Commonwealth Edison
One First National Plaza, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690

November 4, 1981

Mr. A. Schwencer, Chief
Licensing Branch #2
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: LaSalle County Station Units 1 and 2
Containment Purge/Vent Valve Operation
Closure Response to NUREG-0519
Supplement No. 1 (Task II-E.4.2)
NRC Docket Nos. 50-373/374

Reference (a): L. O. DelGeorge letter to A. Schwencer dated May 13, 1981.

Dear Mr. Schwencer:

The purpose of this submittal is to transmit the material required to meet the requirements of NUREG-0519, Supplement 1, Task II-E.4.2, Containment Isolation Dependability. Specifically, before licensing for operation, LaSalle County Station shall provide the basis for the limitation on the containment purge valve opening position.

This report demonstrates that if the butterfly valves are limited to a maximum opening position of 60° or less, these valves will close against the ascending differential pressure and the resulting dynamic loading of a LOCA condition.

It is judged that the submittal of this report satisfies the requirements of NUREG-0519, Supplement 1, Task II-E.4.2. Accordingly, nine (9) copies of the report are provided.

If there are any questions in this regard, please contact this office.

Very truly yours

C E Sargent

C. E. Sargent
Nuclear Licensing Administrator

cc: NRC Resident Inspector - LSCS (w/o att.)

Enclosure

CES/lm

B001
S 1/9

Encls To:
CSB-1
EQB-Advanced
PM-2
PDR-1
LPDR-1
Reg File-1
NSIC-1
NTIS-1

ENGINEERING RESPONSE/NRC QUESTIONS

For LaSalle County Station,
Units 1 and 2

Commonwealth Edison Co.
Sargent and Lundy Engineers

SARGENT & LUNDY

1. REVIEWED & ACCEPTED

ACTION SHOWN DOES NOT RELIEVE CONTRACTOR FROM HIS OBLIGATIONS UNDER THE CONTRACT.

S.I. Herndon BY 9/22/81 DATE

SPEC. NO. PROJ. NO. 4266-00

9-17-81

SARGENT & LUNDY

NAME ROOM

ADDENDUM TO ENGINEERING RESPONSE/NRC QUESTIONS
for LaSalle County Station, Units 1 and 2
Commonwealth Edison Co.
Sargent and Lundy Engineers

This addendum addresses questions raised during telephone conversations with S. L. Herndon, Sargent and Lundy.

1. Clarification of Response 5, page 4:

On page 6, paragraph 1, we state, "The 26" valves are limited to 60° travel by strength considerations and 40° travel due to actuator requirements. Therefore, stops should be set to constrain the 26° subject valves to 40° travel". We can clarify this situation by breaking the problem into several parts;

A. The strength limitation of the valve does limit operation to 60° or less for a 45 psi ΔP as stated and as shown by page 2 of Attachment 1. The subject valves should not be allowed to open beyond 60° in any case where they could experience a 45 psig ΔP.

B. The rated maximum actuator output for these valves is 15,600 in-lb (Attachment 1, page 3). If the net required torque at any angle is greater than 15,600 in-lb_f, then the actuator will not operate the valve. If the net required torque is sufficiently large, damage could occur to the actuator. Limitorque allows actuators to be sized for stall torques less than or equal to 2 x the HBC unit rating. Therefore, the maximum torque this actuator can see without danger of damage is 31,200 in-lb.

C. The net required torque at any angle is a combination of frictional, seating and dynamic torques. These torques combine in various ways to produce a torque which the actuator must overcome to open or close the valve.

For open angles of 60° or less, the net required closing torque is less than the maximum actuator output of 15,600 in-lb for the subject valves with a 45 psi ΔP. That is, the actuator is properly sized to close the subject valves from open angles less than or equal to 60°.

For open angles of 60° or less, the net required opening torque is not always less than the maximum actuator output. The required opening torque drops below 15,600 in-lb for angles of 40° or less. The actuator will provide sufficient torque to open the valve up to 40° but is not sized correctly to open the valve beyond 40°, with a 45 psi ΔP.

For open angles of 60° and less, the maximum torque the actuator could ever see is 23,808 in-lb which is well below the maximum torque rating of 31,200 in-lb. Therefore, there is no danger of actuator damage for angles less than 60° with a 45 psi ΔP.

In summary, the subject valves must be limited to open angles of 60° or less due to strength considerations. The valves may be limited to 40° if the actuator is required to provide complete normal operation (i.e., open the valve as well as close it). If there is no requirement to open the valves beyond 40° with a 45 psi ΔP, then actuator limitations are not a problem and the valve should be limited to open angles of 60° or less.

2. Clarification or Response 12, page 7:

To limit the angle of opening on the subject 26" valves, two adjustments must be made.

1. The limit switch must be set to indicate the correct open angle.

2. Actuator travel stops must be set to stop the actuator and actuate the torque switches at the proper angle.

Instructions for setting the limit switch and travel stops can be found in the Limitorque Instruction Manual and HBC bulletin.

Prepared by Lee Waite
Lee Waite
Nuclear Qualification Engineer

Reviewed by John Dresser
John Dresser
Nuclear Qualification Engineer

FISHER CONTROLS COMPANY

MARSHALLTOWN, IOWA 50158

AUTOMATIC CONTROL EQUIPMENT
SINCE 1880

August 19, 1981

S. L. Herndon
Sargent and Lundy
55 E. Monroe St.
Chicago, IL 60603

Subject: LaSalle County Station - Units 1 and 2
Containment Purge and Vent Valve Operability

Reference: S & L letter dated 3/25/81: S. L. Herndon to John Marks

Mr. Herndon:

Attached is our response to the NRC letter of September 27, 1979 and subsequent clarification of that letter (Attachment 8). See Attachments 7 and 11 for valve construction details.

1. Request:

The ΔP across the valve is in part predicated on the containment pressure and gas density conditions. What were the containment conditions used to determine the ΔP's across the valve at the incremental angle positions during the closure cycle?

Response:

Peak containment pressure and temperature (45 psig, 340°F) was used in determining the fluid conditions across the valve at all angles of rotation. ΔP across the valve was considered equal to peak containment pressure (psig). Material properties were selected (during stress calculations) at peak containment temperatures. The effect of compressible flow in sizing Fisher butterfly valves is best explained by the following:

AIR VS. WATER SERVICE

Whenever a Fisher butterfly valve is in a gas flow application the effects due to compressible flow are taken into consideration while determining the dynamic torque effects for each individual valve selection. This consideration is built into our valve selection procedures and requires a conscious liquid or gas decision in calculating the effective pressure drop of which the dynamic torque is a function.

Fisher's philosophy concerning the effects of compressible flow on butterfly valves is presented in ISA Transactions, Vol. 8, No. 4, entitled "Effect of Fluid Compressibility on Torque in Butterfly

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Valves", written by Floyd P. Harthun (Manager, Product Evaluation, Fisher Controls Co.). A copy of this document is included as Attachment 2 to this letter.

2. Request:

Were the dynamic torque coefficients used for the determination of torques developed based on data resulting from actual flow tests conducted on the particular disc shape/design/size? What was the basis used to predict torques developed in valve sizes different (especially larger valves) than the sizes known to have undergone flow tests?

Response:

In determining allowable pressure drops across a particular butterfly valve at various angles of the disc, Fisher Controls uses classical "mechanics of materials" type equations to calculate stress levels at various worst-case locations in the valve assembly (specifically, various locations along the valve shaft). The approach to the analysis, the equations used, and the combination of the calculated stresses all make up a portion of Fisher's design philosophy for butterfly valves. This analysis approach addresses all of the different states of shear and tensile stress which are applicable to the loading conditions defined.

Establishing the loads that actually exist makes up the remaining portion of our design philosophy for butterfly valves. These loads range from easily calculated loads, such as bending due to pressure differential across the disc, to loads such as packing and dynamic torques which require a certain amount of testing combined with scaling in order to analyze all valve sizes. It is the factor of dynamic torque that produces different stresses at different disc rotations and disc geometries. Through testing and scaling Fisher has produced dynamic torque factors for incremental disc rotations.

The model tests used to establish the dynamic torque values used in sizing were conducted using 4" and 6" test valves with various aspect ratios ranging from 2:1 to 14:1 (such as 3:1, 4:1, 5:1, 8:1, 11:1 and 14:1). The dimensionless aspect ratio (defined as the ratio of the disc diameter to the hub diameter) was judged to be a significant parameter for evaluation of dynamic torques at various open angles.

Capacity and Torque curves obtained from a typical test are enclosed (Attachment 3) to illustrate the method and general shape of the curves for Type 9200 butterfly valves.

3. Request:

Were installation effects accounted for in the determination of dynamic torques developed? Dynamic torques are known to be affected for example, by flow direction through valves with off-set discs, by downstream piping backpressure, by shaft orientation relative to elbows, etc. What was the basis (test data or other) used to predict dynamic torques for the particular valve installation?

Response:

All Fisher sizing data is based on dynamic torque determination tests which were performed with uniform flow profiles and on valve discs with representative geometries. The effects of a non-uniform flow profile, due to piping elbows, "T"-connections, etc., upstream, are discussed below.

PIPING SYSTEM EFFECTS

The concern over geometrical piping system effects is relevant since Fisher typically sizes butterfly valves assuming a uniform flow profile while various piping configurations directly upstream could produce a non-uniform flow as illustrated by Figures A & B of Attachment 4. The two configurations are differentiated by a 90° rotation of the valve shaft with respect to the flow profile.

a. Valve/Flow Orientation, Figure A

If it has been determined that the plant layout is such that the valve is oriented to the flow as depicted in Fig. A (Attachment 4), the non-uniform fluid profile will not produce an additional torque on the valve disc since both "wings" of the disc (as split by the shaft) will be subjected to the same flow with respect to time.

b. Valve/Flow Orientation, Figure B

If it has been determined that plant layout is such that the valve is oriented to the flow as depicted in Fig. B (Attachment 4), the non-uniform flow will effect the performance of the valve. The flow profile shown will produce some amount of torque, Tp, in the direction shown in Fig. B; obviously, if the torque rotational direction is coincident with valve closure, the non-uniform flow profile will assist the safety-mode function of the valve, however, if the torque direction is coincident with valve opening, the profile will be detrimental to the safety-mode function.

The above argument must be coupled with exact installation details by the utility to determine how the safety-mode function of the valve will be affected.

Fisher does not possess quantitative details regarding the effect of non-uniform fluid flow.

All Fisher sizing procedures are based on a pressure drop across the valve that is supplied by our customer; if downstream piping produces a backpressure, and the customer wants to take credit for this effect, the existence of the backpressure should be reflected in the sizing ΔP provided. As stated previously, for the subject accident conditions, the sizing ΔP across the valve is taken to be equal to the peak accident containment pressure; this approach is conservative if backpressure actually does exist.

4. Request:

When comparing the containment pressure response profile against the valve position at a given instant of time, was the valve closure rate vs. time (i.e. constant or other) taken into account? For air operated valves equipped with spring return operators, has the lag time from the time the valve receives a signal to the time the valve starts to stroke been accounted for?

NOTE: Where a butterfly valve assembly is equipped with spring-to-close air operators (cylinder, diaphragm, etc.), there typically is a lag time from the time the isolation signal is received (solenoid valve usually de-energized) to the time the operator starts to move the valve. In the case of an air cylinder, the pilot air on the opening side of the cylinder is approximately 90 psig when the valve is open, and the spring force available may not start to move the piston until the air on this opening side is vented (solenoid valve de-energizes) below about 65 psig, thus the lag time.

Response:

When calculations were performed to determine the maximum allowable open angle (provided in Attachment 1) the assumption was made that the valve had to close against peak containment pressure. Since this (conservative) approach was taken, a time history study was not made, and therefore, valve closure rates and response lags did not have to be considered.

5. Request:

Provide the necessary information for the table shown below for valve positions from the initial open position to the seated position (10° increments if practical).

Valve Position Min. Degress - 90° (full open)	Predicted ΔP (across valve)	Maximum ΔP (capability)

Response:

In determining allowable ΔP vs. angle of opening for the subject valves, there are several considerations to take into account.

1) Allowable ΔP based on the strength of the valve.
2) Allowable ΔP based on available torque from actuator.
3) Allowable ΔP based on the strength of the actuator.

The allowable ΔP based on valve strength is determined by a computer program. The computer program can be described as follows.

For a given valve at some angle of opening, the program begins by calculating the loading. This includes a hydrostatic load on the disc, seating torque, bushi nd packing torque and dynamic torque.

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After the loading is determined, the program calculates stresses in the shaft, key, pin and bushing for a specific ΔP and compares these stresses to a material strength. This strength is based on 1.5 x "S". "S" is the allowable stress figure found in Section VIII of the ASME Boiler and Pressure Vessel Code. S is equal to 1/4 of the minimum tensile strength or 2/3 of the minimum yield strength, whichever is less. For shear stresses 0.75 S is used.

The program calculates stress and changes ΔP iteratively until the allowable strength matches the stress. This determines the maximum allowable pressure drop for that angle of opening based on the stress at a single point. Therefore, this process is done for cases 1, 2, 3, 4 and 5 (as defined below) for each angle of opening.

Case 1 - stress in the shaft at the disc hub due to bending and torsion

Case 2 - stress in the shaft at the disc hub due to torsion and transverse shear

Case 3 - stress at the pinned disc-shaft connection

Case 4 - stress at the keyed actuator-shaft connection

Case 5 - stress at the shaft bushing

The program output shows a ΔP which is calculated at each point for each angle of opening, including two ΔP for case 1 (one based on maximum shear stress, one based on maximum tensile stress) for a total of 6 ΔP's. The smallest ΔP of these 6 is then repeated as allowable ΔP at the bottom of the column. The actuator torque for the lowest ΔP (allowable ΔP) is also listed.

For the 26" subject valves beyond 60° open, the allowable ΔP's (based on valve strength) drop below the accident criterion of 45 psig as shown in Attachment 1. For the 8" subject valves the allowable ΔP is above 45 psig for all open angles.

The required actuator torque vs angle of opening for a 45 psig pressure drop (P_1 = 45 psig, P_2 = ambient) is shown in Attachment 1 for the 8" and 26" valves. The torque at 0° is the torque required to close the valve. This shutoff torque is 12,847 in-lb_f for the 26" valves and 762 in-lb_f for the 8" valves. The torque switch setting on the Limitorque actuators corresponds to a 14,616 in-lb output for the 26" valve and a 2556 in-lb output for the 8" valves. Therefore, the Limitorque actuators provide adequate torque for shutoff against a 45 psig pressure drop.

Attachment 1 shows required torques at open angles for the subject valves. For the 8" valves the maximum required torque is 2390 in-lb_f. The Limitorque actuator will provide 2556 in-lb, before the torque switch will trip. For the 26" valve the maximum required operating torque at angles less than or equal to 40° is 13026 in-lb. The Limitorque actuator on the 26" valves will output 14,616 in-lb_f before tripping out the torque switch.

The 26" valves are limited to 60° travel by strength considerations and 40° travel due to actuator requirements. Therefore, stops should be set to constrain the 26" subject valves to 40° travel.

It is not necessary to make any _ vel constraints on the 8" subject valves.

As stated in the response to request #4, no time-history study has been performed and therefore no "Predicted ΔP" values are provided; the remaining information requested is presented in Attachment 1 to this document.

6. Request:

What Code, standards or other criteria, was the valve designed to? What are the stress allowables (tension, shear, torsion, etc.) used for critical elements such as disc, pins, shaft yoke, etc., in the valve assembly? What load combinations were used?

Response:

The subject butterfly valves were designed according to the ASME Boiler and Pressure Vessel Code, Sections III and VIII. Allowable stresses were also taken from the ASME B & PV Code. Loads considered in the design of these valves includes all typical pressure and flow induced loads. Worst case load combinations are used. Pressure and temperature ratings for these valves can be found in Fisher bulletin 51.4:9200 (Attachment #5).

NOTE: Due to a NRC clerical error in the numbering of requests, there are no items 7 or 8. See pages 1 and 2 of the "clarification of Sept. 27 letter to licensees regarding demonstration of operability of purge and vent valves" (Attachment 8).

9. Request:

For those valve assemblies (with air operators) inside containment, has the containment pressure rise (backpressure) been considered as to its effect on torque margins available (to close and seat the valve) from the actuator? During the closure period, air must be vented from the actuators opening side through the solenoid valve into this backpressure. Discuss the installed actuator bleed configuration and provide basis for not considering this backpressure effect a problem on torque margin. Valve assemblies using 4-way solenoid valve should especially be reviewed.

Response:

This request is not applicable to LaSalle County Station Units 1 and 2 since none of the subject valves are equipped with air operators.

10. Request:

Where air operated valve assemblies use accumulators as the fail-safe feature, describe the accumulator air system configuration and its operation. Provide necessary information to show the adequacy of the accumulator

to stroke the valve, i.e. sizing and operation starting from lower limits of initial air pressure charge. Discuss active electrical components in the accumulator system, and the basis used to determine their qualification for the environmental conditions experienced. Is the accumulator system seismically designed?

Response:

This request is not applicable to LaSalle County Station Units 1 and 2, since none of the subject valves are equipped with accumulators as a fail-safe feature.

11. Request:

For valve assemblies requiring a seal pressurization system (inflatable main seal), describe the air pressurization system configuration and operation, including means used to determine that valve closure and seal pressurization have taken place. Discuss active electrical components in this system, and the basis used to determine their qualification for the environmental condition experienced. Is this system seismically designed?

For this type valve, has it been determined that the "valve travel stops" (closed position) are capable of withstanding the loads imposed at closure during the DBA-LOCA conditions.

Response:

This request is not applicable to LaSalle County Station Units 1 and 2, since none of the subject valves are equipped with inflatable seal rings.

12. Request:

Describe the modification made to the valve assembly to limit the opening angle. With this modification, is there sufficient torque margin available from the operator to overcome any dynamic torques developed that tend to oppose valve closure, starting from the valve's initial open position? Is there sufficient torque margin available from the operator to fully seat the valve? Consider seating torques required with seats that have been at low ambient temperatures.

Response:

Specific questions concerning methods of making appropriate modifications to the Limitorque SMB-000-2/H1BC actuator (to limit the maximum valve opening to 40°) for the subject 26" valves should be addressed directly to Limitorque Corporation, Lynchburg, Virginia.

Attachment 1 and Response #5 should adequately address the subject of appropriate torques for the Limitorque operator.

The effect of temperature on seating torques is not considered significant in our standard actuator sizing technique. If specific data concerning temperature-seating torque relationships is needed, then testing would be required.

13. Request:

Does the maximum torque developed by the valve during closure exceed the maximum torque rating of the operators? Could this affect operability?

Response:

The response to Request #12 and #5, above, in conjunction with the information provided in Attachment 1, should adequately address this subject.

14. Request:

Has the maximum torque value determined in #13 been found to be compatible with torque limiting settings where applicable?

Response:

Response 5 and Attachment 1 adequately address torque switch settings compared to required valve closure torque.

15. Request:

Where electric motor operators are used, has the minimum available voltage to the electric operator under both normal or emergency modes been determined and specified to the operator manufacturer, to assure the adequacy of the operator to stroke the valve at DBA conditions with these lower limit voltages available. Does this reduced voltage operation result in any significant change in stroke timing? Describe the emergency mode power source used.

Response:

Limitorque actuators are designed to operate within ±10% of the nominal voltage without changing the available torque or stroking time rating of the actuator. Since the voltage specification, for LaSalle County Station, Units 1 and 2, is ±10%, no minimum voltage consideration needs to be made.

16. Request:

Where electric operator units are equipped with handwheels, does their design provide for automatic re-engagement of the motor operator following the handwheel mode of operation? If not, what steps are taken to preclude the possibility of the valve being left in the handwheel mode following some maintenance, test, etc., type operation?

Response:

Limitorque electric actuators with handwheels are designed to provide for automatic re-engagement of the motor operator following the handwheel mode of operation. If specific information concerning this design is needed, please consult Limitorque.

17. Request:

Describe the tests and/or analysis performed to establish the qualification of the valve to perform its intended function under the environmental conditions exposed to, during and after the DBA following its long term exposure to the normal plant environment.

Response:

No actuator qualification has been done by Fisher Controls. For all questions concerning qualification of Limitorque actuators, contact Limitorque Corporation, Lynchburg, Virginia.

A. Environmental

No analyses or tests were done to environmentally qualify the subject valves.

1) Pressure-Temperature - the temperature-pressure environmental conditions of 145°F and -0.25 psig fall within the design rating of the valve. (See Attachment 13 for environmental conditions.)

2) Aging - No test or analyses have been done to verify "40 year - end of life" accident capabilities of the subject valves. Fisher recommends that all elastomeric parts be replaced every four years.

3) Radiation - No tests or analyses have been done to qualify the subject valves for a 40 year normal, plus maximum hypothetical accident, integrated radiation dose of 2×10^8 rads. Fisher normally qualifies valves with EPDM seats to 1×10^7 rads. At this level some material degradation may occur, but the effects are considered insignificant. If exposed to 2×10^8 rads, the elastomeric parts of the subject valves may experience significant degradation causing some leakage. Again, Fisher recommends replacement of all elastomeric parts every four years and this will decrease the cumulative radiation exposure for the elastomeric parts being used. If more detailed information is required concerning the effects of radiation on the subject valves, testing may be required.

B. Seismic

1) The seismic analyses done to qualify the subject valves are described in Attachment #6: "Seismic Analyses of 26" Butterfly Valve Assemblies for Commonwealth Edison", and "Seismic Analyses of 8", 20" and 24" Butterfly Valve Assemblies for Commonwealth Edison Company".

18. Request:

What basis is used to establish the qualification of the valve, operators, solenoids, valves? How was the valve assembly (valve/operators) seismically qualified (test, analysis, etc.)?

Response:

The customer design specification is the basis of qualification. The valve assembly was seismically qualified by analysis (see Response 17 and Attachment 6).

19. Request:

Where testing was accomplished, describe the type tests performed, conditions used, etc. Tests (where applicable) such as flow tests, aging simulation (thermal, radiation, wear, vibration endurance, seismic) LOCA-DBA environment (radiation, steam chemicals) should be pointed out.

Response:

No type testing was done on the subject valves.

20. Request:

Where analysis was used, provide the rationale used to reach the decision that analysis could be used in lieu of testing. Discuss conditions, assumptions, other test data, handbook data, and classical problems as they may apply.

Response:

Attachment 10: "Seismic 4 Verification Program for Commonwealth Edison Company" includes an explanation and verification of Fisher Controls analysis procedure which was used to seismically analyze the LaSalle valves.

21. Request:

Have the preventive maintenance instructions (part replacement, lubrication, periodic cycling, etc.) established by the manufacturer been reviewed, and are they being followed? Consideration should especially be given to elastomeric components in valve body, operators, solenoids, etc., where this hardware is installed inside containment.

Response:

Fisher furnishes instruction manuals for each valve assembly component when it is shipped. Instruction sheets are provided for buyout components if available. Attachment 9 to this document is a Type 9200 instruction manual.

Again, Fisher recommends replacement of elastomeric parts at 4-year intervals. The manufacturer's recommendations should be followed on buyout items which include: Limitorque actuators.

The EPDM T-ring is made from extruded sulfur-cured EPDM compound No. 9074, obtained from Ashtabula Rubber Company (70 durometer ± 5, ASTM D 2000-AA-725). Documents listing characteristics and properties

of this material are enclosed in Attachment 12. (Note that NORDEL is DuPont's tradename for EPDM material). The DuPont data shows that the upper temperature limit for continuous service is 145°C (293°F). Since the stated DBE temperature spike of 340°F is a relatively short-time, one-time event the 340°F temperature environment is acceptable. (There may be some loss of sealing capability upon return to room temperature, due to compression set, but the post-DBE pressure differential will be low by that time.

This completes our response to the NRC questions as requested by Fisher Order No. 014-62496-Z In the event there are further inquiries, please contact:

Scott McLagan
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Reviewed by:

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Prepared by:

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/ew

cc Don Woollard
(General Meter and Controls)
Ralph Duff
(Commonwealth Edison)

Enclosures:

Attachment 1 - Allowable ΔP vs. Angle of Opening, Required Torque vs Angle of Opening, and Available Actuator Torques.

Attachment 2 - ISA Transactions, Vol. 8, No. 4; "Effects of Fluid Compressibility on Torque in Butterfly Valves".

Attachment 3 - Capacity and Dynamic Torque Curves Determined in Fisher Lab. Tests for 6" Type 9220 Butterfly Valve.

Attachment 4 - Piping System Sketches

Attachment 5 - Fisher Bulletin 41.4:9200, July 1976; "9200 Series Butterfly Control Valve Bodies for Nuclear Service".

Attachment 6 - "Seismic Analyses of 26" Butterfly Valve Assemblies for Commonwealth Edison" and "Seismic Analyses at 8", 20" and 24" Butterfly Valve Assemblies for Commonwealth Edison."

Attachment 7 - Bill of Material Drawings

Attachment 8 - "Guidelines for Demonstration of Operability of Purge and Vent Valves" and later clarification.

Attachment 9 - 9200 Butterfly Valve Instruction Manual

Attachment 10 - "Seismic 4 Verification Program for Commonwealth Edison Co."

Attachment 11 - Continental Shop Orders 5A094 -01 thru -09; -32; -33 and 5A095 -01 thru -09

Attachment 12 - Material Properties Data for Ethylene-Propylene Elastomers

Attachmer - Environmental Conditions

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Attachment 1 - Allowable ΔP vs. Angle of Opening, Required Torque vs. Angle of Opening and Available Actuator Torques.

ALLOWABLE PRESSURE DROP CALCULATION

LA SALLE COUNTY STATION UNITS 2&3, COMMONWEALTH EDISON CO.
26 INCH TYPE 9220 ADJUSTABLE T-RING BUTTERFLY VALVES
CCN 5A094-01 THRU -09, 5A095-01 THRU -09
PLATE DISC:SA515GR70 STUB SHAFT:SA564GR630 BUSHING:#2, GRAPHITE-BRONZE
CLASS 2 SHAFT (2 INCH DIAM) T=340 F DP=45 PSIG FLUID:AIR
LEE WAITE 6/25/81

INPUT DATA

ANG	0.0	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	0.0
DDISC	24.947	24.947	24.947	24.947	24.947	24.947	24.947	24.947	24.947	0.0
DSHFT	1.997	1.997	1.997	1.997	1.997	1.997	1.997	1.997	1.997	0.0
DLU	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.0
TS	5945.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DTF	0.0	293.000	293.000	293.000	680.000	1580.000	3980.000	5200.000	5200.000	0.0
DPIN	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	0.0
DELTPF	1.000	0.350	0.350	0.350	0.250	0.180	0.110	0.090	0.090	0.0
STSH	98.000	98.000	98.000	98.000	98.000	98.000	98.000	98.000	98.000	0.0
SBUSH	85.000	85.000	85.000	85.000	85.000	85.000	85.000	85.000	85.000	0.0
C1	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.0
C2	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.0
BSHTYP	2	2	2	2	2	2	2	2	2	0

GENERATED VARIABLES

ST	51450.00	51450.00	51450.00	51450.00	51450.00	51450.00	51450.00	51450.00	51450.00	0.0
SS	25725.00	25725.00	25725.00	25725.00	25725.00	25725.00	25725.00	25725.00	25725.00	0.0
SP	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	0.0

OUTPUT

DELTP(1)	195.1326	194.9663	194.9663	194.9663	190.7248	181.5897	165.7041	162.1080	162.1080	0.0
DELTP(2)	187.6376	187.3028	187.3028	187.3028	178.6706	159.2131	121.3182	111.7236	111.7236	0.0
DELTP(3)	161.1555	160.3177	160.3177	160.3177	141.2792	108.9885	65.6898	57.1656	57.1656	0.0
DELTP(4)	287.1892	283.5515	283.5515	283.5515	200.8991	60.7147	4.9486	3.7984	3.7984	0.0
DELTP(5)	244.5503	242.7361	242.7361	242.7361	201.5151	131.6012	37.8531	19.3970	19.3970	0.0
DELTP(6)	138.5944	138.5944	138.5944	138.5944	138.5944	138.5944	138.5944	138.5944	138.5944	0.0
ALOW.DP	138.5944	138.5944	138.5944	138.5944	138.5944	60.7147	4.9486	3.7984	3.7984	0.0
ACT.TORQ	19766.0859	19943.3164	19943.3164	19943.3164	23970.0820	23191.9180	20461.1719	20404.8477	20404.8477	0.0

ALLOWABLE PRESSURE DROP CALCULATION

LA SALLE COUNTY STATION UNITS 2&3, COMMONWEALTH EDISON CO.
8 INCH TYPE 9220 ADJUSTABLE T-RING BUTTERFLY VALVES
CCN 5A094-32.-33:5A095-27.-28 SN BF246703./J
CAST DISC:SA351GRCF8M SHAFT:SA564GR630 BUSHING:#2.GRAPHITE-BRONZE
CCN 5A094-32.-33:5A095-27.-28 SN BF246703.04:BF246713.14
CLASS 3 SHAFT (1 INCH DIAM) T=340 F DP=45PSIG FLUID:AIR
LEE WAITE JUNE 26. 1981

INPUT DATA

ANG	0.0	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	0.0
DDISC	7.994	7.994	7.994	7.994	7.994	7.994	7.994	7.994	7.994	0.0
DSHFT	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.0
CLO	0.685	0.685	0.685	0.685	0.685	0.685	0.685	0.685	0.685	0.0
TS	425.500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DTF	0.0	6.450	10.500	22.500	40.500	76.500	154.500	244.500	244.500	0.0
PPIN	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	45.000	0.0
DELTPF	1.000	0.500	0.250	0.250	0.200	0.200	0.140	0.140	0.140	0.0
SYSH	98.000	98.000	98.000	98.000	98.000	98.000	98.000	98.000	98.000	0.0
SPUSH	85.000	85.000	85.000	65.000	65.000	85.000	85.000	85.000	85.000	0.0
C1	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.0
C2	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.0
BSHTYP	2	2	2	2	2	2	2	2	2	0

GENERATED VARIABLES

ST	51450.00	51450.00	51450.00	51450.00	51450.00	51450.00	51450.00	51450.00	51450.00	0.0
SS	25725.00	25725.00	25725.00	25725.00	25725.00	25725.00	25725.00	25725.00	25725.00	0.0
SB	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	8500.00	0.0

OUTPUT

DELTP(1)	287.3213	2[illegible]3.7561	288.9502	287.9092	286.9170	283.3521	279.3933	269.2678	269.2678	0.0
DELTP(2)	283.2168	[illegible]86.0859	286.4727	284.3940	282.4055	275.1919	267.0376	245.3336	245.3336	0.0
DELTP(3)	418.1675	4[illegible]9.6323	442.9326	426.4309	412.8169	373.2131	338.3945	269.0876	269.0876	0.0
DELTP(4)	812.2319	905.4175	919.7458	848.1069	789.0044	617.0703	465.9116	165.0270	165.0270	0.0
DELTP(5)	645.0937	691.5684	698.71[illegible]	662.9851	633.5093	547.7612	472.3740	322.3145	322.3145	0.0
DELTP(6)	337.1011	337.1011	337.1011	337.1011	337.1011	337.1011	337.1011	337.1011	337.1011	0.0

ALOW.DP	283.2168	286.0859	286.4727	284.3940	282.4055	275.1919	267.0376	165.0270	165.0270	0.0
ACT.TORQ	1944.9111	1726.3259	1692.4446	1861.1248	1998.9143	2392.5935	2729.6187	2970.4785	2970.4785	0.0

REQUIRED TORQUE VS. ANGLE OF OPENING
AND
AVAILABLE ACTUATOR TORQUES

LA SALLE 26" 9220 with Limitorque SMB-000/2-H1BC

ANGLE	FRICTION* TORQUE	SEAT* TORQUE	DYNAMIC* TORQUE	NET REQUIRED CLOSING TORQUE	NET REQUIRED OPENING TORQUE	ACTUATOR TORQUE SWITCH SETTING	MAXIMUM ACTUATOR OUTPUT
0	6902	5945	0	12,847	12,847	14,616	15,600
10	6902	-	2,650	4,252	9,552	14,616	15,600
20	6902	-	6,124	778	13,026	14,616	15,600
30	6902	-	6,124	778	13,026	14,616	15,600
40	6902	-	6,124	778	13,026	14,616	15,600
50	6902	-	10,132	---	17,034	14,616	15,600
60	6902	-	16,906	---	23,808	14,616	15,600
70	6902	-	26,268	33,170	33,170	14,616	15,600
80	6902	-	28,080	34,982	34,982	14,616	15,600
90	6902	-	28,080	34,982	34,982	14,616	15,600

LA SALLE 8" 9220 with Limitorque SMB-000/2-HOBC

ANGLE	FRICTION* TORQUE	SEAT* TORQUE	DYNAMIC* TORQUE	NET REQUIRED CLOSING TORQUE	NET REQUIRED OPENING TORQUE	ACTUATOR TORQUE SWITCH SETTING	MAXIMUM ACTUATOR OUTPUT
0	336	426	0	762	762	2,556	5,340
10	336	-	142	194	478	2,556	5,340
20	336	-	193	143	721	2,556	5,340
30	336	-	156	180	192	2,556	5,340
40	336	-	335	1	671	2,556	5,340
50	336	-	482	---	818	2,556	5,340
60	336	-	910	---	1,246	2,556	5,340
70	336	-	1,298	1,334	1,334	2,556	5,340
80	336	-	2,054	2,390	2,390	2,556	5,340
90	336	-	2,054	2,390	2,390	2,556	5,340

* Friction and seating torque oppose opening and closing.
** Dynamic torque opposes opening (tends to close) for angles up to 60°. Above 60° this torque may tend to open or close.

All torques are in in-lbs.

M39D14

2

Attachment 2 - ISA Transactions, Vol. 8,
No. 4; "Effects of Fluid
Compressibility on Torque
in Butterfly Valves".

REPRINTED FROM

Volume 8, Number 4

1969

INSTRUMENT SOCIETY of AMERICA

ISA TRANSACTIONS

A publication of
INSTRUMENT
SOCIETY
of
AMERICA

Effect of Fluid Compressibility on Torque in Butterfly Valves

FLOYD P. HARTHUN

Compliments of Fisher Controls Company

ISA TRANSACTIONS: 8 (281-286) 1969

Effect of Fluid Compressibility on Torque in Butterfly Valves*

FLOYD P. HARTHUN†
Fisher Governor Company
Marshalltown, Iowa

▶ A technique is presented by which the shaft torque resulting from fluid flow through butterfly valves can be determined with reasonable accuracy for both compressible and incompressible flow. First, the general torque relationship for incompressible flow is established. Then, an effective pressure differential is defined to extend this relationship to include the effect of fluid compressibility. The application of this technique showed very good agreement with experimental test results.

INTRODUCTION

THE APPLICATION of butterfly valves in various automatic control systems requires proper actuator sizing for efficient control. Thus, a thorough knowledge of the fluid reaction forces acting on the valve disc is required. Extensive experimental work[1] has been performed in the past to establish a relationship to determine these forces and thus determine the resultant shaft torque. The general form of this relationship has been established and confirmed. However, by using the classical fluid momentum approach, a similar relationship can be obtained in which the torque is shown to be directly proportional to the measured valve pressure differential for a given disc position. This relationship along with most of the previously published torque information is adequate for incompressible flow. Although the effect of fluid compressibility on torque has been recognized, no useful relationship has been developed. The primary objective of this investigation is to extend the established torque relationship to include the effect of fluid compressibility.

*Presented at the 1968 ISA Annual Conference; revised August, 1969.
†Research Engineer.

DEVELOPMENT OF GENERAL TORQUE RELATIONSHIP

The total shaft torque required to operate butterfly valves can be separated into two major components:

1. Dynamic torque—that portion of the total operating torque attributable to the fluid reaction force of the flowing medium acting on the valve disc.
2. Friction torque—that portion of the total operating torque attributable to friction in the packing and bushings.

Since each of these components is independent of the other, a separate evaluation of each component affords the best approach to this problem. This investigation is limited to an evaluation of the dynamic torque component. If the friction on the valve shaft is assumed to be independent of direction of rotation, it can be readily isolated. The torque required to rotate the valve disc is measured in a clockwise and a counterclockwise direction through full travel. Since friction always opposes motion the difference between these values will be twice the actual shaft friction.

The dynamic torque for butterfly valves is a function of the fluid reaction forces acting on the valve disc. It would be difficult to determine these forces by purely analytical techniques. Experimental determination of the pressures and velocity profiles in the immediate area of the disc would also be quite difficult. However, if a control volume is selected so the boundaries are points of known pressure and velocity, an analysis of these forces can be made from the change in fluid momentum through this control volume.

INCOMPRESSIBLE FLOW

An expression for dynamic torque is developed assuming incompressible flow. This torque is a function of the fluid reaction force, F, and a moment arm, D, which is a characteristic dimension of the valve disc.

$$T_D = f(F, D) \tag{1}$$

Using the fluid momentum approach, the force, F, is given by:

$$F = M\Delta V \tag{2}$$

where

F = sum of external forces acting on fluid
M = mass flow rate
ΔV = fluid velocity change through the control volume

The mass flow rate, M, is given by

$$M = \rho AV \tag{3}$$

By using a proportionality constant, B_1, the mass flow rate can also be defined as

$$M = B_1 A(\rho \Delta P)^{1/2} \tag{4}$$

Equations (3) and (4) are combined to obtain the following expression for fluid velocity:

$$V = B_1(\Delta P/\rho)^{1/2} \tag{5}$$

The velocity change through the control volume, ΔV, in Equation (2) can be expressed in terms of the velocity at the valve disc by use of a proportionality constant, B_2

$$F = B_2 MV \tag{6}$$

By substituting the expressions for mass flow rate Equation (4) and fluid velocity Equation (5) into Equation (6) the force on the valve disc is

$$F = B_1{}^2 B_2 A \Delta P \tag{7}$$

For a given valve size, the flow area, A, for any angle of disc rotation, θ, can be written as

$$A = B_\theta \frac{\pi D^2}{4} \tag{8}$$

The force, F, acts upon a moment arm which is a function of the disc diameter, D. Now, the dynamic torque can be written as

$$T_D = B_3 FD \tag{9}$$

Combining Equations (7), (8), and (9),

$$T_D = \frac{B_1{}^2 B_2 B_3 B_\theta \pi D^3 \Delta P}{4} \tag{10}$$

or

$$T_D = K_1 D^3 \Delta P \tag{10-A}$$

where

$$K_1 = \frac{B_1{}^2 B_2 B_3 B_\theta \pi}{4} = \frac{T_D}{D^3 \Delta P} \tag{10-B}$$

Equation (10-B) is defined as the dimensionless torque coefficient which can be determined experimentally from tests conducted with incompressible flow.

COMPRESSIBLE FLOW

The dynamic torque for butterfly valves is proportional to the mass flow rate and velocity change through a selected control volume for both compressible and incompressible flow (i.e., $T_D \propto M\Delta V$). Therefore, the approach used to obtain an expression for this torque assuming incompressible flow can be extended to compressible flow by re-defining these two variables.

First, assume that the velocity at the valve disc, V_d, is proportional to the velocity change through the control volume. Then, the dynamic torque can be expressed as

$$T_D \propto MV_d \tag{11}$$

The velocity at the valve disc is given by

$$V_d = \frac{M}{\rho_d A} \tag{12}$$

By combining Equations (11) and (12) the dynamic torque is shown to vary directly as the square of the mass flow rate and inversely with the fluid density at the valve disc.

$$T_D \propto \frac{M^2}{\rho_d} \tag{13}$$

Determining the flow rate of a compressible fluid through a control valve by analytical techniques is quite difficult because of valve geometry. The major problem is to establish the pressure differential between the valve inlet and the vena contracta. However, by defining the physical system in which the valve is installed to conform with specifications given by the Fluid Controls Institute (FCI),[2] empirical relationships developed specifically for determining flow rate for control valves can be considered. Several such empirical relationships have been developed; however, only one, the Universal Gas Sizing Equation,[3] has been shown to accurately define the flow rate for any valve configuration. This equation is given by

$$Q = \sqrt{\frac{520}{GT}} P_1 C_1 C_2 C_v \sin\left[\frac{59.64}{C_1 C_2}\sqrt{\frac{\Delta P}{P_1}}\right]_{rad} \tag{14}$$

Equation (14) can be rewritten to obtain an equivalent expression for mass flow rate.

$$M = 1.06\sqrt{\rho_1 P_1}\, C_1 C_2 C_v \sin\left[\frac{59.64}{C_1 C_2}\sqrt{\frac{\Delta P}{P_1}}\right]_{rad} \qquad (15)$$

The sine function in Equations (14) and (15) is used to define the transition between incompressible flow occurring at low pressure ratios ($\Delta P/P_1$) and critical flow.

