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R5FORCE: A PROGRAM TO COMPUTE FLUID INDUCED FORCES USING HYDRODYNAMIC OUTPUT FROM THE RELAP5 CODE

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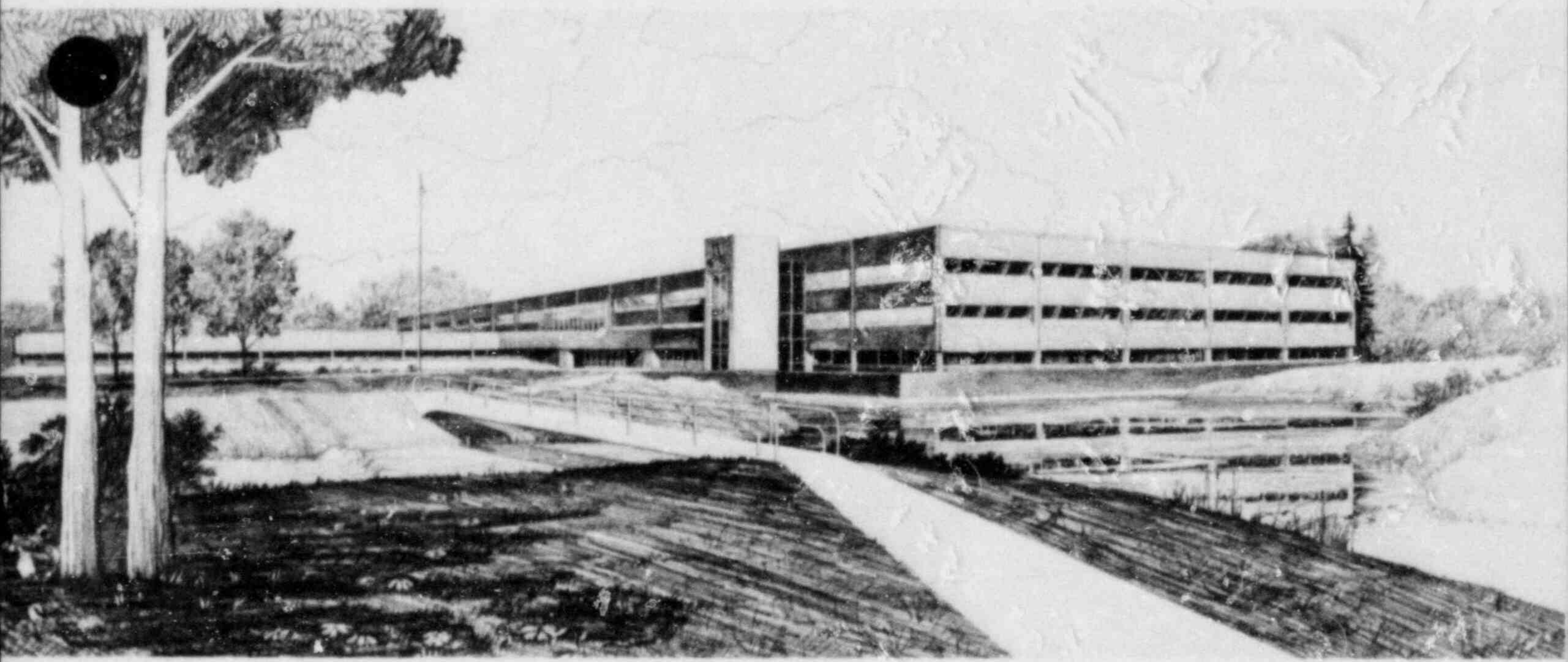
Operated by the U.S. Department of Energy



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INTERIM REPORT

ABSTRACT

This report describes the development of a computer program which operates on hydrodynamic output from the RELAP5/MOD1 program and computes piping hydrodynamic force/time histories for input into various structural analysis codes. The report describes the force calculation theory, showing the development of a general force equation and the solution of this equation within the RELAP5 output structure. To illustrate the calculational method and provide results for discussion, a sample problem is presented. A detailed user manual for the computer program is included as an appendix.

The work was performed in support of the NRC Safety/Relief Valve Program for which EG&G Idaho acted as the System Integrator.

SUMMARY

This report describes the development of a computer program that uses hydrodynamic output from the RELAP5/MOD1 program and computes piping hydraulic force/time histories for input into various structural analysis codes. This program is considered an improvement over existing force calculation techniques available at EG&G Idaho because it solves the force equation using the pressure and wall shear force terms instead of the pressure and fluid acceleration terms, eliminating potential instabilities associated with computing the time derivative in the fluid acceleration term; and uses output from the RELAP5/MOD1 program, an advanced one-dimensional computer program which is fast, accurate and easy to use.

A general equation was constructed to describe the force exerted on a container. This general equation is applicable to a wide variety of pipe force situations and serves as the fundamental relationship for the calculation program. Forces are computed for each RELAP5 hydrodynamic control volume, then summed over designated control volumes to obtain the total force.

The computer program R5FORCE is designed to operate on input, output and calculational phases. During the input phase, system geometry data and user input data are read, stored in memory, and then used to set up control arrays. The calculation phase involves a progression through the RELAP5 output data where all required forces are computed and written to an output file. Upon completion of the requested force calculations, the program provides a summary identifying the maximum positive and negative forces encountered for each volume force, subforce and combined force requested, including the time of the maximum force.

A sample problem was considered to illustrate the calculational technique and provide results for discussion. Two sample problems were used to create results for comparison with existing force calculation techniques available at EG&G Idaho, Inc. The same system was used for both sample problems and consisted of a supply vessel connected by a valve to an

accumulator which was then connected to a relief valve through a short length of piping; a section of relief valve discharge piping was also included. The first transient consisted of a steam filled relief valve inlet line in which the supply vessel pressure was increased until the relief valve opened. The valve separating the supply vessel and the accumulator was then closed, allowing the accumulator to blowdown until the relief valve closed. The second transient was identical to the first except the loop seal in the relief valve inlet piping was filled with subcooled liquid. Force calculations were performed for each transient and results are presented later in this report.

A detailed user manual for R5FORCE is included as an appendix to this report.

CONTENTS

FIGURES

R5FORCE: A PROGRAM TO COMPUTE FLUID INDUCED FORCES USING HYDRODYNAMIC OUTPUT FROM THE RELAP5 CODE

1. INTRODUCTION

There are currently available a number of computer programs (such as RELAP5[1] and TRAC[2]) that have the capability of simulating the transient and steady-state flow behavior in piping systems under both single and two-phase flow conditions. In each of these programs, the primary effort was directed towards predicting the flow behavior in the piping system but did not included the calculation of fluid induced forces. For the design and analysis of piping systems (such as relief valve discharge piping, or systems undergoing pipe rupture, or abnormal valve or pump operation), fluid forces on the piping are an important portion of the overall structural analysis and must be computed.

This report describes the development of a computer program that operates on hydrodynamic output from the RELAP5/MOD1 program and computes piping hydraulic force/time histories for input into various structural analysis codes, such as NUPIPE,[3] SAP[4] OR ADINA[5]. This program is considered an improvement over existing force calculation techniques available at EG&G Idaho (References 6 and 7) because it solves the force equation using the pressure and wall shear force terms instead of the pressure and fluid acceleration terms, eliminating potential instabilities associated with computing the time derivative in the fluid acceleration term; and uses output from the RELAP5/MOD1 program, an advanced one-dimensional computer program that is fast, accurate and easy to use.

Section 2 of this report is a description of the force calculation theory showing the development of a general force equation and how it applies to various system geometries. Section 3 details how these force equations are then solved within the RELAP5 output structure. The resulting computer program R5FORCE is described in Section 4. To illustrate the calculational method and provide results for discussion, a sample problem is considered in Section 5. In Section 6, this sample problem and a slightly modified form of this problem are used in a comparison study with previously existing calculational techniques available at EG&G Idaho. Section 7 includes several conclusions from this work. A detailed user manual for the R5FORCE program is included as an appendix to this report.

This work was conducted for the Nuclear Regulatory Commission's Safety/Relief Valve Program and fulfills a portion of the task described in References 7 and 8. This report will assist in auditing utility safety/relief valve system analyses as requested by the NRC.

2. FORCE CALCULATION THEORY

2.1 General Equation

It is possible to derive a general equation for the net force exerted on a container based upon the following assumptions:

1. Neglect external fluid velocity and shear force effects
2. One-dimensional uniform cross sectional area control volume
3. Normal stress approximated by the quasi steady change in momentum (the local dynamic pressure plus the fluid momentum)
4. Uniform fluid velocity, density, and pressure over the local cross sectional area and uniform shear over the local control volume surface area.

Based on the cross sectional view of the arbitrary shaped container and the notation specified in Figure 1, this equation can be expressed as

$$F = - (P_{I1} + \rho_I u_I^2) A_{I1} + (P_{I2} + \rho_I u_I^2) A_{I2} + P_{E1} A_{E1} - P_{E2} A_{E2} + \tau A_s \quad (1)$$

where

A = volume surface area

P = fluid pressure

u = fluid velocity

ρ = fluid density

τ = shear force per unit area

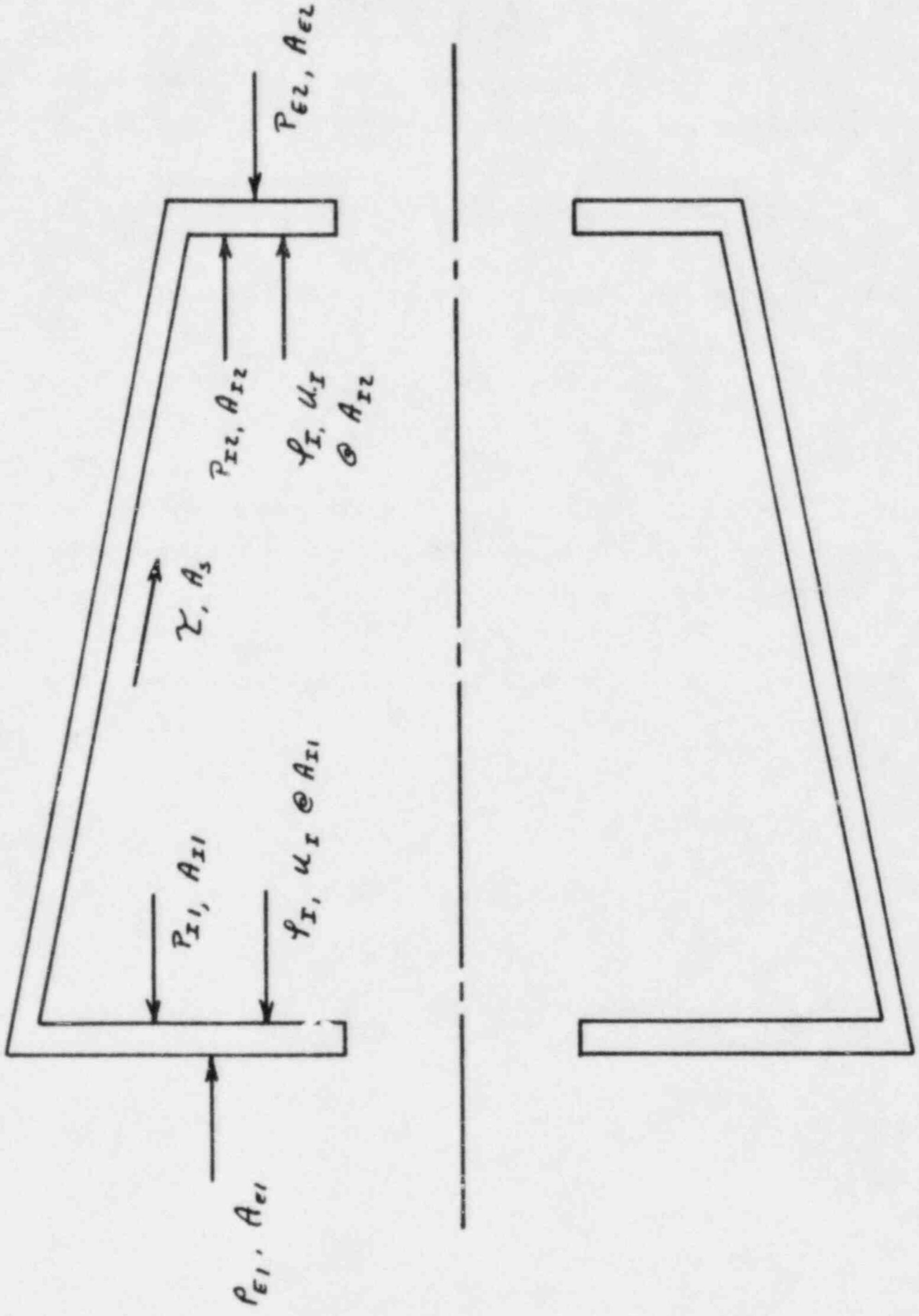

Figure 1. Generalized fluid container

and the subscripts (I) and (E) refer to interior or external conditions, the subscripts (1) and (2) refer to the volume inlet or outlet and the subscript (s) refers to the interior surface area parallel to the flow. The first four terms in this equation represent the forces resulting from the pressure and momentum at Control Surfaces CS1 and CS2. The fifth term represents the force resulting from fluid shear on Control Surface CS3. Starting from basic principles, a detailed development of Equation (1) is included in Appendix A. This equation applies to a wide variety of pipe force situations and serves as the fundamental relationship for the calculation program described herein.

A dynamic structural analysis of a piping system requires that forces be applied, in terms of time histories, at various points or node locations in the piping model. These nodes are generally located near components that result in either a change in flow direction or flow area (such as elbows or bends, reducers, valves or an open pipe end). Since the application of Equation (1) makes it possible to compute a net force for each volume in the hydrodynamic analysis, the total force at any particular node location can be considered to be the sum of the individual forces of each hydrodynamic volume within the control volume defining the nodal force.

Equation (1) is made up of five terms. Two of these terms represent forces associated with the volume inlet junction, two with the volume outlet junction and one with the volume itself. The application of Equation (1) will differ depending on the type of volume end geometry. In particular, a volume can be connected to an adjoining volume in one of four ways:

1. Continued--Adjacent volumes are at the same angle, such as Volumes CV2 and CV3 in Figure 2

2. Bounded--Adjacent volumes are at different angles, such as Volumes CV3 and CV4 in Figure 2

3. Open--A volume represents the end of a pipe, although continued to an adjacent volume in the RELAP5 model, such as Volume CV4 in Figure 2

4. Special--Mechanistic junction models, such as the relief valve between Volumes CV1 and CV2 in Figure 2.

These geometries can also contain area changes between adjacent volumes and a constant or variable throat ratio, simulating an orifice or a valve. Each of these geometries will be discussed in greater detail below.

2.2 Continued Junction

From the previous discussion, the junction connecting Volumes CV2 and CV3 in Figure 2 can be considered to be continued since there is no change in direction between the adjacent volumes. Applying the applicable portions of Equation (1) to the inlet and outlet junctions of a general hydrodynamic control volume results in:

$$F_1 = -(P_{I1} + \rho_I u_I^2) A_{I1} + P_{E1} A_{E1}$$

$$F_2 = (P_{I2} + \rho_I u_I^2) A_{I2} - P_{E2} A_{E2}$$

where

P = fluid pressure

ρ = fluid density

u = fluid velocity

A = area

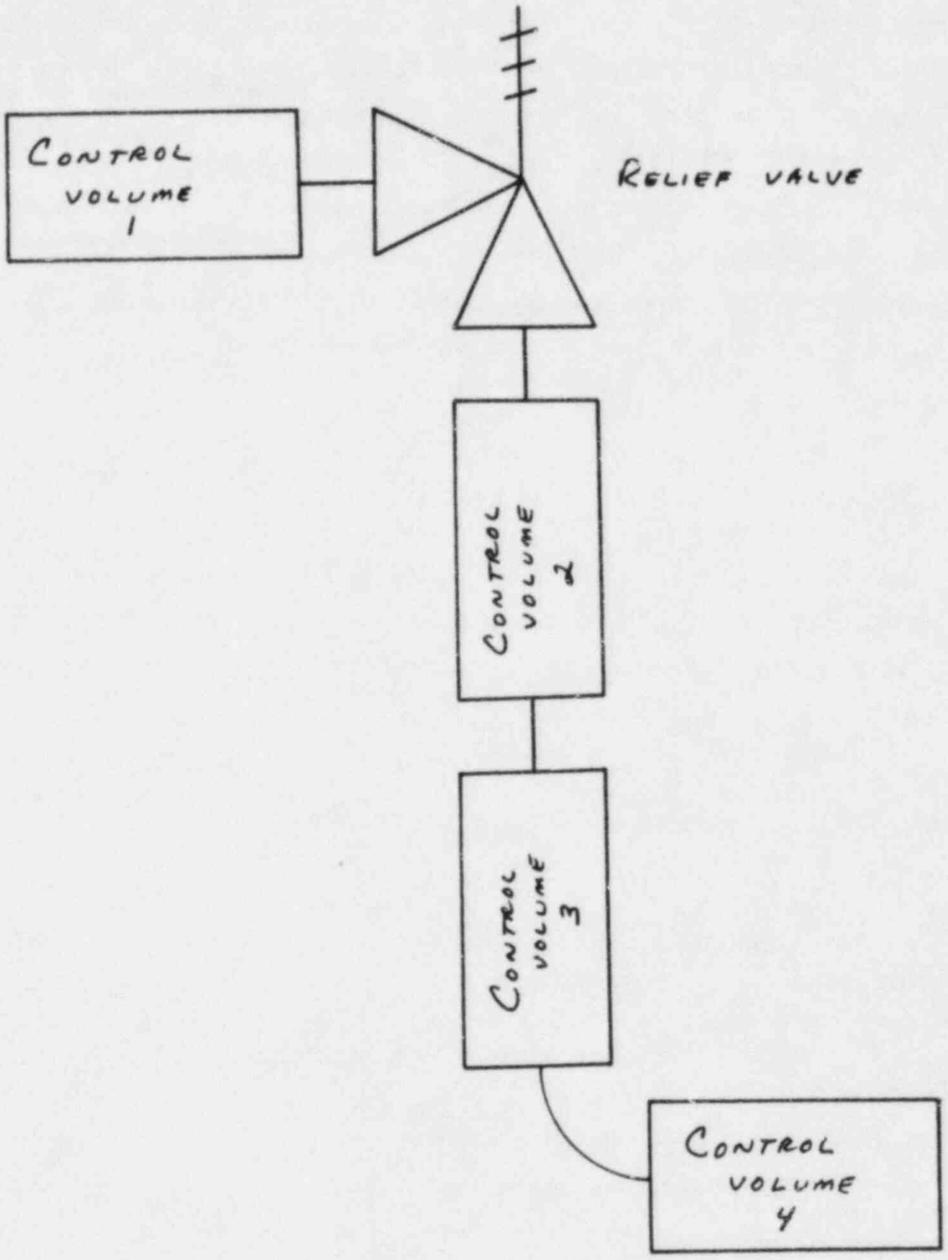

Figure 2. Typical piping/control volume system.

and the subscripts (I) and (E) refer to internal and external conditions, and the subscripts (1) and (2) refer to the inlet and outlet junctions of a control volume, respectively. Thus, there are four internal parameters (P, ρ, u, A) and two external parameters (P, A) that must be determined for the inlet and outlet junction of each control volume.

The external pressure at the inlet and outlet junction are available from the input data to R5FORC. The internal change in momentum and area at the inlet and outlet junction are not available directly in RELAP5, however, they can be computed as discussed in Appendix B.

2.3 Bounded Junction

The junction connecting Volumes CV3 and CV4 in Figure 2 can be considered to be bounded since there is a change in direction between adjacent volumes. Applying the applicable portions of Equation (1) to the inlet and outlet junctions of a general hydrodynamic control volume results in:

$$F_1 = -(P_{I1} + \rho_I u_I^2) A_{I1} + P_{E1} A_{E1}$$

$$F_2 = (P_{I2} + \rho_I u_I^2) A_{I2} - P_{E2} A_{E2}$$

Note: When the $(P + \rho u_I^2)(A)$ term was evaluated for a continued type of junction, the $(P + \rho u_I^2)$ term corresponded to the pressure and momentum approximated from volume conditions impinging on a flow area restriction. For a bounded type of junction, this force will still exist in addition to the force resulting from the pressure and momentum at the junction acting on the pipe during the bend. Expanding the above expressions to account for these force developing areas results in:

$$F_1 = -(P_{I1} + \rho_I u_I^2) A_{I1} - (P_{I1} + \rho_{IJ1} u_{IJ1}^2) A_{IJ1} + P_{E1} A_{E1}$$

$$F_2 = (P_{I2} + \rho_I u_I^2) A_{I2} + (P_{I2} + \rho_{IJ2} u_{IJ2}^2) A_{IJ2} - P_{E2} A_{E2}$$

where the subscript (J) refers to junction conditions.

Note: Since the force on each hydrodynamic control volume is computed, then summed over one or more control volumes with the same elevational angle, the results will be independent of the geometric relationship of the volumes on the other side of a bend. Thus, the results are not dependent on any particular bend angle.

2.4 Open Junction

The outlet junction of Volume CV4 in Figure 2 can be considered to be open, representative of the end of a pipe. Since an open pipe is at the outlet of a piping system, only the outlet junction of a volume will be considered to be open. Applying the applicable portions of Equation (1) to the outlet junction of a general hydrodynamic control volume results in:

$$F_2 = (P_{I2} + \rho_I u_I^2) A_{I2} - P_{E2} A_{E2}$$

2.5 Special Junction

Because of the physical differences between an actual relief valve and the RELAP5 model of a relief valve, the junction connecting Volumes CV1 and CV2 in Figure 2 must be treated with a special mechanistic model. Two special mechanistic models currently exist in the code, one of which is a relief valve model with the orifice on the inlet and the other is a relief valve with the orifice on the outlet. Both of these mechanistic models assume the control volumes connected to the relief valve inlet and outlet are at an angle to each other. Applying the applicable portions of

Equation (1) to the valve inlet (outlet junction of the preceding control volume) and outlet (inlet junction of the following control volume) where the orifice is on the valve outlet results in:

$$F_1 = -(P_{I1} + \rho_I u_I^2) A_{I1} - (P_{IJ1} + \rho_{IJ1} u_{IJ1}^2) A_{IJ1} + P_{E1} A_{E1}$$

$$F_2 = (P_{I2} + \rho_I u_I^2) A_{I2} - P_{E2} A_{E2}$$

where the valve outlet force (F_1) is defined as though it were a bounded junction and the valve inlet force (F_2) is defined as though it were a continued junction, except that area A_{I2} is the full area of the pipe. For the case of the relief valve orifice being on the valve inlet, the above equations would be reversed.

3. COUPLING TO RELAP5

The numerical solution of the two-phase flow equations in RELAP5 is accomplished through the use of a spatial mesh of hydrodynamic control volumes connected by junctions. Fluid properties are defined at the center of each control volume (such as pressure, density and velocity) and at each junction (such as density and velocity). The application of Equation (1) makes it possible to compute a net force for each hydrodynamic control volume in the RELAP5 analysis. In general, each force control volume includes one or more control volumes. Moreover, the force acting on each control volume can be computed, then summed over an entire force control volume.

Examining Equation (1) yields several flow quantities that must be obtained from RELAP5 in order to evaluate the forces acting on a control volume.

These include the following:

1. Control volume pressure
2. Control volume momentum
3. Junction momentum
4. Indication of choking at a junction
5. Control volume shear force.

The control volume pressure is readily available as are the momentum terms and the indication of junction choking. However, both the control volume momentum and junction momentum must be modified for a two-phase flow situation as:

$$\rho u^2 = \alpha_g \rho_g u_g^2 + (1-\alpha_g) \rho_f u_f^2$$

where α is the void fraction and the subscripts (g) and (f) refer to the gas and fluid phases, respectively.

The control volume shear force term is not available directly in RELAP5, however, it can be computed as discussed in Appendix C. To correctly compute the fluid shear however, system components resulting in a frictional loss, such as elbows, must be modeled by modifing the volume roughness rather than by adding an energy loss coefficient at a junction. Modification of the volume roughness is also contained in Appendix C.

Using the internally computed properties, the following quantities are written to the RELAP5 output tape at every successful time step.

1. For each volume:

    a. Control volume pressure
    b. Total wall shear
    c. Control volume momentum

2. For each junction:

    a. Junction throat ratio
    b. Junction momentum
    c. Indication of junction choking

This information can then be used to compute the force on any RELAP5 control volume then summed over designated control volumes to obtain the total force.

4. THE COMPUTER PROGRAM

The computer program that solves the force equations and creates a force/time history is entitled R5FORCE. The program uses output data from RELAP5 in the format described in Appendix C; the code updates used to create this data file are also included in this appendix.

