PALO VERDE NUCLEAR GENERATING STATION

UNITS 1, 2 and 3

PRESSURIZER SAFETY VALVE DISCHARGE PIPING EVALUATION REPORT

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Abstract

The U.S. Nuclear Regulatory Commission (NRC), in NUREG 0578 Section 2.1.2 and NUREG 0737 Item II.D.1, recommended performance testing of PWR safety and relief valves. One aspect of this recommended program was to evaluate the adequacy of safety and relief valve discharge piping and support systems and determine piping dynamic feedback effects on valve operability. At the request of PWR owners, EPRI conducted a test program for PORVs and Safety Valves. One of the objectives of the safety valve test program was to obtain data that could be used to benchmark analytical methods for calculating discharge piping loads.

Results and verified analytical methods from the EPRI Safety Valve Test Program were utilized for an evaluation of the safety valve discharge piping system of Palo Verde Units 1, 2, and 3. This report presents the evaluation which was made in response to the aforementioned NRC recommendation.

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1.0 PURPOSE

The purpose of this analysis is to evaluate the structural adequacy of the pressurizer safety valve discharge piping and support systems during safety valve actuation. Piping feedback effects on valve operability are also determined. Dynamic loadings on the system occur when the safety valves are actuated.

2.0 GENERAL APPROACH

The general approach used in generating the hydraulic forces and structural response to safety valve actuation is described in this section. A brief description of the computer codes used is also presented. The method of analysis is consistent with the methods used in the EPRI Safety Valve Test program, as described in Reference (5).

2.1 Hydraulic Analysis

Pressurizer safety valve discharge transients present complex fluid-structure interaction problems. The fluid and structural portions of the analysis can be decoupled to allow determination of piping hydraulic forces which serve as input loadings to the structural analysis. The calculation of fluid-induced piping forces is accomplished using a two-step procedure. The first step is to determine the transient hydraulic state. The hydraulic data such as pressure (P), density (ρ), and fluid velocity (v) during the transient are required in order to calculate the hydraulic forces. The geometrical data such as pipe flow area (A), length (L), volume (V), and orientation of the piping are also required. The second step is to determine the hydraulic loads by utilizing the transient hydraulic data.

The fluid forces acting on a piping system can be obtained from a momentum balance. These piping forces have two basic components:

wave force, $\frac{d}{dt}\int_V \rho \vec{v}\, dV$

and static surface force $\int_A [P\vec{n} + \rho\vec{v}(\vec{v}\cdot\vec{n})]\, dA$

where $\vec{n}$ is a unit vector normal to flow area. The computer code RELAP5[1] was used to calculate the safety valve downstream piping transient response, while a post-processor of RELAP5, the REFORC[2] code, was used to calculate the hydraulic force-time history.

The RELAP5 code is a thermal-hydraulic program which solves a set of five conservation equations (2-mass, 2-momentum and 1-energy equation) describing the two-phase and two-component fluid. Nonhomogeneity and thermal nonequilibrium of either phase are accounted for in the code. The two-fluid formulation and advanced critical flow correlation of RELAP5, in conjunction with efficient programming techniques and very general modeling capabilities provide a tool to evaluate pressure relief system transients. In using RELAP5, the system is divided into volumes called control volumes. The flow paths between the control volumes are called junctions. The user identifies the system initial conditions such as pressure, temperature, and quality in the volumes and the mass flow rate at the junctions. The code calculates the system transient response downstream of valves after the initiation of safety valve opening.

REFORC is an interface computer code designed to couple RELAP5 with the structural analysis code. REFORC post-processes the output from RELAP5, which is a time history of the flow and state variables, to generate the hydraulic forces at user-specified locations. The output from REFORC can include either wave or static surface (blowdown) forces or a specified combination of these forces. The output format is compatible with the input requirement of the DAGS [3] structural analysis code.

2.2 Piping Structural Analysis

A time history structural analysis of the Palo Verde pressurizer safety valve discharge piping system has been performed to evaluate the structural integrity of the discharge system during safety valve actuation. A three dimensional structural model was developed which includes the pressurizer, safety valves, inlet and discharge piping, and all piping supports. The method of analysis used is similar to that used in the EPRI/CE Safety and Relief Valve Test program.

The basic structural model was defined using the STRUDL computer code. The STRUDL code is a publicly available, well verified code that is widely used in dynamic piping analyses. The STRUDL code was used to generate the mass matrix and linear stiffness matrix for the structure. The consistent mass matrix of the entire structure was reduced by kinematic condensation techniques to those degrees of freedom which represent the loading and significant natural frequencies of the piping system. The stiffness matrix was condensed to the mass degrees of freedom plus support degrees of freedom.

The STRUDL calculated mass and stiffness matrices were then input to the CE developed computer code DAGS (Dynamic Analysis of Gapped Structures), Reference (3). The DAGS computer code has been verified for the dynamic analysis of piping systems with non-linear or gapped piping supports. The STRUDL stiffness matrix was then modified by the DAGS code to include the gapped supports which are present in the Palo Verde discharge system.

The valve actuation forces are hydraulic forcing functions, and were calculated by the RELAP5 computer code as described in the previous section. These forcing functions are applied as input loadings for the dynamic structural analysis.

A more detailed description of the structural modeling and analysis is presented in Section 5. Typical results of the structural analysis are presented in Appendix B.

3.0 PALO VERDE SAFETY VALVE PIPING ARRANGEMENT

3.1 Physical Description

The pressurizer safety valve discharge piping system extends from the safety valve outlet flange to the quench tank inlet nozzle. The Palo Verde system has four safety valves which are independently connected to the pressurizer nozzles at the top head of the pressurizer through separate 6-inch schedule 160 lines. The valves are Dresser model 31709NA. This model has a 6" inlet and 8" outlet. All four valves have the same setpressure, 2500 psia. The portion of the piping system upstream of the safety valves is classified as Quality Class I, Seismic Category I and ASME Safety Related Class 1 piping. Downstream of the safety valves, the four discharge lines continue independently as 8-inch and 10-inch schedule 20 lines in series and join separately with an 18-inch common header which continues to the quench tank. The portion of the piping system downstream of the safety valves is classified as Quality Class IV, Seismic Category V and non-safety related piping. A schematic of jurisdictional boundaries of the Pressurizer Safety Valve Discharge System is shown in Figure 3-1.

3.2 Function of System

The function of the safety valves is to provide overpressure protection of the Reactor Coolant System. The pressurizer safety valve discharge lines receive the discharge from the safety valves and provide the flow path to the quench tank. The Design Basis Events which result in peak pressure greater than the opening set pressure (2500 psia) for the safety valves are treated in the FSAR. The valve inlet condition for each of these events and the sequence of events for each event are presented in Reference (4). The highest peak pressure among those events was 2587 psia for the Loss of Feedwater Inventory event. The greatest pressure ramp rate was 105 psi/sec for the Loss of Condenser Vacuum with Fast Transfer Failure. The valve inlet fluid was limited to saturated steam in all cases.

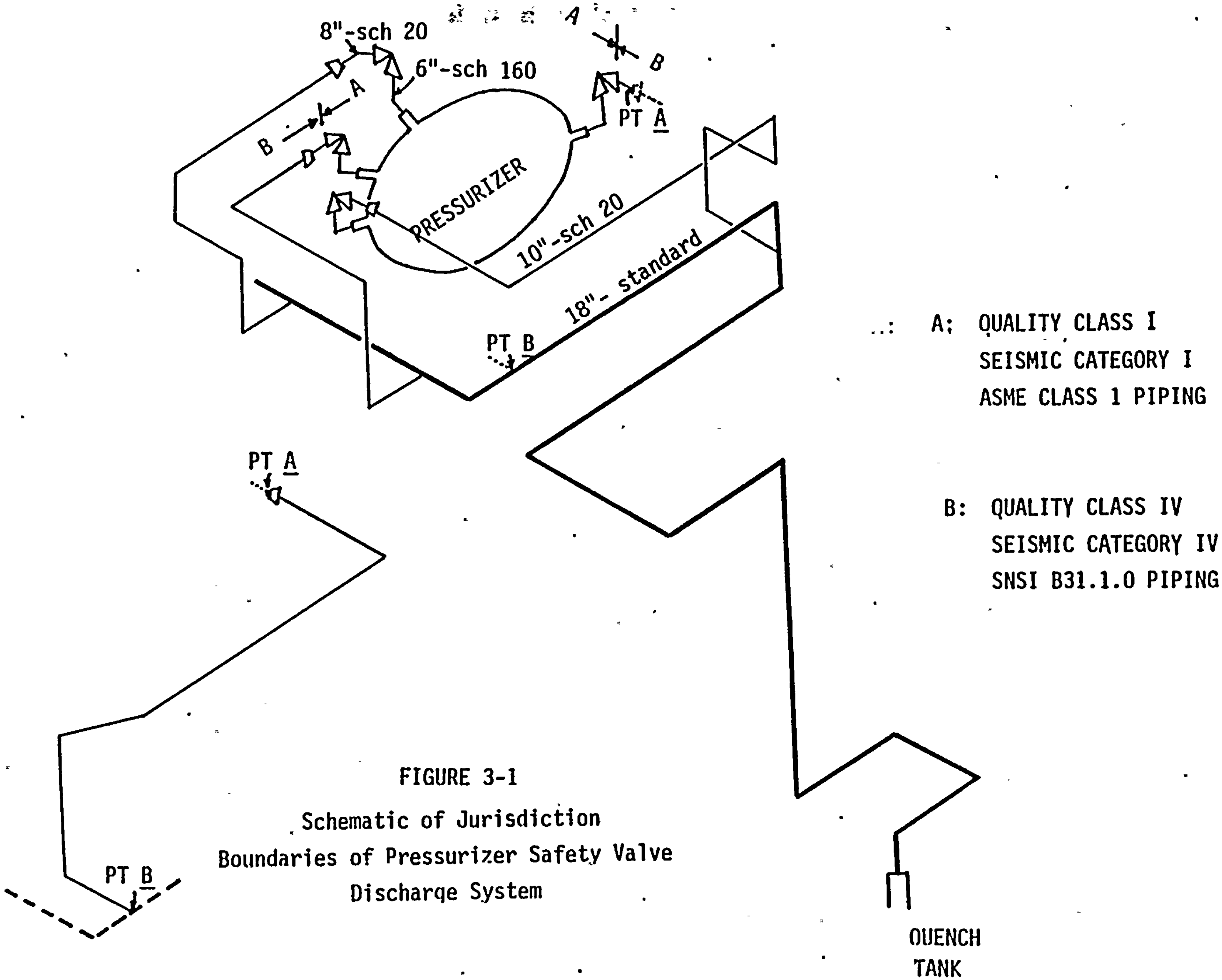


FIGURE 3-1

Schematic of Jurisdiction Boundaries of Pressurizer Safety Valve Discharge System

4.0 APPLICABILITY OF EPRI TEST TO PALO VERDE SAFETY VALVE PIPING SYSTEM

One of the objectives of the EPRI Safety Valve Test Program was to obtain sufficient piping hydraulic load data to permit verification of computer codes and methods which may be utilized for plant unique analysis of safety valve discharge piping systems. The RELAP5 computer code was selected for this verification purpose by the Electric Power Research Institute. The evaluation of the performance of RELAP5 was obtained through comparisons of calculated with experimental structural and hydraulic response data. Experimental data from five EPRI safety valve tests were compared with RELAP5/MOD1 calculations to evaluate the capability of the code to determine the fluid-induced transient loads on downstream piping (see Reference (5)).

The upstream accumulator fluid condition was steam for four selected tests and slightly subcooled liquid for the fifth. The fluid flow transients through the safety valve included steam only, water only, cold water from the loop seal followed by steam and hot water from the loop seal followed by steam. The calculated results for both discharge pipe pressures and support loads compared well with measured test data. Results of the calculations were reported in detail in Reference (5). The conclusion of the study is that RELAP5 is applicable for safety valve discharge forcing function calculations.

5.0 EVALUATION OF PALO VERDE SAFETY VALVE DISCHARGE PIPING

The hydraulic load forcing functions which are applied as input loads for the piping structural analysis were obtained from RELAP5/REFORC. The approach made in generating these forcing functions is described in Section 5.1. The structural analysis is presented in Section 5.2.

5.1 Hydraulic Forcing Function in Safety Valve Discharge Piping

The Palo Verde safety valve discharge piping system was modeled with 142 control volumes linked together by 143 junctions. Figure 3-1 shows the overall system configuration between the pressurizer and the discharge pipe

exit. Figure 5-1 shows the corresponding RELAP5 model between the safety valve and the pipe exit. Four control volumes were independently used to represent the pressurizer upstream condition for the four safety valves. One hundred thirty seven control volumes were used to represent the safety valve downstream piping.

Two parametric studies were conducted to determine the sensitivities of calculated piping segment load to the computing time step size and the number of control volumes which comprise the segment. The major criterion for selection of the maximum time step size is that no wave front may traverse the length of a control volume in one time step. A time step size of .00025 seconds was found to be adequate since the use of other selected smaller RELAP5 time step sizes did not significantly affect the calculated results. Two RELAP5 models, consisting of 142 and 186 control volumes to represent the discharge piping system, were used to conduct a hydraulic nodalization study. Results from the two models were in close agreement. Based upon these comparisons, the 142-volume model was determined to adequately predict both the shape and the magnitude of the forcing functions.

The following conditions were used in calculating the forcing functions:

1) The initial condition of the pressurizer including piping upstream of the safety valve was assumed to be saturated steam at 2600 psia. The highest peak pressure among the design basis events is 2587 psia. This pressure of 2600 psia was held constant during the transient calculation.

2) The EPRI test recorded steam flow rate for the 31709NA valve is 630,000 lb/hr at the valve inlet pressure of 2600 psia. This flowrate was used in the RELAP5 calculations.

3) The discharge piping initial condition was assumed to be air at 100°F and 14.7 psia with a relative humidity of 80 percent.

4) The magnitude of dynamic hydraulic loads developed in a safety valve discharge piping system depends on the valve operating characteristics. A ramp opening time of 12 msec was used in this analysis. This opening time, which was recorded in Test 603 of the EPRI program, was the fastest valve opening time among the test results for the Dresser 6 x 8 valve. Valve opening times are reported in Reference (7).

A total of six different valve opening sequence cases were run using the 142-volume RELAP5 model. These cases were selected as representative of possible valve actuation sequencing for consideration in the piping analysis. Four cases listed below were used for the structural response analysis

Case 1) All four safety valves were actuated simultaneously.

Case 2) Two valves (Valves Nos. 1 and 2 in Figure 5-1) were opened first. When these valves were full open at 12 msec, the other two valves were opened simultaneously.

Case 3) Two valves (Valves Nos. 1 and 2) were opened first, and the other two valves were opened simultaneously after 50 msec.

Case 4) Two valves (Valves Nos. 1 and 2) were opened first, and the other two valves were opened after 100 msec.

The other two cases listed below were not processed through the structural analysis because review of the results indicated they were not design limiting when compared to the four force cases mentioned above.

Case 5) One valve (valve No. 1) was opened first, and the other three valves were opened after 12 msec.

Case 6) Three valves (valve Nos. 1, 2 and 3) were opened first, and the other valve was opened after 12 msec.

Figures A-1 to A-31 show the time histories of the dynamic hydraulic forcing functions for the case of four valves opening simultaneously at the same pipe force segments as specified in Figure 5-1. The direction of developed pipe force is coaxial with a straight pipe segment. The force is positive when directed toward the pressurizer. For the collinearly joined pipe segments, a net summation force is given instead of forces developed in each pipe segment. The forces presented in Appendix A, Figures A-1 to A-30 are the wave forces and the force in Figure A-31 is the thrust force, i.e., the sum of wave and blowdown force.

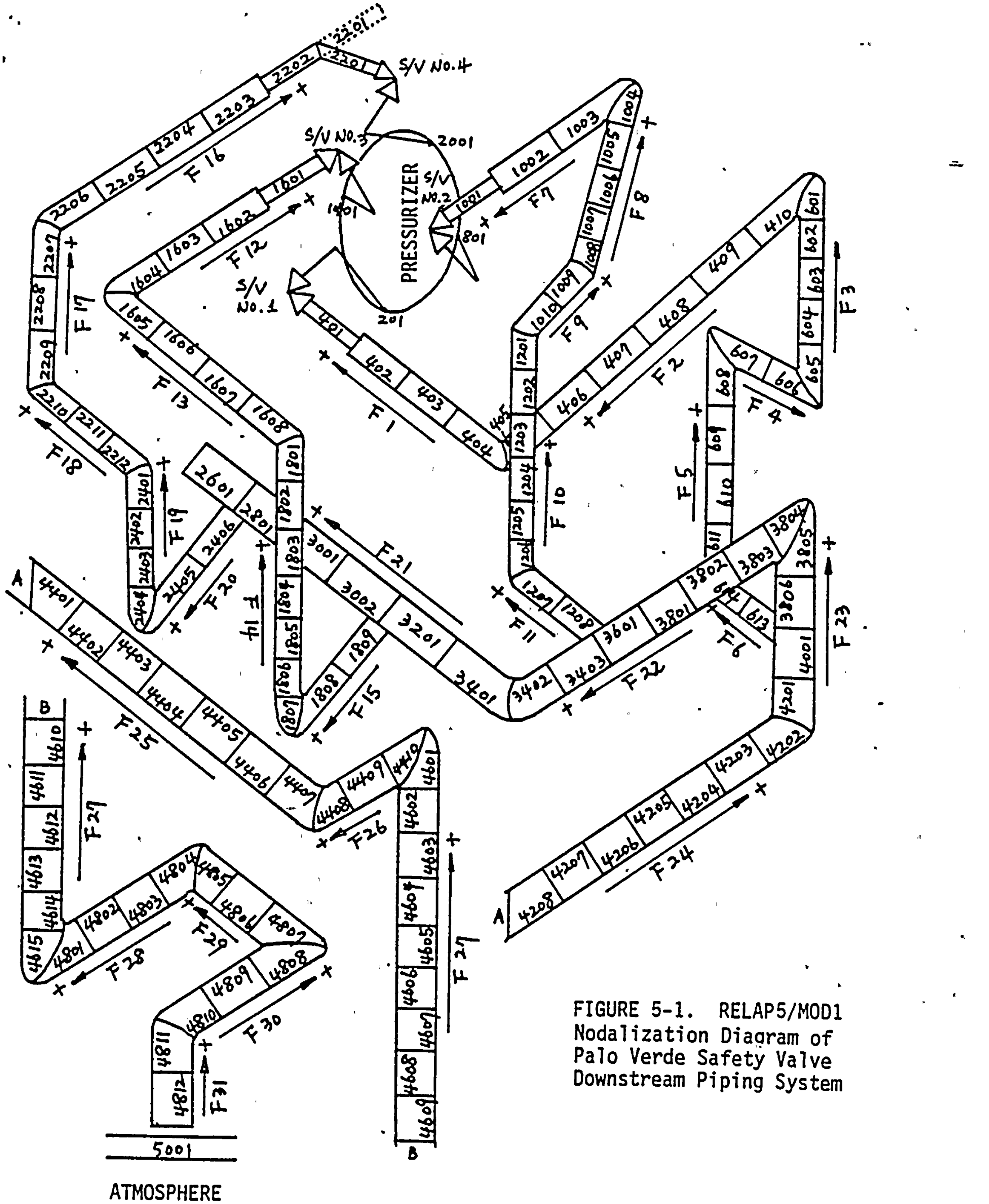


FIGURE 5-1. RELAP5/MOD1 Nodalization Diagram of Palo Verde Safety Valve Downstream Piping System

5.2 Structural Response Analysis of Safety Valve Discharge Piping System

5.2.1 Analytical Model

A computer plot of the Palo Verde discharge piping system is shown on Figure 5.2. This model includes the pressurizer, the four primary safety valves, the inlet piping for each valve, and the discharge system. The discharge piping consists of 8 inch piping which expands shortly after each safety valve discharge flange to a 10 inch line. The 10 inch piping feeds into the main 18 inch discharge piping header which is, in turn, connected to a quench tank. A simplified schematic is presented in Figure 3-1.

Piping schematics in Figures 5-3 to 5-8 describe the structural model and support locations. The locations of hydraulic forcing function application are described in Figure 5-9.

The effect of gapped supports has been considered in the dynamic analysis. For each loading condition considered, a dynamic structural analysis has been performed both with and without gaps. A standard linear analysis was performed for the zero gap analysis. In the gapped analysis, the gaps are located on a best estimate basis considering the effects of dead weight and thermal expansion on the piping system. Where deadweight and thermal expansion tend to move the piping through a gap, the gap is assumed closed and preloaded in that direction, and fully open in the opposite direction.

Gaps sizes are determined from detailed support drawings where possible. Otherwise, the gaps are estimated as follows:

Support Type	Gap (Clearance)
Snubbers	± 1/32
Pipe Clamps	± 1/16
Frames or Stops	± 1/16
All Others	0

When a support is comprised of several of these components, the gaps are combined.

5.2.2 Valve Sequence Loading Conditions

The hydraulic forcing functions during valve discharge have been analyzed for four hypothetical valve actuation sequences. These forcing functions are determined from the RELAP5 hydraulic analyses, as previously described. The four valve actuation sequences considered in the structural analysis are:

1. All four safety valves opening simultaneously.
2. Two valves open simultaneously, the remaining two valves open 12 milliseconds later.
3. Two valves open simultaneously, the remaining two valves open 50 milliseconds later.
4. Two valves open simultaneously, the remaining two valves open 100 milliseconds later.

Other valve actuation sequences were analyzed hydraulically, and the forcing functions for all cases were judged to be enveloped by these four cases for the structural analysis. As previously stated, each loading condition was analyzed for a linear, zero gap system and as a gapped system for a total of eight dynamic structural analyses.

5.2.3 Loading Combinations and Acceptance Criteria

For discharge piping, the actuation of a pressurizer safety valve is considered an ASME Level C (emergency) event. This catagorization of safety valve discharge is in accordance with the recommended guidelines of the EPRI Safety and Relief Valve Piping Subcommittee (Reference 6), and is based on the extremely low probability of actual safety valve actuation. The valve actuation loads are combined with sustained normal operating loads which include dead weight and operating pressure.

The applicable design code for the discharge piping is ANSI B31.1. Equation 12 in ANSI B31.1 is applied to calculate membrane plus bending piping stress. The allowable stress for the piping is 1.8 S_h. This value is 50% higher than the normal stress limit of 1.2 S_h, and is in agreement with the Level C criteria of the ASME code.

The bending moment acting on the safety valve discharge flange due to piping feedback effects is calculated for all four safety valves for each of the eight structural analysis cases previously described. The peak value of bending moment is compared to the as-tested bending moment in the EPRI test program.

Piping support reactions are obtained by combining the valve actuation loads with normal operation loads. These include dead weight and thermal expansion. The calculated peak loads for each support are compared to the support load rating.

5.2.4 Results of Structural Analysis

All calculated stresses in the discharge piping system satisfy the 1.8 S_h allowable stress criteria of ANSI B31.1.

The maximum calculated bending moment on any safety valve discharge flange is 117,200 inch-lbs. This is much less than the EPRI/CE as-tested value of 473,000 inch-lbs for the same model valve, as reported in Reference (7).

Figures B-1 through B-48 represent piping support reactions for the four valve simultaneous actuation load case. These reactions include the effects of gapped supports. A listing of calculated maximum support loads is presented in Table 5-1. These maximum values represent the maximum load at each support from all load cases analyzed.

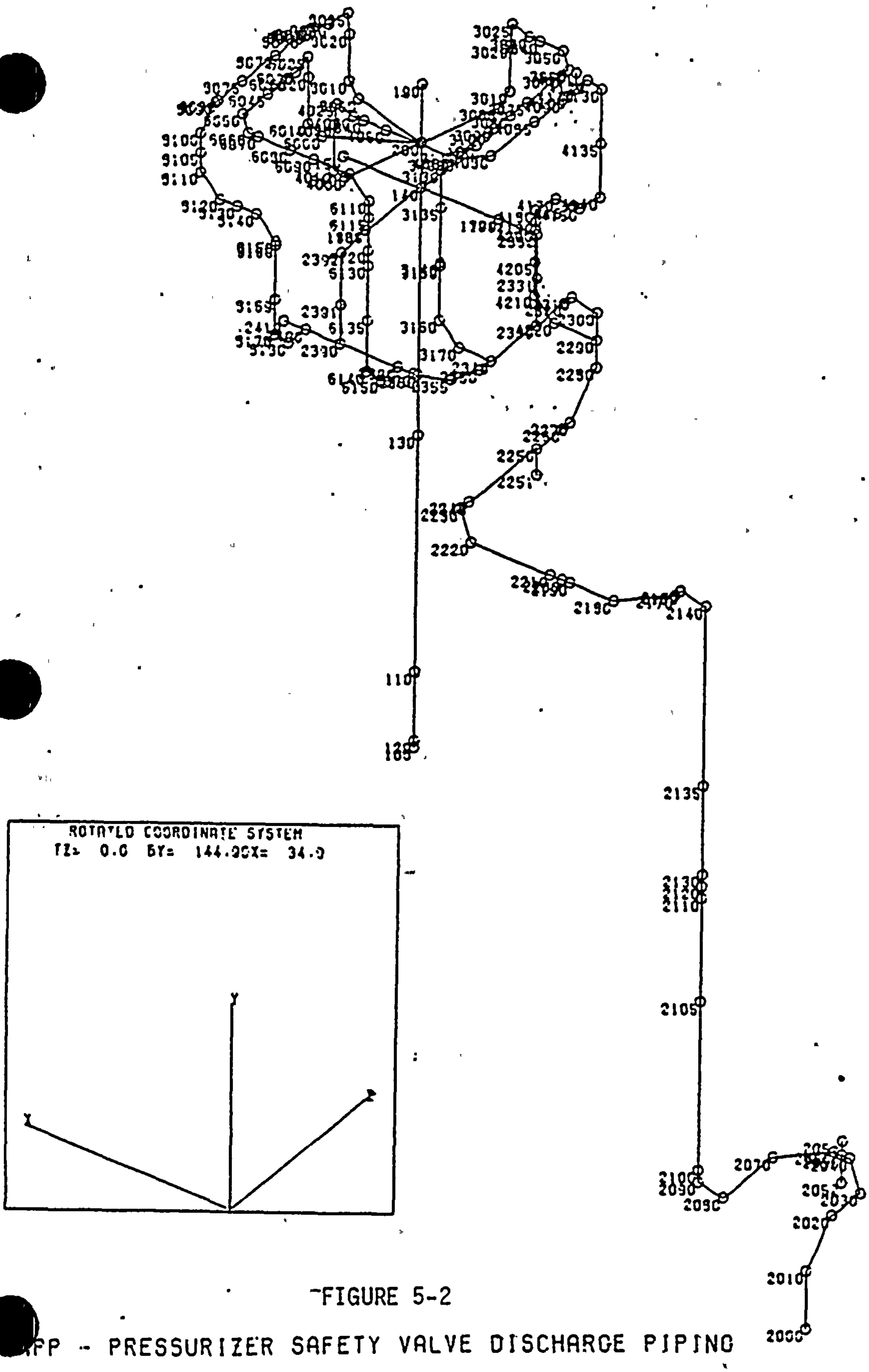
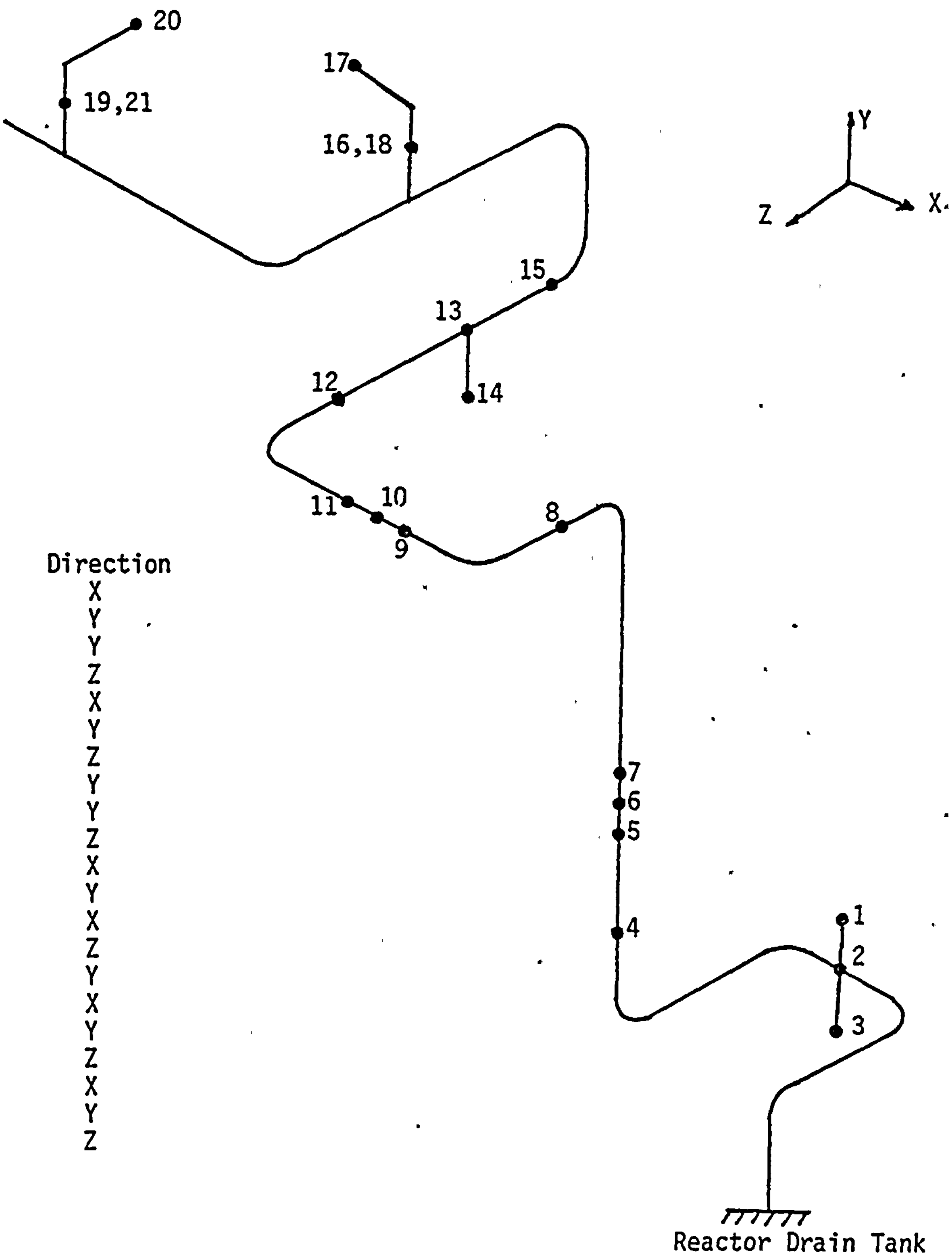


FIGURE 5-2

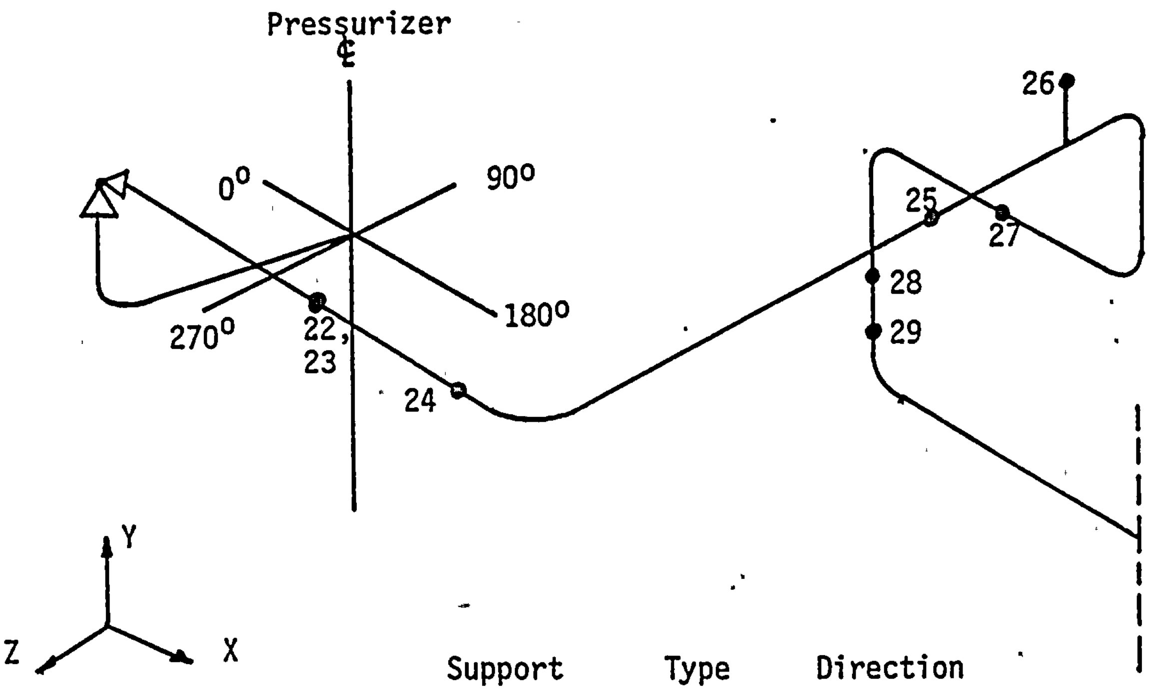
PP - PRESSURIZER SAFETY VALVE DISCHARGE PIPING



Support	Type	Direction
1	STP	X
2	SNB	Y
3	SPR	Y
4	STR	Z
5	STR	X
6	SNB	Y
7	STR	Z
8	SPR	Y
9	SPR	Y
10	SNB	Z
11	STP	X
12	SNB	Y
13	SNB	X
14	STR	Z
15	SNB	Y
16	STP	X
17	STP	Y
18	STP	Z
19	STP	X
20	STP	Y
21	STP	Z

FIGURE 5-3
Line 002 - 18 Inch Header

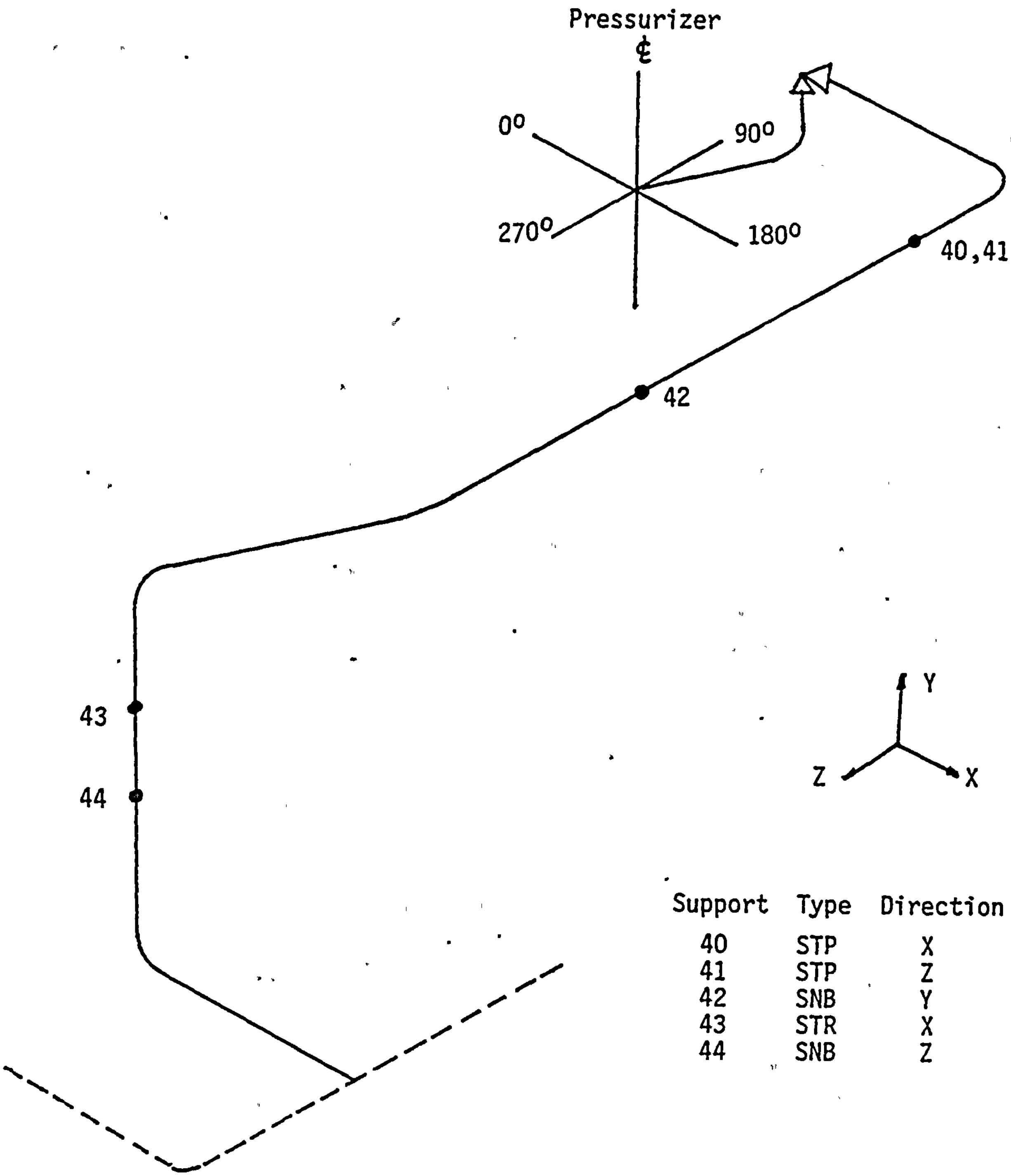
• Gapped Support Joints



Support	Type	Direction
22	STP	X
23	STP	Z
24	SNB	Y
25	STP	X
26	SNB	Z
27	SNB	Y
28	SNB	Z
29	SNB	X