Let

$$\theta = \left[\frac{59.64}{C_1 C_2}\sqrt{\frac{\Delta P}{P_1}}\right]_{rad} \qquad (16)$$

Rewriting Equation (15) in the following manner:

$$M = 1.06\sqrt{\rho_1 P_1}\, C_1 C_2 C_v F \qquad (17)$$

The factor, F, is bounded by the following:

$$F = \sin\theta \quad \text{for } \theta < \pi/2$$
$$F = 1.0 \quad \text{for } \theta \geq \pi/2 \qquad (18)$$

By substituting Equation (17) for the mass flow rate in Equation (13), the dynamic torque for a given valve is given by

$$T_D \propto \frac{\rho_1 P_1 (C_1 C_2 \sin\theta)^2}{\rho_d} \qquad (19)$$

The only parameter in Equation (10) that cannot be readily obtained is the density at the valve disc, ρ_d. Assuming that the change in the ratio of fluid density at the valve inlet to fluid density at the valve disc with increasing pressure ratio is small relative to the total change in mass flow rate, the torque expression can be simplified in the following manner:

$$T_D \propto P_1 (C_1 C_2 \sin\theta)^2 \qquad (20)$$

Therefore, for compressible flow:

$$T_D = K_2 P_1 (C_1 C_2 \sin\theta)^2 \qquad (21)$$

For small values of pressure ratio ($\Delta P/P_1$) Equation (21) reduces to the incompressible torque relationship given by Equation (10-A).

As $\Delta P/P_1 \to 0$

$$\sin\theta = \theta \text{ (radians)}$$

$$T_D = K_2\,(59.64)^2 \Delta P \qquad (22)$$

The expression in Equation (22) is equivalent to the expression in Equation (10-A):

$$K_2 (59.64)^2 \Delta P = K_1 D^3 \Delta P$$

$$K_2 = \frac{K_1 D^3}{(59.64)^2} \qquad (23)$$

By substituting the expression in Equation (23) for the coefficient K_2 in Equation (21), a general expression for dynamic torque for compressible flow is obtained using the dimensionless torque coefficient established for incompressible flow.

$$T_D = K_1 D^3 P_1 \left[\frac{C_1 C_2}{59.64}\right]^2 \sin^2\theta \qquad (24)$$

For convenience the form of Equation (24) is simplified.

$$T_D = K_1 D^3 \Delta P_e \qquad (25)$$

where

$$\Delta P_e = P_1 \left[\frac{C_1 C_2}{59.64}\right]^2 \sin^2\theta \qquad (26)$$

Equation (26) is defined as the pressure differential contributing to the dynamic torque on butterfly valves with conditions of compressible flow.

EXPERIMENTAL RESULTS

The first step in the experimental evaluation was to establish the dimensionless torque coefficient, K_1, as a function of valve disc rotation as defined by Equation (10-B). A test was conducted on a 4-in. valve under the following controlled conditions:

1. The valve was installed in a 4-in. test line with a minimum of 12 pipe diameters of straight pipe upstream.
2. The pressure taps were located according to FCI specifications and attached to the test line according to specifications in the *ASME Power and Test Code.*[4]
3. Water at ambient temperature was used as the flowing medium.
4. The inlet pressure and outlet pressure were held constant.
5. The test was conducted at a low pressure ratio ($\Delta P/P_1 = 0.088$) to ensure incompressible flow.

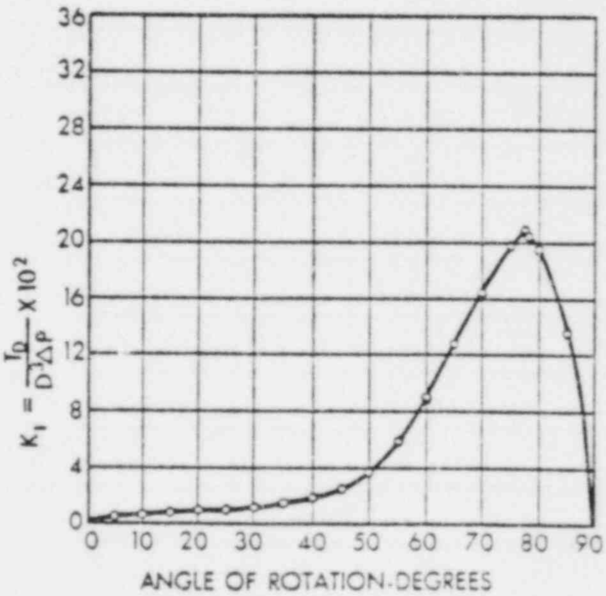


Figure 1. Dimensionless torque coefficient, 4-in. butterfly valve incompressible flow: P_1 = 100 psig, P = 110 psi.

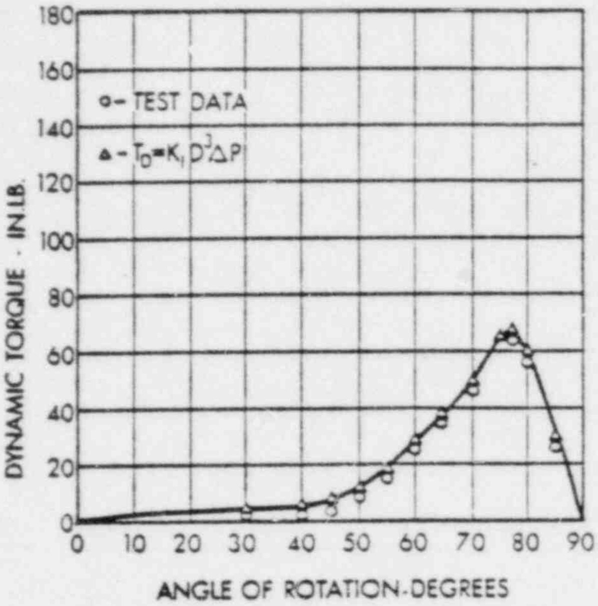


Figure 2. Dynamic torque vs. angle of disc rotation, 4-in. butterfly valve, comparison of experimental results with calculated torque, incompressible flow: $P_1 = 100$ psig, $\Delta P = 5$ psi.

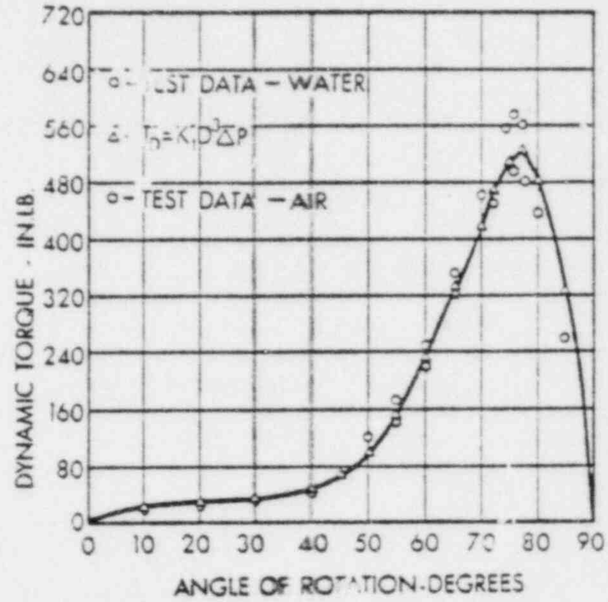


Figure 4. Dynamic torque vs. angle of disc rotation, 8-in. butterfly valve, comparison of experimental results with calculated torque, incompressible flow: $P_1 = 100$ psig, $\Delta P = 5$ psi.

Torque measurements were made at selected increments of disc rotation (0–90°). A transducer, consisting of a steel bar with strain gages attached, was fixed to the valve shaft and used in conjunction with an oscillograph to measure and record the shaft torque. The data from this test were used to determine the dimensionless torque coefficient plotted as a function of disc rotation on Figure 1. The curves plotted on Figure 2 show excellent agreement between measured torque and the torque calculated using this coefficient.

The next step was to verify that the torque coefficient is indeed applicable to other valve sizes provided geometric similarity is reasonably well maintained. The results on Figures 3 and 4 again show very good agreement between measured torque and calculated torque for two 8-in. valves.

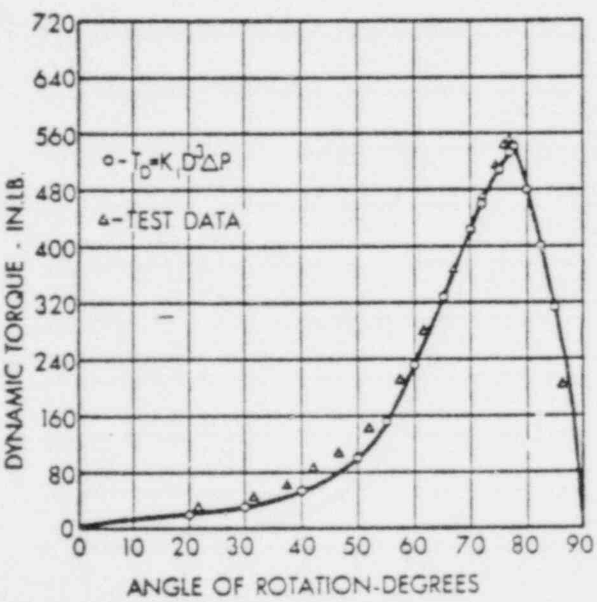


Figure 3. Dynamic torque vs. angle of disc rotation, 8-in. butterfly valve, comparison of experimental results with calculated torque, incompressible flow: $P_1 = 100$ psig, $\Delta P = 5$ psi.

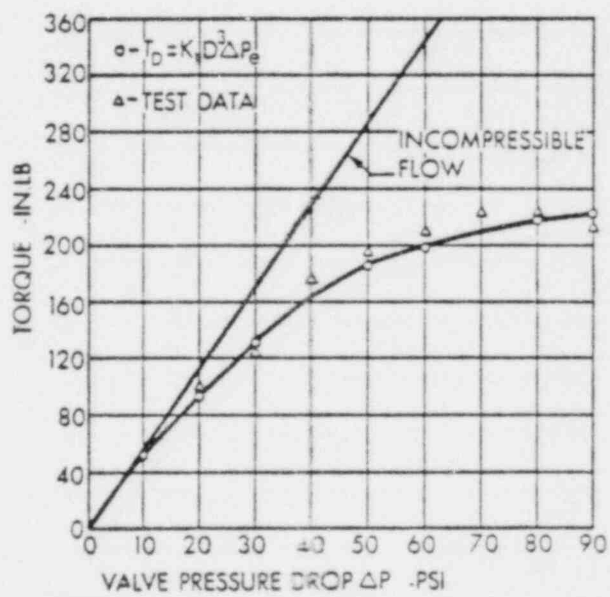


Figure 5. Dynamic torque vs. valve pressure drop, 4-in. butterfly valve, 60° disc rotation, comparison of experimental results with calculated torque, compressible flow: $P_1 = 214.4$ psia, flowing medium = air.

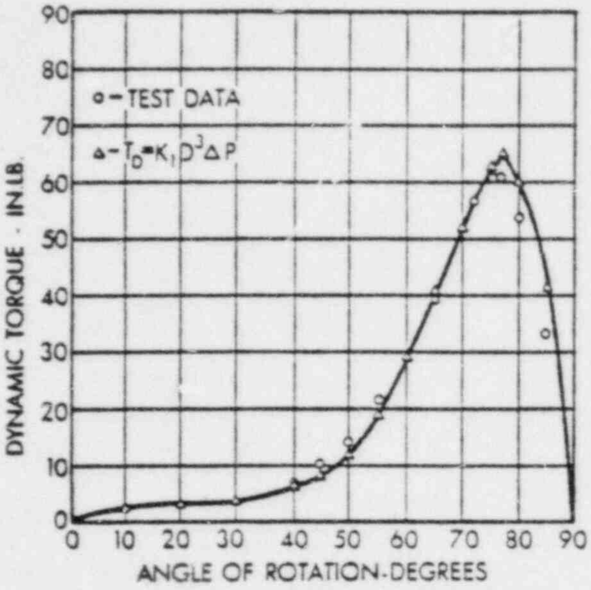


Figure 6. Dynamic torque vs. angle of disc rotation, 4-in. butterfly valve, comparison of experimental results with calculated torque, compressible flow: P_1 = 114.4 psia, ΔP = 5 psi ($\Delta P/P_1$ = 0.0446), flowing medium = air.

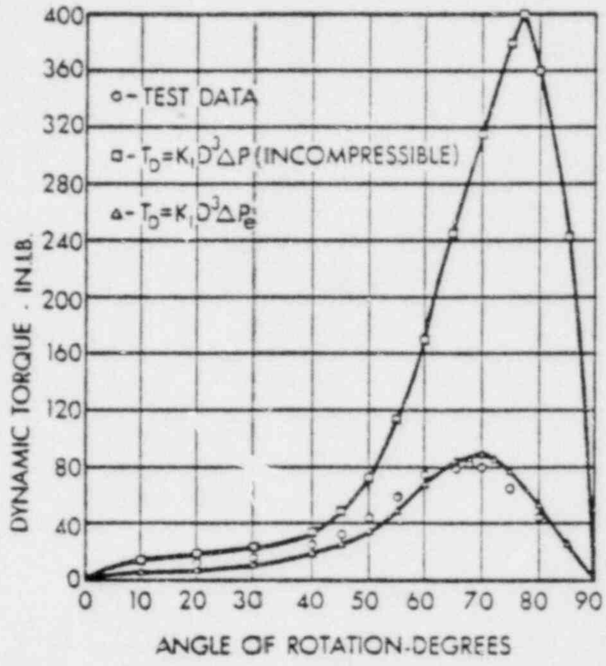


Figure 8. Dynamic torque vs. angle of disc rotation, 4-in. butterfly valve, comparison of test results with calculated torque, compressible flow: P_1 = 64.4 psia, ΔP = 30 psi ($\Delta P/P_1$ = ~~0.466~~), (critical flow) flowing medium = air. 0.466

It should be noted that discs in the two 8-in. valves were of substantially different geometric shape. Using the ratio of disc diameter to hub diameter as an indicator, these ratios were 4.56 : 1 and 3.55 : 1 for the valves used to obtain the data for Figures 3 and 4, respectively. The difference in torque magnitude for these valves with a 5 psi pressure differential shown in Figures 3 and 4 is the result of this difference in geometry. The disc in the 8-in. valve used for the test in Figure 3 was geometrically similar to the disc in the 4-in. test valve used to establish the torque coefficient, K_1.

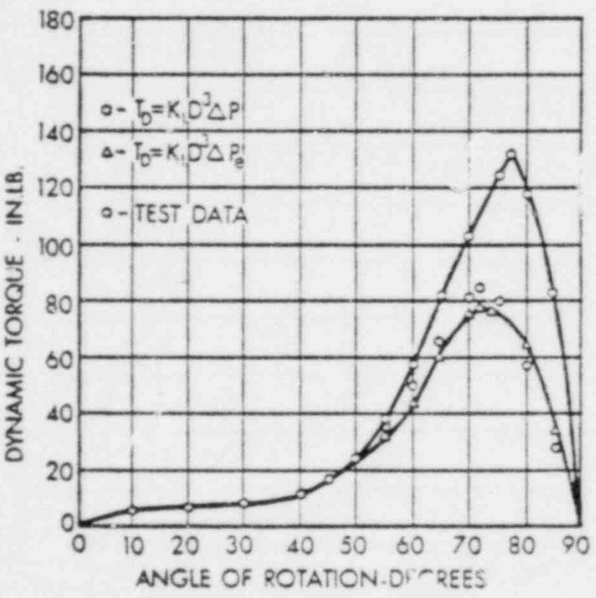


Figure 7. Dynamic torque vs. angle of disc rotation, 4-in. butterfly valve, comparison of experimental results with calculated torque, compressible flow: P_1 = 64.4 psia, ΔP = 10 psi ($\Delta P/P_1$ = ~~0.116~~), flowing medium = air. 0.155

The extension of the dynamic torque relationship to include the effect of fluid compressibility is accomplished by defining an effective pressure differential as shown in Equation (25). The curves on Figure 5 show the transition from incompressible flow to critical flow with increasing pressure ratio for a 4-in. valve set at 60° disc rotation. Here again there is very good agreement between the torque calculated using Equation (24) and the experimental results. The incompressible torque curve is also shown on Figure 5 to emphasize the effect of fluid compressibility.

The curves on Figures 6 through 8 are presented to compare experimental results with torque calculated using Equation (24) for full 90° disc rotation. At low pressure ratios, the torque using air as the flowing medium is essentially equal to the torque for incompressible flow (Figure 6). As the pressure ratio is increased, the effect of fluid compressibility becomes more pronounced as shown in Figure 7. Once critical flow has been attained, no further increase in torque is realized by increasing the valve pressure differential as shown on Figure 8.

CONCLUSIONS

A technique is presented which can be used to determine the dynamic torque for butterfly valves with reasonable accuracy. The basic torque relationship developed for incompressible flow is extended to include the effect of fluid compressibility. The method presented is developed

using the Universal Gas Sizing Equation to define an effective pressure differential for the transition from incompressible flow to critical flow. Application of this method shows excellent agreement with experimental test results.

NOTATION

A = Flow area, in.^{2}
$B_1, B_2,$
B_3, B_4 = Constants of proportionality
$C_1 = C_r C_v$
C_2 = Correction factor for variation in specific heat ratio
C_g = Gas sizing coefficient
C_v = Flo coefficient
C = Nominal valve diameter, in.
F = Force, lb
G = Specific gravity
K_1 = Dimensionless torque coefficient
M = Mass flow rate, lb/s
P_1 = Inlet pressure, psia
ΔP = Valve pressure differential, psi
ΔP_e = Pressure differential affecting dynamic torque
Q_i = Flow rate incompressible fluid, scfh
C_c = Flow rate compressible fluid, scfh
T = Absolute temperature, °R
T_D = Dynamic torque, in. lb
V = Fluid velocity, in./s
ρ_1 = Fluid density at upstream pressure tap, lb/in.^{3}
ρ_d = Fluid density at valve disc, lb/in.^{3}

REFERENCES

1. Keller, I. C., and Salzmann, I. F. January 1936. Aerodynamic Model Tests on Butterfly Valves." *Escher-Wyss News*. 9.
2. *Recommended Voluntary Standards for Measurement Procedure for Determining Control Valve Flow Capacity*. 1958. Fluid Controls Institute, Inc., paper FCI 58-2.
3. Buresh, J. F., and Schuder, C. B. October 1964. "The Development of a Universal Gas Sizing Equation for Control Valves." *ISA Trans.* 3:322–328.
4. *Flow Measurement: Instruments and Apparatus. Supplement to the ASME Power Test Codes*. ASME report PTC 19.5; 4-1959.

3

Attachment 3 - Capacity and Dynamic Torque Curves Determined in Fisher Lab. Tests for 6" Type 9220 Butterfly Valve.

DATE 7-2-76 (WCS)

FISHER CONTROLS COMPANY

PROBLEM 983
REPORT 15
FIGURE 1

FLOW VS TRAVEL CHARACTERISTIC

BODY SIZE 6" DESIGN/TYPE 9200 B/F BODY DWG. F41629-B

SEAL CONSTRUCTION ______ SEAL DWG. ______

MEASURED PROTECTOR RING DIA. ______ PROTECTOR RING DWG ______

BALL/DISC TYPE 7 TO 1 ASPECT RATIO BALL/DISC DWG. 75-115DXX2012-A

VALVE FLOW DIRECTION: ☐NORMAL ☒REVERSE

⊙ WATER TEST

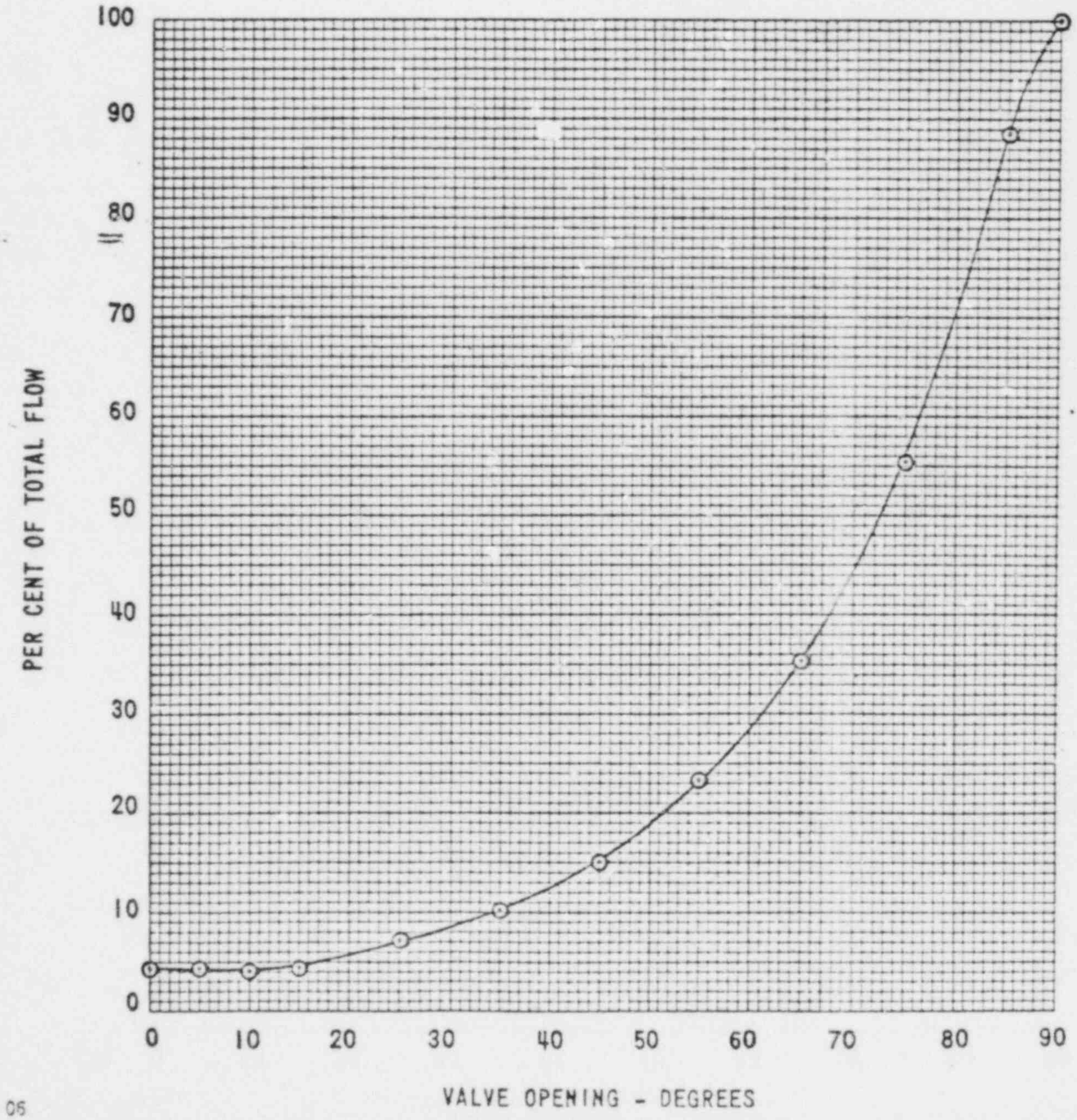
BODY INLET PRESSURE >100 PSIG BODY PRESSURE DROP 2 PSI

AVERAGE C_v = 1690

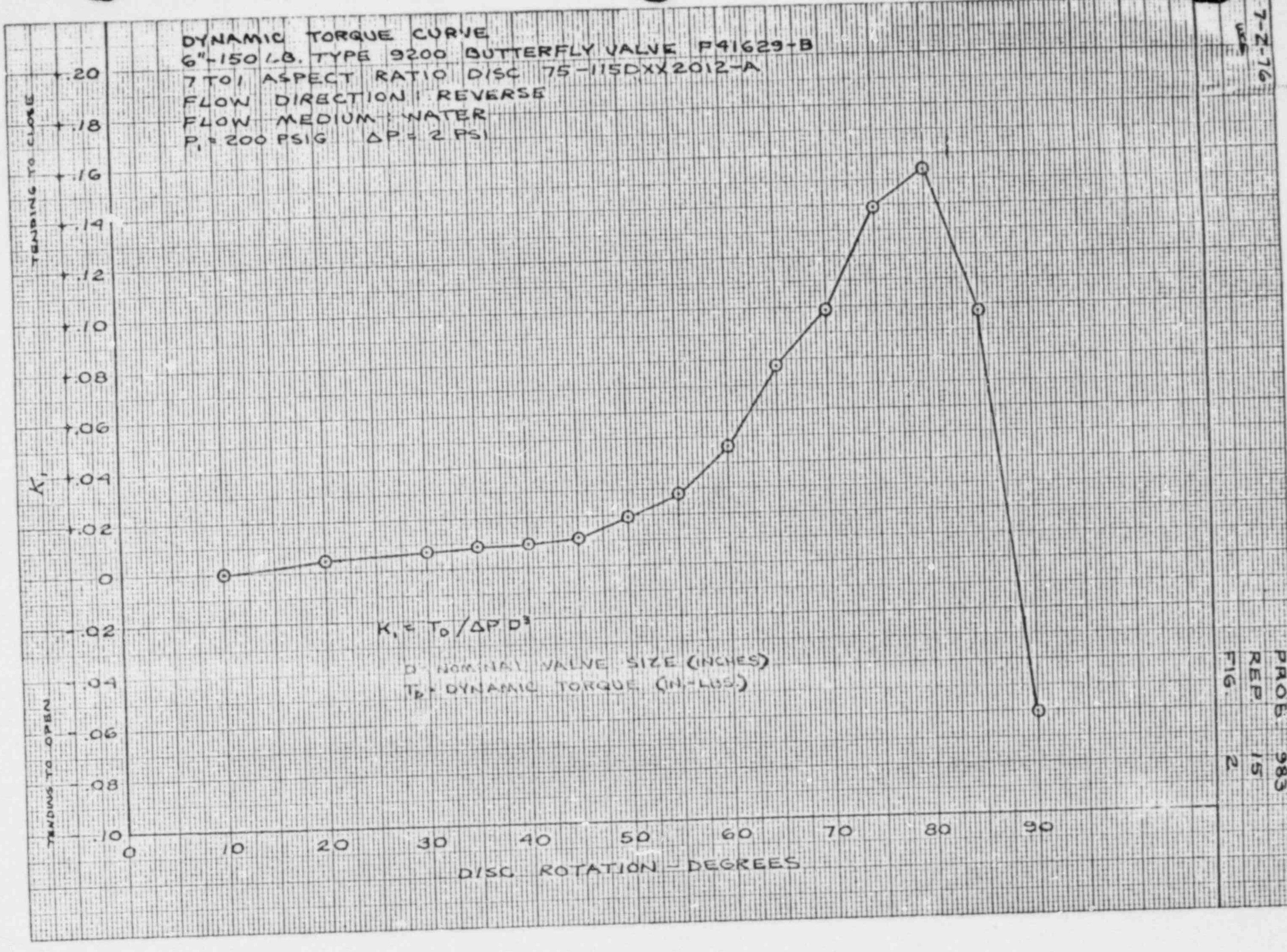
† AIR TEST

BODY INLET PRESSURE ______ PSIA BODY PRESSURE DROP ______

AVERAGE C_g = ______



RES. FORM 06


7-2-76
DYNAMIC TORQUE CURVE
6"-150 LB. TYPE 9200 BUTTERFLY VALVE P41629-B
7 TO 1 ASPECT RATIO DISC 75-115DXX2012-A
FLOW DIRECTION : REVERSE
FLOW MEDIUM : WATER
P1 = 200 PSIG ΔP = 2 PSI
K1 = TD / ΔP D3
D - NOMINAL VALVE SIZE (INCHES)
TD - DYNAMIC TORQUE (IN.-LBS.)
K1
TENDING TO CLOSE
TENDING TO OPEN
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
-.02
-.04
-.06
-.08
-.10
0
10
20
30
40
50
60
70
80
90
DISC ROTATION - DEGREES
PROB. 983
REP. 15
FIG. 2

4

Attachment 4 - Piping System Sketches

BY DGB DATE 4-6-80 SUBJECT SHEET NO. 1 OF
CHKD. BY DATE JOB NO.

ATTACHMENT 4

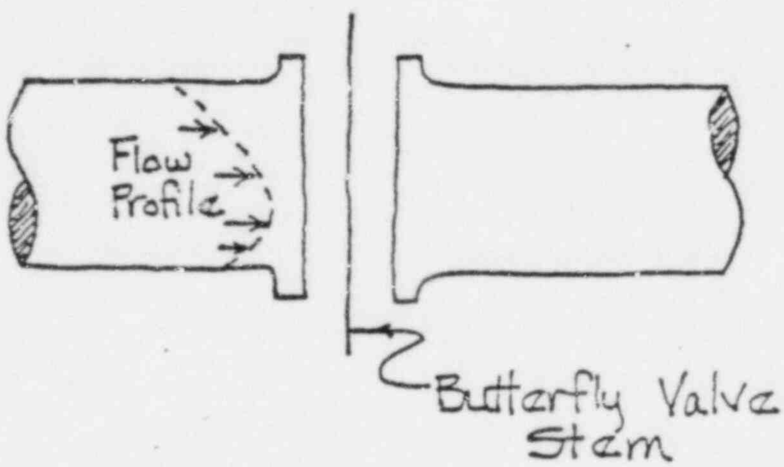


FIGURE A

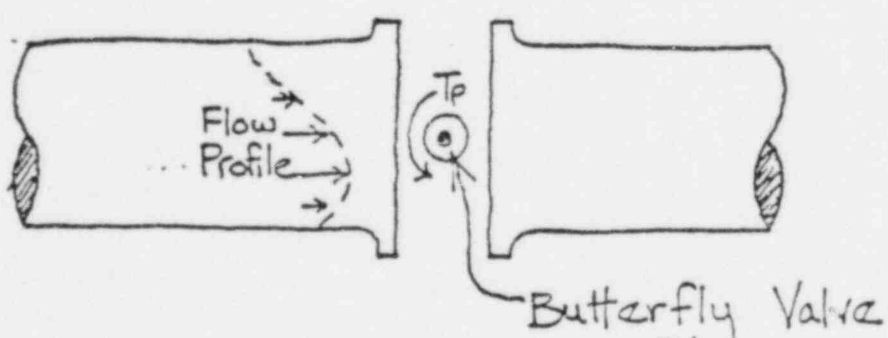


FIGURE B

5

Attachment 5 - Fisher Bulletin 51.4:9200,
July 1976; "9200 Series
Butterfly Control Valve
Bodies for Nuclear Service".

9200 Series Butterfly Control Valve Bodies for Nuclear Service

July 1976 | Bulletin 51.4:9200

Fisher 9200 Series valves are offset-disc butterfly valves with an adjustable elastomer T-ring seat suitable for extremely stringent shutoff requirements. These valves are often used as nuclear-service valves for on/off applications such as containment isolation and for throttling or on/off flow control of component cooling water or auxiliary service fluids.

Design criteria for pressure-retaining components of 9200 Series valves meet the requirements of the ASME (American Society of Mechanical Engineers) Boiler and Pressure Vessel Code, Sections III and VIII, and the valve body assemblies can be furnished with the ASME "N"-stamp symbol.

The standard plate steel or cast steel 9200 Series wafer-style valve is installed between pipeline flanges. An optional steel single-flange style body is available with a pipeline flange on one end and a buttwelding connection on the other end or with a buttwelding connection on both ends. This optional construction can be welded directly to a containment vessel wall.

These valves are available in 4-inch through 96-inch sizes for process temperatures to 400°F and, depending upon size, pressure drops to 150 psi.

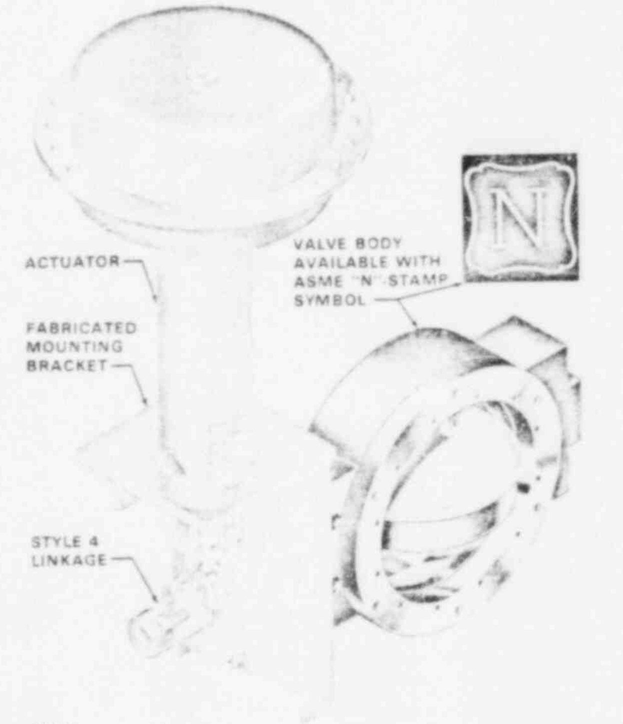


Figure 1. 9200 Series Specification B-1 Valve Body with Type 656 Actuator

Features

• **Compliance with Nuclear Code and Other Requirements**—Fisher Controls Company holds the ASME Certificate of Authorization to use the "N"-stamp symbol on these valve body assemblies. All ASME requirements for Class 1, 2, and 3 nuclear-service valves, as well as special customer assembly, cleaning, painting, and packaging requirements, can be met. In addition, compliance of valve and actuator assemblies with specified seismic and environmental criteria can be documented with seismic analysis calculations and/or actual test results.

• **Economical**—Standard plate steel construction requires less extensive nondestructive examinations than cast construction, reducing cost and delivery time. Standardized valve/actuator size combinations ensure sufficient actuator power while reducing actuator selection time and documentation cost and delay.

• **Excellent Shutoff without Excessive Seating Torque**—Offset disc design allows disc/T-ring contact around 360 degrees of disc circumference. Elastomer T-ring is field adjustable so that shutoff can be maintained without excessive disc/T-ring interference and associated high seating torque. Reduced interference also minimizes T-ring wear to prolong T-ring life.

• **Reduced Leak-Off Piping Requirements**—Sizes through 24 inches use valve shaft packing on one side of valve only; only one leak-off connection to pipe.

Specifications

AVAILABLE CONFIGURATIONS AND BODY SIZES

9200 Series Specification B-1: Offset-disc butterfly control valve body with adjustable elastomer T-ring seat contained between the retaining ring and valve body as shown in figure 2. Valve shaft sealed with packing on actuator side and with a blank-off plate on the other side. Available in ■ 4, ■ 6, ■ 8, ■ 10, ■ 12, ■ 14, ■ 16, ■ 18, ■ 20, and ■ 24-inch sizes

9200 Series Specification C-1: Offset-disc butterfly control valve body with adjustable elastomer T-ring seat contained between the retaining ring and the valve disc face as shown in figure 3. Valve shaft sealed with packing on both sides. Available in ■ 30 through ■ 96-inch sizes in 6-inch increments

BODY STYLE

Flangeless (wafer-type) body with four flange bolt holes (see figures 1 and 4) for installation between two pipeline flanges

END CONNECTION STYLES

4 Through 24-Inch Sizes: Mate with ANSI Class 150 (B16.5) raised-face flanges

30 Through 96-Inch Sizes: Mate with ■ ANSI Class 125 (B16.1) flat-face flanges (through 72-inch size only), ■ AWWA C207 flanges, or ■ MSS SP-44 flanges

MAXIMUM INLET PRESSURE[1]

4 Through 24-Inch Sizes: Compatible with ANSI Class 150 pressure/temperature ratings for temperatures from +20 to +400°F

30 Through 96-Inch Sizes: ■ 75 psig for temperatures from +20 to +400°F (in accordance with ASME Code Case 1678, approved December 16, 1974) or ■ higher pressures upon request

MAXIMUM PRESSURE DROP[1]

Shutoff (0 Degrees of Disc Rotation)

4 Through 24-Inch Sizes: 150 psi

30 Through 96-Inch Sizes: 75 psi

Flowing: See table 1

CONSTRUCTION MATERIALS

Body,[2] Disc,[2] and Retaining Ring[3]: ■ Steel plate (ASME SA515 GR 70) or ■ other materials available upon request

Shaft: 17-4PH stainless steel (ASME SA564 GR630 H1075)

Taper Pins: Same material as shaft

Blank-Off Plate[2] (Through 24-Inch Size Only): 316 stainless steel (ASME SA240 GR316)

Blank-Off Plate Bolting (Through 24-Inch Size Only)

Studs:[2] Steel (ASME SA193 GR B8M)

Nuts:[2] Steel (ASME SA194 GR 8M)

T-Ring: ■ EPDM (ethylene-propylene) or ■ nitrile; ■ Viton[4] is also available for non-nuclear applications

Retaining Ring O-Ring (Through 24-Inch Size Only): EPDM (ethylene-propylene)

Blank-Off Plate Gasket (Through 24-Inch Size Only): Spiral-wound gasket of 304 stainless steel and asbestos

Packing: Alternated rings of Crane[5] 187-I and laminated-graphite (Grafoil[6]) packing

Bushings: ■ Graphite-impregnated bronze (bushing 2) or ■ alloy 6 (bushing 3)

Bushing Retainers and Retainer Tube: 316 stainless steel

Packing Follower: Steel

Packing Lantern Rings and Washers: 316 stainless steel

Packing Box Studs and Nuts: Steel

Thrust Collars

Shaft Diameters to 1-1/2 Inches (Through 18-Inch Valve Size): Cadmium-plated steel clamp-type collars with brass washers between collars and bearing surfaces

Shaft Diameters over 1-1/2 Inches: Bronze collars pinned to valve shaft

Actuator Mounting Bracket: Fabricated Steel

OPERATIVE TEMPERATURE[1, 7]

With EPDM T-Ring: +20 to +300°F

With Nitrile T-Ring: +20 to +200°F

1. None of the pressure or temperature limitations in this bulletin, nor any applicable code limitation, should be exceeded.
2. Pressure-retaining part.
3. Pressure-retaining part on 4-inch through 24-inch sizes only.
4. Trademark of Du Pont Co.
5. Trademark of Crane Packing Co.
6. Trademark of Union Carbide Corp.
7. This term is defined in SAMA Standard PMC 20.1-1973.

Specifications (Continued)

With Viton T-Ring: +20 to +400°F (Do not use with water over 180°F or steam)

ACTUATOR TORQUE REQUIRED
See table 1

FLOW DIRECTION
Flow is permissible in either direction, but valve is normally installed with T-ring retaining ring facing downstream

FLOW COEFFICIENTS
See Fisher Catalog 10

SHUTOFF CLASSIFICATION
Fisher Class VI (less than one bubble per minute using air at a pressure drop of 150 psi for 4 through 24-inch sizes and 75 psi for 30 through 96-inch sizes)

DISC ROTATION
■ Clockwise to open or ■ counterclockwise to open (when viewed from actuator side of valve) through 90 degrees of disc rotation.

ACTUATOR MOUNTING
Fabricated actuator-mounting bracket is used to mount Fisher Type 480-15, 481-15, 656 and 864 actuators. Style 4 adjustable linkage, shown in figure 1, is used with Fisher actuators for travels of 4 inches and less and valve shaft diameters of 1-1/2 inches and less. Fixed linkage is used for longer travels and larger valve shafts.

Actuator can be ■ perpendicular to (standard) or ■ parallel with pipeline (adaptor required for parallel mounting of actuators requiring a mounting bracket) with actuator to ■ right (standard) or ■ left of valve (when viewed from valve inlet)

With perpendicular mounting in horizontal pipeline, actuator can extend ■ above (standard) or ■ below pipeline. With parallel mounting, actuator can extend ■ upstream or ■ downstream.