Figure 3 shows that R5FORCE operates in an input, calculational and output phase. During the input phase, system geometry data (available on the RELAP5 output tape) and user input data are read and stored in memory. This data is then used to set up integer control arrays that contain such information as the force reference numbers, direction indicator flags, and applicable RELAP5 junction and control volume numbers. Once the control arrays are established the calculation phase involves a progression through the RELAP5 output data, where all required forces are computed (at each RELAP5 computational time step) and then written to an output file; forces can also be printed at selected time steps. Upon completion of the requested force calculations, the program provides a summary identifying the maximum positive and negative forces encountered for each volume force, subforce, and combined force requested, including the time of the maximum force. In addition, each computed force can be output in a format suitable for plotting. Pressures at each RELAP5 control volume can also be written to an output file for use as input to structural analysis codes.

In order to be consistent with the basic equations solved in R5FORCE, the following conventions must be followed.

1. The RELAP5 model must be developed in the direction of positive flow.

2. The force direction must be colinear with the pipe axis, in any direction.

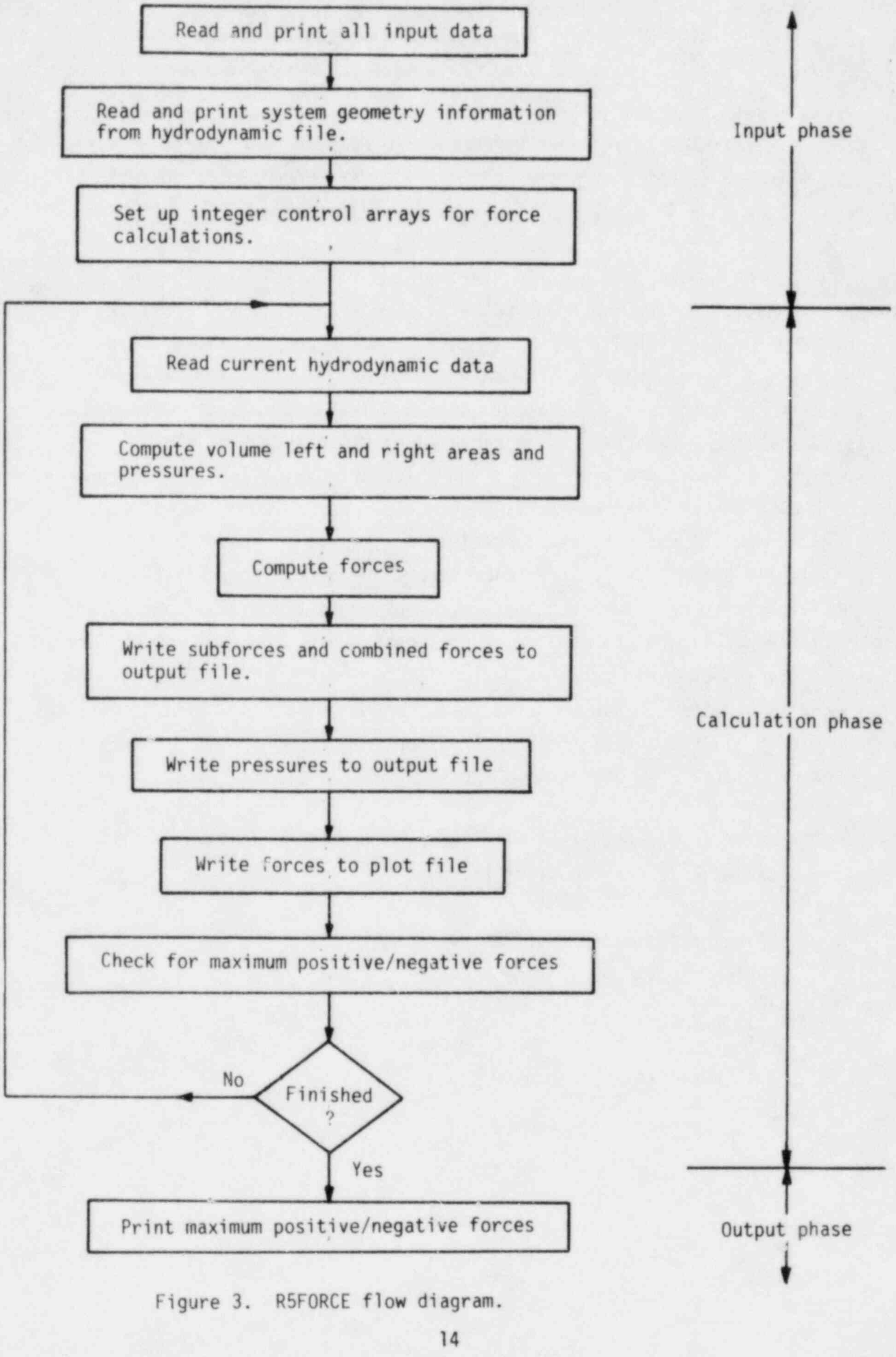

Figure 3. R5FORCE flow diagram.

3. System components resulting in a frictional loss, such as elbows, must be modeled by modifing the volume roughness term, not by the addition of an energy loss coefficient. Note: The roughness cannot be larger than half the volume diameter.

4. Branch components in RELAP5 cannot be included in the definition of a subforce or a combined force.

R5FORCE has been written using Control Data Corporation (CDC) FORTRAN Version 5. The intrinsic functions SHIFT, MASK, LOCF, CMMALF and ENCODE, which are CDC extensions to FORTRAN 77, are utilized and therefore make the program CDC dependent. A listing of R5FORCE is included in Appendix E.

5. SAMPLE PROBLEM

A sample problem is now considered in order to illustrate the application of the methods considered previously, and also to provide results for discussion. Detailed user input instructions for this sample problem are discussed in Appendix F of this report.

The sample problem consisted of a simple relief system as shown in Figure 4. The system involved a pressurized accumulator connected to a relief valve through a short length of piping which served as a loop seal. The relief valve discharge piping terminated as an open pipe segment.

A RELAP5/MOD1 hydrodynamic model of this system was used to generate an input file for force calculations. This model consisted of fluid control volumes connected by junctions and extended through the entire piping system. Each control volume and junction was described in terms of fluid state, geometry, and flow characteristics, with locations selected to ensure adequate representation of the fluid transient.

Upstream from the relief valve, the accumulator and piping initially contained saturated steam at a pressure of 16.55 MPa that was increased linearly to 18.27 MPa in 0.5 s. The discharge piping was assumed to be initially filled with saturated steam at atmospheric pressure; the downstream boundary was maintained at this pressure. The fluid transient considered involved a 40 ms relief valve opening beginning when the relief valve inlet pressure reached 17.24 MPa, which occurred at 0.21 s. Following the valve opening, steady flow in the piping was achieved at approximately 0.5 s, once the supply pressure stopped increasing. The valve separating the supply vessel and the accumulator remained open until 1.0 s, at which time it was closed, allowing the accumulator to blowdown until the relief valve closed at 16.38 MPa at 1.44 s. The problem was terminated at 2.0 s.

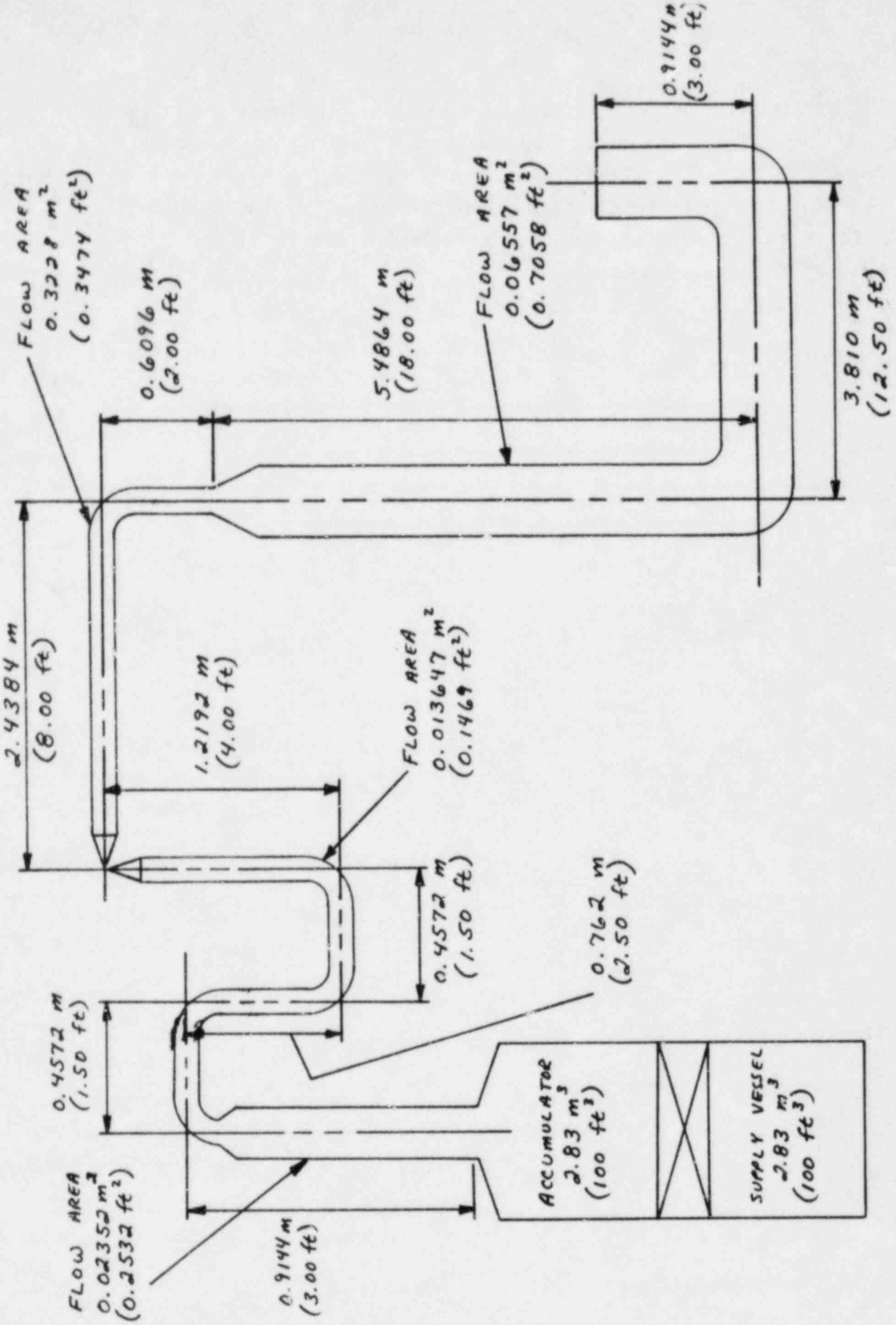

Figure 4. Piping system for sample problem.

A description of the various subforce and combined forces selected for discussion is shown in Figure 5. Figure 6 is a force/time history of subforces SF101 and SF103 which act on opposing elbows as shown in Figure 5, and Figure 7 is the force/time history for the combined force CF201. Figures 8 and 9 describe the subforces and combined force on a pipe leg which includes an area change.

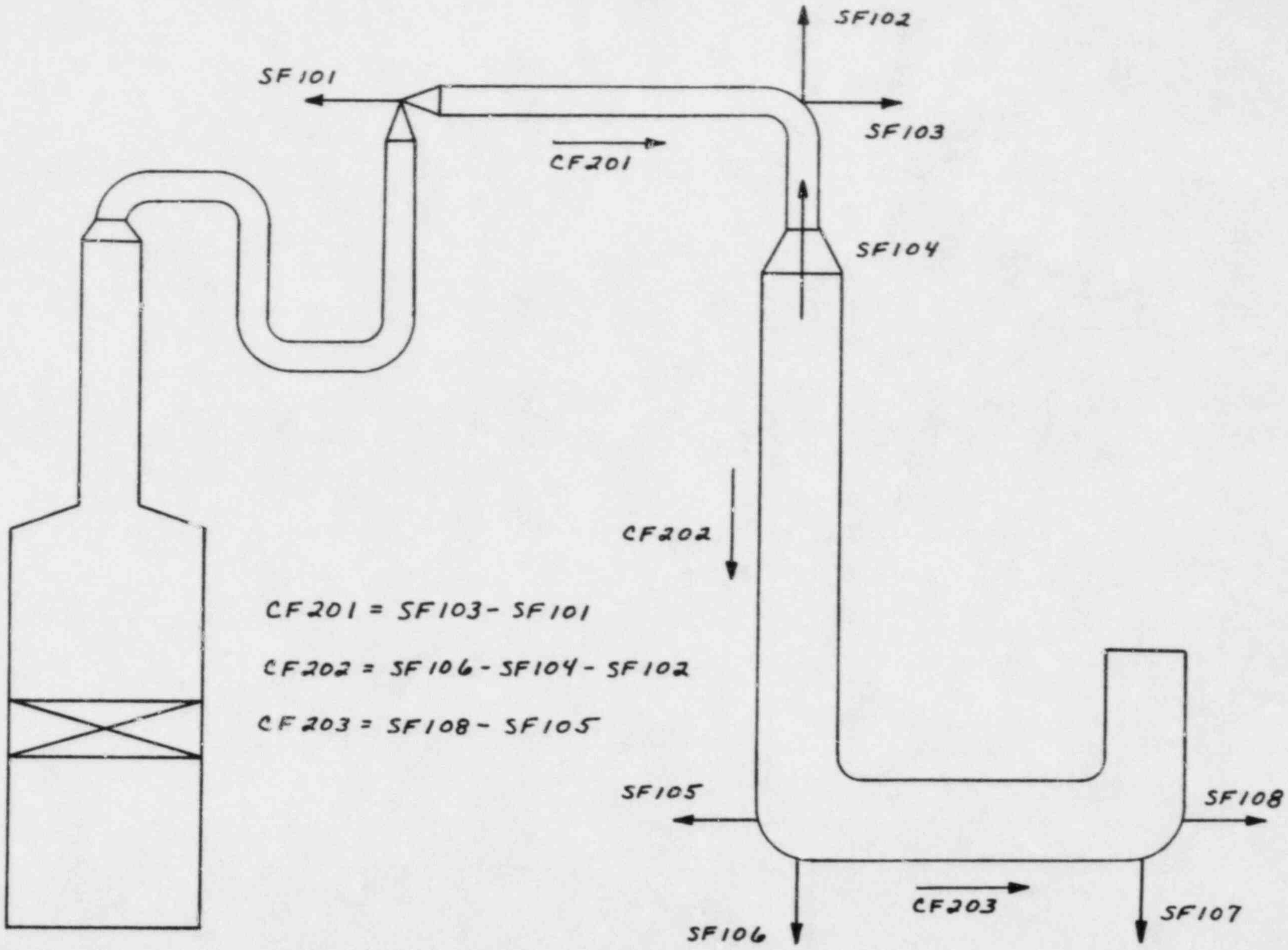

Figure 5. Sample piping system showing selected forces.

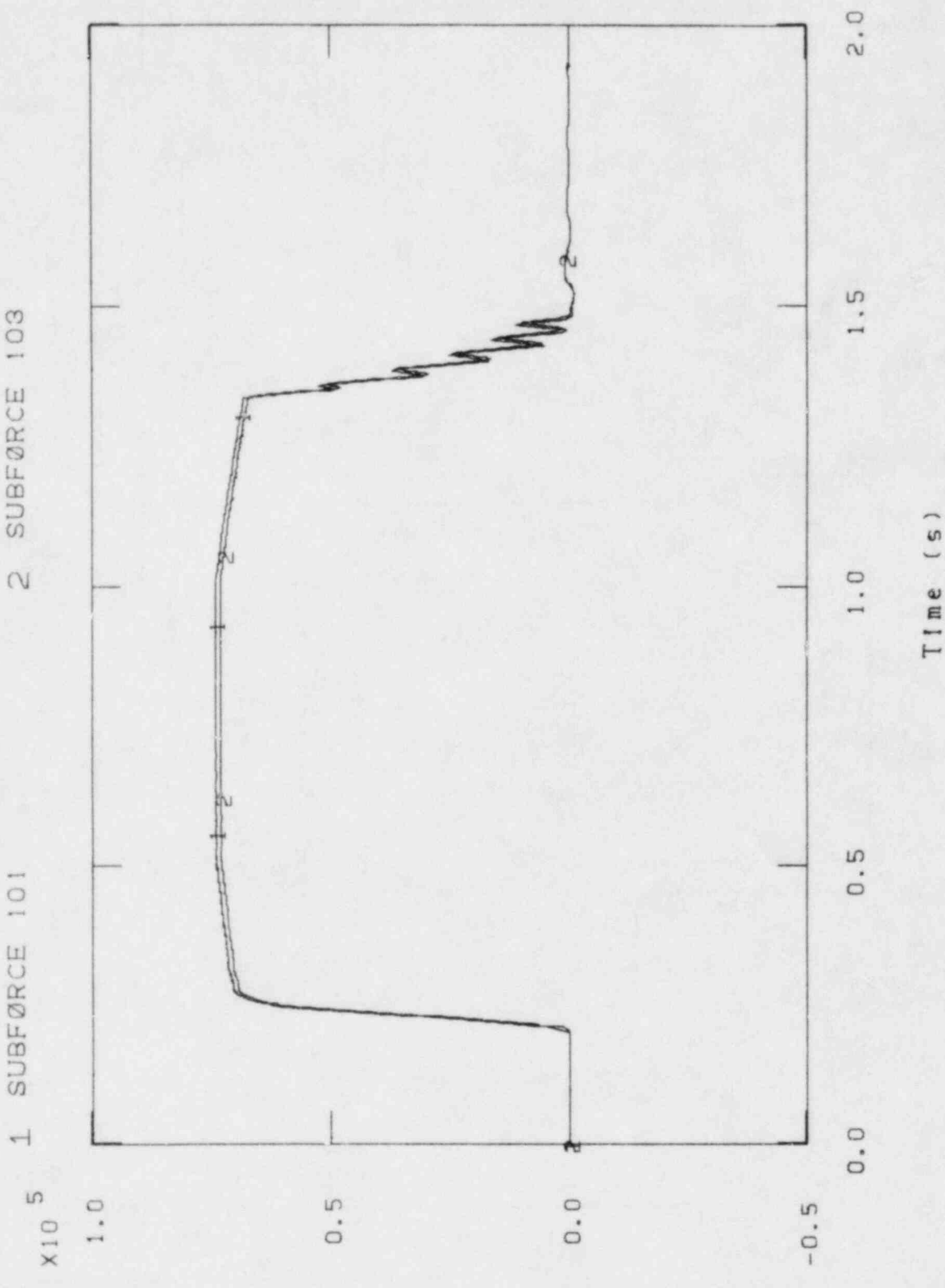

Figure 6. Subforces SF101 and SF103 for the sample problem.

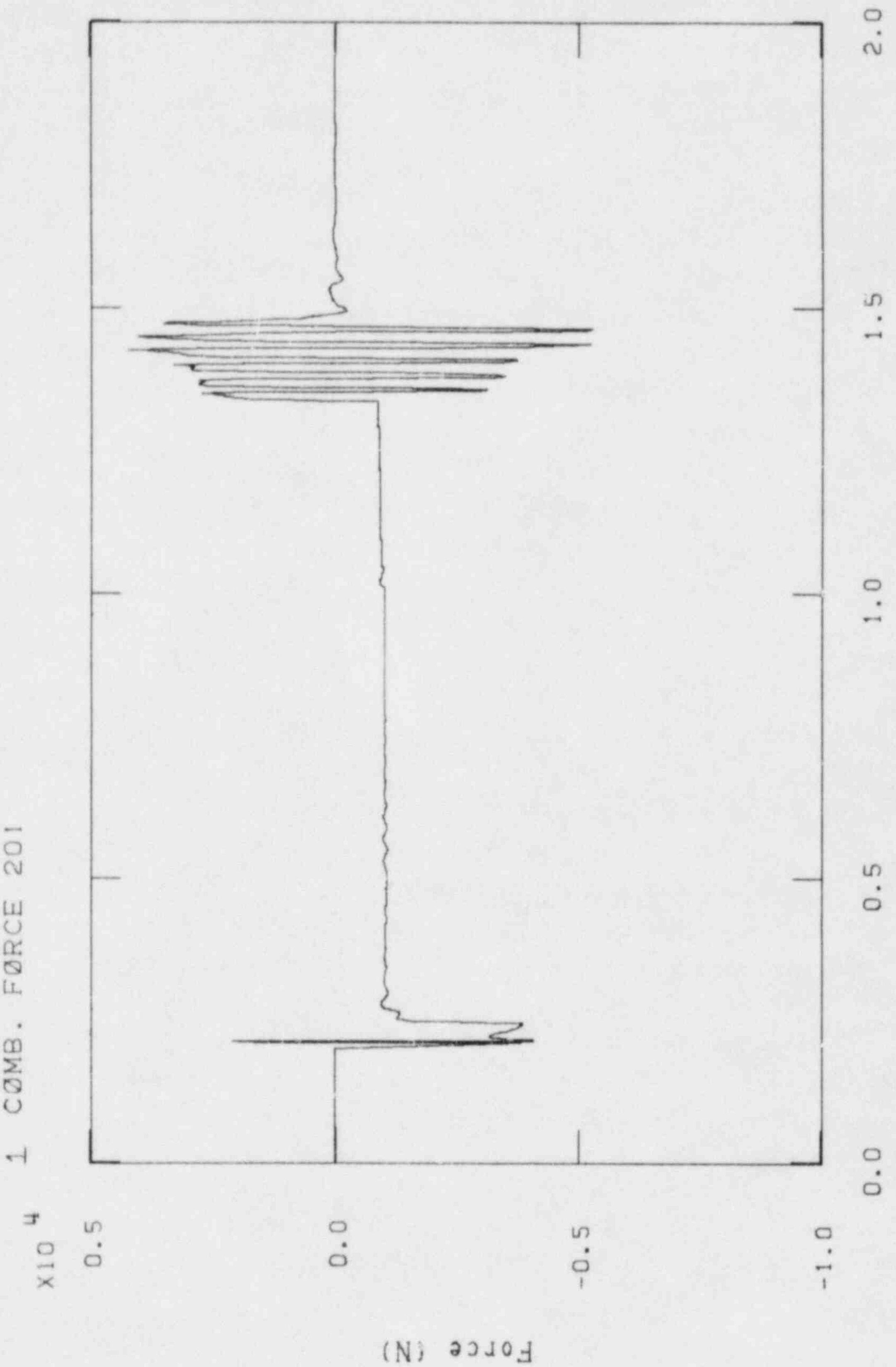

Figure 7. Combined force CF201 for the sample problem.

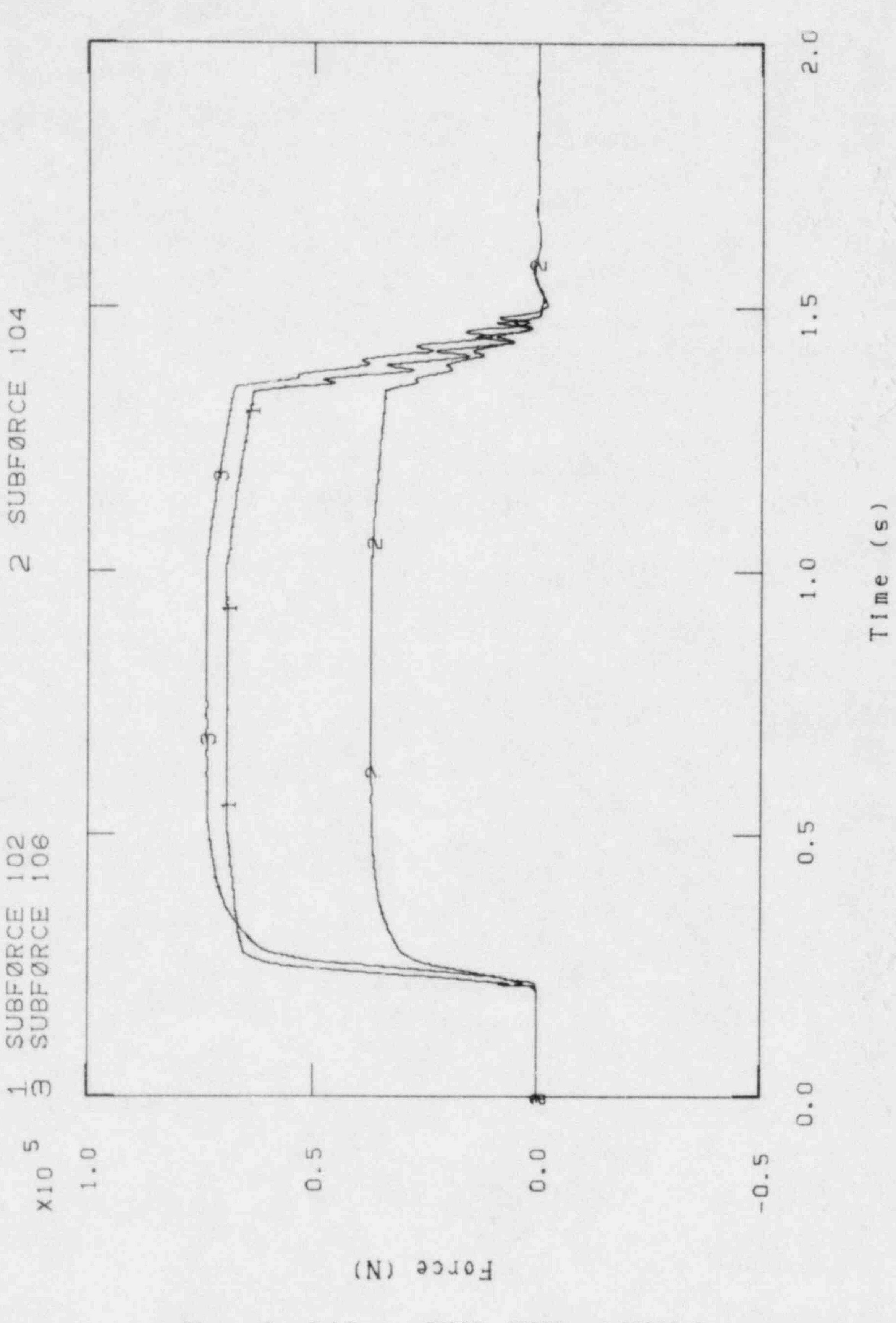

Figure 8. Subforces SF102, SF104 and SF106 for the sample problem.