FIGURE 5-4
SV1 - Line 004 - 10 Inch Discharge Pipe

● Gapped Support Joints

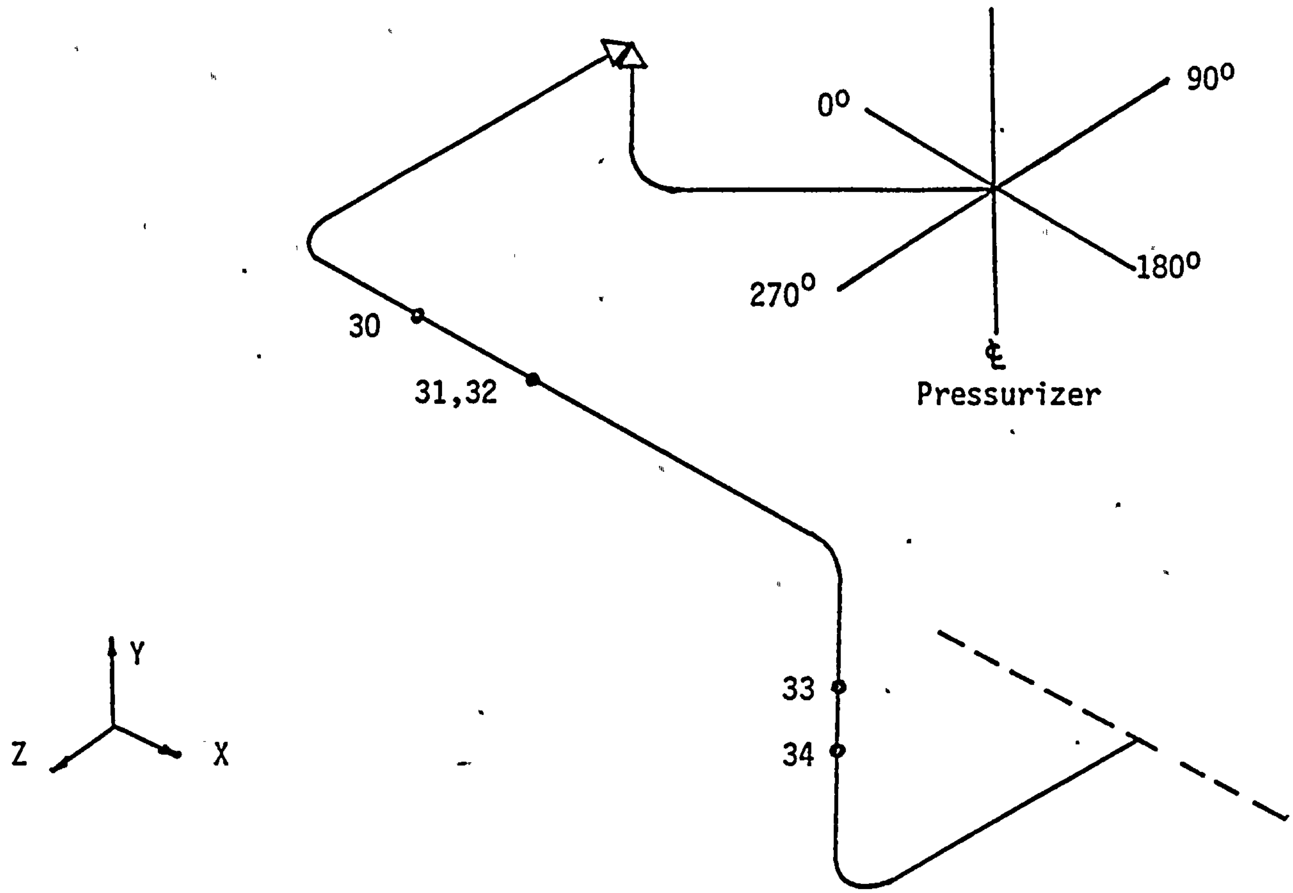


Support	Type	Direction
40	STP	X
41	STP	Z
42	SNB	Y
43	STR	X
44	SNB	Z

FIGURE 5-5

SV2 - Line 103 - 10 Inch Discharge Pipe

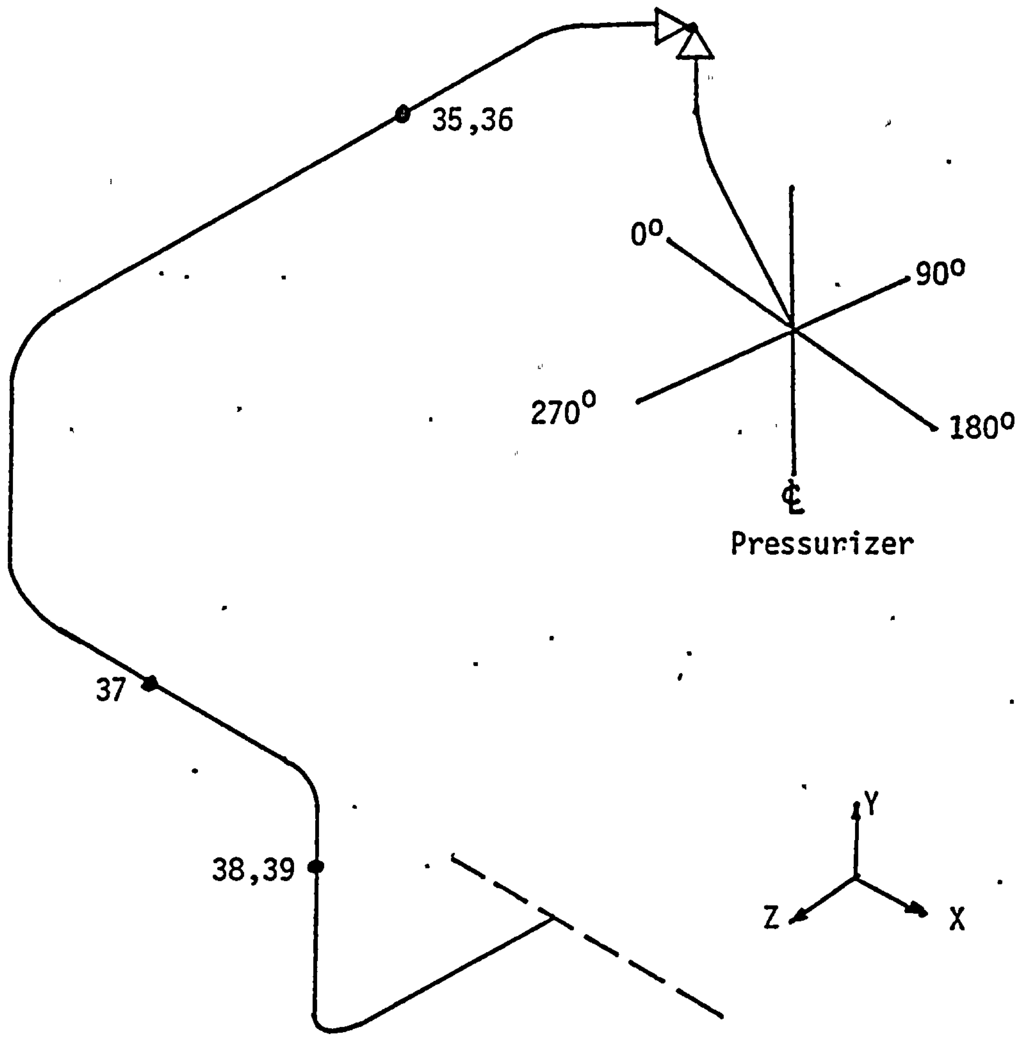
● Gapped Support Joints



Support	Type	Direction
30	SNB	Y
31	STP	X
32	STP	Z
33	SNB	Z
34	SNB	X

FIGURE 5-6
SV3 - Line 006 - 10 Inch Discharge Pipe

● Gapped Support Joints

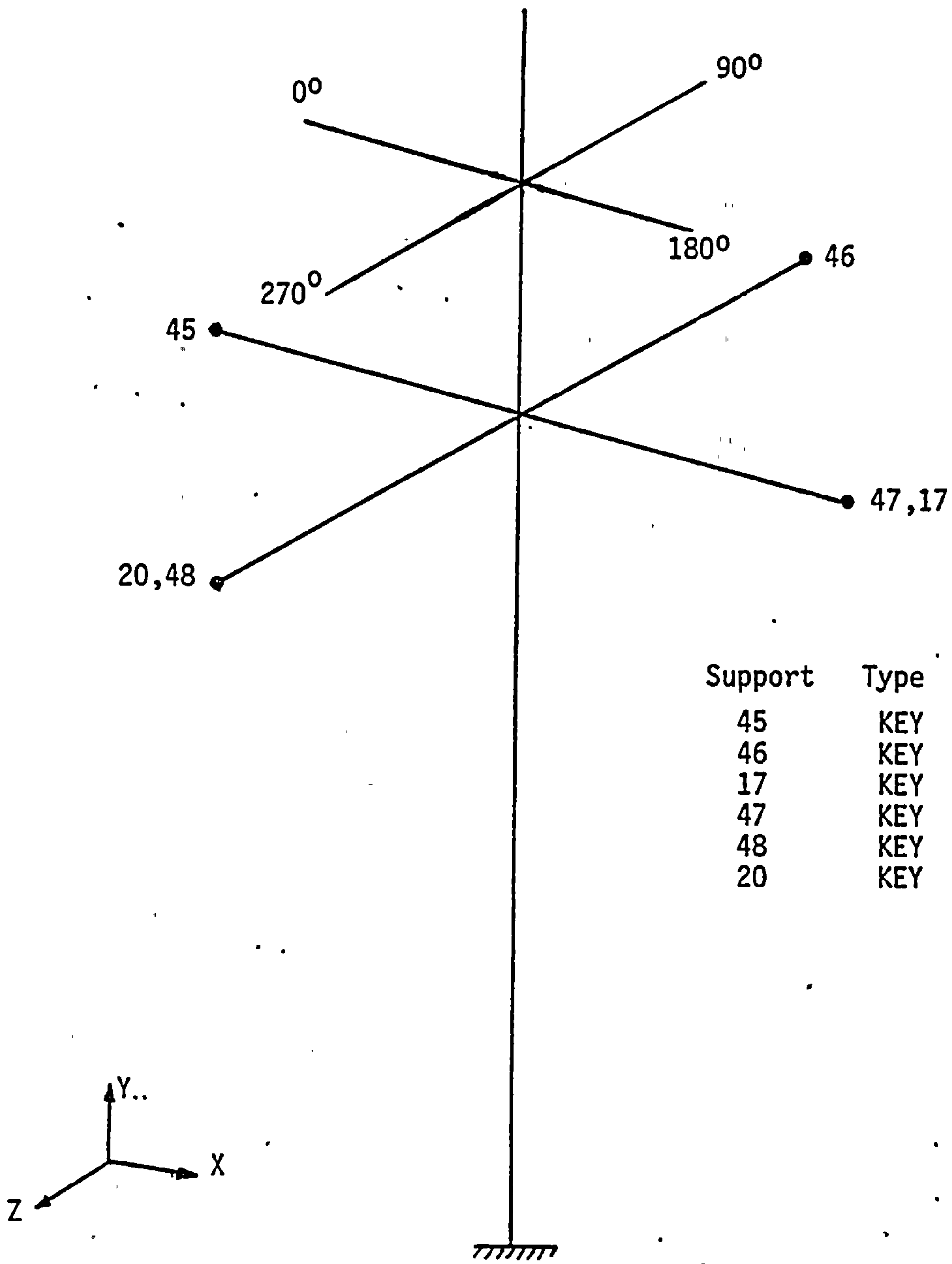


Support	Type	Direction
35	STP	X
36	STP	Z
37	SNB	Y
38	STP	X
39	STP	Z

FIGURE 5-7

SV4 - Line 008 - 10 Inch Discharge Pipe

● Gapped Support Joints



Support	Type	Direction
45	KEY	Z
46	KEY	X
17	KEY	Y
47	KEY	Z
48	KEY	X
20	KEY	Y

FIGURE 5-8
PRESSURIZER

Pressurizer Keys
• Gapped Support Joints

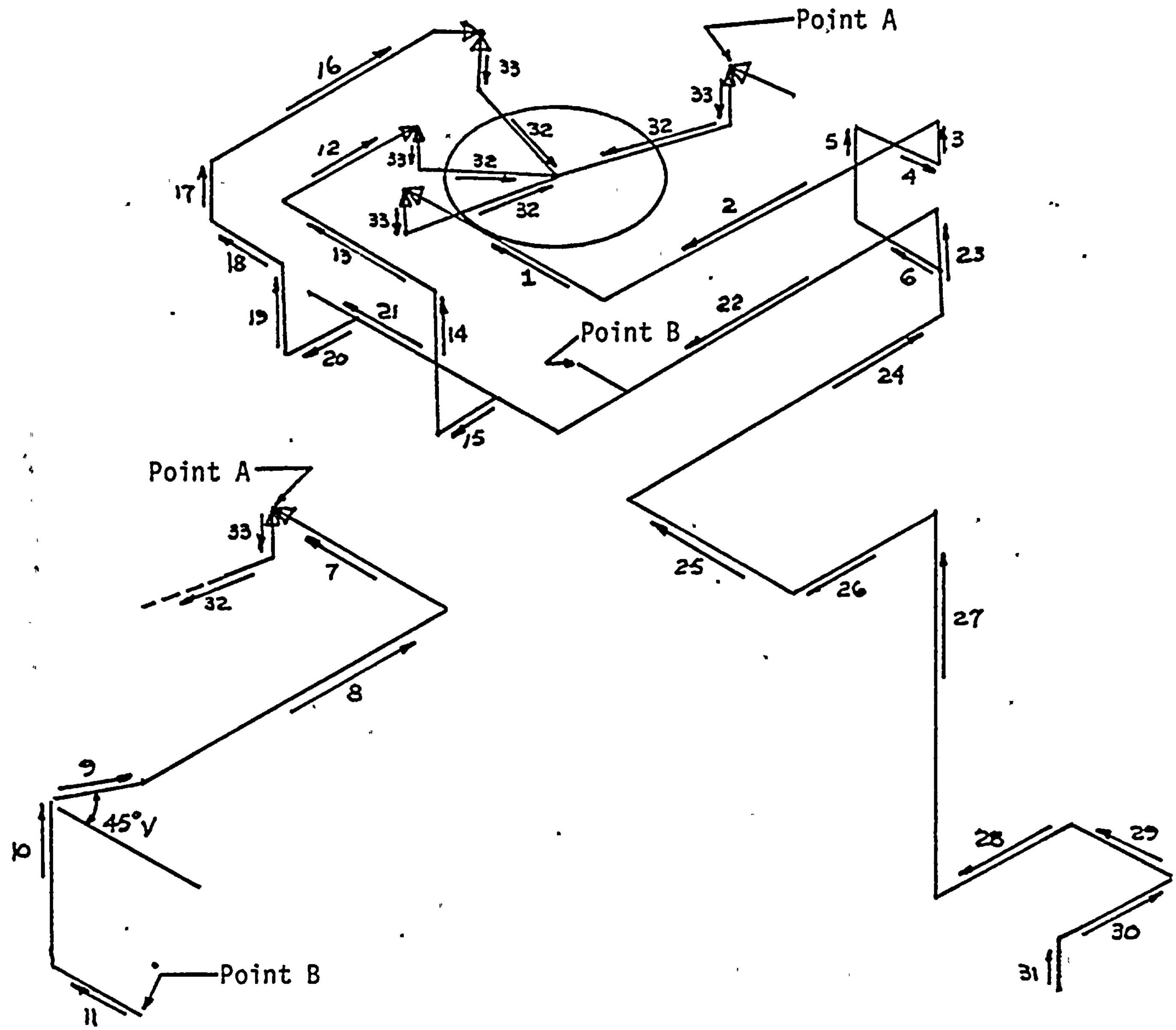


FIGURE 5-9

Applied Loads From Hydraulic Analysis

Table 5-1

Summary of Support Loads

Line	Support	iso.	Direct.[1]	Type[2]	Valve Act.[3] Only (lbs) +	Valve Act.[3] Only (lbs) -	Valve Act. plus N.O. loads (lbs) +	Valve Act. plus N.O. loads (lbs) -	Moment in Pipe[4] at Support (in-lbs)
2	17	278	X	STP	21937	11007	26704	11007	
	18	278	Y	SNB	7898	9623	7898	9623	194,000
	19	278	Y	SPR	0	18	0	1134	
	35	27A	Z	STR	18334	15167	21138	15167	364,000
	36	274	X	STR	5468	11962	5468	13219	307,000
	33	27B	Y	SNB	32082	23008	32082	23008	261,000
	34	27C	Z	STR	5463	8890	5463	9628	217,000
	32	26C	Y	SPR	0	51	0	3769	217,000
	31	269	Y	SPR	0	43	0	1630	177,000
	29	69A	Z	SNB	7606	8328	7606	8328	191,000
	30	69B	X	STP	24658	31948	26183	31948	184,000
	28	268	Y	SNB	10081	8768	10081	8768	269,000
	26	267	X	SNB	9359	10647	9359	10647	
	27	267	Z	STR	10247	23707	10247	26242	360,000
	25	26A	Y	SNB	8232	9785	8232	9785	266,000
	23	44	X	STP	10063	5203	14390	5203	
			Y	STP	5351	12433	5351	15921	777,000
			Z	STP	22962	18804	24363	18804	
	21	101	X	STP	8404	15120	8404	23071	
			Y	STP	8021	13048	8021	14982	335,000
			Z	STP	12490	9448	16815	9448	
4	16	58A	X	STP	6616	14503	6616	14606	
			Z	STP	5894	0	8990	0	108,000
	15	58	Y	SNB	5034	5715	5034	5715	76,000
	18	56B	X	STP	9319	13548	9319	13981	158,000
	14	56	Z	SNB	9905	6911	9905	6911	82,000
	12	53	Y	SNB	9666	10189	9666	10189	93,000
	11	51A	Z	SNB	5673	6428	5673	6428	114,000
	17	51	X	SNB	8657	9182	8657	9182	149,000

TABLE 5-1 (continued)

Summary of Support Loads

Line	Support	iso.	Direct.	Type	Valve Act. Only (lbs) +	Valve Act. Only (lbs) -	Valve Act. plus N.O. loads (lbs) +	Valve Act. plus N.O. loads (lbs) -	Moment in Pipe at Support (in-lbs)
6	13	168	Y	SNB	6201	2941	6201	2941	89,000
	15	169	X	STP	34798	41578	36892	41578	154,000
			Z	STP	10215	3406	14479	3406	
	12	66A	Z	SNB	3559	4747	3559	4747	113,000
	11	166	X	SNB	4202	3558	4202	3558	109,000
8	14	24A	X	STP	3933	10082	3933	13798	234,000
			Z	STP	28471	5623	32446	5623	
	12	234	Y	SNB	14542	8091	14542	8091	193,000
	11	225	X	STP	16812	8288	17714	8288	147,000
			Z	STP	970	6036	970	7275	
103	11	30	X	STP	563	0	5057	0	67,000
			Z	STP	2999	9576	2999	10195	
	12	31	Y	SNB	5787	5196	5787	5196	125,000
	14	34	X	STR	5526	7445	5526	8628	204,000
	15	34A	Z	SNB	3231	3445	3231	3445	195,000
Pzr. Keys	0°	-	Z	Key	3517	3738	3517	3738	N/A
	90°	-	X	Key	3283	3201	3283	3201	N/A
	180°	-	Z	Key	2661	2792	2661	2792	N/A
	270°	-	X	Key	2332	2084	2332	2084	N/A

1. Directions as shown on Bechtel drawings: North is in the minus X direction.

2. Type: STP - stop
   SNB - snubber
   STR - strut
   SPR - spring

3. Loads are imposed on the supports by the piping system.

4. Moments listed are due to valve actuation only.

6.0 SUMMARY AND CONCLUSIONS

The Palo Verde pressurizer safety valve discharge piping system has been evaluated with respect to safety valve actuation. The hydraulic piping forces generated upon valve actuation have been calculated by the RELAP5 computer code, which was benchmarked for this application in the EPRI Safety and Relief Valve Test Program. These hydraulic forces were applied as input loadings to a dynamic structural analysis of the discharge piping system. The structural analysis was performed with the STRUDL and DAGS computer codes, and included the effects of gapped supports on the dynamic response characteristics of the discharge system.

The results of this analysis indicates that the feedback effects of the piping system will not adversely affect valve performance. The calculated piping imposed loading on the safety valves are below those loadings tested in the EPRI program and under which the valves operated satisfactorily.

The calculated piping stresses due to valve actuation plus normal operating loads are within the allowable stress levels of the applicable codes.

The loads at each support location have been determined and are listed in Table 5-1. These support loads have been evaluated and are within the load capability of the appropriate support system.

7.0 REFERENCES

1. RELAP5/MOD1 Code Manual, NUREG/CR-1826, EG&G, Idaho, March, 1982.

2. REFORC, A Computer Program for Calculating Fluid Forces Based on RELAP5 Results, EDS Report No. 01-0650-1194, February, 1982.

3. "Dynamic Analysis of Piecewise Linear Structures", J.S. Lien, R. P. Kassawara, H.B. Smith, Combustion Engineering, presented at ASCE Second Specialty Conference on Structural Design of Nuclear Power Plant Facilities, December, 1975.

4. EPRI Report NP-2318-LD, "Valve Inlet Fluid Conditions for Pressurizer Safety and Relief Valves in Combustion Engineering Designed Plants," April, 1982.

5. EPRI Report NP-2479-LD, "Application of RELAP5/MOD1 for Calculation of Safety and Relief Valve Discharge Piping Hydrodynamic Loads," Intermountain Technologies, Inc., March 1982.

6. EPRI Letter to Utility Contacts - Piping Subcommittee members, dated November 5, 1981.

7. EPRI Report NP-2628-LD "Safety and Relief Valve Test Report", September, 1982.

APPENDIX A

HYDRAULIC FORCING FUNCTIONS

Case Number One: Four Valve Simultaneous Actuation

FIGURE A-1

ARIZONA S/V SISCHARGE PIPING ANALYSIS

PIPING FORCE NO. 1 (142 NODE-MODEL, DT=.25MS)

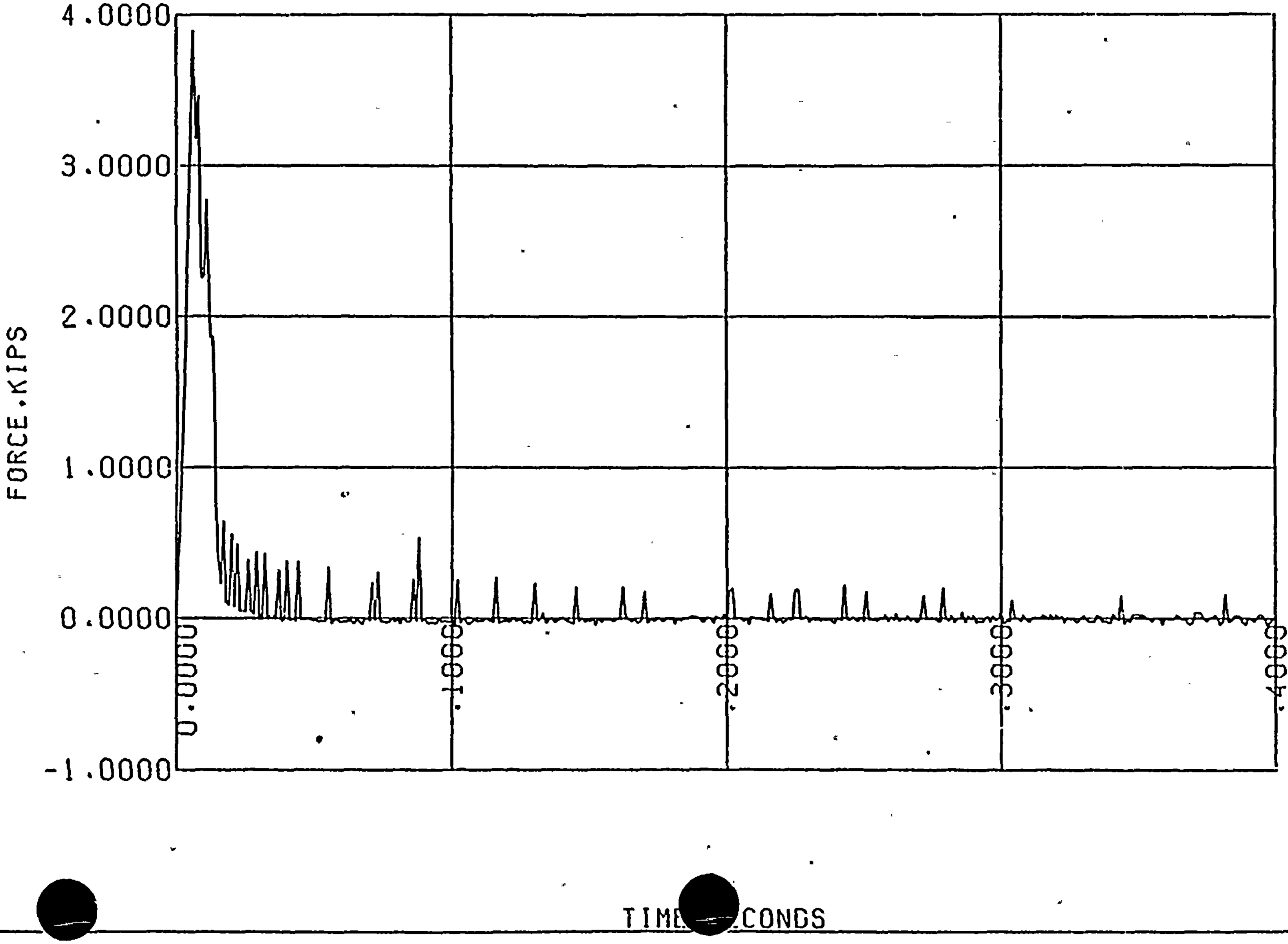


FIGURE A-2

ARIZONA S/V DISCHARGE PIPING ANALYSIS

PIPING FORCE NO.2 (142 NODE-MODEL,DT=.25MS)

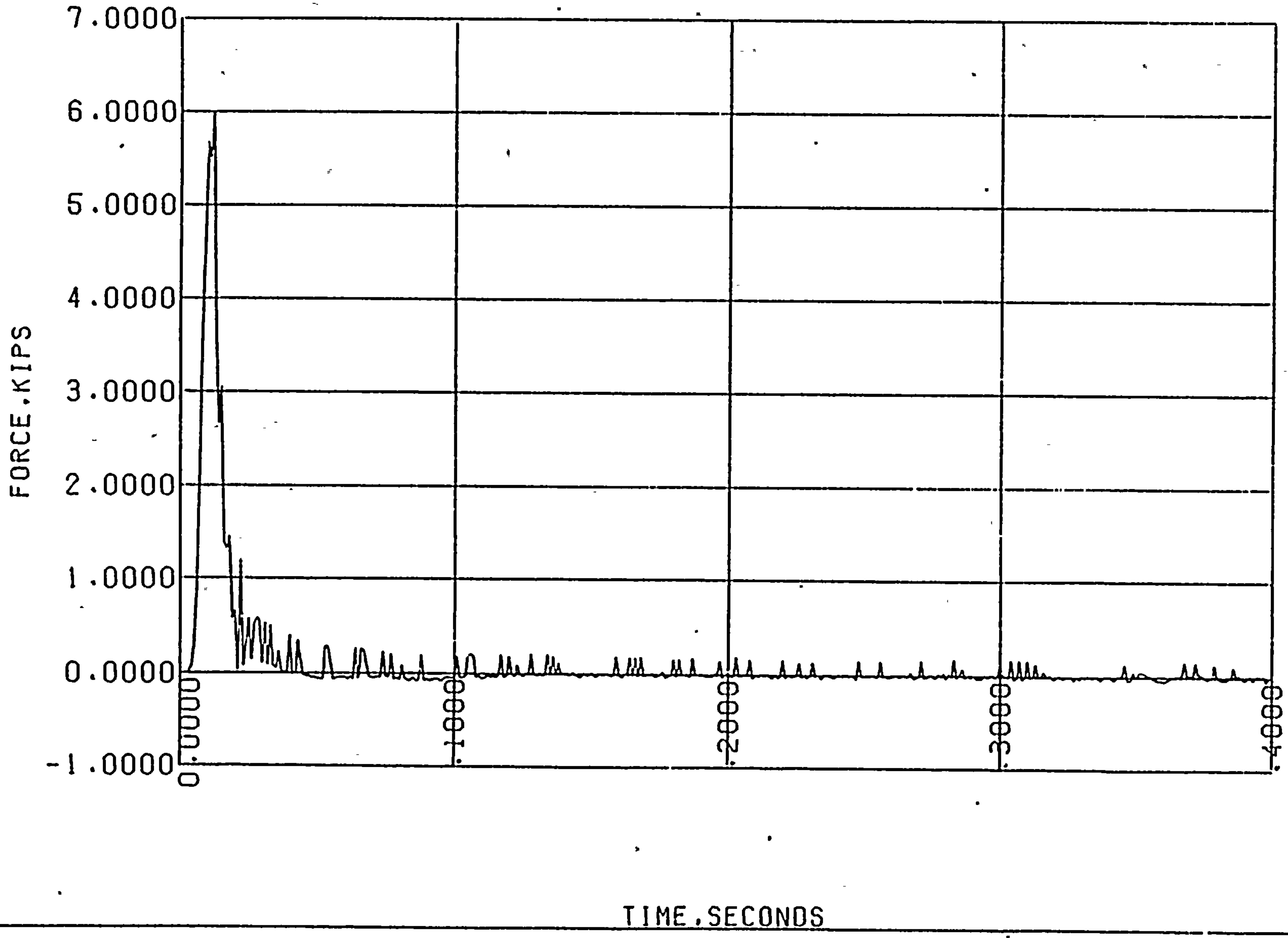
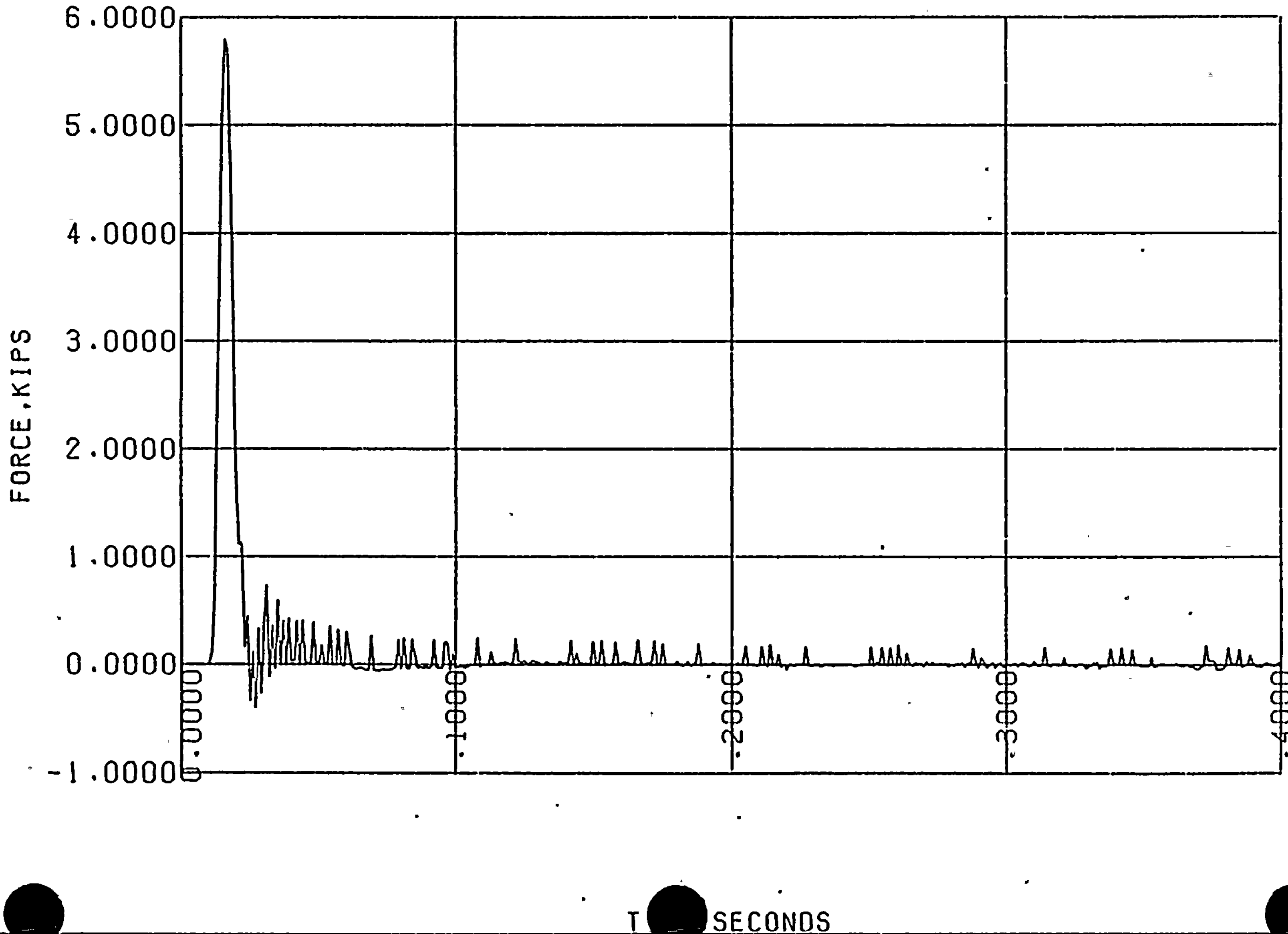


FIGURE A-3
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.3 (142 NODE-MODEL,DT=.25MS)



A-4

FIGURE A-4

ARIZONA S/V DISCHARGE PIPING ANALYSIS

PIPING FORCE NO.4 (142 NODE-MODEL,DT=.25MS)

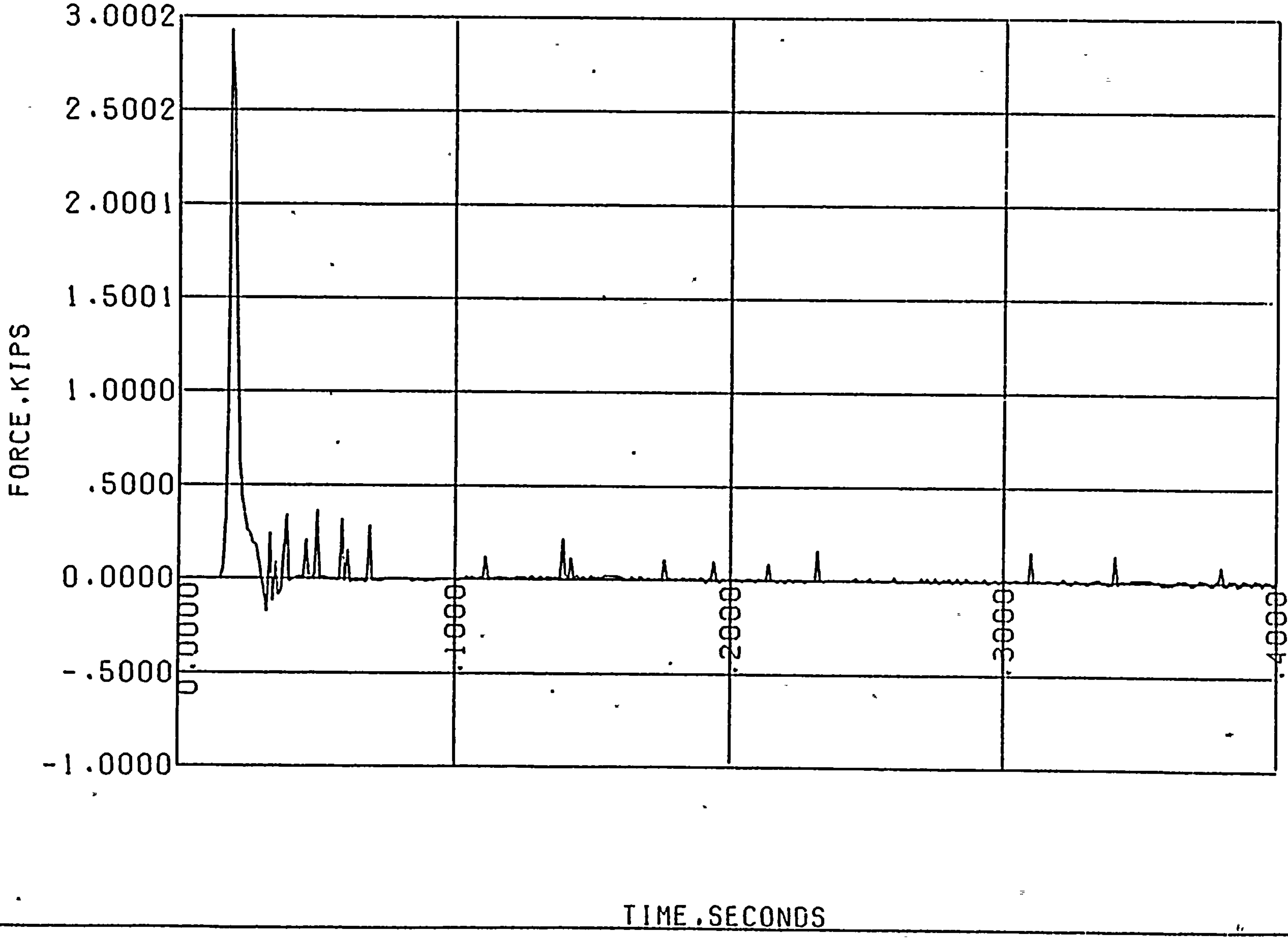


FIGURE A-5.

ARIZONA S/V DISCHARGE PIPING ANALYSIS

PIPING FORCE NO.5 (142 NODE-MODEL, DT=.25MS)

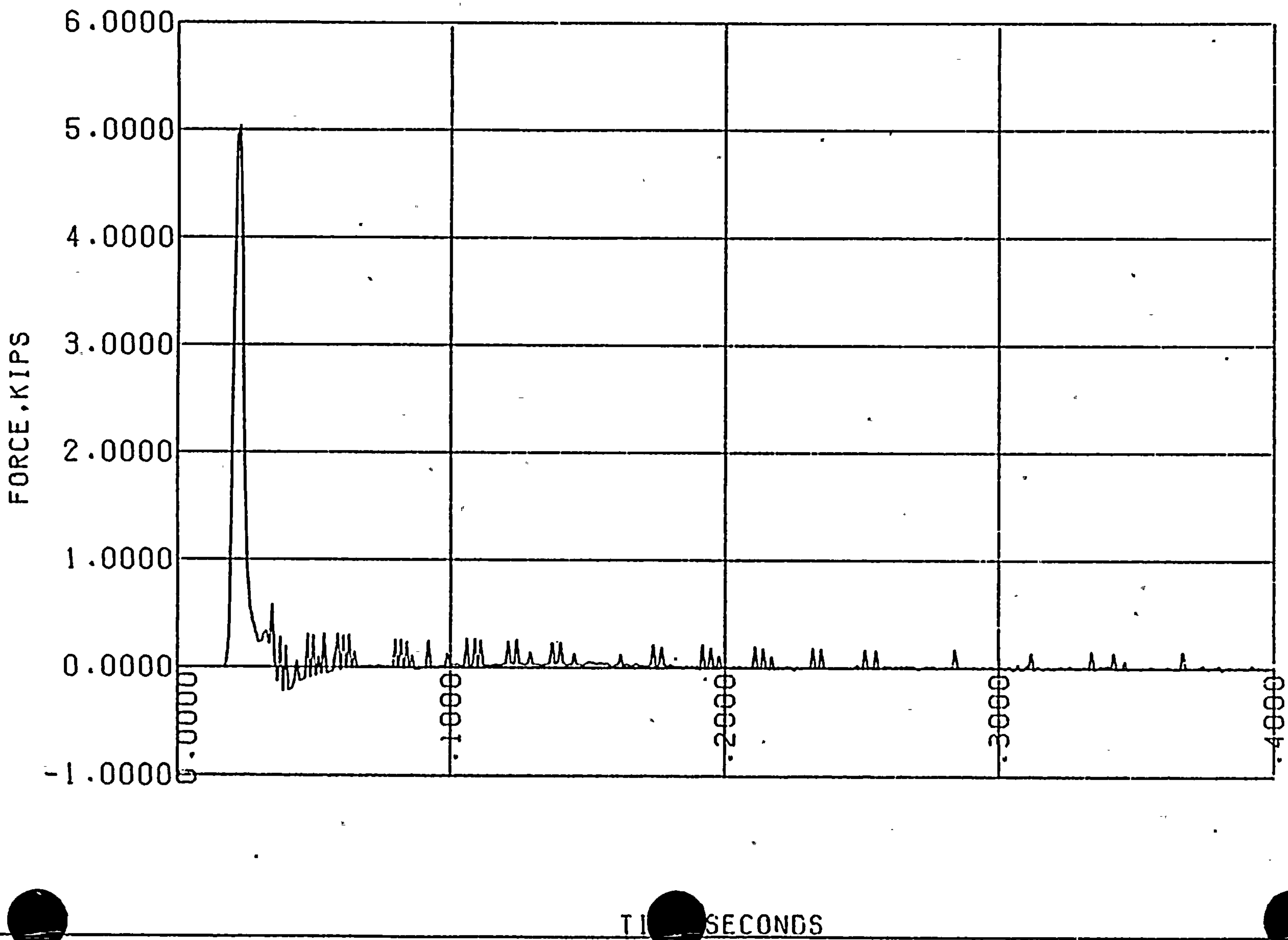


FIGURE A-6
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.6 (142 NODE-MODEL,DT=.25MS)

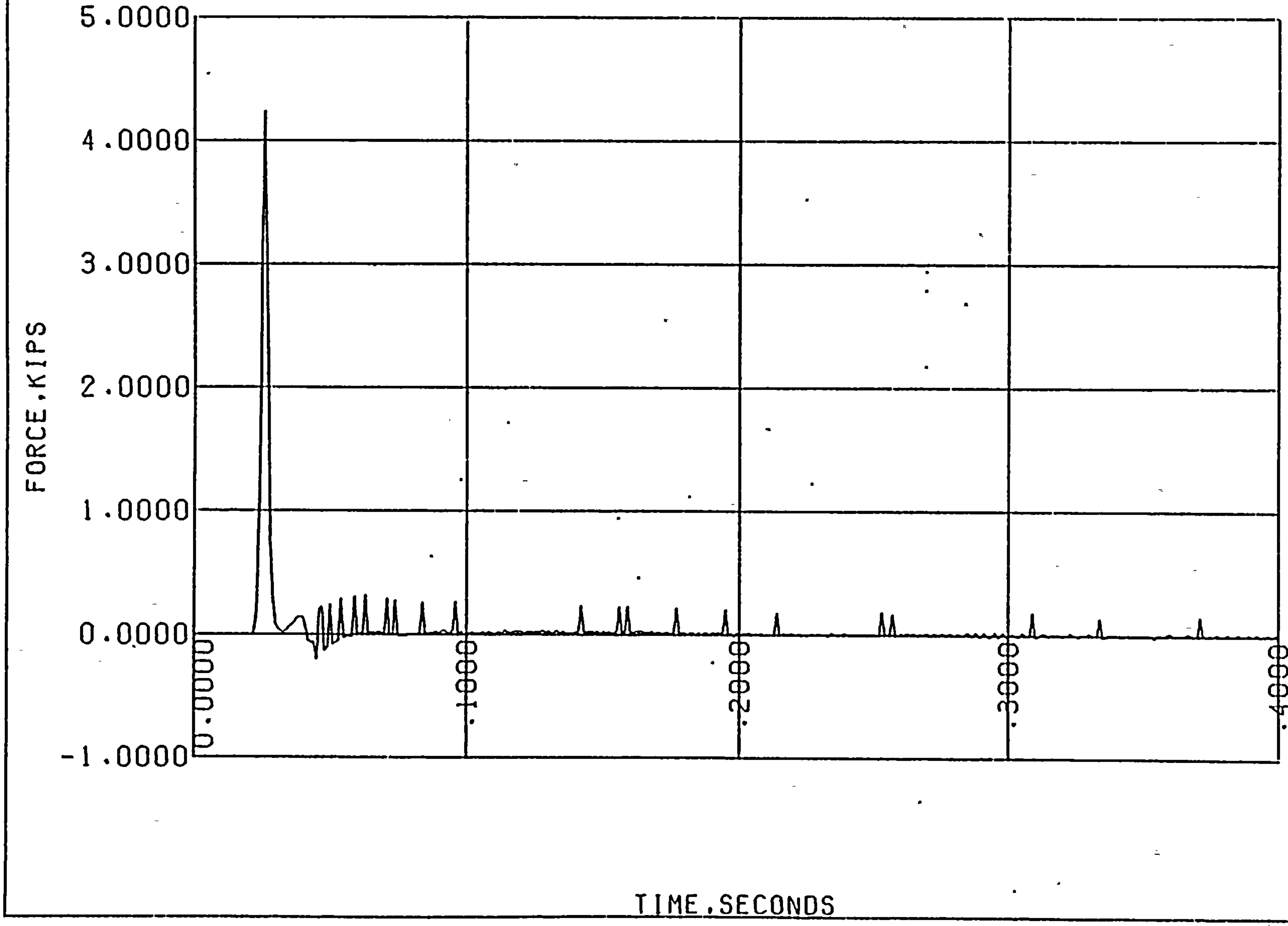


FIGURE A-7

ARIZONA S/V DISCHARGE PIPING ANALYSIS

PIPING FORCE NO.7 (142 NODE-MODEL,DT=.25MS)

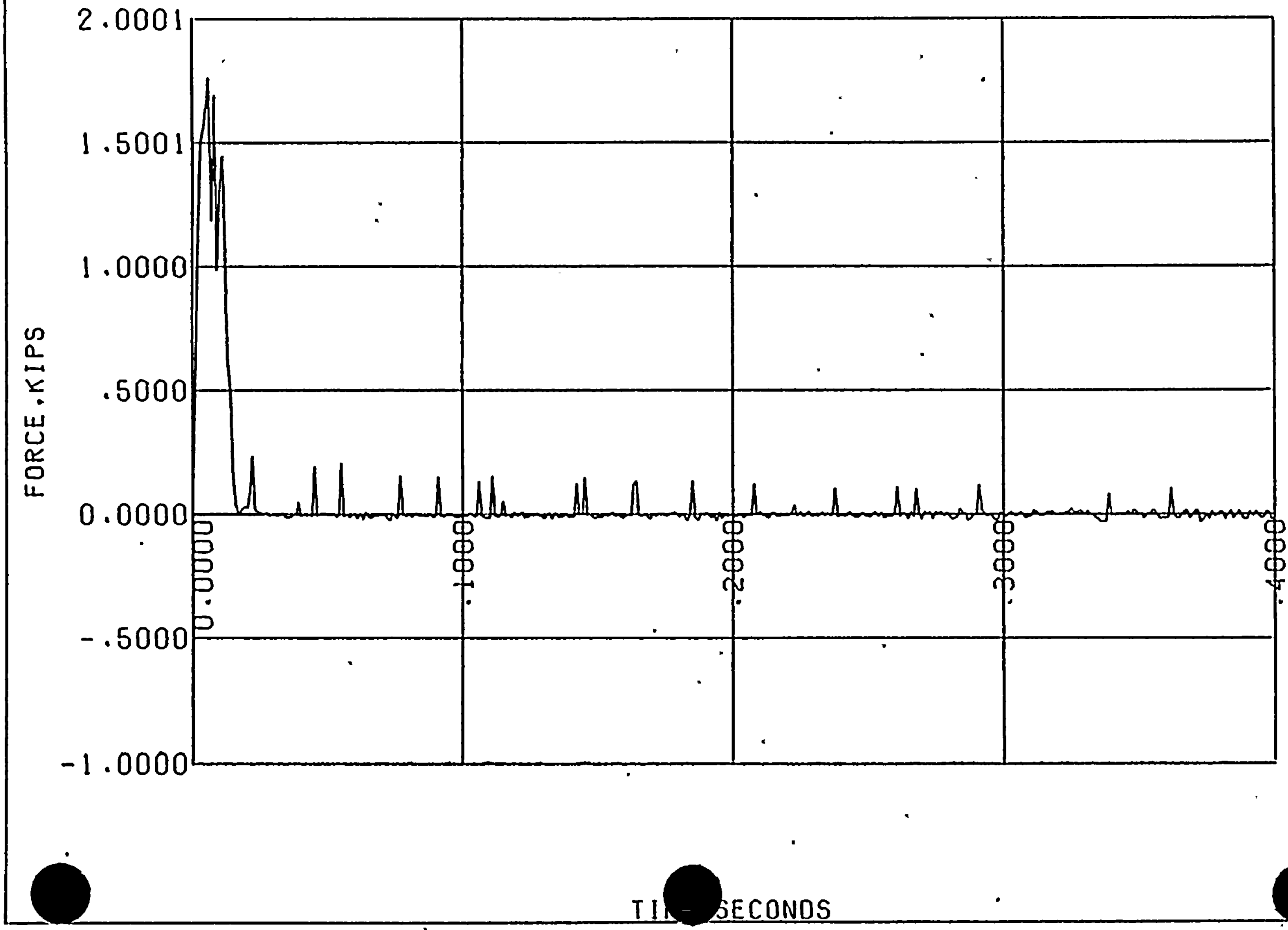


FIGURE A-8
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.8 (142 NODE-MODEL,DT=.25MS)

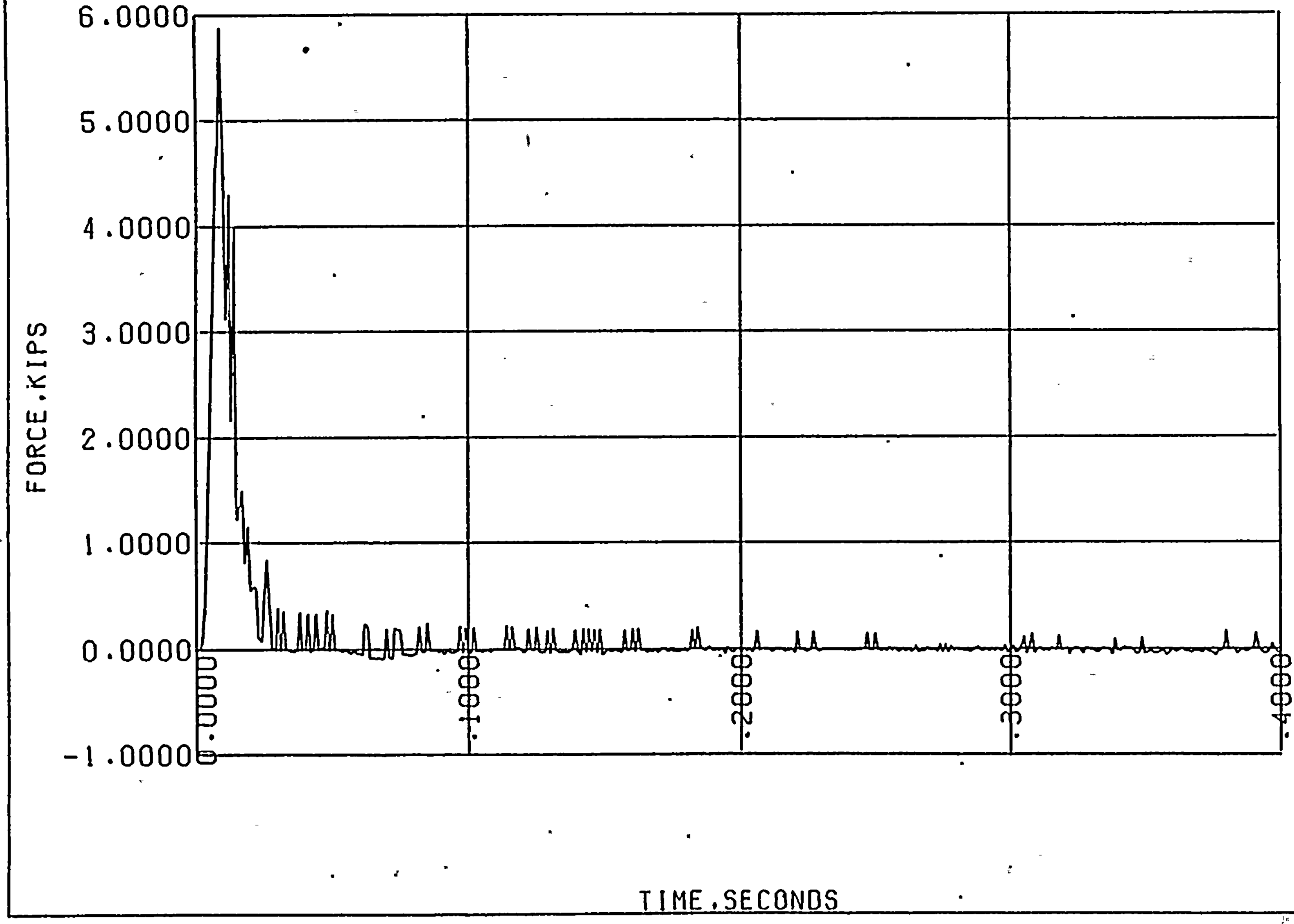


FIGURE A-9
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.9 (142 NODE-MODEL,DT=.25MS)