ACTUATOR/VALVE ACTION
■ Push-down-to-open (extending actuator stem opens valve) or ■ Push-down-to-close (extending actuator stem closes valve)

MATING FLANGE CAPABILTIES
Compatible with welding-neck and slip-on flanges

CODE CLASSIFICATIONS
Valve body, disc, and shaft components designed in accordance with allowable stress levels as specified in ASME Boiler and Pressure Vessel Code, Sections III and VIII

Valve body assemblies available as nuclear code Class 1, 2, or 3 valve with ASME "N"-stamp symbol

TESTING REQUIRED
All nondestructive examinations (NDE) required for Class 1, 2, and 3 nuclear-service valves can be furnished; for current list of NDE requirements, see Fisher Catalog 11

PACKING BOX TYPE
Leak-off type packing box with 1/2-inch NPT female leak-off connection

VALVE SHAFT DIAMETERS
See figure 7

APPROXIMATE WEIGHTS
See figure 7

OPTION
Single-flange steel valve body with ■ full set of flange bolt holes on one end and buttwelding-end connection on the other end as shown in figure 2 or with ■ a buttwelding end connection on both ends. Flanged end connection available as noted in "End Connection Styles" above; buttwelding-end connection available per ■ ANSI B16.25 or ■ as specified

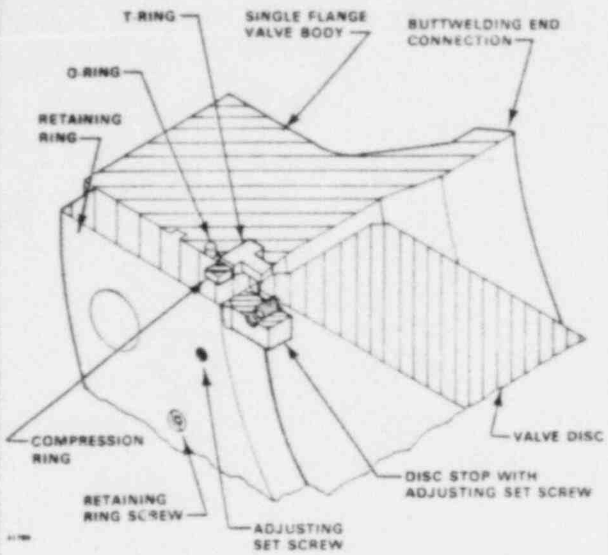


Figure 2. 9200 Series Specification B-1 Valve T-Ring Details (Optional Single-Flange/ Buttwelding End Construction)

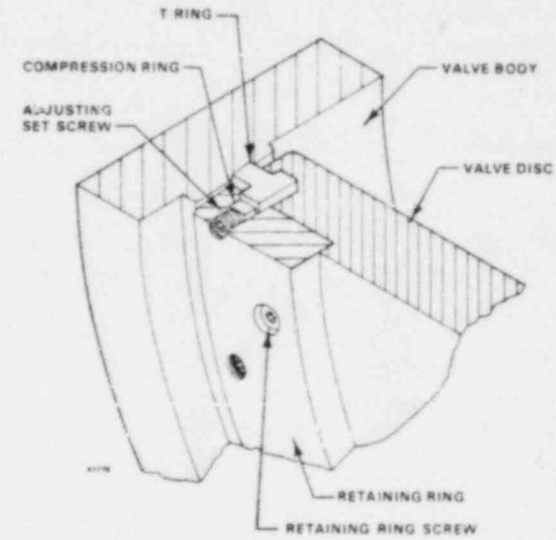


Figure 3. 9200 Series Specification C-1 Valve T-Ring Details

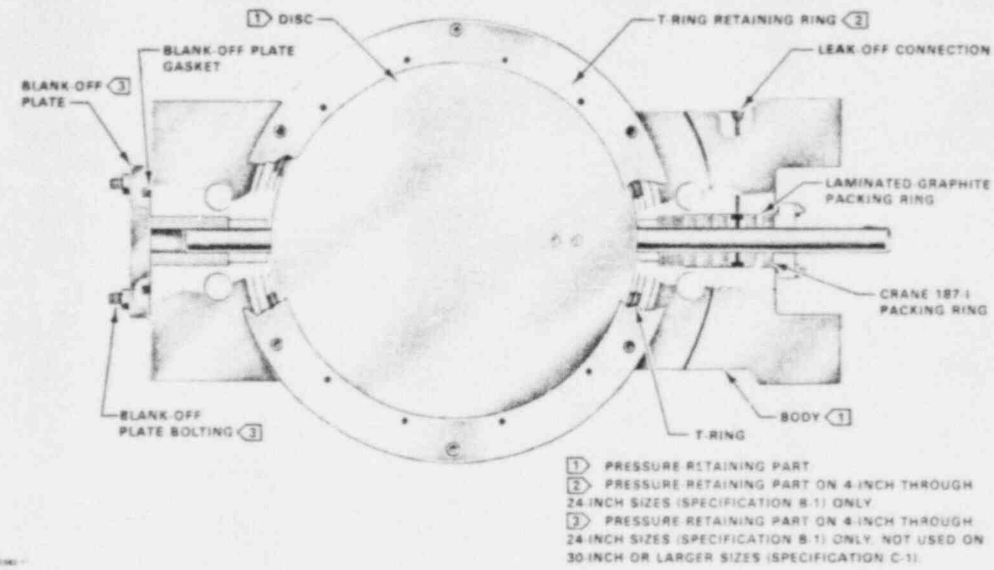


Figure 4. 9200 Series Specification B-1 Valve Body

Valve and Actuator Selection

Note

Valve and actuator selection can be made from table 1 for 4-inch through 72-inch valves, pressure drops to 150 psi (depending upon valve size), and process temperatures from +20 to +400°F (depending upon elastomer T-ring material selected and application).

The torques in the "Actuator Torque Required" column of the table are the maximum torques encountered when the disc is being closed (or opened) against the shutoff (0-degrees of disc rotation) pressure drop shown in the table. Pressure drops shown for open disc angles (60 or 90 degrees) are the maximum flowing drops that the torques in the "Actuator Torque Required" column will permit. (Where necessary, maximum pressure drops shown for open angles have been limited by strength capabilities of construction materials.)

Table 1. Valve and Actuator Selection

VALVE SIZE[1] (INCHES)	VALVE SHAFT DIAMETER (INCHES)	OPERATIVE TEMPERATURE	BUSHING TYPE[2]	MAXIMUM PRESSURE DROP (PSI) Angle of Disc Opening (Degrees) 0	60	90	ACTUATOR TORQUE REQ'D (INCH-POUNDS)	RECOMMENDED ACTUATOR TYPE AND SIZE
4	5/8	EPDM T-Ring: +20 to +300°F; Nitrile T-Ring: +20 to +200°F; Viton T-Ring: +20 to +400°F	2	150	49.7	16.9	410[3]	656 Size 40 w/35 psig supply[4]
			3	150	59.1	21.5	525[3]	656 Size 40 w/35 psig supply[4]
6	3/4		2	150	36.4	12.1	925[3]	656 Size 60 w/35 psig supply[4]
			3	150	46.1	15.0	1250[3]	656 Size 60 w/35 psig supply[4]
8	1		2	150	30.5	10.1	1820[3]	656 Size 60 w/35 psig supply[4]
			3	150	40.4	14.2	2575[3]	480-15 Size 40 w/80 psig supply[5]
10	1		2	150	24.7	8.1	2780[3]	480-15 Size 40 w/80 psig supply[5]
			3	144	16.0	8.1	3960	480-15 Size 60 w/80 psig supply[5]
12	1-1/4		2	150	22.7	7.6	4425[3]	480-15 Size 60 w/80 psig supply[5]
			3	150	27.0	9.0	6550[3]	480 Size 80 w/80 psig supply[5]
14	1-1/4		2	150	19.7	6.5	5360[3]	480-15 Size 60 w/80 psig supply[5]
			3	140	19.5	6.4	7950	864 Size[6] 6 x 20 w/80 psig supply[5]
16	1-1/2		2	150	18.9	6.3	7785[3]	480 Size 80 w/80 psig supply[5]
			3	150	22.5	7.5	11,900[3]	864 Size[6] 6 x 20 w/80 psig supply[5]
18	1-1/2		2	150	15.7	5.0	10,550[3]	864 Size[6] 6 x 20 w/80 psig supply[5]
			3	129	15.0	4.9	15,950	864 Size[6] 8 x 20 w/80 psig supply[5]
20	1-3/4		2	150	16.5	5.4	13,100[3]	864 Size[6] 6 x 20 w/80 psig supply[5]
			3	148	18.0	5.8	20,550	864 Size[6] 8 x 20 w/80 psig supply[5]
24	2		2	150	15.0	4.9	20,700	864 Size[6] 8 x 20 w/80 psig supply[5]
			3	137	15.0	4.9	33,170	864 Size[6] 10 x 20 w/80 psig supply[5]
30	2		2	75	6.5	2.1	17,732[3]	864 Size[6] 8 x 16 w/80 psig supply[5]
			3	75	6.2	2.0	27,932	864 Size[6] 8 x 20 w/80 psig supply[5]
36	2-1/2		2	75	6.3	2.0	28,830	864 Size[6] 8 x 20 w/80 psig supply[5]
			3	75	5.9	2.0	46,830	864 Size[6] 10 x 24 w/80 psig supply[5]
42	2-1/2		2	75	5.5	1.7	40,020	864 Size[6] 10 x 20 w/80 psig supply[5]
			3	75	5.2	1.7	64,770	864 Size[6] 12 x 20 w/80 psig supply[5]
48	3		2	75	5.3	1.7	58,675	864 Size[6] 12 x 20 w/80 psig supply[5]
			3	75	5.1	1.7	97,750	Contact Fisher Representative
54	3-1/2		2	75	5.3	1.7	83,555	Contact Fisher Representative
			3	75	5.0	1.6	141,680	Contact Fisher Representative
60	3-1/2		2	75	4.8	1.5	103,585	Contact Fisher Representative
			3	75	4.6	1.5	175,660	Contact Fisher Representative
66	4		2	75	4.7	1.5	137,570	Contact Fisher Representative
			3	75	4.5	1.5	237,320	Contact Fisher Representative
72	4-1/2		2	75	4.7	1.5	180,130	Contact Fisher Representative
			3	75	4.5	1.5	313,630	Contact Fisher Representative

1. For larger sizes, contact the Fisher sales representative.
2. Bushing 2—graphite-impregnated bronze; bushing 3—alloy 6.
3. Within torque capabilities of Fisher manual handwheel actuators.
4. With or without valve positioner. Selection valid only if full actuator travel, standard 6 to 30 psig (nominal) spring, and positioner supply (or maximum diaphragm input signal) of 35 psig are used.
5. With or without valve positioner. If 480 Series actuator without positioner is desired, substitute Type 481 or 481-15 for Type 480 or 480-15. Section valid only if full actuator travel and minimum positioner supply pressure (or cylinder operating pressure) of 80 psig are used.
6. Cylinder bore diameter (inches) x maximum actuator travel (inches).

All pressure drops shown are within the strength capabilities of the materials shown in the "Specifications" table.

After determining the proper valve size using Fisher Catalog 10 and the sizing nomographs or slide rule, refer to table 1. Check the maximum allowable pressure drop at the appropriate open angle (either 60 or 90 degrees) to be certain it equals or exceeds that which will be encountered in service.

Recommended Fisher actuator types, sizes, and operating pressures for each selection are shown at the right of the table. In addition, other actuator types, such as electric and spring-return pneumatic rotary actuators are also available in recommended combinations with 9200 Series valve bodies. All combinations in table 1 are predetermined to have sufficient torque output at the stated operating conditions.

Selection from among the recommended combinations reduces documentation cost and possibility of delay. Contact the Fisher sales representative if other combinations are required.

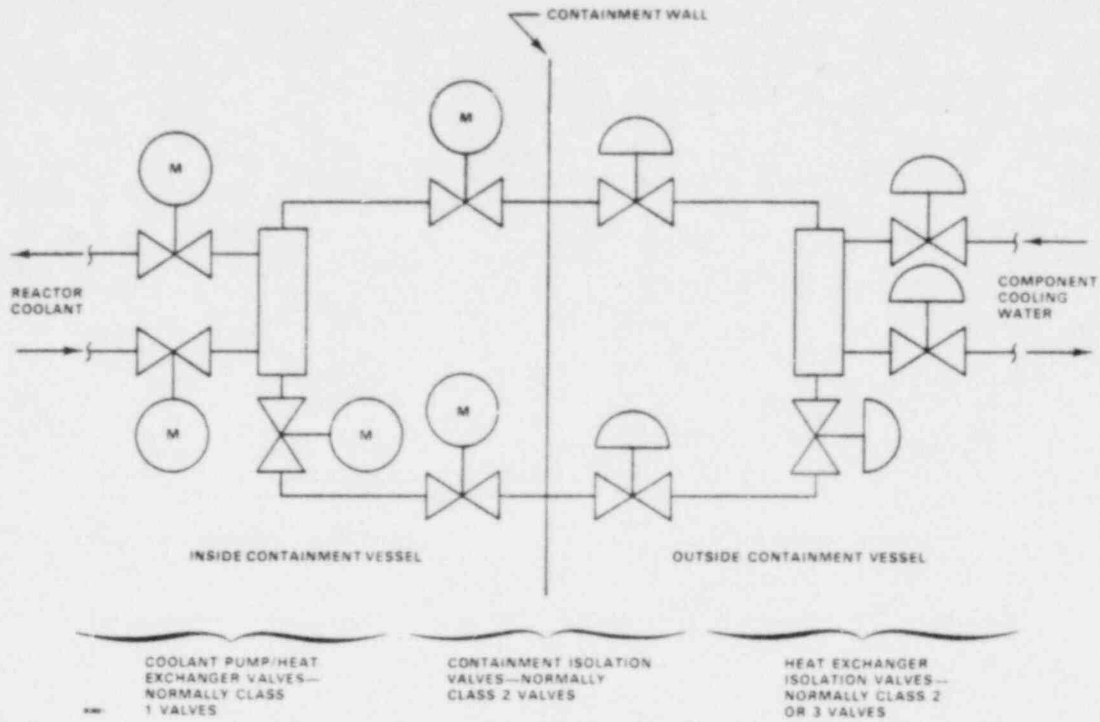


Figure 5. Typical Applications for Class 1, 2, and 3 Nuclear-Service Valves Shown in a Component Cooling System

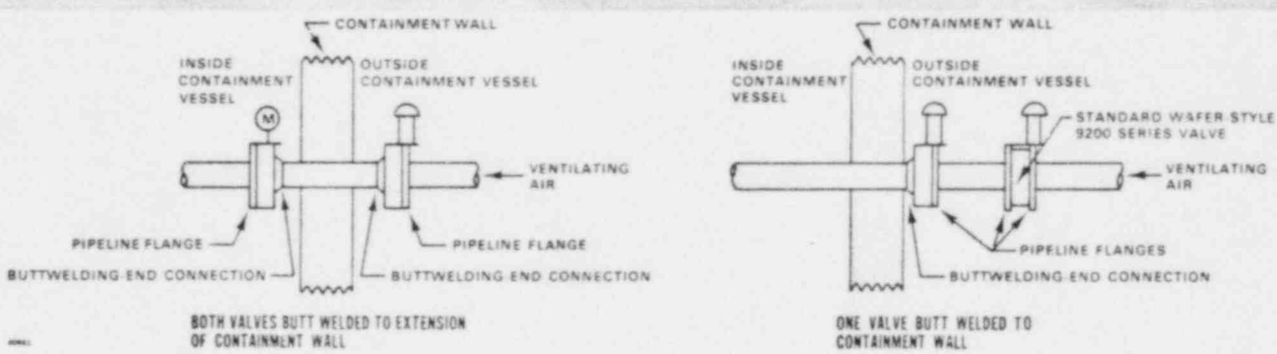


Figure 6. Typical Installations for Single-Flange 9200 Series Valves with One Buttwelding-End Connection and One Flanged Connection (Being Used as Isolation Containment Valves in Ventilating Air System)

Installation

The actuator will be mounted on the valve in the orientation specified when the unit was ordered. This orientation is normally selected based upon the desired mounting position in the pipeline, available space at the point of installation, etc.

For 30-inch and larger valve sizes, factory seat leak testing must be performed with the valve in the same position as is intended for the actual installation. For these larger sizes, install the valve in the same position as was specified when the valve was ordered, or a field re-adjustment of the T-ring may be required to attain the desired shutoff capability. T-ring adjustment is provided by a compression ring and adjusting set screws as shown in figures 2 and 3.

Flow through the valve can be in either direction, but the valve is normally installed with the T-ring retaining ring facing downstream. For 30-inch and larger sizes, it may be desired to install the valve such that the T-ring retaining ring faces the nearest manhole or other pipeline access point. This will facilitate T-ring inspection and maintenance.

VALVE SIZE	LETTERED DIMENSION						MINIMUM ALLOWABLE DIAMETER OF MATING PIPE OR FLANGE	APPROXIMATE WEIGHT OF VALVE BODY ASSEMBLY (POUNDS)
	A	B	C	E*	F	S		
4	4.00	6.50	8.50	6.25	3.25	5/8	3.64	70
6	6.00	7.50	10.50	6.25	3.75	3/4	5.56	100
8	8.00	9.00	10.50	6.25	3.75	1	7.81	130
10	10.00	10.00	12.00	6.25	3.75	1	9.81	175
12	12.00	12.00	14.00	7.62	4.75	1-1/4	11.50	320
14	13.25	13.00	15.50	7.62	4.75	1-1/4	13.00	375
16	15.25	14.50	17.50	7.62	4.75	1-1/2	15.12	475
18	17.00	15.00	18.50	7.62	5.00	1-1/2	16.75	520
20	19.00	17.00	20.50	8.75	5.50	1-3/4	18.88	685
24	23.00	20.00	21.50	8.75	6.00	2	22.75	1040

*Standard E dimensions shown are valid for actuator selections shown in table 1. Special E dimensions may be required for other actuator types.

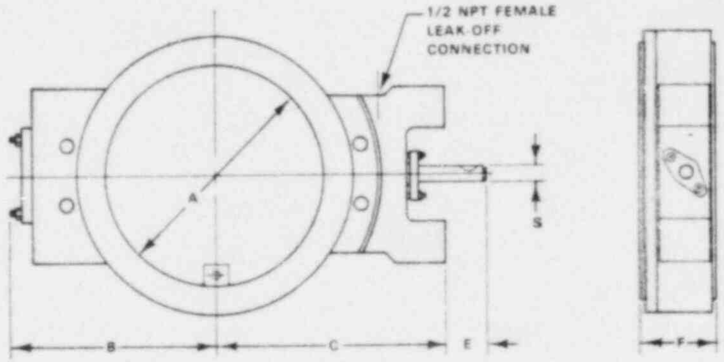


Figure 7. Dimensions (Inches)

The 9200 Series valves are supplied with a disc travel stop. If the valve body and actuator have been ordered separately or if the actuator has been removed for maintenance, be certain that proper rotation direction will be obtained from the actuator before installing.

If spiral-wound line flange gaskets are to be used with the 4-inch through 24-inch sizes, be certain the gaskets are of a type and size that will not overlap the cap screw or adjusting screw holes in the T-ring retaining ring. Under line flange bolting compression, spiral-wound gaskets can be damaged by the cap screw or adjusting screw holes.

Ordering Information

Application

When ordering, specify:

1. Type of Application
   a) Throttling or on/off
   b) Reducing, relief, or back pressure
2. Controlled fluid (include chemical analysis of fluid if possible)
3. Specific gravity of controlled fluid
4. Fluid temperature (normal and minimum and maximum anticipated)
5. Range of flowing inlet pressures
6. Pressure Drops
   a) Range of flowing pressure drops
   b) Maximum at shutoff
7. Flow Rates
   a) Minimum controlled flow
   b) Normal flow
   c) Maximum flow
8. Maximum allowable leakage rate
9. Specify the position in which the valve will be installed (e.g., valve in horizontal pipeline with valve shaft horizontal). Seat leak testing will be performed with the valve in the same position as is intended for the actual installation.
10. Nuclear-code class and all nuclear and special requirements
11. Line size and schedule

Valve Body Information

Refer to the "Specifications" on page 2. Review the description at the right of each specification and in the referenced table. Indicate the choice wherever there is a selection to be made.

Actuator and Accessory Information

Specify the desired actuator type and size from the appropriate actuator bulletin. Also refer to the specific actuator and accessory bulletins for additional ordering information.

Attachment 6 - "Seismic Analyses of 26" Butterfly Valve Assemblies for Commonwealth Edison" and "Seismic Analyses of 8", 20", and 24" Butterfly Valve Assemblies for Commonwealth Edison."

ENGINEERING PROJECT NO. CD75-46
CUSTOMER ORDER NO. 181104
CONTINENTAL CONTROL NO. 5A094 and 5A095
REPRESENTATIVE ORDER NO. 14-62496-A and 14-62496-B

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

SEISMIC ANALYSIS

OF

26"

BUTTERFLY VALVE ASSEMBLIES

FOR

COMMONWEALTH EDISON COMPANY

DATE: January 23, 1978: Revision 1, June 6, 1978

PREPARED BY: Dennis M. Hazel
Dennis M. Hazel, Engineering Associate

REVIEWED BY: Carl D Wilson
Carl D. Wilson, Manager, Testing & Analysis

APPROVED BY: Richard Hoober
Richard E. Hoober, Manager of Engineering

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CONTENTS	PAGE

SCOPE OF ANALYSIS

The butterfly valve assemblies analyzed in this report apply to the following item and tag numbers.

CONTINENTAL CONTROL NO. 5A094

APPENDIX	CONTINENTAL ITEM NO.	CUSTOMER TAG NO.	VALVE SIZE	TYPE	ACTUATOR
B	02	1VQ040	26"	9220	Limitorque SMB-000-2-H1BC
	04	1VQ041			
	09	1VQ036			
C	07	1VQ031			
D	01	1VQ026			
	03	1VQ027			
	05	1VQ029			
	06	1VQ030			
	08	1VQ034			
	20	1VQ037			
	21	1VQ038			

CONTINENTAL CONTROL NO. 5A095

APPENDIX	CONTINENTAL ITEM NO.	CUSTOMER TAG NO.	VALVE SIZE	TYPE	ACTUATOR
B	02	2VQ040	26"	9220	Limitorque SMB-000-2-H1BC
C	07	2VQ031			
D	01	2VQ026			
	03	2VQ027			
	04	2VQ041			
	05	2VQ029			
	06	2VQ030			
	08	2VQ034			
	09	2VQ036			
	14	2VQ037			
	15	2VQ038			

CUSTOMER REQUIREMENTS AND SUMMARY OF RESULTS

Based on the calculations shown in this report, we have demonstrated that the primary steady-state stresses, when combined with the inertial loading resulting from the response to a ground acceleration of 5 'g' in both horizontal directions and 6 'g' in the vertical direction, acting simultaneously produce combined stresses which are safely within the yield stresses of the construction materials, both in tension and in shear.

Also, the calculations predict that the extended parts of each valve assembly have a first natural frequency of vibration greater than 33 Hertz.

In summary, this analysis demonstrates mathematically that the equipment supplied by Fisher Controls Company meets the requirements of the Sargent and Lundy Specification J2940 for Commonwealth Edison Company, LaSalle County Station, Units 1 and 2.

APPENDIX A

FISHER Controls MARSHALLTOWN, IOWA	STANDARDS AND SPECIFICATIONS COVER SHEET	NO. ES 117	B
	SEISMIC ANALYSIS OF ROTARY VALVE ASSEMBLIES FOR NUCLEAR SERVICE	BY	
		APVD R.Z.	12-12-77
		PAGE 0.1 OF	
		REV REH	4-4-78

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Specification Revision	Date	Approved by
B	4-7-78	R. Zeigler

FISHER Controls
SHALLTOWN, IOWA

STANDARDS AND SPECIFICATIONS COVER SHEET

SEISMIC ANALYSIS OF ROTARY VALVE ASSEMBLIES FOR NUCLEAR SERVICE

NO. ES 117 3
BY E.R. 12/8/77
APVD R.B. 12-12-77
PAGE 0.2 OF
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TABLE OF CONTENTS

I. PURPOSE:

The purpose of this engineering standard is to establish a standard method of three dimensional seismic analysis of actuator-valve assemblies subjected to triaxial seismic loading.

II. PROCEDURE

II.A The Order Engineer is assigned the responsibility for performing a seismic analysis. The format for the seismic analysis is outlined in this standard.

II.A.1 The seismic analysis will normally consist of a copy of this standard; a cover letter summarizing the results along with a listing of the applicable order numbers, and tag numbers; a set of assembly drawings depicting the constructions analyzed; a sketch of the analytical models; copies of the computer output sheets listing the input and output data along with the acceptable values; and copies of seismic tests of the valve mounted accessories (if required).

II.A.2 Unless the customer's specification states otherwise, the following will be assumed:

(1) The valve is installed in a horizontal pipeline with the valve shaft mounted horizontal (Figure III-1).

(2) The stresses due to seismic loads are to be combined by square root of the sum of the squares (SRSS).

(3) The acceptance criteria contained in Section VIII of this standard are to be used.

(4) The resonant frequency is not required.

II.A.3 An Engineer (Senior Design Engineer, Design Engineer, or Engineering Associate) other than the one performing the original calculations is responsible for reviewing the seismic analysis and signing the cover letter along with the originator of the report.

II.B The Engineering Coordinator is assigned the responsibility for maintaining and distributing the seismic analyses.

II.B.1 The analyses are to be reproduced and the originals filed in a permanent area in a systematic manner.

II.B.2 The analyses are not to be revised. In the event that the valve construction changes after the analysis is performed, a new analysis shall be performed superseding the old analysis.

III. NOMENCLATURE

III.A Equation Symbols

All variables will be defined near the equations or figures in which they appear.

III.B Special Symbols

(1) ● - Joint

(2) ⊙ - Vector out of the plane of the paper.

(3) ⊗ - Vector into the plane of the paper.

(4) (•) - Concentrated mass at a model joint.

(5) [5] - Element number.

(6) ⑥ - Joint number.

(7) ●---● - Element neutral axis.

(8) ▭ - Rigid link.

(9) ↱—↲ - Moment about an axis normal to plane of paper.

(10) ⊙—⊗ - Moment about an axis in the plane of the paper.

(11) [ ] - Matrix

(12) { } - Vector

III.C Coordinate System of the Actuator-Valve Assembly

All rectangular coordinate systems used are right-handed. The primary coordinate system is illustrated for a typical assembly in Figure III-1. The primary coordinate system will be referred to as the system coordinates.

III.D Geometric Variables

The geometric variables listed in Tables III-1 the III-4 are used to provide cross-section and bolt joint input data to the computer program (SEISMIC 4) that performs the seismic analysis. In addition, the system coordinates for each joint of the finite element model, the interconnection between the elements and rigid links, the constraint conditions between elements and boundaries, the lumped inertia properties of the accessories and the seismic and operating loads must be specified.

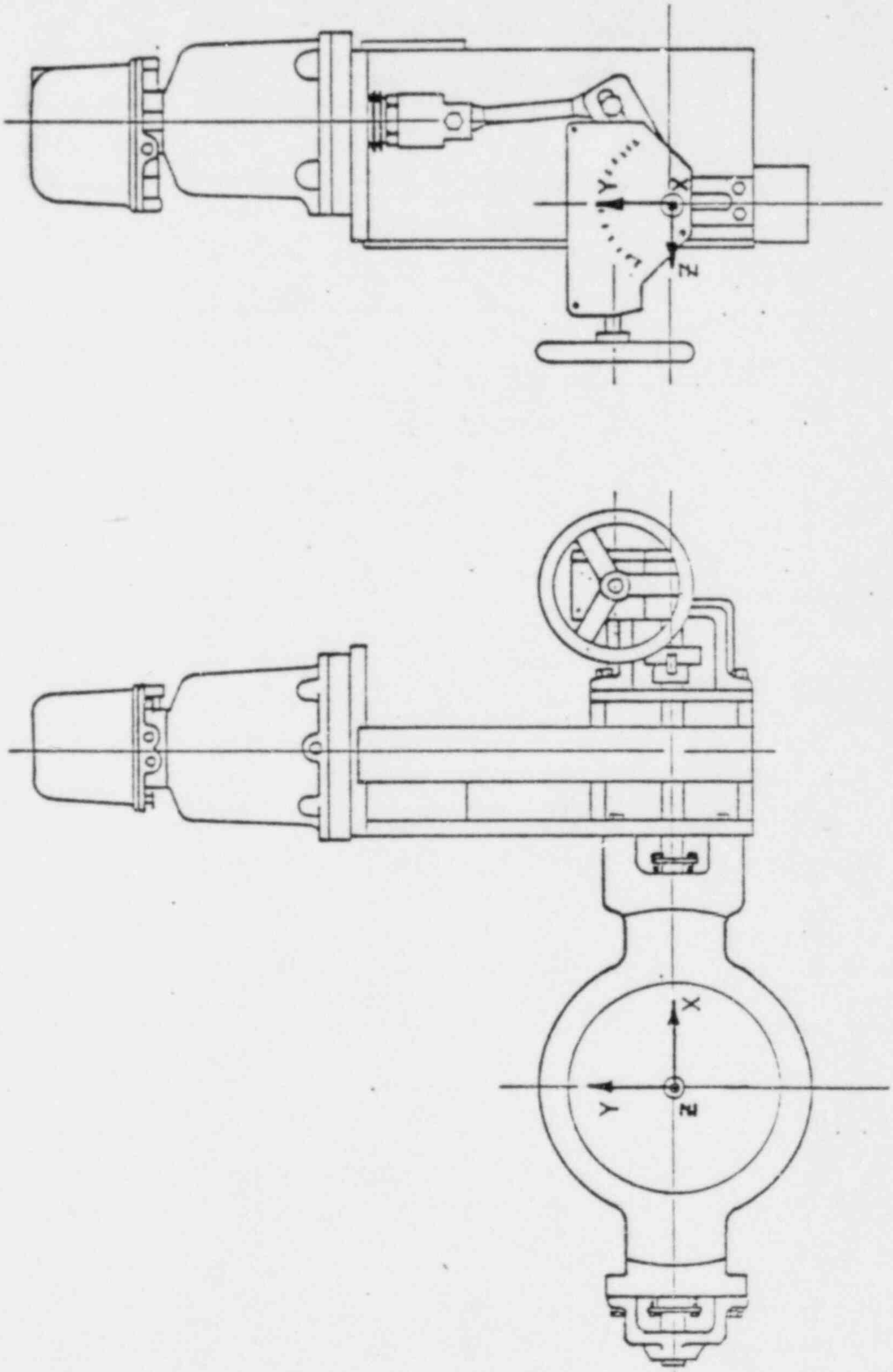
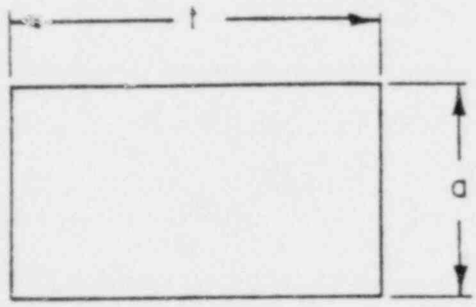


FIGURE III-1

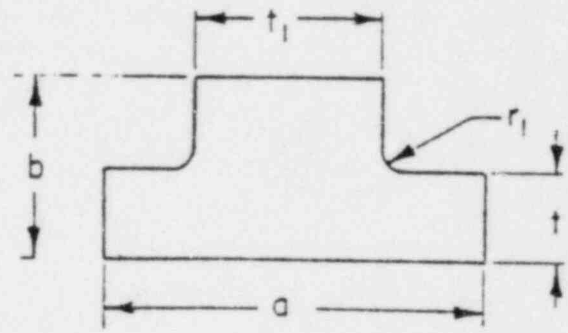
TABLE III-1
STANDARD ELEMENT CROSS-SECTIONAL PARAMETERS

GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
a	III-2	Diameter or Length	inches
b	III-2 except (i)	Length	inches
	III-2 (i)	Angle	degrees
c	III-2 (e)(h)	Length	inches
t, t_1, t_2	III-2	Thickness	inches
r_1, r_2	III-2	Fillet Radius	inches



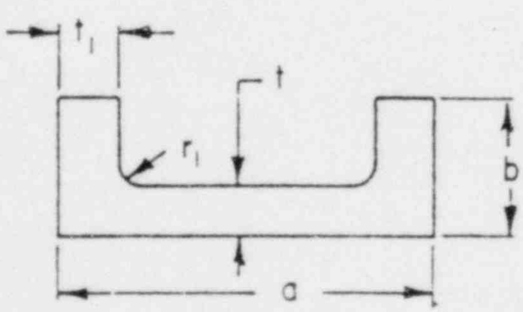
RECTANGLE

Figure III-2(a)



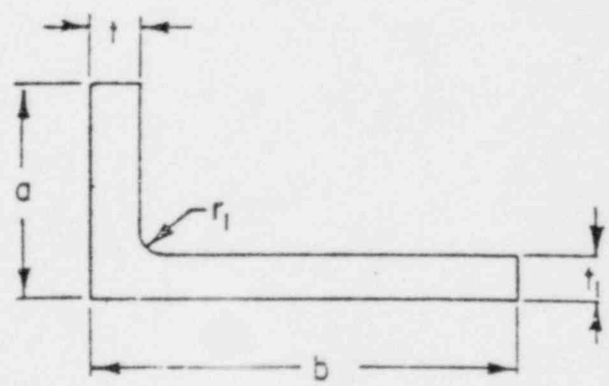
TEE

Figure III-2(b)



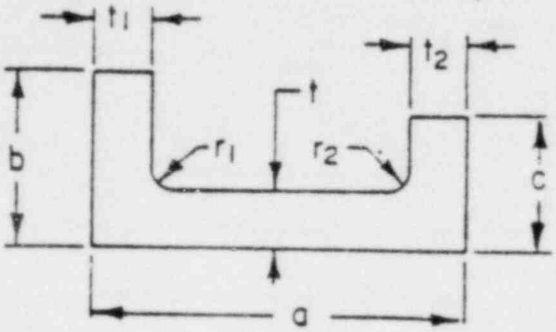
CHANNEL

Figure III-2(c)



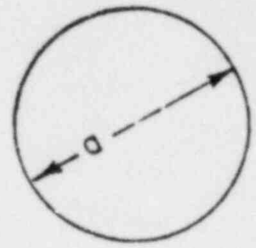
ANGLE

Figure III-2(d)



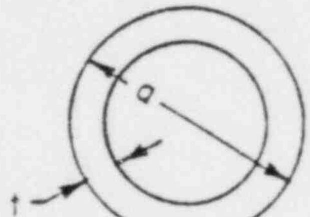
UNEQUAL LEG CHANNEL

Figure III-2(e)



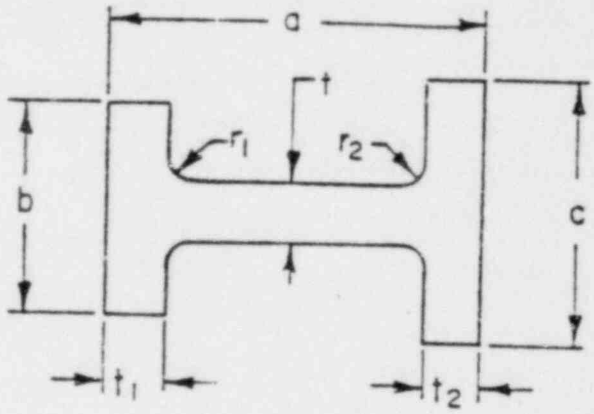
CYLINDER

Figure III-2(f)



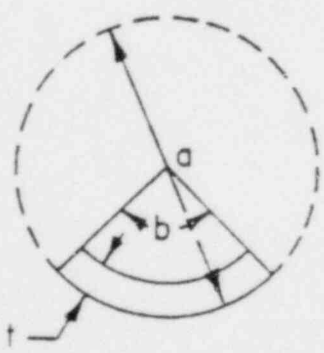
HOLLOW CYLINDER

Figure III-2(g)



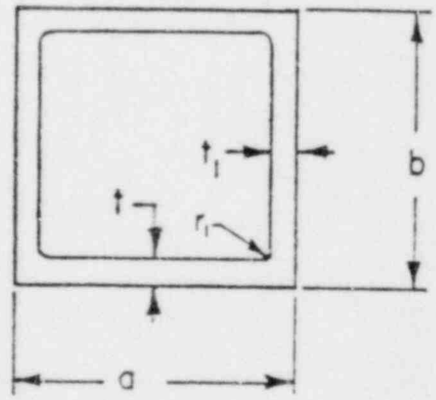
I or H

Figure III-2(h)



HOLLOW CIRCULAR SEGMENT

Figure III-2(i)



BOX

Figure III-2(j)

FIGURES III-2 STANDARD CROSS SECTIONS

TABLE III-2

NONSTANDARD CROSS-SECTIONAL PARAMETERS (STRAIGHT ELEMENT)

GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
A	III-3	Area - $\iint dx_1 dx_3$	$(\text{inch})^2$
I_1	III-3	Bending Moment of Inertia = $\iint (x_3)^2 dx_1 dx_3$	$(\text{inches})^4$
I_2	III-3	Twisting Moment of Inertia.[1]	$(\text{inches})^4$
I_3	III-3	Bending Moment of Inertia = $\iint (x_1)^2 dx_1 dx_3$	$(\text{inches})^4$
κ_1, κ_3	III-3	Shear deflection factors associated with x_1 and x_3 directions, respectively.[2]	
X_5, Z_5	III-3	Distance from centroid to shear center in x_1 and x_3 directions, respectively.[3]	inches
γ	III-3	Angle from reference direction to x_1 principal direction.	degrees
x_1, x_3	III-3	Coordinates in cross section	inches
x_1', x_3'	III-3	Reference directions	
C_1, C_3		$C_1 = x_1$, $C_3 = x_3$ coefficients for bending stress computation	inches
C		Coefficient for torsional shear stress computation at stress point.[4]	inches

1, 2, 3, 4 - Refer to references in Section X.

TABLE III-3

NONSTANDARD CROSS-SECTIONAL PARAMETERS (CURVED ELEMENT)

GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
A	III-4	Area = $\iint dx_1dx_2$	$(\text{inches})^2$
I_1	III-4	Inplane Bending Moment of Inertia = $\iint (x_2)^2\, dx_1dx_3$	$(\text{inches})^4$
I_2	III-4	Second Moment of Area $= \iint (x_1)^2\, dx_1dx_2$	$(\text{inches})^4$
I_3	III-4	Twisting Moment of Inertia.[1]	$(\text{inches})^4$
κ_1, κ_2	III-4	Shear deflection factors associated with x_1 and x_2 directions, respectively.[2]	
Z	III-4	Bending Modulus[5] $= R^2 \iint (x_1/[R-x_1])\, dx_1dx_2$ $= I_2\ (1 + c_1/R^2 + c_2/R^4)$	$(\text{inches})^4$
c_1, c_2	III-4	Coefficients to define bending Modulus Z.[6]	$(\text{inches})^2$, $(\text{inches})^4$
R	III-4	Radius to Centroid of Area	inches
x_1, x_3	III-4	Coordinates in cross section	inches
C_1, C_2		$C_1 = x_1$ and $C_2 = x_3$ coefficients for bending stress computation	inches
C		Coefficient for torsional shear stress computation at stress point.[4]	

1, 2, 4, 5, 6 - Refer to References in Section X.

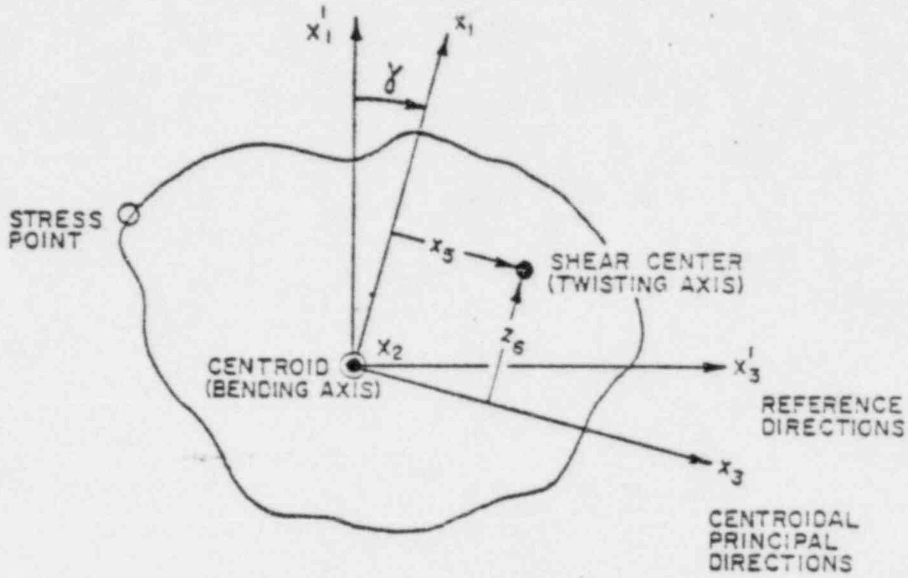


Figure III-3 Cross-Section for Straight Element

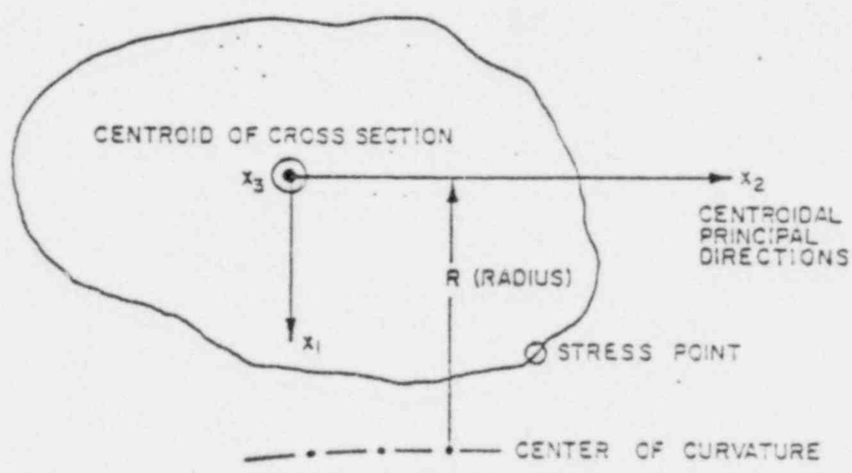
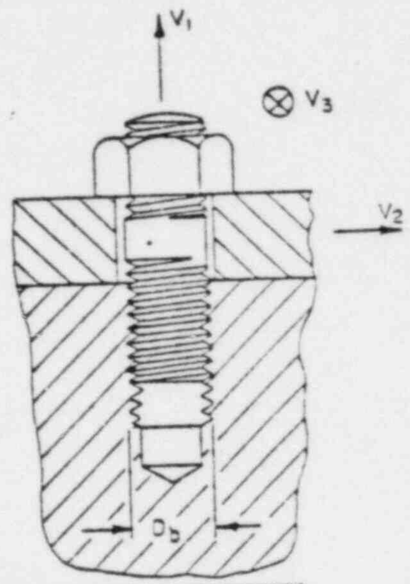


Figure III-4 Cross-Section for Curved Element

TABLE III-4
BOLT JOINT PARAMETERS

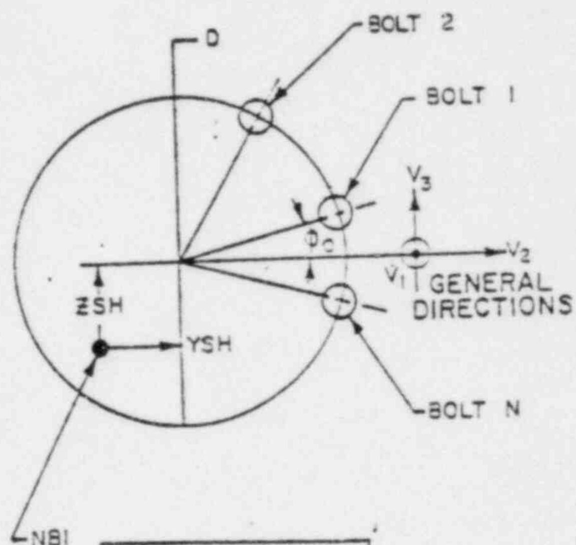
GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPITION	UNITS
NBI	III-5	Joint Number at which bolt reaction is referenced.	
V_1	III-5	Vector parallel to bolt axis	
V_2, V_3	III-5	Vectors (which are orthogonal to V_1) in bolt joint plane.	
D_b	III-5 (a)	Nominal Bolt Diameter	inches
n		Number of threads per inch	$(inch)^{-1}$
A_b		Root Area[7] = $\pi/4 \, (D_b - 1.22687/n)^2$ for all Unified American Threads.	$(inches)^2$
N	III-5 (b)(c) III-5 (d)	Number of bolts, or Number of bolts in line.	
YSH, ZSH	III-5	Coordinates in V_2 and V_3 direction, respectively, from reference joint NBI to center of bolt joint pattern.	inches
D	III-5 (b)	Diameter of Bolt Circle.	inches
ϕ_o	III-5 (b)	Angle from V_2 direction to Bolt No. 1. Only 0 or 180/N permitted.	degrees
S	III-5 (c)(d)	Spacing between bolts on line = S/(N-1)	inches
YO	III-5 (c)	Distance from pivot edge to bolt line for leg pattern, or	inches
	III-5 (d)	Spacing between bolt lines for pad pattern.	inches
YE, ZT, ZB	III-5	Distances from pivot edges to bolts.	inches

[7] - Refer to References in Section X.