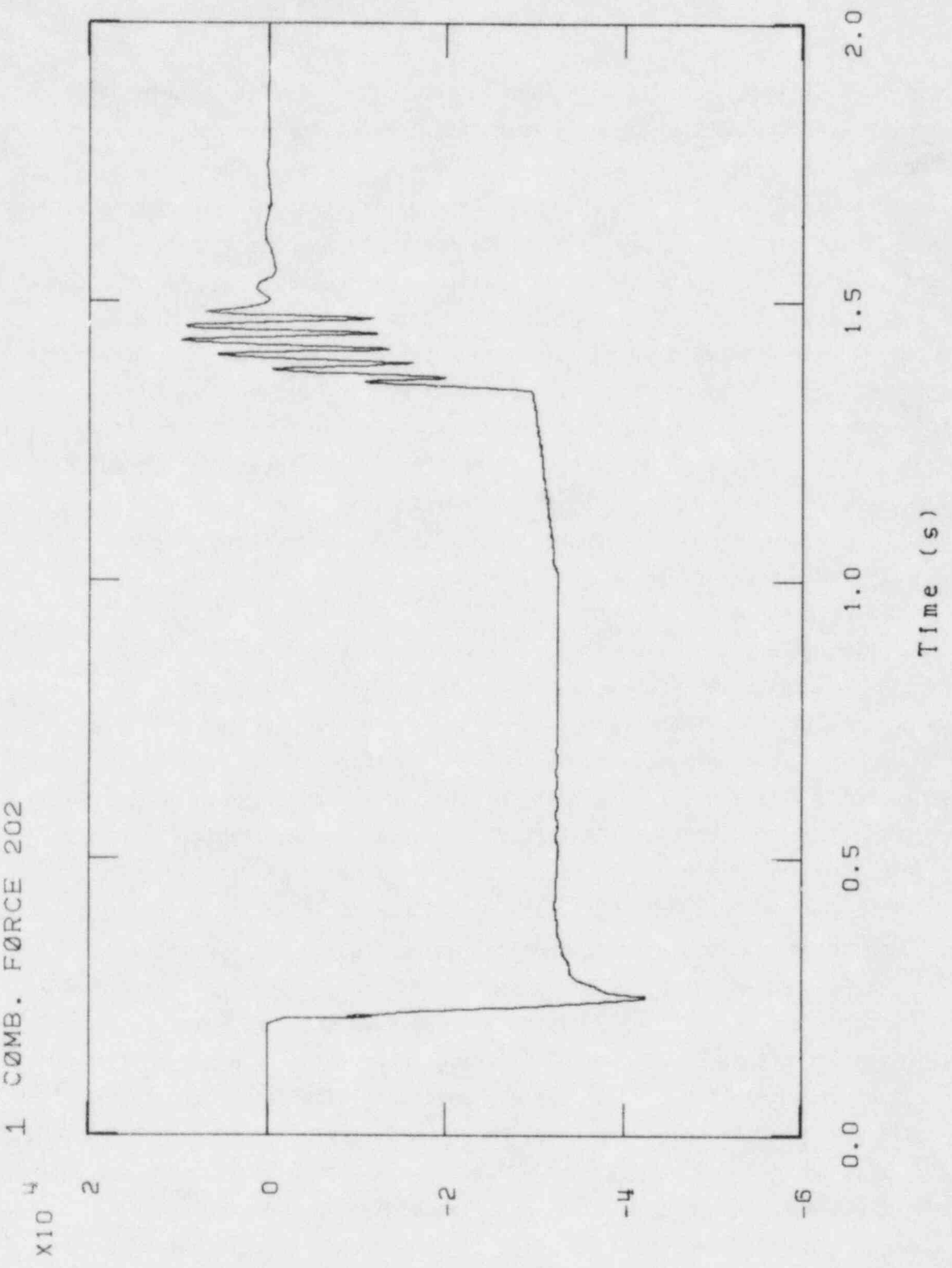

Figure 9. Combined force CF202 for the sample problem.

6. COMPARISON WITH EXISTING TECHNIQUES

At EG&G Idaho, Inc., fluid induced forces have typically been approximated from RELAP5 hydrodynamic output by using only the pressure and momentum force terms applied at various points in the piping; this technique is documented in Reference 6 and will herein be referred to as the old approach. Recently, another technique to approximate the fluid induced forces was generated which utilized the pressure and momentum force terms in addition to a fluid acceleration term; this technique is documented in Reference 7 and will herein be referred to as the modified approach. This section provides a brief comparison between the old and modified approaches and the new approach used in the R5FORCE program. Refering to Figure 5, subforces SF105 and SF108, and the sum of these forces, CF203, will be used for the comparison. Two fluid transients were used, the sample problem discussed in Section 5 and the same sample problem with a liquid slug in the loop seal.

Evaluating the Section 5 sample problem first, Figures 10 and 11 provide time history information for subforces SF105 and SF108, respectively. Note that prior to and during the early stages of valve opening, the force predictions by the old, modified and new methods were very similar; as the fluid velocity became significant however, there were slight differences between the techniques. This was more evident in the time history of combined force CF203 which is shown in Figure 12. The modified and new methods predicted a peak force of approximately 7000 N (occurring immediately after the relief valve opened) which eventually approached zero as steady flow was achieved. The old approach predicted a higher maximum force of approximately 11,000 N which then decreased to a relatively constant value of 4000 N during steady flow. This significant force observed at steady state is not consistent with theory and is the result of neglecting the frictional shear force term. By computing the pressure and momentum forces at two points in a piping system, the momentum change between the two points is not balanced by the shear force, resulting in an unrealistic combined force. This was the only significant difference observed between the old and the modified and new approaches. Differences between the modified and new method are slight, however, the new method will eliminate instabilities and data spikes previously encountered with the modified method, as shown in the next sample problem.

Evaluating the second sample problem, a liquid slug in the loop seal, Figures 13, 14, and 15 provide time history information for subforces SF105 and SF108 and combined force CF203, respectively. The trends of this evaluation are identical to those noted is the first sample problem, except for data spikes associated with the modified method. The effect of these data spikes is clearly shown in Figure 16 for the modified method versus Figure 17 for the new method; combined force CF203 over the time range of 0.2 to 0.5 seconds. The old approach predicted a maximum force of approximately 47,000 N, decreasing to a relative constant value of 4,000 N during steady flow. The modified and new approaches are effectively identical except for the data spikes associated with the modified method. The new method predicted a peak force of approximately 41,000 N whereas the modified method, because of the data spikes, predicted a higher peak force of approximately 65,000 N. The modified method in this example would have resulted in peak forces approximately 60% higher than the new method, due entirely to data spikes. Other problems run with both methods have resulted in peak modified forces many orders of magnitude higher than the new method. In such situations, the user is required to examine the data in detail to eliminate potential data spikes, if possible.

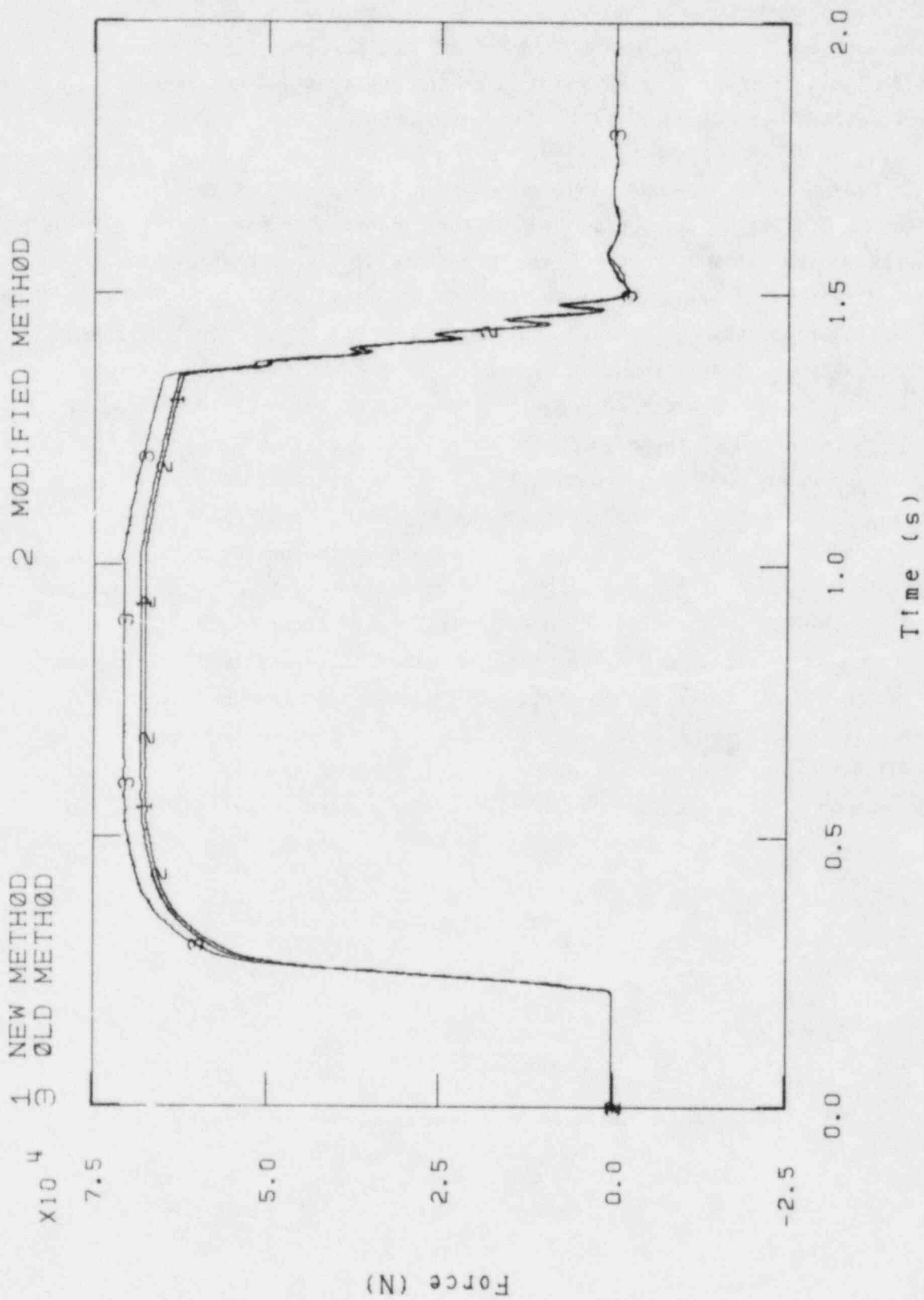

Figure 10. Comparison of the old, modified and new approaches for subforce SF105 for the sample problem.

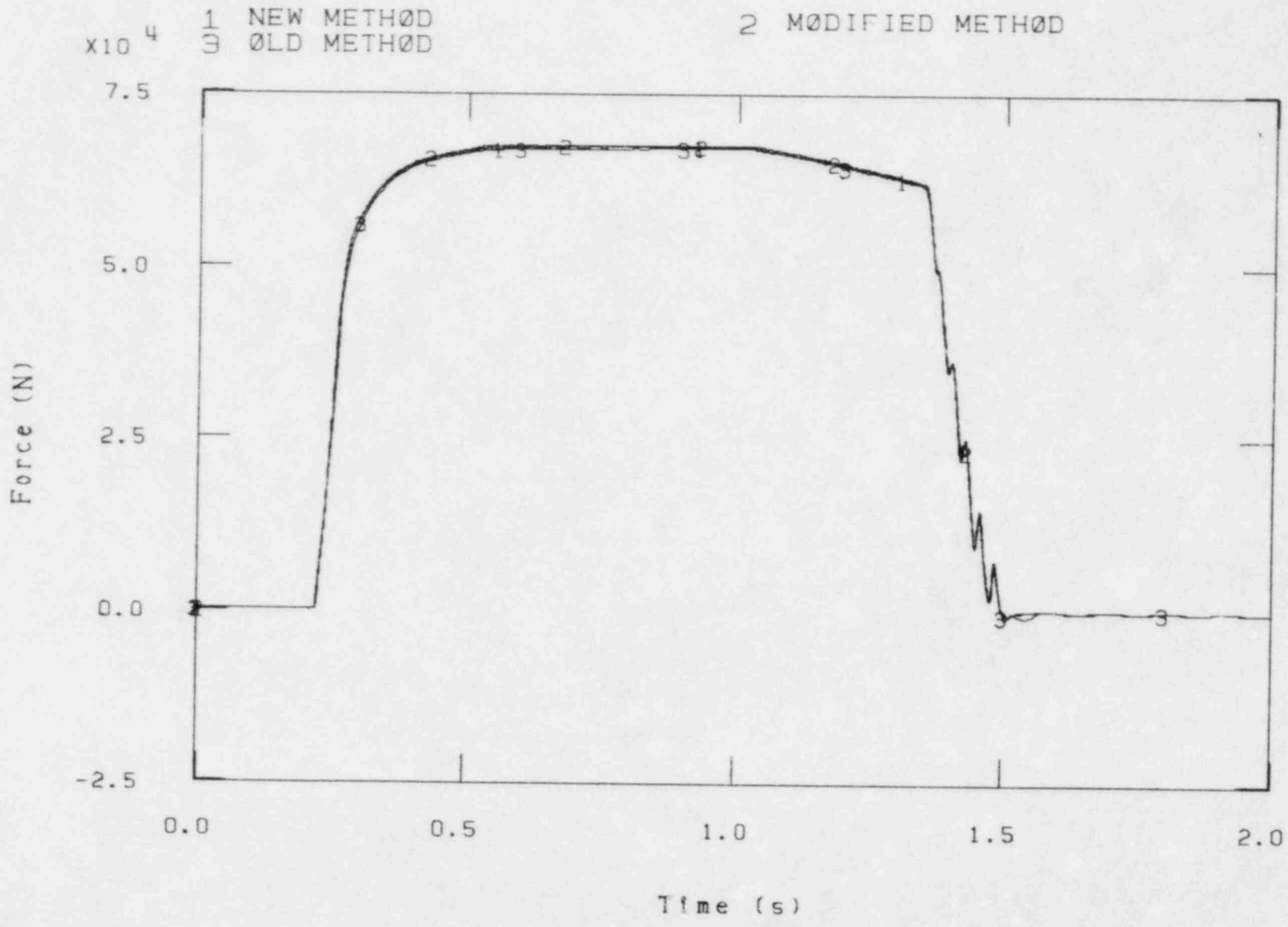

Figure 11. Comparison of the old, modified and new approaches for subforce SF108 for the sample problem.

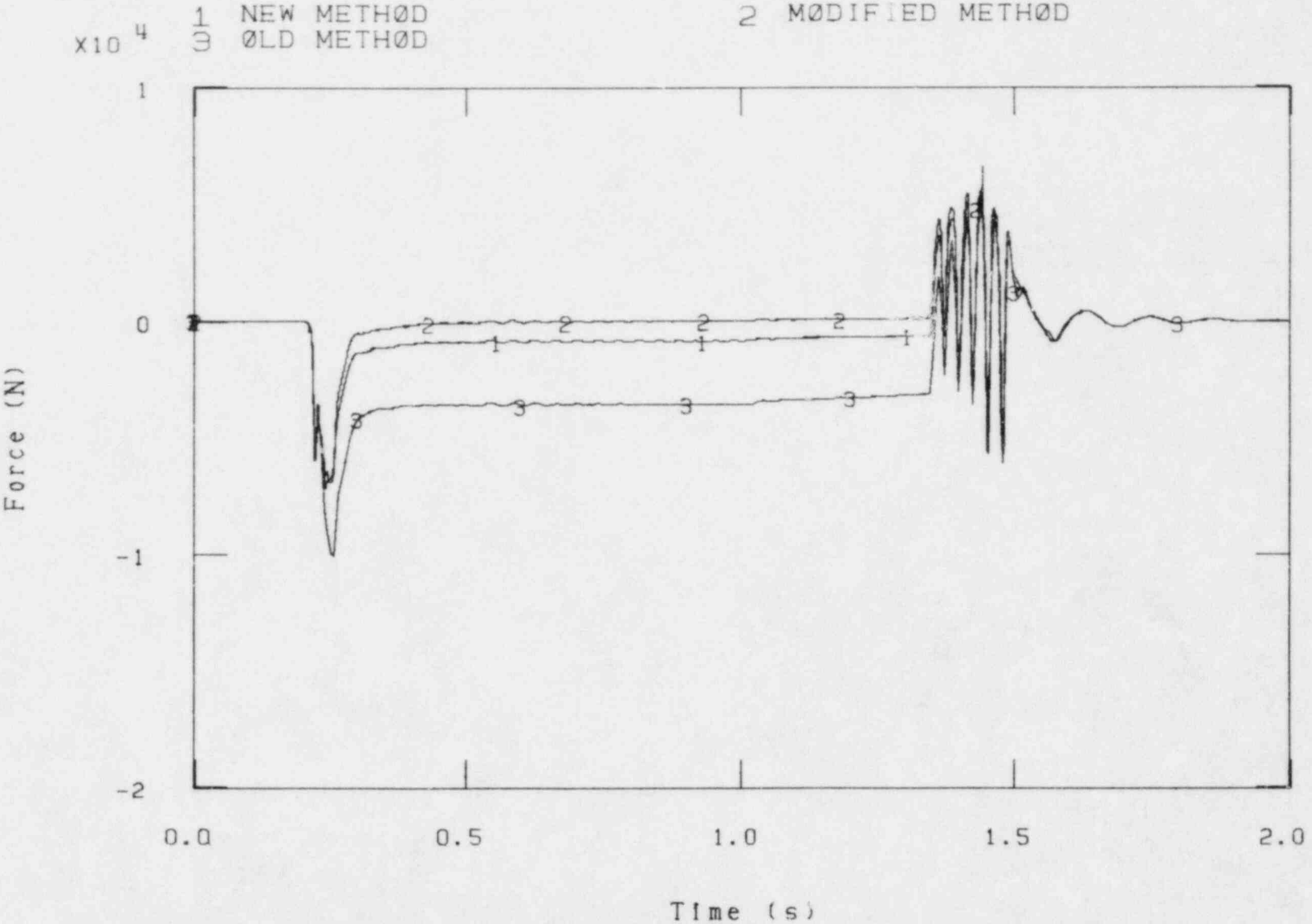

Figure 12. Comparison of the old, modified and new approaches for combined force CF203 for the sample problem.

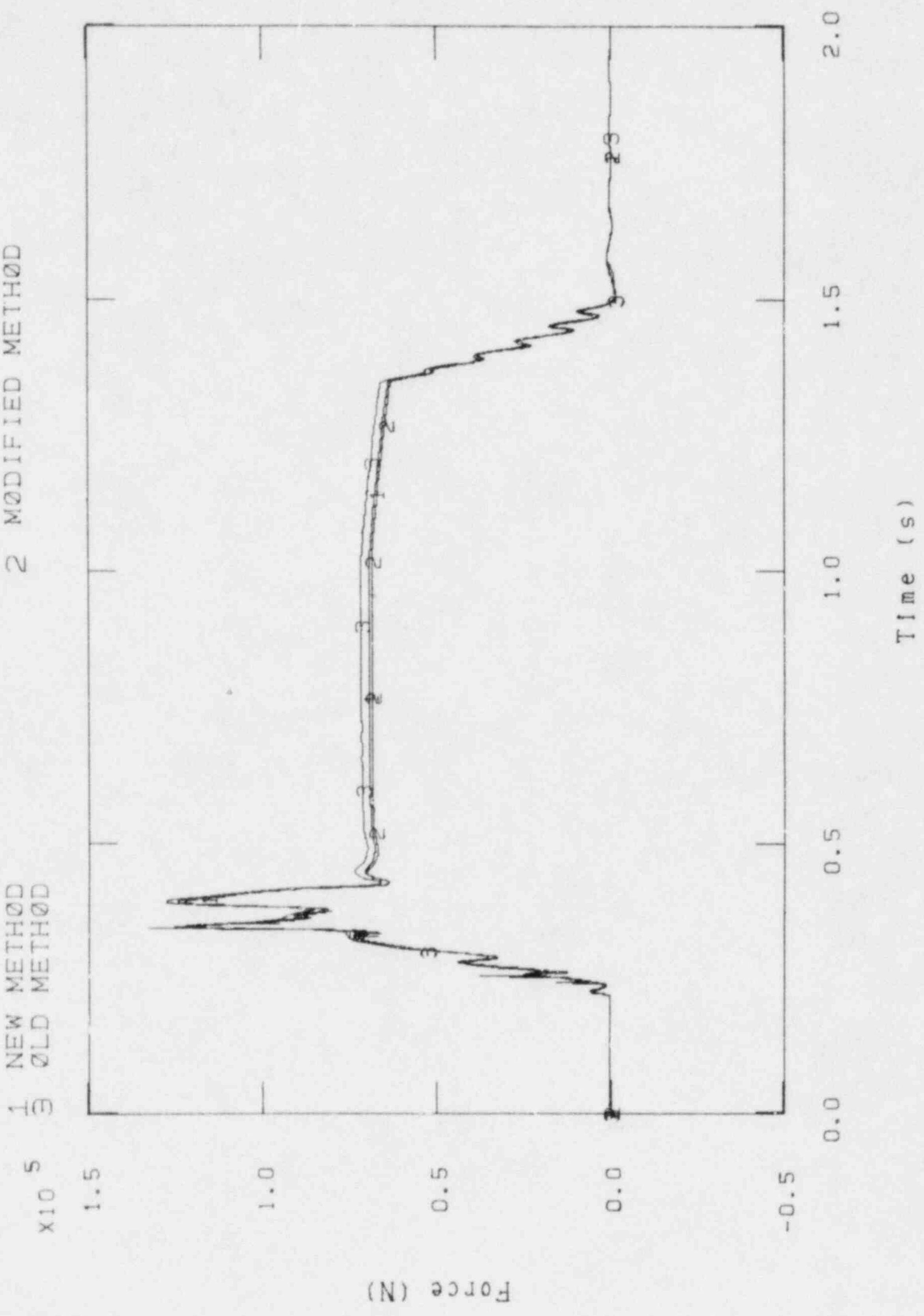

Figure 13. Comparison of the old, modified and new approaches for subforce SF105 for the second sample problem.