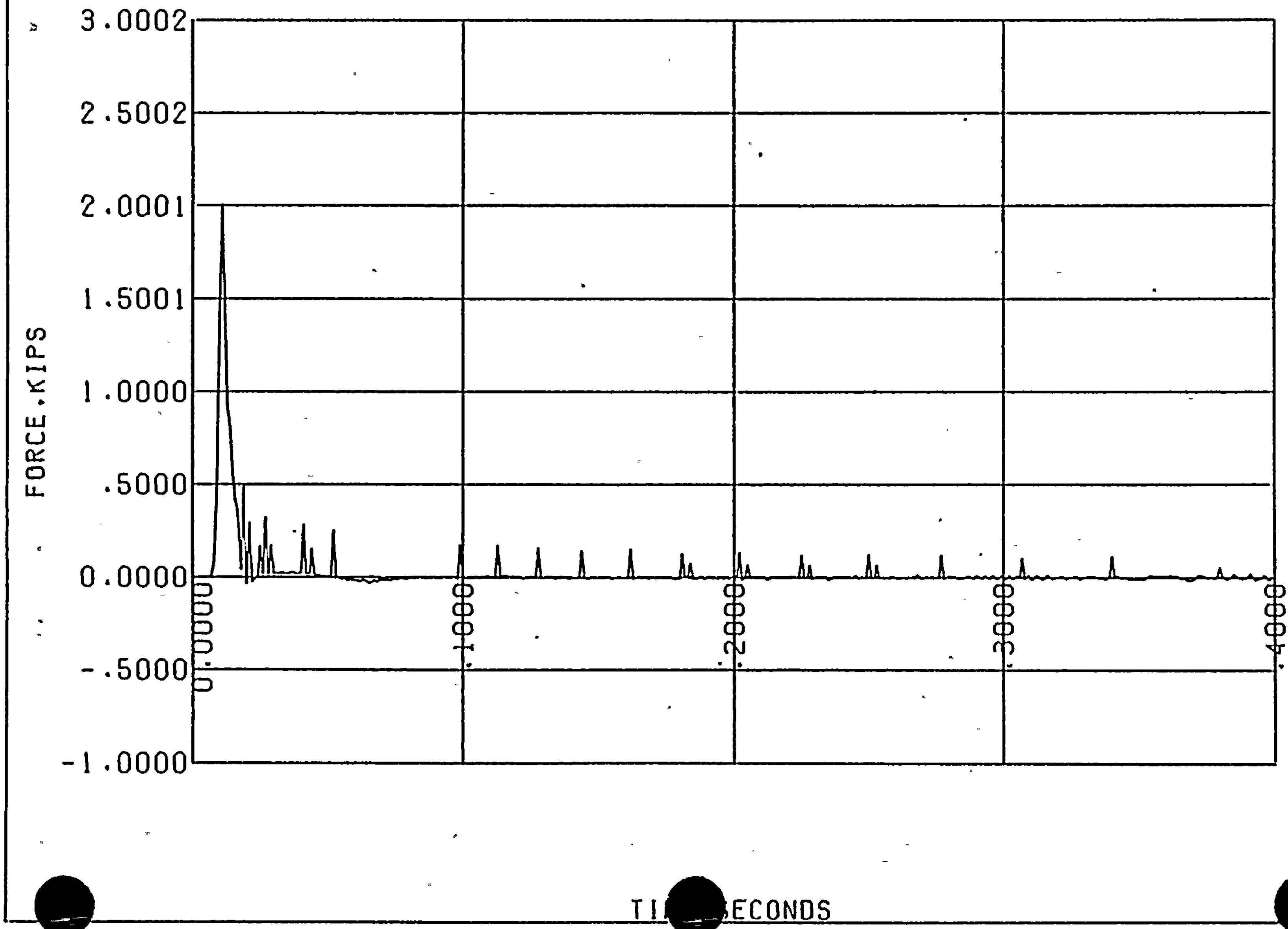


FIGURE A-10
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.10 (142 NODE-MODEL, DT=.25MS)

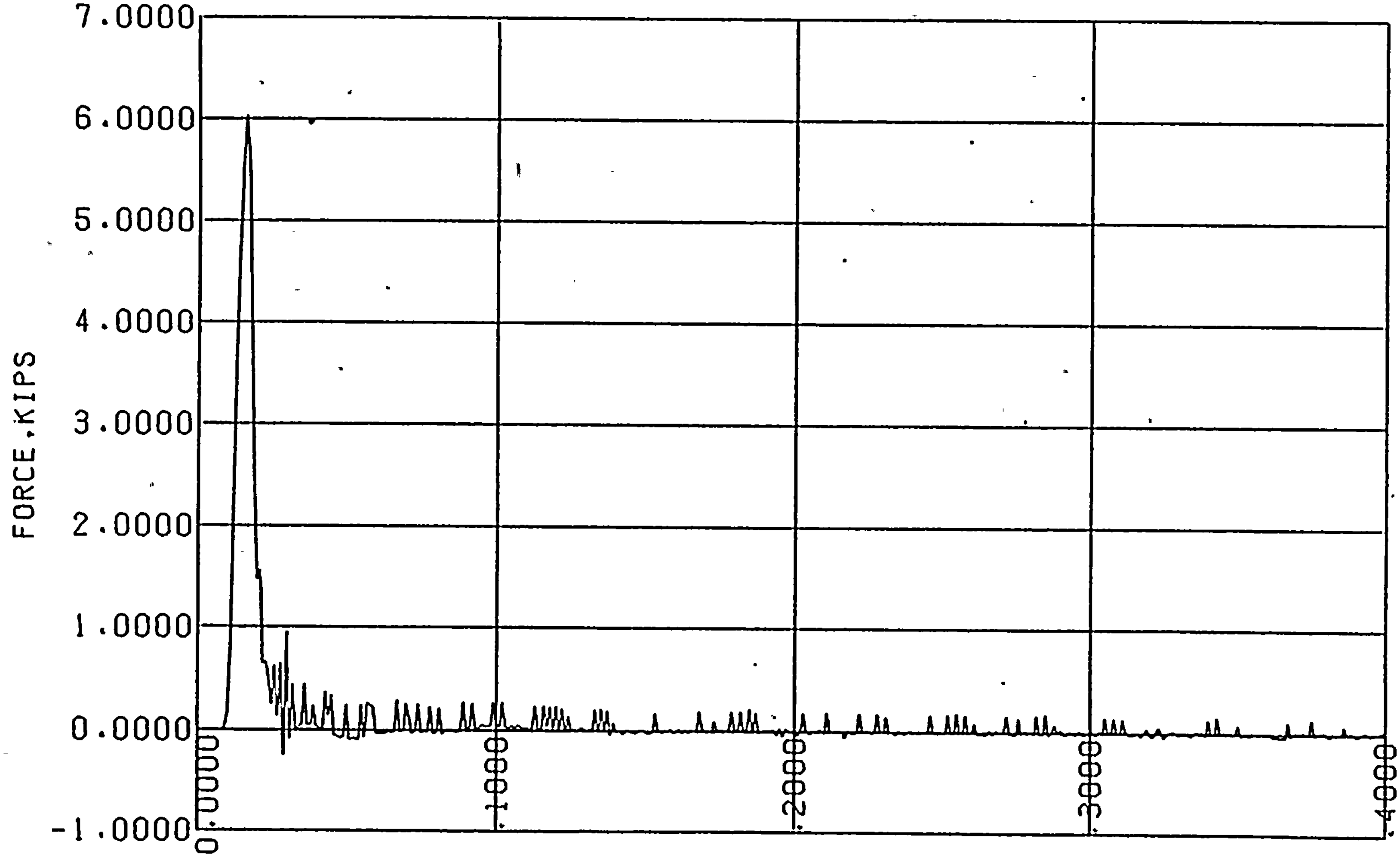


FIGURE A-11
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.11 (142 NODE-MODEL,DT=.25MS)

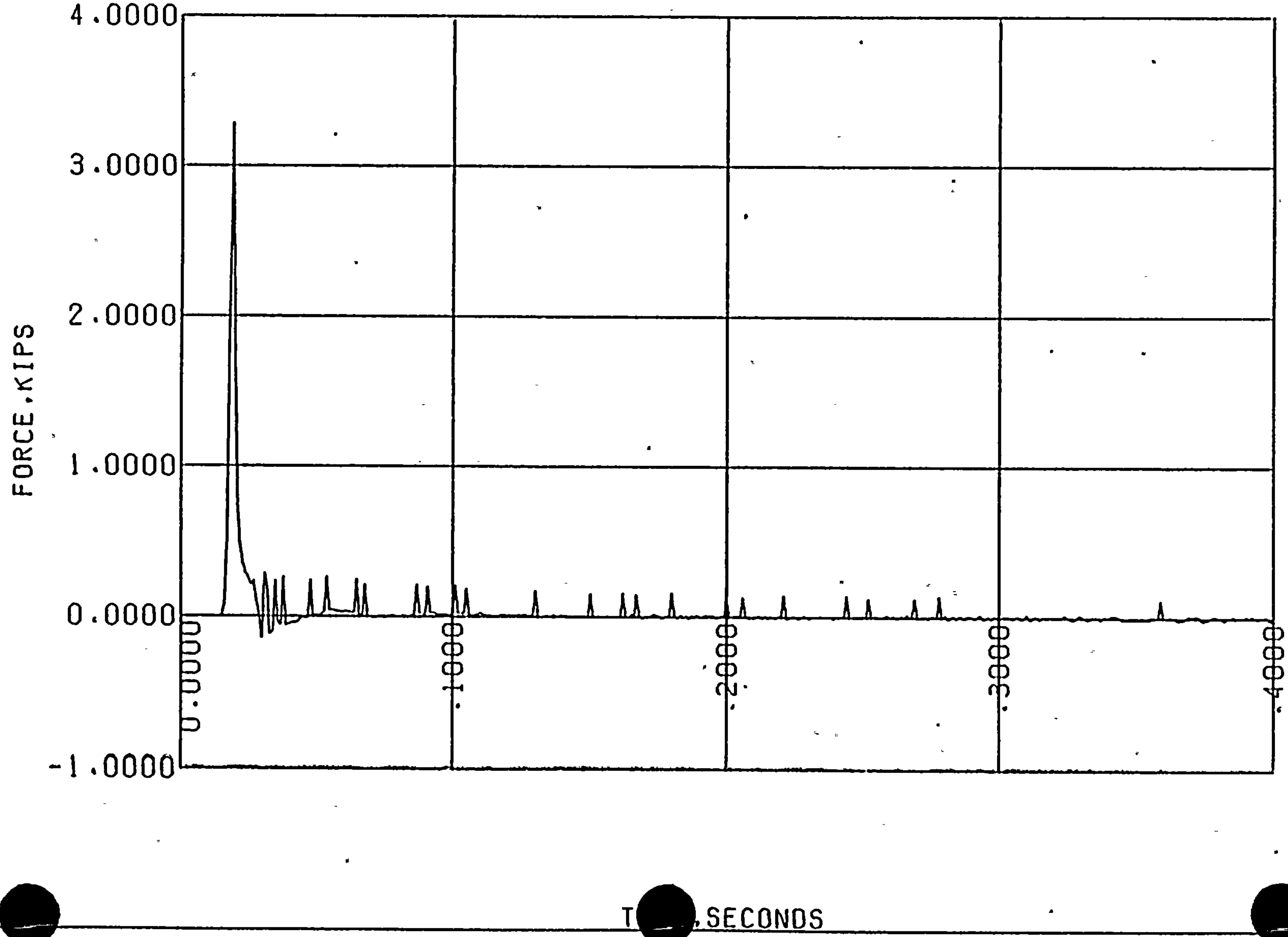


FIGURE A-12
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.12 (142 NODE-MODEL,DT=.25MS)

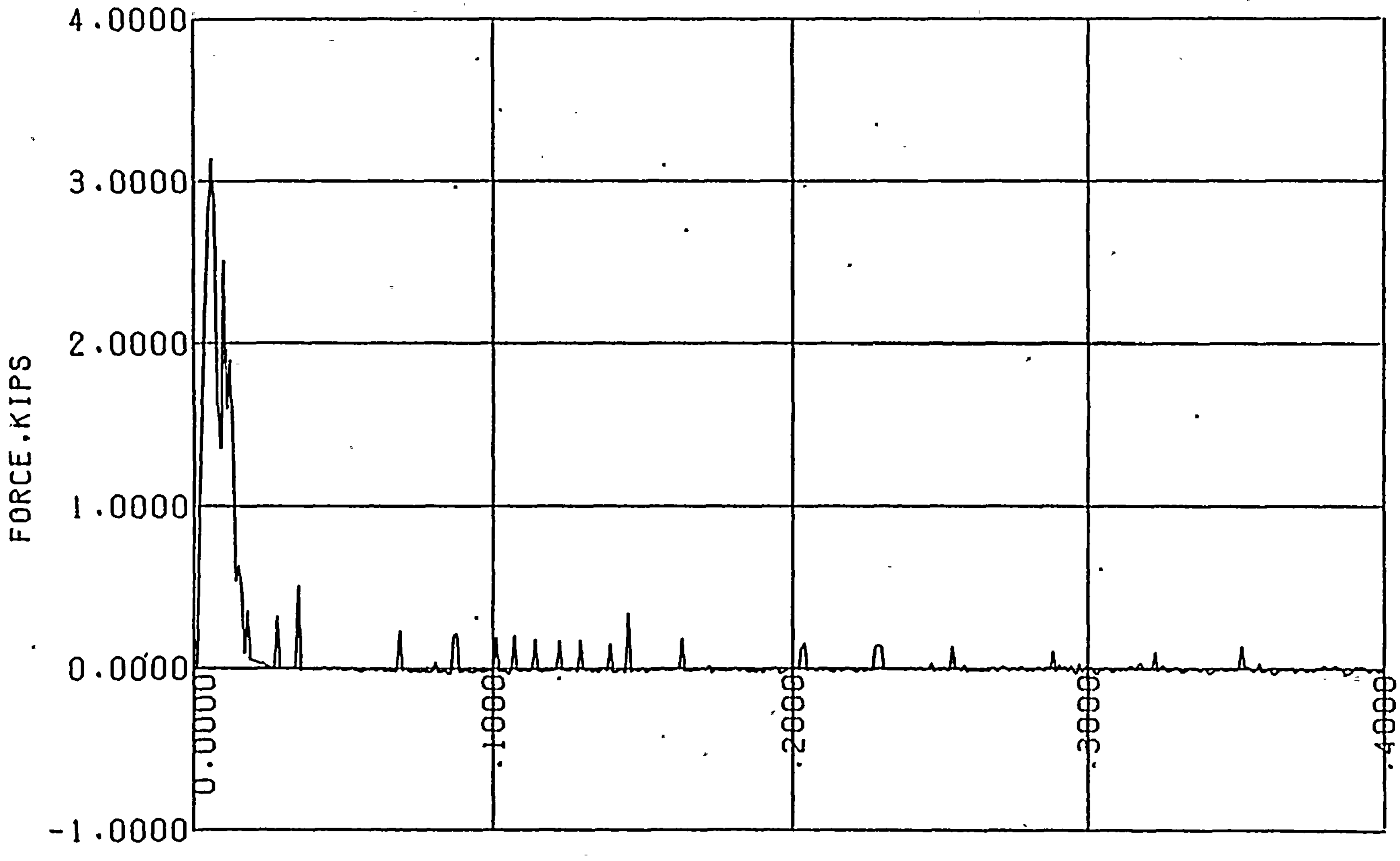


FIGURE A-13
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.13 (142 NODE-MODEL,DT=.25MS)

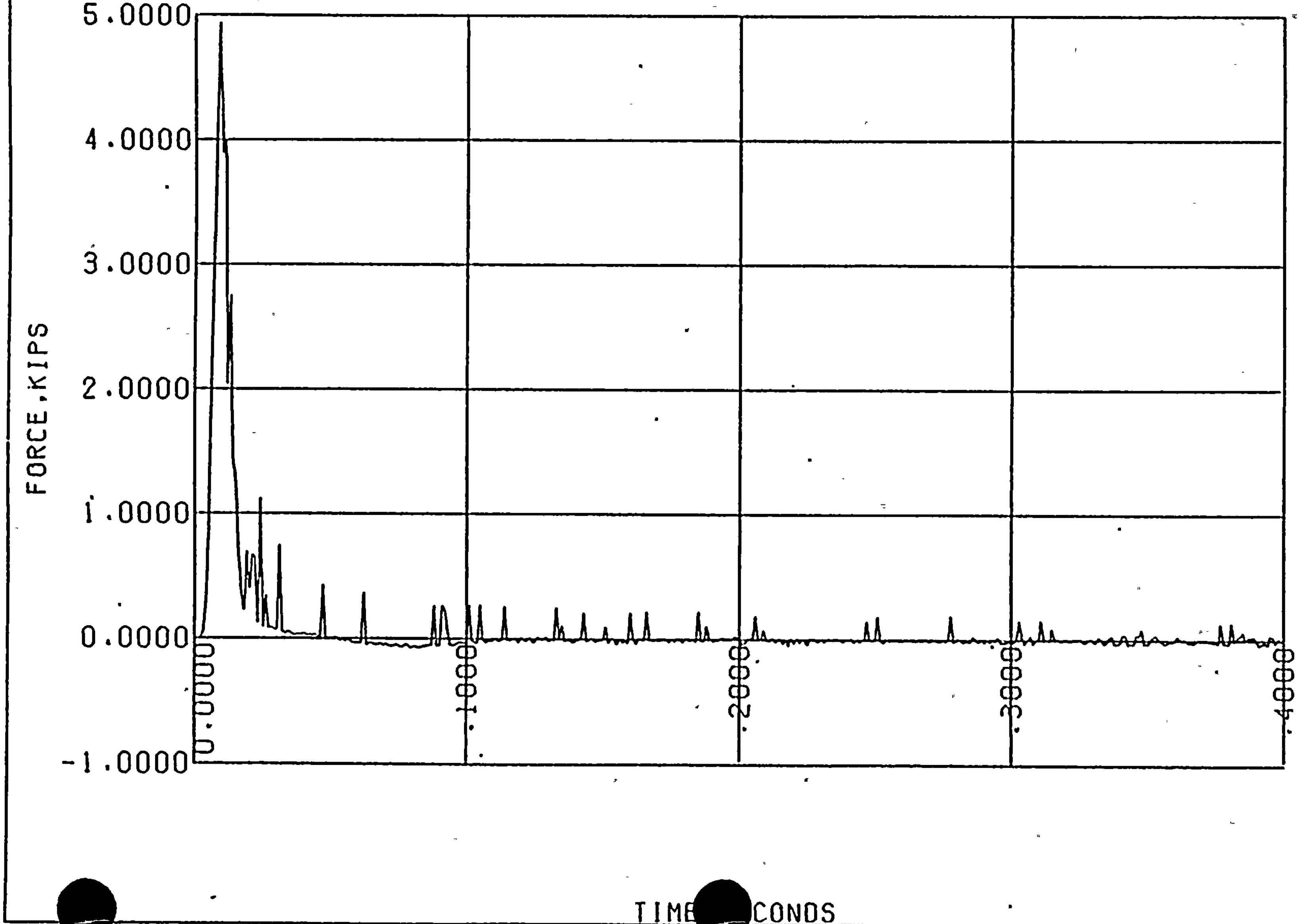


FIGURE A-14
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.14 (142 NODE-MODEL,DT=.25MS)

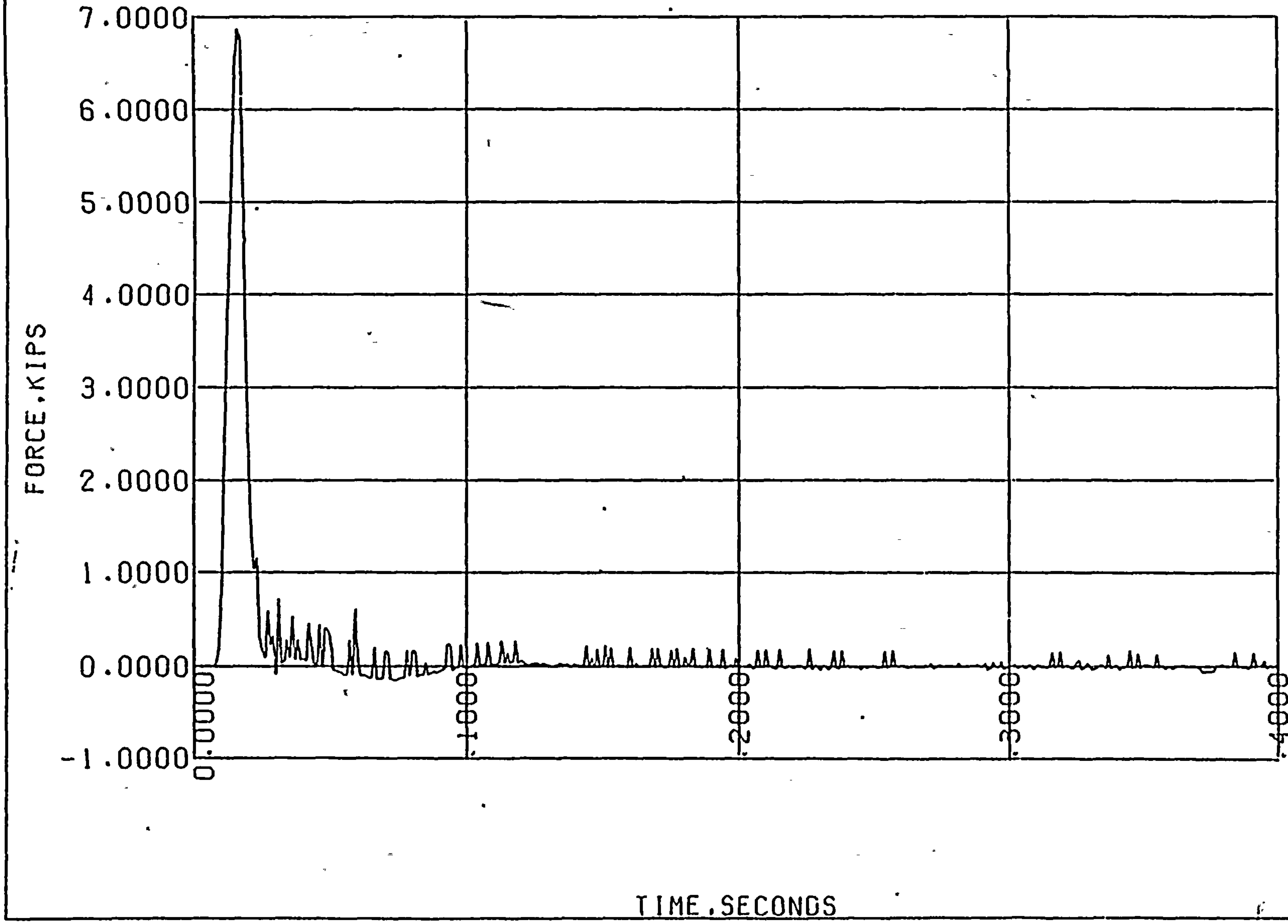


FIGURE A-15

ARIZONA S/V DISCHARGE PIPING ANALYSIS

PIPING FORCE NO.15 (142 NODE-MODEL, DT=.25MS)

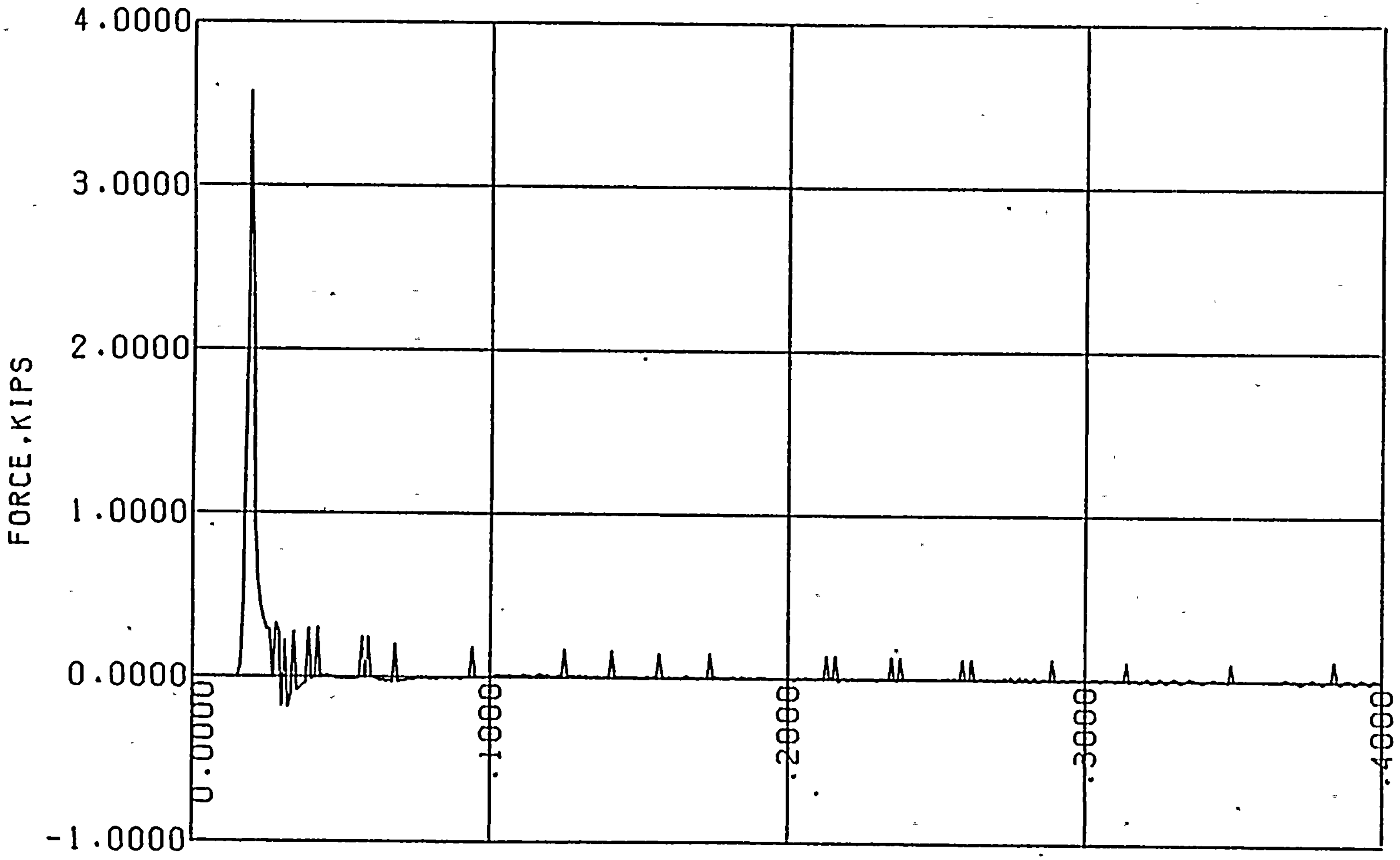


FIGURE A-16

ARIZONA S/V DISCHARGE PIPING ANALYSIS

PIPING FORCE NO.16 (142 NODE-MODEL,DT=.25MS)

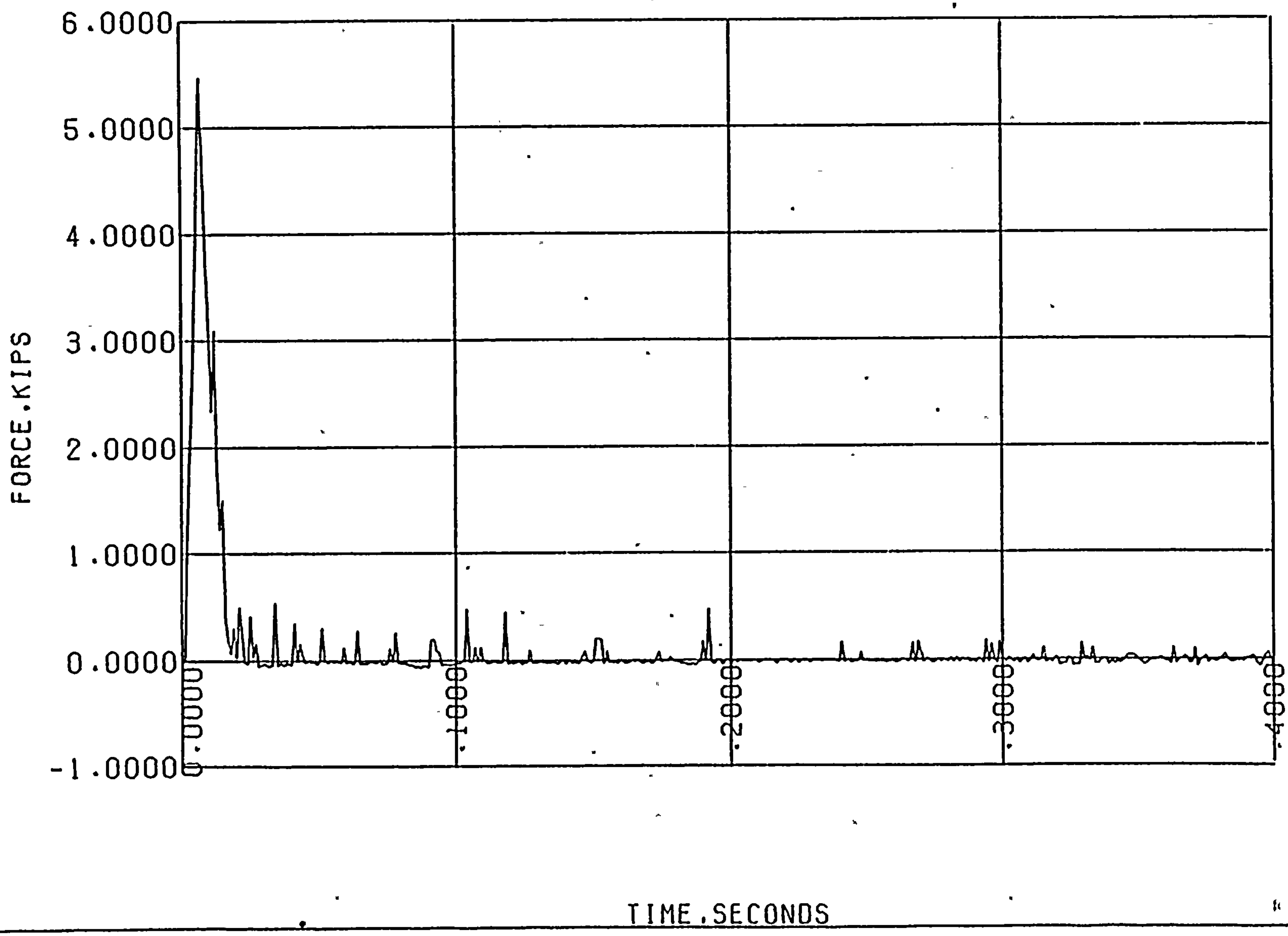


FIGURE A-17
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.17 (142 NODE-MODEL,DT=.25MS)

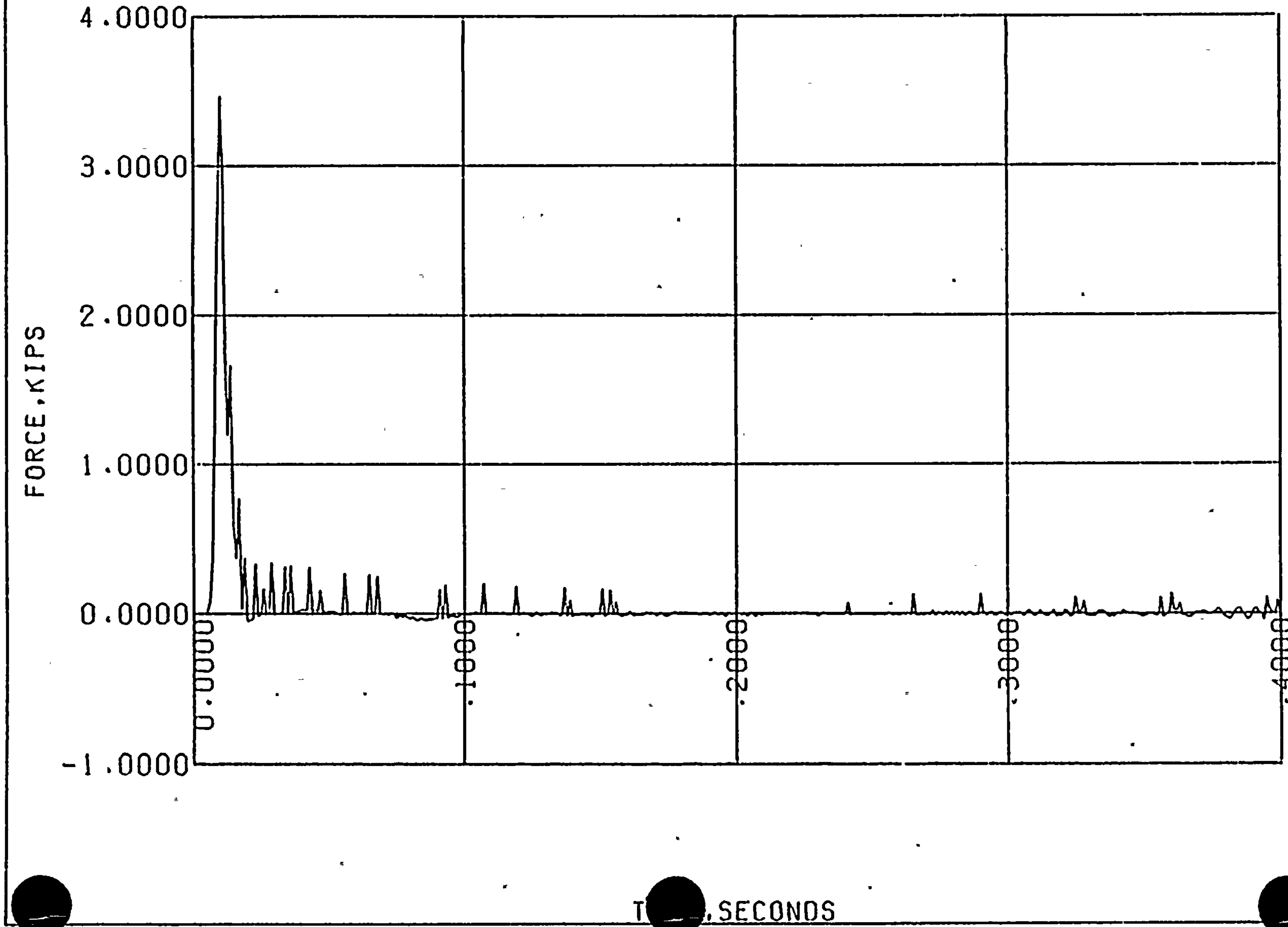


FIGURE A-18

ARIZONA S/V DISCHARGE PIPING ANALYSIS

PIPING FORCE NO.18 (142 NODE-MODEL, DT=.25MS)

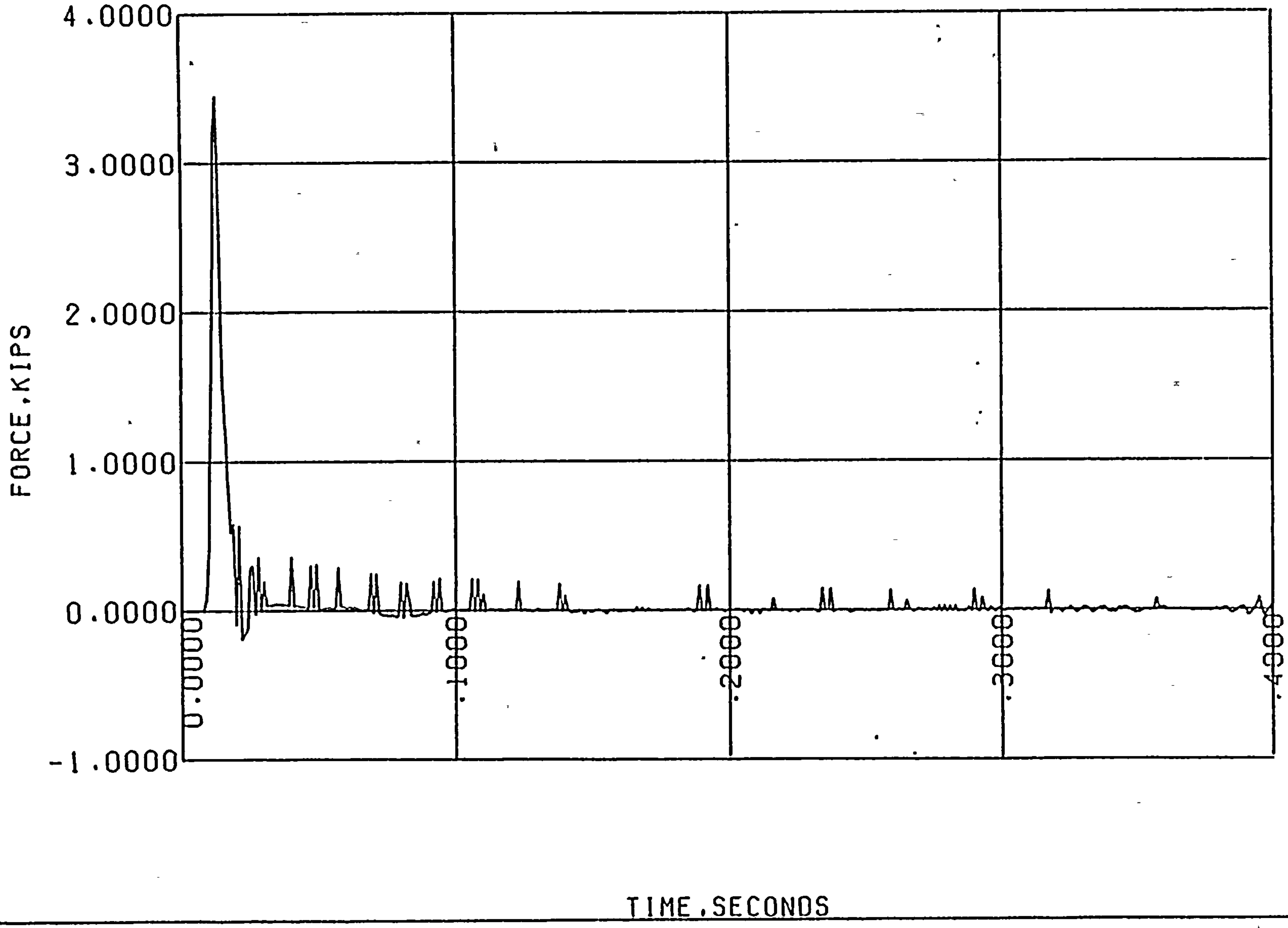


FIGURE A-19

ARIZONA S/V DISCHARGE PIPING ANALYSIS

PIPING FORCE NO.19 (142 NODE MODEL,DT=.25MS)

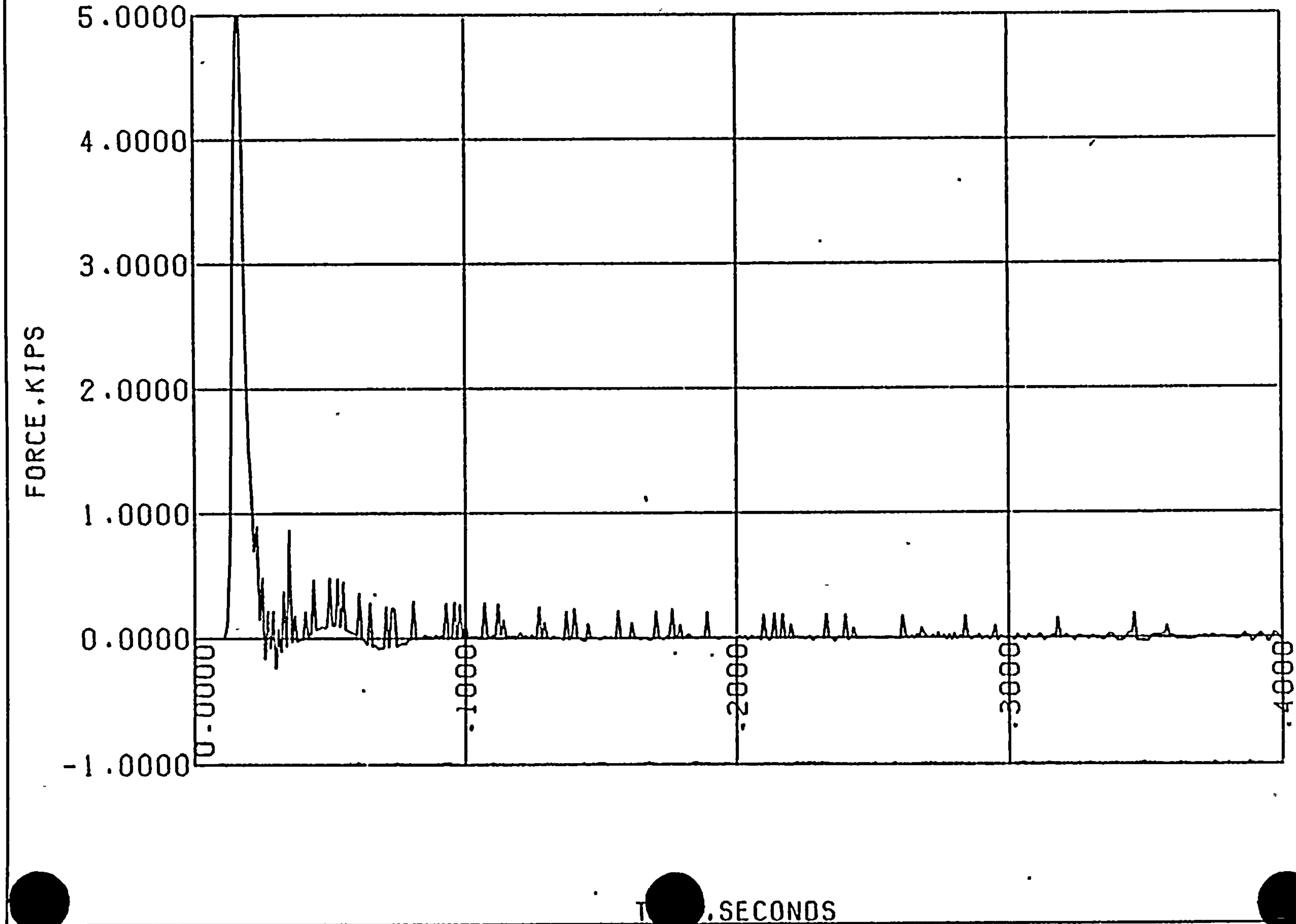


FIGURE A-20
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.20 (142 NODE MODEL,DT=.25MS)