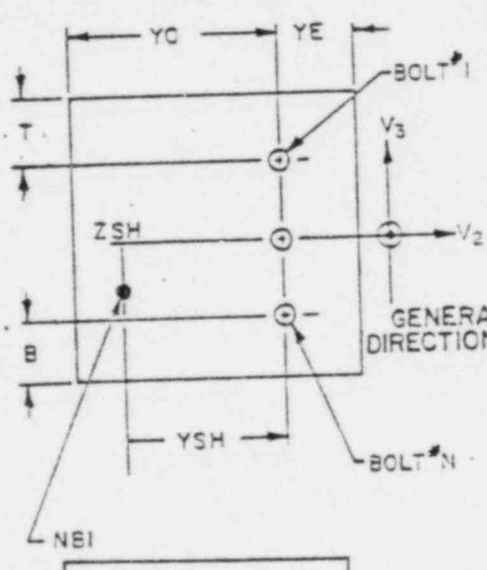
BOLT VECTORS

Figure III-5(a)



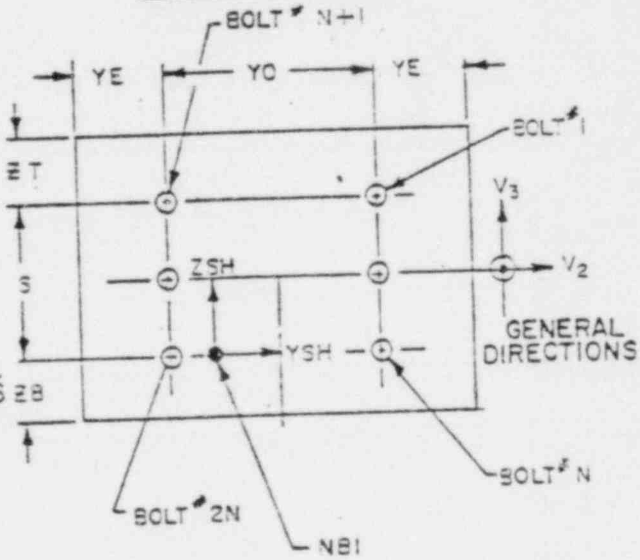
BOLT CIRCLE

Figure III-5(b)



LEG

Figure III-5(c)



PAD

Figure III-5(d)

FIGURES III-5 BOLTED JOINT INPUT PARAMETERS

IV. MODELING OF THE ACTUATOR-VALVE ASSEMBLY

IV.A Mathematical Model Components and Features

The model for the actuator-valve assembly is constructed from two basic types of beam elements each with distributed masses. These elements are referred to as a thick straight beam and a thick curved beam.[5] The ends of these beam elements are referred to as joints in the model. The joints can have as many as six degrees of freedom or as few as zero degrees of freedom (complete fixity). There are five types of joints: an equilibrium joint with independent displacements and rotations; an auxiliary joint with dependent displacements and rotations; a boundary joint with at least one degree of fixity; a spring boundary joint with at least one degree of elastic constraint; and a reference joint (which may be one of the above) at which bolting forces and moments are computed or the center of a curved element is defined.[8]

IV.A.1 Thick Straight Beam

The Element Coordinate System in which forces and moments are computed for the straight beam element is illustrated in Figure IV-1. The 2-axis lies along the centroidal axis of the beam from the joint at end two to end one. Positive directions of rotation about the 1, 2, and 3-axis obey the right-hand rule. The coordinates in the cross-section, x_1, x_3, are in the direction of the 1 and 3 axes (Figure III-3). The twisting axis[3] of the beam is parallel to but need not coincide with the centroidal axis. Shear deflection[2] is considered in the derivation of the stiffness and mass matrices.

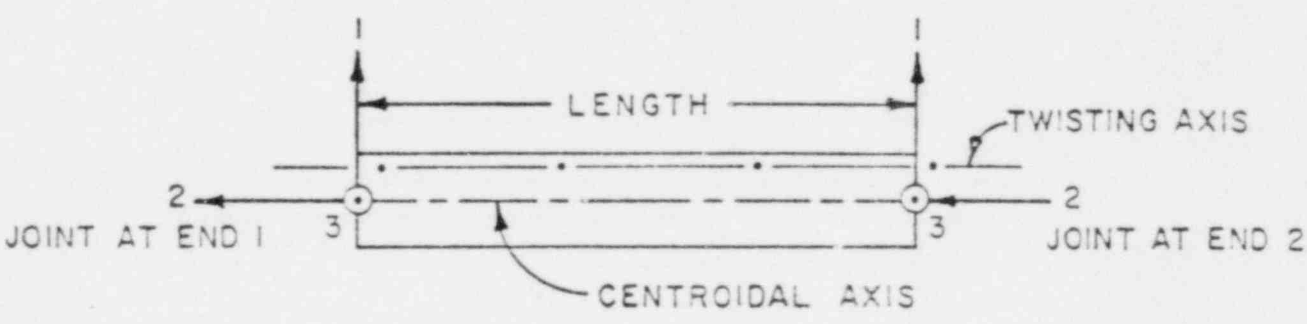


FIGURE IV-1

ELEMENT COORDINATE SYSTEM FOR A THICK STRAIGHT BEAM

2, 3, 5, 8 - Refer to References in Section X.

IV.A.2 Thick Curved Beam

The element coordinate system in which forces and moments are computed for each end of the curved beam element is illustrated in Figure IV-2. The positive direction of the 1 axis always is towards the center of curvature. The 3-axis is tangent to the centroidal axis. The radius of curvature is the distance from the center of curvature to the centroidal axis of the curved beam element. Positive directions of rotation about the 1, 2, and 3-axis obey the right-hand rule. The coordinates in the cross-section, x_1, x_2 are in the direction of the 1 and 2 axes (Figure III-4). The shift of bending axis from centroidal axis[5] and shear deflection[2] is considered in the derivation of the stiffness and mass matrices.

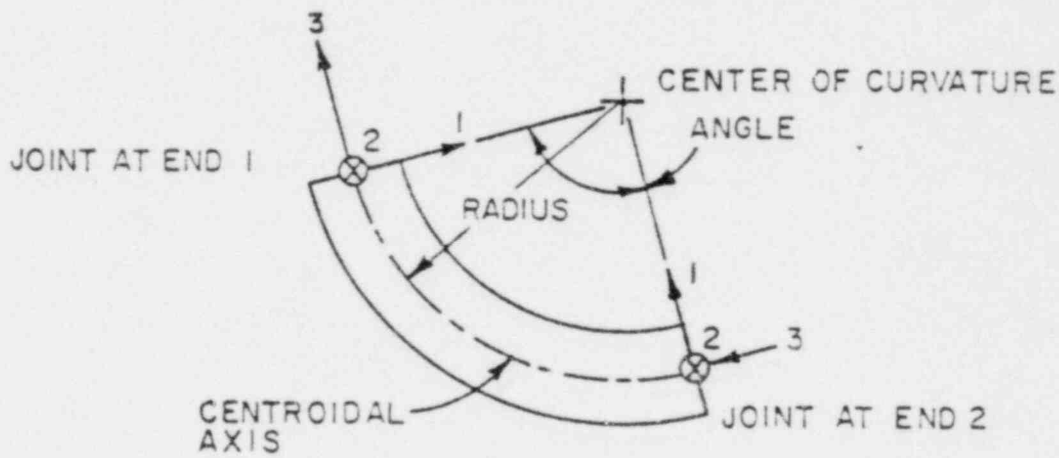


FIGURE IV-2

ELEMENT COORDINATE SYSTEM FOR A THICK CURVED BEAM

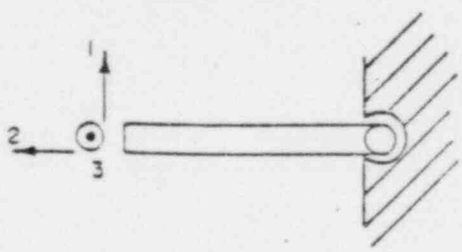
2, 5 - Refer to References in Section X.

IV.A.3 Element End Releases[9]

There are normally six degrees of freedom considered (three displacements and three rotations) at each joint. Any of these degrees of freedom may be specified as constrained or unconstrained, or as having an elastic connection to the adjacent elements. Figures IV-3 thru IV-6 describe typical release mechanisms. In Figure IV-3 end two of a straight element is released for degree of freedom six (rotation about 3-axis) representing a pin joint. In Figure IV-4 degree of freedom two (displacement along 2-axis) is released representing a slide connection. In Figure IV-5, a ball joint is modeled by releasing all rotations (degrees of freedom 4, 5, and 6). Figure IV-6 has an elastic connection to adjacent elements at end two in the axial and transverse directions.

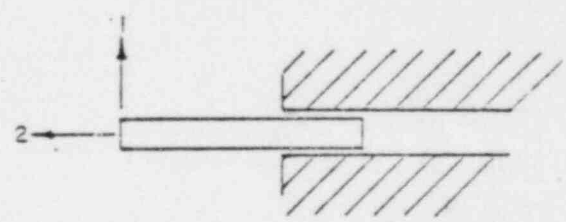
PIN CONNECTION

Figure IV-3



SLIDE CONNECTION

Figure IV-4



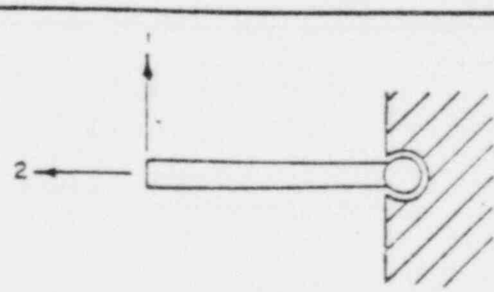


Figure IV-5

BALL CONNECTION

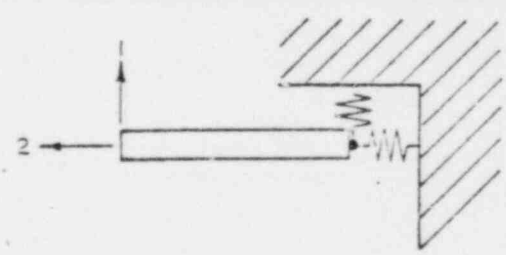


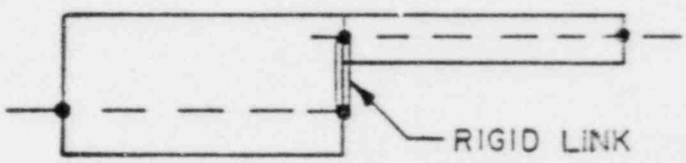
Figure IV-6

BI-AXIAL SPRING CONNECTION

9 - Refer to References in Section X.

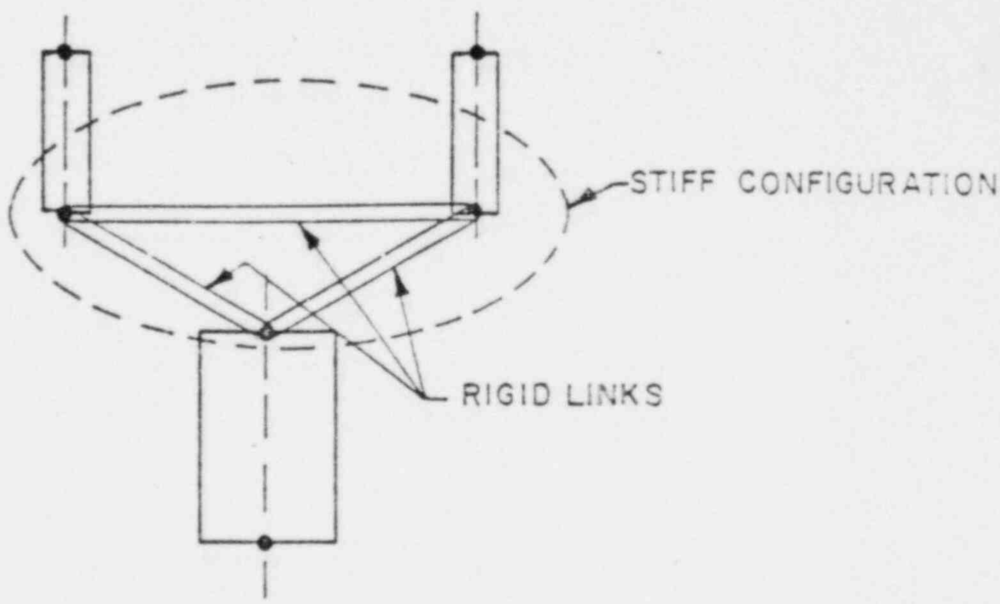
IV.A.4 Rigid Link[10]

A rigid link between any auxiliary joint and any equilibrium joint can be modeled exactly. A kinematic transformation of the element's stiffness and mass matrices is used for this purpose. Rigid links ensure that the rotation of all joints so connected are the same and that the displacements of all joints are related through the vector distances from each other. The rigid link mechanism may be used to accurately model elements joined off their centroidal axes, Figure IV-7, or extremely inelastic members of a physical structure as shown in Figure IV-8. In the latter example, any two of the three indicated rigid links may be specified.



ELEMENTS WITH CENTROIDAL AXES NOT ALIGNED

Figure IV-7



ELEMENTS JOINED THROUGH INELASTIC MEMBER
FIGURE IV-8

10 - Refer to References in Section X.

IV.A.5 Lumped Inertia Properties

Each elastic element in the mathematical model has an associated consistent mass matrix which accounts for a uniform distribution of mass.[5] Inertia other than this may be defined for accessories, rigid portions that were not modeled elastically (e.g., Figure IV-8) and shaft-disc assemblies. The inertia properties may be specified as lumped masses acting at any joint or at any coordinate from any joint. The lumped mass may act in all or only in some of the system coordinate directions. For example, a mass attached to a shaft supported by a journal and thrust bearing may be specified to act in the transverse directions of the journal and in the axial direction of the thrust bearing. Centroidal principal moments of inertia aligned to the system coordinates may be specified at any joint.

IV.A.6 Spring Boundaries and Constraints[8]

Boundary joints of the model may be attached to the external boundary with either complete or elastic fixity in any of the six system degrees of freedom (three translational and three rotational). Thus, a hanger may be modeled by means of uniaxial spring, and the piping or body (assumed rigid) may be modeled by specifying complete fixity.

IV.A.7 Cross section Properties[11]

The built-in standard cross sections in SEISMIC 4 as depicted in Figures III-2 may be used to define the properties of any straight or curved element. For special constructions, the Order Engineer may input nonstandard properties as described in Table III-1 and Figures III-3 and Figures III-4 to fit the modeling need.

V. MATHEMATICAL ANALYSIS

The SEISMIC 4 computer program employs the modeling features as described in Section IV.A to yield response to seismic excitation and operational loads and to compute system resonant frequency.

V.A Synthesis of Stiffness, Mass and Load Matrices[12]

The exact stiffness and consistent mass matrices are derived for each element (Section IV.A.1 and IV.A.2). A three column load matrix is

---

5, 8, 11, 12 - Refer to References in Section X.

determined from the mass matrix for unit gravitational loads in each of the system directions. Any required release (Section IV.A.3) or kinematic transformation (Section IV.A.4) is performed. The resulting matrices are then transformed from their element to the system coordinates and accumulated forming the system stiffness and mass matrices and three columns of the system load matrix. Lumped inertia properties (Section IV.A.5) are added to the system mass matrix and appropriate forces are added to the three unit gravitational load columns. Operational loads other than deadweight, consisting of concentrated forces and moments at any joint, comprise a fourth column of the system load matrix. Prescribed boundary conditions (Section IV.A.6) are then imposed on the system matrices, yielding:

[K] System Stiffness Matrix, symmetric (usually banded),

[M] System Mass Matrix, symmetric (usually banded),

[F] System Load Matrix, composed of three unit gravitational load columns and one operational load column.

V.B Gravitational and Operational Load Solution

The deformation due to the static unit gravitational and operational loads derives from the solution of the matrix equation:

$$[K]\,[X] = [F] \qquad \text{(V.B-1)}$$

where [K] and [F] were defined in Section V.A, and [X] is a four column deformation matrix; the first three are responses to the unit graviational loads in each of the system coordinates and the fourth the response to the operational loading condition not including deadweight. Each column of [X] consists of deflections in the system X, Y, Z directions, rotations about the system X, Y, Z directions for each equilibrium joint. The corresponding deformations for auxiliary joints are computed by employment of the kinematic transformations (Section IV.A.4).

V.C Determination of the Fundamental Resonant Frequency

A complete seismic analysis of any structural system includes the structural analysis for the dynamic loads caused by the vibratory earthquake motion of its supports. There are two general methods of analysis for dynamic loading depending upon the characteristics of the system. The equivalent static analysis, which is employed here, is applicable and conservative for actuator systems that can be shown to have no natural frequencies less than a specified amount. Thus, the lowest or fundamental frequency must be computed.

The fundamental resonant frequency is found by determining the smallest eigenvalue, λ, and corresponding eigenvector {u} from the undamped free vibration equation:[13]

$$([K] - \lambda [M]) \{u\} = \{0\} \qquad \text{(V.C-1)}$$

where [K] and [M] are the system stiffness and mass matrices (Section V.A), {u} is the eigenvector corresponding to the smallest eigenvalue λ, and is normalized in the SEISMIC 4 computer program so that the largest displacement or rotation at any equilibrium joint is plus or minus one, {0} is a null vector.

The fundamental resonant frequency, f, is then determined by:

$$f = \sqrt{\lambda}/(2\pi) \qquad \text{(V.C-2)}$$

the algorithm[14] used to determine values for λ is based on an iteration procedure on equation V.C-1 using as starting values the unit gravitational deformations (Section V.B).

V.D Calculation of Element Forces and Moments[15]

The force and moment response of the ends of the elements due to the four column load matrix [F] (Section V.A) are determined from:

$$[p] = [k]\,[S] - [m]\,[g] \qquad \text{(V.D-1)}$$

where [p] is a four column matrix consisting of the element forces and moments at each end (thus, twelve rows),

[k] is the element stiffness matrix,

[m] is the element mass matrix, both described in Section IV.A.1 and Section IV.A.2,

[g] is a four column matrix; the first three consist of unit gravitational loads, the fourth a null column, and

[S] is a four column matrix consisting of the deformation response to unit gravitational and operational loads extracted from the system solution matrix [X] (Section V.B). The extraction of [S] from [X] involves transformation from system to element end coordinates (Sections IV.A.1 and IV.A.2) and accounting for any kinematic transformations (IV.A.4) or releases (IV.A.3).

13, 14, 15 - Refer to References in Section X.

V.E Calculation of Junction Reactions

The resultant reactions [P] due to the four basic loading conditions (Section V.B) is determined at all boundary joints and at any specified cut in the model. The element forces and moments [p] (Section V.D) for all elements joining at a boundary or on one side of the cut are employed to determine the junction reaction. The rigid link transformation (Section IV.A.4) is performed on [p] prior to transformation from the element coordinates (A.1 and A.2) to the system coordinate (Section III.C) and adding to [P].

VI. DETERMINATION OF SEISMIC AND OPERATIONAL FORCES AND MOMENTS

The resultant element end [p] (Section V.D) and junction [P] (Section V.E) reactions (forces and moments) for each of the unit loading conditions may be superimposed, because of the linear nature of elastic, small deformation systems,[12] to yield the reactions for any magnitude and direction of seismic excitation and any actuator orientation with respect to gravitational and seismic acceleration.

In this seismic analysis computer program, the capability is provided for the specification of any vertical gravitational direction with an associated G-level and two different G-levels for each of the two mutually perpendicular horizontal directions.

The Order Engineer may define the vertical gravitational direction by specifying to the SEISMIC 4 computer program a clue; either X-UP, Y-UP, Z-UP, or SKEW (along with the vertically downward vector, {V}). Another clue may be used to define one horizontal direction, {H1}, (the other horizontal direction {H2} is mutually perpendicular).

The corresponding seismic directions and their vector components with respect to the system coordinates for typical specifications are shown in Figure VI-1.

The resultant reactions on the element ends or junctions for the operational load is a superposition of the fourth column of [p] or [P] with some linear combination of the first three rows corresponding to the acceleration of gravity in the {V} direction, to account for deadweight.

12 - Refer to References to Section X.

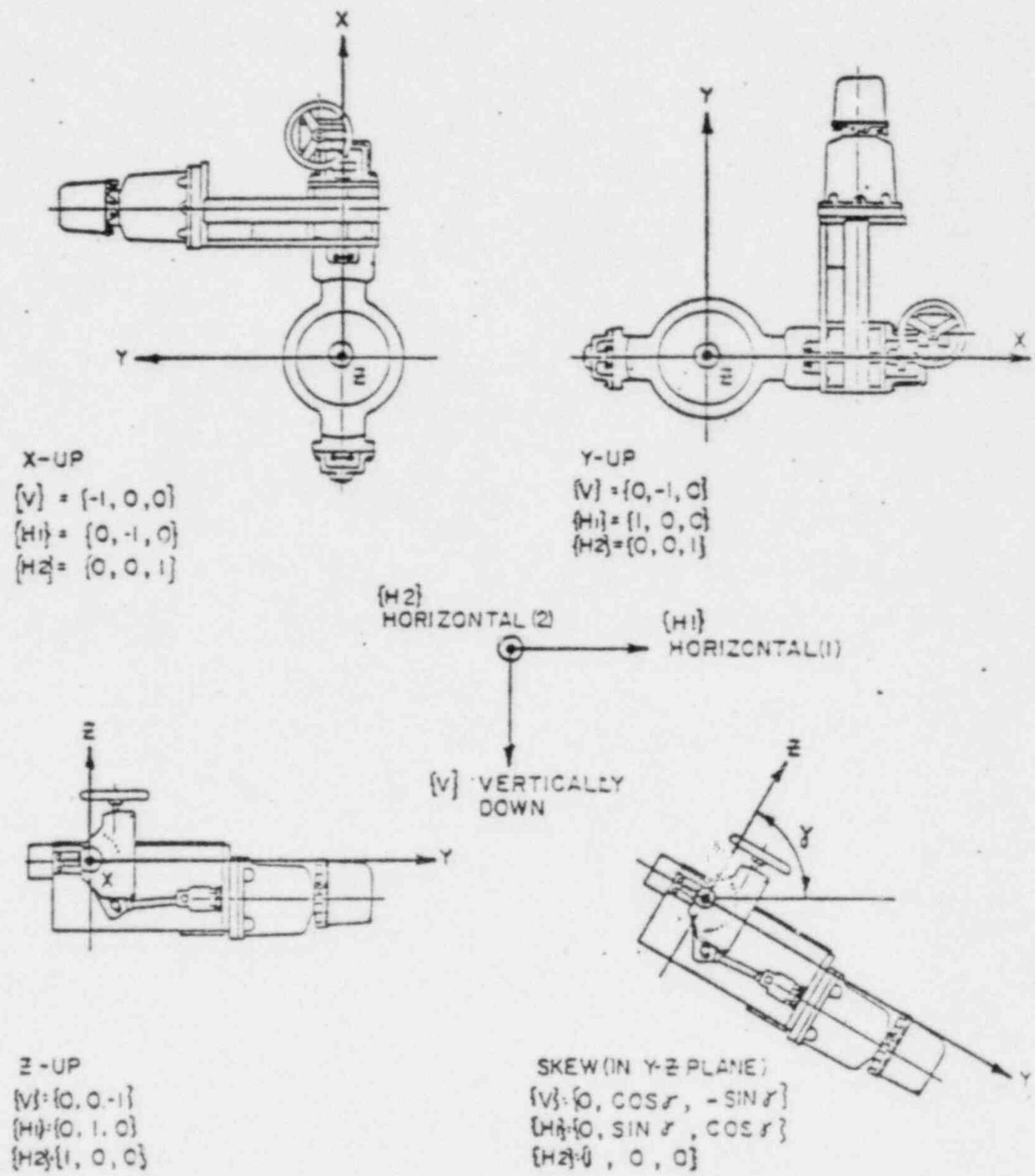


FIGURE VI-1 Typical Seismic Directions

VII. DETERMINATION OF STRESSES

The stress analysis of the actuator-valve assembly is carried out for the locations specified by the engineer. All straight and curved beam element ends may be selected. All bolted joints connecting one section to another or to the body may be selected. The portion of the structure on either side of a bolted joint is represented by a plane designation. The plane being defined for the ends of the elements that load the joint (refer to Figure VII-1 for typical locations where stresses are computed). The numerical designations refer to subsections in Section VII that follow. A detailed explanation of the methods for determining the stress components is presented in each particular section.

In general, the stresses at these locations are arrived at in the following manner. The element end and junction reactions for the seismic and operational loads were calculated as described in Section VI.

Normal and shear stress components for each of these four independent loading conditions are computed in accordance with the procedures in the following subsections. The seismic normal and shear stress components depending upon specifications are combined in any of three ways: direct sum, SRSS[16] (Square Root of the Sum of the Squares), or the sum of the absolute values. Each combined seismic normal and shear stress component is either added to, or subtracted from, the operational stress component, whichever yields the combined component with the larger magnitude. Either the maximum absolute principal stress, P_{max}, or the maximum stress intensity, S_{max},[17] is then computed (Equations VII-1 through 5) in accordance to specifications.

$$\tau_{max} = \sqrt{(\sigma/2)^2 + (\tau)^2} \qquad \text{(VII-1)}$$

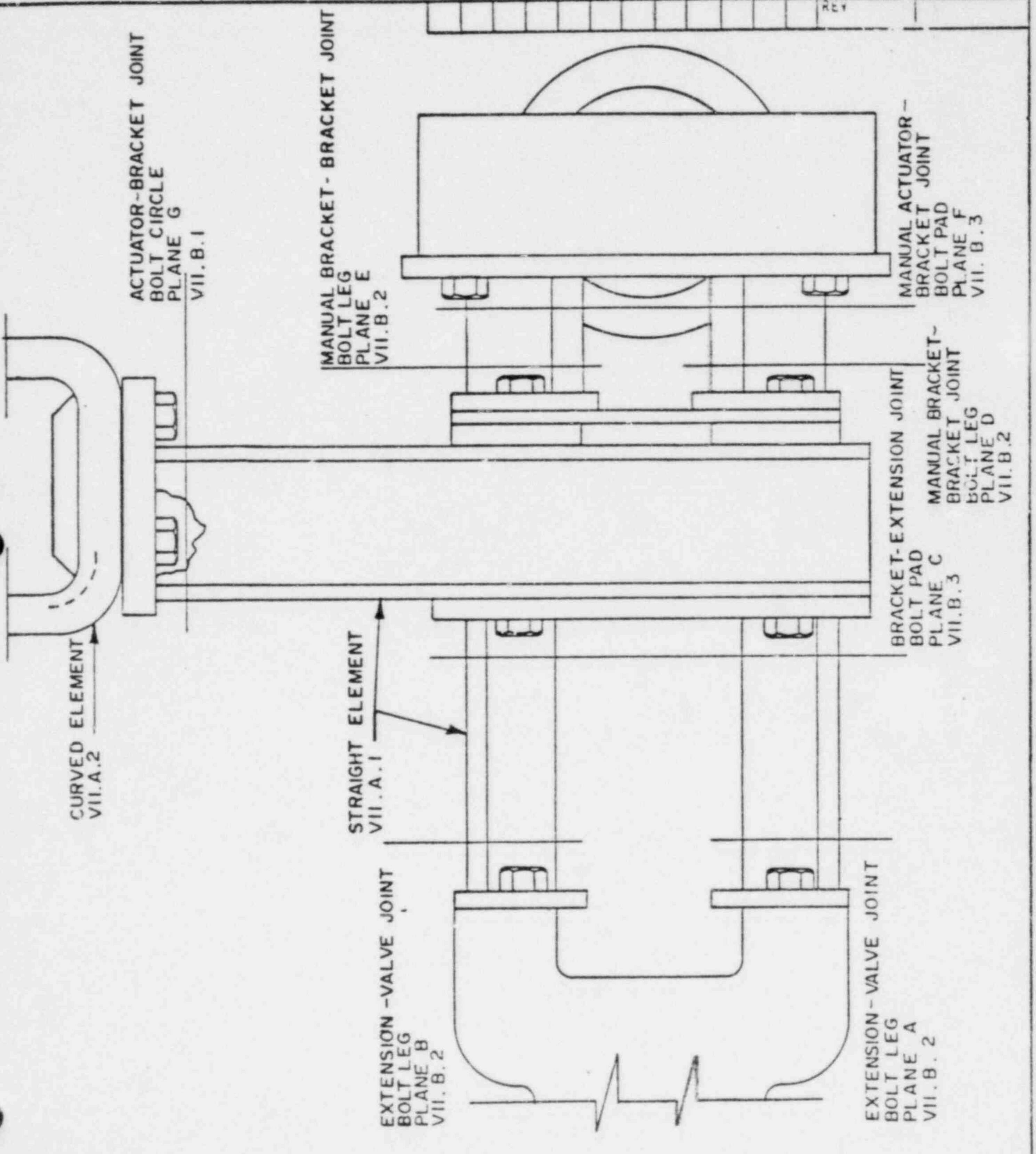
$$\sigma_{P_{max}} = (\sigma/2) + \tau_{max} \qquad \text{(VII-2)}$$

$$\sigma_{P_{min}} = (\sigma/2) - \tau_{max} \qquad \text{(VII-3)}$$

$$S_{max} = \text{largest of } 2\,\tau_{max}, \text{ or } (\sigma_{P_{max}} - \sigma_{P_{min}}) \qquad \text{(VII-4)}$$

$$P_{max} = \text{largest of } \sigma_{P_{max}}, \text{ or } |\sigma_{P_{min}}| \qquad \text{(VII-5)}$$

16, 17 - Refer to References in Section X.



SECTIONS WHERE STRESSES ARE COMPUTED
FIGURE VII-1

where σ is the surface fiber stress at a point on beam or the average axial stress in a bolt,

τ is a shear stress at a point on a beam or the average shear stress in a bolt,

τ_{max} is the maximum shear stress,

$\sigma_{P_{max}}$ is the maximum principal stress,

$\sigma_{P_{min}}$ is the minimum principal stress, with the third principal stress assumed zero (beam surface point or average through bolt).

P_{max} or S_{max}, designated the "total" stress is compared against the appropriate stress limit in Section VIII of this standard.

VII.A Beam Stress Computation

The end force and moment reactions for each of the four independent load conditions comprise each column of [p], derived in Section V.D and transformed in Section VI.

$$\begin{Bmatrix} F_1^{(1)} \\ F_2^{(1)} \\ F_3^{(1)} \\ M_1^{(1)} \\ M_2^{(1)} \\ M_3^{(1)} \\ F_1^{(2)} \\ F_2^{(2)} \\ F_3^{(2)} \\ M_1^{(2)} \\ M_2^{(2)} \\ M_3^{(2)} \end{Bmatrix} = \{P\} \qquad \text{(VII.A-1)}$$

where $F_i^{(j)}$ i = 1, 2, 3 and j = 1, 2 are the reaction forces in the element, i direction for end j of the beam, and

$M_i^{(j)}$ are the reaction moments.

{p} represents any column of [P].

In the following subsections, the beam stress-reaction relations are presented with a sketch of the reaction sign conventions (Figures VII-2 and VII-4).

At both ends of the beam, at several selected points on the cross-section, a surface fiber stress, σ, and a shear stress, τ, is computed. σ and τ are then introduced into equations VII-1 to 5 for the computation of the "total" stress at each point.

VII.A.1 Straight Beam Stress

The end reactions as described in Section VII.A are aligned with the element coordinates as shown in Figure VII-2.

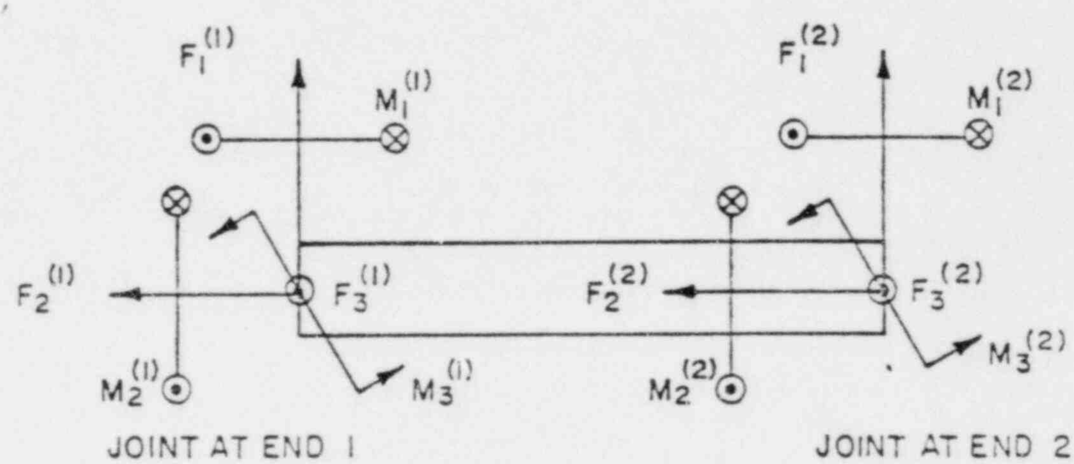


Figure VII-2

The stress at any point on the cross section, at either end, may be determined from the forces, F_1, F_2, F_3, and the moments, M_1, M_2, M_3, (superscript (1) or (2) denoting end, will be omitted in the following text), the cross-sectional properties for the end, A, I_1, I_2, I_3, the bending stress coefficients, C_1, C_3, and the torsional shear stress coefficients, C, as described in Table III-2 and Figure III-3.

Thus, the fiber stress[15] is

$$\sigma = \pm (F_2/A - C_3M_1/I_1 + C_1M_3/I_3) \qquad \text{(VII.A.1-1)}$$

[15] - Refer to References in Section X.

The shear stress may be written, conservatively, assuming that the torsional shear[1] acts in the same direction as the transverse component of shear and the transverse component, which is zero on the outer surfaces, is taken as an average across the section:

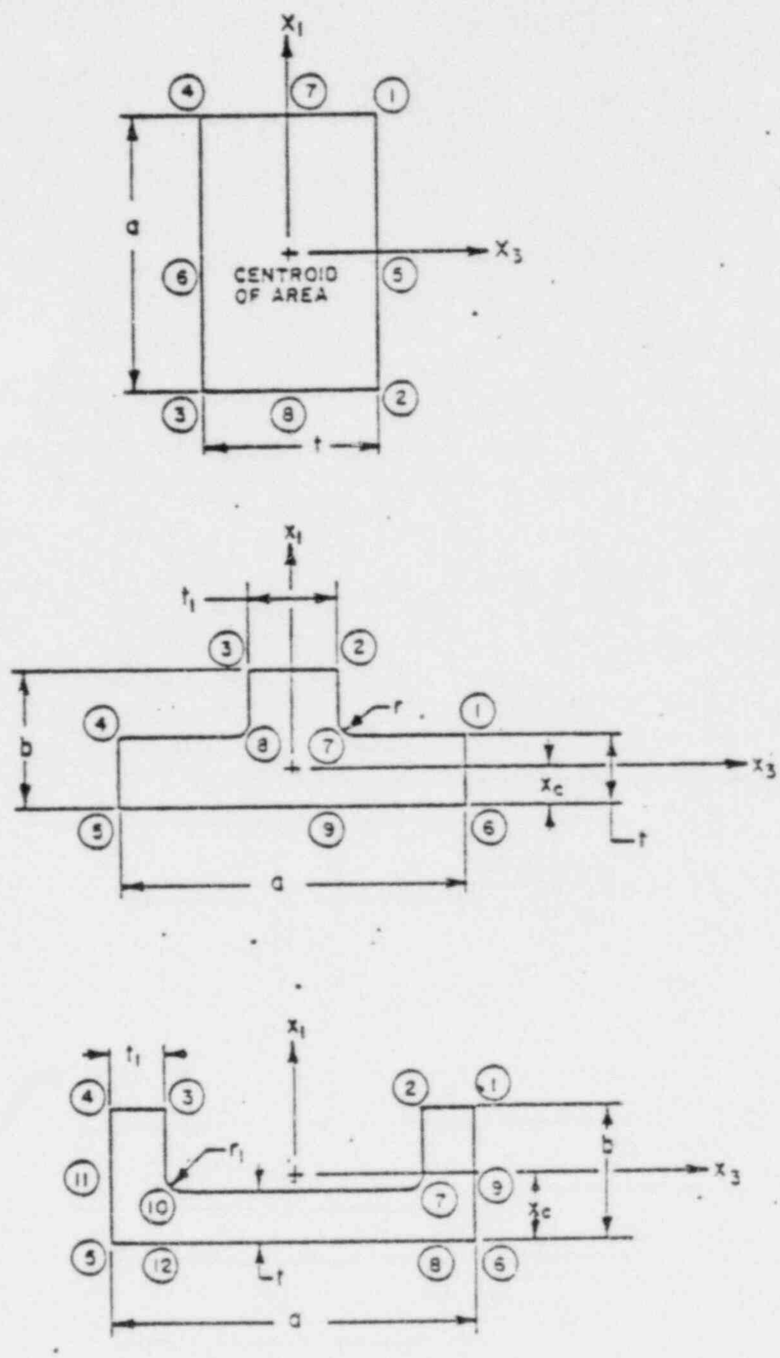
$$\tau = \pm \left[\left| (CM_2/I_2) \right| + \sqrt{(F_1)^2 + (F_3)^2}/A \right] \qquad \text{(VII.A.1-2)}$$

In the above equations, the + sign is employed for end one of the element and the - sign for end 2.

For standard sections (Figures III-2) A, I_1, I_2, I_3, and sets of C_1, C_3, and C are determined in the SEISMIC 4 computer program from the input parameters described in Table III-1.[11] The coefficients for the stress points are chosen at extreme fibers and near points at which the largest inscribed circle touches the boundary. For the standard sections, points, indicated by encircled numbers, are shown on Figures VII-3. Note that $C_1 = x_1$ and $C_3 = x_3$.