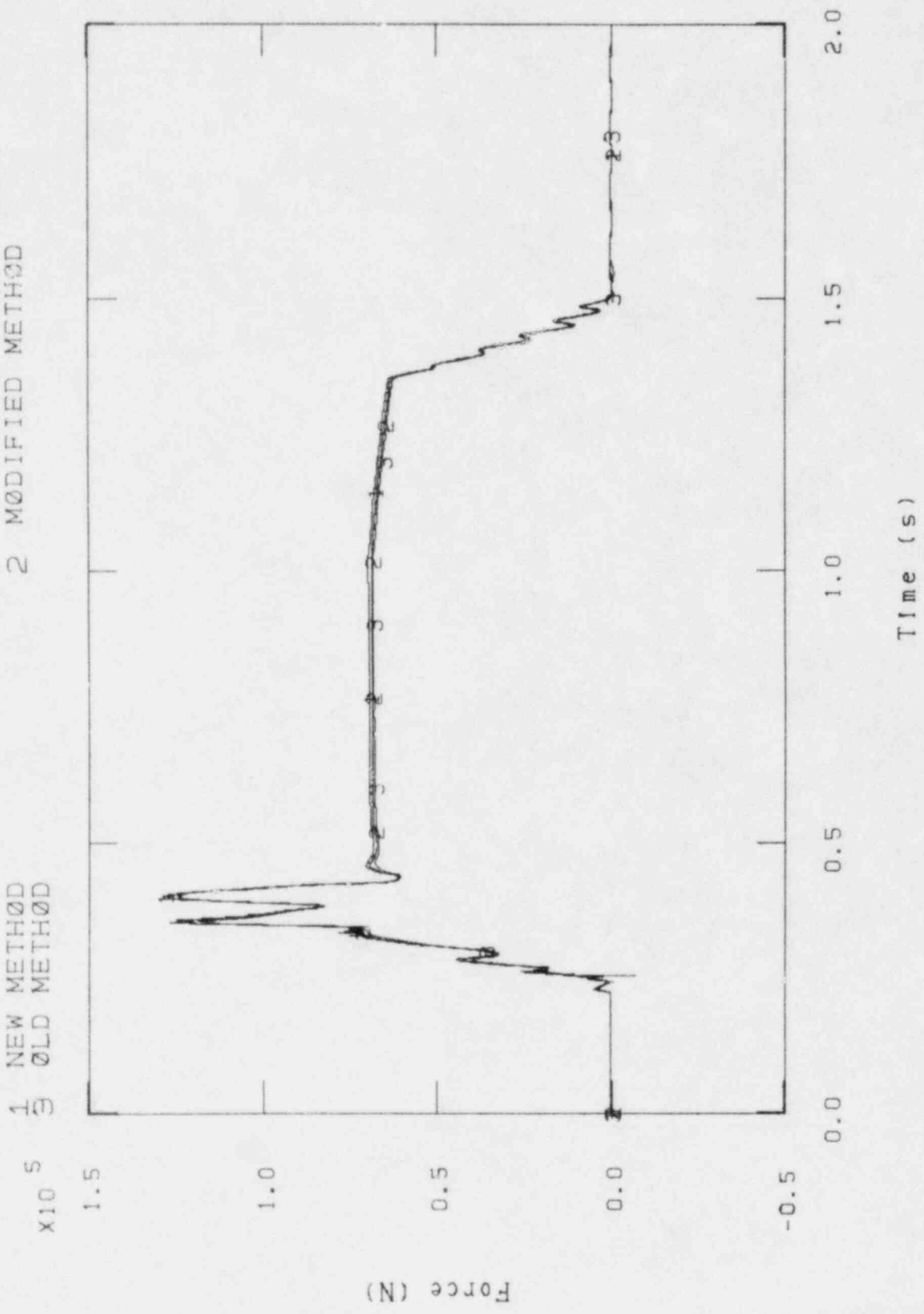

Figure 14. Comparison of the old, modified and new approaches for subforce SF108 for the second sample problem.

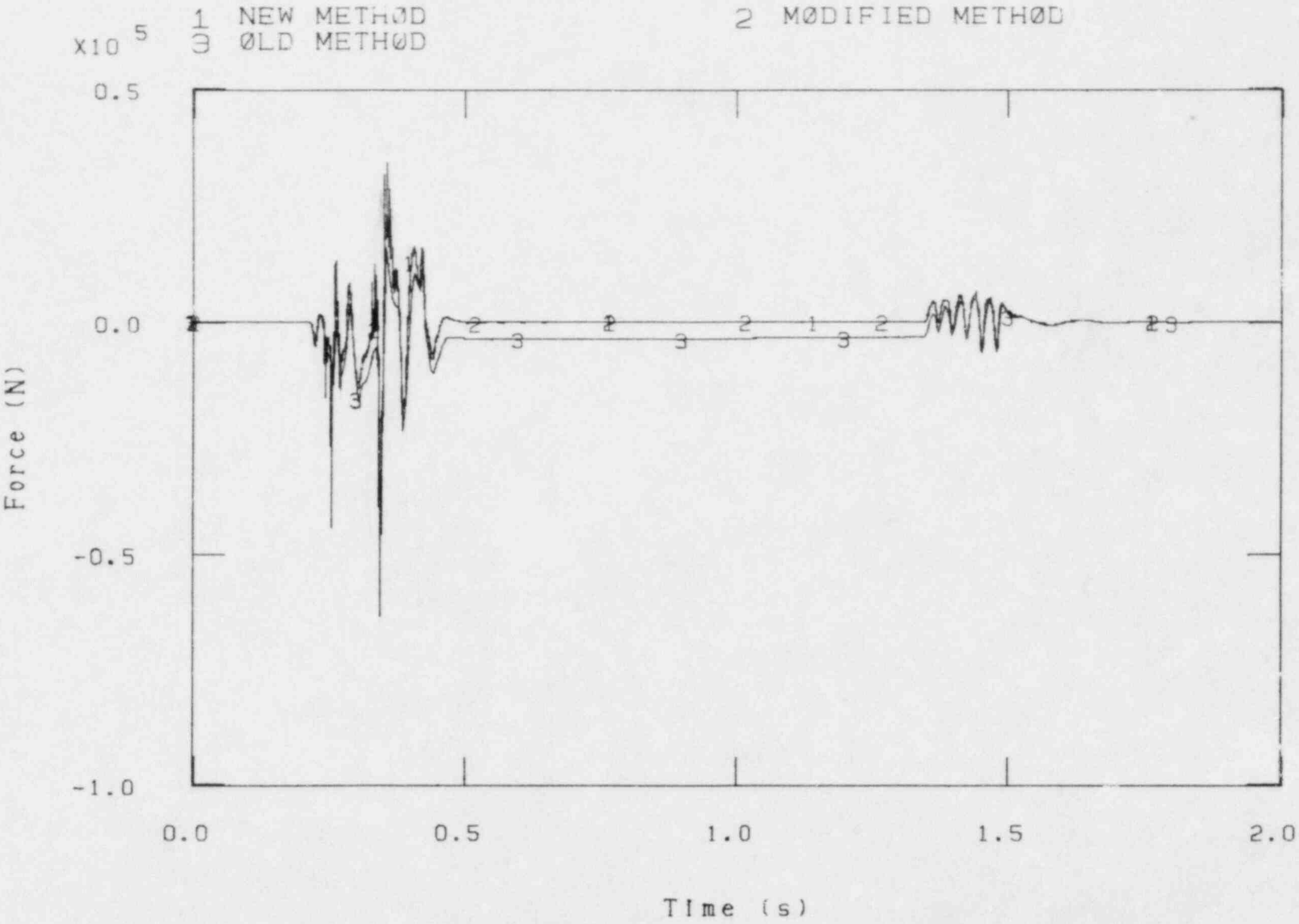

Figure 15. Comparison of the old, modified and new approaches for combined force CF203 for the second sample problem.

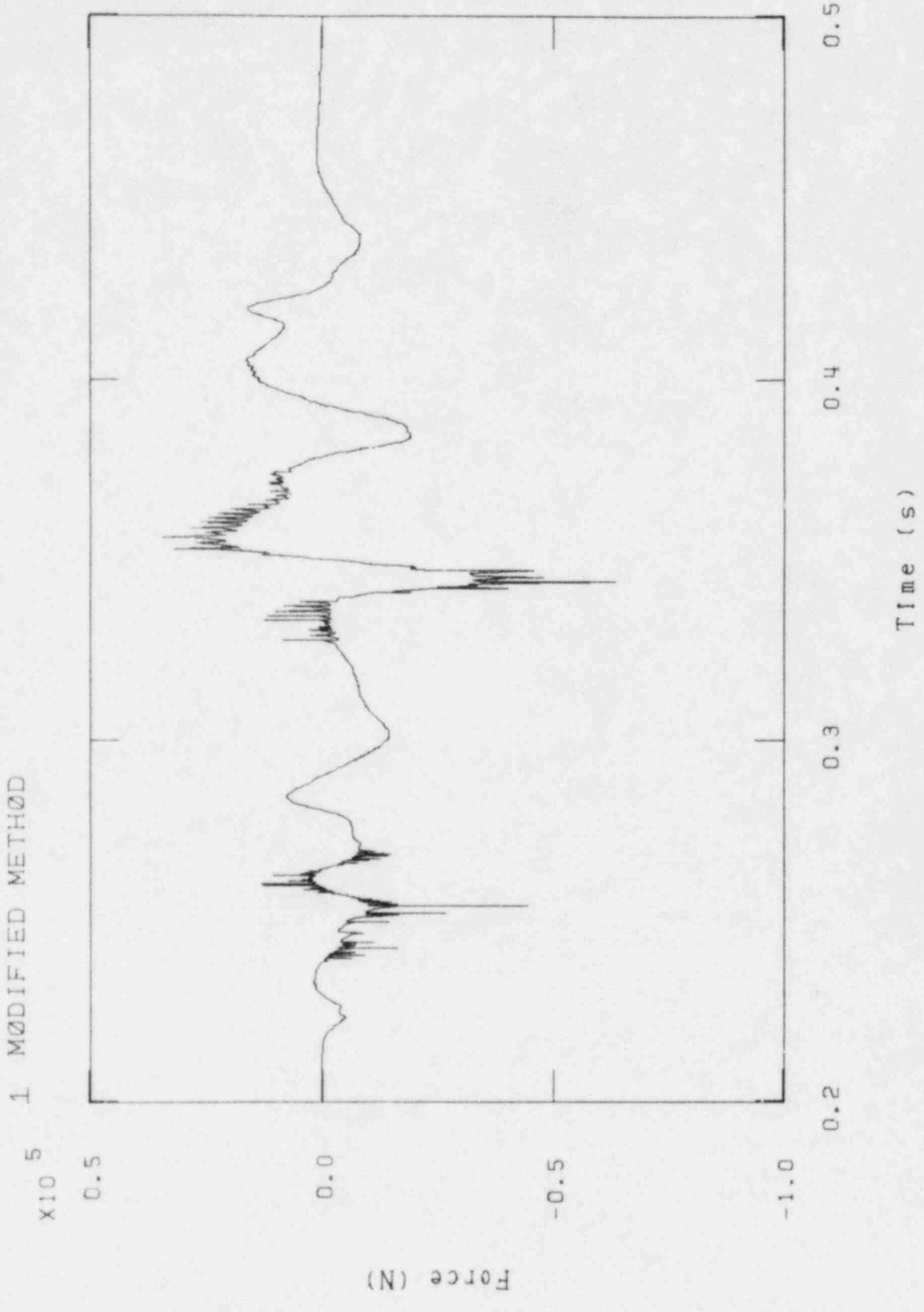

Figure 16. Modified approach for combined force CF203 for the second sample problem from 0.2 t 0.5 seconds.

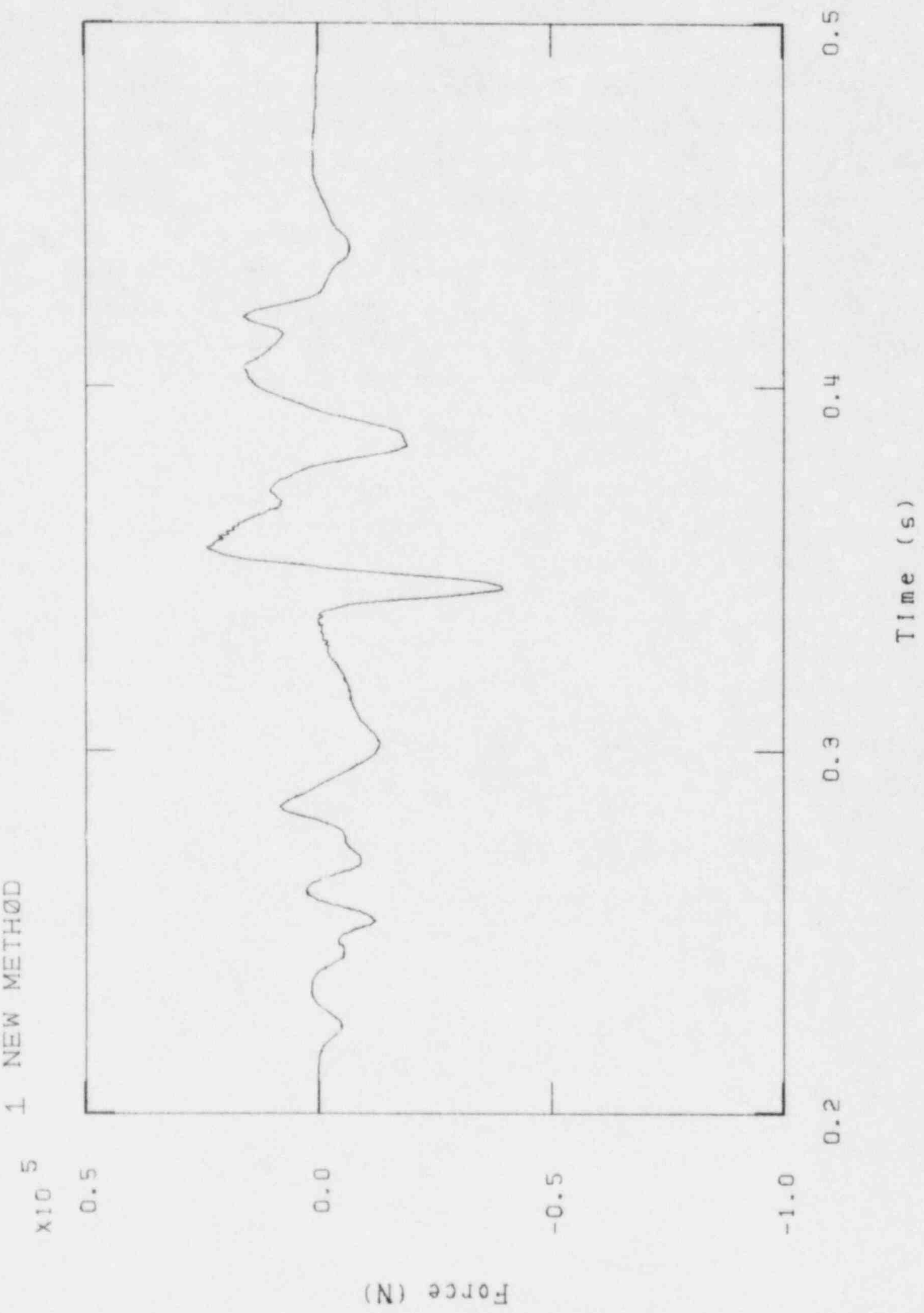

Figure 17. New approach for combined force CF 203 for the second sample problem from 0.2 to 0.5 seconds.

7. CONCLUSIONS

An approach has been outlined and a computer program developed for transient and steady state force calculations using hydrodynamic output data from the RELAP5/MOD1 computer code. This program is considered an improvement over existing force calculation techniques available at EG&G Idaho because it solves the force equation using the pressure and wall shear force terms instead of the pressure and fluid acceleration terms, eliminating potential instabilities associated with computing the time derivative in the fluid acceleration term; and uses output from the RELAP5/MOD1 program, an advanced one-dimensional computer program that is fast, accurate and easy to use.

It must be understood that verification studies with the R5FORCE program have been very limited and no comparison with experimental data has yet been made.

8. REFERENCES

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2. J. W. Spore, et. al., *TRAC-BD1, An Advanced Best-Estimate Computer Program for Boiling Water Reactor Loss-of-Coolant Accident Analysis*, Vols. 1-4, NUREG/CR-2178, October 1981.

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6. A. G. Ware, *Blazer User Manual*, RE-A-80-134, December 1980.

7. R. L. Williamson, *FORCE1: A Program to Compute Fluid Induced Forces Using Hydrodynamic Output from the RELAP5 Code*, EGG-EA-5631, October 1981.

8. J. R. Larson, *An Evaluation of the Capabilities of RELAP4/MOD6, RELAP4/MOD7, RELAP5/MOD"0" and TRAC-P1A to Calculate the Thermal-Hydraulic Behavior of Reactor Safety/Relief Valve Systems*, EGG-CAAD-5483, June 1981.

APPENDIX A

DEVELOPMENT OF THE GENERAL FORCE EQUATION

APPENDIX A

DEVELOPMENT OF THE GENERAL FORCE EQUATION

A force can be exerted on a container in only three ways:

1. By means of pressure which acts on the surface of the container
2. By means of a shear force (friction) between a fluid and the surface of the container
3. By means of an interaction between the container and a structural support member.

Consider the cross sectional view of the arbitrary shaped container shown in Figure A-1 where:

S_n = local normal stress

τ = local shear stress

ds = differential surface element

P = local pressure

ρ = local density

u = local fluid velocity

$\bar{n}$ = unit vector normal to a surface

$\bar{n}_T$ = unit vector tangent to a surface

$\bar{C}$ = unit vector in the desired force direction

A = area

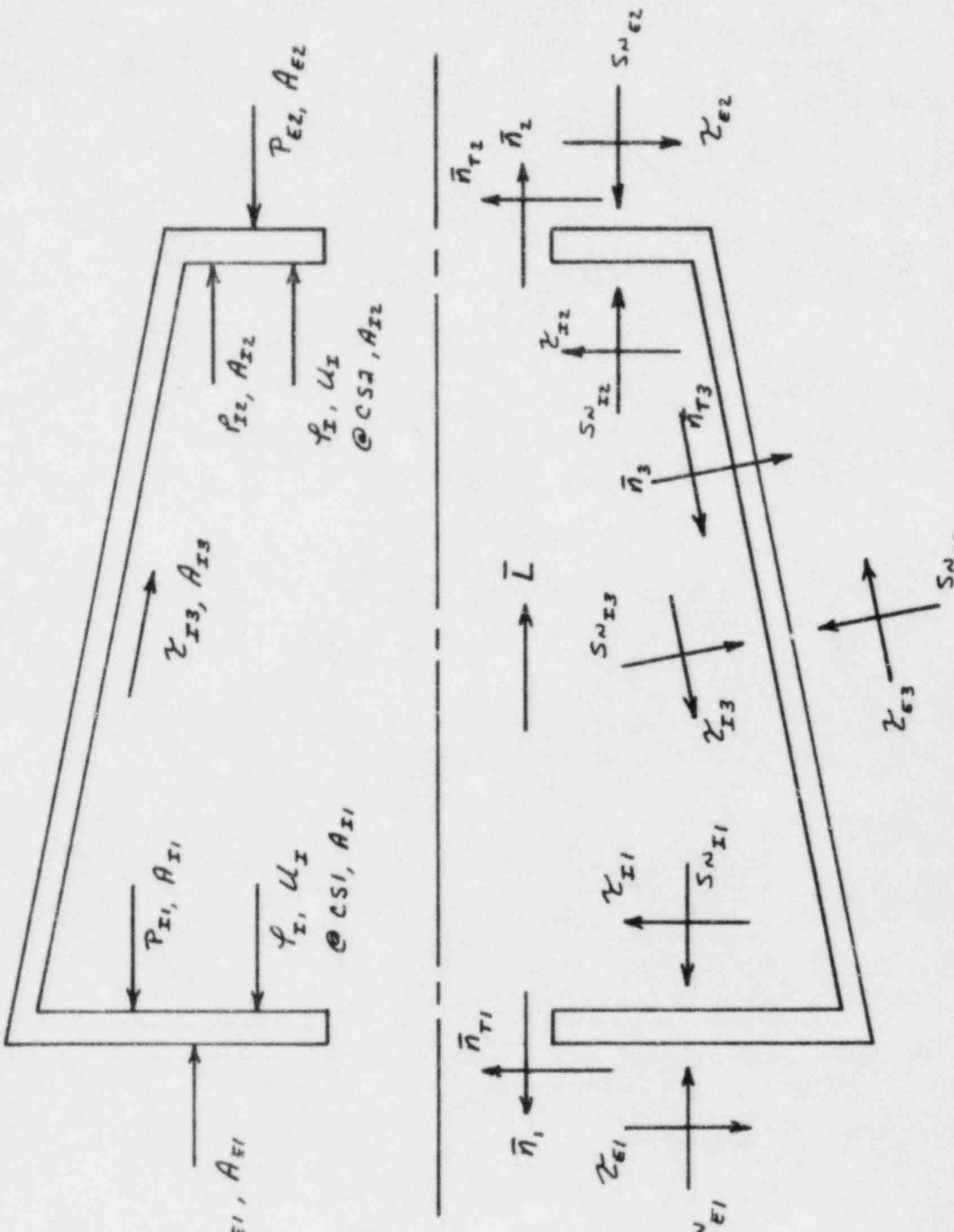


Figure A-1. Generalized fluid container.

with the following subscript notation:

I = internal

E = external

1 = control surface 1 (inlet)

2 = control surface 2 (outlet)

3 = control surface 3

The force acting on the control surface in the direction [can then be written as the sum of two surface integrals, or

$$F = \iint_S S_n(\bar{n} \cdot \bar{[})ds + \iint_S \tau \, (\bar{n}_T \cdot \bar{[}) \, ds \qquad \text{(A-1)}$$

For an inviscid treatment, the shear term in Equation (A-1) is not used and the force is obtained utilizing only the normal force term. When viscous losses are considered, the shear force term in Equation (1) is generally difficult to evaluate. Through an application of the law of conservation of momentum, as alternate form of Equation (1) can be derived (footnote)* and written in one-dimensional form as

$$F = -\frac{\partial}{\partial t} \iiint \frac{\dot{M}_I}{A_I} \, dV_I - (P_{I1} + \rho_{I1} U_{I1}^2) A_{I1} + (P_{I2} + \rho_{I2} U_{I2}^2) A_{I2} \qquad \text{(A-2)}$$

---

*R. L. Williamson, FORCE1: A Program to Compute Fluid Induced Forces Using Hydrodynamic Output from the RELAP5 Code, EGG-EA-5631, October 1981.

This technique is used extensively to evaluate fluid forces acting on a container. However, this technique has potential instabilities associated with computing the time derivative in the fluid acceleration term, often requiring various smoothing techniques to make the output useful.

If however, the shear force and pressure distribution are known for a container, Equation (A-1) can be used directly to obtain the fluid force on the container. Expanding Equation (A-1) over the three control surfaces identified in Figure A-1 and neglecting gravitational forces results in the following:

$$
\begin{aligned}
F = & \iint_{CS1} S_{n_{I1}} (\bar{n}_1 \cdot \bar{C}) ds_{CS1} + \iint_{CS2} S_{n_{I2}} (\bar{n}_2 \cdot \bar{C}) \, ds_{CS2} \\
& + \iint_{CS3} S_{n_{I3}} (\bar{n}_3 \cdot \bar{C}) ds_{CS3} + \iint_{CS1} \tau_{I1} (\bar{n}_{T1} \cdot \bar{C}) \, ds_{CS1} \\
& + \iint_{CS2} \tau_{I2} (\bar{n}_{T2} \cdot \bar{C}) ds_{CS2} + \iint_{CS3} \tau_{I3} (\bar{n}_{T3} \cdot \bar{C}) ds_{CS3} \\
& - \iint_{CS1} S_{n_{E1}} (\bar{n}_1 \cdot \bar{C}) ds_{CS1} - \iint_{CS2} S_{N_{E2}} (\bar{n}_2 \cdot \bar{C}) ds_{CS2} \\
& - \iint_{CS3} S_{n_{E3}} (\bar{n}_3 \cdot \bar{C}) ds_{CS3} - \iint_{CS1} \tau_{E1} (\bar{n}_{T1} \cdot \bar{C}) ds_{CS1} \\
& - \iint_{CS2} \tau_{E2} (\bar{n}_{T2} \cdot \bar{C}) ds_{CS2} - \iint_{CS3} \tau_{E3} (\bar{n}_{T3} \cdot \bar{C}) ds_{CS3} \qquad \text{(A-2)}
\end{aligned}
$$

Summing forces in the direction of fluid flow ($\bar{C}$) and:

1. Neglecting external shear force effects, and

2. Recognizing that for the one-dimensional uniform cross sectional area control volume assumption in RELAP5:

$$(\bar{n}_3 \cdot \bar{C}) = 0$$

$$(\bar{n}_{T1} \cdot \bar{C}) = 0$$

$$(\bar{n}_{T2} \cdot \bar{C}) = 0$$

Results in

$$\begin{aligned} F = & \iint_{CS1} S_{n_{I1}} (\bar{n}_1 \cdot \bar{C}) ds_{CS1} + \iint_{CS2} S_{n_{I2}} (\bar{n}_2 \cdot \bar{C}) ds_{CS2} \\ & + \iint_{CS3} \tau_{I3} (\bar{n}_{T3} \cdot \bar{C}) ds_{CS3} - \iint_{CS1} S_{n_{E1}} (\bar{n}_1 \cdot \bar{C}) ds_{CS1} \\ & - \iint_{CS2} S_{n_{E2}} (\bar{n}_2 \cdot \bar{C}) ds_{CS2} \end{aligned} \qquad (A\text{-}3)$$

Since the local static pressure distribution is not known, the normal stress will be defined in terms of the quasi steady change in momentum (the local static pressure plus the fluid momentum). In addition, the external fluid velocity effects will be neglected which is consistent with neglecting the external shear force effects, resulting in

$$\begin{aligned} F = & \iint_{CS1} (P_{I1} + \rho_I u_I^2)(\bar{n}_1 \cdot \bar{C}) ds_{CS1} \\ & + \iint_{CS2} (P_{I2} + \rho_I u_I^2)(\bar{n}_2 \cdot \bar{C}) ds_{CS2} \end{aligned}$$

$$+ \iint_{CS3} \tau_{I3} (\bar{n}_{T3} \cdot \bar{C}) ds_{CS3} - \iint_{CS1} P_{E1} (\bar{n}_1 \cdot \bar{C}) ds_{CS1}$$

$$- \iint_{CS2} P_{E2} (\bar{n}_2 \cdot \bar{C}) ds_{CS3} \qquad (A-4)$$

Now, assuming that the fluid velocity, density and pressure are uniform over the local cross-sectional area and that the shear is uniform over the local control volume surface area, which is consistant with the one-dimensional approximation used in RELAP5, results in the following:

$$F = (P_{I1} + \rho_I u_I^2)(\bar{n}_1 \cdot \bar{C}) A_{I1} + (P_{I2} + \rho_I u_I^2)(\bar{n}_2 \cdot \bar{C}) A_{I2}$$

$$+ \tau_{I3} (\bar{n}_{T3} \cdot \bar{C}) A_{I3} - P_{E1} (\bar{n}_1 \cdot \bar{C}) A_{E1} - P_{E2} (\bar{n}_2 \cdot \bar{C}) A_{E2} \qquad (A-5)$$

For the one-dimensional uniform cross-sectional area control volume assumption in RELAP5, the following unit vectors can be evaluated from Figure A-1:

$$(\bar{n}_1 \cdot \bar{C}) = -1$$

$$(\bar{n}_2 \cdot \bar{C}) = 1$$

$$(\bar{n}_{T3} \cdot \bar{C}) = 1$$

Substituting these expressions into Equation (A-5) yields the following expression for the force acting on a container:

$$F = -(P_{I1} + \rho_I u_I^2)(A_{I1}) + (P_{I2} + \rho_I u_I^2)(A_{I2})$$

$$+ \tau_{I3} A_{I3} + P_{E1} A_{E1} - P_{E2} A_{E2} \qquad \text{(A-6)}$$

APPENDIX B

DEVELOPMENT OF THE JUNCTION PRESSURE AND JUNCTION AREA TERMS

APPENDIX B

DEVELOPMENT OF THE JUNCTION PRESSURE AND JUNCTION AREA TERMS

A general equation for the force exerted on a container has been developed and can be expressed as

$$F = -(P_{I1} + \rho_I u_I^2) A_{I1} + (P_{I2} + \rho_I u_I^2) A_{I2} + P_{E1} A_{E1} - P_{E2} A_{E2} + \tau A_s \quad (B-1)$$

where

A = volume surface area

P = fluid pressure

u = fluid velocity

ρ = fluid density

τ = shear force per unit area

and the subscripts (I) and (E) refer to interior or external conditions, the subscripts (1) and (2) refer to the volume inlet or outlet and the subscript (s) refers to the interior surface area parallel to the flow.