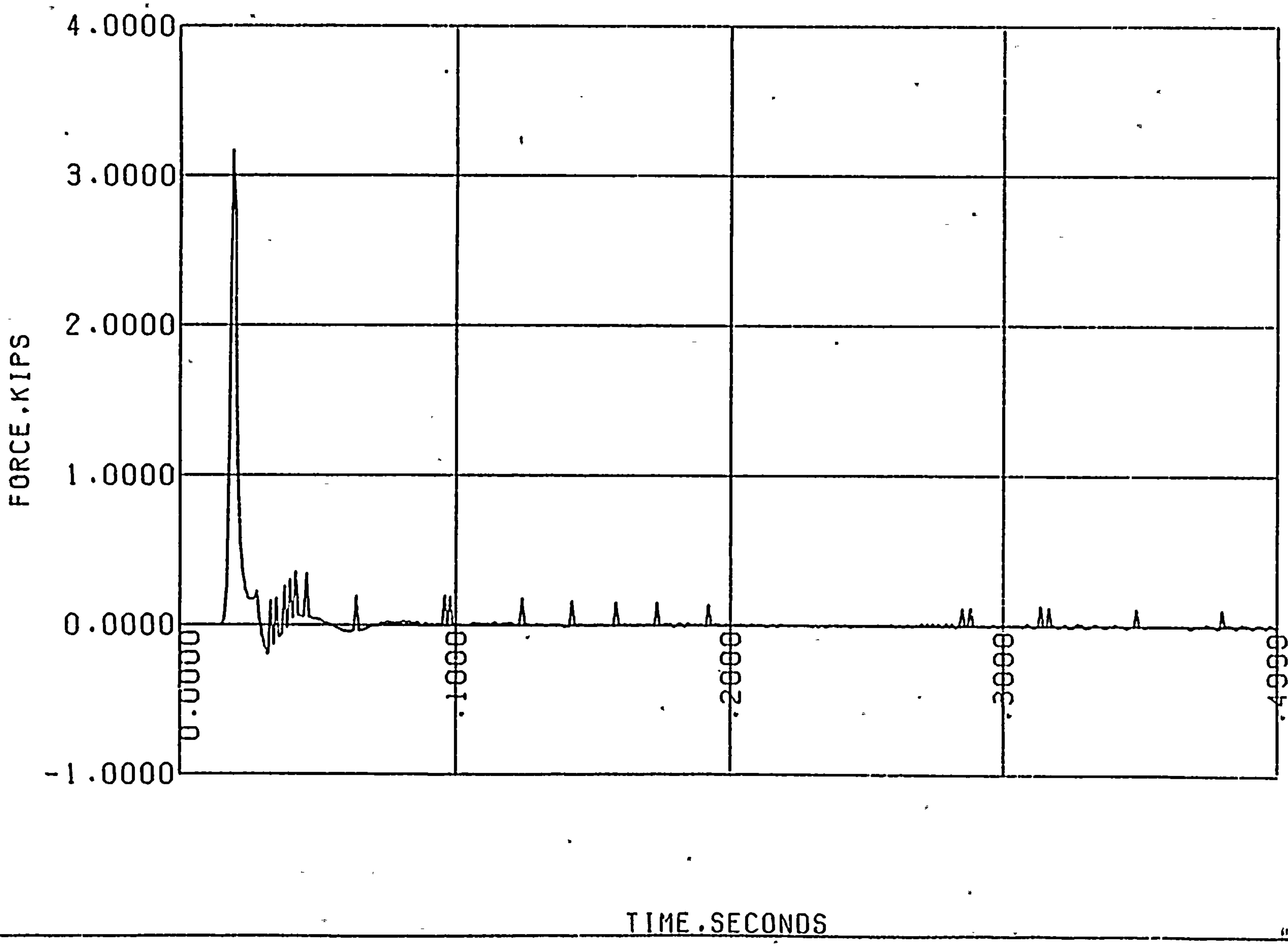


FIGURE A-21
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.21 (142 NODE MODEL, DT=.25MS)

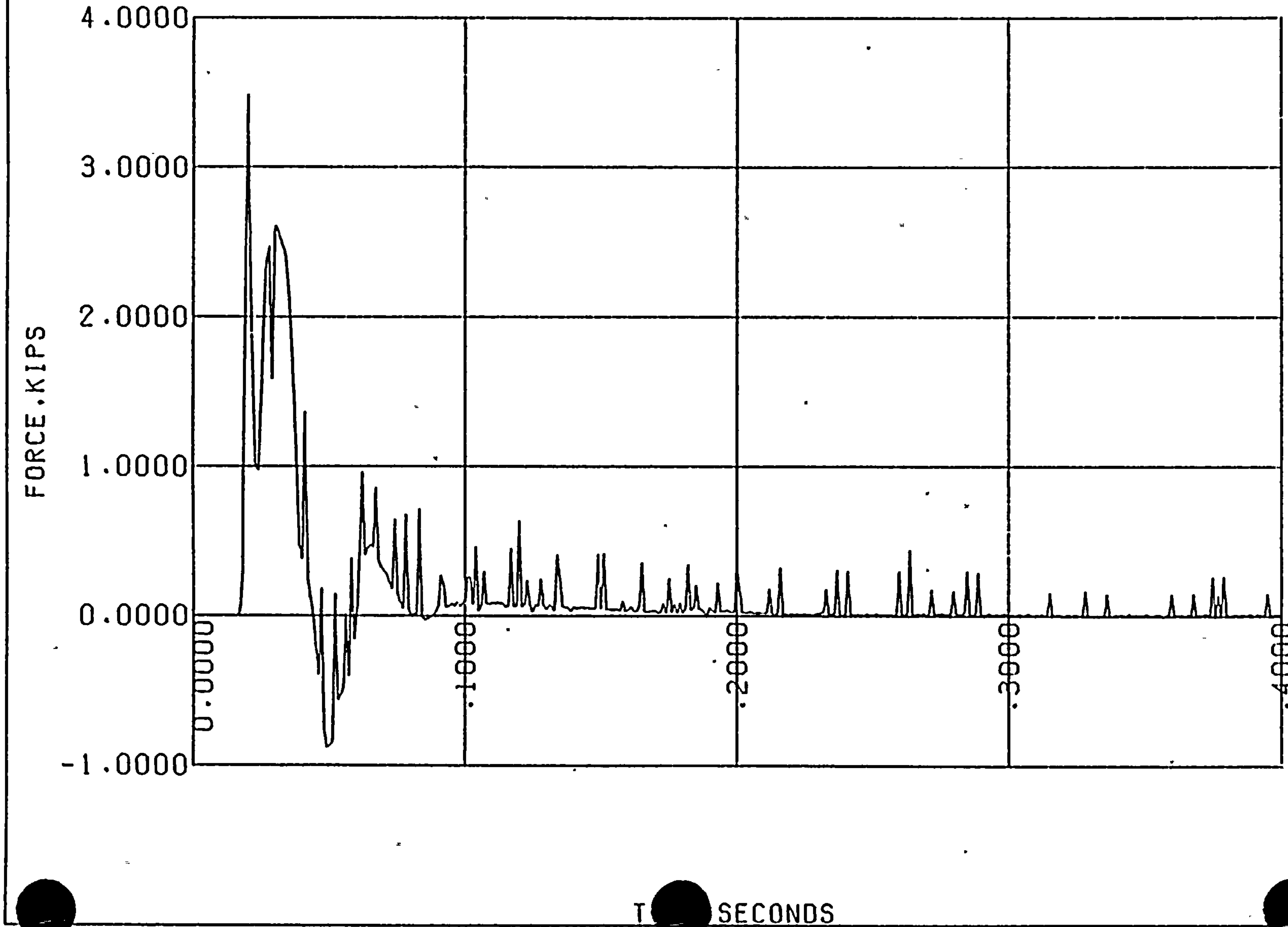


FIGURE A-22
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.22 (142 NODE MODEL,DT=.25MS)

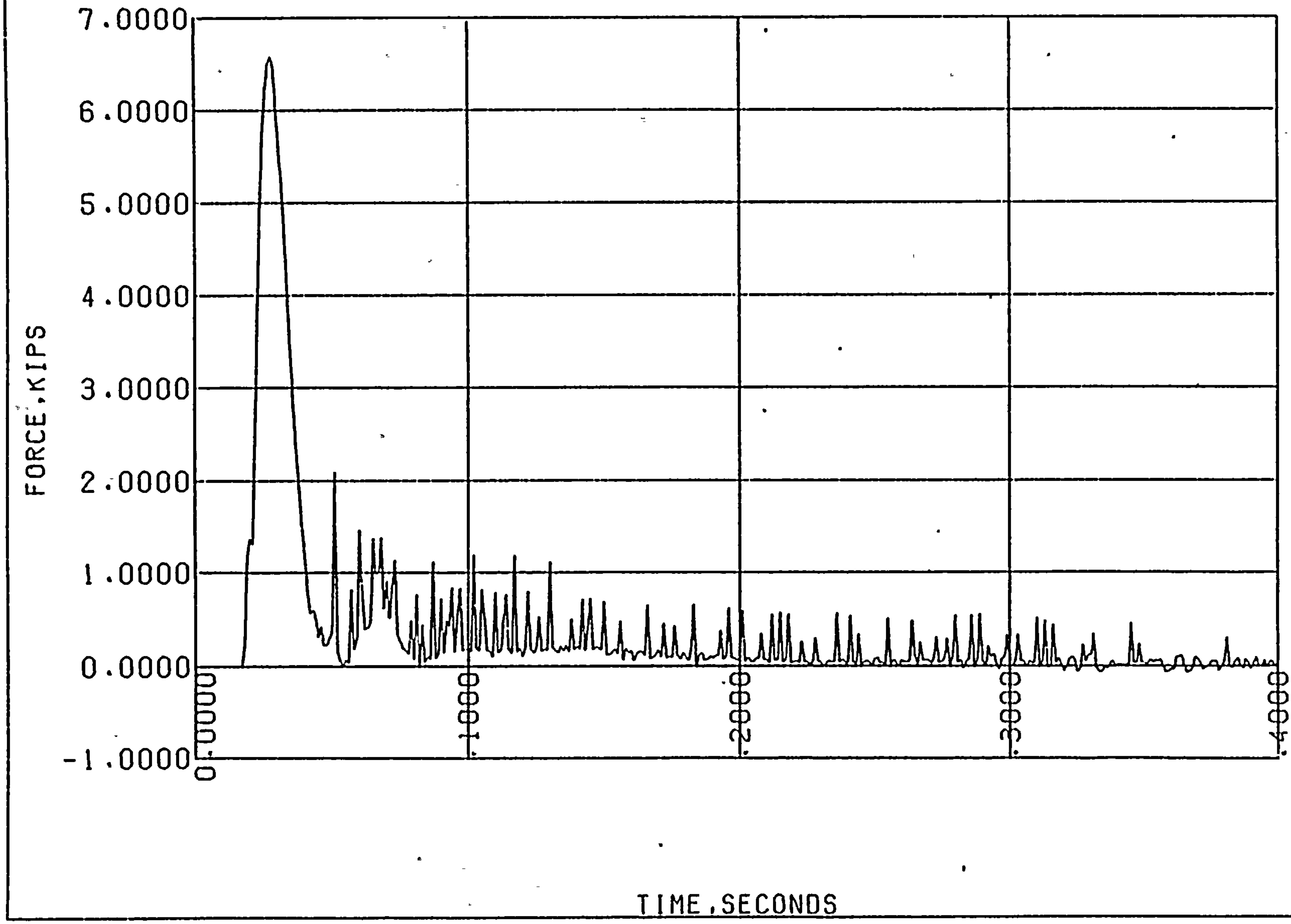


FIGURE A-23

ARIZONA S/V DISCHARGE PIPING ANALYSIS

PIPING FORCE NO.23 (142 NODE MODEL,DT=.25MS)

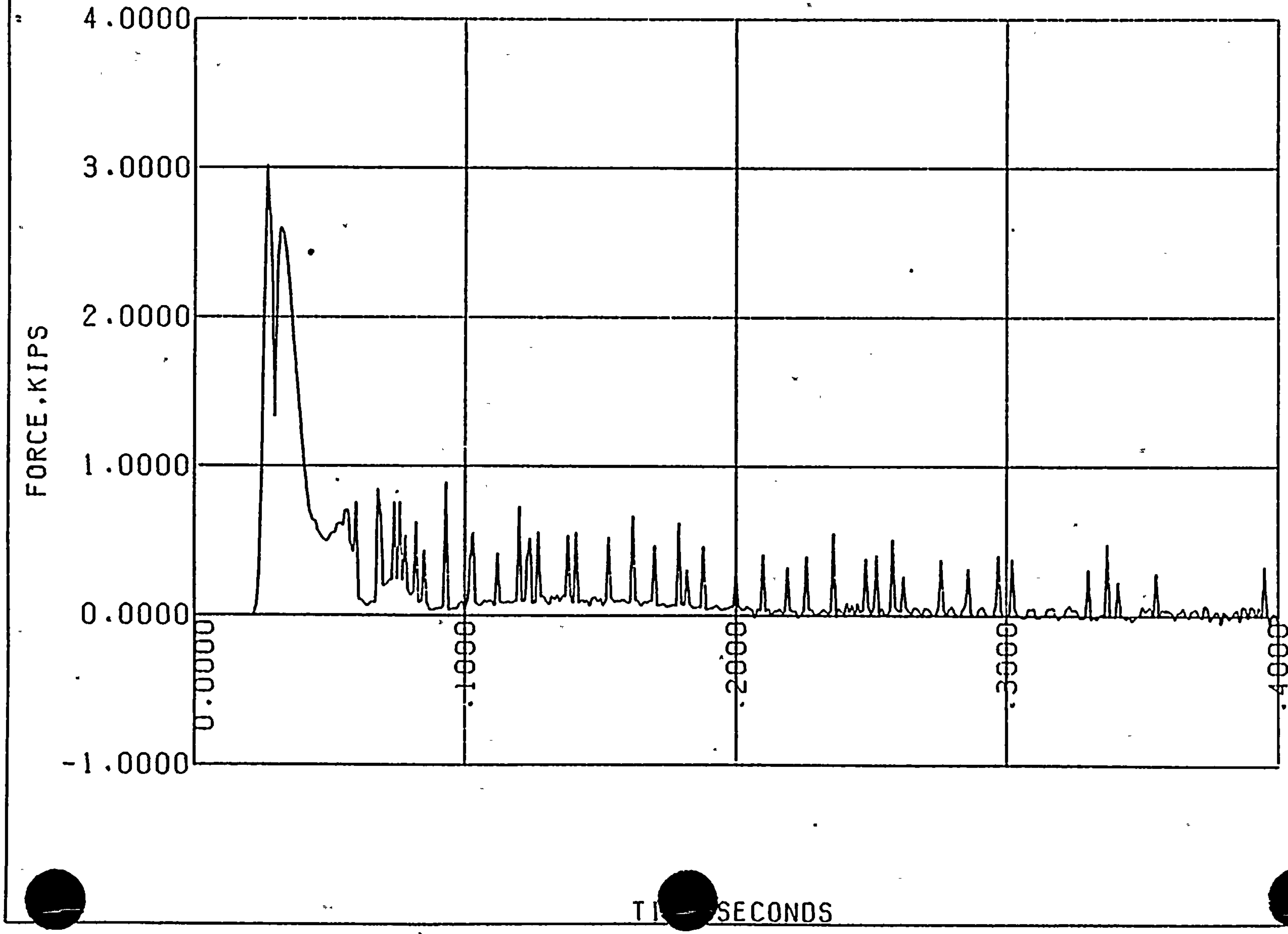


FIGURE A-24
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.24 (142 NODE MODEL,DT=.25MS)

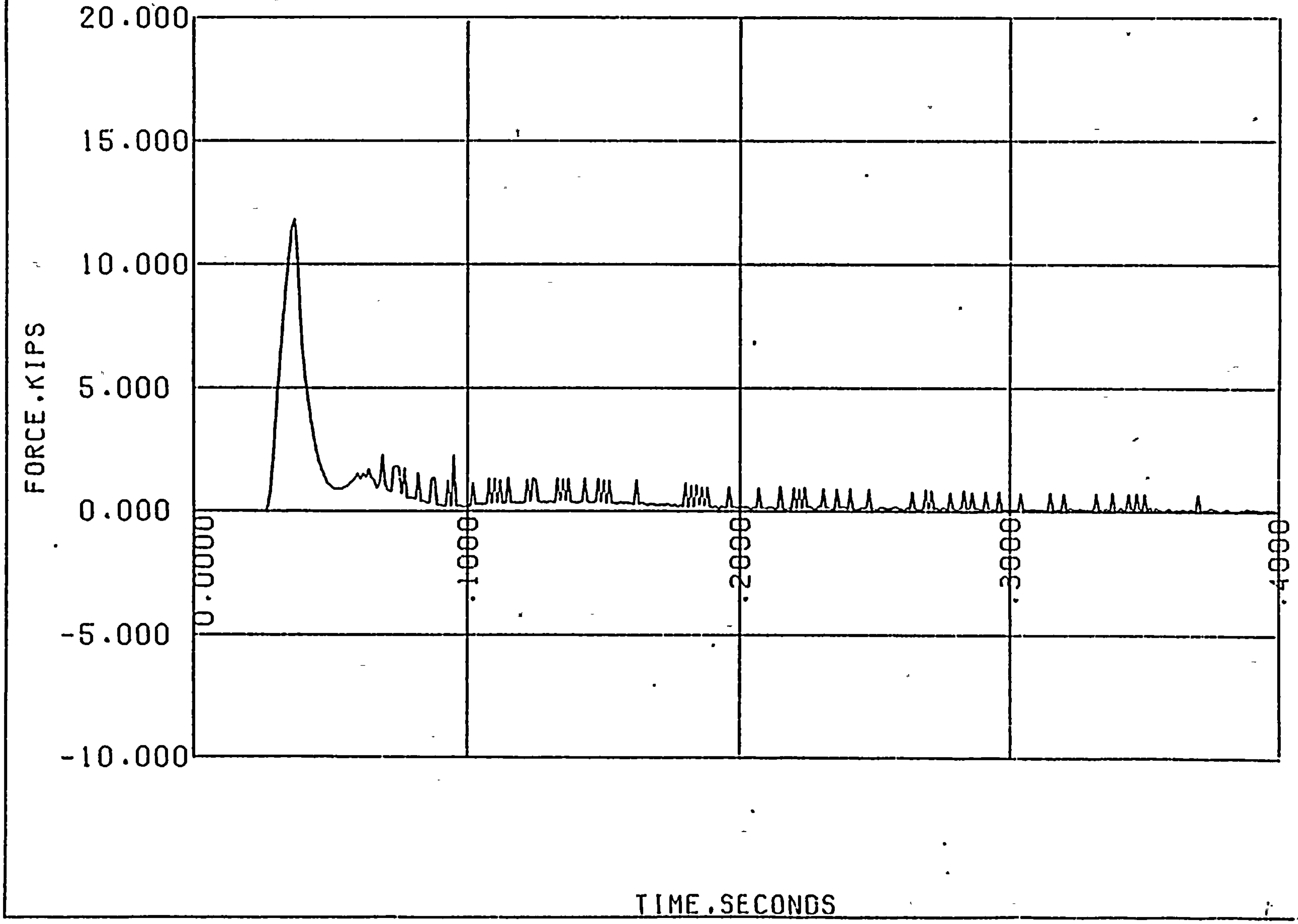


FIGURE A-25
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO. 25 (142 NODE-MODEL, DT=.25MS)

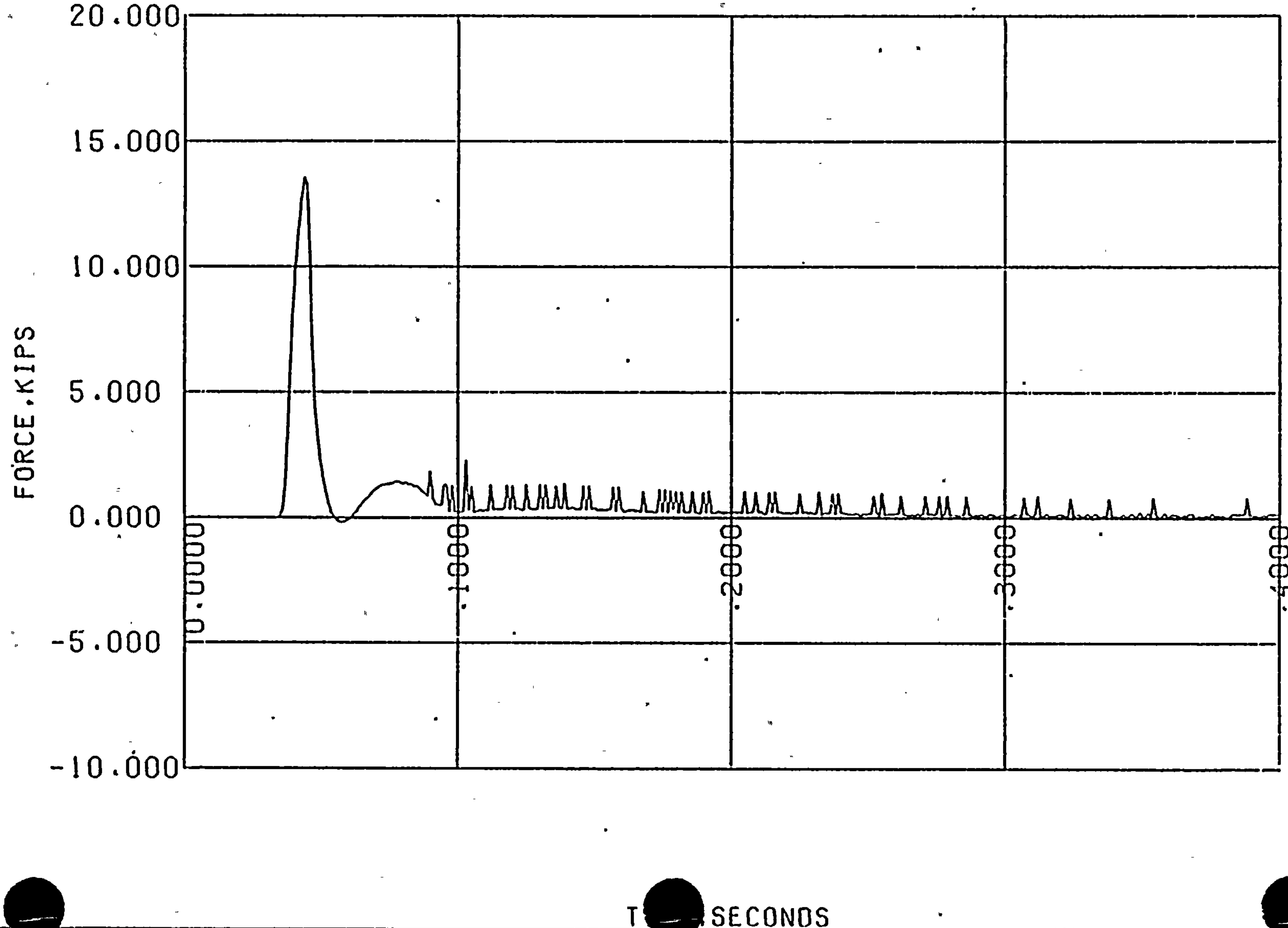


FIGURE A-26
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.26 (142 NODE-MODEL,DT=.25MS)

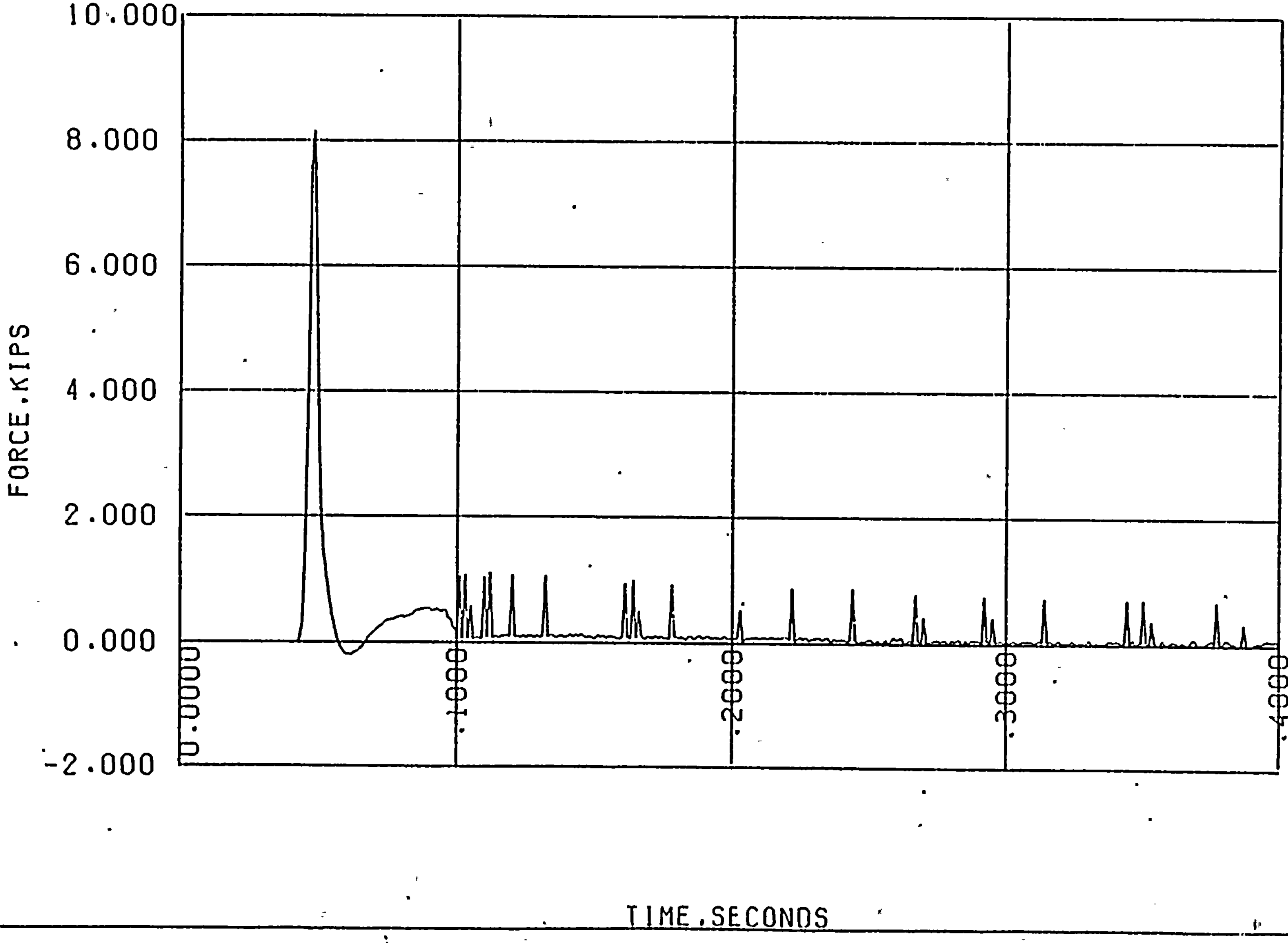


FIGURE A-27
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.27 (142 NODE-MODEL,DT=.25MS)

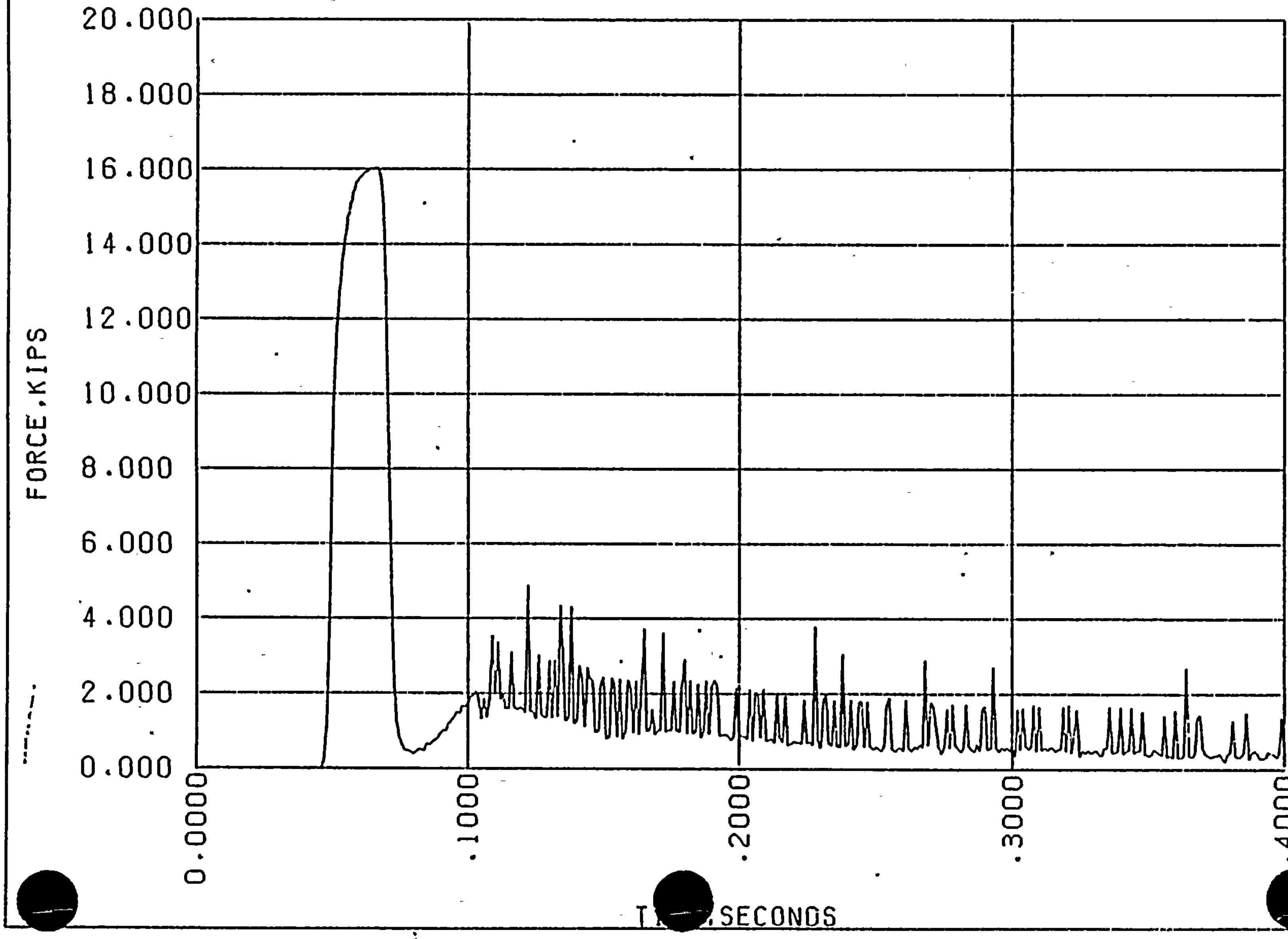


FIGURE A-28

ARIZONA S/V DISCHARGE PIPING ANALYSIS

PIPING FORCE NO.28 (142 NODE-MODEL,DT=.25MS)

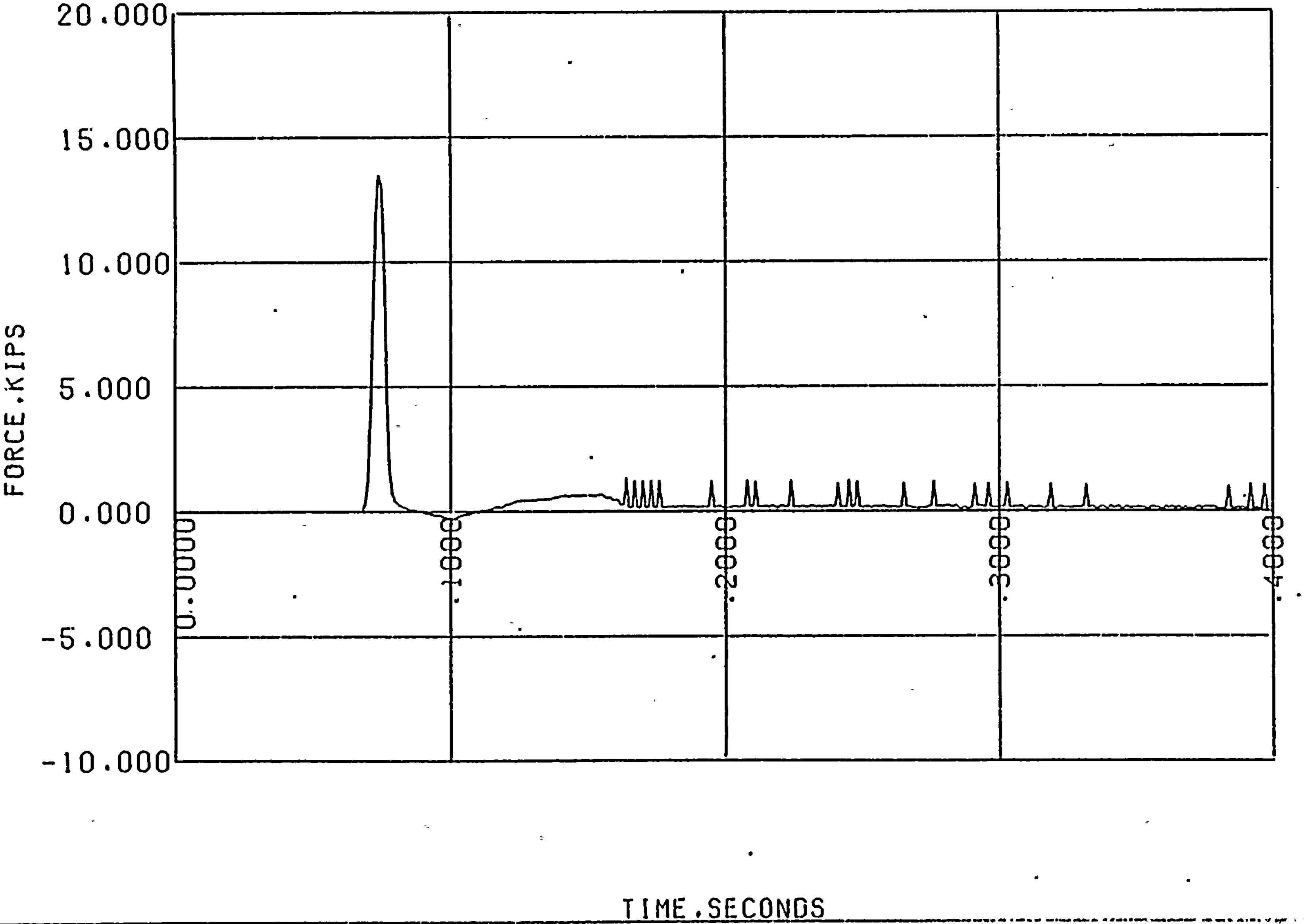
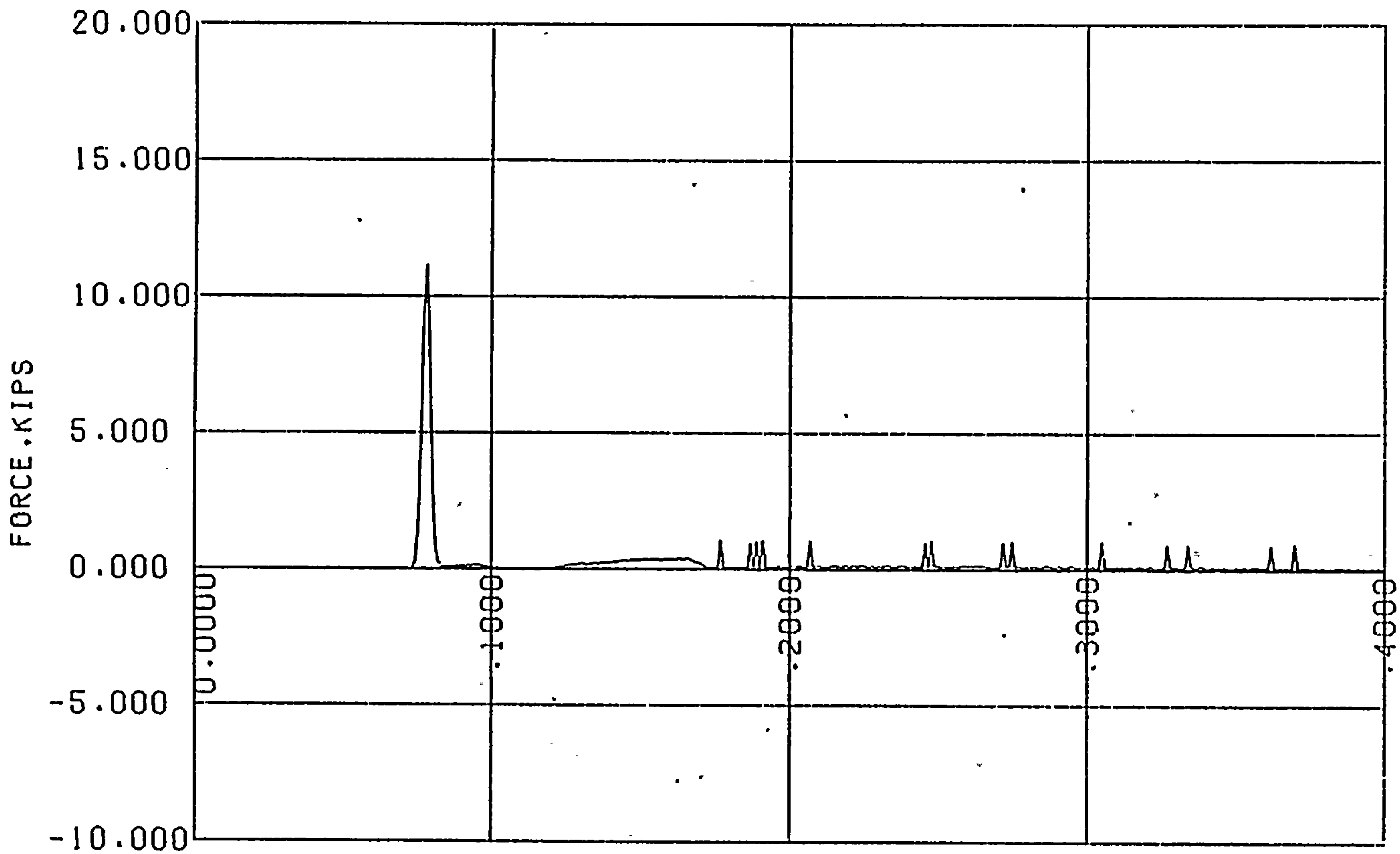


FIGURE A-29
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.29 (142 NODE-MODEL,DT=.25MS)



SECONDS

FIGURE A-30
ARIZONA S/V DISCHARGE PIPING ANALYSIS
PIPING FORCE NO.30 (142 NODE-MODEL,DT=.25MS)

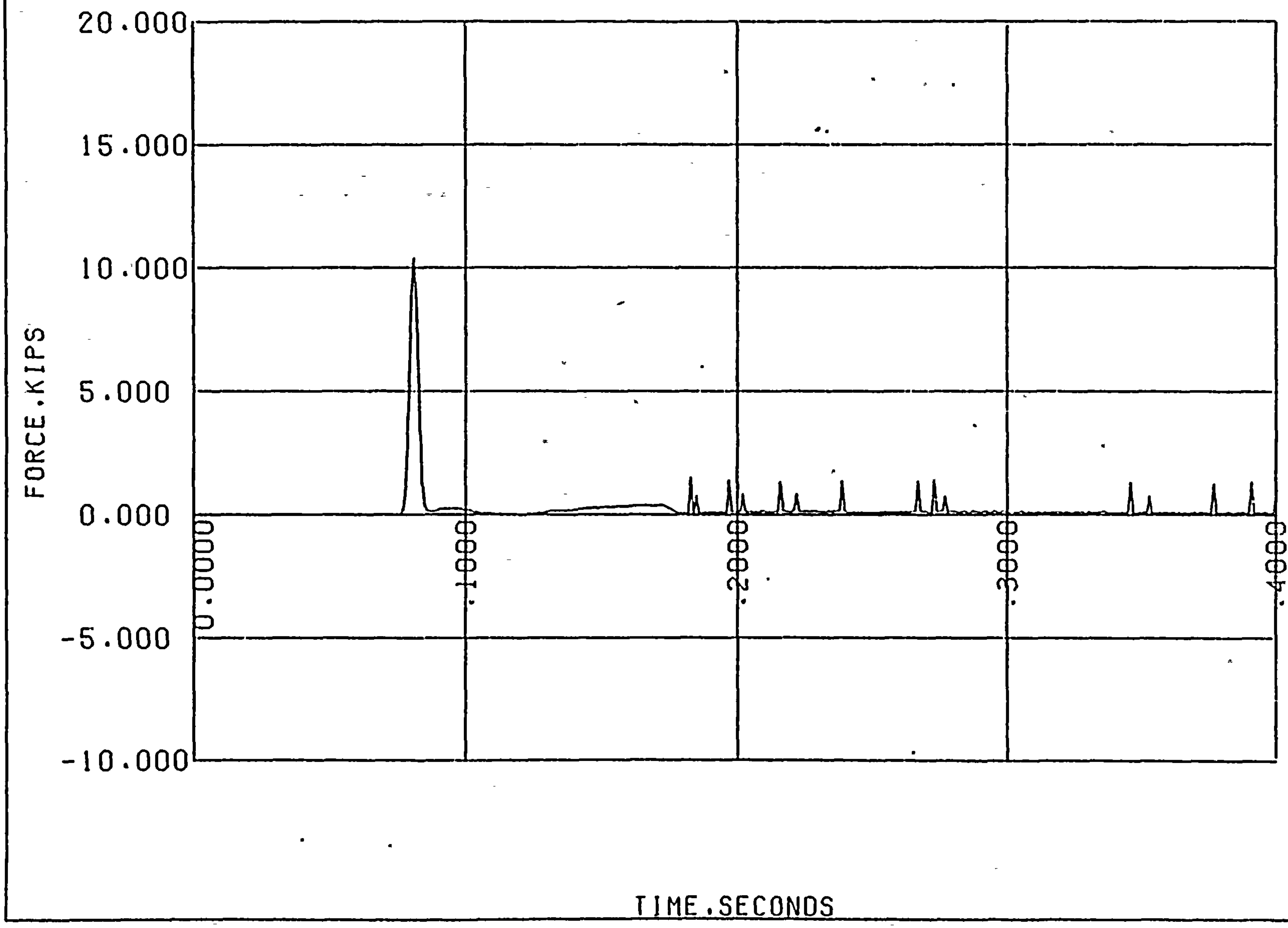
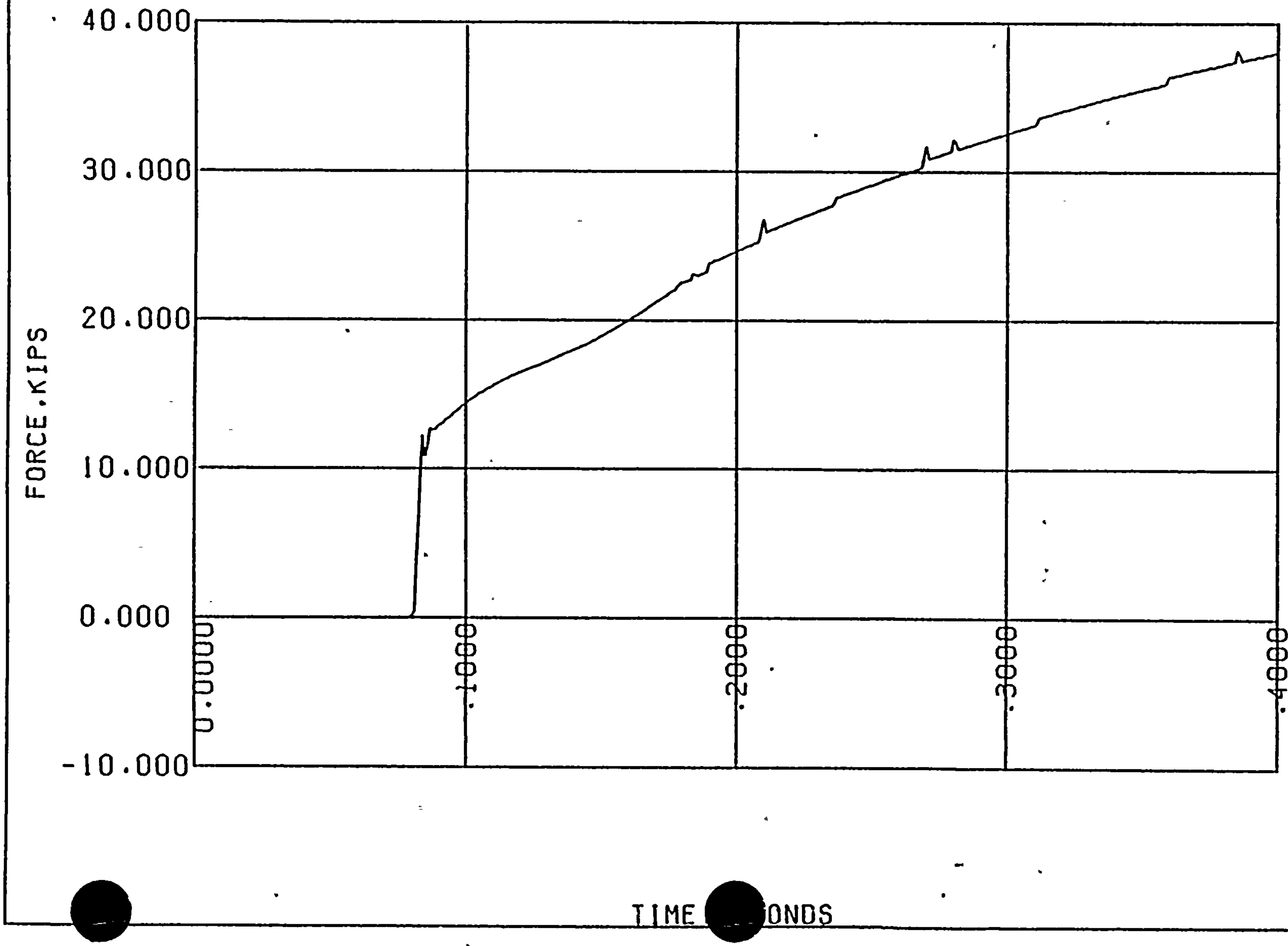