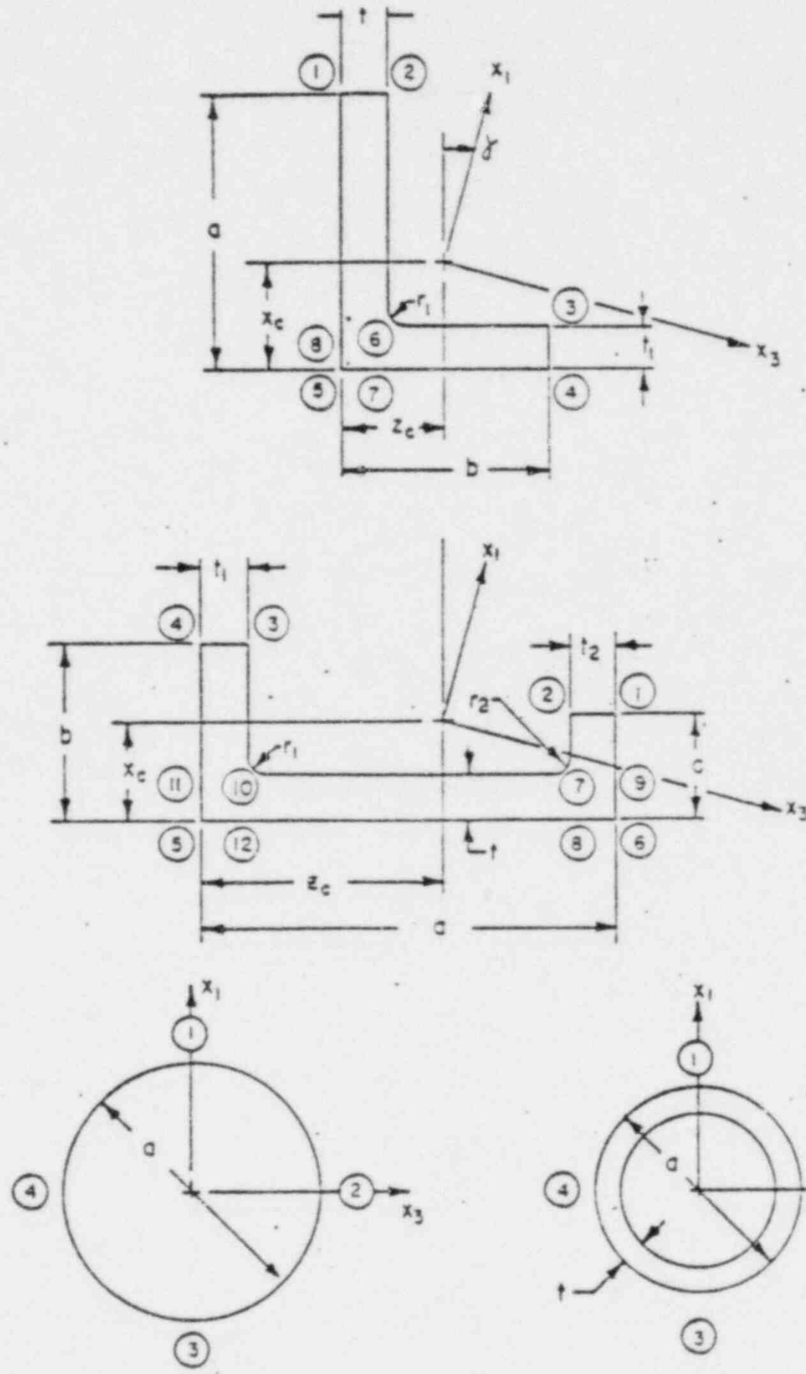
For nonstandard cross-sections C, C_1 and C_3 are entered directly along with the other section properties (Table III-2).

1, 11 - Refer to References in Section X.



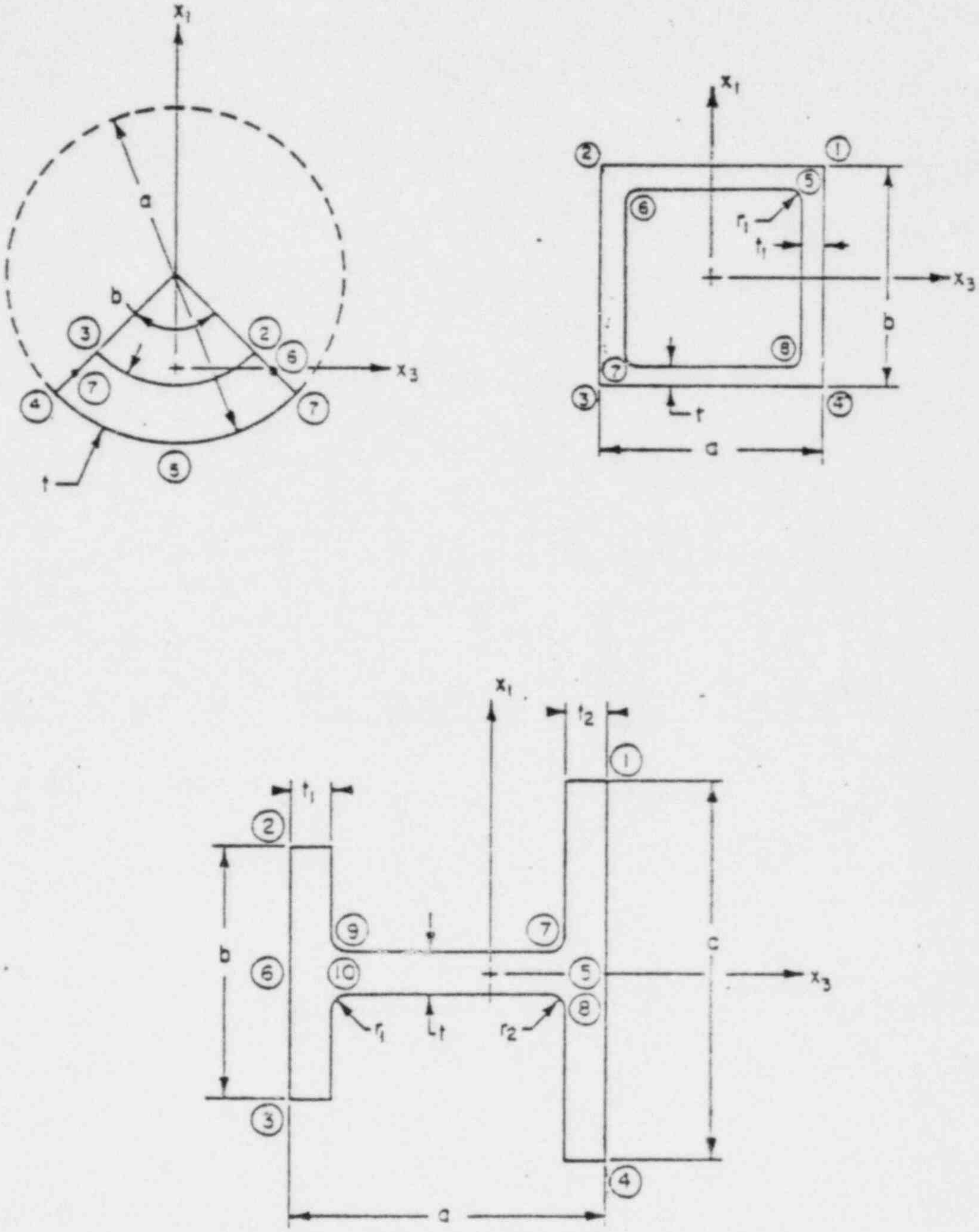
STRESS LOCATIONS STANDARD CROSS SECTIONS

FIGURES VII-3



STRESS LOCATIONS STANDARD CROSS SECTIONS

FIGURES VII-3



STRESS LOCATIONS STANDARD CROSS SECTIONS

FIGURES VII-3

VII.A.2 Curved Beam Stress

The end reactions as described in Section VII.A are aligned with the element end coordinates as shown in Figure VII-4.

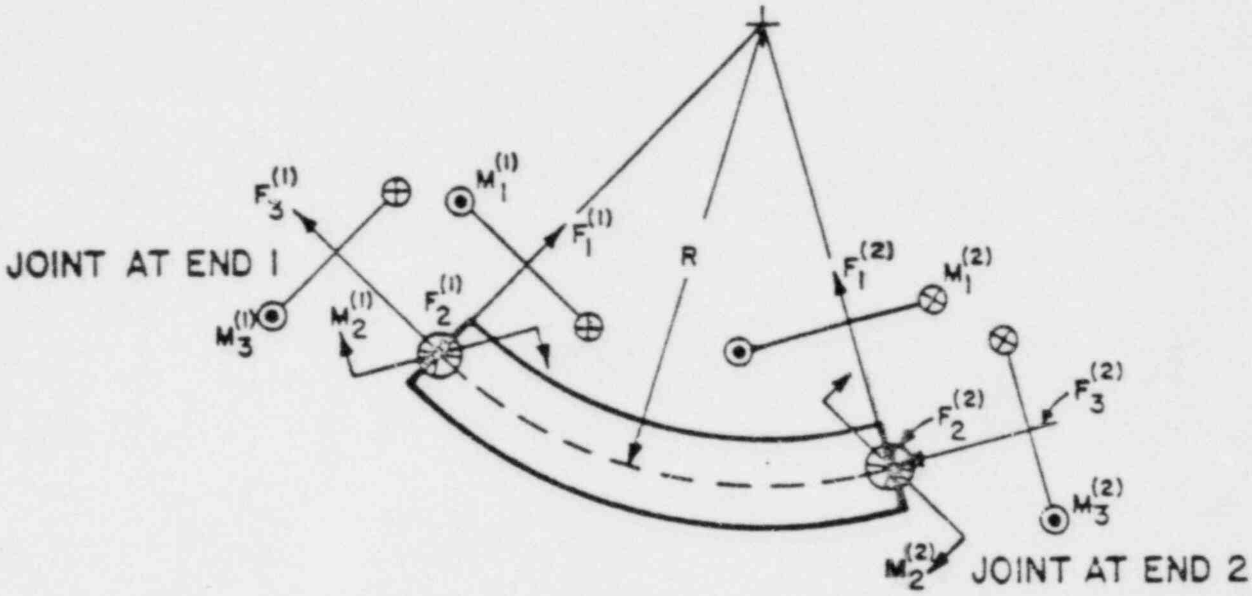


Figure VII-4

The stress at any point on the cross-section, at either end, may be determined from the forces, F_1, F_2, F_3, and the moments, M_1, M_2, M_3, the cross-section properties for the end, A, Z, I_1 and I_3, the bending stress coefficients, C_1, C_2, the torsional shear stress coefficient, C, and the radius to the centroid, R, as described in Table III-3 and Figure III-4.

The fiber stress[5] is:

$$\sigma = \pm \{(F_3 + M_2/R)/A - C_1RM_2/[Z(R - C_1)] + C_2M_1/I_1\} \qquad \text{(VII.A.2-1)}$$

The shear stress may be written, using the same conservative assumptions as in the development of equation VII.A.1-2.

$$\tau = \pm [\,|(CM_3/I_3)| + \sqrt{(F_1)^2 + (F_2)^2}/A] \qquad \text{(VII.A.2-2)}$$

5 - Refer to References in Section X.

where the + sign is employed for end one of the element and the - sign for end 2.

For standard sections (Figures III-2), A, Z, I_1, I_3 and sets of C_1, C_2 and C are determined in the SEISMIC 4 computer program in the same manner as for the straight standard cross-sections,[11] Figures VII-3.

Because of the difference in coordinate systems, (x_1, x_2, x_3) for a curved element corresponds to $(x_1, -x_3, -x_2)$ for a straight element (compare Figures IV-1 and IV-2). Therefore, for a curved element $C_1 = x_1$ and $C_2 = x_3$ in Figures VII-3. For nonstandard cross sections, C, C_1 and C_2 are entered directly with the other section properties (Table III-3).

VII.B Bolted Joint Stresses[18]

The junction reactions, [P], described in Section V.E and transformed to yield three independent seismic loads and the operational load including deadweight as described in Section VI, are the basis for computation of bolt joint loads and stresses. Each of the four independent columns of [P], designated {P}, has force and moment components in the system coordinate directions X, Y and Z.

$$\{P\} = \begin{Bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{Bmatrix} \qquad \text{(VII.B-1)}$$

{P} is transformed to the bolt configuration coordinate system defined by specified vectors, $\{V_1\}$, $\{V_2\}$ and $\{V_3\}$, and then shifted to the reference center of the configuration by the specified coordinates YSH and ZSH, described in Table III.D-4 and Figures III.D-4.

$\{V_1\}$ is parallel to the bolt axes in the direction toward the elements used to define the junction reactions (Section V.E).

The transformed load in the bolt configuration coordinate system is designated {B}:

11, 18 - Refer to References in Section X.

$$\{B\} = \begin{Bmatrix} f_1 \\ f_2 \\ f_3 \\ m_1 \\ m_2 \\ m_3 \end{Bmatrix} \qquad \text{(VII.B-2)}$$

where f_i ($i = 1, 2, 3$) are the forces acting at the reference center of the configuration in the V_i direction, and m_i are the moments.

f_2, f_3, m_1 will be used to compute two average shear stress components τ_2 and τ_3, and f_1, m_2, m_3 will be used to compute average axial stress, σ.

τ_2 and τ_3 are shear stress components in the V_2 and V_3 directions. These shear components for each independent seismic load and the operational load will be combined in the specified manner (Section VII). After combination, a single shear stress, τ, will be computed, which, along with σ, will be introduced into equations VII-1 to 5 for computation of "total" stress in each bolt:

$$\tau = \sqrt{(\tau_2)^2 + (\tau_3)^2} \qquad \text{(VII.B-3)}$$

Implicit in the computation of τ_2 and τ_3 is the conservative assumption that the shearing forces are resisted by the bolts and not by friction between the flanges.

In the following Sections VII.B.1 and VII.B.2, the stresses σ and τ for each bolt in the configuration will be computed so that there is equilibrium with the load {B} and flange reactions.

VII.B.1 Bolt Circle

The forces and moments on the bolt circle configuration consisting of N bolts may be depicted as in Figure VII-5.

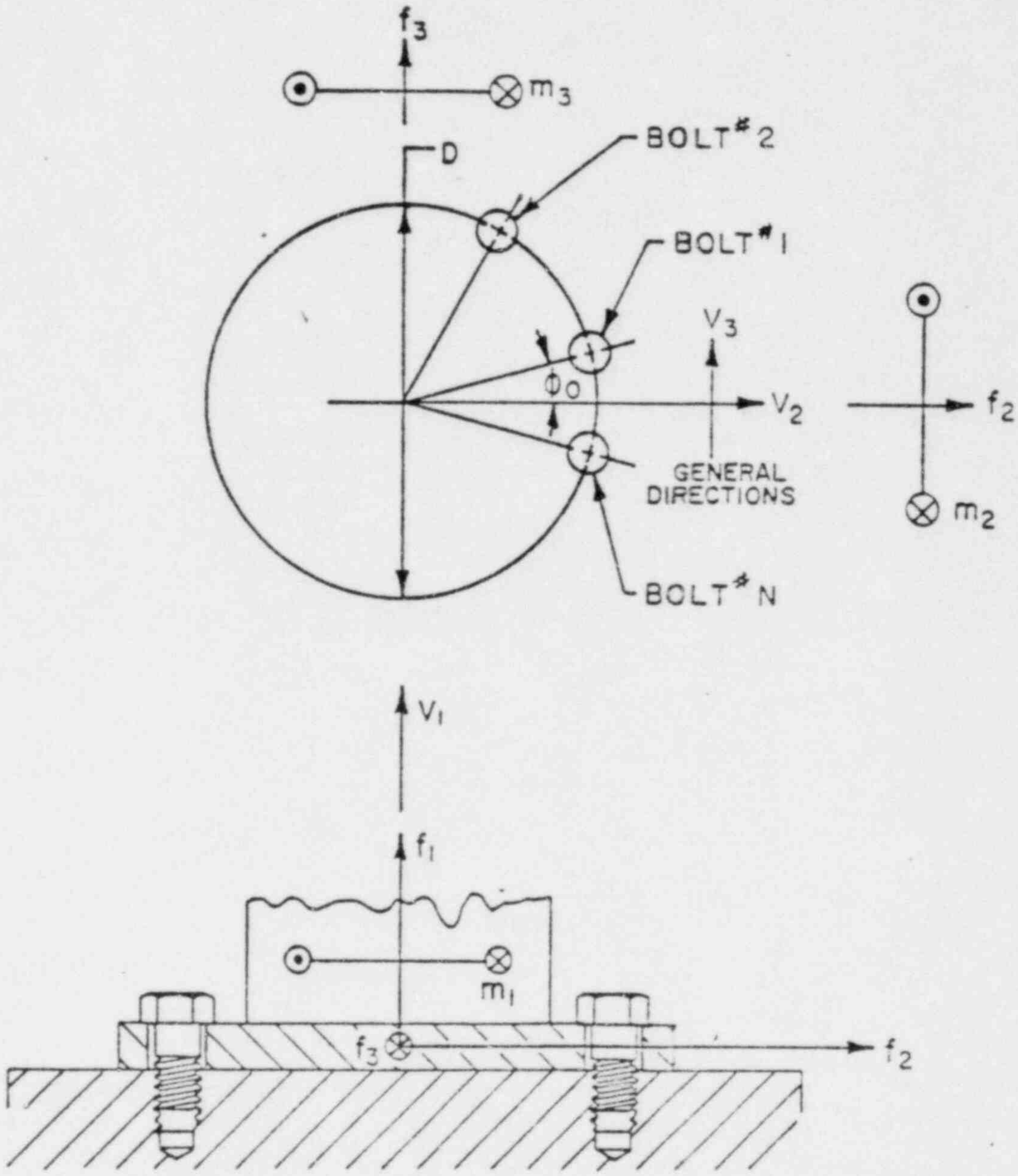


Figure VII-5
BOLT CIRCLE

The specified parameters for the bolt circle, N, ϕ_o, D and A_b are described in Table III-4 and Figure III-5(b).

The angular location, ϕ_i, in degrees, for the ith bolt, (i = 1, 2, 3, ...N), is:

$$\phi_i = 360(i - 1)/N + \phi_o \qquad \text{(VII.B.1-1)}$$

The inplane forces, f_2, f_3, will be assumed to be distributed uniformly to each bolt. In addition, the twisting moment, m_1, will be equilibrated by equal tangential shear forces with components in the $\{V_2\}$ and $\{V_3\}$ directions.

Thus,

$$V_{f_2}^{(i)} = (f_2 - \sin \phi_i (2m_1)/D)/N \qquad \text{(VII.B.1-2)}$$

$$V_{f_3}^{(i)} = (f_3 + \cos \phi_i (2m_1)/D)/N \qquad \text{(VII.B.1-3)}$$

The average total shear stress components on the ith bolt are thus,

$$\tau_1 = V_{f_2}^{(i)}/A_b \qquad \text{(VII.B.1-4)}$$

$$\tau_2 = V_{f_3}^{(i)}/A_b \qquad \text{(VII.B.1-5)}$$

where D is the bolt circle diameter, and

A_b is the root area of each bolt.

The axial force, f_1, and bending moments, m_2, m_3, will be assumed to be in equilibrium with the bolt axial forces, thus, the axial force in the ith bolt is:

$$A^{(i)} = [f_1 + (4/D)(m_2 \sin \phi_i - m_3 \cos \phi_i)]/N \qquad \text{(VII.B.1-6)}$$

It can be shown that for at least three evenly spaced bolts (i.e., N = 3),

$$\sum_{i=1}^{N} A^{(i)} = f_1 \qquad \text{(VII.B.1-7)}$$

$$\sum_{i=1}^{N} A^{(i)} \left(\frac{D}{2} \sin \phi_i\right) = m_2 \qquad \text{(VII.B.1-8)}$$

$$\sum_{i=1}^{N} A^{(i)} \left(\frac{D}{2} \cos \phi_i\right) = m_3 \qquad \text{(VII.B.1-9)}$$

The average axial stress for the ith bolt is, thus,

$$\sigma = A^{(i)}/A_b \qquad \text{(VII.B.1-10)}$$

For the operational loading condition a gasket force, F_g, may be specified which adds to the axial force. This total, if positive, is used to compute the axial stress for each bolt under operational conditions; if negative, it is assumed that the flanges react in compression and σ for those bolts with $A^{(i)} + F_g/N < 0$ is assumed zero.

$$\sigma_{\text{operational}} = A^{(i)} + (F_g/N)/A_b \qquad \text{(VII.B.1-11)}$$

VII.B.2 Bolted Joint Leg Configuration

A commonly used bolted connection between components in an actuator-valve assembly is designated a Leg Configuration with a single line of N evenly spaced bolts on a rectangular, nearly inelastic pad. Figure VII-6 depicts a typical configuration with the forces and moments acting.

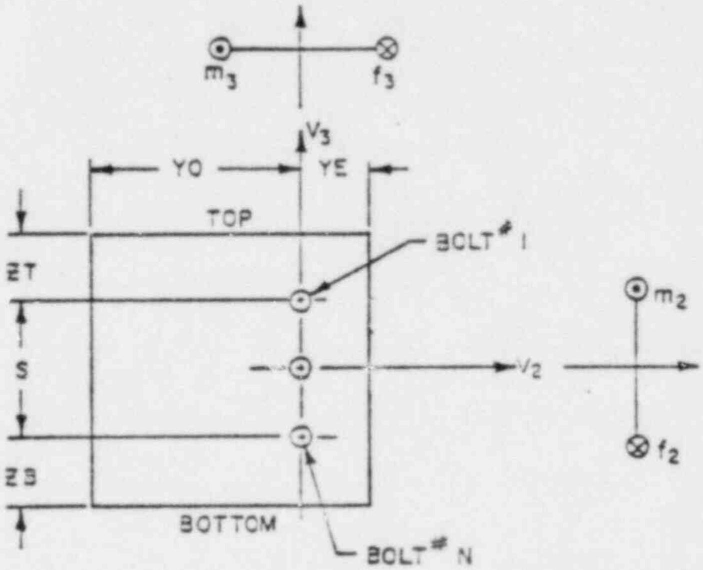
The specified parameters for this configuration, N, S, ZB, ZT, YO, YE and A_b are described in Table III-4 and Figure III-5(c).

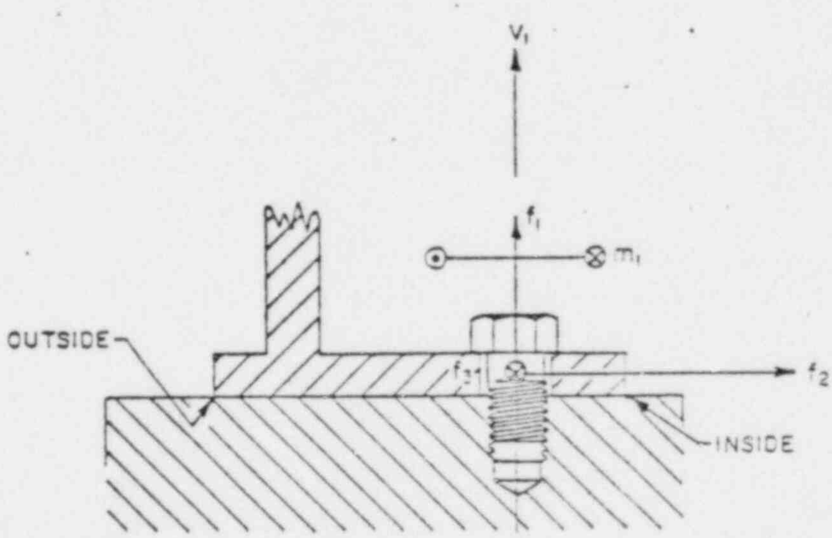
The distance, V, from the reference center to the ith bolt (i = 1, 2, ...N) in the V_3 direction is:

$$V_3^{(i)} = S(N + 1 - 1 - 2i)/(2(N - 1)) \qquad \text{(VII.B.2-1)}$$

The inplane forces, f_2, f_3, are assumed to be distributed uniformly to each bolt. In addition, the twisting moment, m_1, is assumed to be distributed as shear forces, $V_m^{(i)}$, in the V_2 direction on each bolt, which are proportional to $V_3^{(i)}$.

$$V_m^{(i)} = m_1 (N + 1 - 2i) C_M \qquad \text{(VII.B.2-2)}$$





LEG CONFIGURATION

FIGURE VII-6

with,

$$C_M = 6/(S \cdot N \cdot (N + 1)) \qquad \text{(VII.B.2-3)}$$

It can be shown that these shear forces do indeed equilibrate with the twisting moment.

$$\sum_{i=1}^{N} V_m^{(i)} V_3^{(i)} = m_1 \qquad \text{(VII.B.2-4)}$$

Thus, the shear forces on the ith bolt in the V_2 and V_3 directions are:

$$V_{f_2}^{(i)} = f_2/N - V_m^{(i)} \qquad \text{(VII.B.2-5)}$$

$$V_{f_3}^{(i)} = f_3/N \qquad \text{(VII.B.2-6)}$$

and the average total shear stress components on the ith bolt is:

$$\tau_2 = V_{f_2}^{(i)}/A_b \qquad \text{(VII.B.2-7)}$$

$$\tau_3 = V_{f_3}^{(i)}/A_b \qquad \text{(VII.B.2-8)}$$

where A_b is the root area of each bolt.

The axial force, f_1, and bending moment, m_3, is assumed to be reacted by a total load, f_1', for all the bolts and a contact reaction at either the inside or outside pivot edges (Figure VII-6). Both possible pivot edges are postulated; the one that yields tension for the bolt load and the smallest compression through the pivot reaction is selected.

For contact on inside edge

$$f_1' = f_1 + m_3/YE \qquad \text{(VII.B.2-8)}$$

For contact on outside edge

$$f_1' = f_1 - m_3/YO \qquad \text{(VII.B.2-9)}$$

For no contact which implies $m_3 = 0$

$$f_1' = f_1 \quad \text{(VII.B.2-10)}$$

For the condition that neither postulated contact edge yields bolt tension

$$f_1' = 0 \quad \text{(VII.B.2-11)}$$

Next, f_1' and m_2 will be assumed to be reacted by individual axial loads in each bolt, $A^{(i)}$, and a pivot reaction about either the top or bottom edges (Figure VII-6) depending upon the sense of m_2.

If $m_2 = 0$

$$A^{(i)} = f_1'/N \quad \text{(VII.B.2-12)}$$

If $m_2 < 0$ (Pivot about top edge)

$$A^{(i)} = [f_1' (S/2 + ZB) + m_2][S(N - i)/(N-1) + ZB]/C_B \quad \text{(VII.B.2-13)}$$

where

$$C_B = N \left[\frac{S^2 (N + 1)}{12(N - 1)} + (S/2 + ZB)^2\right] \quad \text{(VII.B.2-14)}$$

If $m_2 > 0$ (Pivot about bottom edge)

$$A^{(i)} = [f_1'(S/2 + ZT) - m_2][S(i - 1)/(N - 1) + ZT]/C_T \quad \text{(VII.B.2-15)}$$

where

$$C_T = N \left[\frac{S^2 (N + 1)}{12(N - 1)} + (S/2 + ZT)^2\right] \quad \text{(VII.B.2-16)}$$

For the seismic loads, for which f_1, m_2, m_3, may reverse all together in sign, equations VII.B.2-8 through 2-16 are reevaluated yielding another set of axial loads, $A^{(i)}{}_k$ for each bolt; the largest value for each bolt is retained and then the average axial bolt stress is taken as:

$$\sigma = A^{(i)}/A_b \quad \text{(VII.B.2-17)}$$

VII.B.3 Bolted Joint Pad Configuration

The bolted connection between components in an actuator-valve assembly that consists of a nearly inelastic rec-

tangular pad with two parallel lines, each with N evenly spaced, bolts, is designated a pad configuration. Figure VII-7 depicts such a configuration with forces and moments acting.

The specified parameters for this configuration, N, S, ZB, ZT, YO, YE and A_b are described in Table III-4 and Figure III-5(d).

The location of the ith bolt may be written in terms of the coordinates, $V_2^{(i)}$, $V_3^{(i)}$, in the plane parallel to vectors, $\{V_2\}$, $\{V_3\}$, respectively.

For $1 \leq i \leq N$

$$V_2^{(i)} = YO/2 \qquad \text{(VII.B.3-1)}$$

$$V_3^{(i)} = S(N + 1 - 2i)/(2(N - 1)) \qquad \text{(VII.B.3-2)}$$

For $N + 1 \leq i \leq 2N$

$$V_2^{(i)} = -YO/2 \qquad \text{(VII.B.3-3)}$$

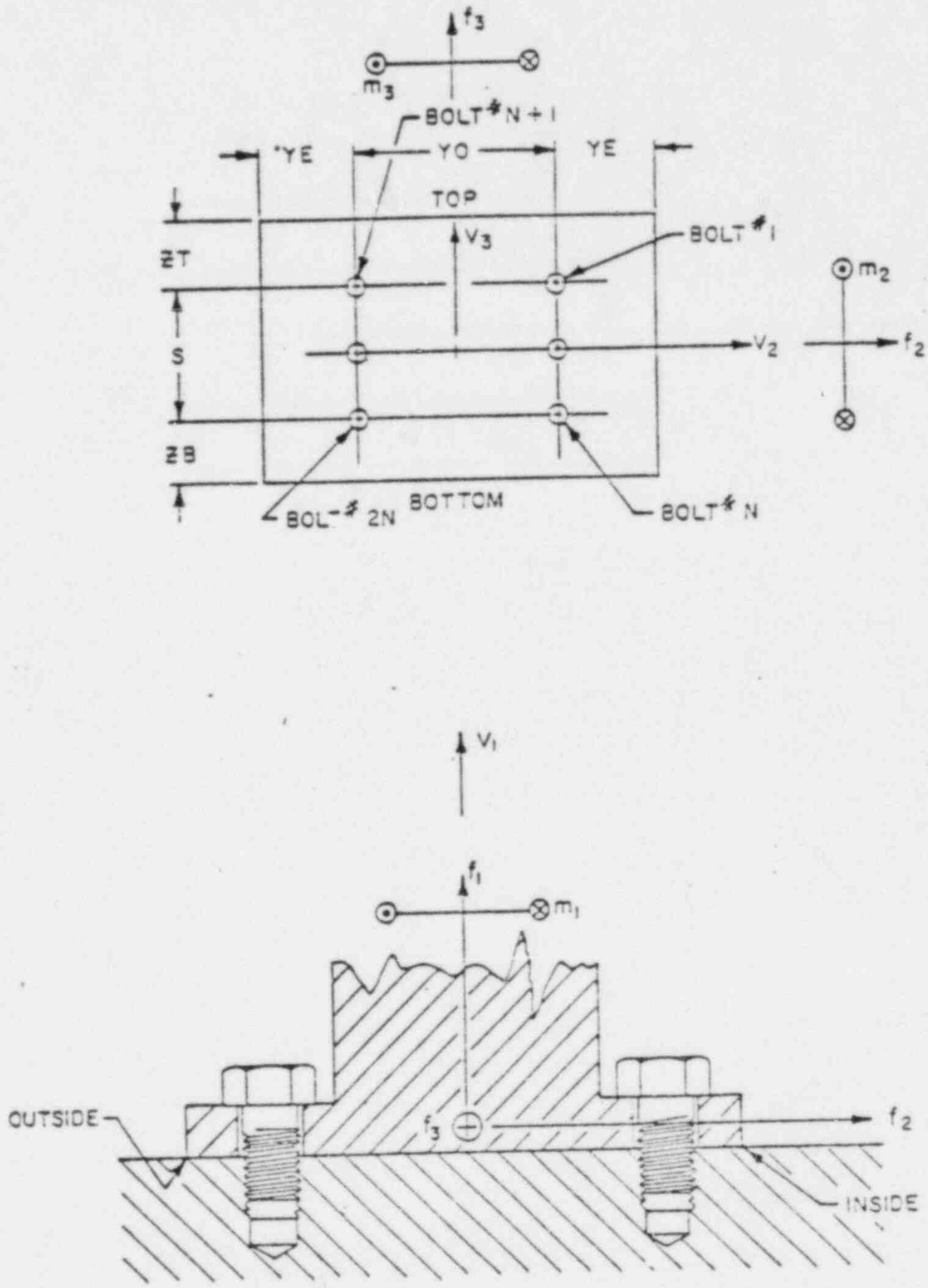
$$V_3^{(i)} = S(3N + 1 - 2i)/(2(N-1)) \qquad \text{(VII.B.3-4)}$$

and the distance is:

$$d_i = \sqrt{(V_2^{(i)})^2 + (V_3^{(i)})^2} \qquad \text{(VII.B.3-5)}$$

The inplane forces, f_2, f_3, are assumed to be distributed uniformly on each of the 2N bolts. In addition, the twisting moment, m_1, is assumed to be distributed as tangentially acting shear forces, $V_m^{(i)}$, proportional to the distance, d_i, from the reference center of the bolt pattern.

$$V_m^{(i)} = m_1\, d_1/(2N\, C_M) \qquad \text{(VII.B.3-6)}$$



PAD CONFIGURATION

FIGURE VII-7

where:

$$C_M = 1/[(YO/2)^2 + S^2(N + 1)/(12(N - 1))] \qquad \text{(VII.B.3-7)}$$

It can be shown that these shear forces do equilibrate with the twisting moment:

$$\sum_{i=1}^{2N} V_m^{(i)} d_i = m_1 \qquad \text{(VII.B.3-8)}$$

Taking the components of $V_m^{(i)}$ in the V_2 and V_3 directions and adding to the shear developed by f_2 and f_3 yields the two shear force components on each of the i bolts.

$$V_{f_2}^{(i)} = (f_2 - C_M V_3^{(i)} m_1)/(2N) \qquad \text{(VII.B.3-9)}$$

$$V_{f_3}^{(i)} = (f_3 + C_M V_2^{(i)} m_1)/(2N) \qquad \text{(VII.B.3-10)}$$

and the average total shear stress components on the ith bolt are:

$$\tau_2 = V_{f_2}^{(i)}/A_b \qquad \text{(VII.B.3-11)}$$

$$\tau_3 = V_{f_3}^{(i)}/A_b \qquad \text{(VII.B.3-12)}$$

where A_b is the root area of each bolt.

The axial force, f_1, and the bending moment, m_3, is assumed to be reacted by total loads on the inside row of bolts (1 to N), $f_1^{(I)}$, the outside row of bolts (N + 1 to 2N), $f_1^{(o)}$, and either a reaction on the inside or outside pivot edges (Figure VII-7).

Various pivoting mechanisms may be postulated. For $f_1 \geq 0$ and $m_3 = 0$, no pivoting about the V_3 axis occurs.

$$f_1^{(I)} = f_1^{(o)} = f_1/2 \qquad \text{(VII.B.3-13)}$$

For $m_3 > 0$, pivoting is on the inside edge

$$f_1^{(I)} = YE \cdot T_I \qquad \text{(VII.B.3-14)}$$

$$f_1^{(o)} = (YE + YO) \cdot T_I \qquad \text{(VII.B.3-15)}$$

where:

$$T_I = [(f_1/2)(YO + 2\cdot YE) + m_3]/[(YE)^2 + (YE + YO)^2] \quad \text{(VII.B.3-16)}$$

For $m_3 < 0$, pivoting is on the outside edge:

$$f_1^{(I)} = (YE + YO)\cdot T_O \quad \text{(VII.B.3-17)}$$

$$f_1^{(o)} = YE\cdot T_O$$

where:

$$T_O = [(f_1/2)(YO + 2\cdot YE) - m_3]/[(YE)^2 + (YE + YO)^2] \quad \text{(VII.B.3-18)}$$

For $f_1 \leq o$ and $m_3 = 0$, then f_1 is assumed reacted entirely by the two contact edges:

$$F_1^{(I)} = f_1^{(o)} = 0 \quad \text{(VII.B.3-19)}$$

$f_1^{(I)}$ and $f_1^{(o)}$ are assumed to uniformly load in the axial direction each bolt in the respective rows, thus,

$$\bar{A}^{(i)} = f_1^{(I)}/N \quad 1 \leq i \leq N$$

$$= f_1^{(o)}/N \quad N + 1 \leq i \leq 2N \quad \text{(VII.B.3-20)}$$

Next, an additional load, $\bar{\bar{A}}^{(i)}$, on each bolt caused by m_2 is computed based on the assumption of pivoting about either the top or bottom edge (Figure VII-7) depending upon the sense of m_2.

If $m_2 = 0$

$$\bar{\bar{A}}^{(i)} = \bar{\bar{A}}^{(i + N)} = 0 \quad 1 \leq i \leq N \quad \text{(VII.B.3-21)}$$

If $m_2 > 0$ (Pivot about bottom edge)

$$\bar{\bar{A}}^{(i)} = \bar{\bar{A}}^{(i + N)} = (m_2/2)[(S(N - i)/(N - 1) + ZB]/C_B \quad 1 \leq i \leq N \quad \text{(VII.B.3-22)}$$

where:

$$C_B = N[(S/2 + ZB)^2 + S^2 (N + 1)/(12(N - 1))] \quad \text{(VII.B.3-23)}$$

If $m_2 < 0$ (Pivot about top edge)

$$\bar{\bar{A}}^{(i)} = \bar{\bar{A}}^{(i+N)} + (m_2/2)[S(i-1)/(N-1) + ZT]/C_T \qquad \text{(VII.B.3-24)}$$

where:

$$C_T = N[(S/2 + ZT)^2 + S^2 (N+1)/(12(N-1))] \qquad \text{(VII.B.3-25)}$$

The total axial load on the ith bolt is then:

$$A^{(i)} = \bar{A}^{(i)} + \bar{\bar{A}}^{(i)} \text{ for } 1 \leq i \leq 2N \qquad \text{(VII.B.3-26)}$$

For seismic loads for which f_1, m_2, m_3, may reverse all together in sign, equations VII.B.3-13 through 3-26, are reevaluated yielding another set of axial loads, $A^{(i)}$, for each bolt; the largest value for each bolt is retained, then the average bolt stress may be taken as:

$$\sigma = A^{(i)}/A_b \qquad \text{(VII.B.3-27)}$$

VIII. ACCEPTANCE CRITERIA

If the purchaser's design specification does not include acceptance criteria or if the acceptance criteria are incomplete, this section will be used to determine the acceptability of the equipment.

VIII.A. Pressure Retaining Structures

Table VIII.A.-1

Valve Classification	Section Analyzed	Stress Limits[1,2,3,4,5,6]
Active	Bonnet	$(\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.5S$ $\sigma_s \leq 0.6S$
	Bolting	$\sigma_m \leq 2S$
Non-active	Bonnet	$(\sigma_m \text{ or } \sigma_L) + \sigma_b \leq S_y$ $\sigma_s \leq 0.6S_y$
	Bolting	$\sigma_m \leq 2S$

VIII.A. Pressure Retaining Structures (continued)

Notes to Table VIII.A.-1

1. The symbols are defined as follows:

   σ_m - general membrane stress. This stress is equal to the average stress across the solid section under consideration, excludes discontinuities and concentrations and is produced only by mechanical loads.

   σ_L - local membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.

   σ_b - bending stress. This stress is equal to the linear varying portion of the stress across the solid section under consideration, excludes discontinuities and concentrations, and is produced only by mechanical loads.

   σ_s - shear stress. This stress is the average primary shear stress across a section loaded in pure shear.

   S_y - yield strength.

   S - stress intensity for Class 1 valves or the allowable stress for Class 2 and 3 valves taken from Appendix 1 to Section III.

2. The stress limit for cast iron, ASTM 48 Class 30, is 15000 psi for all cases.

3. For the purposes of selecting the appropriate material properties and stress limits the actuator yoke, the yoke locknut or actuator-to-bonnet bolting shall be assumed to be at ambient temperature while the bonnet and the bonnet-to-body bolting shall be assumed to be at the service temperature.

4. The value for S for materials not listed in Appendix I to Section III shall be determined in the following manner:

   For Class 1 valves the lesser of:

   1/3 of the minimum specified tensile strength
   or
   2/3 of the minimum specified yield strength.

   For Class 2 and 3 valves the lesser of:

   1/4 of the minimum specified tensile strength
   or
   5/8 of the minimum specified yield strength.

   These values shall be selected for the appropriate temperature as specified in note 4.

5. A casting quality factor of 1.0 shall be assumed in satisfying these limits for Class 2 and 3 valves.

6. For bolted joints the bolt prestress is assumed to be equal to 2S. The bolt will not be considered overstressed until the bolt stress exceeds the bolt prestress.

VIII.B. Non-pressure Retaining Structures

For non-pressure retaining structures the stress limit will not exceed 90% of the specified minimum yield strength of the material.

IX. REVISION TO THIS STANDARD

Revisions to this standard must be approved by the Director of Engineering Services or the Vice President of Engineering and Research.

X. REFERENCES

(1) Roark and Young, "Formulas for Stress and Strain," Chapter 9 (corresponds to K).

(2) Ibid, Article 7.10 (corresponds to F).

(3) Ibid, Article 7.14, Table 14 and Paz, et al., "Computer Determination of the Shear Center of Open and Closed Sections".

