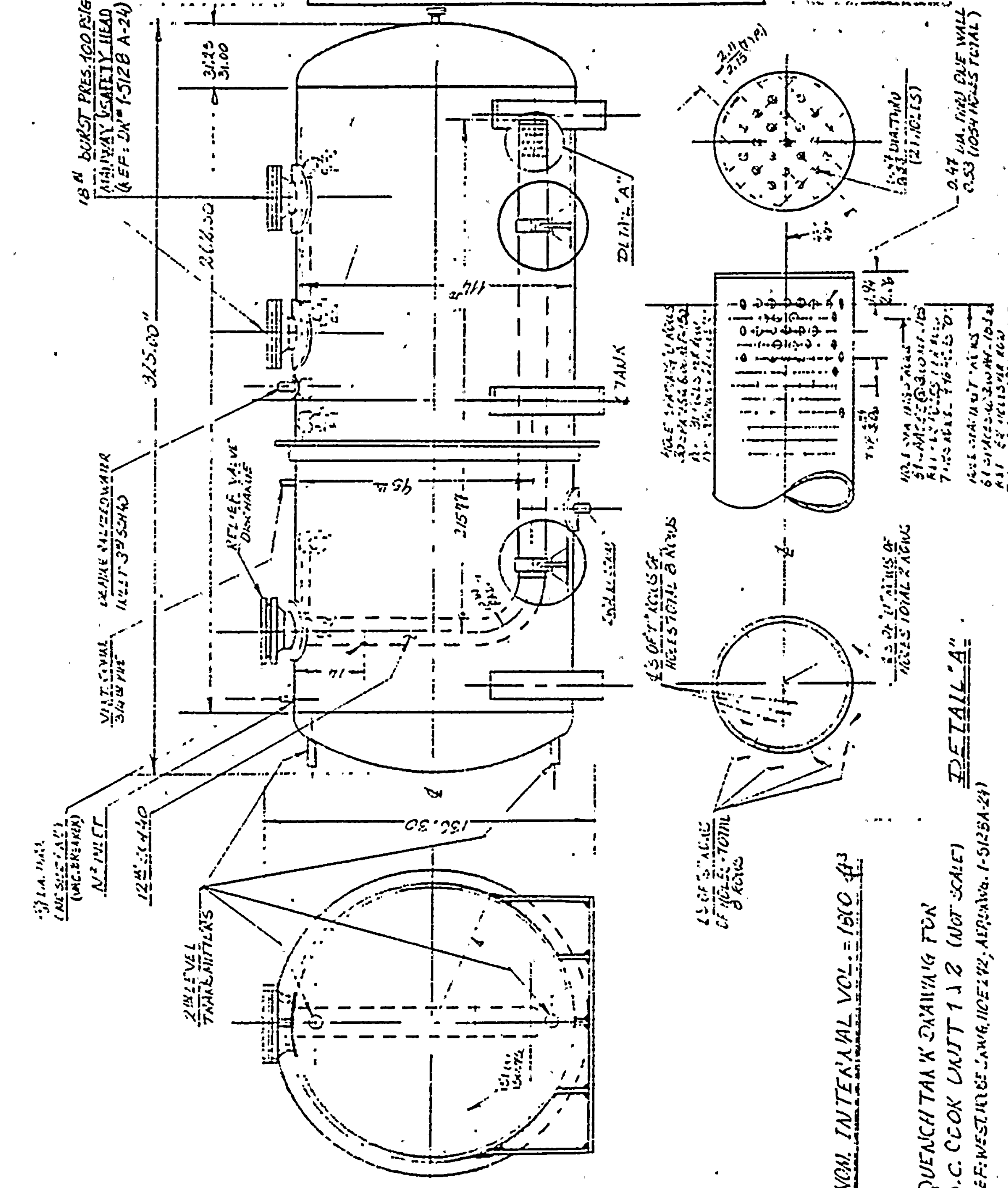


FIGURE 4. 2.1-1

BY BAT DATE 1-17-83
CHKD. BY CNM DATE 3-11-83

DONALD C. COOK
NUCLEAR GEN. STATION UNITS 1&2
RELAP5 QUENCH TANK MODELING

SHEET NO. 2 OF 6
PROJ. NO. 5364

RELAP5 MODEL OF THE QUENCH TANK

REMARKS:

1. QUENCH TANK WAS MODELED AS A SERIES OF "PIPE COMPONENTS" WITH APPROPRIATE FLOW AREAS AND LOSS COEFFICIENTS
2. WATER LEVEL IN THE QUENCH TANK IS AT THE SAME HEIGHT AS THE WATER LEVEL IN THE SPARGER
3. THE SECTION OF THE SPARGER WITH DISCHARGE HOLES WAS MODELED AS A PIPE WITH ITS LENGTH EQUAL TO THE LENGTH OF THE SPARGER WITH THE TOTAL NUMBER OF HOLE AREAS EQUAL TO FLOW AREA OF THE SPARGER (REF. DETAIL DRW "A")
4. RUPTURE DISCS WERE MODELED AS A TRIP VALVE WHICH OPENS AT THE BURST PRESSURE OF 100 psig.
5. VACUUM BREAKER HOLE WITH DIA. = 0.25 - 0.31 IN AND LOCATED 14 INCHES FROM THE TOP OF THE QUENCH TANK WAS IGNORED IN THE MODELING.

V = NOMINAL INTERNAL VOLUME OF THE TANK = 1800 ft^3 (W.H. Dr.# 110E272)

TANK IS 82% FULL OF WATER. (REF. TELECON LBS WITH SAM ULAN DATED 1-14-83)

V_1 = WATER VOLUME IN THE QUENCH TANK = 1476 ft^3

V_2 = AIR VOLUME IN THE QUENCH TANK = 324 ft^3

FIGURE 4.2.1-2

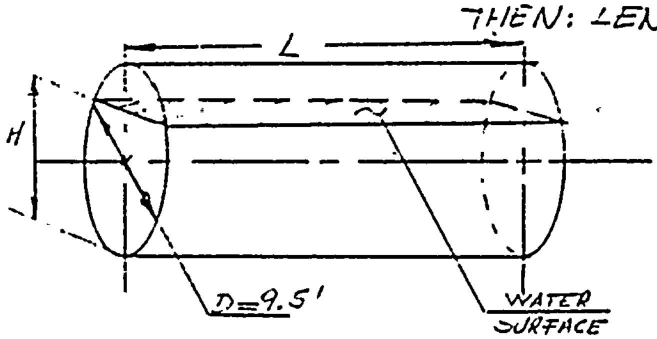
BY 3AI DATE 1-17-83
CHKD. BY CMM DATE 3-11-83

DONALD C. COOK
NUCLEAR GEN. STATION UNITS 1 & 2
RELAP5 QUENCH TANK MODELING

SHEET NO. 3 OF 6
PROJ. NO. 5364

IF QUENCH TANK IS A CYLINDER WITH $D = 114\ \underline{IN}$ INSIDE DIA.

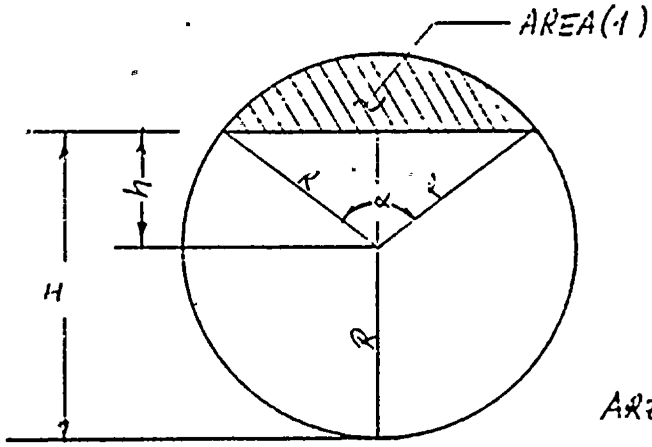
THEN: LENGTH $L = \dfrac{V}{\left(\frac{D}{2}\right)^2 \pi}$



$$L = \frac{1800}{\left(\frac{9.5}{2}\right)^2 \pi}$$

$$L = 25.3943\ ft$$

H – HEIGHT OF THE WATER LEVEL FROM BOTTOM OF THE TANK



$$AREA(1) = \frac{R^2}{2}(\hat{\alpha} - \sin\alpha) \qquad \text{EQN}-(1)$$

WHERE: $\hat{\alpha}$; IN RADIANS

α ; IN DEGREES

$$AREA(1) = \frac{\text{AIR VOLUME}}{\text{HEIGHT OF CYL.}} = \frac{V_2}{L} = \frac{324}{25.3943}$$

$$AREA(1) = 12.7588\ ft^2$$

SUBSTITUTING INTO EQN (1)

$$12.7588 = \frac{22.5625}{2}(\hat{\alpha} - \sin\alpha)$$

$$13.1310 = \hat{\alpha} - \sin\alpha$$

BY TRIAL AND ERROR:

$\underline{\alpha \approx 116.5^\circ}$

FIGURE 4.2.1-3

$$h = R \cos \frac{\alpha}{2}$$

$$h = 4.75 \cos \frac{116.5}{2}$$

$$h = 2.4995$$

$$H = h + R = 4.75 + 2.4995$$

$H \approx 87^{IN} = 7.25$ ft HEIGHT OF WATER SURFACE FROM THE BOTTOM OF THE QUENCH TANK.

$D - H = 27^{IN} = 2.25$ ft FROM THE TOP OF THE QUENCH TANK TO THE WATER SURFACE.

FROM WATER SURFACE TO THE CENTER OF THE HORIZONTAL SECTION OF THE SPARGER $\approx 68^{IN} = 5.6667$ ft

HEIGHT OF WATER LEVEL IN QUENCH TANK MODEL MUST BE ALSO = 5.6667 ft

VOLUME OF WATER IN QUENCH TANK = 1476 ft³

SURFACE AREA BETWEEN WATER AND AIR = $\frac{1476}{5.6667} = 260.4706$ ft²

VOLUME OF AIR IN QUENCH TANK = 324 ft³

HEIGHT OF AIR VOLUME IN RELAP MODEL = $\frac{324}{260.4706} = 1.2439$ ft

FIGURE 4.2.1-4

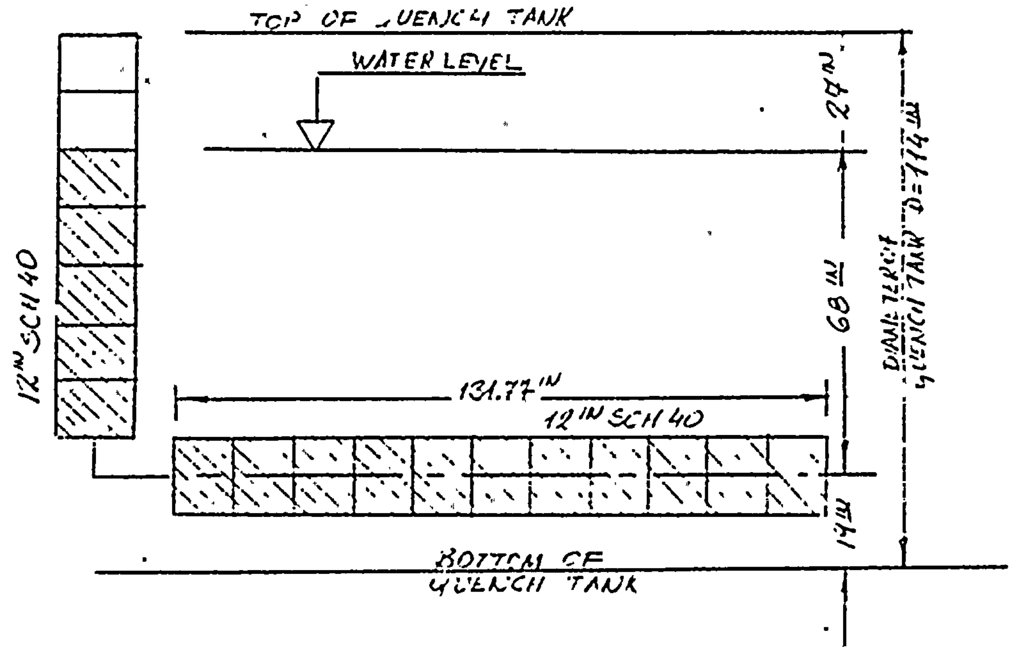
BY BAT DATE 1-17-83
CHKD. BY CHM DATE 3-11-83

DONALD C. COOK
NUCLEAR GEN. STATION UNITS 1 & 2
RELAP5 QUENCH TANK MODELING

SHEET NO. 5 OF 6
PROJ. NO. 5364

FIGURE 4.2.1-5

SPARGER MODELING



AREA OF EACH HOLE ON SPARGER SIDE = 0.14.63 in² = 0.0014 ft²

TOTAL FLOW AREA OF ALL THE SIDE HOLES = 1054 × 0.0014 = 1.4366 ft²

FLOW AREA OF 12 IN SCH 40 PIPE = 0.7773 ft²

ALL THE HOLES ARE DISTRIBUTED EVENLY @ 183 IN LENGTH FROM THE TIP OF THE SPARGER

AREA RATIOS = $\frac{0.7773}{1.4366}$ = 0.541 REPRESENTS THE SECTION OF THE SPARGER WHICH INCLUDES ALL THE HOLES WITH THE TOTAL AREAS EQUAL TO THE FLOW AREA OF THE 12 IN SCH 40 PIPE.

1 − 0.541 = .459

183 × 0.459 = 83.9977 ≈ 84.0 IN = 7 ft THE LENGTH WHICH MUST BE EXCLUDED FROM THE TIP

TOTAL LENGTH OF HORIZONTAL SECTION = 215.77 IN (REF DRW ON Page 1)

THIS LENGTH IN RELAP MODEL = 215.77 − 84 = 131.77 ≈ 11 ft

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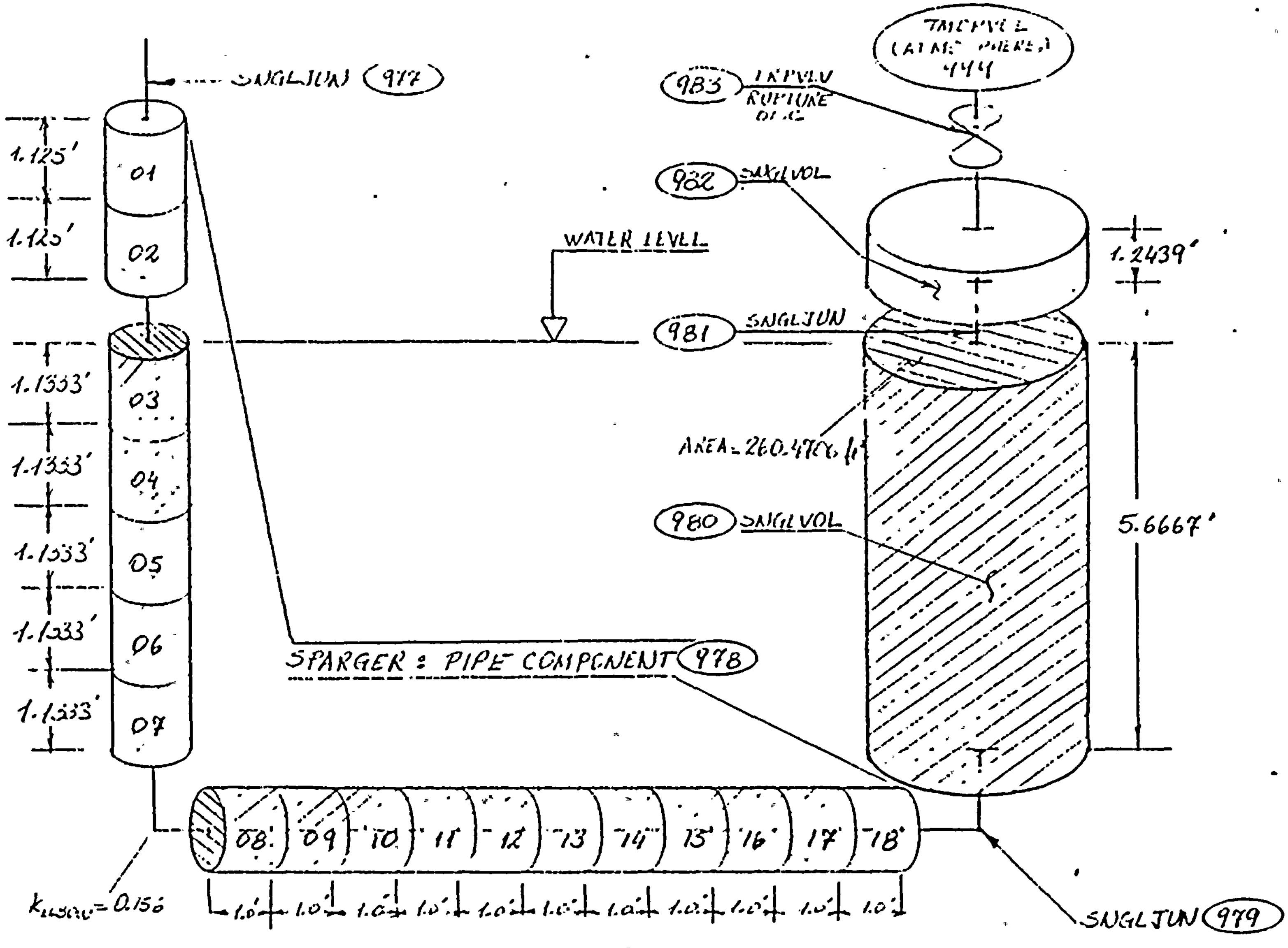
BY JAT DATE 1-17-83
CHKD. BY CHH DATE 3-11-83

DONALD C. COOK
NUCLEAR GEN. STATION UNITS 1 & 2
RELAP5 QUENCH TANK MODELING

SHEET NO. 6 OF 6
PROJ. NO. 5364



RELAP5 QUENCH TANK MODEL

FIGURE 4.2.1-6

Valve orifice areas were calculated using the EPRI Safety and Relief Valve Test Report (Reference 16) and RELAP (Run ID BAICDRO) implementing rated flows. Calculated values are included in Figure 4.6.1.

4.2.3 Discharge piping was modeled from all safety and power operated relief valves to the quench tank. This discharge piping included the following pipe sizes:

3 inch, 12 inch	SCH 40
4 inch, 6 inch	SCH 40S
4 inch	SCH 120
3 inch, 6 inch	SCH 160

Friction factors for long and short radius elbows and reducers were taken from technical paper #410 by Crane (Reference 19). Calculations of these frictional losses are included in Appendix A. The discharge piping is defined in segments of straight sections from; elbow to elbow, valve to elbow, etc. The SV model is modeled from one safety valve to the quench tank. This is a simplified model which was determined to be an adequate representation of safety valve discharge piping and is referred to as "The Quarter Model". This Quarter Model was used to get bounding loads for the cold loop seal discharge, and is further explained in Section 4.4.

4.2.4 The Quench Tank was modeled in two parts: the sparger and the tank itself, using cylindrical volumes containing water and air. The quench tank volumes were taken from Westinghouse Dwg. No. 110E272 (Reference 15).

The sparger for D.C. Cook is a perforated pipe submerged in the water within the quench tank as indicated in Figure 4.2.1 of this report. It is represented in RELAP as a pipe similarly submerged and of equal volume.

4.3 RELAP Model Control Volumes

The "Evaluation of RELAP5/MOD1 for Calculation of Safety/Relief Valve Discharge Piping Hydrodynamic Loads" report prepared by Intermountain Technologies Inc. (Reference 18) recommends using ten or more control volumes per bounded segment when modeling valve discharge piping for RELAP5, while avoiding significant control volume length differences to preserve pressure wave shapes. The ten control volume criteria recommended by ITI was adhered to by TES in all cases, except in piping arcs and in segments less than three feet in length. The D.C. Cook discharge piping is modeled using as few as one control volume per segment (pipe segments with lengths less than 0.5 feet) and up to thirty-two control volumes per segment.

Arc modeling for Unit 2 is represented in Figure 4.3.1. All arcs for Unit 2 were modeled in RELAP as having no fluid losses. Essentially, RELAP calculates these as straight sections of pipe. REPIPE, however, distributes the calculated forces to pre-assigned node points matching the TES structural models.

Average control volume lengths used for the D.C. Cook RELAP Unit 2 model were:

Pipe Size	Average C.V. Length
3 inch SCH 160	0.5264 feet
6 inch SCH 160	0.5019 feet
4 inch SCH 40S	0.5056 feet
6 inch SCH 40S	0.8871 feet
12 inch SCH 40	0.8526 feet
3 inch SCH 40	0.4744 feet
4 inch SCH 120	0.4471 feet

The schematics of the discharge systems modeled in RELAP for the PORV Unit 2 model and the SRV quarter model are given in Figures 4.7.1 and 4.7.2, respectively.

Quench Tank modeling was achieved using twenty control volumes and twenty junctions. Eighteen volumes comprise the sparger model while the remaining two are single volumes modeling the water and air spaces of the quench tank. The water and air volumes as determined from Westinghouse Dwg. No. 110E272 (Reference 15) were input to RELAP to insure proper quenching capacity. Eighteen control volumes forming the sparger are initially 88% full of water representing a submerged pipe. The discharge holes were modeled as a single hole with an area of .7773 ft.^{2}, at a point on the sparger where the sum of the small hole areas equals the 12 inch schedule 40 discharge area.

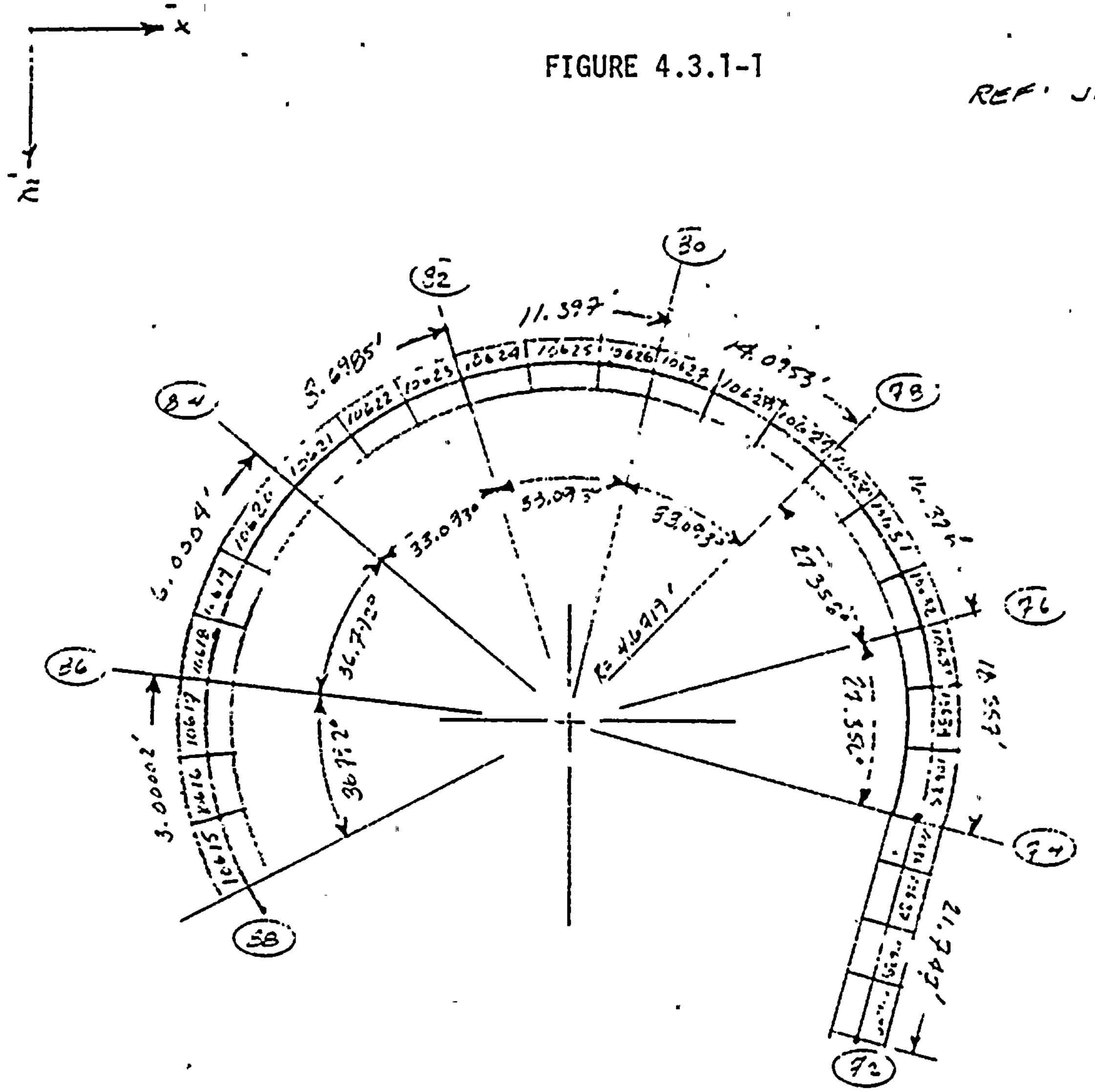
Finally, the tank rupture disk is modeled as a pressure actuated valve placed on the air volume and set to blow out at 100 psig discharging to atmosphere. Figure 4.2.1 represents the D.C. Cook Unit 2 Quench Tank.

TELEDYNE ENGINEERING SERVICES

BY JMM DATE 1-17-83 | RELAP MODEL 1/4 MODEL | SHEET NO. 1 OF 1
CHKD. BY CJC DATE 2-17-83 | ARC 1 LEVEL 669'-2" UNIT 2 | PROJ. NO. 5364

FIGURE 4.3.1-1

REF: JBM CALC 12-31-81



COMPONENT 106   6IN PIPE SCH 40S

VOLUMES 10615 → 10639

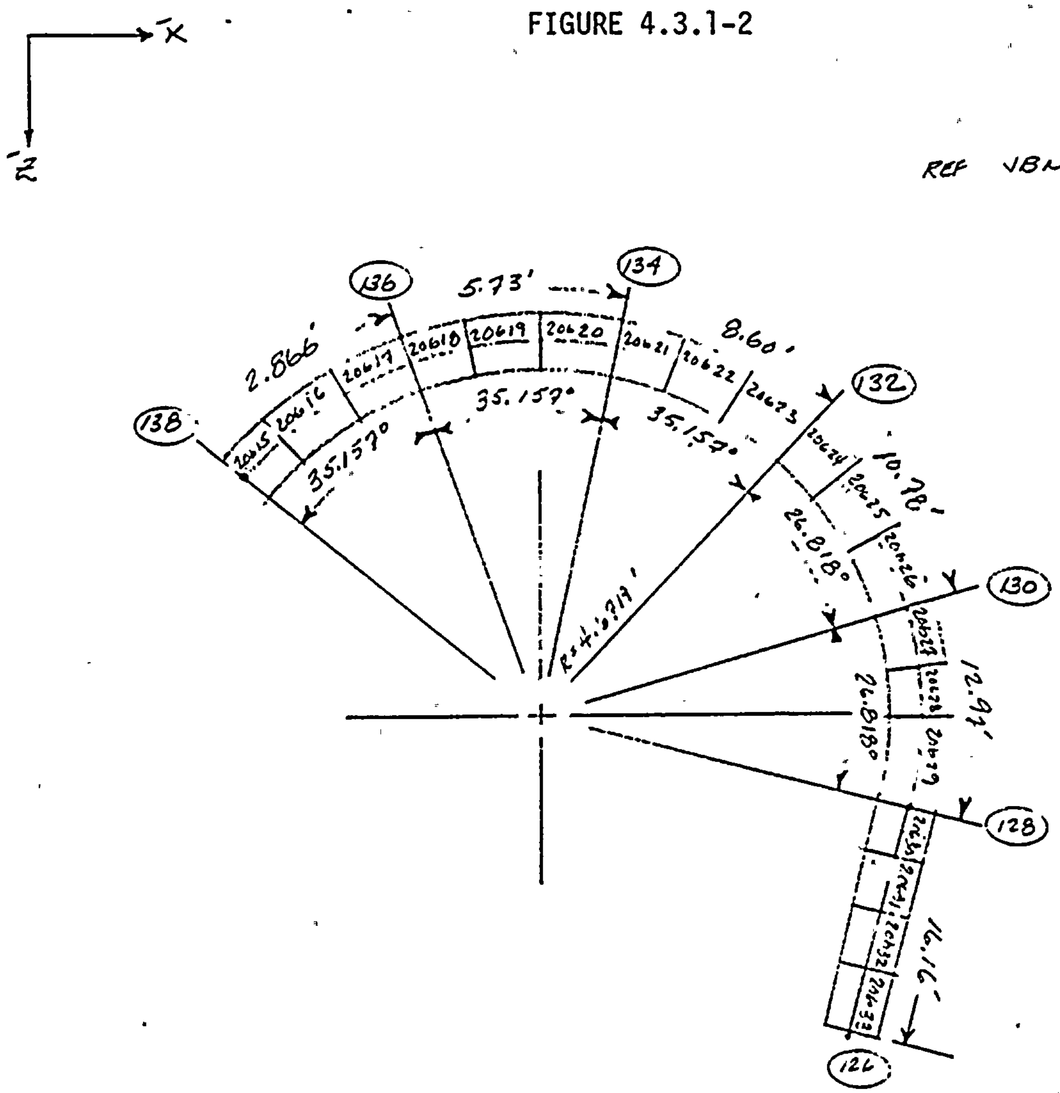
BY CHM DATE 1-17-83
CHKD. BY CJC DATE 2-17-83

RELAP MODEL
ARC 2 LEVEL 670'-10" UNIT 2

SHEET NO. 1 OF 1
PROJ. NO. 5364

FIGURE 4.3.1-2

REF VBM CALC 12-31-81



COMPONENT 206

VOLUMES 20615 → 20633

TELEDYNE ENGINEERING SERVICES

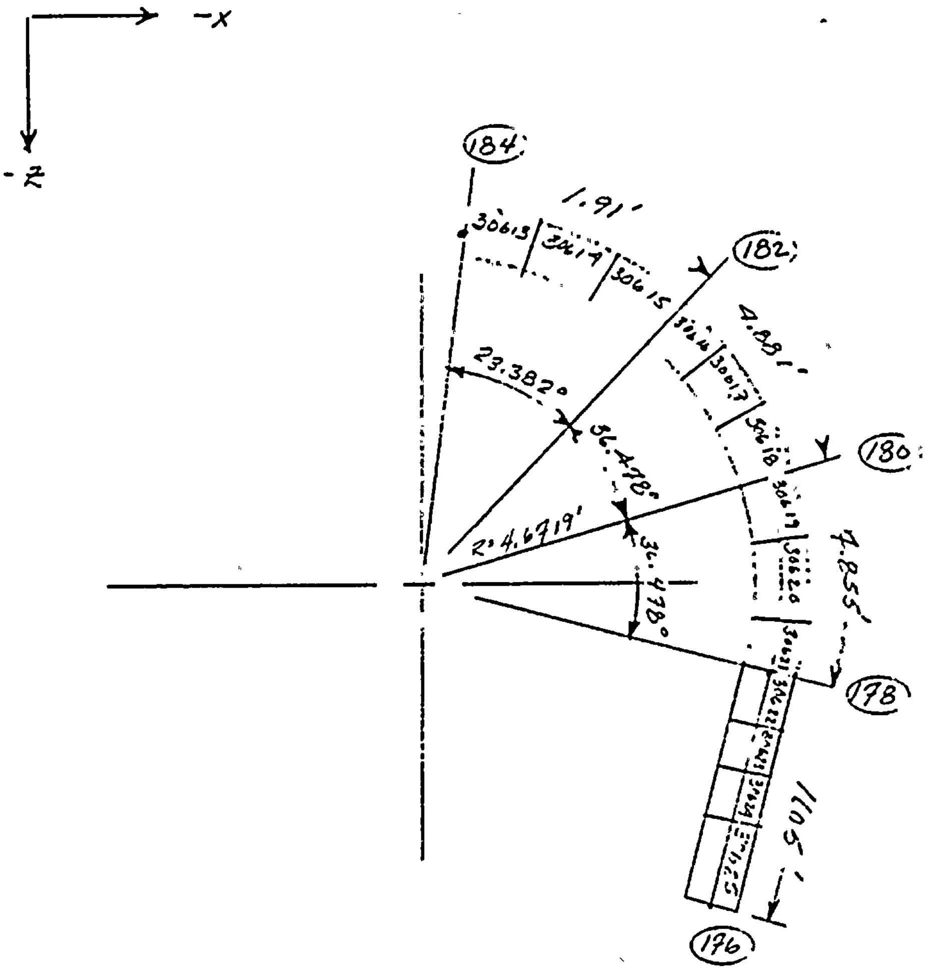
BY CHM DATE 1-17-83
CHKD. BY CJC DATE 2-17-83

RELAP MODEL
ARC 3 LEVEL 672'-6" UNIT 2

SHEET NO. 1 OF 1
PROJ. NO. 5364

FIGURE 4.3.1-3

REF: JBM CALC 12-31-81



COMPONENT- 306

VOLUMES- 30613 → 30625

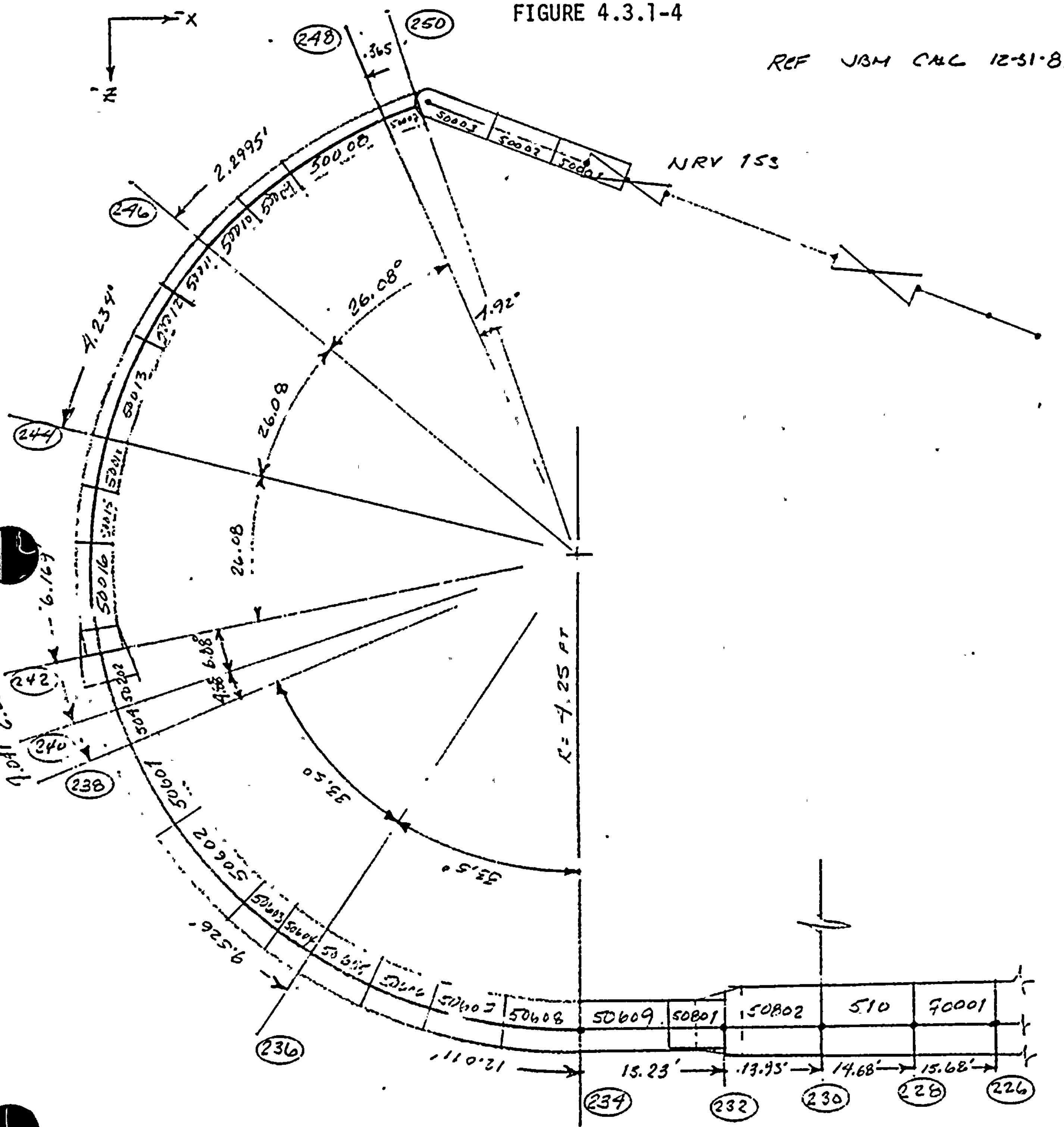
TELEDYNE ENGINEERING SERVICES

BY CMM DATE 1-14-83
CHKD. BY CJC DATE 2-17-83

RELAP MODEL ARC B
ARC LEVEL 684'-9" UNIT 2

SHEET NO. 1 OF 1
PROJ. NO. 5364

FIGURE 4.3.1-4



ELEVATION Δ = 0.5" - NEGLIGIBLE

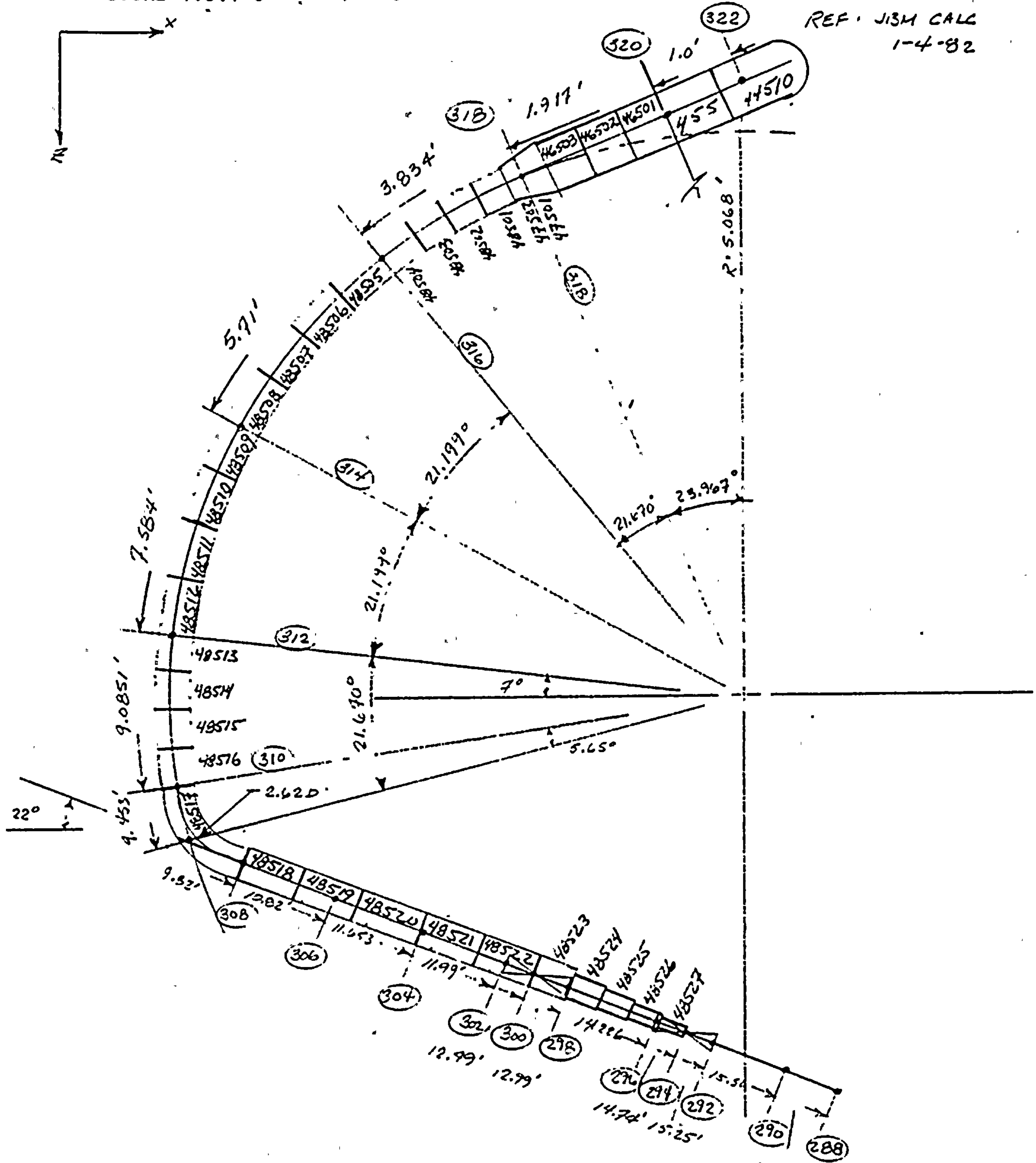
TELEDYNE ENGINEERING SERVICES

BY CHM DATE 1-14-83 CHKD. BY KJG DATE 6-7-83

RELAP MODEL ARC A
ARC LEVEL 686'-6" UNIT 2

SHEET NO. 1 OF 1
PROJ. NO. 5364

FIGURE 4.3.1-5 PORV MODELING



ELEVATION Δ ~ 2" NEGLIGIBLE.

4.4 Quarter Model

A review of the testing that was done at Combustion Engineering in Connecticut indicated that the as-built analysis for the safety valves could potentially fail the system. The cold loop seal discharge test at C.E. produced loads of 175 Kips. The D.C. Cook Unit 2 pressurizer has three safety valves with a loop seal larger than the C.E. test facility loop seal, therefore, it was decided to make a small RELAP model of the D.C. Cook Safety Valve discharge line. This model contains one safety valve (SV-45C) including corresponding loop seal, and discharge piping through arc level 669'-2" up to, but not including, the quench tank. This model would be less expensive to run than the full three valve model.

The results of this Quarter Model confirmed TES's suspicion that the cold loop seal case would fail. At this point, TES was able to make a parametric study of loop seal temperature and valve opening times versus peak loads, as shown below. Only the steam discharge proved to be acceptable, therefore, TES is recommending draining the loop seals.

Loop Seal Condition	Loop Seal Temperature (°F)	Position of Loop Seal	Valve Opening Time (Sec)	Max Load (LBF)
Cold	141°	Upstream	0.010	115,000
Cold	141°	Downstream	0.010	174,000
Hot	350°	Upstream	0.010	156,000
Hot	350°	Upstream	0.090	109,000
Hot	350°	Upstream	0.130	124,000
Hot (Sat. Water)	650°	Upstream	0.090	38,000
Steam	650°	Upstream	0.010	6,000

The loop seal temperature distribution was calculated and input to RELAP, and is included in Appendix A. The temperatures used for the cold loop seal ranged from 584.4° at the pressurizer to 141.1° at the valve.

4.5 Unit 2 PORV Model

The inlet piping to the PORV's is sloped toward the valves and, during normal operating conditions, a saturated water (condensate) loop seal is formed (at the inlet to the PORV).

As specified in American Electric Power's letter of November 29, 1982, (Reference 2) referring to PORV transient conditions, the following cases were to be analyzed:

Case	Transient
1	Condensate/Steam Discharge
2	400° Solid Liquid Discharge

In the D.C. Cook Unit 1 "as-built" analysis, it was determined that Case 2 was the controlling case (Reference TES Report TR-5364-1, Section 4.5.2). Therefore, only the Case 1 analysis is presented here.

As in the Unit 1 "as-built" analysis, the 400°F solid water case exhibited unstable behavior (oscillations in the flow rate). At approximately .400 seconds the flow suddenly decreases approximately 30 lbm/sec in 1msec. This behavior can be seen plotted in Section 4.7.1. A careful review of the RELAP output did not reveal a good physical reason for such behavior. The reasons for such behavior could be

1. A sudden reduction in the valve area vs. time data.

2. A build up of back pressure in the discharge line which will cause the valve flow rate to suddenly decrease.

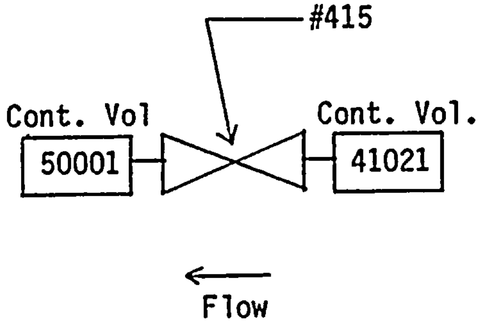
3. A sudden decrease in pressure in the pressurizer boundary condition which would result in reduced flow.

All these things were considered to determine if they were possible sources of the flow rate fluctuation. The review indicated that they were not the source of the problem.

A partial tabulation of this review is shown below:

UNIT 2

Valve Junction



Reference
RELAP RUN BHFRBGO
UNIT 2 400-600 msec
Solid Case

	Junction #415 Mass Flow LBM/Sec.	Cont. Vol. #41021 Thermodynamic Quality	Cont. Vol. #41021 Pressure (PSI)	Cont. Vol. #50001 Pressure (PSI)	Cont. Vol. #50001 Thermodynamic Quality
.407	105.9	0.0	2160.9	248.15	.0088
.408	106.4	0.0	2169.2	248.50	.0088
.409	83.6	0.0	2996.7	247.73	.0089

It can be seen that the downstream pressure does not exhibit a sudden increase that would reduce the flow through the valve. The upstream quality remains zero indicating that the flow through the valve is subcooled.

The pressure increases upstream which corresponds to a sudden reduction in flow area, however, the flow area increases, it does not decrease. The pressurizer time dependent volume does not exhibit any sudden change in pressure which would correspond to this flow change.

Past experience with the RELAP programs has shown problems with subcooled water and low quality steam flow. These problems have manifested themselves as severe oscillations in the flow rate. It is TES's opinion that the results from the RELAP run are highly conservative and overpredict the fluid forces.

When the fluid forces from this RELAP run were combined with the seismic, deadweight, and thermal expansion loads, the code allowables were slighlty exceeded. Since the principal fluid loads appear to be a result of an instability in the flow rate predicted by RELAP and not a result of an actual physical phenomena, it was decided that these loads were overly conservative and could justifiably be reduced by 20% at the structural input point. The fluid forces presented in Section 4.8 and elsewhere in Section 4.0 are the "as calculated" loads and have not been reduced by 20%.

It should be noted that an alternative modeling practice that could have been employed in the solution of this problem would have been to make the PORV valves time dependent junctions and specify the valve flow rate, however, this method requires the elimination of upstream piping. At the beginning of this project it was decided to place the entire system, upstream and downstream piping, in one model as the flow instability was not anticipated. Had this alternative been used, the flow rate oscillation and the resulting forces would not have occurred.

4.6 Valve Flow Rate Calculation

The following values were used in valve modeling considerations:

Valve Type	TES Flow Rate Calculated LBM/HR	Max Rating* For Steam @ 3% Accum.	Bore Area (IN^2)	Opening Time (Sec)
Crosby Safety Relief Valve	523,332	435,000	3.6 in^2	0.010 (Ref. 18)
Masoneilan Power Operated Relief Valve	199,000	--	--	1.0 (Ref. 16)

* The maximum rating for steam at 3% accumulation value is from the Crosby Valve and Gage Safety Valve Drawing No. H-51688, Revision A (Reference 13).

4.6.1 The valve flow rates used in the RELAP analysis of the SRVs were obtained by increasing the ASME rated flow by 15%; 10% to consider the ASME underating of the theoretical flow and 5% to cover tolerances. TES flow rate calculations are included in Figure 4.6.1.

$W_T = 51.5\ AP$ Napier's Eq.

ASME rated flow:

$W_R = 51.5A\ (1.03P + 14.7)(.9)(.975)C$ (Ref. 17)

where:

W_T = theoretical flow

W_R = rated flow

coefficients:

1.03 - applies 3% accumulation

0.975 - valve flow coefficient

0.9 - represents theoretical flow rate reduced 10% to equal ASME rating

The equation TES uses to calculate the valve flow rate is

$Wmax = 1.05 \times 51.5A\ (1.03P + 14.7)C(0.975)$

This is an increase of 15% above the ASME rated flow as explained above.

4.6.2 The Masoneilan PORV maximum flow rate for steam was taken from the EPRI Safety and Relief Valve Test Report (Reference 16) as 199,000 lbm/hr (Table 4.5.1-1b). A valve opening time of 1.0 second is used based on total valve opening times of all Masoneilan valves tested, times are listed in Table 4.5.2-1. Since full open times averaged 2.76 seconds, with a minimum value of 1.64 seconds, TES has assumed 100% opening in 1.0 second, because independent testing has shown that flow is not always directly proportional to stem travel. Most often full flow is obtained before full stem travel. Because 1 second is a very long opening time, this was not considered overly conservative.

TELEDYNE ENGINEERING SERVICES

BY KJG DATE 6-2-83
CHKD. BY CMM DATE 6-3-83

CROSBY 6M6 VALVE
RELAP5 MODEL FLOW AREA CALCULATIONS

SHEET NO. 1 OF 2
PROJ. NO. 5364

FIGURE 4.6.1-1

Ref:
1. ASME Sec III N.B.-7731.1 and N.B. 7734.2 (1980)
2. CROSBY 6M6 Model HB-BP-86 Valve Drawing No. H-51688 Rev. A.
3. Computer Run BAICDRØ

CROSBY 6M6 Valve Properties

Manufacturer : CROSBY Valve & Gage Company
Type : Spring loaded Safety Valve
Drawing No : H-51688 Revision A
Bore Area : 3.600 in²
Design Setpoint Pressure : 2485 psig
Model No. : HB-BP-86 (6M6)

Calculation of Max Flow Rate (W_{max})

The following assumptions and considerations are made in determining W_{max}.

1) This calculation is used only to determine a Relap5 orifice size and does not necessarily represent pressurizer input conditions.

2) The max flow W_{max} was increased by 5%. This accounts for the 5% flowrate tolerance discussed in NB-7734.2

USING Ref 1.

$$W_{max} = 1.05 \times 51.5 \times 3.600(2485 \times 1.03 + 14.7)C\,(0.975)$$

$$C = \frac{0.1906\,P_{set} - 1000}{0.2292\,P_{set} - 1061} \qquad P_{set} = 2485 \text{ psig}$$

$C = 1.0711$ after substituting,

$$W_{max} = 523{,}340.55 \text{ lb/hr}$$

Fig.4.6.1-1

BY KJG DATE 6-2-83
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CROSBY 6M6 VALVE
RELAP5 MODEL FLOW AREA CALCULATION

SHEET NO. 2 OF 2
PROJ. NO. 5364

FIGURE 4.6.1-2

SV

W_{max} = 523,340.55 lb/hr = 145.37 lb/sec

USING THE COMPUTER RUN BAICDRØ

Valve full open area in the run BAICDRØ = 0.0232 ft^2

Flow rate @ full opening = 153.19 lb/sec

Flow rate @ 90% opening of the valve = 138.01 lb/sec

RELAP5 flow area which delivers W_{max} = 145.37 lb/sec is calculated by interpolation.

$$A_{flow} = \left[0.9 + 0.1\,\frac{145.37 - 138.01}{153.19 - 138.01}\right](0.0232)$$

$$= 0.022\ ft^2\ (SV)$$

PORV

Similarly,

W_{max} = 199,000 lb/hr = 55.28 lb/sec

Flow area to deliver 55.28 lb/sec

$$A_{flow} = \left[0.3 + 0.1\,\frac{55.28 - 48.001}{63.4 - 48.001}\right]0.0232$$

$$= 0.00806\ ft^2\ (PORV)$$

4.7 RELAP Plots

The following plots represent RELAP mass flows, pressures and qualities at various points along the discharge piping. Since RELAP had to be restarted, the plot time scales may vary (i.e. 0.0 - 0.2 seconds or 0.0 - 0.400 seconds). Also, the ordinate axis may not always be correct; many times multipliers will be off (CDC is aware of this problem in RELAP). However, the plots do depict the trend accurately and are calculated and reported in RELAP every 0.001 seconds. Correct peaks and times at which they occur are listed with each trace.

Plot Set	Transient
4.7.1 Unit 2	400° Solid Liquid Case
4.7.2 Quarter Model	Cold Loop Seal/Steam Case

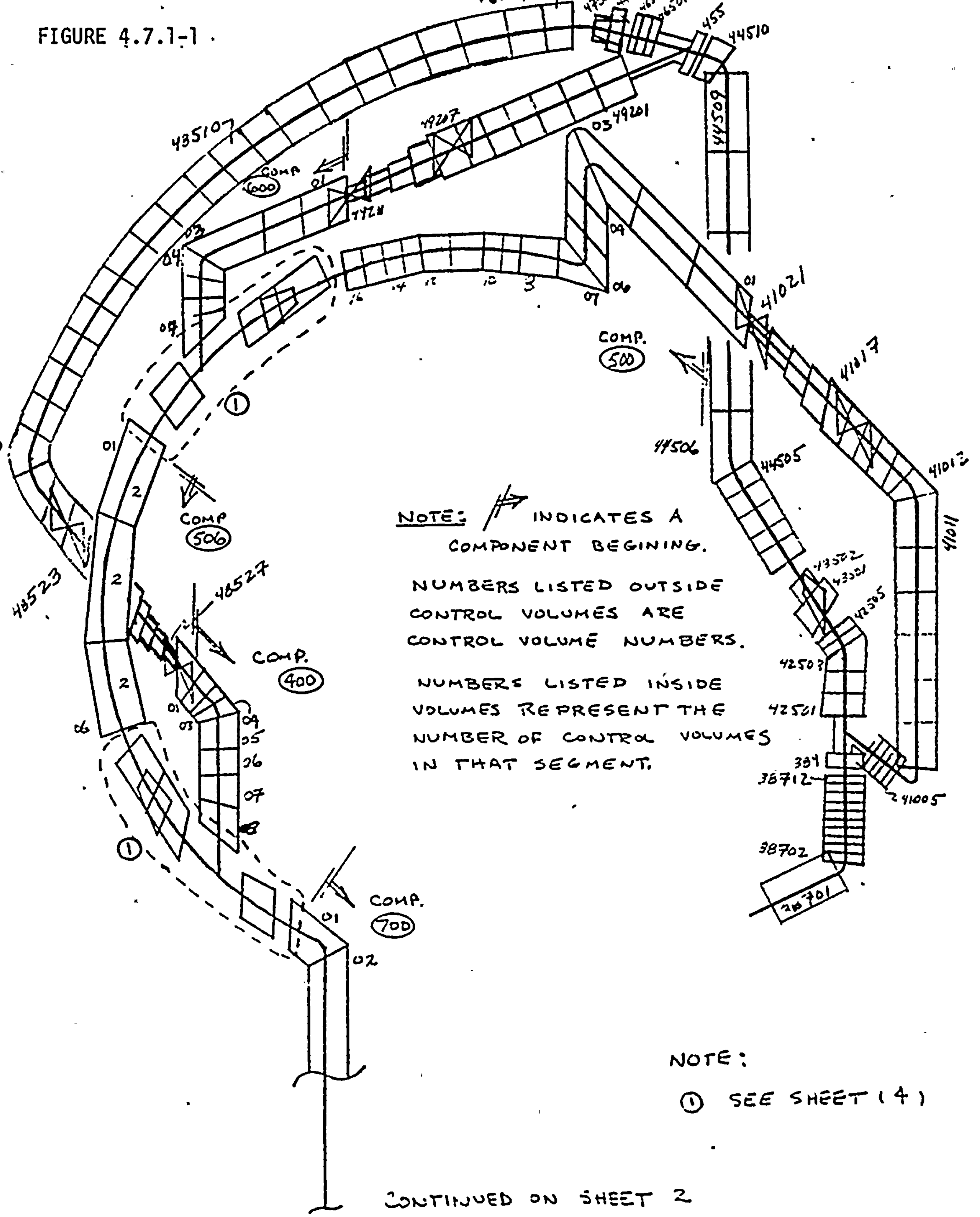
A RELAP volume schematic precedes each plot set.

4.7.1 <u>Unit 2 - 400^o Solid Liquid Case</u>

PORV MODEL

BY CJC DATE 3-11-83	RELAP MODEL SCHEMATIC UNIT 2 PORV SECTION	SHEET NO. 1 OF 1
CHKD. BY CUM DATE 3-11-83		PROJ. NO. 5364

FIGURE 4.7.1-1



CONTINUED ON SHEET 2

TELEDYNE ENGINEERING SERVICES

PORV MODEL

BY CTC DATE 3-11-83
CHKD. BY CHM DATE 3-11-83

RELAP MODEL SCHEMATIC
UNIT 2 SRV SECTION

SHEET NO. 2 OF 6
PROJ. NO. 5364

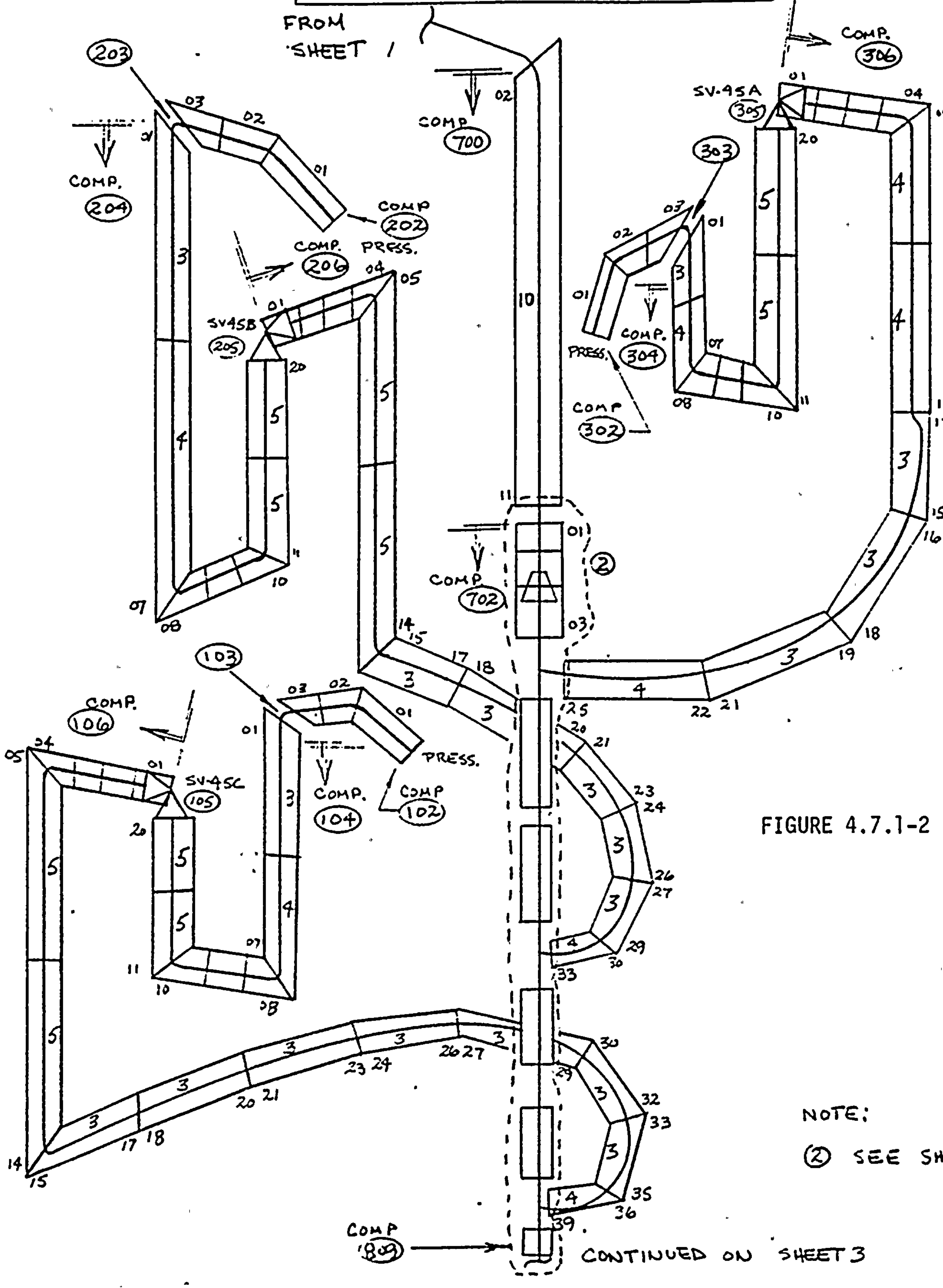


FIGURE 4.7.1-2

NOTE:

② SEE SHEET (5)

TELEDYNE ENGINEERING SERVICES

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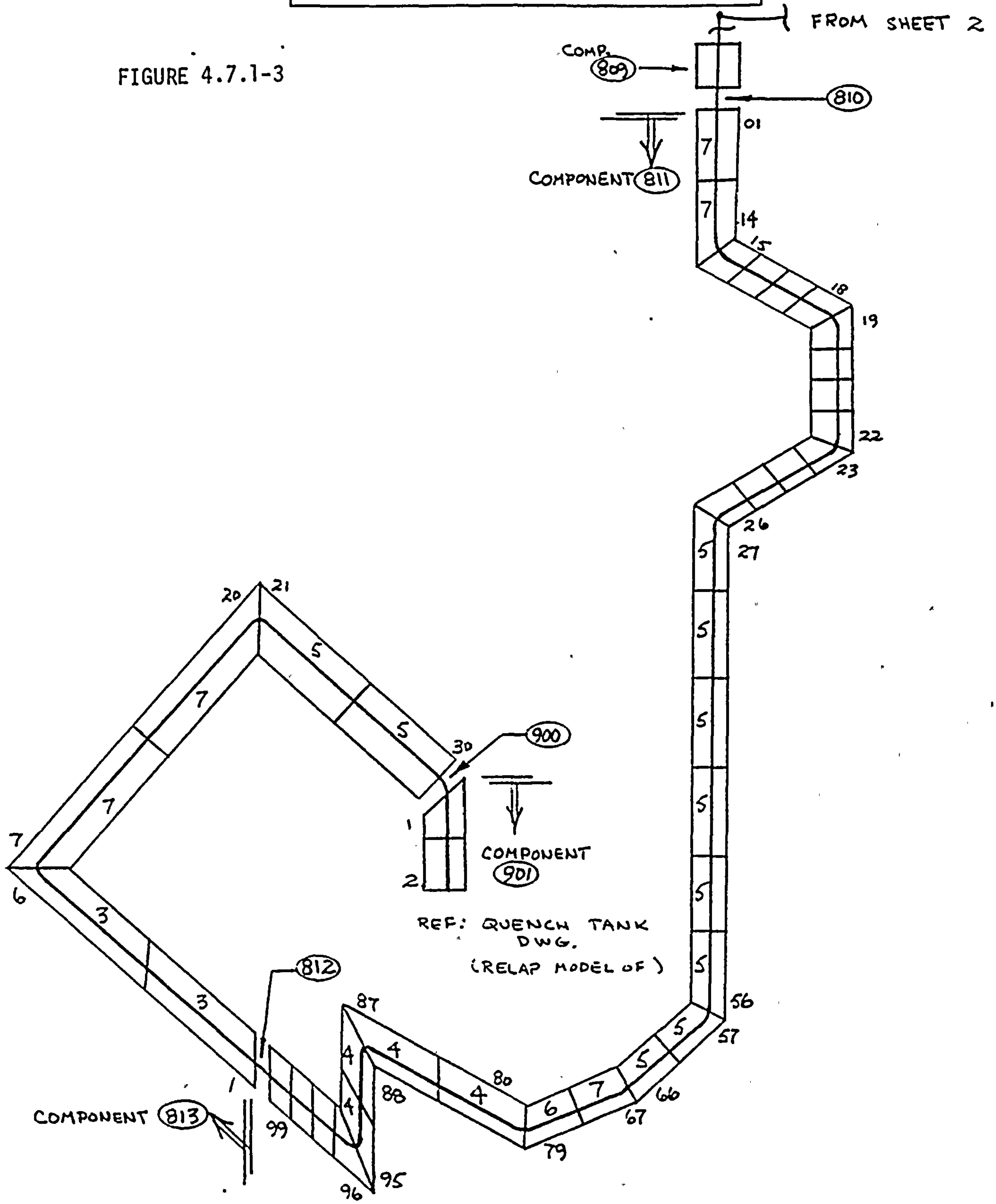
PORV MODEL

BY CJC DATE 3-11-83
CHKD. BY CMM DATE 3-11-83

RELAP MODEL SCHEMATIC
UNIT 2 12" DWNSTRM. SECTION

SHEET NO. 3 OF 6
PROJ. NO. 5364

FIGURE 4.7.1-3

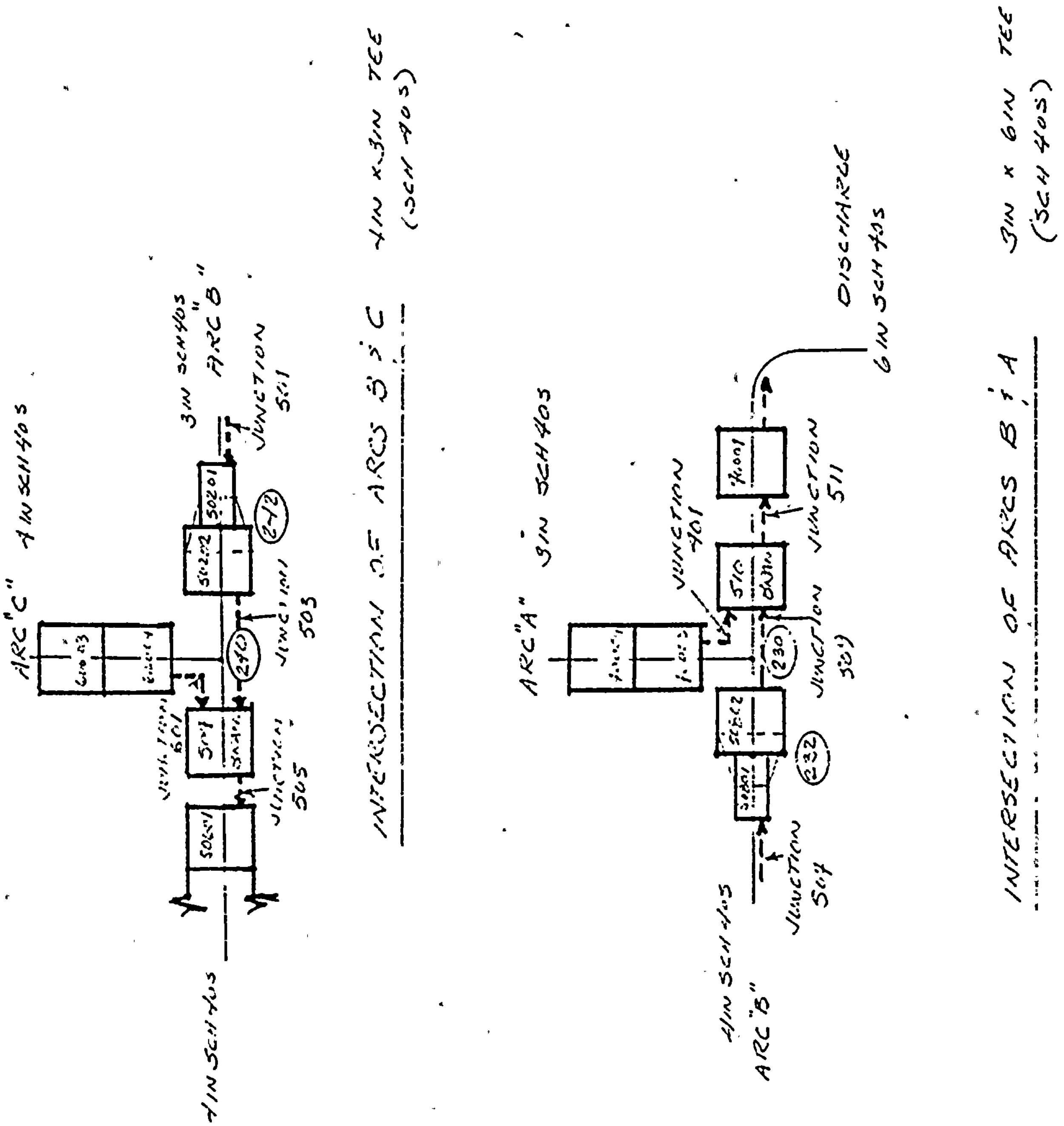


BY CHM DATE 1-19-83
CHKD. BY CJC DATE 2-17-83

RELAP5 MODEL
UNIT 2 BRANCHES & TEES.

SHEET NO. 4 OF 6
PROJ. NO. 5364

FIGURE 4.7.1-4

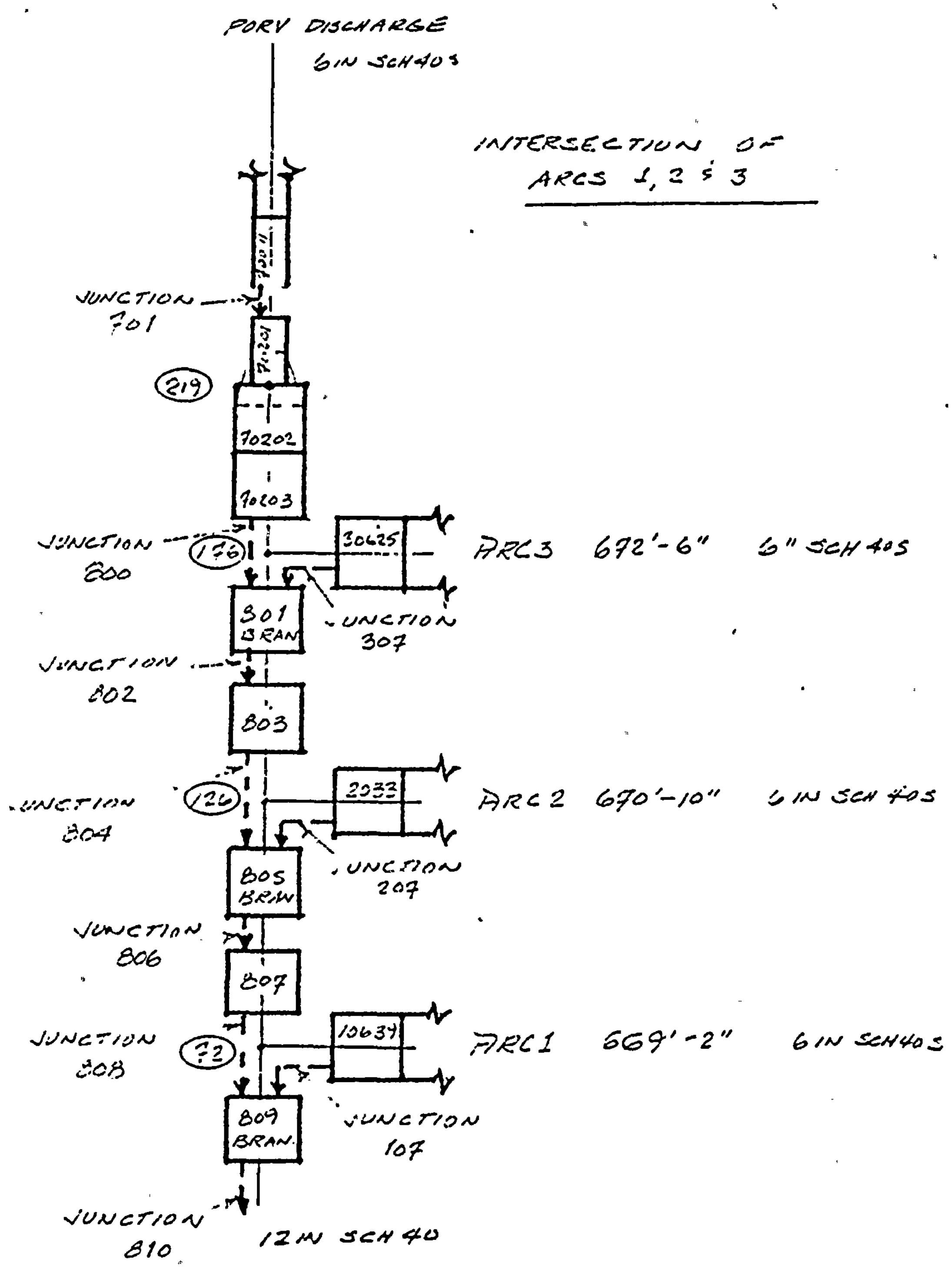


BY CMM DATE 1-19-83
CHKD. BY CJC DATE 2-17-83

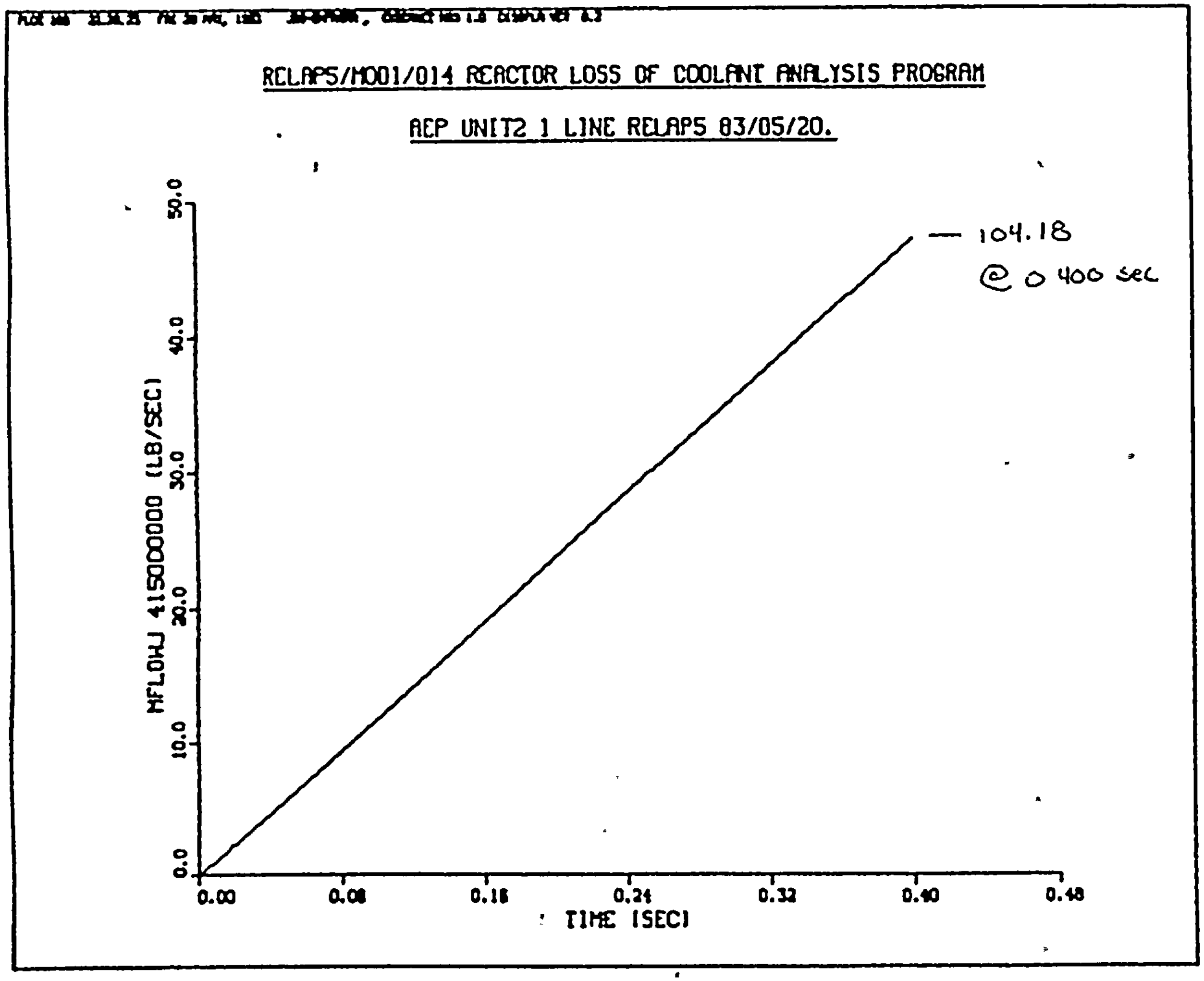
RELAP5 MODEL
UNIT2 BRANCHES & TEES

SHEET NO. 5 OF 6
PROJ. NO. 5364

FIGURE 4.7.1-5



BY KJG DATE 5-21-83
CHKD. BY CHL DATE 5-28-83



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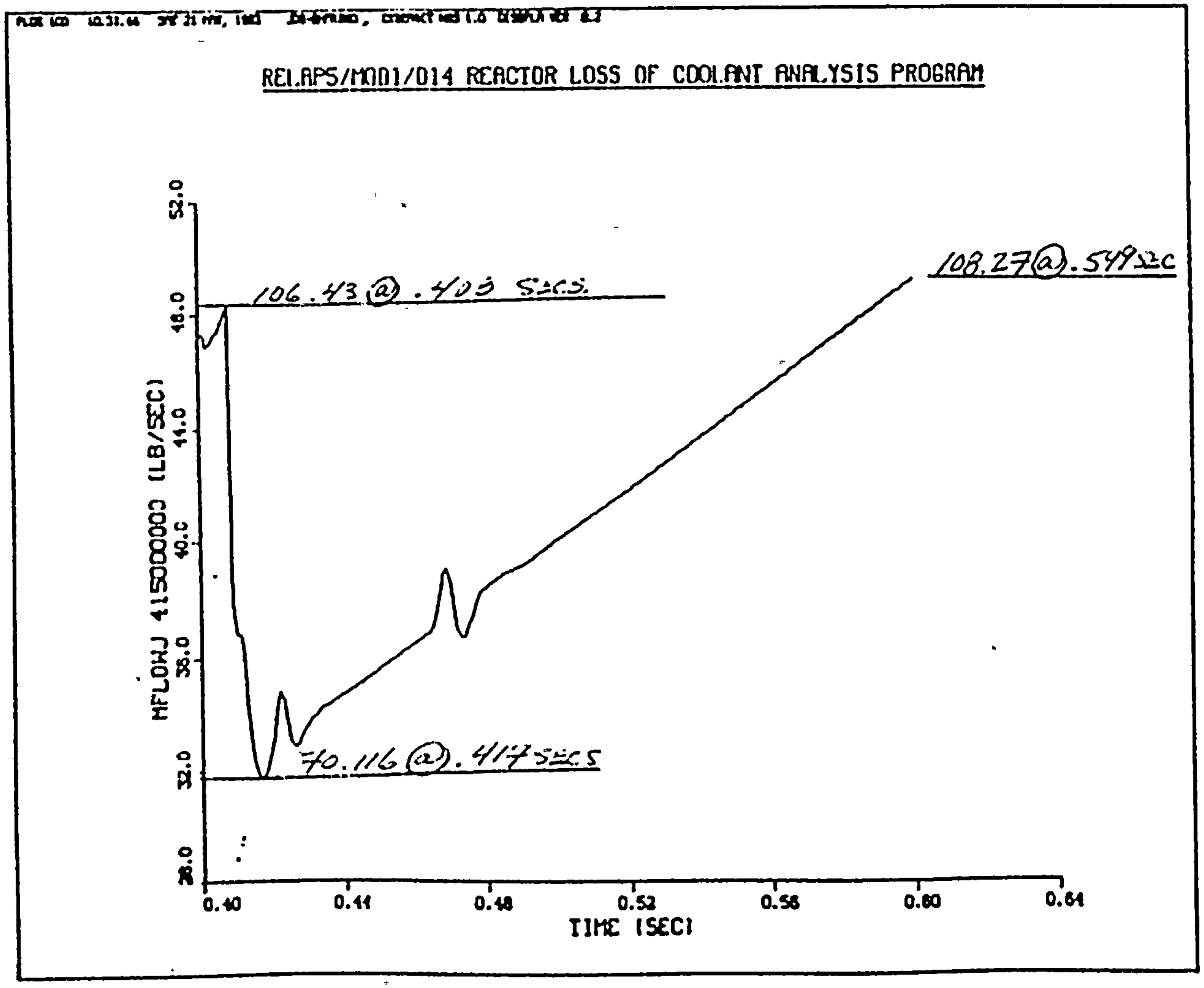
CHKD. BY CWH DATE 5-28-83



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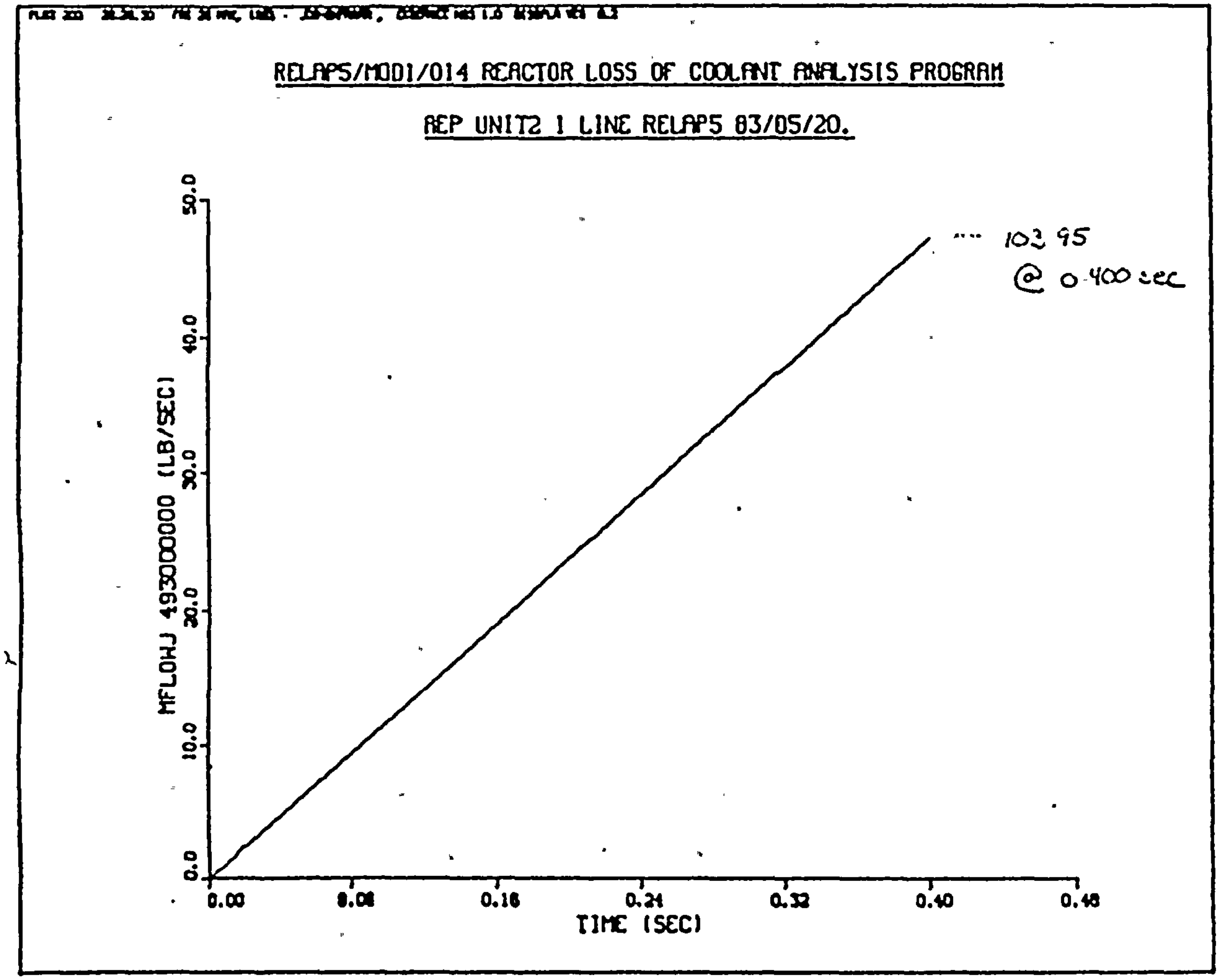
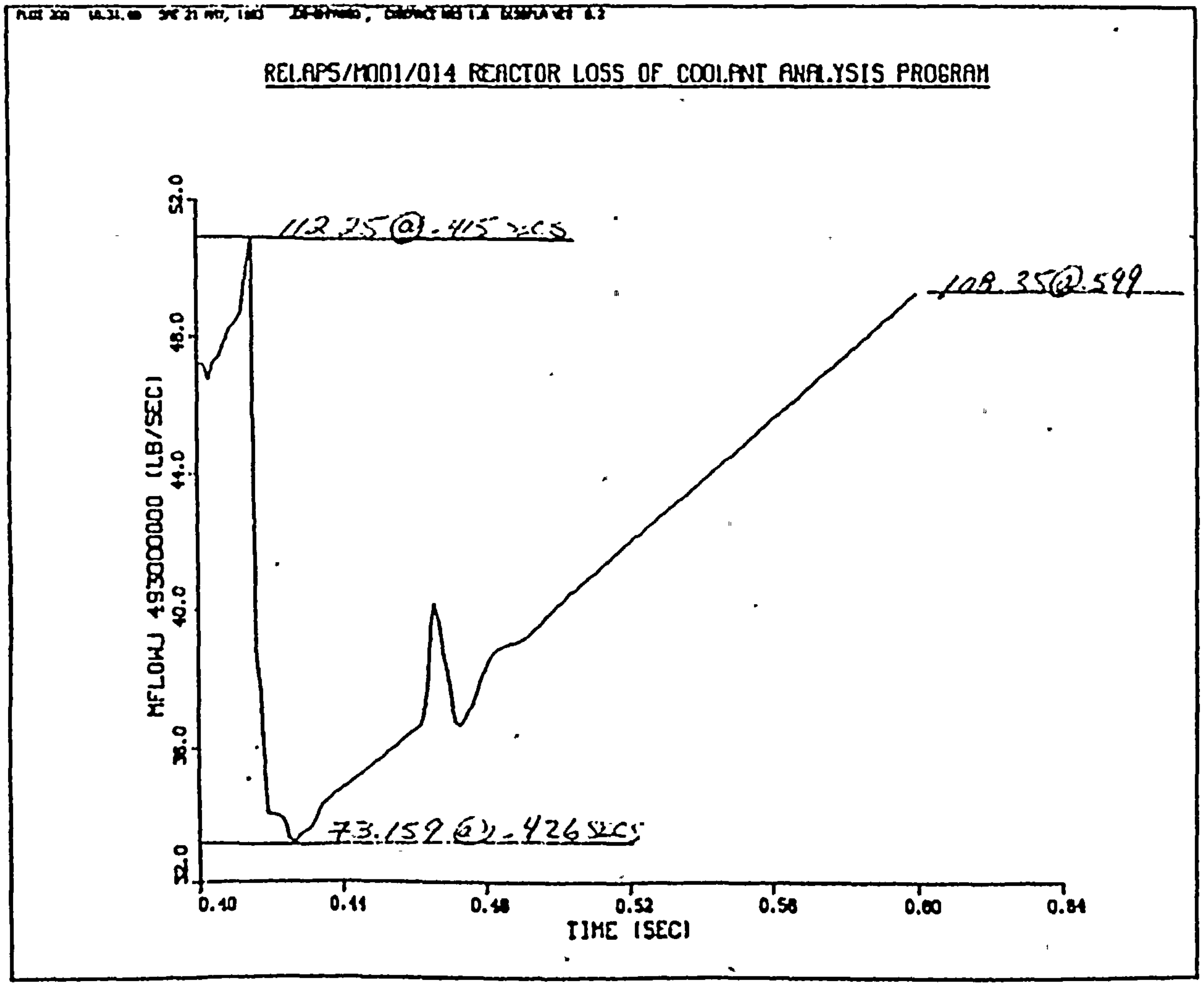
CHKD. BY CHK DATE 5-28-83




RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
MFLOWJ 493000000 (LB/SEC)
TIME (SEC)
52.0
48.0
44.0
40.0
36.0
32.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64
112.75 @ .415 secs
108.35 @ .599
73.152 @ .426 secs

BY KJG DATE 5-21-83
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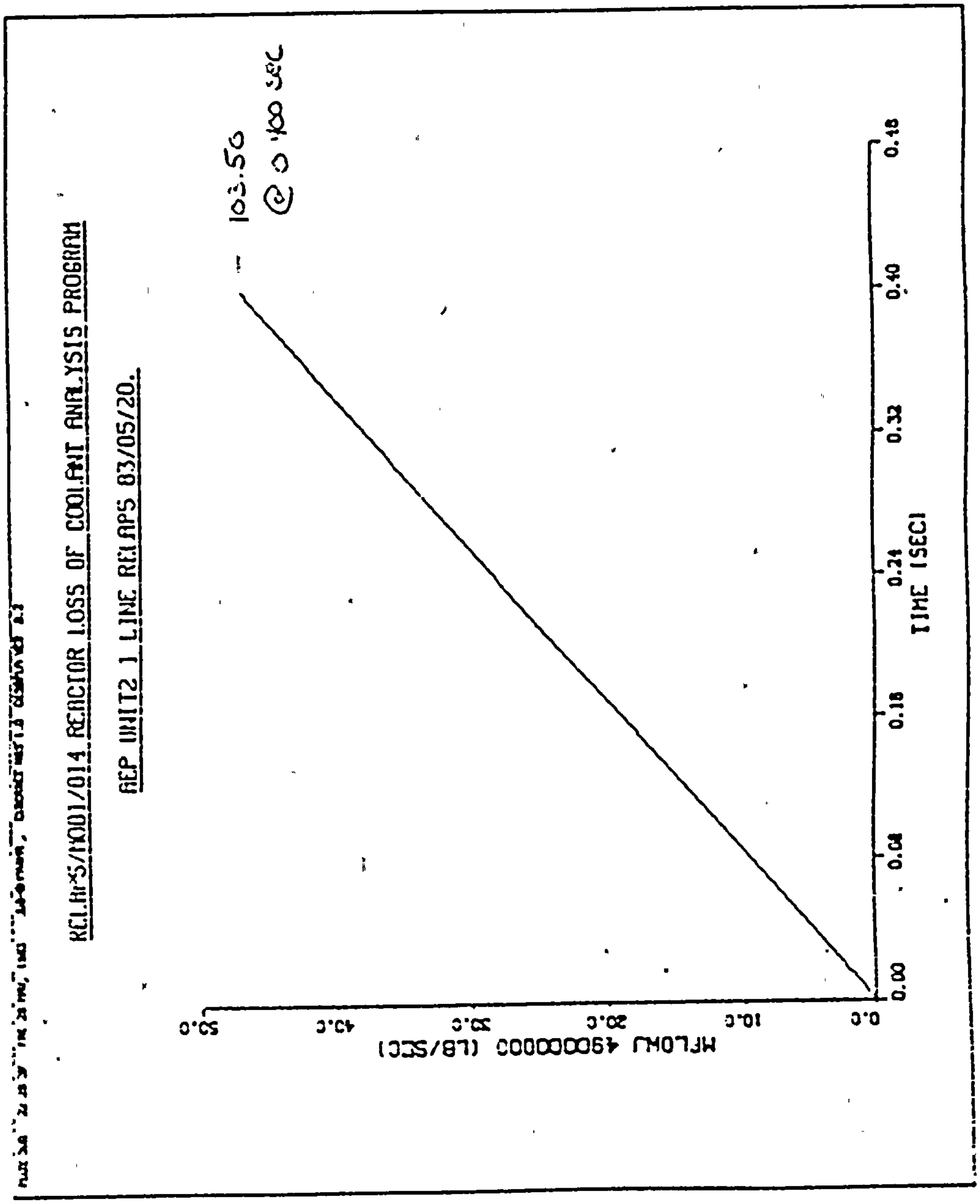
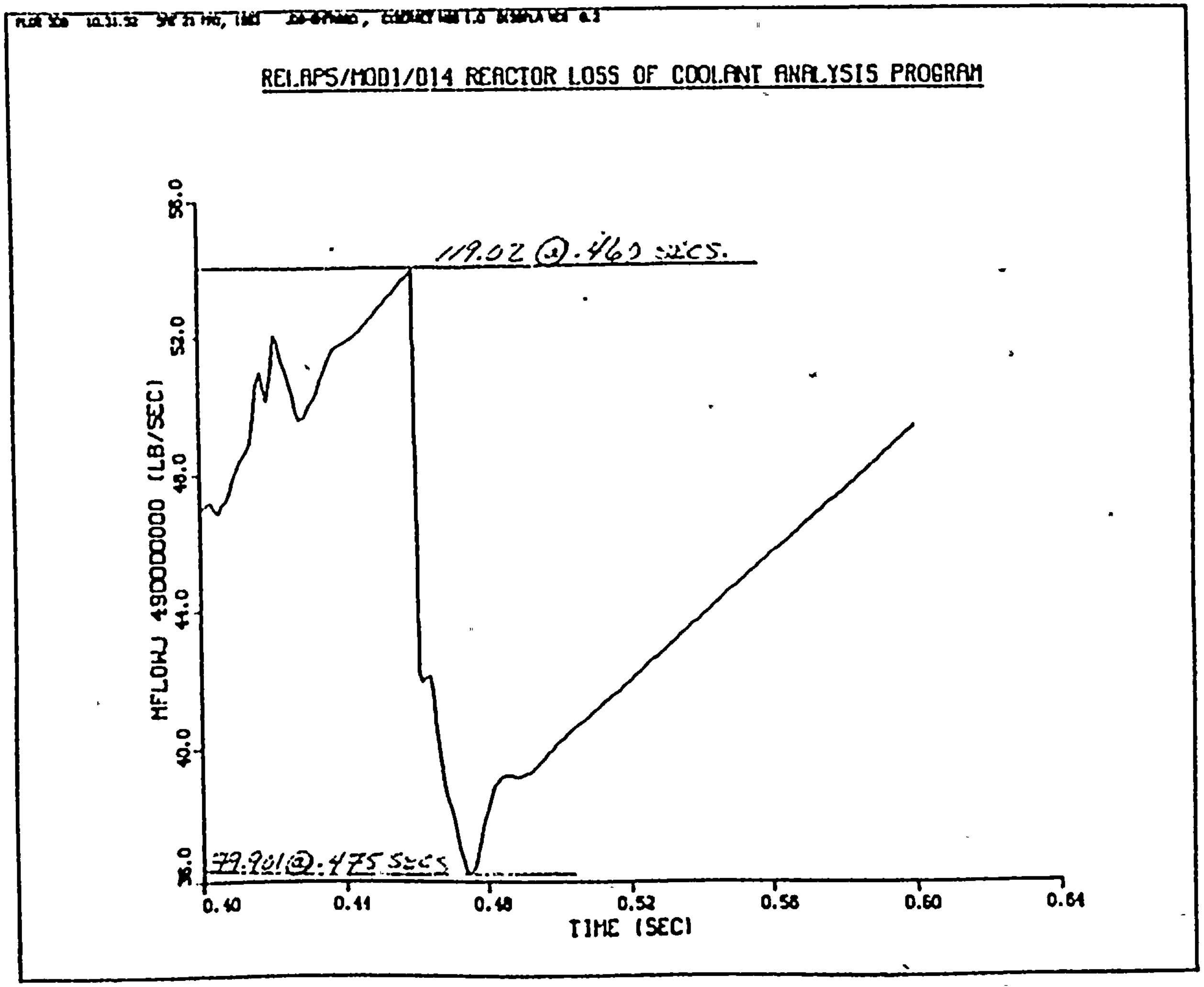
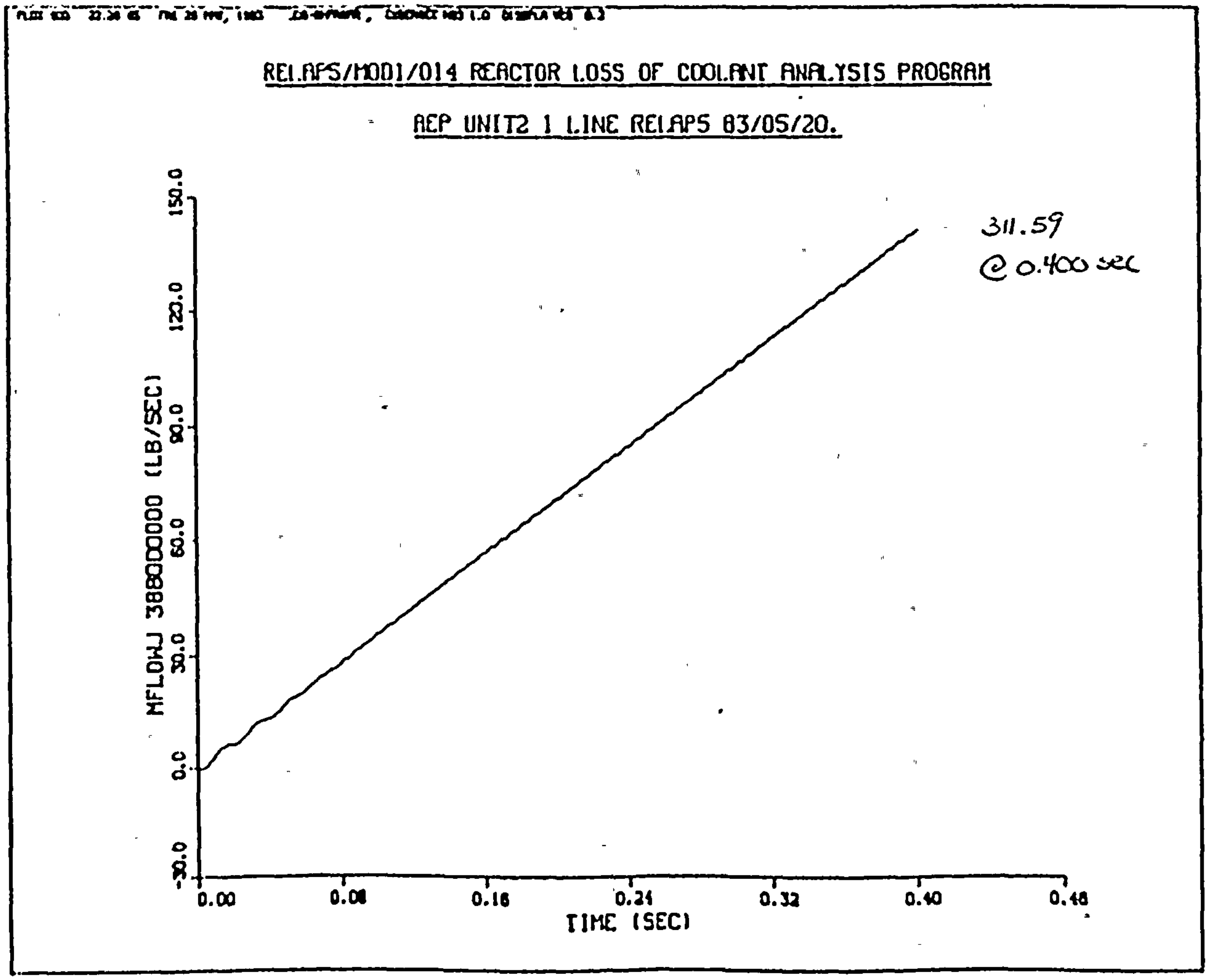
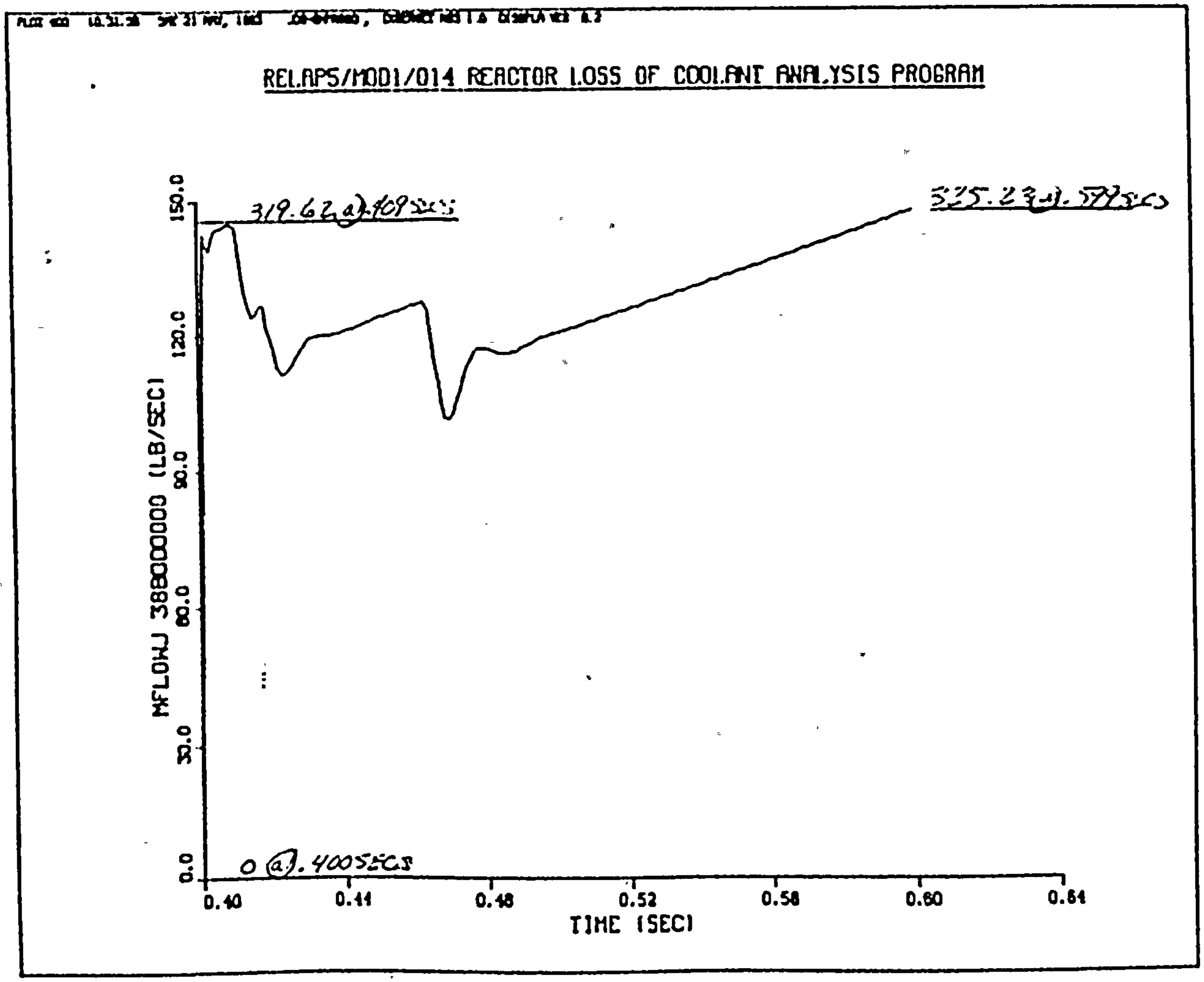