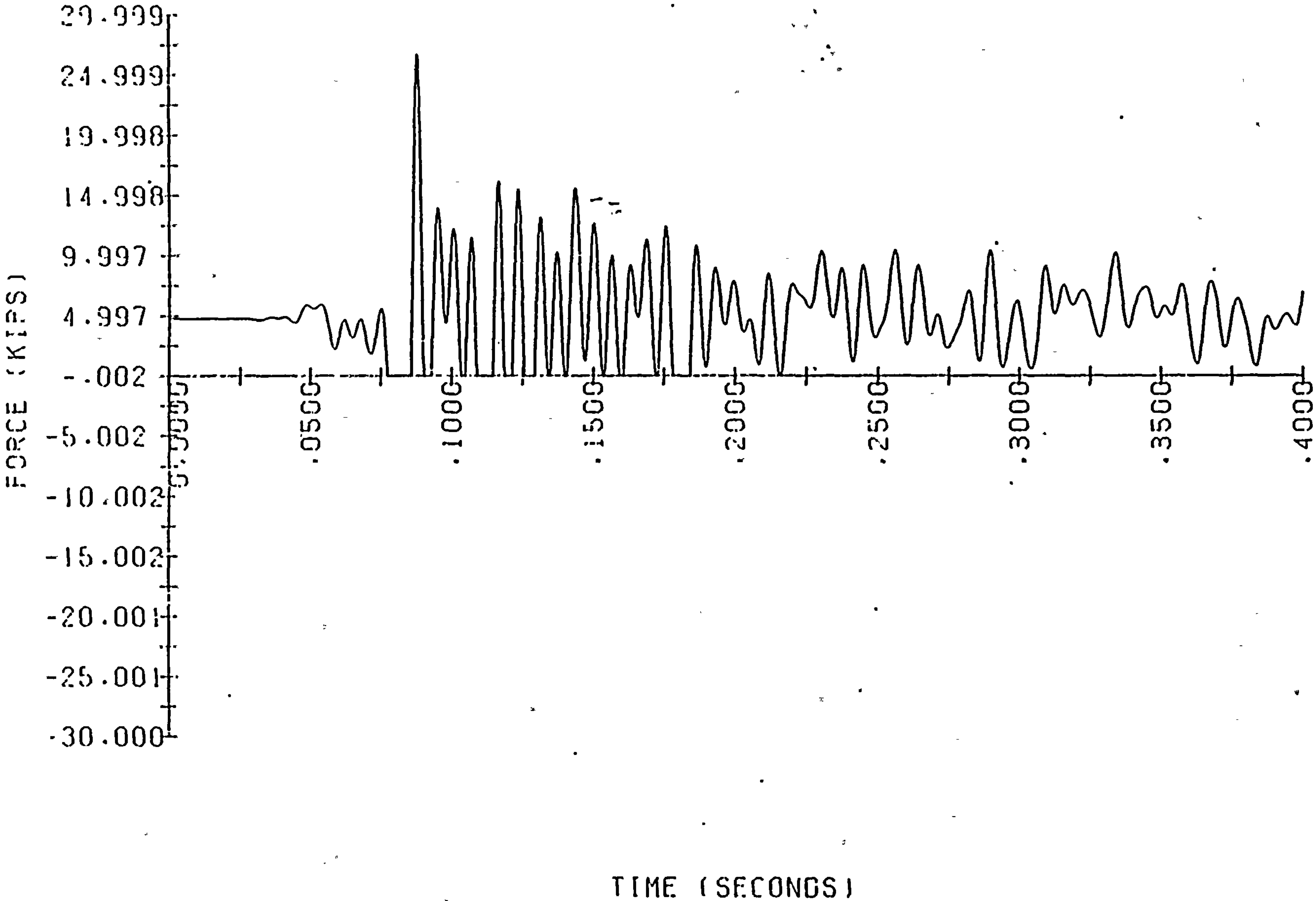
FIGURE A-31
ARIZONA S/V SISCHARGE PIPING ANALYSIS
PIPING FORCE NO.31 (142 NODE-MODEL,DT=.25MS)



APPENDIX B

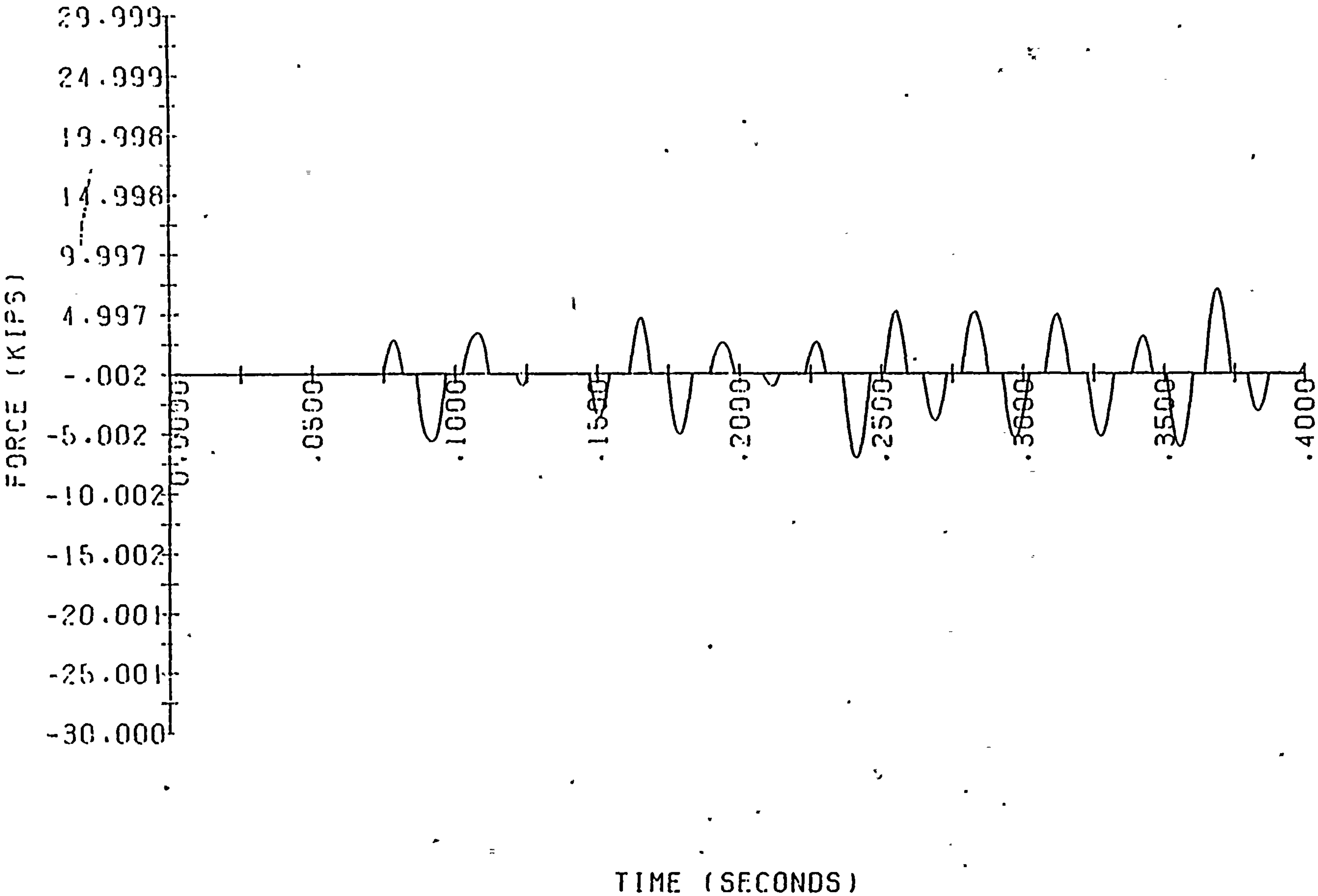
PIPING SUPPORT LOADS, GAPPED ANALYSIS

Case Number One: Four Valve Simultaneous Actuation



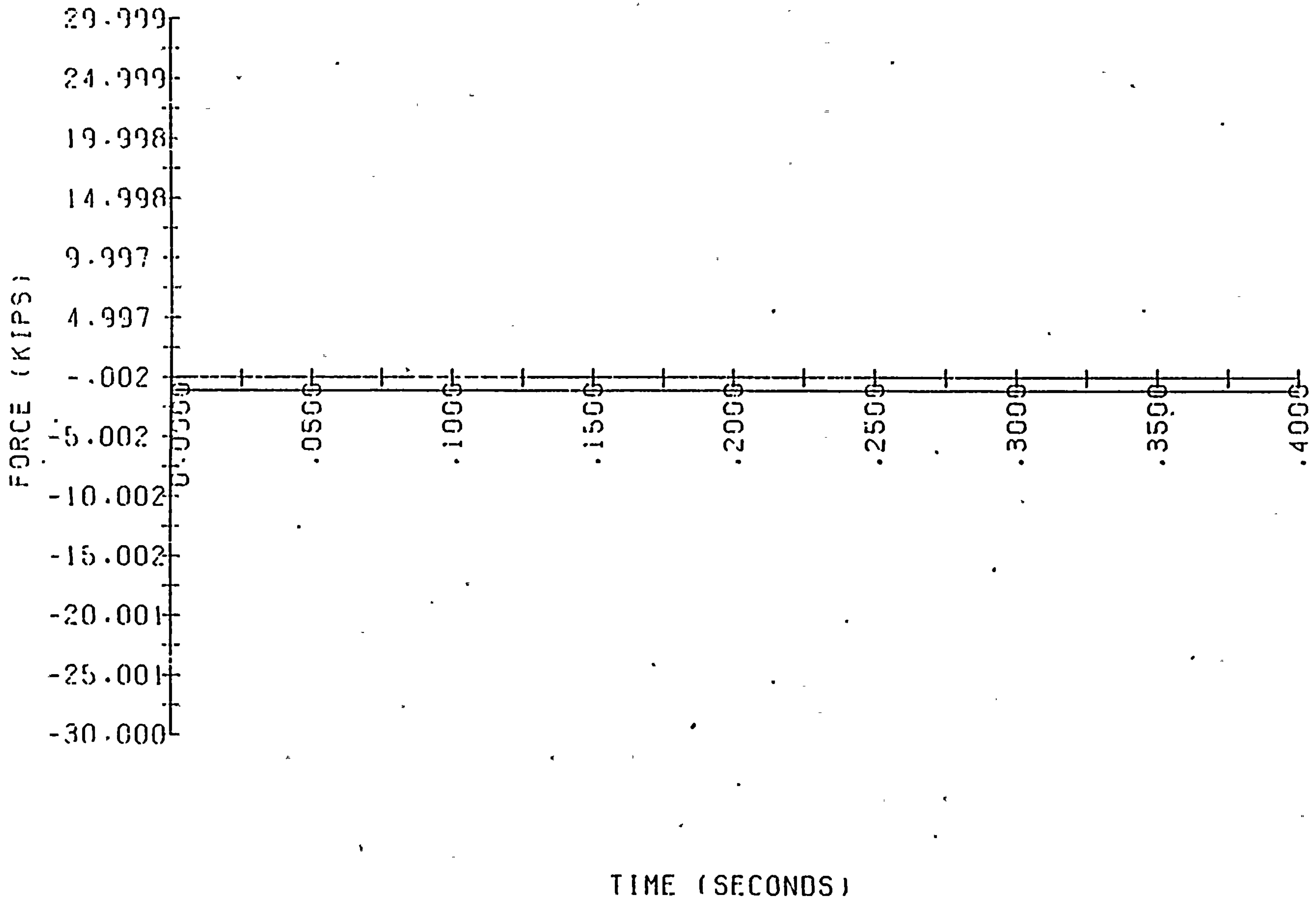
********** FORCE IN DAGS GAP NUMBER 1 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



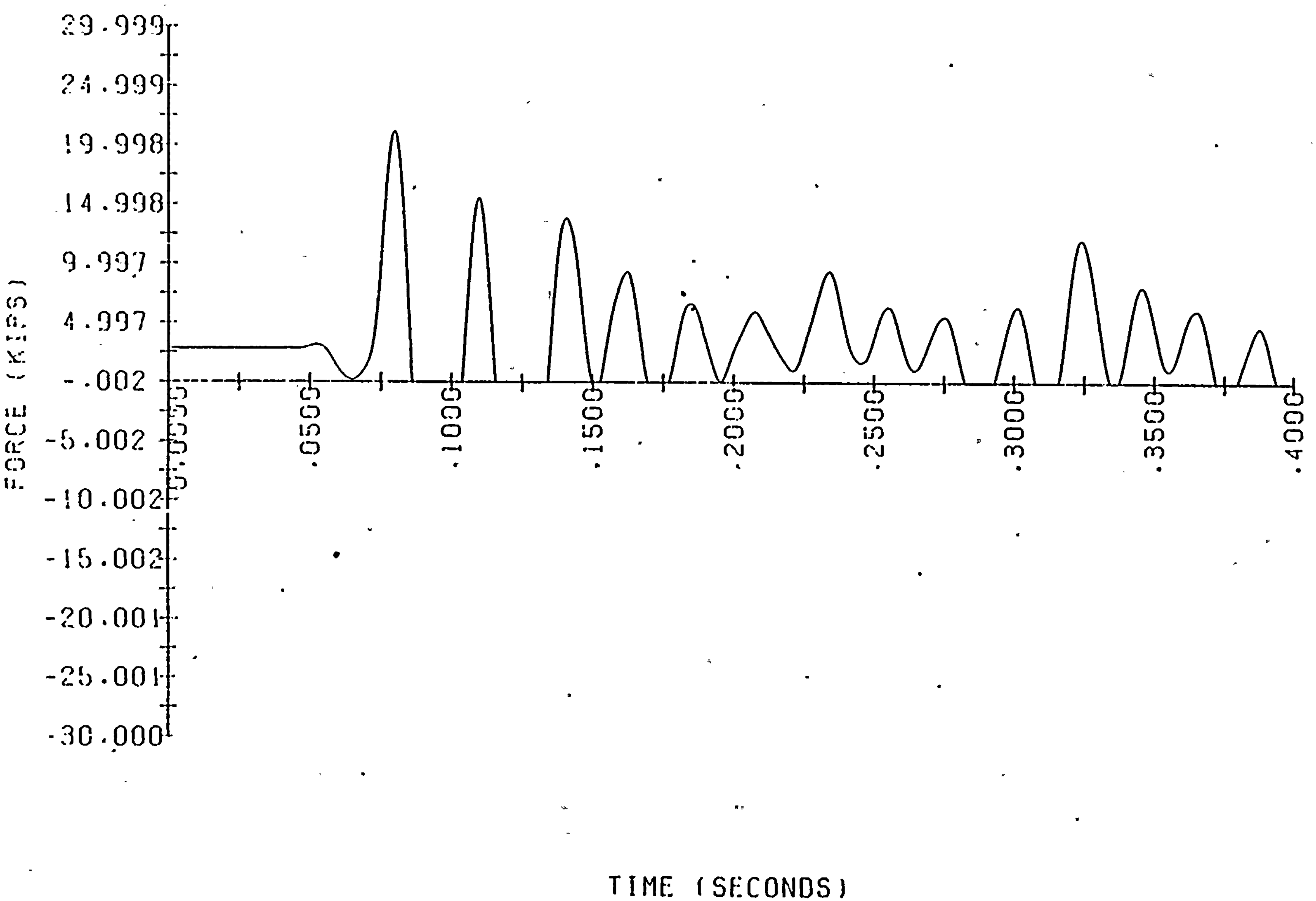
********** FORCE IN DAGS GAP NUMBER 2 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



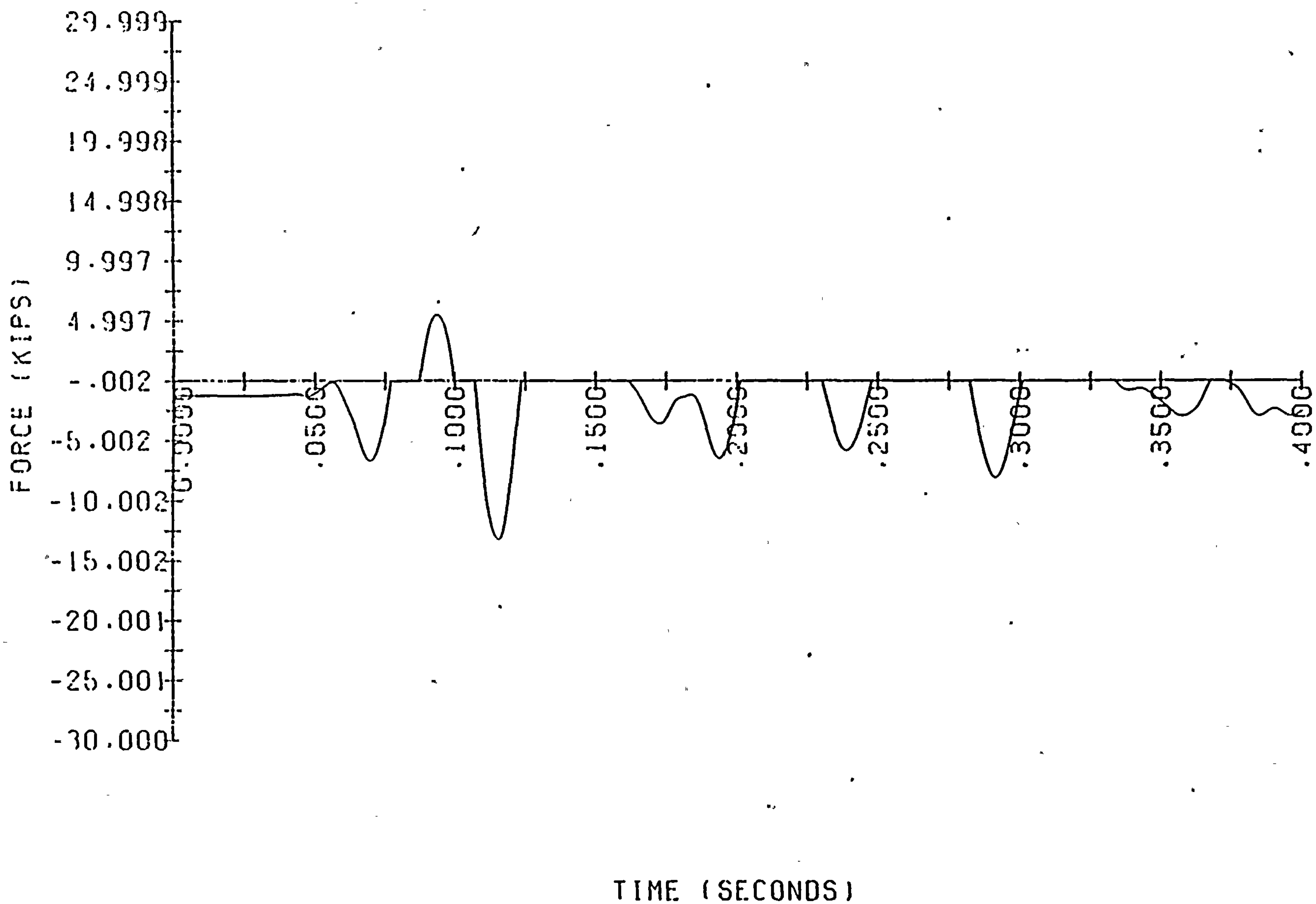
*********** FORCE IN DAGS GAP NUMBER 3 ***********

PALO VERDE P/R SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



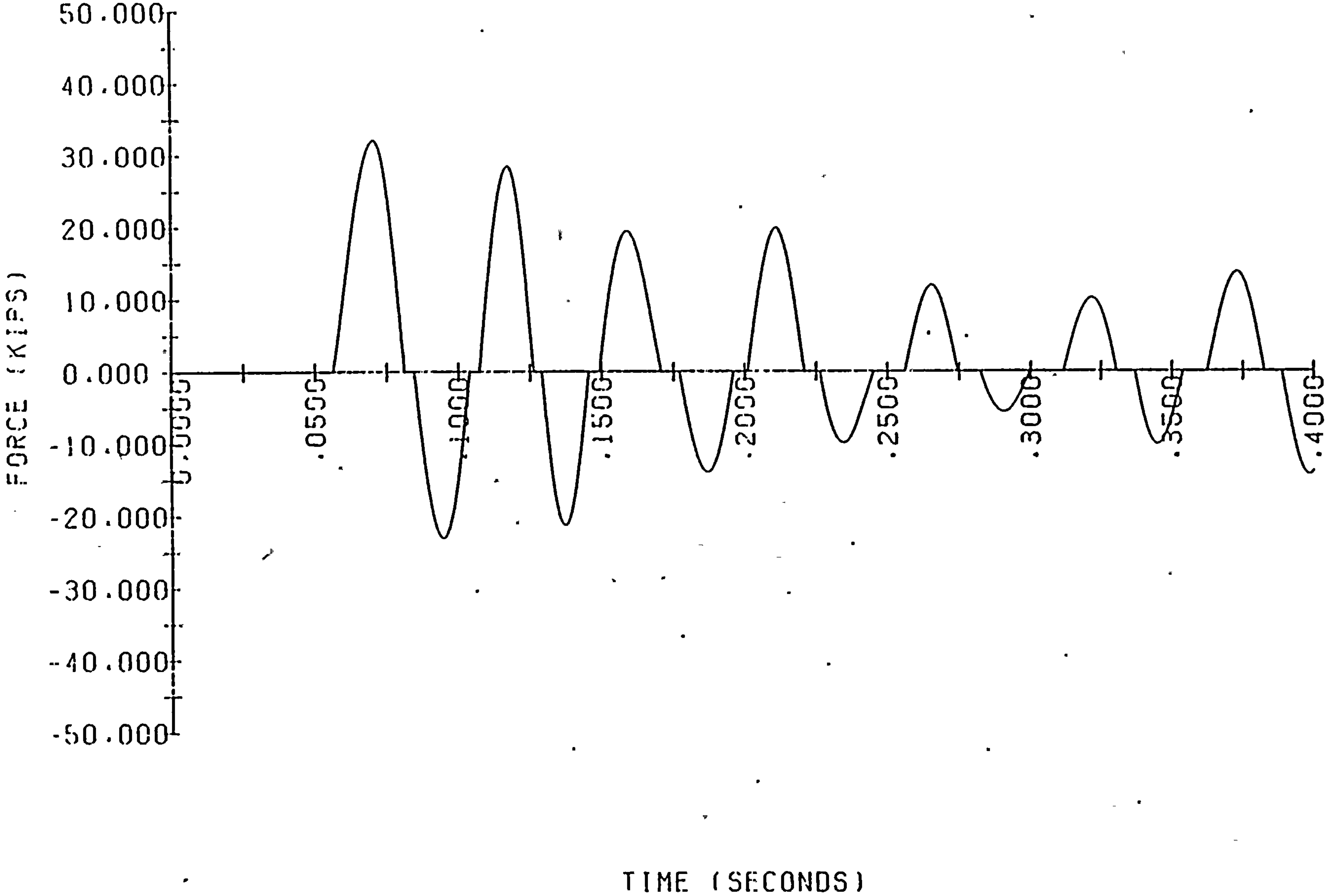
********** FORCE IN DAGS GAP NUMBER 4 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



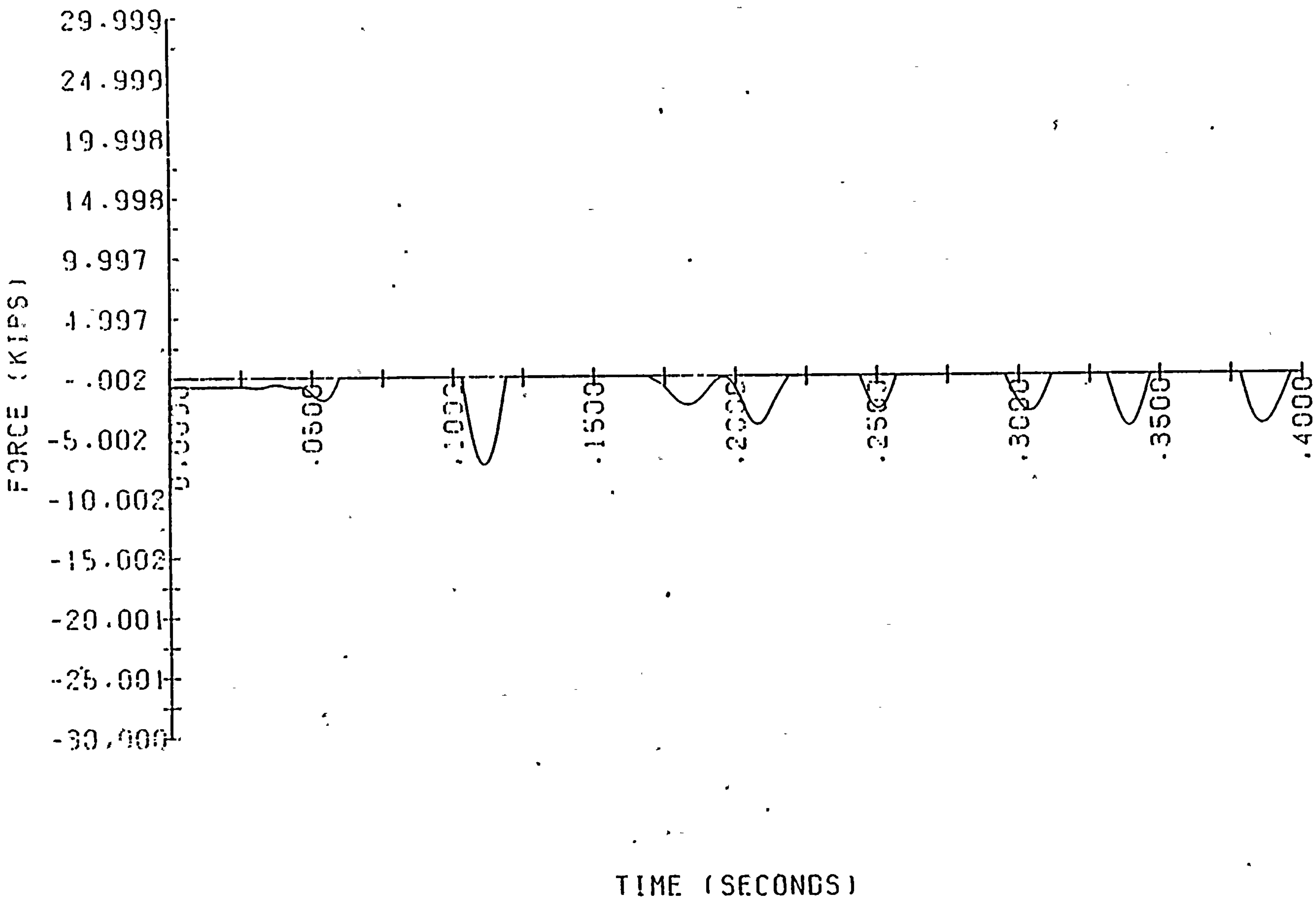
*********** FORCE IN DAGS GAP NUMBER 5 ***********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



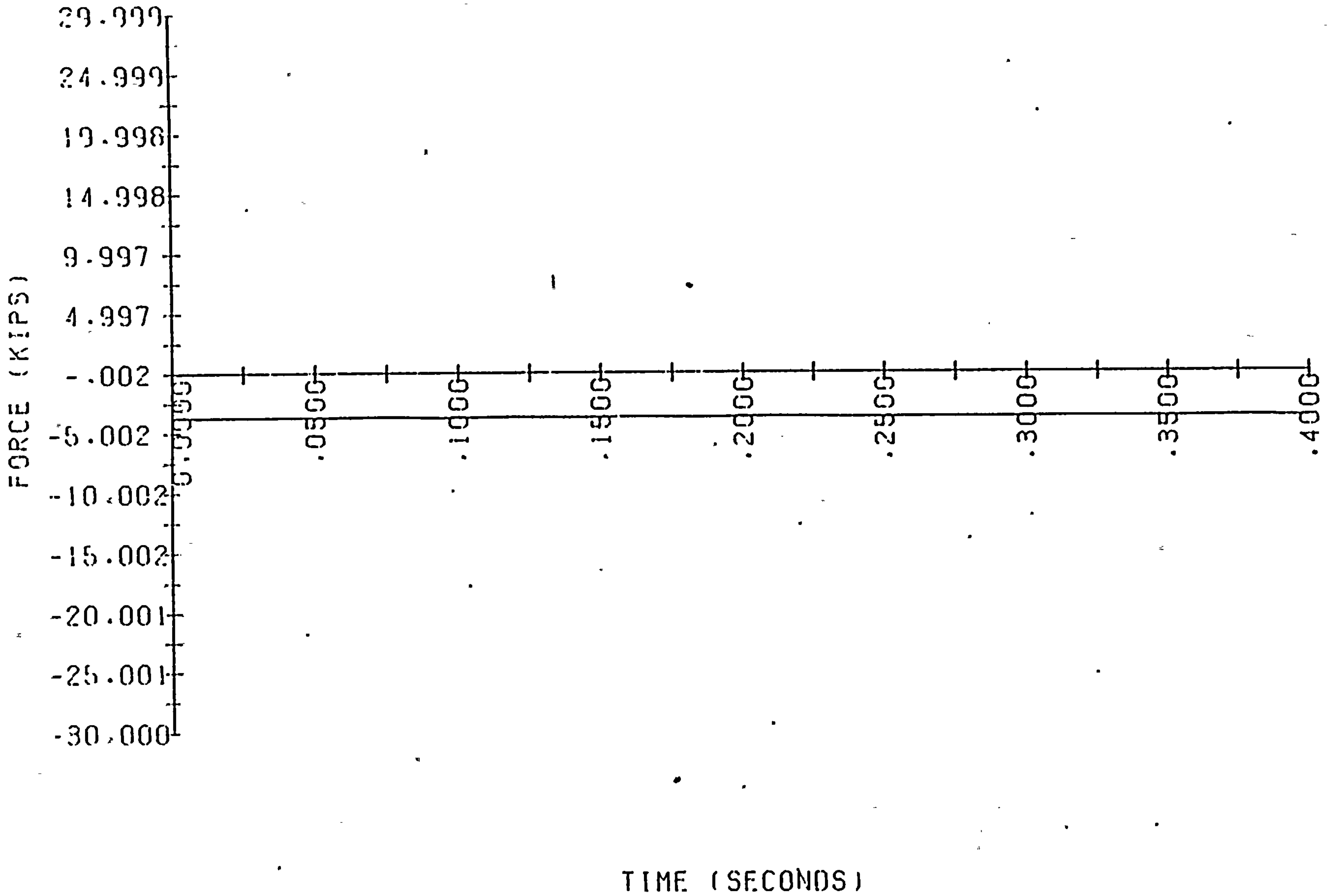
********** FORCE IN DAGS GAP NUMBER 6 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



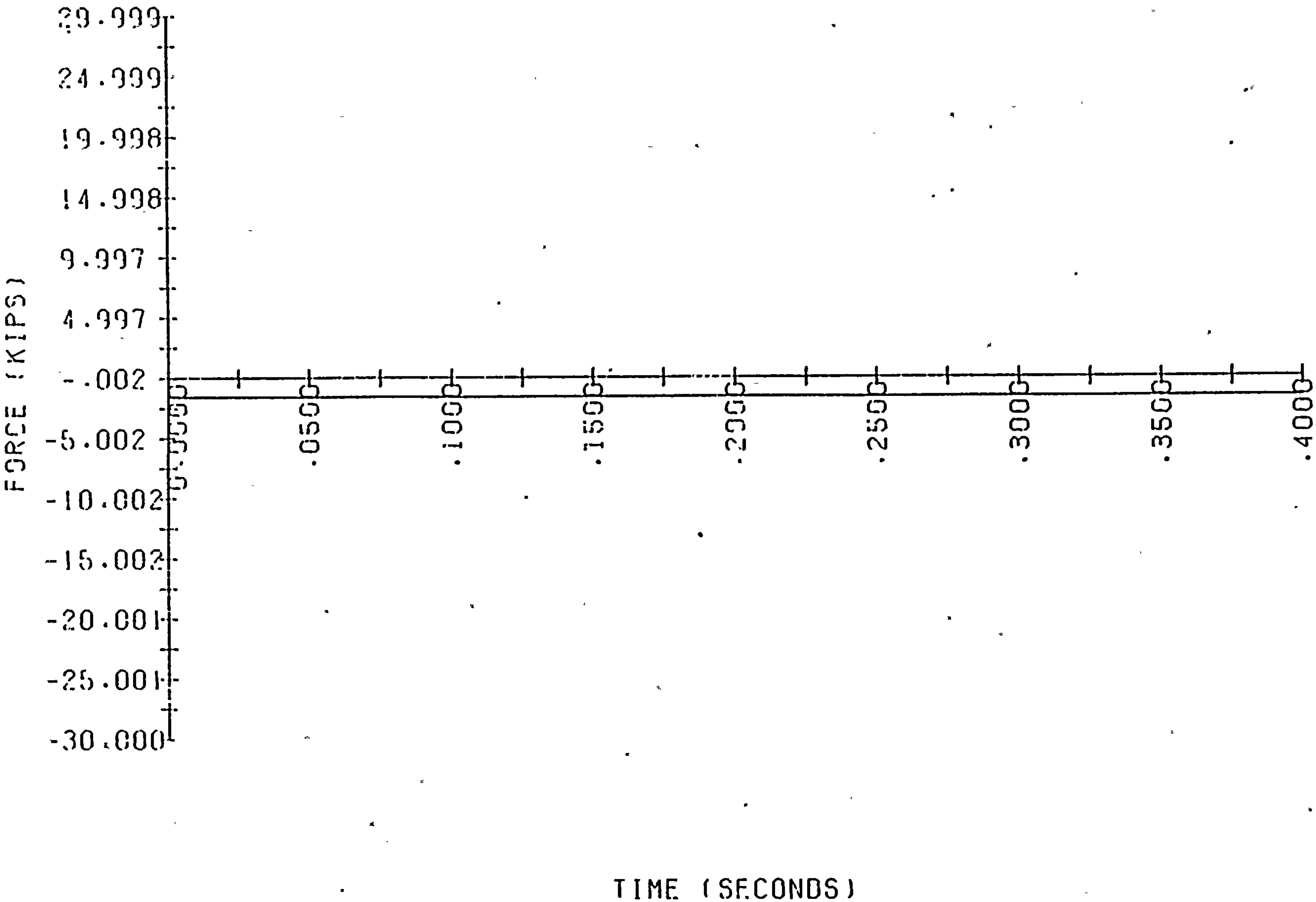
*********** FORCE IN DAGS GAP NUMBER 7 ***********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



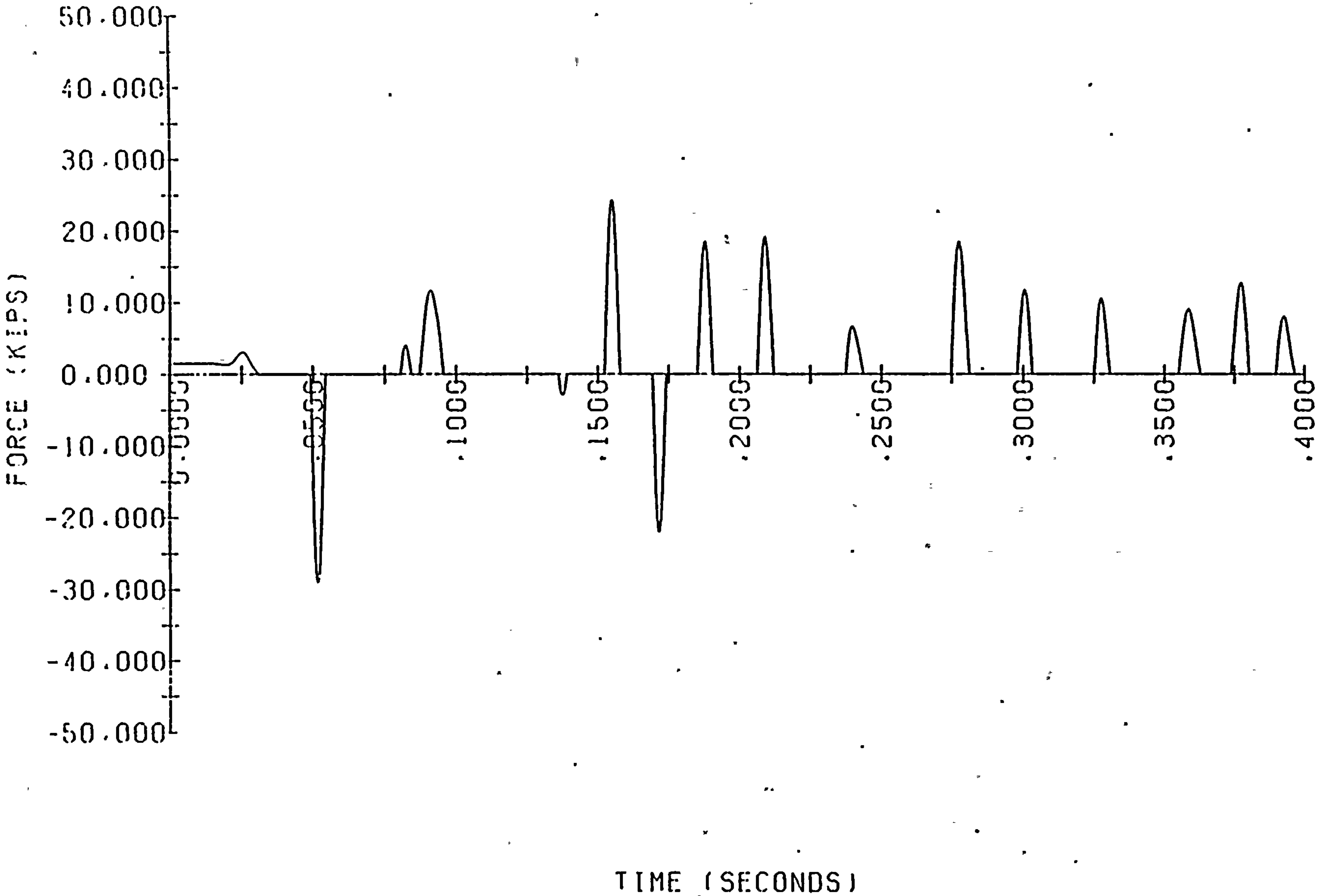
********** FORCE IN DAGS GAP NUMBER 8 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



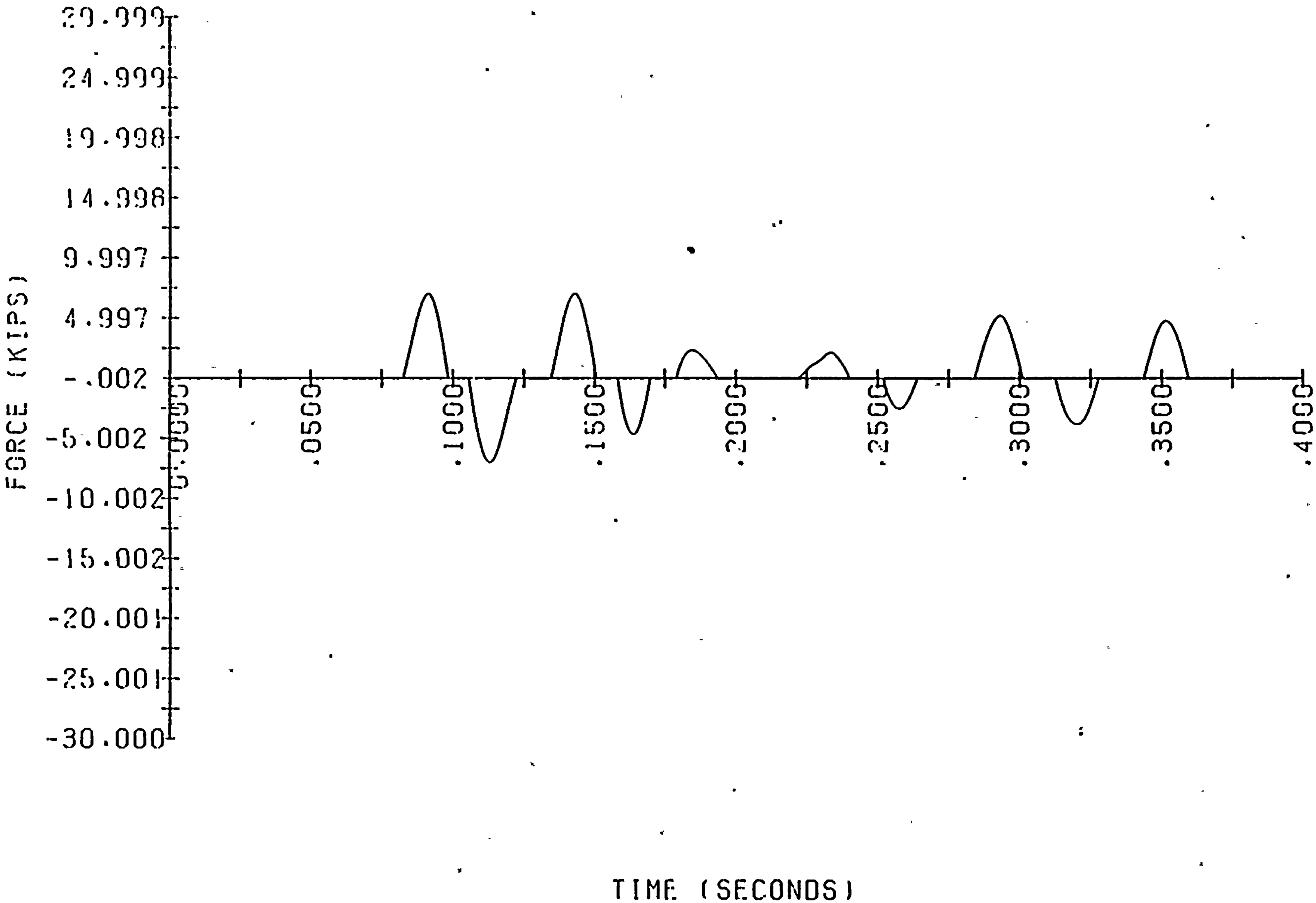
********** FORCE IN DAGS GAP NUMBER 9 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



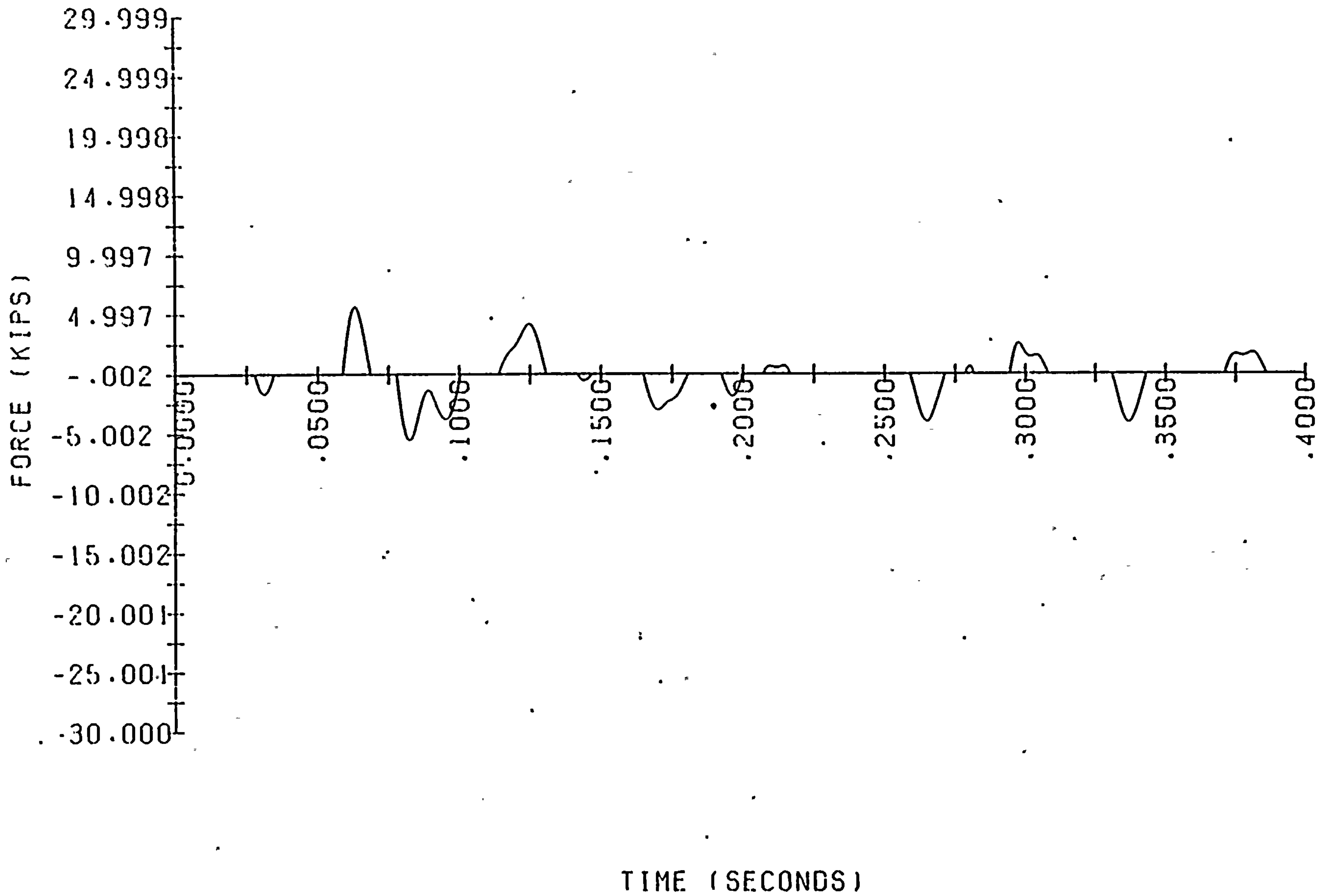
********** FORCE IN DAGS GAP NUMBER 11 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