(4) Roark and Young, "Formulations for Stress and Strain", Chapter 9, Table 20, and Den Hartog "Advanced Strength of Materials," Chapter 1.

(5) Zudans, "Consistent Mass Matrix for Thick Beams," Section 2.

(6) Fishman, "Computation of Bending Modulus for Curved Beams."

(7) Rothbart, H.A., Mechanical Design and Systems Handbook, Section 20.

(8) Zudans, et al., "FELAP$_{TM}$, Finite Element Computer Program Input Description and User's Guide," Section III.2.

(9) Fishman, "Joint Release for Consistent Mass Elements," and Zudans, et al., "FELAP$_{TM}$, Finite Element Computer Program Theory Manual," Section 2.6.

(10) Ibid, Section 2.7.

(11) Roark and Young, "Formulas for Stress and Strain," Tables 1, 14, 20 and Fishman, Tung, Lin and Tsai, "Computation of Cross-Section Properties."

(12) Przemiencki, "Theory of Matrix Structural Analysis," Section 3.4; Zudans, "Survey of Advanced Structural Design Analysis Techniques", Section 2; and Archer, "Consistent Matrix Formulations for Structural Analysis Using Finite-Element Techniques."

(13) Harris and Crede, "Shock and Vibration Handbook," Volume 1, Section 2.

(14) "Theory for Real Eigenvalue Analysis," Nastran Theoretical Manual, Section 10.4.2.

(15) Zudans, et al., "FELAP™ Finite Element Computer Program Input Description and User's Guide," pp. 5-35, 38.

(16) Chu, et al., "Spectral Treatment of Actions of Three Earthquake Components on Structures."

(17) Timoshenko and Goodier, "Theory of Elasticity," Section 9; and ASME Boiler and Pressure Vessel Code, Section III, Article NB-3215.

(18) Fishman, "Analysis of Bolted Joint Configurations".

(19) ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components," Appendix I.

XI. BIBLIOGRAPHY

Archer, John S., "Consistent Matrix Formulations for Structural Analysis Using Finite-Element Techniques," AIAA Journal, Vol. 3, October, 1965, pp. 1910-1918.

ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components," Subsections NA and NB, American Society of Mechanical Engineers, 1974.

Chu, S.L., Amin, M. and Singh, S., "Spectral Treatment of Actions of Three Earthquake Components on Structures," Nuclear Engineering and Design 21 (1972), pp. 126-136.

Den Hartog, J.P., "Advanced Strength of Materials," McGraw Hill, 1952.

Fishman, Howard M., "Analysis of Bolted Joint Configurations," Franklin Institute Research Laboratories Technical Note, 1977.

Fishman, Howard M., "Computation of Bending Modulus for Curved Beams," Franklin Institute Research Laboratories Technical Note, 1977.

Fishman, Howard M., "Joint Release for Consistent Mass Matrix," Franklin Institute Research Laboratories Technical Note, 1977.

Fishman, H.M.; Tung, C.; Lin, Y.L.; and Tsai, H.C.; "Computation of Cross-Section Properties," Franklin Institute Research Laboratories Technical Note, 1977.

Harris, Cyril M. and Crede, Charles E., editors, "Shock and Vibration Handbook," Volume 1, McGraw-Hill, 1961.

"NASTRAN, Theoretical Manual," National Aeronautics and Space Administration, 1972.

Paz, M.; Strehl, C.P.; and Schrader, P.; "Computer Determination of the Shear Center of Open and Closed Sections," Computers & Structures, Vol. 6, 1976, pp. 117-125.

Przemienicki, J.S., "Theory of Matrix Structural Analysis," McGraw-Hill, 1968.

Rothbart, H.A., editor, "Mechanical Design and Systems Handbook," McGraw-Hill, 1964.

Roark, Raymond J. and Young, Warren C., "Formulas for Stress and Strain," Fifth Edition, McGraw-Hill, 1975.

Timoshenko, S. and Goodier, J.N., "Theory of Elasticity," McGraw-Hill, 1951.

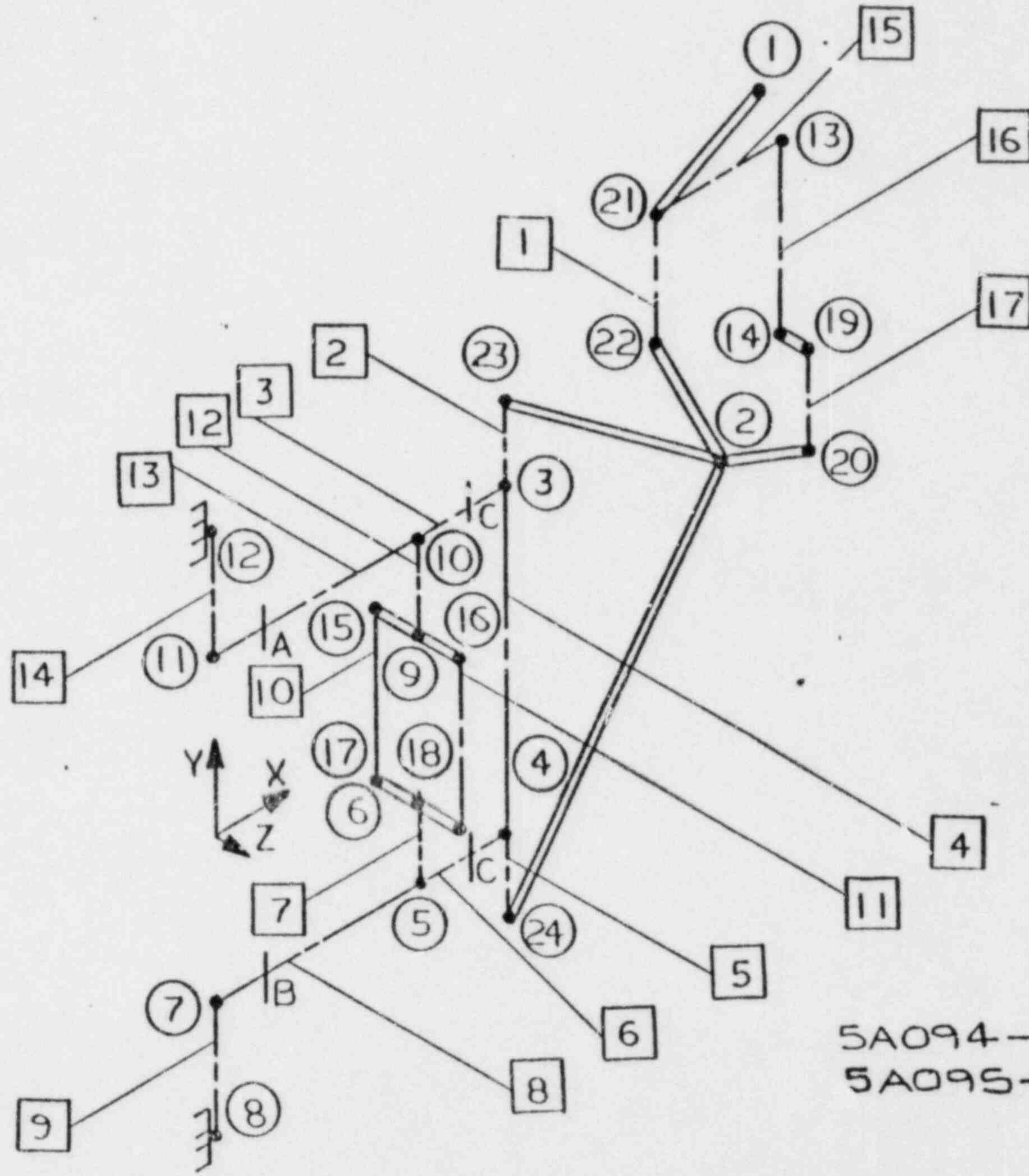
Zudans, Zenons, "Consistent Mass Matrix for Thick Beams," ASME Publication 76-WA/PVP-13, July, 1976.

Zudans. Zenons, "Survey of Advanced Structural Design Analysis Techniques," ASME Publication 69-DE-13, January, 1969.

Zudans, Z.; Fishman, H.M.; and Reddi, M.M., "FELAP$_{TM}$. Finite Element Computer Program Input Description and User's Guide," Franklin Institute Research Laboratories Technical Report, Fourth Revision, May, 1976.

Zudans, Z.; Fishman, H.M.; and Reddi, M.M.; "FELAP$_{TM}$, Finite Element Computer Program, Theory Manual," Franklin Institute Research Laboratories Technical Report, October, 1974.

APPENDIX B



5A094-02,04,09
5A095-02

FISHER CONTROLS COMPANY

SEISMIC-4

SEISMIC ANALYSIS

OF

ROTARY VALVES

MATERIAL PROPERTY INPUT DATA

MAT. NO.	DESCRIPTION	YOUNG'S MOD/10(6)	POISSON'S RATIO	MASS DENS/10(-4)	ALLOWABLE STRESS/10(3)
1	STEEL	30.000	0.283	7.240	27.000
2	BOLTING	30.000	0.283	7.240	82.800
3	ADAPTER	15.000	0.300	6.750	15.000

SARGENT AND LUNDY ENGINEERS
COMMONWEALTH EDISON COMPANY

CC NO 5A094
5A095

VALVE SIZE 26 VALVE TYPE 9220

ACTUATOR LIMITORQUE SMB-000-2/H18C

CUSTOMER ORDER NO 181104

CUSTOMER TAG NO 1VQ040
1VQ041
1VQ036
2VQ040

CERTIFIED DRAWING NO G254450
G269188

CROSS SECTION DRAWING NO F429278

BRACKET DRAWING NO G342524

DATE OF THIS REPORT / JUNE 5, 1978 DA

C O N T R O L I N P U T D A T A

MANUAL INPUT GENERATION FOR VALVE ANALYSIS

SEISMIC STRESSES ARE SUPERIMPOSED BY SQUARE ROOT OF SUM OF SQUARES

STRESS ALLOWABLES ARE COMPARED TO MAXIMUM PRINCIPAL STRESS

MASS, STIFFNESS, LOAD AND STRESS MATRICES ARE NOT PRINTED

STATIC SEISMIC ANALYSIS TO BE PERFORMED

OPERATIONAL LOAD ANALYSIS TO BE PERFORMED

DYNAMIC MODAL ANALYSIS TO BE PERFORMED WITH EVALUATION

C R O S S - S E C T I O N D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS		
1	TUBE	A = 4.875 ,	T = 1.060 ,	
2	RECTANGULAR	A = 9.000 ,	T = .5600 ,	
3	CHANNEL	A = 8.000 ,	T = .4870 ,	B = 2.530 ,
		T1= .3900 ,	R1= .3200 ,	
4	RECTANGULAR	A = 9.000 ,	T = .5600 ,	
5	RECTANGULAR	A = 9.000 ,	T = .5600 ,	
6	CHANNEL	A = 8.000 ,	T = .4870 ,	B = 2.530 ,
		T1= .3900 ,	R1= .3200 ,	
7	RECTANGULAR	A = 4.000 ,	T = .3750 ,	
8	CHANNEL	A = 8.000 ,	T = .4870 ,	B = 2.530 ,
		T1= .3900 ,	R1= .3200 ,	
9	RECTANGULAR	A = 9.000 ,	T = .5600 ,	
10	RECTANGULAR	A = 1.080 ,	T = .3750 ,	
11	RECTANGULAR	A = 1.080 ,	T = .3750 ,	
12	RECTANGULAR	A = 4.000 ,	T = .3750 ,	
13	CHANNEL	A = 8.000 ,	T = .4870 ,	B = 2.530 ,
		T1= .3900 ,	R1= .3200 ,	
14	RECTANGULAR	A = 9.000 ,	T = .5600 ,	
15	RECTANGULAR	A = 7.000 ,	T = .6250 ,	
16	RECTANGULAR	A = 7.000 ,	T = .6250 ,	
17	RECTANGULAR	A = 7.000 ,	T = .6250 ,	

JOINT COORDINATE DATA

JOINT NO.	X	Y	Z
1	12.250000	12.312000	-3.190000
2	9.685000	0.200000	-1.200000
3	5.940000	3.565000	0.0
4	5.940000	-3.565000	0.0
5	3.910000	-3.565000	0.0
6	3.910000	-1.960000	0.0
7	0.0	-3.565000	0.0
8	0.0	-4.750000	0.0
9	3.910000	1.960000	0.0
10	3.910000	3.565000	0.0
11	0.0	3.565000	0.0
12	0.0	4.750000	0.0
13	13.565000	8.440000	-3.500000
14	13.565000	3.500000	-3.500000
15	3.910000	1.960000	-1.460000
16	3.910000	1.960000	1.460000
17	3.910000	-1.960000	-1.460000
18	3.910000	-1.960000	1.460000
19	13.565000	3.500000	0.0
20	13.565000	0.200000	0.0
21	9.565000	8.440000	-3.500000
22	9.565000	5.440000	-3.500000
23	5.940000	4.625000	0.0
24	5.940000	-4.625000	0.0

B O U N D A R Y, S P R I N G & B O L T J O I N T. D A T A

JOINT NO.	TYPE-MAT /FIXITY	PLANE-DIRECTION OR DESCRIPTION			SPRING & BOLT JOINT PARAMETERS					
8	111111	BODY								
12	111111	BODY								
12	LEG 2	A	+X +Y	N.T=	2.10	.D/A=	0.7500.	YE=	1.1250
				YO=	9.5000.	YSH=	0.0 .	S=	2.7500
				ZT=	1.6250.	ZB=	1.6250.	ZSH=	0.0
8	LEG 2	B	+X -Y	N.T=	2.10	.D/A=	0.7500.	YE=	1.1250
				YO=	9.5000.	YSH=	0.0 .	S=	2.7500
				ZT=	1.6250.	ZB=	1.6250.	ZSH=	0.0
23	PAD 2	C	-X +Y	N.T=	2.11	.D/A=	0.6250.	YE=	0.6900
				YO=	9.2500.	YSH=	0.0 .	S=	3.8000
				ZT=	1.4000.	ZB=	1.4000.	ZSH=	0.0

C O N C E N T R A T E D M A S S D A T A

JOINT NO.	LUMPED MASS	FOR DIR.	SHIFT DISTANCE OR MOMENT OF INERTIA X	Y	Z
1	0.284679	XYZ	0.0	0.0	0.0
2	0.323499	XYZ	0.0	0.0	0.0
6	0.646998	X	0.0	0.0	0.0
9	0.646998	X	0.0	0.0	0.0

C O N C E N T R A T E D L O A D D A T A

JOINT NO.	. . . . FORCES. . . . X	Y	Z	. . . .MOMENTS. . . . X	Y	Z
2	0.0	0.0	0.0	12750.0	0.0	0.0

ELEMENT INPUT DATA

EL. NO.	JOINTS		LENGTH /RADIUS	ANGLE	AREA	MOMENTS OF INERTIA I-11	I-22	I-33	MATERIAL DESCRIPTION
1	21	22	3.000		12.7043	24.8969	49.7939	24.8969	ADAPTER
2	23	3	1.060		5.0400	0.1317	0.5062	34.0200	STEEL
3	3	10	2.030		5.4895	43.8702	0.3899	2.4406	STEEL
4	3	4	7.130		5.0400	0.1317	0.5062	34.0200	STEEL
5	4	24	1.060		5.0400	0.1317	0.5062	34.0200	STEEL
6	4	5	2.030		5.4895	43.8702	0.3899	2.4406	STEEL
7	5	6	1.605		1.5000	0.0176	0.0662	2.0000	STEEL
8	5	7	3.910		5.4895	43.8702	0.3899	2.4406	STEEL
9	8	7	1.185		5.0400	0.1317	0.5062	34.0200	STEEL
10	15	17	3.920		0.4050	0.0047	0.0148	0.0394	STEEL
11	16	18	3.920		0.4050	0.0047	0.0148	0.0394	STEEL
12	10	9	1.605		1.5000	0.0176	0.0662	2.0000	STEEL
13	10	11	3.910		5.4895	43.8702	0.3899	2.4406	STEEL
14	12	11	1.185		5.0400	0.1317	0.5062	34.0200	STEEL
15	21	13	4.000		4.3750	0.142	0.5376	17.8646	STEEL
16	13	14	4.940		4.3750	0.1424	0.5376	17.8646	STEEL
17	19	20	3.300		4.3750	0.1424	0.5376	17.8646	STEEL
	23	2			RIGID LINK				
	24	2			RIGID LINK				
	15	9			RIGID LINK				
	16	9			RIGID LINK				
	17	6			RIGID LINK				
	18	6			RIGID LINK				
	22	2			RIGID LINK				
	21	1			RIGID LINK				
	19	14			RIGID LINK				
	20	2			RIGID LINK				

S T A T I C A N A L Y S I S

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM X DIR.

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.000524	-0.000072	0.001035	-0.000000	-0.000109	-0.000012
2	0.000178	-0.000039	0.000755	-0.000000	-0.000110	-0.000008
3	0.000058	-0.0[illegible]011	0.000343	-0.000000	-0.000058	-0.000005
4	0.000020	-0.00[illegible]11	0.000344	-0.000000	-0.000059	-0.000007
5	0.000020	-0.0000[illegible]3	0.000225	-0.000000	-0.000058	-0.000008
6	0.000566	-0.00000[illegible]	0.000225	-0.000000	-0.000058	-0.000433
7	0.000015	0.000001	-0.000000	-0.000000	-0.000057	-0.000005
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000587	-0.000001	0.000225	-0.000000	-0.000058	0.000424
10	0.000054	-0.000000	0.000225	-0.000000	-0.000058	0.000002
11	0.000040	-0.000001	-0.000000	0.000000	-0.000057	0.000009
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.000511	-0.000070	0.001179	-0.000000	-0.000109	-0.000006
14	0.000472	-0.000069	0.001180	-0.000000	-0.000112	-0.000010
15	0.000671	-0.000001	0.000225	-0.000000	-0.000058	0.000424
16	0.000502	-0.000000	0.000225	-0.000000	-0.000058	0.000424
17	0.000650	-0.000003	0.000225	-0.000000	-0.000058	-0.000433
18	0.000481	-0.000003	0.000225	-0.000000	-0.000058	-0.000433
19	0.000079	-0.000069	0.001180	-0.000000	-0.000112	-0.000010
20	0.000046	-0.000069	0.001180	-0.000000	-0.000110	-0.000008
21	0.000510	-0.000039	0.000741	-0.000000	-0.000109	-0.000012
22	0.000470	-0.000039	0.000741	-0.000000	-0.000110	-0.000008
23	0.000079	-0.000011	0.000343	-0.000000	-0.000110	-0.000008
24	0.000009	-0.000011	0.000344	-0.000000	-0.000110	-0.000008

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE. SYSTEM Y DIR.

JOINT NO.	. . . DEFLECTION X	. . . Y	Z	. . . ROTATION X	. . . Y	Z
1	-0.000114	0.000887	0.001218	0.000099	-0.000000	0.000011
2	-0.000002	0.000660	0.000019	0.000099	0.000000	0.000008
3	0.000015	0.000509	0.000352	0.000099	-0.000039	0.000074
4	-0.000015	0.000509	-0.000352	0.000099	0.000040	0.000074
5	-0.000019	0.000338	-0.000233	0.000065	0.000040	0.000081
6	-0.000079	0.000338	-0.000128	0.000065	0.000022	0.000003
7	-0.000026	0.000001	-0.000002	-0.000000	0.000040	0.000074
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000079	0.000338	0.000128	0.000065	-0.000021	0.000003
10	0.000019	0.000338	0.000232	0.000065	-0.000040	0.000081
11	0.000026	0.000001	0.000002	-0.000000	-0.000040	0.000074
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.000075	0.000922	0.000836	0.000099	-0.000000	0.000007
14	-0.000033	0.000922	0.000346	0.000099	0.000001	0.000009
15	0.000110	0.000433	0.000128	0.000065	-0.000021	0.000003
16	0.000048	0.000243	0.000128	0.000065	-0.000021	0.000003
17	-0.000110	0.000433	-0.000128	0.000065	0.000022	0.000003
18	-0.000048	0.000243	-0.000128	0.000065	0.000022	0.000003
19	-0.000031	0.000574	0.000346	0.000099	0.000001	0.000009
20	-0.000002	0.000574	0.000019	0.000099	0.000000	0.000008
21	-0.000075	0.000889	0.000836	0.000099	-0.000000	0.000011
22	-0.000046	0.000887	0.000539	0.000099	0.000000	0.000008
23	-0.000039	0.000510	0.000458	0.000099	0.000000	0.000008
24	0.000039	0.000510	-0.000458	0.000099	0.000000	0.000008

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Z DIR.

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.001335	0.000842	0.007747	0.000269	-0.000421	0.000000
2	0.000502	0.000317	0.003432	0.000265	-0.000419	-0.000000
3	-0.000000	-0.000000	0.002748	0.000265	-0.000408	-0.000000
4	0.000000	-0.000000	0.000869	0.000264	-0.000197	-0.000000
5	0.000000	-0.000000	0.000568	0.000174	-0.000195	-0.000000
6	0.000000	-0.000000	0.000847	0.000174	-0.000244	-0.000000
7	0.000000	-0.000000	-0.000002	0.000000	-0.000192	-0.000000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.000000	-0.000000	0.001530	0.000174	-0.000359	0.000000
10	-0.000000	-0.000000	0.001810	0.000174	-0.000408	-0.000000
11	-0.000000	-0.000000	0.000009	-0.000000	-0.000404	-0.000000
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.001465	0.000930	0.007255	0.000267	-0.000420	0.000001
14	0.001468	0.000930	0.005935	0.000266	-0.000420	0.000000
15	0.000524	0.000254	0.001530	0.000174	-0.000359	0.000000
16	-0.000524	-0.000255	0.001530	0.000174	-0.000359	0.000000
17	0.000357	0.000254	0.000847	0.000174	-0.000244	-0.000000
18	-0.000356	-0.000254	0.000847	0.000174	-0.000244	-0.000000
19	-0.000000	-0.000000	0.005935	0.000266	-0.000420	0.000000
20	-0.000000	-0.000000	0.005057	0.000265	-0.000419	-0.000000
21	0.001465	0.000926	0.005577	0.000269	-0.000421	0.000000
22	0.001465	0.000926	0.004768	0.000265	-0.000419	-0.000000
23	-0.000000	-0.000000	0.003035	0.000265	-0.000419	-0.000000
24	-0.000000	-0.000000	0.000588	0.000265	-0.000419	-0.000000

DEFORMATION RESPONSE TO OPERATIONAL LOADS (NOT INCLUDING DEADWEIGHT)

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.000003	0.007021	0.027099	0.002202	0.000001	-0.000000
2	-0.000001	0.002639	0.000432	0.002202	0.000001	-0.000000
3	-0.000000	-0.000003	0.007814	0.002202	-0.000878	-0.000000
4	0.000000	-0.000003	-0.007822	0.002202	0.000879	-0.000000
5	0.000000	-0.000002	-0.005170	0.001449	0.000886	-0.000000
6	0.000000	-0.000002	-0.002844	0.001449	0.000478	-0.000000
7	0.000000	-0.000000	-0.000046	-0.000002	0.000884	-0.000000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.000000	-0.000002	0.002838	0.001449	-0.000477	-0.000000
10	-0.000000	-0.000002	0.005164	0.001449	-0.000885	-0.000000
11	-0.000000	-0.000000	0.000046	-0.000002	-0.000883	-0.000000
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.000004	0.007704	0.018571	0.002202	0.000001	-0.000000
14	-0.000004	0.007704	0.007694	0.002202	0.000001	-0.000000
15	0.000695	0.002114	0.002838	0.001449	-0.000477	-0.000000
16	-0.000696	-0.002118	0.002838	0.001449	-0.000477	-0.000000
17	-0.000697	0.002114	-0.002844	0.001449	0.000478	-0.000000
18	0.000698	-0.002118	-0.002844	0.001449	0.000478	-0.000000
19	0.000000	-0.000003	0.007694	0.002202	0.000001	-0.000000
20	0.000000	-0.000003	0.000427	0.002202	0.000001	-0.000000
21	-0.000004	0.007704	0.018576	0.002202	0.000001	-0.000000
22	-0.000004	0.007704	0.011970	0.002202	0.000001	-0.000000
23	0.000000	-0.000003	0.010180	0.002202	0.000001	-0.000000
24	-0.000000	-0.000003	-0.010188	0.002202	0.000001	-0.000000

D Y N A M I C   A N A L Y S I S

RESONANT FREQUENCY = 38.5 HERTZ (IN Z-DIRECTION OR Y-ROTATION)

* * * * NORMALIZED EIGENVECTOR * * * *

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.150921	0.136495	1.000000	0.041558	-0.047184	-0.000099
2	0.056616	0.055550	0.378930	0.040890	-0.046897	-0.000043
3	0.000819	0.006628	0.340005	0.040902	-0.048994	0.000846
4	-0.000382	0.006630	0.049648	0.040868	-0.016359	0.000911
5	-0.000408	0.004479	0.032037	0.026933	-0.016086	0.001036
6	-0.001137	0.004487	0.075262	0.026933	-0.023682	-0.000036
7	-0.000461	0.000016	-0.000504	-0.000003	-0.015733	0.001000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.001531	0.004526	0.180768	0.026937	-0.041413	-0.000024
10	0.000795	0.004535	0.224000	0.026941	-0.048979	0.001020
11	0.000750	0.000014	0.001194	-0.000054	-0.048537	0.001075
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.165169	0.150145	0.900570	0.041210	-0.047120	0.000186
14	0.165505	0.150150	0.696619	0.041096	-0.047129	-0.000046
15	0.061994	0.043854	0.180768	0.026937	-0.041413	-0.000024
16	-0.058932	-0.034802	0.180768	0.026937	-0.041413	-0.000024
17	0.033438	0.043809	0.075262	0.026933	-0.023682	-0.000036
18	-0.035713	-0.034834	0.075262	0.026933	-0.023682	-0.000036
19	0.000552	0.006314	0.696619	0.041096	-0.047129	-0.000046
20	0.000340	0.006315	0.560890	0.040890	-0.046897	-0.000043
21	0.165165	0.149644	0.712400	0.041558	-0.047184	-0.000099
22	0.164704	0.149601	0.587565	0.040890	-0.046897	-0.000043
23	0.000530	0.006642	0.384238	0.040890	-0.046897	-0.000043
24	0.000133	0.006642	0.006007	0.040890	-0.046897	-0.000043

S T A T I C   S E I S M I C   A N A L Y S I S

THE VALVE AXIS IS POSITIONED Y-UP

ACCELERATION OF GRAVITY, G = 386.400

DIRECTION OF SEISMIC ACCELERATION	NO. OF G'S	COMPONENTS OF UNIT ACCELERATION IN VALVE COORDINATE SYSTEM X-COMP.	Y-COMP.	Z-COMP.
HORIZONTAL(1)	5.000	0.0	0.0	-1.0000
HORIZONTAL(2)	5.000	1.0000	0.0	0.0
VERTICAL	5.000	0.0	-1.0000	0.0

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	2.	-7.	-423.	-2111.	916.	-22.
	22	-2.	7.	473.	3454.	-916.	27.
2	23	-1542.	2.	-0.	-1.	290.	-1447.
	3	1550.	-2.	0.	1.	-290.	-192.
3	3	0.	-0.	1789.	-591.	840.	2.
	10	-0.	0.	-1804.	-3057.	-840.	-1.
4	3	239.	0.	-0.	1.	876.	1028.
	4	-189.	-0.	0.	1.	-876.	498.
5	4	-239.	-2.	1.	1.	-6184.	-1081.
	24	247.	2.	-1.	-1.	6184.	823.
6	4	-0.	1.	429.	-7060.	-582.	-1.
	5	0.	-1.	-413.	6206.	582.	1.
7	5	6.	0.	-0.	0.	118.	26.
	6	-3.	-0.	0.	-0.	-118.	-20.
8	5	-1.	1.	407.	-6324.	-608.	-1.
	7	1.	-1.	-377.	4790.	608.	-1.
9	8	-369.	1.	-1.	-0.	4789.	166.
	7	377.	-1.	1.	1.	-4789.	-608.
10	15	1.	-6.	23.	-45.	25.	1.
	17	1.	6.	-23.	-45.	-25.	-1.
11	16	1.	6.	-23.	45.	25.	1.
	18	1.	-6.	23.	45.	-25.	-1.
12	10	5.	0.	-0.	0.	118.	24.
	9	-2.	-0.	0.	-0.	-118.	-16.
13	10	1.	-0.	1811.	2947.	866.	1.
	11	-1.	0.	-1841.	-10087.	-866.	1.
14	12	1850.	-1.	-0.	-1.	-10089.	3053.
	11	-1841.	1.	0.	1.	10089.	-866.
15	21	-126.	1.	-7.	21.	18.	-558.
	13	151.	-1.	7.	8.	-18.	5.
16	13	-149.	7.	1.	-8.	4.	15.
	14	179.	-7.	-1.	3.	-4.	-826.
17	19	-180.	8.	1.	-3.	8.	803.
	20	200.	-8.	-1.	-1.	-8.	-1430.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	8	-1.	-1.	-369.	166.	-4789.	-0.
BODY	12	0.	-1.	1850.	-3053.	-10089.	-1.
A +X+Y	12	0.	-1.	1841.	-3048.	-10087.	-1.
B +X-Y	8	-1.	-1.	-377.	161.	-4790.	-0.
C -X+Y	23	1.	1.	-1360.	-1357.	6470.	2.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	592.	19.	4.	-1.	138.	-2056.
	22	-642.	-19.	-4.	-10.	-138.	3907.
2	23	-1.	-277.	-1578.	793.	-1431.	-1.
	3	1.	277.	1586.	884.	1431.	-0.
3	3	-360.	1614.	1.	-1431.	1.	848.
	10	360.	-1630.	-1.	1429.	-1.	-1578.
4	3	0.	82.	28.	-36.	0.	0.
	4	-0.	-82.	22.	14.	-0.	-0.
5	4	1.	-277.	-271.	158.	1430.	-0.
	24	-1.	277.	279.	134.	-1430.	1.
6	4	-360.	-249.	-0.	1430.	-1.	-173.
	5	360.	234.	0.	-1429.	1.	-557.
7	5	-0.	74.	-1256.	1706.	0.	0.
	6	0.	-74.	1253.	308.	-0.	-0.
8	5	-434.	1023.	-0.	1429.	-0.	-1148.
	7	434.	-1053.	0.	-1429.	0.	-547.
9	8	0.	434.	-1061.	706.	-1429.	0.
	7	-0.	-434.	1053.	547.	1429.	-0.
10	15	0.	37.	1.	156.	0.	0.
	17	-0.	-37.	2.	-154.	-0.	0.
11	16	0.	37.	1.	156.	0.	0.
	18	-0.	-37.	2.	-154.	-0.	0.
12	10	0.	74.	1255.	-1700.	0.	0.
	9	-0.	-74.	-1251.	-311.	-0.	-0.
13	10	-434.	2884.	1.	-1430.	0.	-122.
	11	434.	-2914.	-1.	1428.	-0.	-1573.
14	12	1.	434.	2923.	-1885.	1428.	1.
	11	-1.	-434.	-2914.	-1573.	-1428.	-0.
15	21	-4.	42.	19.	-73.	-1.	-33.
	13	4.	-18.	-19.	-1.	1.	18.
16	13	-4.	-19.	18.	1.	19.	-1.
	14	4.	19.	13.	-14.	-19.	-18.
17	19	-4.	-19.	-13.	14.	-26.	82.
	20	4.	19.	33.	61.	26.	-95.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	8	-1061.	-434.	0.	0.	1429.	706.
BODY	12	-2923.	434.	1.	-1.	1428.	-1885.
A +X+Y	12	-2914.	434.	1.	-1.	1428.	-1880.
B +X-Y	8	-1053.	-434.	0.	0.	1429.	701.
C -X+Y	23	1365.	0.	-2.	5.	-2861.	-1353.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	-3.	-660.	-12.	201.	43.	-1731.
	22	3.	720.	12.	-165.	-43.	1721.
2	23	-402.	-779.	-1314.	2170.	-1325.	-141.
	3	402.	788.	1314.	-777.	1325.	-285.
3	3	-819.	1745.	498.	-1719.	58.	-2315.
	10	837.	-1745.	-498.	707.	-58.	634.
4	3	96.	30.	431.	-1538.	394.	344.
	4	-96.	30.	-431.	-1531.	-394.	344.
5	4	-403.	787.	-1314.	-777.	-1323.	-284.
	24	403.	-778.	1314.	2170.	1323.	-143.
6	4	819.	-1745.	498.	-1717.	58.	2315.
	5	-838.	1745.	-498.	706.	-58.	-633.
7	5	0.	-7.	56.	-199.	53.	1.
	6	-0.	3.	-56.	110.	-53.	-0.
8	5	844.	-1801.	499.	-758.	58.	832.
	7	-880.	1801.	-499.	-1191.	-58.	2540.
9	8	-499.	-891.	1801.	406.	-1191.	-649.
	7	499.	881.	-1801.	-2540.	1191.	58.
10	15	-0.	1.	38.	-75.	11.	-0.
	17	0.	1.	-38.	-75.	-11.	-0.
11	16	-0.	1.	18.	-34.	11.	-0.
	18	0.	1.	-18.	-34.	-11.	-0.
12	10	-0.	6.	56.	-199.	53.	-1.
	9	0.	-2.	-56.	110.	-53.	0.
13	10	-845.	1801.	498.	-759.	58.	-833.
	11	881.	-1801.	-498.	-1189.	-58.	-2540.
14	12	498.	891.	1801.	406.	-1190.	649.
	11	-498.	-881.	-1801.	-2540.	1190.	-58.
15	21	12.	-3.	-1.	-40.	-3.	43.
	13	-12.	3.	-29.	-16.	3.	5.
16	13	13.	-29.	-3.	17.	5.	-4.
	14	-13.	65.	3.	-1.	-5.	66.
17	19	12.	-65.	-3.	1.	-6.	160.
	20	-12.	89.	3.	10.	6.	-119.

TYPE	JNT. NO.	. . . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	8	1801.	891.	-499.	-649.	1191.	406.
BODY	12	-1801.	891.	498.	-649.	-1190.	406.
A +X+Y	12	-1801.	881.	498.	-649.	-1189.	406.
B +X-Y	8	1801.	880.	-499.	-649.	1191.	406.
C -X+Y	23	-0.	-1638.	-0.	-3436.	-2.	-7812.

REACTION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

ELT. NO.	JNT. NO.	ELEMENT FORCES F1	F2	F3	ELEMENT MOMENTS M1	M2	M3
1	21	-1.	-111.	-3.	34.	13.	-289.
	22	1.	120.	3.	-23.	-13.	287.
2	23	1423.	-131.	-220.	364.	4688.	499.
	3	-1423.	132.	220.	-130.	-4688.	1009.
3	3	-137.	293.	-1763.	6080.	-206.	-388.
	10	140.	-293.	1763.	-2501.	206.	106.
4	3	-341.	5.	72.	-258.	-1393.	-1215.
	4	341.	5.	-72.	-258.	1393.	-1216.
5	4	1424.	132.	-221.	-130.	4682.	1007.
	24	-1424.	-131.	221.	364.	-4682.	502.
6	4	137.	-293.	-1764.	6075.	-207.	388.
	5	-140.	293.	1764.	-2495.	207.	-106.
7	5	-0.	-1.	9.	-33.	-188.	-2.
	6	0.	1.	-9.	18.	188.	1.
8	5	142.	-302.	-1764.	2682.	-206.	139.
	7	-148.	302.	1764.	4215.	206.	426.
9	8	1764.	-149.	302.	68.	4216.	2297.
	7	-1764.	148.	-302.	-426.	-4216.	-206.
10	15	0.	0.	-32.	63.	-40.	1.
	17	-0.	0.	32.	63.	40.	1.
11	16	0.	0.	41.	-81.	-40.	1.
	18	-0.	0.	-41.	-81.	40.	1.
12	10	1.	1.	9.	-33.	-188.	2.
	9	-1.	-0.	-9.	18.	188.	-1.
13	10	-142.	302.	-1763.	2686.	-205.	-140.
	11	148.	-302.	1763.	4208.	205.	-426.
14	12	-1763.	149.	302.	68.	4209.	-2295.
	11	1763.	-148.	-302.	-426.	-4209.	206.
15	21	3.	-1.	-0.	-7.	-1.	11.
	13	-3.	1.	-5.	-3.	1.	1.
16	13	1.	-5.	-1.	3.	1.	4.
	14	-1.	11.	1.	-0.	-1.	2.
17	19	2.	-12.	-1.	0.	-1.	36.
	20	-2.	16.	1.	2.	1.	-28.

TYPE	JNT. NO.	BOUNDARY OR JUNCTION REACTION FX	FY	FZ	MX	MY	MZ
BODY	8	302.	149.	1764.	2297.	-4216.	68.
BODY	12	-302.	149.	-1763.	2295.	4209.	68.
A +X+Y	12	-302.	148.	-1763.	2294.	4208.	68.
B +X-Y	8	302.	148.	1764.	2296.	-4215.	68.
C -X+Y	23	0.	-274.	-1.	12163.	5.	-1312.