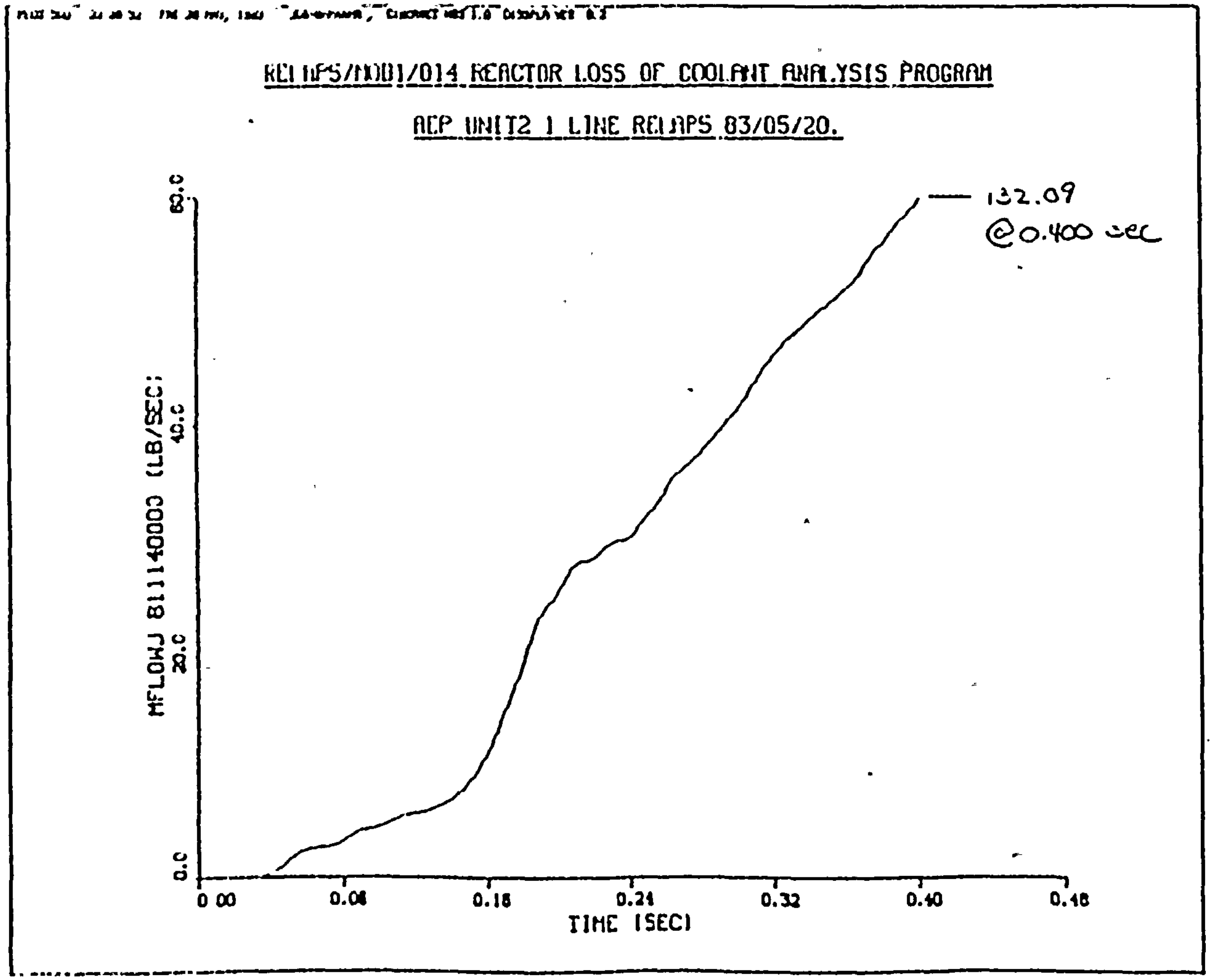
BY. KTG DATE 5-21-82
CHKD. BY CMM DATE 5-28-83




RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/05/20.
MFLOWJ 388000000 (LB/SEC)
150.0
120.0
90.0
60.0
30.0
0.0
-30.0
0.00
0.08
0.16
0.24
0.32
0.40
0.48
TIME (SEC)
311.59
@ 0.400 sec

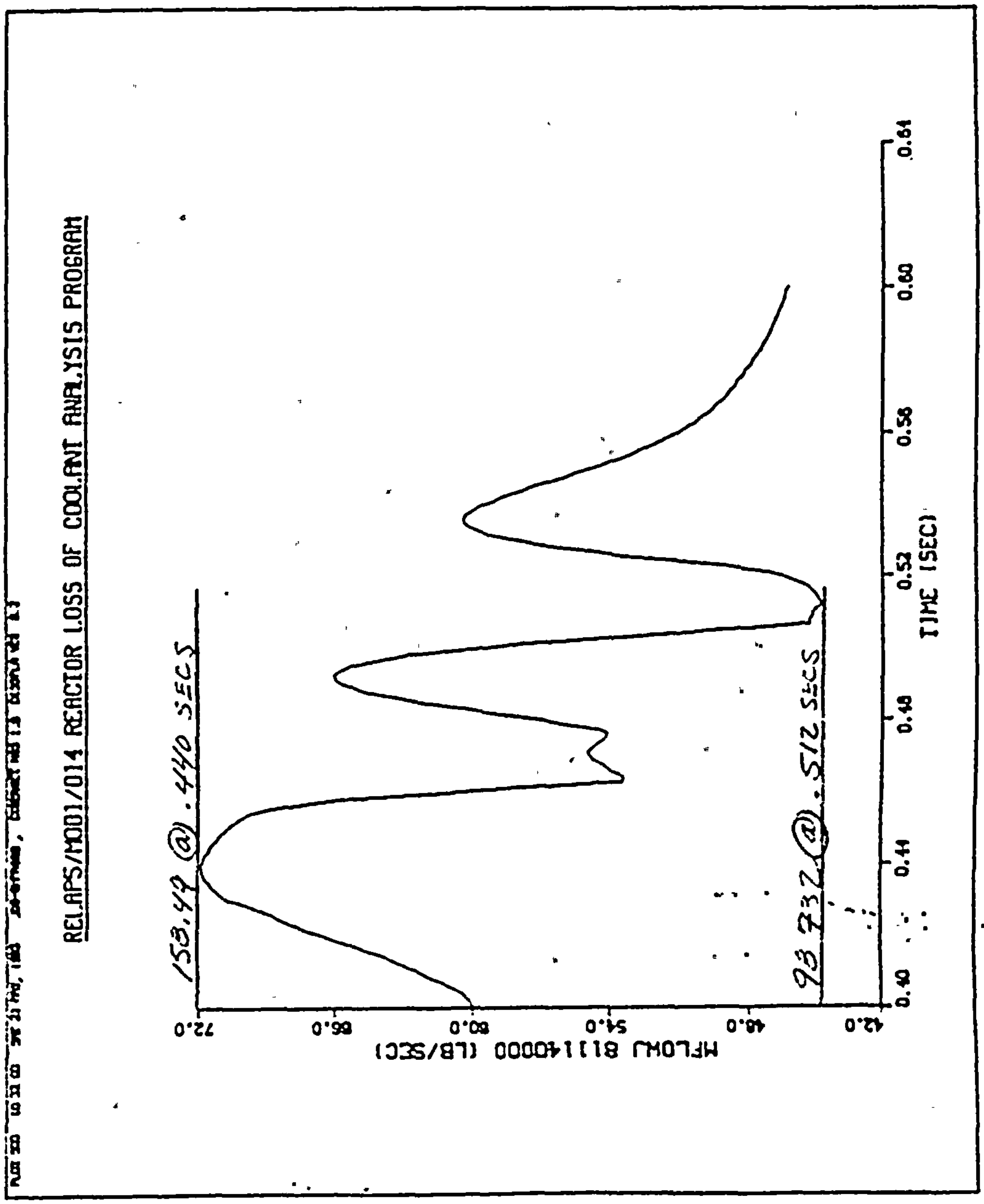
BY KTG DATE 5-21-83
CHKD. BY CHM DATE 5-28-83



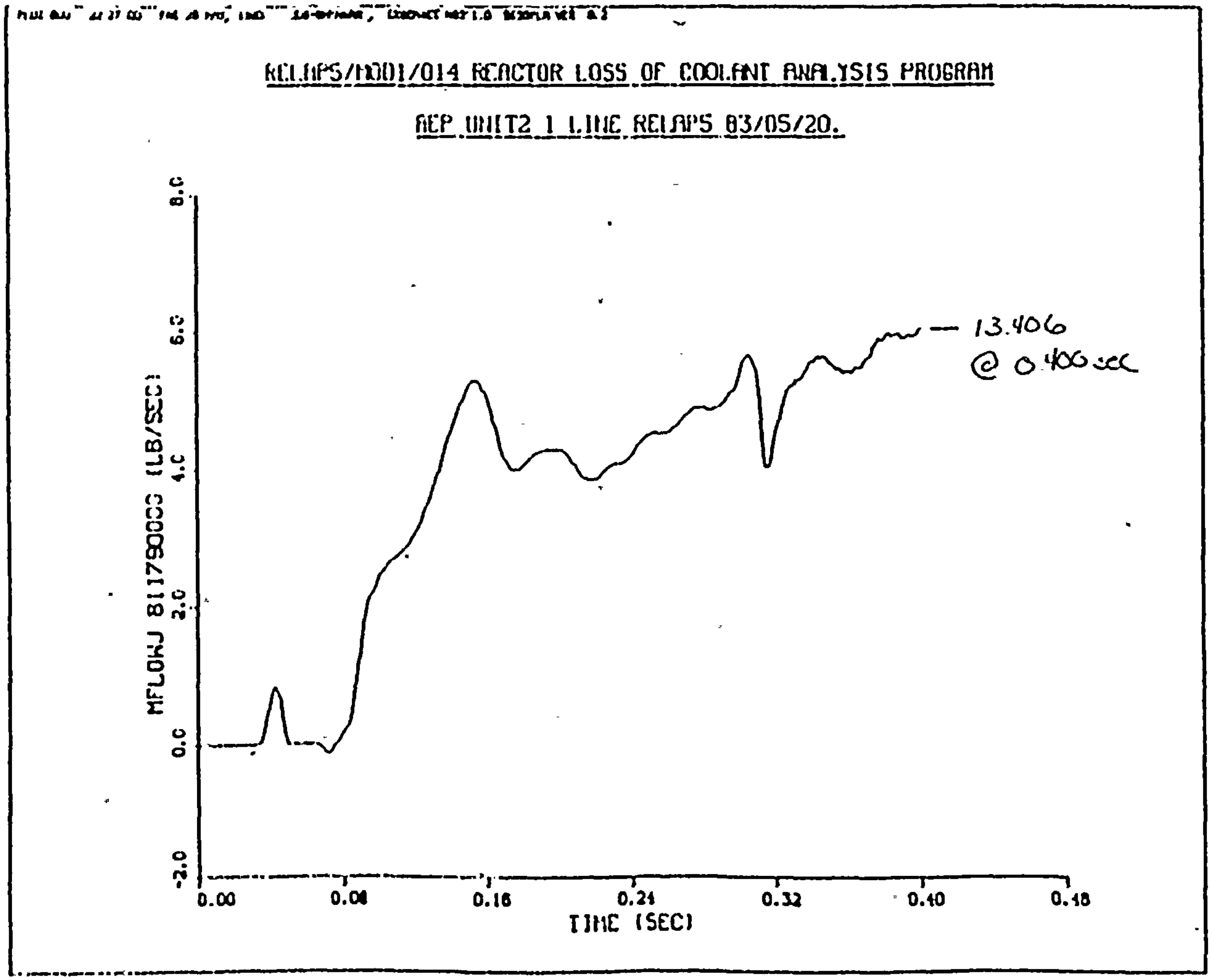


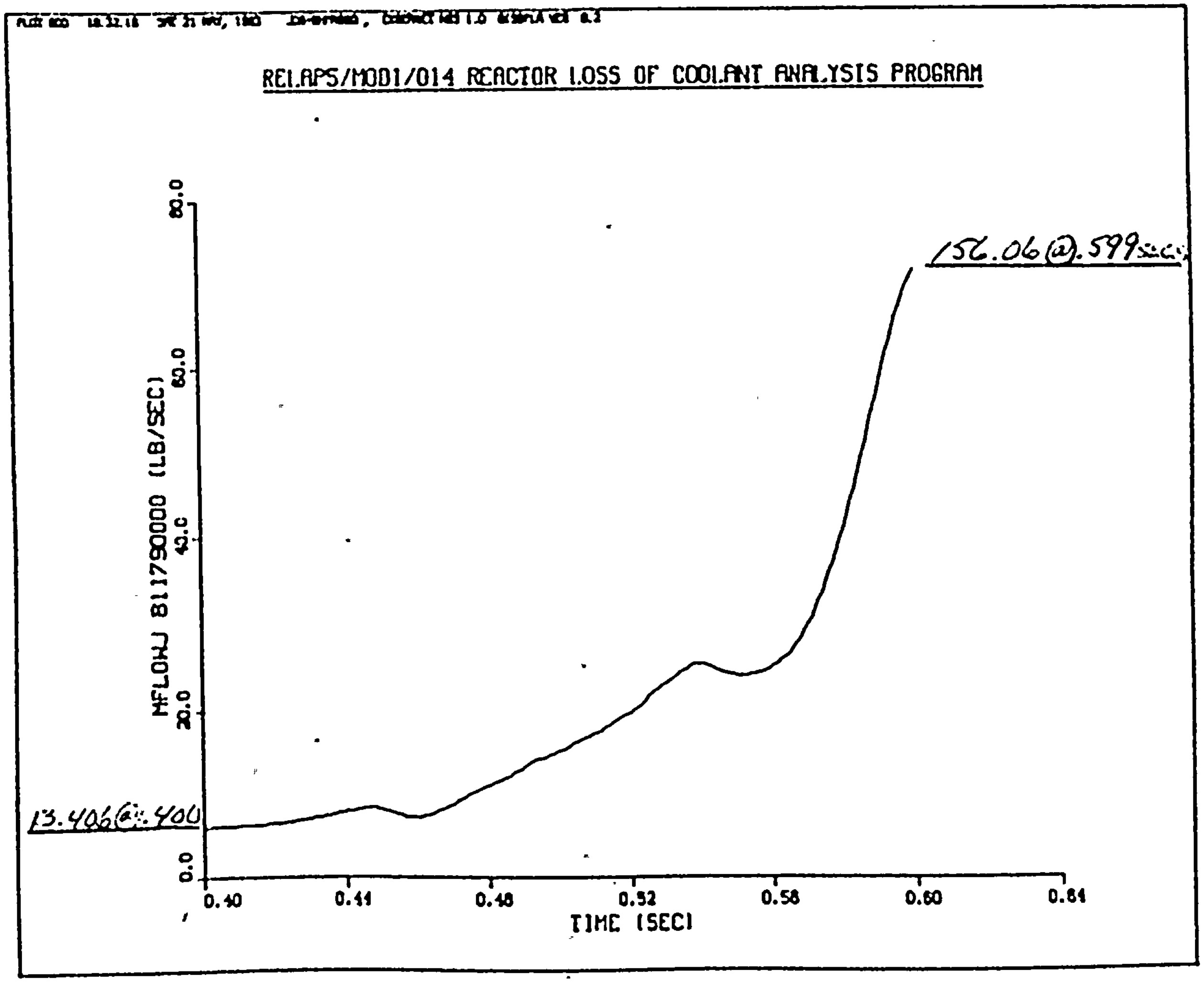
RELAPS/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
ACP UNIT2 1 LINE RELAPS 83/05/20.
MFLOWJ 81114000 (LB/SEC)
0.0
20.0
40.0
60.0
0.00
0.08
0.16
0.24
0.32
0.40
0.48
TIME (SEC)
132.09
@0.400 sec

BY KTG DATE 5-21-83
CHKD. BY CMM DATE 5-28-83

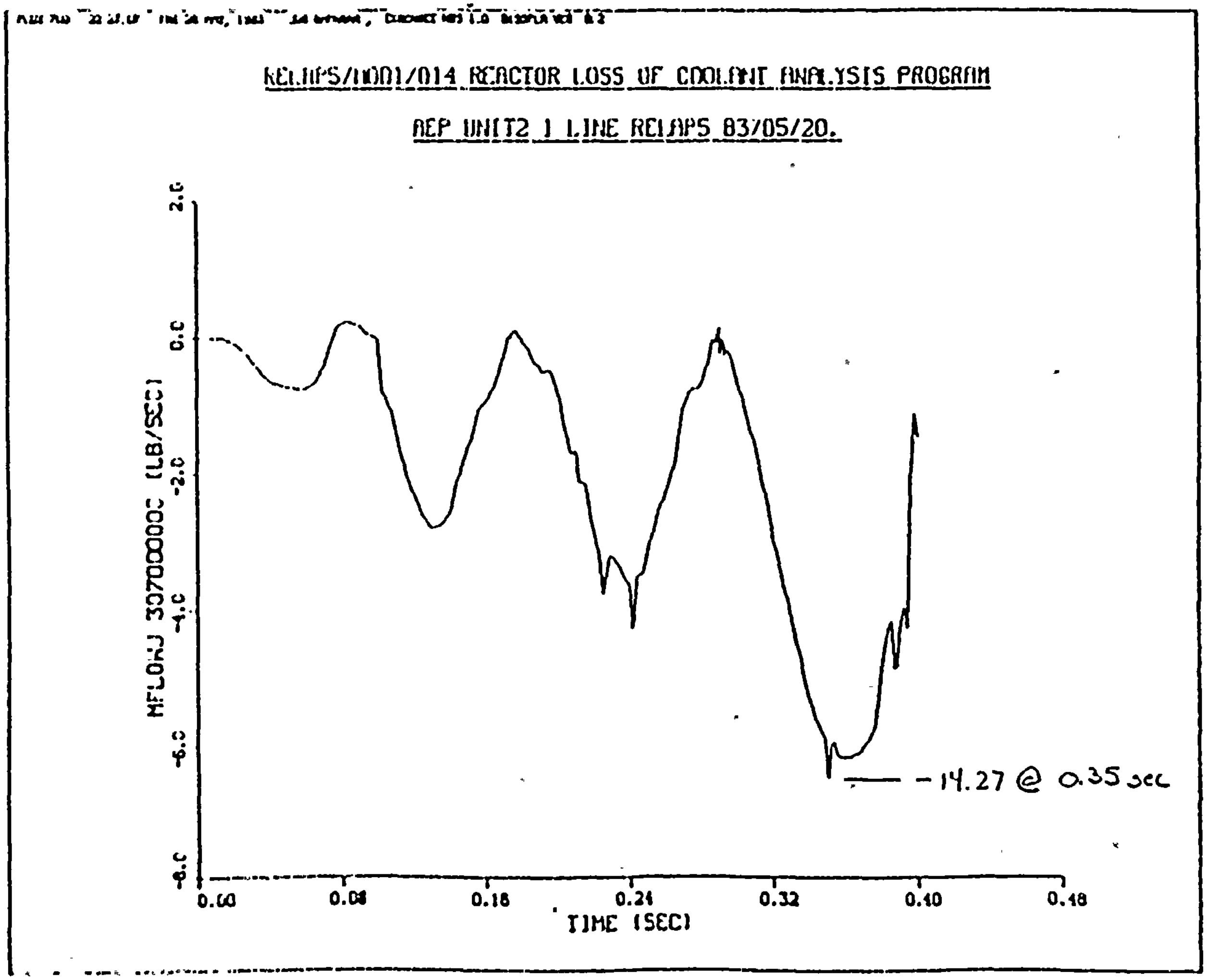


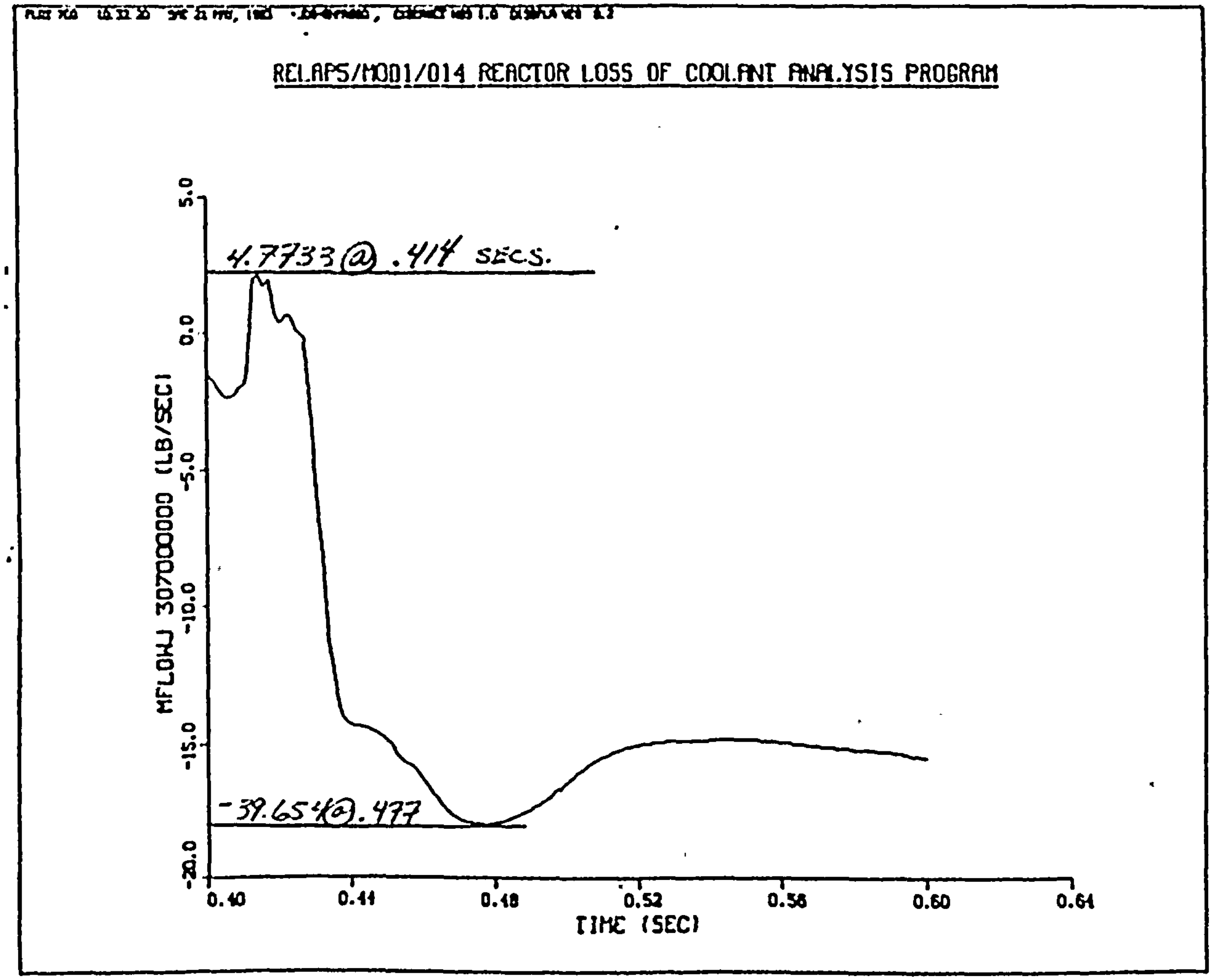
BY KJG DATE 5-21-83
CHKD. BY CHW DATE 5-28-83



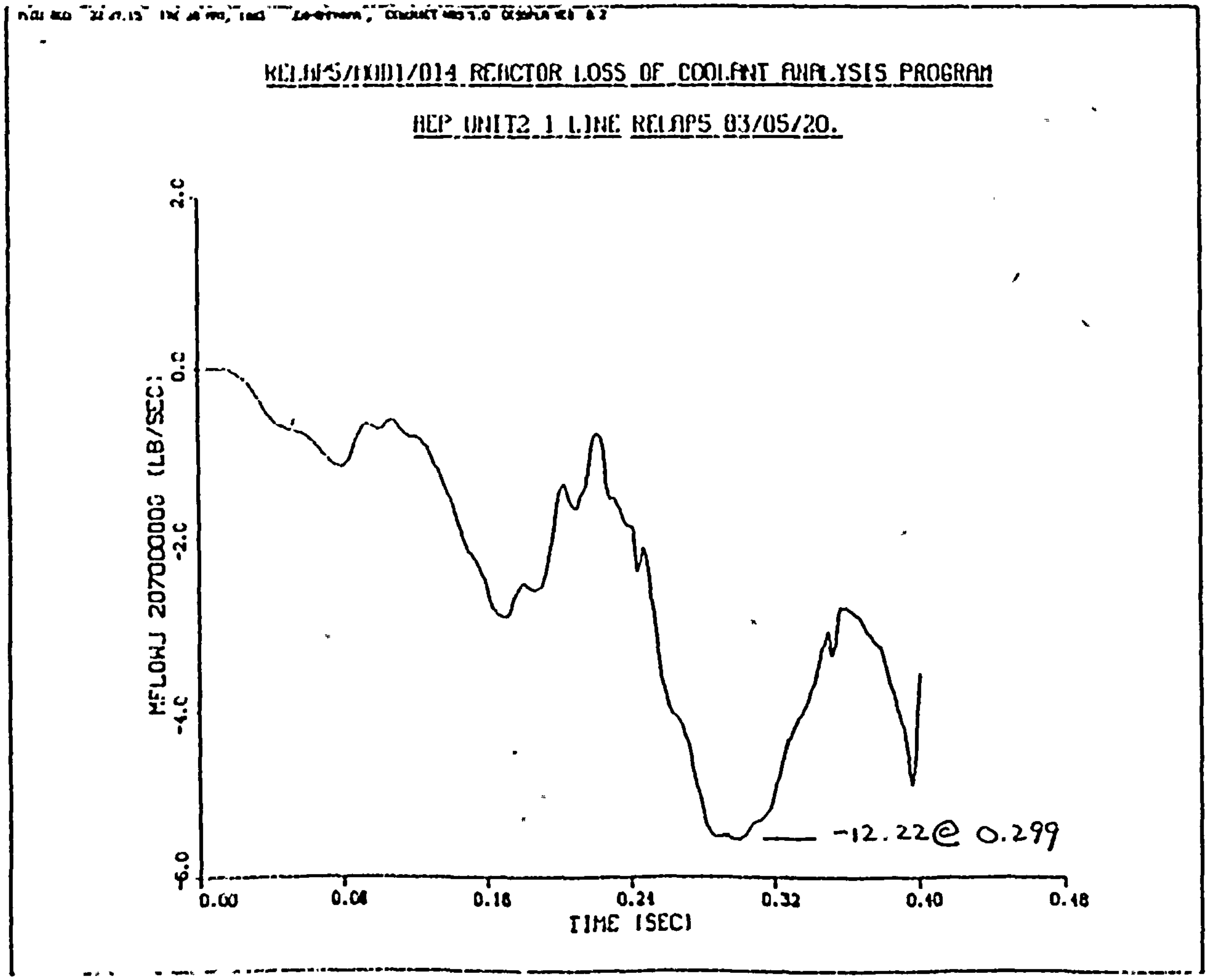

RELAPS/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
MFLOWJ 811790000 (LB/SEC)
0.0
20.0
40.0
60.0
80.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)
13.406 @ .400
156.06 @ .599 sec

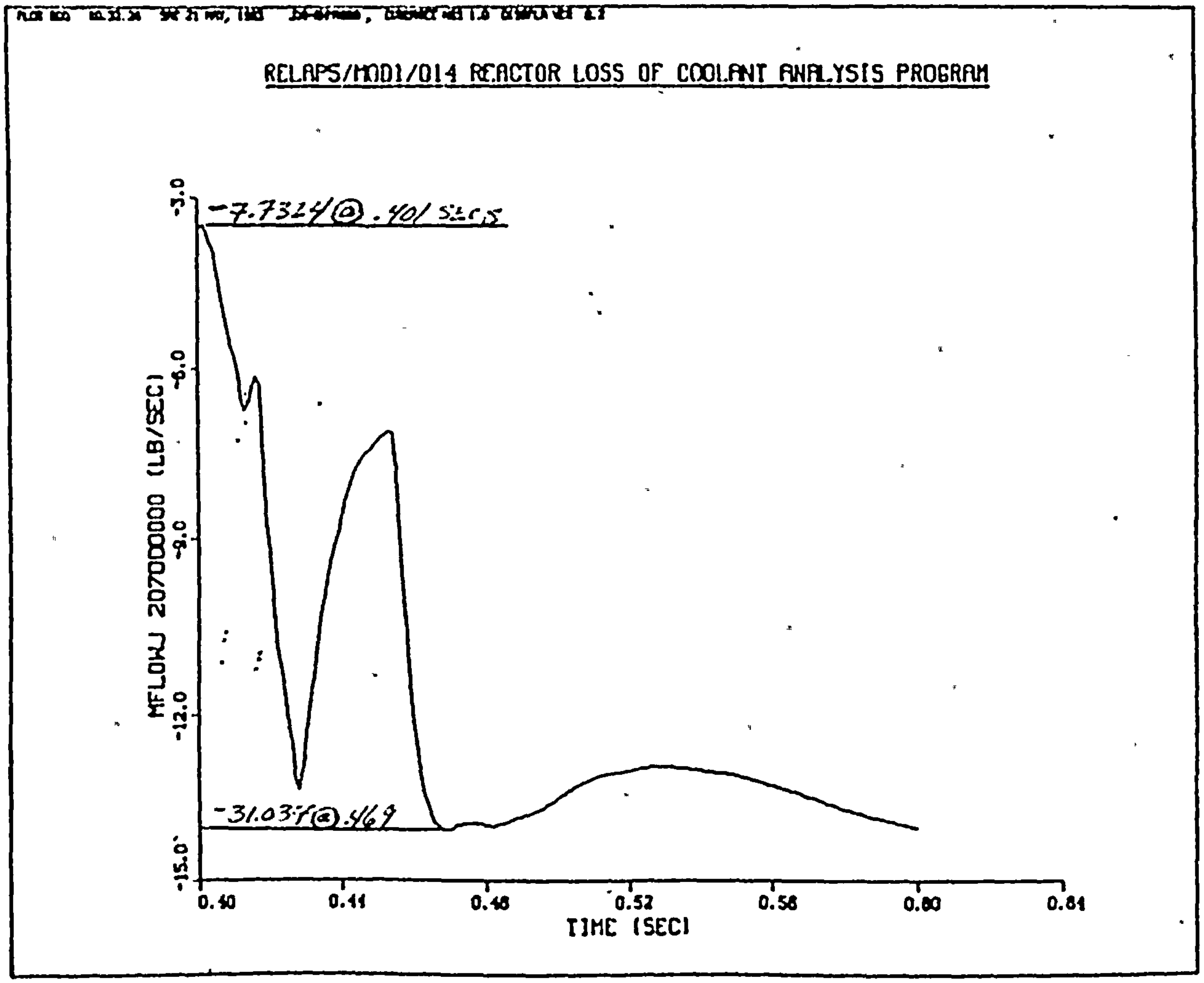
BY KJG DATE 5-21-83
CHKD. BY CHH DATE 5-28-83



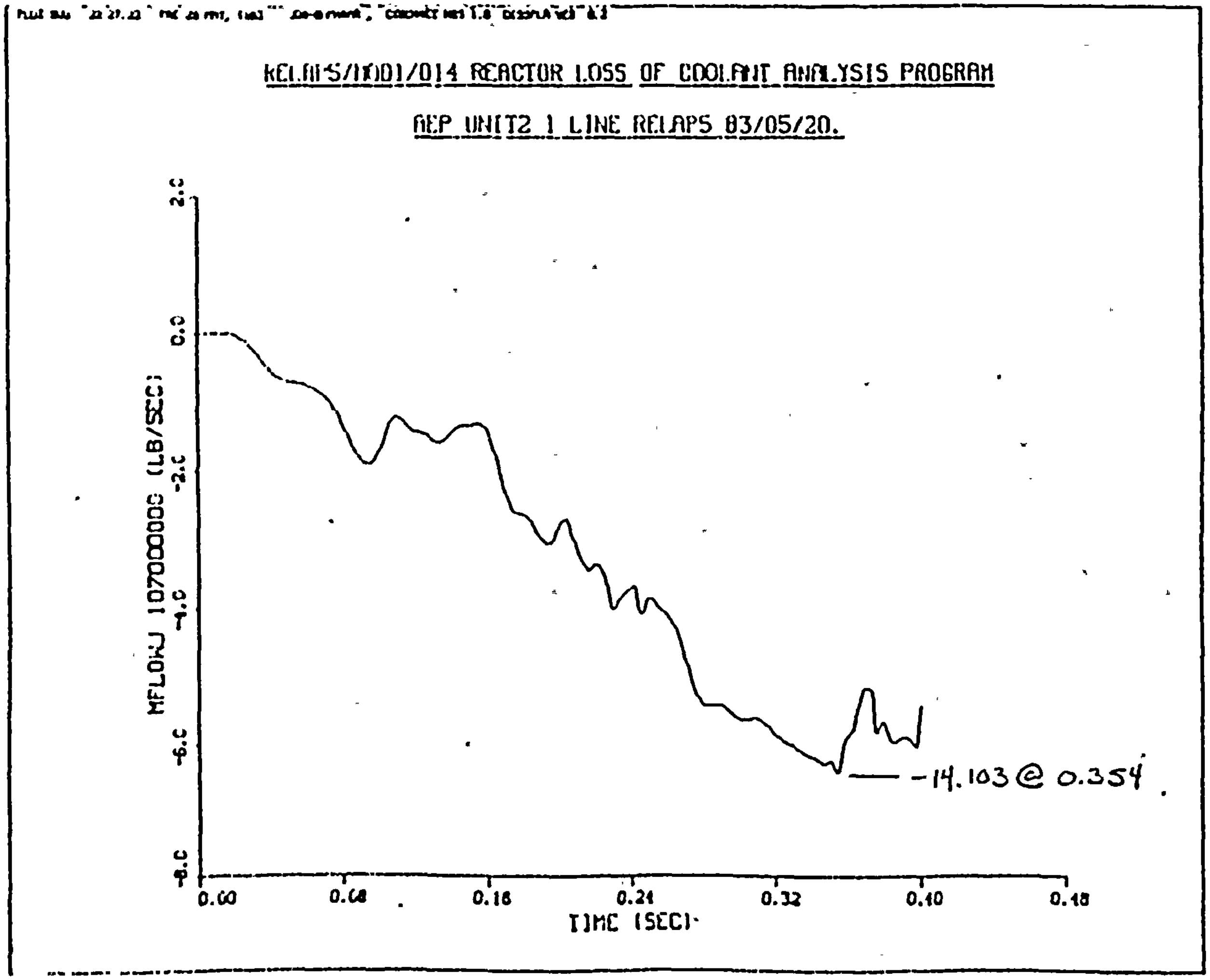

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
MFLOWJ 307000000 (LB/SEC)
5.0
0.0
-5.0
-10.0
-15.0
-20.0
TIME (SEC)
0.40
0.44
0.48
0.52
0.56
0.60
0.64
4.7733 @ .414 SECS.
-39.654 @ .477

BY KJG DATE 5-21-83
CHKD. BY CHL DATE 5-28-83




RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
-7.7324 @ .401 SECS
-31.0354 @ .469
MFLOWJ 207000000 (LB/SEC)
-3.0
-6.0
-9.0
-12.0
-15.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)

BY KJG DATE 5-21-83
CHKD. BY CHY DATE 5-28-83



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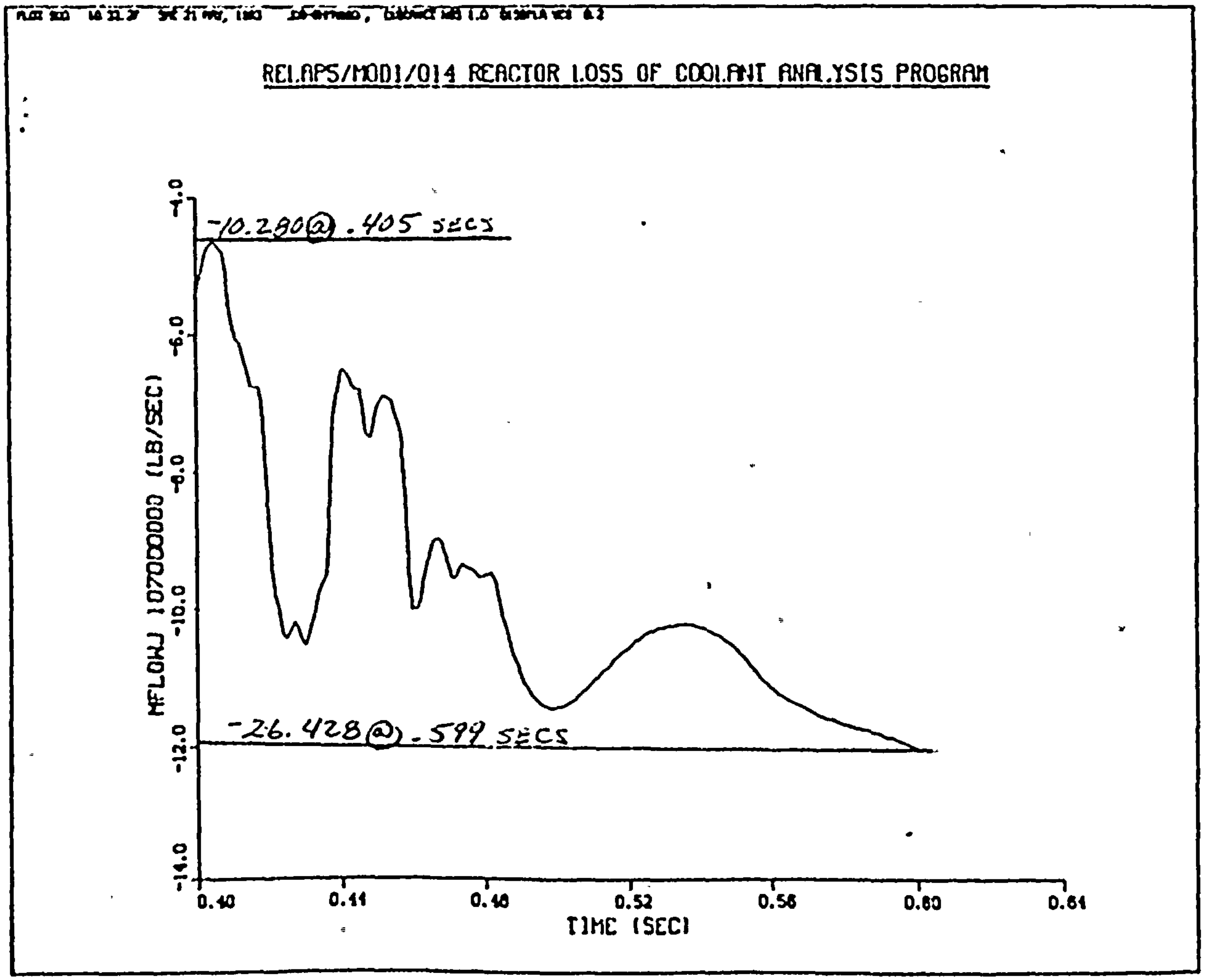

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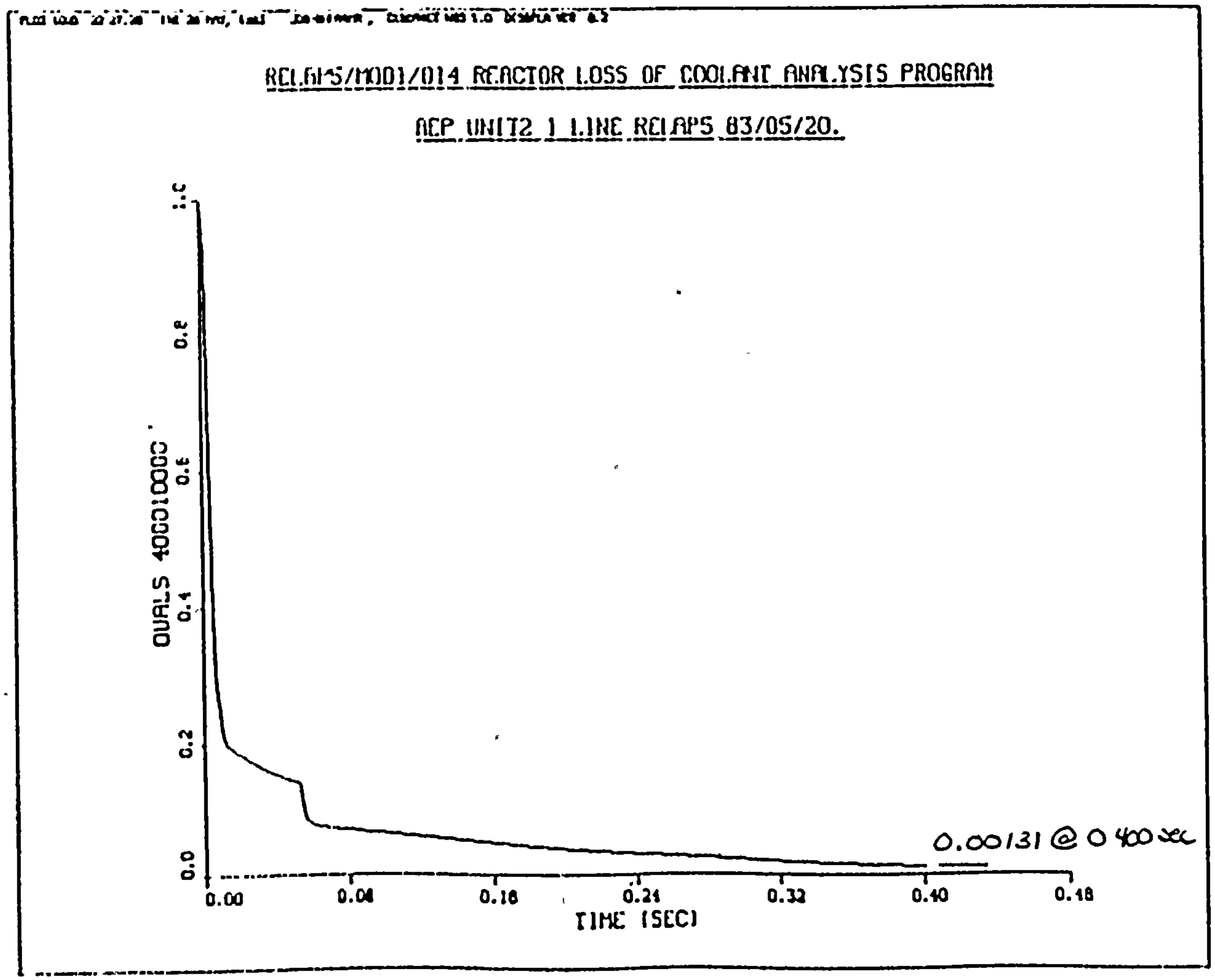

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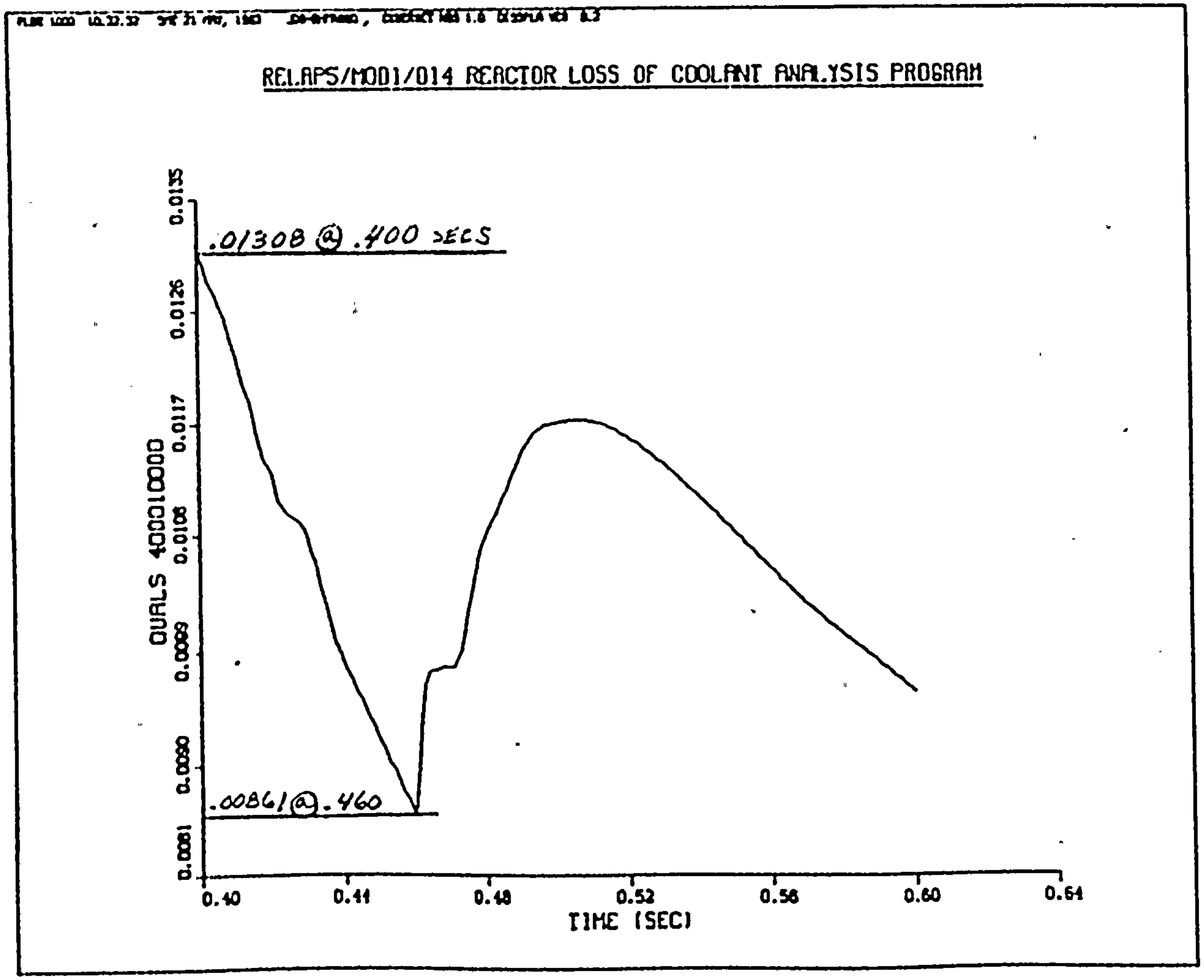

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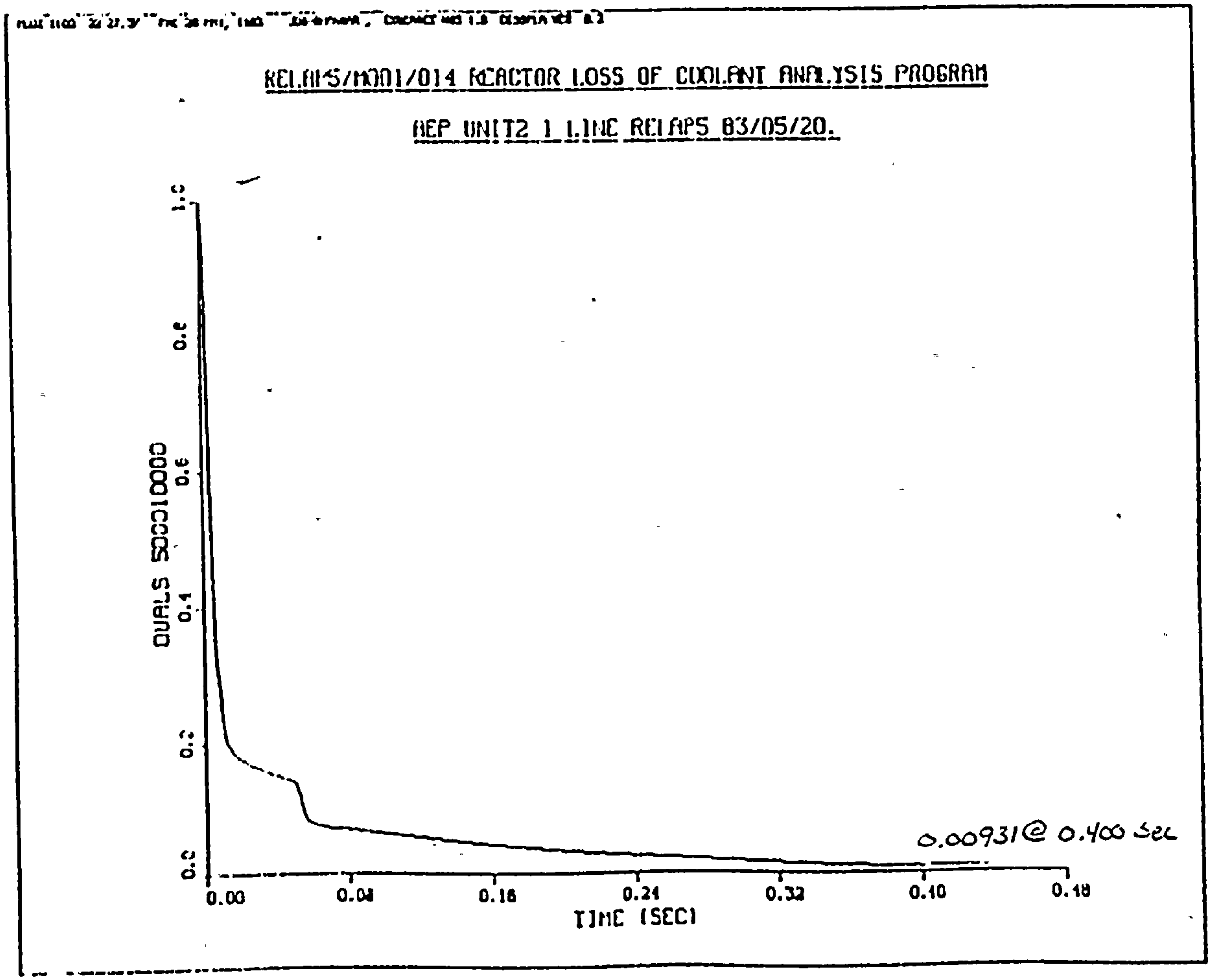
CHKD. BY CHH DATE 5-28-83



BY. KTG DATE 5-21-83
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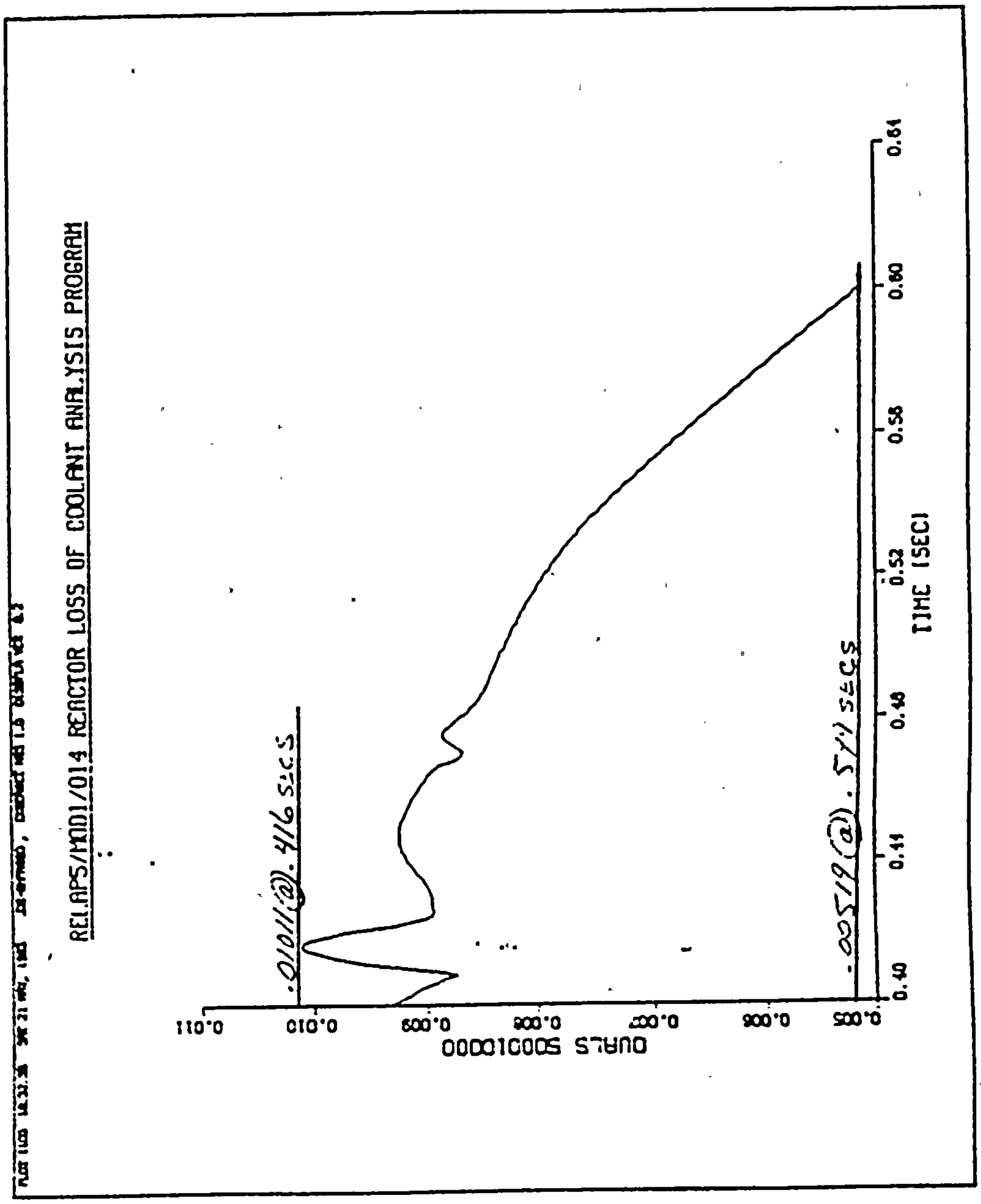

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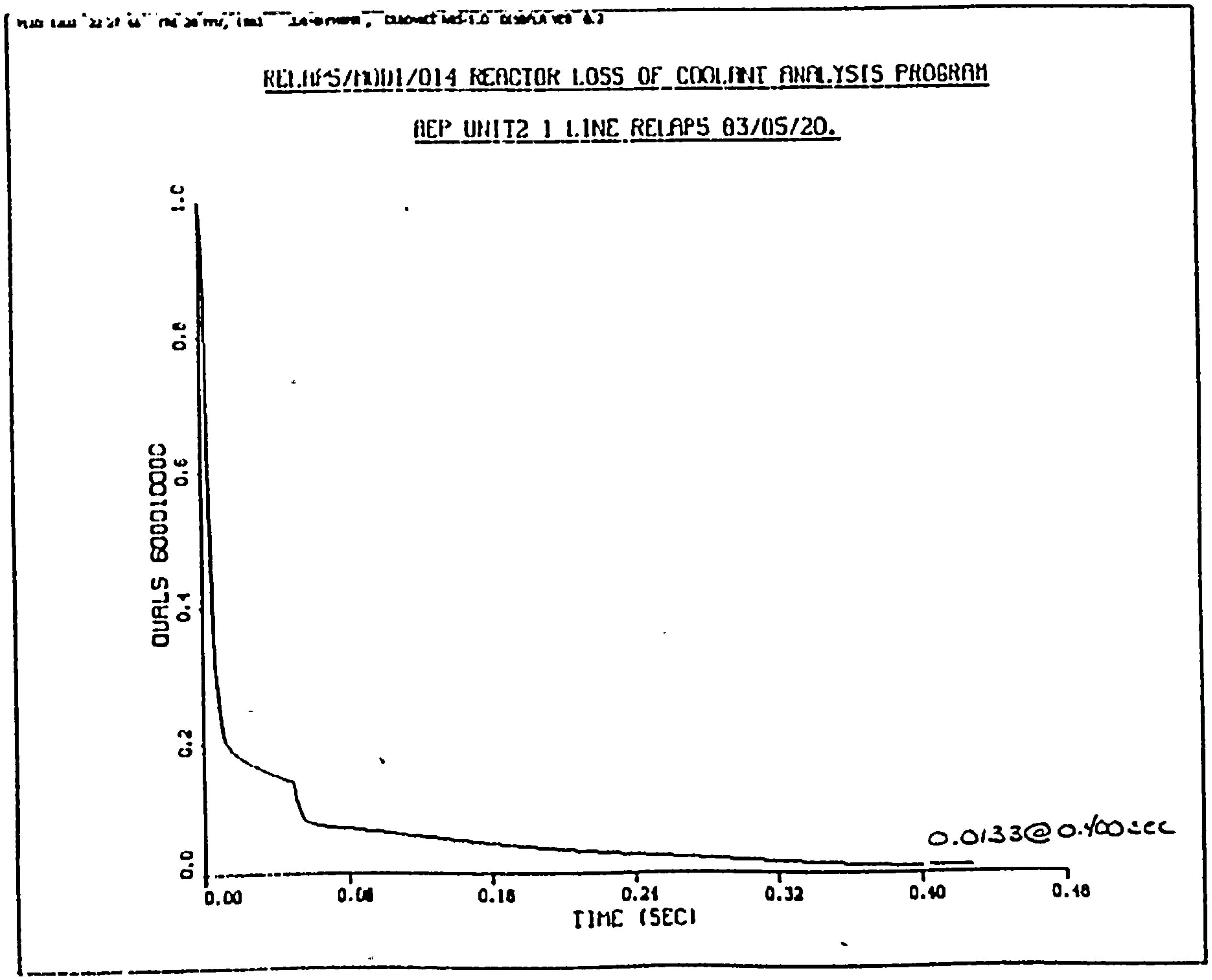
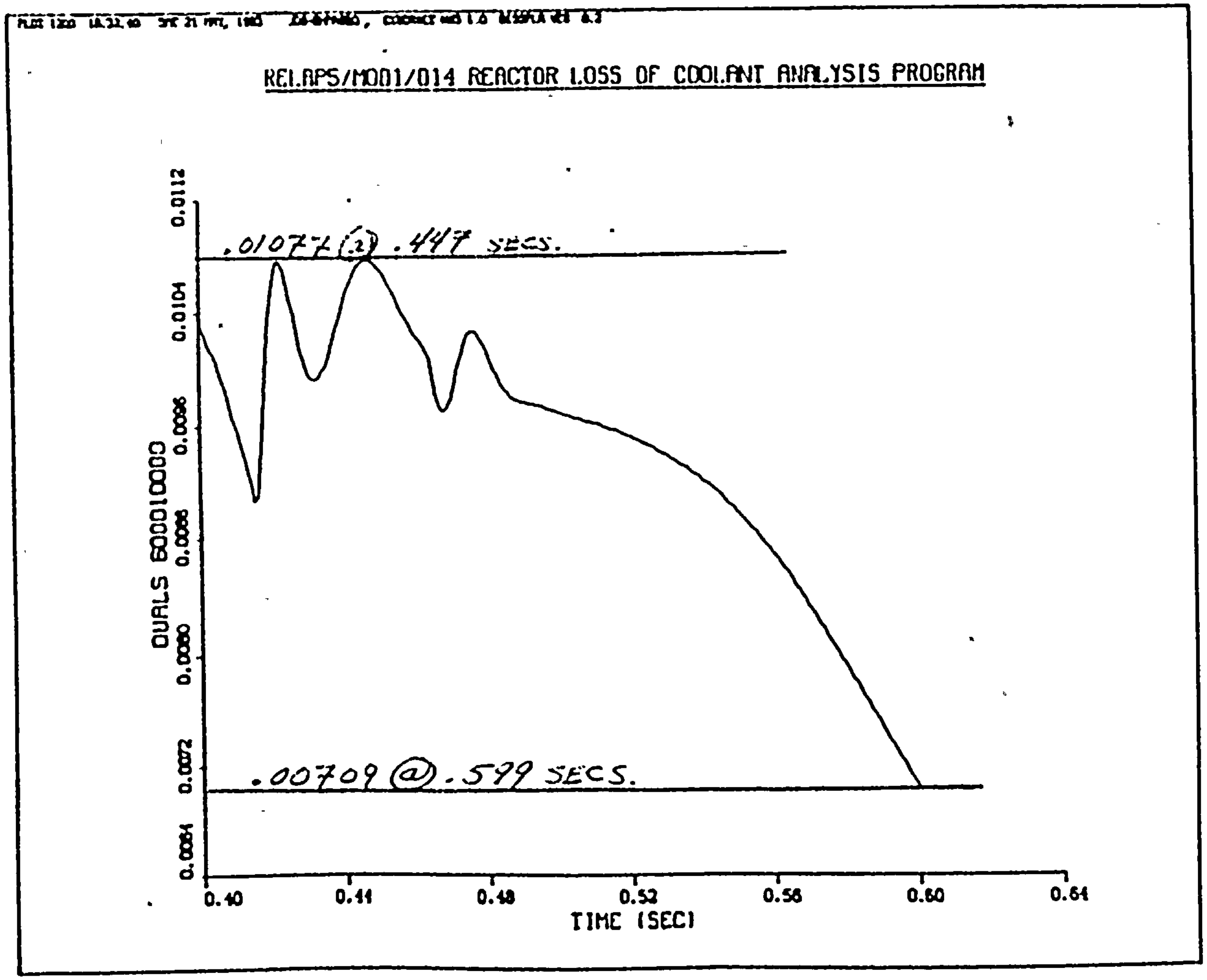
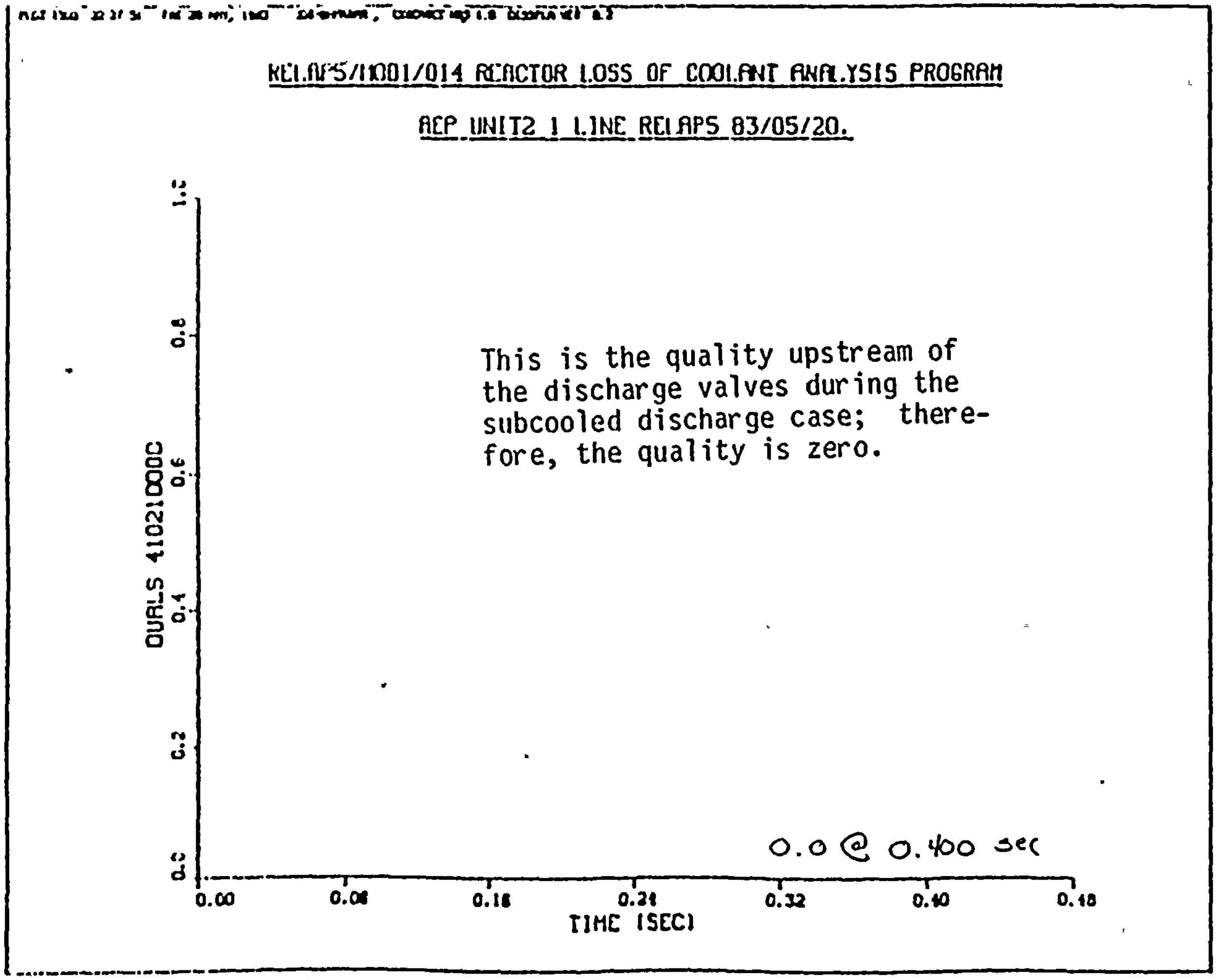
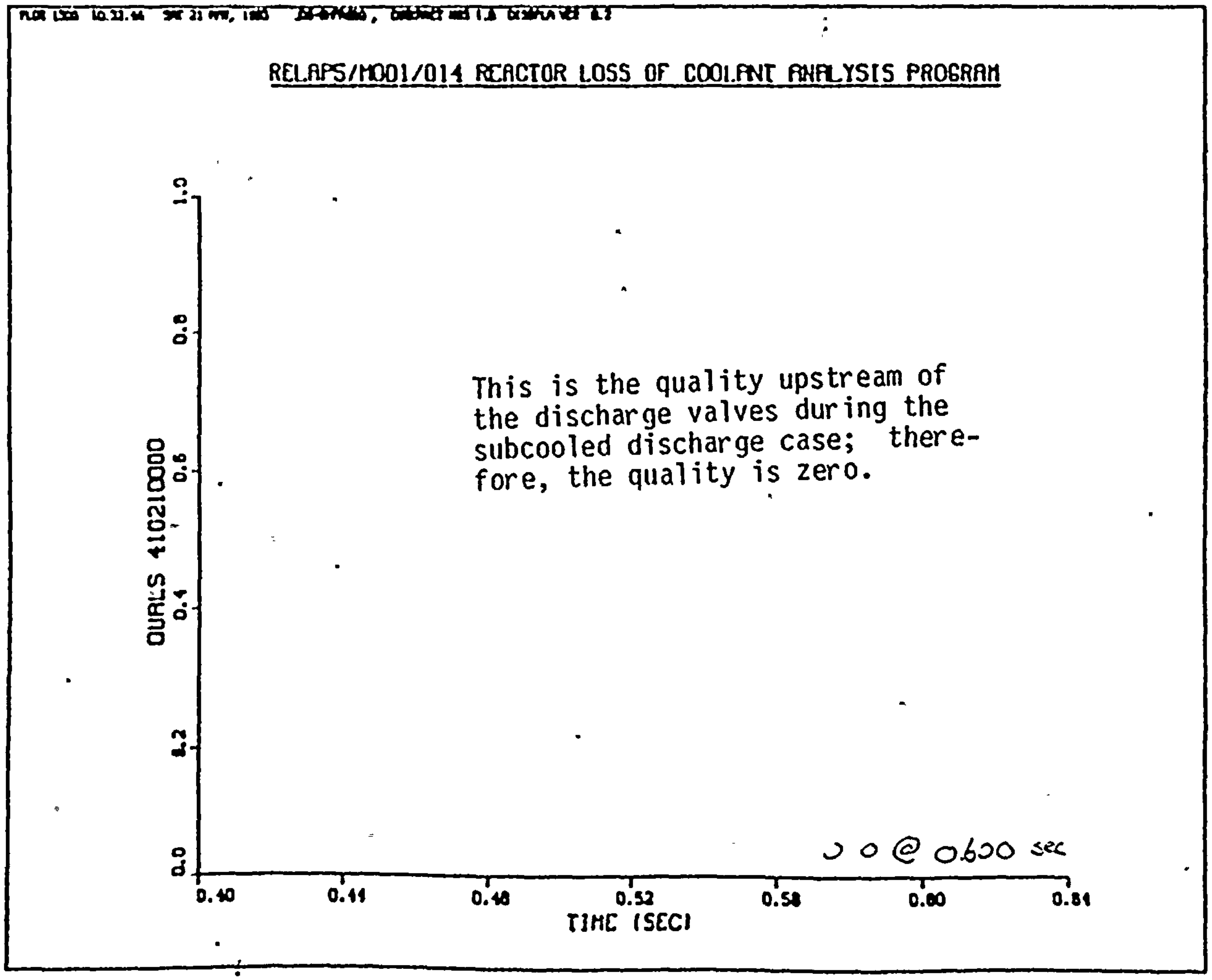
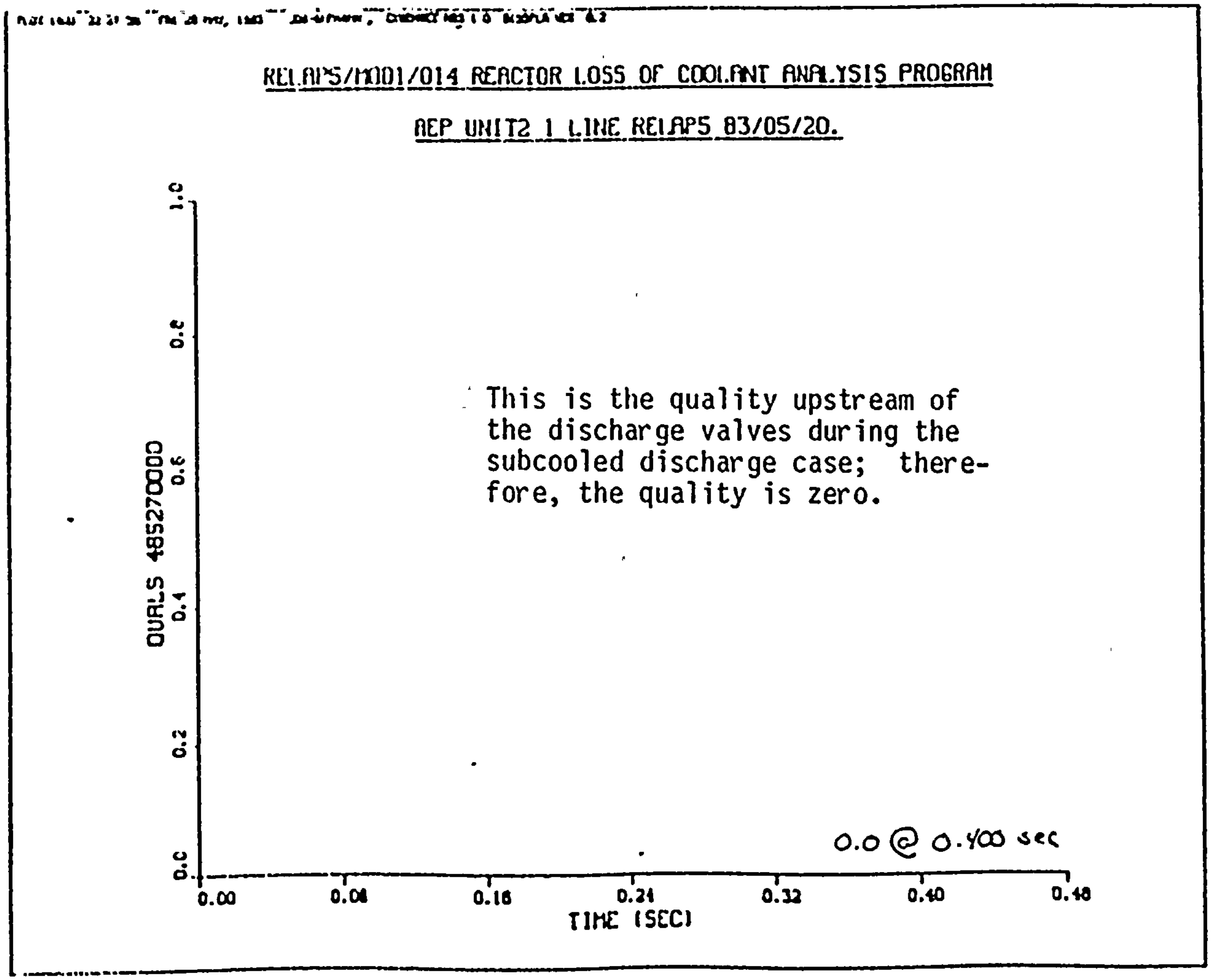


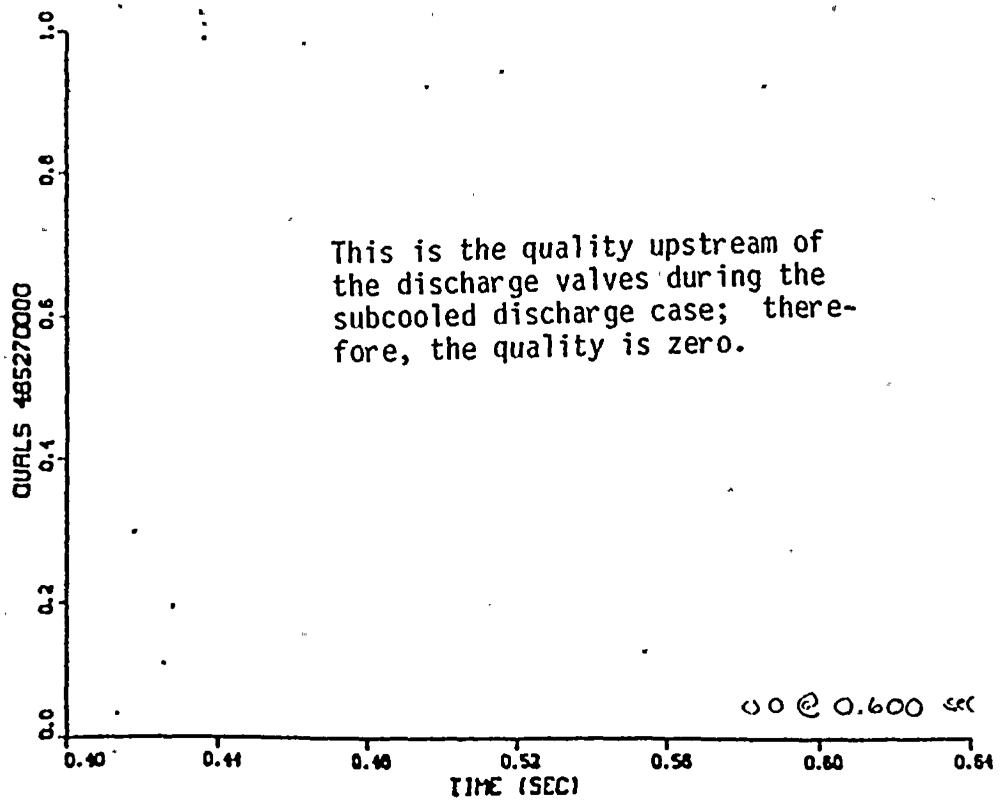

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
QUALS 60010000
0.0064
0.0072
0.0080
0.0088
0.0096
0.0104
0.0112
.01077 @ .447 SECS.
.00709 @ .599 SECS.
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)


RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/05/20.
QUALS 410210000
TIME (SEC)
0.00
0.08
0.16
0.24
0.32
0.40
0.48
0.0
0.2
0.4
0.6
0.8
1.0
This is the quality upstream of the discharge valves during the subcooled discharge case; therefore, the quality is zero.
0.0 @ 0.400 sec

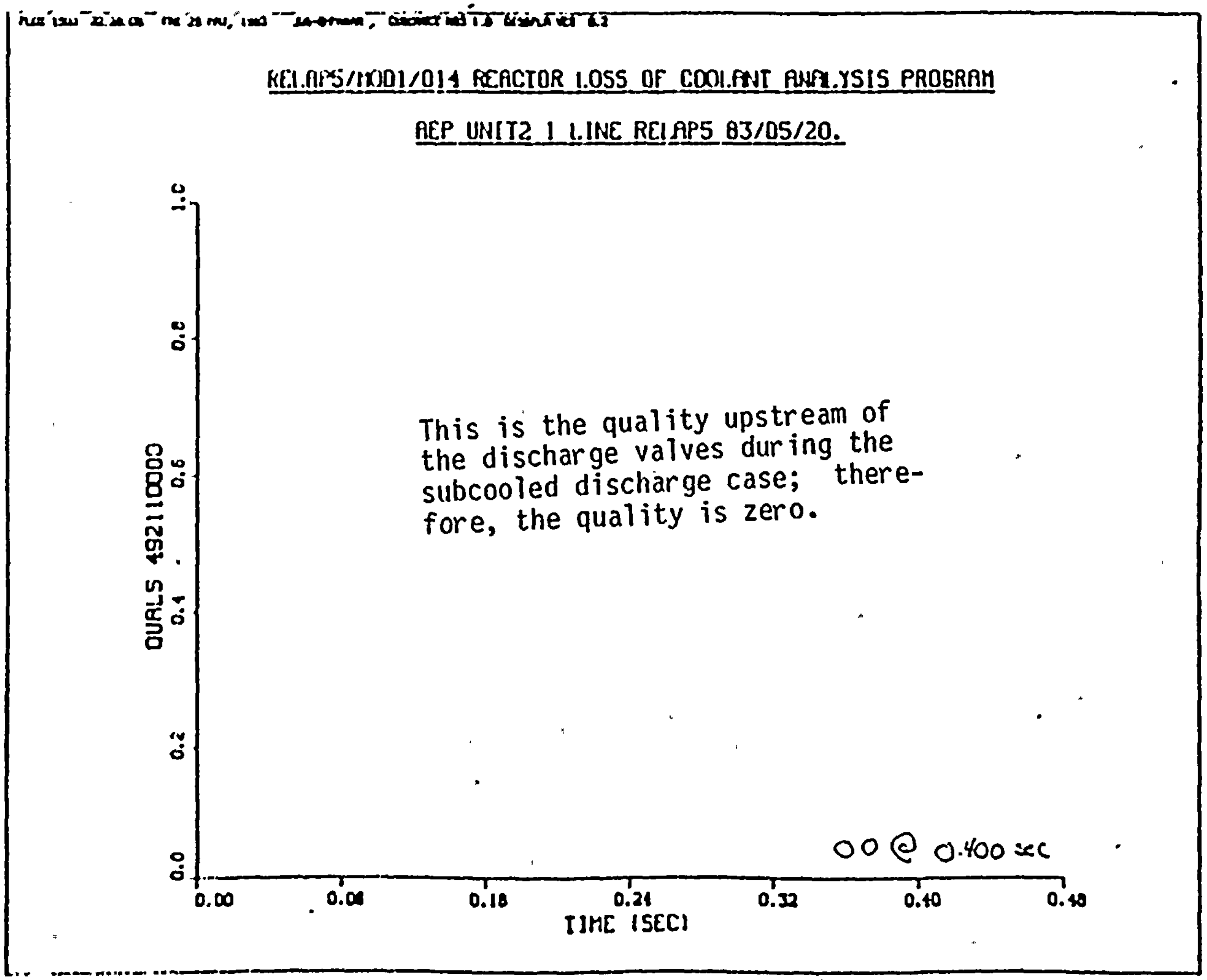

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
QUALS 410210000
TIME (SEC)
0.0
0.2
0.4
0.6
0.8
1.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64
This is the quality upstream of the discharge valves during the subcooled discharge case; therefore, the quality is zero.
0 0 @ 0.600 sec

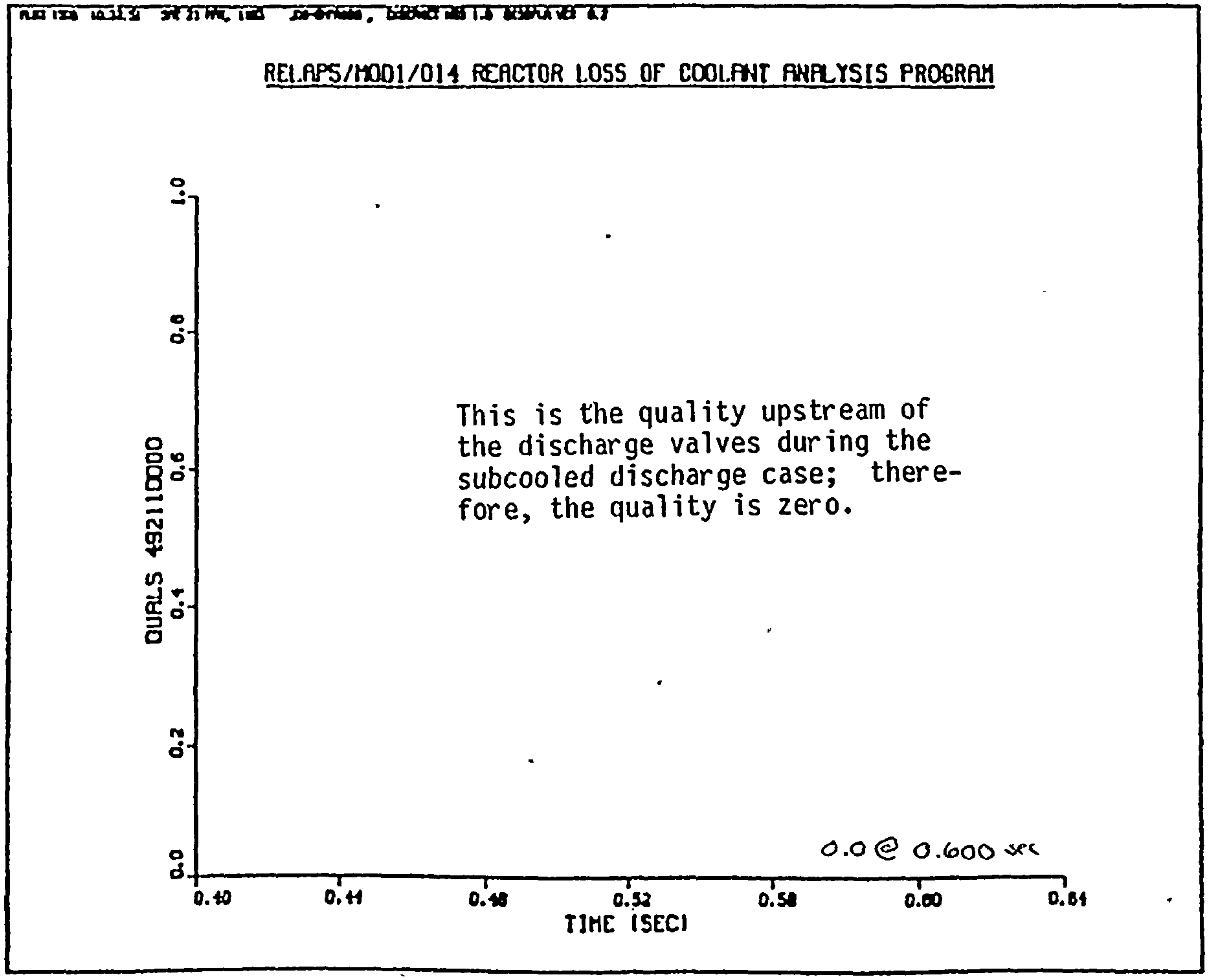

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/05/20.
QUALS 485270000
TIME (SEC)
This is the quality upstream of the discharge valves during the subcooled discharge case; therefore, the quality is zero.
0.0 @ 0.400 sec

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

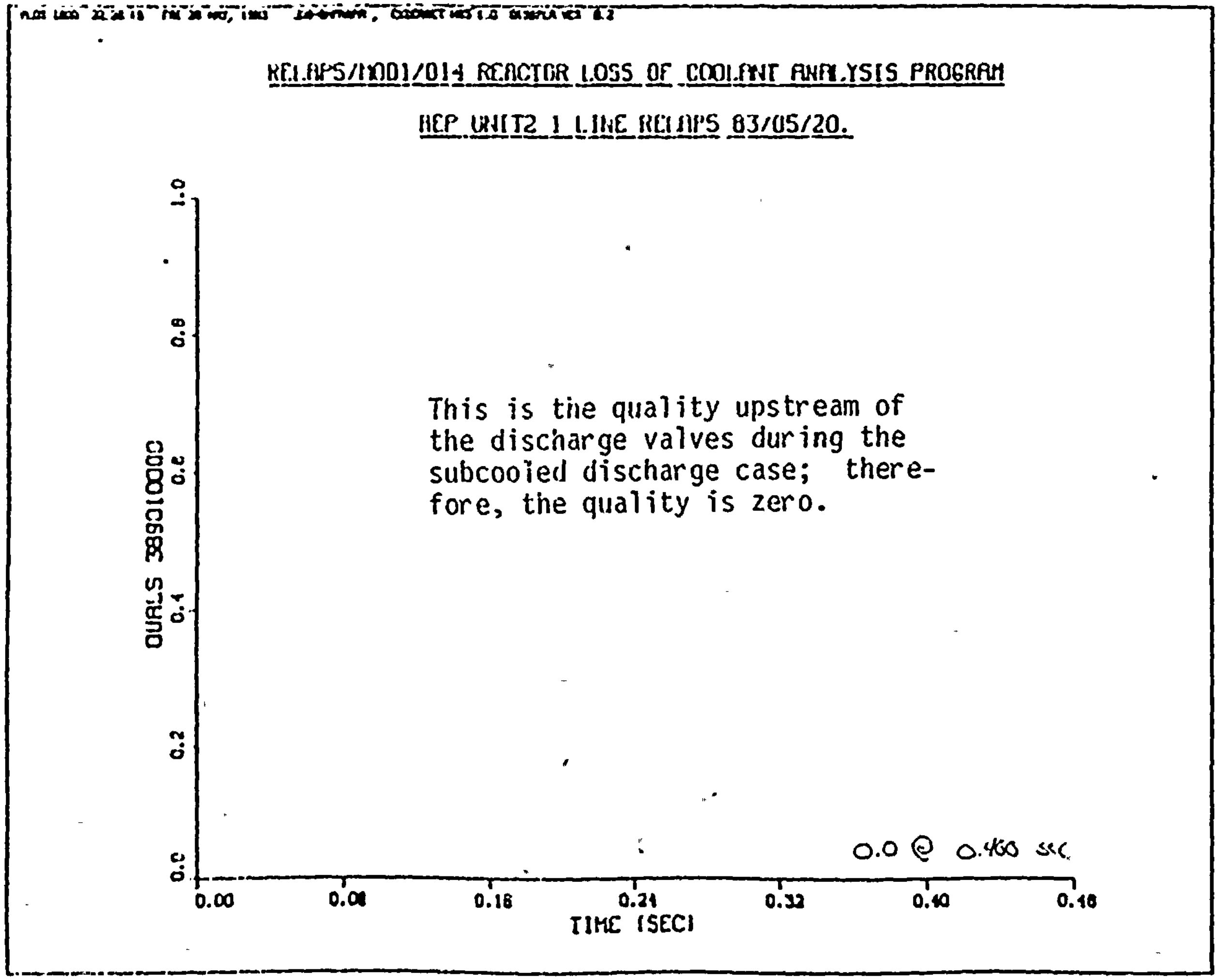


BY KJG DATE 5-21-83
CHKD. BY CHL DATE 5-28-83

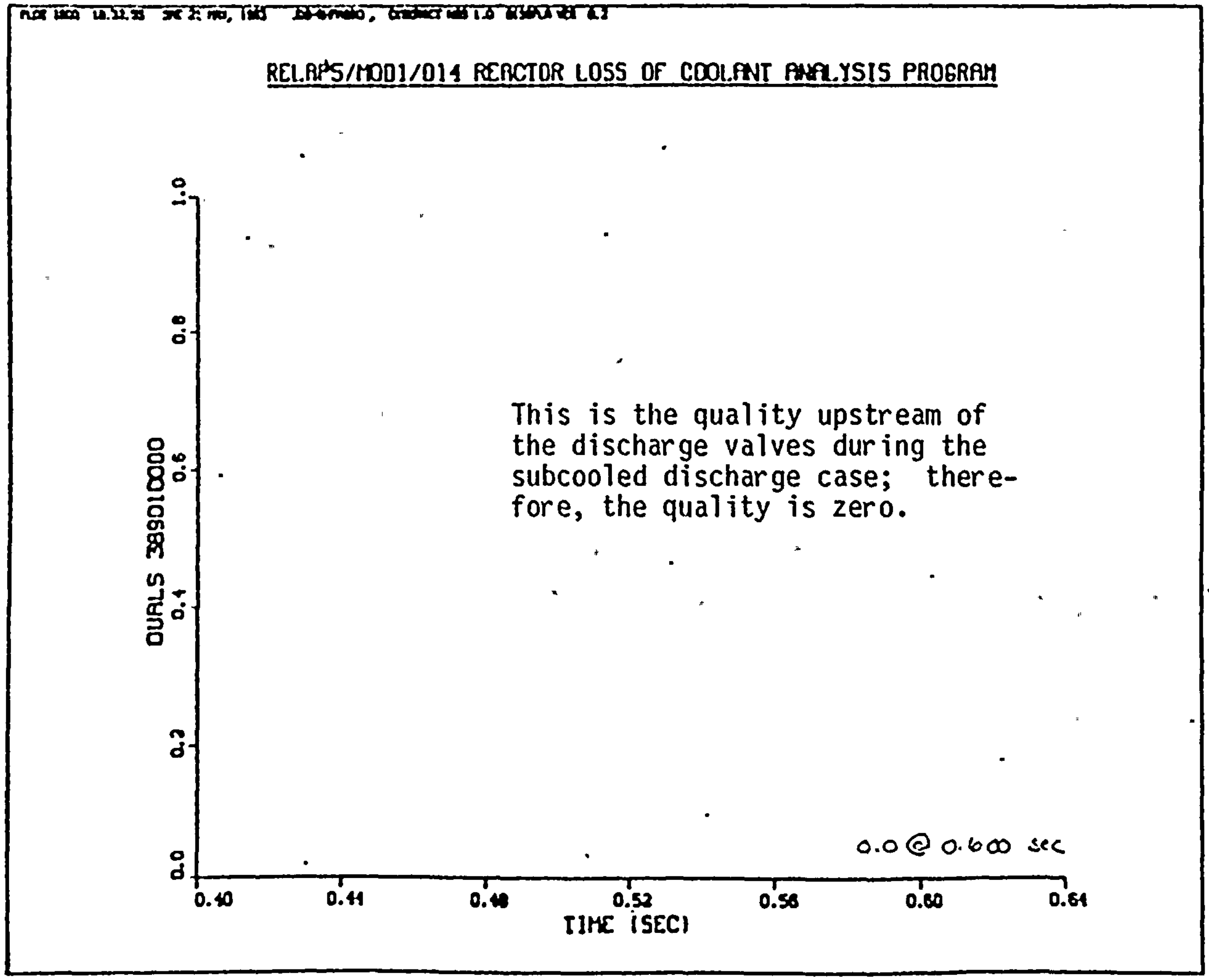



RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
QUALS 492110000
0.0
0.2
0.4
0.6
0.8
1.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)
This is the quality upstream of the discharge valves during the subcooled discharge case; therefore, the quality is zero.
0.0 @ 0.600 sec

BY KJG DATE 5-21-83
CHKD. BY CHY DATE 5-25-83

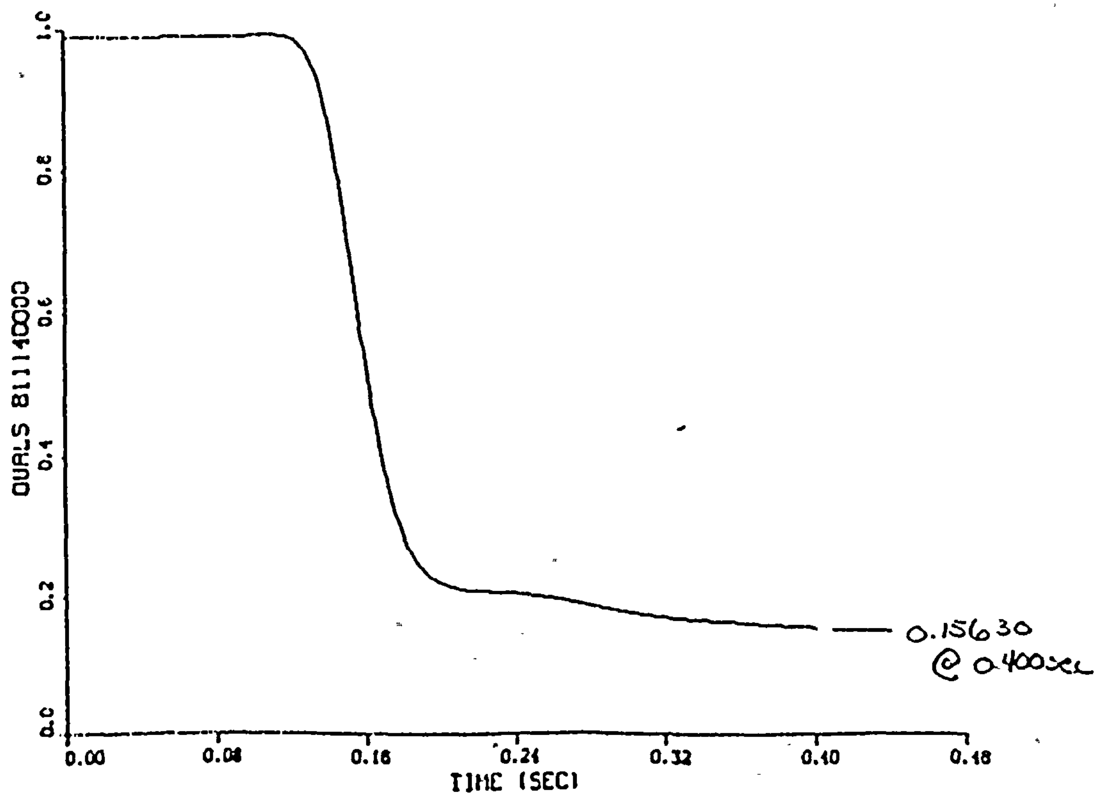


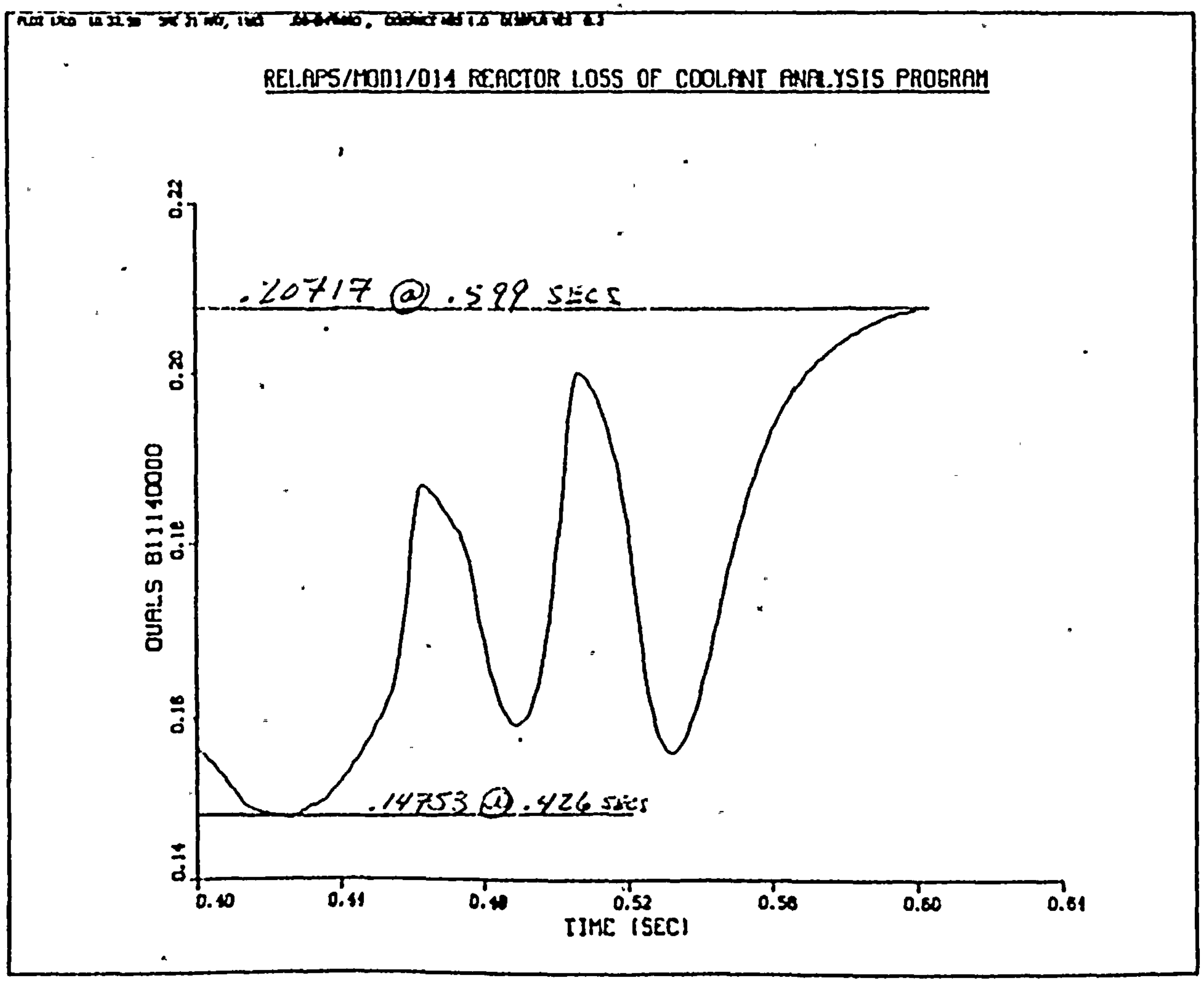
BY KTG DATE 5-21-83
CHKD. BY CWH DATE 5-28-83

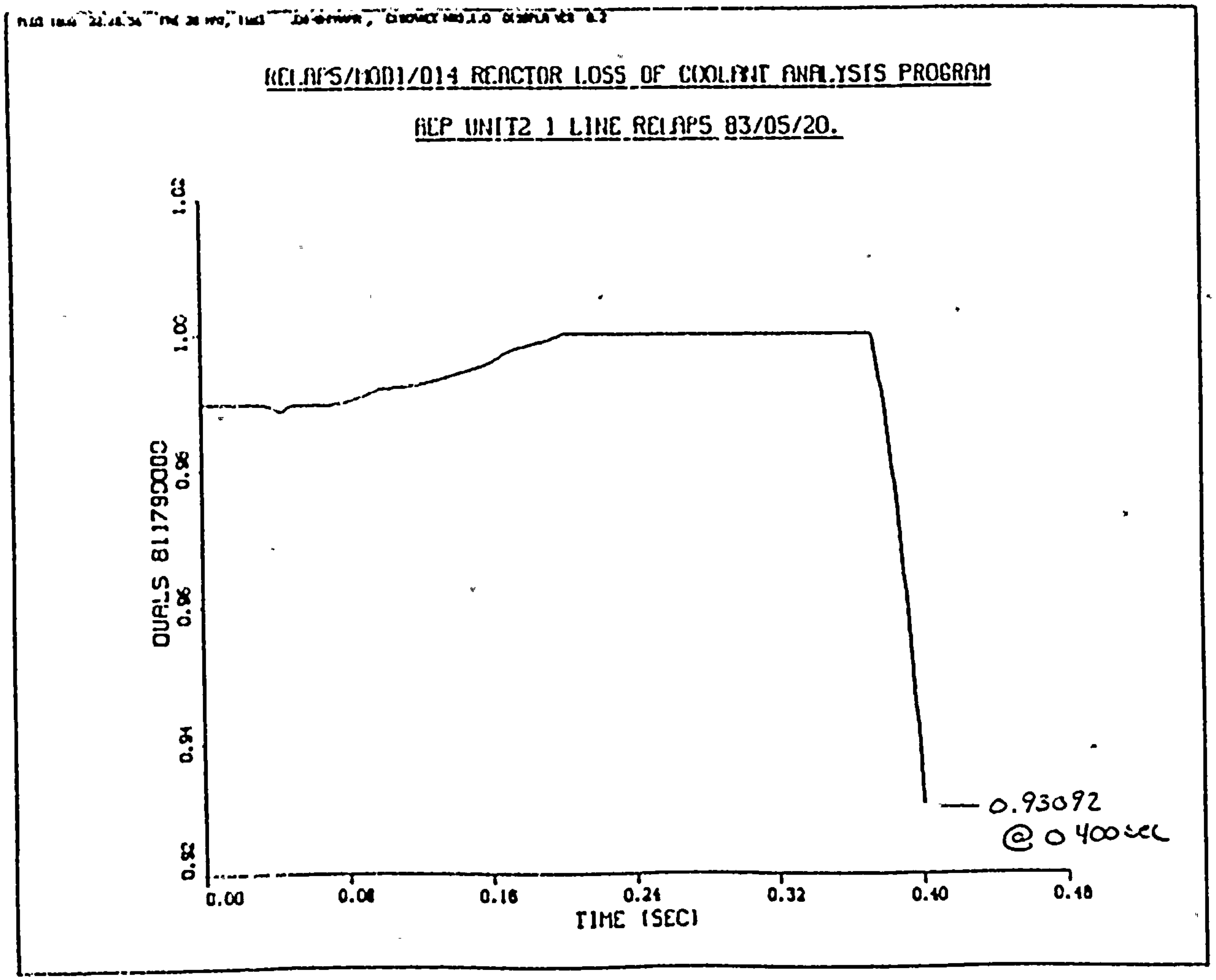


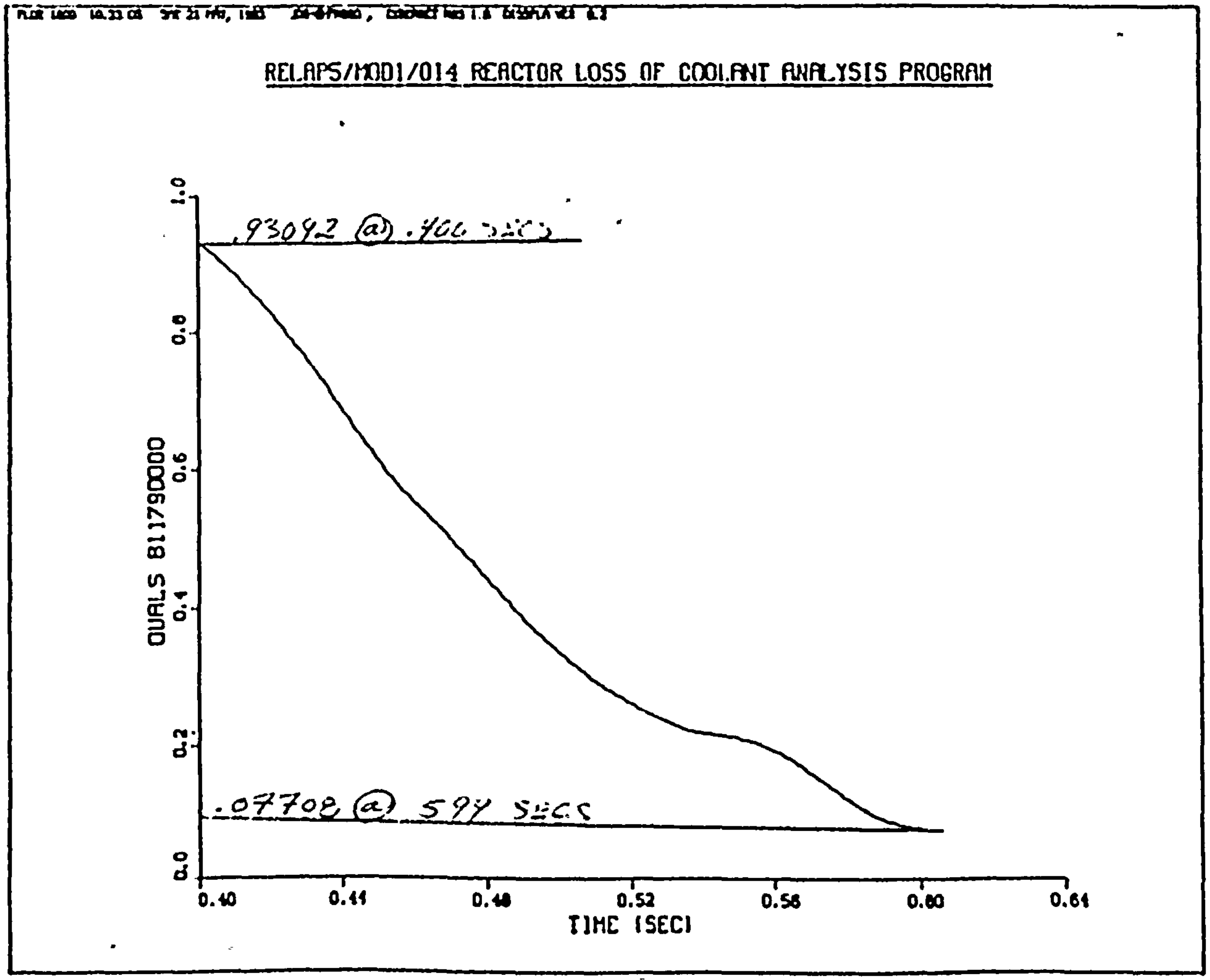
RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

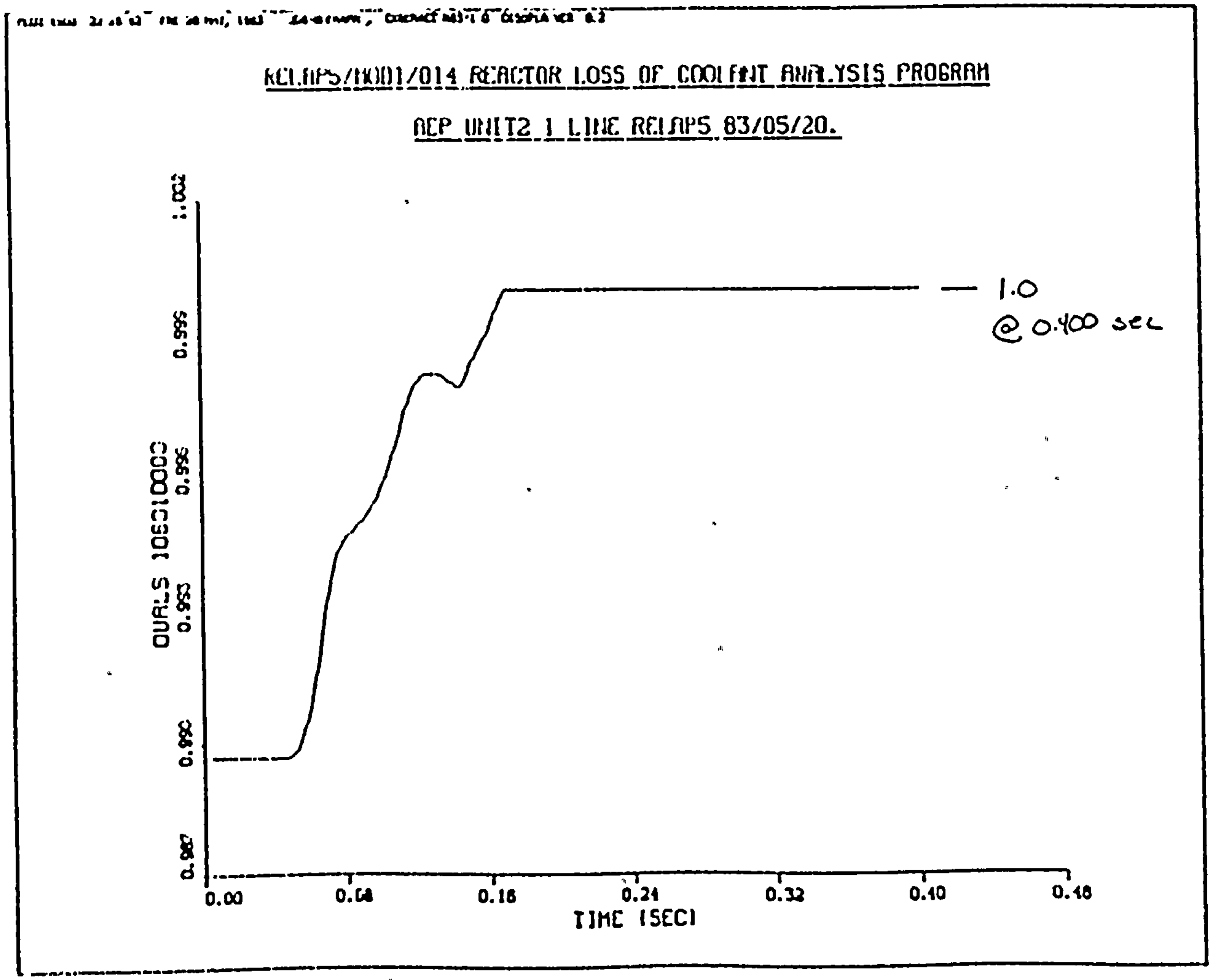
AEP UNIT2 1 LINE RELAP5 83/05/20.