Equation (B-1) is made up of five terms. Two of these terms represent forces associated with the volume inlet junction, two with the volume outlet junction and one with the volume itself. The application of Equation (B-1) will differ depending on the type of volume end geometry. In particular, a volume can be connected to an adjoining volume in one of four ways:

1. Continued--Adjacent volumes are at the same angle, such as Volumes CV2 and CV3 in Figure B-1

2. Bounded--Adjacent volumes are at different angles, such as Volumes CV3 and CV4 in Figure B-1

3. Open--A volume represents the end of a pipe, although continued to an adjacent volume in the RELAP5 model, such as Volume CV4 in Figure B-1

4. Special--Mechanistic junction models, such as the relief valve between Volumes CV1 and CV2 in Figure B-1.

These geometries can also contain area changes between adjacent volumes and a constant or variable junction throat ratio, simulating an orifice or a valve. The volume pressure and momentum, shear force and shear force area terms are readily available on the RELAP5 output tape. The internal and external quasi steady change in momentum at the inlet and outlet junction of each computational volume and the areas that the change in momentum acts on must be computed.

1. Development of the Junction Change in Momentum Term

The internal and external change in momentum (pressure plus momentum flux) at the inlet and outlet junction of each computational volume must be determined in order to determine the forces acting on that volume. The external pressure is defined through the input data and defaults to 14.7 psia (0.101 MPa) for all junction types except an open junction. For an open junction, the external pressure is defined as the pressure plus momentum flux in the adjacent downstream volume of the RELAP5 model. This will allow the effects of variable discharge conditions to be included in the analysis.

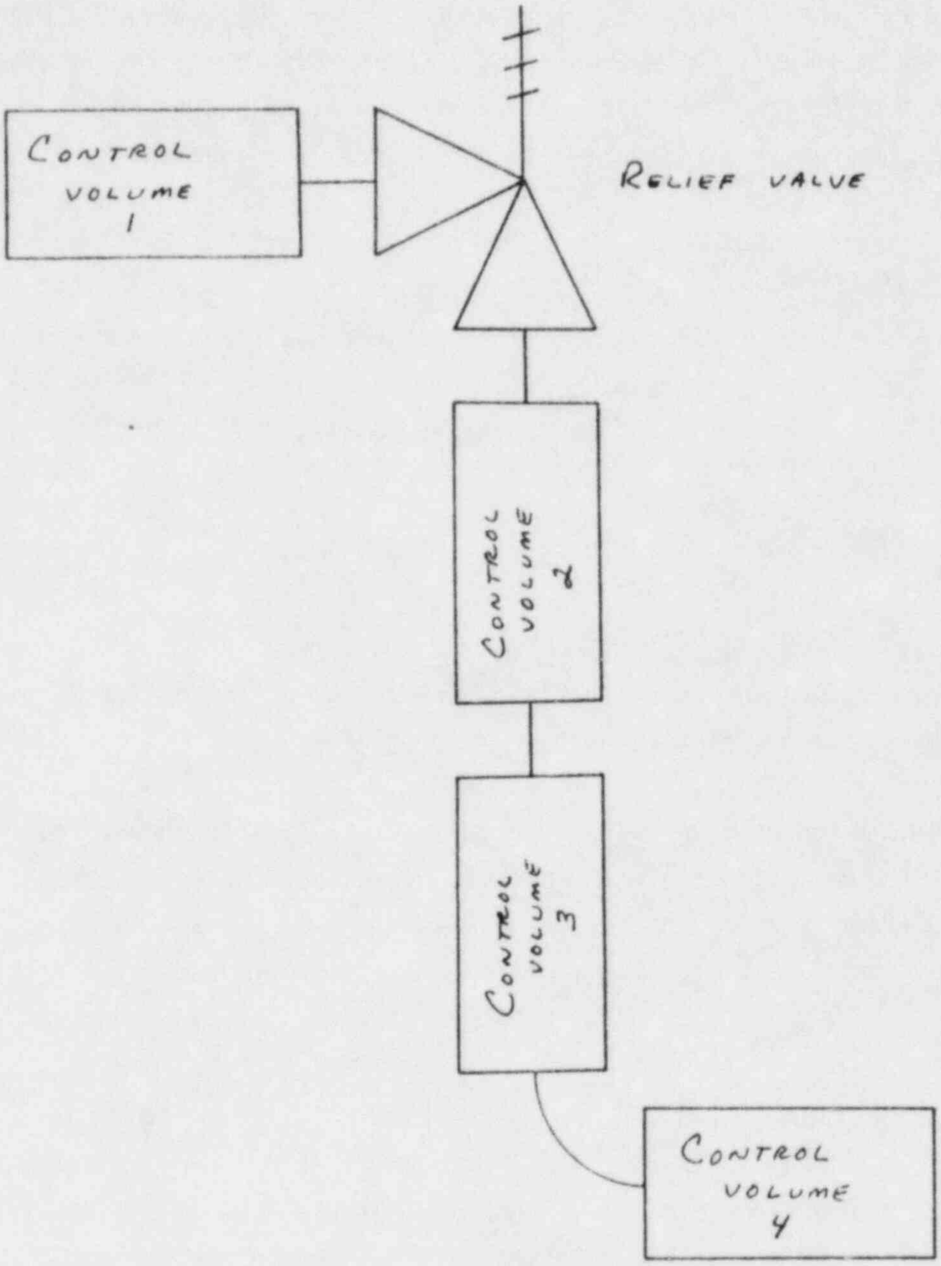


Figure B-1. Typical piping/control volume system.

The internal change in momentum is defined as the pressure plus momentum flux in a volume. The change in momentum at a junction must be approximated from the volume change in momentum. Only the outlet junction change in momentum will be developed for each junction type, the inlet junction change in momentum development being identical with the exception of the open junction which is not allowed as an inlet junction.

Continued Junction

Figure B-2 shows the location of the desired outlet junction change in momentum team. This quantity will be approximated using a ratio of the adjacent volume quantities and volume lengths as

$$(P + \rho U^2)_J = \frac{(P+\rho U^2)_2 \, DL_3 + (P+\rho U^2)_3 \, DL_2}{DL_2 + DL_3} \tag{B-2}$$

This method will provide a reasonable approximation of the outlet junction change in momentum except for the following situations:

1. If the downstream volume (volume 3) is a time dependent volume, then DL_3 will be zero. For this situation, the computational and upstream volumes (volumes 1 and 2) will be used to approximate the outlet junction change in momentum as

$$(P + \rho U^2)_J = (P + \rho U^2)_2 + \frac{DL_2}{DL_1 + DL_2} \left[(P + \rho U^2)_2 - (P + \rho U^2)_1 \right] \tag{B-3}$$

2. If the outlet junction is choked or an area restriction (orifice, valve) exists at the junction, a non-linear decrease in the hydraulic head will occur and the adjacent change in momentum cannot be used to determine the outlet junction change in momentum. For this situation, the computational and upstream volumes (volumes 1 and 2) will be used to approximate the outlet junction change in momentum as discussed in item 1.

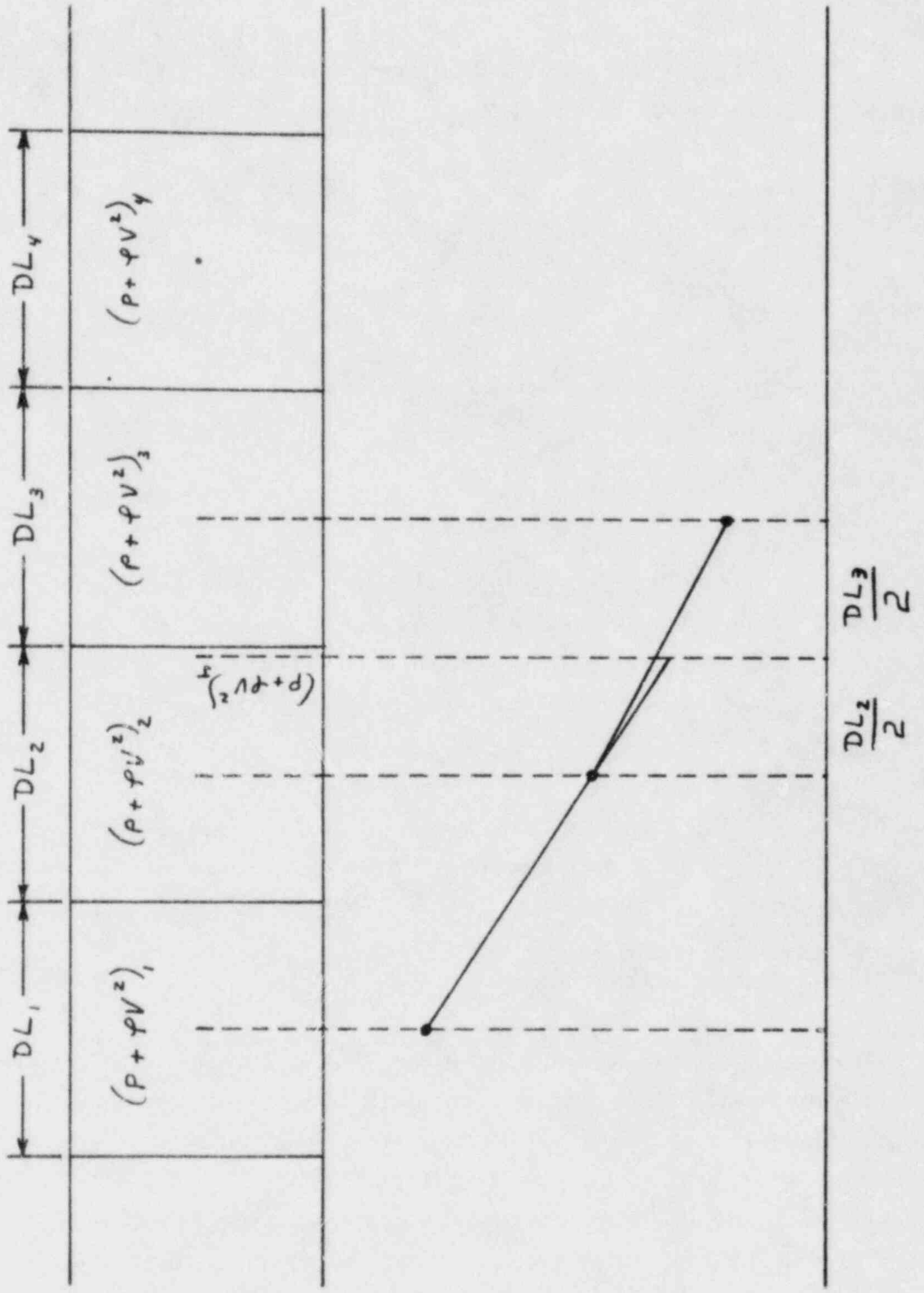


Figure B-2. Outlet junction change in momentum approximation method.

3. If either items 1 or 2 exist and if either the upstream volume (volume 1) is a time dependent volume (DL_1 will be zero) or the inlet junction is choked or an area restriction (orifice, valve) exists, the junction change in momentum will be set equal to the volume change in momentum.

4. If a downstream volume does not exist, then the junction change in momentum will be set equal to the volume change in momentum.

Bounded Junction

The internal change in momentum for this type of junction is identical to the continued junction.

Open Junction

The internal change in momentum for an open junction will be determined by methods 2 and 3 for the continued junction. The other techniques are not applicable since there is no physical piping downstream of an open pipe (Volume 3 would not exist).

Special Junction

The internal change in momentum for this type of junction is identical to the continued junction.

2. Development of the Junction Area Term

The areas that the internal and external change in momentum acts on in each computational volume must be determined in order to determine the forces acting on that volume. Only the outlet junction area will be developed for each junction type, the inlet junction area development being identical with the exception of the open junction which is not allowed as an inlet junction. RELAP5 internal and output termnology will be used in the development of the following expressions.

Continued Junction

Figure B-3A shows the geometric configuration of a typical continued junction. The internal area must account for the effects of an area change between adjacent volumes and a junction flow area which could be larger or smaller than the computational volume. The effects of these two geometries are accounted for as

$$A_{IR} = A_{V2} - \text{minimum} \begin{vmatrix} A_{J2} * TR_{J_2} \\ A_{V3} \end{vmatrix} \tag{B-6}$$

A zero or negative result means that there will be no area for the junction change in momentum to act on, thus there will be no force at that location.

The external area must account for the effects of an area change between adjacent volumes. The effect of this geometry is accounted for as

$$A_{ER} = A_{V2} - A_{V3} \tag{B-7}$$

Bounded Junction

Figure B-3B shows the geometric configuration of a typical bounded junction. The internal area must account for the effects of an area change between the volume and the junction (A_{IR1}) as well as the area of the junction (A_{IR2}). The effects of these two geometries are accounted for as

$$A_{IR1} = A_{V1} - A_{J1} * TR_{J1} \tag{B-8}$$

$$A_{IR2} = A_{J1} * TR_{J1} \tag{B-9}$$

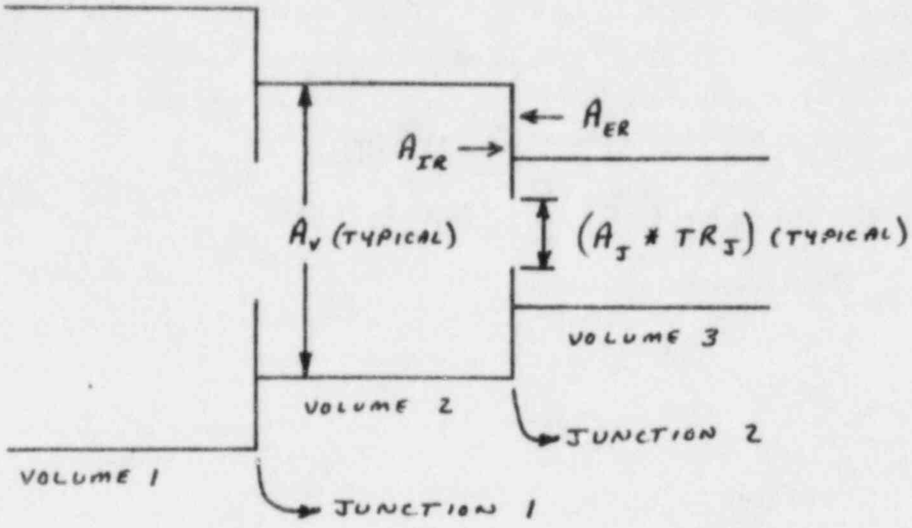


Figure B-3A. Continued junction geometric configuration.

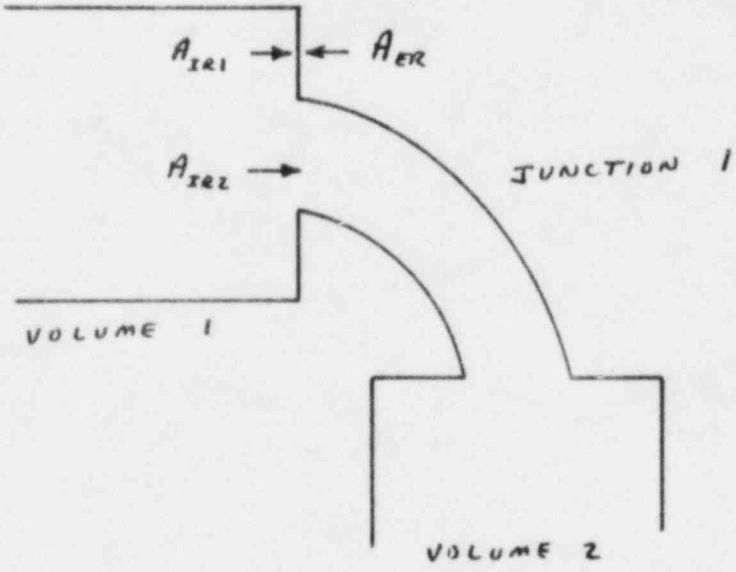


Figure B-3B. Bounded junction geometric configuration.

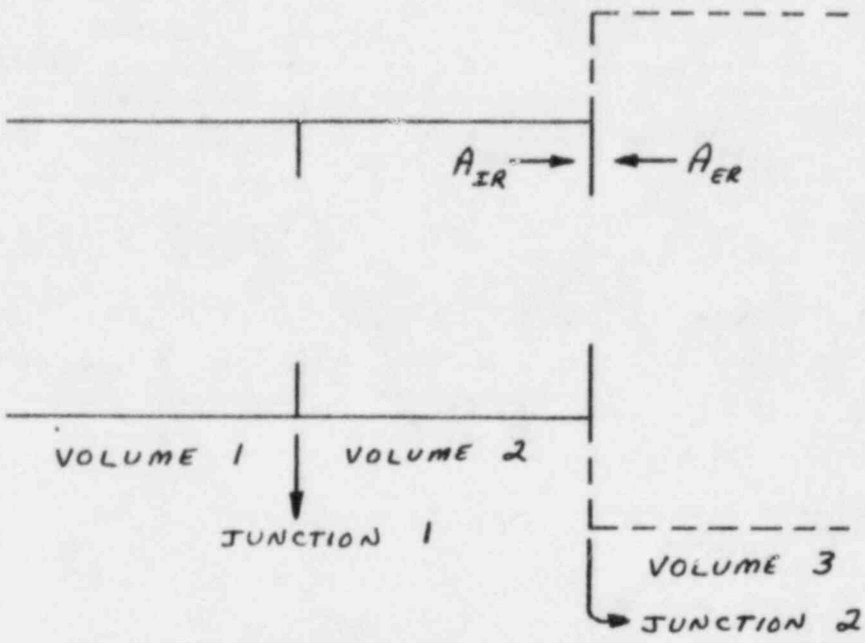


Figure B-3C. Open junction geometric configuration.

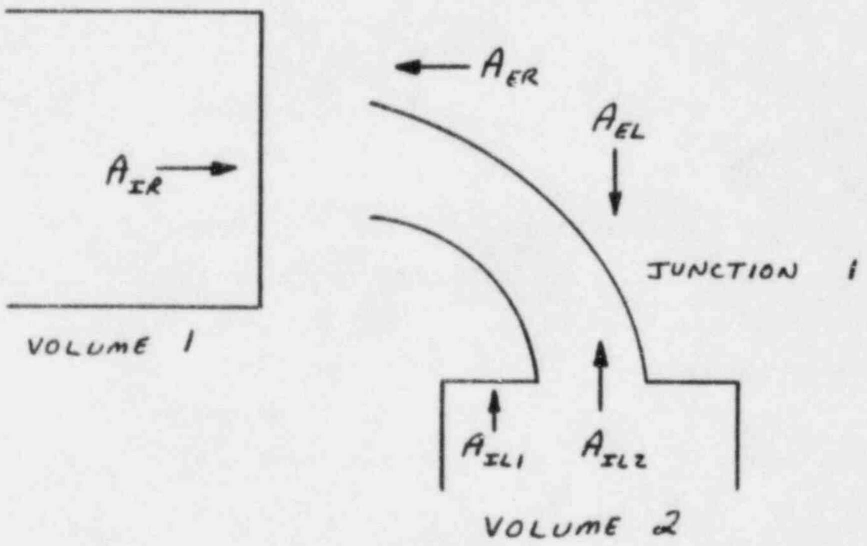


Figure B-3D. Special relief valve geometric configuration with the orifice on the valve outlet.