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	-0.006674	-0.004212	-0.038737	-0.001345	0.002103	-0.000000
2	-0.002512	-0.001586	-0.017161	-0.001323	0.002093	0.000000
3	0.000000	0.000002	-0.013739	-0.001324	0.002041	0.000000
4	-0.000000	0.000002	-0.004345	-0.001322	0.000986	0.000000
5	-0.000000	0.000001	-0.002841	-0.000869	0.000975	0.000000
6	-0.000000	0.000001	-0.004237	-0.000870	0.001221	0.000000
7	-0.000000	0.000000	0.000009	-0.000000	0.000959	0.000000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000000	0.000001	-0.007651	-0.000871	0.001794	-0.000000
10	0.000000	0.000001	-0.009049	-0.000872	0.002040	0.000000
11	0.000000	0.000000	-0.000046	0.000002	0.002020	0.000000
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.007326	-0.004652	-0.036276	-0.001333	0.002101	-0.000007
14	-0.007342	-0.004652	-0.029676	-0.001330	0.002098	-0.000001
15	-0.002619	-0.001271	-0.007651	-0.000871	0.001794	-0.000000
16	0.002620	0.001273	-0.007651	-0.000871	0.001794	-0.000000
17	-0.001783	-0.001269	-0.004237	-0.000870	0.001221	0.000000
18	0.001782	0.001271	-0.004237	-0.000870	0.001221	0.000000
19	0.000000	0.000002	-0.029676	-0.001330	0.002098	-0.000001
20	0.000000	0.000002	-0.025283	-0.001323	0.002093	0.000000
21	-0.007326	-0.004628	-0.027883	-0.001345	0.002103	-0.000000
22	-0.007327	-0.004628	-0.023841	-0.001323	0.002093	0.000000
23	0.000000	0.000002	-0.015175	-0.001323	0.002093	0.000000
24	0.000000	0.000002	-0.002938	-0.001323	0.002093	0.000000

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.002621	-0.000358	0.005174	-0.000000	-0.000547	-0.000062
2	0.000888	-0.000197	0.003773	-0.000000	-0.000549	-0.000038
3	0.000289	-0.000053	0.001717	-0.000000	-0.000292	-0.000026
4	0.000098	-0.000057	0.001719	-0.000000	-0.000293	-0.000034
5	0.000101	-0.000017	0.001127	-0.000000	-0.000290	-0.000040
6	0.002828	-0.000015	0.001127	-0.000000	-0.000290	-0.002165
7	0.000077	0.000003	-0.000000	-0.000000	-0.000286	-0.000024
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.002933	-0.000003	0.001126	-0.000000	-0.000290	0.002119
10	0.000269	-0.000000	0.001126	-0.000000	-0.000290	0.000008
11	0.000200	-0.000003	-0.000000	0.000000	-0.000286	0.000047
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.002553	-0.000348	0.005895	-0.000001	-0.000547	-0.000028
14	0.002362	-0.000347	0.005900	-0.000001	-0.000562	-0.000052
15	0.003356	-0.000003	0.001126	-0.000000	-0.000290	0.002119
16	0.002509	-0.000002	0.001126	-0.000000	-0.000290	0.002119
17	0.003252	-0.000015	0.001127	-0.000000	-0.000290	-0.002165
18	0.002404	-0.000014	0.001127	-0.000000	-0.000290	-0.002165
19	0.000395	-0.000344	0.005900	-0.000001	-0.000562	-0.000052
20	0.000230	-0.000344	0.005902	-0.000000	-0.000549	-0.000038
21	0.002552	-0.000193	0.003706	-0.000000	-0.000547	-0.000062
22	0.002348	-0.000193	0.003706	-0.000000	-0.000549	-0.000038
23	0.000397	-0.000055	0.001717	-0.000000	-0.000549	-0.000038
24	0.000047	-0.000055	0.001719	-0.000000	-0.000549	-0.000038

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.000697	-0.005323	-0.007309	-0.000593	0.000000	-0.000064
2	0.000010	-0.003962	-0.000117	-0.000594	-0.000000	-0.000050
3	-0.000091	-0.003054	-0.002109	-0.000594	0.000237	-0.000446
4	0.000091	-0.003054	0.002111	-0.000594	-0.000237	-0.000446
5	0.000112	-0.002027	0.001395	-0.000391	-0.000239	-0.000487
6	0.000474	-0.002027	0.000768	-0.000391	-0.000129	-0.000017
7	0.000155	-0.000007	0.000012	0.000000	-0.000239	-0.000442
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.000474	-0.002027	-0.000766	-0.000391	0.000129	-0.000017
10	-0.000112	-0.002027	-0.001394	-0.000391	0.000239	-0.000487
11	-0.000155	-0.000007	-0.000012	0.000000	0.000238	-0.000442
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.000448	-0.005532	-0.005015	-0.000595	0.000000	-0.000044
14	0.000198	-0.005530	-0.002077	-0.000595	-0.000004	-0.000054
15	-0.000662	-0.002598	-0.000766	-0.000391	0.000129	-0.000017
16	-0.000286	-0.001456	-0.000766	-0.000391	0.000129	-0.000017
17	0.000662	-0.002598	0.000768	-0.000391	-0.000129	-0.000017
18	0.000285	-0.001456	0.000768	-0.000391	-0.000129	-0.000017
19	0.000185	-0.003447	-0.002077	-0.000595	-0.000004	-0.000054
20	0.000010	-0.003445	-0.000116	-0.000594	-0.000000	-0.000050
21	0.000448	-0.005334	-0.005013	-0.000593	0.000000	-0.000064
22	0.000276	-0.005323	-0.003231	-0.000594	-0.000000	-0.000050
23	0.000234	-0.003060	-0.002748	-0.000594	-0.000000	-0.000050
24	-0.000234	-0.003060	0.002750	-0.000594	-0.000000	-0.000050

DEFORMATION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

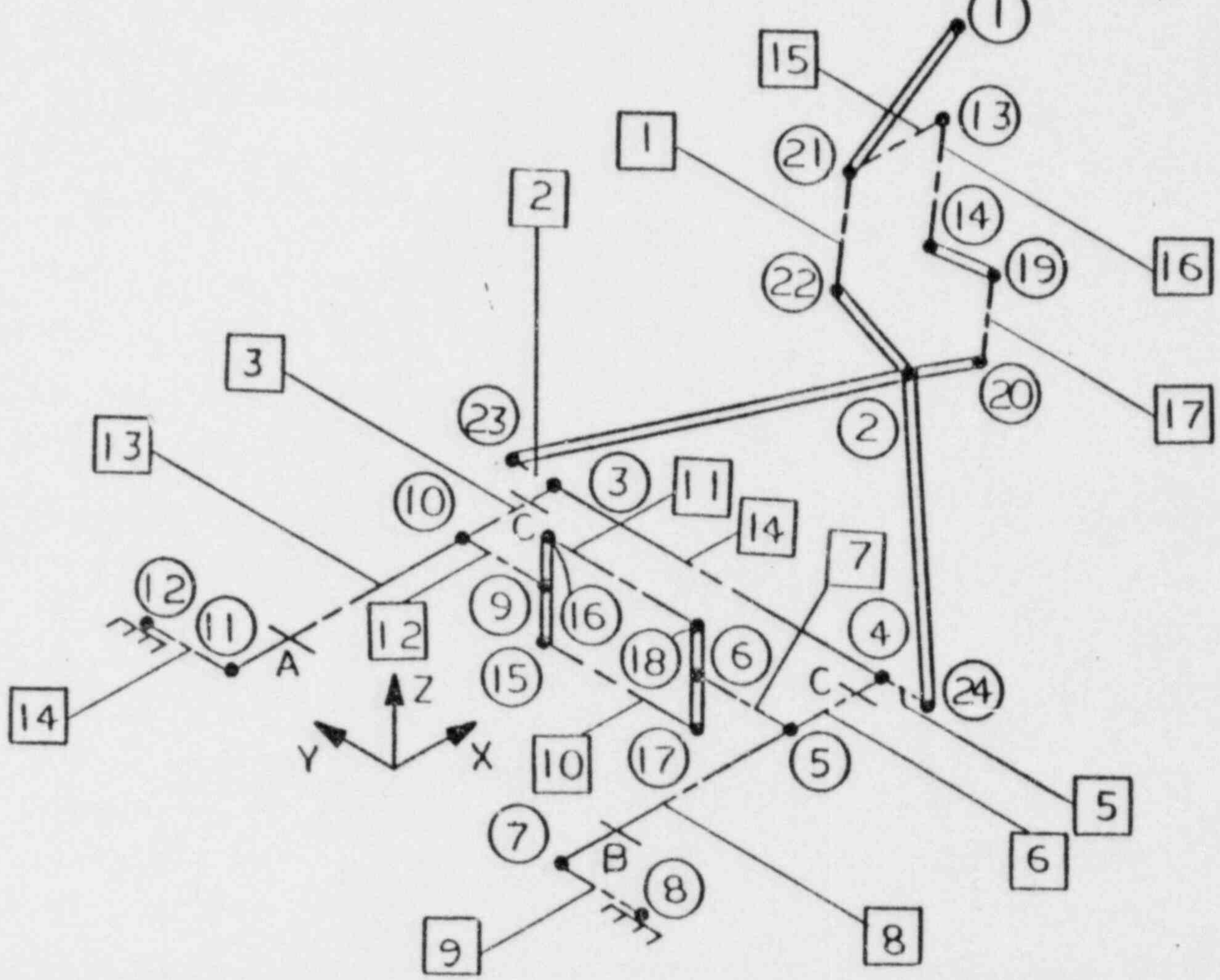
JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.000113	0.006134	0.025881	0.002103	0.000001	-0.000011
2	0.000000	0.001979	0.000412	0.002103	0.000001	-0.000008
3	-0.000015	-0.000512	0.007462	0.002103	-0.000838	-0.000075
4	0.000015	-0.000512	-0.007470	0.002103	0.000840	-0.000075
5	0.000019	-0.000340	-0.004937	0.001384	0.000846	-0.000082
6	0.000079	-0.000340	-0.002716	0.001384	0.000456	-0.000003
7	0.000026	-0.000001	-0.000044	-0.000001	0.000844	-0.000074
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.000079	-0.000340	0.002711	0.001384	-0.000455	-0.000003
10	-0.000019	-0.000340	0.004932	0.001384	-0.000845	-0.000082
11	-0.000026	-0.000001	0.000044	-0.000001	-0.000843	-0.000074
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.000071	0.006782	0.017735	0.002103	0.000001	-0.000007
14	0.000029	0.006782	0.007347	0.002103	0.000001	-0.000009
15	0.000585	0.001681	0.002711	0.001384	-0.000455	-0.000003
16	-0.000744	-0.002360	0.002711	0.001384	-0.000455	-0.000003
17	-0.000587	0.001681	-0.002716	0.001384	0.000456	-0.000003
18	0.000746	-0.002360	-0.002716	0.001384	0.000456	-0.000003
19	0.000031	-0.000578	0.007347	0.002103	0.000001	-0.000009
20	0.000002	-0.000577	0.000408	0.002103	0.000001	-0.000008
21	0.000071	0.006815	0.017741	0.002103	0.000001	-0.000011
22	0.000042	0.006817	0.011432	0.002103	0.000001	-0.000008
23	0.000039	-0.000513	0.009722	0.002103	0.000001	-0.000008
24	-0.000039	-0.000513	-0.009730	0.002103	0.000001	-0.000008

E V A L U A T I O N O F V A L V E

DEFORMATION RESPONSE OF COMBINED STATIC SEISMIC AND OPERATIONAL LOADS

JOINT	. . .DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.007317	0.012931	0.065640	0.003573	0.002174	-0.000100
2	0.002669	0.006251	0.017983	0.003553	0.002165	-0.000072
3	-0.000318	-0.003567	0.021468	0.003553	-0.002914	-0.000521
4	0.000149	-0.003567	-0.012598	0.003552	0.001895	-0.000522
5	0.000170	-0.002367	-0.008297	0.002337	0.001892	-0.000570
6	0.002947	-0.002367	-0.007167	0.002338	0.001718	-0.002168
7	0.000199	-0.000009	-0.000059	-0.000002	0.001873	-0.000516
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.003050	-0.002367	0.010482	0.002339	-0.002277	-0.002122
10	-0.000311	-0.002367	0.014157	0.002339	-0.002919	-0.000568
11	-0.000279	-0.000009	0.000091	-0.000004	-0.002897	-0.000518
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.007842	0.014018	0.054827	0.003563	0.002172	-0.000060
14	0.007744	0.014017	0.037675	0.003560	0.002172	-0.000084
15	0.004894	0.004573	0.010482	0.002339	-0.002277	-0.002122
16	-0.004383	-0.004294	0.010482	0.002339	-0.002277	-0.002122
17	-0.004354	0.004573	-0.007167	0.002338	0.001718	-0.002168
18	0.003752	-0.004293	-0.007167	0.002338	0.001718	-0.002168
19	0.000467	-0.004042	0.037675	0.003560	0.002172	-0.000084
20	0.000231	-0.004039	0.026371	0.003553	0.002165	-0.000072
21	0.007842	0.013880	0.046312	0.003573	0.002174	-0.000100
22	0.007741	0.013873	0.035775	0.003553	0.002165	-0.000072
23	0.000500	-0.003573	0.025239	0.003553	0.002165	-0.000072
24	-0.000277	-0.003573	-0.014106	0.003553	0.002165	-0.000072

APPENDIX C



5A094-07
5A095-07

FISHER CONTROLS COMPANY

SEISMIC-4

SEISMIC ANALYSIS

OF

ROTARY VALVES

MATERIAL PROPERTY INPUT DATA

MAT. NO.	DESCRIPTION	YOUNG'S MOD/10(6)	POISSON'S RATIO	MASS DENS/10(-4)	ALLOWABLE STRESS/10(3)
1	STEEL	30.000	0.283	7.240	27.000
2	BOLTING	30.000	0.283	7.240	82.800
3	ADAPTER	15.000	0.300	6.750	15.000

SARGENT AND LUNDY ENGINEERS
COMMONWEALTH EDISON COMPANY

CC NO 5A094
5A095

VALVE SIZE 26 VALVE TYPE 9220

ACTUATOR LIMITORQUE SMB-000-2/H18C

CUSTOMER ORDER NO 181104

CUSTOMER TAG NO 1VQ031
2VQ031

CERTIFIED DRAWING NO G269218

CROSS SECTION DRAWING NO F429278

BRACKET DRAWING NO G34252A

DATE OF THIS REPORT / JUNE 5, 1978 DA

C O N T R O L I N P U T D A T A

MANUAL INPUT GENERATION FOR VALVE ANALYSIS

SEISMIC STRESSES ARE SUPERIMPOSED BY SQUARE ROOT OF SUM OF SQUARES

STRESS ALLOWABLES ARE COMPARED TO MAXIMUM PRINCIPAL STRESS

MASS, STIFFNESS, LOAD AND STRESS MATRICES ARE NOT PRINTED

STATIC SEISMIC ANALYSIS TO BE PERFORMED

OPERATIONAL LOAD ANALYSIS TO BE PERFORMED

DYNAMIC MODAL ANALYSIS TO BE PERFORMED WITH EVALUATION

C R O S S - S E C T I O N D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS
1	TUBE	A = 4.875 , T = 1.060 ,
2	RECTANGULAR	A = 9.000 , T = .5600 ,

C R O S S - S E C T I O N   D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS					
3	CHANNEL	A =	8.000 ,	T =	.4870 ,	B =	2.530 ,
		T1=	.3900 ,	R1=	.3200 ,		
4	RECTANGULAR	A =	9.000 ,	T =	.5600 ,		
5	RECTANGULAR	A =	9.000 ,	T =	.5600 ,		
6	CHANNEL	A =	8.000 ,	T =	.4870 ,	B =	2.530 ,
		T1=	.3900 ,	R1=	.3200 ,		
7	RECTANGULAR	A =	4.000 ,	T =	.3750 ,		
8	CHANNEL	A =	8.000 ,	T =	.4870 ,	B =	2.530 ,
		T1=	.3900 ,	R1=	.3200 ,		
9	RECTANGULAR	A =	9.000 ,	T =	.5600 ,		
10	RECTANGULAR	A =	1.080 ,	T =	.3750 ,		
11	RECTANGULAR	A =	1.080 ,	T =	.3750 ,		
12	RECTANGULAR	A =	4.000 ,	T =	.3750 ,		
13	CHANNEL	A =	8.000 ,	T =	.4870 ,	B =	2.530 ,
		T1=	.3900 ,	R1=	.3200 ,		
14	RECTANGULAR	A =	9.000 ,	T =	.5600 ,		
15	RECTANGULAR	A =	7.000 ,	T =	.6250 ,		
16	RECTANGULAR	A =	7.000 ,	T =	.6250 ,		
17	RECTANGULAR	A =	7.000 ,	T =	.6250 ,		

JOINT COORDINATE DATA

JOINT NO.	X	Y	Z
1	12.250000	3.190000	12.312000
2	12.250000	1.200000	0.200000
3	5.940000	3.565000	0.0
4	5.940000	-3.565000	0.0
5	3.910000	-3.565000	0.0
6	3.910000	-1.960000	0.0
7	0.0	-3.565000	0.0
8	0.0	-4.750000	0.0
9	3.910000	1.960000	0.0
10	3.910000	3.565000	0.0
11	0.0	3.565000	0.0
12	0.0	4.750000	0.0
13	13.565000	3.500000	8.440000
14	13.565000	3.500000	3.500000
15	3.910000	1.960000	-1.460000
16	3.910000	1.960000	1.460000
17	3.910000	-1.960000	-1.460000
18	3.910000	-1.960000	1.460000
19	13.565000	0.0	3.500000
20	13.565000	0.0	0.200000
21	9.565000	3.500000	8.440000
22	9.565000	3.500000	5.440000
23	5.940000	4.625000	0.0
24	5.940000	-4.625000	0.0

B O U N D A R Y, S P R I N G & B O L T J O I N T, D A T A

JOINT NO.	TYPE-MAT /FIXITY	PLANE-DIRECTION OR DESCRIPTION		SPRING & BOLT JOINT PARAMETERS					
8	111111	BODY							
12	111111	BODY							
12	LEG 2	A	+X +Y	N.T=	2.10	.D/A=	0.7500,	YE=	1.1250
				YO=	9.5000,	YSH=	0.0 .	S=	2.7500
				ZT=	1.6250,	ZB=	1.6250,	ZSH=	0.0
8	LEG 2	B	+X -Y	N.T=	2.10	.D/A=	0.7500,	YE=	1.1250
				YO=	9.5000,	YSH=	0.0 .	S=	2.7500
				ZT=	1.6250,	ZB=	1.6250,	ZSH=	0.0
23	PAD 2	C	-X +Y	N.T=	2.11	.D/A=	0.6250,	YE=	0.6900
				YO=	9.2500,	YSH=	0.0 .	S=	3.8000
				ZT=	1.4000,	ZB=	1.4000,	ZSH=	0.0

C O N C E N T R A T E D M A S S D A T A

JOINT NO.	LUMPED MASS	FOR DIR.	SHIFT DISTANCE OR MOMENT OF INERTIA X	Y	Z
1	0.284679	XYZ	0.0	0.0	0.0
2	0.323499	XYZ	0.0	0.0	0.0
6	0.646998	X	0.0	0.0	0.0
9	0.646998	X	0.0	0.0	0.0

C O N C E N T R A T E D L O A D D A T A

JOINT NO.	. . . . FORCES. . . . X	Y	Z	. . . .MOMENTS. . . . X	Y	Z
2	0.0	0.0	0.0	12750.0	0.0	0.0

E L E M E N T   I N P U T   D A T A

EL. NO.	JOINTS		LENGTH /RADIUS	ANGLE	AREA	MOMENTS OF INERTIA I-11	I-22	I-33	MATERIAL DESCRIPTION
1	21	22	3.000		12.7043	24.8969	49.7939	24.8969	ADAPTER
2	23	3	1.060		5.0400	0.1317	0.5062	34.0200	STEEL
3	3	10	2.030		5.4895	43.8702	0.3899	2.4406	STEEL
4	3	4	7.130		5.0400	0.1317	0.5062	34.0200	STEEL
5	4	24	1.060		5.0400	0.1317	0.5062	34.0200	STEEL
6	4	5	2.030		5.4895	43.8702	0.3899	2.4406	STEEL
7	5	6	1.605		1.5000	0.0176	0.0662	2.0000	STEEL
8	5	7	3.910		5.4895	43.8702	0.3899	2.4406	STEEL
9	8	7	1.185		5.0400	0.1317	0.5062	34.0200	STEEL
10	15	17	3.920		0.4050	0.0047	0.0148	0.0394	STEEL
11	16	18	3.920		0.4050	0.0047	0.0148	0.0394	STEEL
12	10	9	1.605		1.5000	0.0176	0.0662	2.0000	STEEL
13	10	11	3.910		5.4895	43.8702	0.3899	2.4406	STEEL
14	12	11	1.185		5.0400	0.1317	0.5062	34.0200	STEEL
15	21	13	4.000		4.3750	0.1424	0.5376	17.8646	STEEL
16	13	14	4.940		4.3750	0.1424	0.5376	17.8646	STEEL
17	19	20	3.300		4.3750	0.1424	0.5376	17.8646	STEEL
	23	2			RIGID LINK				
	24	2			RIGID LINK				
	15	9			RIGID LINK				
	16	9			RIGID LINK				
	17	6			RIGID LINK				
	18	6			RIGID LINK				
	22	2			RIGID LINK				
	20	2			RIGID LINK				
	19	14			RIGID LINK				
	21	1			RIGID LINK				

S T A T I C   A N A L Y S I S

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM X DIR.

JOINT NO.	. . .DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.003690	-0.000025	-0.002772	0.000000	0.000297	-0.000003
2	0.000106	-0.000022	-0.002760	0.000000	0.000292	-0.000003
3	0.000046	-0.000004	-0.000914	0.000000	0.000156	-0.000001
4	0.000032	-0.000005	-0.000916	0.000000	0.000156	-0.000003
5	0.000031	-0.000002	-0.000601	0.000000	0.000155	-0.000006
6	0.000572	-0.000002	-0.000600	0.000000	0.000155	-0.000430
7	0.000023	0.000001	0.000000	0.000000	0.000152	-0.000006
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000580	0.000001	-0.000600	0.000000	0.000155	0.000427
10	0.000043	0.000001	-0.000600	0.000000	0.000155	0.000004
11	0.000032	-0.000001	0.000000	-0.000000	0.000152	0.000008
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.002540	-0.000027	-0.003144	0.000000	0.000290	-0.000003
14	0.001095	-0.000026	-0.003144	0.000000	0.000295	-0.000006
15	0.000354	0.000001	-0.000600	0.000000	0.000155	0.000427
16	0.000806	0.000000	-0.000600	0.000000	0.000155	0.000427
17	0.000346	-0.000002	-0.000600	0.000000	0.000155	-0.000430
18	0.000798	-0.000002	-0.000600	0.000000	0.000155	-0.000430
19	0.001076	-0.000026	-0.003145	0.000000	0.000295	-0.000006
20	0.000103	-0.000026	-0.003145	0.000000	0.000292	-0.000003
21	0.002540	-0.000017	-0.001974	0.000000	0.000297	-0.000003
22	0.001645	-0.000016	-0.001974	0.000000	0.000292	-0.000003
23	0.000057	-0.000004	-0.000914	0.000000	0.000292	-0.000003
24	0.000031	-0.000004	-0.000916	0.000000	0.000292	-0.000003

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE, SYSTEM Y DIR.

POINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.000034	0.003872	-0.000841	-0.000269	-0.000000	0.000012
2	-0.000012	0.000629	-0.000315	-0.000265	-0.000000	0.000010
3	0.000011	0.000512	-0.000939	-0.000265	0.000105	0.000076
4	-0.000011	0.000512	0.000941	-0.000265	-0.000106	0.000076
5	-0.000015	0.000338	0.000622	-0.000174	-0.000107	0.000082
6	-0.000077	0.000338	0.000342	-0.000174	-0.000058	0.000004
7	-0.000023	0.000001	0.000005	0.000000	-0.000106	0.000073
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000077	0.000338	-0.000341	-0.000174	0.000057	0.000004
10	0.000015	0.000338	-0.000621	-0.000174	0.000106	0.000082
11	0.000023	0.000001	-0.000005	0.000000	0.000106	0.000073
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.000037	0.002841	-0.000928	-0.000267	0.000001	0.000011
14	-0.000039	0.001521	-0.000928	-0.000266	-0.000000	0.000011
15	-0.000007	0.000084	-0.000341	-0.000174	0.000057	0.000004
16	0.000160	0.000593	-0.000341	-0.000174	0.000057	0.000004
17	0.000007	0.000084	0.000342	-0.000174	-0.000058	0.000004
18	-0.000161	0.000593	0.000342	-0.000174	-0.000058	0.000004
19	-0.000001	0.001521	0.000003	-0.000266	-0.000000	0.000011
20	-0.000000	0.000642	0.000003	-0.000265	-0.000000	0.000010
21	-0.000037	0.002797	-0.000925	-0.000269	-0.000000	0.000012
22	-0.000036	0.001989	-0.000925	-0.000265	-0.000000	0.000010
23	-0.000046	0.000513	-0.001223	-0.000265	-0.000000	0.000010
24	0.000046	0.000513	0.001225	-0.000265	-0.000000	0.000010

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Z DIR.

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.005906	-0.001214	0.005342	0.000098	-0.000481	-0.000000
2	-0.000096	-0.000020	0.005138	0.000099	-0.000479	-0.000000
3	0.000000	0.000000	0.002346	0.000099	-0.000374	0.000000
4	-0.000000	0.000000	0.001646	0.000098	-0.000295	0.000000
5	-0.000000	0.000000	0.001081	0.000065	-0.000294	0.000000
6	-0.000000	0.000000	0.001185	0.000065	-0.000312	-0.000000
7	-0.000000	0.000000	0.000002	0.000000	-0.000290	0.000000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000000	0.000000	0.001439	0.000065	-0.000355	-0.000000
10	0.000000	0.000000	0.001543	0.000065	-0.000373	0.000000
11	0.000000	0.000000	0.000006	-0.000000	-0.000369	0.000000
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.004044	-0.000833	0.005995	0.000099	-0.000476	-0.000000
14	-0.001679	-0.000345	0.005995	0.000099	-0.000479	0.000001
15	0.000518	0.000095	0.001439	0.000065	-0.000355	-0.000000
16	-0.000518	-0.000095	0.001439	0.000065	-0.000355	-0.000000
17	0.000455	0.000095	0.001185	0.000065	-0.000312	-0.000000
18	-0.000455	-0.000095	0.001185	0.000065	-0.000312	-0.000000
19	-0.001677	-0.000345	0.005649	0.000099	-0.000479	0.000001
20	-0.000096	-0.000020	0.005649	0.000099	-0.000479	-0.000000
21	-0.004044	-0.000832	0.004081	0.000098	-0.000481	-0.000000
22	-0.002604	-0.000537	0.004079	0.000099	-0.000479	-0.000000
23	0.000000	0.000000	0.002455	0.000099	-0.000479	-0.000000
24	-0.000000	0.000000	0.001543	0.000099	-0.000479	-0.000000

DEFORMATION RESPONSE TO OPERATIONAL LOADS (NOT INCLUDING DEADWEIGHT)

POINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.000027	-0.027102	0.007001	0.002201	0.000002	0.000000
2	0.000000	-0.000440	0.002620	0.002201	0.000002	0.000000
3	0.000000	0.000001	0.007808	0.002201	-0.000877	0.000000
4	-0.000000	0.000001	-0.007823	0.002201	0.000880	0.000000
5	-0.000000	0.000000	-0.005170	0.001449	0.000887	0.000000
6	-0.000000	0.000000	-0.002845	0.001449	0.000478	0.000000
7	-0.000000	0.000000	-0.000046	-0.000002	0.000884	0.000000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000000	0.000000	0.002835	0.001449	-0.000476	-0.000000
10	0.000000	0.000000	0.005160	0.001449	-0.000864	0.000000
11	0.000000	0.000000	0.000046	-0.000002	-0.000882	0.000000
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.000019	-0.018579	0.007680	0.002201	0.000002	0.000000
14	0.000008	-0.007704	0.007680	0.002201	0.000002	0.000000
15	0.000695	0.002116	0.002835	0.001449	-0.000476	-0.000000
16	-0.000695	-0.002115	0.002835	0.001449	-0.000476	-0.000000
17	-0.000699	0.002116	-0.002845	0.001449	0.000478	0.000000
18	0.000698	-0.002115	-0.002845	0.001449	0.000478	0.000000
19	0.000008	-0.007704	-0.000025	0.002201	0.000002	0.000000
20	0.000000	-0.000440	-0.000025	0.002201	0.000002	0.000000
21	0.000019	-0.018579	0.007689	0.002201	0.000002	0.000000
22	0.000012	-0.011975	0.007689	0.002201	0.000002	0.000000
23	-0.000000	0.000001	0.010174	0.002201	0.000002	0.000000
24	0.000000	0.000001	-0.010189	0.002201	0.000002	0.000000

D Y N A M I C   A N A L Y S I S

RESONANT FREQUENCY = 34.3 HERTZ (IN Z-DIRECTION OR Y-ROTATION)

* * * * NORMALIZED EIGENVECTOR * * * *

JOINT NO.	. . .DEFLECTION X	. . . Y	Z	. . . ROTATION X	. . . Y	Z
1	-1.000000	-0.205623	0.863363	0.016333	-0.081444	0.000024
2	-0.017469	-0.007917	0.828721	0.016250	-0.080642	0.000114
3	-0.001491	-0.005376	0.357777	0.016264	-0.057084	-0.000551
4	-0.000097	-0.005381	0.242388	0.016232	-0.044115	-0.000781
5	-0.000028	-0.003615	0.158897	0.010699	-0.043784	-0.000853
6	0.000508	-0.003647	0.176070	0.010700	-0.046814	0.000088
7	0.000106	-0.000016	0.000004	0.000014	-0.043143	-0.000747
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.001909	-0.003788	0.217999	0.010706	-0.053861	0.000063
10	-0.001375	-0.003819	0.235182	0.010709	-0.056855	-0.000786
11	-0.001155	-0.000009	0.000679	-0.000037	-0.056180	-0.001021
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.684663	-0.142265	0.972462	0.016328	-0.080430	0.000036
14	-0.285635	-0.061554	0.972411	0.016314	-0.080997	0.000385
15	0.076727	0.011842	0.217999	0.010706	-0.053861	0.000063
16	-0.080546	-0.019419	0.217999	0.010706	-0.053861	0.000063
17	0.068857	0.011976	0.176070	0.010700	-0.046814	0.000088
18	-0.067841	-0.019269	0.176070	0.010700	-0.046814	0.000088
19	-0.284287	-0.061554	0.915314	0.016314	-0.080997	0.000385
20	-0.017332	-0.007767	0.915265	0.016250	-0.080642	0.000114
21	-0.684655	-0.142446	0.649748	0.016333	-0.081444	0.000024
22	-0.440294	-0.093373	0.649573	0.016250	-0.080642	0.000114
23	-0.001733	-0.005390	0.375528	0.016250	-0.080642	0.000114
24	-0.000674	-0.005390	0.225217	0.016250	-0.080642	0.000114

S T A T I C   S E I S M I C   A N A L Y S I S

THE VALVE AXIS IS POSITIONED Z-UP

ACCELERATION OF GRAVITY, G = 386.400

DIRECTION OF SEISMIC ACCELERATION	NO. OF G'S	COMPONENTS OF UNIT ACCELERATION IN VALVE COORDINATE SYSTEM X-COMP.	Y-COMP.	Z-COMP.
HORIZONTAL(1)	5.000	0.0	1.0000	0.0
HORIZONTAL(2)	5.000	1.0000	0.0	0.0
VERTICAL	6.000	0.0	0.0	-1.0000

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	1.	-7.	-424.	-2111.	918.	-22.
	22	-1.	7.	474.	3458.	-918.	25.
2	23	-894.	651.	1291.	-1906.	-2952.	-315.
	3	894.	-658.	-1291.	538.	2952.	-633.
3	3	683.	-1651.	1110.	-3828.	130.	1823.
	10	-698.	1651.	-1110.	1576.	-130.	-421.
4	3	214.	-25.	-360.	1284.	877.	764.
	4	-214.	-25.	360.	1284.	-877.	766.
5	4	-896.	-657.	1291.	538.	-2945.	-627.
	24	896.	650.	-1291.	-1906.	2945.	-322.
6	4	-683.	1651.	1110.	-3822.	131.	-1823.
	5	699.	-1651.	-1110.	1568.	-131.	421.
7	5	0.	6.	-46.	166.	118.	1.
	6	-0.	-2.	46.	-91.	-118.	-1.
8	5	-704.	1697.	1110.	-1686.	130.	-586.
	7	734.	-1697.	-1110.	-2654.	-130.	-2226.
9	8	-1110.	742.	-1697.	-214.	-2655.	-1446.
	7	1110.	-734.	1697.	2226.	2655.	130.
10	15	-0.	-1.	-0.	0.	25.	-0.
	17	0.	-1.	0.	0.	-25.	-0.
11	16	-0.	-1.	-46.	91.	25.	-0.
	18	0.	-1.	46.	91.	-25.	-0.
12	10	-0.	-5.	-46.	166.	118.	-1.
	9	0.	2.	46.	-91.	-118.	0.
13	10	704.	-1697.	1110.	-1692.	129.	586.
	11	-734.	1697.	-1110.	-2647.	-129.	2226.
14	12	1110.	-742.	-1697.	-215.	-2647.	1444.
	11	-1110.	734.	1697.	2226.	2647.	-129.
15	21	126.	1.	7.	-22.	18.	557.
	13	-150.	-1.	-7.	-8.	-18.	-5.
16	13	150.	7.	-1.	8.	4.	-16.
	14	-180.	-7.	1.	-3.	-4.	829.
17	19	181.	7.	-1.	3.	8.	-805.
	20	-201.	-7.	1.	1.	-8.	1434.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	8	-1697.	-742.	-1110.	-1446.	2655.	-214.
BODY	12	1697.	-742.	1110.	-1444.	-2647.	-215.
A +X+Y	12	1697.	-734.	1110.	-1444.	-2647.	-214.
B +X-Y	8	-1697.	-734.	-1110.	-1445.	2654.	-214.
C -X+Y	23	-0.	1366.	1.	-7657.	-6.	8126.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	592.	19.	4.	-2.	137.	-2053.
	22	-641.	-19.	-4.	-10.	-137.	3903.
2	23	3.	-277.	-997.	503.	3815.	3.
	3	-3.	277.	1005.	558.	-3815.	0.
3	3	-360.	1031.	-3.	3816.	-2.	528.
	10	360.	-1046.	3.	-3809.	2.	-1259.
4	3	-0.	82.	26.	-29.	-1.	-1.
	4	0.	-82.	24.	21.	1.	-0.
5	4	-1.	-277.	310.	-168.	-3809.	1.
	24	1.	277.	-302.	-156.	3809.	-3.
6	4	-360.	333.	0.	-3808.	1.	147.
	5	360.	-349.	-0.	3807.	-1.	-877.
7	5	0.	74.	-1256.	1704.	-0.	-0.
	6	-0.	-74.	1253.	309.	0.	0.
8	5	-433.	1605.	0.	-3808.	1.	-827.
	7	433.	-1635.	-0.	3807.	-1.	-868.
9	8	-0.	433.	-1643.	1075.	3807.	-1.
	7	0.	-433.	1635.	868.	-3807.	1.
10	15	0.	37.	1.	155.	-0.	0.
	17	-0.	-37.	1.	-155.	0.	0.
11	16	0.	37.	1.	155.	-0.	0.
	18	-0.	-37.	1.	-155.	0.	0.
12	10	-0.	74.	1255.	-1702.	-0.	-0.
	9	0.	-74.	-1252.	-310.	0.	-0.
13	10	-434.	2302.	-3.	3812.	-2.	-443.
	11	434.	-2332.	3.	-3802.	2.	-1252.
14	12	-2.	434.	2340.	-1516.	-3802.	-4.
	11	2.	-434.	-2332.	-1252.	3802.	2.
15	21	4.	42.	-19.	73.	-1.	34.
	13	-4.	-18.	19.	1.	1.	-19.
16	13	4.	-19.	-18.	-1.	19.	1.
	14	-4.	19.	-13.	14.	-19.	18.
17	19	4.	-18.	13.	-14.	-26.	-81.
	20	-4.	18.	-33.	-61.	26.	93.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	8	-1643.	-433.	-0.	-1.	-3807.	1075.
BODY	12	-2340.	434.	-2.	4.	-3802.	-1516.
A +X+Y	12	-2332.	434.	-3.	5.	-3802.	-1511.
B +X-Y	8	-1635.	-433.	-0.	-2.	-3807.	1070.
C -X+Y	23	1364.	-0.	4.	-7.	7624.	3442.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	-5.	-654.	-12.	200.	42.	-1726.
	22	5.	714.	12.	-165.	-42.	1711.
2	23	-1175.	-0.	1.	-0.	3507.	-1500.
	3	1183.	0.	-1.	-1.	-3507.	251.
3	3	-0.	-1.	1311.	3109.	910.	-1.
	10	0.	1.	-1330.	-5790.	-910.	0.
4	3	126.	0.	0.	-0.	392.	659.
	4	-66.	-0.	-0.	-0.	-392.	23.
5	4	383.	0.	0.	-0.	-6144.	-820.
	24	-375.	-0.	-0.	0.	6144.	1221.
6	4	0.	-0.	-320.	-6528.	-795.	0.
	5	-0.	0.	338.	7196.	795.	-0.
7	5	7.	-0.	0.	-0.	53.	31.
	6	-3.	0.	-0.	0.	-53.	-23.
8	5	0.	-0.	-345.	-7255.	-826.	0.
	7	-0.	0.	381.	8675.	826.	0.
9	8	391.	-0.	0.	0.	8677.	1284.
	7	-381.	0.	-0.	-0.	-8677.	-826.
10	15	1.	-7.	10.	-20.	11.	1.
	17	1.	7.	-10.	-20.	-11.	-1.
11	16	1.	7.	-10.	20.	11.	1.
	18	1.	-7.	10.	20.	-11.	-1.
12	10	7.	-0.	0.	-0.	53.	30.
	9	-2.	0.	-0.	0.	-53.	-23.
13	10	-0.	-1.	1338.	5746.	942.	-1.
	11	0.	1.	-1374.	-11047.	-942.	0.
14	12	1384.	0.	-1.	1.	-11049.	2576.
	11	-1374.	-0.	1.	0.	11049.	-942.
15	21	-12.	-3.	1.	40.	-3.	-43.
	13	12.	3.	29.	16.	3.	-5.
16	13	-13.	-29.	3.	-16.	5.	4.
	14	13.	65.	-3.	1.	-5.	-66.
17	19	-12.	-64.	3.	-1.	-6.	-158.
	20	12.	89.	-3.	-10.	6.	118.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	8	0.	0.	391.	1284.	-8677.	0.
BODY	12	1.	0.	1384.	-2576.	-11049.	1.
A +X+Y	12	1.	0.	1374.	-2569.	-11047.	1.
B +X-Y	8	0.	0.	381.	1278.	-8675.	0.
C -X+Y	23	-1.	-0.	-1631.	4123.	9637.	-1.

REACTION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	-1.	-110.	-3.	33.	12.	-288.
	22	1.	120.	3.	-24.	-12.	285.
2	23	1294.	0.	0.	-0.	5494.	274.
	3	-1293.	-0.	-0.	0.	-5494.	1098.
3	3	0.	-0.	-1628.	6886.	-65.	0.
	10	-0.	0.	1624.	-3585.	65.	-0.
4	3	-336.	-0.	-0.	0.	-1393.	-1162.
	4	346.	0.	0.	0.	1393.	-1269.
5	4	1555.	-0.	0.	0.	3875.	917.
	24	-1553.	0.	-0.	-0.	-3875.	730.
6	4	-0.	0.	-1899.	5269.	-349.	-0.
	5	0.	-0.	1902.	-1410.	349.	0.
7	5	1.	0.	-0.	0.	-188.	3.
	6	-0.	-0.	0.	-0.	188.	-3.
8	5	-0.	0.	-1904.	1595.	-353.	-0.
	7	0.	-0.	1910.	5861.	353.	-0.
9	6	1912.	0.	-0.	-0.	5862.	2618.
	7	-1910.	-0.	0.	0.	-5862.	-354.
10	15	0.	-1.	-37.	72.	-40.	1.
	17	-0.	1.	37.	72.	40.	0.
11	16	0.	1.	37.	-72.	-40.	1.
	18	-0.	-1.	-37.	-72.	40.	0.
12	10	2.	0.	-0.	0.	-188.	7.
	9	-1.	-0.	0.	-0.	188.	-5.
13	10	0.	-0.	-1623.	3772.	-58.	0.
	11	-0.	0.	1617.	2561.	58.	0.
14	12	-1615.	-0.	-0.	0.	2562.	-1973.
	11	1617.	0.	0.	1.	-2562.	58.
15	21	-3.	-1.	0.	7.	-1.	-10.
	13	3.	1.	5.	3.	1.	-1.
16	13	-1.	-5.	1.	-3.	1.	-3.
	14	1.	11.	-1.	0.	-1.	-3.
17	19	-2.	-11.	1.	-0.	-1.	-33.
	20	2.	15.	-1.	-2.	1.	25.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	8	-0.	-0.	1912.	2618.	-5862.	-0.
BODY	12	0.	-0.	-1615.	1973.	2562.	0.
A +X+Y	12	0.	-0.	-1617.	1974.	2561.	-0.
B +X-Y	8	-0.	-0.	1910.	2617.	-5861.	-0.
C -X+Y	23	-0.	0.	-272.	13417.	1617.	-0.