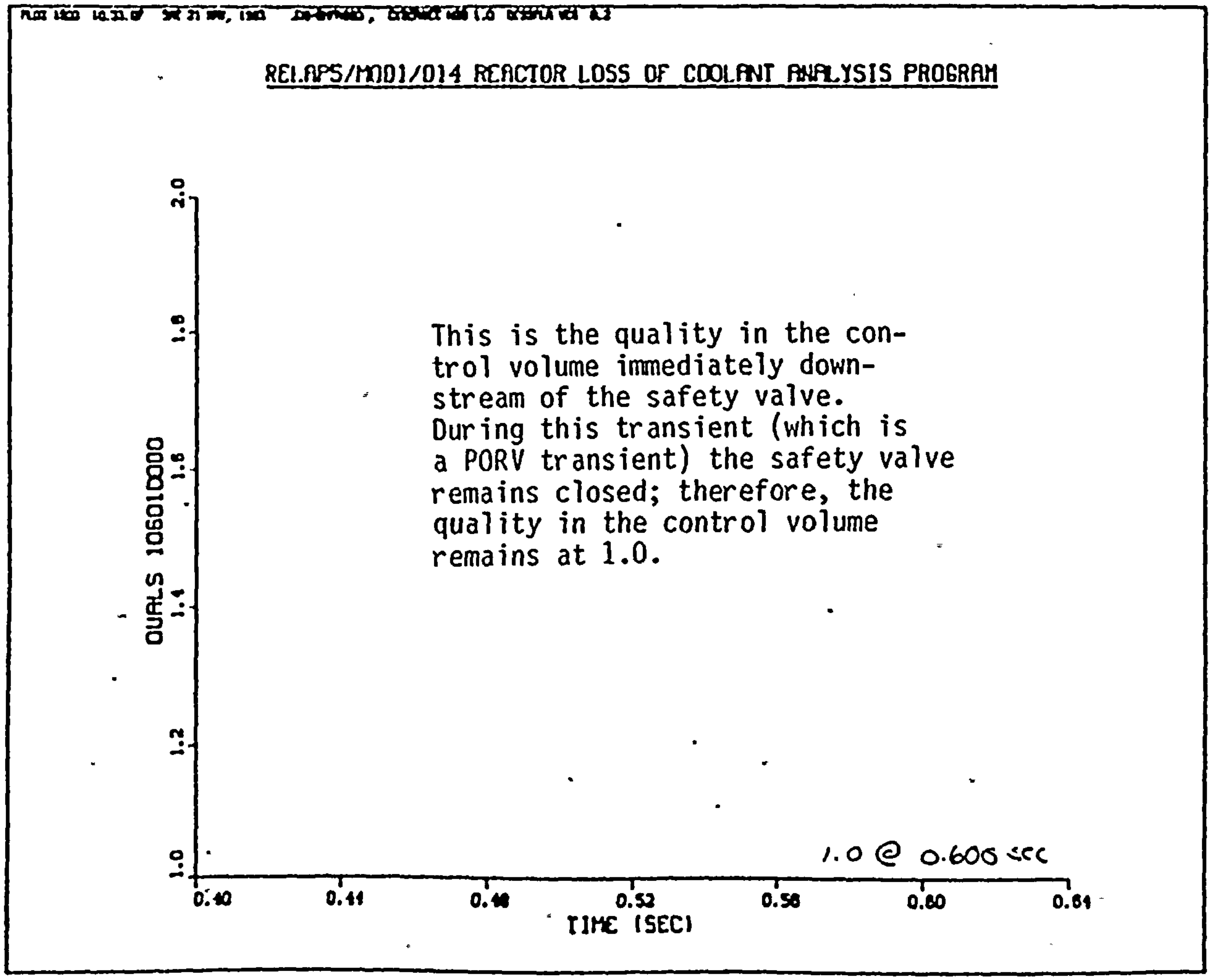



RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
QUALS B1114000
0.14
0.16
0.18
0.20
0.22
TIME (SEC)
0.40
.20717 @ .599 SECS
.14753 @ .426 SECS


RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/05/20.
QUALS 81179000
1.02
1.00
0.98
0.96
0.94
0.92
0.00
0.08
0.16
0.24
0.32
0.40
0.48
TIME (SEC)
0.93092
@ 0.400 sec

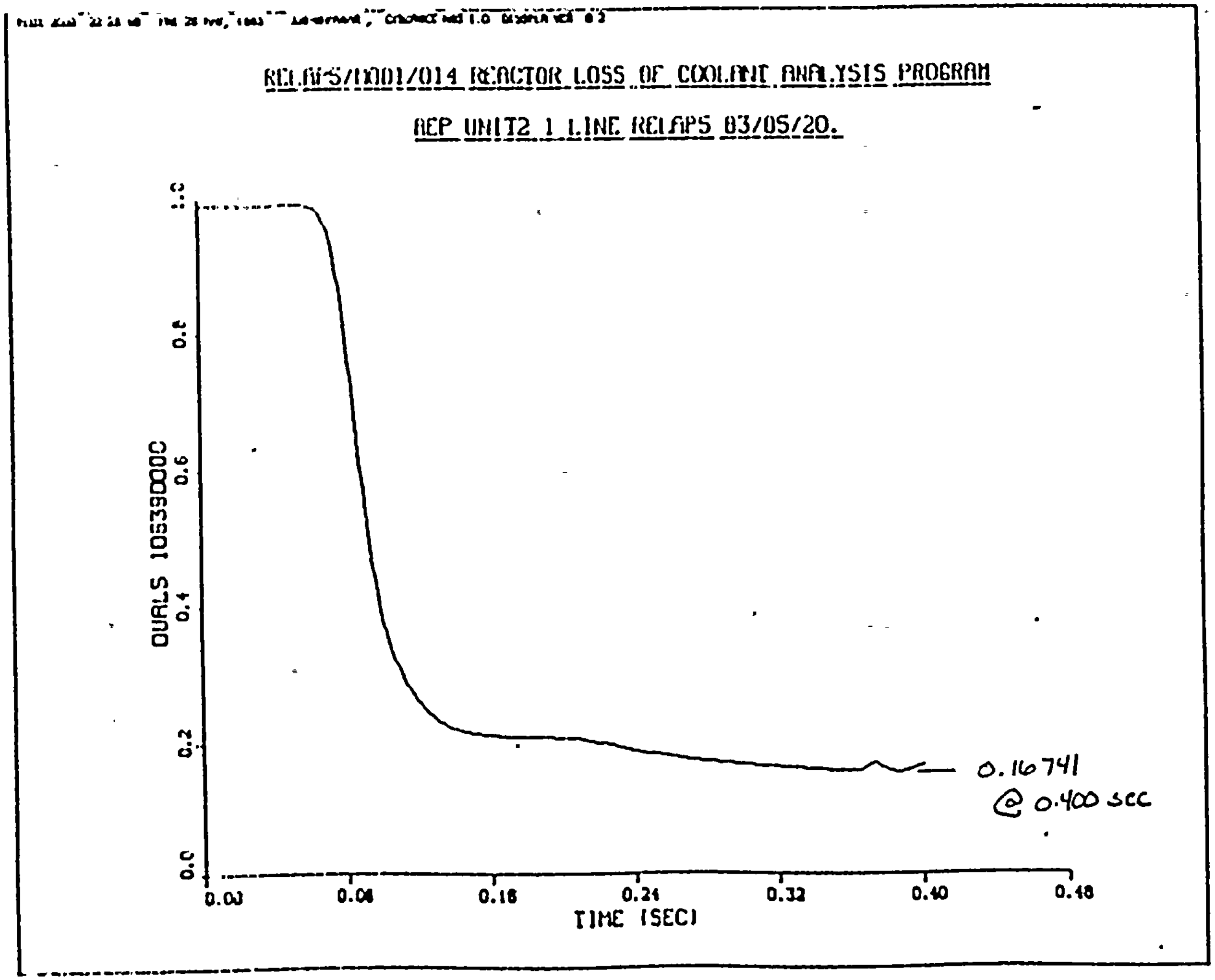

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
QUALS 81179000
1.0
0.8
0.6
0.4
0.2
0.0
.93042 @ .400 secs
.07708 @ .594 secs
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)

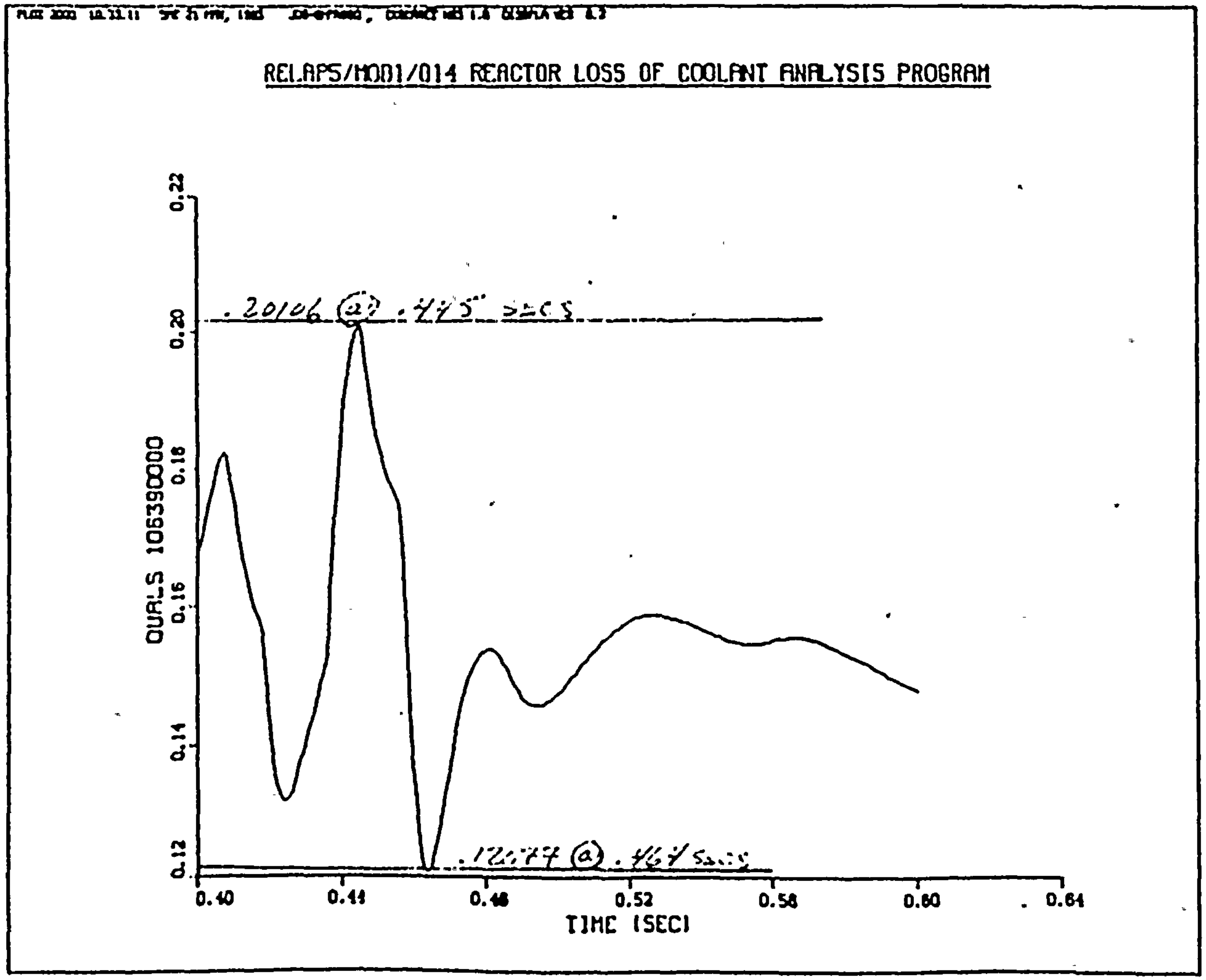

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/05/20.
1.002
0.999
0.996
0.993
0.990
0.987
QUALS 10501000
0.00
0.08
0.16
0.24
0.32
0.40
0.48
TIME (SEC)
1.0
@ 0.400 sec


RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
QUALS 105010000
TIME (SEC)
This is the quality in the control volume immediately downstream of the safety valve. During this transient (which is a PORV transient) the safety valve remains closed; therefore, the quality in the control volume remains at 1.0.
1.0 @ 0.600 sec

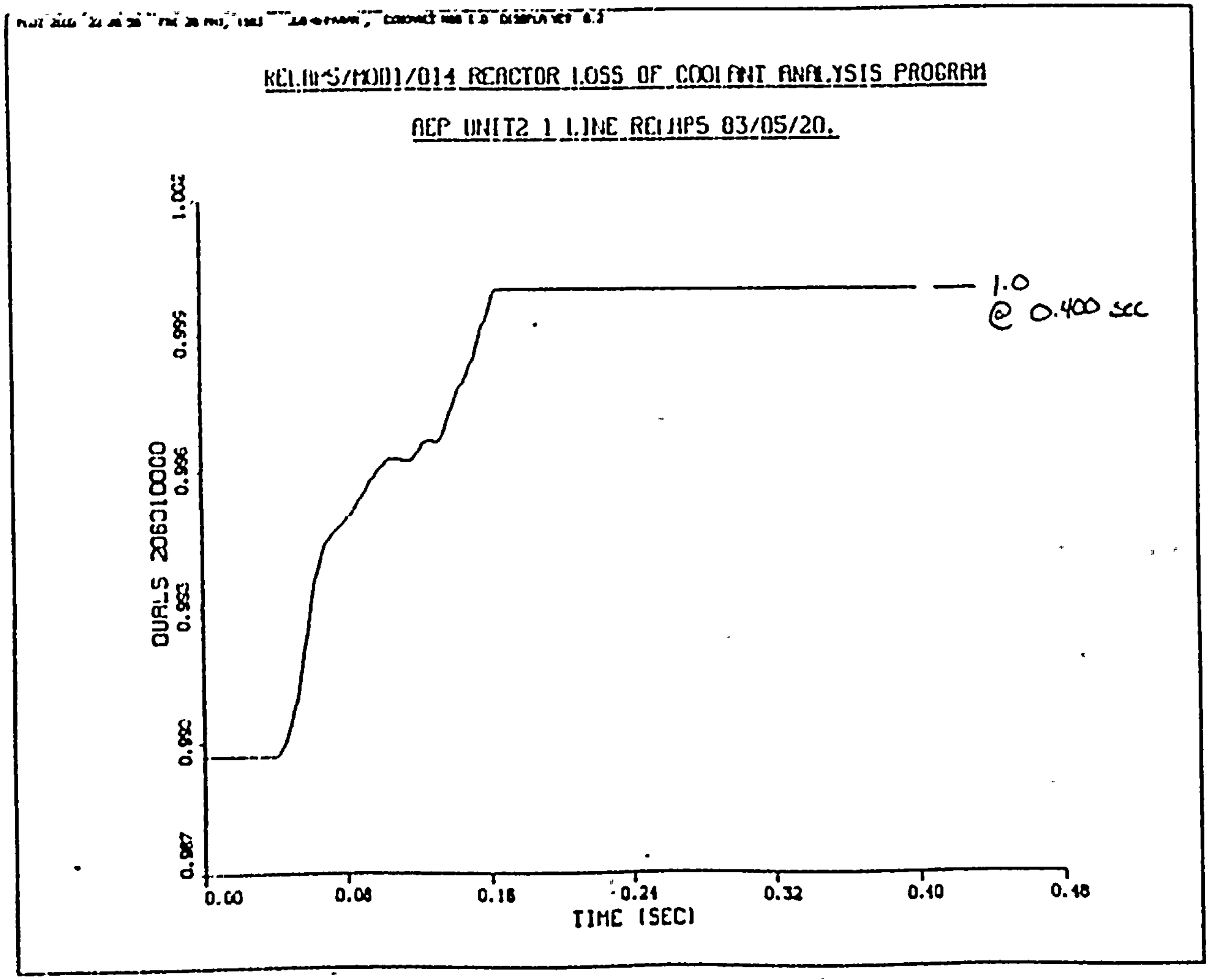
4-73

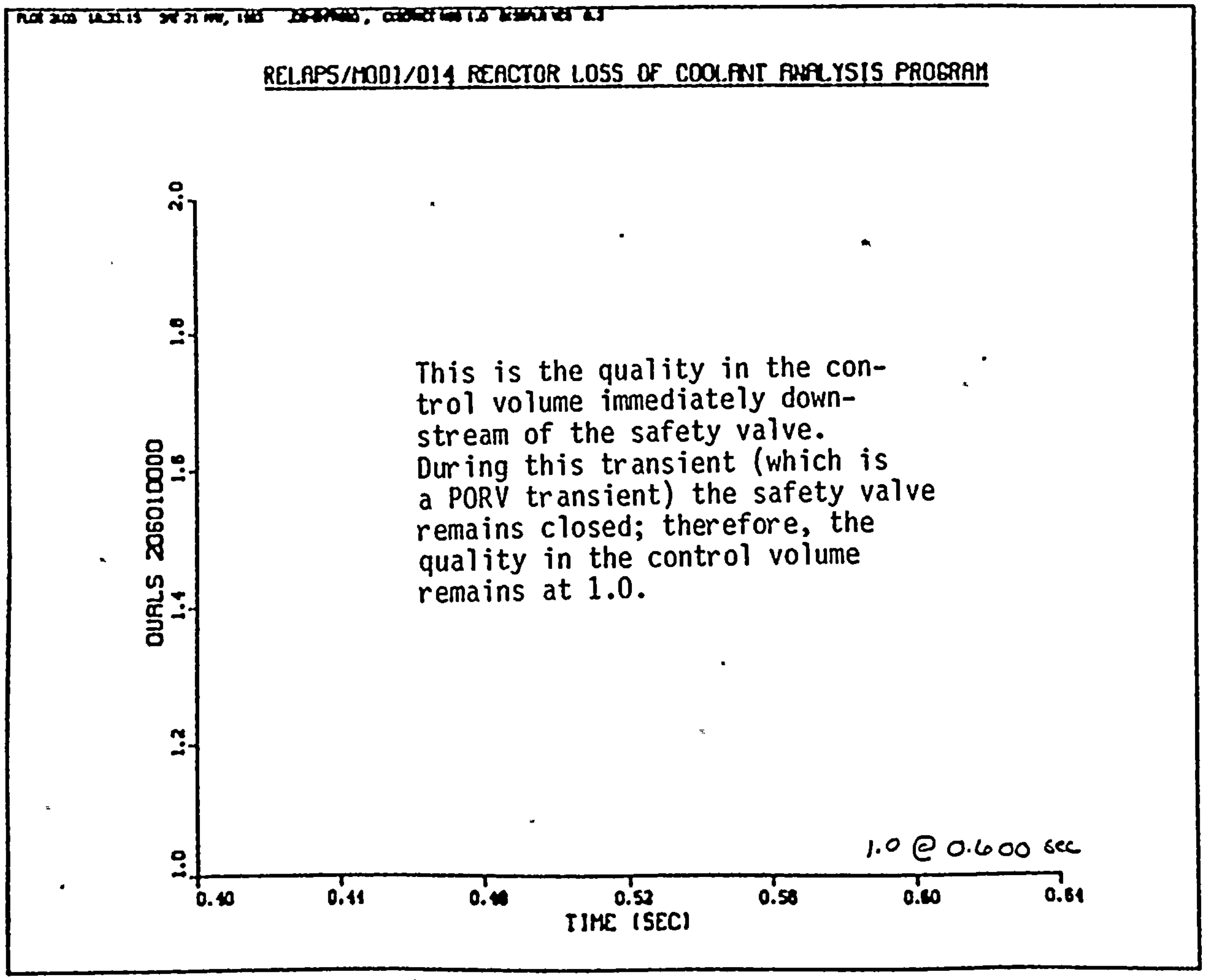
BY KJG DATE 5-21-83
CHKD. BY CHY DATE 5-28-83



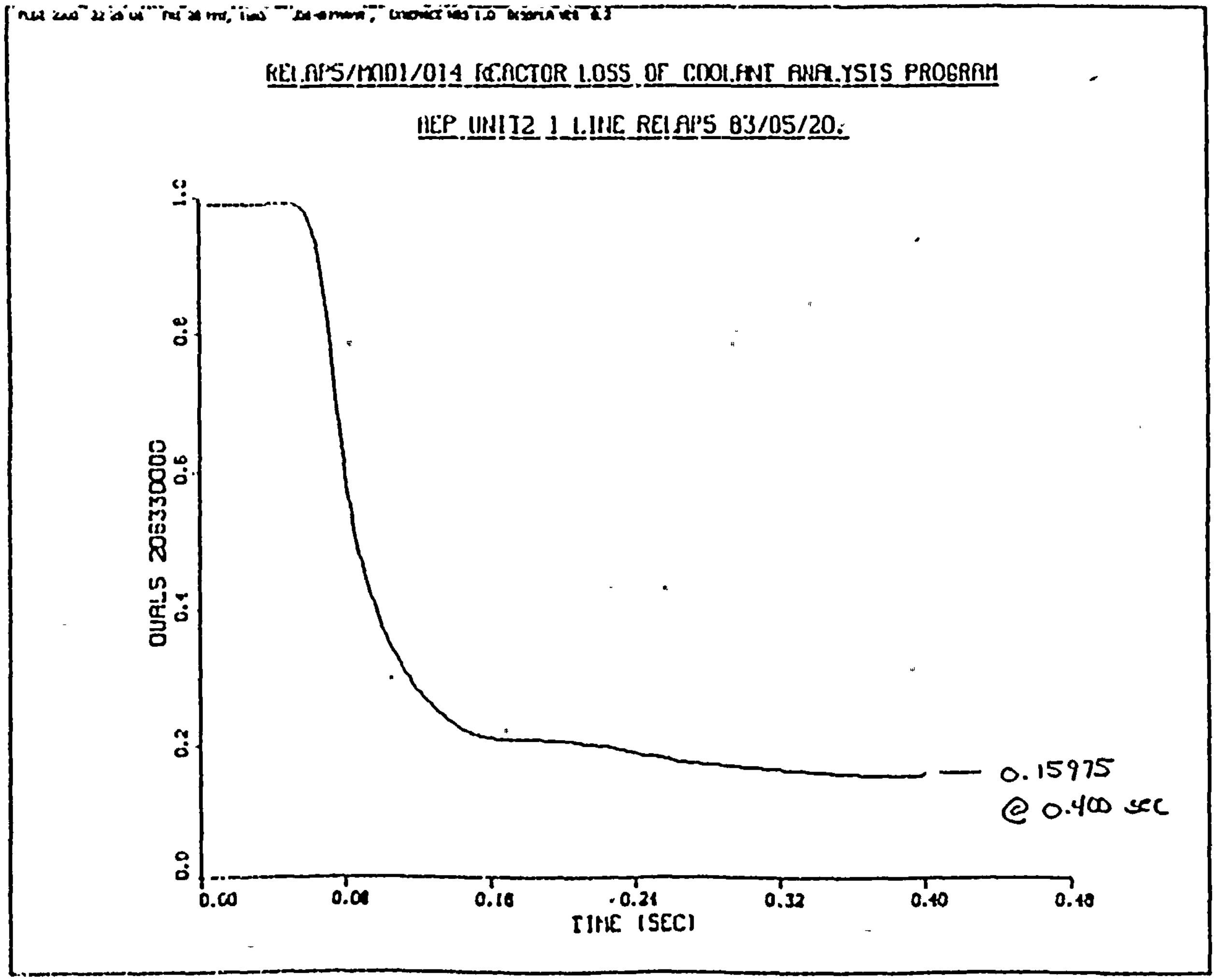

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
QUALS 106390000
0.12
0.14
0.16
0.18
0.20
0.22
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)

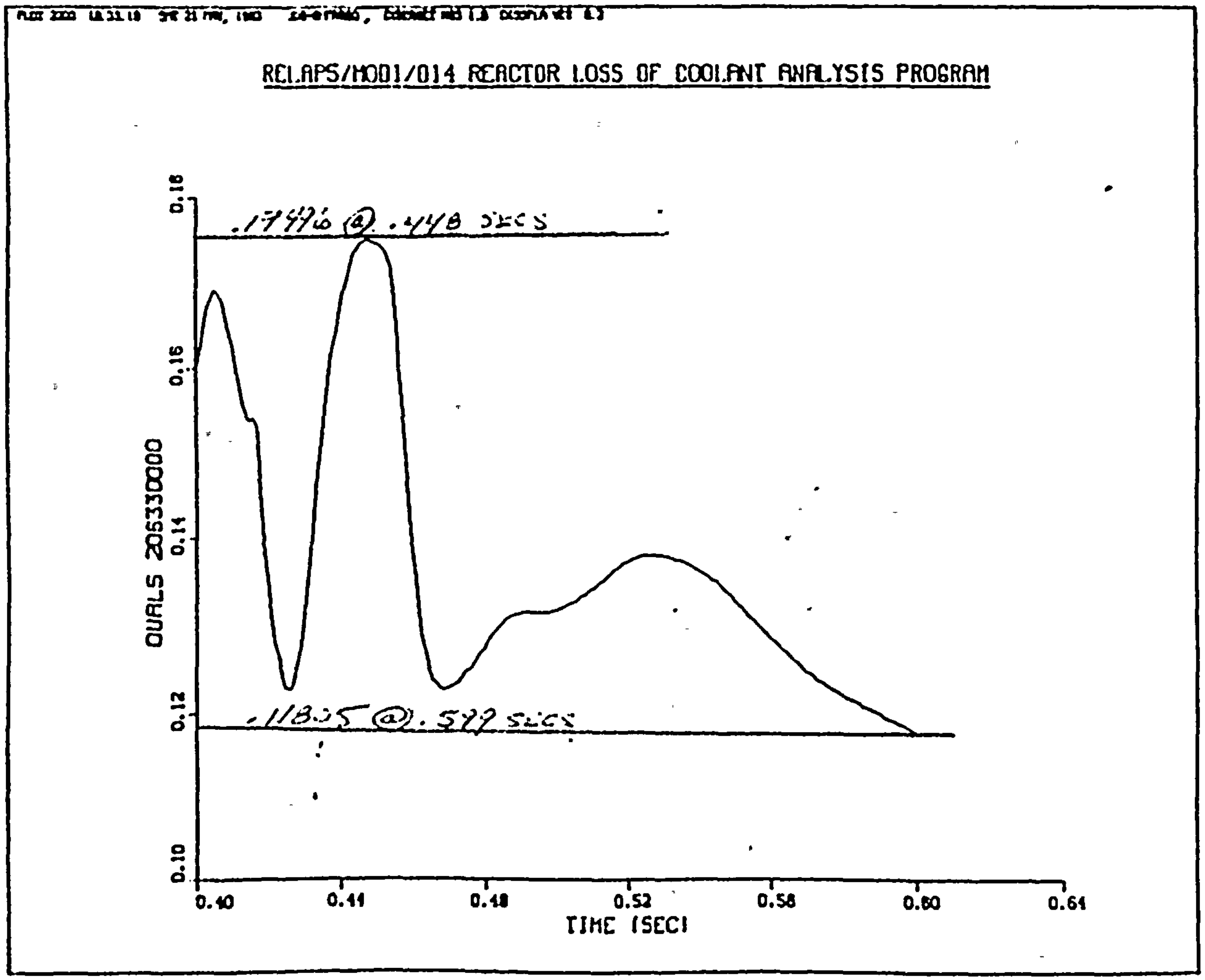
BY KJG DATE 5-21-83
CHKD. BY CHH DATE 5-27-83



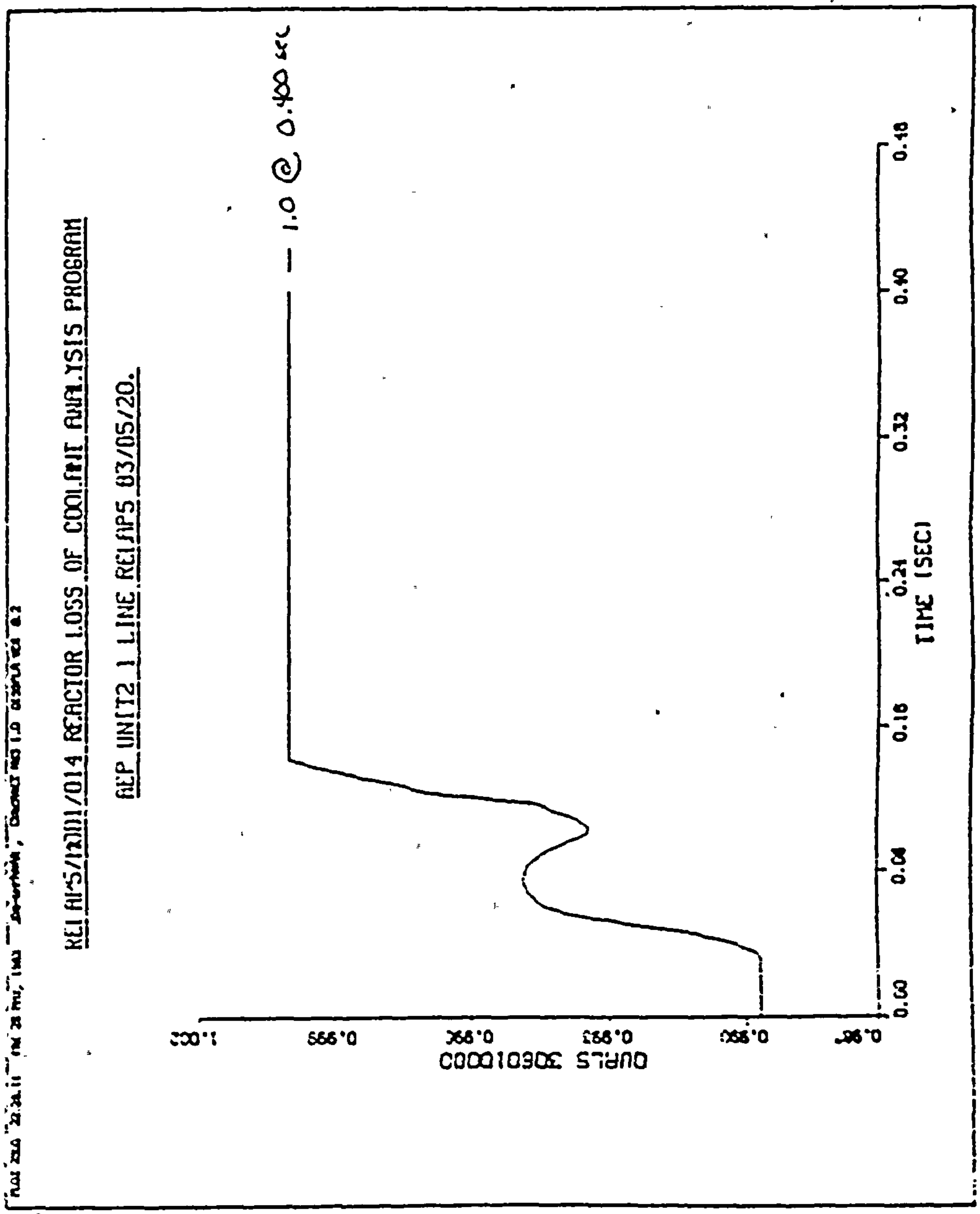

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
QUALS 206010000
2.0
1.8
1.6
1.4
1.2
1.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)
This is the quality in the control volume immediately downstream of the safety valve. During this transient (which is a PORV transient) the safety valve remains closed; therefore, the quality in the control volume remains at 1.0.
1.0 @ 0.600 sec

BY KJG DATE 5-21-83
CHKD. BY CHY DATE 5-28-83

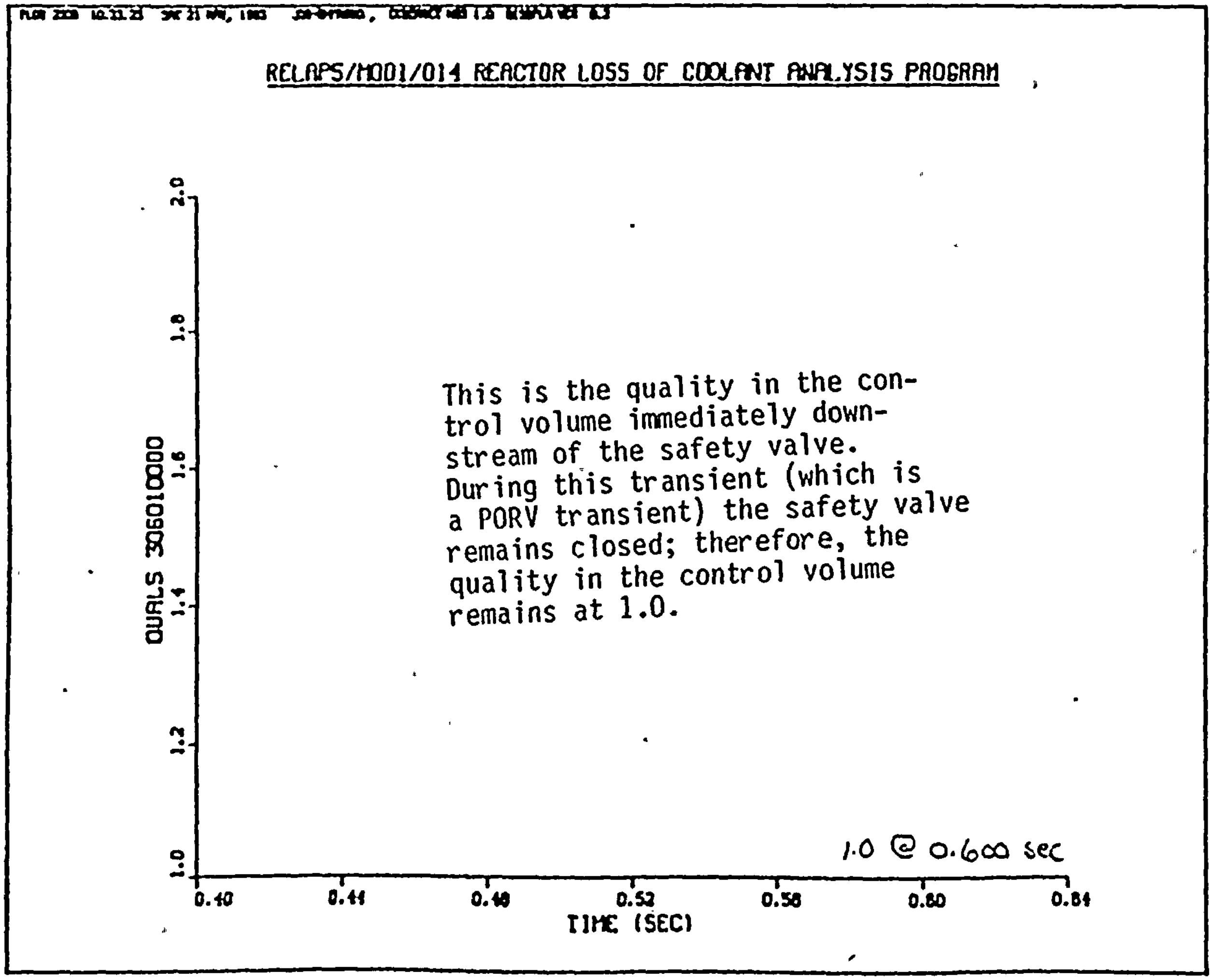



RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
QVALS 205330000
TIME (SEC)
0.10
0.12
0.14
0.16
0.18
0.40
0.44
0.48
0.52
0.56
0.60
0.64
.17496 @ .448 SECS
.11835 @ .599 SECS

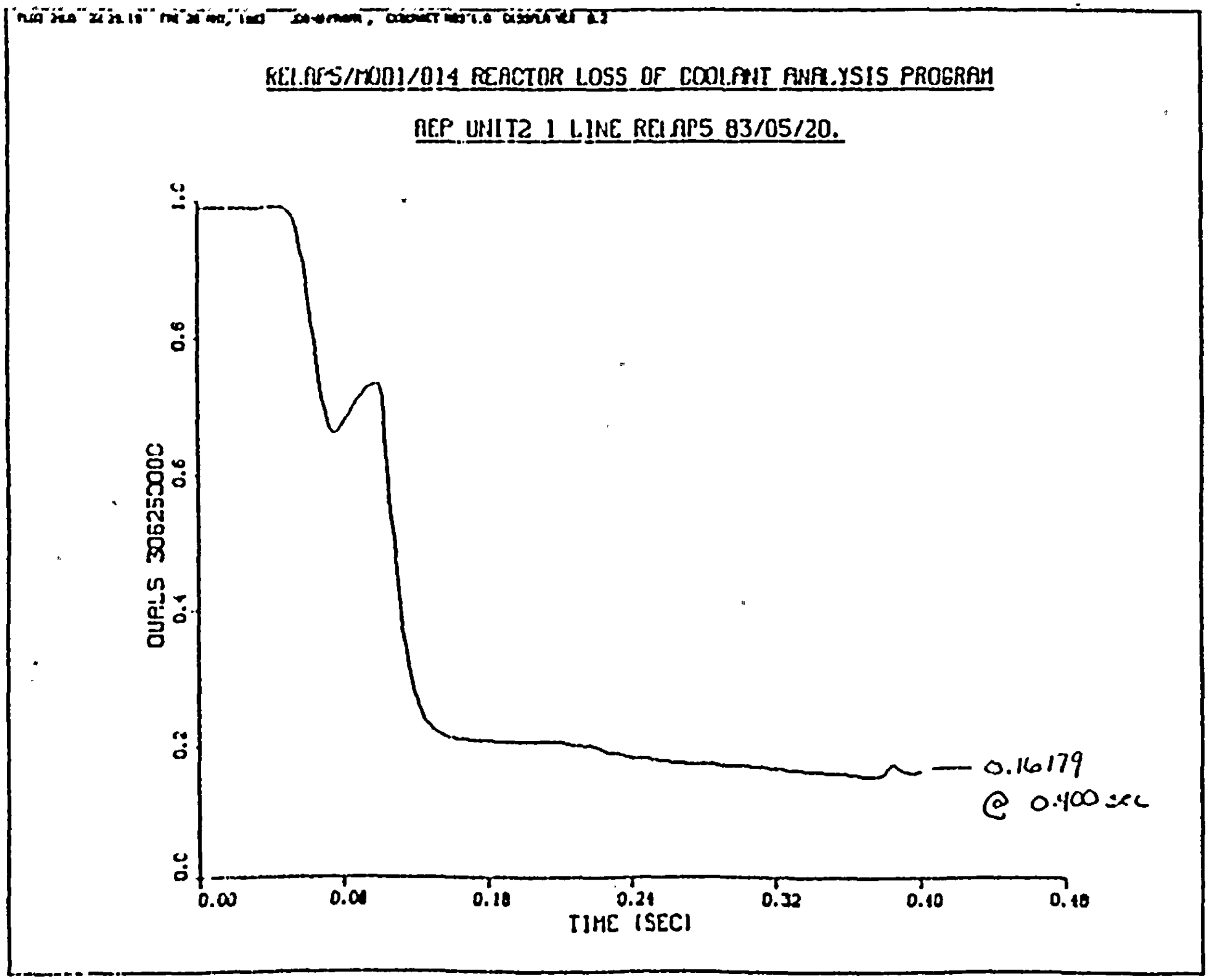
BY KJG DATE 5-21-83
CHKD. BY CHW DATE 5-28-83



BY KG DATE 5-21-83
CHKD. BY CWH DATE 5-28-83



BY KJG DATE 5-21-83
CHKD. BY CHY DATE 5-25-83



BY KTG DATE 5-21-83
CHKD. BY CMM DATE 5-28-83

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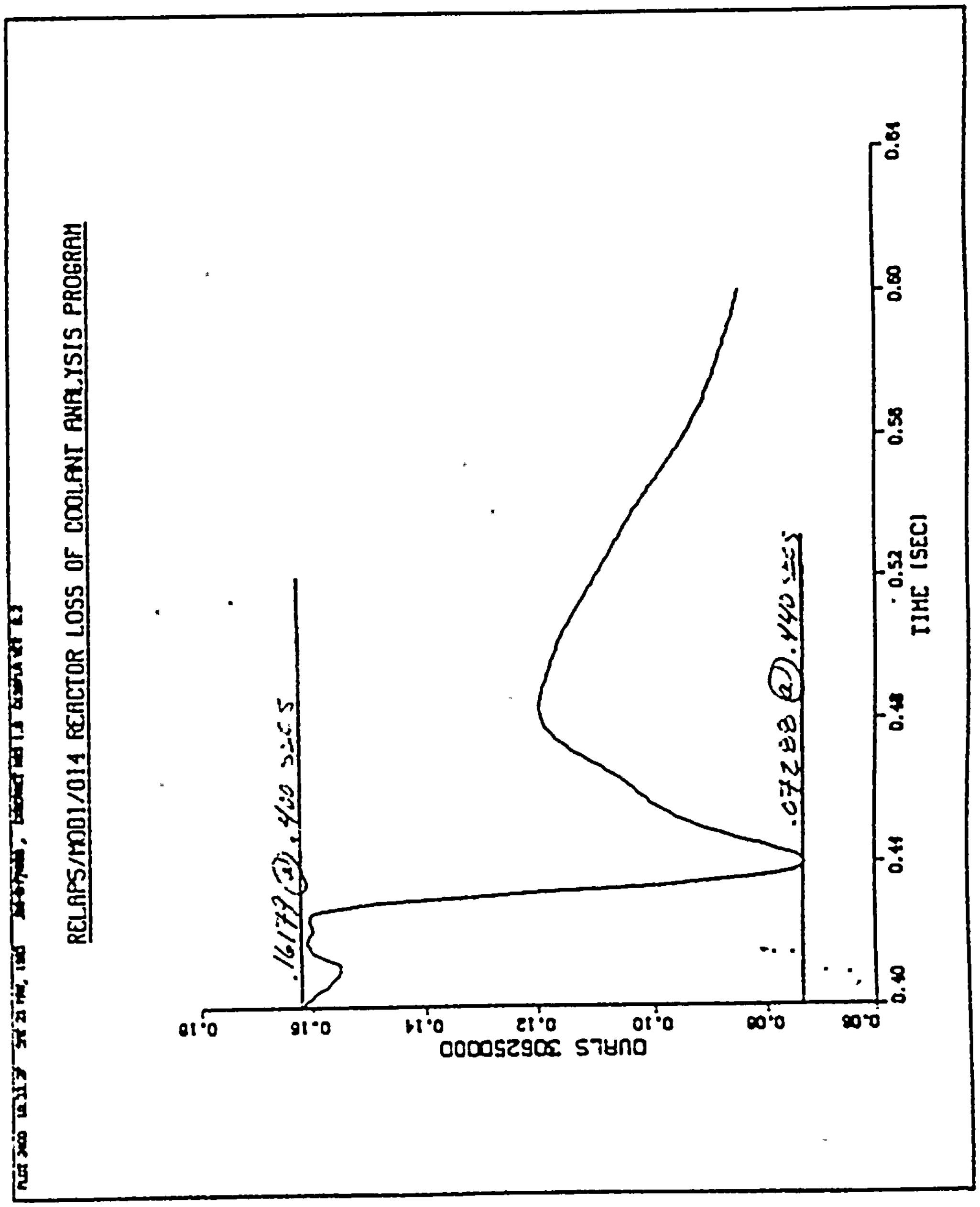

BY KJG DATE 5-21-83
CHKD. BY CHY DATE 5-28-83

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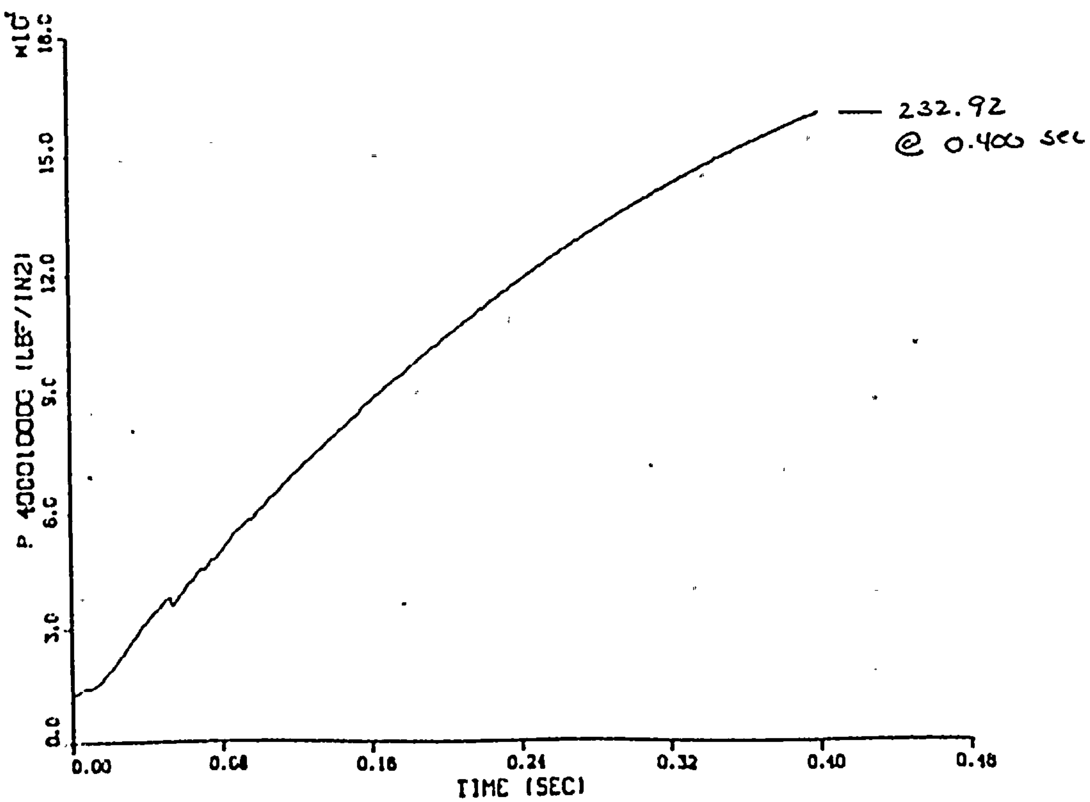
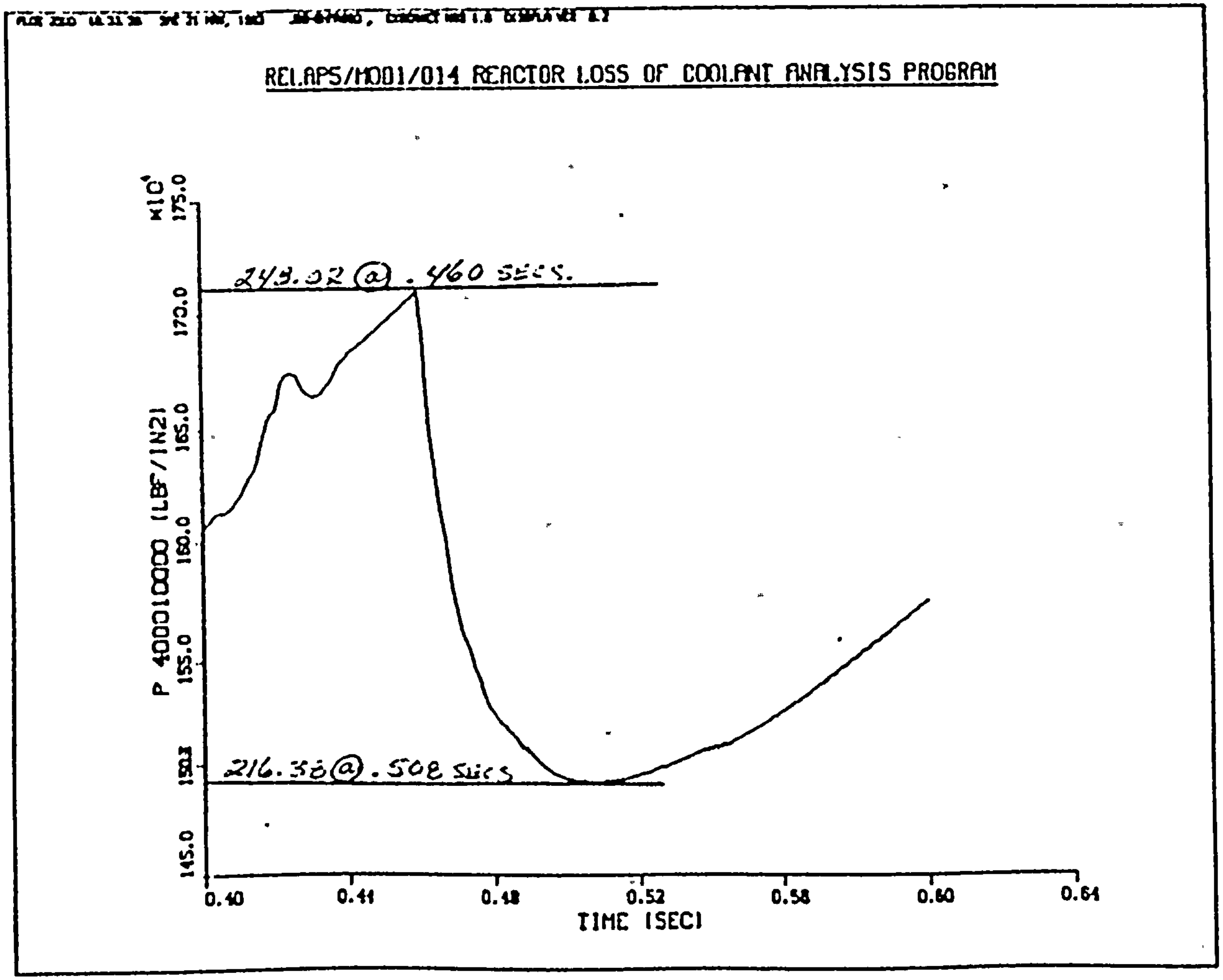
RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

AEP UNIT2 1 LINE RELAPS 83/05/20.




RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
249.02 @ .460 SECS.
216.38 @ .508 SECS
P 400010000 (LBF/IN2)
x10¹
175.0
170.0
165.0
160.0
155.0
145.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)

BY KJG DATE 5-21-83
CHKD. BY CHM DATE 5-28-83

TELEDYNE ENGINEERING SERVICES

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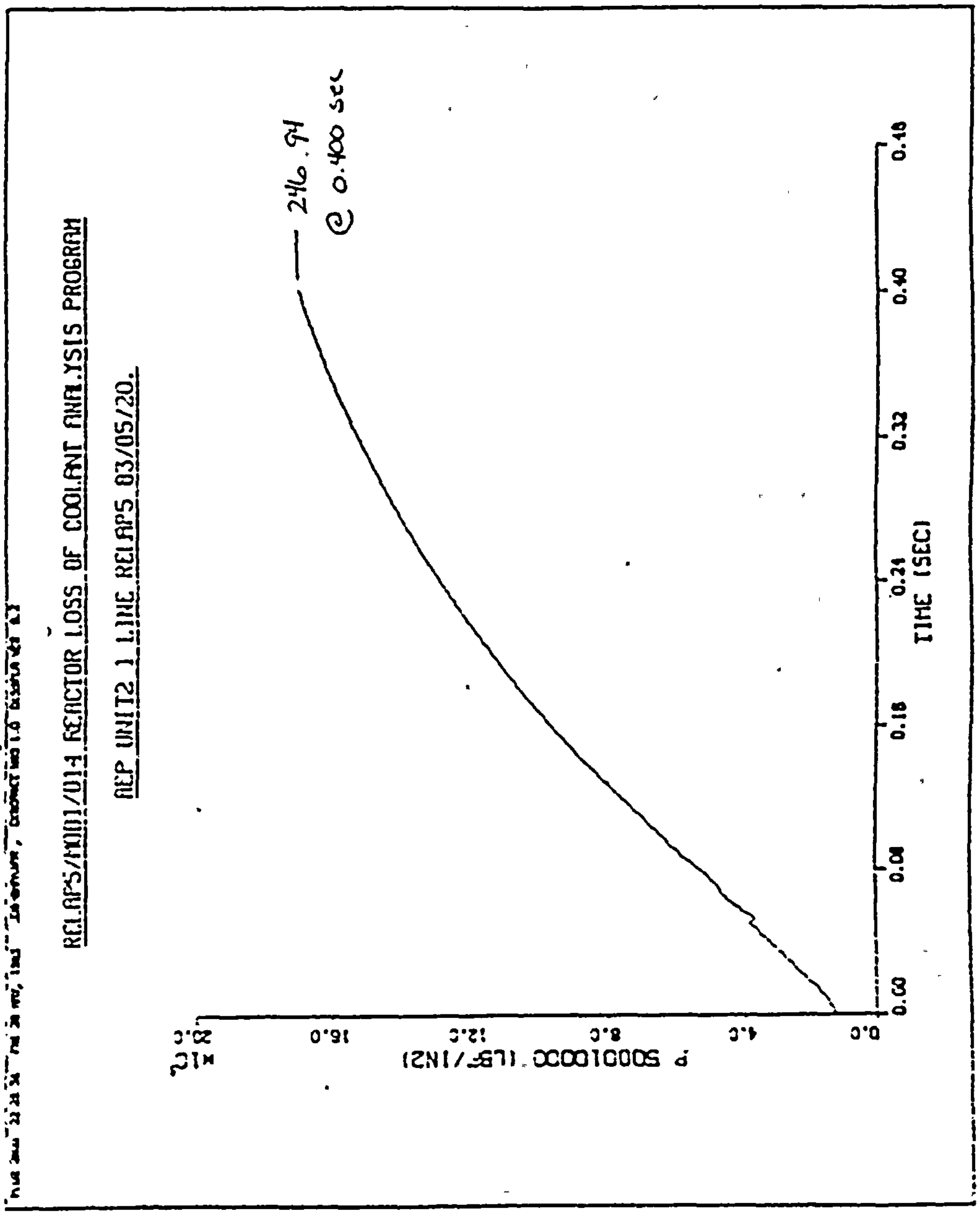
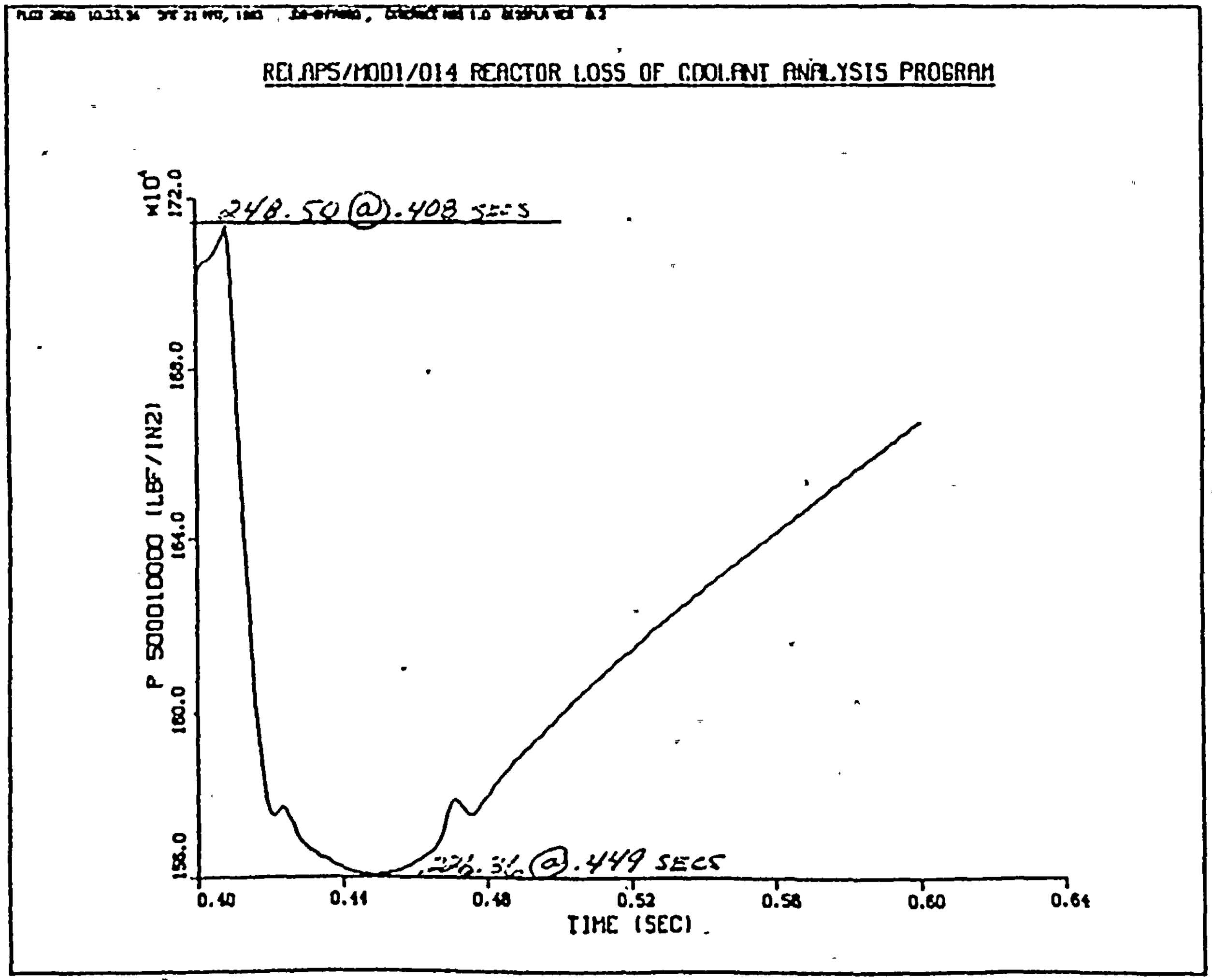


BY KTG DATE 5-24-83
CHKD. BY CMM DATE 5-28-83



BY KJG DATE 5-21-83
CHKD. BY CHH DATE 5-28-83

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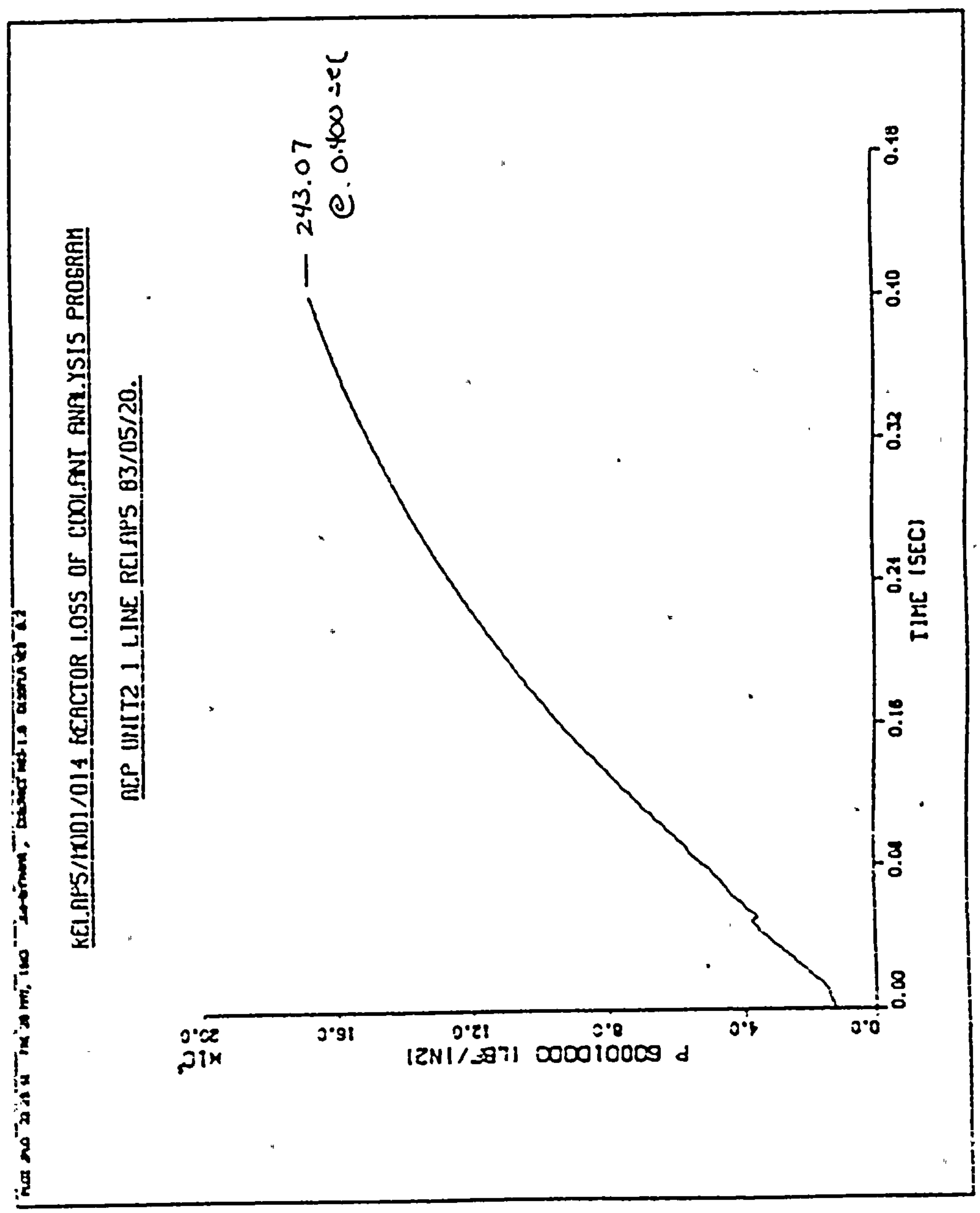
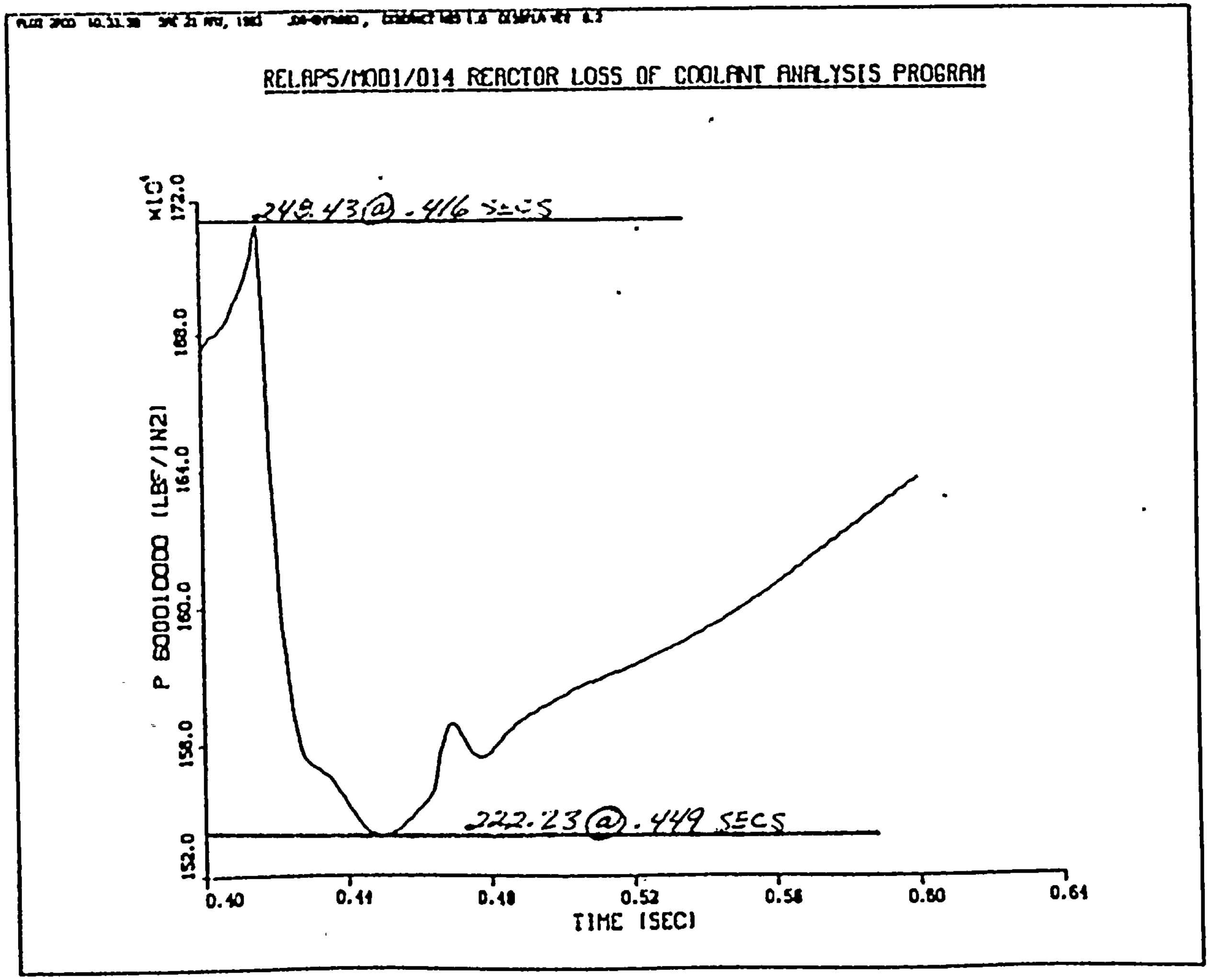
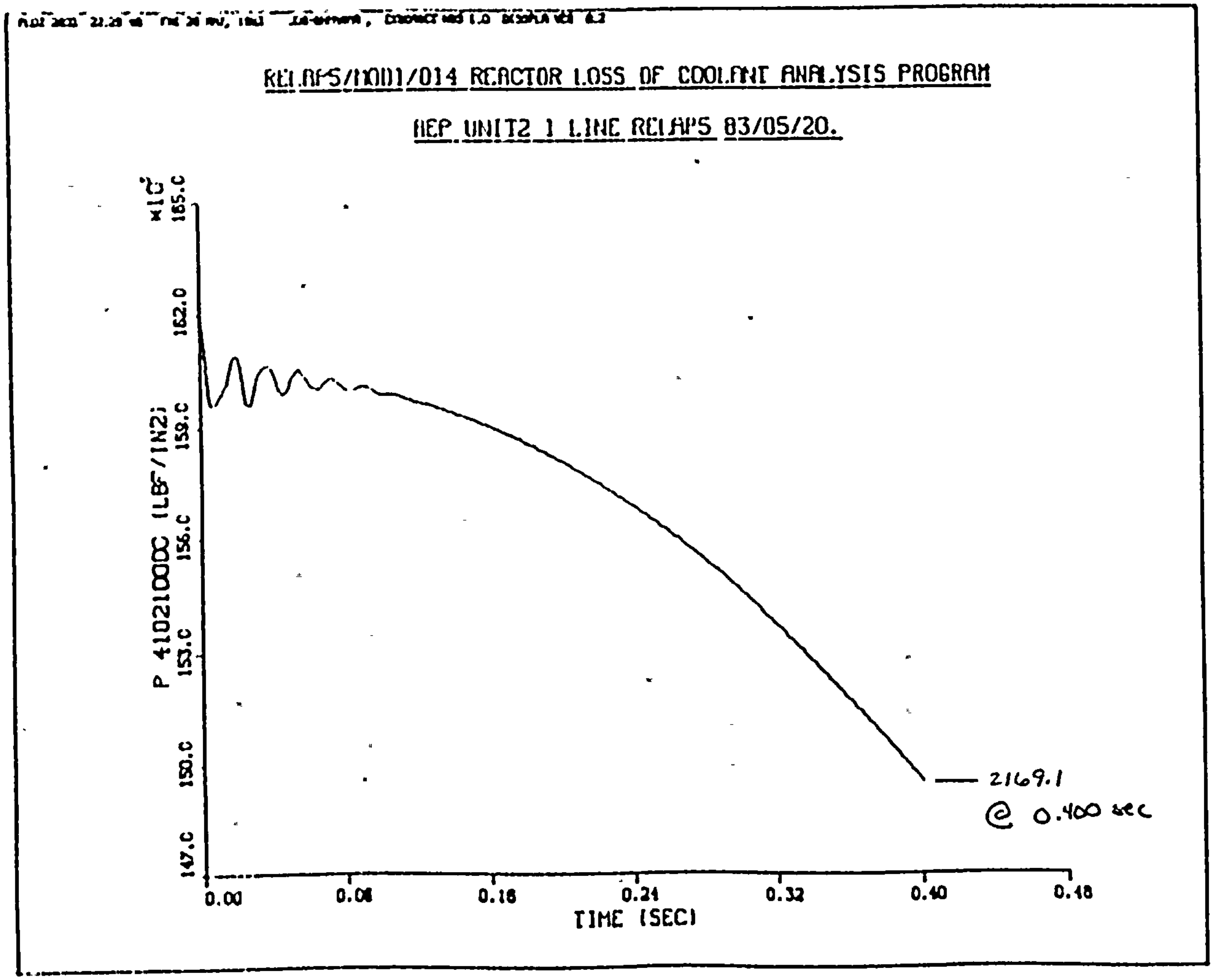
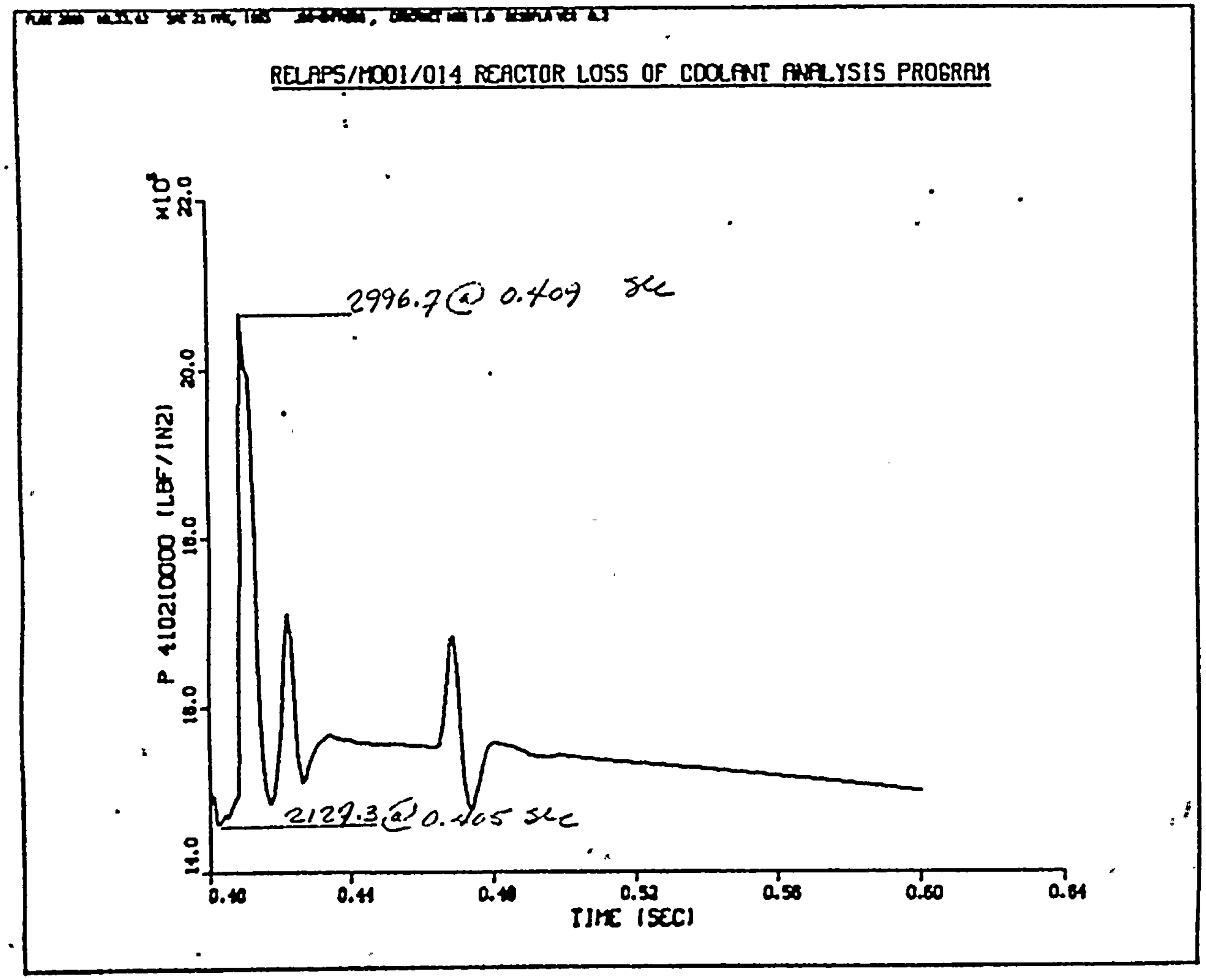


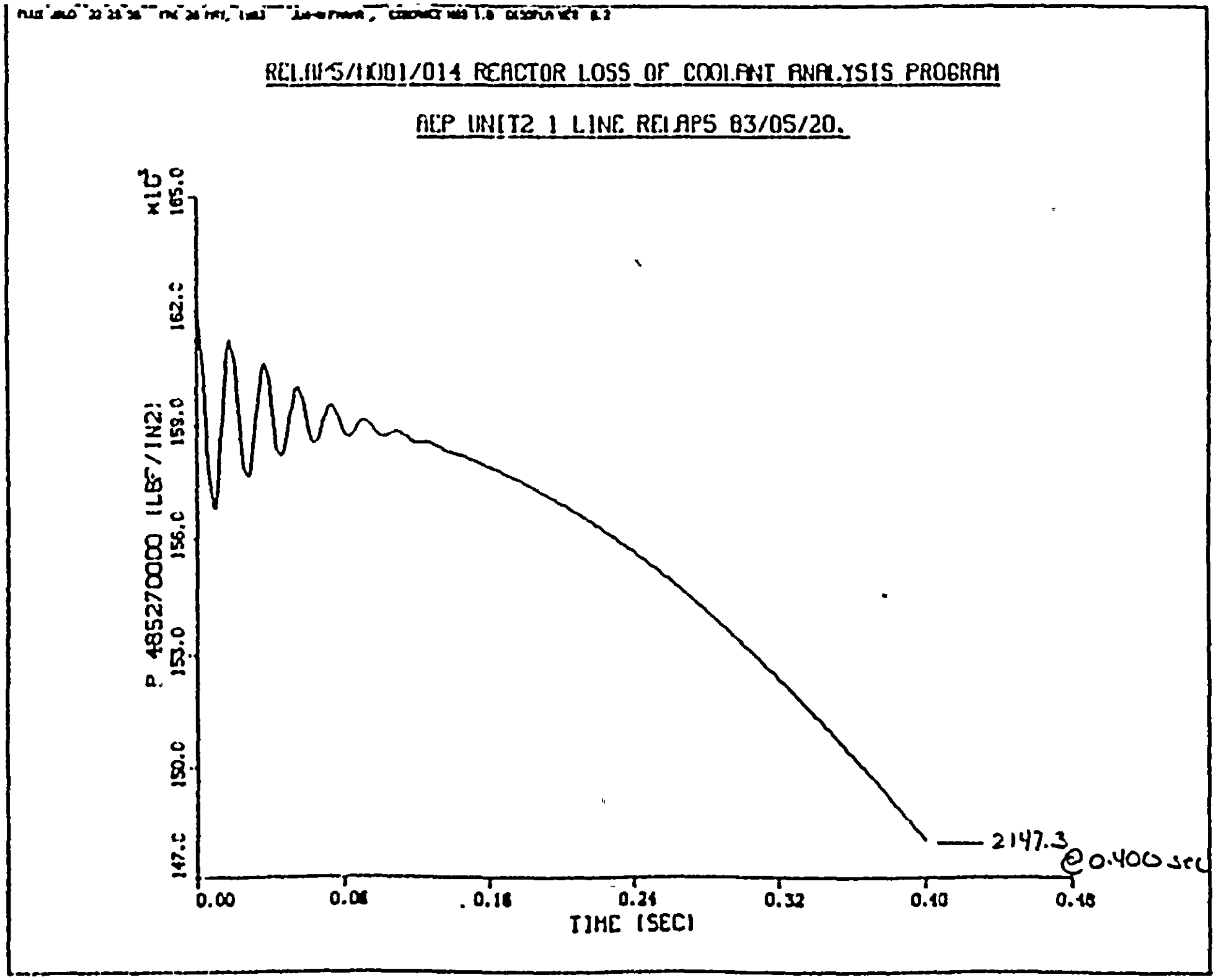
BY KTG DATE 5-21-83
CHKD. BY CMM DATE 5-28-83

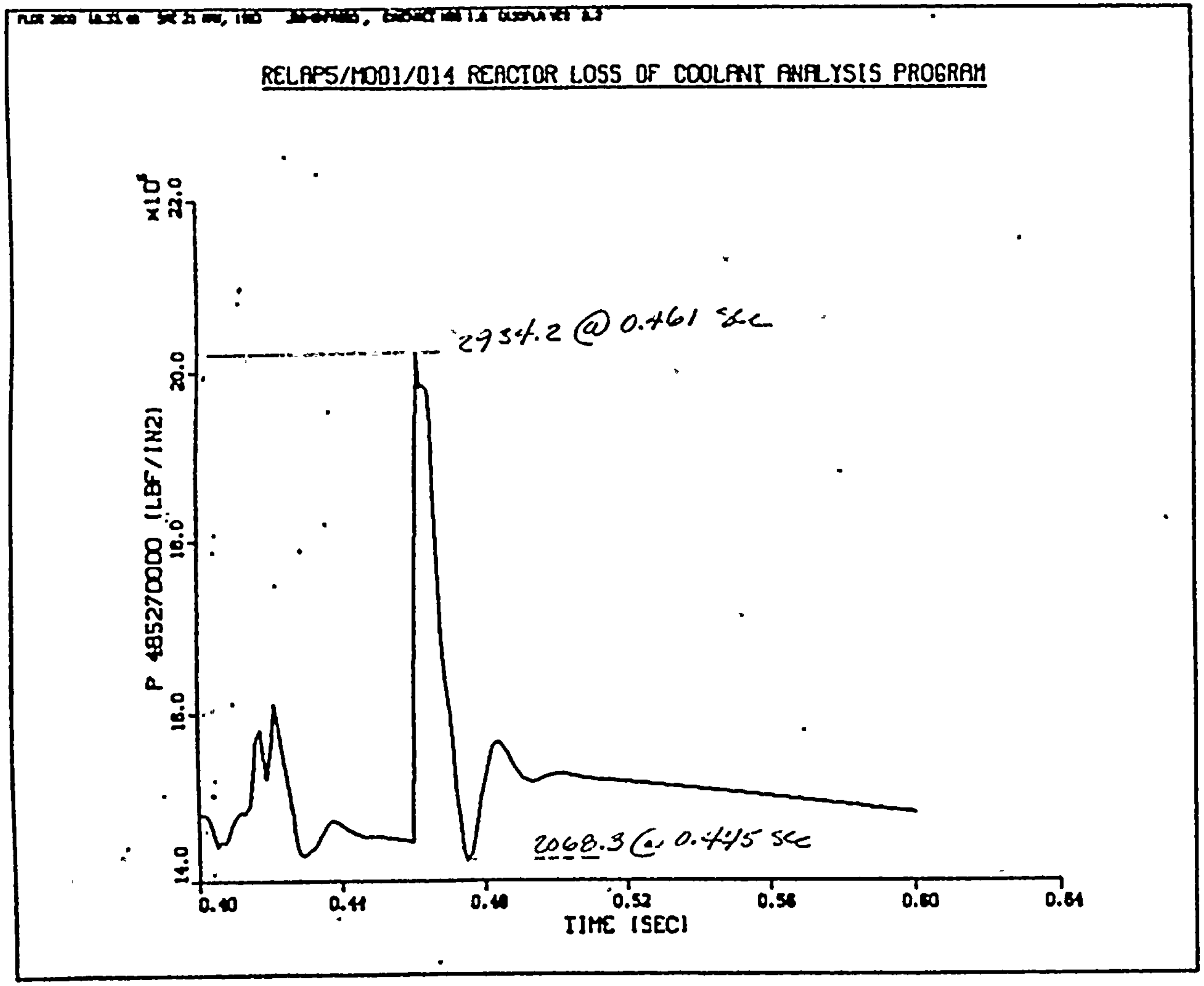



RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/05/20.
P 410210000 (LBF/IN2) x10^1
165.0
162.0
159.0
156.0
153.0
150.0
147.0
0.00
0.08
0.16
0.24
0.32
0.40
0.48
TIME (SEC)
2169.1
@ 0.400 sec

BY KJG DATE 5-21-83
CHKD. BY [illegible] DATE 5-28-83




RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/05/20.
x10³
P 48527000 (LBF/IN2)
165.0
162.0
159.0
156.0
153.0
150.0
147.0
0.00
0.08
0.16
0.24
0.32
0.40
0.48
TIME (SEC)
2147.3
@0.400 sec


RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
P 485270000 (LBF/IN2)
x10²
22.0
20.0
18.0
16.0
14.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)
2934.2 @ 0.461 sec
2068.3 @ 0.495 sec

TELEDYNE ENGINEERING SERVICES

BY KJG DATE 5-21-83.