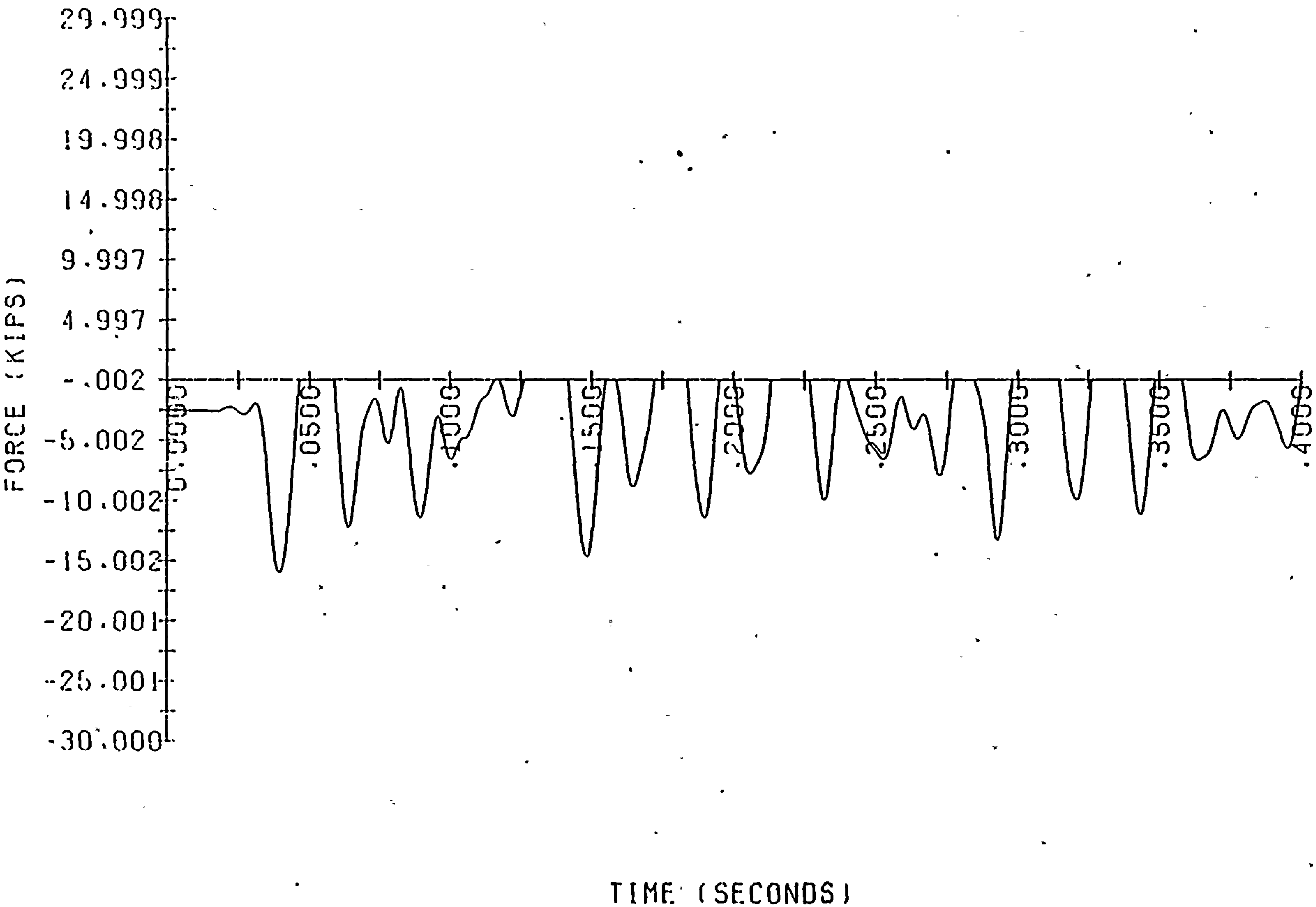
********** FORCE IN DAGS GAP NUMBER 12 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



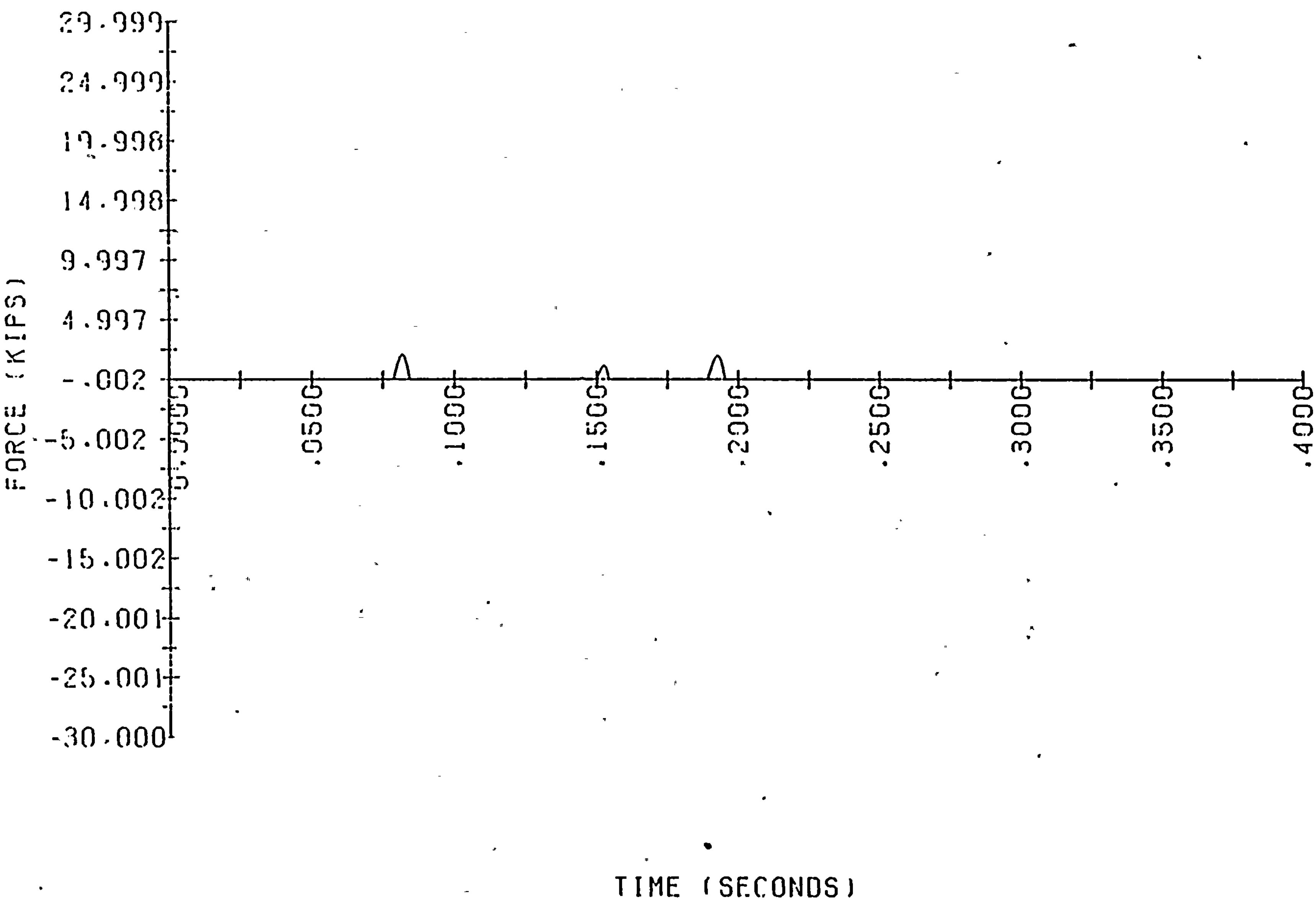
********** FORCE IN DAGS GAP NUMBER 13 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



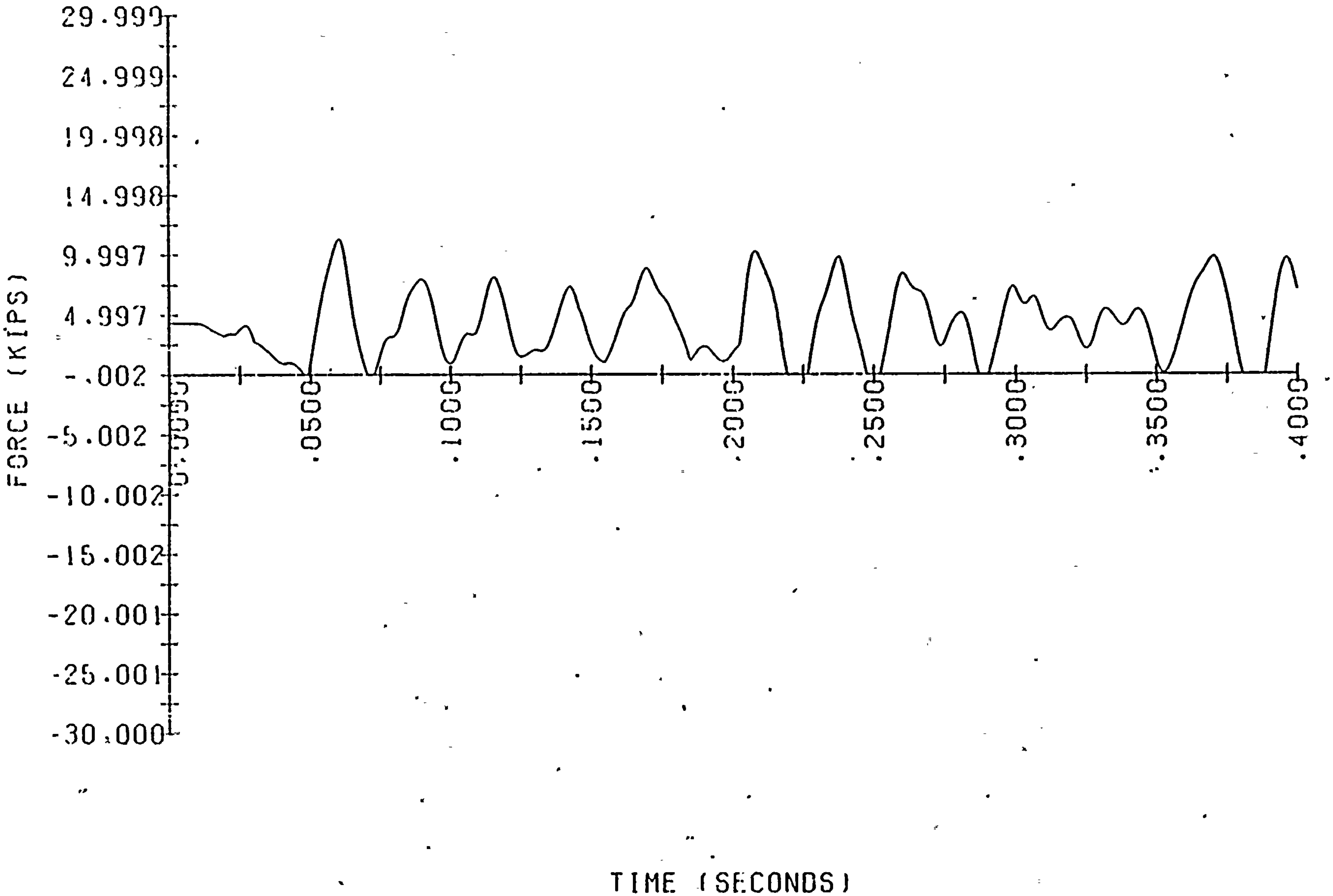
********** FORCE IN DAGS GAP NUMBER 14 **********

PALO VERDE P/R SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS

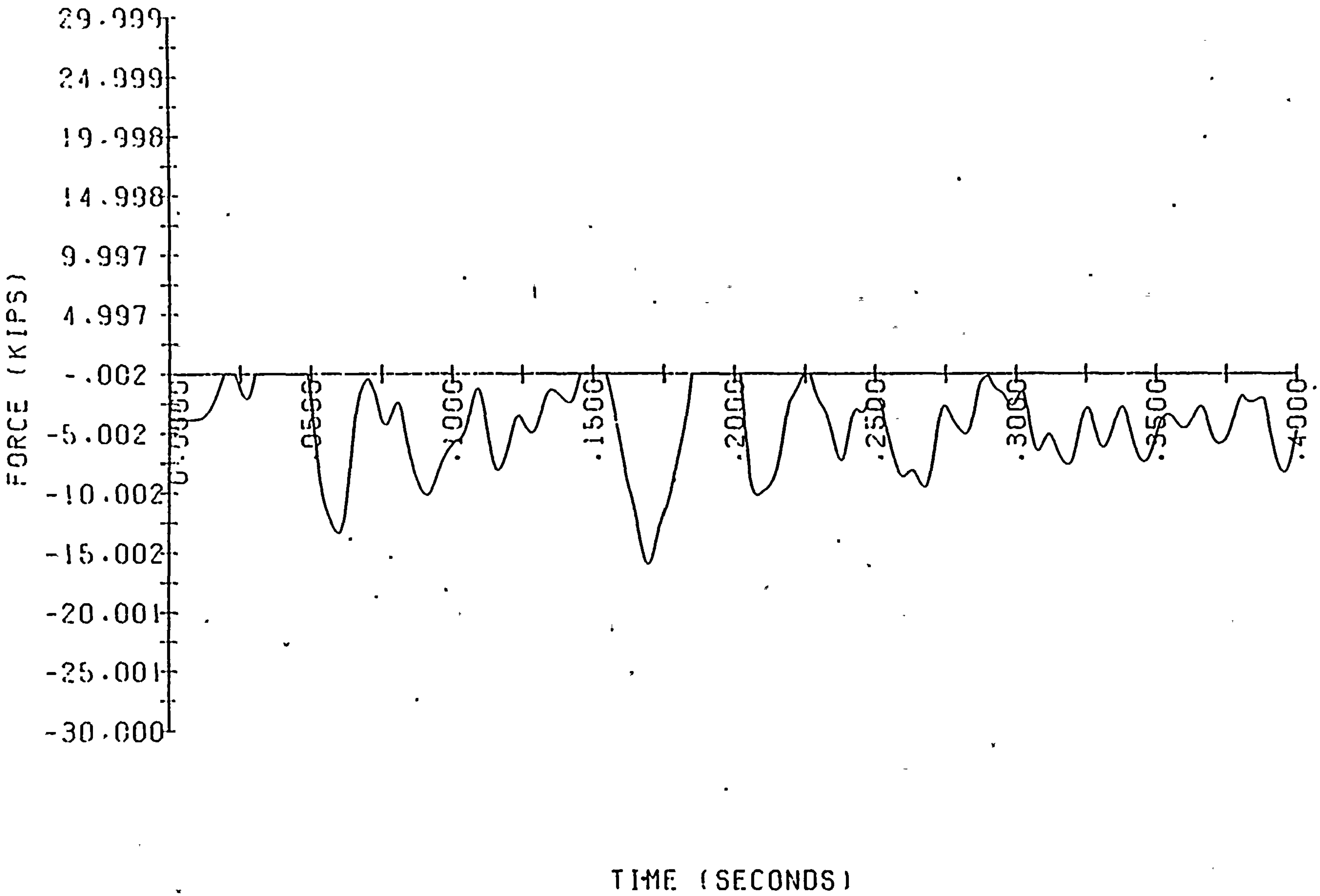


********** FORCE IN DAGS GAP NUMBER 15 **********

PALO VERDE P/R SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS

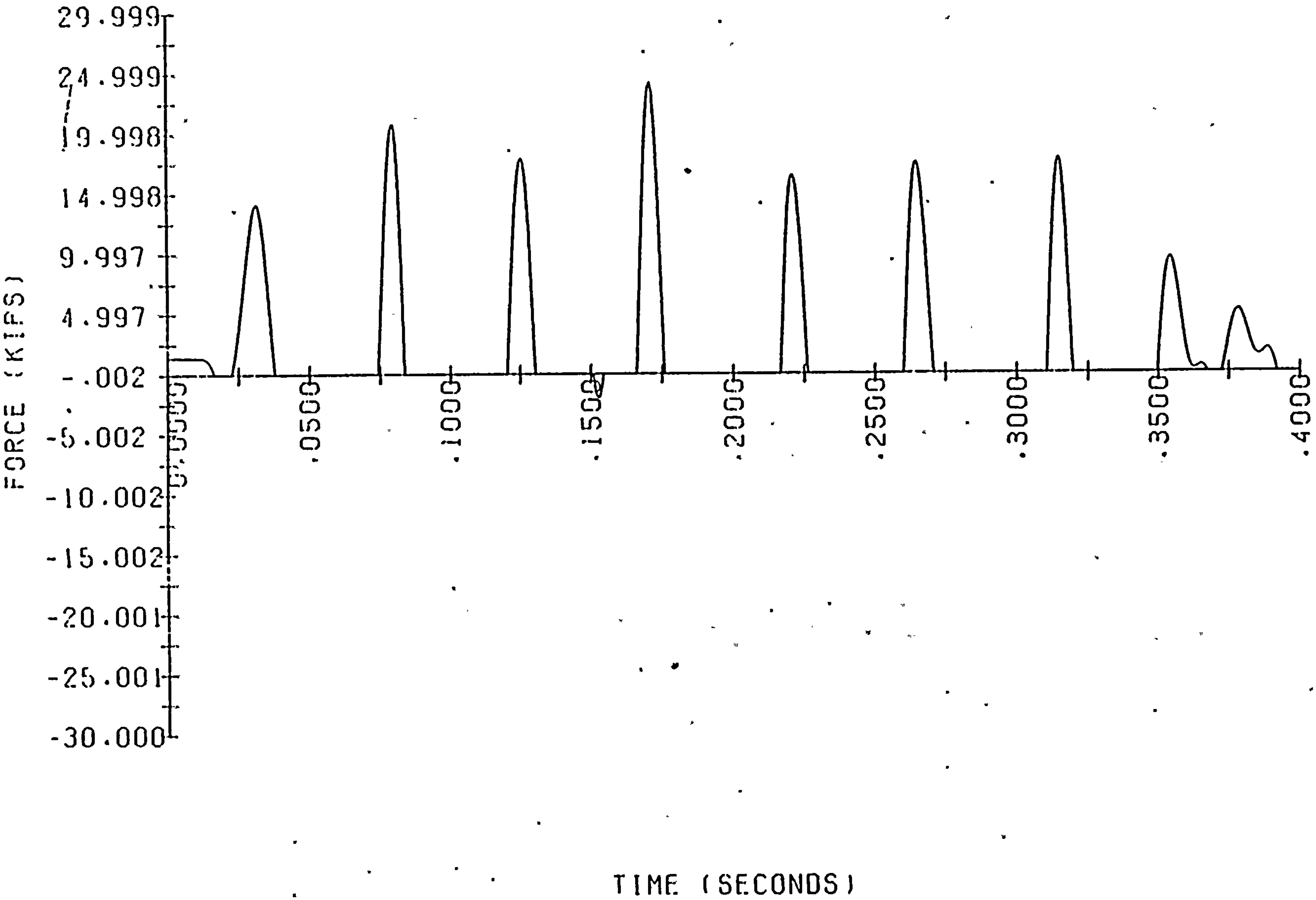


********** FORCE IN DAGS GAP NUMBER 16 **********
PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



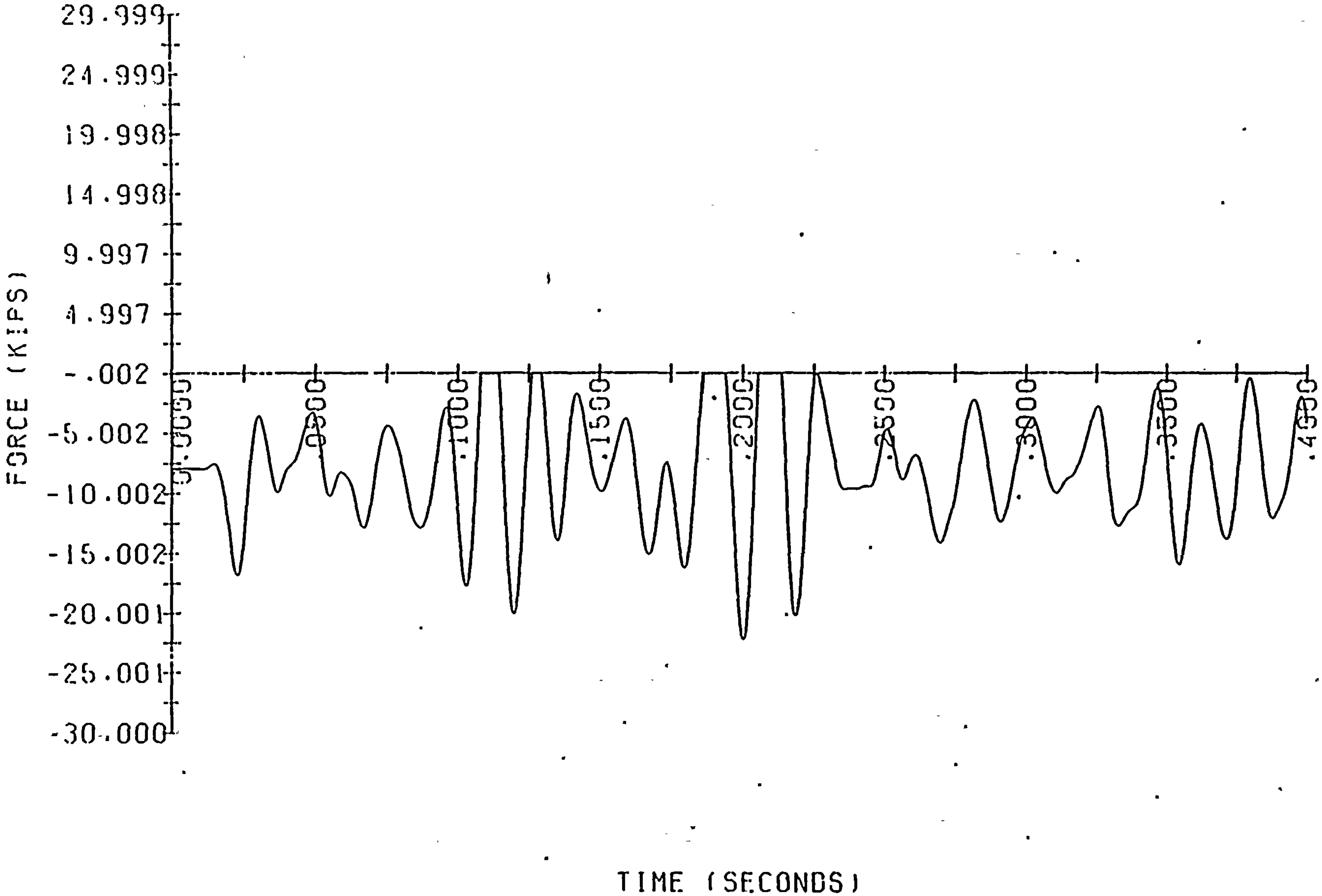
********** FORCE IN DAGS GAP NUMBER 17 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



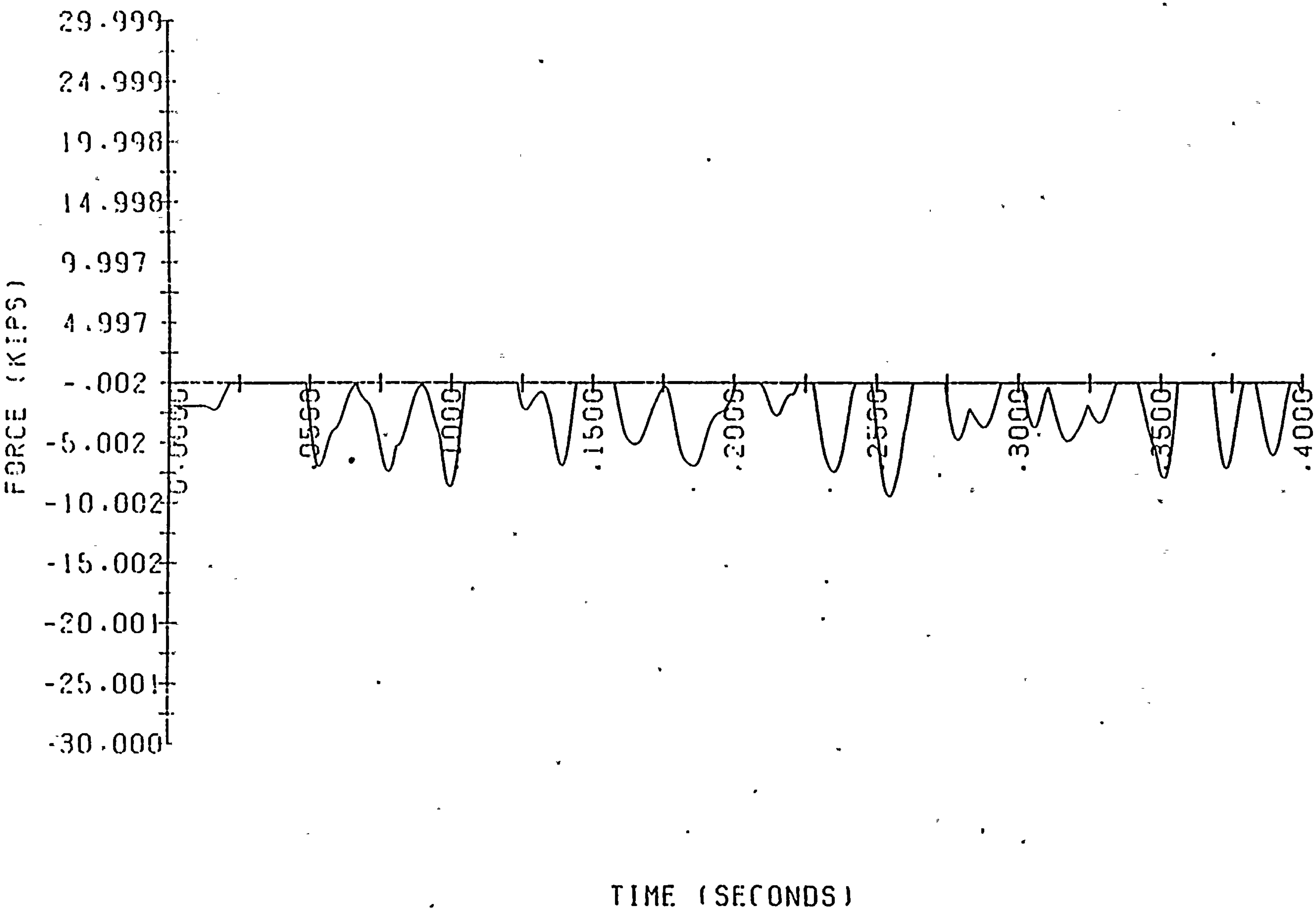
********** FORCE IN DAGS GAP NUMBER 18 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



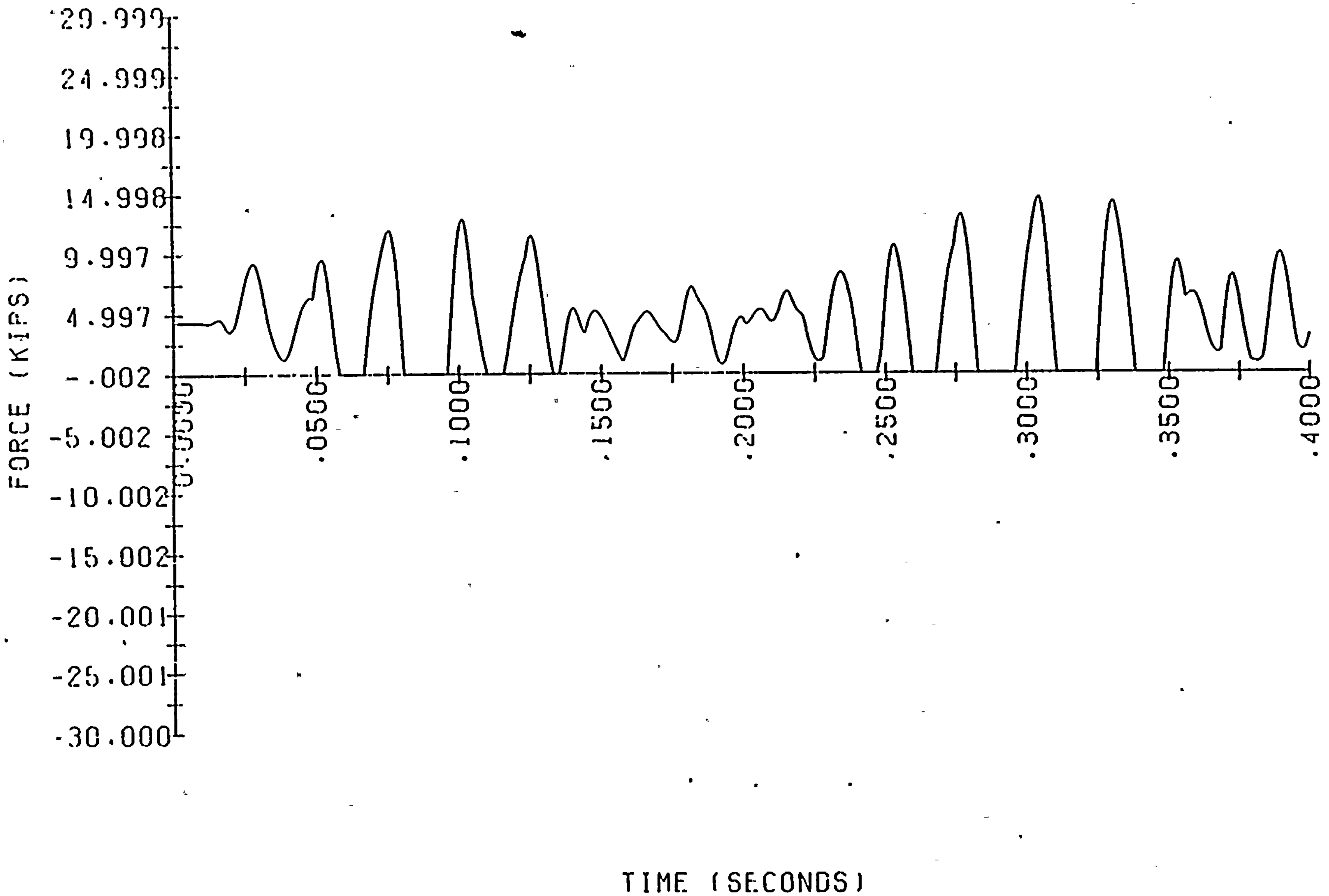
********** FORCE IN DAGS GAP NUMBER 19 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS

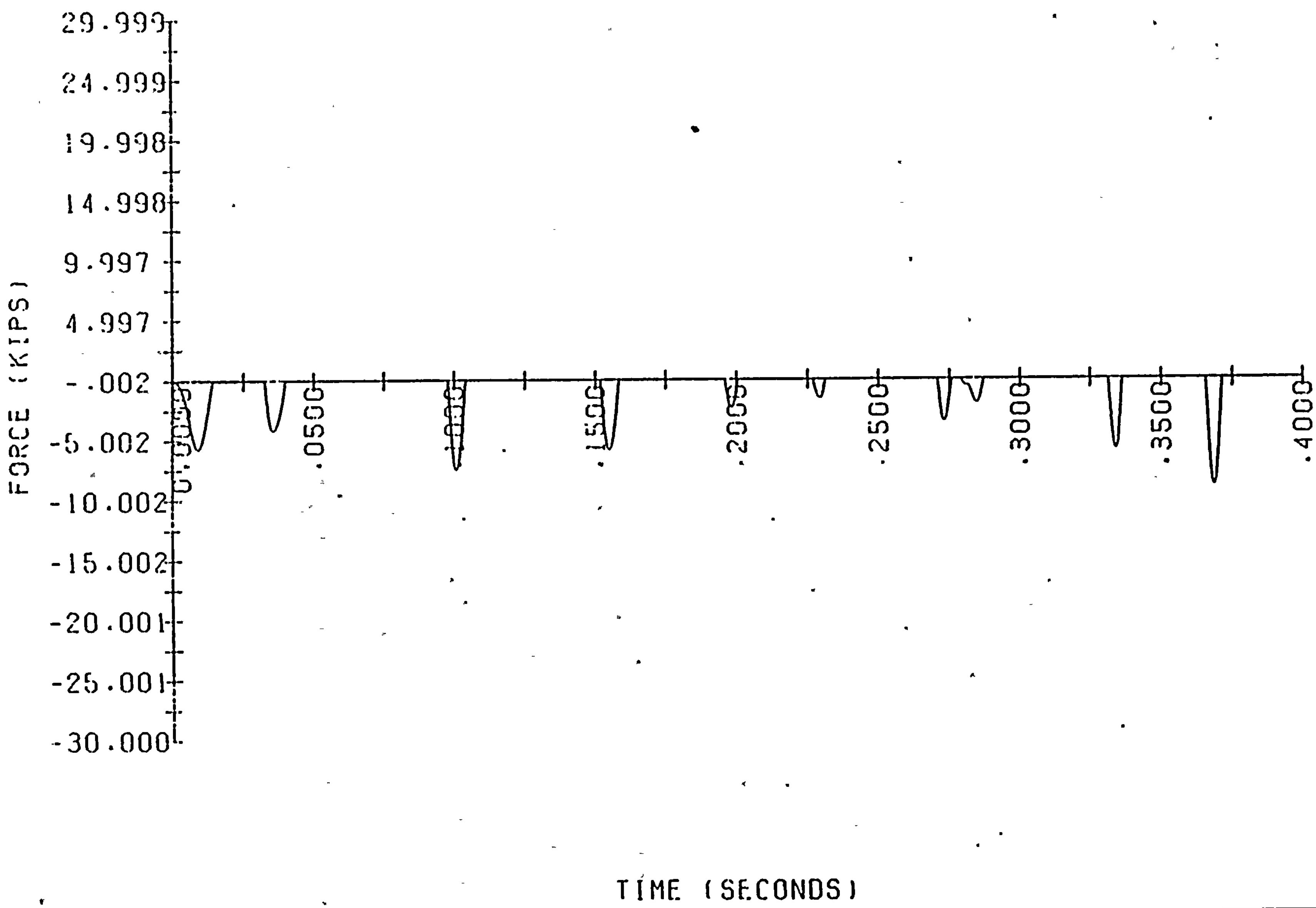


*********** FORCE IN DAGS GAP NUMBER 20 ***********

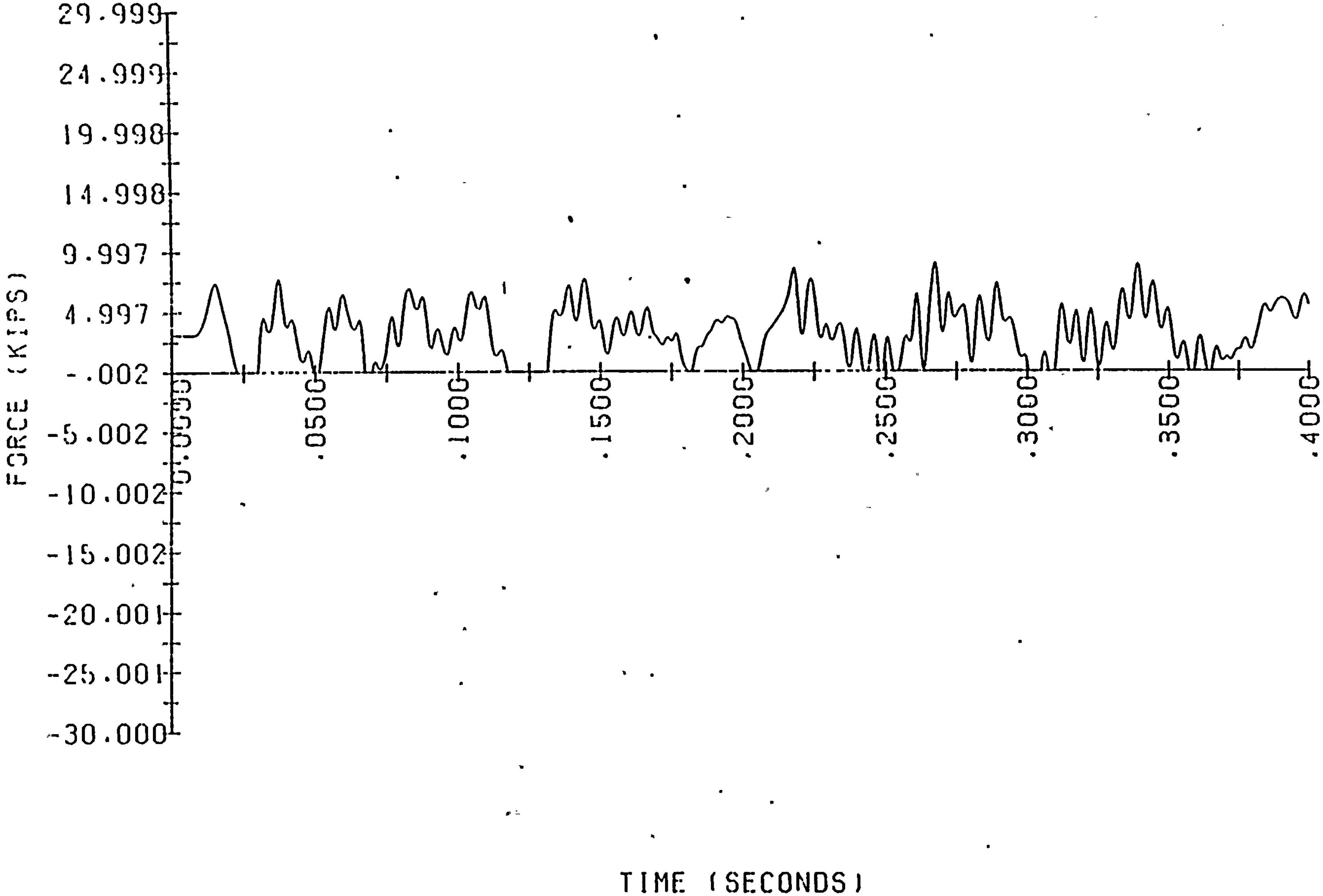
PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



********** FORCE IN DAGS GAP NUMBER 21 **********
PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS

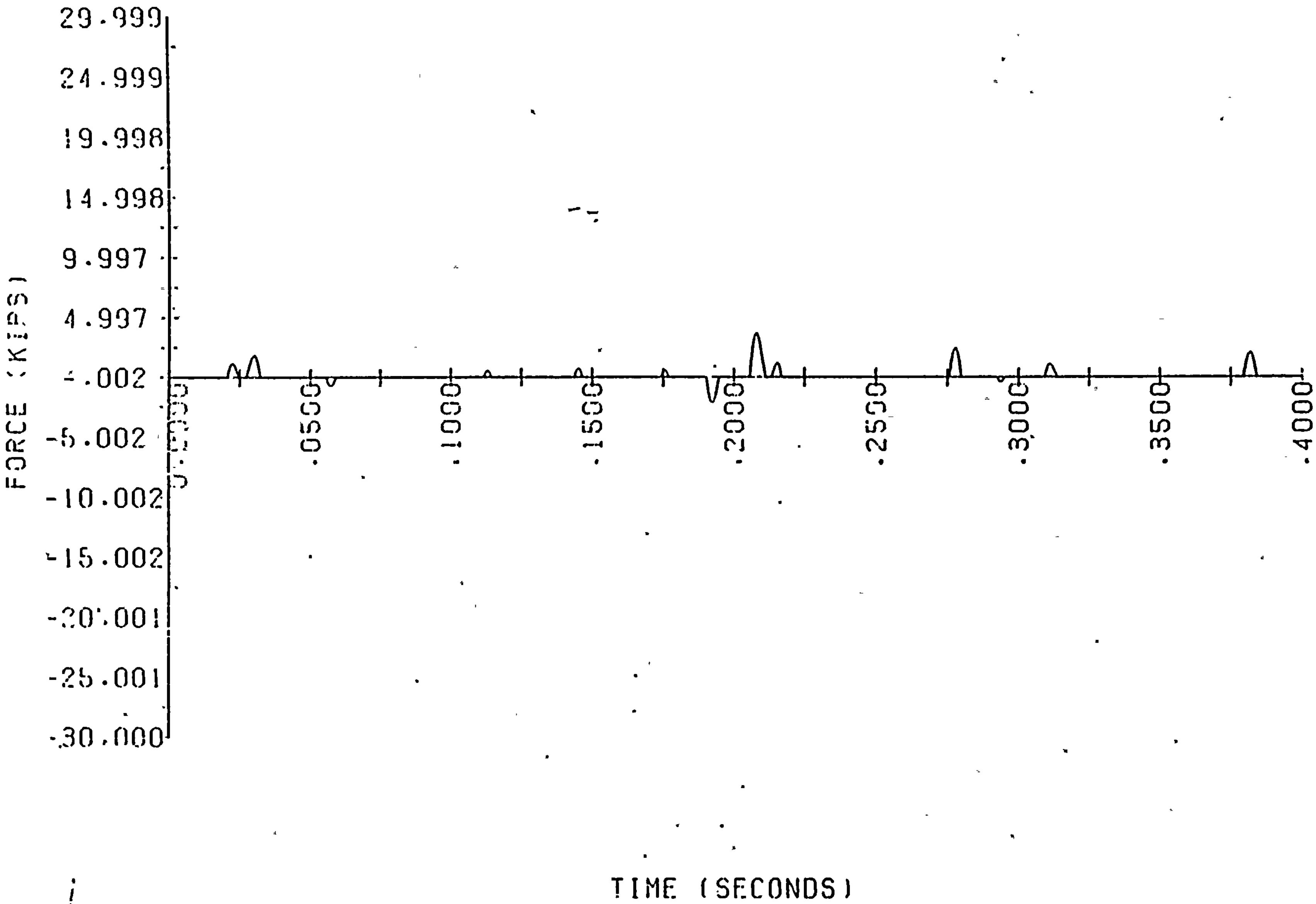


********** FORCE IN DAGS GAP NUMBER 22 **********
PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



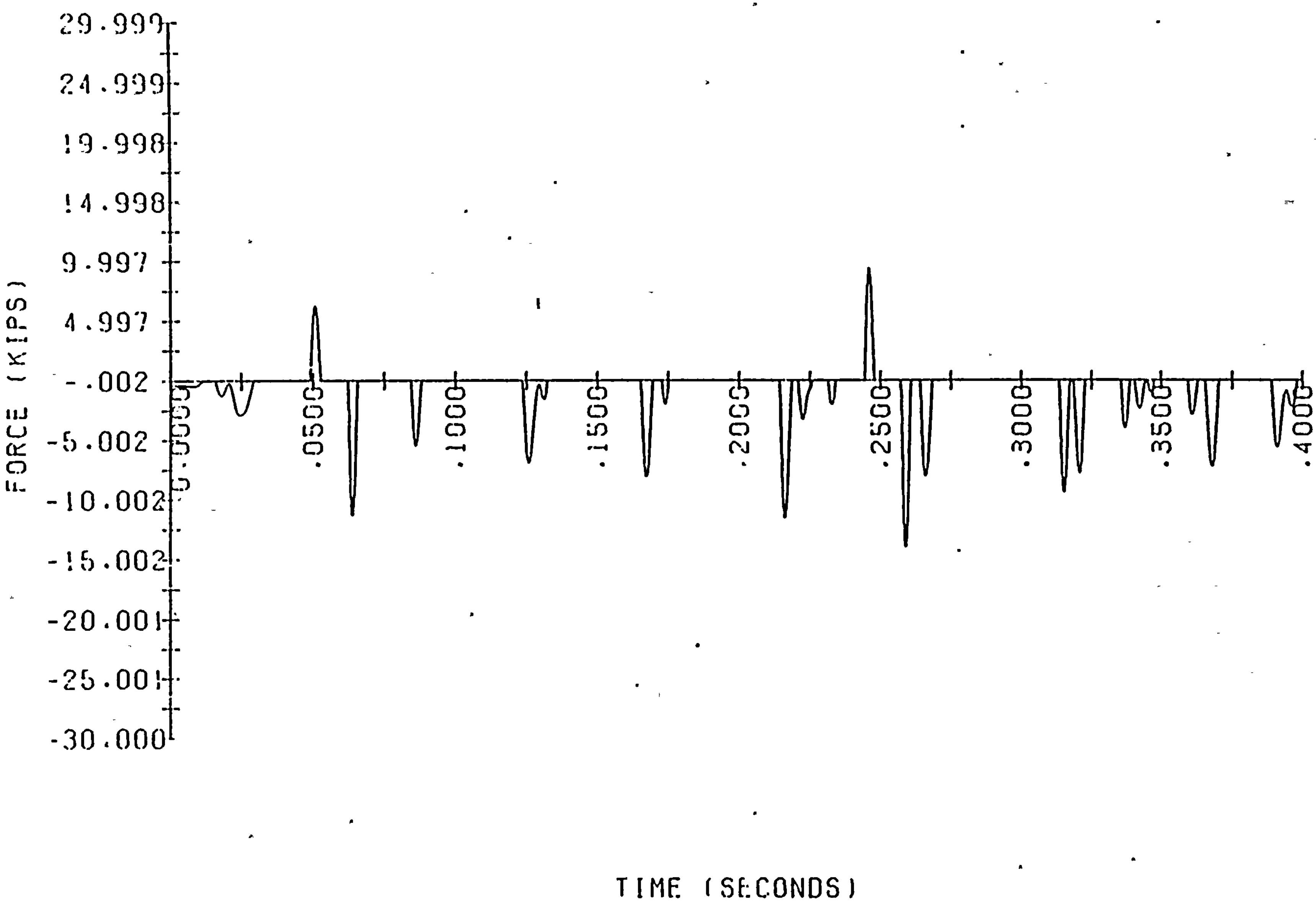
********** FORCE IN DAGS GAP NUMBER 23 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