The external area must account for the effects of an area change between the computational volume and the junction as well as the bend. These geometries are accounted for as

$$A_{ER} = A_{V1} \quad (B-10)$$

Open Junction

Figure B-3C shows the geometric configuration of a typical open junction. The internal area must account for the effects of a junction flow area which could be larger or smaller than the computational volume. The effect of this geometry is accounted for as

$$A_{IR} = A_{V2} - A_{J2} * TR_{J2} \quad (B-11)$$

The external area must account for the effects of a junction flow area which could be larger or smaller than the computational volume. The effect of this geometry is accounted for as

$$A_{ER} = A_{V2} - A_{J2} * TR_{J2} \quad (B-12)$$

Special Junction

Figure B-3D shows the geometric configuration of the special relief valve mechanistic model with the orifice on the valve outlet. The mechanistic model with the orifice on the valve inlet can be obtained by interchanging the inlet and outlet junction areas. The internal area must account for the effects of a dead end for one junction and a bounded junction for the other. The effects of these two geometries are accounted for as

$$A_{IR} = A_{V1} \quad (B-13)$$

$$A_{IL1} = A_{V2} - A_{J1} * TR_{J1} \qquad (B\text{-}14)$$

$$A_{IL2} = A_{J1} * TR_{J1} \qquad (B\text{-}15)$$

The external area must account for the effects of a bend. This geometry is accounted for as

$$A_{ER} = A_{V1} \qquad (B\text{-}16)$$

$$A_{EL} = A_{V2} \qquad (B\text{-}17)$$

APPENDIX C

DEVELOPMENT OF THE SHEAR FORCE COMPONENT AND MODIFICATION OF THE RELAP5 ROUGHNESS TERM

APPENDIX C

DEVELOPMENT OF THE SHEAR FORCE COMPONENT AND MODIFICATION OF THE RELAP5 ROUGHNESS TERM

1. DEVELOPMENT OF THE SHEAR FORCE COMPONENT

The force component attribution to shear can be considered to be the sum of the shear forces for the gas and fluid, or

$$F_{shear} = F_{shear_g} + F_{shear_f} \tag{C-1}$$

where the shear force for each phase is equal to the shearing stress, or the wall friction per unit area for the phase times the pipe surface area proportional to the phase, or

$$F_{shear_g} = (\tau_g)\,(\alpha_g)\,(\pi\ D\ L) \tag{C-2}$$

$$F_{shear_f} = (\tau_f)\,(\alpha_f)\,(\pi\ D\ L) \tag{C-3}$$

Reference (1) defines the wall friction drag coefficient as one eighth of the phasic friction factor times the absolute velocity times the pipe perimeter proportional to the phase divided by the pipe cross sectional area and the phasic void fraction, or

$$FW_g = \frac{\lambda_g\ u_g\ PER_g}{8\ A\ \alpha_g} \tag{C-4}$$

$$FW_f = \frac{\lambda_f\ u_f\ PER_f}{8\ A\ \alpha_f} \tag{C-5}$$

The pipe perimeter proportional to the phase can be expressed as the phasic void fraction times the pipe perimeter (4A/D), or

$$PER_g = (\alpha_g)(PER) = \frac{4\ A\ \alpha_g}{D} \qquad (C\text{-}6)$$

$$PER_f = (\alpha_f)(PER) = \frac{4\ A\ \alpha_f}{D} \qquad (C\text{-}7)$$

Substituting the above into Equations (C-4) and (C-5) and solving for λ_f and λ_g yields

$$\lambda_g = \frac{(FW_g)\ (2\ D)}{u_g} \qquad (C\text{-}8)$$

$$\lambda_f = \frac{(FW_f)\ (2\ D)}{u_f} \qquad (C\text{-}9)$$

The wall friction per unit area is defined as one eighth of the friction factor times the phasic density times the velocity times the absolute velocity, or

$$\tau_g = \frac{1}{8}\lambda_g\ \rho_g\ u_g\ \ u_g \qquad (C\text{-}10)$$

$$\tau_f = \frac{1}{8}\lambda_f\ \rho_f\ u_f\ \ u_f \qquad (C\text{-}11)$$

Substituting Equations (C-8) and (C-9) into the above yields

$$\tau_g = \frac{FW_g\ D\ \rho_g\ u_g}{4} \qquad (C\text{-}12)$$

$$\tau_f = \frac{FW_f\ D\ \rho_f\ u_f}{4} \qquad (C\text{-}13)$$

Substituting the above into Equations (C-2) and (C-3) yields

$$F_{shear_g} = \frac{FW_g\, D^2 \rho_g\, u_g\, \alpha_g\, \pi\, L}{4} \qquad \text{(C-14)}$$

$$F_{shear_f} = \frac{FW_f\, D^2 \rho_f\, u_f\, \alpha_f\, \pi\, L}{4} \qquad \text{(C-15)}$$

2. MODIFICATION OF THE RELAP5 ROUGHNESS TERM

Due to the solution technique used in R5FORCE, system components which result in a frictional loss, such as elbows, must be modeled by modifing the volume roughness rather than by adding a form loss coefficient at a junction. Form losses, such as orifices and valves, must still be calculated by the addition of an energy loss coefficient or an area change at a junction. This section of the appendix discusses how to modify the volume roughness term to account for frictional losses.

Currently, frictional loss geometries such as elbows are modeled by adding an energy loss coefficient at a junction. This energy loss coefficient is the product of the turbulent friction factor and the L-over-D ratio, or

$$K = f_t\ (L/D)_L \qquad \text{(C-16)}$$

where f_t is based on the Colebrook Equation,

$$\frac{1}{\sqrt{f}} = -2\ \log_{10} \left[\frac{E}{3.7\ D} + \frac{2.51}{R_e \sqrt{f}} \right] \qquad \text{(C-17)}$$

Assuming tubulent flow (R_e = large), this expression can be simplified to

$$\frac{1}{\sqrt{f_t}} = -2 \log_{10} \frac{E}{3.7\ D}$$

or,

$$f_t = \left[\frac{1}{-2 \log_{10} \frac{E}{3.7\ D}}\right]^2 \tag{C-18}$$

To modify the volume roughness, an equivalent turbulent friction factor must be determined as the sum of the above $f_t\ (L/D)_L$ and the $f_t\ (L/D)_v$ of the volume being modified, or

$$f_e\ (L/D)_v = f_t\ (L/D)_v + f_t\ (L/D)_L$$

or,

$$f_e = f_t \frac{(L/D)_v + (L/D)_L}{(L/D)_v} \tag{C-19}$$

The equivalent turbulent friction factor can now be used to calculate an equivalent volume roughness by rearranging Equation (C-18) as

$$E_e = 3.7\ D\ 10^{\frac{1}{-2\sqrt{f_e}}} \tag{C-20}$$

Using this value [Equation (C-20)] of volume roughness instead of the normal pipe roughness will incorporate the effects of frictional losses into the shear term.

An an example, consider an elbow in a RELAP5 model which has an L-over-D loss of 16 ($K = 16\ f_t$). The length and diameter of the volume upstream of the elbow is 1.60 ft and 0.6651 ft (L/D = 2.406), and downstream of the elbow is 2.00 ft and 0.6651 ft (L/D = 3.007). The pipe roughness (E) is nominally 0.00015 ft.

Half the elbow resistance (L/D = 8) will be added to the volume upstream of the elbow and half downstream of the elbow. From Equation (C-18), the turbulent friction factor can be calculated for both volumes as,

$$f_t = \frac{1}{-2 \log_{10} \frac{0.00015}{(3.7)(0.6651)}}^{\,2}$$

$$f_t = 0.01407$$

The equivalent turbulent friction factor can now be determined from Equation (C-19) as,

$$f_e \text{ (upstream)} = 0.01407 \; \frac{2.406 + 8}{2.406}$$

$$= 0.0614$$

$$f_e \text{ (downstream)} = 0.01407 \; \frac{3.007 + 8}{3.007}$$

$$= 0.520$$

The equivalent volume roughness can now be calculated using Equation (C-20) as,

$$E_e \text{ (upstream)} = (3.7)(0.6651)\, 10^{\frac{1}{-2\sqrt{0.0614}}}$$

$$= 0.02314$$

$$E_e \text{ (downstream)} = (3.7)(0.6651)\ 10^{-\frac{1}{-2\sqrt{0.0520}}}$$

$$= 0.01542$$

Using these E_e values for the respective volume roughness terms will simulate the effects of an elbow.

APPENDIX D

RELAP5 CODE UPDATES AND OUTPUT TAPE FORMAT

APPENDIX D

RELAP5 CODE UPDATES AND OUTPUT TAPE FORMAT

1. RELAP5 CODE UPDATES

```
*IDENT JCWTEST
*DELETE RELAP5.6
     * TAPE6=OUTPUT,DEBUG=OUTPUT,PLOTFL,STH2XT,TAPE23)
*BEFORE MOVER.56
C
C ********************************************
C *** UPDATES TO WRITE A JCW STRESS TAPE   ***
C *** AT EVERY SUCCESSFUL TIMESTEP         ***
C *** (WRITES TO TAPE 23)                  ***
C ********************************************
C
C ***************   JCW TAPE   ***************

      DATA JFLAG/0/
      IF(JFLAG.NE.0) GO TO 85
      JFLAG = 1
C
C - WRITE TOTAL NUMBER OF VOLUMES AND JUNCTIONS
C
      NVOLUMS = 1 + (IVE - IV)/(IVSKP)
      NJUNCTS = 1 + (IJE - IJ)/(IJSKP)
      WRITE(23) NVOLUMS,NJUNCTS
C
C - COMPUTE AND WRITE CONTROL VOLUME GEOMETRY
C
      DO 83 I=IV,IVE,IVSKP
      IF(DL(I).EQ.0.0)DZDL = 3.0
      IF(DL(I).NE.0.0)DZDL = DZ(I)/(DL(I)*4.903325)
   83 WRITE(23) VOLNO(I),AVOL(I),DZDL,DL(I)
C
C - WRITE CONNECTION AND CONTROL PARAMETERS FOR JUNCTIONS
C
      DO 84 I=IJ,IJE,IJSKP
   84 WRITE(23) JUNNO(I),AJUN(I),IJ1(I),IJ2(I)
C
C - WRITE THE PROBLEM TIME
C
   85 WRITE(23) TIMEHY
C
C - LOOP THROUGH CONTROL VOLUMES
C
      DO 86 I=IV,IVE,IVSKP
C
C - COMPUTE AVERAGE VOLUME SHEAR FORCE AND VOLUME PV**2 TERM
C
      PIE=3.1415927
      FRF=FWALF(I)*VELF(I)*VOIDF(I)*DL(I)*PIE*DIAMV(I)**2*RHOF(I)*0.25
      FRG=FWALG(I)*VELG(I)*VOIDG(I)*DL(I)*PIE*DIAMV(I)**2*RHOG(I)*0.25
      FRTOT=FRF+FRG
      PV2V=VOIDF(I)*RHOF(I)*VELF(I)**2+
     &      VOIDG(I)*RHOG(I)*VELG(I)**2
C
C - WRITE VOLUME INFORMATION TO TAPE
C
   86 WRITE(23) P(I),FRTOT,PV2V
C
C - LOOP THROUGH JUNCTIONS
C
      DO 87 I=IJ,IJE,IJSKP
C
C - COMPUTE JUNCTION PV**2 TERM
C
      PV2J=0.0
      IF(ATHROT(I).GT.0.0) PV2J=
     &  VOIDFJ(I)*RHOFJ(I)*(VELFJ(I)/ATHROT(I))**2+
     &  VOIDGJ(I)*RHOGJ(I)*(VELGJ(I)/ATHROT(I))**2
C
C - WRITE JUNCTION INFORMATION TO TAPE
C
   87 WRITE(23) ATHROT(I),PV2J,IJ2(I)
```

2. OUTPUT TAPE FORMAT

System Geometry (written once).

1. Total Number of Volumes; Total Number of Junctions

2. For each volume, Volume Number; Volume Area; Volume Inclination; Volume Length

3. For each junction, Junction Number; Junction Area; "From" Junction Control Flag; "To" Junction Control Flag.

Output Data (written every time step)

1. Time

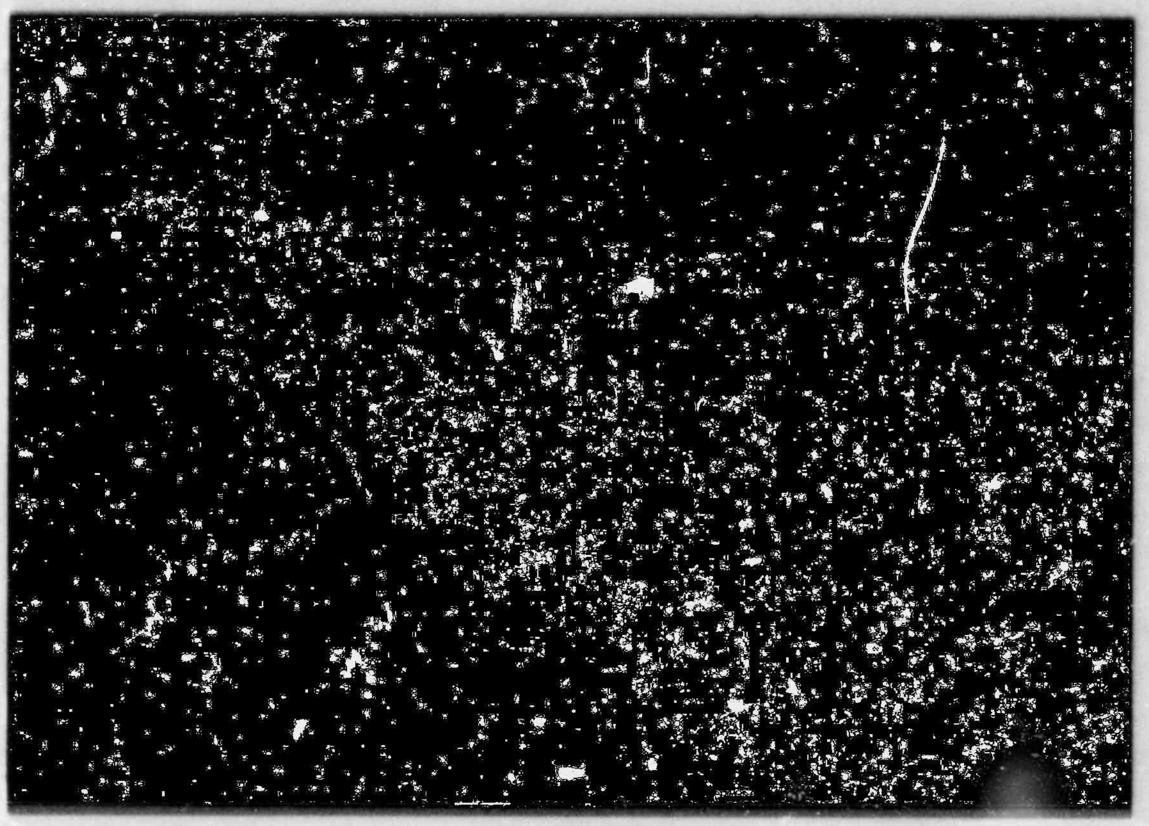
2. For each volume, Volume Pressure; Average Volume Shear Force; Average Volume Momentum Flux

3. For each junction, Junction Throat Ratio; Average Junction Momentum Flux, "To" Junction Control Flag (Contains "To" Junction Choking Flag).

APPENDIX E

R5FORCE PROGRAM LISTING
(MICROFILM)

R5FORCE PROGRAM LISTING



APPENDIX F

PROGRAM USERS GUIDE

APPENDIX F

PROGRAM USERS GUIDE

The purpose of this appendix is to provide sufficient information to permit application of the R5FORCE program to a typical piping system. Included are a description of the force modeling strategy, detailed user input instructions, and a sample problem. It is recommended that the main body of this report be read and understood prior to using the program.

1. FORCE MODELING STRATEGY

The RELAP5 code numerically computes the fluid transient response within a piping system by dividing the system into a number of hydrodynamic control volumes connected by junctions. Associated with each control volume and junction is a nine digit integer reference number. This reference number is written to the RELAP5 hydrodynamic output tape and is therefore available for use in the force calculation program. In the R5FORCE input instructions, force control volumes can then be constructed simply by specifying the applicable RELAP5 control volume reference numbers.

2. R5FORCE INPUT AND OUTPUT

This section provides detailed input instructions and a discussion of the various modeling rules and sign conventions used in the R5FORCE program.

2.1 Input Instructions

All input data is in free format input and default information is contained in parenthesis. Input data need not be entered if default values are aceptable.

Card Number	PARAMETER
=	Title Card, with the "=" sign in Column 1
100	Output Units, "BRITISH" or "METRIC" (BRITISH)
	Input Units, "BRITISH" or "METRIC" (BRITISH)
200	Time Between Printouts, seconds (1.0)
	Start Time, seconds (0.0)
	Finish Time, seconds (1.0×10^{12})
300	Ambient Pressure, psia or Pa (14.7 psia or 0.101 MPa)
400	Type of Printed Output: Output contains problem definition and summary output in addition to the following options: "CHECK"--input check only, problem stops at the end of input processing "NONE"--no output at requested printout times "FORCES"--Subforce and combined force output at requested printout times "ALL"--Subforce, combined force and volume force output at requested printout times (FORCES)
500	Maximum Number of Subforces Per Combined Force (5)

600	Junction number of bends when both adjacent volumes are horizontal (more than one junction number can be on a card)
620	Junction number of a special geometry, such as a relief valve, with an orifice at the outlet but not at the inlet. This geometry assumes the adjacent volumes are at angles to each other. (More than one junction number can be on a card)
640	Same as the 620 card except the orifice is at the inlet only, not the outlet.
700	Initial force zeroing "NONZERO"--Do not zero initial forces
1XXX	Subforce input information for all geometries except an open pipe (XXX is the subforce number) Direction of subforce relative to the RELAP5 model. A positive number is in the direction of positive flow in the RELAP5 model and a negative number is in the direction of negative flow in the RELAP5 model. Beginning control volume number of the subforce relative to the RELAP5 model Ending control volume number of the subforce relative to the RELAP5 model. If this control volume number is the same as the beginning control volume number, either a zero may be entered or the control volume number may be repeated. Combined Force Number/Direction relative to subforce direction. A positive number is in the direction of the subforce and a negative number is in the opposite direction of the subforce. Note that a combined force number need not be entered.
2XXX	Subforce input information for an open pipe. Input identical to card 1XXX.

2.2 Force Direction Conventions

In order to be consistent with the basic equations solved in R5FORCE, the following conventions must be followed.

1. The RELAP5 model must be developed in the direction of positive flow.

2. The force direction must be colinear with the pipe axis, in any direction.

3. System components which result in a frictional loss, such as elbows, must be modeled by modifing the volume roughness rather than by adding an energy loss coefficient at a junction.

4. Branch components in RELAP5 cannot be included in the definition of a subforce or a combined force.

2.3. Output

The R5FORCE program writes information to both an output file (which is usually printed) and a disk or tape file (for structural input).

The output file contains an echo of all input data, information about input data processing, and then force results at requested printout times. This information is considered self-explanatory and will be shown in a sample problem to be discussed later.

Two disk or tape files are currently written at every time step in the following format:

(1) TIME, FORCE 1, FORCE 2, ..., FORCE N,
(2) TIME, PRESSURE 1, PRESSURE 2, ..., PRESSURE M,

where N is the total number of subforces and combined forces and M is the total number of RELAP5 hydrodynamic control volumes. The force file is called TAPE13. In addition, a plotting file called OOSCRA is generated which contains force versus time information in a Common Word Addressable File (CWAF) formated data file. The last page of input processing (in the previously discussed output file) provides a description of the time/force array. For reference purposes, the total number of time steps on the disk or tape file is also written on the output file following the last time step. Also written out is a summary of the maximum positive and negative volume forces, subforces and combined forces.

3. SAMPLE PROBLEM

A detailed sample problem is now presented to help users become familiar with the use of the R5FORCE program.

The piping system geometry and fluid transient used for the sample problem have been previously described in the main body of this report. Figure F-1 shows the piping system and includes a description of the subforces and combined forces to be computed. Figure F-2 is a RELAP5 nodalization diagram of this system showing the hydrodynamic control volumes and junctions as well as each of the control volumes used for force calculations. Note that in general, a force control volume is made up of several hydrodynamic control volumes. A description of the required R5FORCE input data for this sample problem is listed in Figure F-3.

Prior to performing any calculations the R5FORCE program provides an echo of the input data (Figure F-3), and then processes this data. During processing, the user is provided with a description of the RELAP5 hydrodynamic model, information on each of the component and combined forces, a description of the output format of the force file, the initial forces in the system at time zero and the resultant zeroed forces at time zero. Note that all later force values are in reference to the zeroed force values. Appendix G contains a copy of this input processing description for the sample problem.

Figures F-4, F-5, and F-6 represent sample force results at times 0.1, 0.25, and 0.7 s, respectfully. At 0.1 s, the relief valve is completely closed and the only significant unbalanced force (see the combined forces in Figure F-4) occurs upstream of the relief valve which is undergoing rapid pressurization. At 0.25 s the relief valve is in the process of opening and there exists significant unbalanced forces at all points in the system. At 0.7 s the flow is essentially at steady-state and the unbalanced forces are small.

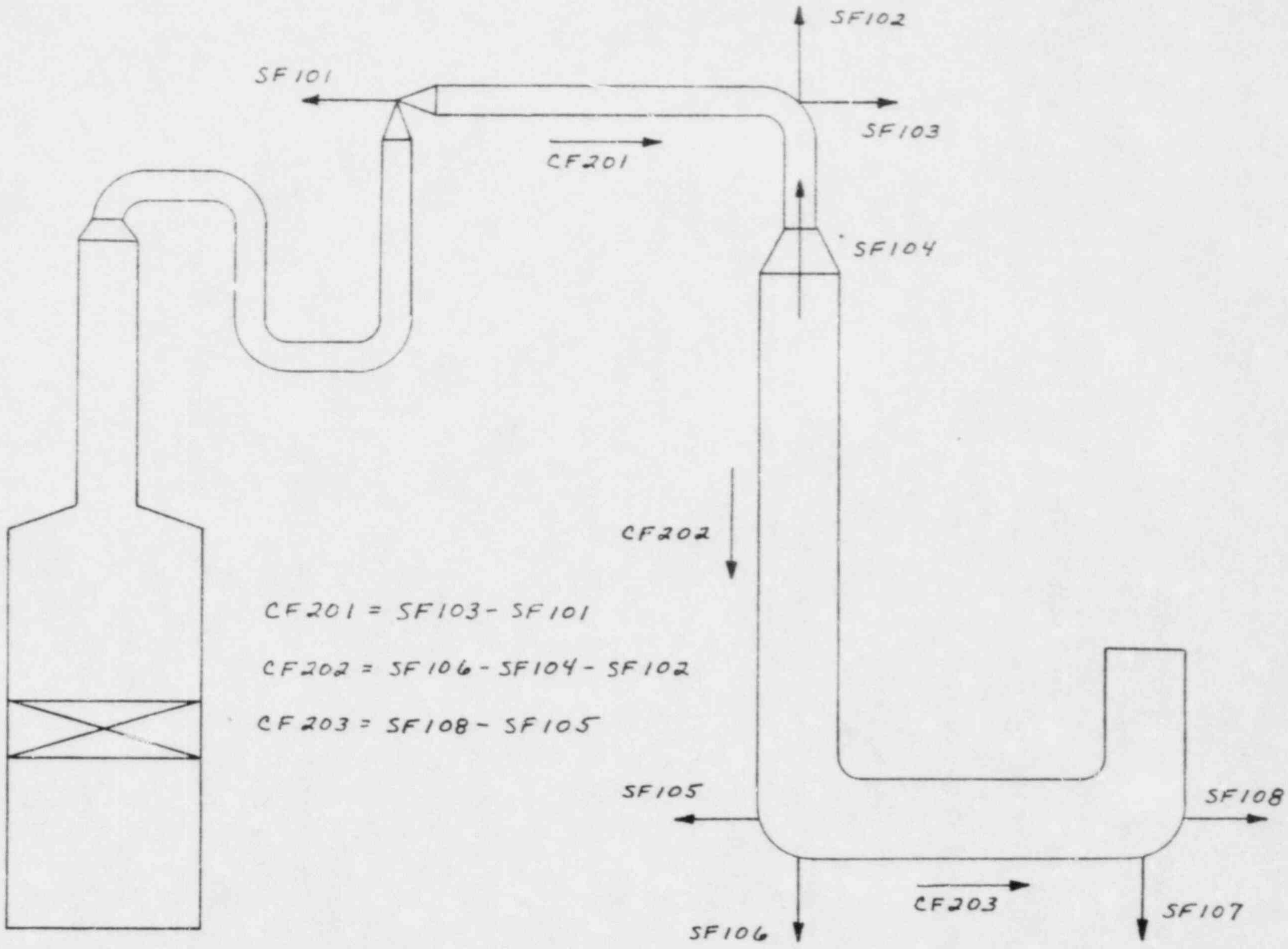


Figure F-1. Sample piping system showning selected forces.