CHKD. BY CHH DATE 5-28-83

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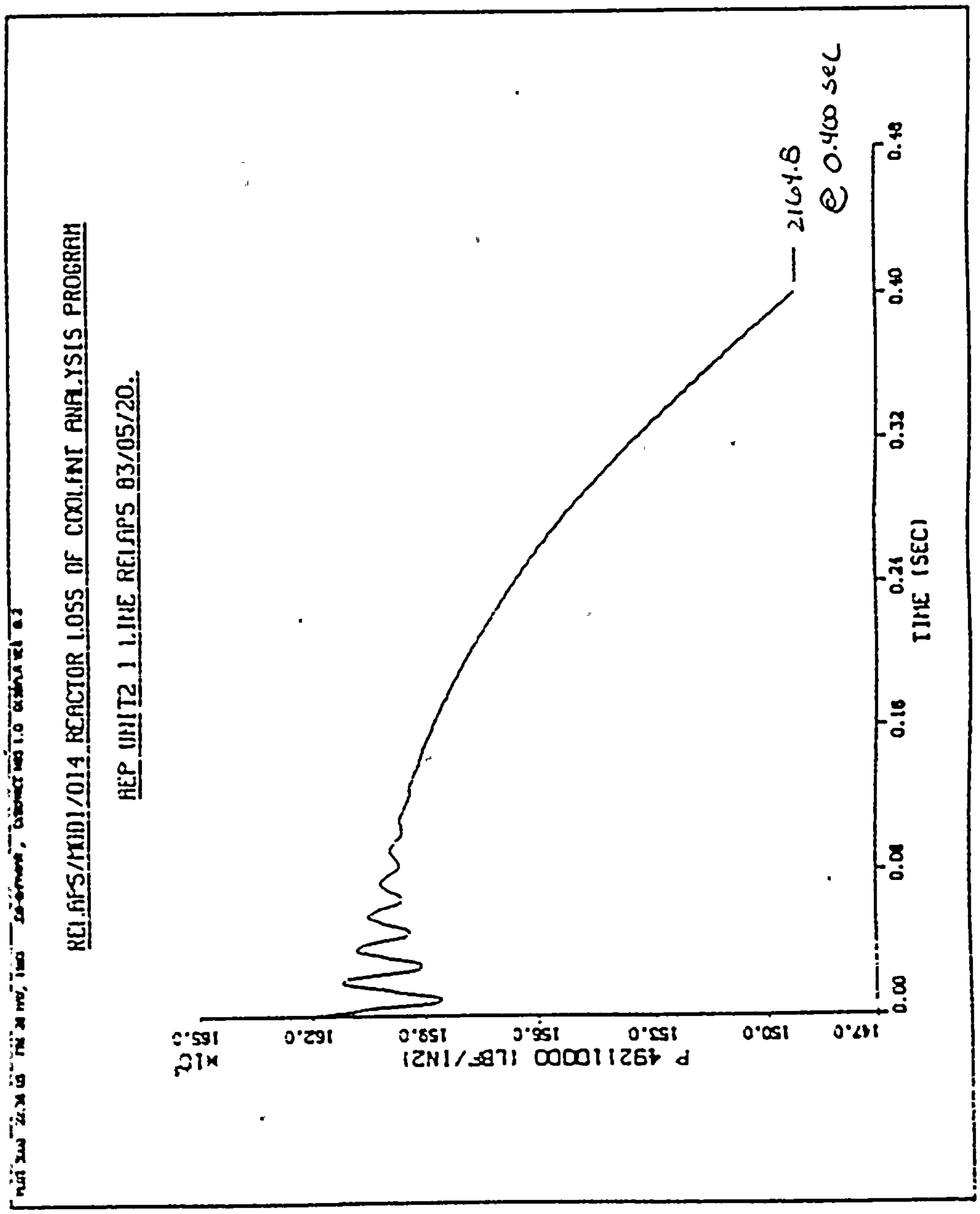
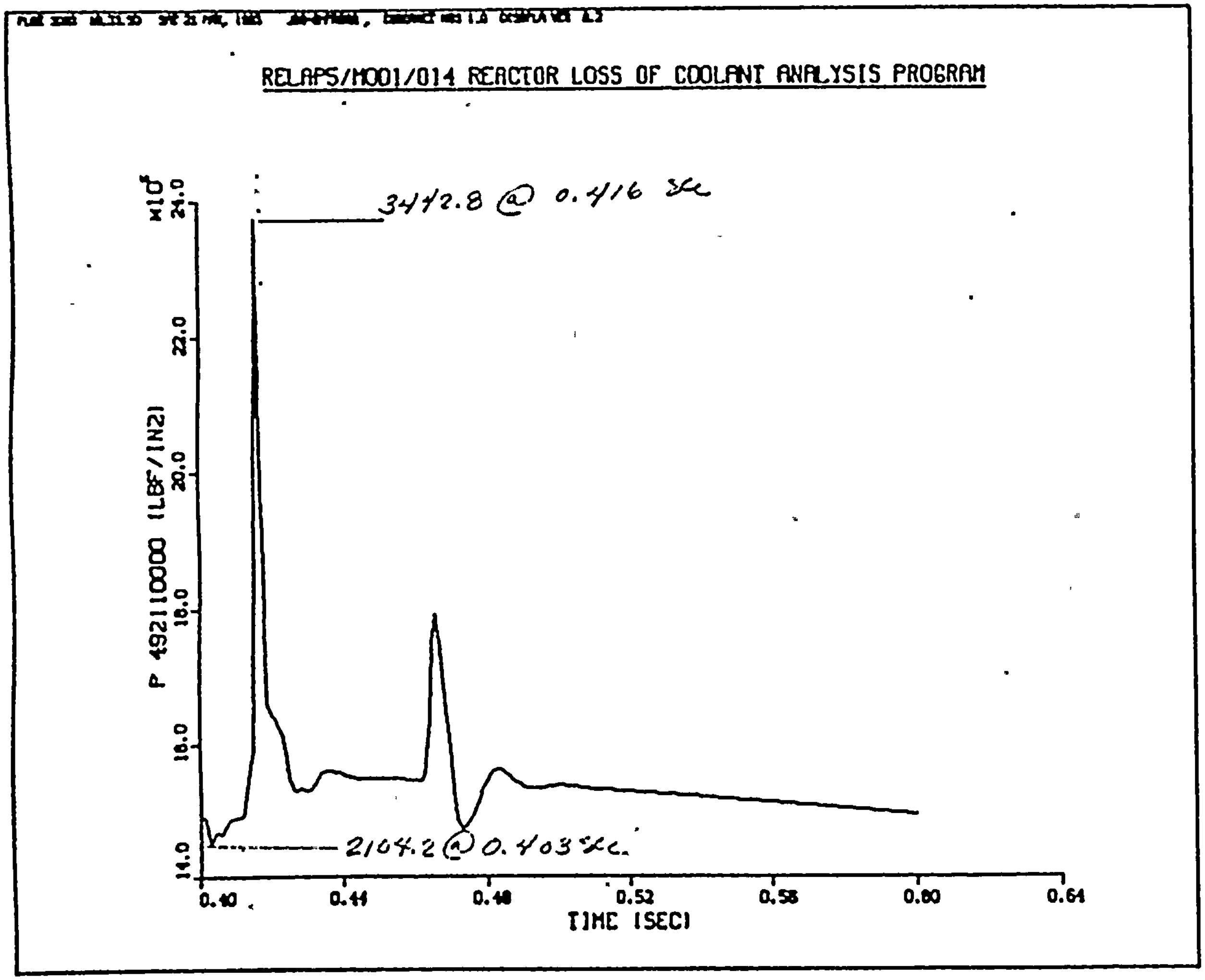
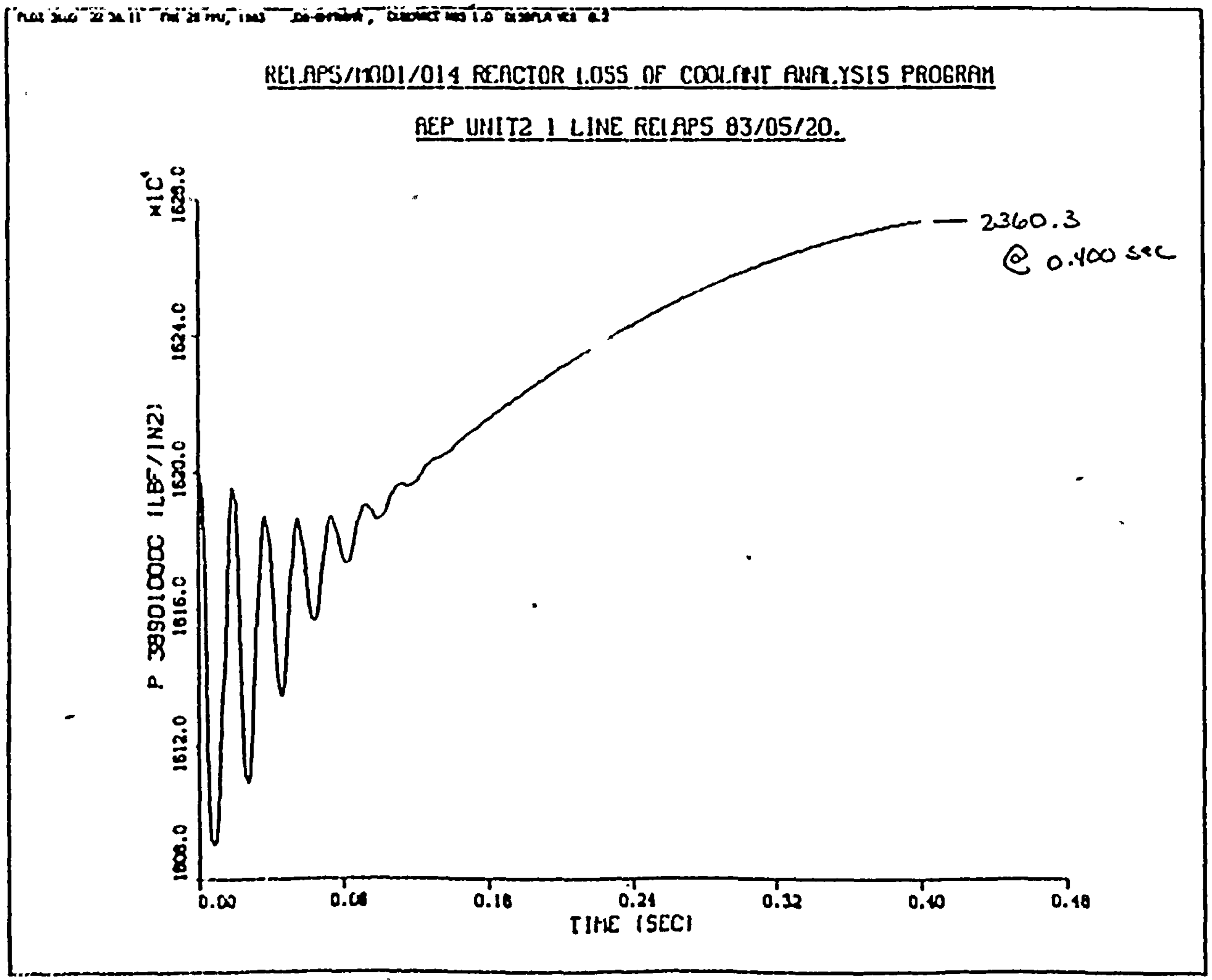



RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
P 492110000 (LBF/IN2)
x10²
24.0
22.0
20.0
18.0
16.0
14.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)
3442.8 @ 0.416 sec
2104.2 @ 0.403 sec



BY KJG DATE 5-21-83
CHKD. BY CHK DATE 5-28-83

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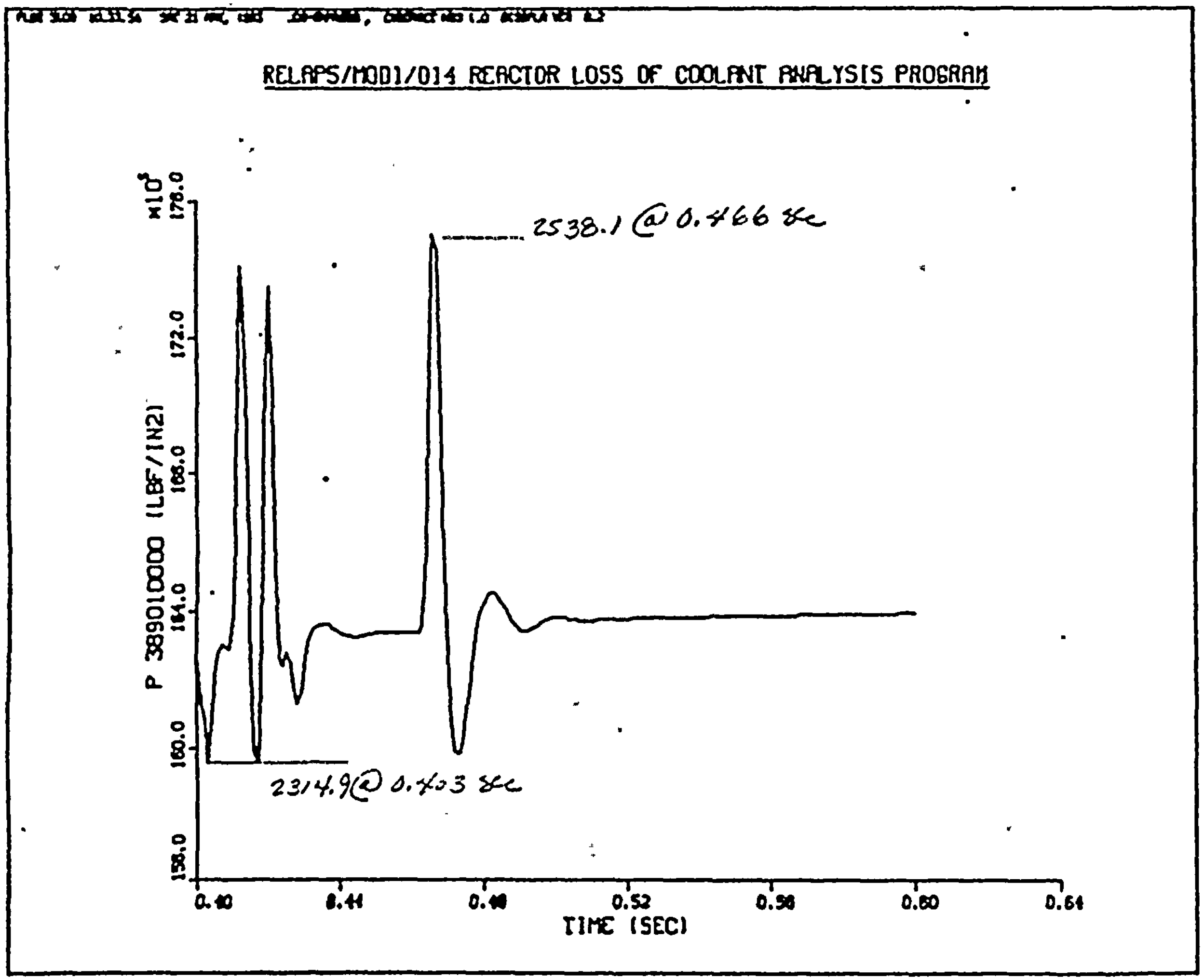
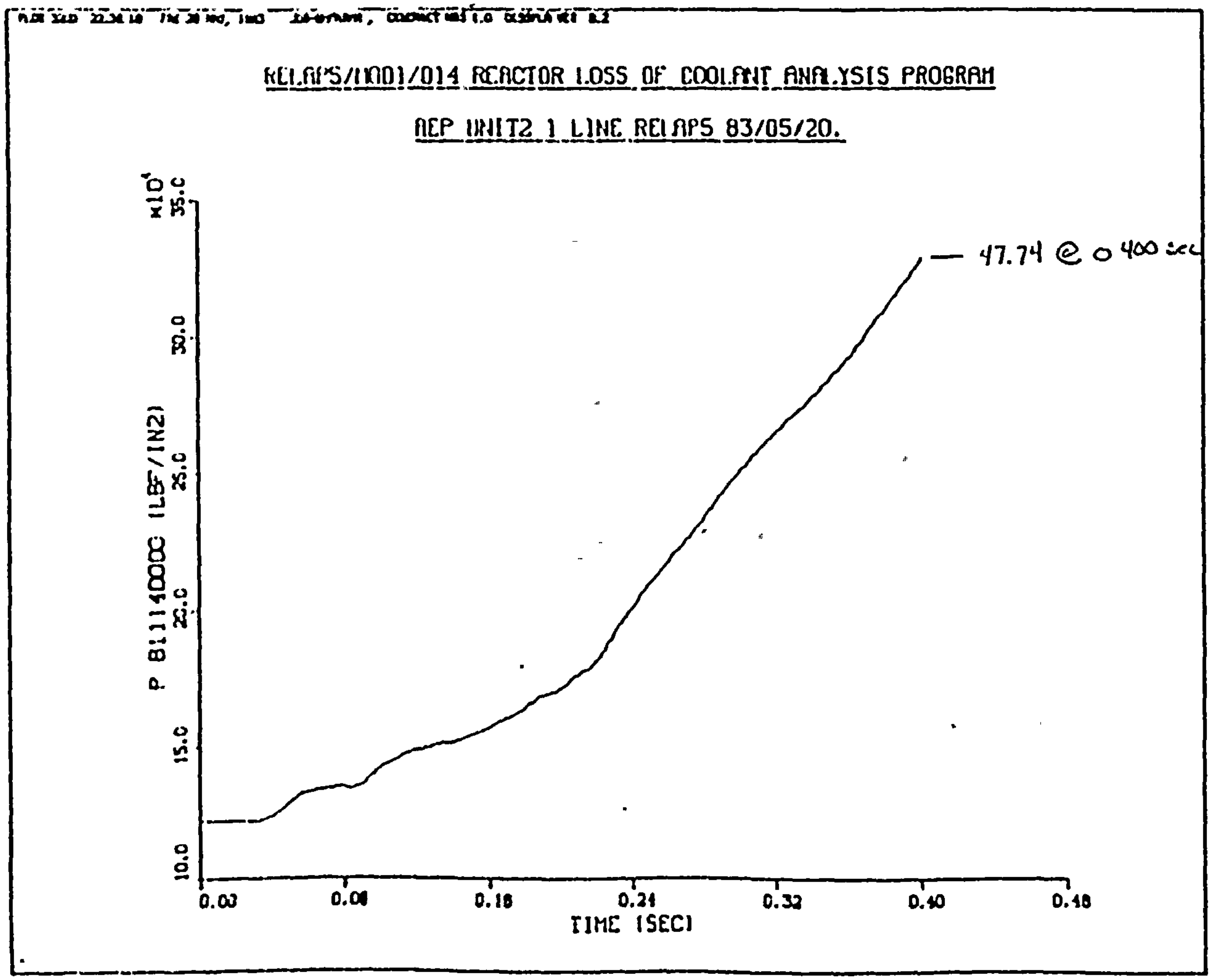

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
P 389010000 (LBF/IN2)
x10^1
156.0
160.0
164.0
168.0
172.0
176.0
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)
2538.1 @ 0.466 sec
2314.9 @ 0.403 sec

BY KJG DATE 5-21-83
CHKD. BY CHM DATE 5-28-83



BY KJG DATE 5-21-83
CHKD. BY CHM DATE 5-28-83

TELEDYNE ENGINEERING SERVICES

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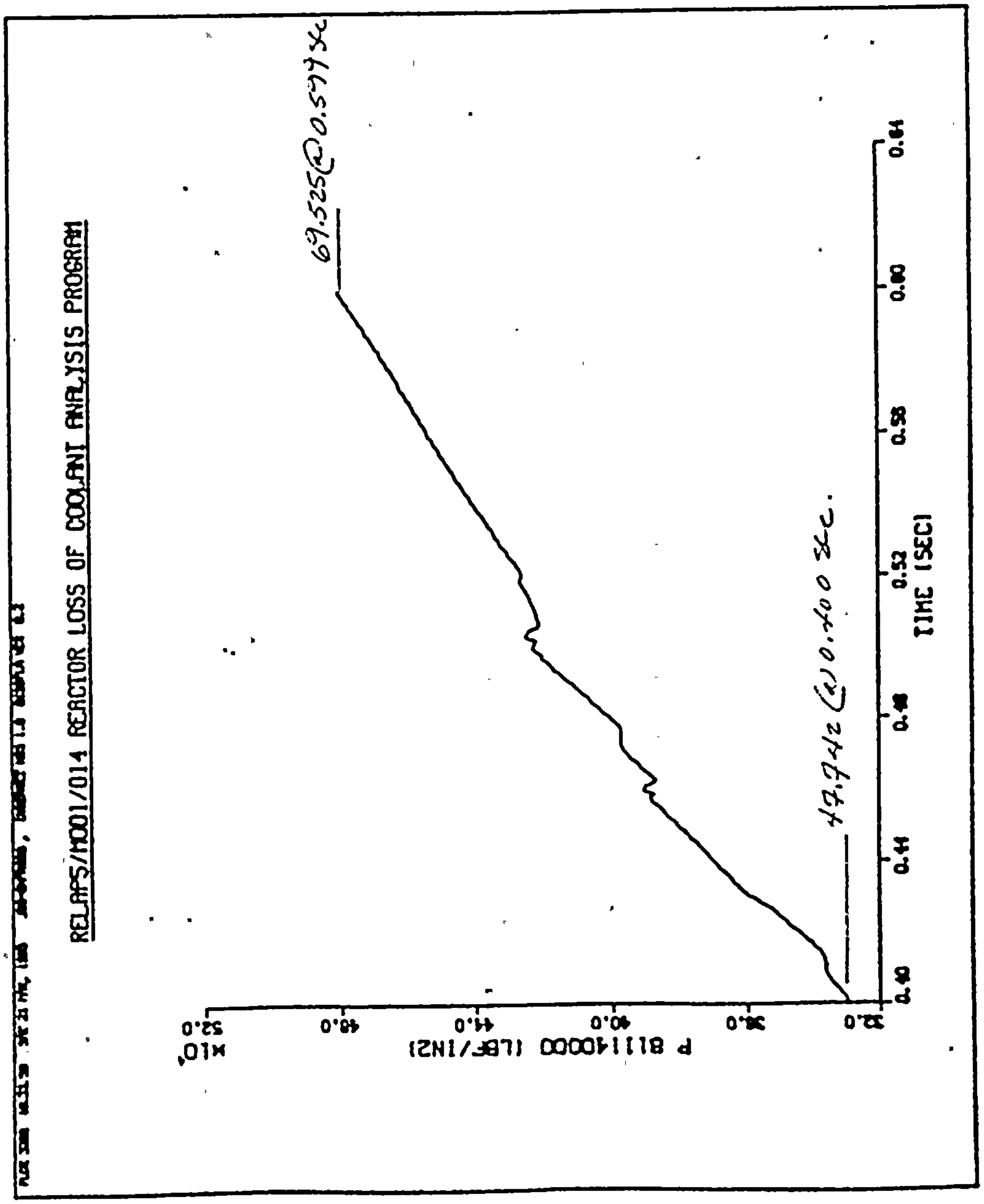
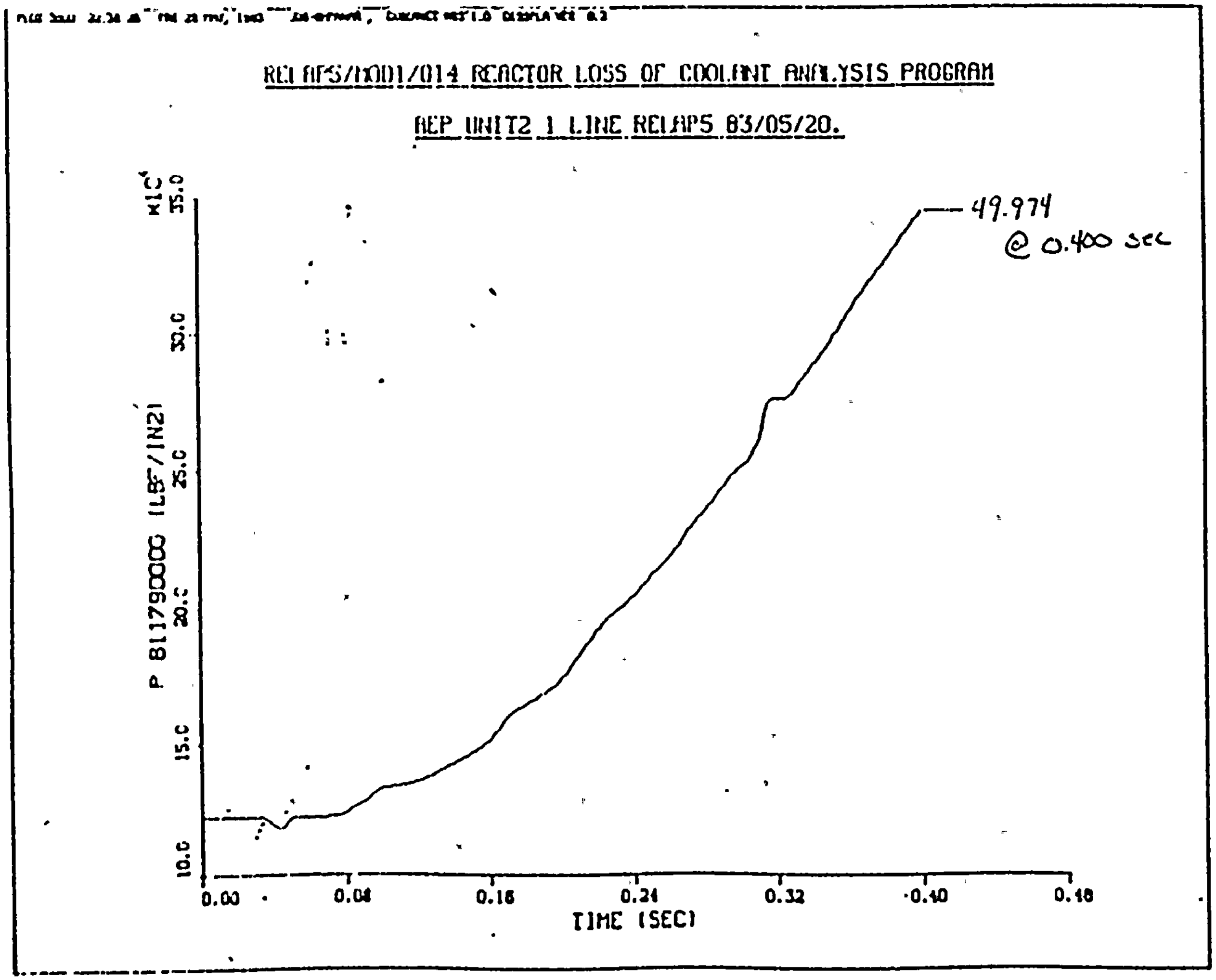
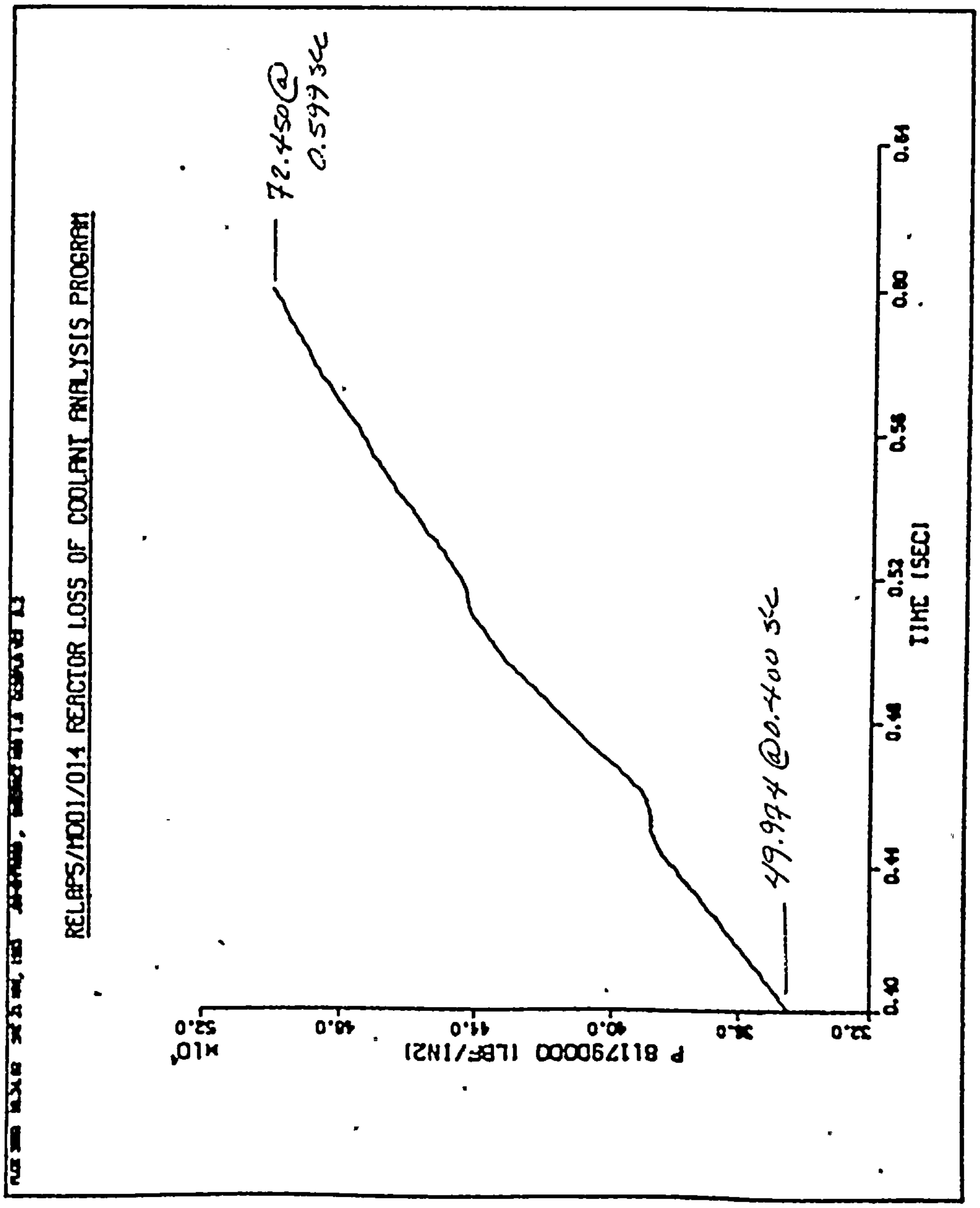
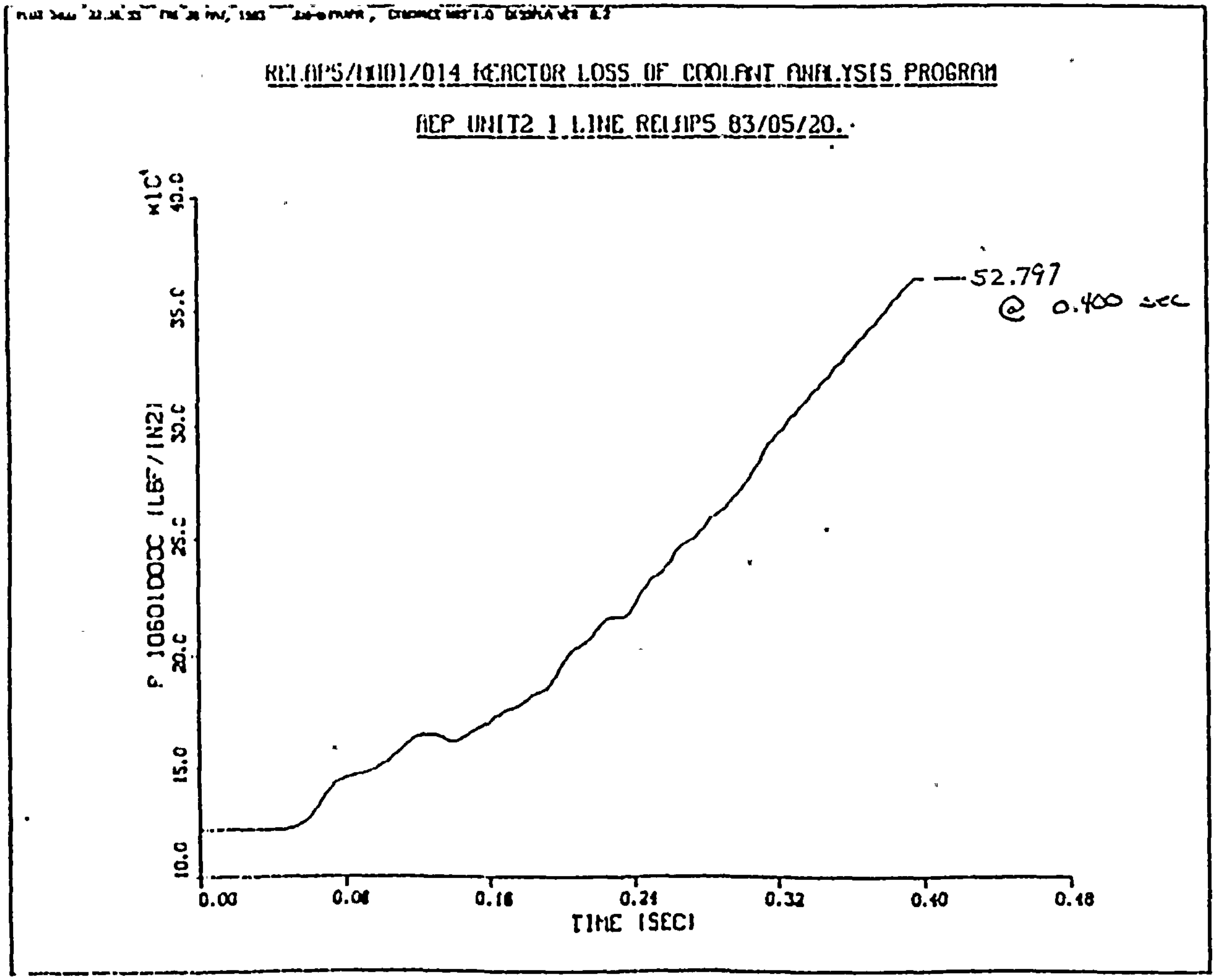
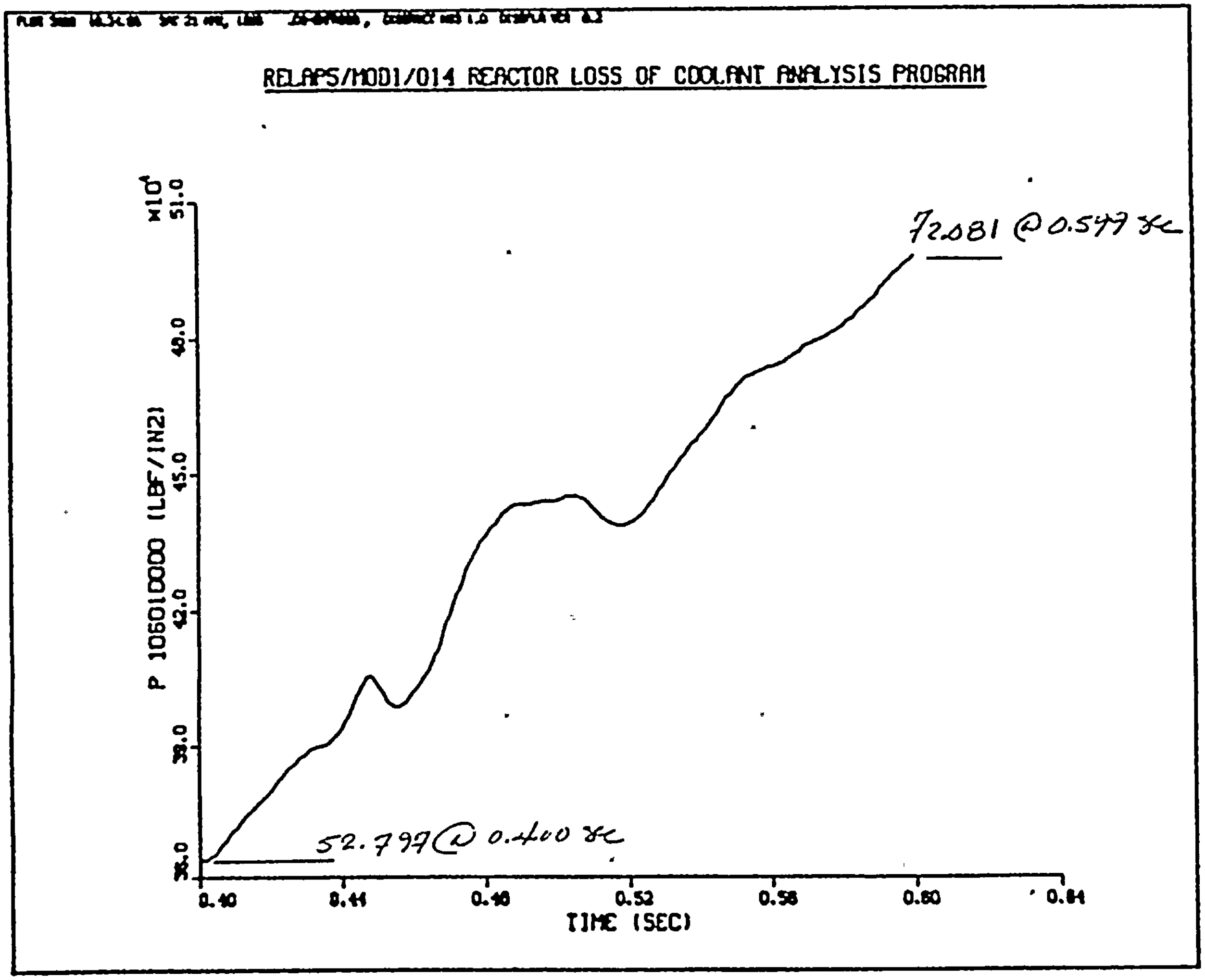



RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/05/20.
P 81179000 (LBF/IN2)
×10^1
10.0
15.0
20.0
25.0
30.0
35.0
0.00
0.08
0.16
0.24
0.32
0.40
0.48
TIME (SEC)
49.974
@ 0.400 sec

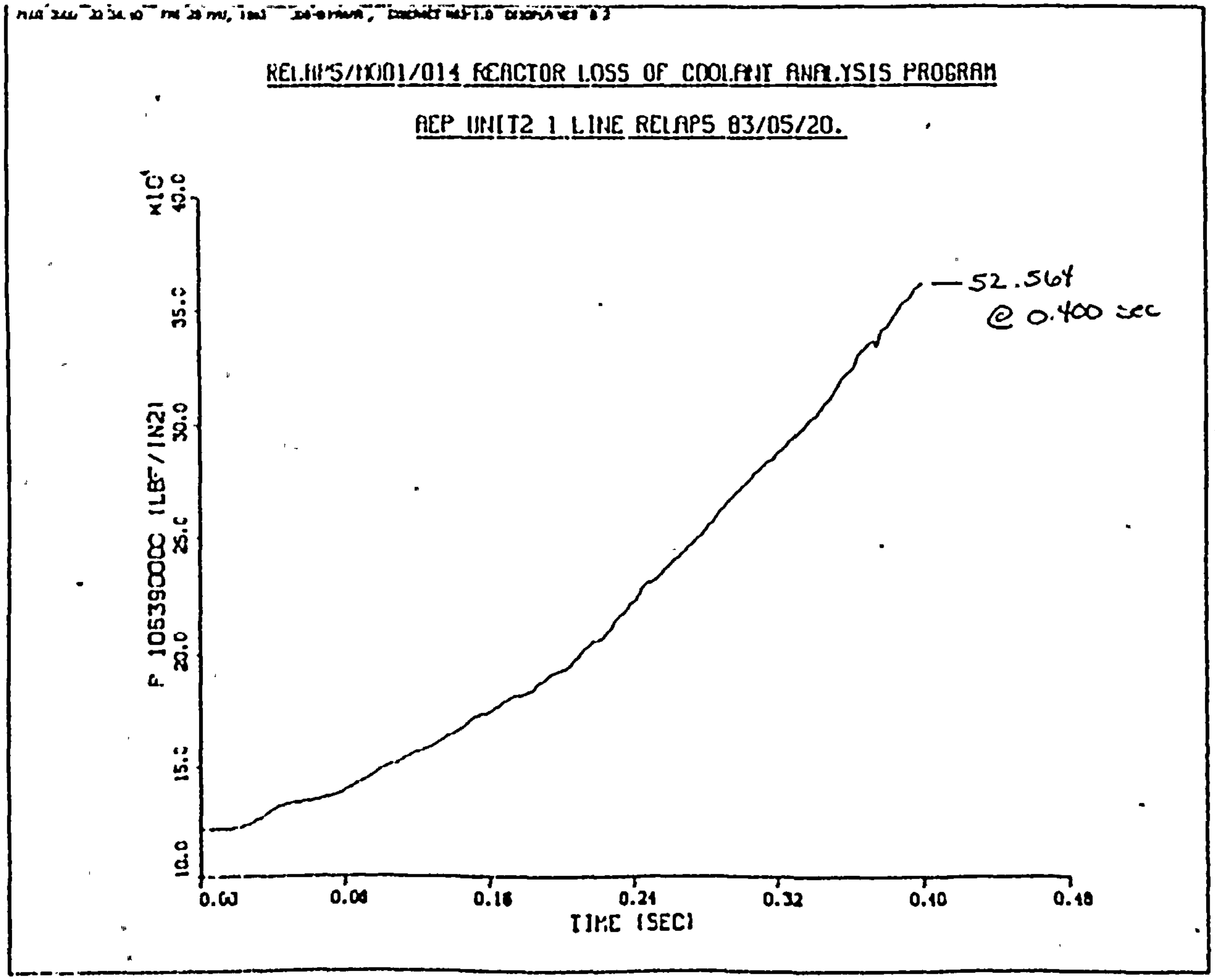

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
P 81179OOOO (LBF/IN2)
x10[4]
32.0
36.0
40.0
44.0
48.0
52.0
TIME (SEC)
0.40
0.44
0.48
0.52
0.56
0.60
0.64
72.450 @ 0.599 sec
49.974 @ 0.400 sec

BY KJG DATE 5-21-83
CHKD. BY CHL DATE 5-28-83

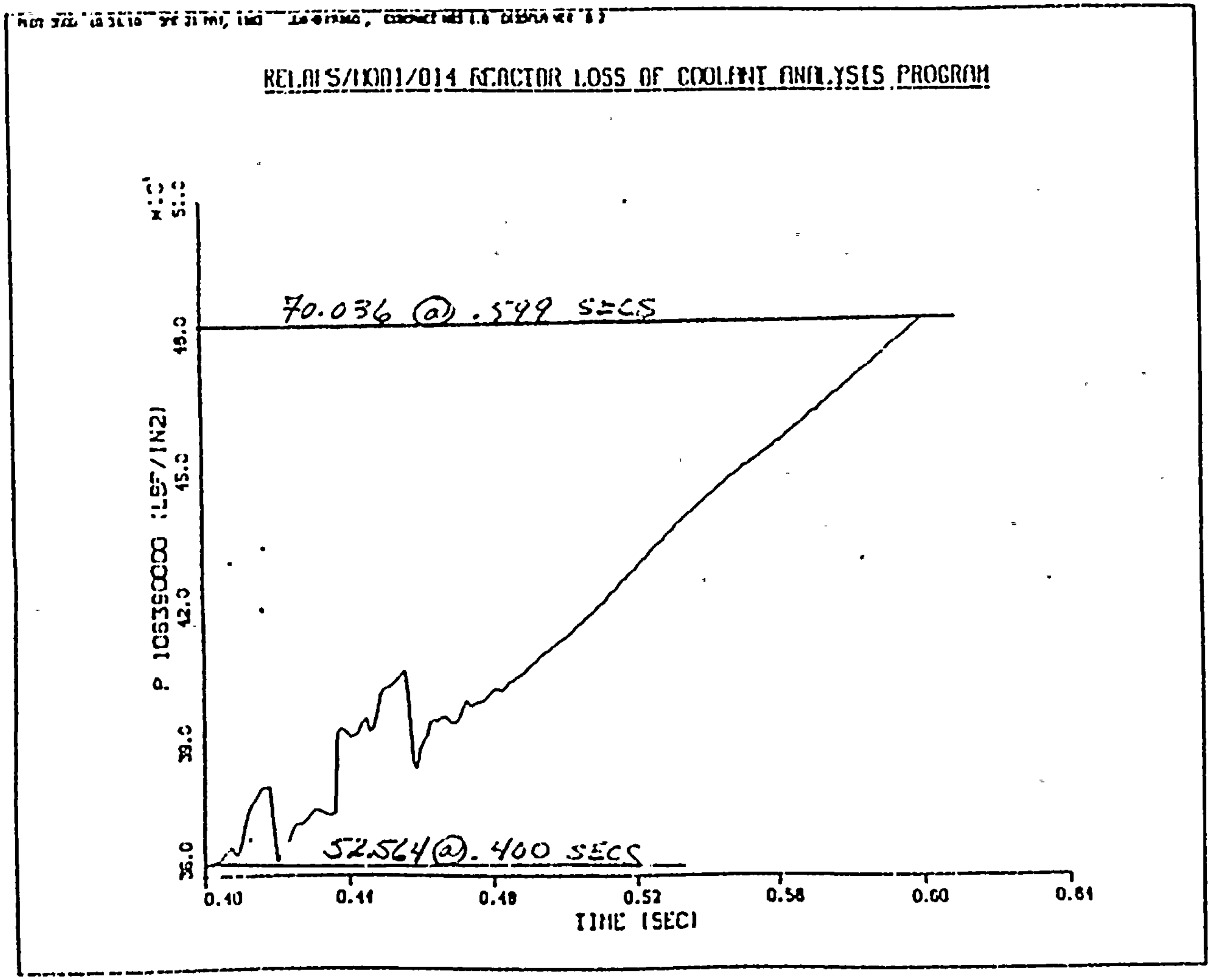



RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
P 10601000 (LBF/IN2)
x10^1
TIME (SEC)
72.081 @ 0.599 sec
52.797 @ 0.400 sec

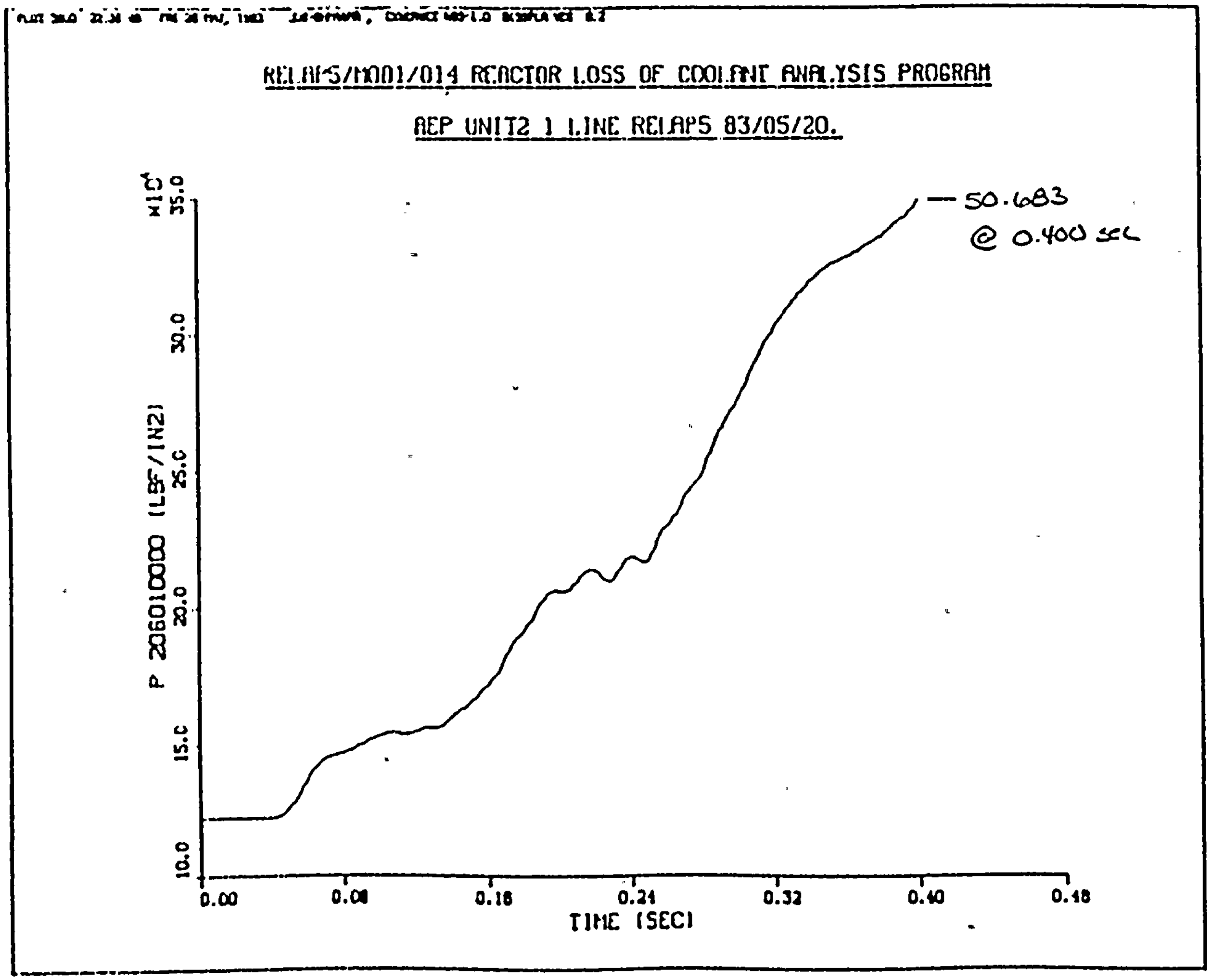
BY KJG DATE 5-21-83
CHKD. BY CHY DATE 5-28-83

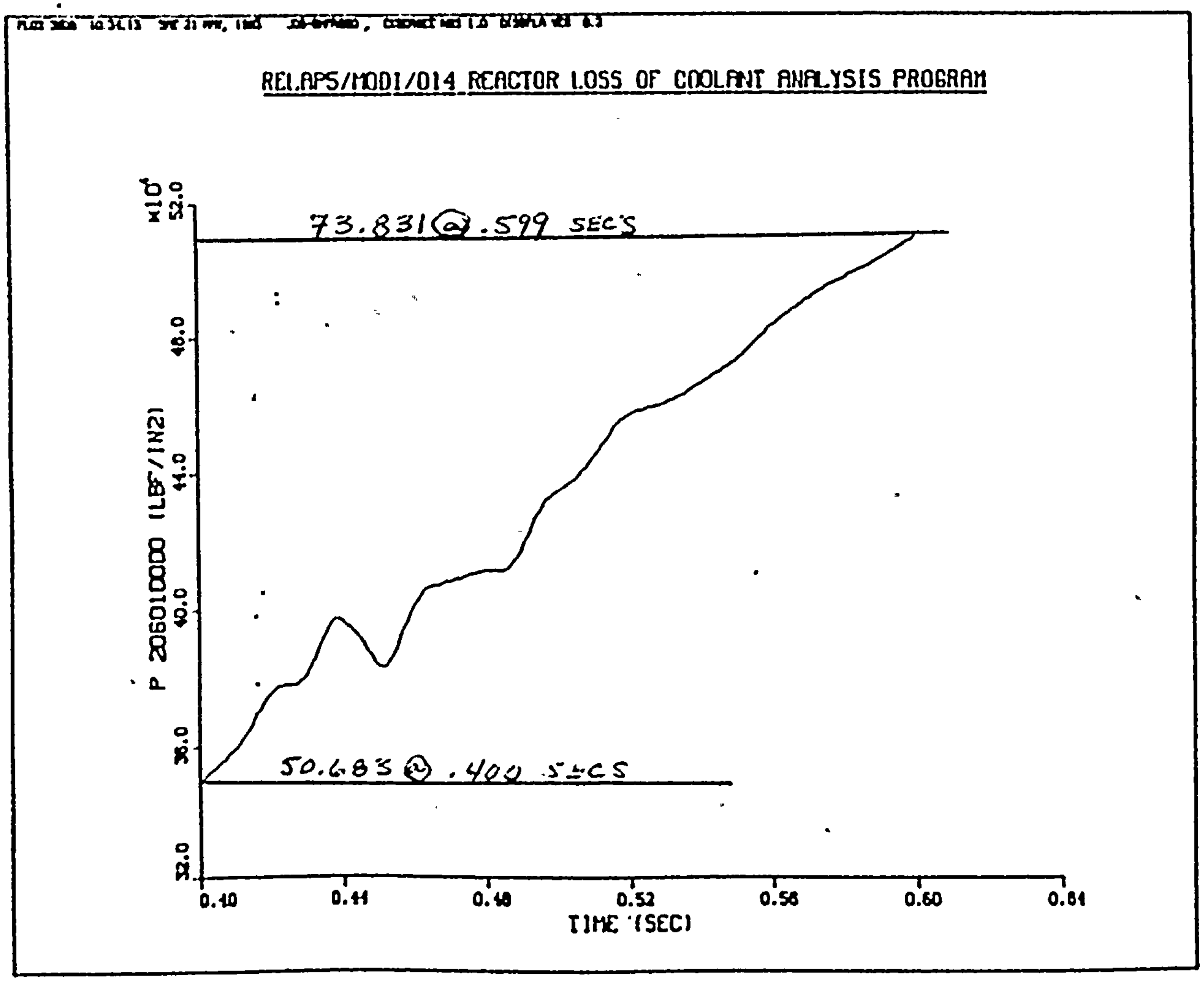


BY ____ DATE ____
CHKD. BY CNM DATE 5-26-8?



BY KJG DATE 5-21-83
CHKD. BY CHH DATE 5-28-83




RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
73.831 @ .599 SECS
50.683 @ .400 SECS
x10¹
52.0
48.0
44.0
40.0
36.0
32.0
P 205010000 (LBF/IN2)
0.40
0.44
0.48
0.52
0.56
0.60
0.64
TIME (SEC)

TELEDYNE ENGINEERING SERVICES

BY KJG DATE 5-21-83
CHKD. BY CHH DATE 5-28-83

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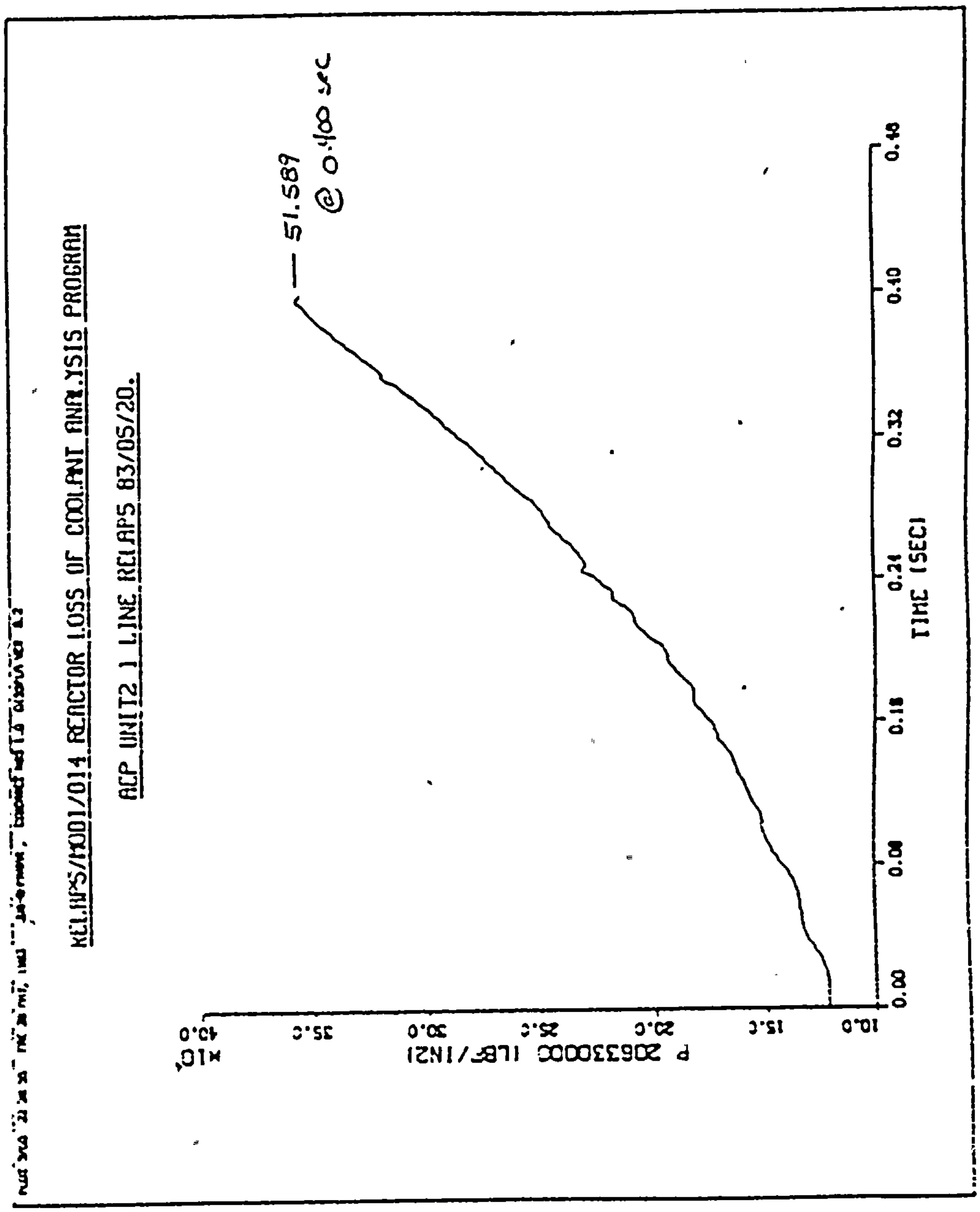
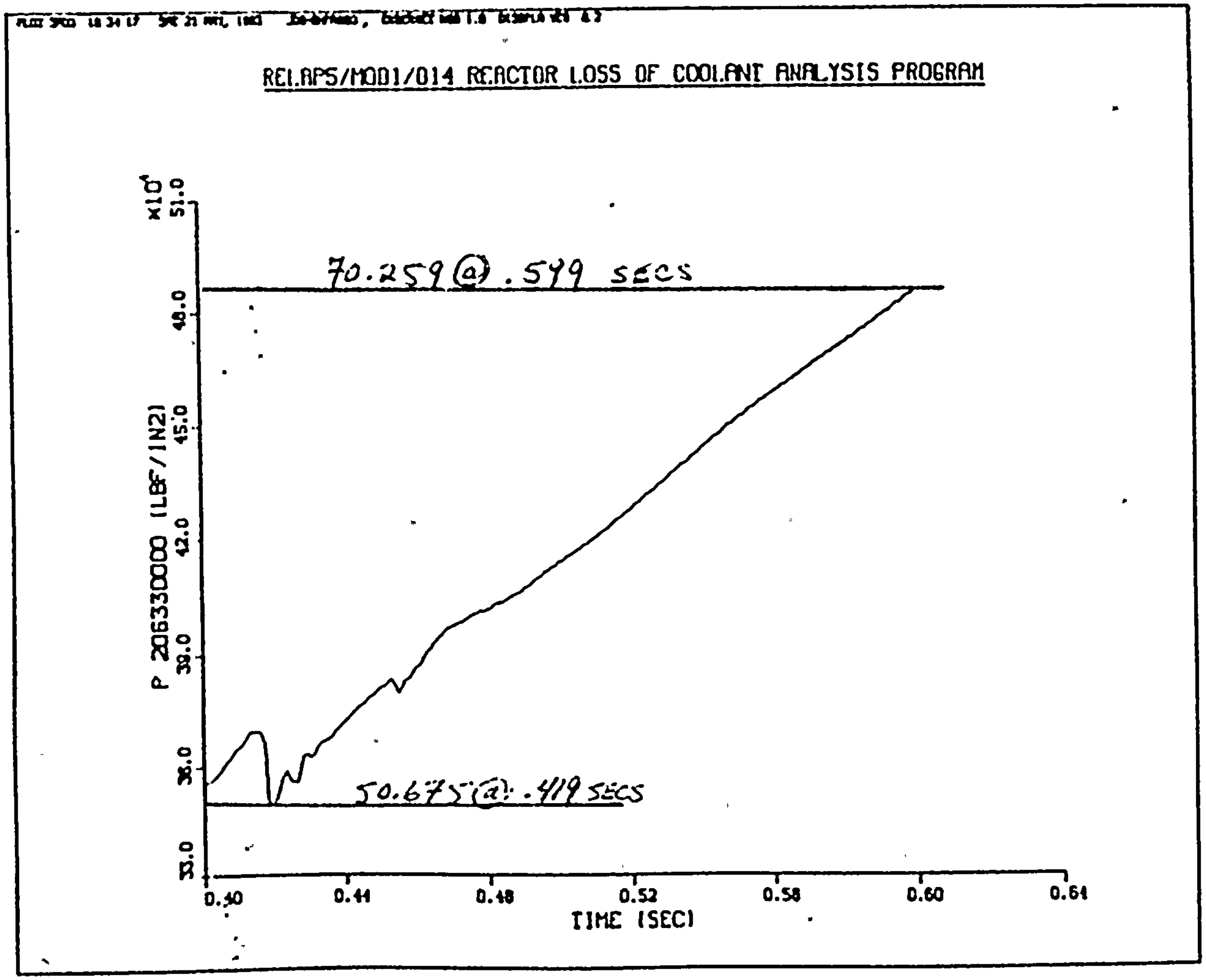
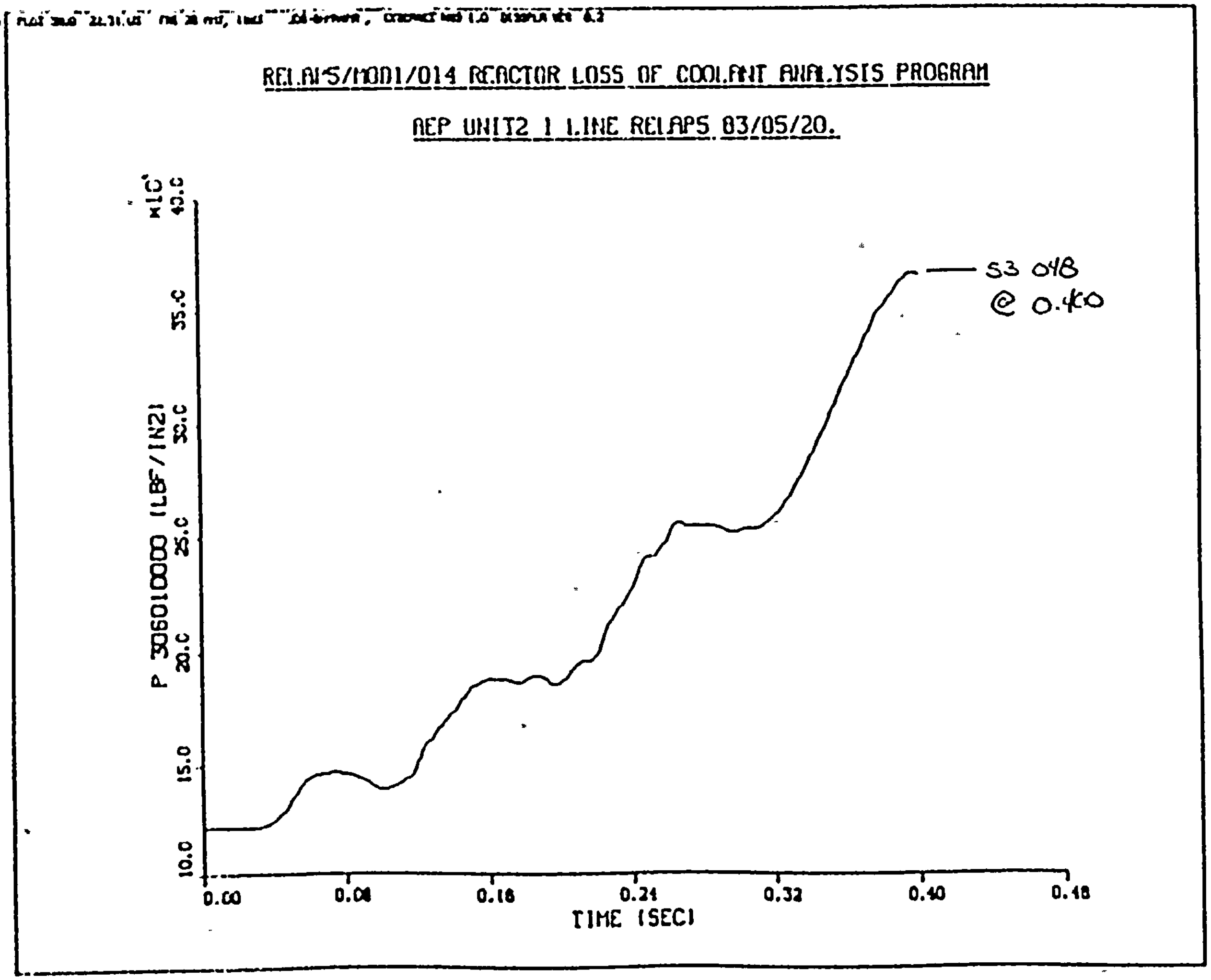
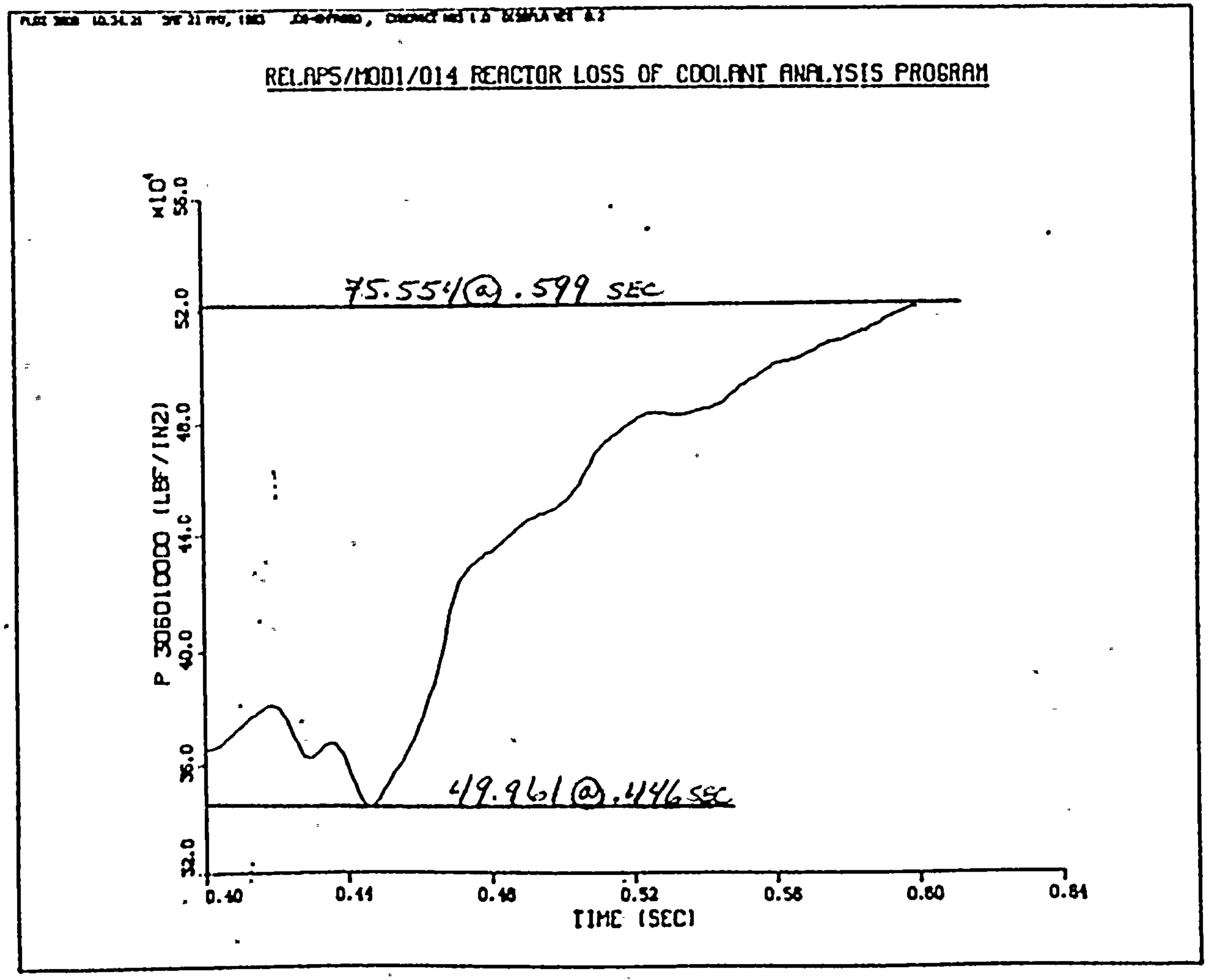


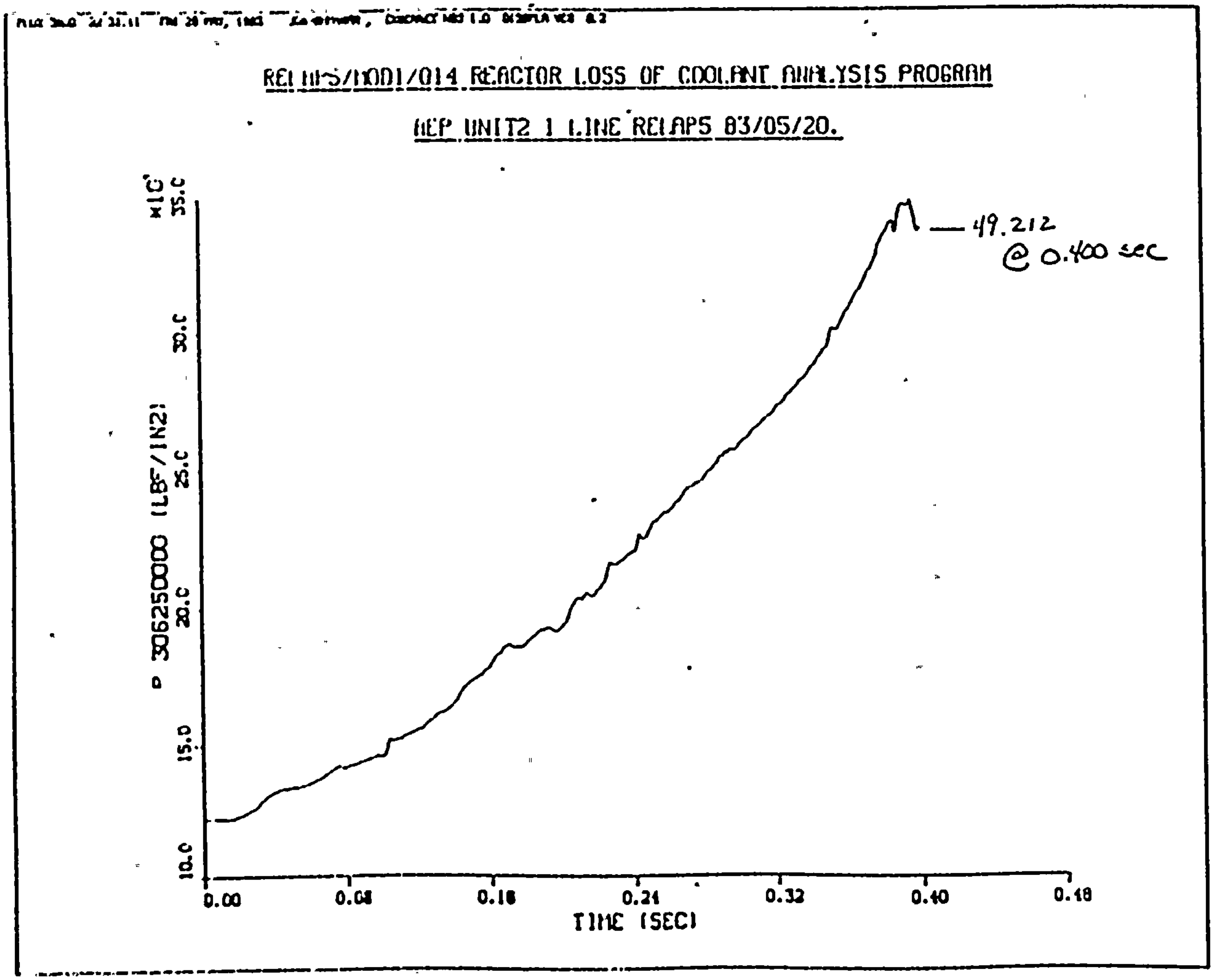
BY KTG DATE 5-21-83
CHKD. BY CWM DATE 5-28-83




RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAPS 83/05/20.
P 306010000 (LBF/IN2)
x10'
40.0
35.0
30.0
25.0
20.0
15.0
10.0
0.00
0.08
0.16
0.24
0.32
0.40
0.48
TIME (SEC)
53 048
@ 0.40

BY KG DATE 5-21-83
CHKD. BY CMM DATE 5-28-83





BY KJG DATE 5-21-83
CHKD. BY CHW DATE 5-28-83

TELEDYNE ENGINEERING SERVICES

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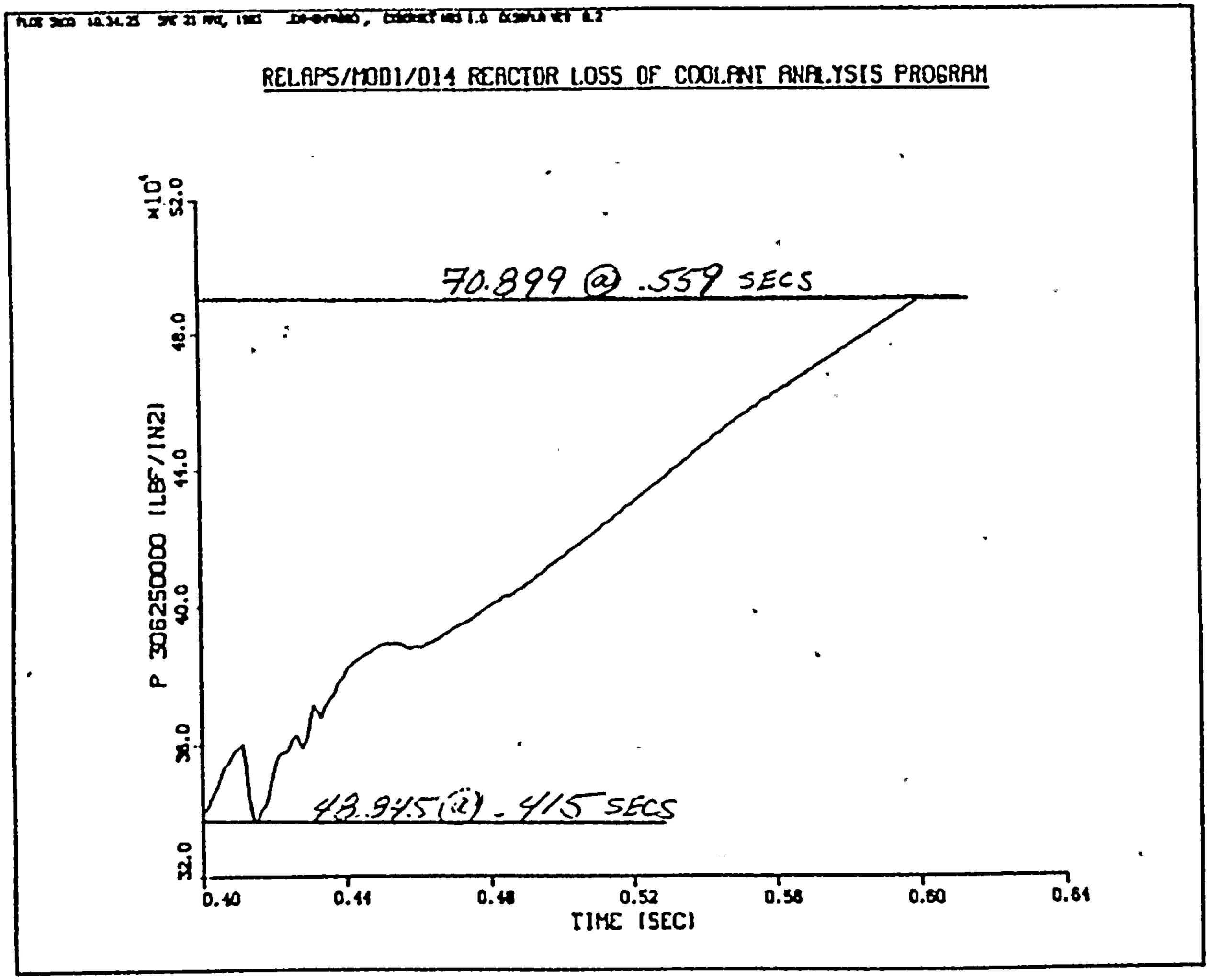
BY KTG DATE 5-21-83
CHKD. BY CWM DATE 5-28-83



4.7.2 Quarter Model - Cold Loop Seal/Steam Case

TELEDYNE ENGINEERING SERVICES

BY JMM DATE 1-12-83
CHKD. BY [illegible] DATE 5-24-83

1/4 MODEL SRV DISCHARGE LINE - UNIT 2

SHEET NO. 1 OF 1
PROJ. NO. 5364

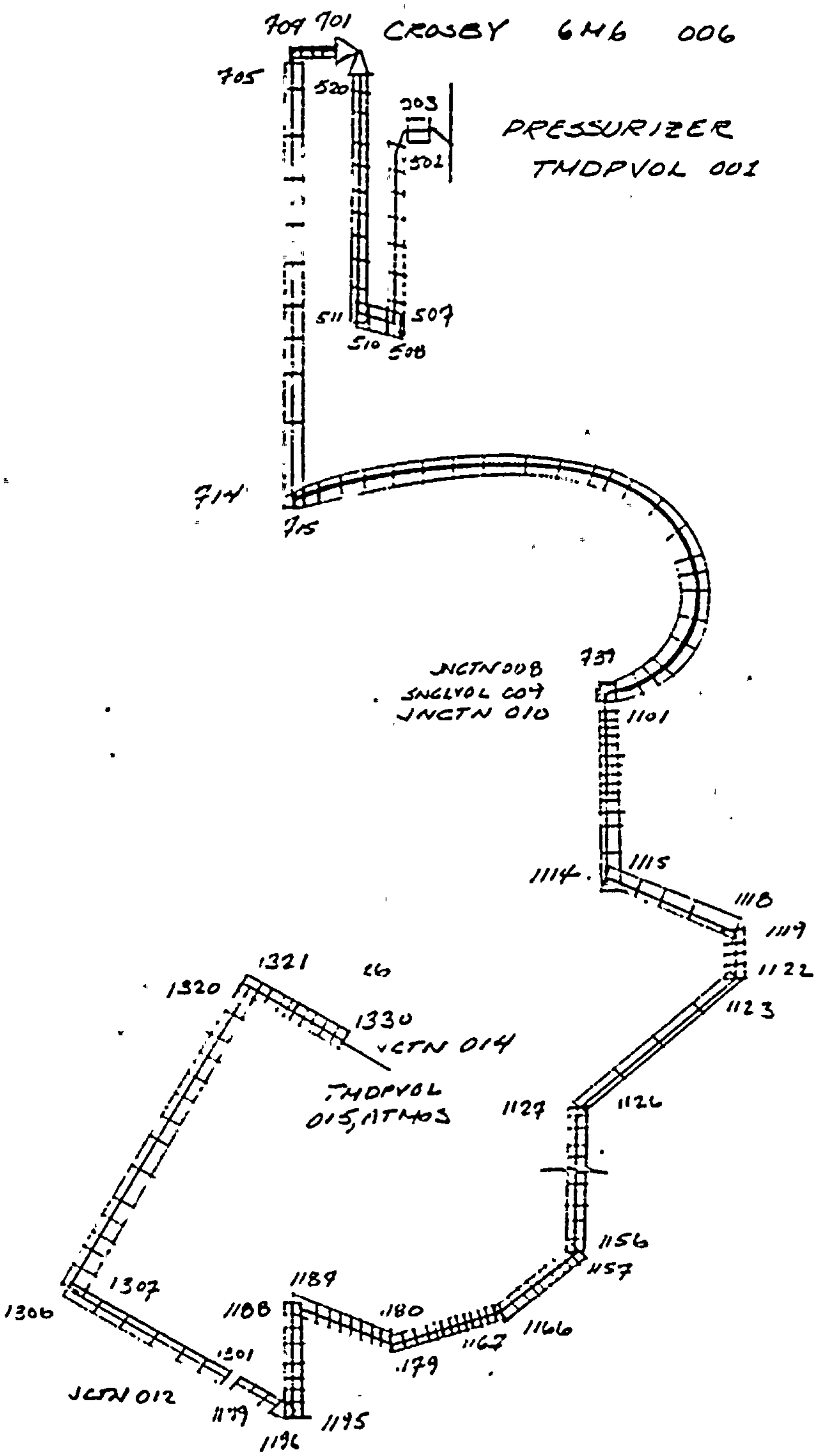
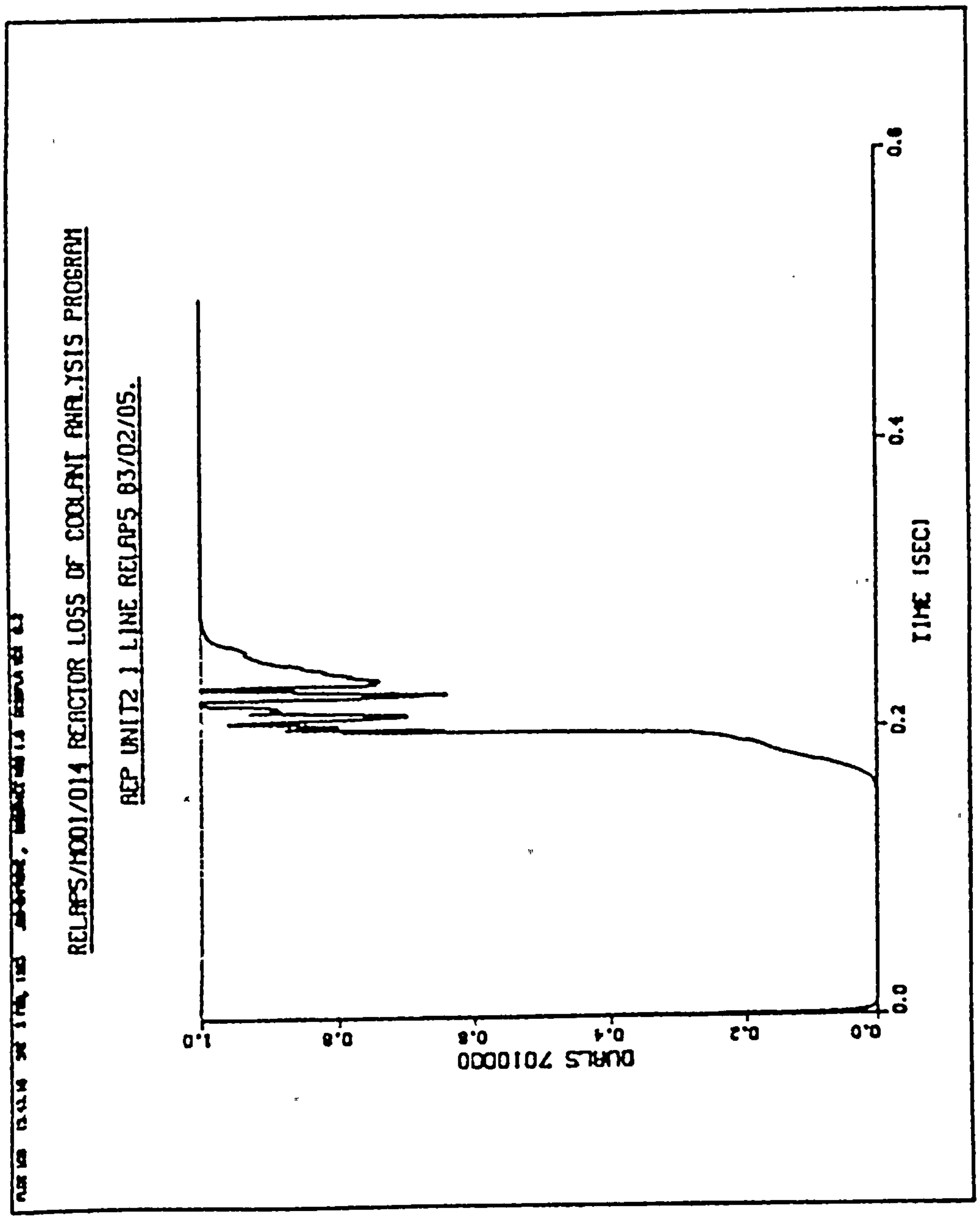
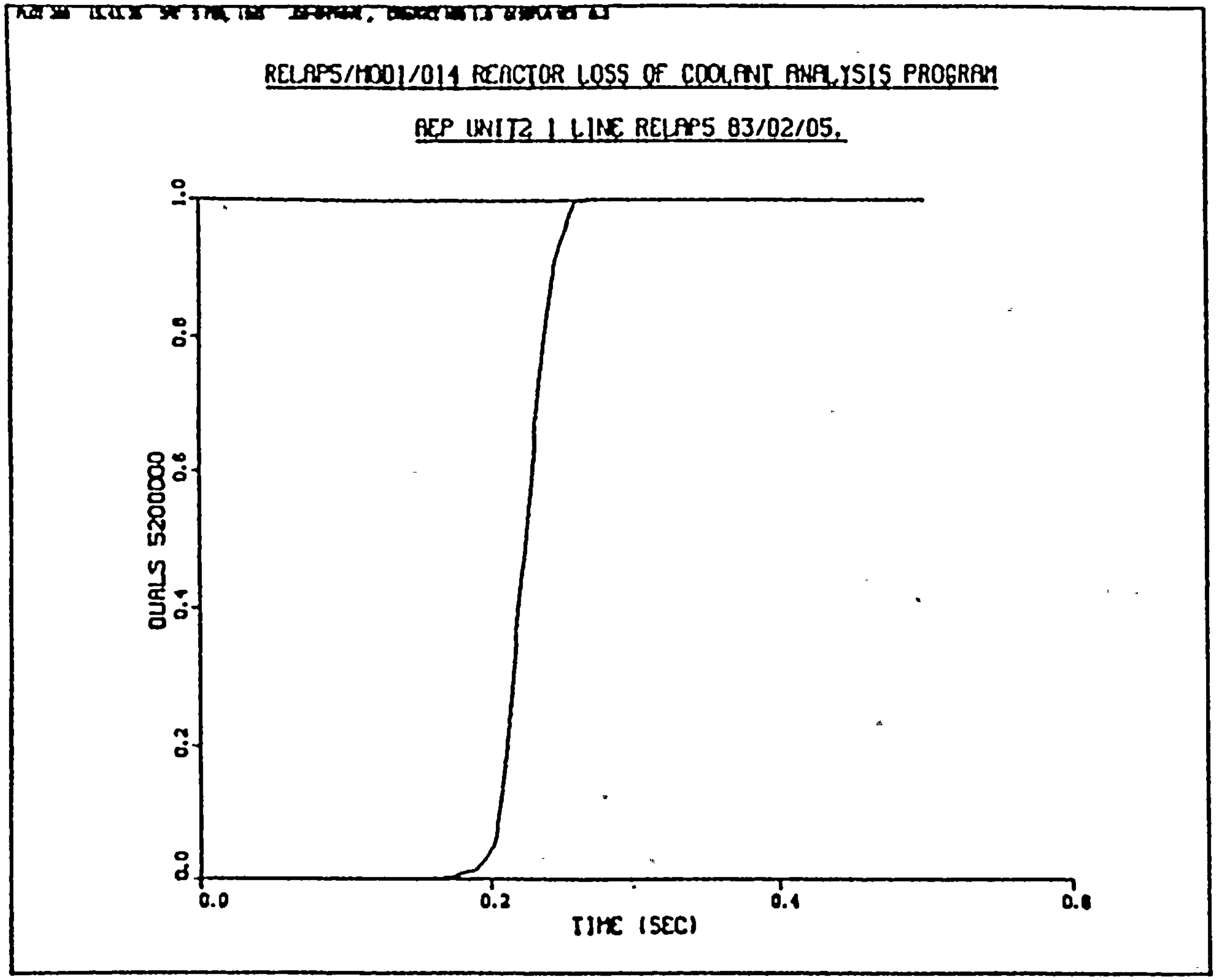


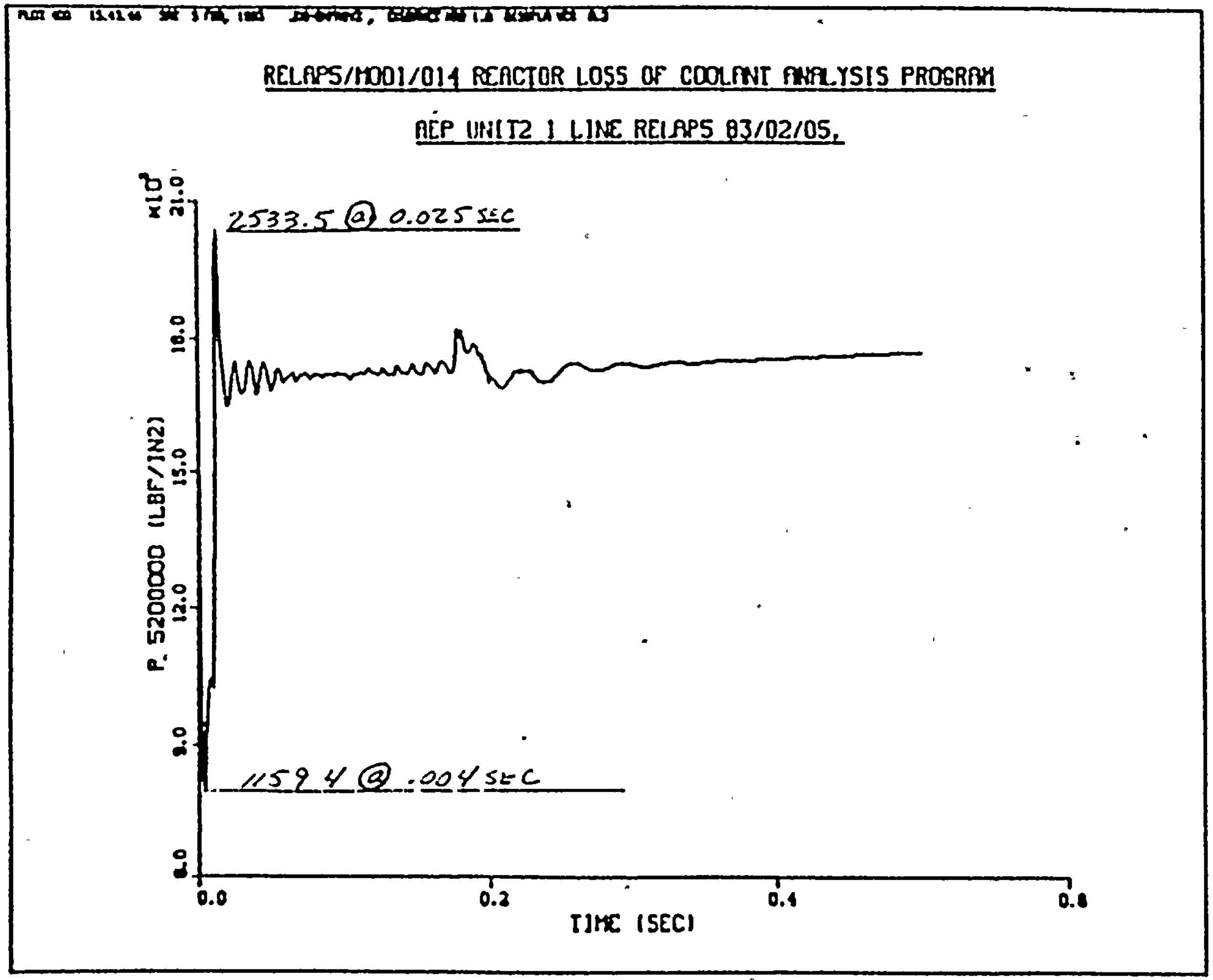
FIGURE 4.7.2-1

TELEDYNE ENGINEERING SERVICES

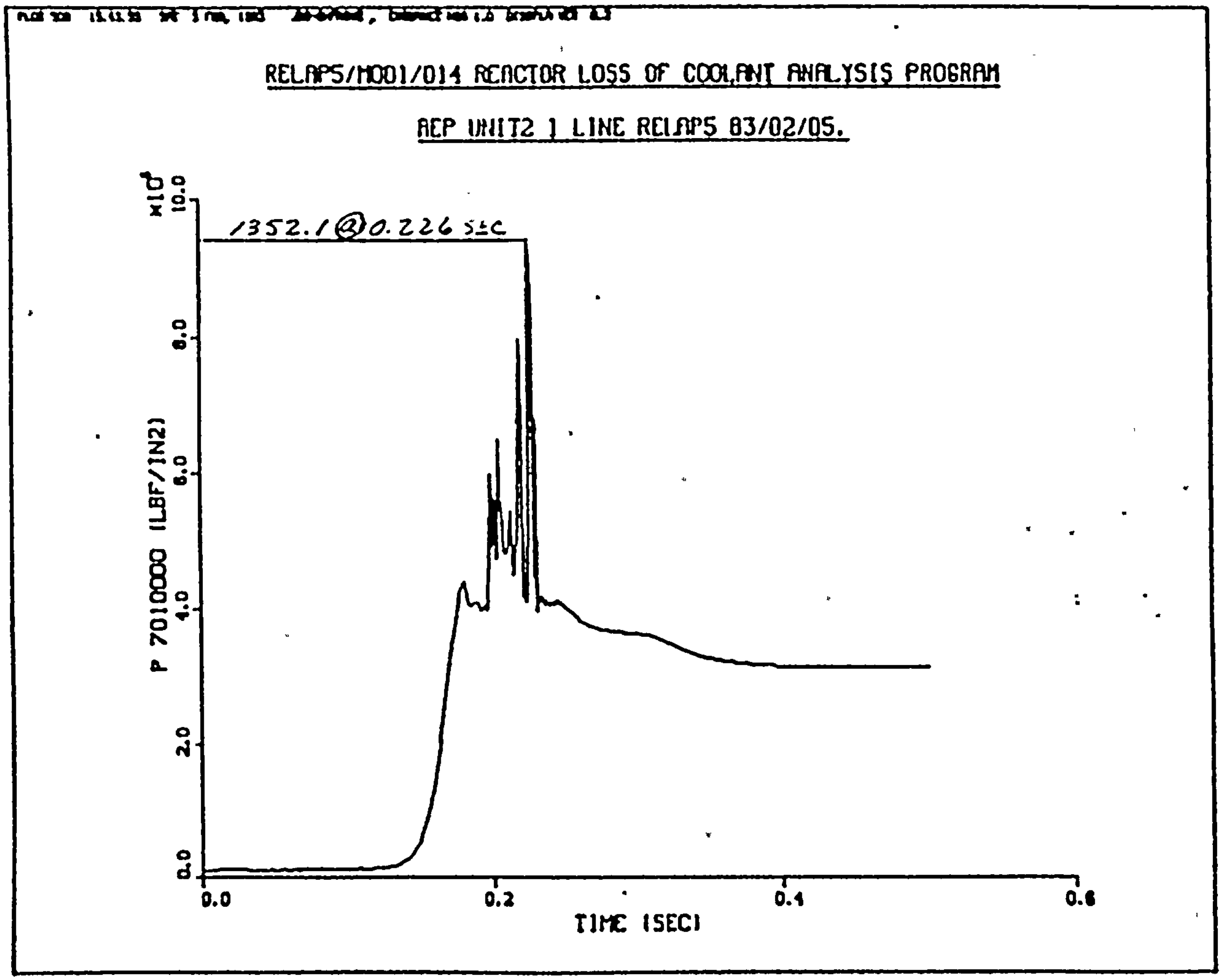


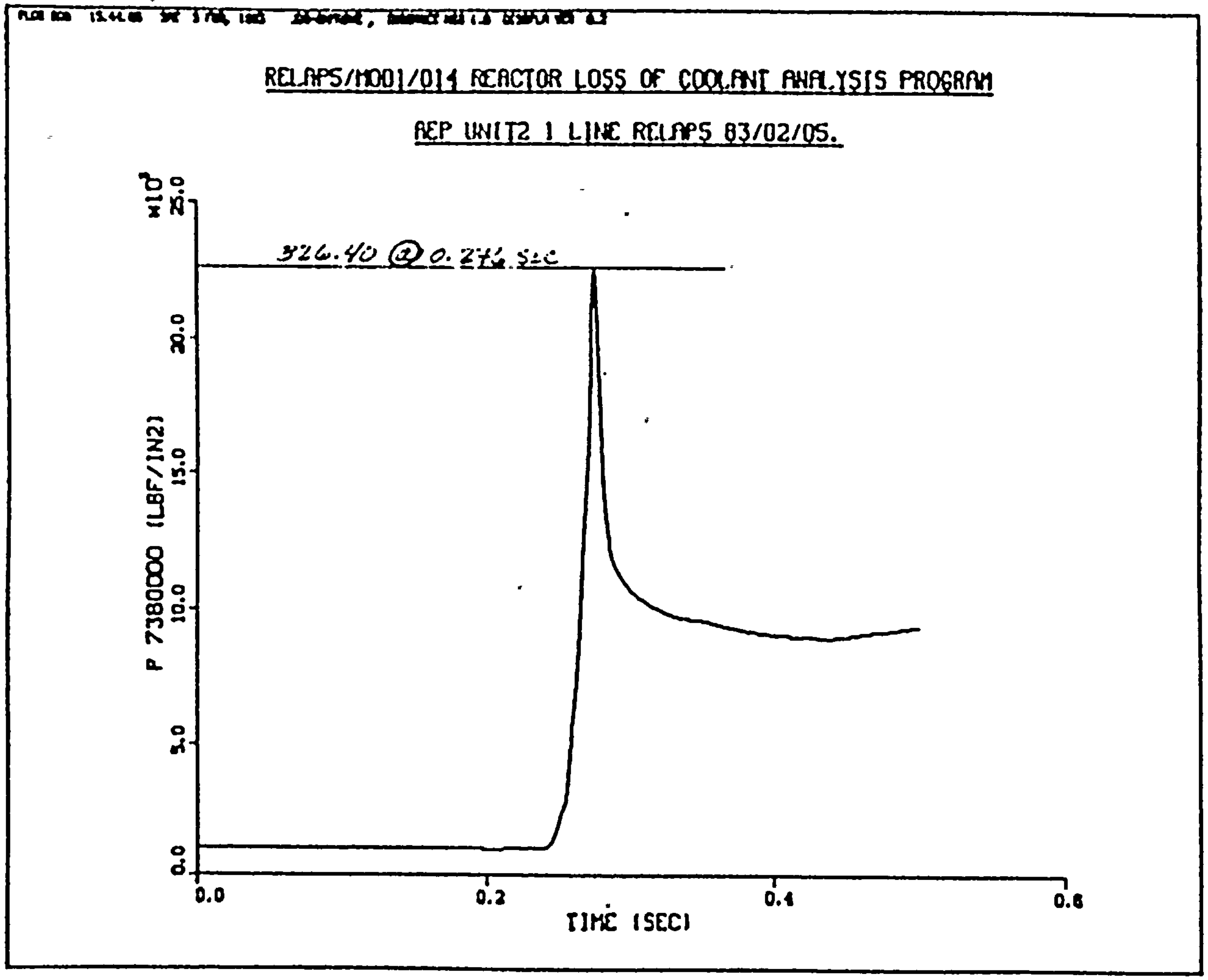


TELEDYNE ENGINEERING SERVICES



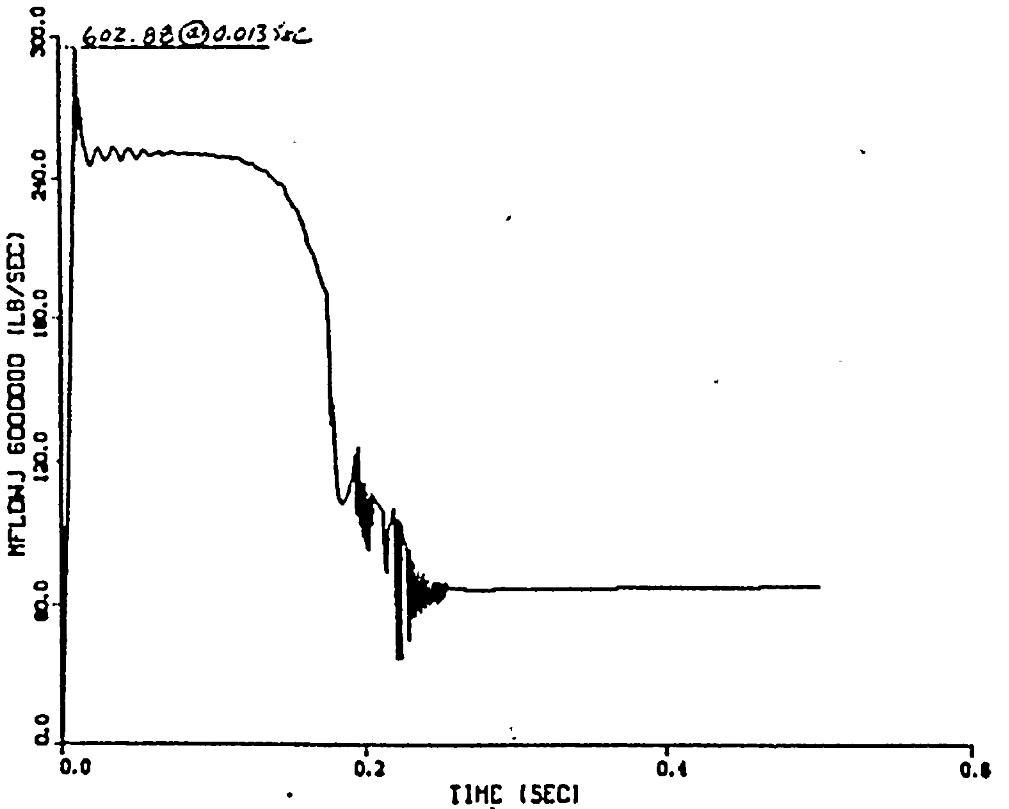
TELEDYNE ENGINEERING SERVICES


RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/02/05.
1352.1 @ 0.226 SEC
$\times10^{2}$
P 701000 (LBF/IN2)
TIME (SEC)
0.0
2.0
4.0
6.0
8.0
10.0
0.2
0.4
0.6

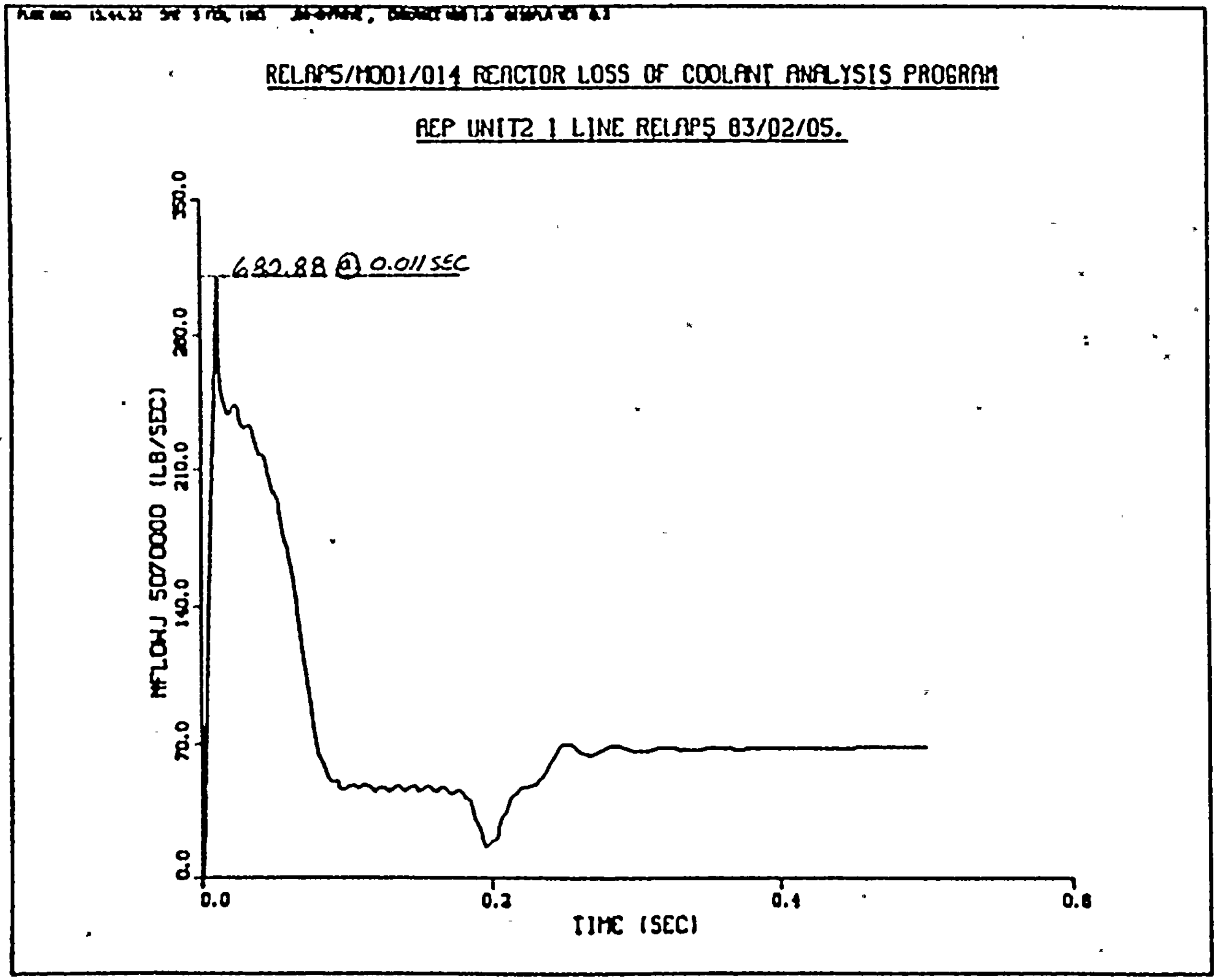

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/02/05.
326.40 @ 0.272 sec
P 7380000 (LBF/IN2)
x10²
0.0
5.0
10.0
15.0
20.0
25.0
0.0
0.2
0.4
0.6
TIME (SEC)

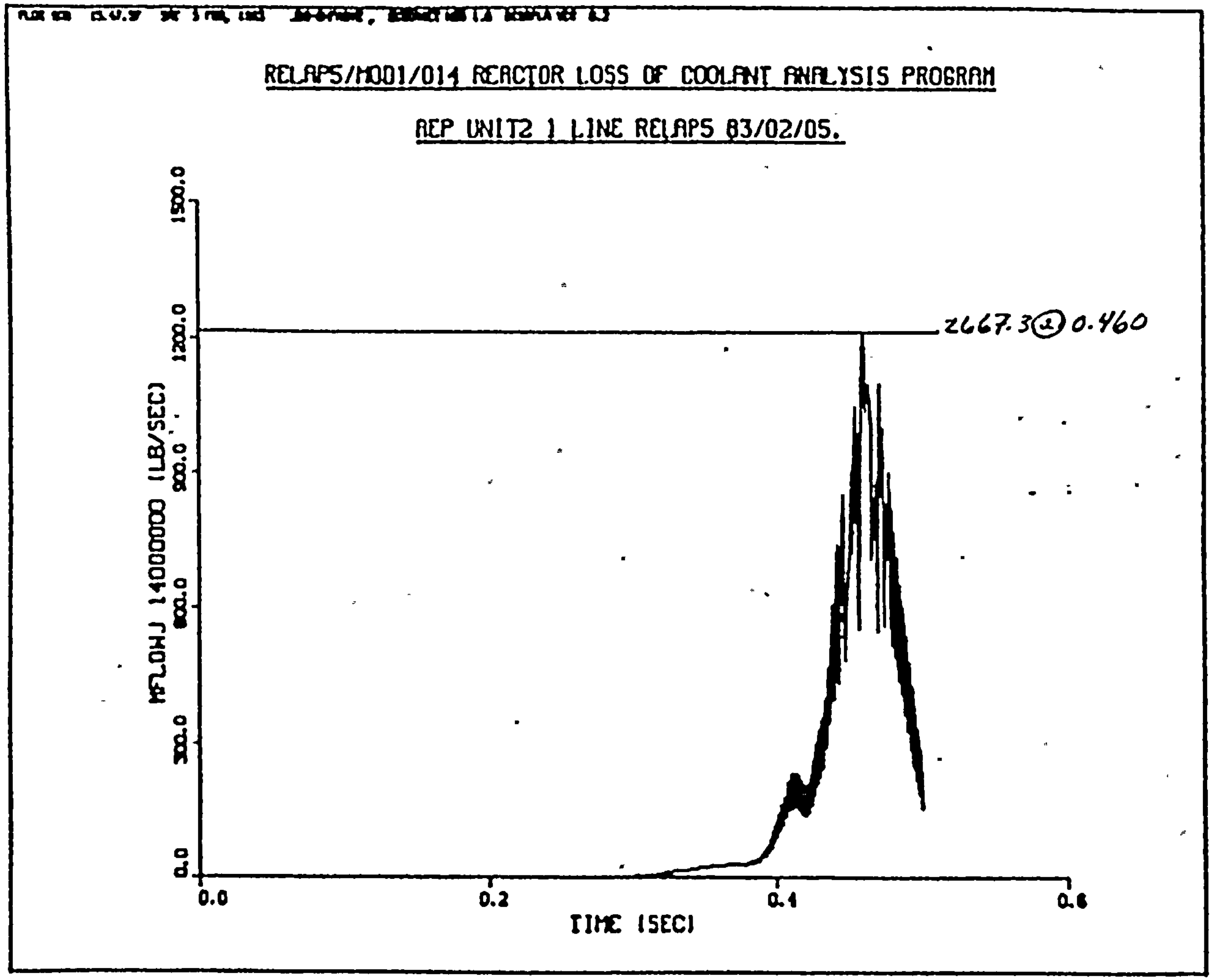
RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM

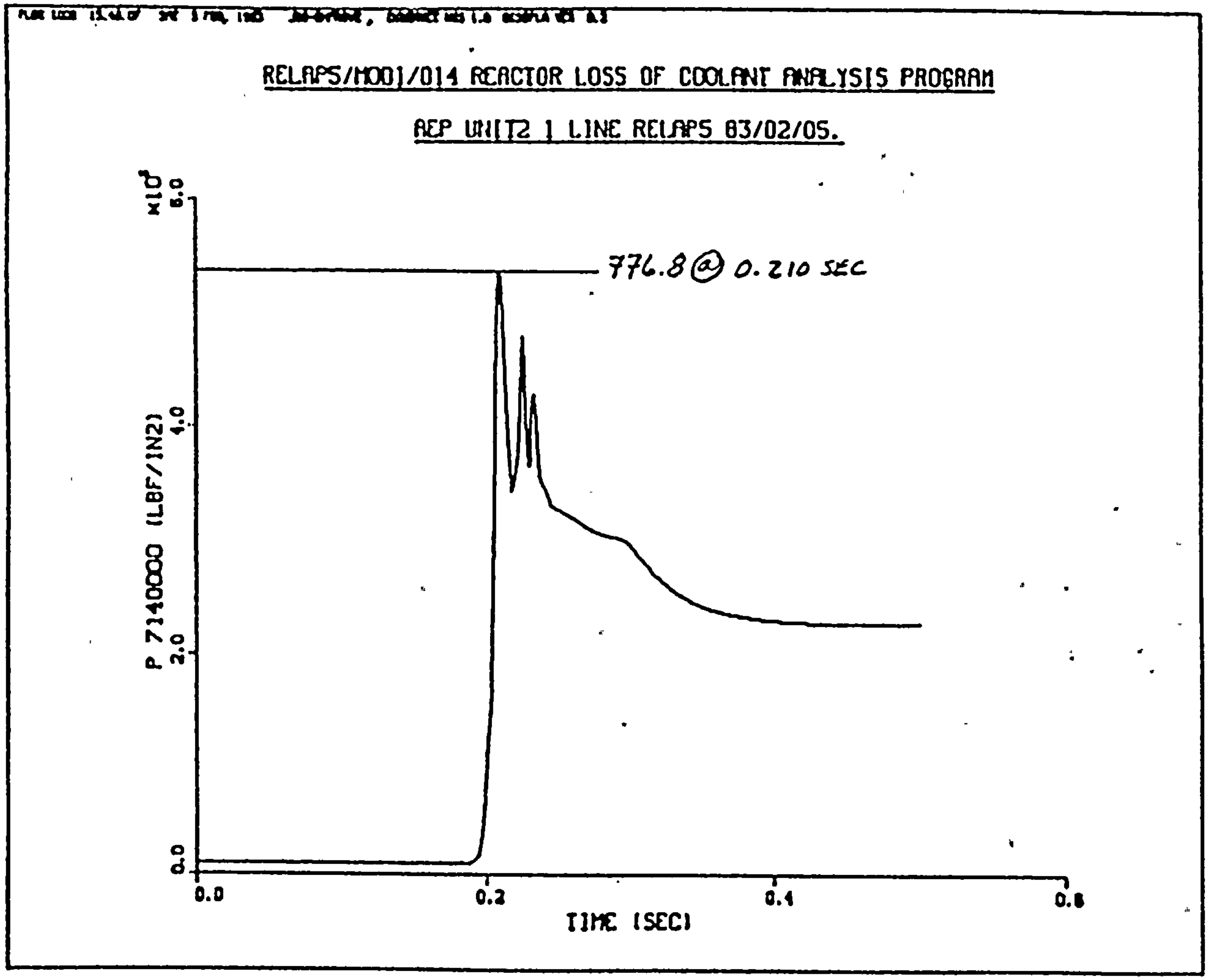
BCP UNIT2 1 LINE RELAP5 83/02/05.