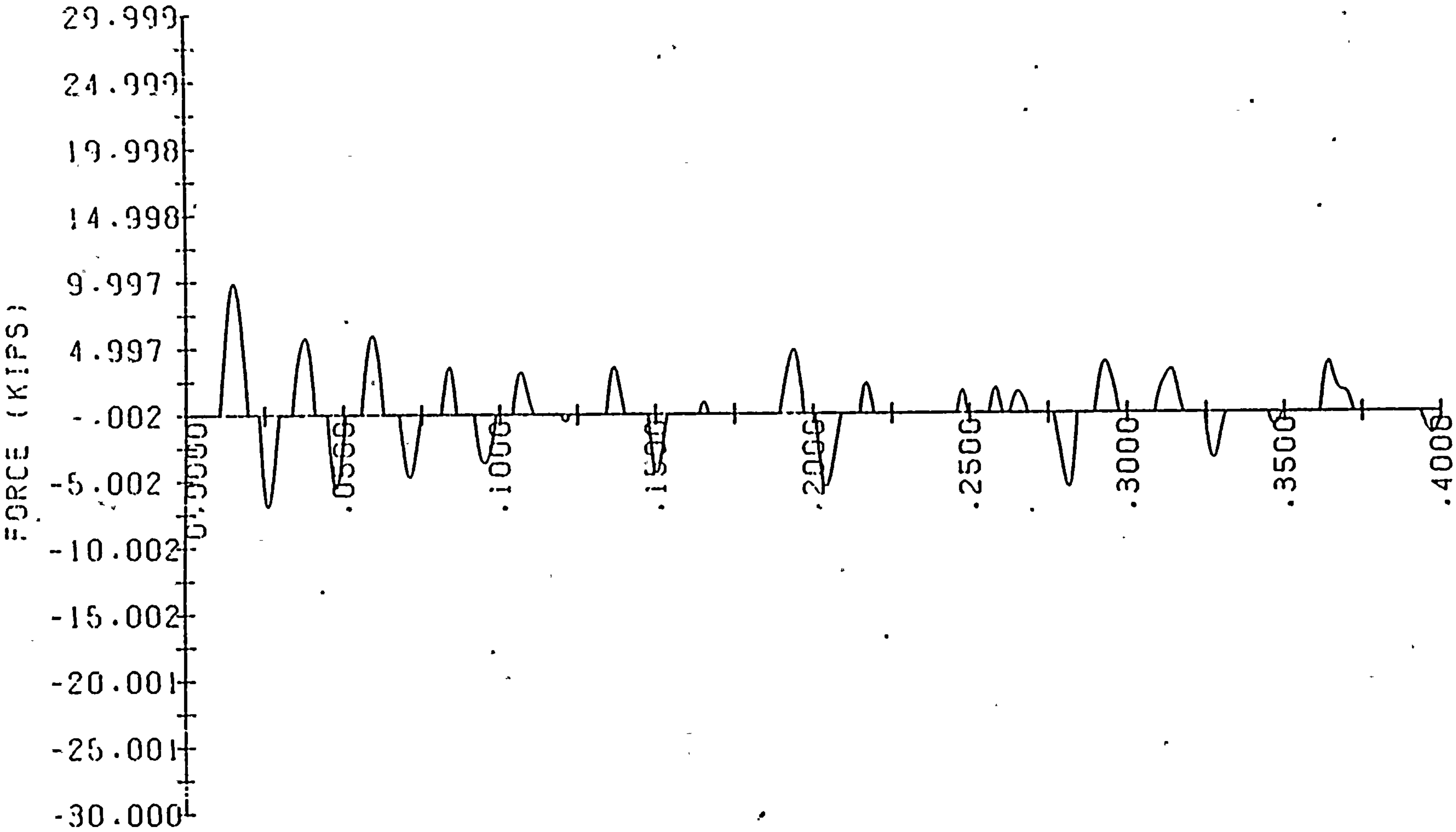
********** FORCE IN DAGS GAP NUMBER 24 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



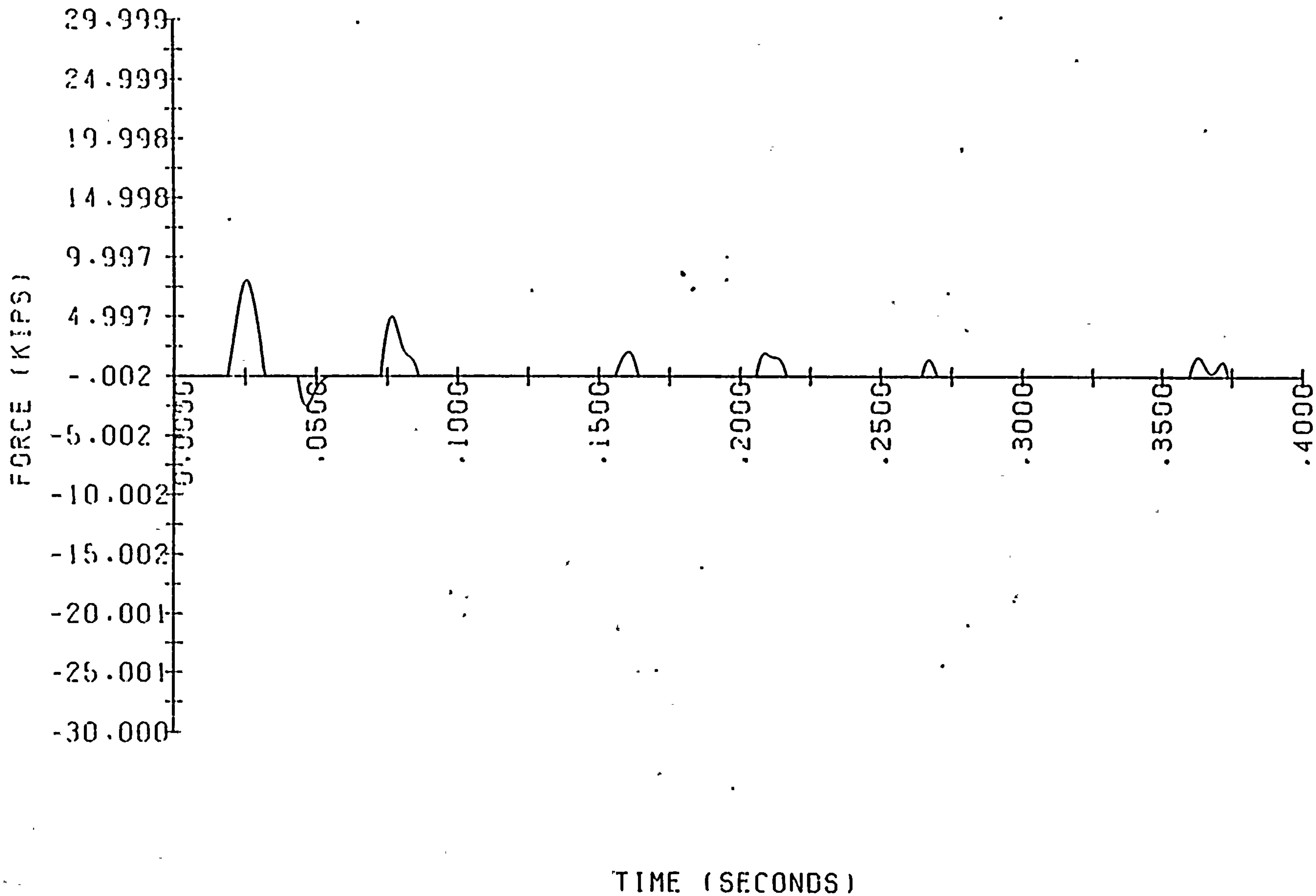
********** FORCE IN DAGS GAP NUMBER 25 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



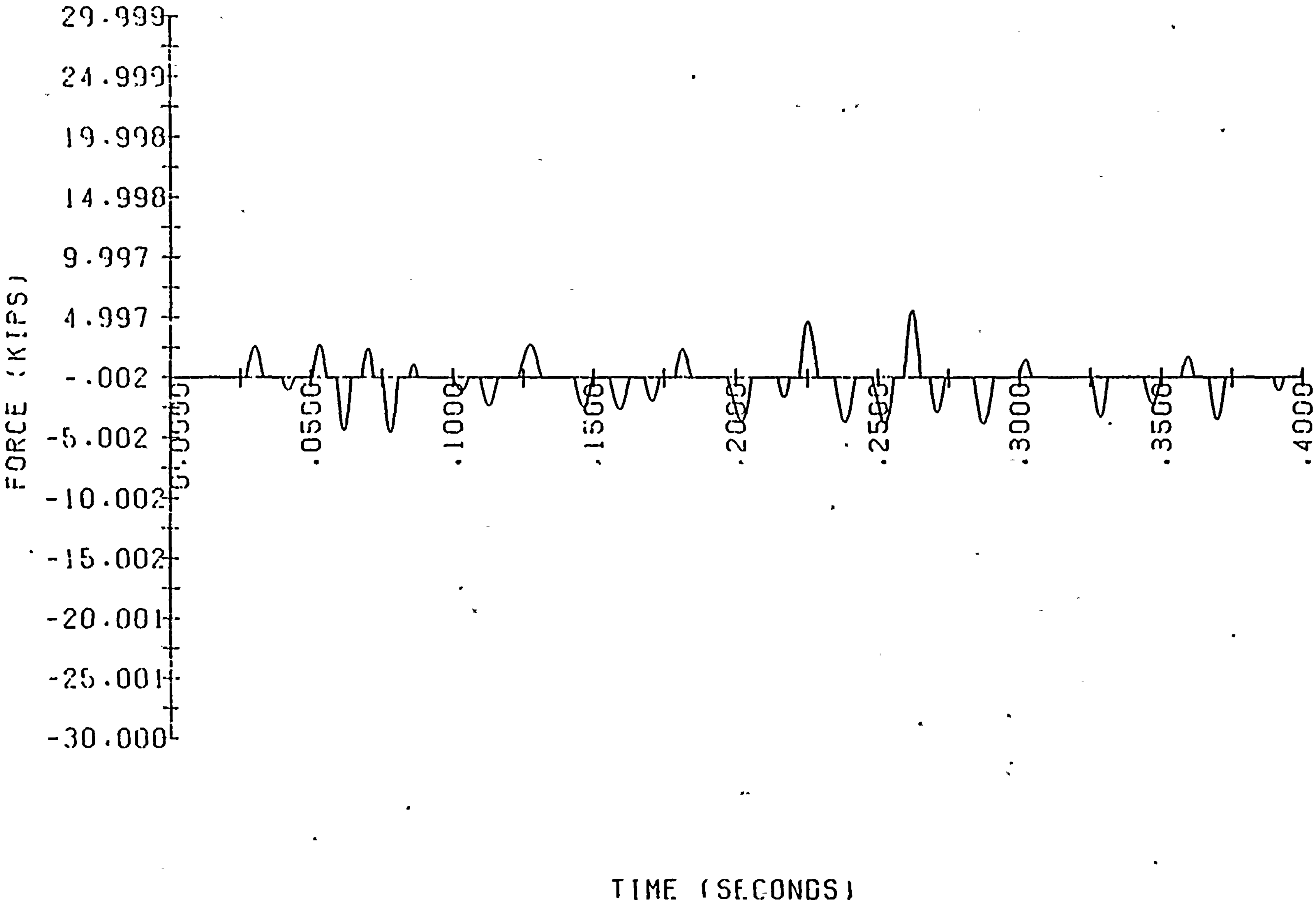
********** FORCE IN DAGS GAP NUMBER 26 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



********** FORCE IN DAGS GAP NUMBER 27 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



*********** FORCE IN DAGS GAP NUMBER 28 ***********

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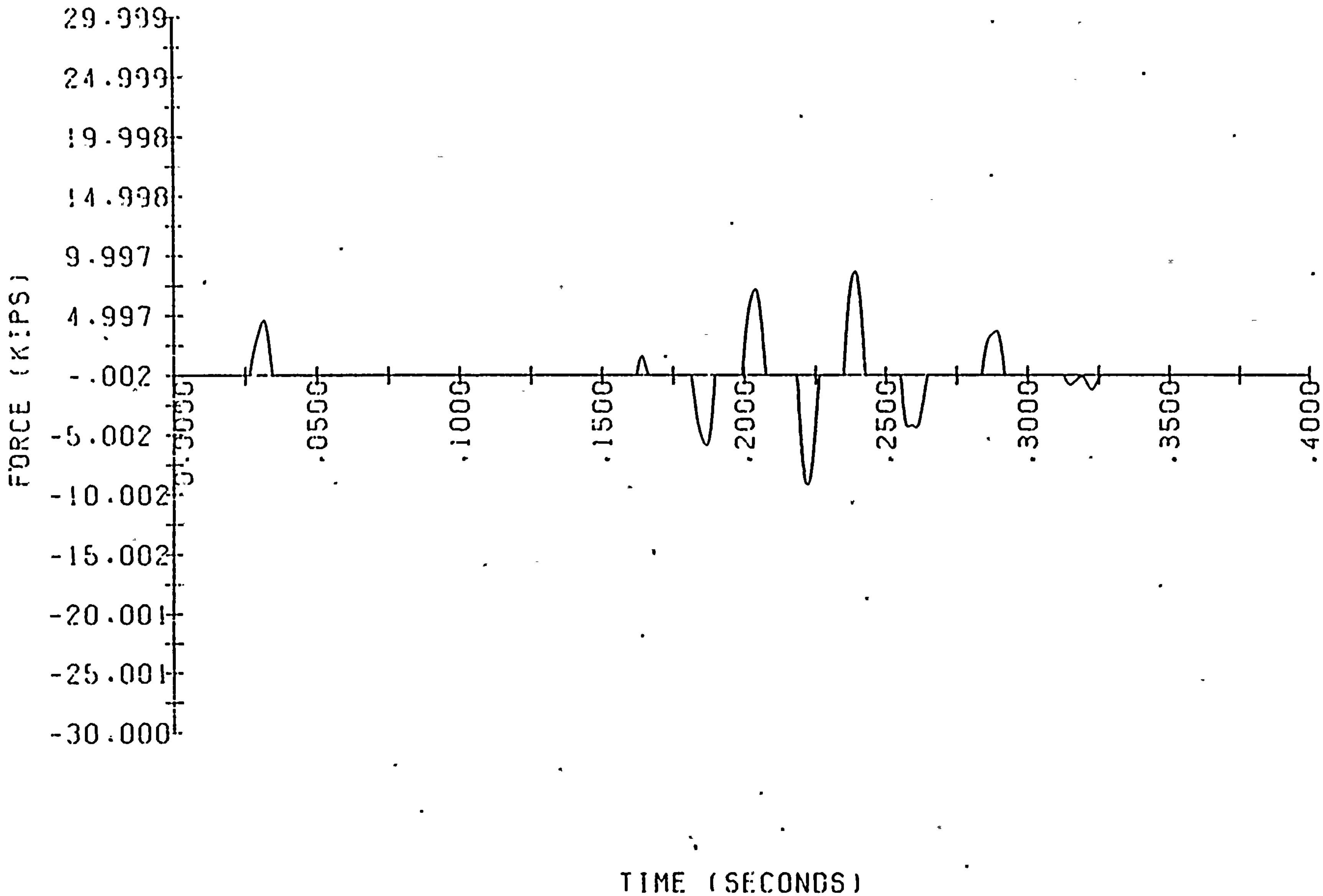
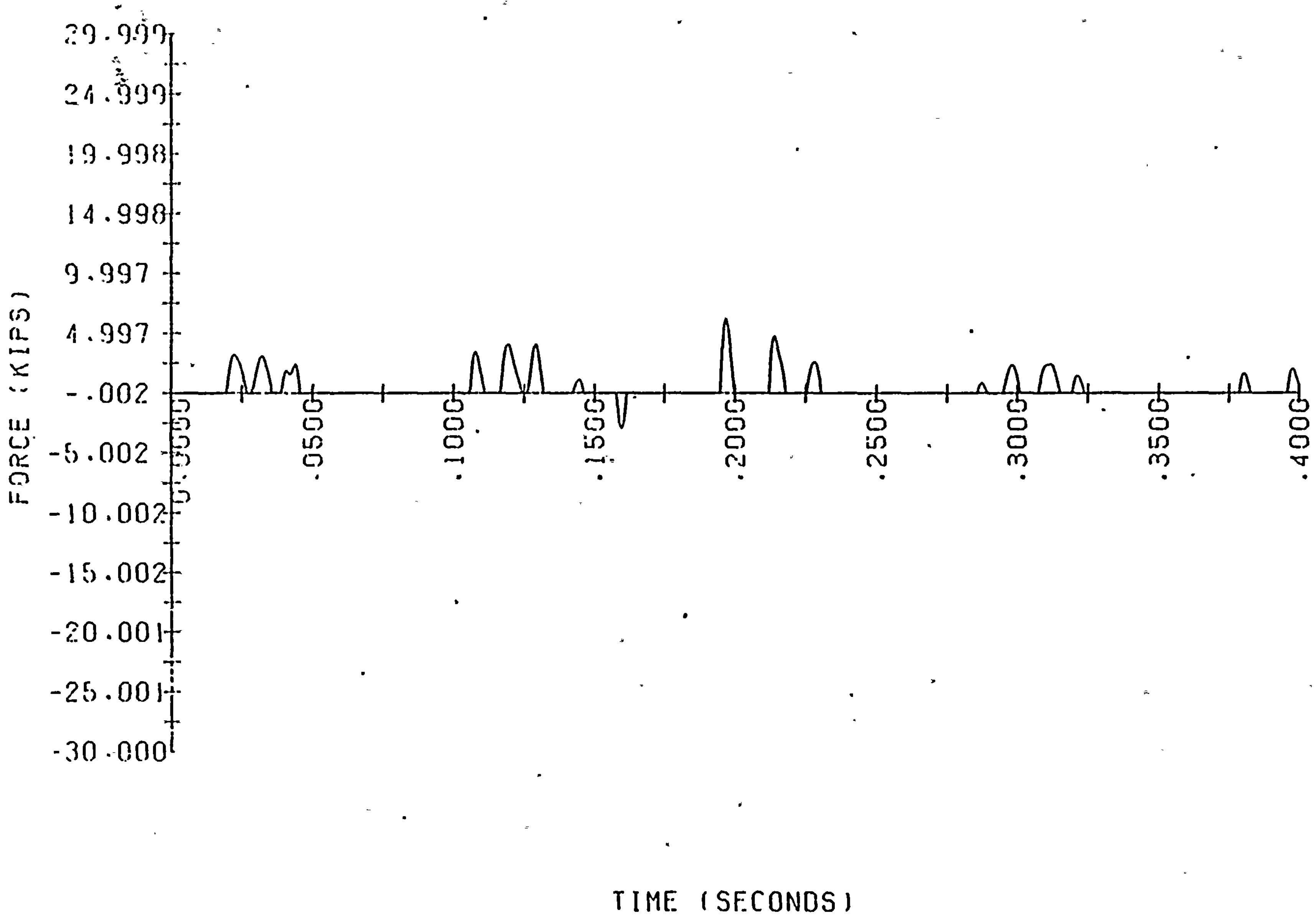


*********** FORCE IN DAGS GAP NUMBER 29 ***********

PALO VERDE P/R SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



********** FORCE IN DAGS GAP NUMBER 30 **********

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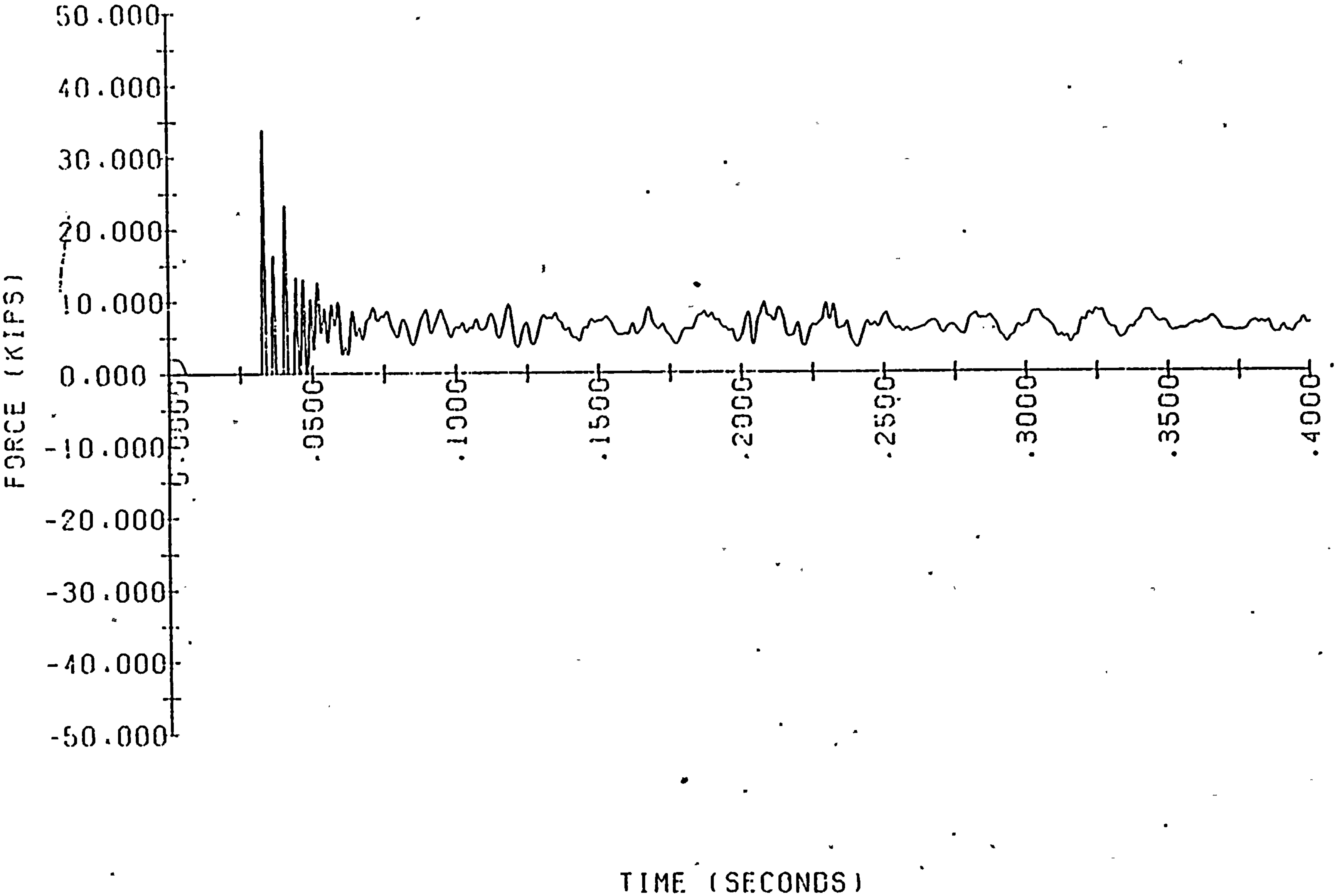

*********** FORCE IN DAGS GAP NUMBER 31 ***********

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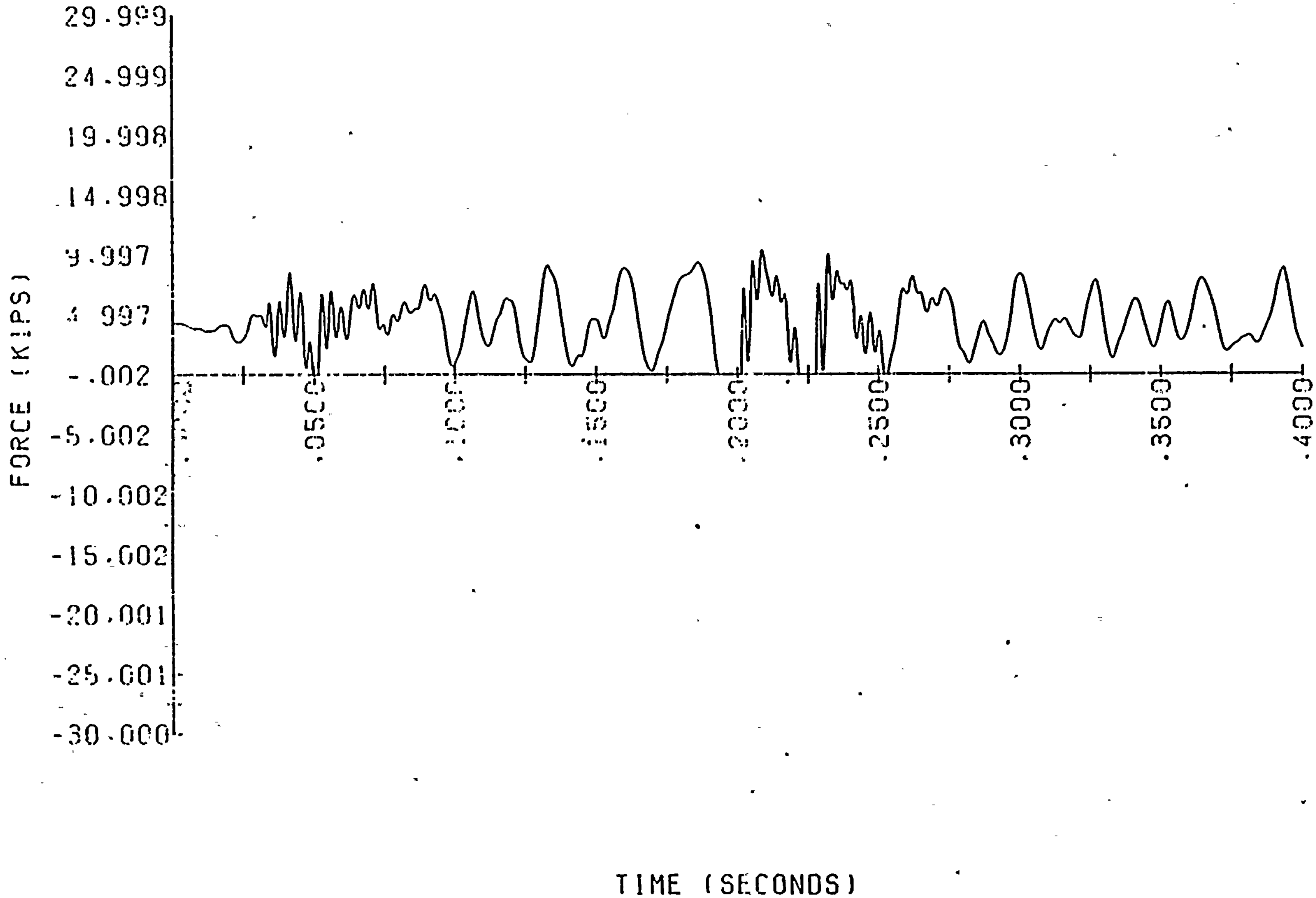
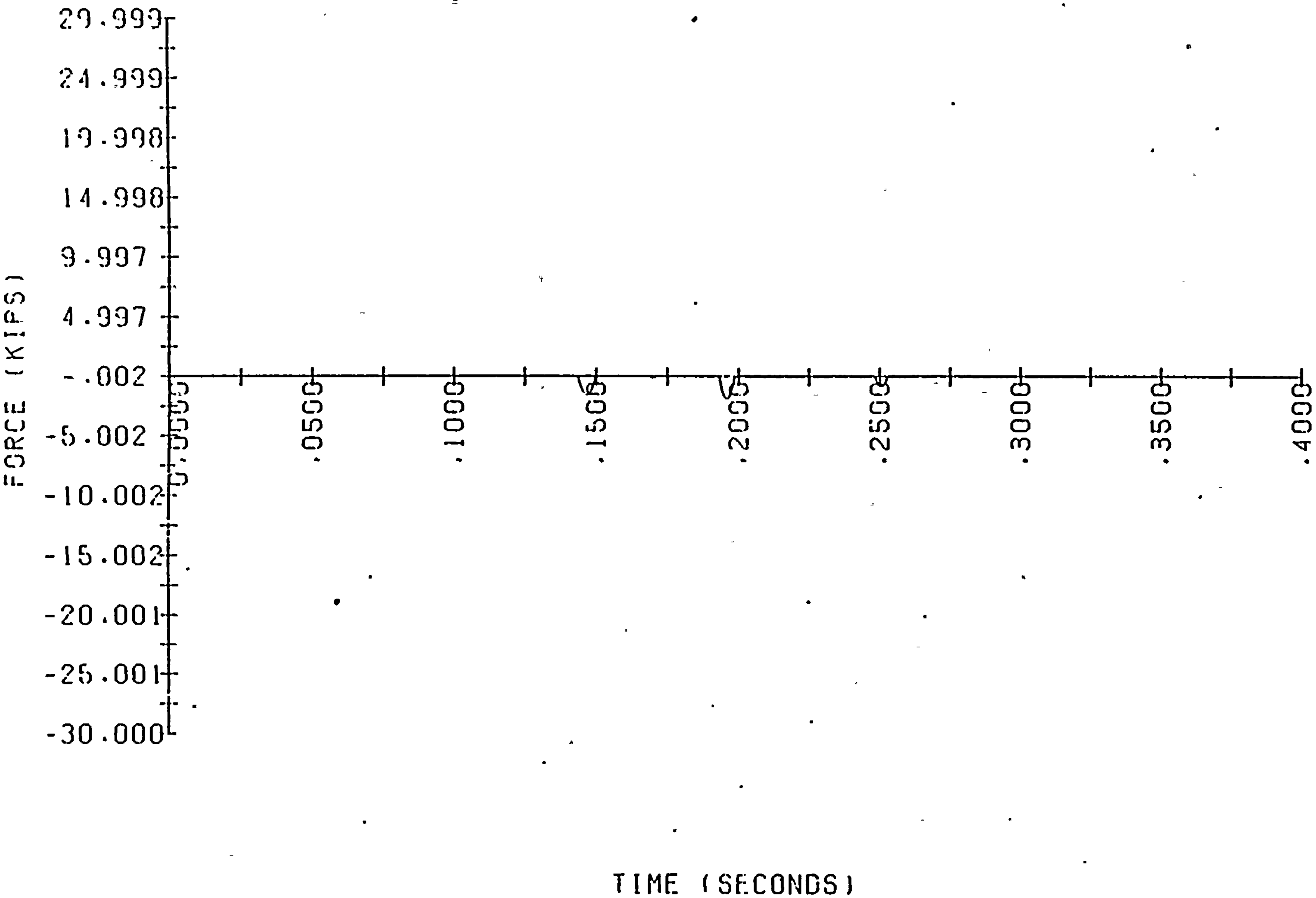


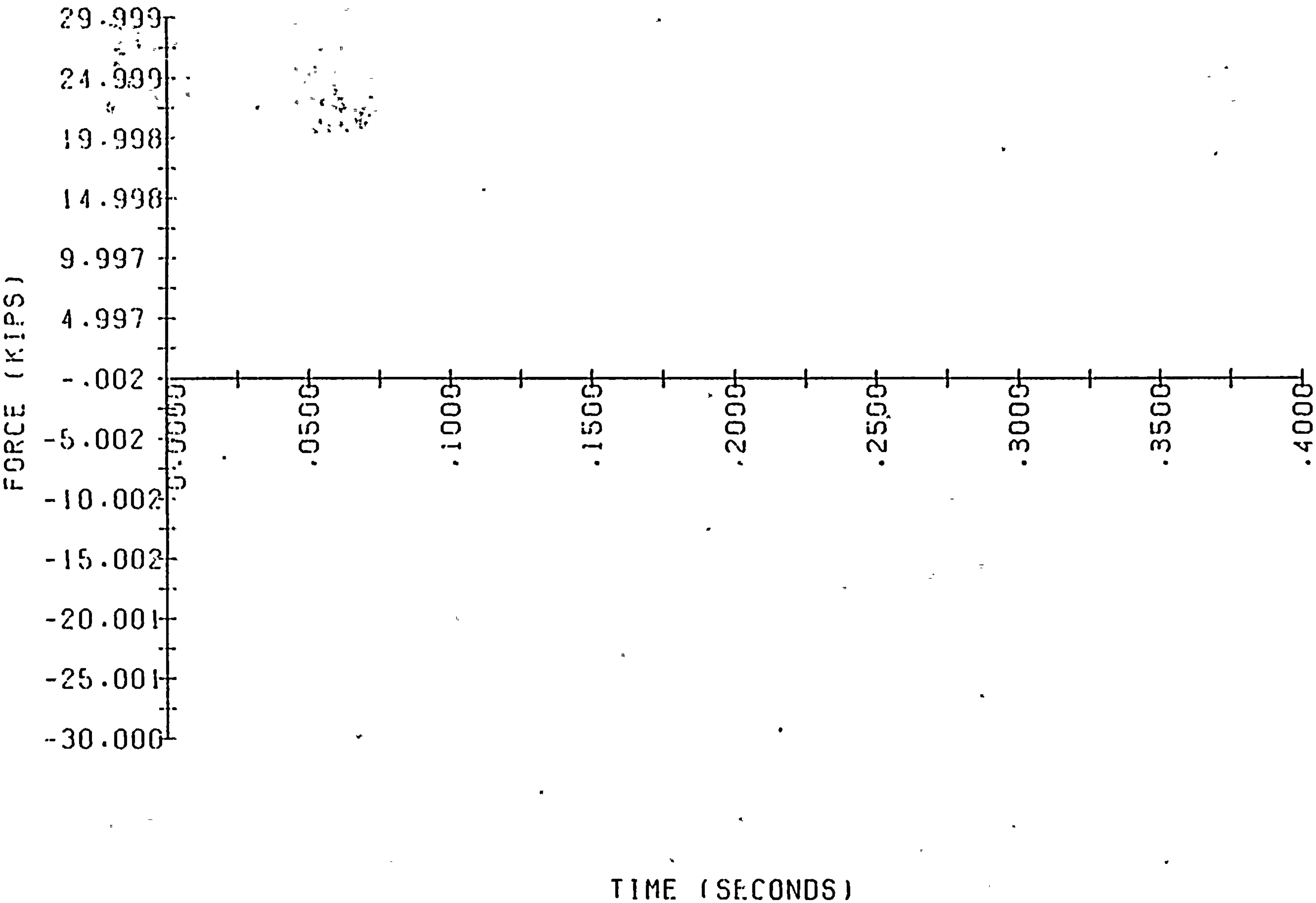
*********** FORCE IN DAGS GAP NUMBER 32 ***********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



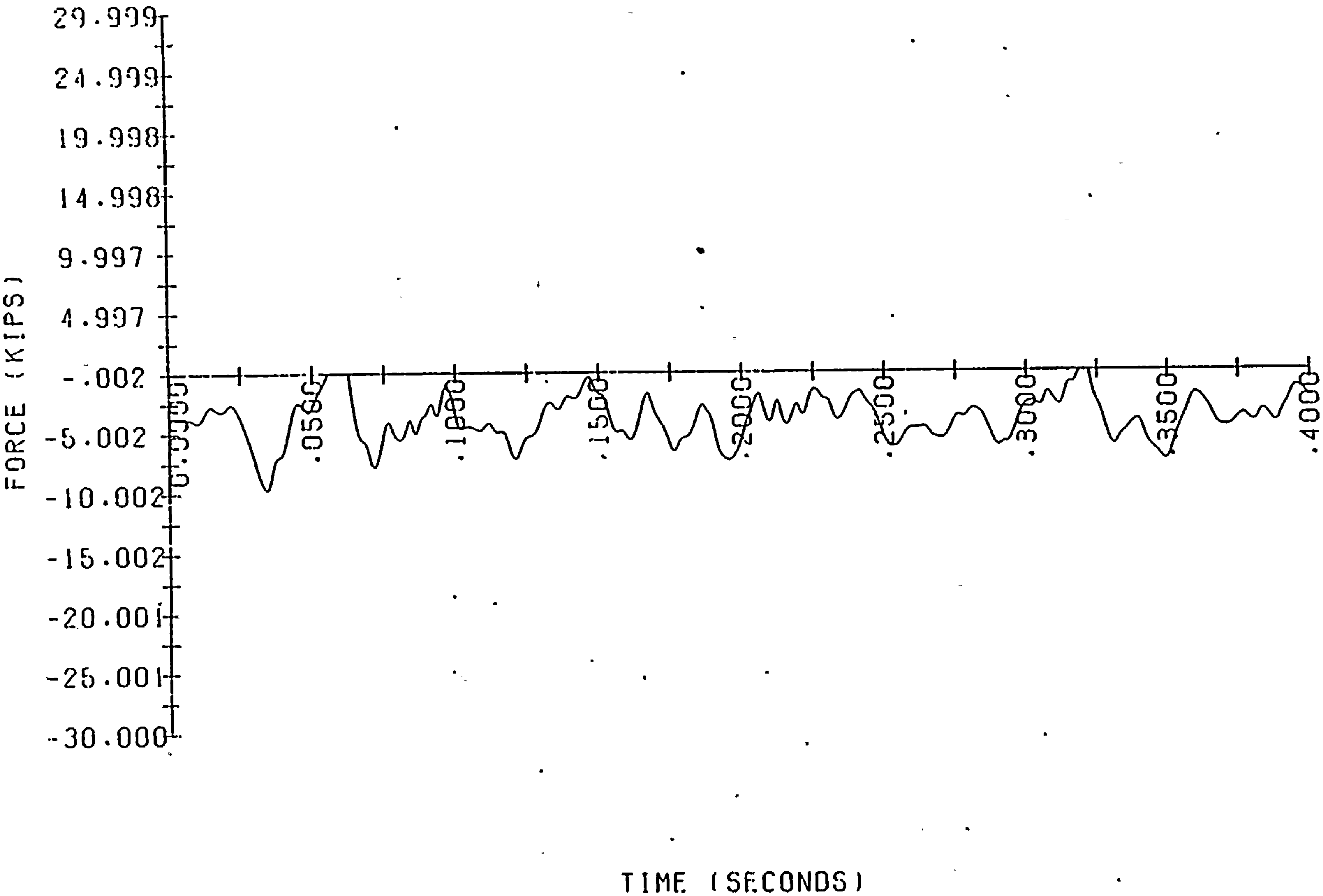
********** FORCE IN DAGS GAP NUMBER 33 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



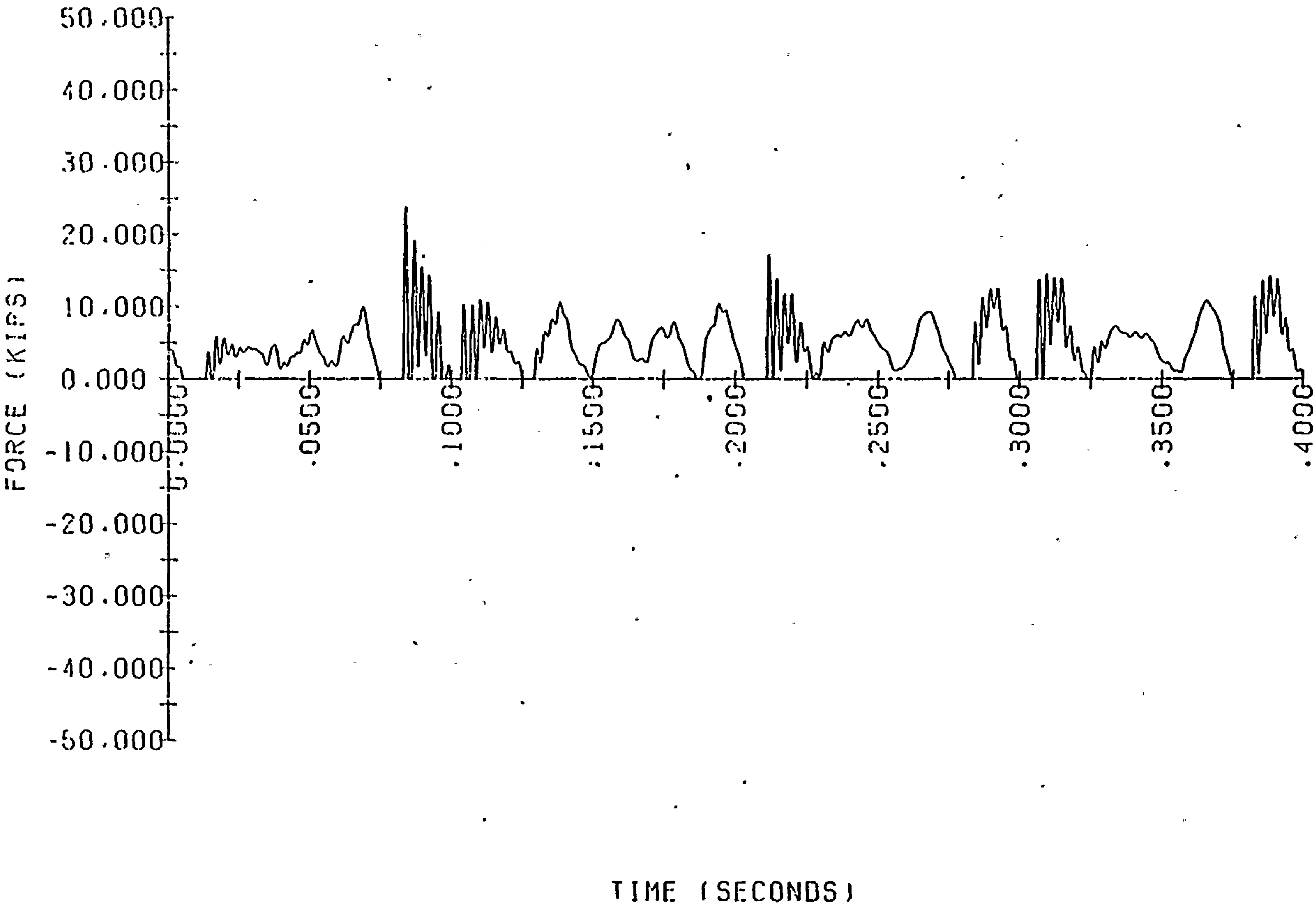
********** FORCE IN DAGS GAP NUMBER 34 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