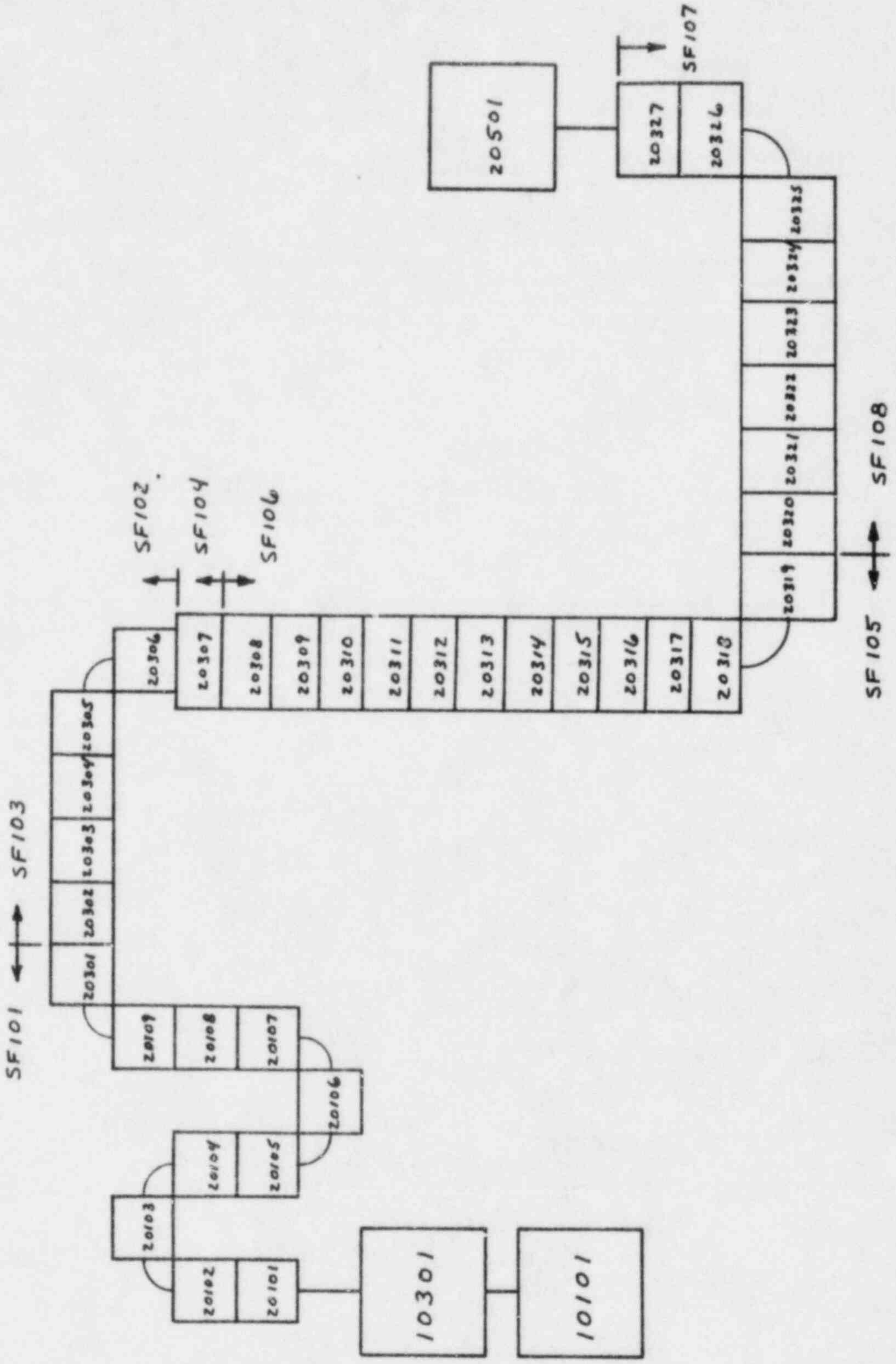


Figure F-2. RELAP5 nodalization diagram of sample piping system.

```
           0         1         2         3         4         5         6         7         8
           12345678901234567890123456789012345678901234567890123456789012345678901234567890

     1     * SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL
     2      100,METRIC
     3      200,0.05
     4      400,ALL
     5      640,202000000
     6     1101,-1,203010000,        0,-201
     7     1102,-1,203060000,203070000,-202
     8     1103,+1,203020000,203050000,+201
     9     1104,-1,203080000,        0,-202
    10     1105,-1,203200000,        0,-203
    11     1106,+1,203090000,203190000,+202
    12     2107,-1,203270000,203280000
    13     1108,+1,203210000,203280000,+203
           0         1         2         3         4         5         6         7         8
           12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Figure F-3. R5FORCE input data echo of sample piping system.

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - VOLUME FORCE DATA
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                          10/15/82          12.03.20.
PROBLEM TIME =  1.0000E-01        DATA SET NUMBER =     21

                                    INLET INT.        OUTLET INT.       INLET EXT.       OUTLET EXT.
  VOL. NUM.        SHEAR FORCE      FORCE             FORCE             FORCE            FORCE            TOTAL FORCE
                   (NEWTONS)        (NEWTONS)         (NEWTONS)         (NEWTONS)        (NEWTONS)        (NEWTONS)

  10101000         0.              -3.24208E+05      0.                0.               0.              -3.24208E+05
  10301000          .15092          0.                3.14177E+05      0.               0.               3.14177E+05
  20101000         1.51006E-02      0.                0.               0.               0.               1.51006E-02
  20102000         1.91061E-02      0.                7998.2           0.               0.               7998.2
  20103000         3.14390E-02     -4638.8            4638.4           0.               0.               -.45299
  20104000         1.49200E-02     -4638.4            0.               0.               0.              -4638.3
  20105000         1.03400E-02      0.                4641.5           0.               0.               4641.5
  20106000         9.38446E-03     -4641.5            4639.1           0.               0.              -2.3825
  20107000         3.19775E-03     -4639.1            0.               0.               0.              -4639.1
  20108000         9.12936E-04      0.                0.               0.               0.               9.12936E-04
  20109000         1.65904E-04      0.                4618.8           0.               0.               4618.8
  20301000        -4.30713E-08       .73835           0.               0.               0.                .73835
  20302000        -1.29288E-07      0.                0.               0.               0.              -1.29288E-07
  20303000        -2.15708E-07      0.                0.               0.               0.              -2.15708E-07
  20304000        -3.02446E-07      0.                0.               0.               0.              -3.02446E-07
  20305000        -3.89567E-07      0.                -.73175          0.               0.               -.73175
  20306000        -2.67914E-07       .73175           0.               0.               0.                .73175
  20307000        -3.22313E-07      0.                0.               0.               0.              -3.22313E-07
  20308000        -2.89757E-07       .66008           0.               0.               0.                .66008
  20309000        -3.68050E-07      0.                0.               0.               0.              -3.68050E-07
  20310000        -4.46625E-07      0.                0.               0.               0.              -4.46625E-07
  20311000        -5.25280E-07      0.                0.               0.               0.              -5.25280E-07
  20312000        -6.03766E-07      0.                0.               0.               0.              -6.03766E-07
  20313000        -6.81788E-07      0.                0.               0.               0.              -6.81788E-07
  20314000        -7.59976E-07      0.                0.               0.               0.              -7.59976E-07
  20315000        -8.34883E-07      0.                0.               0.               0.              -8.34883E-07
  20316000        -9.09012E-07      0.                0.               0.               0.              -9.09012E-07
  20317000        -9.86811E-07      0.                0.               0.               0.              -9.86811E-07
  20318000        -1.05386E-06      0.                0.               0.               0.              -1.05386E-06
  20319000        -1.12216E-06      0.                 .58939          0.               0.                .58938
  20320000        -1.38547E-06      -.58939           0.               0.               0.               -.58939
  20321000        -1.46236E-06      0.                0.               0.               0.              -1.46236E-06
  20322000        -1.53130E-06      0.                0.               0.               0.              -1.53130E-06
  20323000        -1.59252E-06      0.                0.               0.               0.              -1.59252E-06
  20324000        -1.72381E-06      0.                0.               0.               0.              -1.72381E-06
  20325000        -1.76985E-06      0.                0.               0.               0.              -1.76985E-06
  20326000        -1.80389E-06      0.                 .36318          0.               0.                .36317
  20327000        -1.49297E-06      -.36318           0.               0.               0.               -.36318
  20329000        -1.50019E-06      0.                0.               0.               0.              -1.50019E-06
  20501000         0.              -3.03611E-07       3.26894E-07      0.               0.               2.32831E-08
```

Figure F-4. R5FORCE results at 0.1 s.

```
FORCE-TIM    TORY FROM RELAP5 OUTPUT DATA - SUBFORCE AND COMBINED FORCE DATA
 SAMPLE PRO     - RELIEF VALVE DISCHARGE W/O LOOP SEAL                     10/15/82          12.03.20.
PROBLEM TIM        0000E-01          DATA SET NUMBER =     21

 FORCE                          INLET INT.        OUTLET INT.       INLET EXT.        OUTLET EXT.
 NUMBER        SHEAR FORCE      FORCE             FORCE             FORCE             FORCE             TOTAL FORCE
               (NEWTONS)        (NEWTONS)         (NEWTONS)         (NEWTONS)         (NEWTONS)         (NEWTONS)

 SF101          4.30713E-08     -.73835           0.                0.                0.                -.73835
 SF102          6.10227E-07     -.73175           0.                0.                0.                -.73175
 SF103         -1.03701E-06     0.                -.73175           0.                0.                -.73175
 SF104          2.89757E-07     -.66008           0.                0.                0.                -.66008
 SF105          1.36547E-06      .58939           0.                0.                0.                 .58939
 SF106         -8.28520E-06     0.                 .58939           0.                0.                 .58938
 SF107          2.99316E-06      .36318           0.                0.                0.                 .36318
 SF108         -9.88371E-06     0.                 .36318           0.                0.                 .36317
 CF201         -1.08006E-06      .73835           -.73175           0.                0.                6.60486E-03
 CF202         -9.18519E-06     1.3918             .58939           0.                0.                1.9812
 CF203         -1.12692E-05     -.58939            .36318           0.                0.                -.22622
```

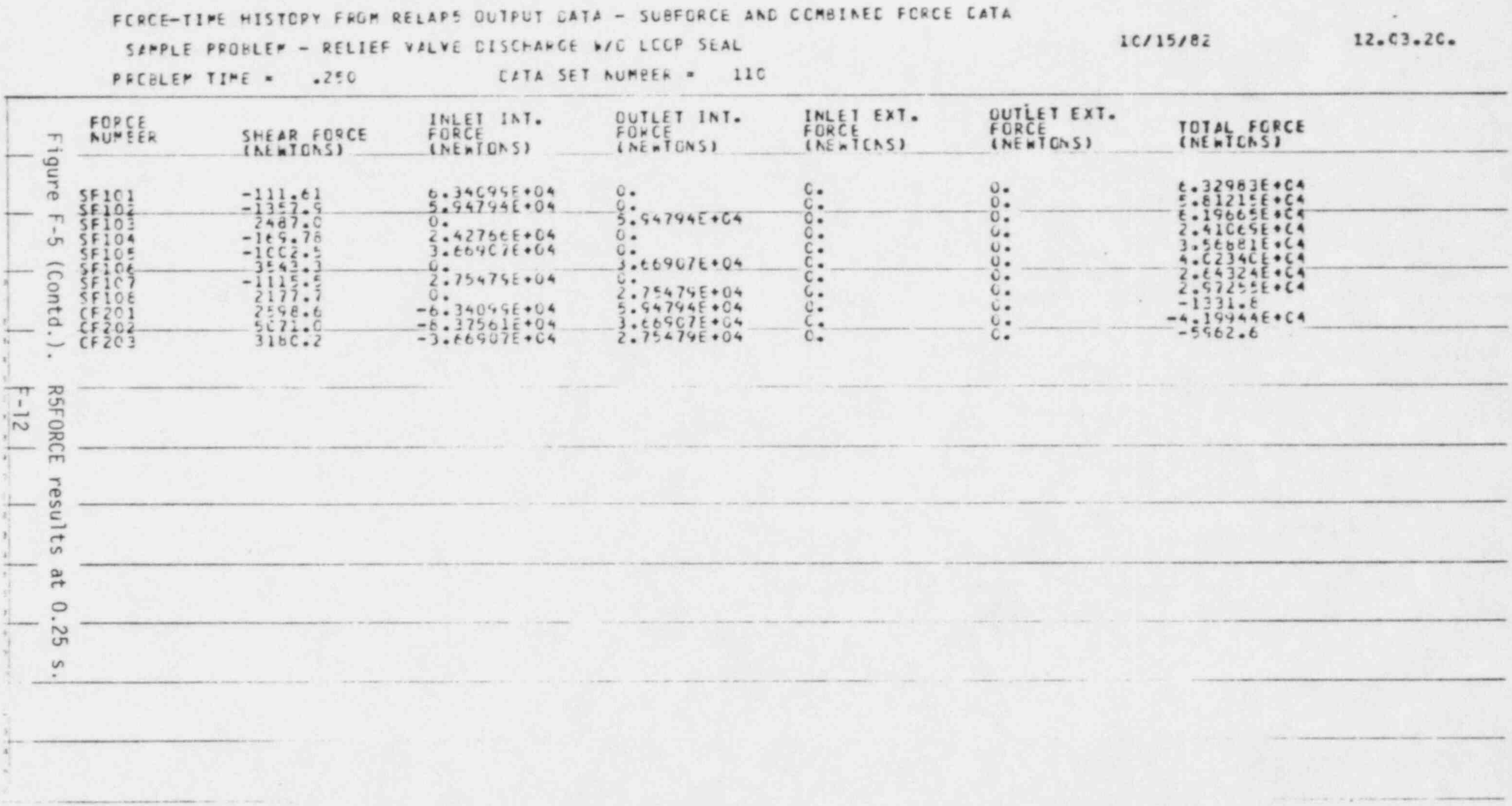
Figure F-4 (Contd.). R5FROCE results at 0.1 s.

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - VOLUME FORCE DATA
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                                          10/15/82            12.03.20.
PROBLEM TIME =    .250          DATA SET NUMBER =    110

                                      INLET INT.        OUTLET INT.       INLET EXT.        OUTLET EXT.
  VOL. NUM.          SHEAR FORCE      FORCE             FORCE             FORCE             FORCE             TOTAL FORCE
                     (NEWTONS)        (NEWTONS)         (NEWTONS)         (NEWTONS)         (NEWTONS)         (NEWTONS)

  101010000          0.               -8.10589E+05      0.                0.                0.                -8.10589E+05
  103010000           1.7649           0.               7.92193E+05       0.                0.                 7.92195E+05
  201010000           55.903           0.               0.                0.                0.                  55.903
  201020000           121.31           0.               1.92319E+04       0.                0.                 1.93532E+04
  201030000           306.37          -1.23216E+04      1.12919E+04       0.                0.                -723.24
  201040000           206.49          -1.12919E+04      0.                0.                0.                -1.10854E+04
  201050000           208.24           0.                9852.6           0.                0.                 1.00609E+04
  201060000           315.16          -9852.6            9246.6           0.                0.                -290.84
  201070000           205.34          -9246.6           0.                0.                0.                -9041.3
  201080000           113.82           0.               0.                0.                0.                  113.82
  201090000           133.29           0.                8413.0           0.                0.                  8546.3
  203010000           111.61          -6.34099E+04      0.                0.                0.                -6.32983E+04
  203020000           357.13           0.               0.                0.                0.                  357.13
  203030000           436.44           0.               0.                0.                0.                  436.44
  203040000           474.26           0.               0.                0.                0.                  474.26
  203050000           1219.2           0.               5.94794E+04       0.                0.                 6.06986E+04
  203060000           1036.5          -5.94794E+04      0.                0.                0.                -5.84429E+04
  203070000           321.37           0.               0.                0.                0.                  321.37
  203080000           169.78          -2.42766E+04      0.                0.                0.                -2.41069E+04
  203090000           235.61           0.               0.                0.                0.                  235.61
  203100000           259.17           0.               0.                0.                0.                  259.17
  203110000           268.15           0.               0.                0.                0.                  268.15
  203120000           270.00           0.               0.                0.                0.                  270.00
  203130000           267.84           0.               0.                0.                0.                  267.84
  203140000           263.41           0.               0.                0.                0.                  263.41
  203150000           257.55           0.               0.                0.                0.                  257.55
  203160000           251.02           0.               0.                0.                0.                  251.02
  203170000           243.61           0.               0.                0.                0.                  243.61
  203180000           236.09           0.               0.                0.                0.                  236.09
  203190000           990.67           0.               3.66907E+04       0.                0.                 3.76813E+04
  203200000           1002.5          -3.66907E+04      0.                0.                0.                -3.56881E+04
  203210000           255.61           0.               0.                0.                0.                  255.61
  203220000           254.79           0.               0.                0.                0.                  254.79
  203230000           251.82           0.               0.                0.                0.                  251.82
  203240000           258.25           0.               0.                0.                0.                  258.25
  203250000           250.27           0.               0.                0.                0.                  250.27
  203260000           906.95           0.               2.75479E+04       0.                0.                 2.84548E+04
  203270000           861.51          -2.75479E+04      0.                0.                0.                -2.66864E+04
  203280000           253.95           0.               0.                0.                0.                  253.95
  205010000          0.               -866.28            932.06           0.                0.                  65.785
```

Figure F-5. R5FORCE results at 0.25 s



```
  FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - SUBFORCE AND COMBINED FORCE DATA
   SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                              10/15/82          12.03.20.
  PROBLEM TIME =    .250           DATA SET NUMBER =   110
--------------------------------------------------------------------------------------------------------------------
  FORCE                            INLET INT.       OUTLET INT.      INLET EXT.       OUTLET EXT.
  NUMBER         SHEAR FORCE       FORCE            FORCE            FORCE            FORCE            TOTAL FORCE
                 (NEWTONS)         (NEWTONS)        (NEWTONS)        (NEWTONS)        (NEWTONS)        (NEWTONS)

 SF101             -111.61         6.34099E+04      0.               0.               0.               6.32983E+04
 SF102            -1357.9          5.94794E+04      0.               0.               0.               5.81215E+04
 SF103             2487.0          0.               5.94794E+04      0.               0.               6.19665E+04
 SF104             -169.78         2.42766E+04      0.               0.               0.               2.41069E+04
 SF105            -1002.5          3.66907E+04      0.               0.               0.               3.56881E+04
 SF106             3543.3          0.               3.66907E+04      0.               0.               4.02340E+04
 SF107            -1115.5          2.75479E+04      0.               0.               0.               2.64324E+04
 SF108             2177.7          0.               2.75479E+04      0.               0.               2.97255E+04
 CF201             2598.6         -6.34099E+04      5.94794E+04      0.               0.              -1331.8
 CF202             5071.0         -8.37561E+04      3.66907E+04      0.               0.              -4.19944E+04
 CF203             3180.2         -3.66907E+04      2.75479E+04      0.               0.              -5962.6
```

Figure F-5 (Contd.). R5FORCE results at 0.25 s.

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - VOLUME FORCE DATA
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                              10/15/82          12.03.20.
PROBLEM TIME =    .700            DATA SET NUMBER =    830

                                   INLET INT.       OUTLET INT.      INLET EXT.      OUTLET EXT.
 VOL. NUM.       SHEAR FORCE       FORCE            FORCE            FORCE           FORCE            TOTAL FORCE
                 (NEWTONS)         (NEWTONS)        (NEWTONS)        (NEWTONS)       (NEWTONS)        (NEWTONS)

 101010000       0.                -1.62091E+06     0.               0.              0.               -1.62091E+06
 103010000        1.2352           0.               1.58155E+06      0.              0.                1.58156E+06
 201010000        58.768           0.               0.               0.              0.                 58.768
 201020000        126.08           0.               4.12556E+04      0.              0.                4.13816E+04
 201030000        314.61           -2.51492E+04     2.48453E+04      0.              0.                 10.652
 201040000        208.70           -2.48453E+04     0.               0.              0.               -2.46366E+04
 201050000        208.65           0.               2.43725E+04      0.              0.                2.45812E+04
 201060000        316.12           -2.43725E+04     2.40681E+04      0.              0.                 11.680
 201070000        208.28           -2.40681E+04     0.               0.              0.               -2.38598E+04
 201080000        117.52           0.               0.               0.              0.                 117.52
 201090000        140.79           0.               2.35310E+04      0.              0.                2.36717E+04
 203010000        109.50           -7.40630E+04     0.               0.              0.               -7.39535E+04
 203020000        347.87           0.               0.               0.              0.                 347.87
 203030000        427.08           0.               0.               0.              0.                 427.08
 203040000        473.88           0.               0.               0.              0.                 473.88
 203050000        1265.2           0.               7.04152E+04      0.              0.                7.16804E+04
 203060000        1120.5           -7.04152E+04     0.               0.              0.               -6.92947E+04
 203070000        361.53           0.               0.               0.              0.                 361.53
 203080000        200.69           -3.71006E+04     0.               0.              0.               -3.68999E+04
 203090000        243.13           0.               0.               0.              0.                 243.13
 203100000        258.05           0.               0.               0.              0.                 258.05
 203110000        265.03           0.               0.               0.              0.                 265.03
 203120000        269.17           0.               0.               0.              0.                 269.17
 203130000        272.21           0.               0.               0.              0.                 272.21
 203140000        274.84           0.               0.               0.              0.                 274.84
 203150000        277.36           0.               0.               0.              0.                 277.36
 203160000        279.89           0.               0.               0.              0.                 279.89
 203170000        282.48           0.               0.               0.              0.                 282.48
 203180000        285.16           0.               0.               0.              0.                 285.16
 203190000        1260.1           0.               6.94259E+04      0.              0.                7.06860E+04
 203200000        1340.5           -6.94259E+04     0.               0.              0.               -6.80855E+04
 203210000        355.02           0.               0.               0.              0.                 355.02
 203220000        367.55           0.               0.               0.              0.                 367.55
 203230000        377.89           0.               0.               0.              0.                 377.89
 203240000        405.94           0.               0.               0.              0.                 405.94
 203250000        416.40           0.               0.               0.              0.                 416.40
 203260000        1623.5           0.               6.58143E+04      0.              0.                6.74381E+04
 203270000        1668.4           -6.58143E+04     0.               0.              0.               -6.41459E+04
 203280000        575.37           0.               0.               0.              0.                 575.37
 205010000       0.                -871.27           937.44          0.              0.                 66.164
```

Figure F-6. R5FORCE results at 0.7 s.

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - SUBFORCE AND COMBINED FORCE DATA
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                        10/15/82          12.03.20.
PROBLEM TIME =    .700              DATA SET NUMBER =    830

 FORCE                           INLET INT.       OUTLET INT.      INLET EXT.       OUTLET EXT.
 NUMBER         SHEAR FORCE      FORCE            FORCE            FORCE            FORCE             TOTAL FORCE
                (NEWTONS)        (NEWTONS)        (NEWTONS)        (NEWTONS)        (NEWTONS)         (NEWTONS)

 SF101          -109.50          7.40630E+04      0.               0.               0.                7.39535E+04
 SF102          -1482.0          7.04152E+04      0.               0.               0.                6.89332E+04
 SF103           2514.0          0.               7.04152E+04      0.               0.                7.29292E+04
 SF104          -200.69          3.71006E+04      0.               0.               0.                3.68999E+04
 SF105          -1340.5          6.94259E+04      0.               0.               0.                6.80855E+04
 SF106           3967.4          0.               6.94259E+04      0.               0.                7.33934E+04
 SF107          -2243.8          6.58143E+04      0.               0.               0.                6.35705E+04
 SF108           3546.7          0.               6.58143E+04      0.               0.                6.93605E+04
 CF201           2623.5         -7.40630E+04      7.04152E+04      0.               0.               -1024.3
 CF202           5650.1         -1.07516E+05      6.94259E+04      0.               0.               -3.24397E+04
 CF203           4887.1         -6.94259E+04      6.58143E+04      0.               0.                1275.5
```

Figure F-6 (Contd.) R5FORCE results at 0.7 s.

Upon completion of the requested force calculations, the R5FORCE program provides a summary identifying the maximum positive and negative forces encountered for each volume force, subforce and combined force requested, including the time of the maximum force. Appendix H contains a copy of this output for the sample problem.

APPENDIX G

SAMPLE PROBLEM INPUT PROCESSING DESCRIPTION

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - INPUT DESCRIPTION OF SUBFORCES
SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                 .        10/15/82          12.03.20.

SUBFORCE NUM.    DIRECTION    BEG. CV. NUM.    END. CV. NUM.    FROM JUN. TYPE    TO JUN. TYPE    FORCE COMB. NUM.

     101            -1         203010000        203010000                                              -201
     102            -1         203060000        203070000          BOUNDED                             -202
     103            +1         203020000        203050000                            BOUNDED           +201
     104            -1         2030[illegible]000        203080000                                              -202
     105            -1         203200000        203200000          BOUNDED                             -203
     106            +1         203090000        203190000                            BOUNDED           +202
     107            -1         203270000        203260000          BOUNDED           OPEN
     108            +1         203210000        203260000                            BOUNDED           +203
```

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - DESCRIPTION OF RELAP5 HYDRODYNAMIC VOLUMES AND JUNCTIONS
SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                                10/15/82          12.03.20.