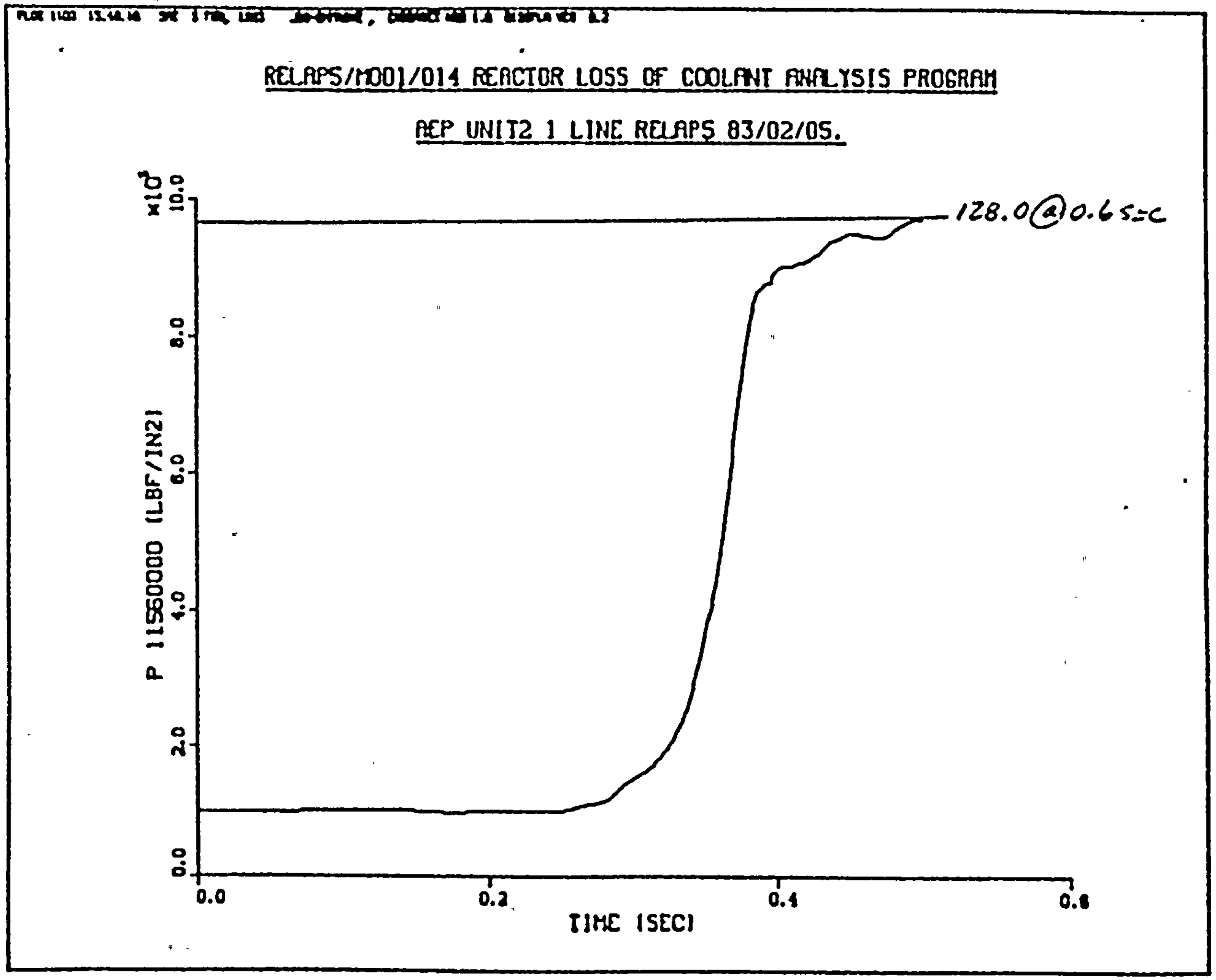
TELEDYNE ENGINEERING SERVICES


RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
AEP UNIT2 1 LINE RELAP5 83/02/05.
MFLOWJ 507000000 (LB/SEC)
682.88 @ 0.011 SEC
0.0
70.0
140.0
210.0
0.0
0.2
0.4
TIME (SEC)

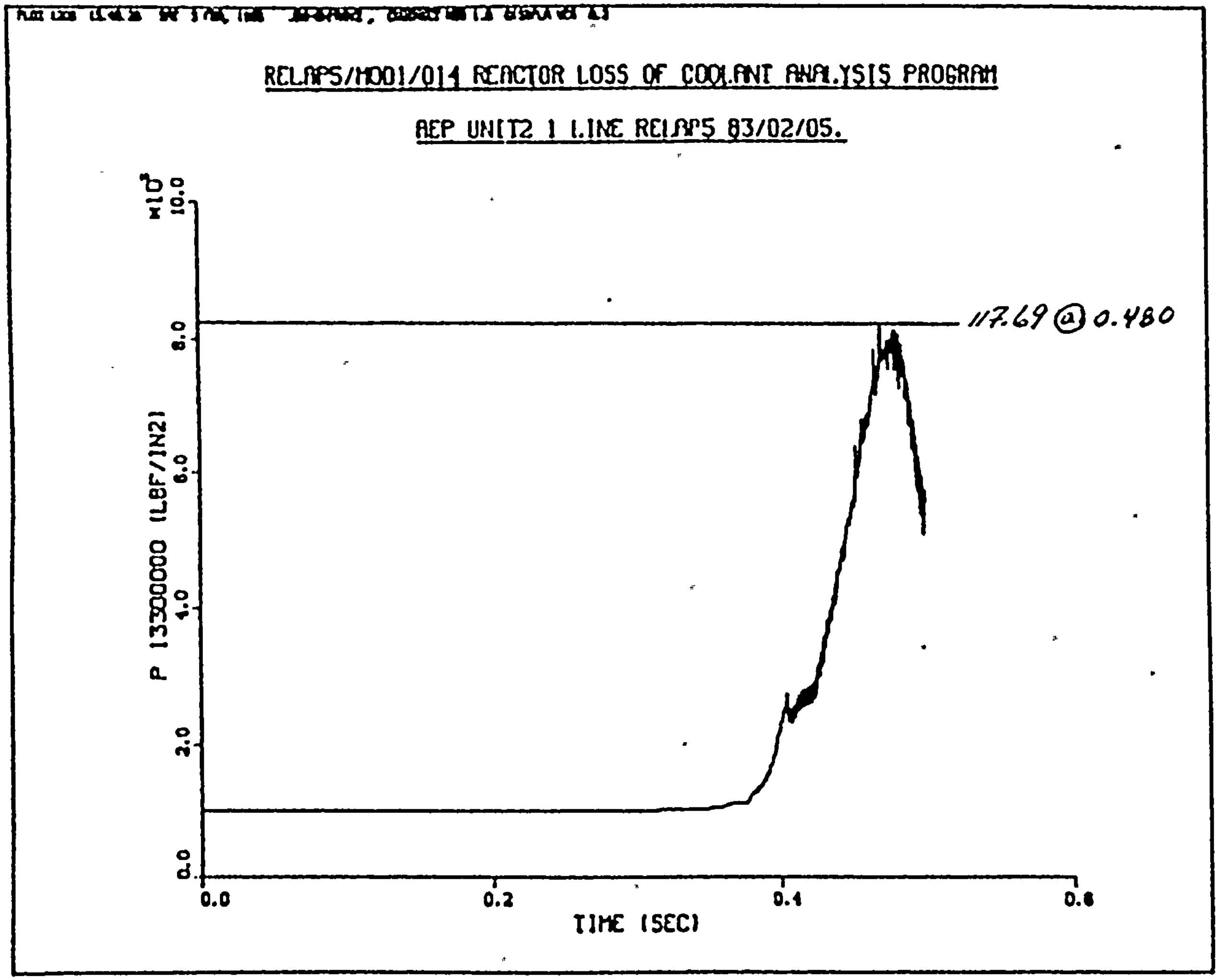

RELAP5/MOD1/014 REACTOR LOSS OF COOLANT ANALYSIS PROGRAM
REP UNIT2 1 LINE RELAP5 83/02/05.
MFLOWJ 140000000 (LB/SEC)
0.0
300.0
600.0
900.0
1200.0
1500.0
TIME (SEC)
0.0
0.2
0.4
0.6
2667.3 ① 0.460



TELEDYNE ENGINEERING SERVICES



TELEDYNE ENGINEERING SERVICES



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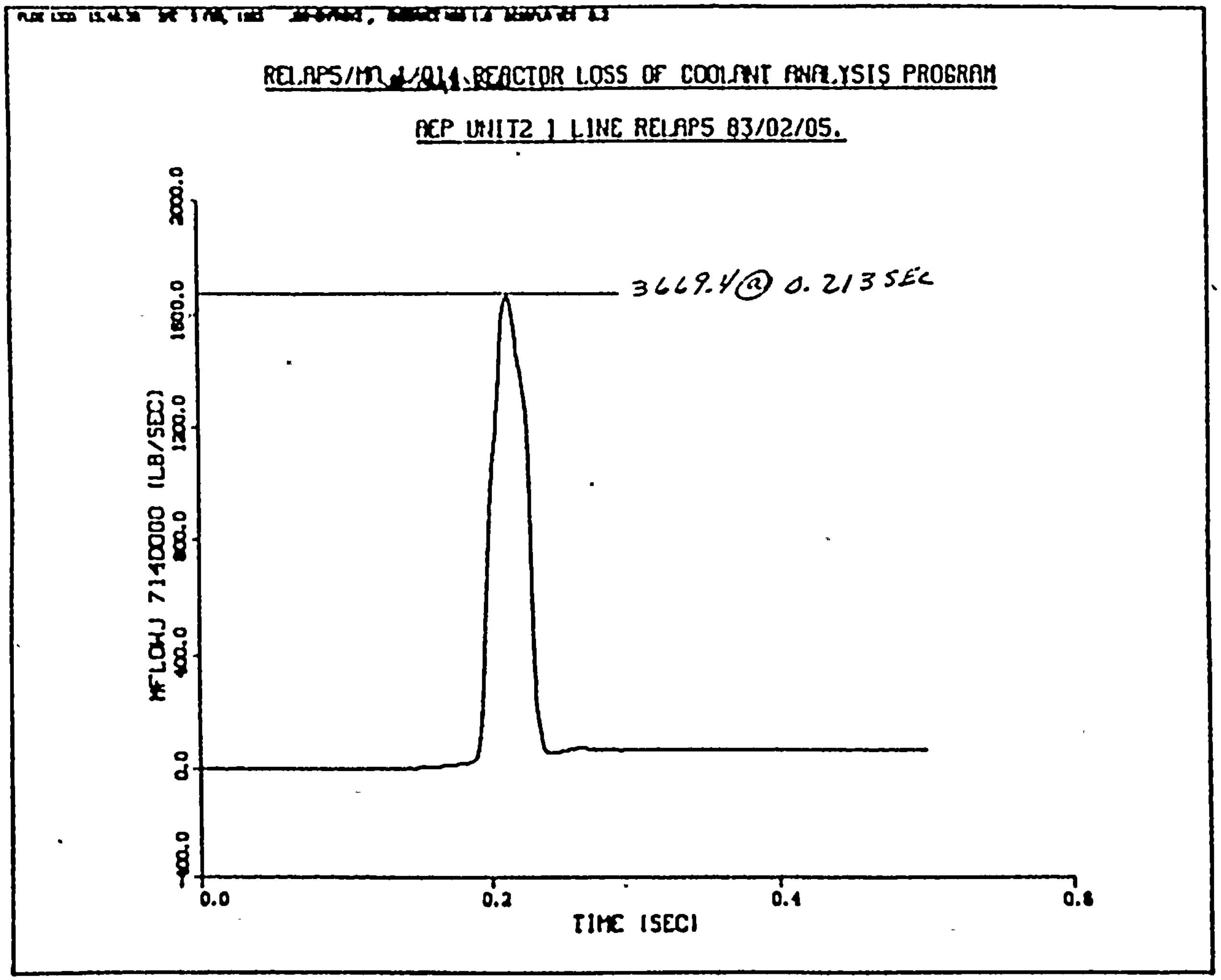
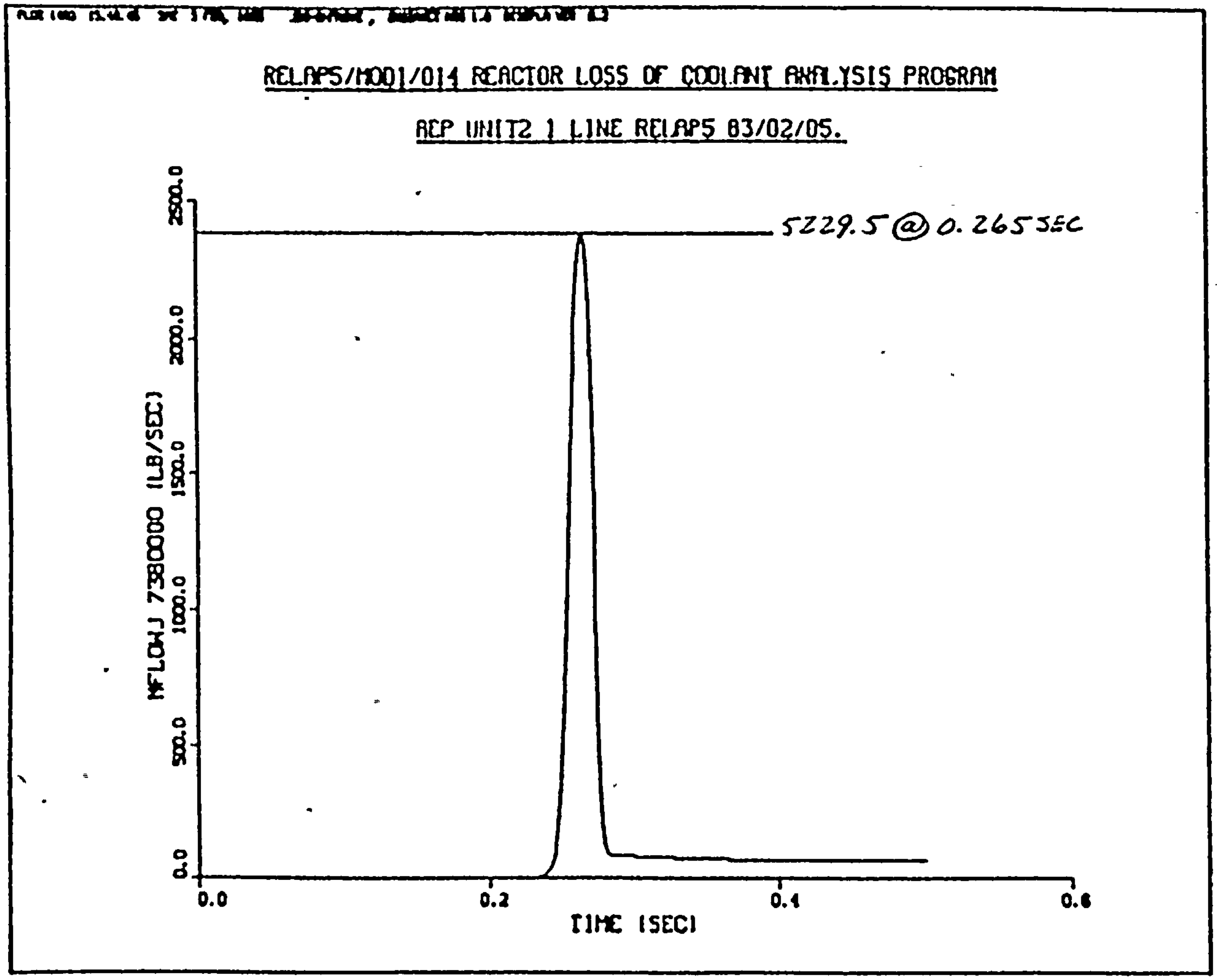
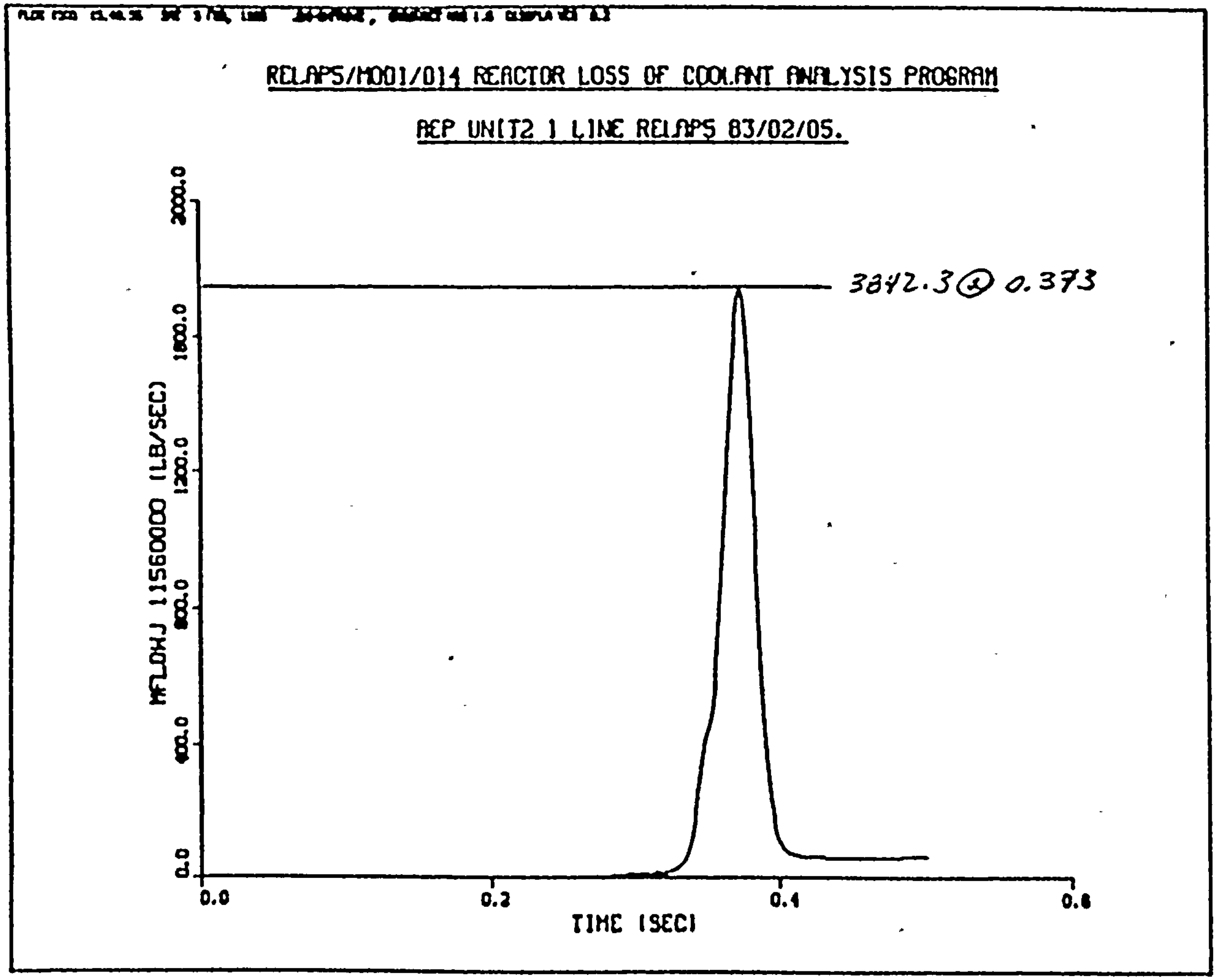
ENGINEERING SERVICES



TELEDYNE ENGINEERING SERVICES



TELEDYNE ENGINEERING SERVICES



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4.8 Force Time History Plots

The following are force versus time plots for each pipe segment at a node point described by the structural model. A drawing indicating force placement precedes each set. Since the force time histories were plotted after balancing and merging(i.e. SAP2SAP and MERGE), each plot is unbalanced force versus time from 0.0 to 0.6 seconds. The problem was run to 0.6 seconds because all significant forces in the area of concern (piping about the PORV's) had diminished in this time.

Unit 2 (PORV)	67 segments
Quarter Model	26 segments

Plot Set	Transient
4.8.1 Unit 2 PORV	400° Solid Liquid Case
4.8.2 Quarter Model	Cold Loop Seal/Steam Case

4.8.1 Unit 2 - 400° Solid Liquid Case

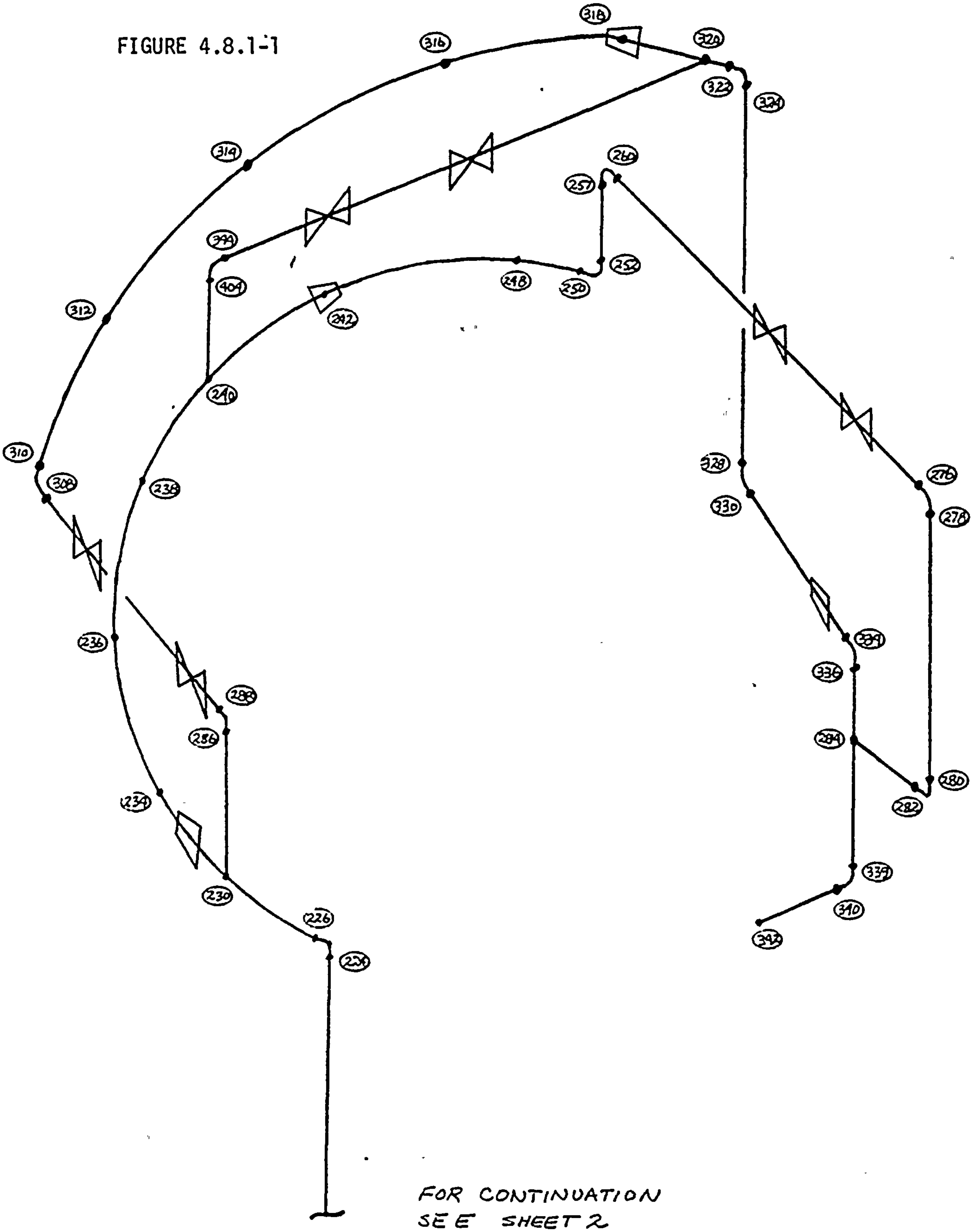
TELEDYNE ENGINEERING SERVICES

BY CJC DATE 3-11-83
CHKD. BY CHM DATE 3-11-83

UNIT 2 STRUCTURAL NODE POINTS
PORV SECTION

SHEET NO. 1 OF 3
PROJ. NO. 5364

FIGURE 4.8.1-1



FOR CONTINUATION
SEE SHEET 2

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CHKD. BY CMM DATE 3-11-83

UNIT 2 STRUCTURAL NODE POINTS
SRV SECTION

PROJ. NO. 5364

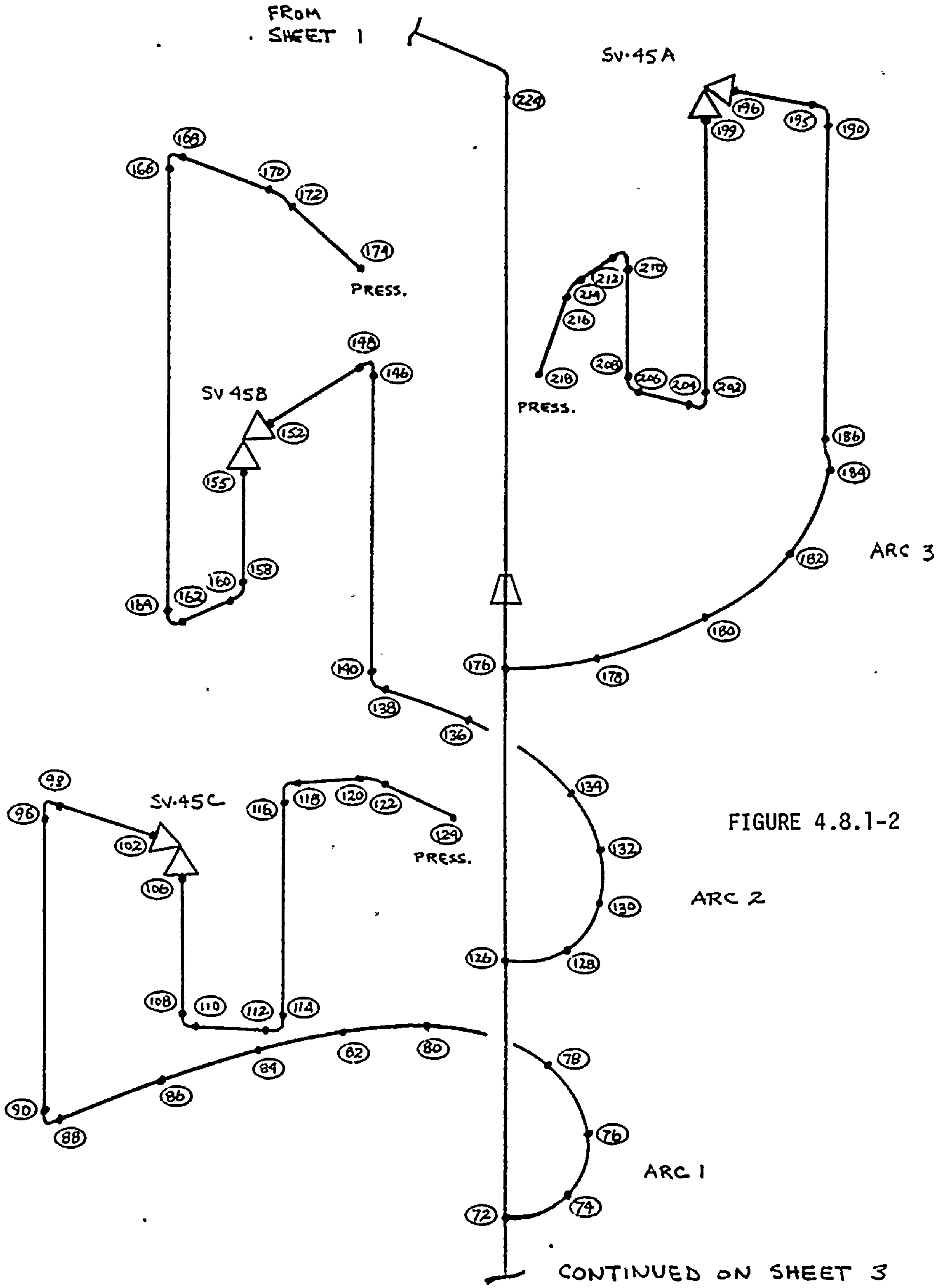

FIGURE 4.8.1-2

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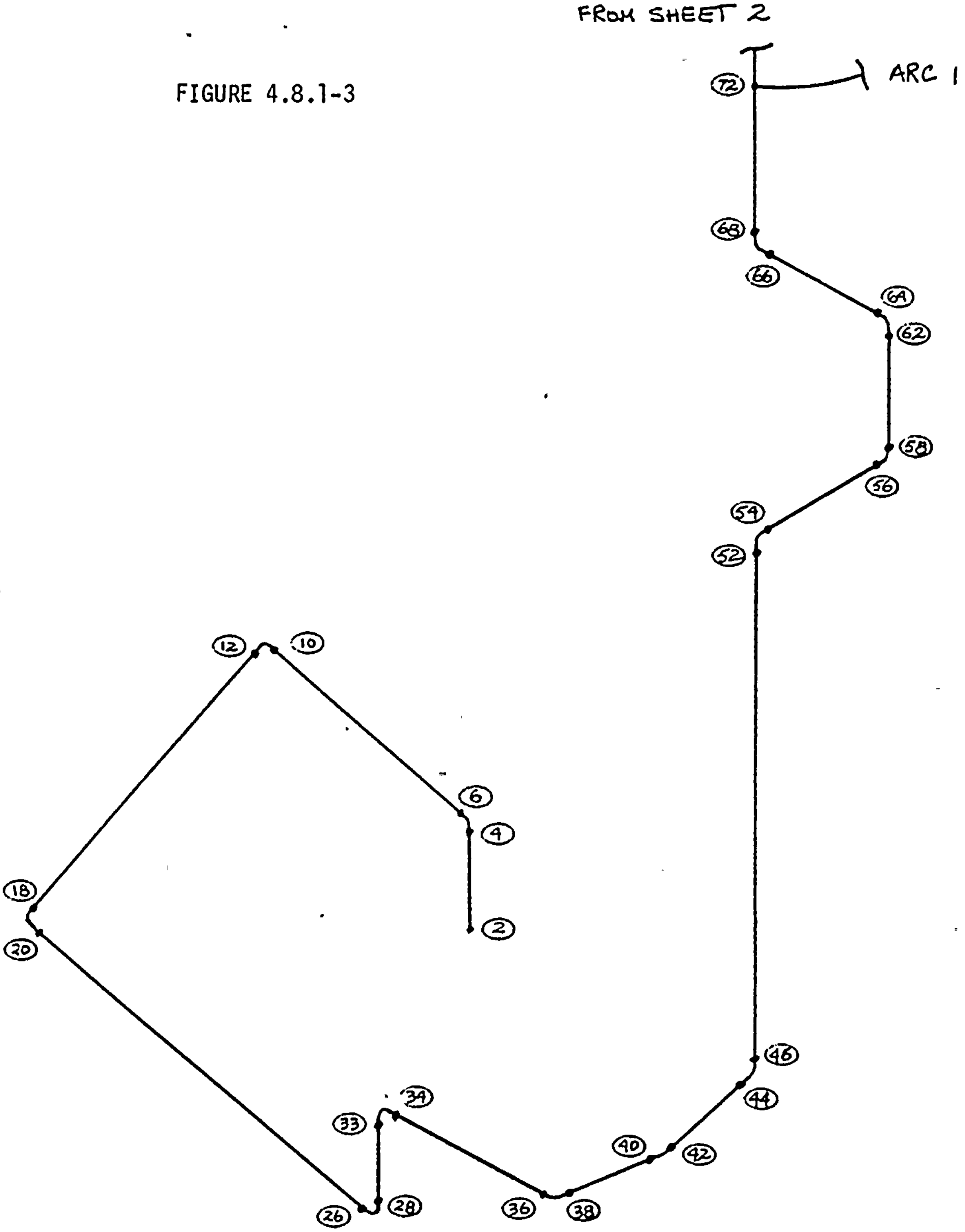
CHKD. BY CMM DATE 3-11-83

UNIT 2 STRUCTURAL NODE POINTS
12" DWNSTRM. SECTION

SHEET NO. 3 OF 3
PROJ. NO. 5364

FIGURE 4.8.1-3



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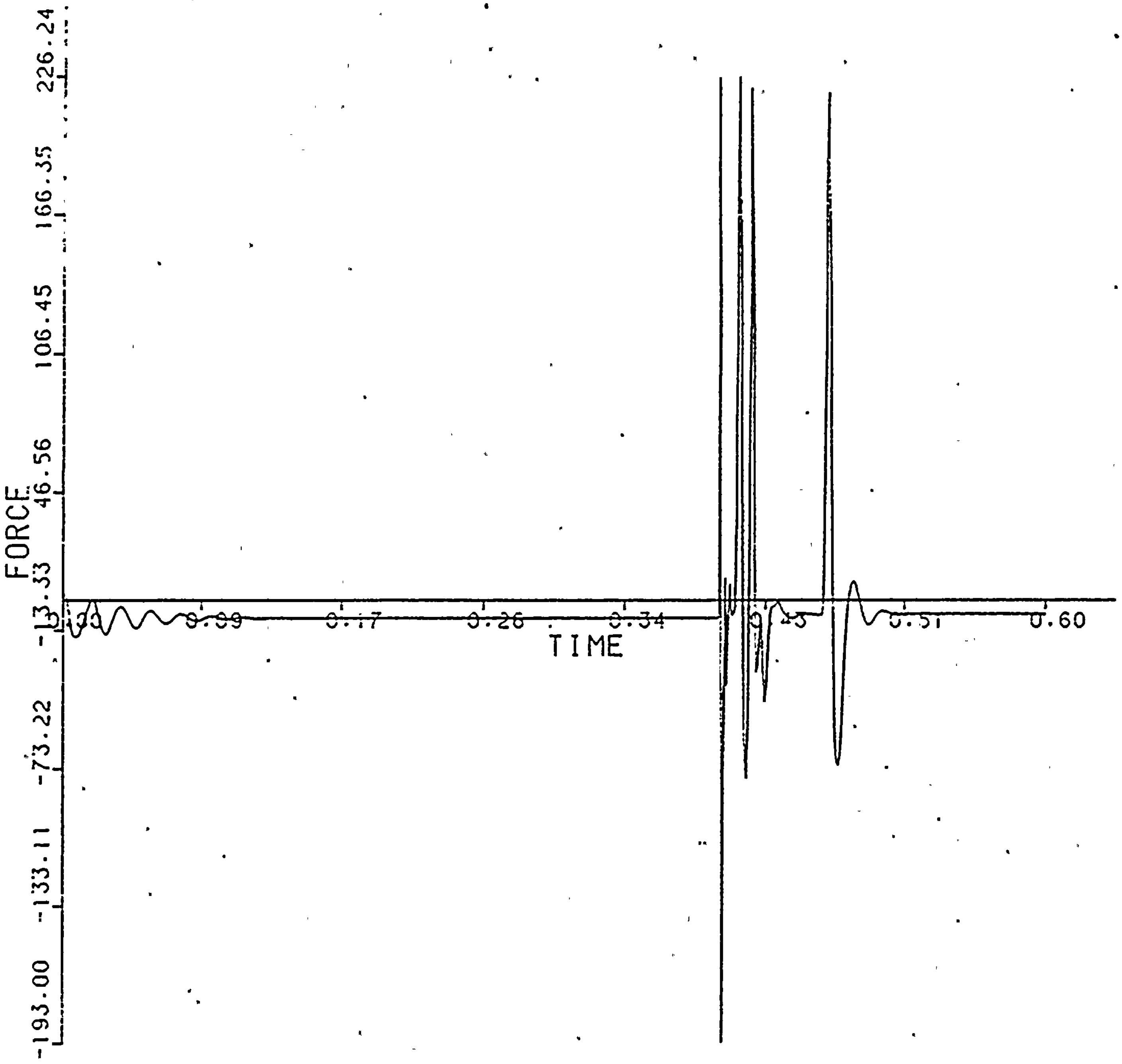
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 1. MAGNITUDE AT NODE POINT 340



BY MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

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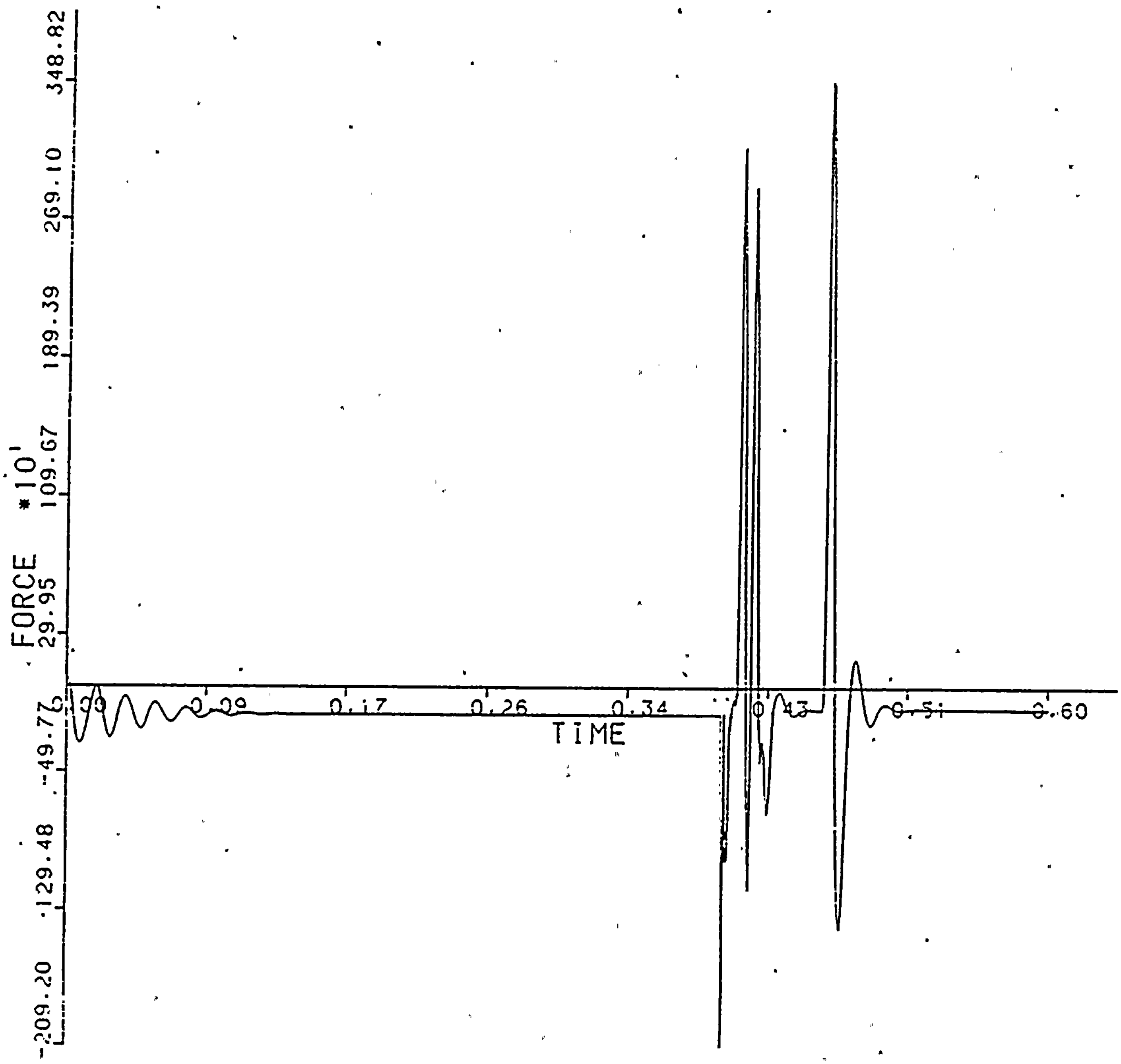
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 2, MAGNITUDE AT NODE POINT 338



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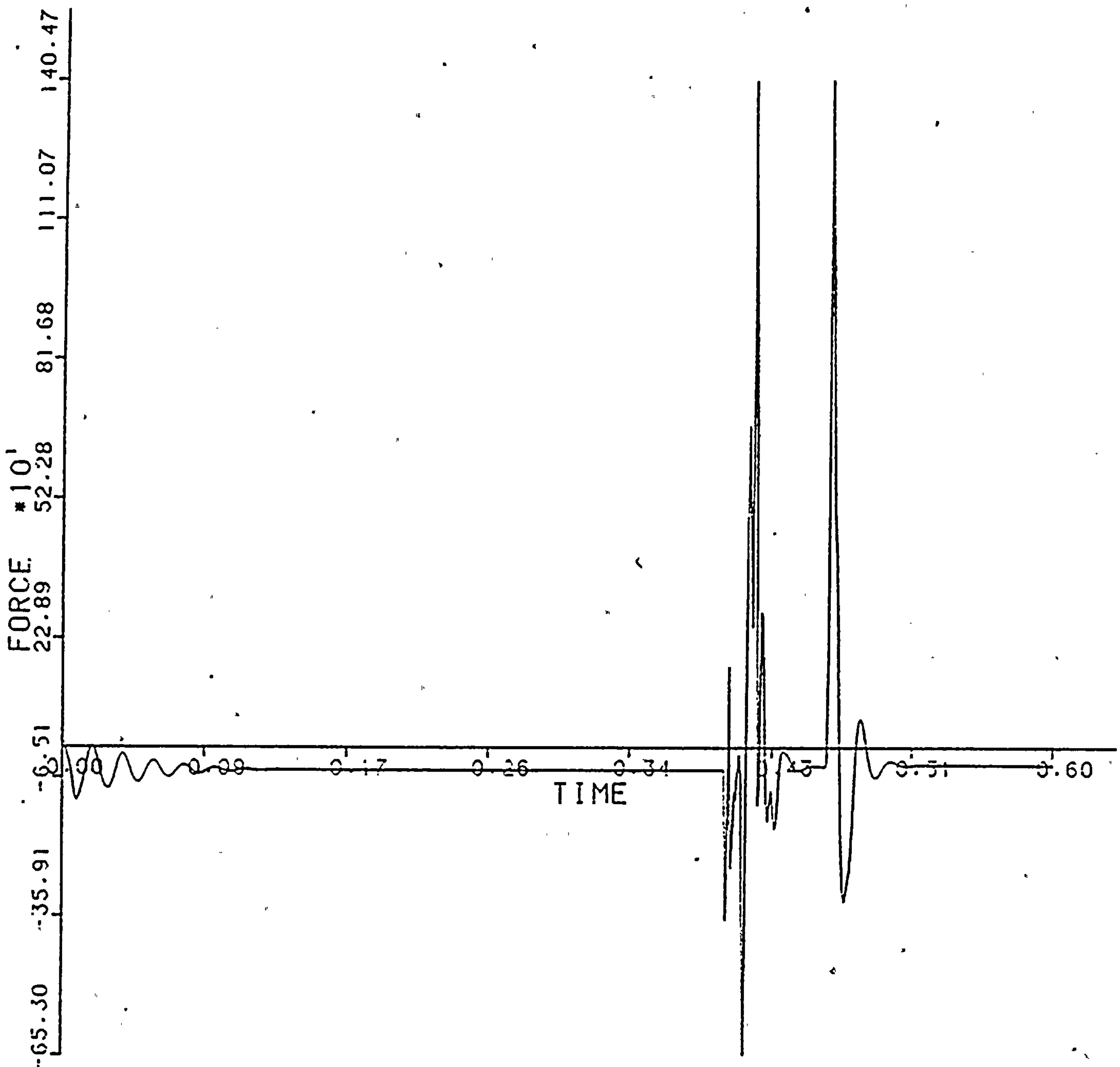
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 3. MAGNITUDE AT NODE POINT 332



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CHKD. BY KJG DATE 6-7-83

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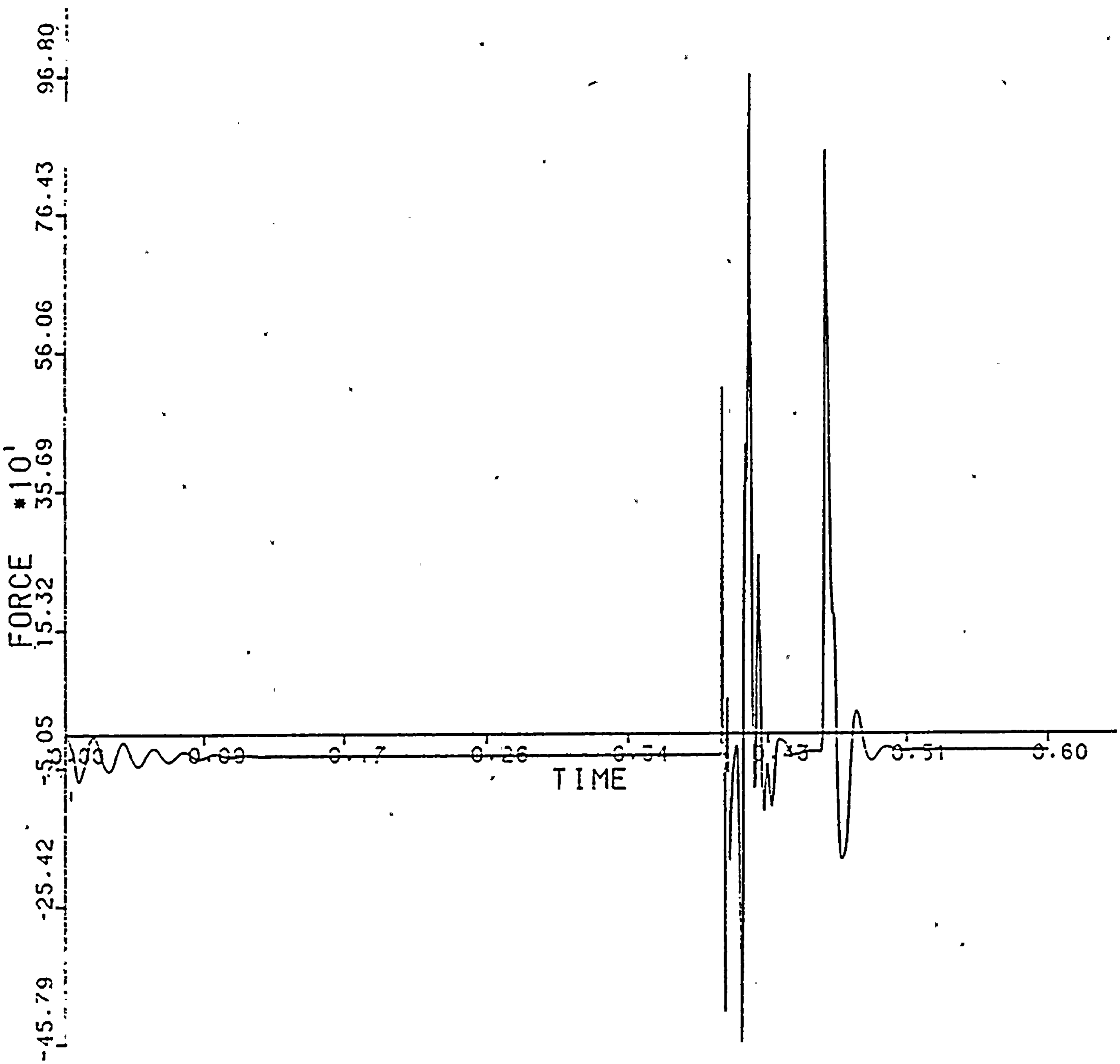
ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 4, MAGNITUDE AT NODE POINT 326



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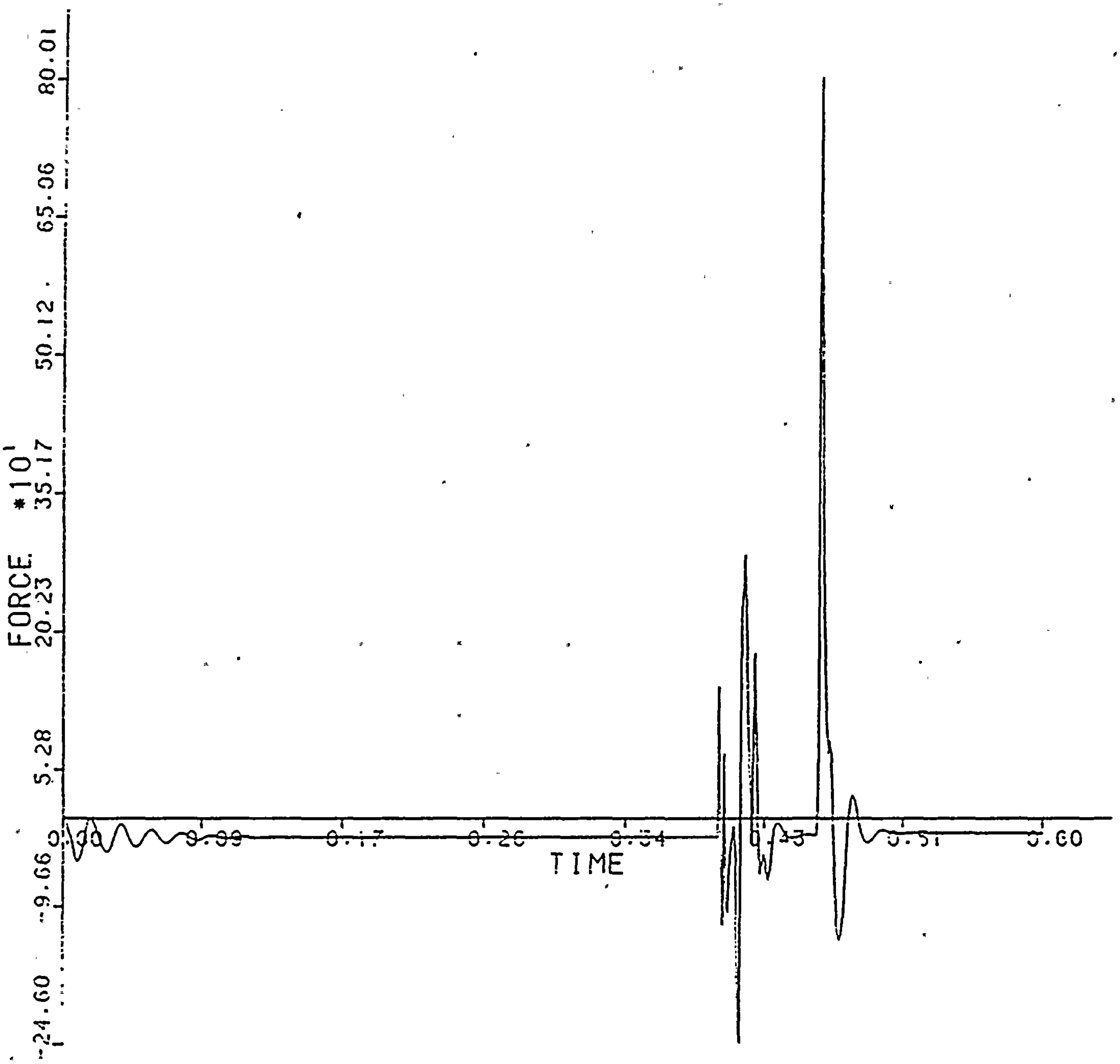
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 5, MAGNITUDE AT NODE POINT 320



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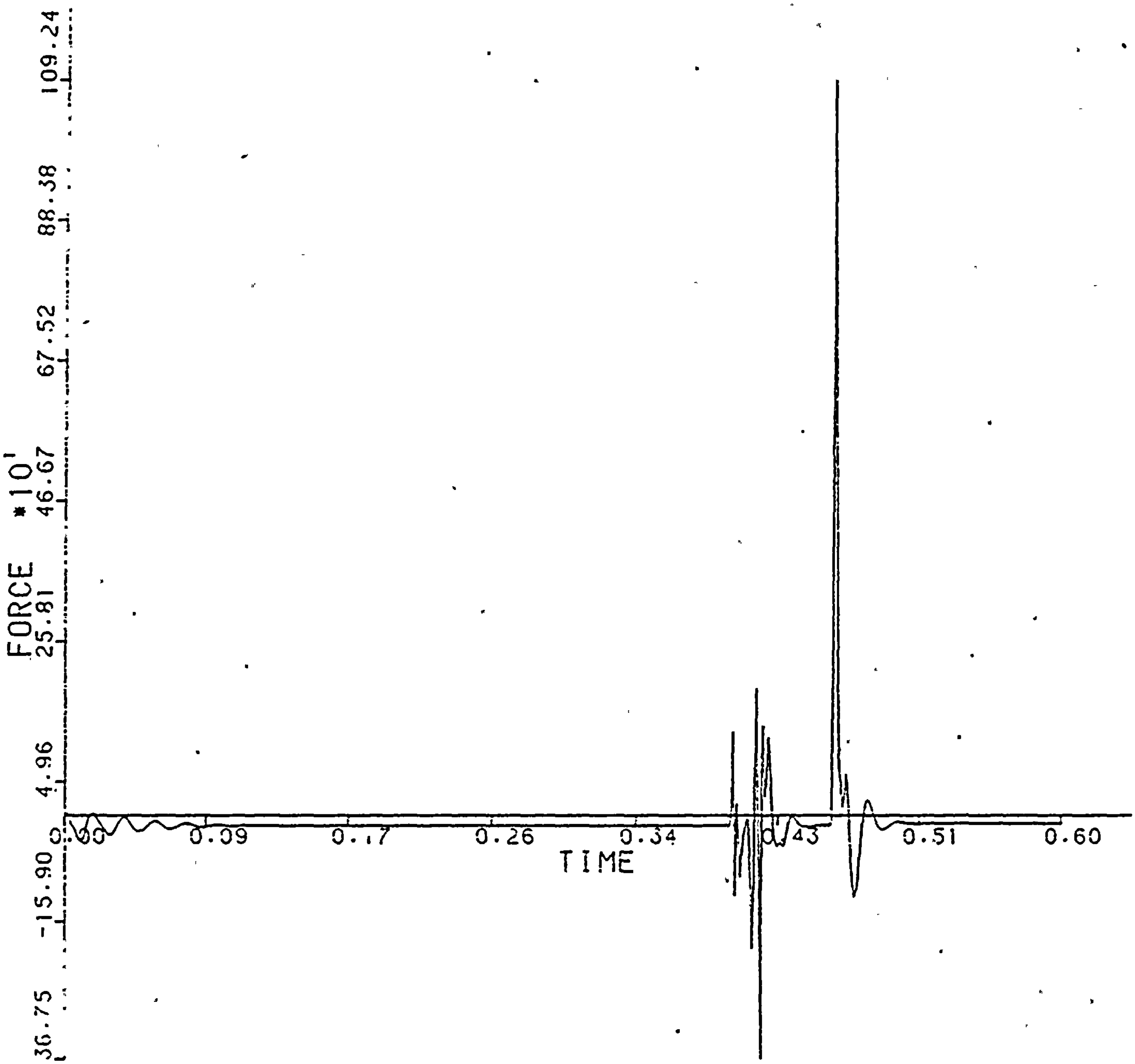
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 6, MAGNITUDE AT NODE POINT 316



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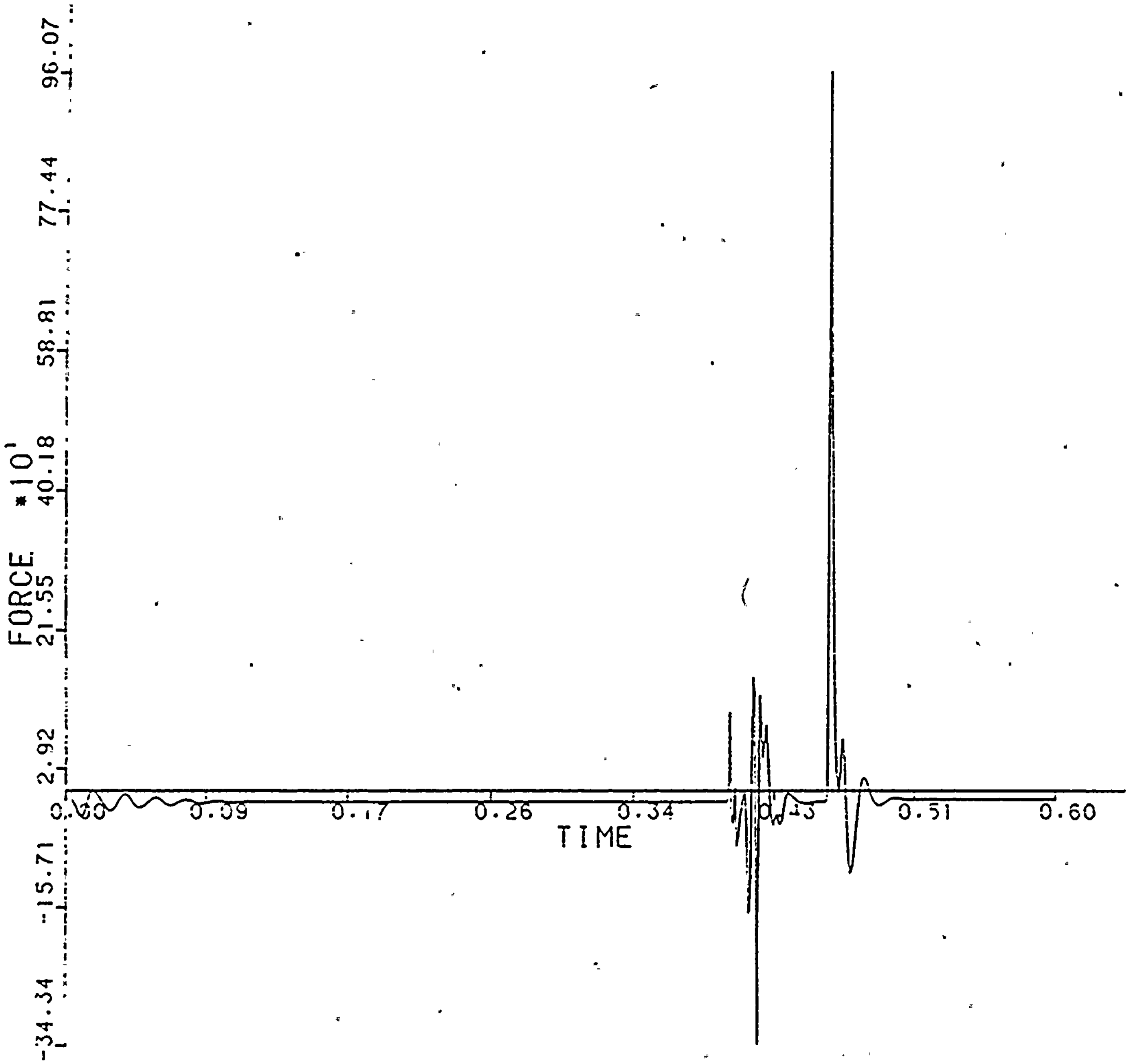
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 7, MAGNITUDE AT NODE POINT 314



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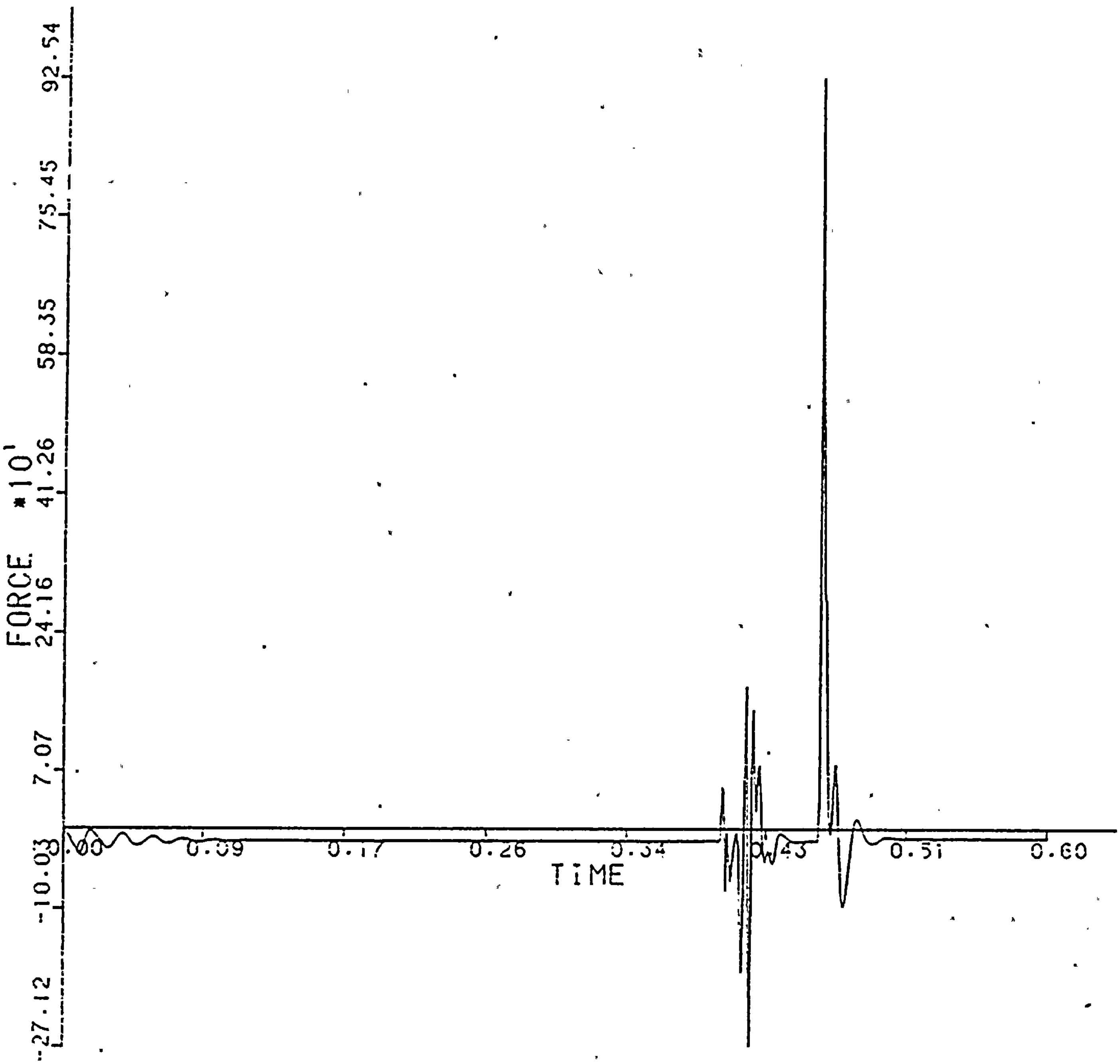
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 8, MAGNITUDE AT NODE POINT 3:2



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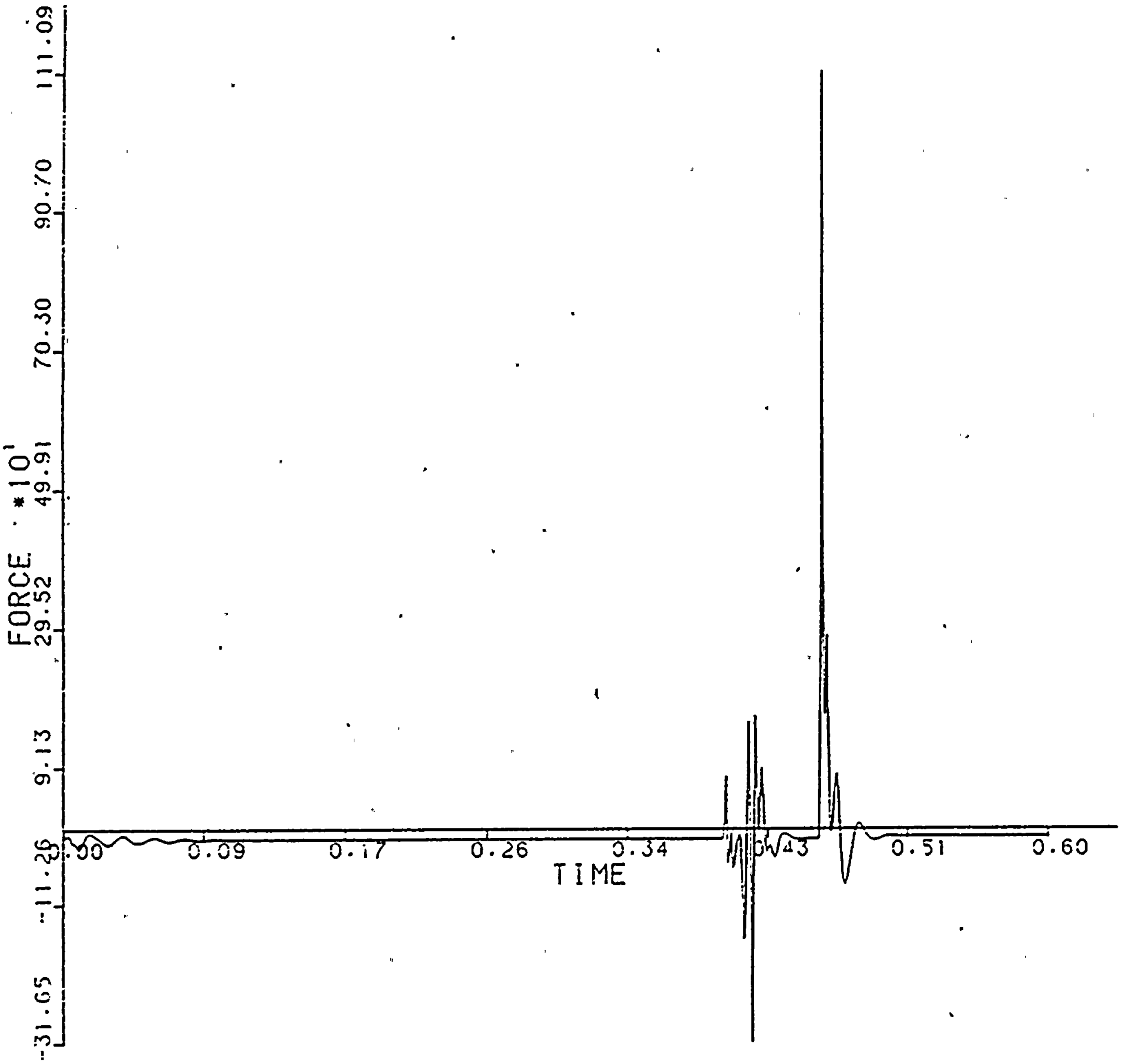
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 9. MAGNITUDE AT NODE POINT 310



BY MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

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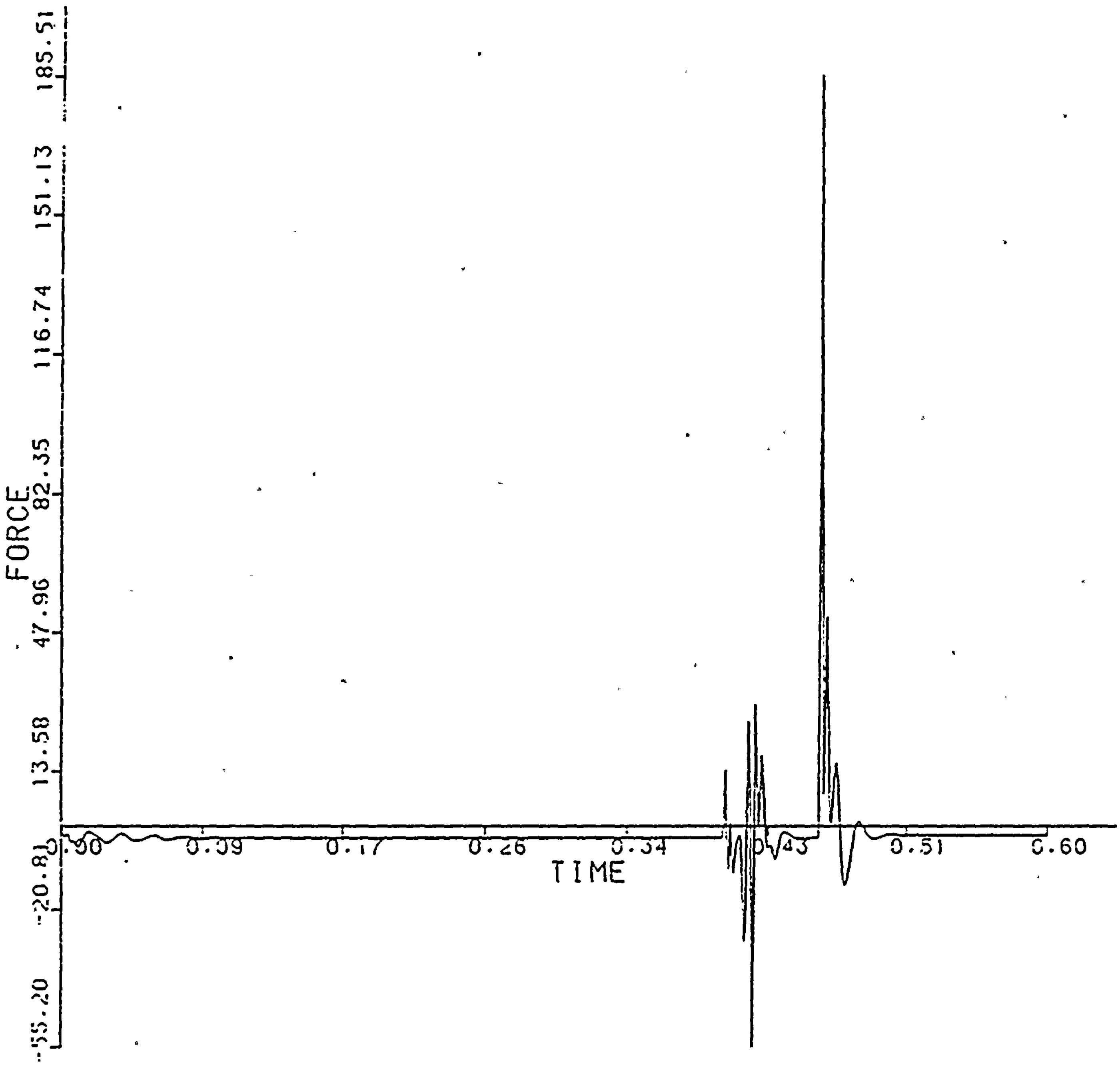
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 10. MAGNITUDE AT NODE POINT 308



BY MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

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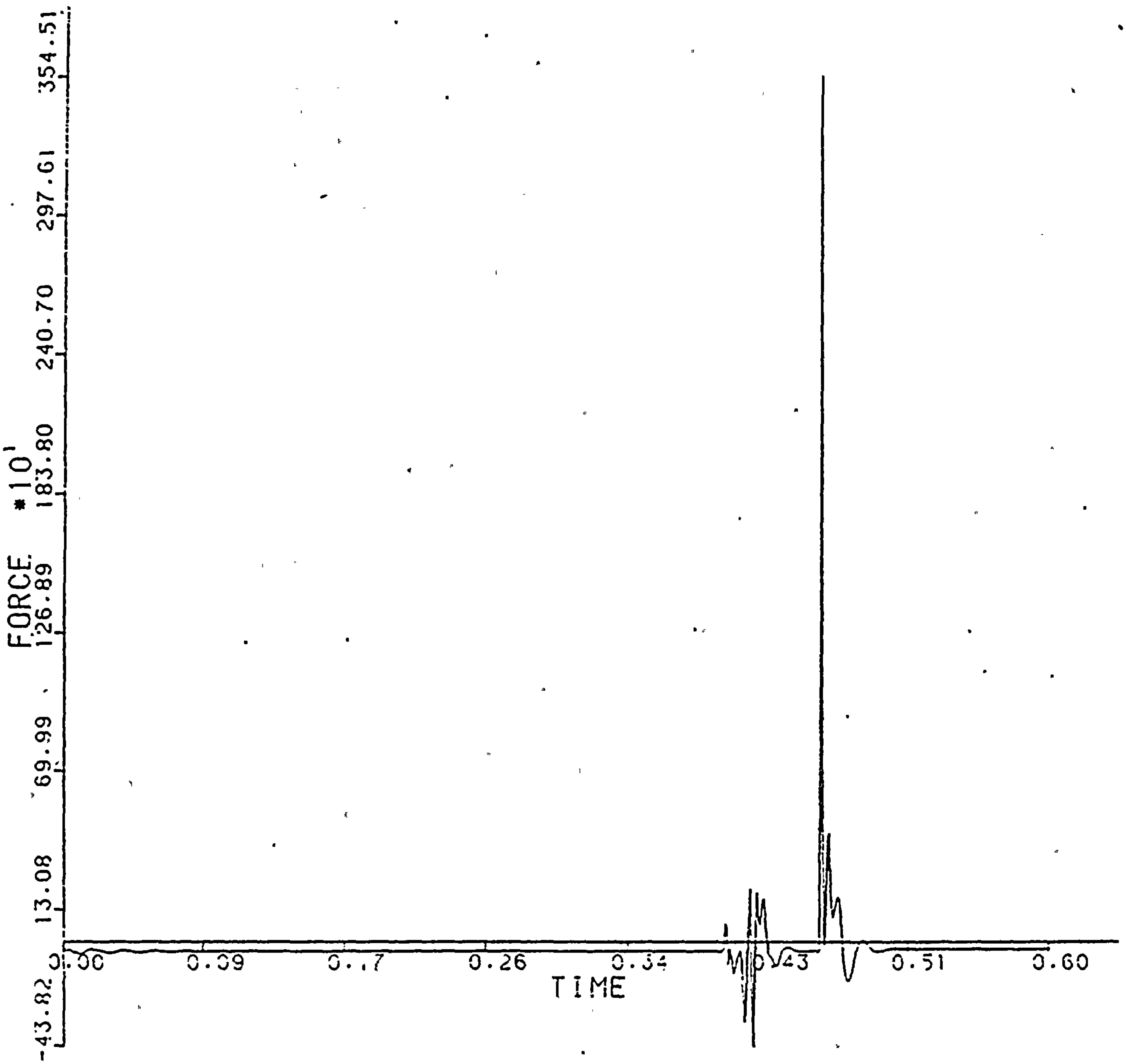
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 11, MAGNITUDE AT NODE POINT 298



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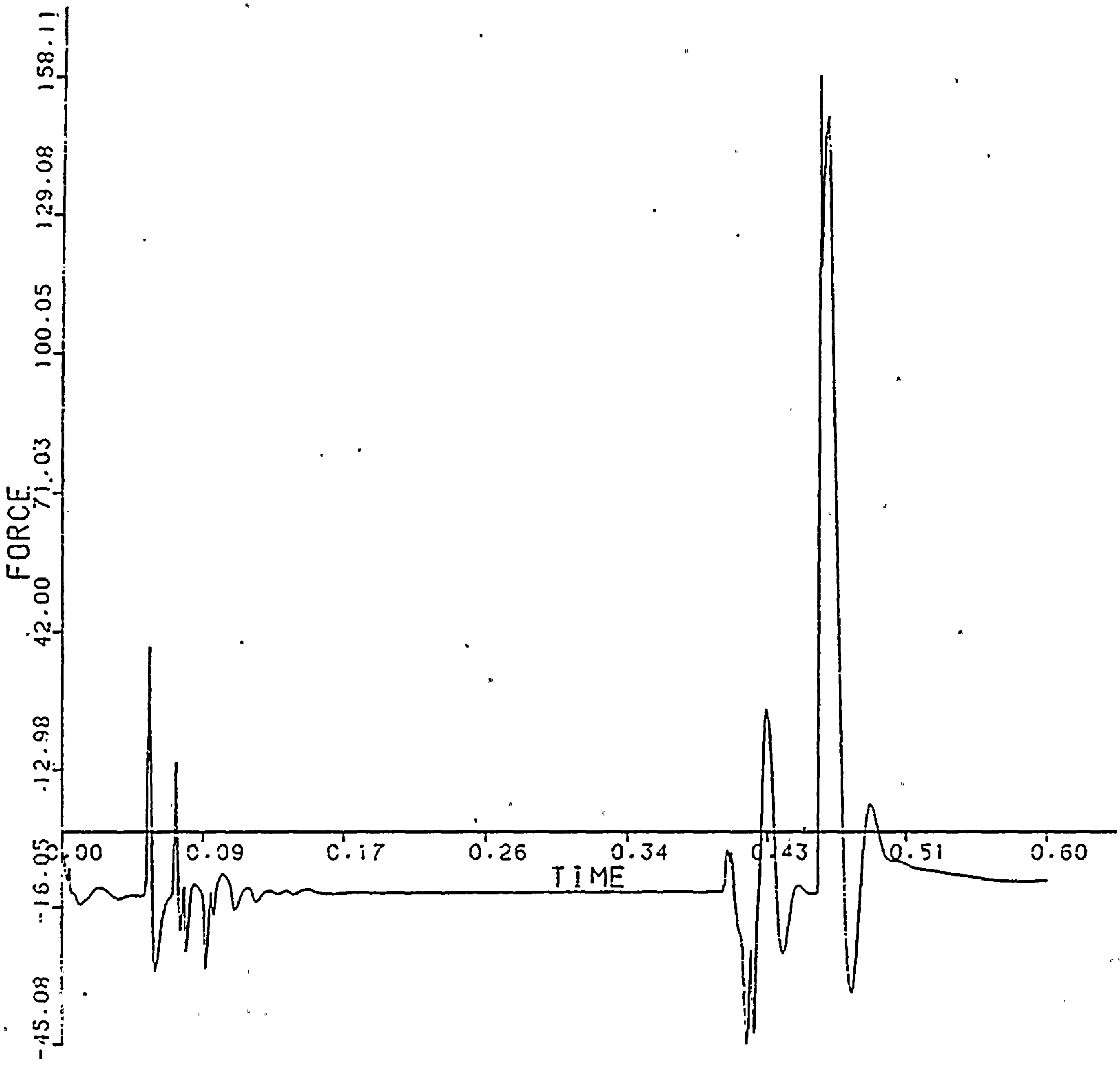
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 12, MAGNITUDE AT NODE POINT 290



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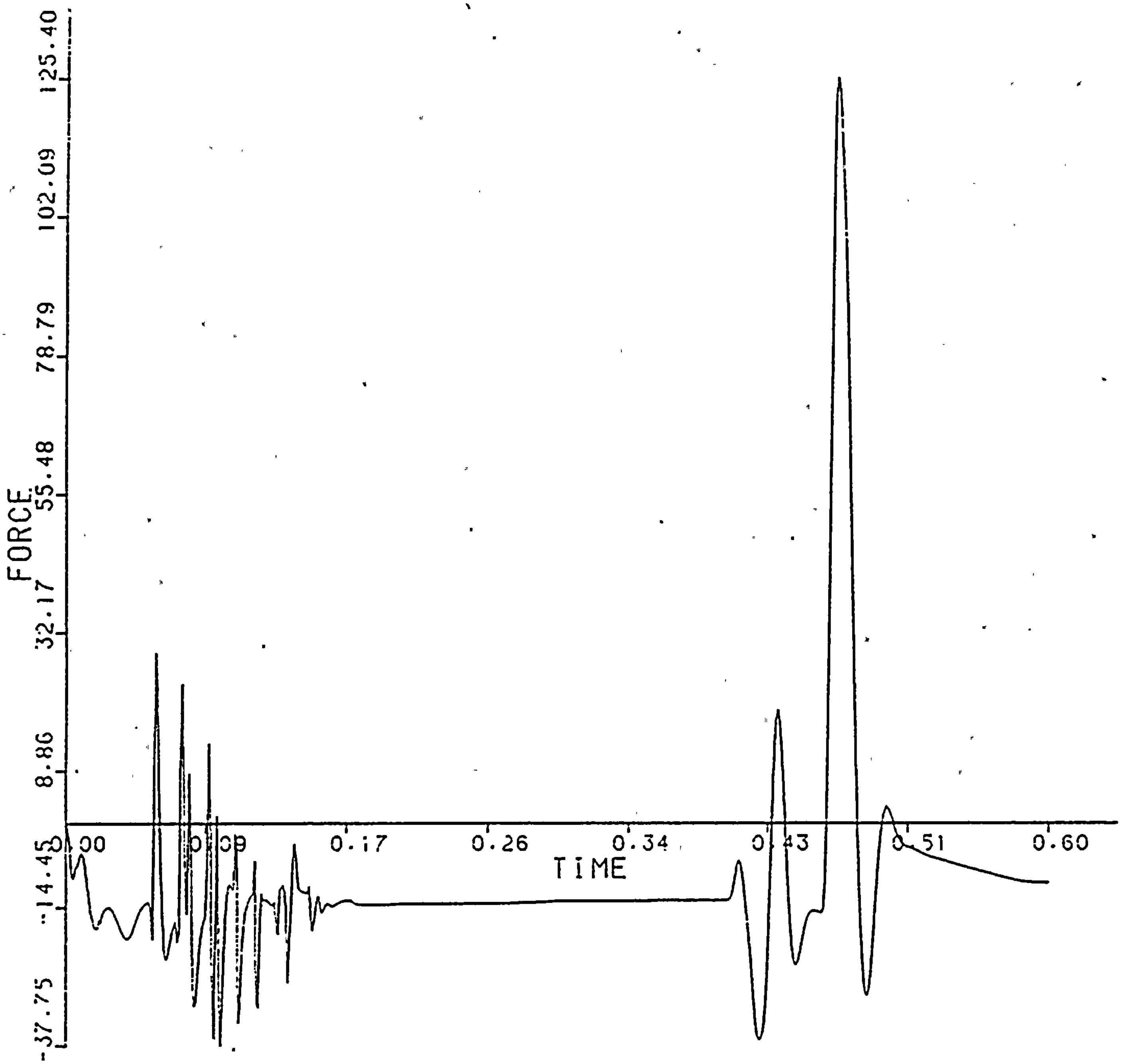
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 13. MAGNITUDE AT NODE POINT 286



BY *MR* DATE *6-2-83*
CHKD. BY *KJG* DATE *6-7-83*

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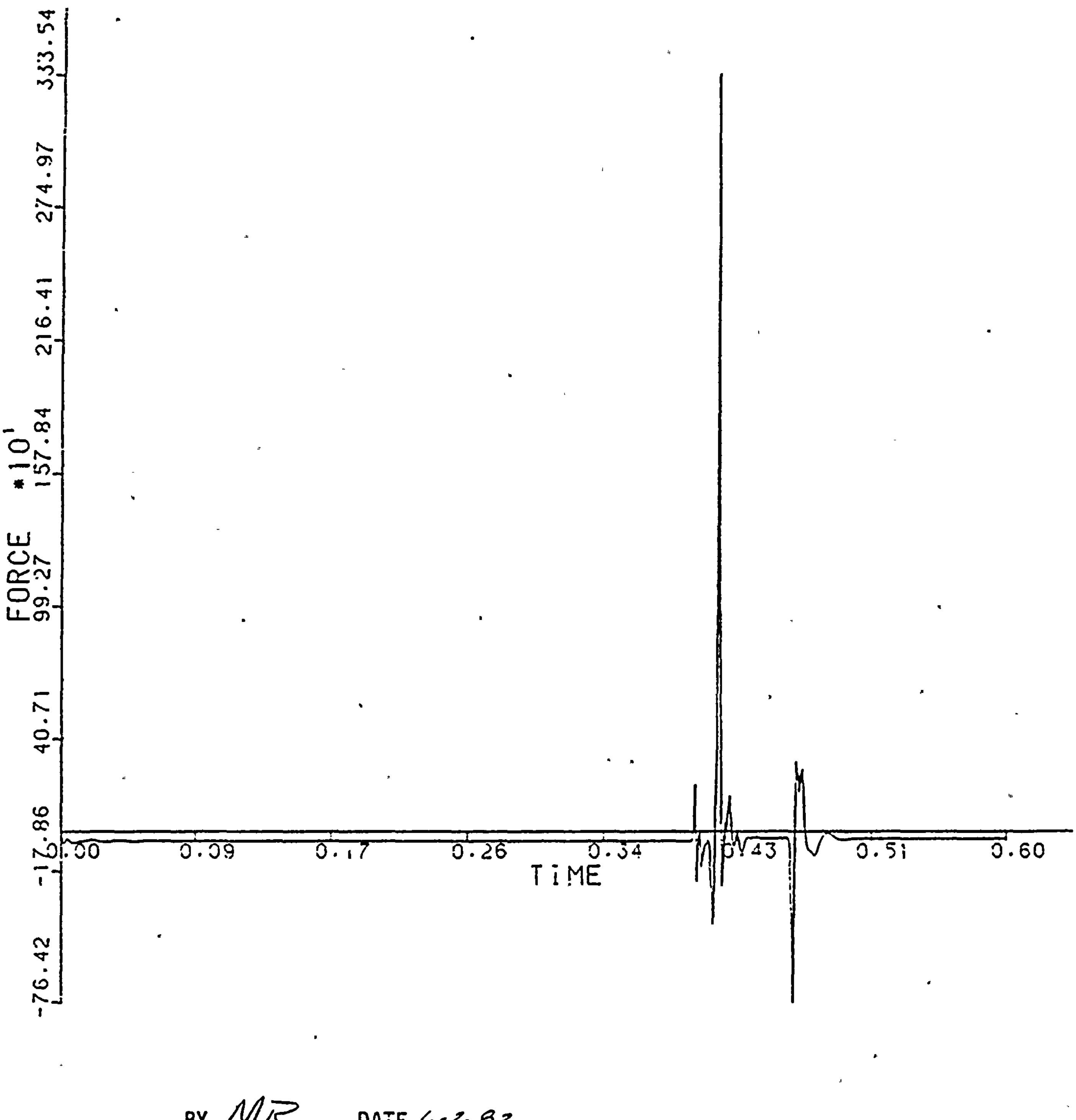
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 14. MAGNITUDE AT NODE POINT 352



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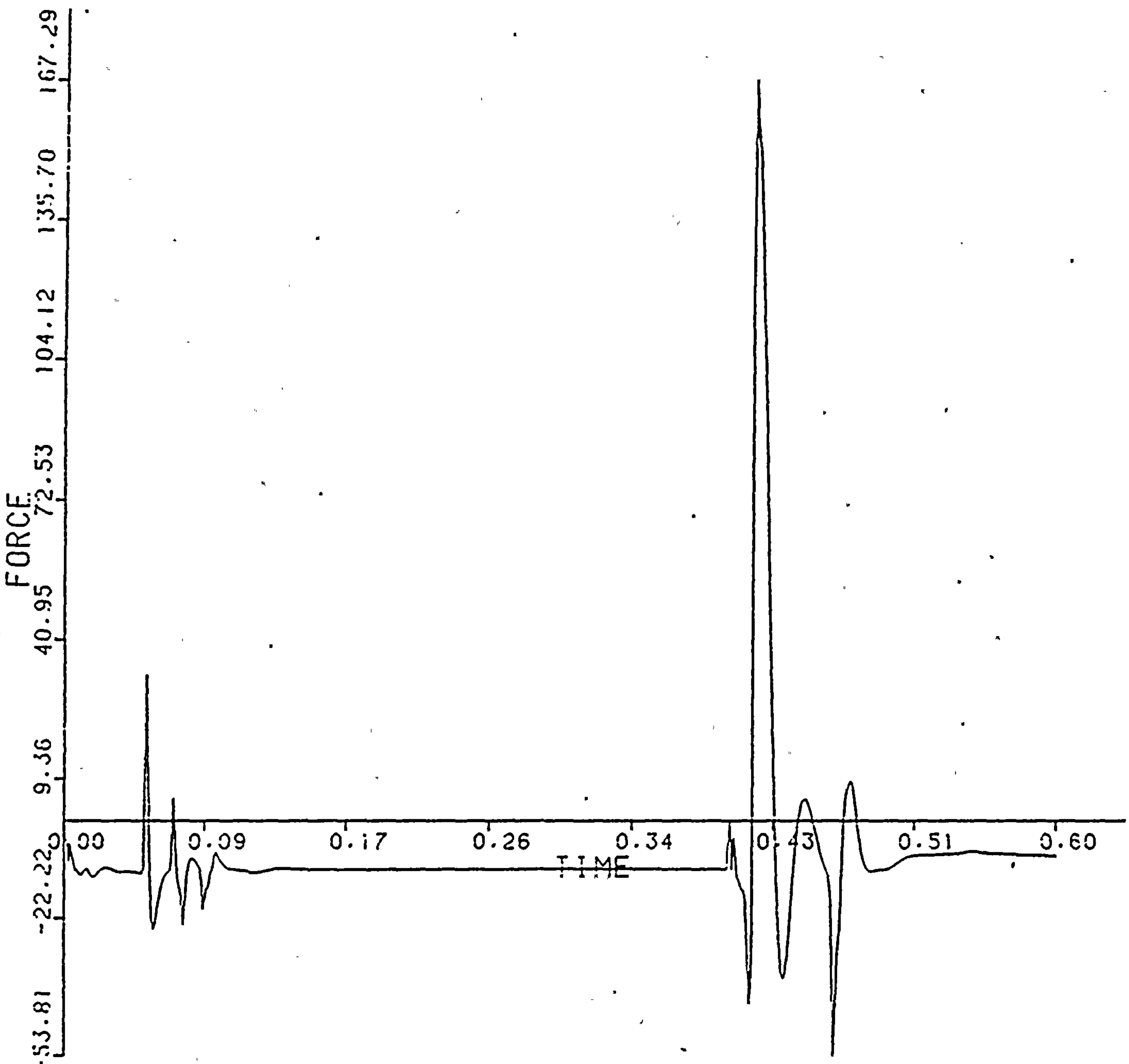
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 15, MAGNITUDE AT NODE POINT 344



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CHKD. BY KJG DATE 6-7-83

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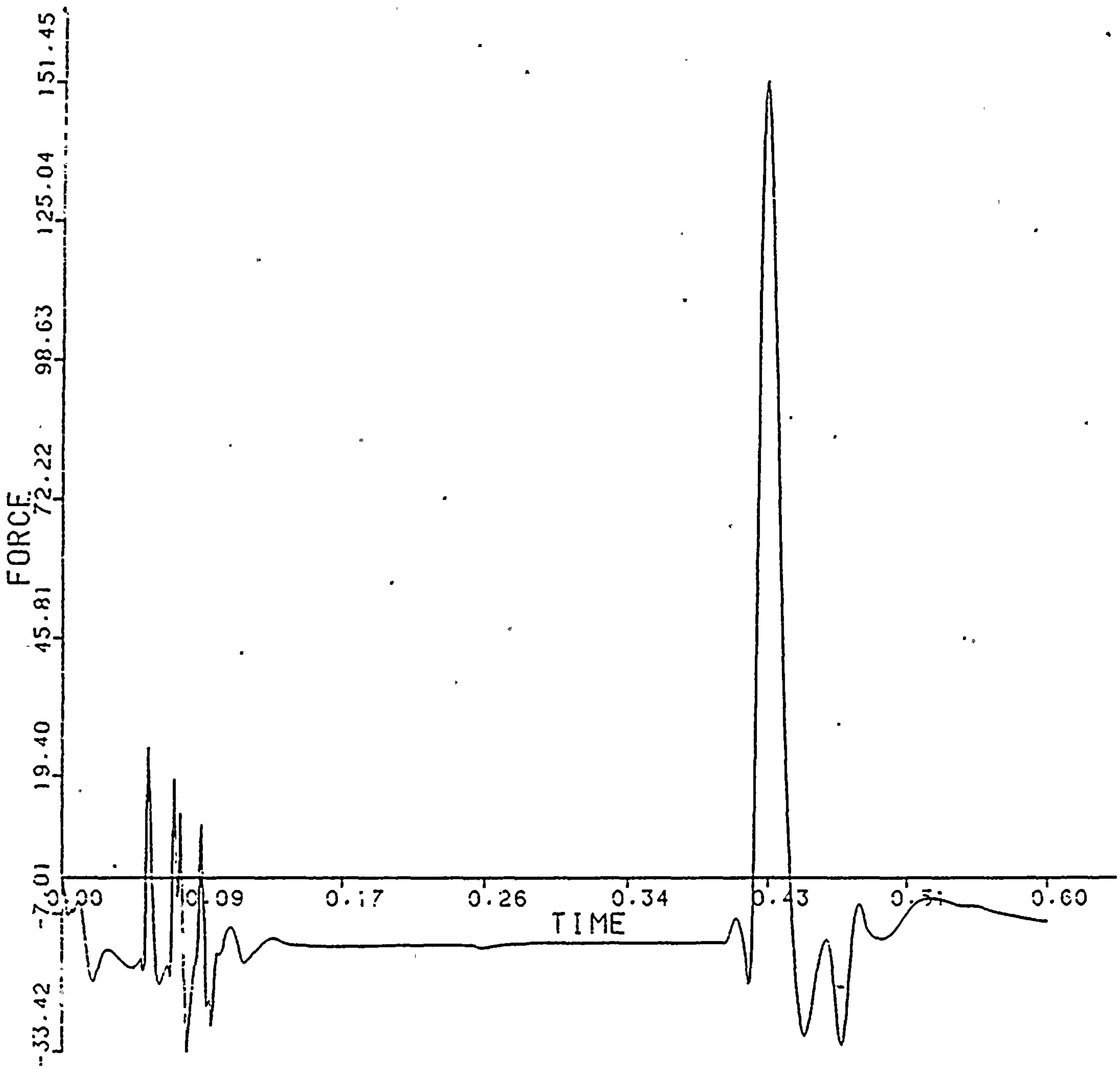
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 16, MAGNITUDE AT NODE POINT 240



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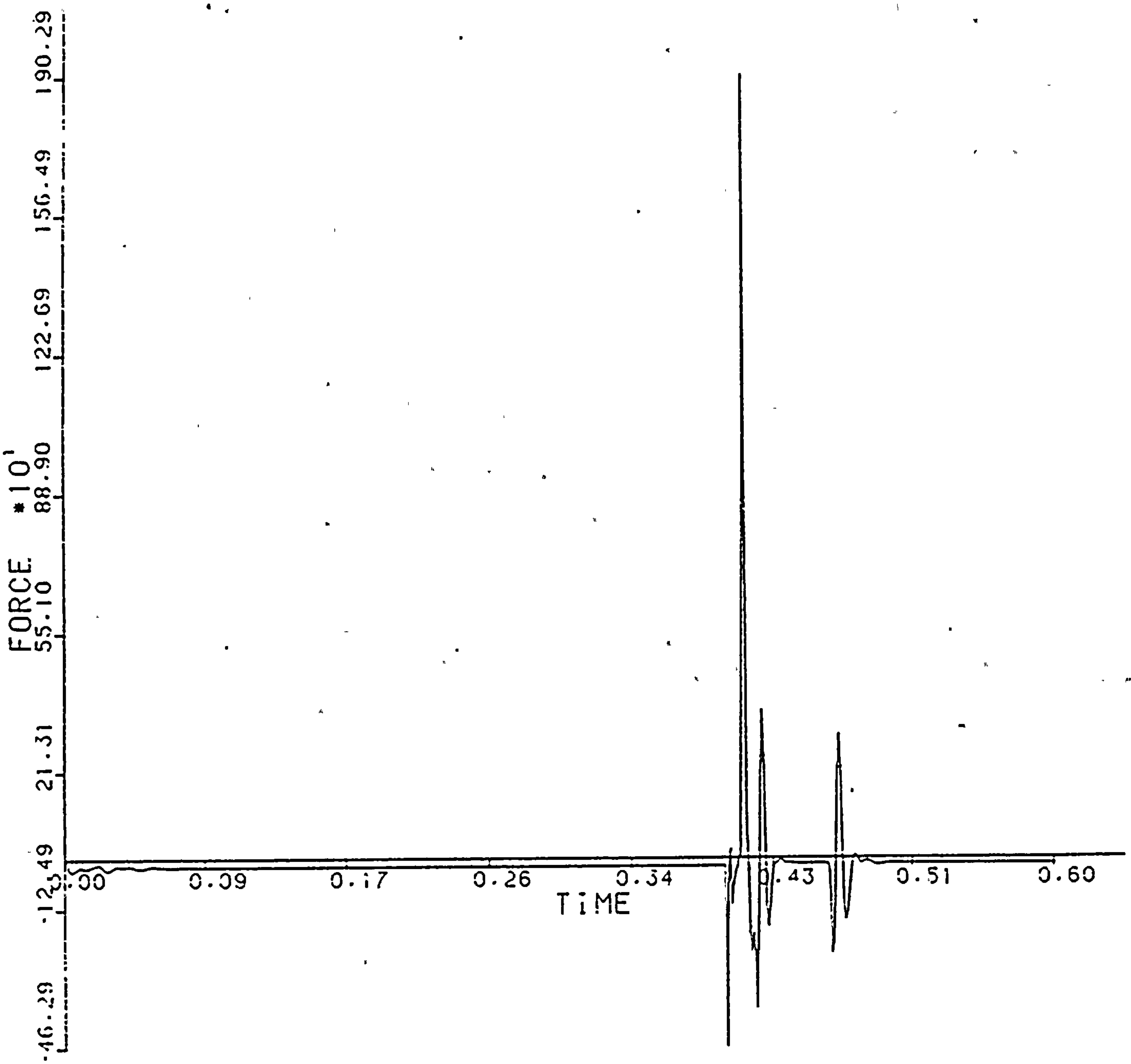
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 17, MAGNITUDE AT NODE POINT 282