********** FORCE IN DAGS GAP NUMBER 35 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



********** FORCE IN DAGS GAP NUMBER 36 **********

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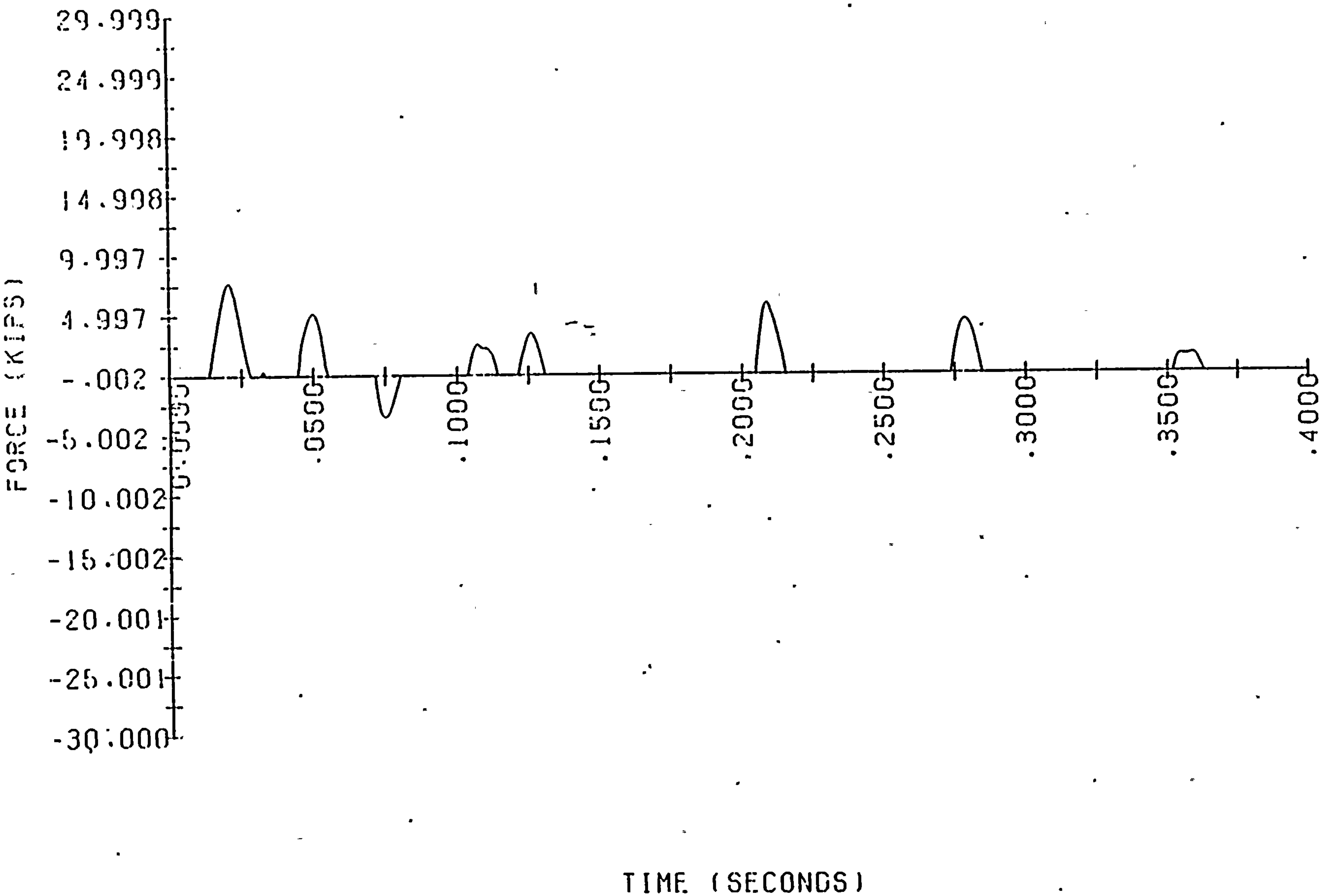
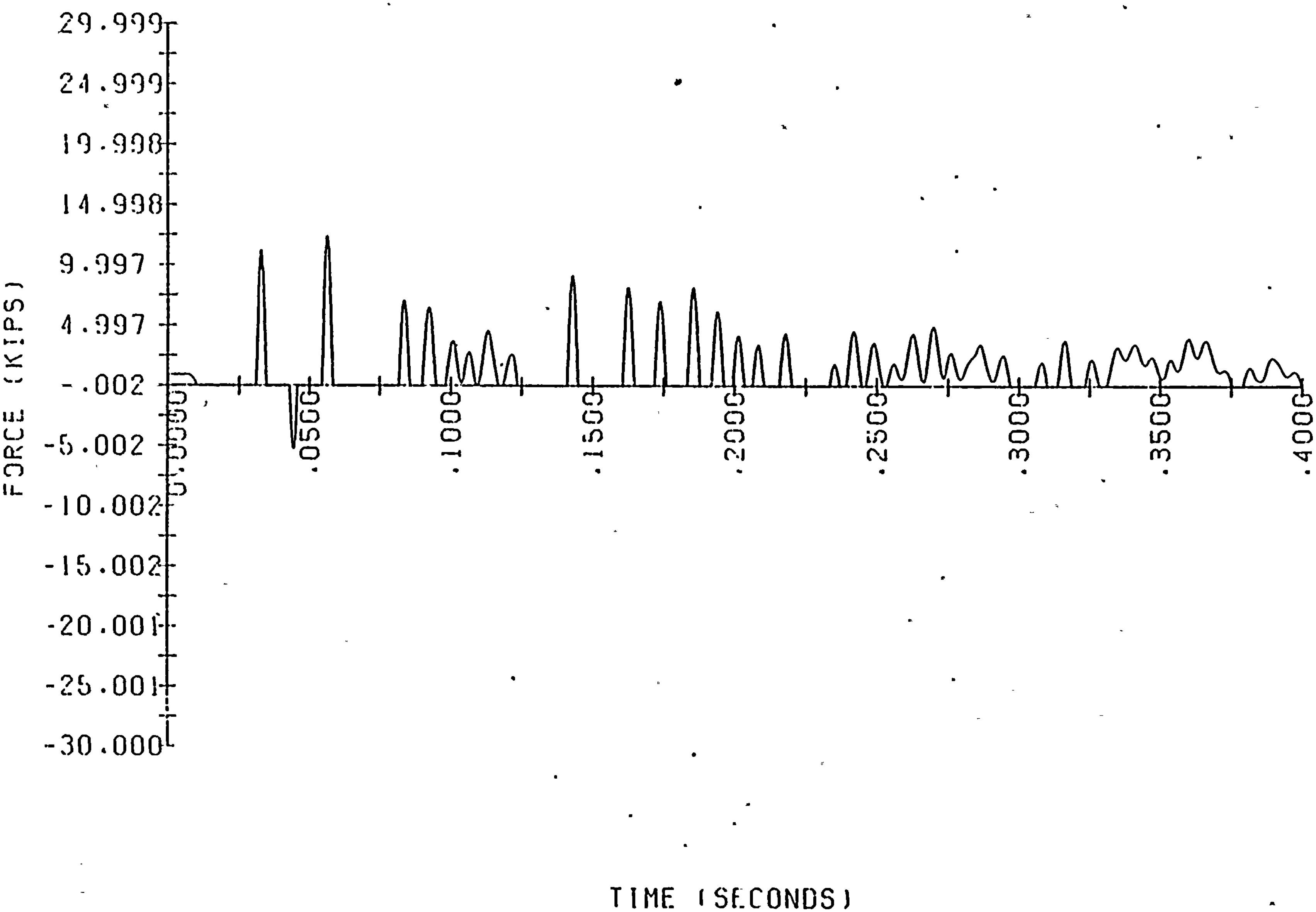


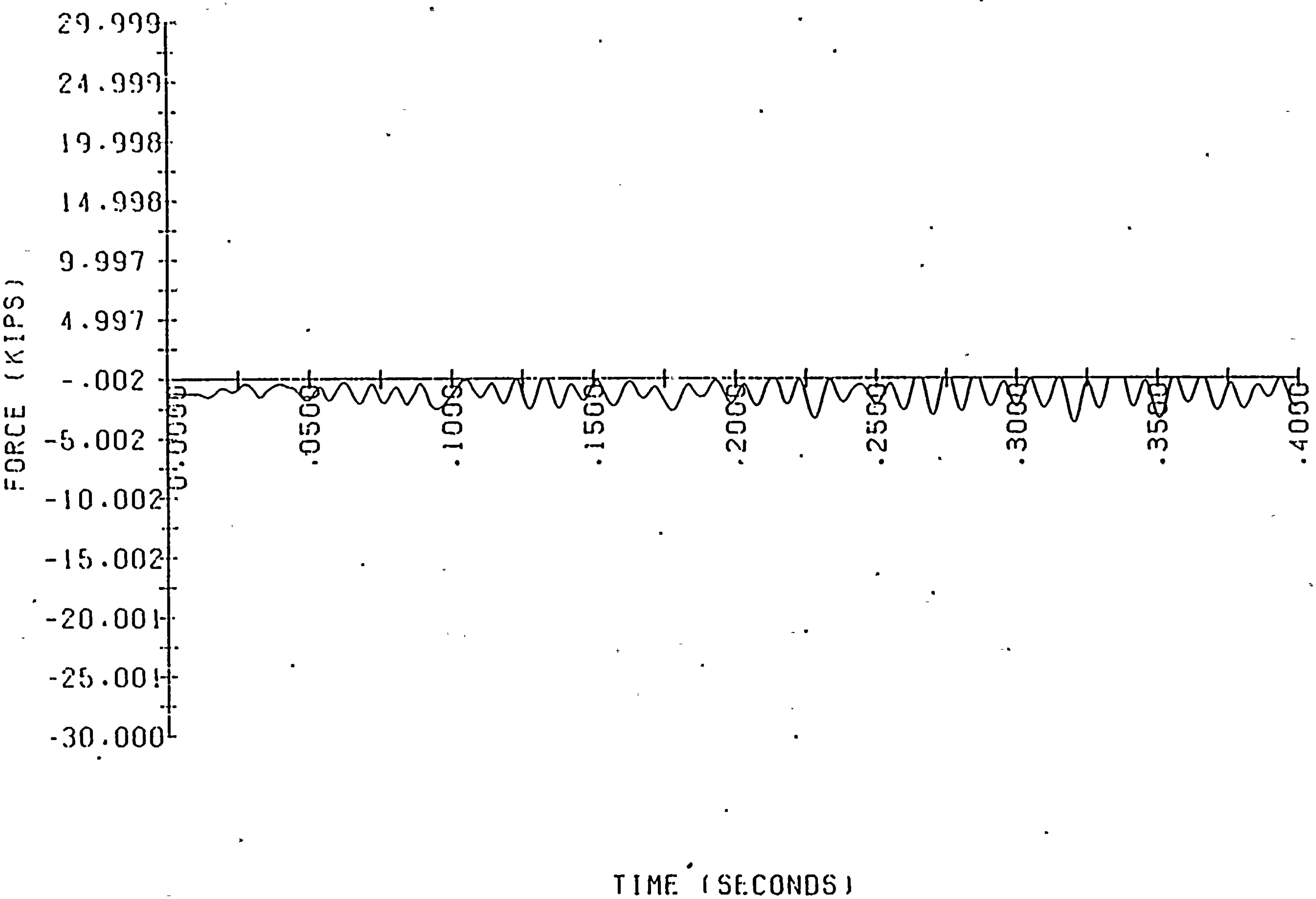
********** FORCE IN DACS GAP NUMBER 37 **********

PALO VERDE P/R SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



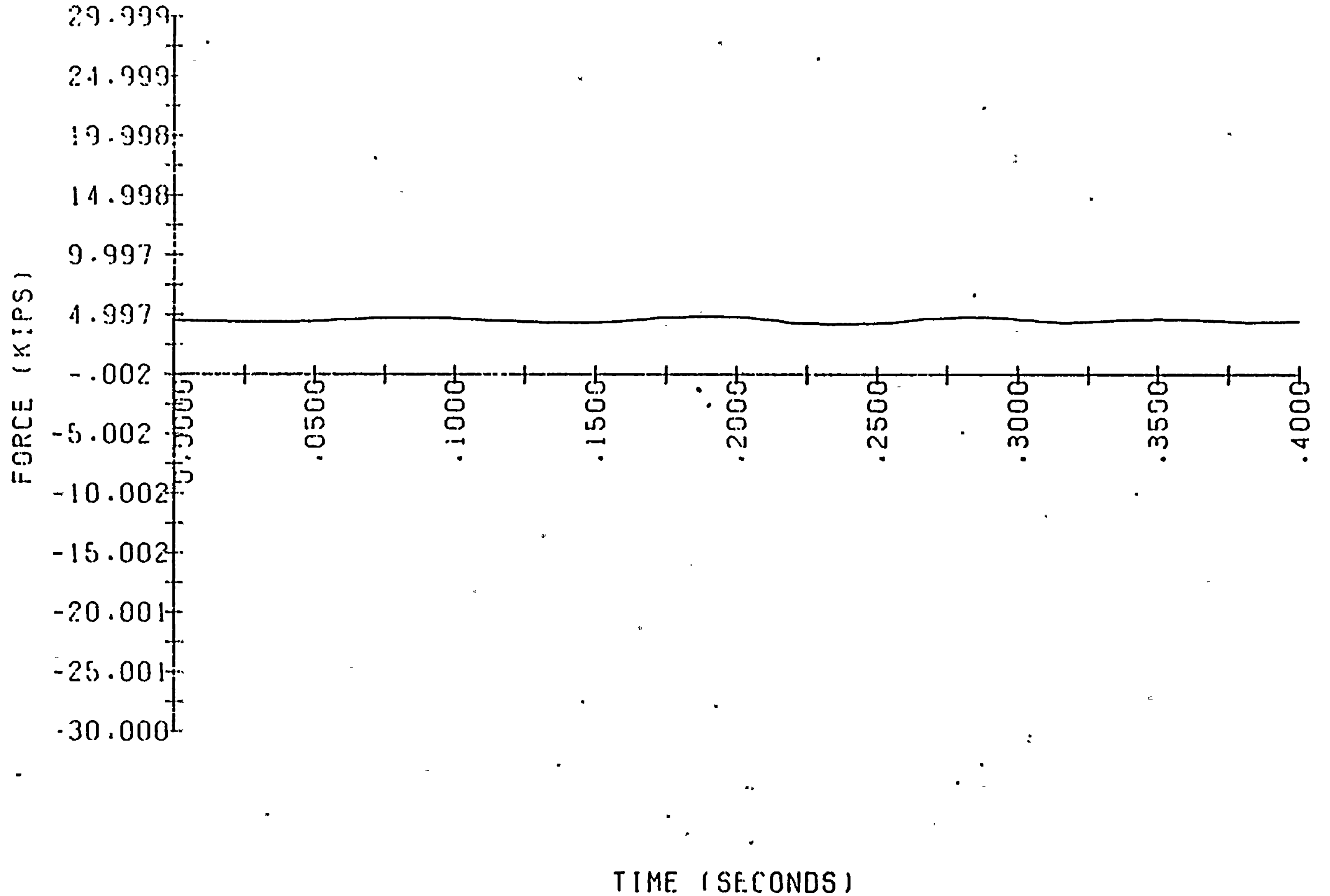
********** FORCE IN DAGS GAP NUMBER 38 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



********** FORCE IN DAGS GAP NUMBER 39 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



********** FORCE IN DAGS GAP NUMBER 40 **********
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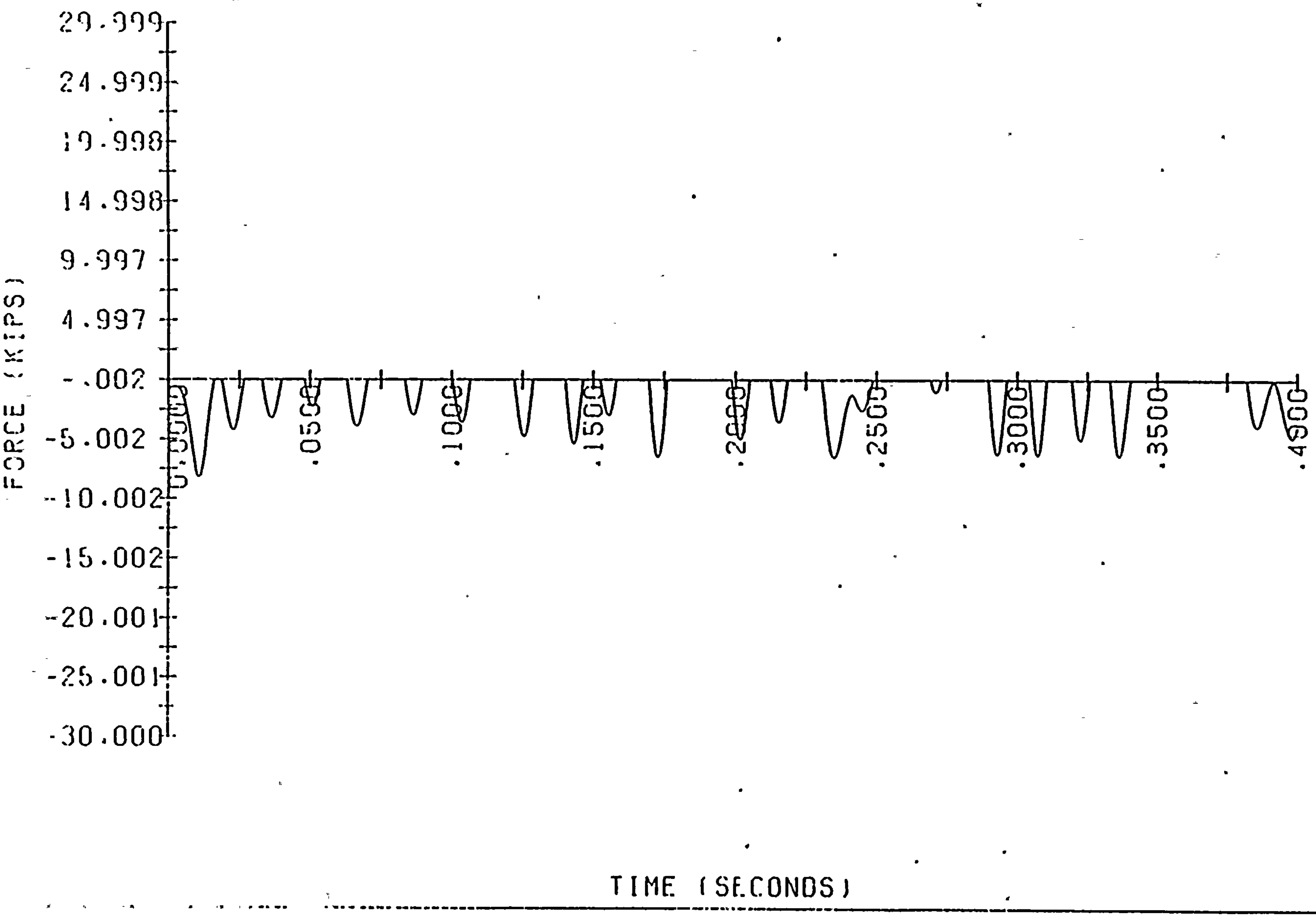
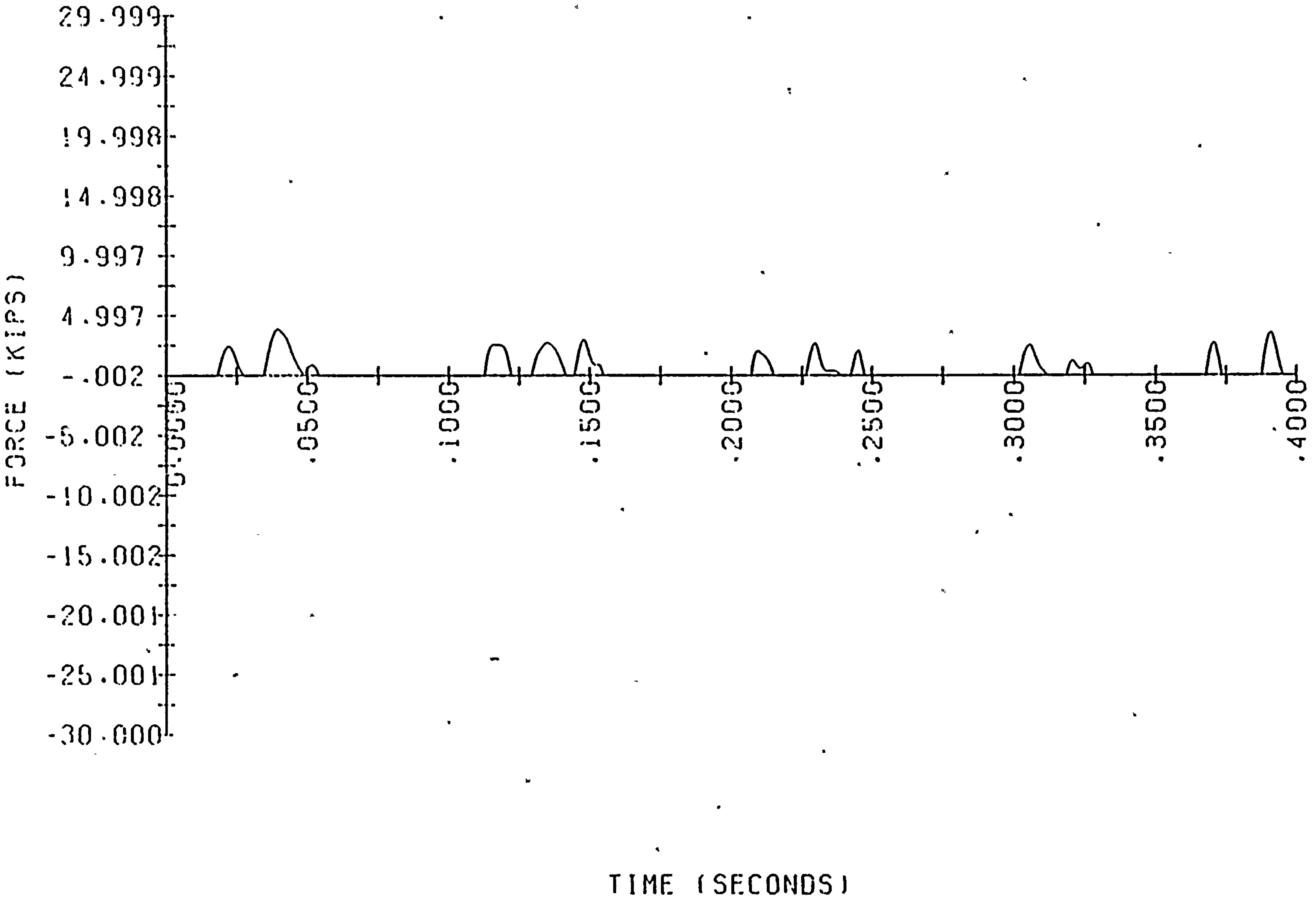


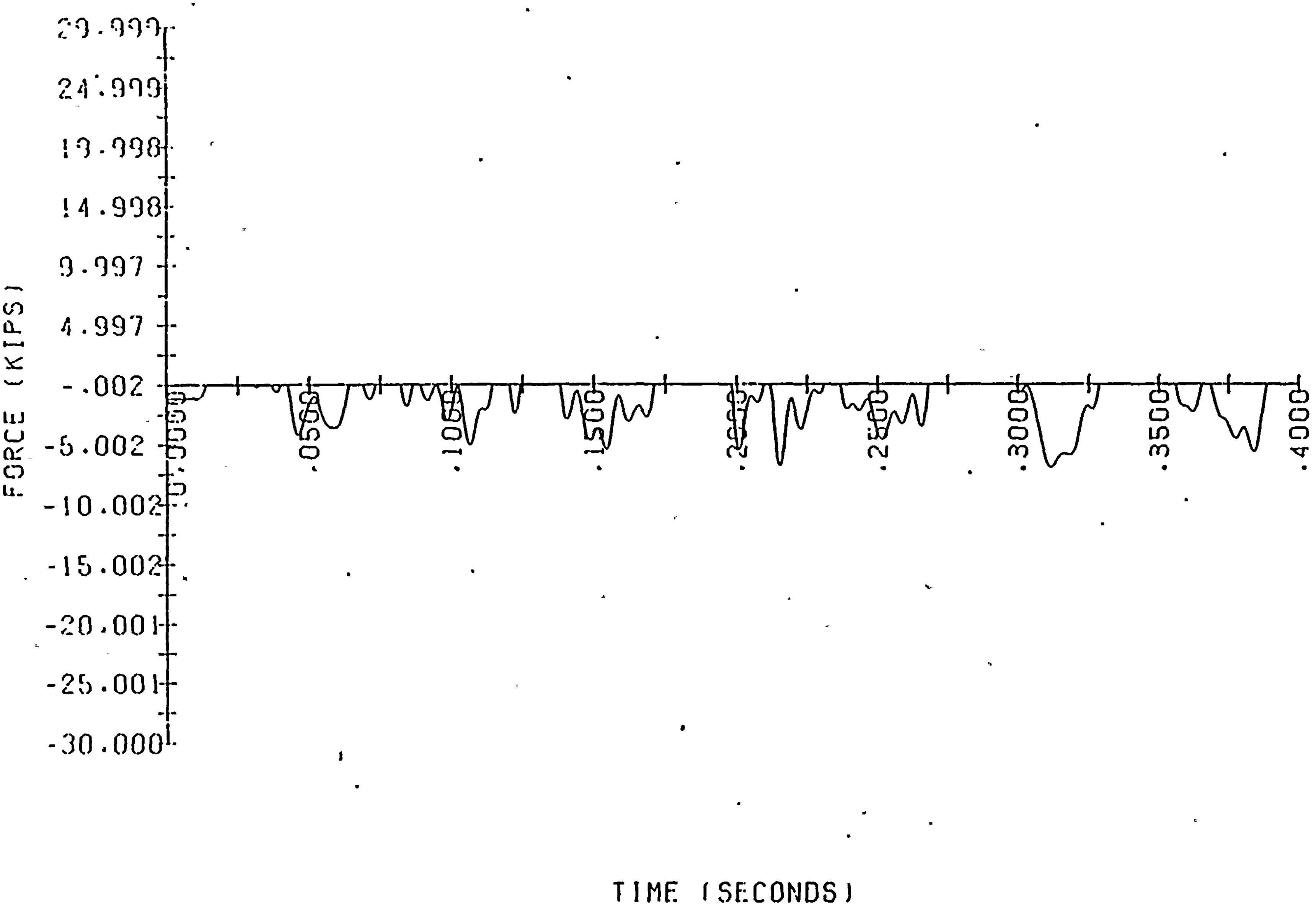
********** FORCE IN DAGS GAP NUMBER 41 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



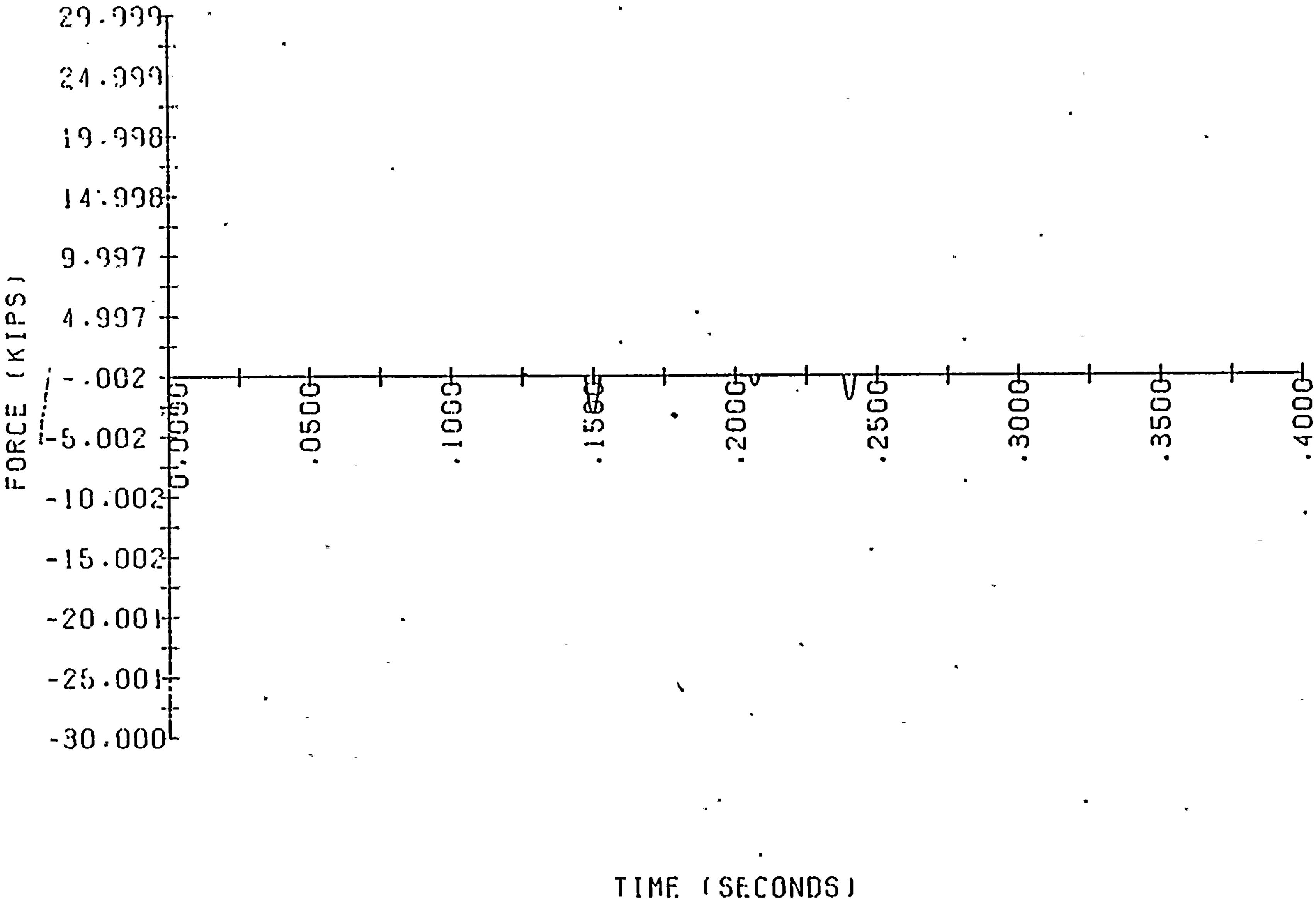
********** FORCE IN DAGS GAP NUMBER 42 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



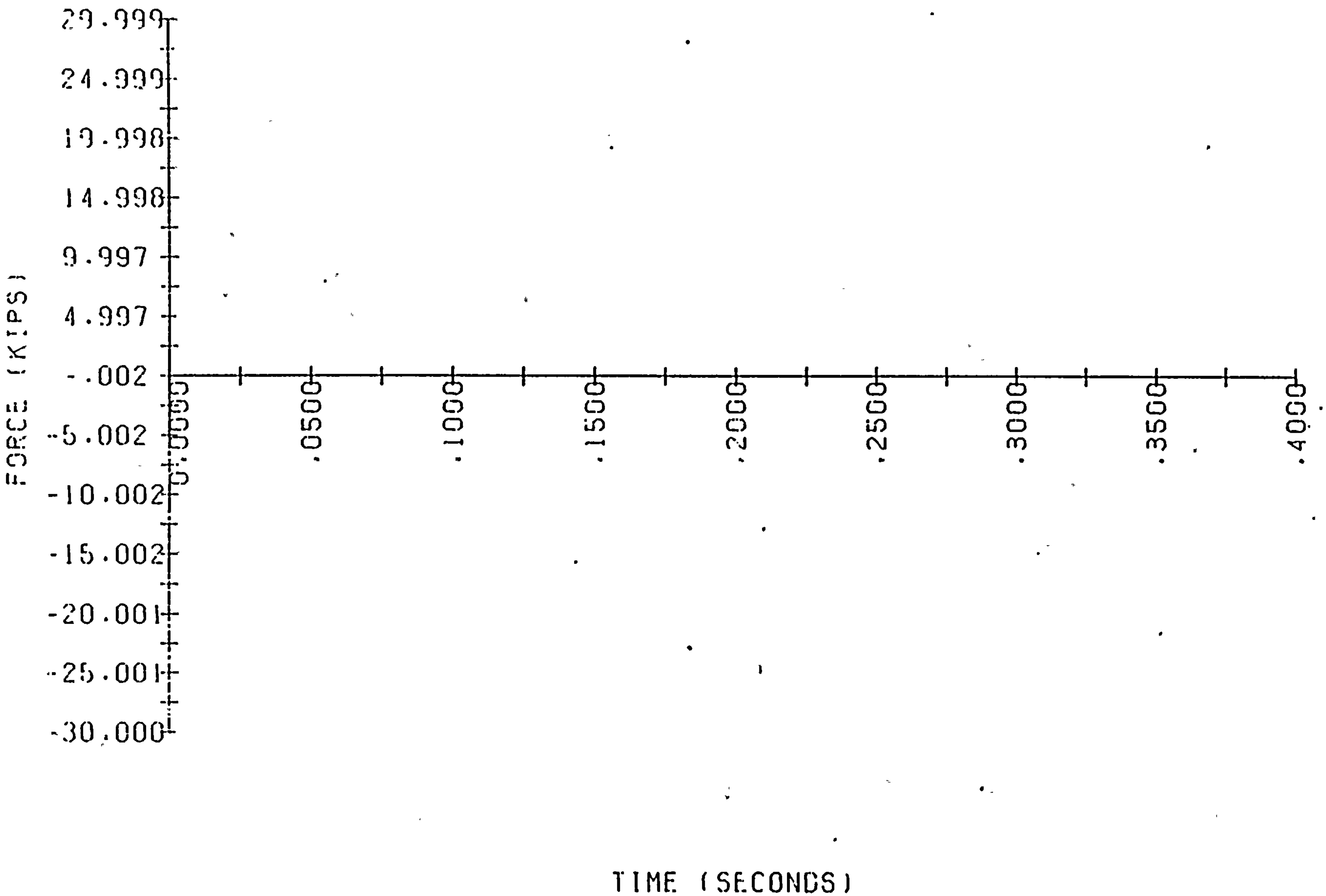
*********** FORCE IN DAGS GAP NUMBER 43 ***********

PALO VERDE P/R SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



********** FORCE IN DAGS GAP NUMBER 44 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



********** FORCE IN DAGS GAP NUMBER 45 **********

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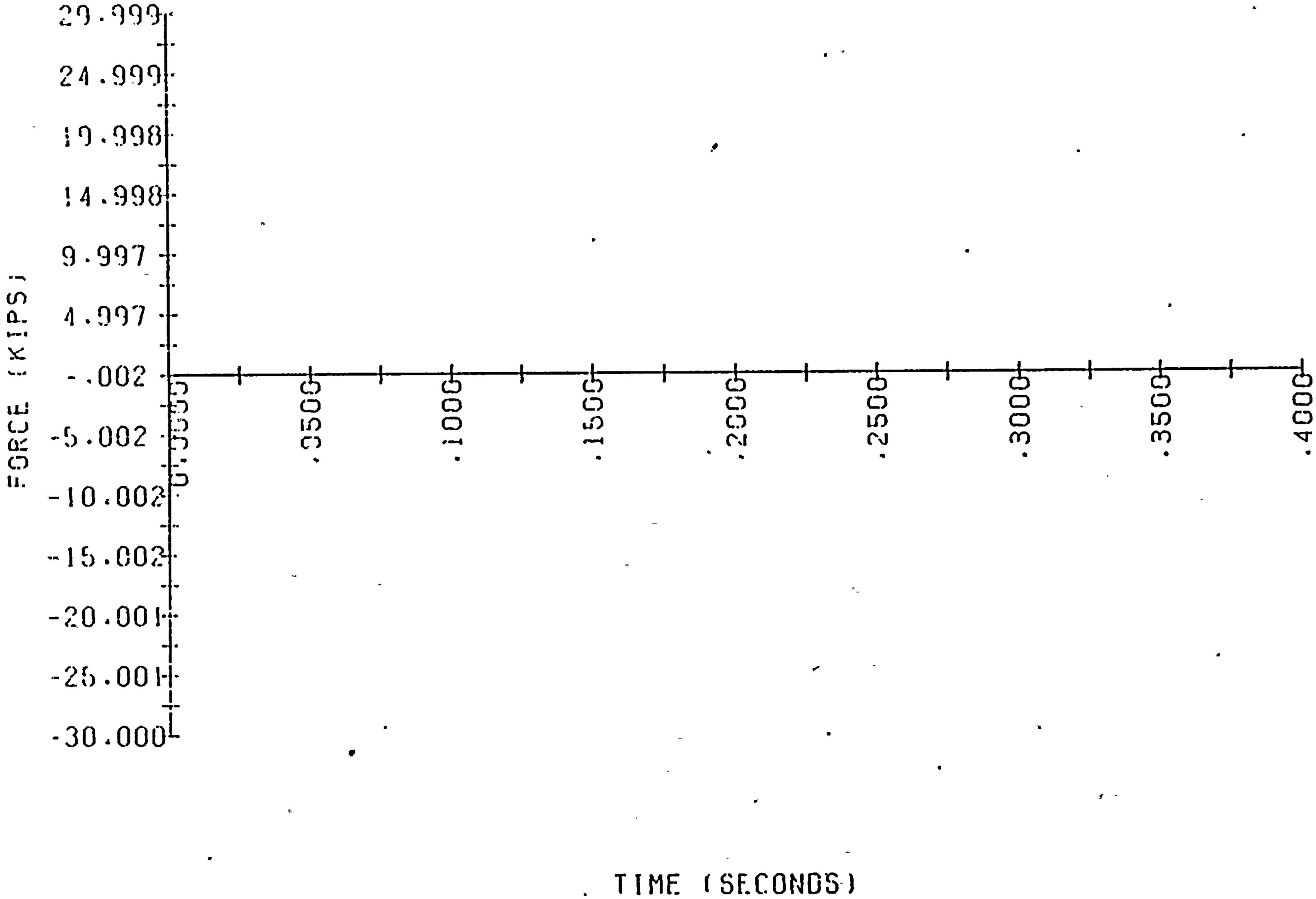

********** FORCE IN DAGS GAP NUMBER 46 **********

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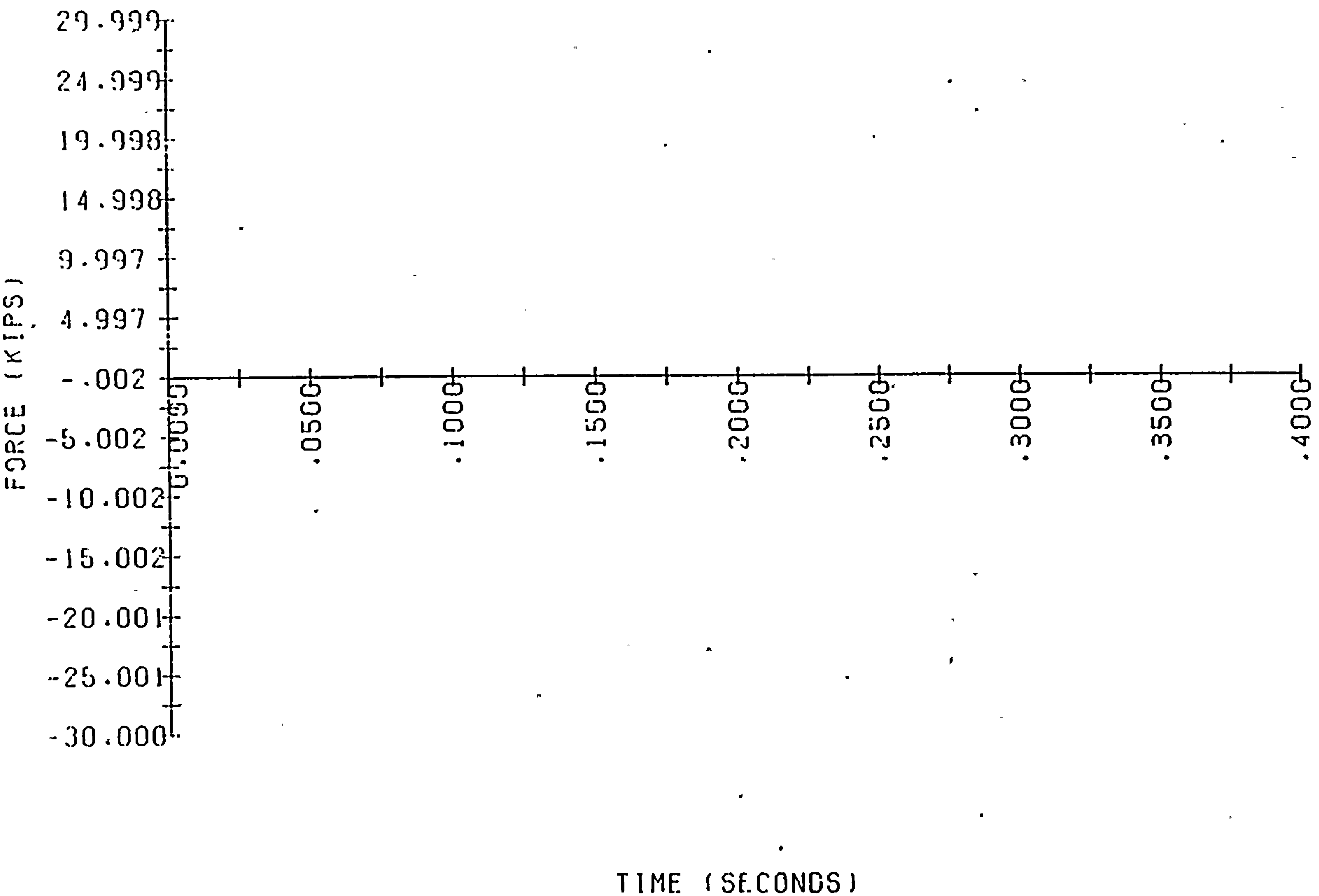
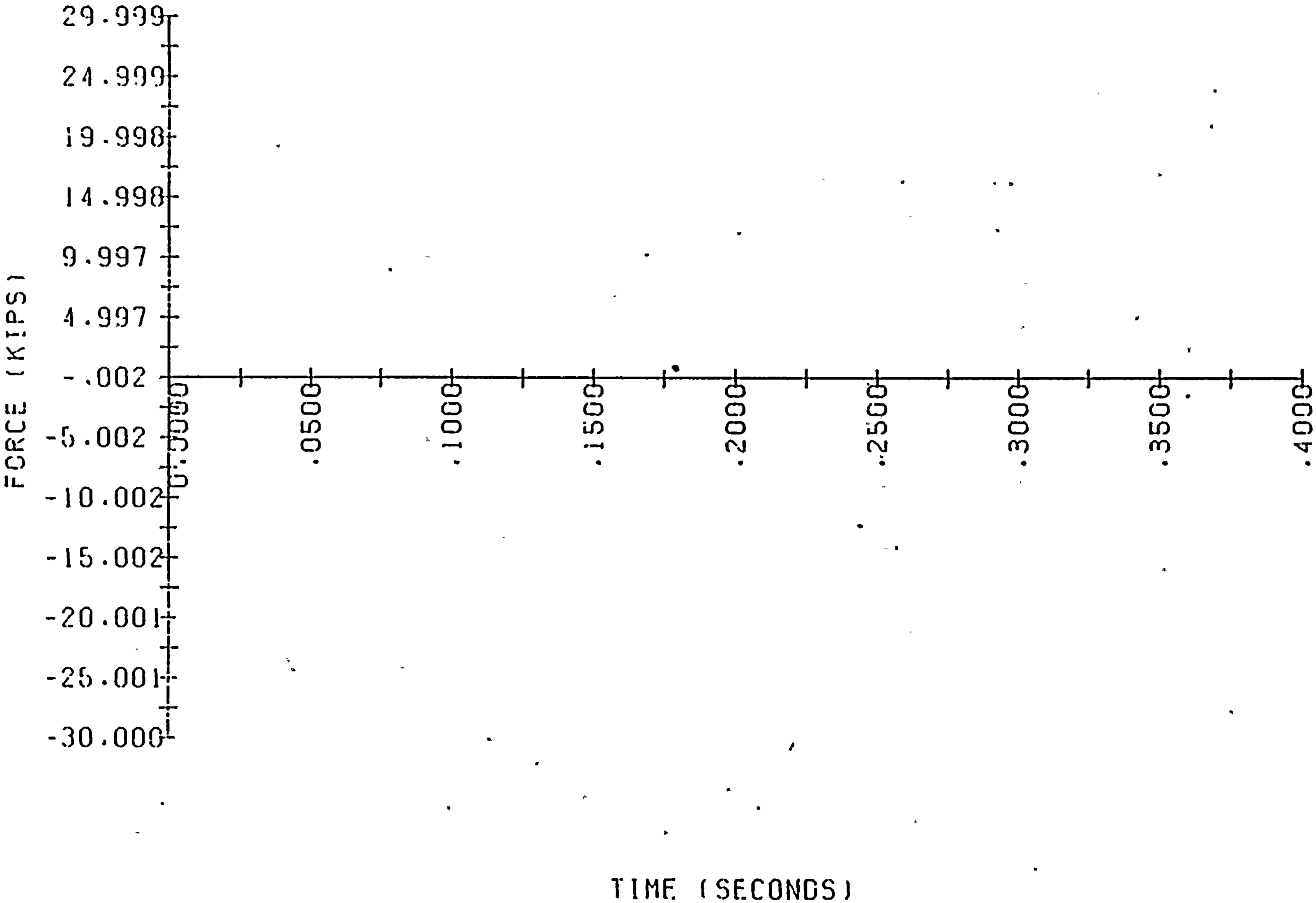


********** FORCE IN DAGS GAP NUMBER 47 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS



********** FORCE IN DAGS GAP NUMBER 48 **********

PALO VERDE PZR SV DISCHARGE PIPING SUPPORT LOADS (W/GAP) - 4 VALVES SIMULTANEOUS