                                                                FROM JUNCTION INFORMATION                TO JUNCTION INFORMATION
VOL. NUM.   LENGTH   AREA          FROM VOL.   TO VOL.     NUMBER      AREA          TYPE   NUMBER      AREA          TYPE
                     (SQ. METERS)                                      (SQ. METERS)                     (SQ. METERS)

101010000   0.       .94031        101010000   103010000   102000000   .94031               102000000   .94031
103010000   3.0114   .94031        103010000   201010000   104000000   2.35230E-02          104000000   2.35230E-02
201010000   .45720   2.35230E-02   201010000   201020000   201010000   2.35230E-02          201010000   2.35230E-02
201020000   .45720   2.35230E-02   201020000   201030000   201020000   1.36475E-02          201020000   1.36475E-02   BOUND
201030000   .45720   1.36475E-02   201030000   201040000   201030000   1.36475E-02   BOUND  201030000   1.36475E-02   BOUND
201040000   .38100   1.36475E-02   201040000   201050000   201040000   1.36475E-02   BOUND  201040000   1.36475E-02
201050000   .38100   1.36475E-02   201050000   201060000   201050000   1.36475E-02          201050000   1.36475E-02   BOUND
201060000   .45720   1.36475E-02   201060000   201070000   201060000   1.36475E-02   BOUND  201060000   1.36475E-02   BOUND
201070000   .38100   1.36475E-02   201070000   201080000   201070000   1.36475E-02   BOUND  201070000   1.36475E-02
201080000   .38100   1.36475E-02   201080000   201090000   201080000   1.36475E-02          201080000   1.36475E-02
201090000   .45720   1.36475E-02   201090000   203010000   202000000   1.36475E-02          202000000   1.36475E-02   BOUND
203010000   .48768   3.22745E-02   203010000   203020000   203010000   3.22745E-02          203010000   3.22745E-02
203020000   .48768   3.22745E-02   203020000   203030000   203020000   3.22745E-02          203020000   3.22745E-02
203030000   .48768   3.22745E-02   203030000   203040000   203030000   3.22745E-02          203030000   3.22745E-02
203040000   .48768   3.22745E-02   203040000   203050000   203040000   3.22745E-02          203040000   3.22745E-02
203050000   .48768   3.22745E-02   203050000   203060000   203050000   3.22745E-02          203050000   3.22745E-02   BOUND
203060000   .30480   3.22745E-02   203060000   203070000   203060000   3.22745E-02   BOUND  203060000   3.22745E-02
203070000   .30480   3.22745E-02   203070000   203080000   203070000   3.22745E-02          203070000   3.22745E-02
203080000   .45720   6.55710E-02   203080000   203090000   203080000   6.55710E-02          203080000   6.55710E-02
203090000   .45720   6.55710E-02   203090000   203100000   203090000   6.55710E-02          203090000   6.55710E-02
203100000   .45720   6.55710E-02   203100000   203110000   203100000   6.55710E-02          203100000   6.55710E-02
203110000   .45720   6.55710E-02   203110000   203120000   203110000   6.55710E-02          203110000   6.55710E-02
203120000   .45720   6.55710E-02   203120000   203130000   203120000   6.55710E-02          203120000   6.55710E-02
203130000   .45720   6.55710E-02   203130000   203140000   203130000   6.55710E-02          203130000   6.55710E-02
203140000   .45720   6.55710E-02   203140000   203150000   203140000   6.55710E-02          203140000   6.55710E-02
203150000   .45720   6.55710E-02   203150000   203160000   203150000   6.55710E-02          203150000   6.55710E-02
203160000   .45720   6.55710E-02   203160000   203170000   203160000   6.55710E-02          203160000   6.55710E-02
203170000   .45720   6.55710E-02   203170000   203180000   203170000   6.55710E-02          203170000   6.55710E-02
203180000   .45720   6.55710E-02   203180000   203190000   203180000   6.55710E-02          203180000   6.55710E-02
203190000   .45720   6.55710E-02   203190000   203200000   203190000   6.55710E-02          203190000   6.55710E-02   BOUND
203200000   .53340   6.55710E-02   203200000   203210000   203200000   6.55710E-02   BOUND  203200000   6.55710E-02
203210000   .53340   6.55710E-02   203210000   203220000   203210000   6.55710E-02          203210000   6.55710E-02
203220000   .53340   6.55710E-02   203220000   203230000   203220000   6.55710E-02          203220000   6.55710E-02
203230000   .53340   6.55710E-02   203230000   203240000   203230000   6.55710E-02          203230000   6.55710E-02
203240000   .55870   6.55710E-02   203240000   203250000   203240000   6.55710E-02          203240000   6.55710E-02
203250000   .55870   6.55710E-02   203250000   203260000   203250000   6.55710E-02          203250000   6.55710E-02
203260000   .55870   6.55710E-02   203260000   203270000   203260000   6.55710E-02          203260000   6.55710E-02   BOUND
203270000   .45720   6.55710E-02   203270000   203280000   203270000   6.55710E-02   BOUND  203270000   6.55710E-02
203280000   .45720   6.55710E-02   203280000   205010000   204000000   6.55710E-02          204000000   6.55710E-02   OPEN
205010000   0.       .92903
```

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - DESCRIPTION OF FORCE ARRAY WRITTEN TO THE STRUCTURAL OUTPUT FILE
SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                              10/15/82          12.03.20.

ARRAY INDEX NUMBER     FORCE NUMBER      SUBFORCE COMPONENTS OF A COMBINED FORCE
                                        ('+' IMPLIES ADDITION; '-' IMPLIES SUBTRACTION)

       001                SF1C1
       002                SF1C2
       003                SF1C3
       004                SF1C4
       005                SF1C5
       006                SF1C6
       007                SF1C7
       008                SF1C8
       009                CF2C1         -101      +103
       010                CF2C2         -102      -104      +106
       011                CF2C3         -105      +108
```

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - INITIALIZED VOLUME FORCE DATA
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                              10/15/82          12.03.20.
TIME ZERO =  0.

                                           INLET INT.      OUTLET INT.     INLET EXT.      OUTLET EXT.
     VOL. NUM.         SHEAR FORCE         FORCE           FORCE           FORCE           FORCE           TOTAL FORCE
                       (NEWTONS)           (NEWTONS)       (NEWTONS)       (NEWTONS)       (NEWTONS)       (NEWTONS)

     101010000         0.                  -1.55598E+07    0.              9.53036E+04     0.              -1.54645E+07
     103010000         0.                   0.             1.51705E+07     0.              -9.29195E+04     1.50776E+07
     201010000         0.                   0.             0.              0.              0.               0.
     201020000         0.                   0.             3.89246E+05     0.              -2364.1          3.86882E+05
     201030000         0.                  -2.25830E+05    2.25830E+05      1383.2         -1383.2          0.
     201040000         0.                  -2.25830E+05    0.               1383.2         0.              -2.24447E+05
     201050000         0.                   0.             2.25830E+05     0.              -1383.2          2.24447E+05
     201060000         0.                  -2.25830E+05    2.25830E+05      1383.2         -1383.2          0.
     201070000         0.                  -2.25830E+05    0.               1383.2         0.              -2.24447E+05
     201080000         0.                   0.             0.              0.              0.               0.
     201090000         0.                   0.             2.25830E+05     0.              -1383.2          2.24447E+05
     203010000         0.                  -3271.1         0.               3271.1         0.              -1.45519E-11
     203020000         0.                   0.             0.              0.              0.               0.
     203030000         0.                   0.             0.              0.              0.               0.
     203040000         0.                   0.             0.              0.              0.               0.
     203050000         0.                   0.              3271.1         0.              -3271.1          1.45519E-11
     203060000         0.                  -3271.1         0.               3271.1         0.              -1.45519E-11
     203070000         0.                   0.             0.              0.              0.               0.
     203080000         0.                  -3374.7         0.               3374.7         0.              -1.45519E-11
     203090000         0.                   0.             0.              0.              0.               0.
     203100000         0.                   0.             0.              0.              0.               0.
     203110000         0.                   0.             0.              0.              0.               0.
     203120000         0.                   0.             0.              0.              0.               0.
     203130000         0.                   0.             0.              0.              0.               0.
     203140000         0.                   0.             0.              0.              0.               0.
     203150000         0.                   0.             0.              0.              0.               0.
     203160000         0.                   0.             0.              0.              0.               0.
     203170000         0.                   0.             0.              0.              0.               0.
     203180000         0.                   0.             0.              0.              0.               0.
     203190000         0.                   0.              6645.8         0.              -6645.8          2.91038E-11
     203200000         0.                  -6645.8         0.               6645.8         0.              -2.91038E-11
     203210000         0.                   0.             0.              0.              0.               0.
     203220000         0.                   0.             0.              0.              0.               0.
     203230000         0.                   0.             0.              0.              0.               0.
     203240000         0.                   0.             0.              0.              0.               0.
     203250000         0.                   0.             0.              0.              0.               0.
     203260000         0.                   0.              6645.8         0.              -6645.8          5.82077E-11
     203270000         0.                  -6645.8         0.               6645.8         0.              -5.82077E-11
     203280000         0.                   0.             0.              0.              0.               0.
     205010000         0.                  -8.75141E+04    9.41600E+04     8.75141E+04     -9.41600E+04     0.
```

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - INITIALIZED SUBFORCE AND COMBINED FORCE DATA
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                        10/15/82          12.03.20.
TIME ZERO =  0.

  FORCE                         INLET INT.       OUTLET INT.      INLET EXT.       OUTLET EXT.
  NUMBER      SHEAR FORCE       FORCE            FORCE            FORCE            FORCE            TOTAL FORCE
              (NEWTONS)         (NEWTONS)        (NEWTONS)        (NEWTONS)        (NEWTONS)        (NEWTONS)

 SF101        0.                 3271.1          0.               -3271.1          0.               1.45519E-11
 SF102        0.                 3271.1          0.               -3271.1          0.               1.45519E-11
 SF103        0.                0.                3271.1          0.               -3271.1          1.45519E-11
 SF104        0.                 3374.7          0.               -3374.7          0.               1.45519E-11
 SF105        0.                 6645.8          0.               -6645.8          0.               2.91038E-11
 SF106        0.                0.                6645.8          0.               -6645.8          2.91038E-11
 SF107        0.                 6645.8          0.               -6645.8          0.               5.82077E-11
 SF108        0.                0.                6645.8          0.               -6645.8          5.82077E-11
 CF201        0.                -3271.1           3271.1           3271.1          -3271.1          0.
 CF202        0.                -6645.8           6645.8           6645.8          -6645.8          0.
 CF203        0.                -6645.8           6645.8           6645.8          -6645.8          2.91038E-11
```

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - VOLUME FORCE DATA
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                                   10/15/82            12.03.20.
PROBLEM TIME =  0.               DATA SET NUMBER =      1

                                    INLET INT.        OUTLET INT.       INLET EXT.        OUTLET EXT.
     VOL. NUM.     SHEAR FORCE      FORCE             FORCE             FORCE             FORCE             TOTAL FORCE
                   (NEWTONS)        (NEWTONS)         (NEWTONS)         (NEWTONS)         (NEWTONS)         (NEWTONS)

     101010000     0.               0.                0.                0.                0.                0.
     103010000     0.               0.                0.                0.                0.                0.
     201010000     0.               0.                0.                0.                0.                0.
     201020000     0.               0.                0.                0.                0.                0.
     201030000     0.               0.                0.                0.                0.                0.
     201040000     0.               0.                0.                0.                0.                0.
     201050000     0.               0.                0.                0.                0.                0.
     201060000     0.               0.                0.                0.                0.                0.
     201070000     0.               0.                0.                0.                0.                0.
     201080000     0.               0.                0.                0.                0.                0.
     201090000     0.               0.                0.                0.                0.                0.
     203010000     0.               0.                0.                0.                0.                0.
     203020000     0.               0.                0.                0.                0.                0.
     203030000     0.               0.                0.                0.                0.                0.
     203040000     0.               0.                0.                0.                0.                0.
     203050000     0.               0.                0.                0.                0.                0.
     203060000     0.               0.                0.                0.                0.                0.
     203070000     0.               0.                0.                0.                0.                0.
     203080000     0.               0.                0.                0.                0.                0.
     203090000     0.               0.                0.                0.                0.                0.
     203100000     0.               0.                0.                0.                0.                0.
     203110000     0.               0.                0.                0.                0.                0.
     203120000     0.               0.                0.                0.                0.                0.
     203130000     0.               0.                0.                0.                0.                0.
     203140000     0.               0.                0.                0.                0.                0.
     203150000     0.               0.                0.                0.                0.                0.
     203160000     0.               0.                0.                0.                0.                0.
     203170000     0.               0.                0.                0.                0.                0.
     203180000     0.               0.                0.                0.                0.                0.
     203190000     0.               0.                0.                0.                0.                0.
     203200000     0.               0.                0.                0.                0.                0.
     203210000     0.               0.                0.                0.                0.                0.
     203220000     0.               0.                0.                0.                0.                0.
     203230000     0.               0.                0.                0.                0.                0.
     203240000     0.               0.                0.                0.                0.                0.
     203250000     0.               0.                0.                0.                0.                0.
     203260000     0.               0.                0.                0.                0.                0.
     203270000     0.               0.                0.                0.                0.                0.
     203280000     0.               0.                0.                0.                0.                0.
     205010000     0.               0.                0.                0.                0.                0.
```

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - SUBFORCE AND COMBINED FORCE DATA
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                                10/15/82          12.03.20.
PROBLEM TIME =  0.              DATA SET NUMBER =      1

   FORCE                          INLET INT.        OUTLET INT.       INLET EXT.        OUTLET EXT.
   NUMBER        SHEAR FORCE      FORCE             FORCE             FORCE             FORCE             TOTAL FORCE
                 (NEWTONS)        (NEWTONS)         (NEWTONS)         (NEWTONS)         (NEWTONS)         (NEWTONS)

  SF101          0.               0.                0.                0.                0.                0.
  SF102          0.               0.                0.                0.                0.                0.
  SF103          0.               0.                0.                0.                0.                0.
  SF104          0.               0.                0.                0.                0.                0.
  SF105          0.               0.                0.                0.                0.                0.
  SF106          0.               0.                0.                0.                0.                0.
  SF107          0.               0.                0.                0.                0.                0.
  SF108          0.               0.                0.                0.                0.                0.
  CF201          0.               0.                0.                0.                0.                0.
  CF202          0.               0.                0.                0.                0.                0.
  CF203          0.               0.                0.                0.                0.                0.
```

APPENDIX H

SAMPLE PROBLEM OUTPUT SUMMARY

```
FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - SUMMARY OF MAXIMUM POSITIVE VOLUME FORCES

SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                          10/15/82          12.03.20.

                                                                                                  TIME OF
   FORCE                        INLET INT.      OUTLET INT.     INLET EXT.     OUTLET EXT.     MAXIMUM         MAXIMUM
   NUMBER       SHEAR FORCE     FORCE           FORCE           FORCE          FORCE           FORCE           FORCE
                (NEWTONS)       (NEWTONS)       (NEWTONS)       (NEWTONS)      (NEWTONS)       (NEWTONS)       (SECONDS)

  101010000    0.              -1.62089E+06     1.71807E+07     0.             0.              1.55598E+07     1.00
  103010000     1.2286          0.              1.59679E+06     0.             0.              1.59679E+06     .510
  201010000    67.772           0.              0.              0.             0.              67.772          .257
  201020000    127.49           0.              4.18364E+04     0.             0.              4.19659E+04     .510
  201030000    8.6579          -2785.0           5492.0         0.             0.               2715.6         1.43
  201040000    .97451           7349.3          0.              0.             0.               7350.2         1.44
  201050000    210.02           0.              2.48932E+04     0.             0.              2.51032E+04     .555
  201060000    13.647          -7283.7           9144.2         0.             0.               1874.2         1.43
  201070000    2.2067           1.10155E+04     0.              0.             0.              1.10177E+04     1.44
  201080000    118.66           0.              0.              0.             0.               118.66         .549
  201090000    141.43           0.              2.42385E+04     0.             0.              2.43800E+04     .556
  203010000    4.13412E-03      1317.2          0.              0.             0.               1317.2         1.52
  203020000    363.48           0.              0.              0.             0.               363.48         .246
  203030000    441.15           0.              0.              0.             0.               441.15         .247
  203040000    476.55           0.              0.              0.             0.               476.55         .248
  203050000    1266.1           0.              7.05485E+04     0.             0.              7.18146E+04     1.01
  203060000    .34317           1220.6          0.              0.             0.               1220.9         1.52
  203070000    362.35           0.              0.              0.             0.               362.35         .561
  203080000    .27366           1233.1          0.              0.             0.               1233.4         1.51
  203090000    264.26           0.              0.              0.             0.               264.26         .273
  203100000    294.56           0.              0.              0.             0.               294.56         .273
  203110000    311.11           0.              0.              0.             0.               311.11         .273
  203120000    320.89           0.              0.              0.             0.               320.89         .273
  203130000    326.55           0.              0.              0.             0.               326.55         .273
  203140000    329.30           0.              0.              0.             0.               329.30         .273
  203150000    329.70           0.              0.              0.             0.               329.70         .273
  203160000    328.02           0.              0.              0.             0.               328.02         .274
  203170000    324.40           0.              0.              0.             0.               324.40         .274
  203180000    318.98           0.              0.              0.             0.               318.98         .274
  203190000    1261.6           0.              6.95467E+04     0.             0.              7.08083E+04     1.02
  203200000    9.9079           1979.7          0.              0.             0.               1989.6         1.50
  203210000    363.39           0.              0.              0.             0.               363.39         .277
  203220000    368.76           0.              0.              0.             0.               368.76         .279
  203230000    376.35           0.              0.              0.             0.               376.35         .572
  203240000    406.37           0.              0.              0.             0.               406.37         .612
  203250000    416.76           0.              0.              0.             0.               416.76         .614
  203260000    1624.7           0.              6.59022E+04     0.             0.              6.75268E+04     1.02
  203270000    10.636            434.13         0.              0.             0.               444.76         1.50
  203280000    575.64           0.              0.              0.             0.               575.64         .616
  205010000    0.               -916.76          986.38         0.             0.               69.619         .261
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H-1

H-2

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FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - SUMMARY OF MAXIMUM NEGATIVE VOLUME FORCES
SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                                  10/15/82          12.03.20.

                                                                                                          TIME OF
   FORCE                            INLET INT.       OUTLET INT.      INLET EXT.      OUTLET EXT.      MAXIMUM          MAXIMUM
   NUMBER         SHEAR FORCE       FORCE            FORCE            FORCE           FORCE            FORCE            FORCE
                  (NEWTONS)         (NEWTONS)        (NEWTONS)        (NEWTONS)       (NEWTONS)        (NEWTONS)        (SECONDS)

  101010000      0.                -1.62112E+06     0.               0.              0.              -1.62112E+06       .500
  103010000       1.1357           -1.71762E+07     1.57597E+06      0.              0.              -1.56002E+07      1.00
  201010000      -3.1200            0.              0.               0.              0.                -3.1200         1.44
  201020000       .33296            0.             -8676.9           0.              0.                -8676.5         1.47
  201030000       1.1871             5114.0        -7349.3           0.              0.                -2234.1         1.44
  201040000       210.21           -2.52530E+04     0.               0.              0.              -2.50428E+04       .511
  201050000       1.2379            0.             -1.01950E+04      0.              0.              -1.01938E+04      1.44
  201060000       25.450           -4891.7          3489.0           0.              0.                -1377.2          .219
  201070000       209.19           -2.46631E+04     0.               0.              0.              -2.44539E+04       .556
  201080000      -.38203            0.              0.               0.              0.                -.38203         1.49
  201090000       2.0258            0.             -1.08923E+04      0.              0.              -1.08903E+04      1.44
  203010000       109.64           -7.41691E+04     0.               0.              0.              -7.40592E+04       .559
  203020000      -.26045            0.              0.               0.              0.                -.26045         1.54
  203030000      -.66047            0.              0.               0.              0.                -.66047         1.54
  203040000      -1.1840            0.              0.               0.              0.                -1.1340         1.54
  203050000       .31977            0.             -1220.6           0.              0.                -1220.3         1.52
  203060000       1121.1           -7.05485E+04     0.               0.              0.              -6.94274E+04      1.01
  203070000      -1.6197            0.              0.               0.              0.                -1.6197         1.54
  203080000       201.01           -3.71723E+04     0.               0.              0.              -3.69713E+04      1.01
  203090000      -1.5789            0.              0.               0.              0.                -1.5789         1.54
  203100000      -2.0607            0.              0.               0.              0.                -2.0607         1.54
  203110000      -2.5355            0.              0.               0.              0.                -2.5355         1.54
  203120000      -2.9839            0.              0.               0.              0.                -2.9839         1.54
  203130000      -3.3921            0.              0.               0.              0.                -3.3921         1.54
  203140000      -3.7512            0.              0.               0.              0.                -3.7512         1.54
  203150000      -4.0570            0.              0.               0.              0.                -4.0570         1.54
  203160000      -4.3083            0.              0.               0.              0.                -4.3083         1.54
  203170000      -4.5073            0.              0.               0.              0.                -4.5073         1.54
  203180000      -4.6550            0.              0.               0.              0.                -4.6550         1.54
  203190000       8.1956            0.             -1979.7           0.              0.                -1971.5         1.50
  203200000       1341.9           -6.95467E+04     0.               0.              0.              -6.82048E+04      1.02
  203210000      -5.7894            0.              0.               0.              0.                -5.7894         1.54
  203220000      -5.7456            0.              0.               0.              0.                -5.7456         1.54
  203230000      -5.5877            0.              0.               0.              0.                -5.5877         1.54
  203240000      -5.6737            0.              0.               0.              0.                -5.6737         1.54
  203250000      -5.6360            0.              0.               0.              0.                -5.6360         1.55
  203260000       12.707            0.             -434.13           0.              0.                -421.42         1.50
  203270000       1666.7           -6.59022E+04     0.               0.              0.              -6.42335E+04      1.02
  203280000      -4.3892            0.              0.               0.              0.                -4.3892         1.55
  205010000      0.                 0.              0.               0.              0.               0.               0.
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FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - SUMMARY OF MAXIMUM POSITIVE SUBFORCES
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                            10/15/82          12.03.20.

                                                                                                   TIME OF
   FORCE                       INLET INT.       OUTLET INT.      INLET EXT.       OUTLET EXT.      MAXIMUM          MAXIMUM
   NUMBER     SHEAR FORCE      FORCE            FORCE            FORCE            FORCE            FORCE            FORCE
              (NEWTONS)        (NEWTONS)        (NEWTONS)        (NEWTONS)        (NEWTONS)        (NEWTONS)        (SECONDS)

   101          -109.64        7.41691E+04      0.               0.               0.               7.40592E+04       .559
   102         -1462.8         7.05485E+04      0.               0.               0.               6.90658E+04      1.01
   103          2515.5         0.               7.05485E+04      0.               0.               7.30641E+04      1.01
   104          -201.01        3.71723E+04      0.               0.               0.               3.69713E+04      1.01
   105         -1341.9         6.95467E+04      0.               0.               0.               6.82048E+04      1.02
   106          3972.9         0.               6.95466E+04      0.               0.               7.35195E+04      1.01
   107         -2244.0         6.59022E+04      0.               0.               0.               6.36582E+04      1.02
   108          3546.9         0.               6.59022E+04      0.               0.               6.94511E+04      1.02
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FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - SUMMARY OF MAXIMUM NEGATIVE SUBFORCES
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                              10/15/82         12.03.20.

                                                                                                        TIME OF
  FORCE                          INLET INT.      OUTLET INT.     INLET EXT.      OUTLET EXT.     MAXIMUM        MAXIMUM
  NUMBER      SHEAR FORCE        FORCE           FORCE           FORCE           FORCE           FORCE          FORCE
              (NEWTONS)          (NEWTONS)       (NEWTONS)       (NEWTONS)       (NEWTONS)       (NEWTONS)      (SECONDS)

  101       -4.13412E-03       -1317.2          0.              0.              0.             -1317.2          1.52
  102        -.49926           -1220.6          0.              0.              0.             -1221.1          1.52
  103         .52006            0.             -1220.6          0.              0.             -1220.1          1.52
  104        -.27366           -1233.1          0.              0.              0.             -1233.4          1.51
  105       -9.9079            -1979.7          0.              0.              0.             -1969.6          1.50
  106        18.477             0.             -1979.7          0.              0.             -1961.2          1.50
  107       -13.059            -434.13          0.              0.              0.             -447.19          1.50
  108        31.658             0.             -434.13          0.              0.             -402.47          1.50
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FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - SUMMARY OF MAXIMUM POSITIVE COMBINED FORCES
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                         10/15/82          12.03.20.

                                                                                                  TIME OF
FORCE                     INLET INT.      OUTLET INT.     INLET EXT.      OUTLET EXT.    MAXIMUM   MAXIMUM
NUMBER     SHEAR FORCE    FORCE           FORCE           FORCE           FORCE          FORCE     FORCE
           (NEWTONS)      (NEWTONS)       (NEWTONS)       (NEWTONS)       (NEWTONS)      (NEWTONS) (SECONDS)

201        236.74         -5192.1          9197.6         0.              0.             4242.3    1.43
202        847.04         -1.216368E+04   2.11611E+04     0.              0.             9864.6    1.43
203        1019.7         -1.18567E+04    1.71427E+04     0.              0.             6305.7    1.44
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FORCE-TIME HISTORY FROM RELAP5 OUTPUT DATA - SUMMARY OF MAXIMUM NEGATIVE COMBINED FORCES
 SAMPLE PROBLEM - RELIEF VALVE DISCHARGE W/O LOOP SEAL                                  10/15/82        12.03.20.

                                                                                                          TIME OF
FORCE                        INLET INT.      OUTLET INT.     INLET EXT.      OUTLET EXT.    MAXIMUM         MAXIMUM
NUMBER      SHEAR FORCE      FORCE           FORCE           FORCE           FORCE          FORCE           FORCE
            (NEWTONS)        (NEWTONS)       (NEWTONS)       (NEWTONS)       (NEWTONS)      (NEWTONS)       (SECONDS)

                                                                                            -5456.8         1.46
201          153.60          -9424.1          3813.6         0.              0.             -4.24248E+04    .248
202          4806.3         -8.12292E+04     3.39981E+04     0.              0.             -6902.5         .247
203          2754.6         -3.22165E+04     2.25594E+04     0.              0.


     ****  2184 TIME-FORCE RECORDS HAVE BEEN WRITTEN TO THE STRUCTURAL OUTPUT FILE
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