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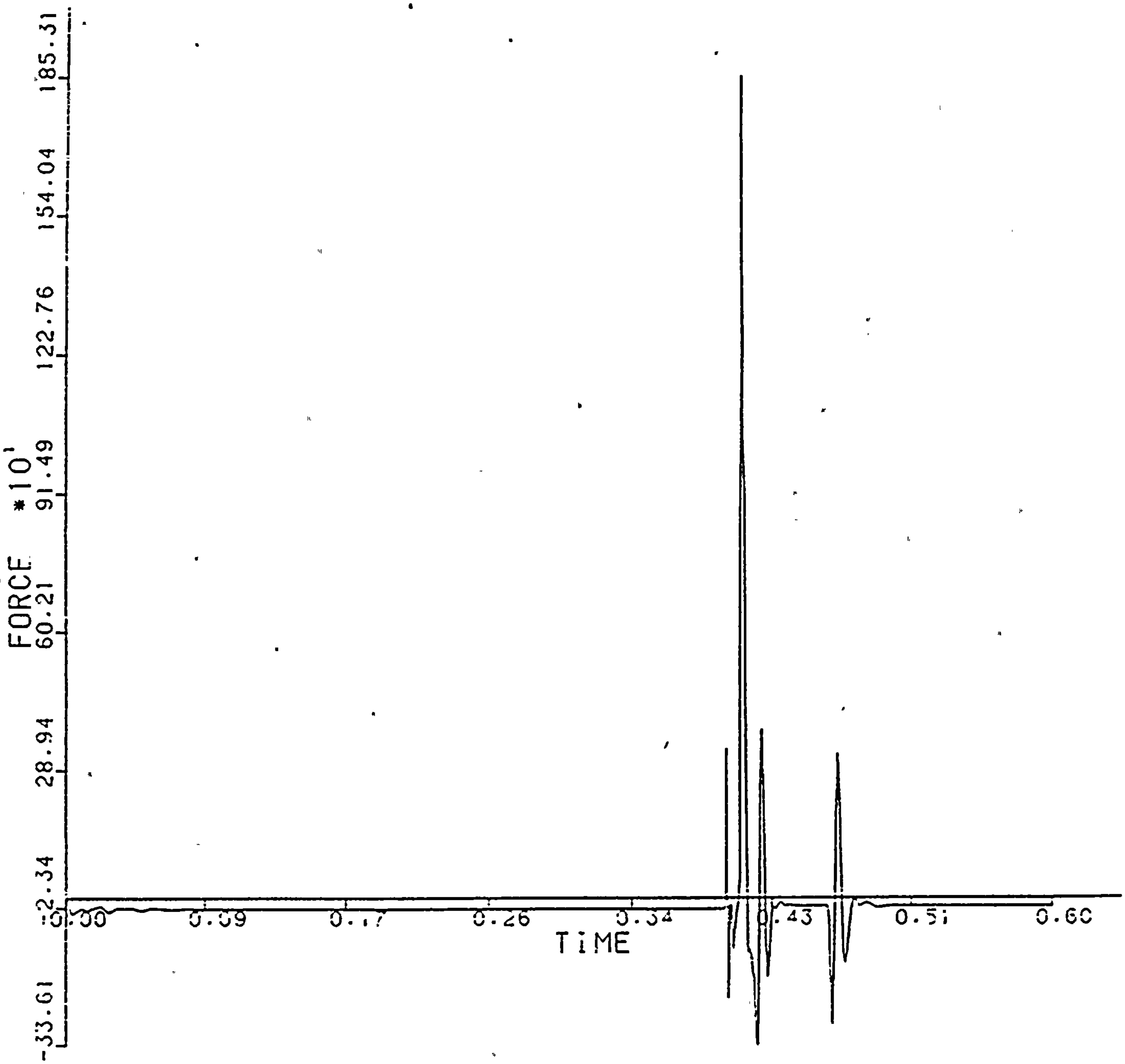
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 18. MAGNITUDE AT NODE POINT 280



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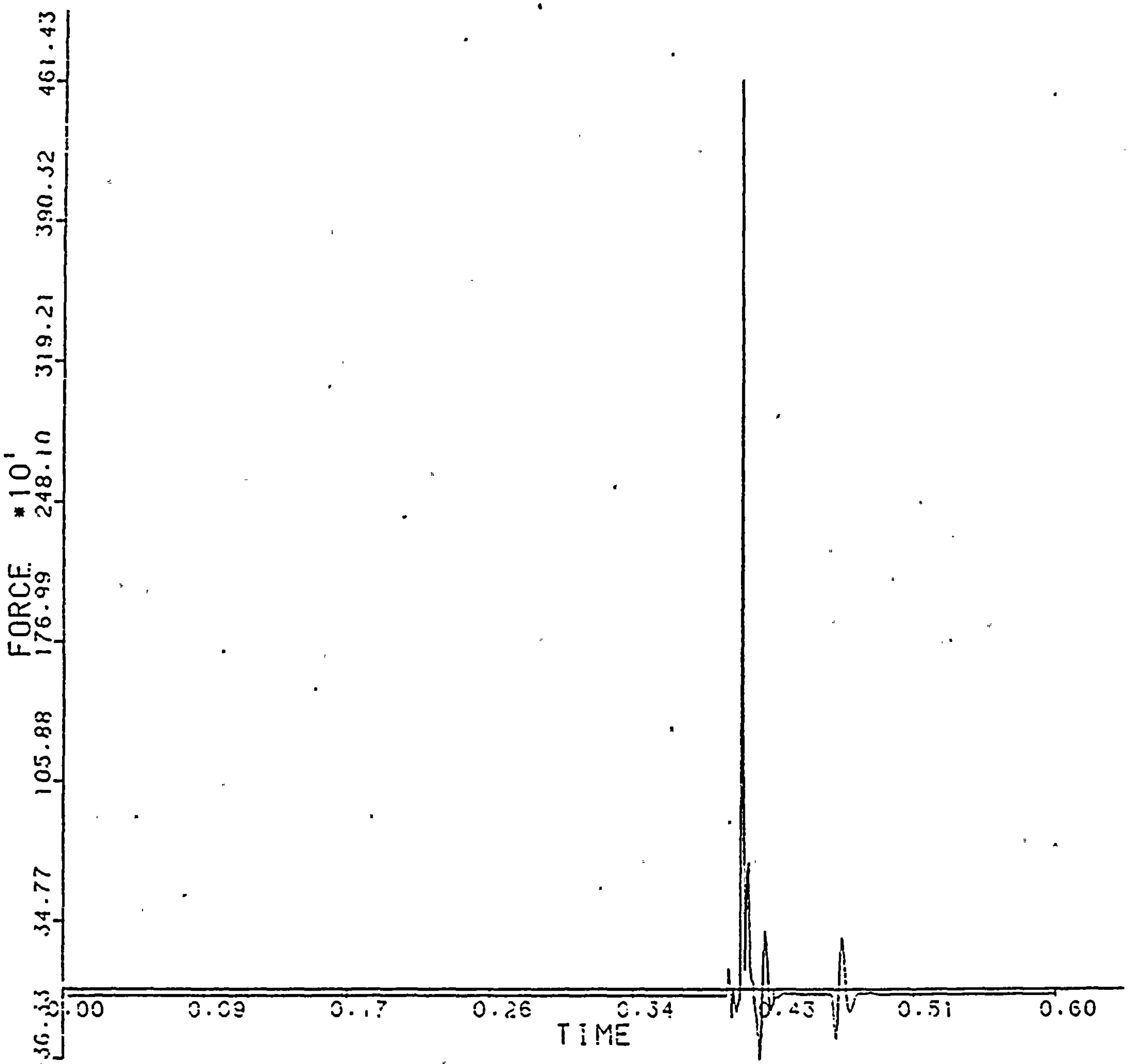
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 19, MAGNITUDE AT NODE POINT 272



BY MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

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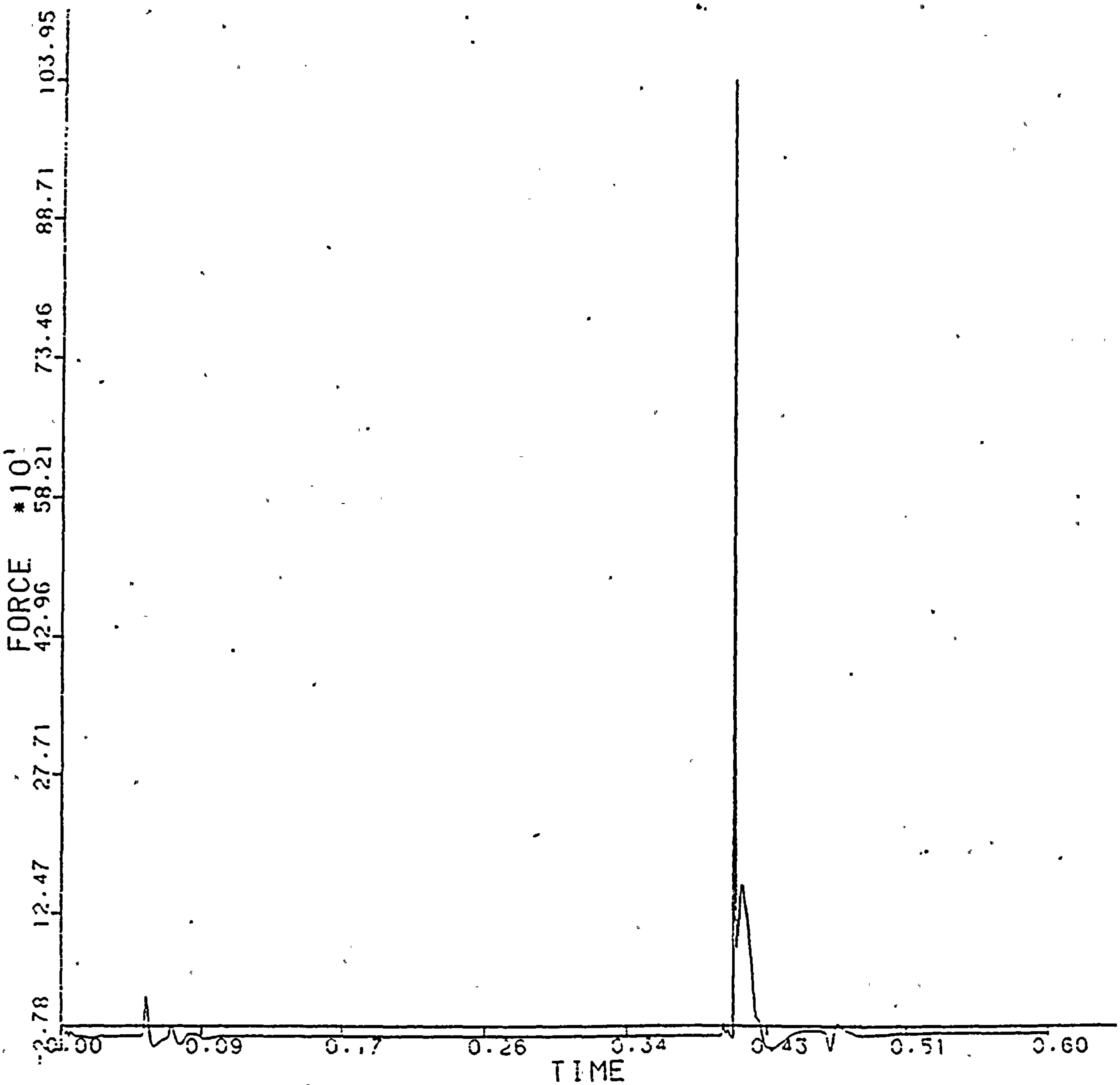
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 20. MAGNITUDE AT NODE POINT 262



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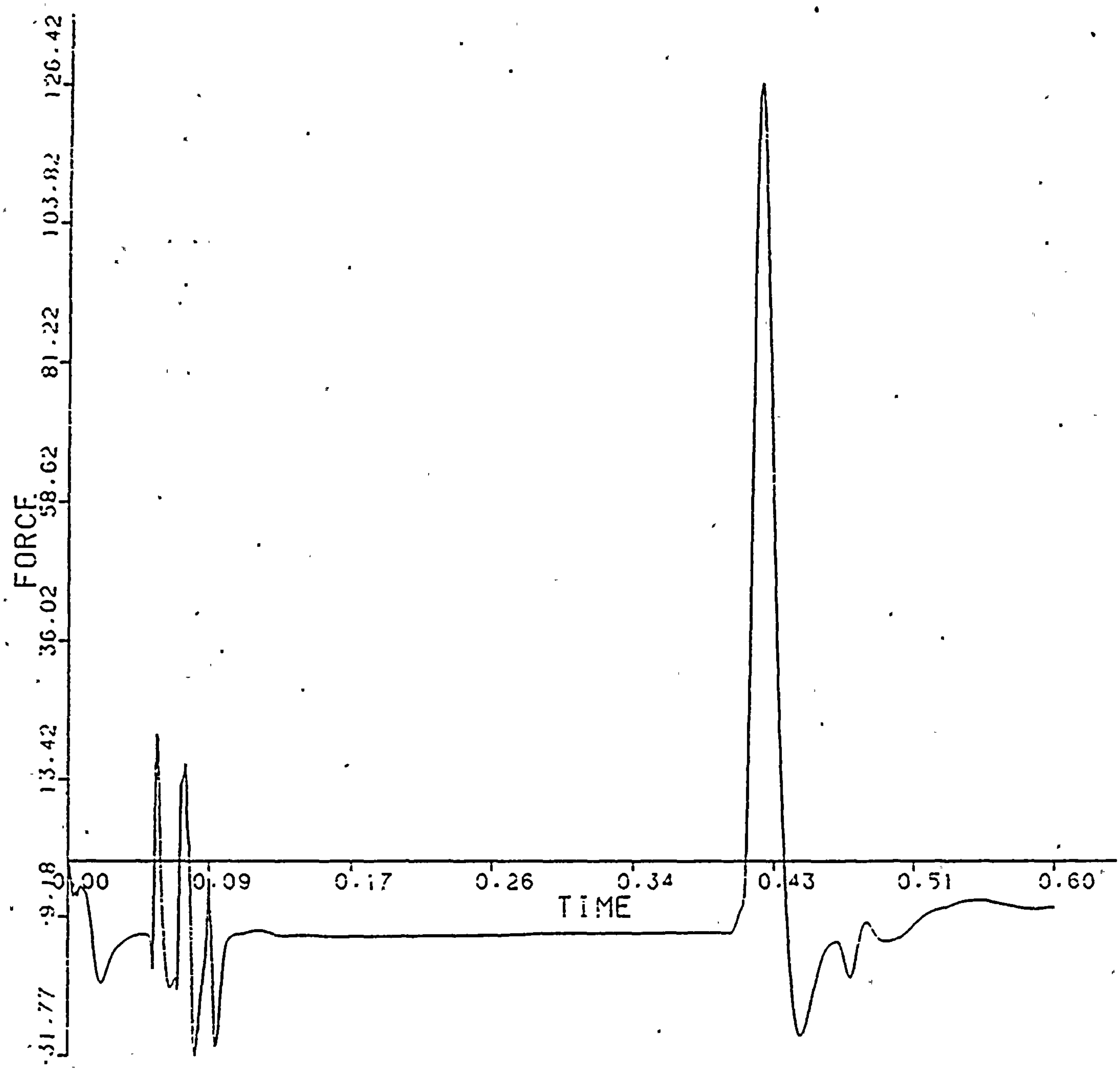
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 21. MAGNITUDE AT NODE POINT 257



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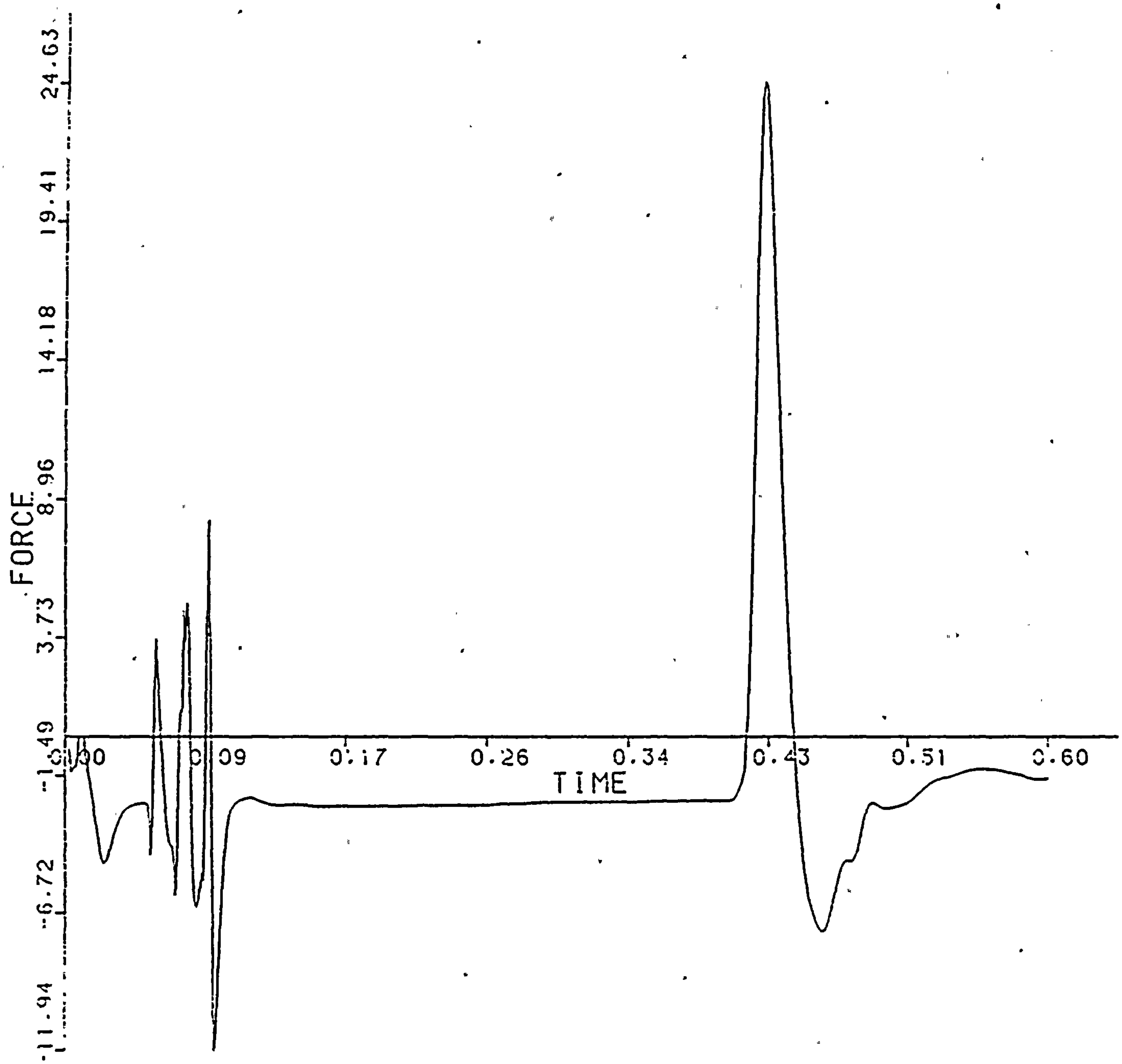
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 22. MAGNITUDE AT NODE POINT 250



BY MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

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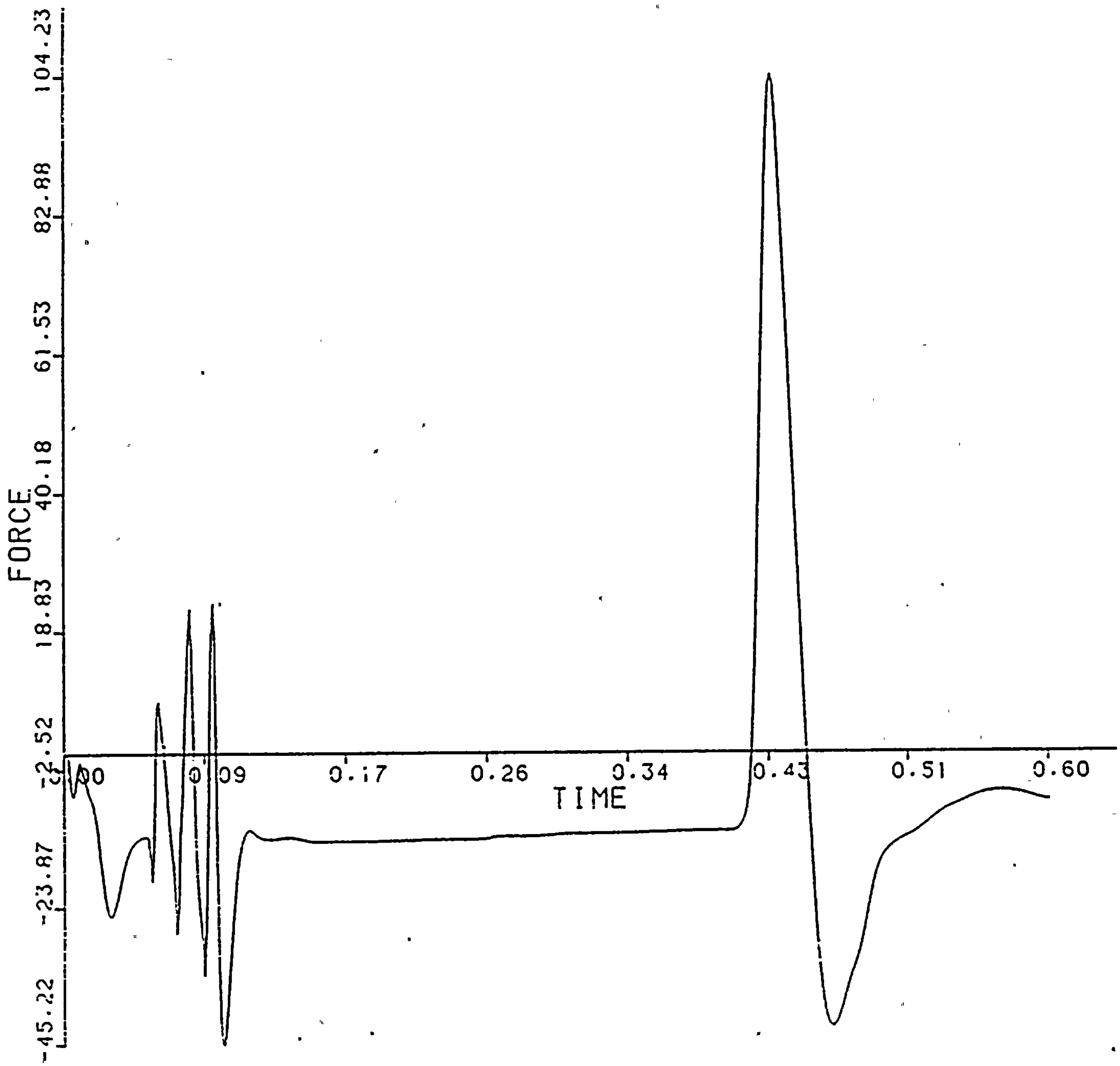
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 23. MAGNITUDE AT NODE POINT 248



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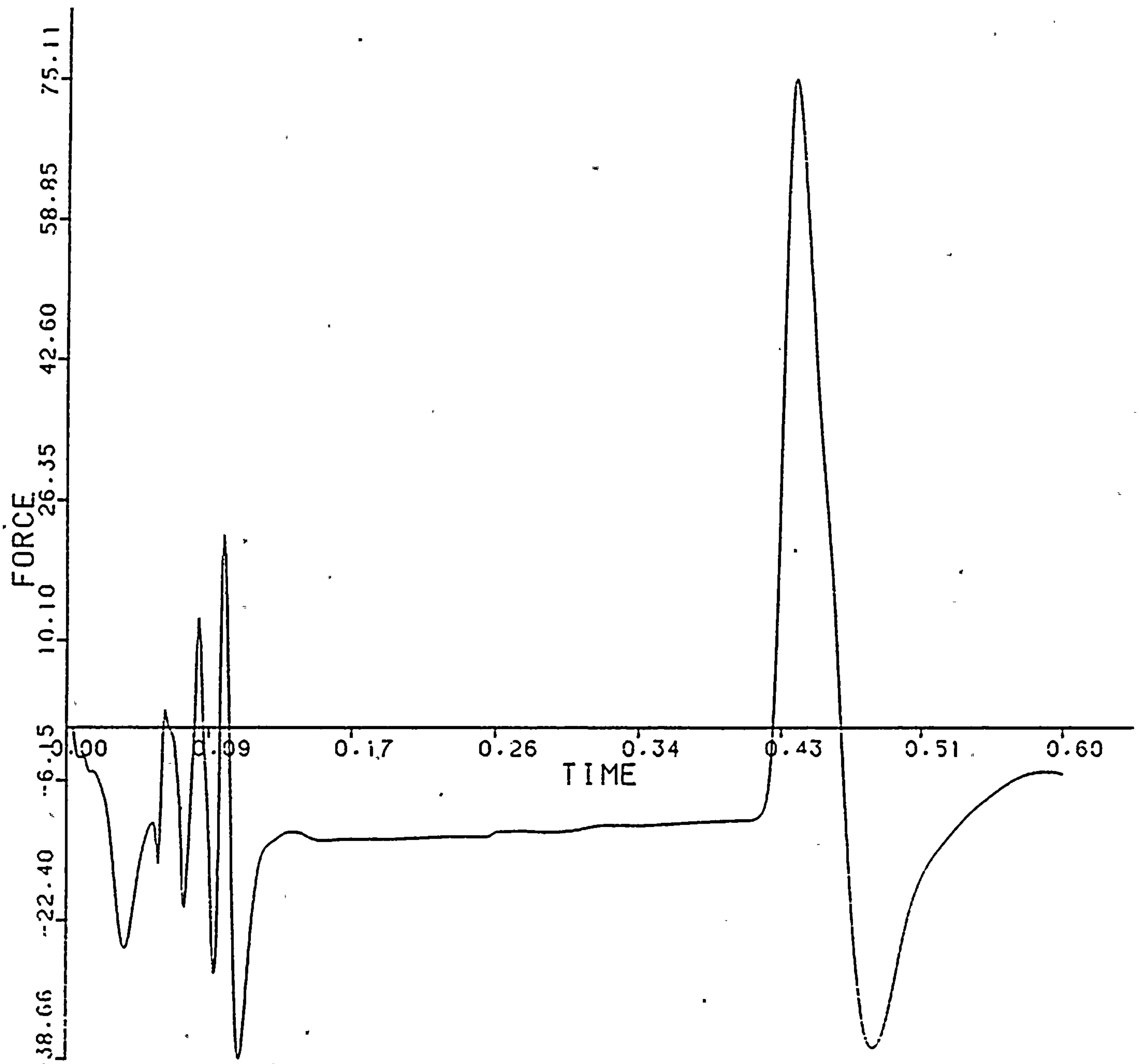
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 24. MAGNITUDE AT NODE POINT 246



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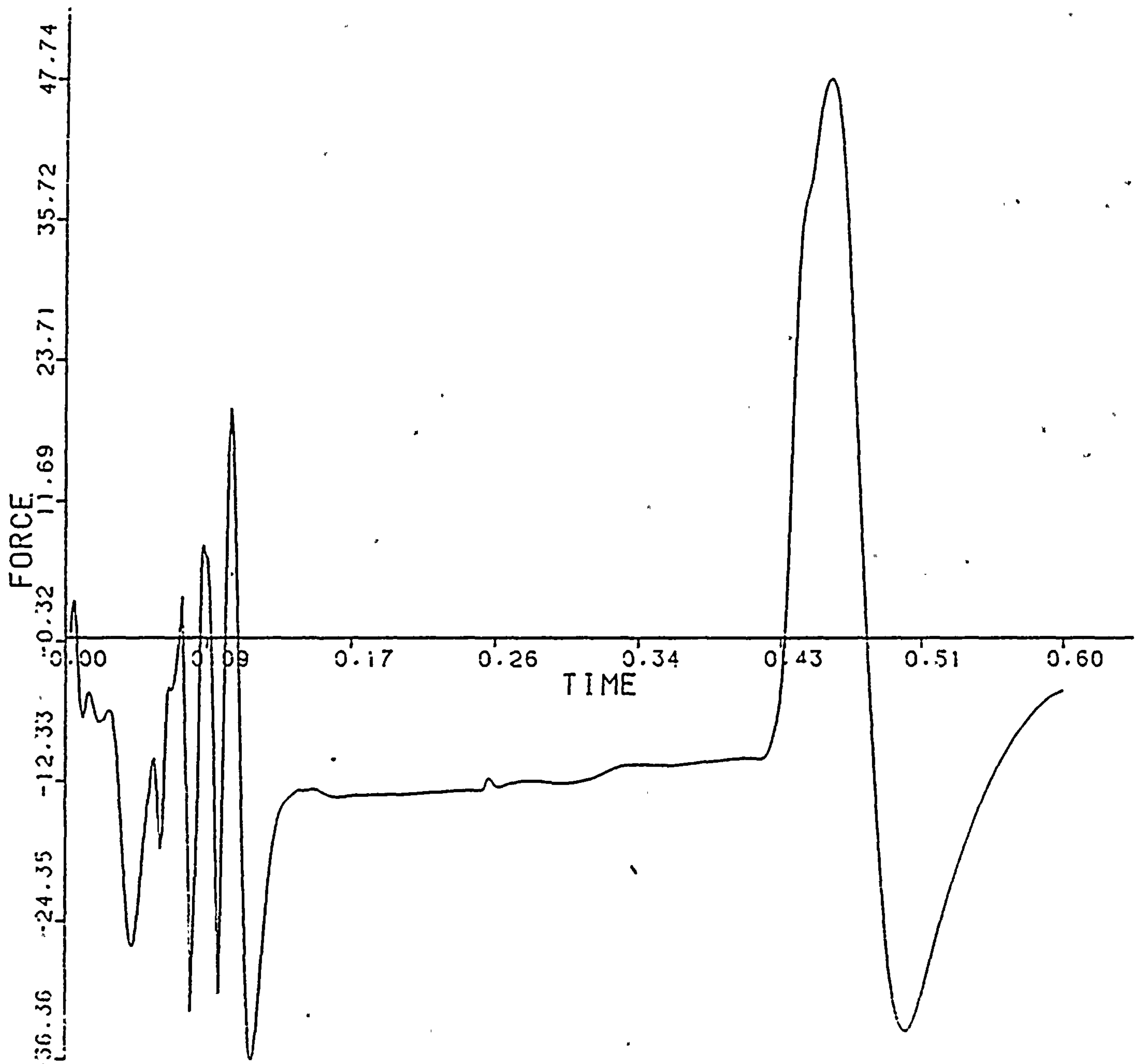
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 25. MAGNITUDE AT NODE POINT 244



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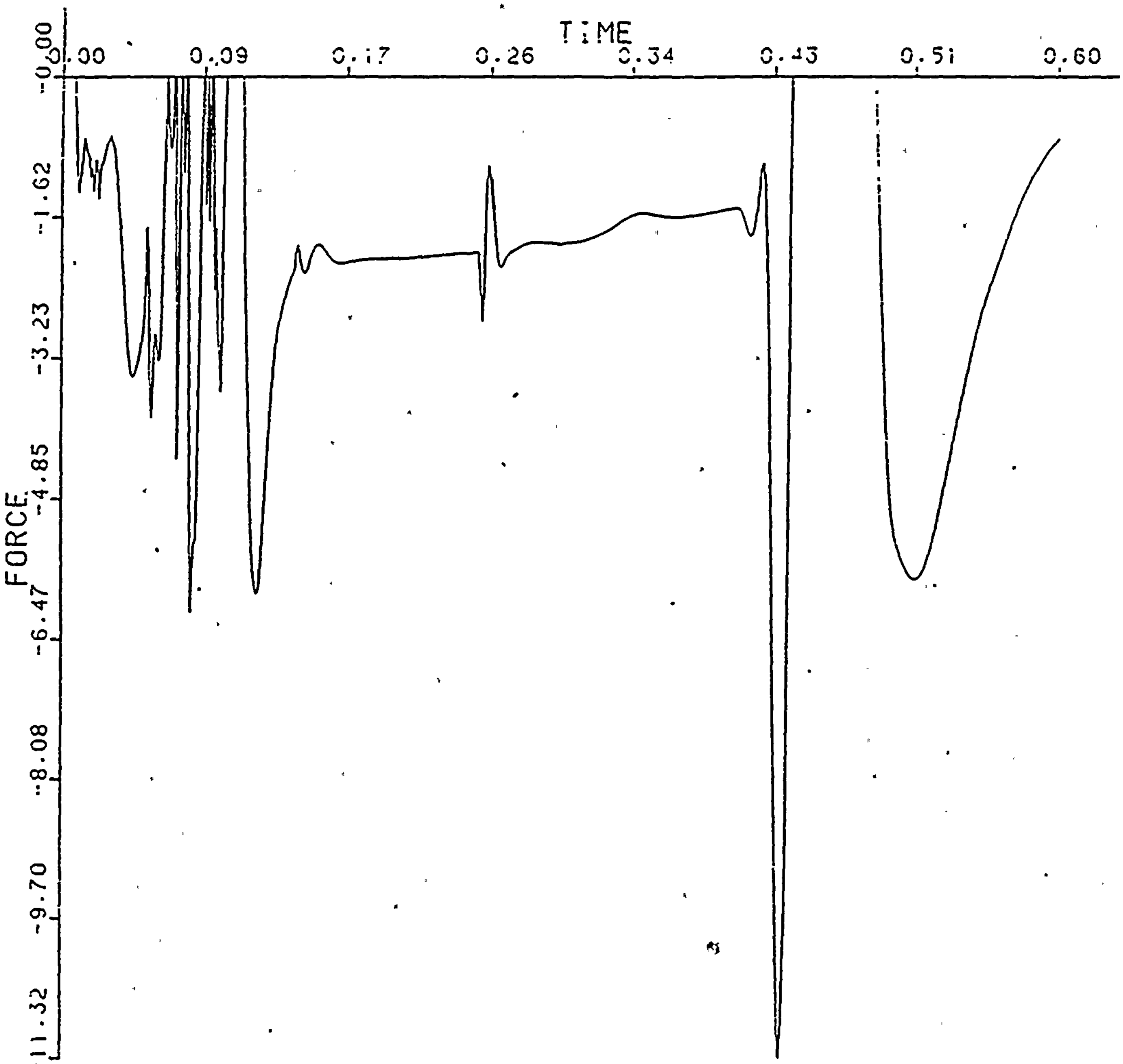
TIME/FORCE TABLE 26. MAGNITUDE AT NODE POINT 242



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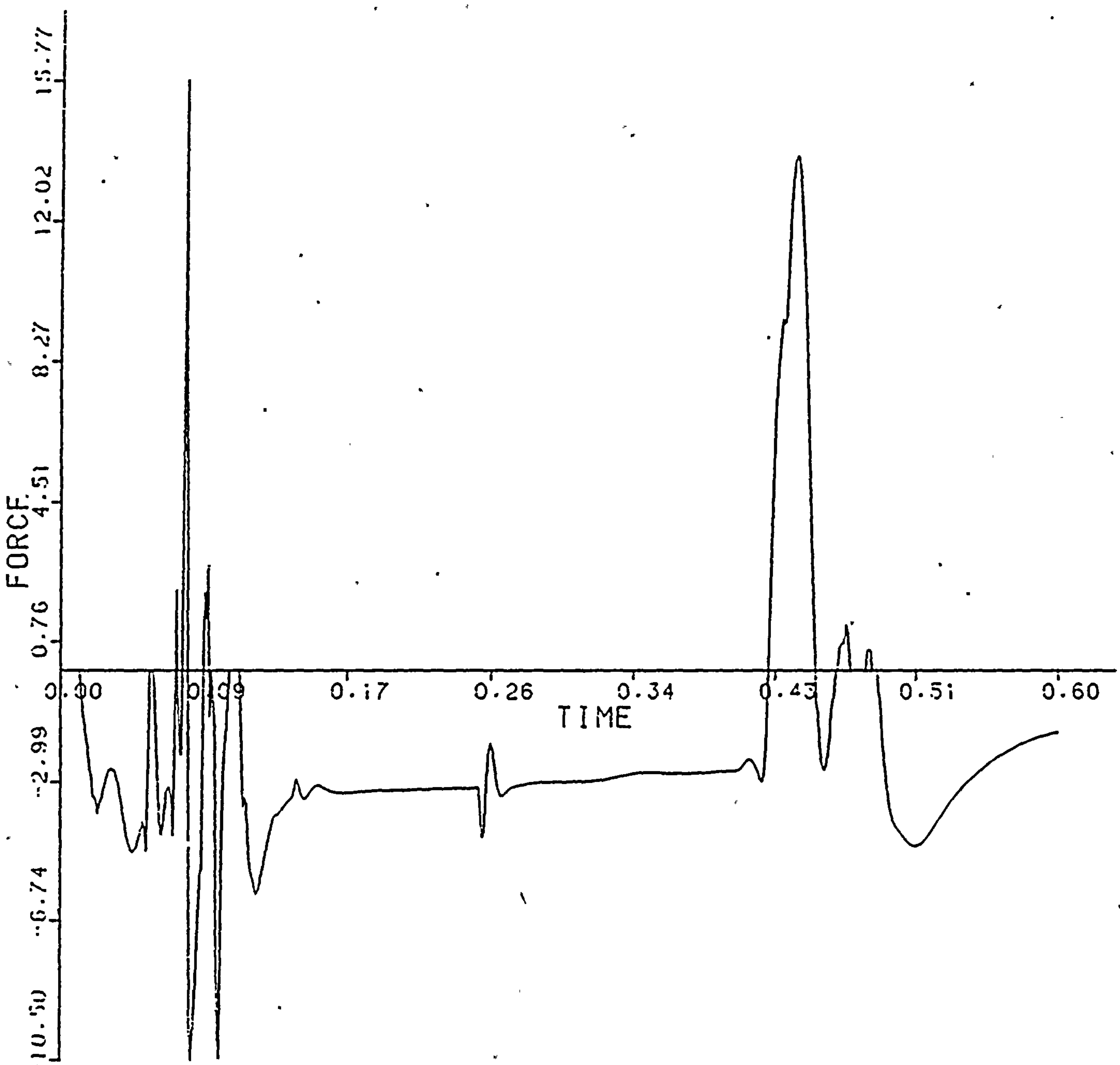
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 27, MAGNITUDE AT NODE POINT 238



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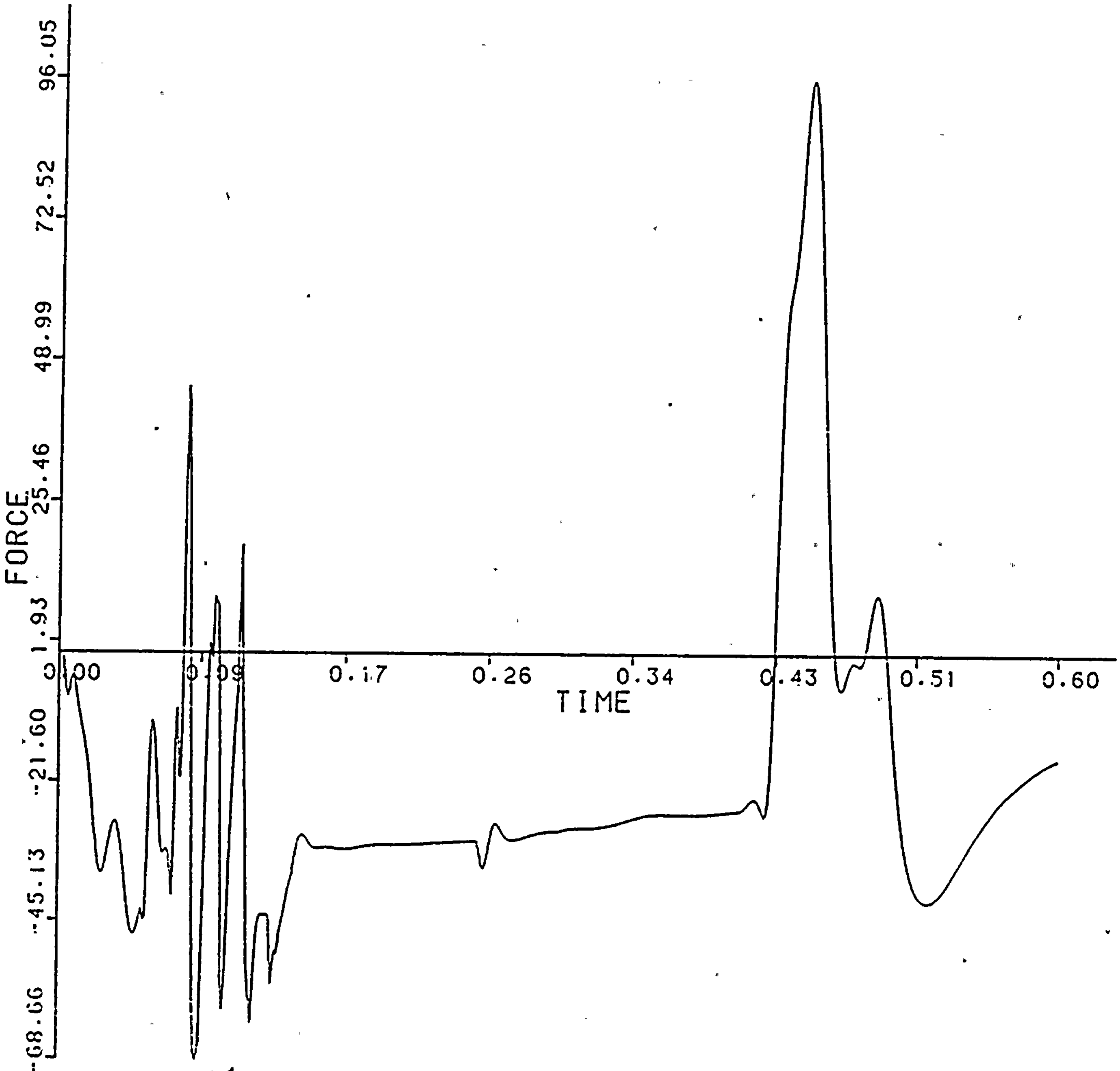
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 28. MAGNITUDE AT NODE POINT 236



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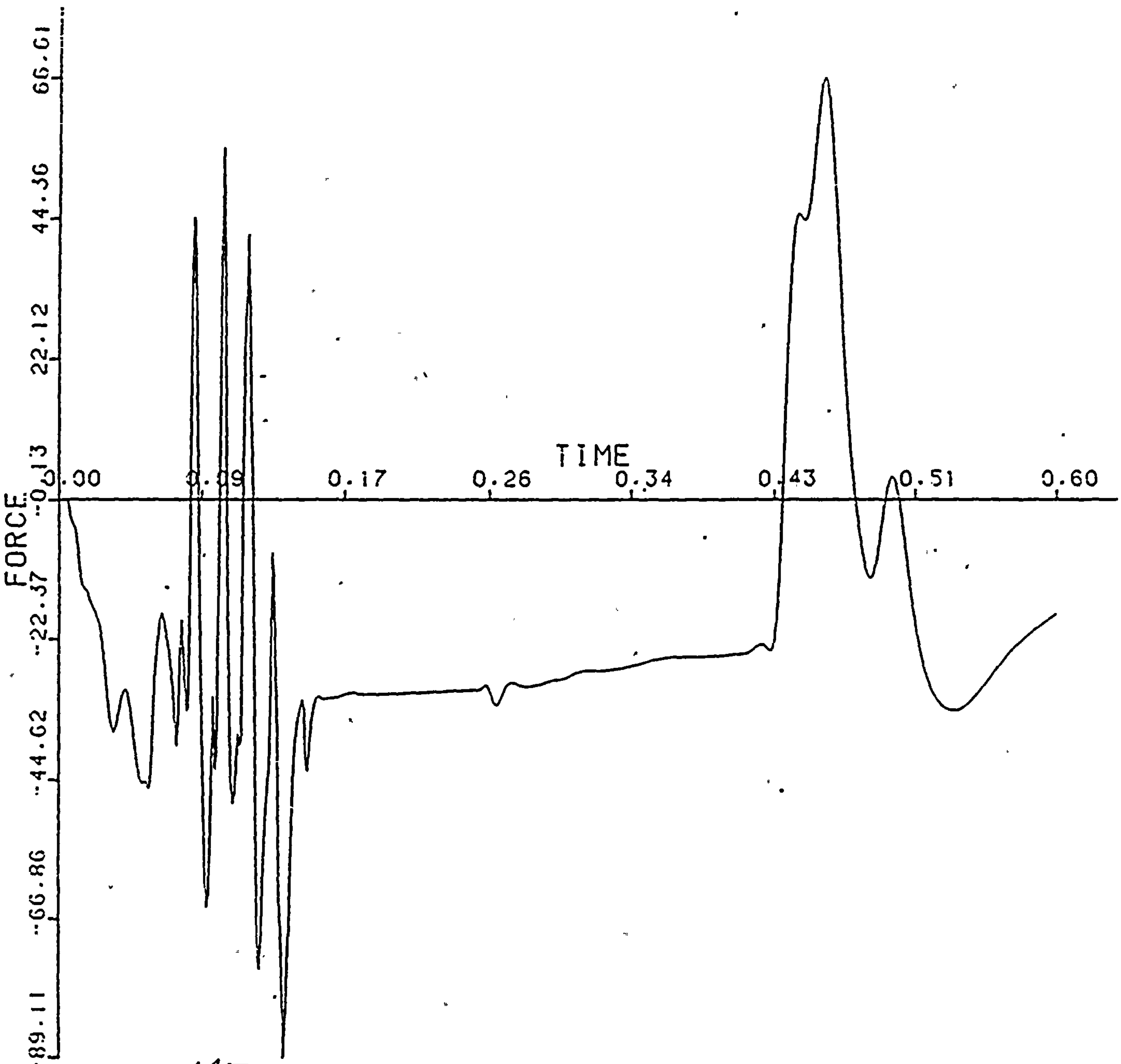
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 29. MAGNITUDE AT NODE POINT 234



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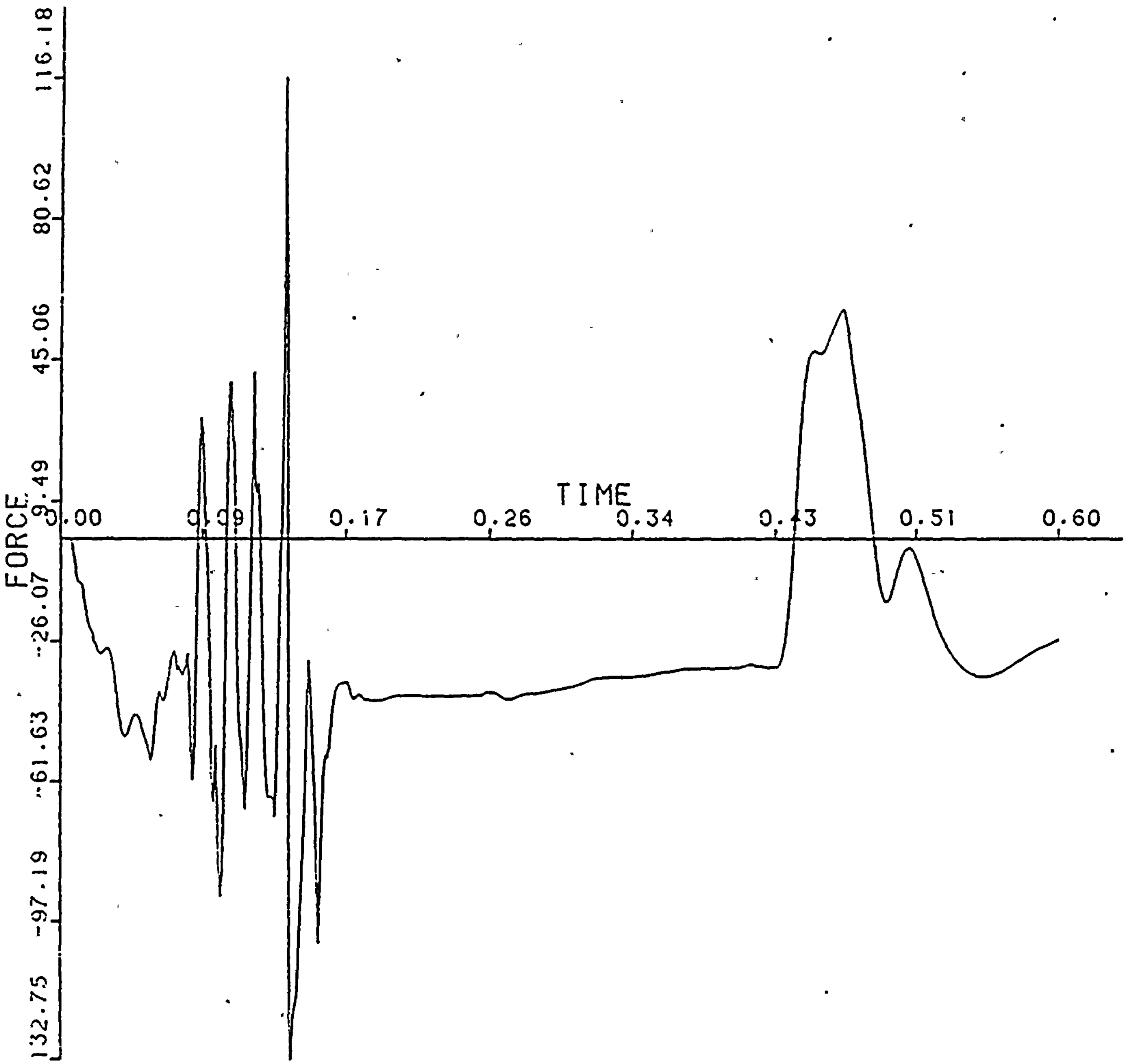
TIME/FORCE TABLE 30, MAGNITUDE AT NODE POINT 226



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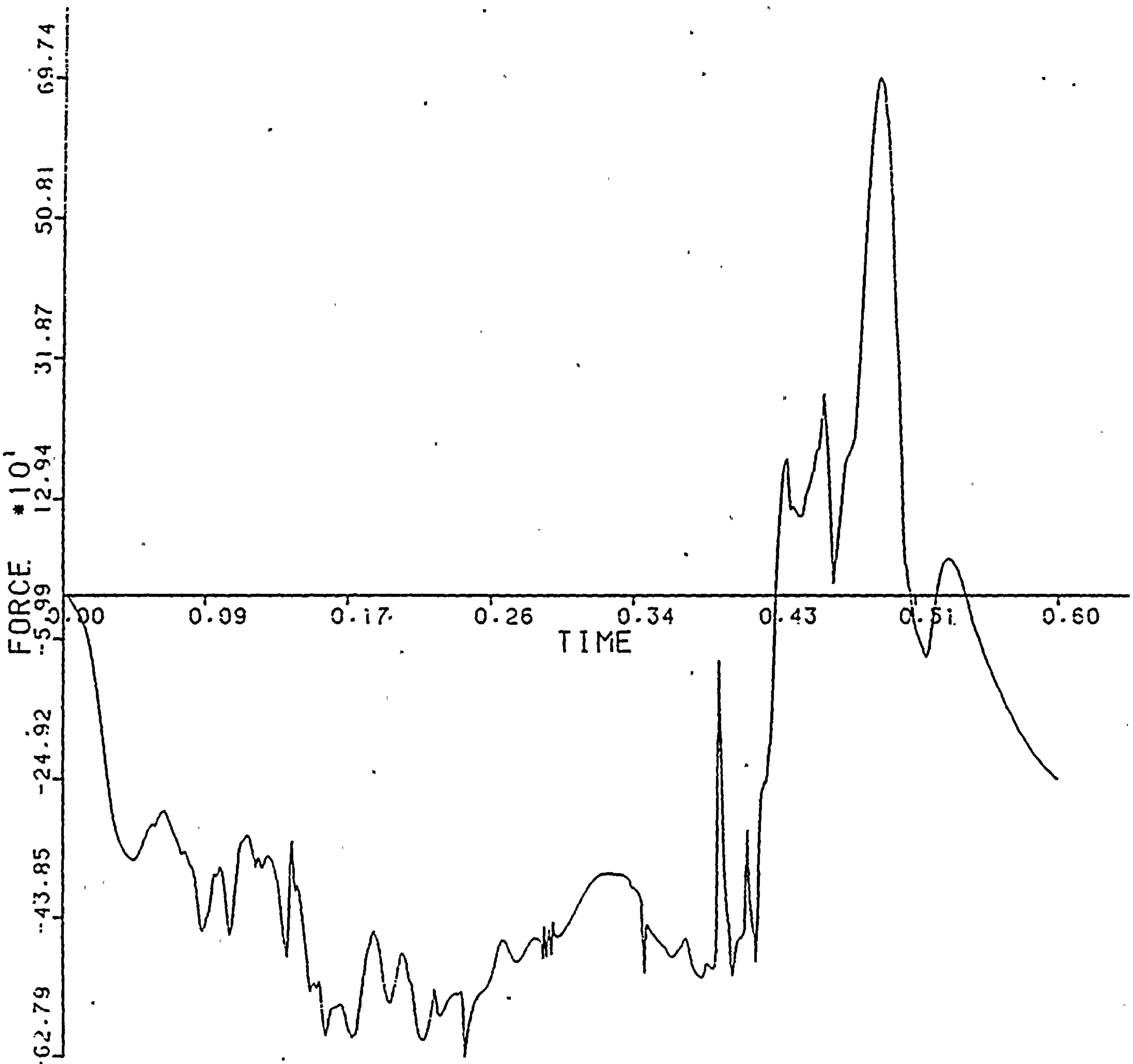
TIME/FORCE TABLE 31. MAGNITUDE AT NODE POINT 219



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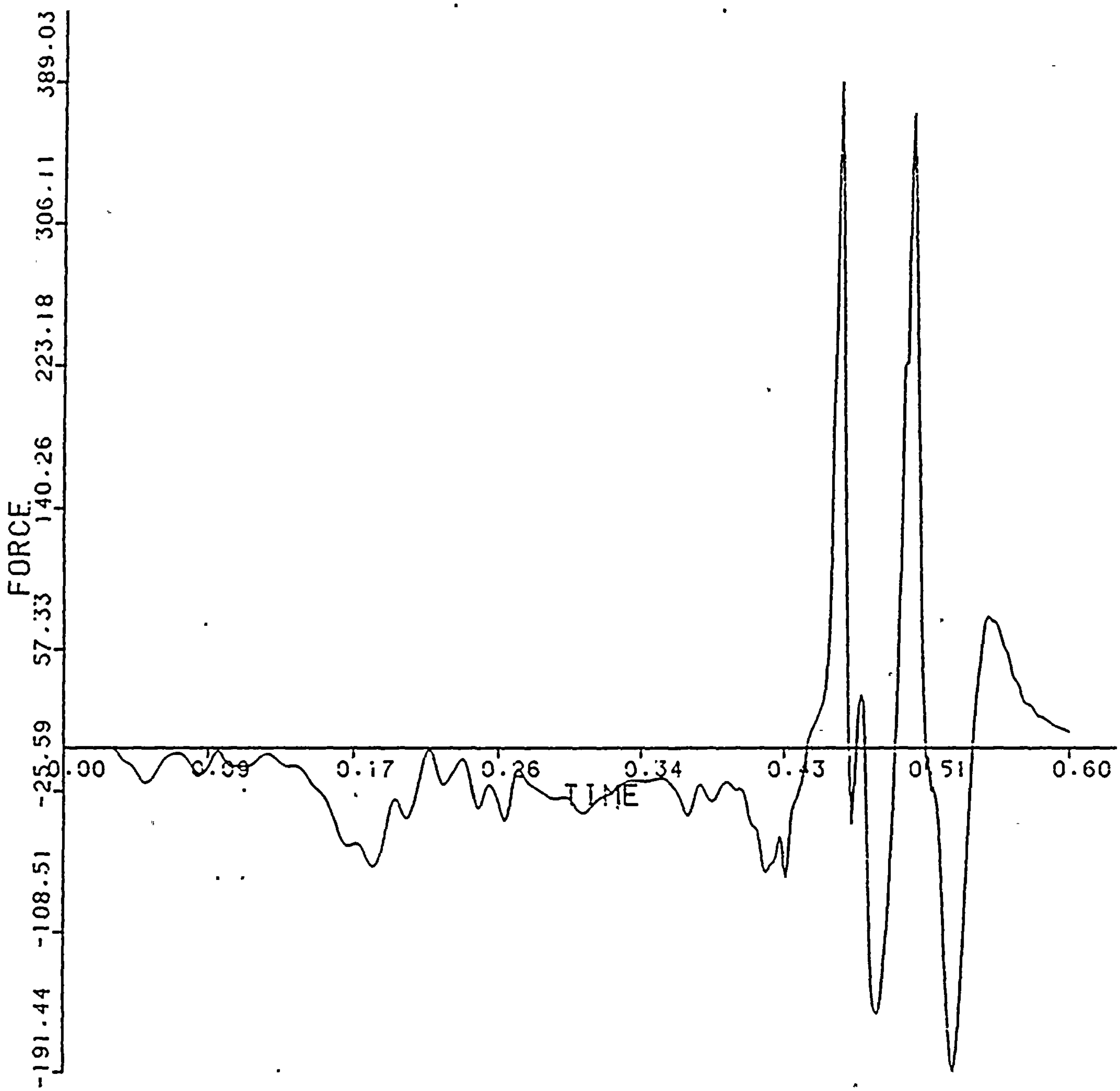
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 32, MAGNITUDE AT NODE POINT 64



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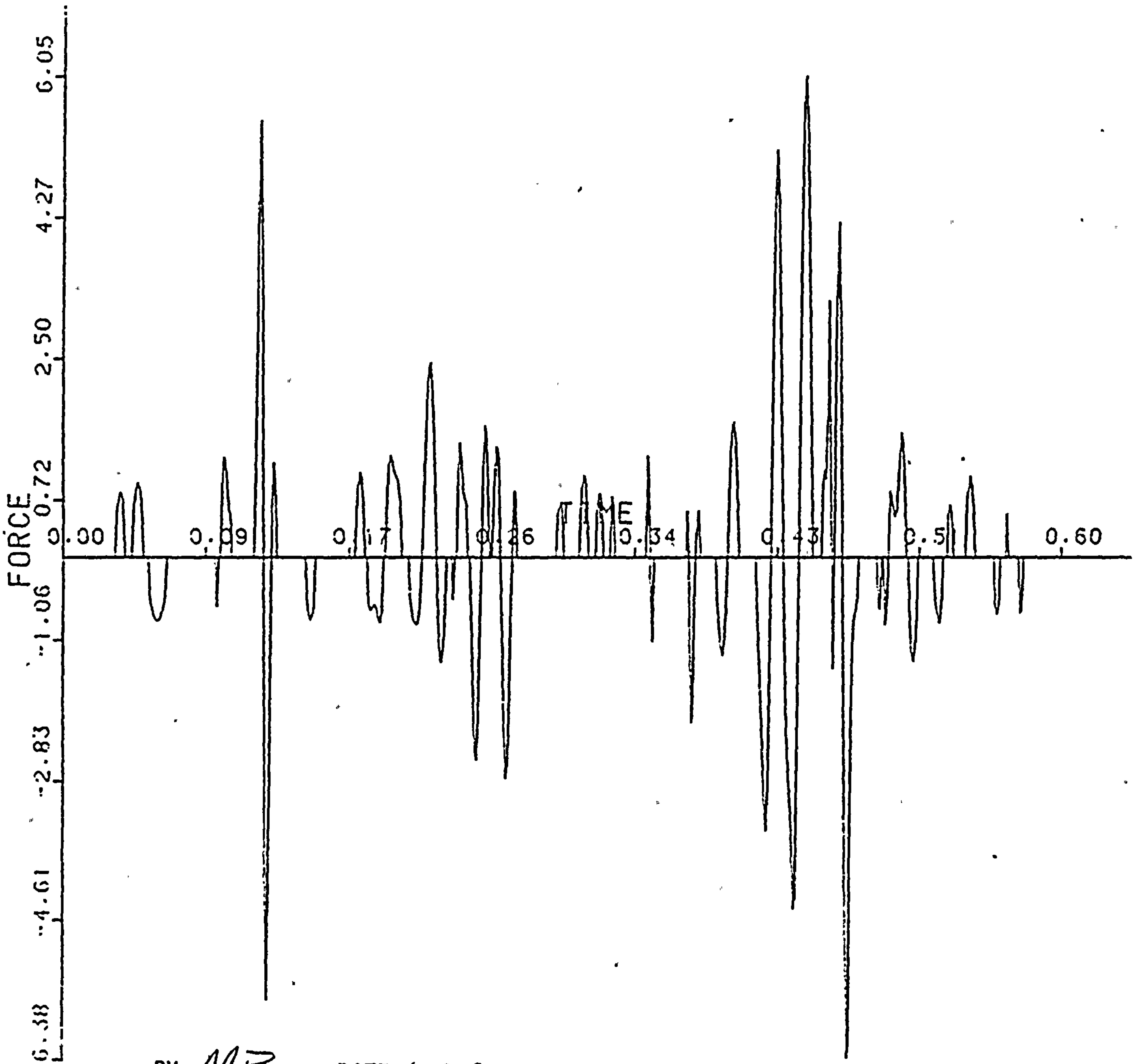
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE · 33. MAGNITUDE AT NODE POINT 195



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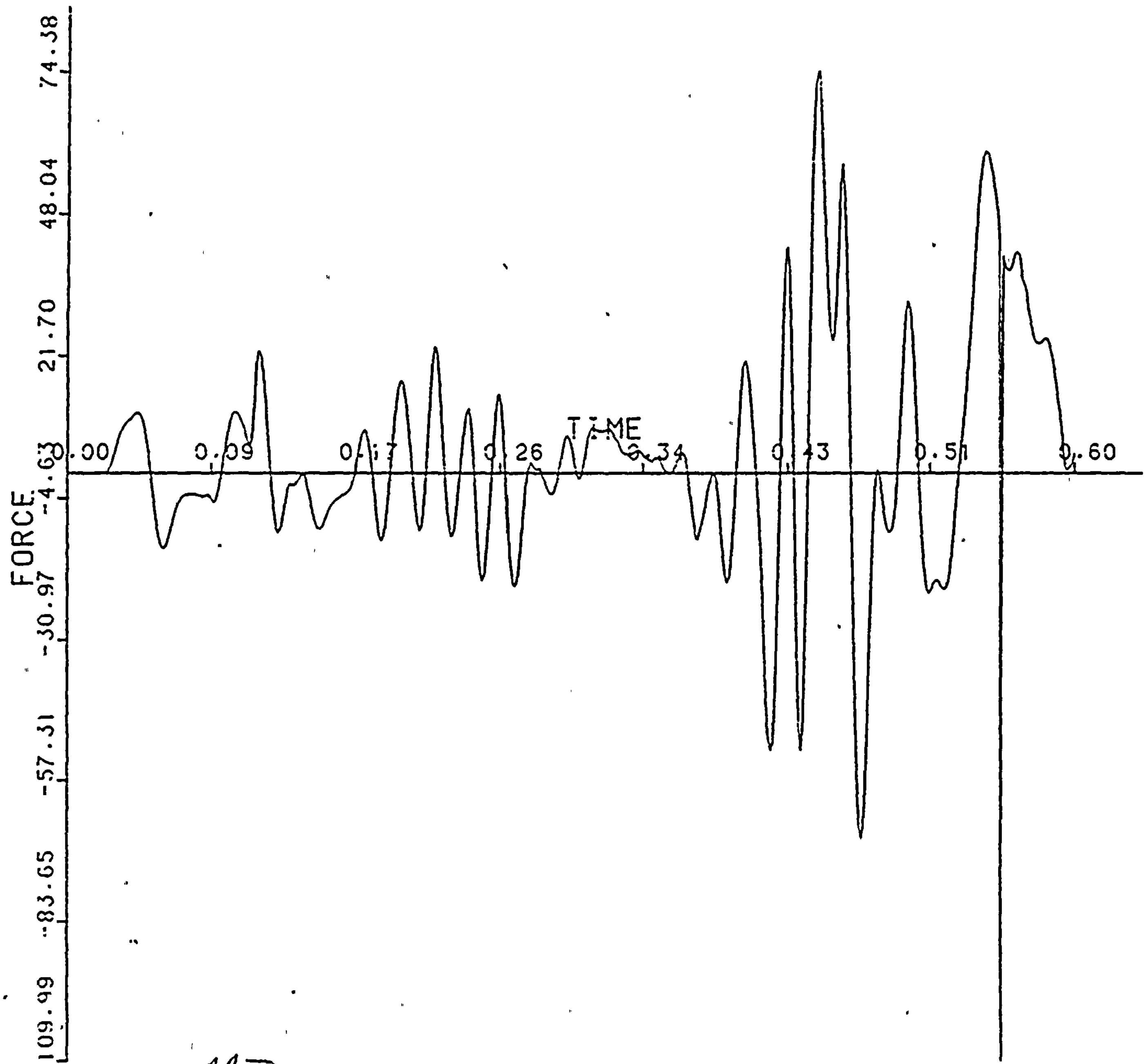
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE . 34, MAGNITUDE AT NODE POINT 187



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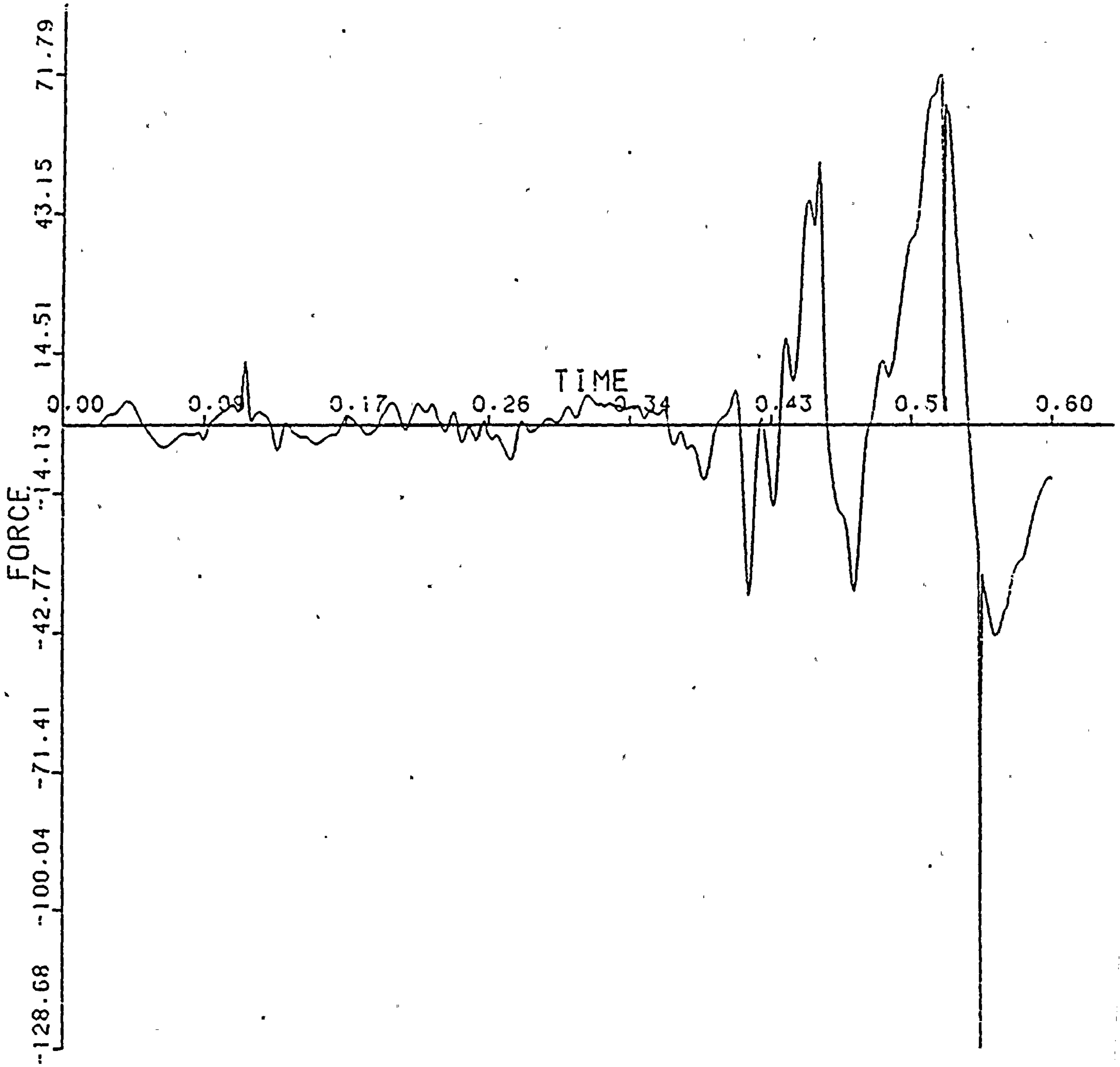
TIME/FORCE TABLE 35. MAGNITUDE AT NODE POINT 184



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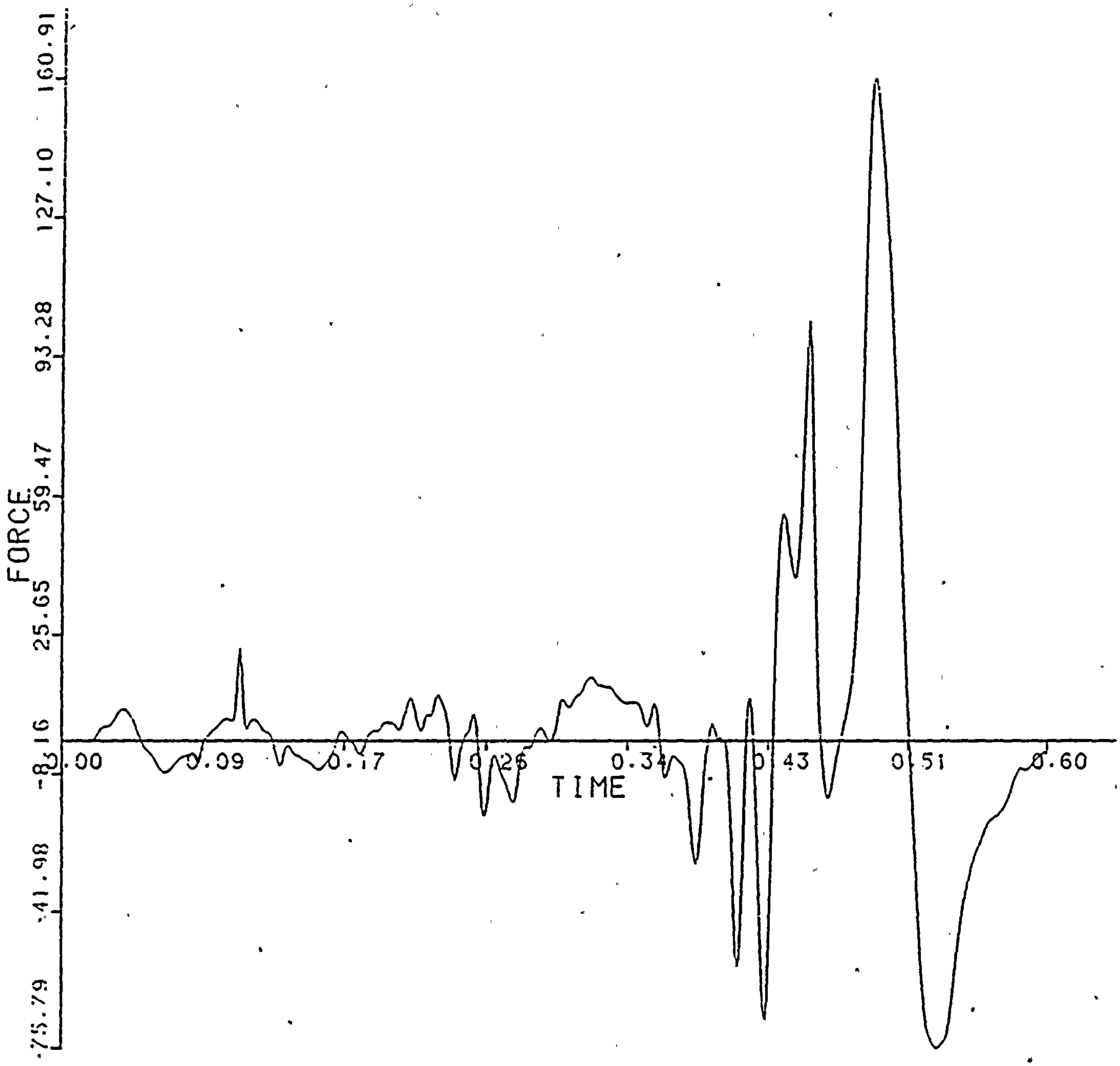
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 36. MAGNITUDE AT NODE POINT 182



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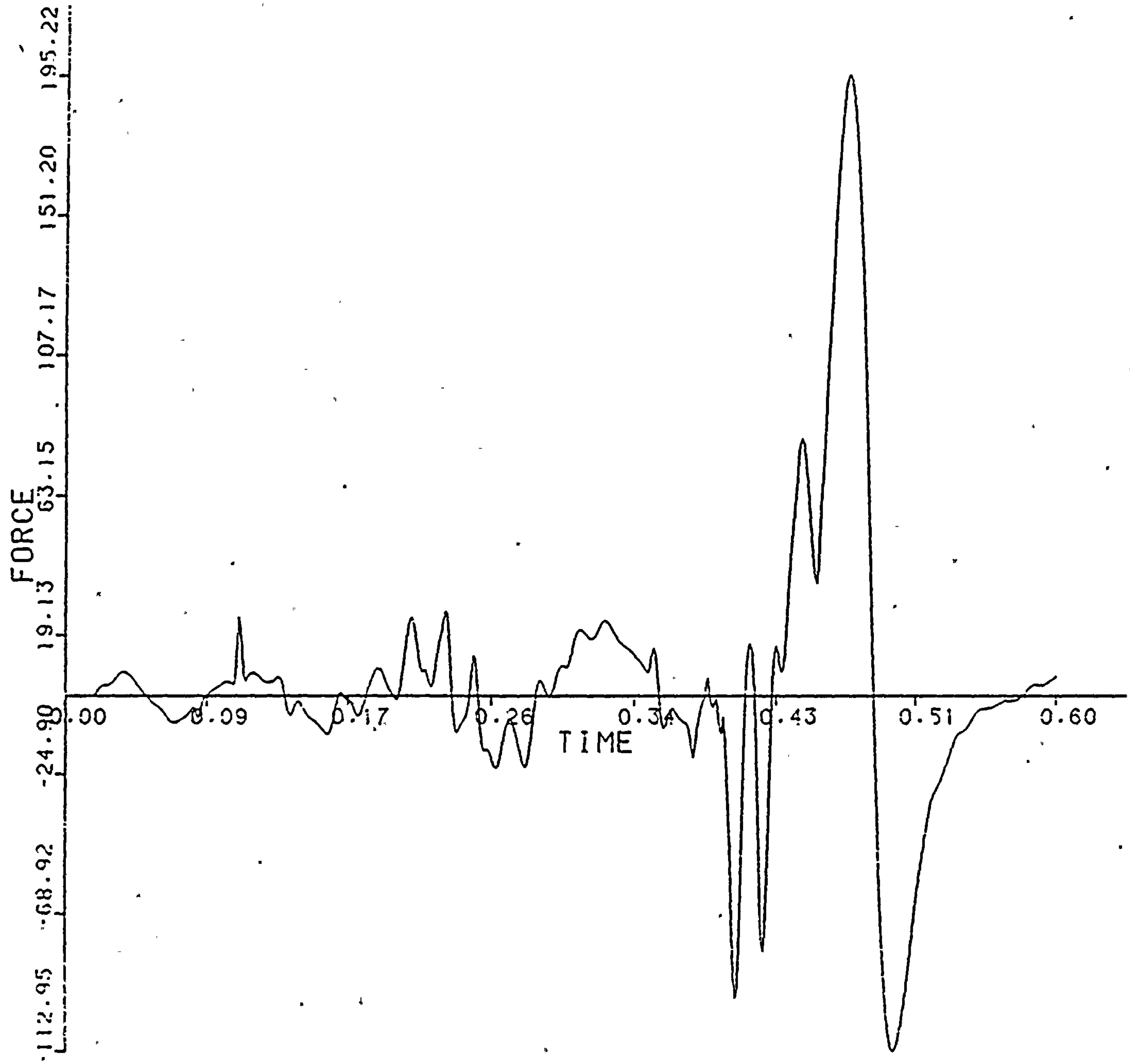
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 37. MAGNITUDE AT NODE POINT 180



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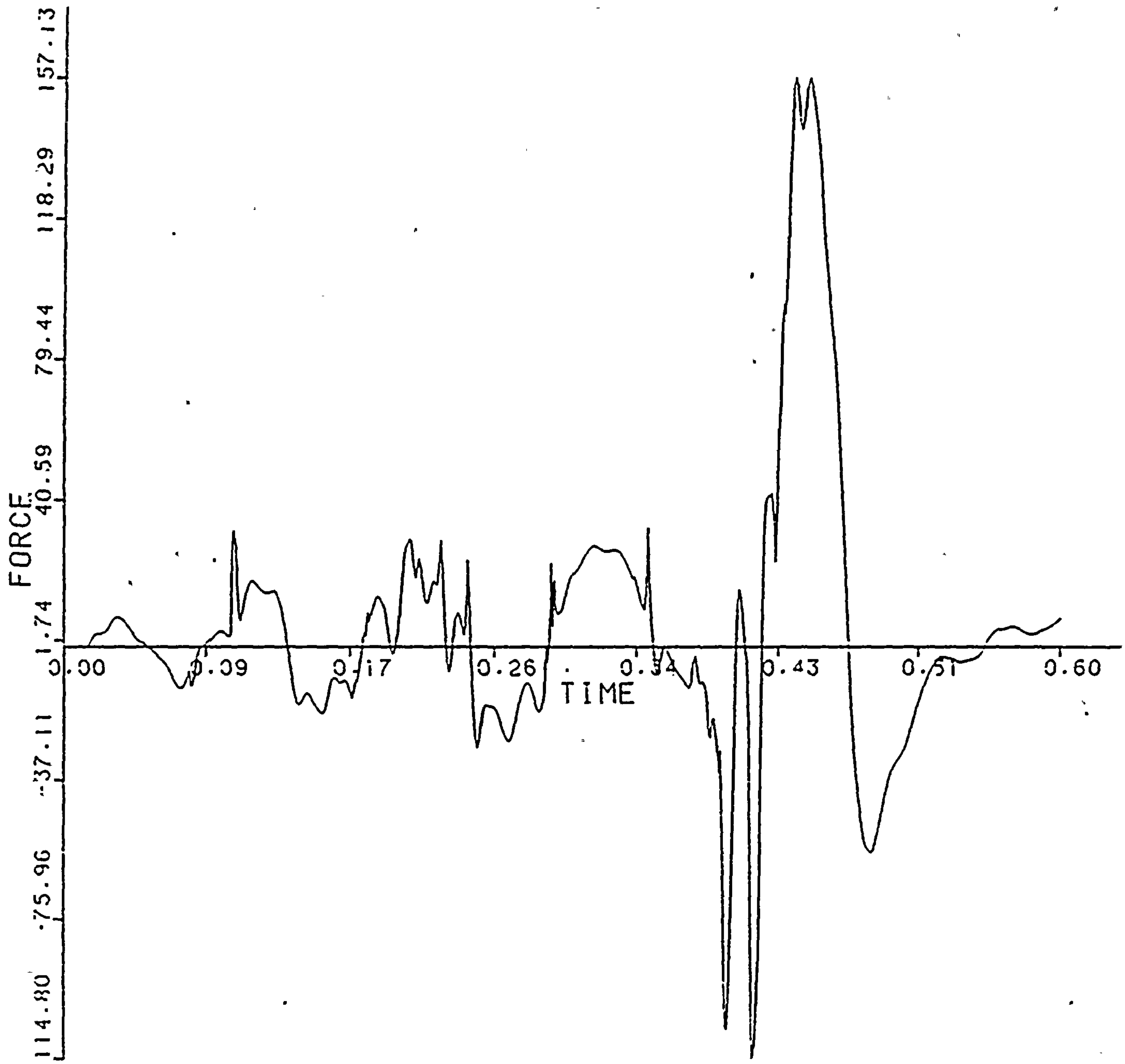
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 38. MAGNITUDE AT NODE POINT 178



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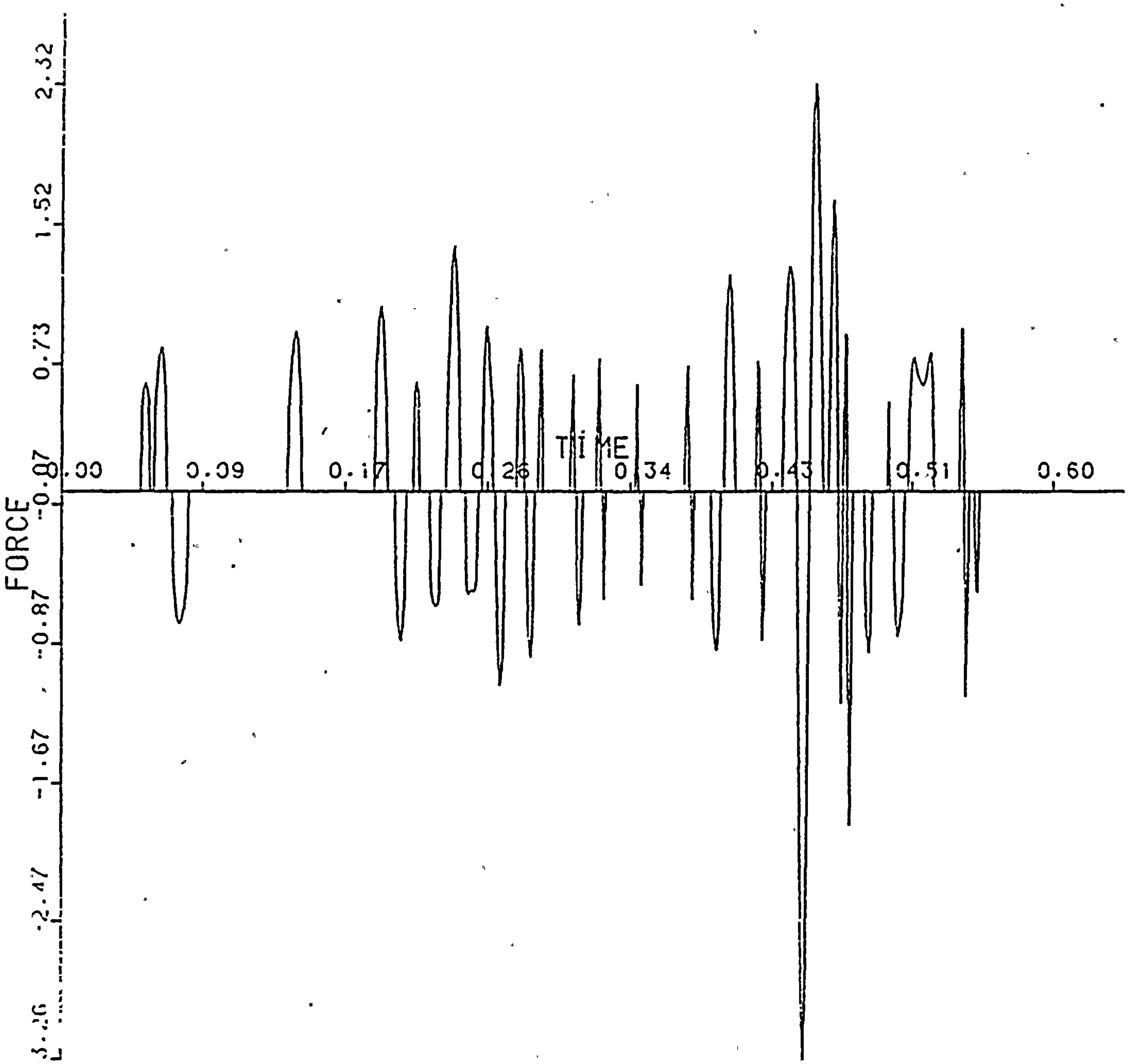
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 39. MAGNITUDE AT NODE POINT 98.



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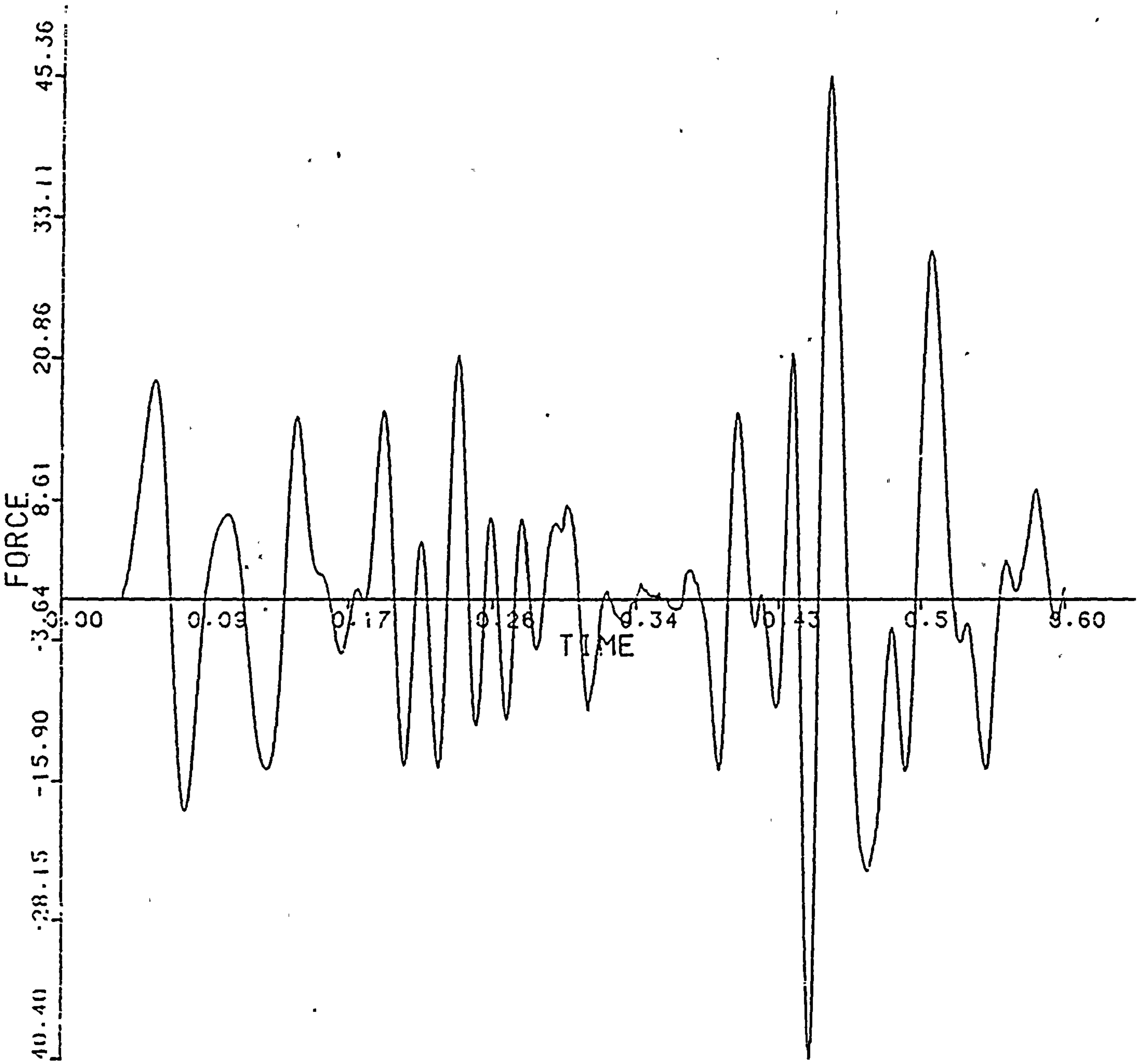
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 40, MAGNITUDE AT NODE POINT 97



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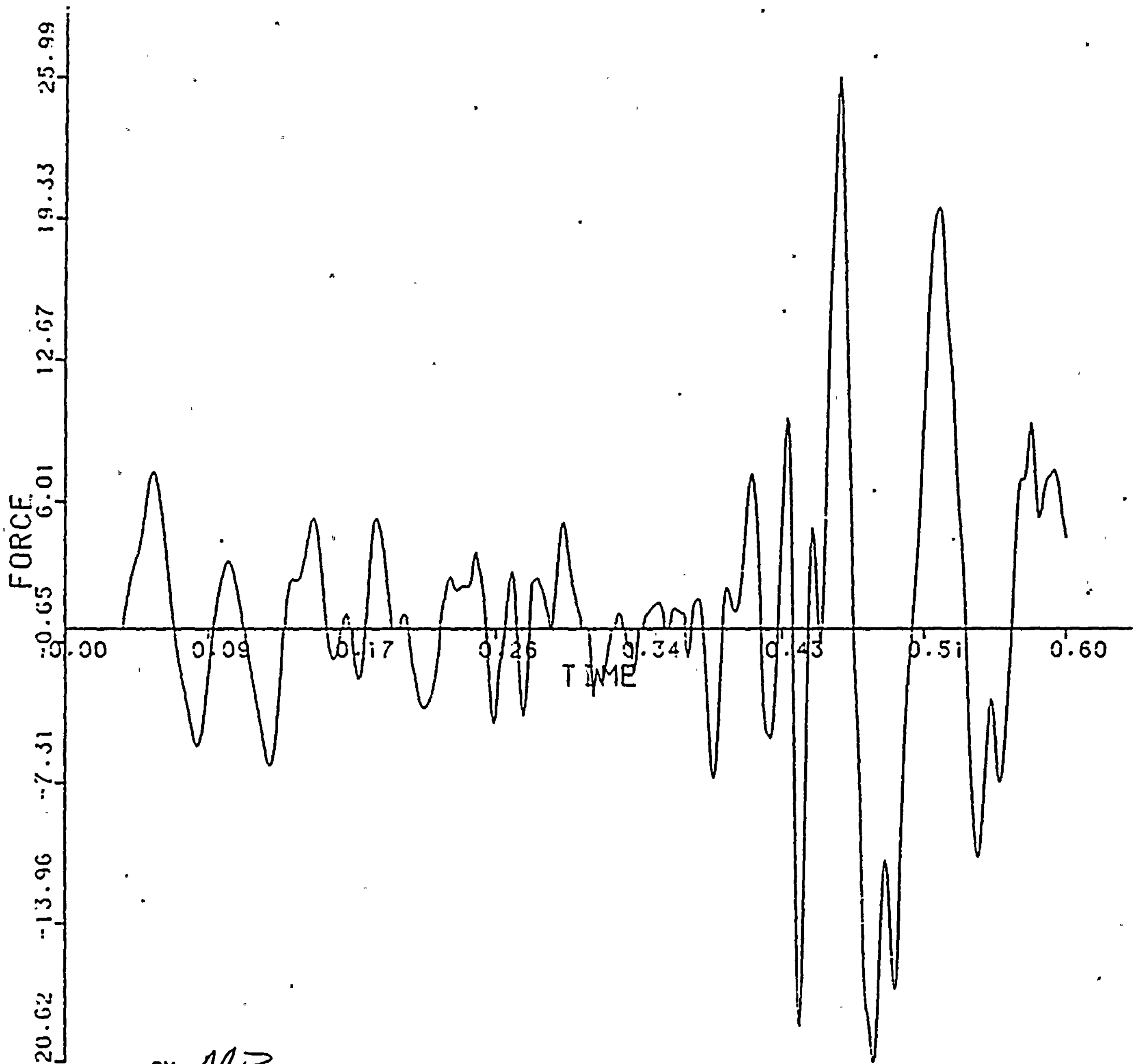
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 41, MAGNITUDE AT NODE POINT 88



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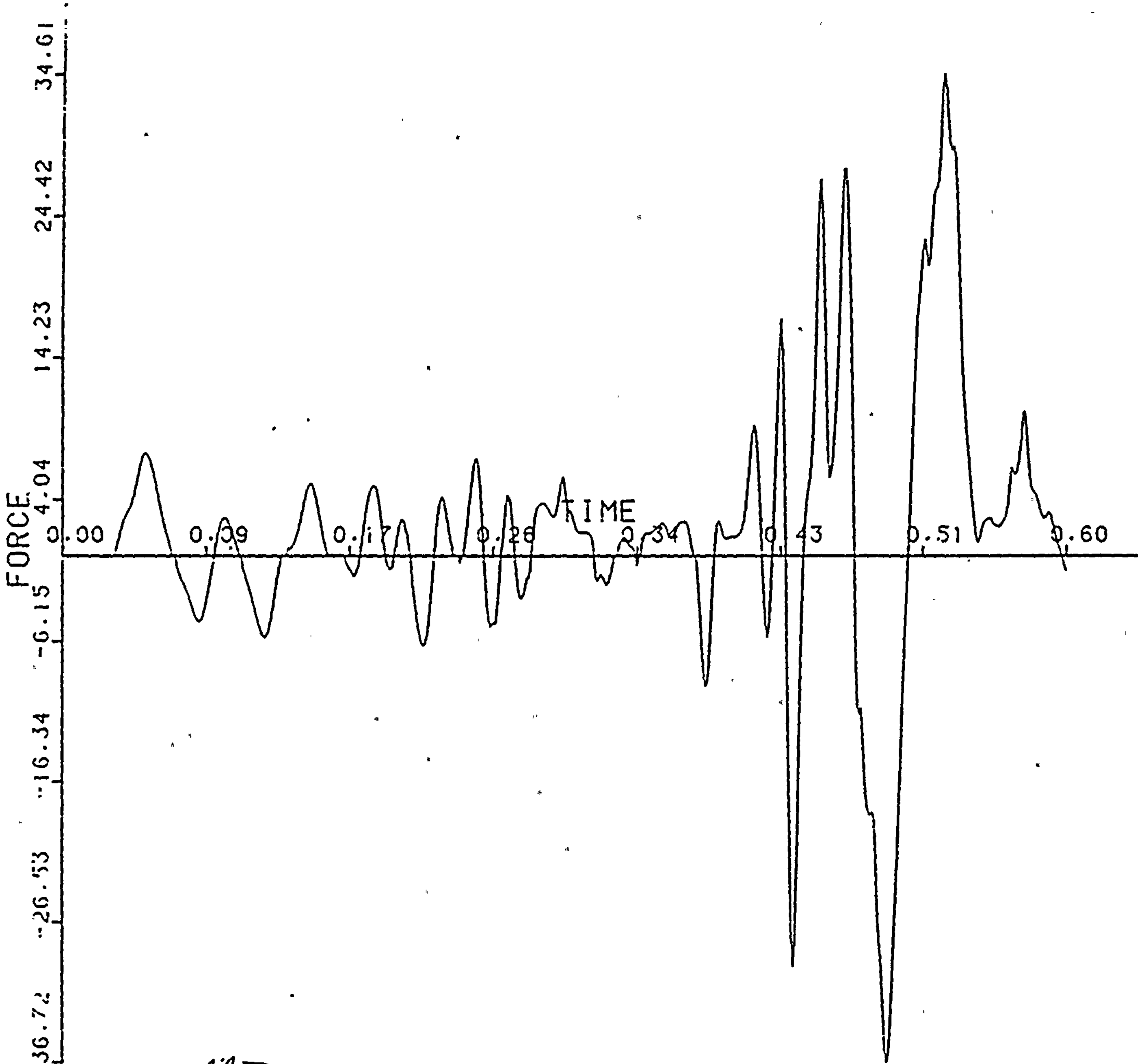
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 42. MAGNITUDE AT NODE POINT 86



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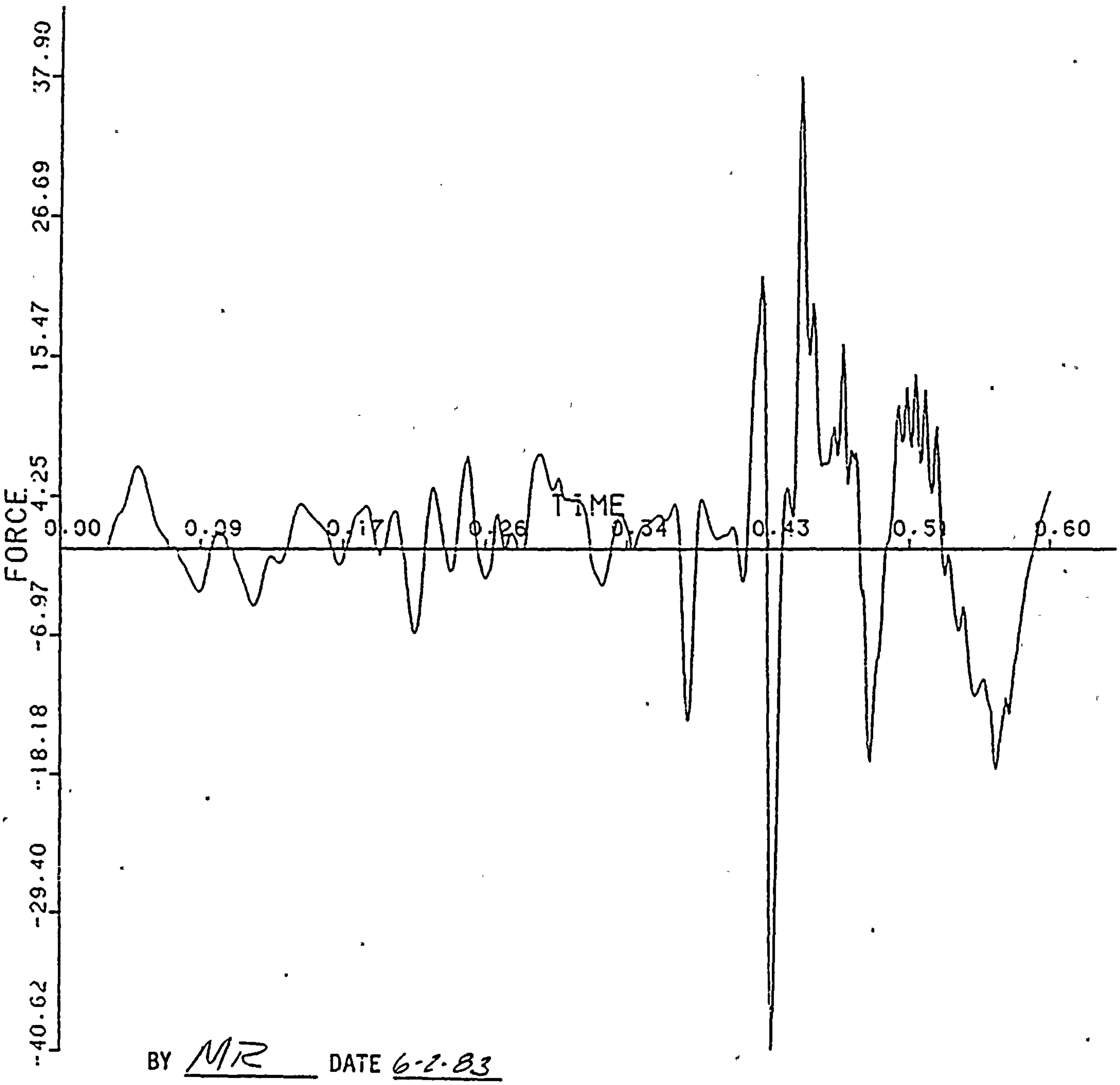
TIME/FORCE TABLE 43, MAGNITUDE AT NODE POINT 84



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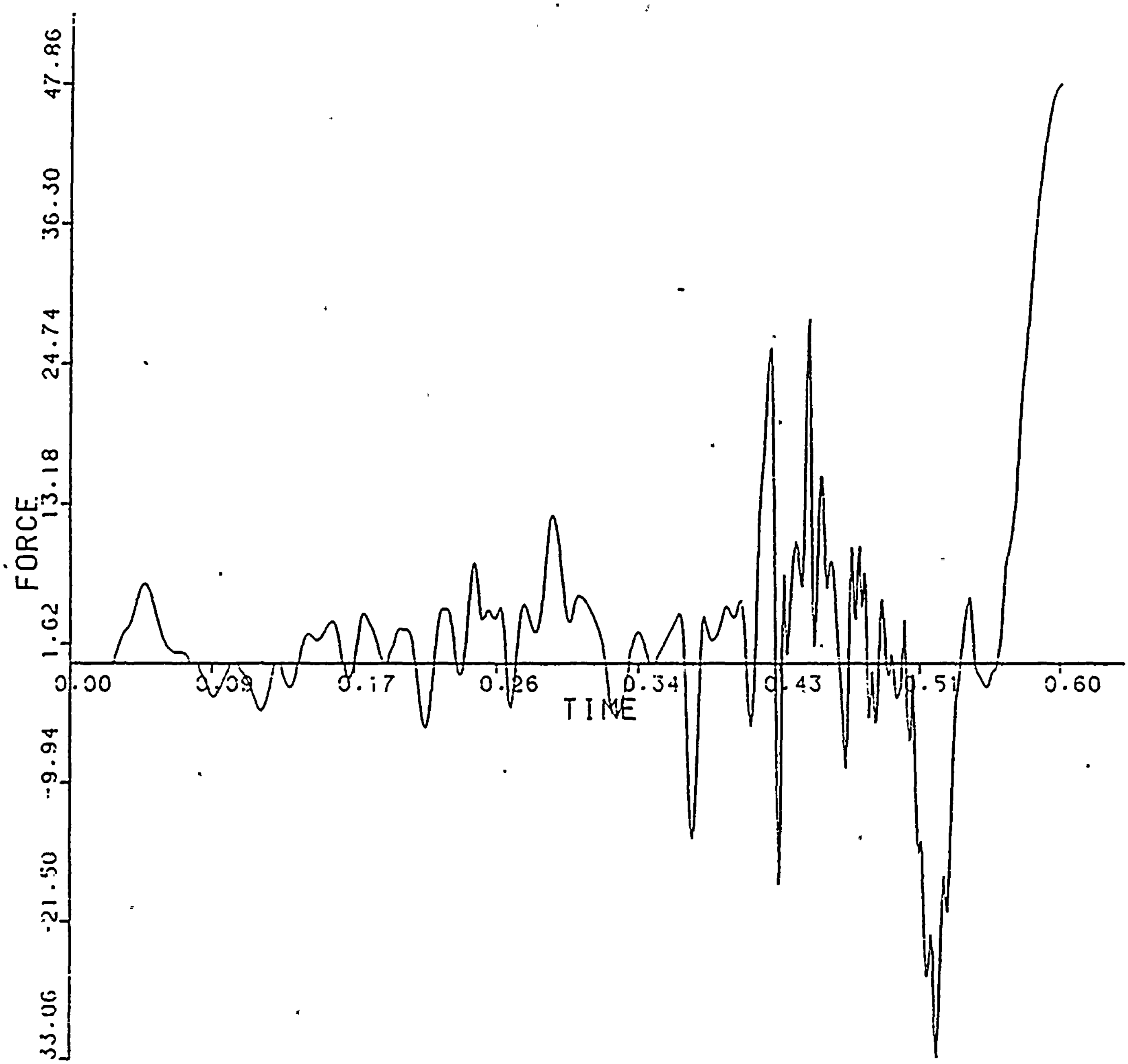
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 44, MAGNITUDE AT NODE POINT 82



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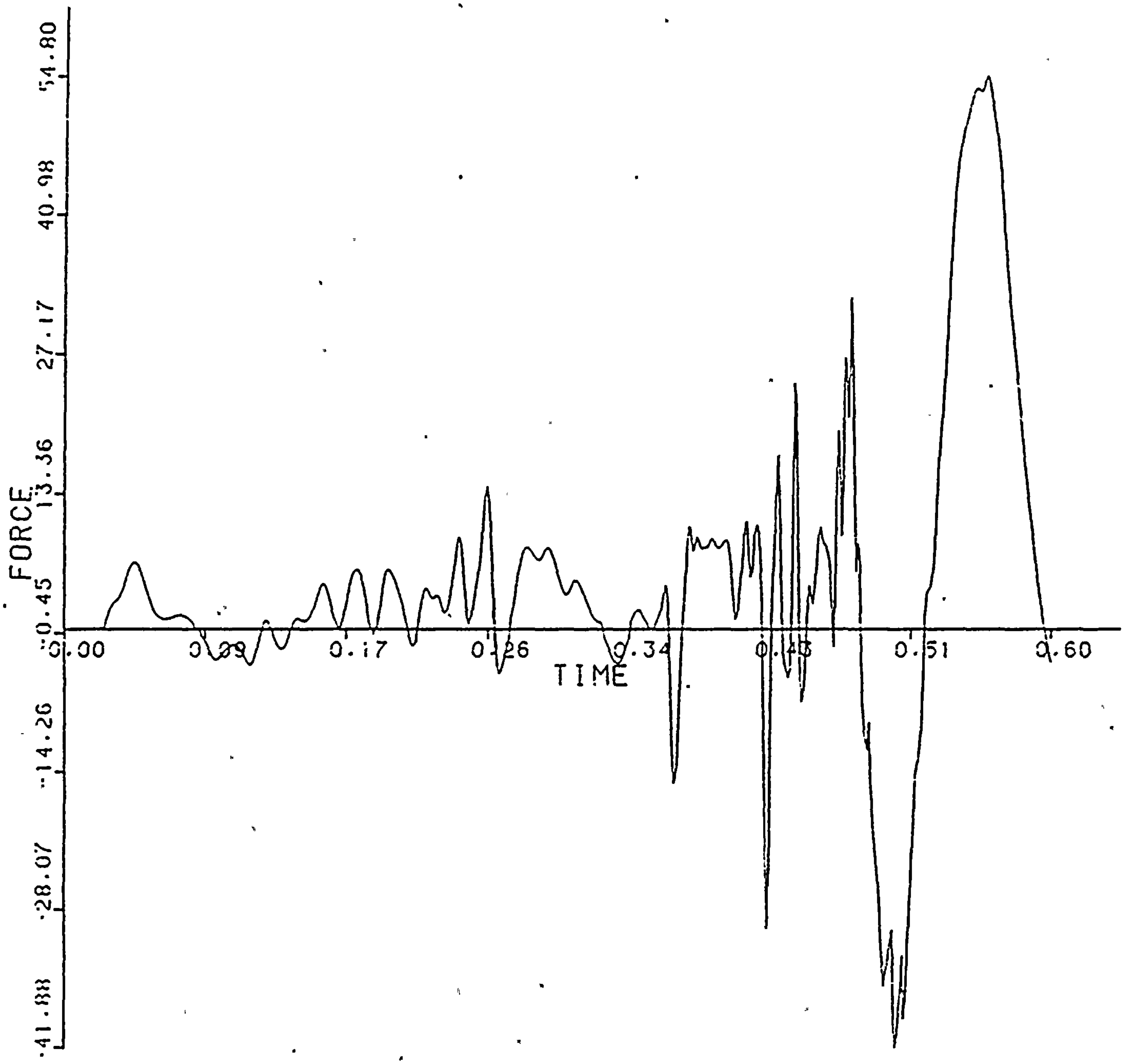
TIME/FORCE TABLE 45, MAGNITUDE AT NODE POINT 80



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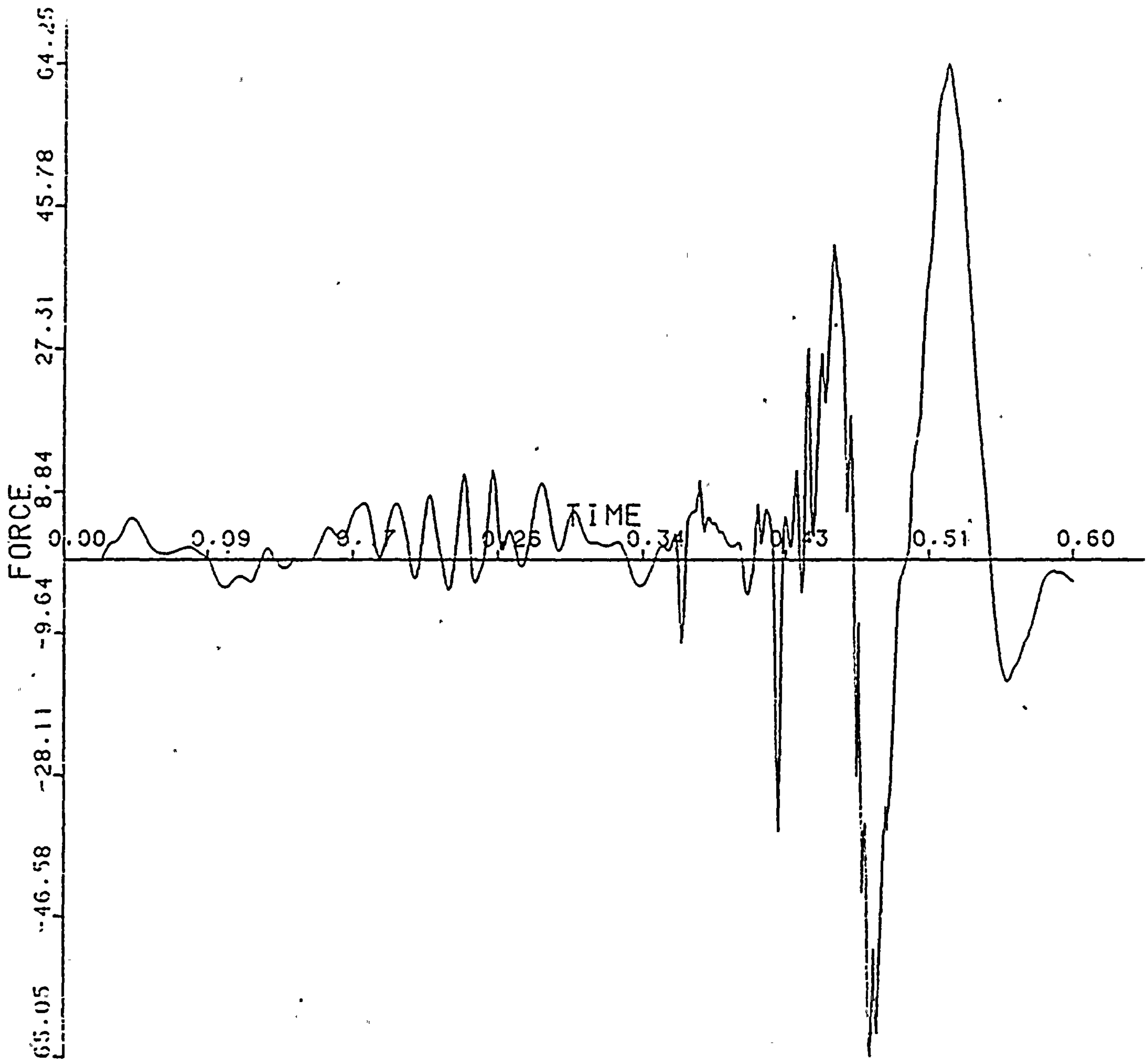
TIME/FORCE TABLE 46. MAGNITUDE AT NODE POINT 78



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SAP2SAP VERIFICATION 5364 6-JUN-83
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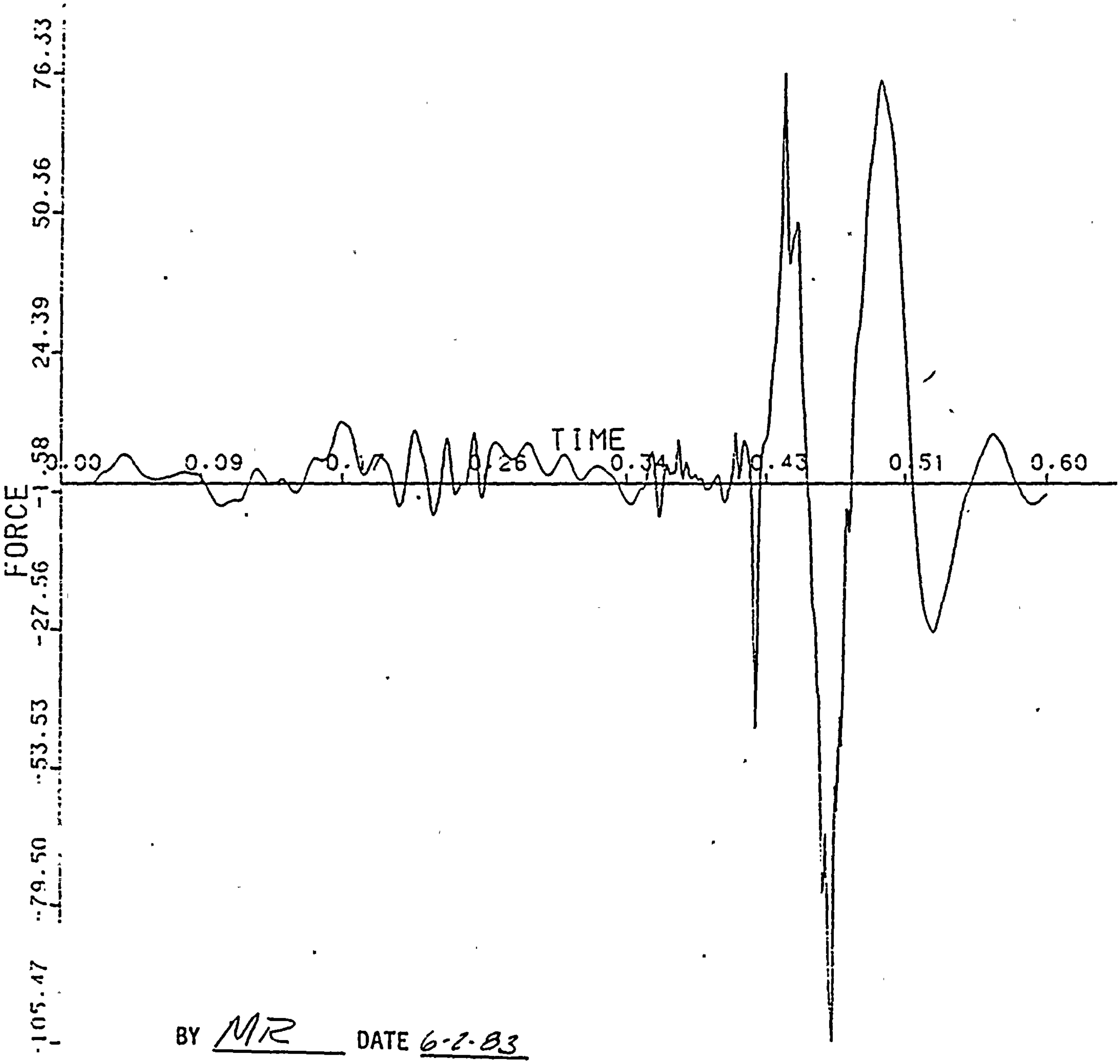
TIME/FORCE TABLE 47, MAGNITUDE AT NODE POINT 76



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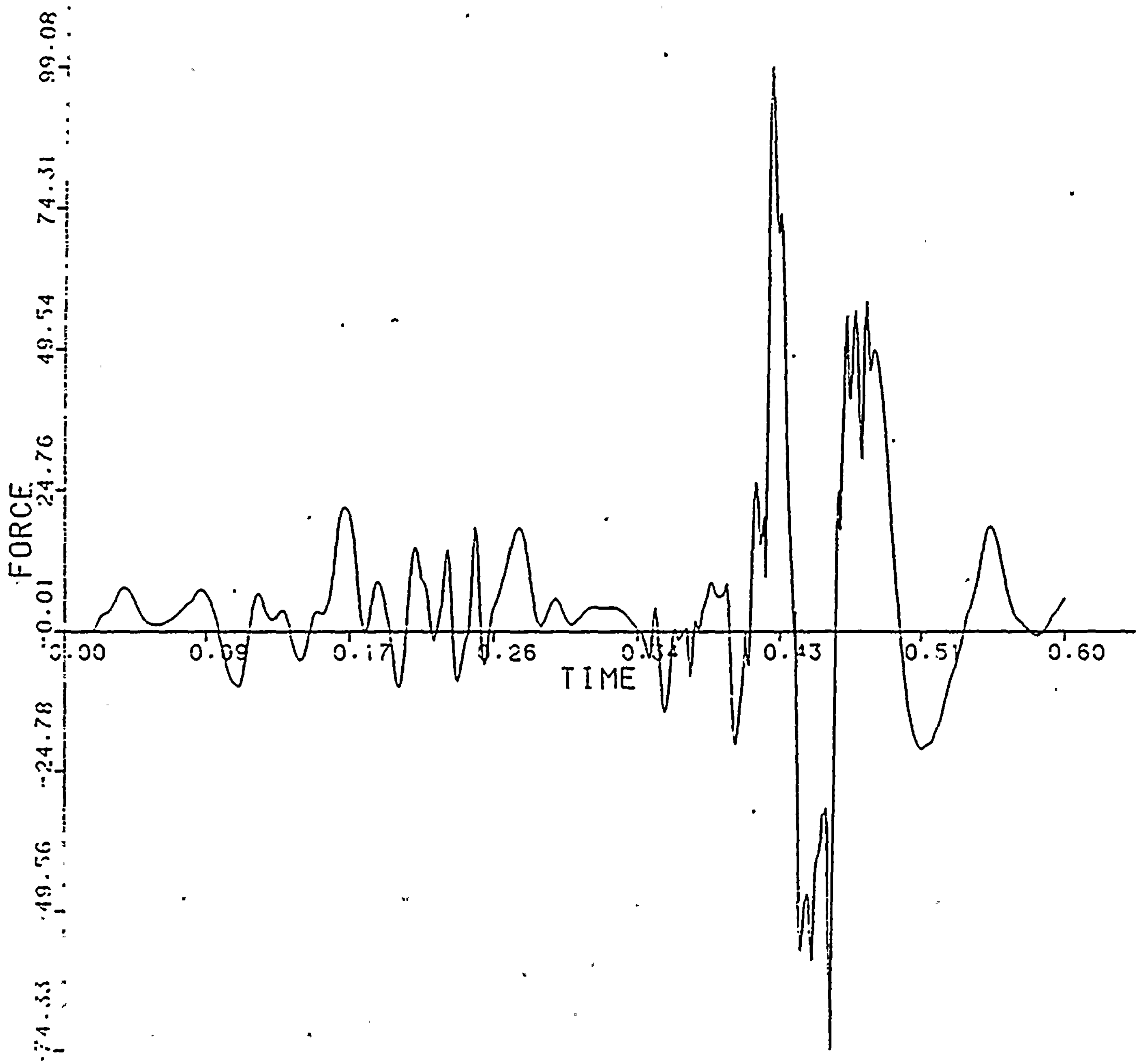
TIME/FORCE TABLE 48. MAGNITUDE AT NODE POINT 74



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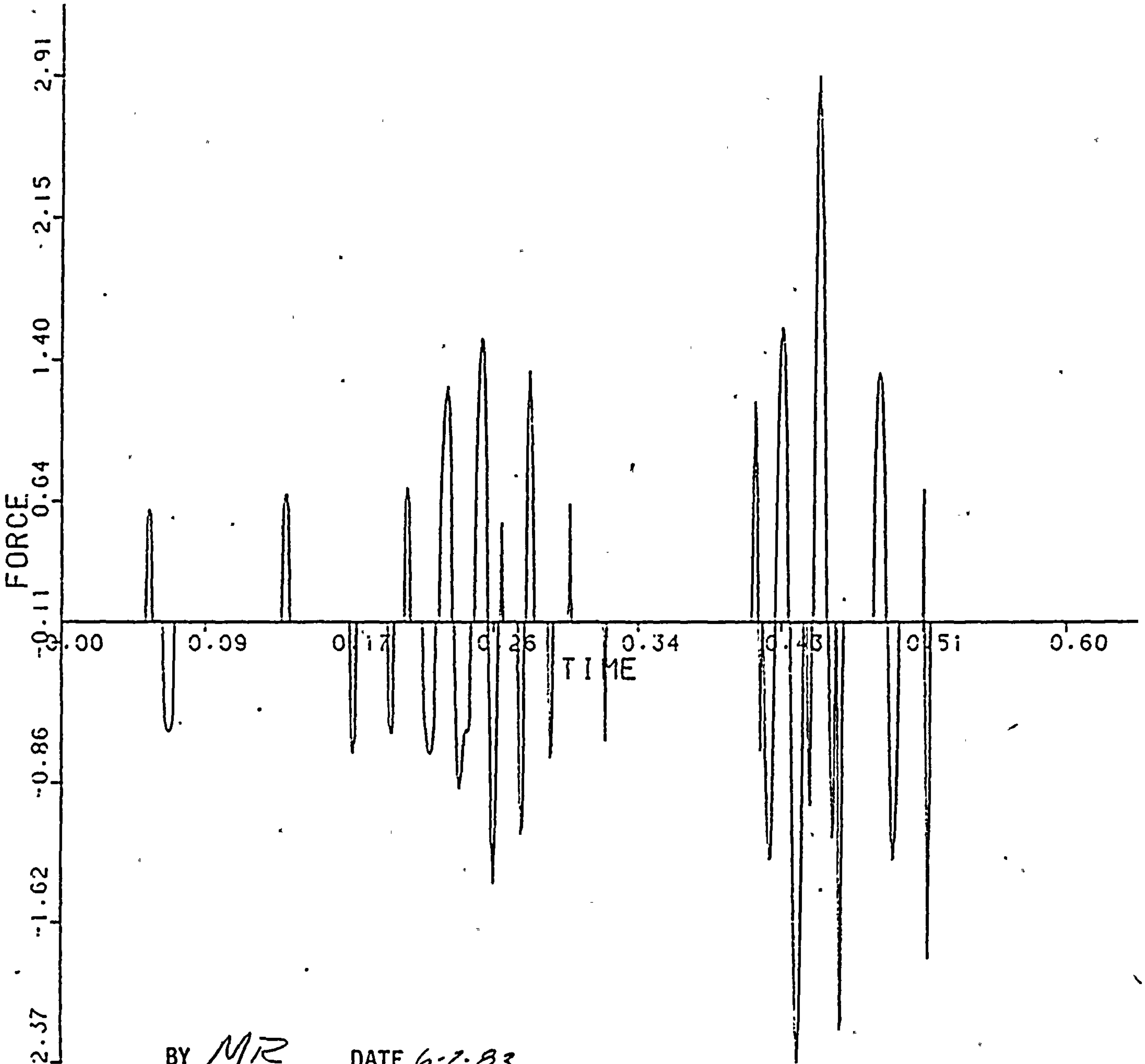
TIME/FORCE TABLE 49. MAGNITUDE AT NODE POINT 148



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SAP2SAP VERIFICATION 5364 6-JUN-83
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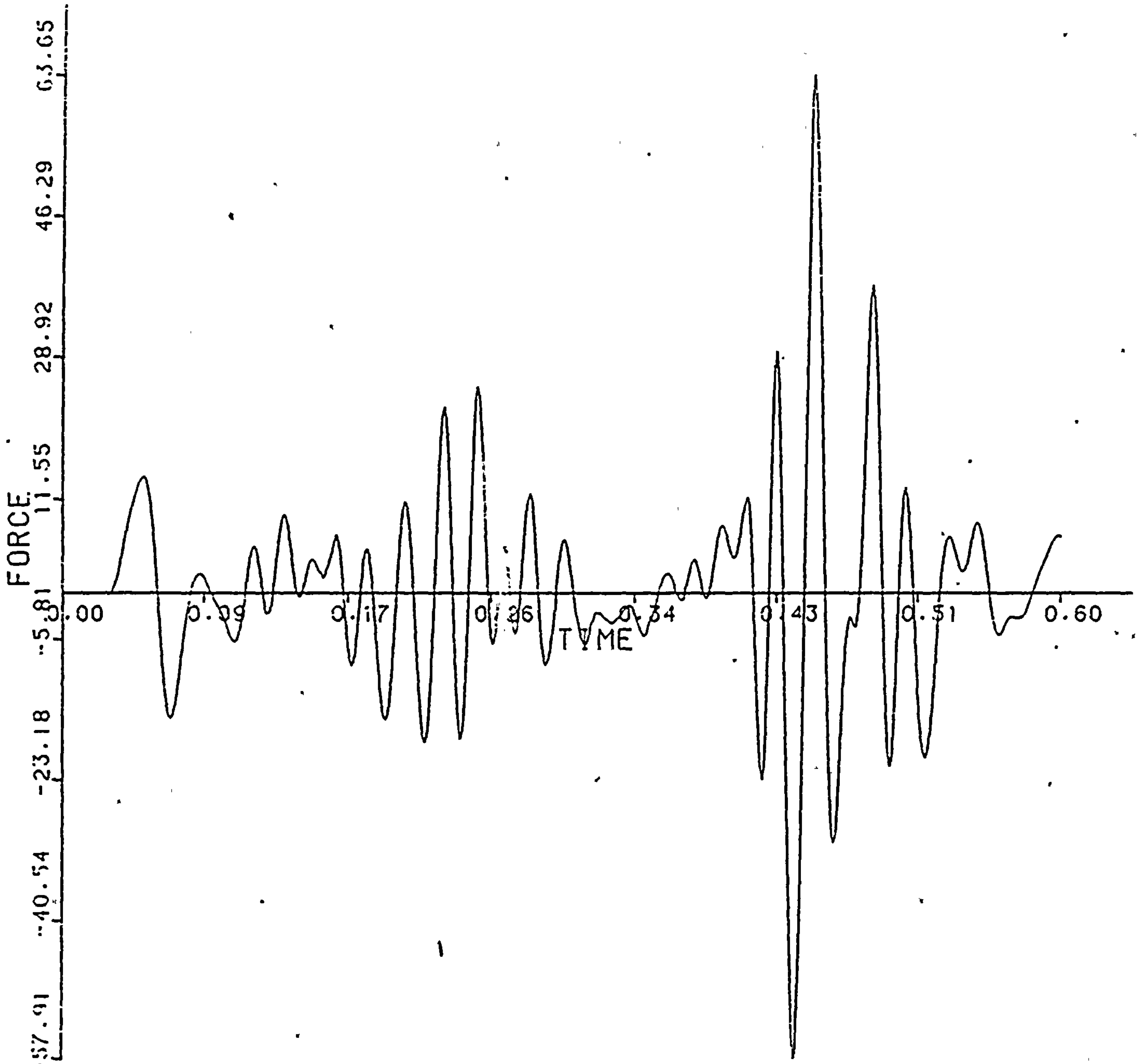
TIME/FORCE TABLE 50. MAGNITUDE AT NODE POINT 143



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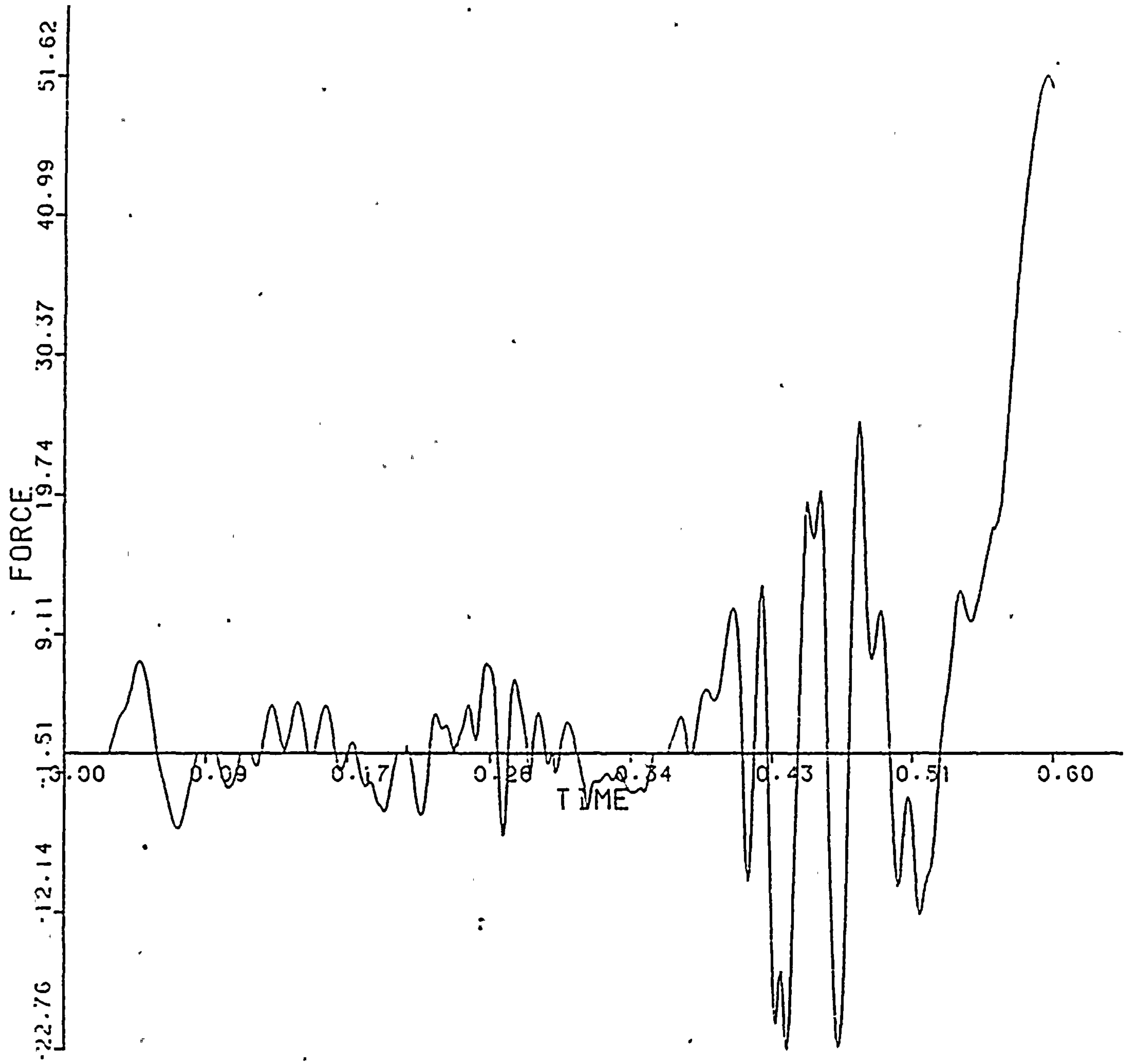
TIME/FORCE TABLE 51. MAGNITUDE AT NODE POINT 138



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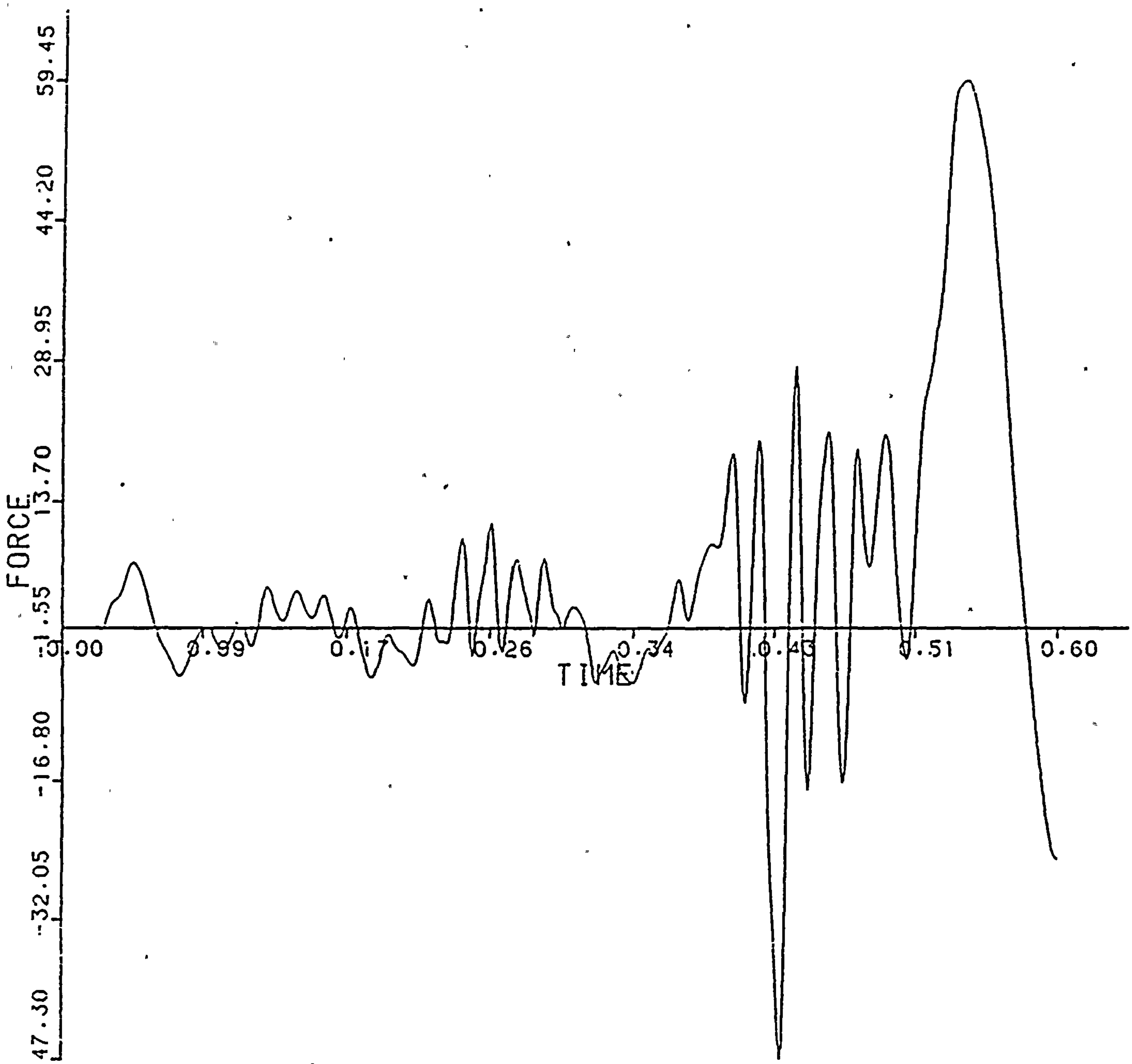
TIME/FORCE TABLE 52, MAGNITUDE AT NODE POINT 136



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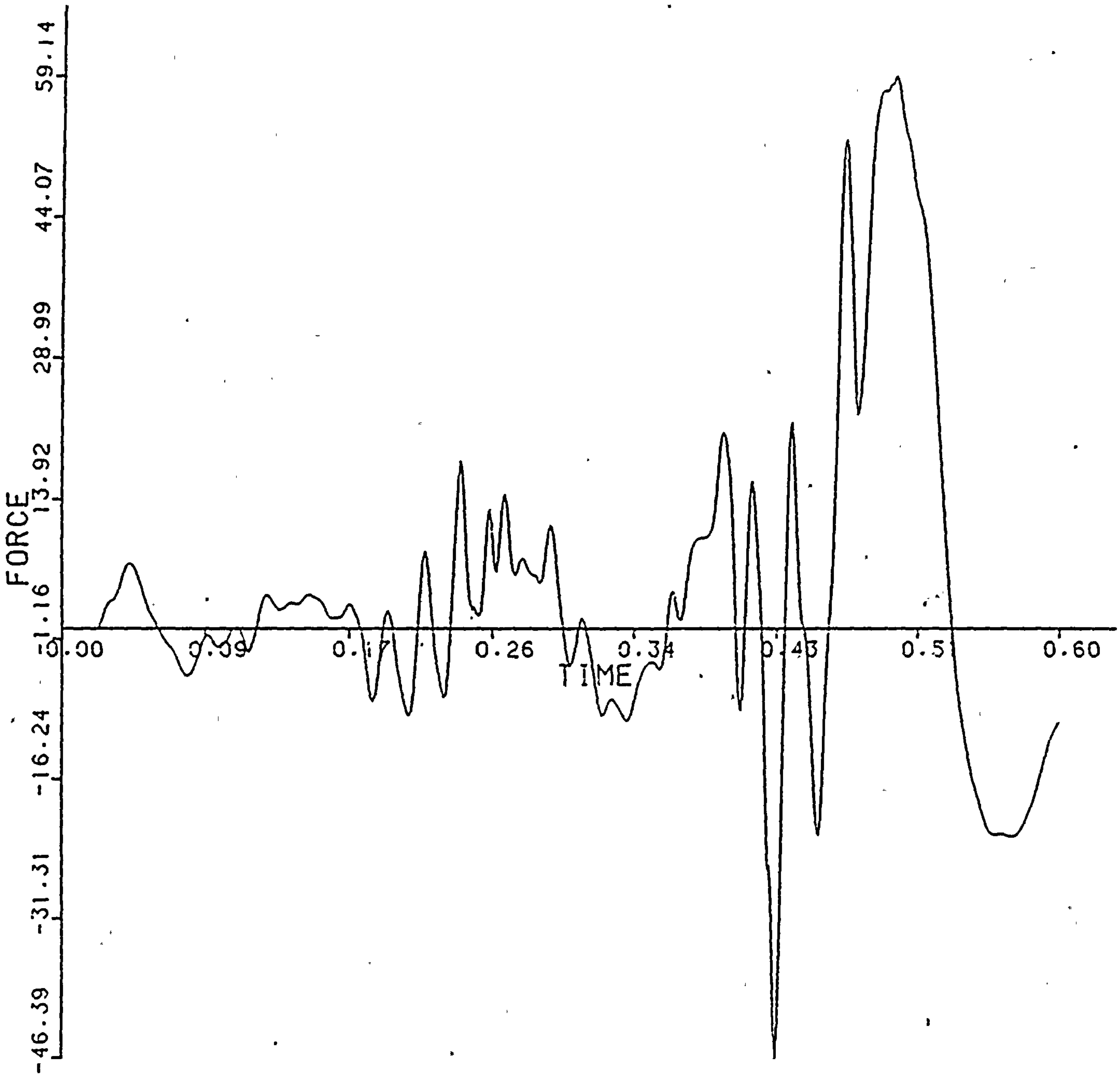
TIME/FORCE TABLE 53, MAGNITUDE AT NODE POINT 134



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SAP2SAP VERIFICATION 5364 6-JUN-83
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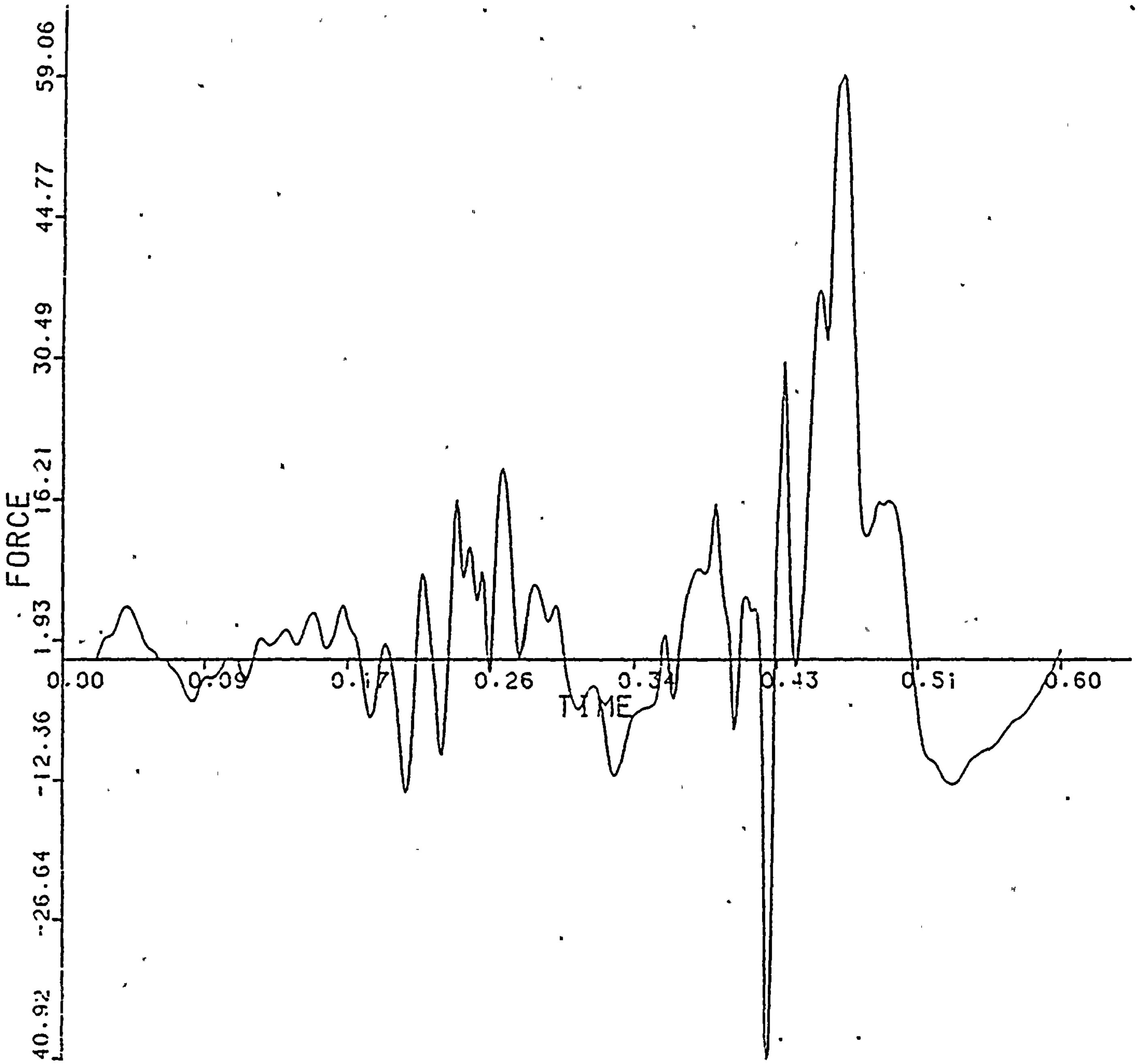
TIME/FORCE TABLE 54. MAGNITUDE AT NODE POINT 132



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SAP2SAP VERIFICATION 5364 6-JUN-83
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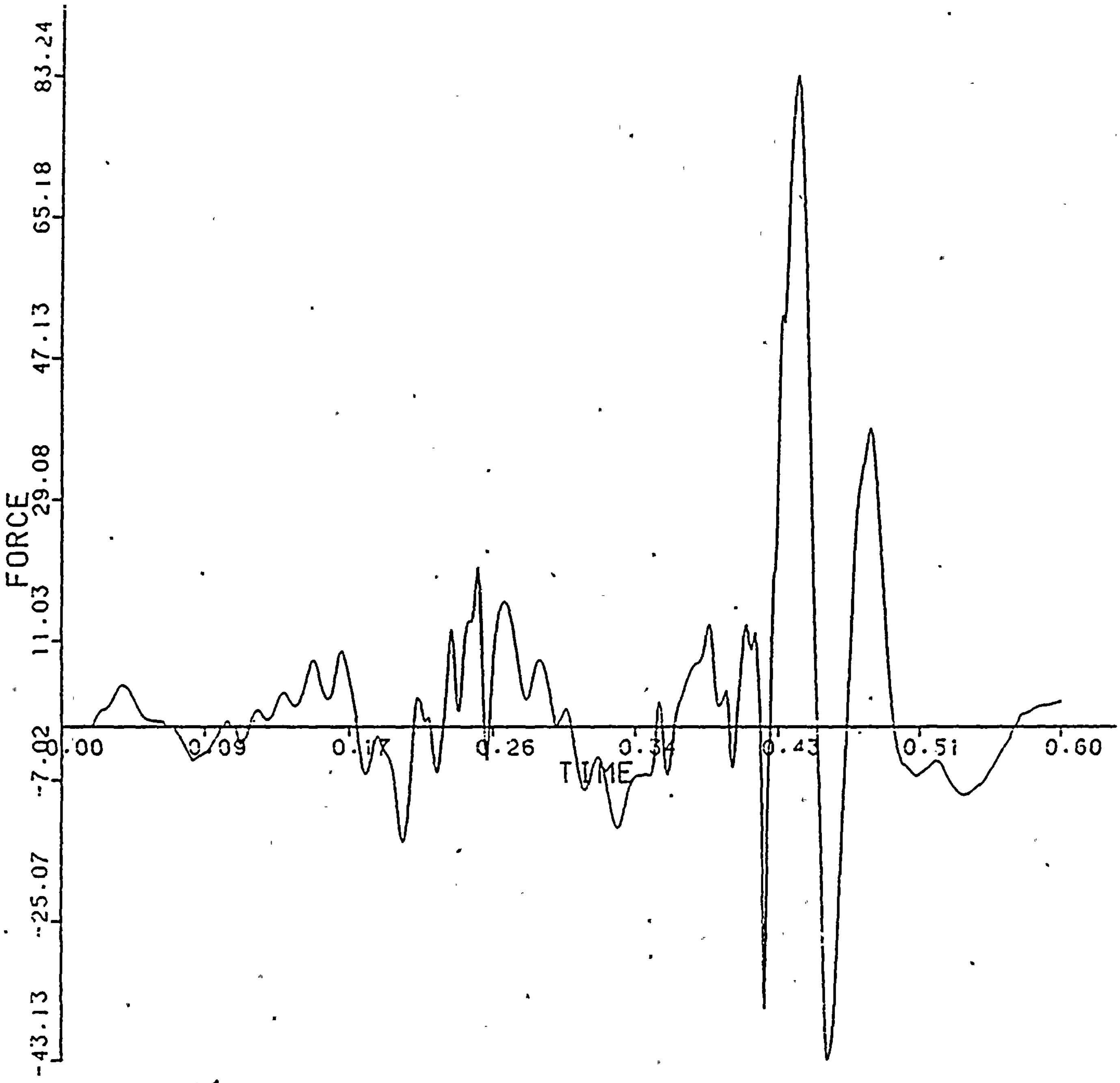
TIME/FORCE TABLE 55, MAGNITUDE AT NODE POINT 130



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SAP2SAP VERIFICATION 5364 6-JUN-83
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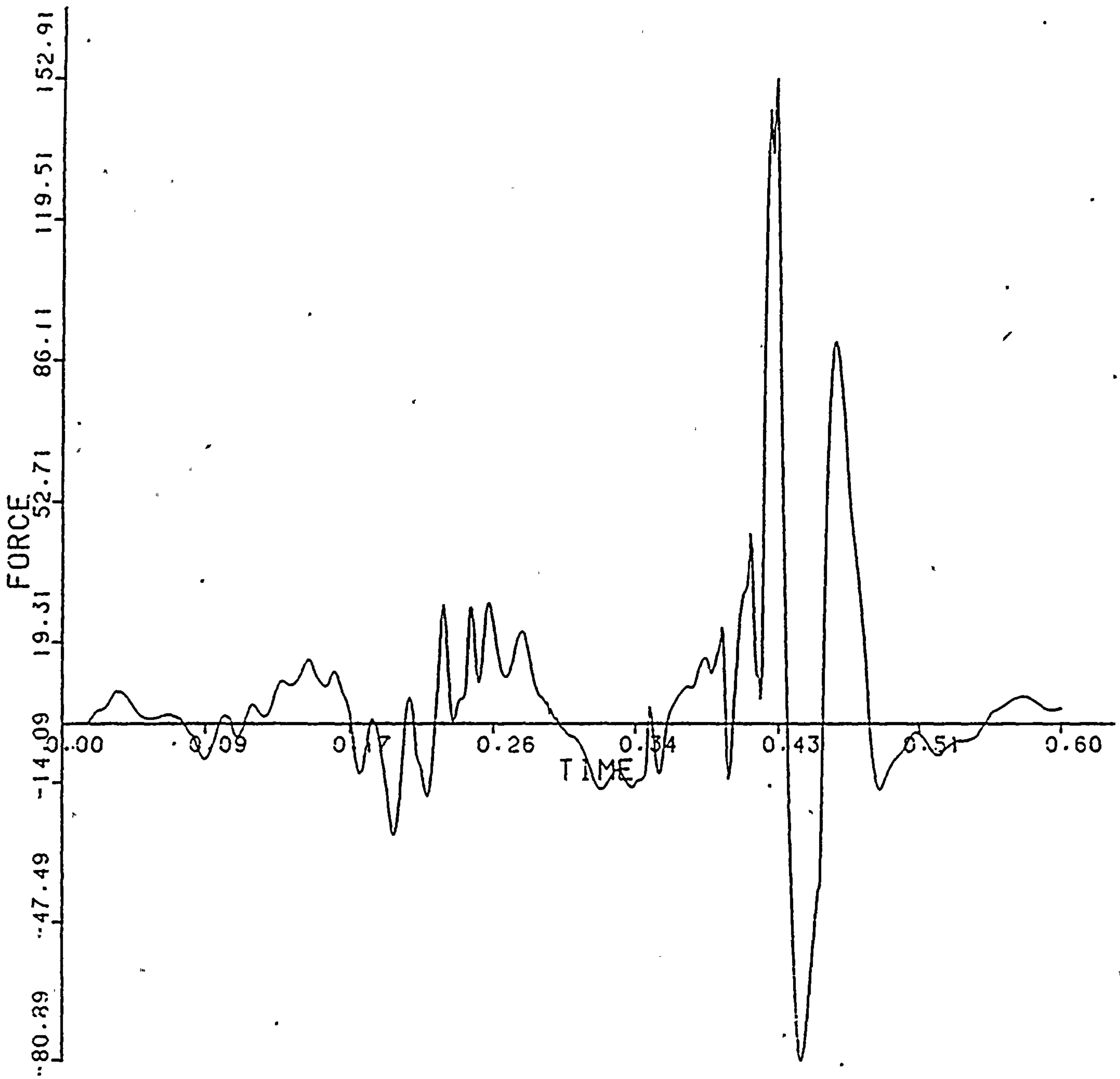
TIME/FORCE TABLE 56, MAGNITUDE AT NODE POINT 128



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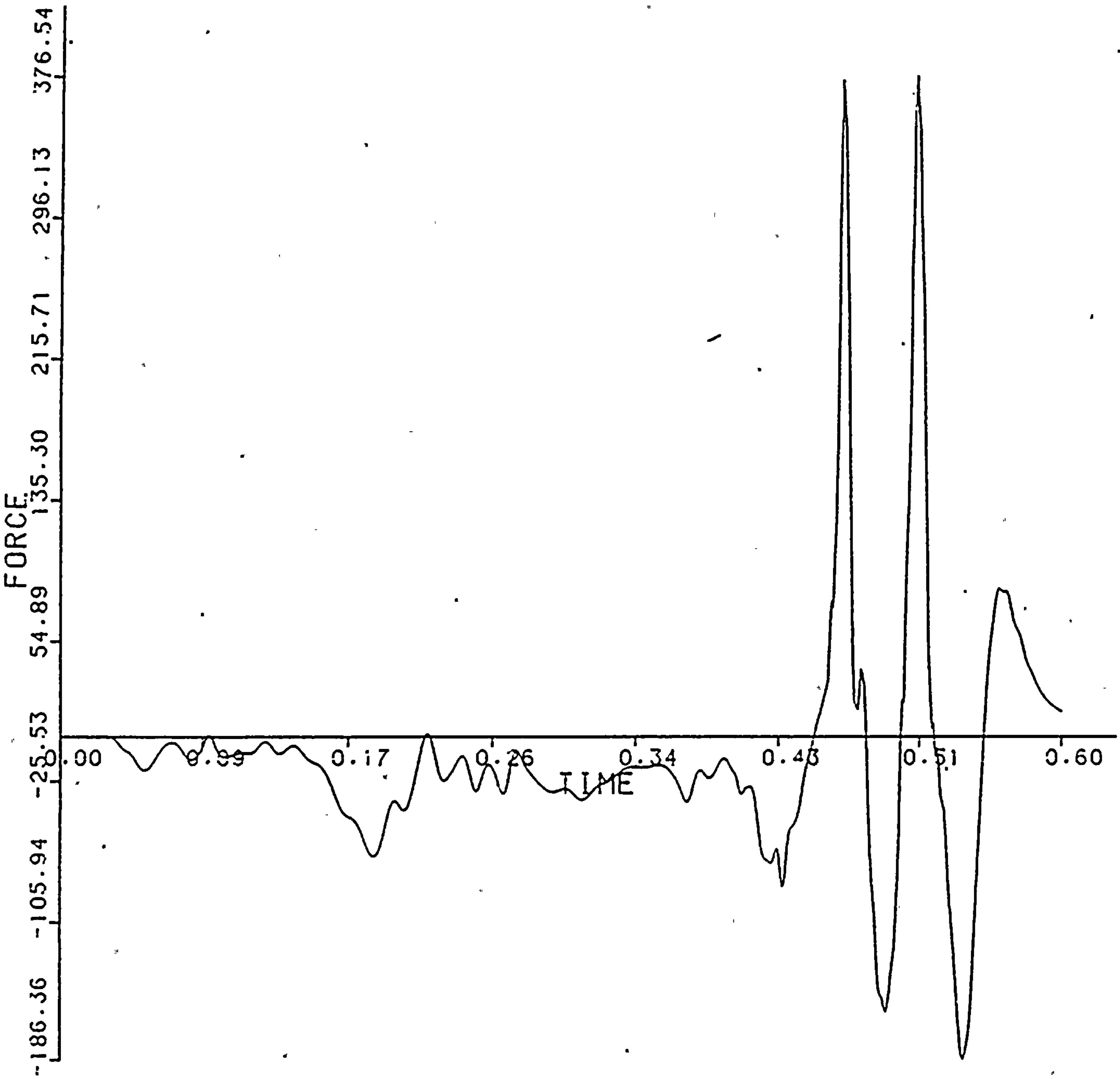
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 57, MAGNITUDE AT NODE POINT 60



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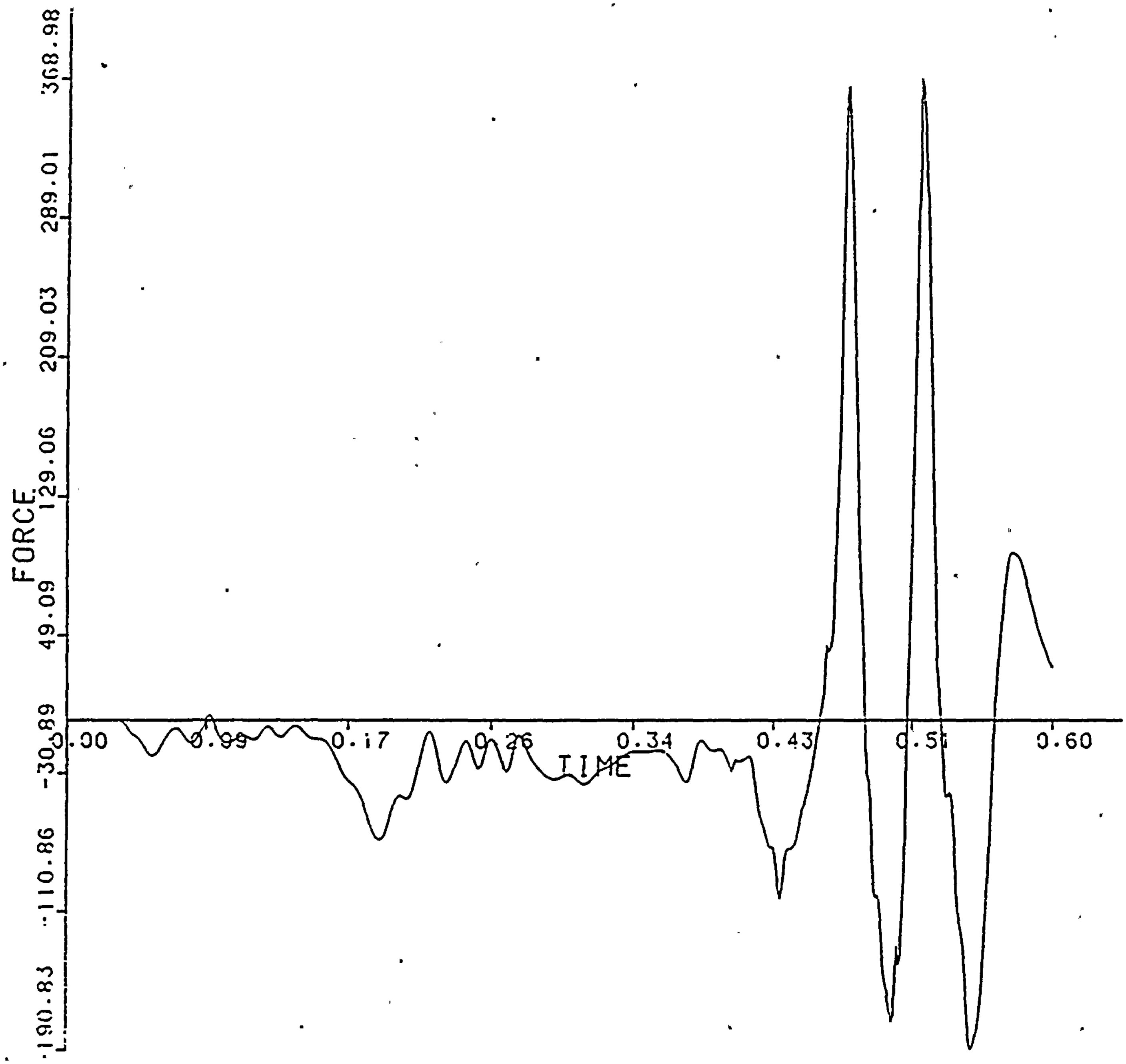
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 58. MAGNITUDE AT NODE POINT 56



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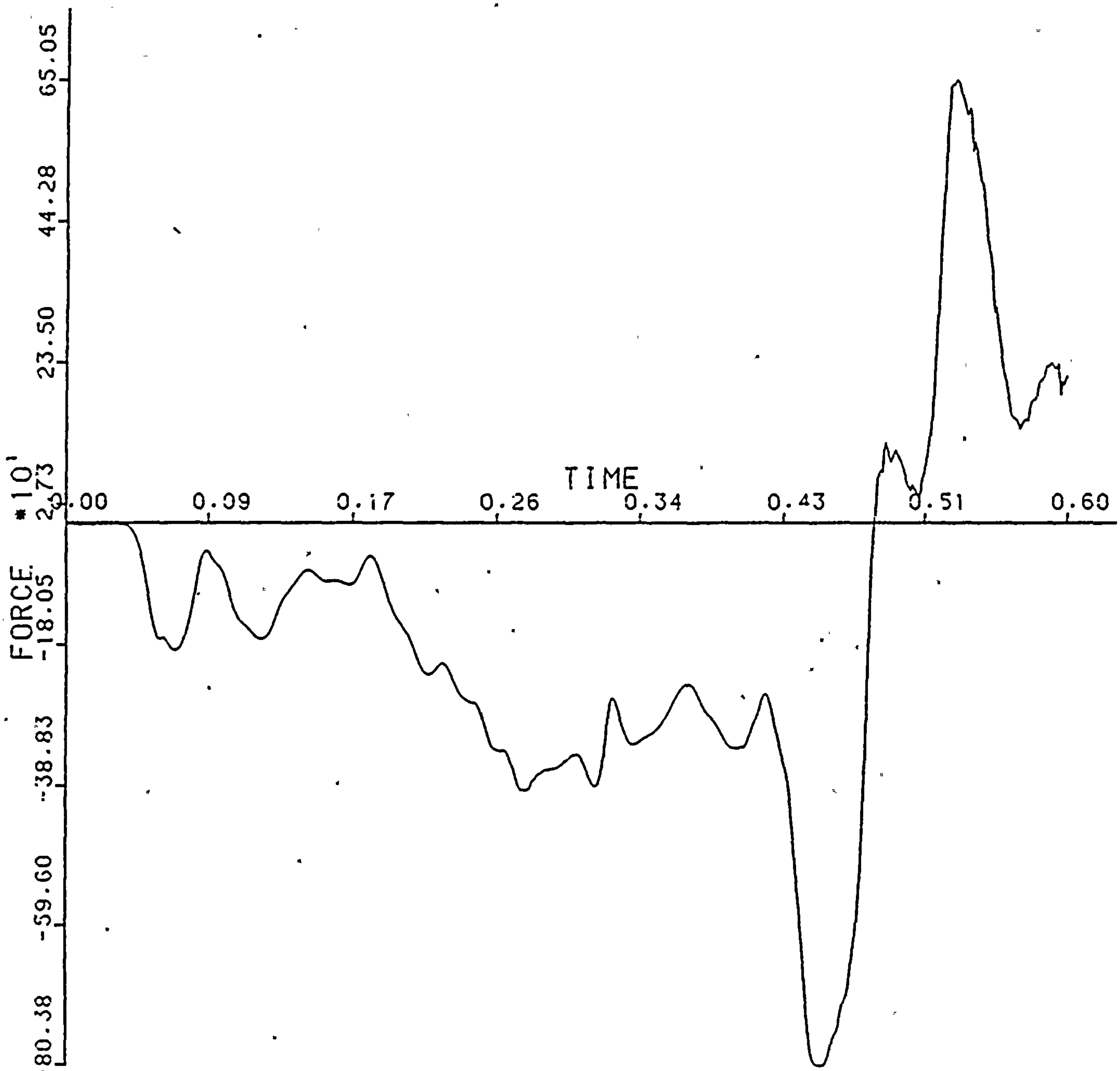
TIME/FORCE TABLE 59. MAGNITUDE AT NODE POINT 48



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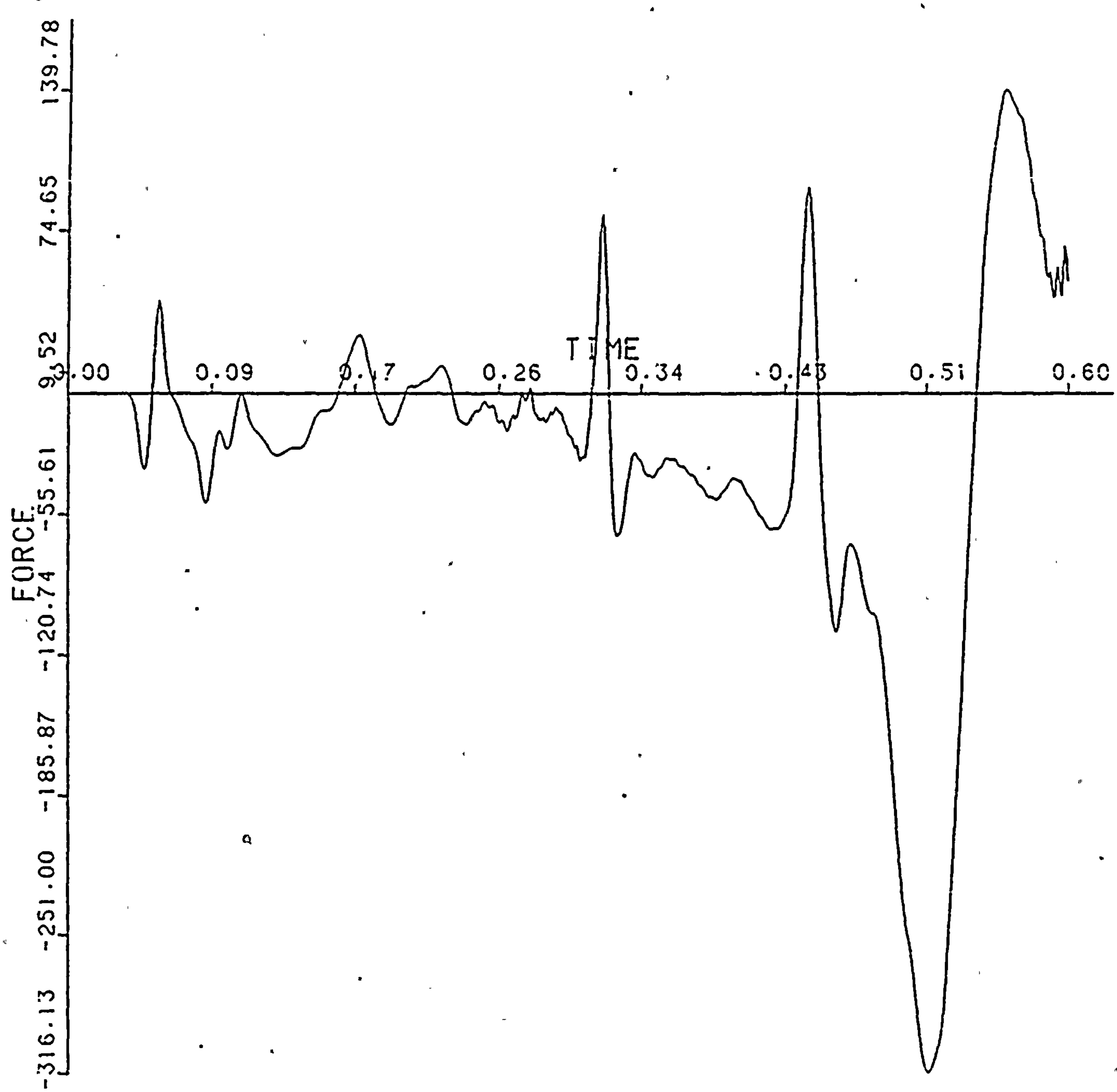

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SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
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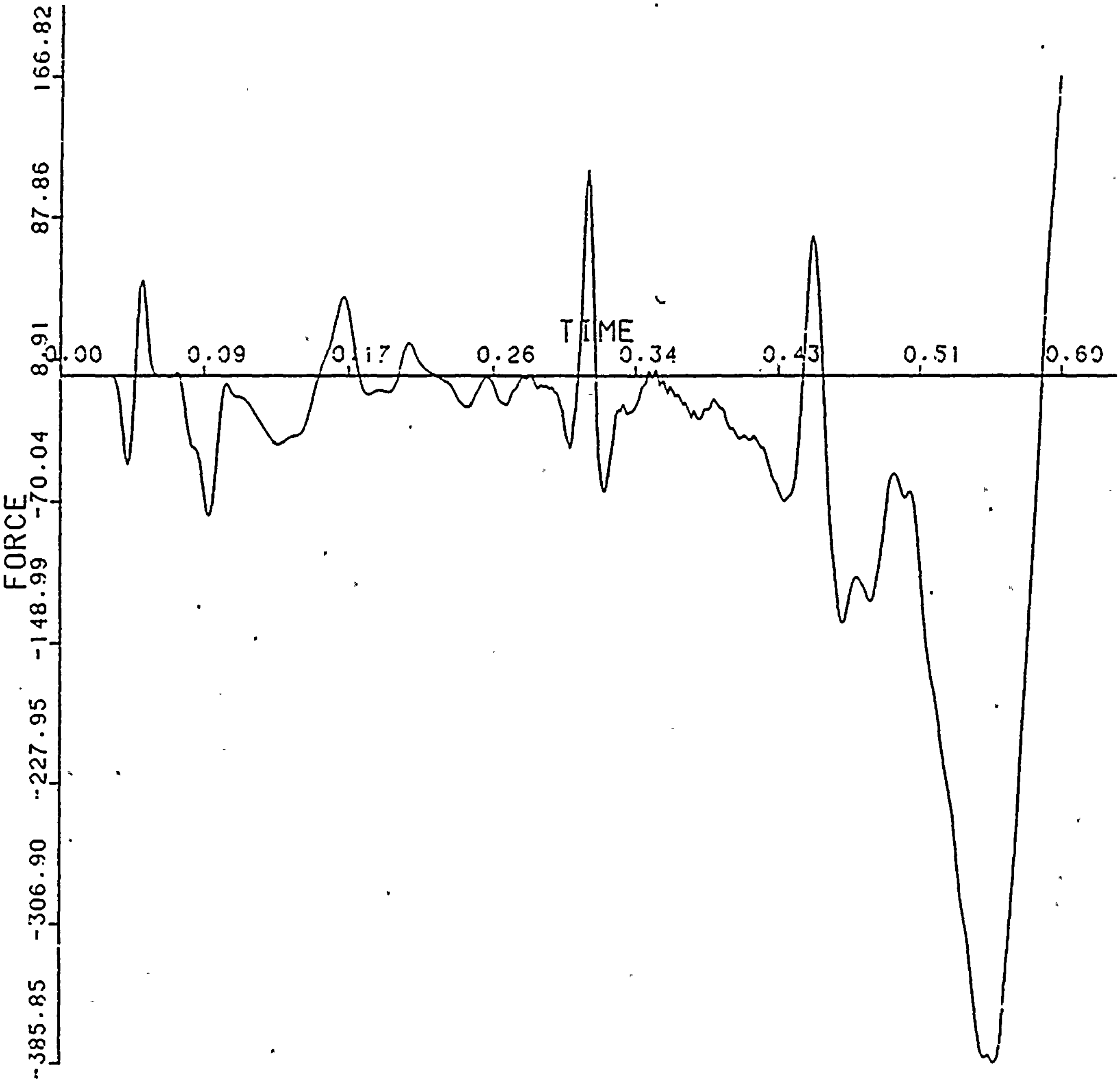

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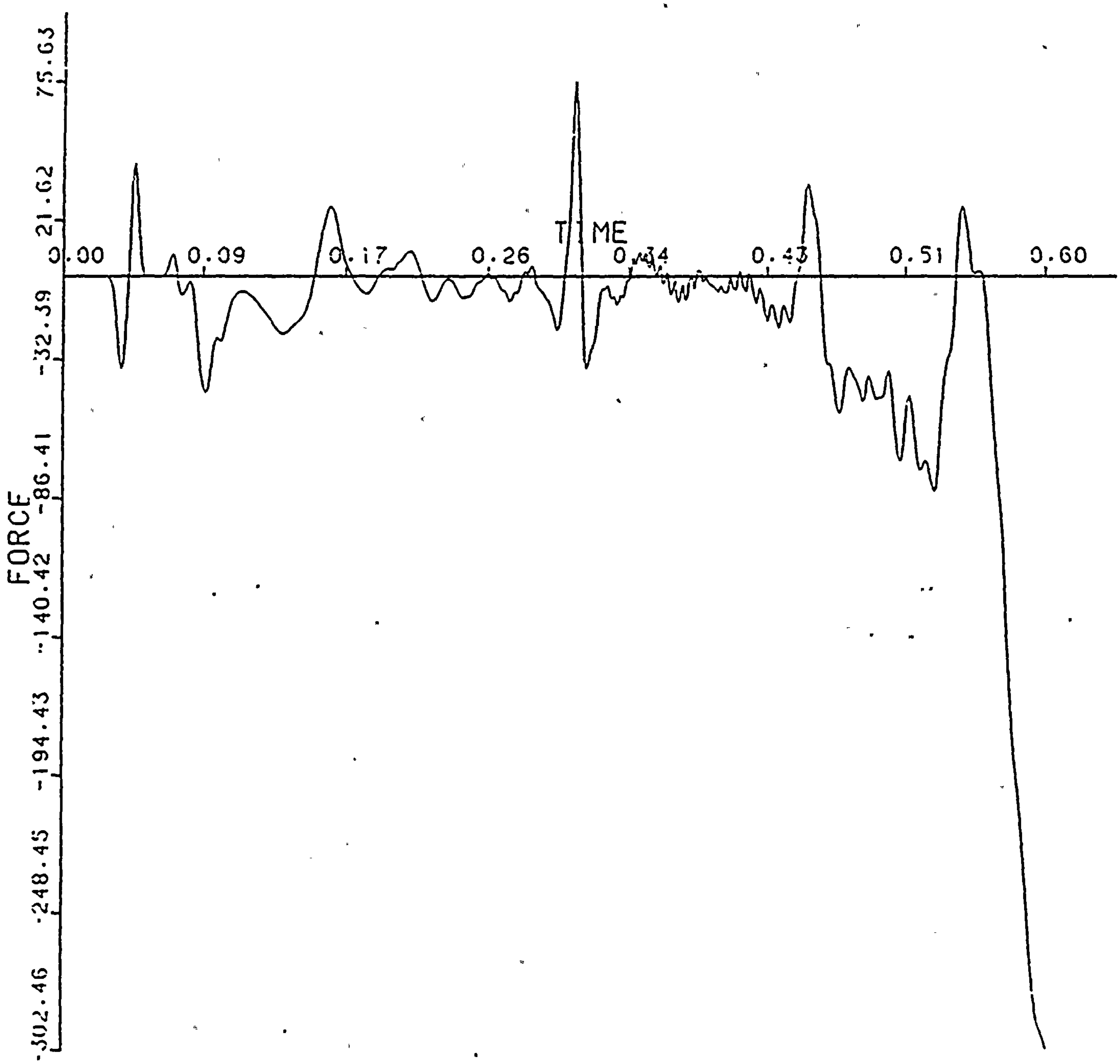
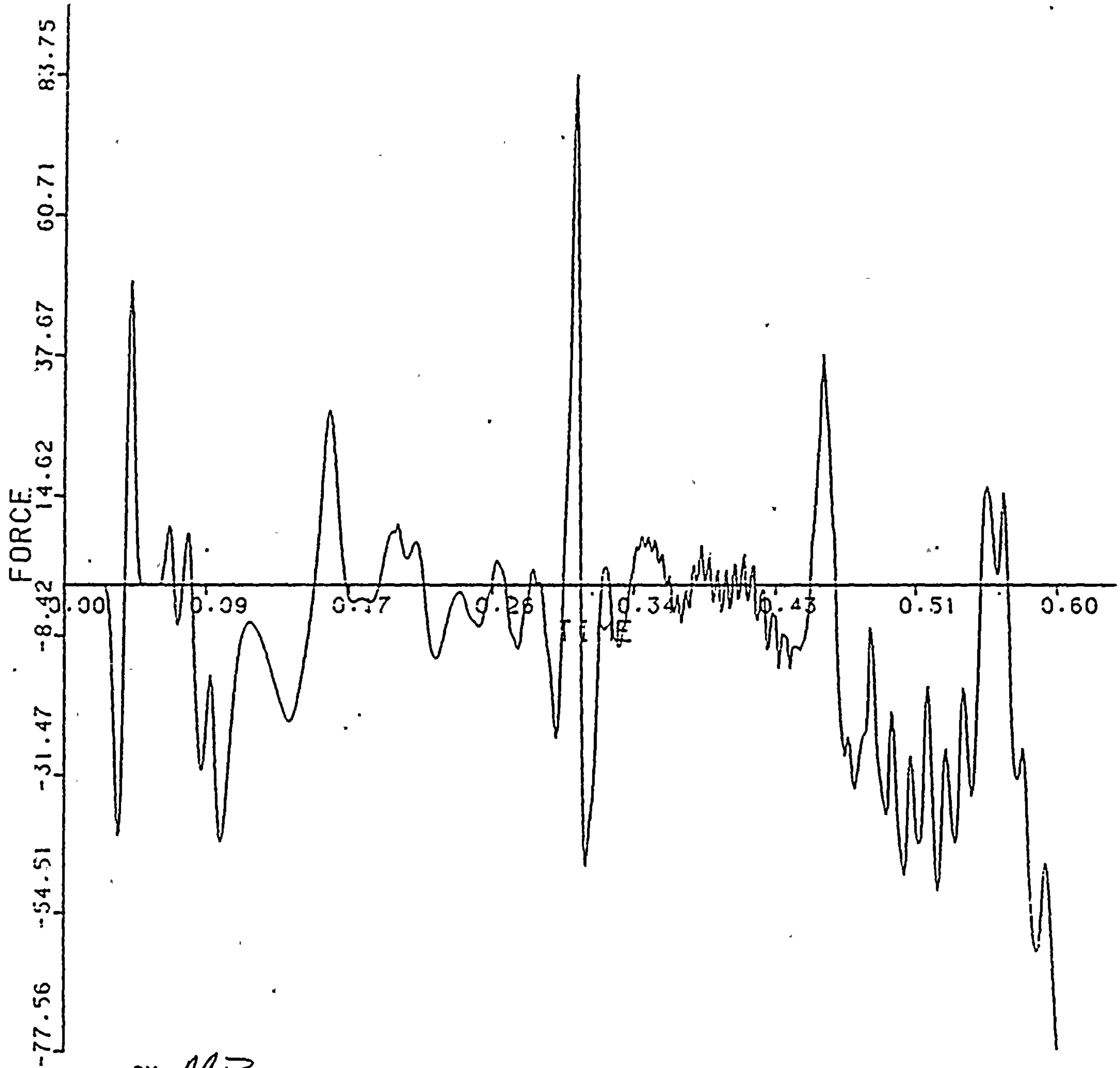
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 62. MAGNITUDE AT NODE POINT 36



BY MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

TELEDYNE
ENGINEERING SERVICES

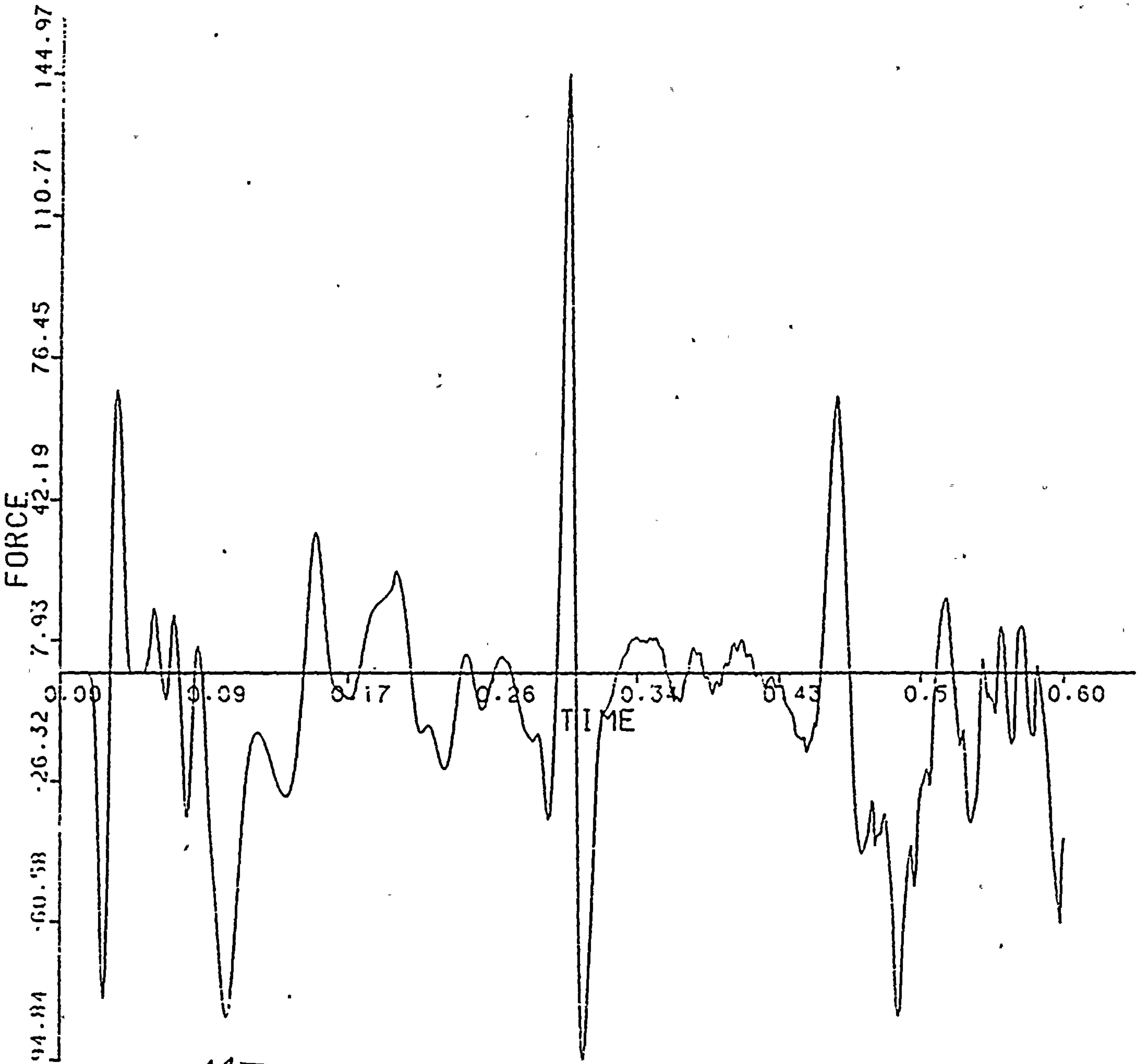
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 63. MAGNITUDE AT NODE POINT 33



BY MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

TELEDYNE
ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 64. MAGNITUDE AT NODE POINT 24



BY MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

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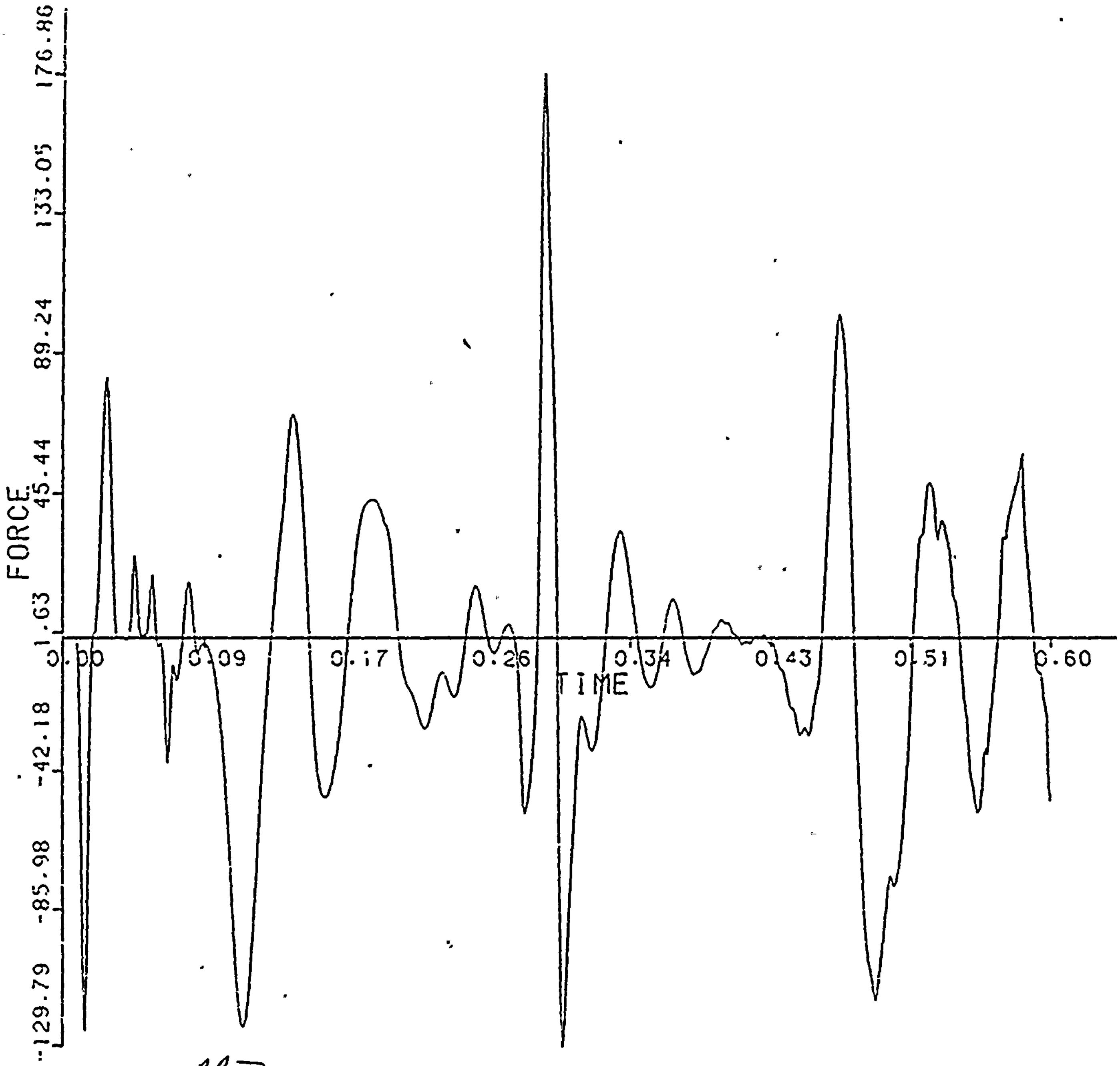
TELEDYNE
ENGINEERING SERVICES

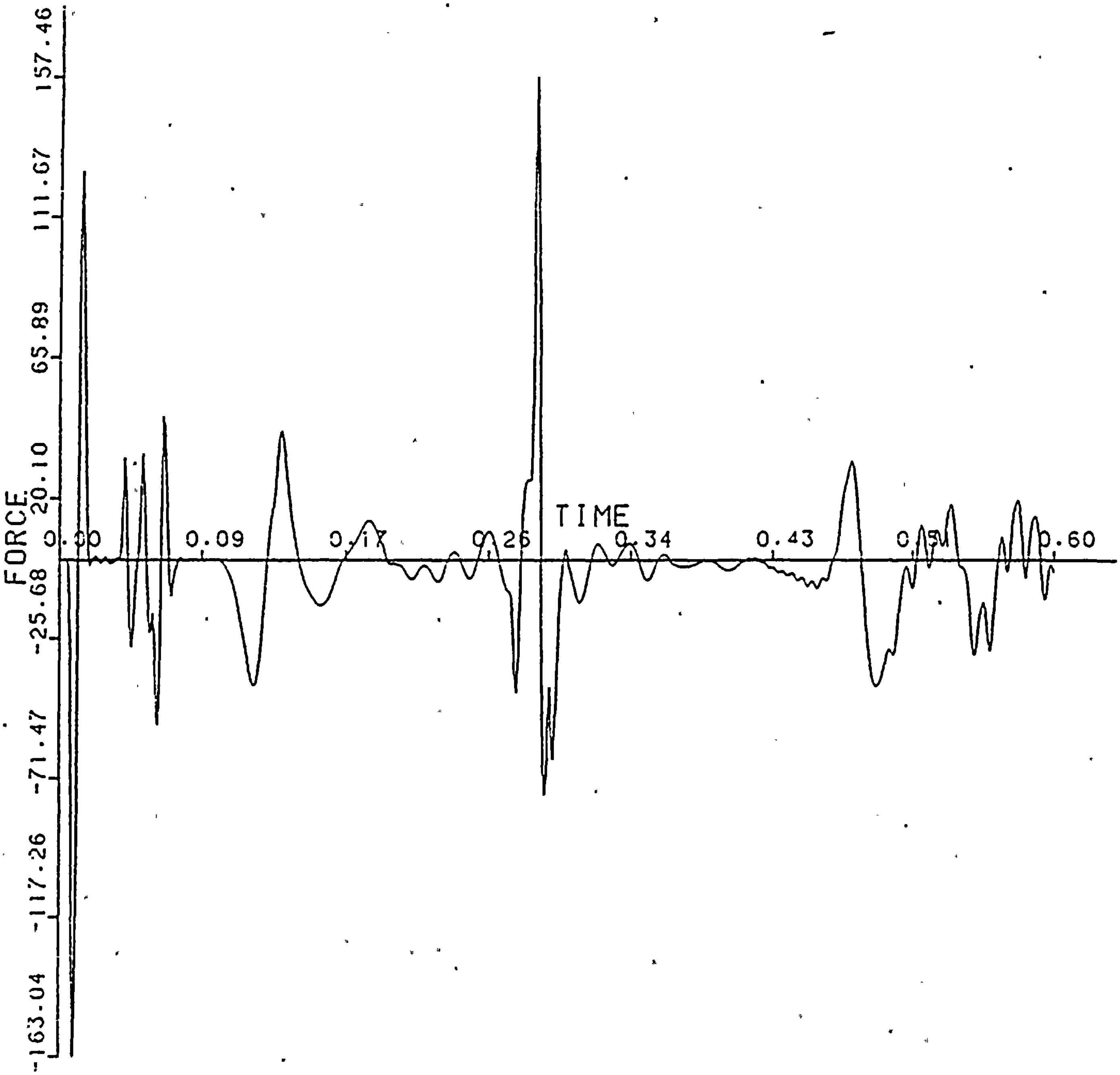
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 65, MAGNITUDE AT NODE POINT 14



BY. MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

TELEDYNE
ENGINEERING SERVICES

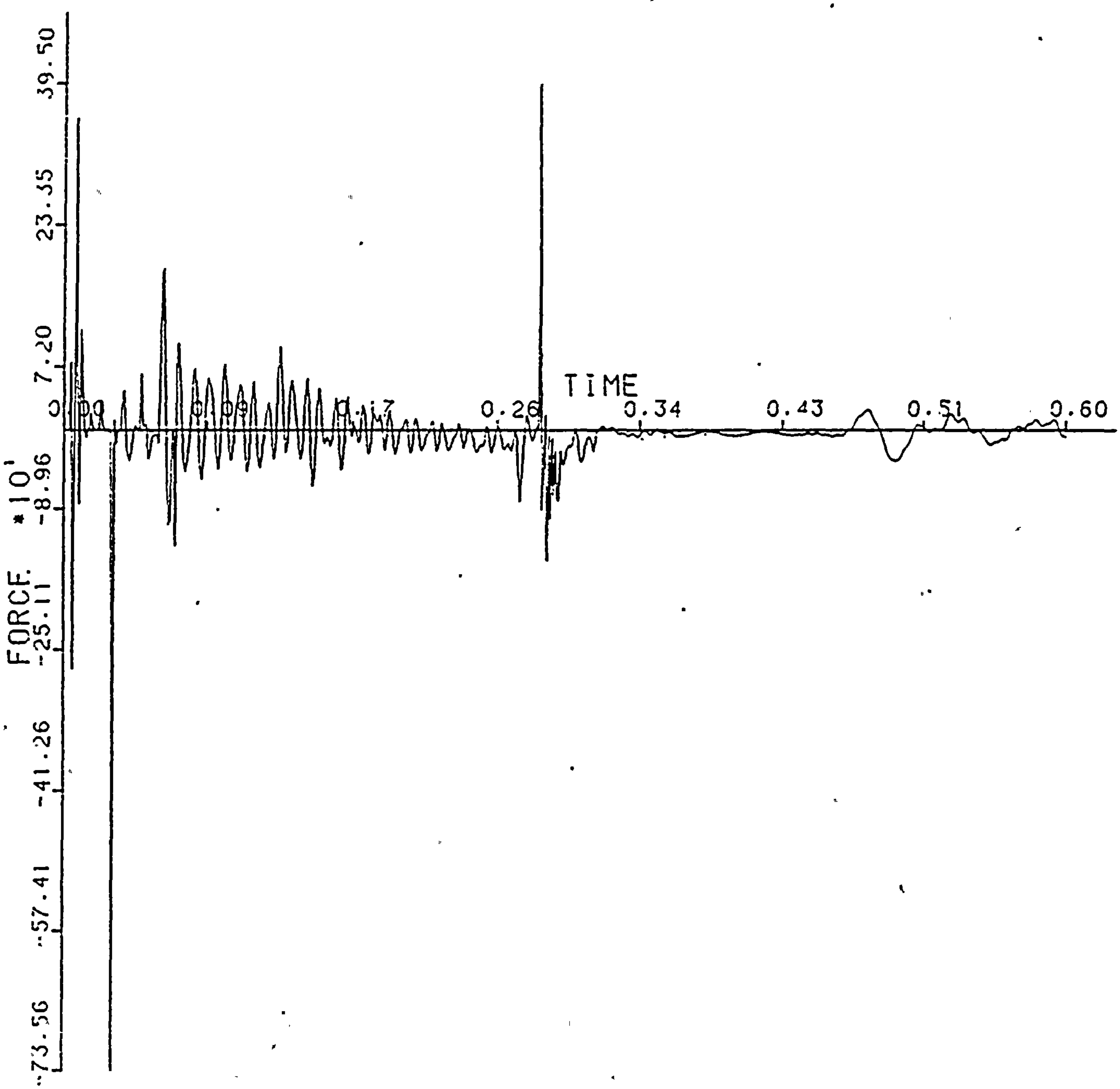
SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 66. MAGNITUDE AT NODE POINT 8



BY MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

TELEDYNE
ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 6-JUN-83
UN2 YEL-RED SOLID 400F 0-600MS
TIME/FORCE TABLE 67. MAGNITUDE AT NODE POINT 4



BY MR DATE 6-2-83
CHKD. BY KJG DATE 6-7-83

4.8.2 Quarter Model - Cold Loop Seal/Steam Case

TELEDYNE ENGINEERING SERVICES

BY CMM	DATE 3-16-83	1/4 MODEL LENGTHS & NODES (SRV) ANALYSIS	SHEET NO. 1 OF 1
CHKD. BY KJG	DATE 5-24-83		PROJ. NO. 5364

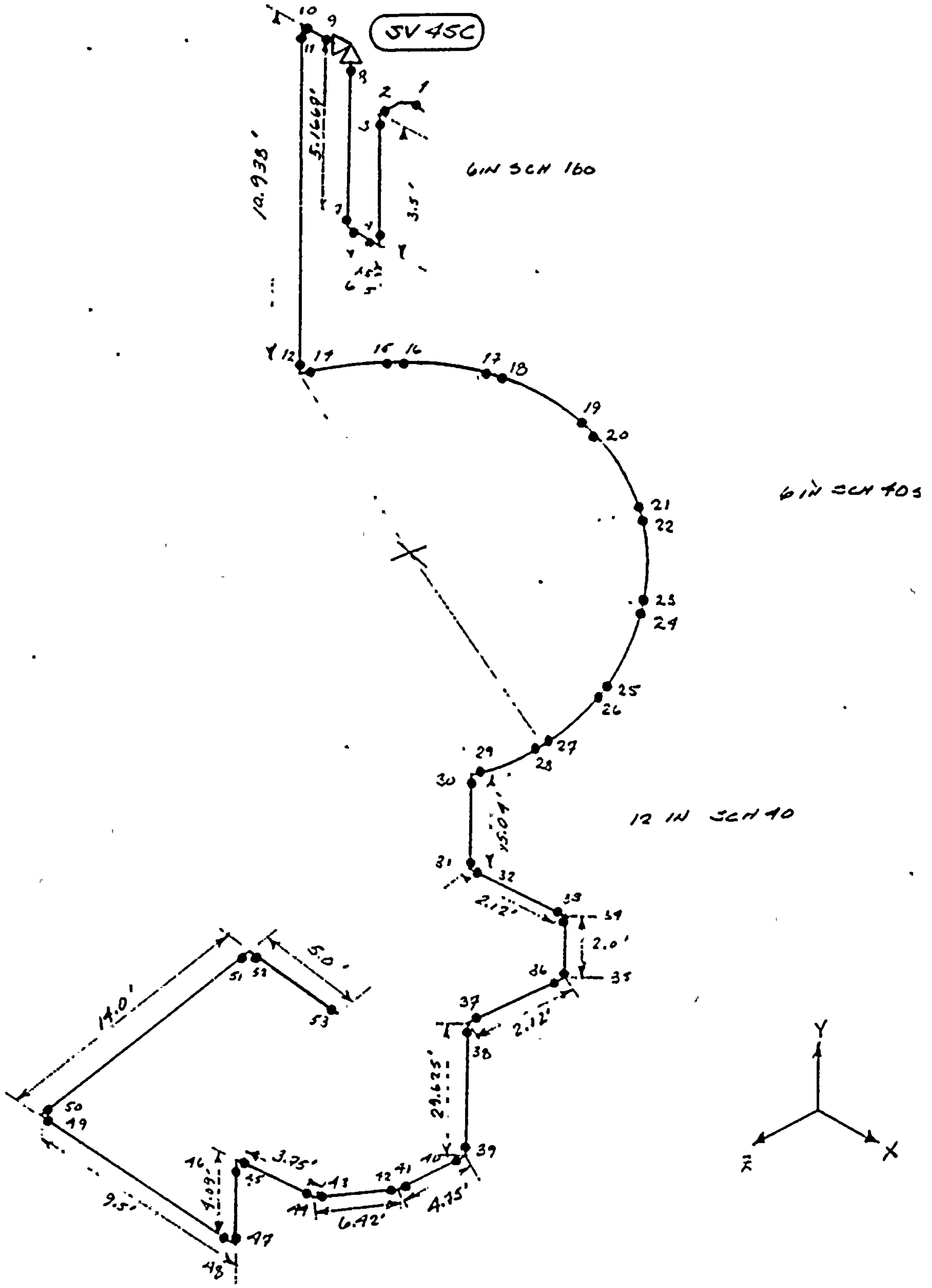


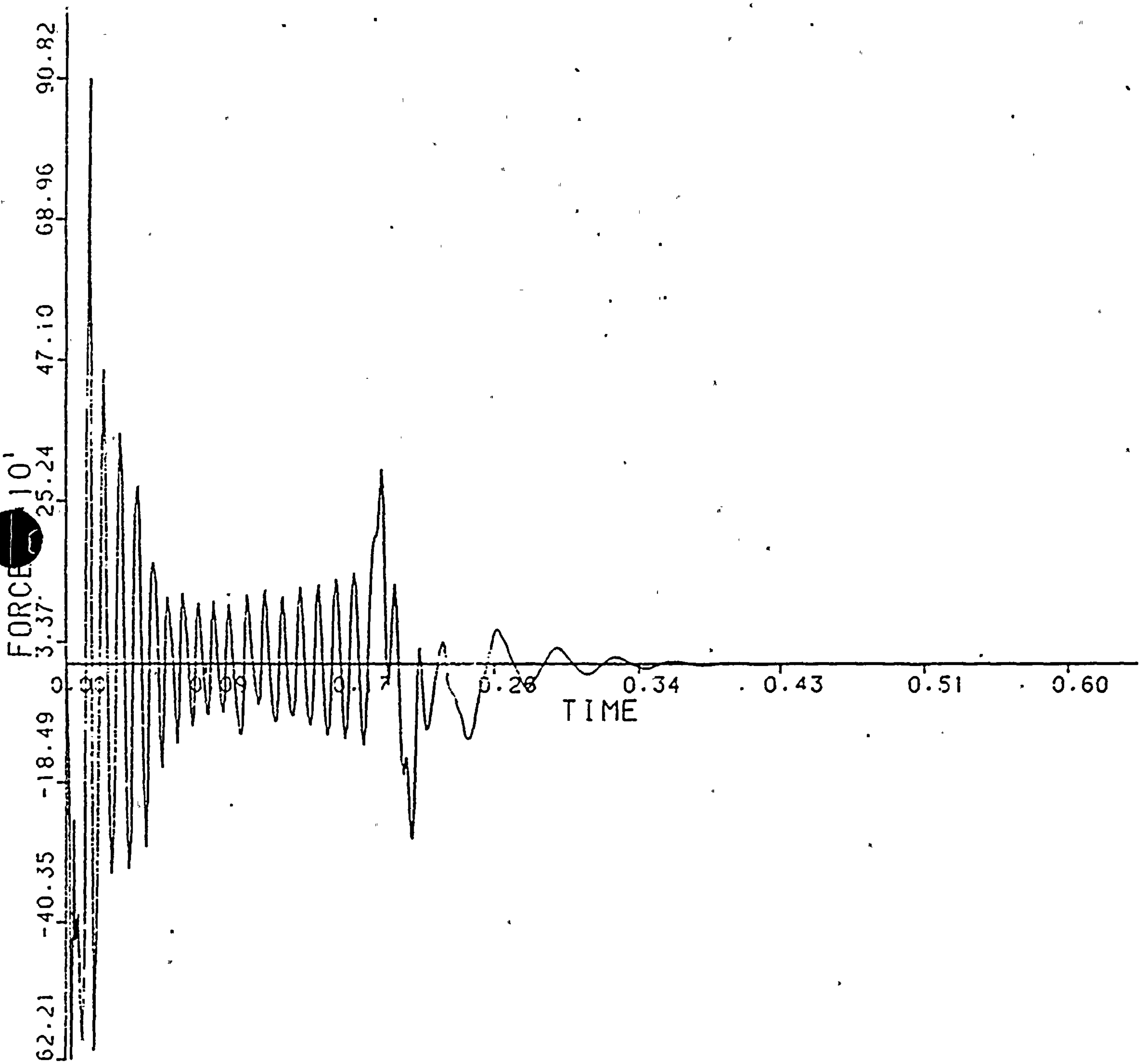
FIGURE 4.8.2-1

4-203 TELEDYNE ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 24-MAY-83

QUARTER MODEL UNIT 2 LOOPSEAL

TIME/FORCE TABLE 1, MAGNITUDE AT NODE POINT 118



DONE BY: [signature] DATE: 5-26-83

CHKD BY: [initials] DATE: 5-27-83

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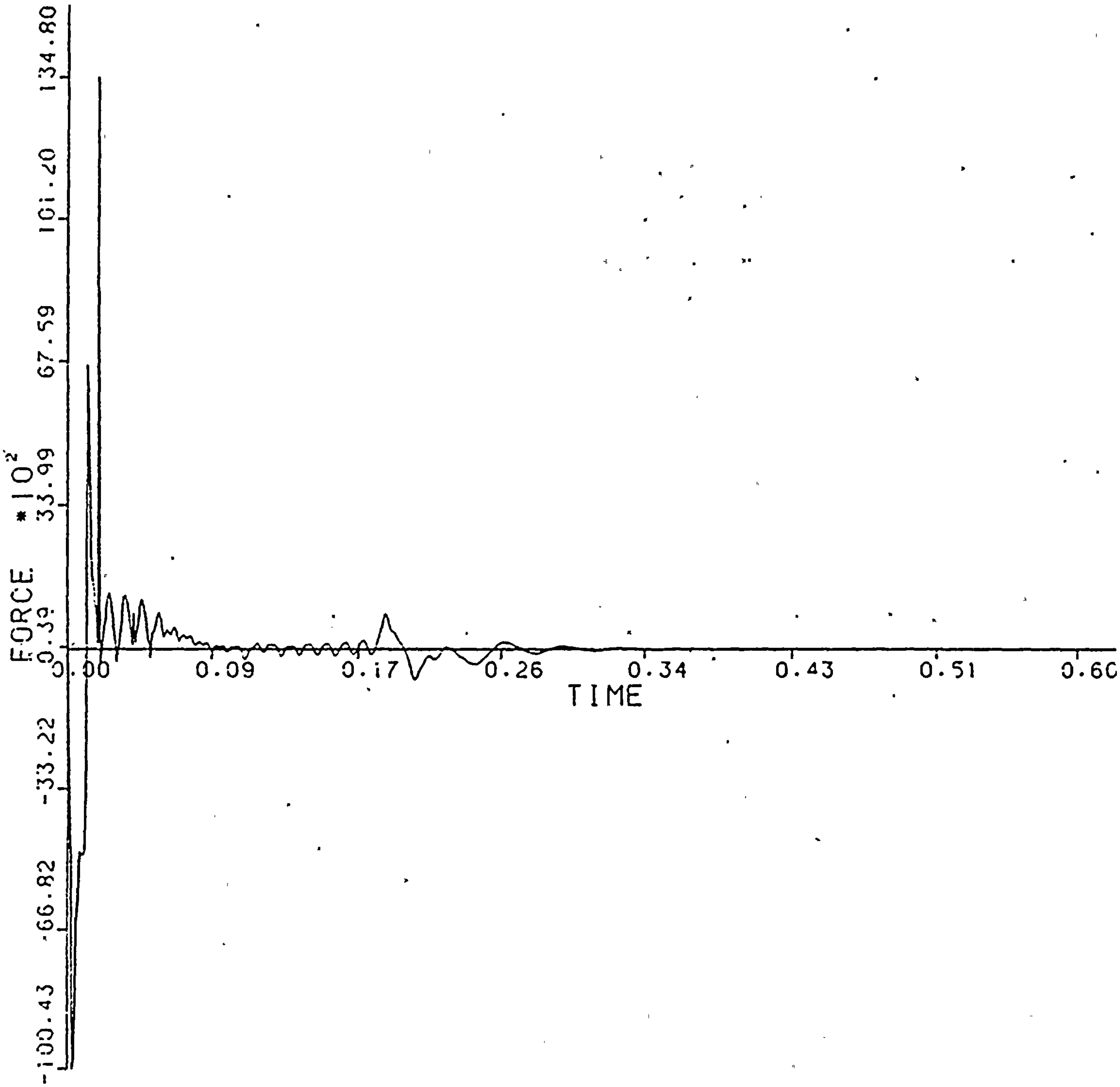
TELEDYNE
ENGINEERING SERVICES

[illegible] VERIFICATION 5364 [illegible] MAY 83
QUARTER-MODEL [illegible]
[illegible] FORCE [illegible] MAGNITUDE AT NODE POINT [illegible]



DONE BY: [illegible] DATE: [illegible]
CHKD BY: [illegible] DATE: [illegible]

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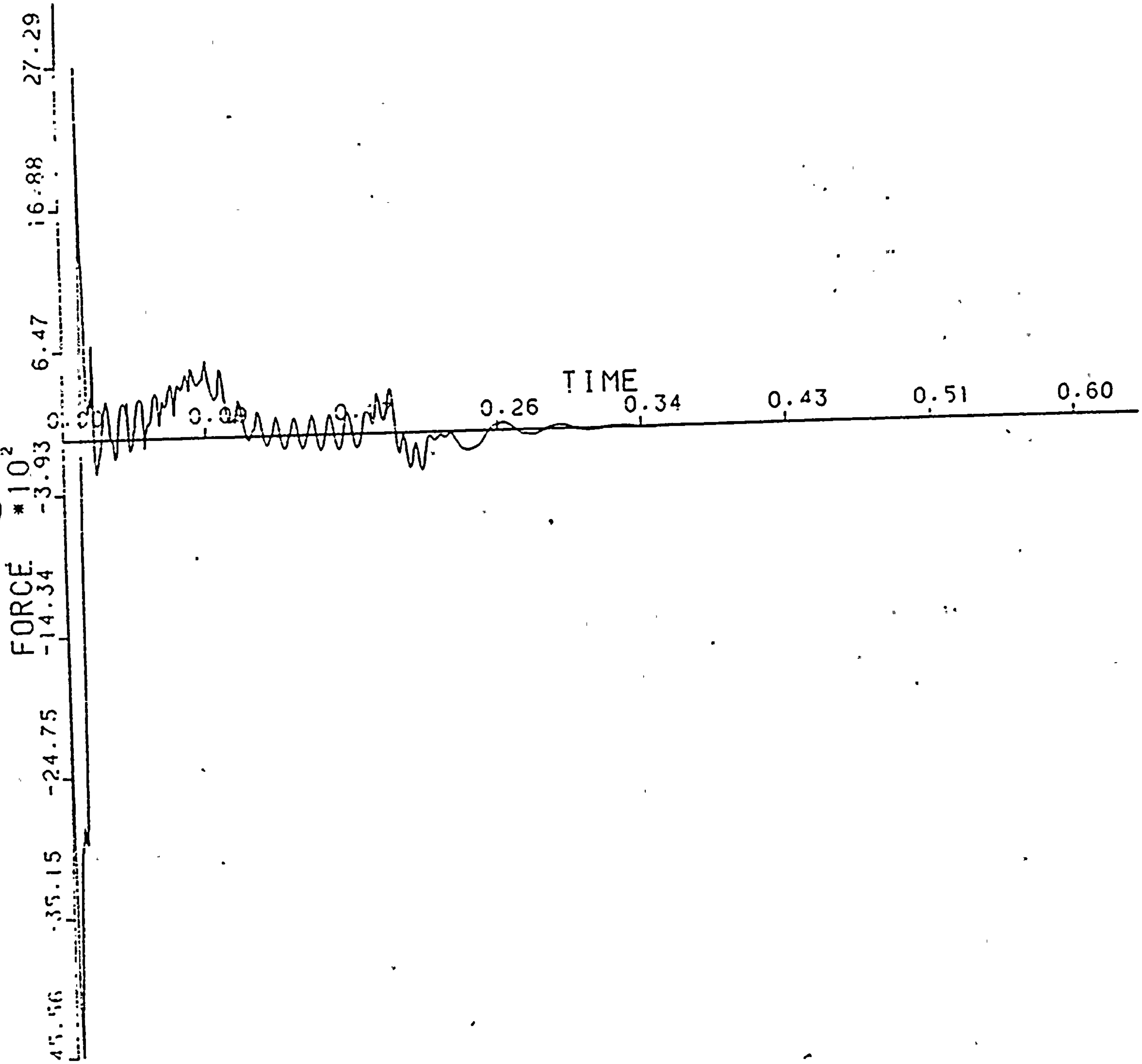
4-205 TELEDYNE ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 3. MAGNITUDE AT NODE POINT 111



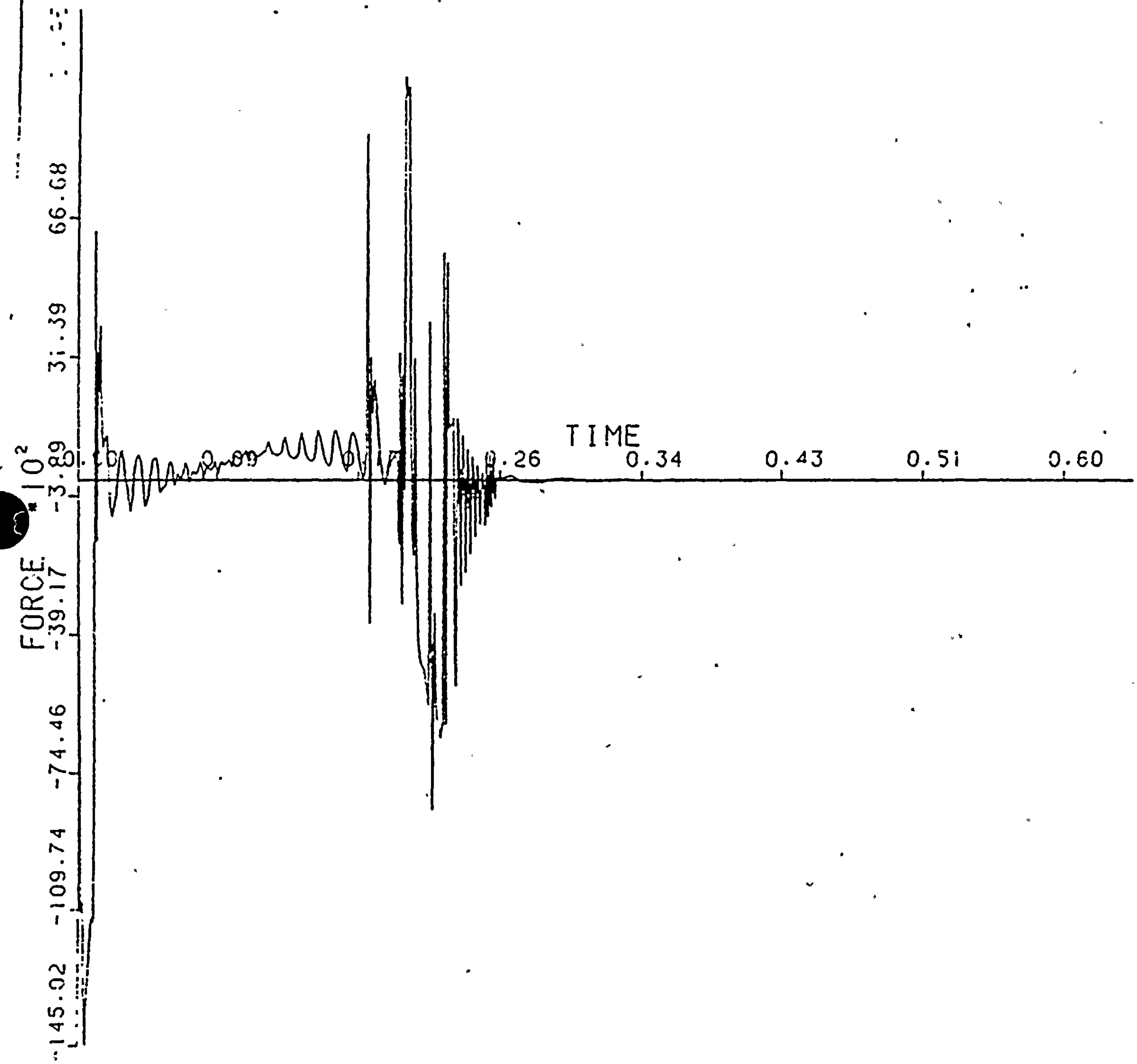
DONE BY: DATE: 5-26-83
CHKD BY: DATE: 5-27-83

TELEDYNE ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364   24-MAY-83

QUARTER MODEL UNIT 2 LOOPSEAL

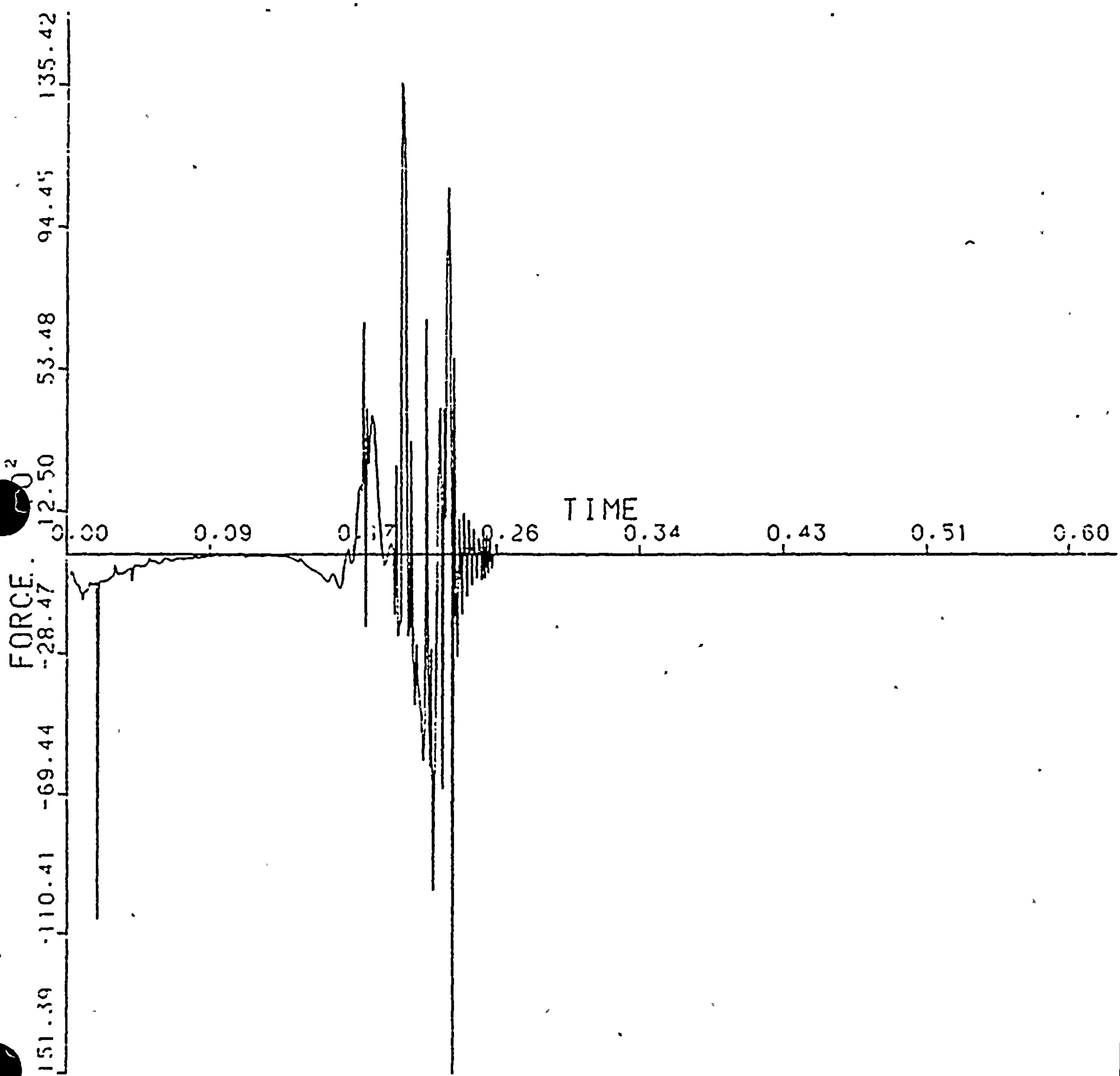
TIME/FORCE TABLE   4, MAGNITUDE AT NODE POINT   107



DONE BY: [illegible] DATE: [illegible]
CHKD BY: [illegible] DATE: [illegible]

TELEDYNE
ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 5, MAGNITUDE AT NODE POINT 98



DONE BY Cu DATE: 5-26-83
CHKD BY: EJG DATE: 5-27-83

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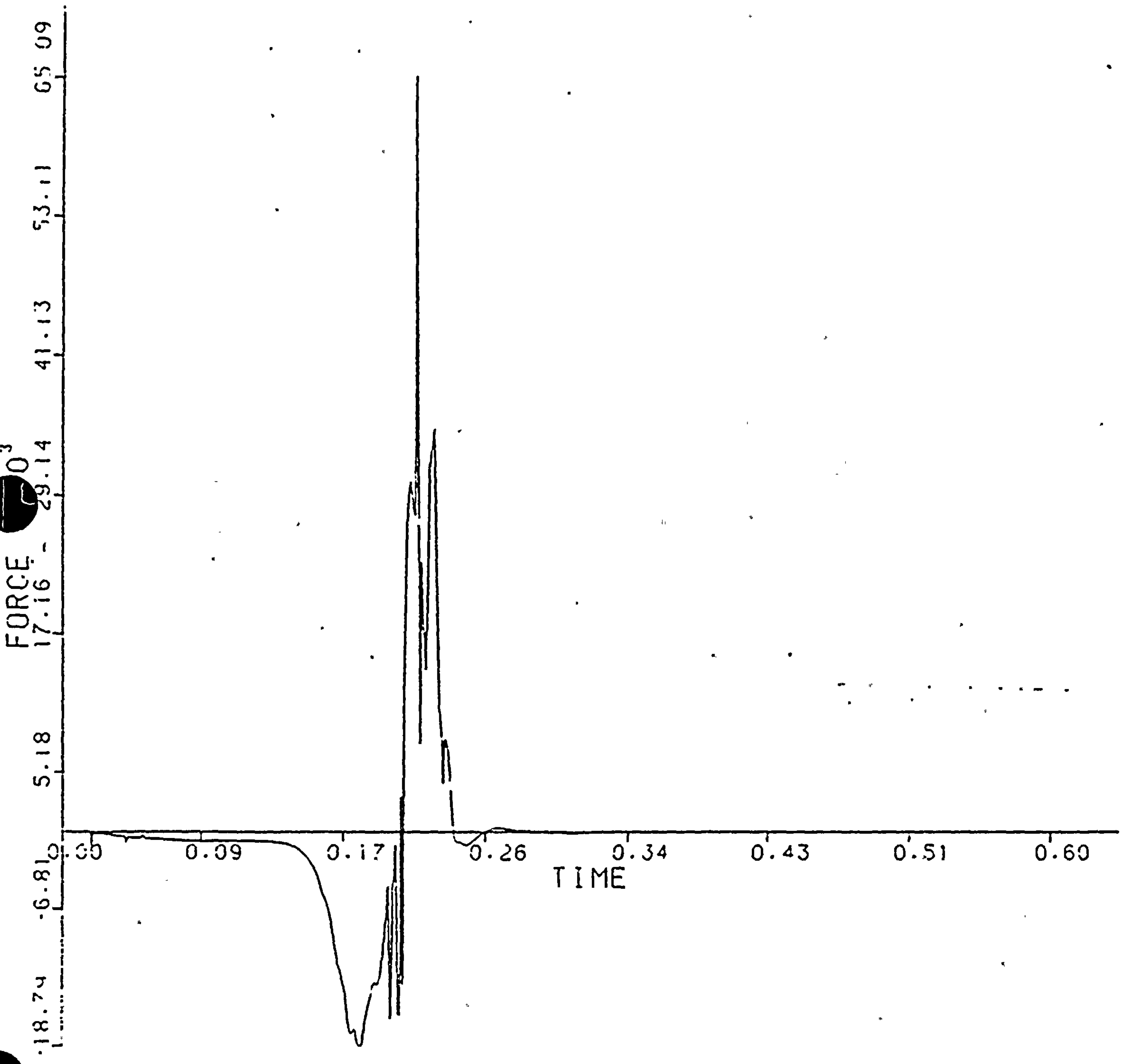
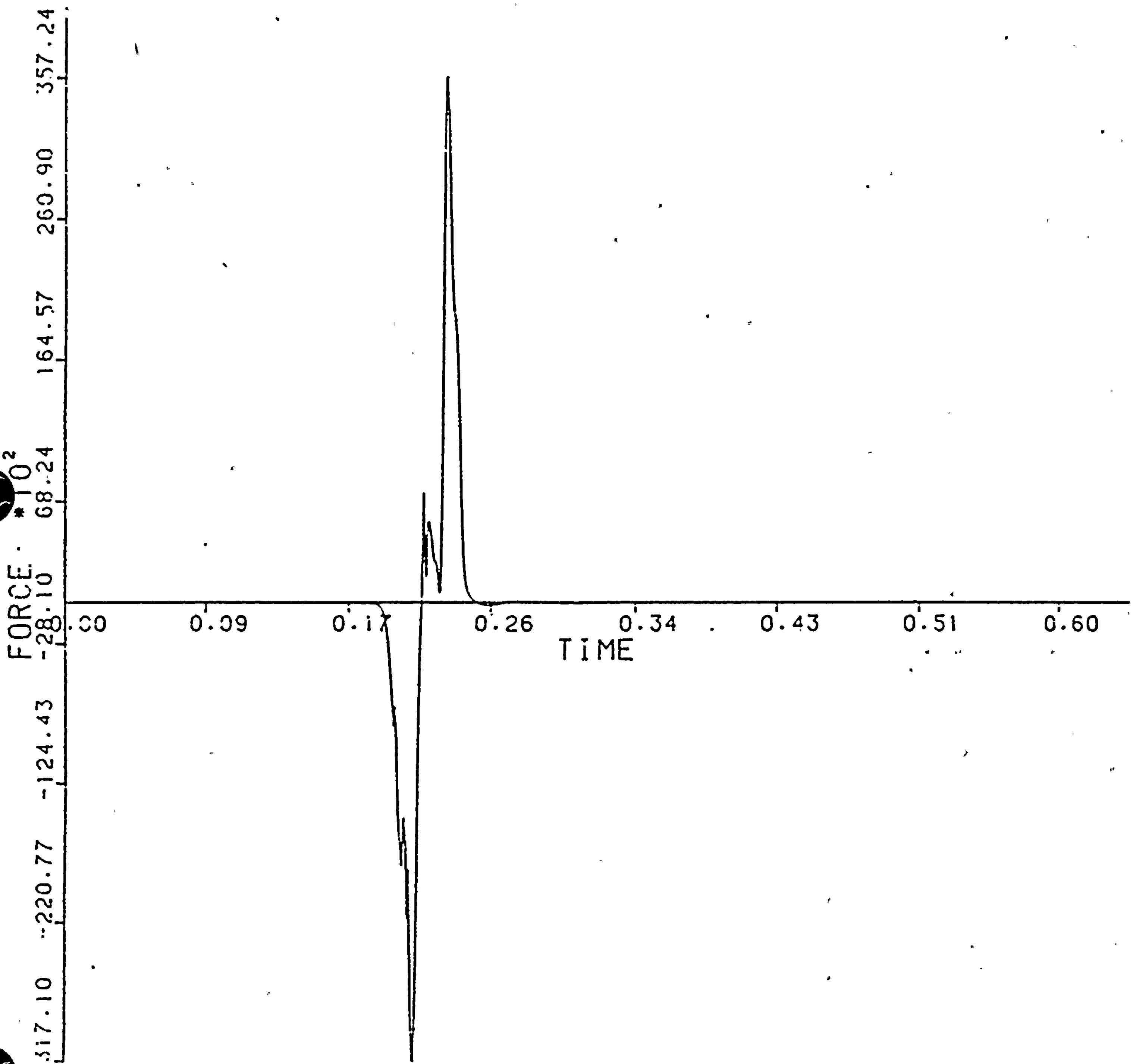
SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 6, MAGNITUDE AT NODE POINT 90



DONE BY: DATE:
CHKD BY: DATE:

TELEDYNE ENGINEERING SERVICES
24-MAY-83

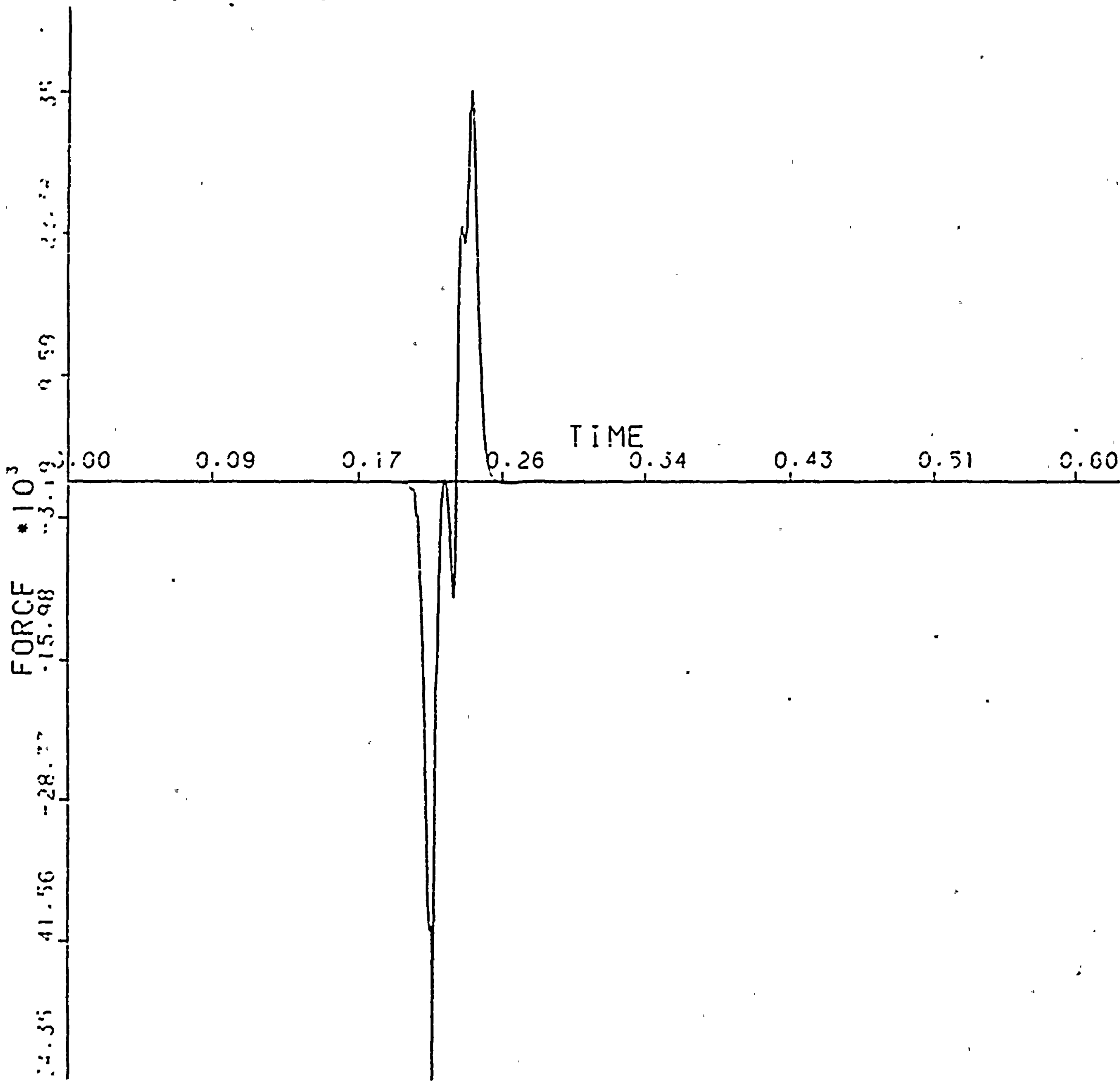
SAP2SAP VERIFICATION 5364
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 7, MAGNITUDE AT NODE POINT 88



DONE BY: DATE: 5-26-83
CHKD BY: DATE: 5-27-83

TELEDYNE ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE S. MAGNITUDE AT NODE POINT 86



DONE BY: DATE:
CHKD BY: DATE:

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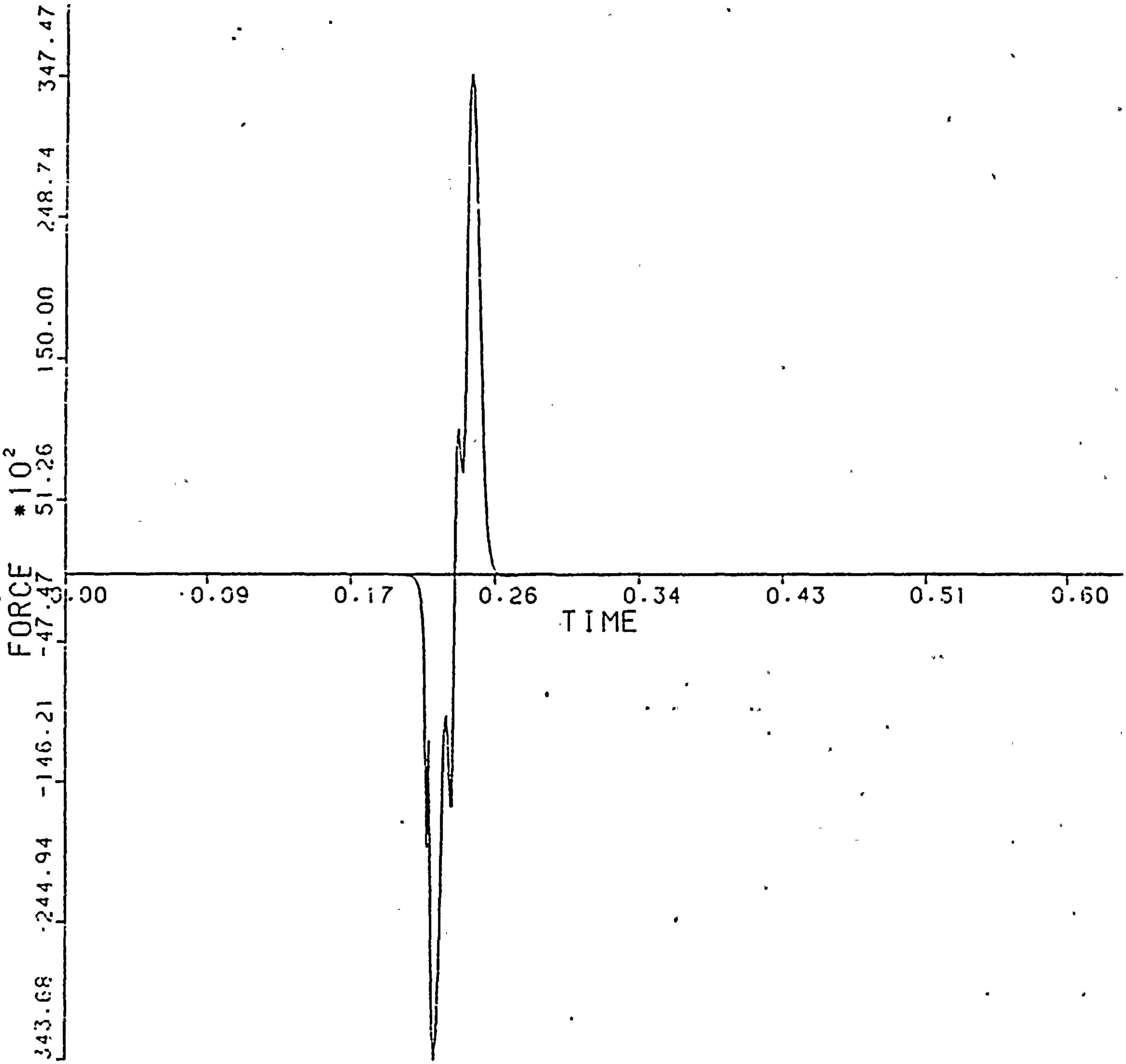
SAP2SAP VERIFICATION 5364 24-MAY-83

QUARTER MODEL UNIT 2 LOOPSEAL

TIME/FORCE TABLE 9. MAGNITUDE AT NODE POINT 84



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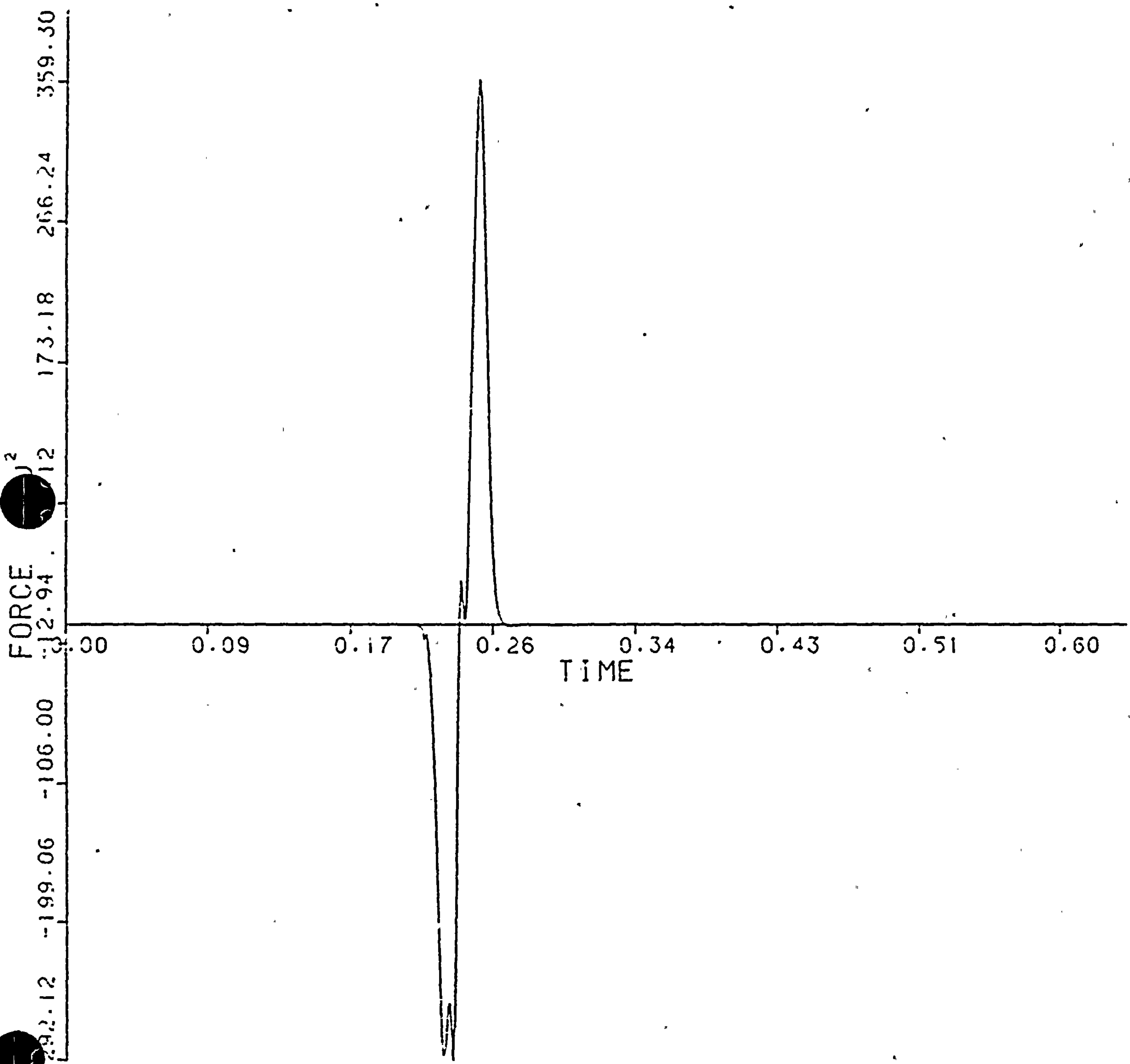
SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 10, MAGNITUDE AT NODE POINT 82



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CHKD BY: DATE:

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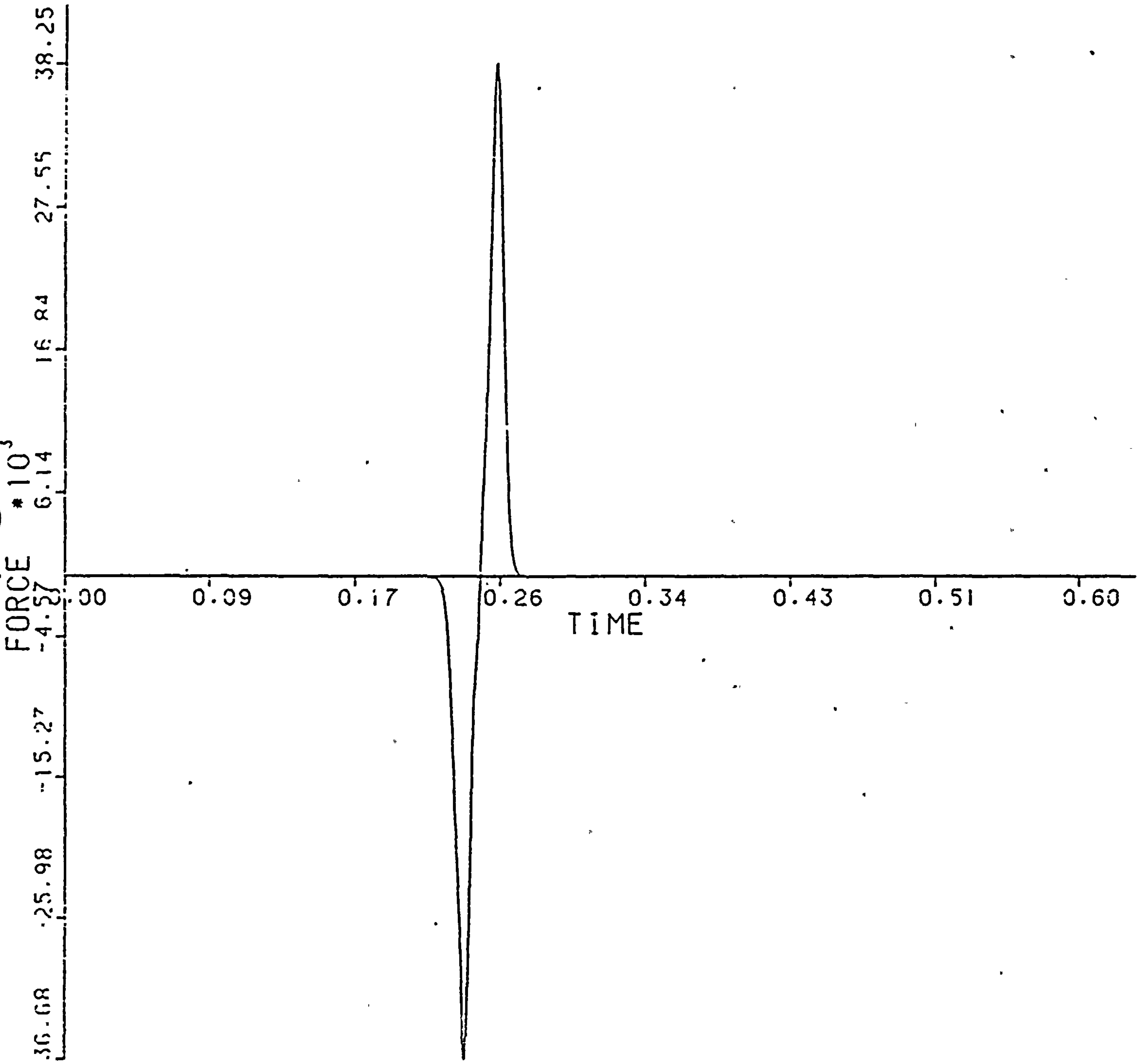
SAP2SAP VERIFICATION 5364 24-MAY-83

QUARTER MODEL UNIT 2 LOOPSEAL

TIME/FORCE TABLE 11. MAGNITUDE AT NODE POINT 80



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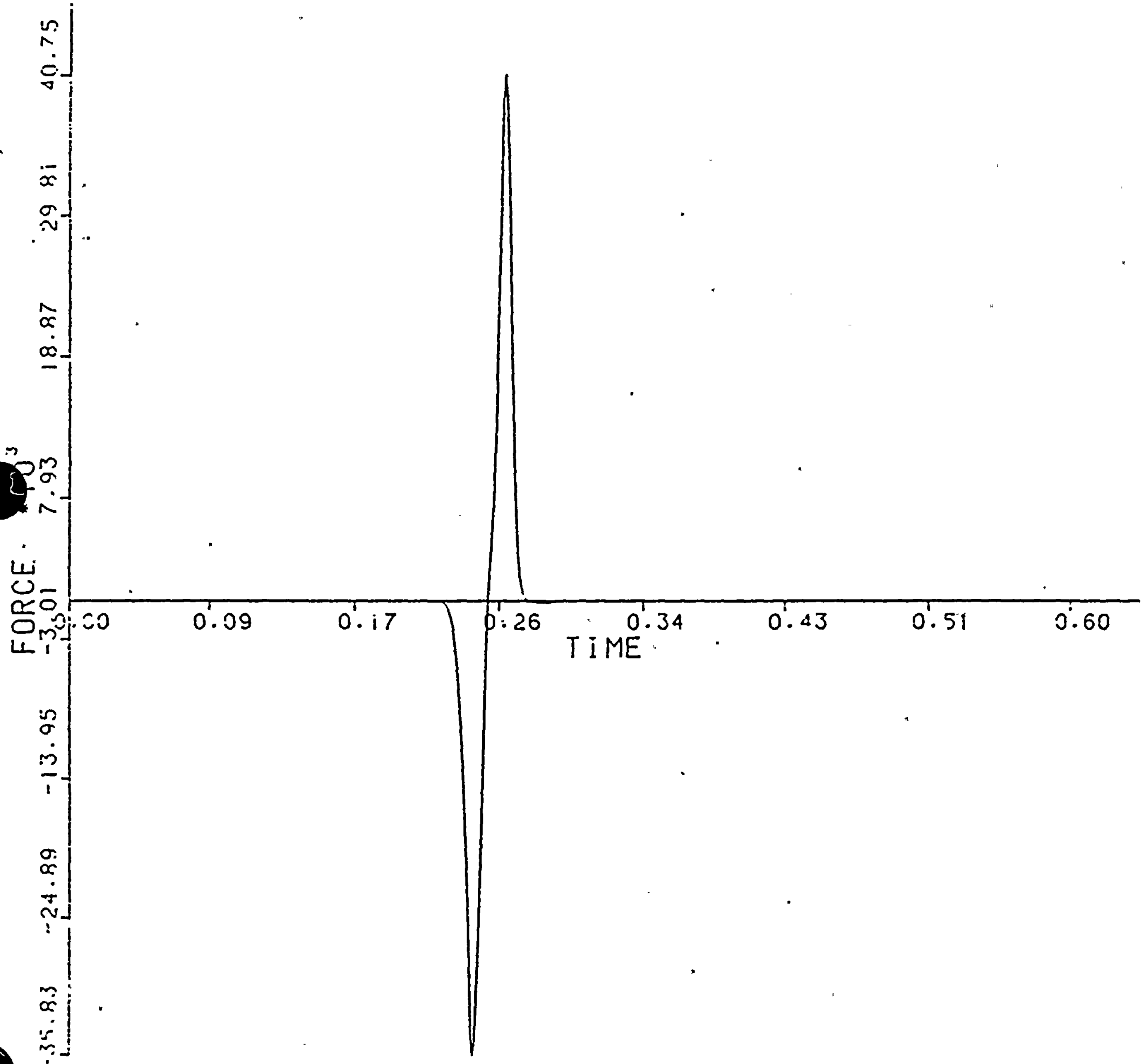
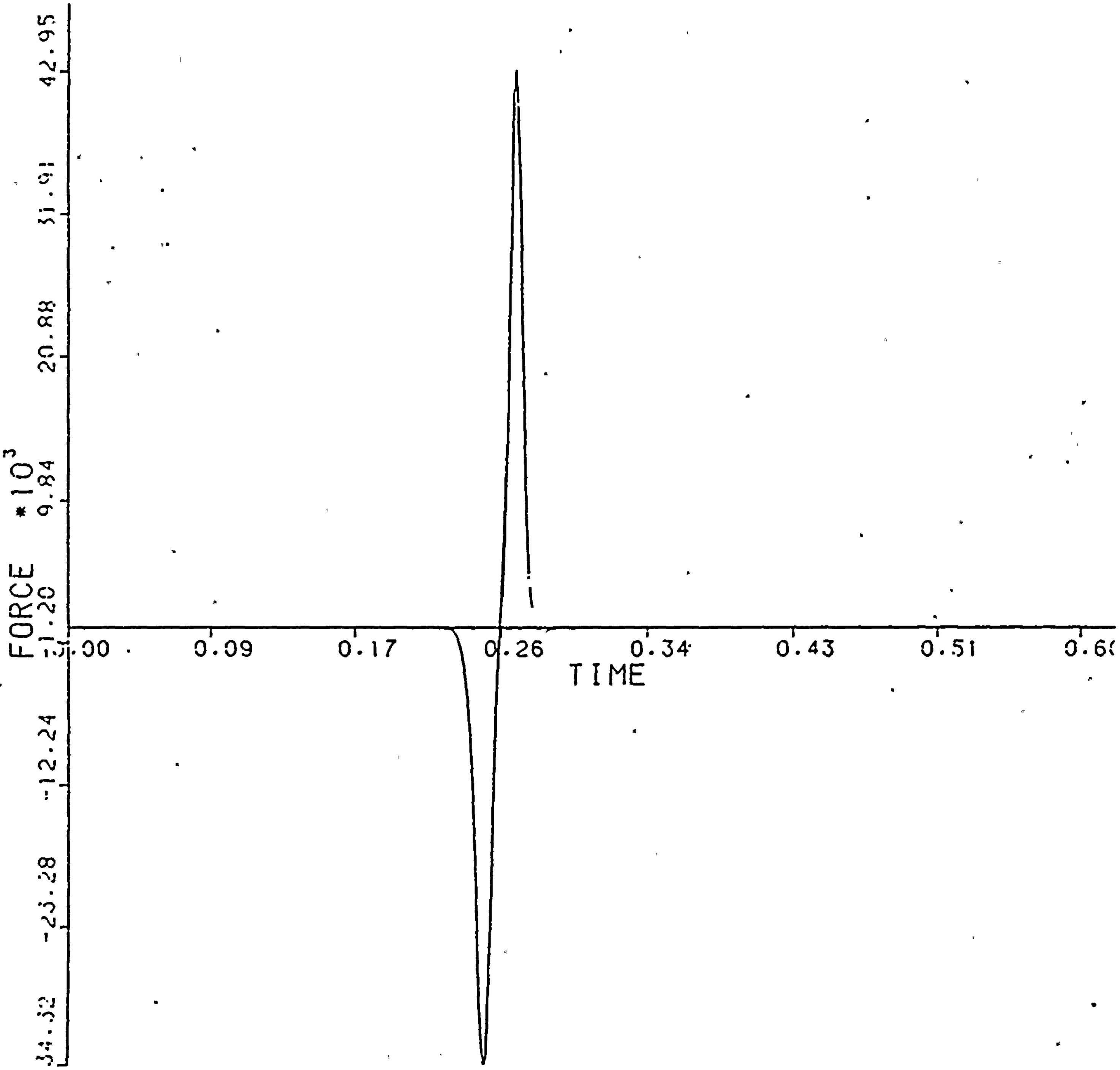
SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 12, MAGNITUDE AT NODE POINT 78



DONE BY: DATE: 5-25-83
CHKD BY: DATE: 5-27-83

TELEDYNE
ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 13. MAGNITUDE AT NODE POINT 76



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CHKD BY: DATE:

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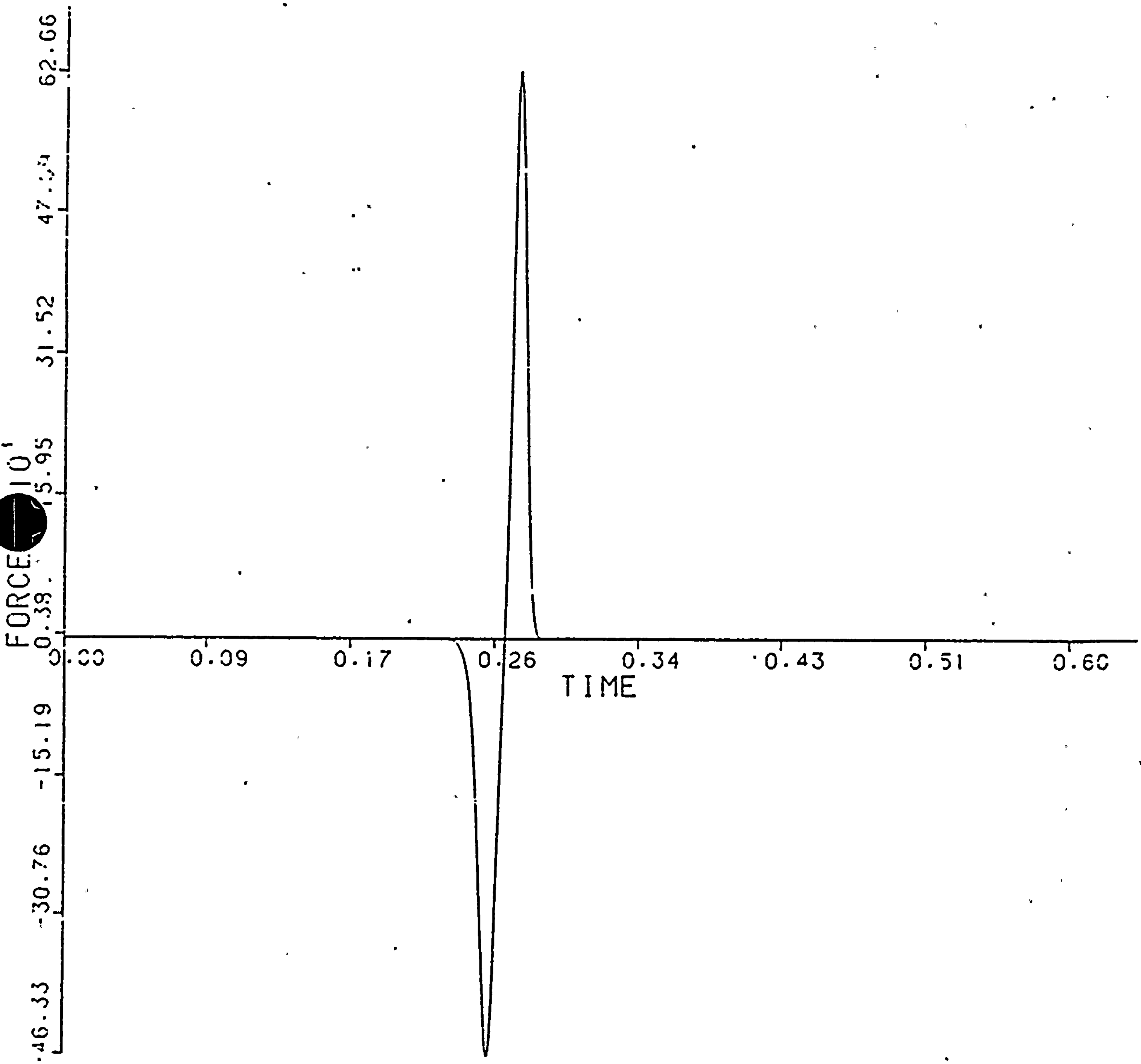
SAP2SAP VERIFICATION 5364 24-MAY-83

QUARTER MODEL UNIT 2 LOOPSEAL

TIME/FORCE TABLE 14, MAGNITUDE AT NODE POINT 74



DONE BY: CWL DATE: 5-26-83
CHKD BY: KJG DATE: 5-27-83

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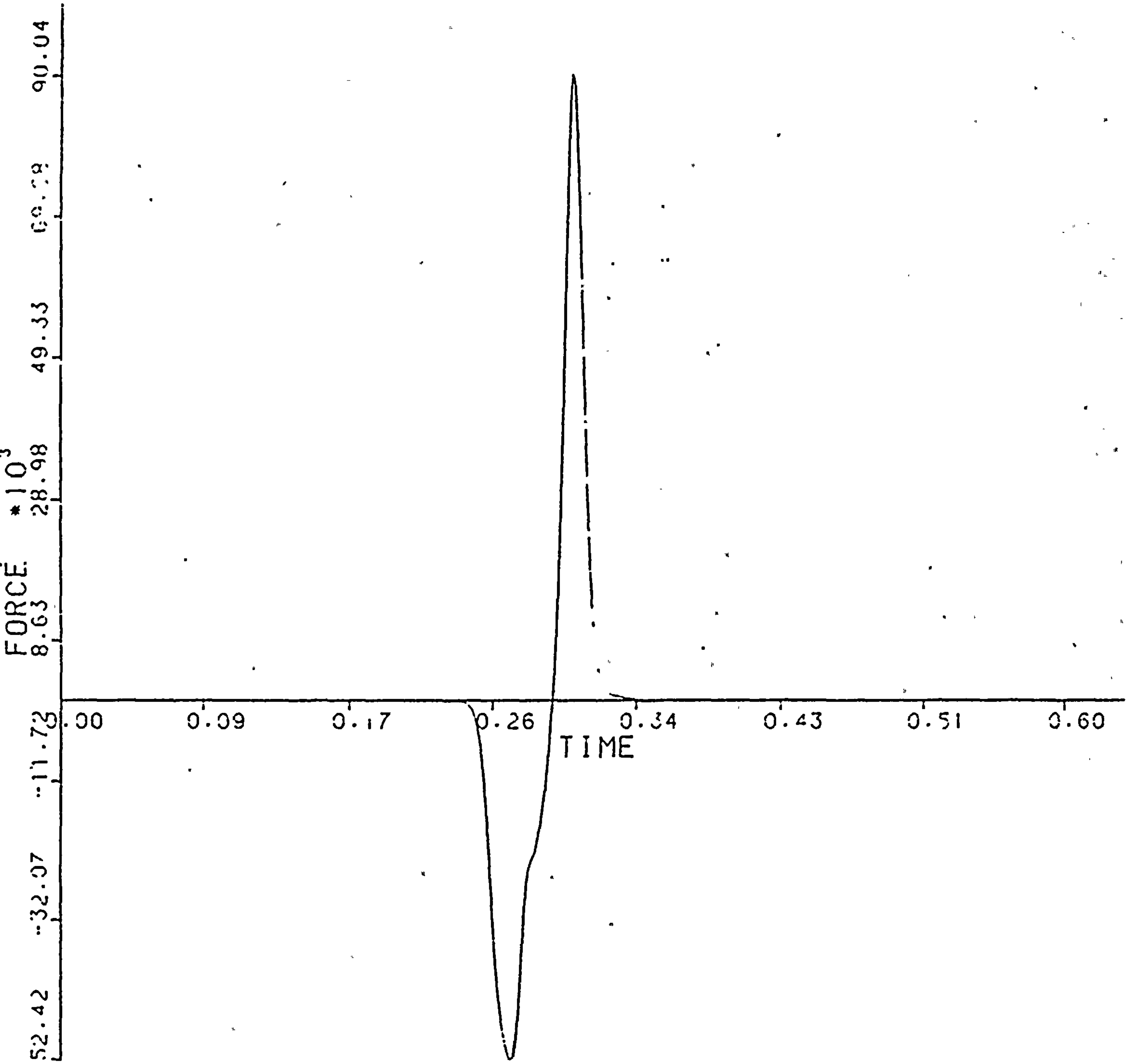
SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 15, MAGNITUDE AT NODE POINT 70



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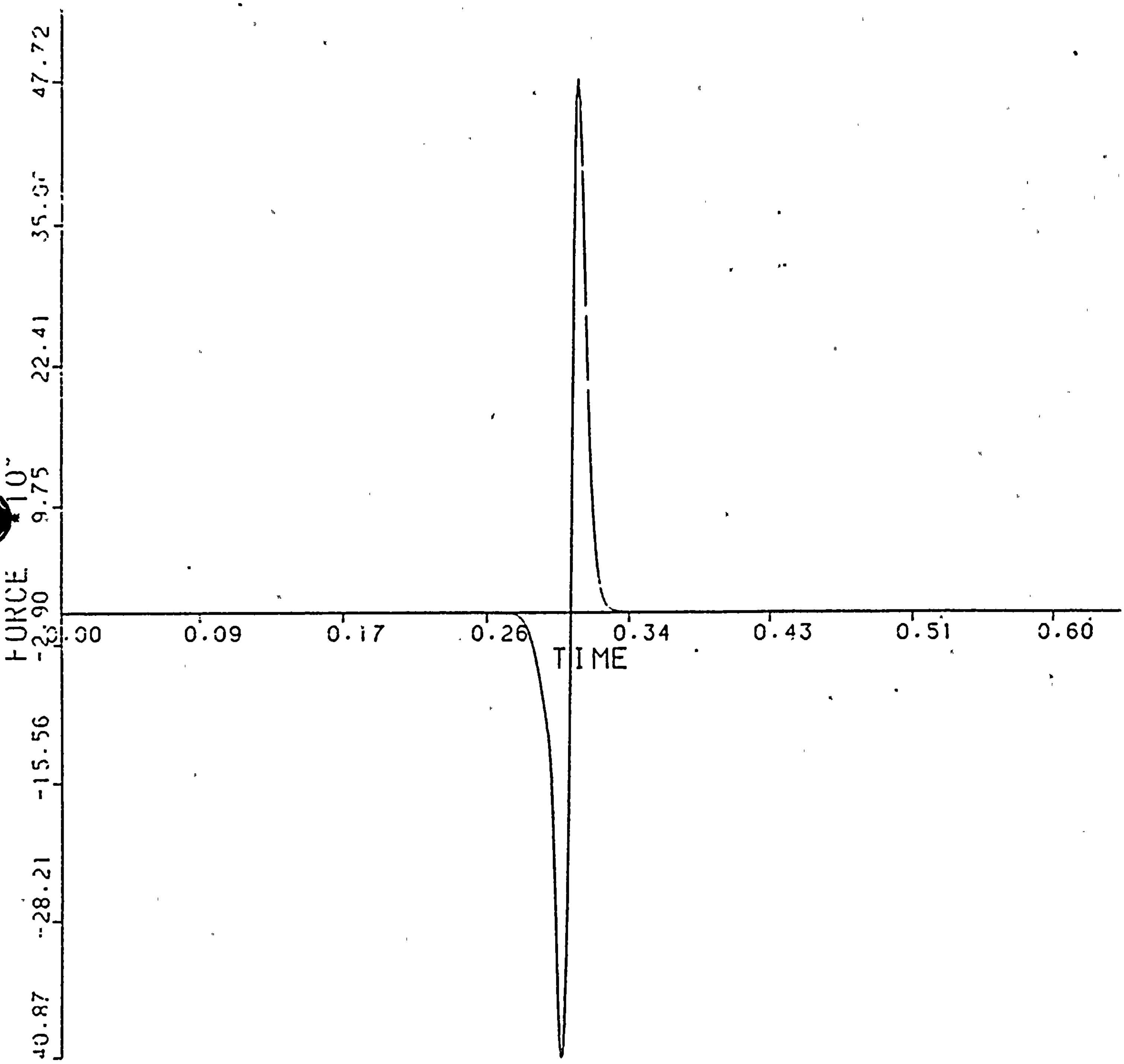
SAP2SAP VERIFICATION 5364 24-MAY-83

QUARTER MODEL UNIT 2 LOOPSEAL

TIME/FORCE TABLE 16, MAGNITUDE AT NODE POINT 64



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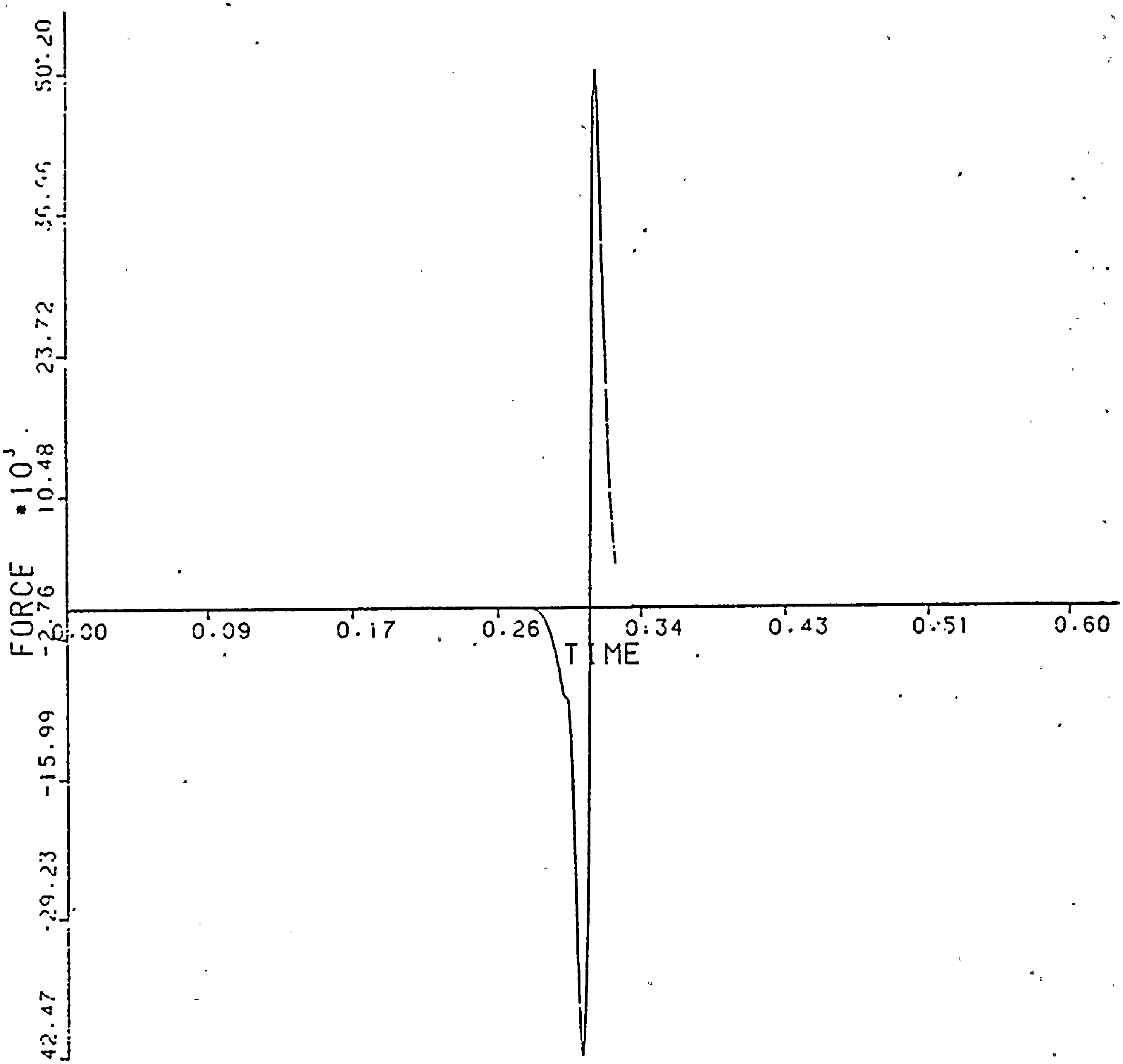
SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 17. MAGNITUDE AT NODE POINT 60



DONE BY: DATE: 5-26-83
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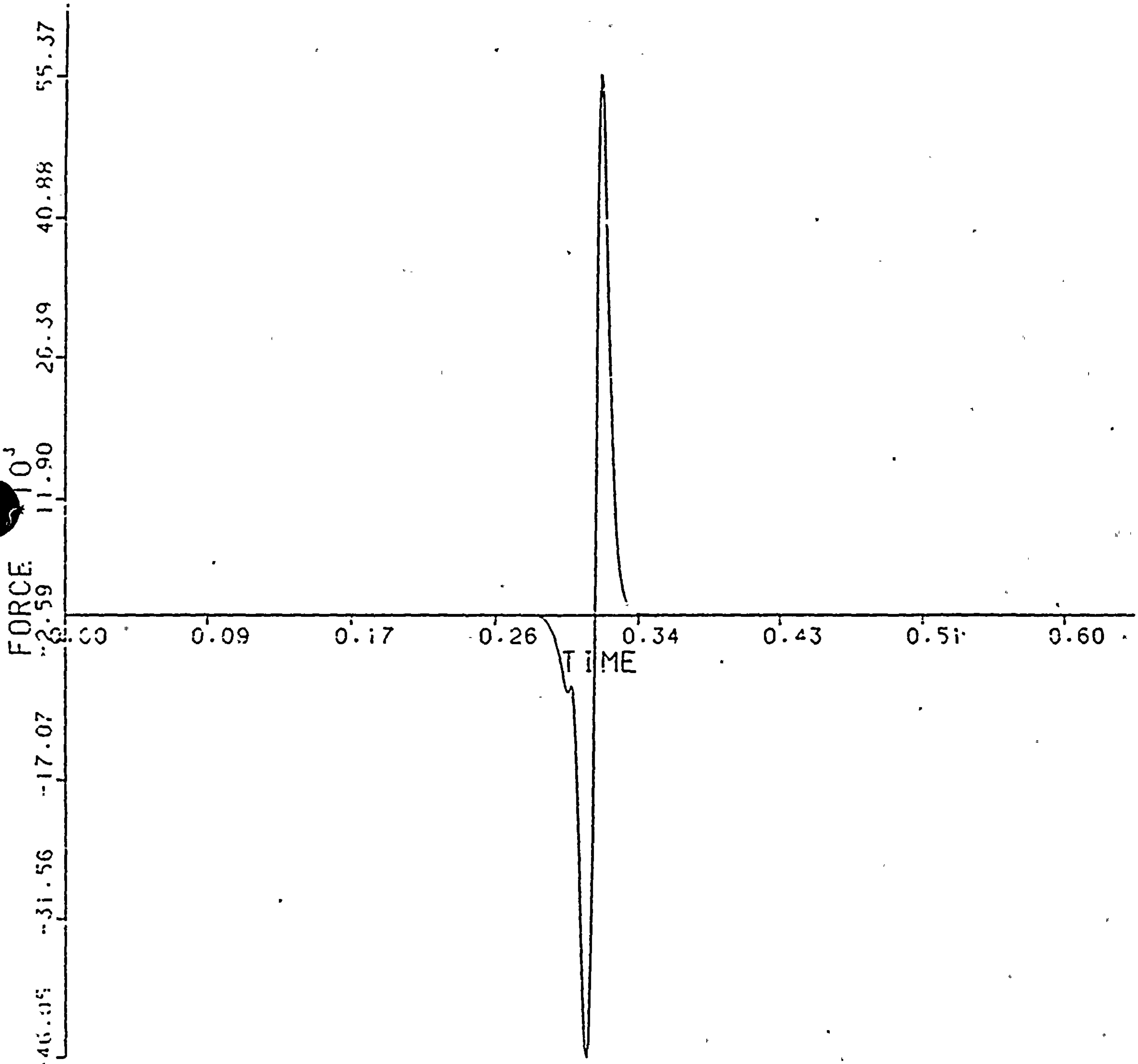
SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 1S. MAGNITUDE AT NODE POINT 54



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CHKD BY: DATE: 5-27-83

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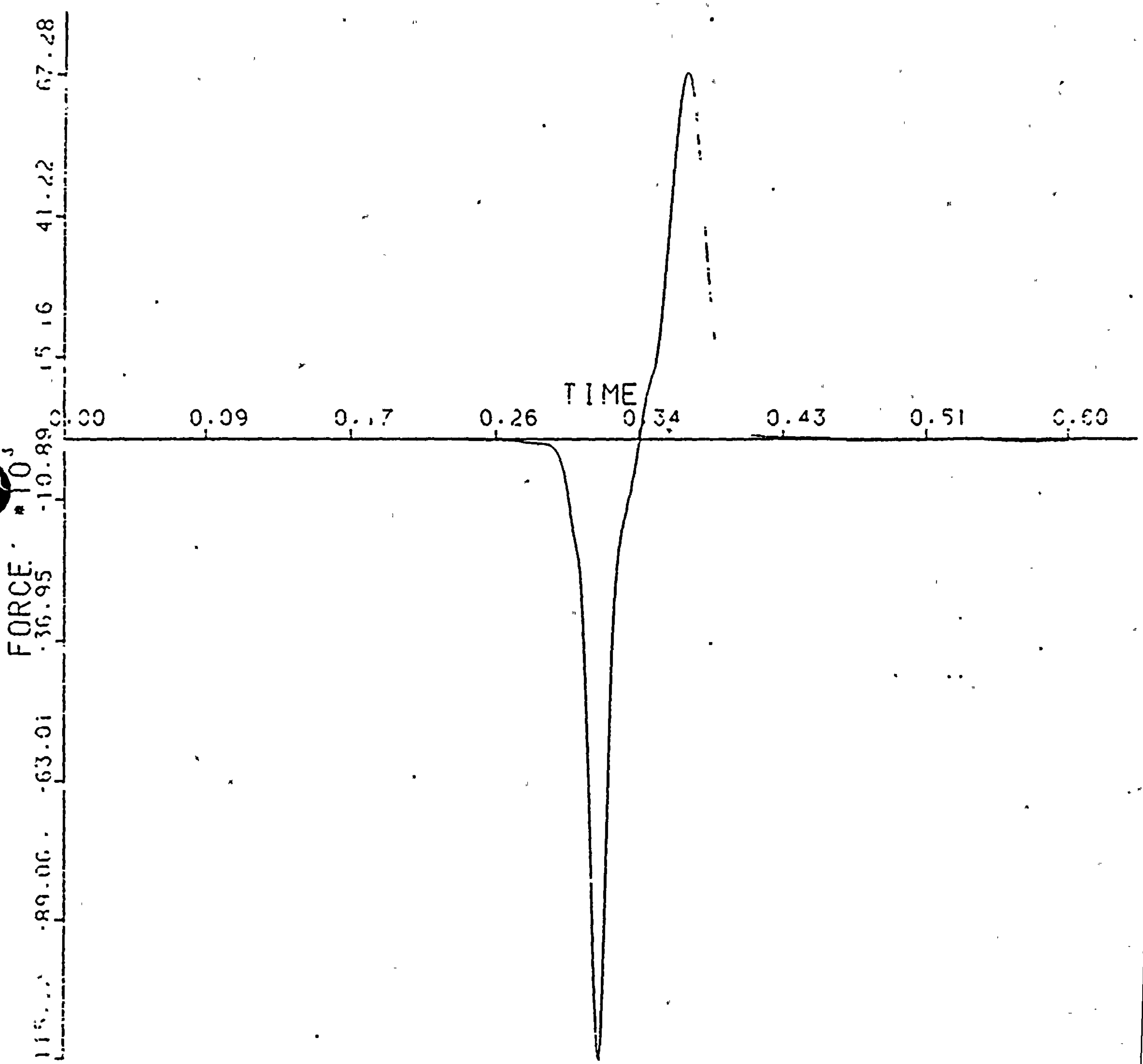
SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 19, MAGNITUDE AT NODE POINT 48



DONE BY: DATE: 5-25-83
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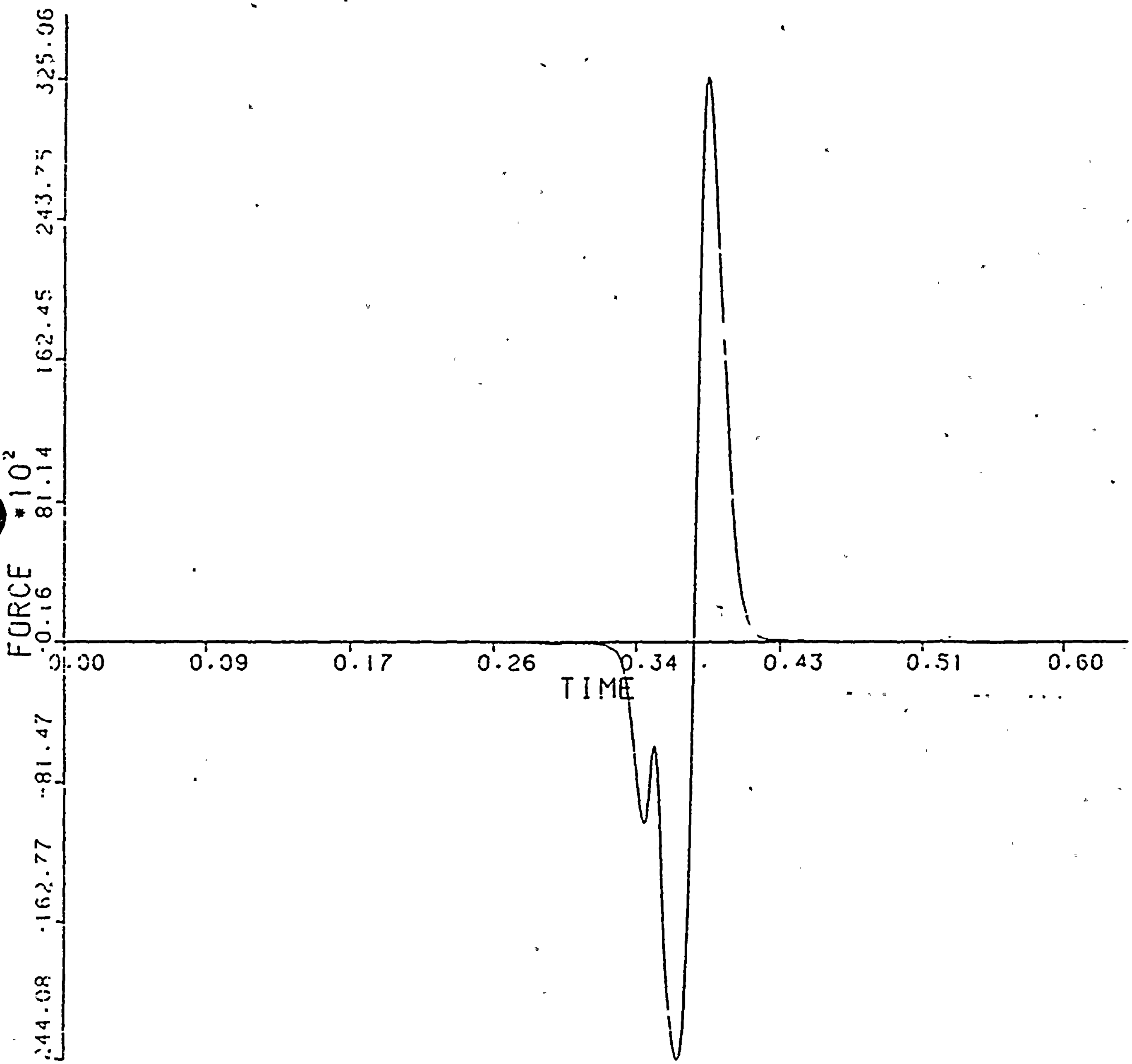
SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 20. MAGNITUDE AT NODE POINT 42



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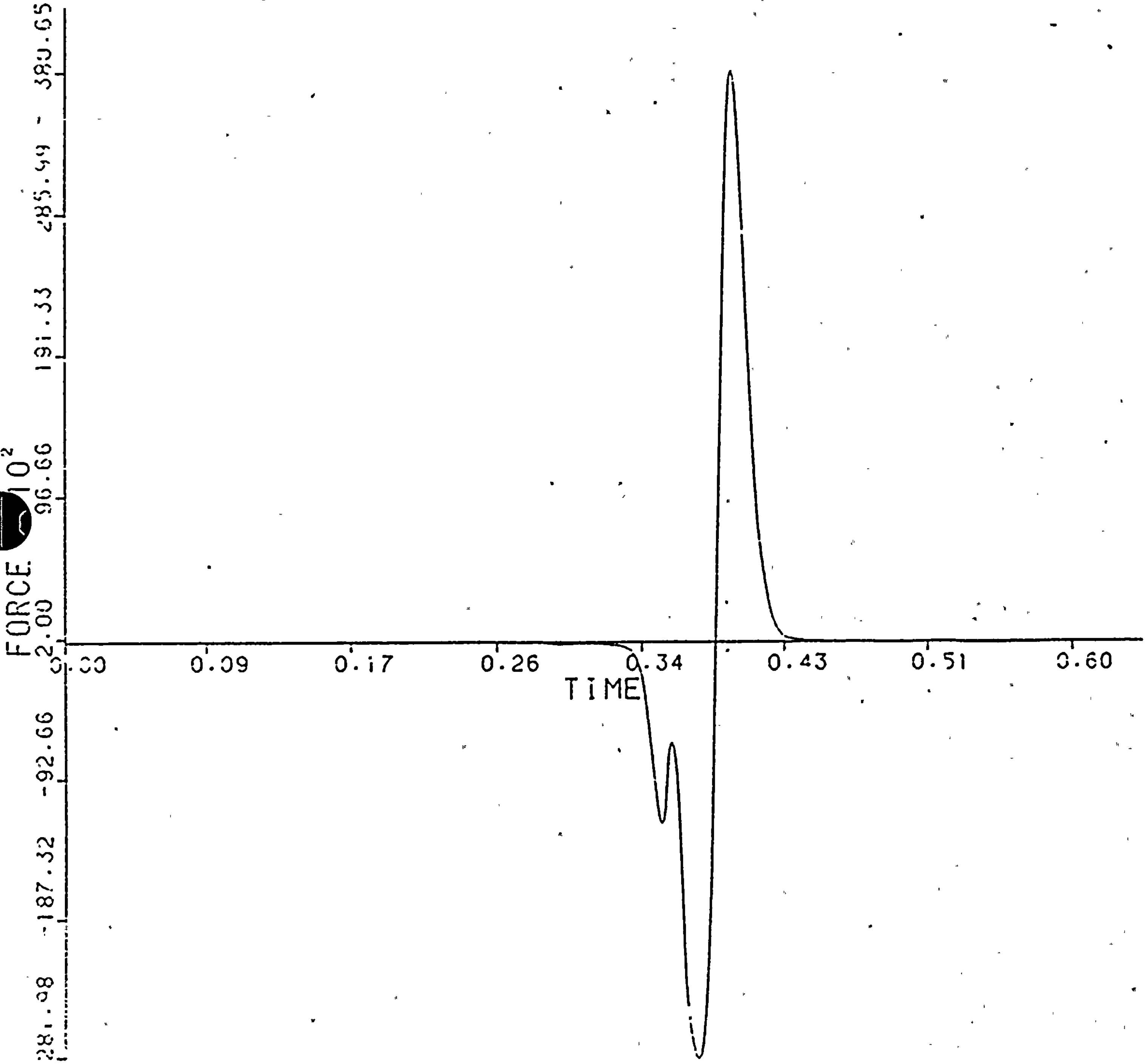
SAP2SAP VERIFICATION 5364 24-MAY-93

QUARTER MODEL UNIT 2 LOOPSEAL

TIME/FORCE TABLE 21. MAGNITUDE AT NODE POINT 38



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CHKD BY: [signature] DATE: 5-27-93

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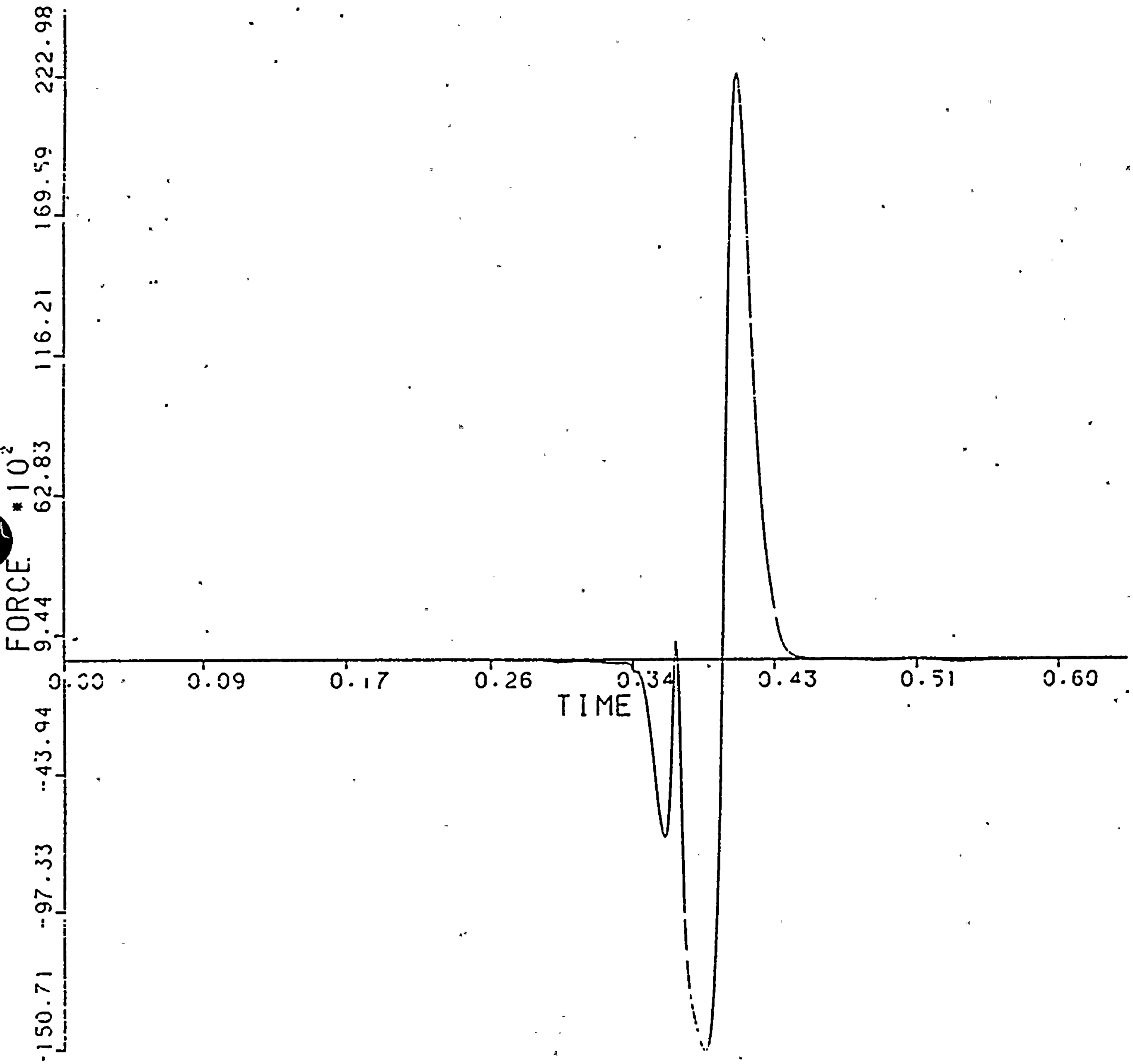
TELEDYNE
ENGINEERING SERVICES

SAP_SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 22, MAGNITUDE AT NODE POINT 34



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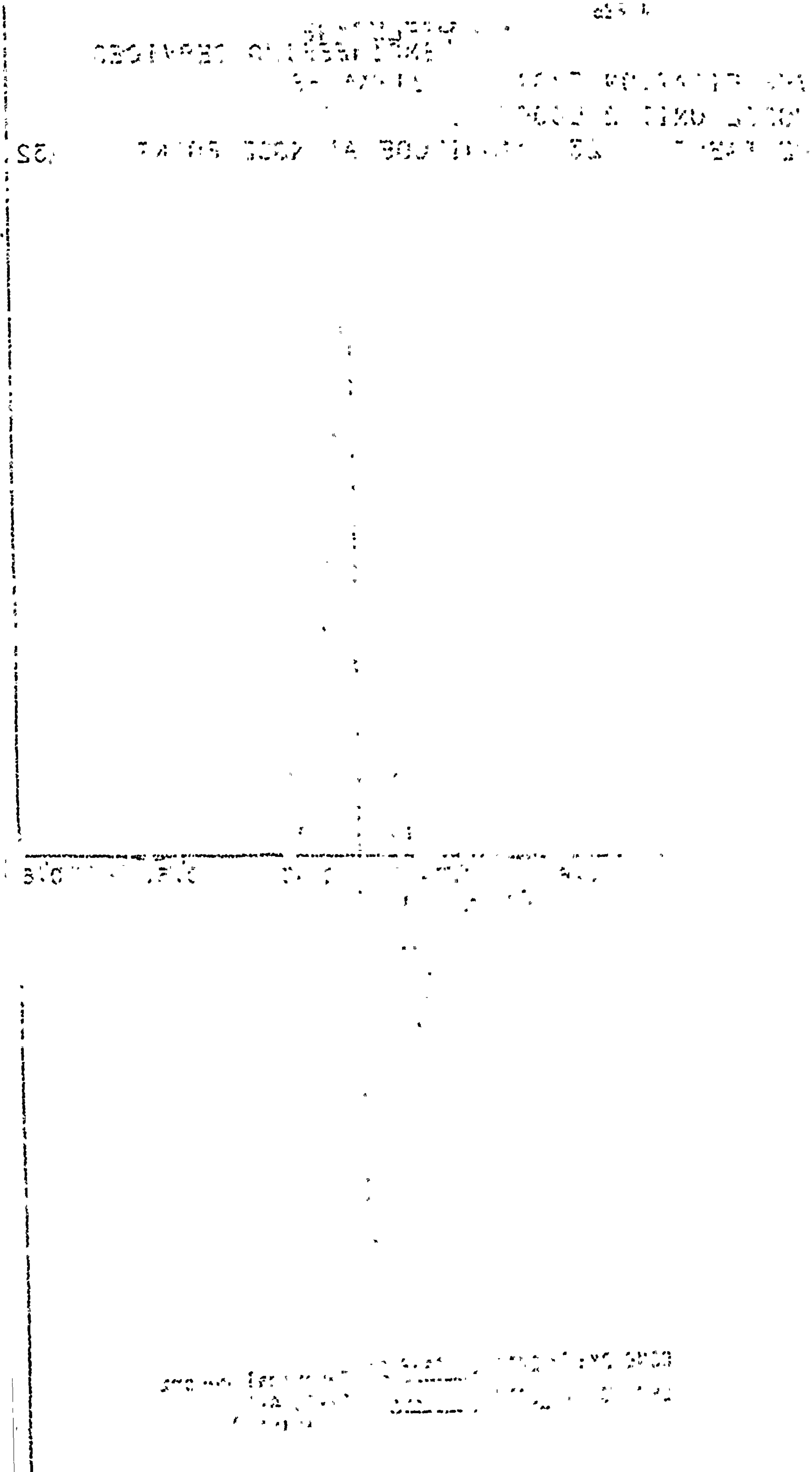
CHKD BY: ___ DATE: 5-27-83



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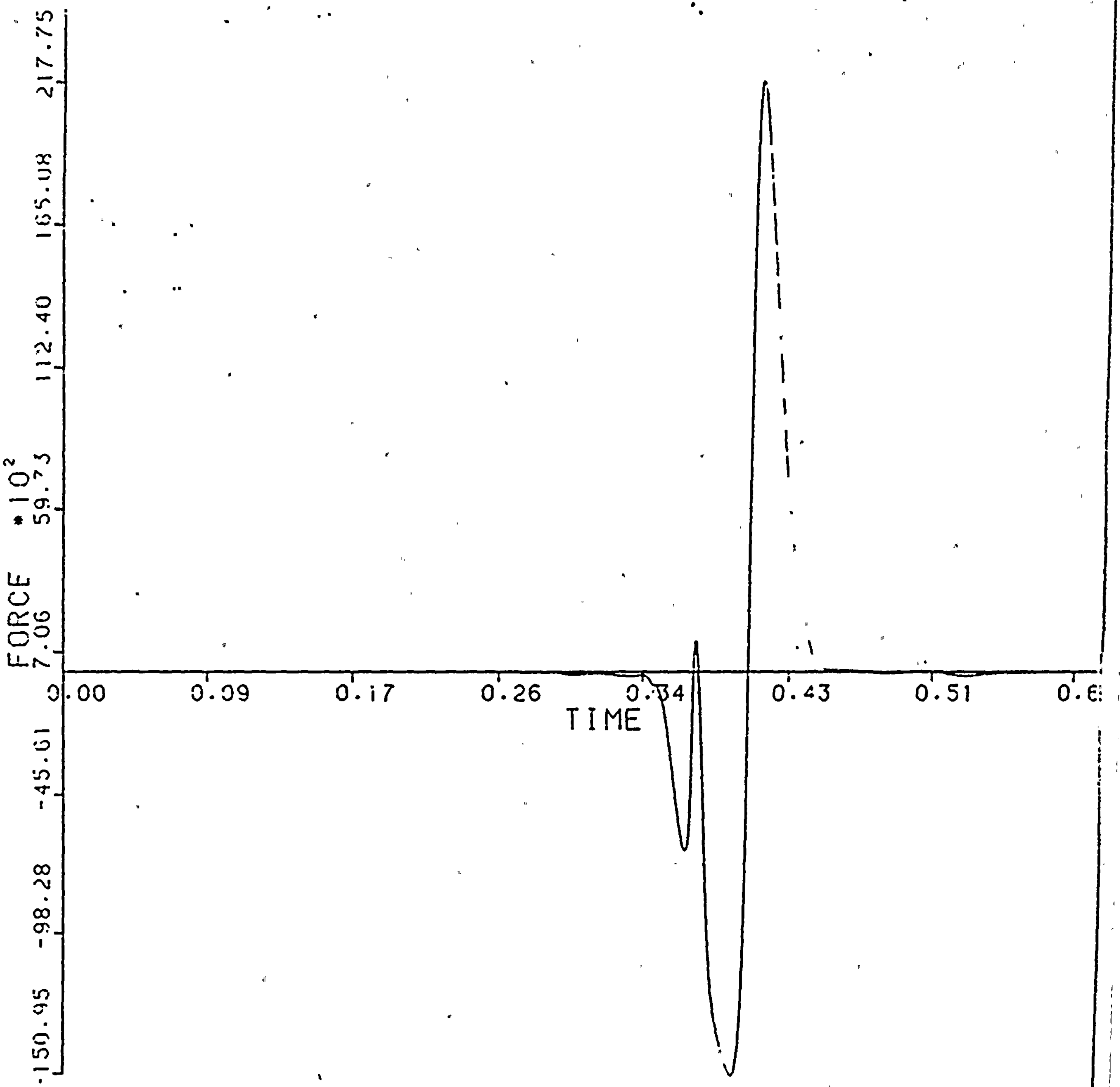
SAP..SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 23. MAGNITUDE AT NODE POINT 32



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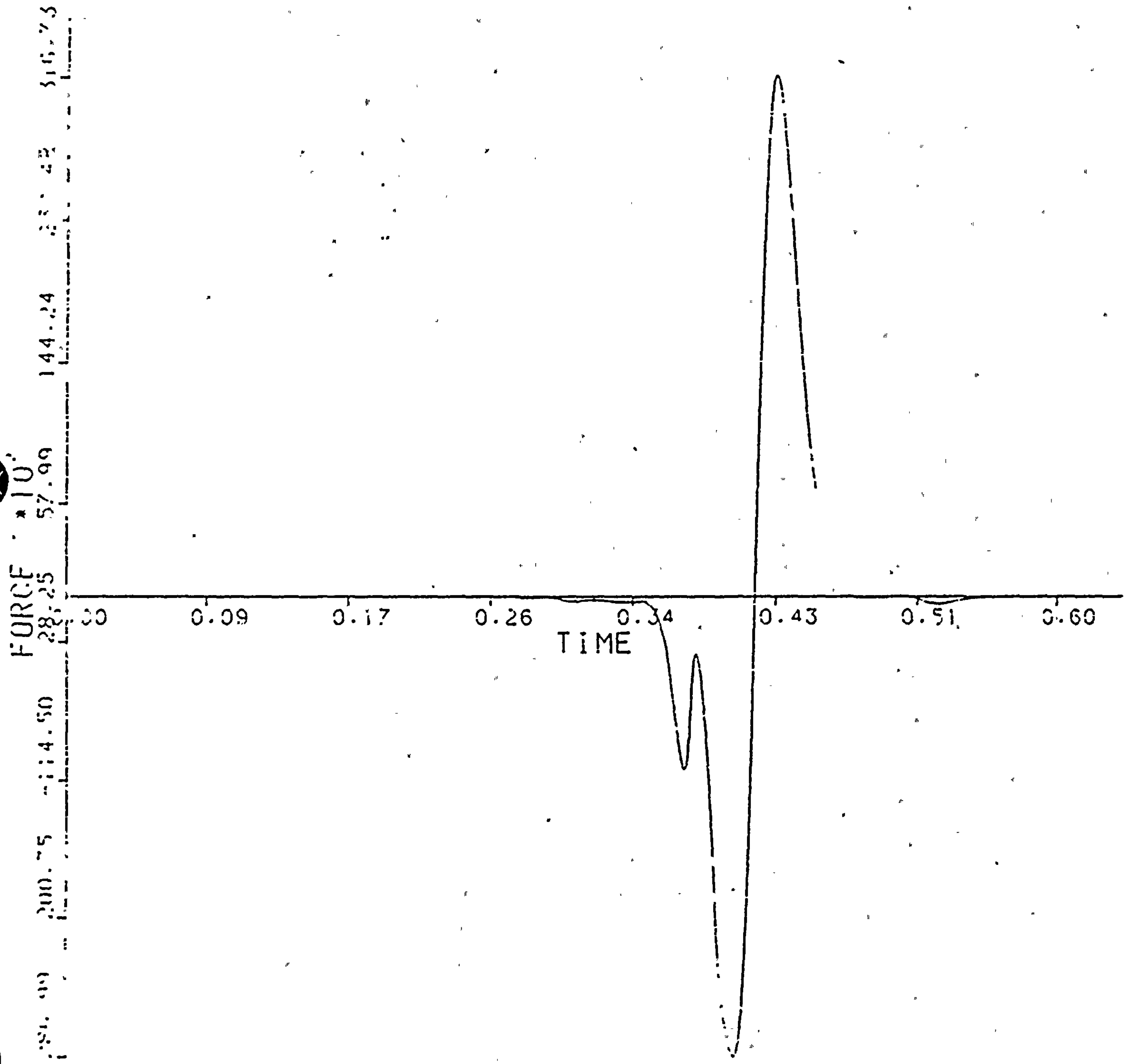
TELEDYNE ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 24-MAY-83
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 24. MAGNITUDE AT NODE POINT 21



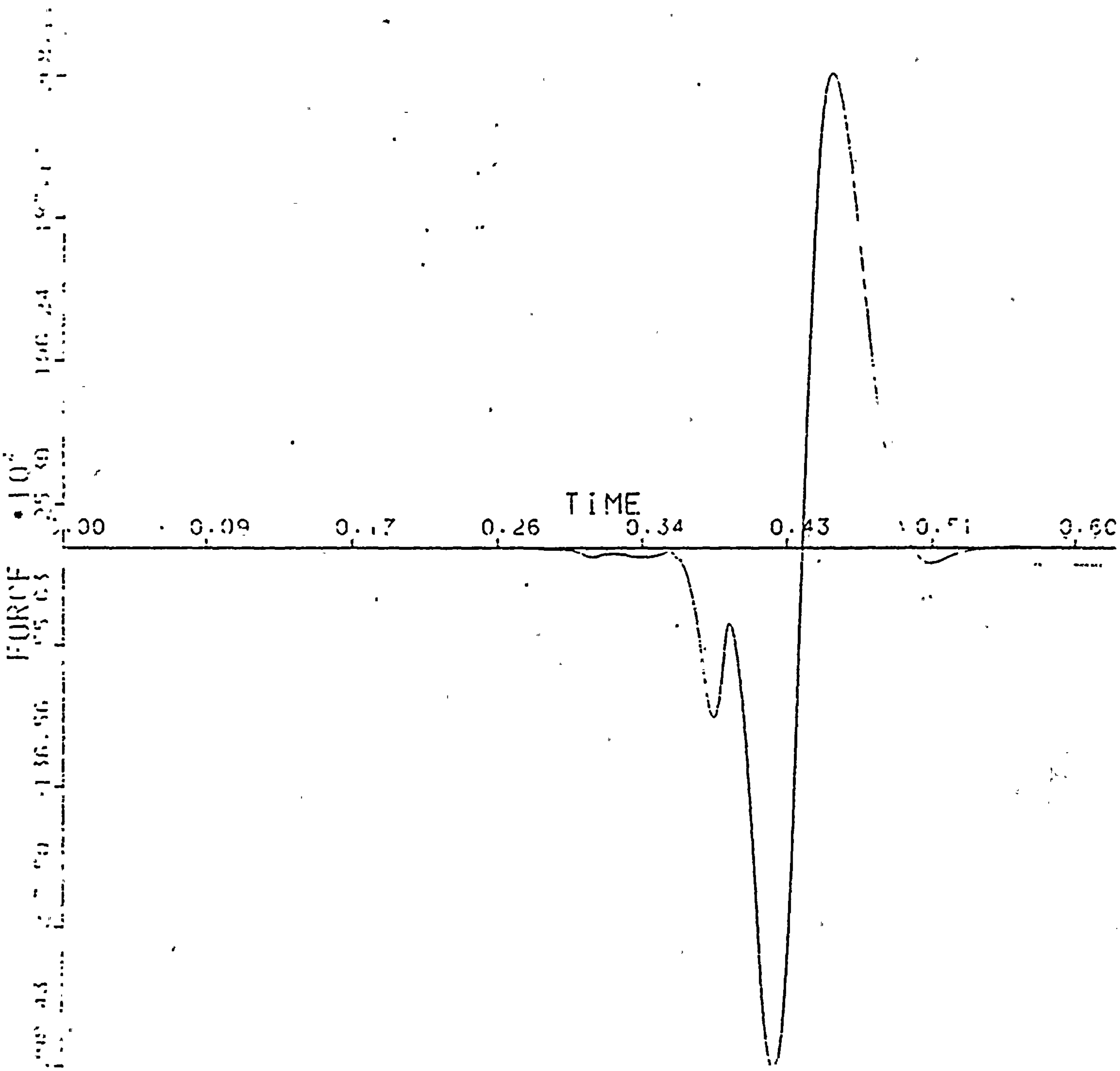
DONE BY: DATE:
CHKD BY: DATE:

TELEDYNE ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 24-MAY-83

QUARTER MODEL UNIT 1 LOOPSEAL

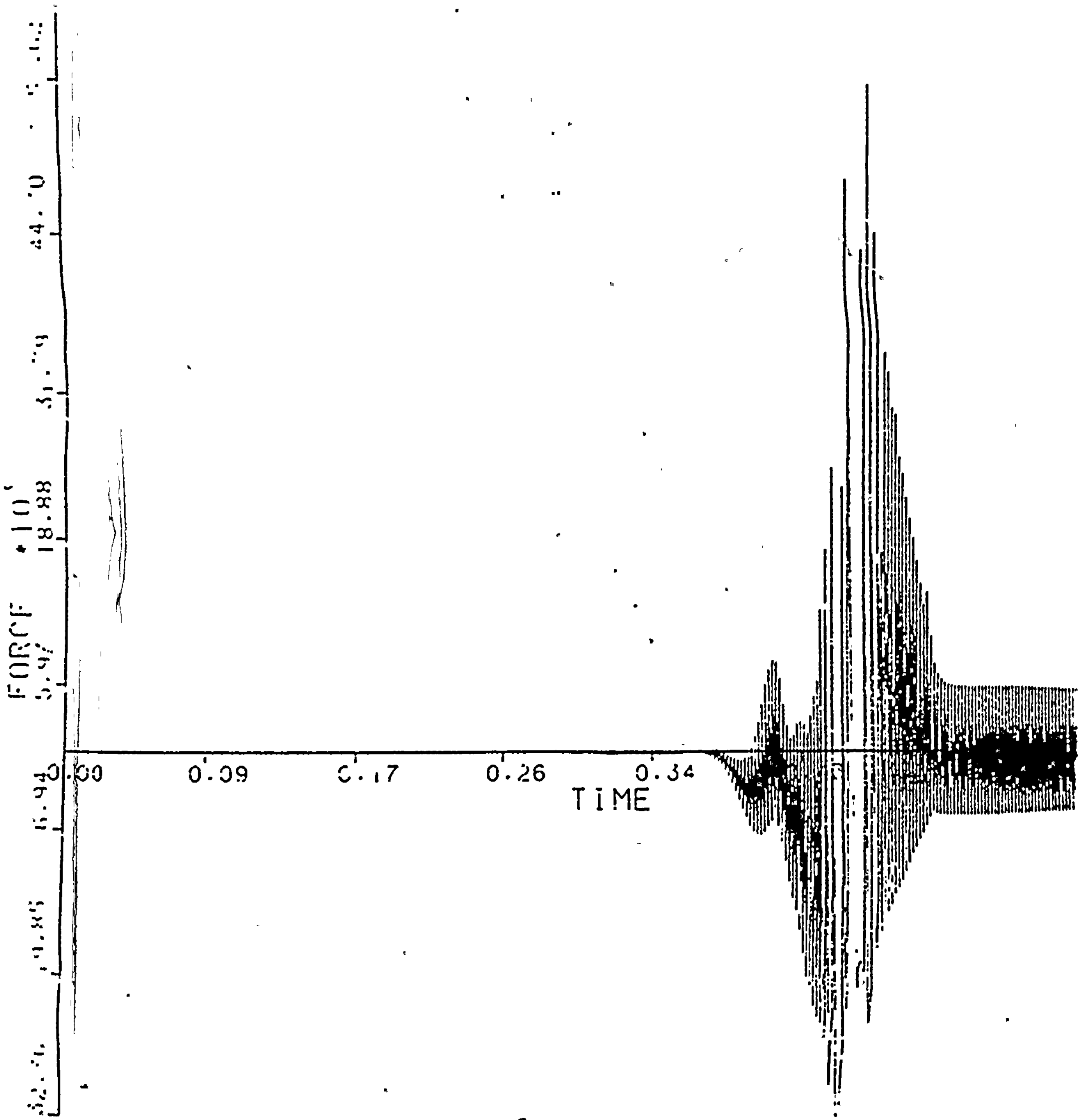
TIME HISTORY TABLE ... MAGNITUDE AT NODE POINT 12



DONE BY: DATE: 5-26-83
CHKD BY: DATE: 5-27-83

TELEDYNE ENGINEERING SERVICES

SAP2SAP VERIFICATION 5364 24-MAY-83.
QUARTER MODEL UNIT 2 LOOPSEAL
TIME/FORCE TABLE 26. MAGNITUDE AT NODE POINT



DONE BY: DATE: 5-26-83
CHKD BY: DATE: 5-27-83

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