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	-0.000172	0.019358	-0.004203	-0.001346	-0.000001	0.000060
2	-0.000060	0.003143	-0.001575	-0.001323	-0.000001	0.000050
3	0.000056	0.002558	-0.004694	-0.001323	0.000527	0.000378
4	-0.000056	0.002558	0.004704	-0.001323	-0.000529	0.000378
5	-0.000076	0.001692	0.003109	-0.000871	-0.000533	0.000409
6	-0.000384	0.001692	0.001711	-0.000871	-0.000288	0.000019
7	-0.000116	0.000006	0.000027	0.000001	-0.000532	0.000366
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000384	0.001692	-0.001705	-0.000871	0.000286	0.000019
10	0.000076	0.001692	-0.003103	-0.000871	0.000531	0.000409
11	0.000116	0.000006	-0.000027	0.000001	0.000530	0.000366
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.000186	0.014207	-0.004641	-0.001334	0.000005	0.000057
14	-0.000194	0.007604	-0.004641	-0.001330	-0.000001	0.000054
15	-0.000034	0.000420	-0.001705	-0.000871	0.000286	0.000019
16	0.000802	0.002964	-0.001705	-0.000871	0.000286	0.000019
17	0.000036	0.000420	0.001711	-0.000871	-0.000288	0.000019
18	-0.000804	0.002964	0.001711	-0.000871	-0.000288	0.000019
19	-0.000005	0.007604	0.000015	-0.001330	-0.000001	0.000054
20	-0.000000	0.003209	0.000015	-0.001323	-0.000001	0.000050
21	-0.000186	0.013987	-0.004623	-0.001346	-0.000001	0.000060
22	-0.000182	0.009944	-0.004623	-0.001323	-0.000001	0.000050
23	-0.000232	0.002563	-0.006116	-0.001323	-0.000001	0.000050
24	0.000232	0.002563	0.006126	-0.001323	-0.000001	0.000050

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.018448	-0.000123	-0.013860	0.000001	0.001486	-0.000013
2	0.000531	-0.000110	-0.013799	0.000001	0.001462	-0.000014
3	0.000229	-0.000019	-0.004571	0.000001	0.000778	-0.000007
4	0.000158	-0.000023	-0.004581	0.000001	0.000780	-0.000016
5	0.000154	-0.000012	-0.003004	0.000001	0.000774	-0.000030
6	0.002861	-0.000009	-0.003002	0.000001	0.000773	-0.002151
7	0.000115	0.000003	0.000000	0.000000	0.000762	-0.000031
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.002900	0.000003	-0.002999	0.000001	0.000773	0.002134
10	0.000217	0.000005	-0.002998	0.000001	0.000773	0.000018
11	0.000162	-0.000003	0.000000	-0.000000	0.000761	0.000039
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.012700	-0.000136	-0.015721	0.000001	0.001452	-0.000013
14	0.005475	-0.000132	-0.015720	0.000001	0.001476	-0.000028
15	0.001771	0.000004	-0.002999	0.000001	0.000773	0.002134
16	0.004028	0.000001	-0.002999	0.000001	0.000773	0.002134
17	0.001732	-0.000008	-0.003002	0.000001	0.000773	-0.002151
18	0.003990	-0.000011	-0.003002	0.000001	0.000773	-0.002151
19	0.005379	-0.000132	-0.015723	0.000001	0.001476	-0.000028
20	0.000514	-0.000129	-0.015723	0.000001	0.001462	-0.000014
21	0.012700	-0.000084	-0.009870	0.000001	0.001486	-0.000013
22	0.008224	-0.000079	-0.009871	0.000001	0.001462	-0.000014
23	0.000287	-0.000021	-0.004570	0.000001	0.001462	-0.000014
24	0.000157	-0.000021	-0.004582	0.000001	0.001462	-0.000014

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.035437	0.007262	-0.032054	-0.000590	0.002866	0.000000
2	0.000574	0.000118	-0.030827	-0.000592	0.002872	0.000000
3	-0.000000	-0.000000	-0.014077	-0.000593	0.002244	-0.000000
4	0.000000	-0.000000	-0.009874	-0.000591	0.001772	-0.000000
5	0.000000	-0.000000	-0.006483	-0.000388	0.001761	-0.000000
6	0.000000	-0.000000	-0.007107	-0.000389	0.001871	0.000000
7	0.000000	-0.000000	-0.000010	-0.000001	0.001737	-0.000000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.000000	-0.000000	-0.008634	-0.000390	0.002127	0.000000
10	-0.000000	-0.000000	-0.009261	-0.000391	0.002237	-0.000000
11	-0.000000	-0.000000	-0.000035	0.000002	0.002214	-0.000000
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.024262	0.004998	-0.035973	-0.000592	0.002866	0.000001
14	0.010073	0.002072	-0.035971	-0.000593	0.002876	-0.000003
15	-0.003106	-0.000570	-0.008634	-0.000390	0.002127	0.000000
16	0.003106	0.000570	-0.008634	-0.000390	0.002127	0.000000
17	-0.002731	-0.000568	-0.007107	-0.000389	0.001871	0.000000
18	0.002732	0.000567	-0.007107	-0.000389	0.001871	0.000000
19	0.010061	0.002072	-0.033896	-0.000593	0.002876	-0.000003
20	0.000574	0.000118	-0.033894	-0.000592	0.002872	0.000000
21	0.024262	0.004994	-0.024488	-0.000590	0.002886	0.000000
22	0.015625	0.003220	-0.024477	-0.000592	0.002872	0.000000
23	-0.000000	-0.000000	-0.014731	-0.000592	0.002872	0.000000
24	0.000000	-0.000000	-0.009256	-0.000592	0.002872	0.000000

DEFORMATION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.005934	-0.025689	0.001658	0.002103	0.000483	0.000000
2	0.000096	-0.000420	-0.002518	0.002103	0.000481	0.000000
3	0.000000	0.000001	0.005462	0.002102	-0.000503	0.000000
4	-0.000000	0.000001	-0.009469	0.002103	0.001175	0.000000
5	-0.000000	0.000000	-0.006251	0.001384	0.001180	0.000000
6	-0.000000	0.000000	-0.004030	0.001384	0.000790	0.000000
7	-0.000000	0.000000	-0.000047	-0.000002	0.001174	0.000000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000000	0.000000	0.001396	0.001384	-0.000121	0.000000
10	0.000000	0.000000	0.003617	0.001384	-0.000511	0.000000
11	0.000000	0.000000	0.000040	-0.000001	-0.000513	0.000000
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.004062	-0.017746	0.001685	0.002103	0.000480	0.000000
14	0.001686	-0.007359	0.001685	0.002103	0.000482	-0.000001
15	0.000177	0.002021	0.001396	0.001384	-0.000121	0.000000
16	-0.000177	-0.002020	0.001396	0.001384	-0.000121	0.000000
17	-0.001154	0.002021	-0.004030	0.001384	0.000790	0.000000
18	0.001154	-0.002020	-0.004030	0.001384	0.000790	0.000000
19	0.001685	-0.007359	-0.005674	0.002103	0.000482	-0.000001
20	0.000096	-0.000420	-0.005674	0.002103	0.000481	0.000000
21	0.004062	-0.017746	0.003608	0.002103	0.000483	0.000000
22	0.002616	-0.011438	0.003610	0.002103	0.000481	0.000000
23	-0.000000	0.000001	0.007719	0.002103	0.000481	0.000000
24	0.000000	0.000001	-0.011732	0.002103	0.000481	0.000000

EVALUATION OF VALVE

DEFORMATION RESPONSE OF COMBINED STATIC SEISMIC AND OPERATIONAL LOADS

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.045885	-0.046571	0.036832	0.003573	0.003729	0.000061
2	0.000681	-0.003567	-0.036329	0.003553	0.003704	0.000052
3	0.000236	0.002559	0.020990	0.003552	-0.002936	0.000378
4	-0.000168	0.002559	-0.021327	0.003552	0.003162	0.000378
5	-0.000172	0.001692	-0.014043	0.002338	0.003176	0.000410
6	-0.002886	0.001692	-0.011932	0.002338	0.002835	0.002151
7	-0.000164	0.000007	-0.000077	-0.000003	0.003144	0.000367
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.002925	0.001692	0.010694	0.002338	-0.002403	0.002134
10	0.000230	0.001692	0.013633	0.002338	-0.002937	0.000410
11	0.000199	0.000007	0.000084	-0.000003	-0.002912	0.000368
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.031448	-0.032807	0.041216	0.003562	0.003693	0.000059
14	0.013153	-0.015241	0.041214	0.003559	0.003714	-0.000061
15	0.003753	0.002729	0.010694	0.002338	-0.002403	0.002134
16	-0.005326	-0.005038	0.010694	0.002338	-0.002403	0.002134
17	-0.004388	0.002727	-0.011932	0.002338	0.002835	0.002151
18	0.006055	-0.005038	-0.011932	0.002338	0.002835	0.002151
19	0.013093	-0.015241	-0.043039	0.003559	0.003714	-0.000061
20	0.000867	-0.003634	-0.043037	0.003553	0.003704	0.000052
21	0.031448	-0.032599	0.030412	0.003573	0.003729	0.000061
22	0.020274	-0.021891	0.030404	0.003553	0.003704	0.000052
23	-0.000369	0.002563	0.024311	0.003553	0.003704	0.000052
24	0.000280	0.002563	-0.023739	0.003553	0.003704	0.000052

BEAM STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS

ELM NO.	JNT NO.	STRESS NO.	COORDINATES C1	C3/2	C	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE	FI JN
2	23	5	0.0	0.28	0.56	15.7	27.0	STEEL	0.58		2
3	3	10	-0.05	-3.49	0.77	3.3	27.0	STEEL	0.12		
4	3	5	0.0	0.28	0.56	4.4	27.0	STEEL	0.16		
5	24	5	0.0	0.28	0.56	15.7	27.0	STEEL	0.58		2
6	4	7	-0.05	3.49	0.77	3.5	27.0	STEEL	0.13		
7	5	6	0.0	-0.19	0.37	18.6	27.0	STEEL	0.69		
8	7	7	-0.05	3.49	0.77	3.6	27.0	STEEL	0.13		
9	7	5	0.0	0.28	0.56	20.8	27.0	STEEL	0.77		
10	15	6	0.0	-0.19	0.35	9.4	27.0	STEEL	0.35		1
11	16	6	0.0	-0.19	0.35	10.4	27.0	STEEL	0.38		1
12	10	5	0.0	0.19	0.37	18.5	27.0	STEEL	0.69		1
13	11	10	-0.05	-3.49	0.77	3.3	27.0	STEEL	0.12		1
14	11	6	0.0	-0.28	0.56	19.9	27.0	STEEL	0.74		1

BOLTED JOINT STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS
(N=NUMBER OF BOLTS. AREA=AREA PER BOLT)

BOLT JNT	JOINT LOC.	DESCRIPTION TYPE	N	AREA	BOLT NO.	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE	DI-
12	A	LEG	2	0.31	1	16.4	82.8	BOLTING	0.20		-
8	B	LEG	2	0.31	2	16.3	82.8	BOLTING	0.20		-
23	C	PAD	4	0.21	4	12.2	82.8	BOLTING	0.15		-

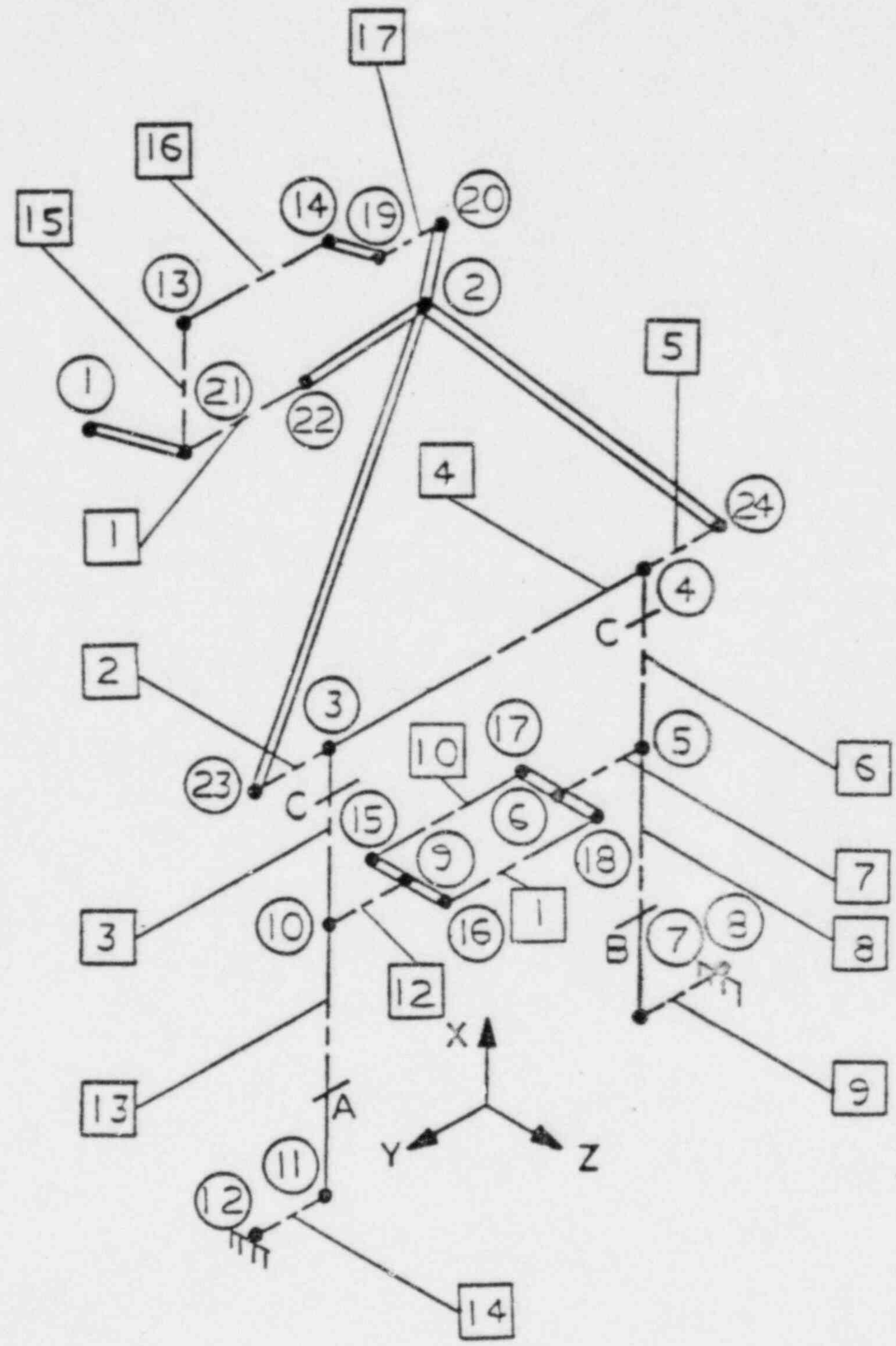
THIS EQUIPMENT IS ACCEPTABLE FOR THE SPECIFIED SEISMIC DISTURBANCE

THIS REPORT HAS BEEN PREPARED BY /

DAVE POPOVICH
Dave Popovich
FISHER CONTROLS COMPANY

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

APPENDIX D



5A094-01, 03, 05, 06, 08, 20
5A095-01, 03, 04, 05, 06, 08
09, 14, 15

FISHER CONTROLS COMPANY

SEISMIC-4

SEISMIC ANALYSIS

OF

ROTARY VALVES

MATERIAL PROPERTY INPUT DATA

MAT. NO.	DESCRIPTION	YOUNG'S MOD/10(6)	POISSON'S RATIO	MASS DENS/10(-4)	ALLOWABLE STRESS/10(3)
1	STEEL	30.000	0.283	7.240	27.000
2	BOLTING	30.000	0.283	7.240	82.800
3	ADAPTER	15.000	0.300	6.750	15.000

SARGENT AND LUNDY ENGINEERS
COMMONWEALTH EDISON COMPANY

CC NO 5A094
5A095

VALVE SIZE 26 VALVE TYPE 9220

ACTUATOR LIMITORQUE SMB-000-2/H1BC

CUSTOMER ORDER NO 181104

CUSTOMER TAG NO 1VQ026
1VQ027
1VQ029
1VQ030
1VQ034
1VQ037
1VQ038
2VQ026
2VQ027
2VQ029
2VQ030
2VQ034
2VQ036
2VQ037
2VQ038
2VQ041

CERTIFIED DRAWING NO G269198
G269208

CROSS SECTION DRAWING NO F429278
F429288

BRACKET DRAWING NO G34252A

DATE OF THIS REPORT / JUNE 5, 1978 DA

C O N T R O L   I N P U T   D A T A

MANUAL INPUT GENERATION FOR VALVE ANALYSIS

SEISMIC STRESSES ARE SUPERIMPOSED BY SQUARE ROOT OF SUM OF SQUARES

STRESS ALLOWABLES ARE COMPARED TO MAXIMUM PRINCIPAL STRESS

MASS, STIFFNESS, LOAD AND STRESS MATRICES ARE NOT PRINTED

STATIC SEISMIC ANALYSIS TO BE PERFORMED

OPERATIONAL LOAD ANALYSIS TO BE PERFORMED

DYNAMIC MODAL ANALYSIS TO BE PERFORMED WITH EVALUATION

C R O S S - S E C T I O N   D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS			
1	TUBE	A = 4.875 ,	T = 1.060 ,		
2	RECTANGULAR	A = 9.000 ,	T = .5600 ,		
3	CHANNEL	A = 8.000 ,	T = .4870 ,	B = 2.530 ,	
		T1= .3900 ,	R1= .3200 ,		
4	RECTANGULAR	A = 9.000 ,	T = .5600 ,		
5	RECTANGULAR	A = 9.000 ,	T = .5600 ,		
6	CHANNEL	A = 8.000 ,	T = .4870 ,	B = 2.530 ,	
		T1= .3900 ,	R1= .3200 ,		
7	RECTANGULAR	A = 4.000 ,	T = .3750 ,		
8	CHANNEL	A = 8.000 ,	T = .4870 ,	B = 2.530 ,	
		T1= .3900 ,	R1= .3200 ,		
9	RECTANGULAR	A = 9.000 ,	T = .5600 ,		
10	RECTANGULAR	A = 1.080 ,	T = .3750 ,		
11	RECTANGULAR	A = 1.080 ,	T = .3750 ,		
12	RECTANGULAR	A = 4.000 ,	T = .3750 ,		
13	CHANNEL	A = 8.000 ,	T = .4870 ,	B = 2.530 ,	
		T1= .3900 ,	R1= .3200 ,		
14	RECTANGULAR	A = 9.000 ,	T = .5600 ,		
15	RECTANGULAR	A = 7.000 ,	T = .6250 ,		
16	RECTANGULAR	A = 7.000 ,	T = .6250 ,		
17	RECTANGULAR	A = 7.000 ,	T = .6250 ,		

JOINT COORDINATE DATA

JOINT NO.	X	Y	Z
1	12.250000	12.312000	-3.190000
2	9.685000	0.200000	-1.200000
3	5.940000	3.565000	0.0
4	5.940000	-3.565000	0.0
5	3.910000	-3.565000	0.0
6	3.910000	-1.960000	0.0
7	0.0	-3.565000	0.0
8	0.0	-4.750000	0.0
9	3.910000	1.960000	0.0
10	3.910000	3.565000	0.0
11	0.0	3.565000	0.0
12	0.0	4.750000	0.0
13	13.565000	8.440000	-3.500000
14	13.565000	3.500000	-3.500000
15	3.910000	1.960000	-1.460000
16	3.910000	1.960000	1.460000
17	3.910000	-1.960000	-1.460000
18	3.910000	-1.960000	1.460000
19	13.565000	3.500000	0.0
20	13.565000	0.200000	0.0
21	9.565000	8.440000	-3.500000
22	9.565000	5.440000	-3.500000
23	5.940000	4.625000	0.0
24	5.940000	-4.625000	0.0

BOUNDARY, SPRING & BOLT JOINT DATA

JOINT NO.	TYPE-MAT /FIXITY	PLANE-DIRECTION OR DESCRIPTION		SPRING & BOLT JOINT PARAMETERS		
8	111111	BODY				
12	111111	BODY				
12	LEG 2	A	+X +Y	N.T= 2.10 ,D/A=	0.7500, YE=	1.1250
				YO= 9.5000,YSH=	0.0 , S=	2.7500
				ZT= 1.6250, ZB=	1.6250,ZSH=	0.0
8	LEG 2	B	+X -Y	N.T= 2.10 ,D/A=	0.7500, YE=	1.1250
				YO= 9.5000,YSH=	0.0 , S=	2.7500
				ZT= 1.6250, ZB=	1.6250,ZSH=	0.0
23	PAD 2	C	-X +Y	N.T= 2.11 ,D/A=	0.6250, YE=	0.6900
				YO= 9.2500,YSH=	0.0 , S=	3.8000
				ZT= 1.4000, ZB=	1.4000,ZSH=	0.0

CONCENTRATED MASS DATA

JOINT NO.	LUMPED MASS	FOR DIR.	SHIFT DISTANCE OR MOMENT OF INERTIA X	Y	Z
1	0.284679	XYZ	0.0	0.0	0.0
2	0.323499	XYZ	0.0	0.0	0.0
6	0.646998	X	0.0	0.0	0.0
9	0.646998	X	0.0	0.0	0.0

CONCENTRATED LOAD DATA

JOINT NO.	FORCES X	FORCES Y	FORCES Z	MOMENTS X	MOMENTS Y	MOMENTS Z
2	0.0	0.0	0.0	12750.0	0.0	0.0

ELEMENT INPUT DATA

EL. NO.	JOINTS		LENGTH /RADIUS	ANGLE	AREA	MOMENTS OF INERTIA I-11	I-22	I-33	MATERIAL DESCRIPTION
1	21	22	3.000		12.7043	24.8969	49.7939	24.8969	ADAPTER
2	23	3	1.060		5.0400	0.1317	0.5062	34.0200	STEEL
3	3	10	2.030		5.4895	43.8702	0.3899	2.4406	STEEL
4	3	4	7.130		5.0400	0.1317	0.5062	34.0200	STEEL
5	4	24	1.060		5.0400	0.1317	0.5062	34.0200	STEEL
6	4	5	2.030		5.4895	43.8702	0.3899	2.4406	STEEL
7	5	6	1.605		1.5000	0.0176	0.0662	2.0000	STEEL
8	5	7	3.910		5.4895	43.8702	0.3899	2.4406	STEEL
9	8	7	1.185		5.0400	0.1317	0.5062	34.0200	STEEL
10	15	17	3.920		0.4050	0.0047	0.0148	0.0394	STEEL
11	16	18	3.920		0.4050	0.0047	0.0148	0.0394	STEEL
12	10	9	1.605		1.5000	0.0176	0.0662	2.0000	STEEL
13	10	11	3.910		5.4895	43.8702	0.3899	2.4406	STEEL
14	12	11	1.185		5.0400	0.1317	0.5062	34.0200	STEEL
15	21	13	4.000		4.3750	0.1424	0.5376	17.8646	STEEL
16	13	14	4.940		4.3750	0.1424	0.5376	17.8646	STEEL
17	19	20	3.300		4.3750	0.1424	0.5376	17.8646	STEEL
	23	2			RIGID LINK				
	24	2			RIGID LINK				
	15	9			RIGID LINK				
	16	9			RIGID LINK				
	17	6			RIGID LINK				
	18	6			RIGID LINK				
	22	2			RIGID LINK				
	21	1			RIGID LINK				
	19	14			RIGID LINK				
	20	2			RIGID LINK				

S T A T I C   A N A L Y S I S

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM X DIR.

JOINT NO.	. . .DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.000524	-0.000072	0.001035	-0.000000	-0.00[illegible]	-0.000012
2	0.000178	-0.000039	0.000755	-0.000000	-0.0001[illegible]	-0.000008
3	0.000058	-0.000011	0.000343	-0.000000	-0.00005[illegible]	-0.000005
4	0.000020	-0.000011	0.000344	-0.000000	-0.000059	-0.000007
5	0.000020	-0.000003	0.000225	-0.000000	-0.000058	-0.000008
6	0.000566	-0.000003	0.000225	-0.000000	-0.000058	-0.000433
7	0.000015	0.000001	-0.000000	-0.000000	-0.000057	-0.000005
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000587	-0.000001	0.000225	-0.000000	-0.000058	0.000424
10	0.000054	-0.000000	0.000225	-0.000000	-0.000058	0.000002
11	0.000040	-0.000001	-0.000000	0.000000	-0.000057	0.000009
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.000511	-0.000070	0.001179	-0.000000	-0.000109	-0.000006
14	0.000472	-0.000069	0.001180	-0.000000	-0.000112	-0.000010
15	0.000671	-0.000001	0.000225	-0.000000	-0.000058	0.000424
16	0.000502	-0.000000	0.000225	-0.000000	-0.000058	0.000424
17	0.000650	-0.000003	0.000225	-0.000000	-0.000058	-0.000433
18	0.000481	-0.000003	0.000225	-0.000000	-0.000058	-0.000433
19	0.000079	-0.000069	0.001180	-0.000000	-0.000112	-0.000010
20	0.000046	-0.000069	0.001180	-0.000000	-0.000110	-0.000008
21	0.000510	-0.000039	0.000741	-0.000000	-0.000109	-0.000012
22	0.000470	-0.000039	0.000741	-0.000000	-0.000110	-0.000006
23	0.000079	-0.000011	0.000343	-0.000000	-0.000110	-0.000008
24	0.000009	-0.000011	0.000344	-0.000000	-0.000110	-0.000008

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE,SYSTEM Y DIR.

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	-0.000116	0.000887	0.001218	0.000099	-0.000000	0.000011
2	-0.000002	0.000660	0.000019	0.000099	0.000000	0.000008
3	0.000015	0.000509	0.000352	0.000099	-0.000039	0.000074
4	-0.000015	0.000509	-0.000352	0.000099	0.000040	0.000074
5	-0.000019	0.000338	-0.000233	0.000065	0.000040	0.000081
6	-0.000079	0.000338	-0.000128	0.000065	0.000022	0.000003
7	-0.000026	0.000001	-0.000002	-0.000000	0.000040	0.000074
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000079	0.000338	0.000128	0.000065	-0.000021	0.000003
10	0.000019	0.000338	0.000232	0.000065	-0.000040	0.000081
11	0.000026	0.000001	0.000002	-0.000000	-0.000040	0.000074
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.000075	0.000922	0.000836	0.000099	-0.000000	0.000007
14	-0.000033	0.000922	0.000346	0.000099	0.000001	0.000009
15	0.000110	0.000433	0.000128	0.000065	-0.000021	0.000003
16	0.000048	0.000243	0.000128	0.000065	-0.000021	0.000003
17	-0.000110	0.000433	-0.000128	0.000065	0.000022	0.000003
18	-0.000048	0.000243	-0.000128	0.000065	0.000022	0.000003
19	-0.000031	0.000574	0.000346	0.000099	0.000001	0.000009
20	-0.000002	0.000574	0.000019	0.000099	0.000000	0.000008
21	-0.000075	0.000889	0.000836	0.000099	-0.000000	0.000011
22	-0.000046	0.000887	0.000539	0.000099	0.000000	0.000008
23	-0.000039	0.000510	0.000458	0.000099	0.000000	0.000006
24	0.000039	0.000510	-0.000458	0.000099	0.000000	0.000006

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE. SYSTEM Z DIR.

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.001335	0.000842	0.007747	0.000269	-0.000421	0.000000
2	0.000502	0.000317	0.003432	0.000265	-0.000419	-0.000000
3	-0.000000	-0.000000	0.002748	0.000265	-0.000408	-0.000000
4	0.000000	-0.000000	0.000869	0.000264	-0.000197	-0.000000
5	0.000000	-0.000000	0.000568	0.000174	-0.000195	-0.000000
6	0.000000	-0.000000	0.000847	0.000174	-0.000244	-0.000000
7	0.000000	-0.000000	-0.000002	0.000000	-0.000192	-0.000000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.000000	-0.000000	0.001530	0.000174	-0.000359	0.000000
10	-0.000000	-0.000000	0.001810	0.000174	-0.000408	-0.000000
11	-0.000000	-0.000000	0.000009	-0.000000	-0.000404	-0.000000
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.001465	0.000930	0.007255	0.000267	-0.000420	0.000001
14	0.001468	0.000930	0.005935	0.000266	-0.000420	0.000000
15	0.000524	0.000254	0.001530	0.000174	-0.000359	0.000000
16	-0.000524	-0.000255	0.001530	0.000174	-0.000359	0.000000
17	0.000357	0.000254	0.000847	0.000174	-0.000244	-0.000000
18	-0.000356	-0.000254	0.000847	0.000174	-0.000244	-0.000000
19	-0.000000	-0.000000	0.005935	0.000266	-0.000420	0.000000
20	-0.000000	-0.000000	0.005057	0.000265	-0.000419	-0.000000
21	0.001465	0.000926	0.005577	0.000269	-0.000421	0.000000
22	0.001465	0.000926	0.004768	0.000265	-0.000419	-0.000000
23	-0.000000	-0.000000	0.003035	0.000265	-0.000419	-0.000000
24	-0.000000	-0.000000	0.000568	0.000265	-0.000419	-0.000000

DEFORMATION RESPONSE TO OPERATIONAL LOADS (NOT INCLUDING DEADWEIGHT)

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.000003	0.007021	0.027099	[illegible]	0.000001	-0.000000
2	-0.000001	0.002639	0.000432	[illegible]	0.000001	-0.000000
3	-0.000000	-0.000003	0.007814	[illegible]	-0.000878	-0.000000
4	0.000000	-0.000003	-0.007822	[illegible]	0.000879	-0.000000
5	0.000000	-0.000002	-0.005170	[illegible]	0.000886	-0.000000
6	0.000000	-0.000002	-0.002844	[illegible]	0.000478	-0.000000
7	0.000000	-0.000000	-0.000046	[illegible]	0.000684	-0.000000
8	0.0	0.0	0.0	[illegible]	0.0	0.0
9	-0.000000	-0.000002	0.002838	0.0	-0.000477	-0.000000
10	-0.000000	-0.000002	0.005164	[illegible]	-0.000865	-0.000000
11	-0.000000	-0.000000	0.000046	[illegible]	-0.000883	-0.000000
12	0.0	0.0	0.0	[illegible]	0.0	0.0
13	-0.000004	0.007704	0.018571	0.0	0.000001	-0.000000
14	-0.000004	0.007704	0.007694	[illegible]	0.000001	-0.000000
15	0.000695	0.002114	0.002838	[illegible]	-0.000477	-0.000000
16	-0.000696	-0.002118	0.002838	[illegible]	-0.000477	-0.000000
17	-0.000697	0.002114	-0.002844	[illegible]	0.000478	-0.000000
18	0.000698	-0.002118	-0.002844	[illegible]	0.000478	-0.000000
19	0.000000	-0.000003	0.007694	[illegible]	0.000001	-0.000000
20	0.000000	-0.000003	0.000427	[illegible]	0.000001	-0.000000
21	-0.000004	0.007704	0.018576	[illegible]	0.000001	-0.000000
22	-0.000004	0.007704	0.011970	[illegible]	0.000001	-0.000000
23	0.000000	-0.000003	0.010180	[illegible]	0.000001	-0.000000
24	-0.000000	-0.000003	-0.010188	[illegible]	0.000001	-0.000000

D Y N A M I C   A N A L Y S I S

RESONANT FREQUENCY = 38.5 HERTZ (IN Z-DIRECTION OR Y-ROTATION)

* * * * NORMALIZED EIGENVECTOR * * * *

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.150921	0.136495	1.000000	0.041558	-0.047184	-0.000099
2	0.056616	0.055550	0.378930	0.040890	-0.046897	-0.000043
3	0.000819	0.006628	0.340005	0.040902	-0.048994	0.000848
4	-0.000382	0.006630	0.049648	0.040868	-0.016359	0.000911
5	-0.000408	0.004479	0.032037	0.026933	-0.016086	0.001036
6	-0.001137	0.004-87	0.075262	0.026933	-0.023682	-0.000036
7	-0.000461	0.000016	-0.000504	-0.000003	-0.015733	0.001000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.001531	0.004526	0.180768	0.026937	-0.041413	-0.000024
10	0.000795	0.004535	0.224000	0.026941	-0.048979	0.001020
11	0.000750	0.000014	0.001194	-0.000054	-0.048537	0.001075
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.165169	0.150145	0.900570	0.041210	-0.047120	0.000186
14	0.165505	0.150150	0.696619	0.041096	-0.047129	-0.000046
15	0.061994	0.043854	0.180768	0.026937	-0.041413	-0.000024
16	-0.058932	-0.034802	0.180768	0.026937	-0.041413	-0.000024
17	0.033438	0.043809	0.075262	0.026933	-0.023682	-0.000036
18	-0.035713	-0.034834	0.075262	0.026933	-0.023682	-0.000036
19	0.000552	0.006314	0.696619	0.041096	-0.047129	-0.000046
20	0.000340	0.006315	0.560690	0.040890	-0.046897	-0.000043
21	0.165165	0.149644	0.712400	0.041558	-0.047184	-0.000099
22	0.164704	0.149601	0.587565	0.040890	-0.046897	-0.000043
23	0.000530	0.006642	0.384238	0.040890	-0.046897	-0.000043
24	0.000133	0.006642	0.006007	0.040890	-0.046897	-0.000043

S T A T I C   S E I S M I C   A N A L Y S I S

THE VALVE AXIS IS POSITIONED X-UP

ACCELERATION OF GRAVITY, G = 386.400

DIRECTION OF SEISMIC ACCELERATION	NO. OF G'S	COMPONENTS OF UNIT ACCELERATION IN VALVE COORDINATE SYSTEM X-COMP.	Y-COMP.	Z-COMP.
HORIZONTAL(1)	5.000	0.0	0.0	1.0000
HORIZONTAL(2)	5.000	0.0	1.0000	0.0
VERTICAL	5.000	-1.0000	0.0	0.0

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	-2.	7.	423.	2111.	-916.	22.
	22	2.	-7.	-473.	-3454.	916.	-27.
2	23	1542.	-2.	0.	1.	-290.	1447.
	3	-1550.	2.	-0.	-1.	290.	192.
3	3	-0.	0.	-1789.	591.	-840.	-2.
	10	0.	-0.	1804.	3057.	840.	1.
4	3	-239.	-0.	0.	-1.	-876.	-1028.
	4	189.	0.	-0.	-1.	876.	-496.
5	4	239.	2.	-1.	-1.	6184.	1081.
	24	-247.	-2.	1.	1.	-6184.	-823.
6	4	0.	-1.	-429.	7060.	582.	1.
	5	-0.	1.	413.	-6206.	-582.	-1.
7	5	-6.	-0.	0.	-0.	-118.	-20.
	6	3.	0.	-0.	0.	118.	20.
8	5	1.	-1.	-407.	6324.	608.	1.
	7	-1.	1.	377.	-4790.	-608.	1.
9	8	369.	-1.	1.	0.	-4789.	-166.
	7	-377.	1.	-1.	-1.	4789.	608.
10	15	-1.	6.	-23.	45.	-25.	-1.
	17	-1.	-6.	23.	45.	25.	1.
11	16	-1.	-6.	23.	-45.	-25.	-1.
	18	-1.	6.	-23.	-45.	25.	1.
12	10	-5.	-0.	0.	-0.	-118.	-24.
	9	2.	0.	-0.	0.	118.	16.
13	10	-1.	0.	-1811.	-2947.	-866.	-1.
	11	1.	-0.	1841.	10087.	866.	-1.
14	12	-1850.	1.	0.	1.	10089.	-3053.
	11	1841.	-1.	-0.	-1.	-10089.	866.
15	21	126.	-1.	7.	-21.	-18.	556.
	13	-151.	1.	-7.	-8.	18.	-5.
16	13	149.	-7.	-1.	8.	-4.	-15.
	14	-179.	7.	1.	-3.	4.	826.
17	19	180.	-8.	-1.	3.	-8.	-803.
	20	-200.	8.	1.	1.	8.	1430.

TYPE	JNT. NO.	. . . . . . BOUNDARY OR FX	JUNCTION FY	REACTION FZ	. . . . . MX	MY	MZ
BODY	8	1.	1.	369.	-166.	4789.	0.
BODY	12	-0.	1.	-1850.	3053.	10089.	1.
A +X+Y	12	-0.	1.	-1841.	3048.	10087.	1.
B +X-Y	8	1.	1.	377.	-161.	4790.	0.
C -X+Y	23	-1.	-1.	1360.	1357.	-6470.	-2.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	3.	550.	10.	-168.	-36.	1443.
	22	-3.	-600.	-10.	138.	36.	-1434.
2	23	335.	649.	1095.	-1808.	1104.	118.
	3	-335.	-656.	-1095.	646.	-1104.	237.
3	3	682.	-1454.	-415.	1432.	-49.	1929.
	10	-698.	1454.	415.	-589.	49.	-528.
4	3	-80.	-25.	-359.	1281.	-328.	-286.
	4	80.	-25.	359.	1281.	328.	-287.
5	4	335.	-656.	1095.	648.	1103.	237.
	24	-335.	648.	-1095.	-1808.	-1103.	119.
6	4	-683.	1454.	-415.	1431.	-49.	-1929.
	5	698.	-1454.	415.	-588.	49.	528.
7	5	-0.	6.	-47.	166.	-44.	-0.
	6	0.	-2.	47.	-91.	44.	0.
8	5	-704.	1501.	-416.	632.	-49.	-694.
	7	734.	-1501.	416.	993.	49.	-2117.
9	8	416.	742.	-1501.	-338.	993.	541.
	7	-416.	-734.	1501.	2117.	-993.	-49.
10	15	0.	-1.	-32.	63.	-10.	0.
	17	-0.	-1.	32.	63.	10.	0.
11	16	0.	-1.	-15.	29.	-10.	0.
	18	-0.	-1.	15.	29.	10.	0.
12	10	0.	-5.	-47.	166.	-44.	0.
	9	-0.	2.	47.	-91.	44.	-0.
13	10	704.	-1501.	-415.	633.	-48.	694.
	11	-734.	1501.	415.	991.	48.	2117.
14	12	-415.	-742.	-1501.	-339.	991.	-541.
	11	415.	734.	1501.	2117.	-991.	48.
15	21	-10.	3.	0.	34.	3.	-36.
	13	10.	-3.	24.	14.	-3.	-4.
16	13	-10.	24.	3.	-14.	-4.	4.
	14	10.	-54.	-3.	1.	4.	-55.
17	19	-10.	54.	3.	-1.	5.	-133.
	20	10.	-74.	-3.	-8.	-5.	99.

TYPE	JNT. NO.	. . . . . BOUNDARY OR FX	JUNCTION FY	REACTION . . . . . FZ	MX	MY	MZ
BODY	8	-1501.	-742.	416.	541.	-993.	-338.
BODY	12	1501.	-742.	-415.	541.	991.	-339.
A +X+Y	12	1501.	-734.	-415.	540.	991.	-338.
B +X-Y	8	-1501.	-734.	416.	541.	-993.	-338.
C -X+Y	23	0.	1365.	0.	2864.	1.	6510.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	-710.	-22.	-4.	1.	-165.	2468.
	22	770.	22.	4.	12.	165.	-4688.
2	23	1.	332.	1894.	-952.	1717.	1.
	3	-1.	-332.	-1903.	-1061.	-1717.	0.
3	3	431.	-1937.	-1.	1717.	-1.	-1018.
	10	-431.	1955.	1.	-1715.	1.	1893.
4	3	-0.	-99.	-34.	43.	-0.	-0.
	4	0.	99.	-27.	-17.	0.	0.
5	4	-1.	333.	326.	-190.	-1716.	0.
	24	1.	-333.	-335.	-160.	1716.	-1.
6	4	431.	299.	0.	-1716.	1.	207.
	5	-431.	-281.	-0.	1715.	-1.	669.
7	5	0.	-89.	1508.	-2047.	-0.	-0.
	6	-0.	89.	-1504.	-370.	0.	0.
8	5	520.	-1227.	0.	-1715.	0.	1378.
	7	-520.	1263.	-0.	1715.	-0.	656.
9	8	-0.	-520.	1273.	-847.	1715.	-0.
	7	0.	520.	-1263.	-656.	-1715.	0.
10	15	-0.	-44.	-1.	-187.	-0.	-0.
	17	0.	44.	-2.	185.	0.	-0.
11	16	-0.	-44.	-1.	-187.	-0.	-0.
	18	0.	44.	-2.	185.	0.	-0.
12	10	-0.	-89.	-1506.	2040.	-0.	-0.
	9	0.	89.	1502.	374.	0.	0.
13	10	520.	-3461.	-1.	1717.	-1.	146.
	11	-520.	3497.	1.	-1713.	1.	1888.
14	12	-1.	-520.	-3507.	2262.	-1714.	-1.
	11	1.	520.	3497.	1888.	1714.	1.
15	21	4.	-50.	-22.	88.	1.	40.
	13	-4.	21.	22.	2.	-1.	-22.
16	13	5.	22.	-21.	-2.	-22.	1.
	14	-5.	-22.	-15.	17.	22.	21.
17	19	5.	22.	15.	-17.	31.	-99.
	20	-5.	-22.	-39.	-73.	-31.	114.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	8	1273.	520.	-0.	-0.	-1715.	-847.
BODY	12	3507.	-520.	-1.	1.	-1714.	2262.
A +X+Y	12	3497.	-520.	-1.	2.	-1713.	2257.
B +X-Y	8	1263.	520.	-0.	-1.	-1715.	-841.
C -X+Y	23	-1637.	-0.	2.	-6.	3433.	1623.

REACTION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	21	-118.	-4.	-2.	0.	-21.	411.
	22	128.	4.	2.	6.	21.	-781.
2	23	1491.	54.	314.	-157.	5195.	523.
	3	-1491.	-54.	-316.	-177.	-5195.	1056.
3	3	71.	-321.	-1846.	6653.	-216.	-171.
	10	-71.	324.	1846.	-2905.	216.	316.
4	3	-357.	-17.	-5.	6.	-1459.	-1273.
	4	357.	17.	-5.	-4.	1459.	-1274.
5	4	1491.	57.	53.	-32.	4617.	1054.
	24	-1491.	-57.	-54.	-25.	-4617.	526.
6	4	73.	48.	-1847.	6075.	-217.	36.
	5	-73.	-45.	1847.	-2326.	217.	111.
7	5	-0.	-15.	251.	-341.	-197.	-2.
	6	0.	15.	-251.	-62.	197.	1.
8	5	88.	-206.	-1847.	2522.	-216.	230.
	7	-68.	212.	1847.	4700.	216.	112.
9	8	1847.	-88.	214.	-141.	4700.	2405.
	7	-1847.	88.	-212.	-112.	-4700.	-216.
10	15	0.	-7.	-39.	44.	-42.	1.
	17	-0.	7.	38.	106.	42.	1.
11	16	0.	-7.	38.	-107.	-42.	1.
	18	-0.	7.	-39.	-45.	42.	1.
12	10	1.	-15.	-251.	340.	-197.	2.
	9	-1.	15.	250.	62.	197.	-1.
13	10	86.	-575.	-1846.	3098.	-215.	24.
	11	-86.	581.	1846.	4121.	215.	312.
14	12	-1847.	-86.	-583.	377.	4122.	-2404.
	11	1847.	86.	581.	312.	-4122.	215.
15	21	2.	-8.	-4.	15.	0.	11.
	13	-2.	4.	4.	0.	-0.	-4.
16	13	-0.	3.	-4.	-0.	-4.	5.
	14	0.	-3.	-3.	3.	4.	-5.
17	19	1.	3.	3.	-3.	5.	-8.
	20	-1.	-3.	-7.	-12.	-5.	11.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	8	214.	88.	1847.	2405.	-4700.	-141.
BODY	12	583.	-86.	-1847.	2404.	4122.	377.
A +X+Y	12	581.	-86.	-1846.	2403.	4120.	376.
B +X-Y	8	212.	88.	1847.	2404.	-4700.	-140.
C -X+Y	23	-273.	-1.	-0.	12735.	578.	261.

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

JOINT	. . .DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.006674	0.004212	0.038737	0.001345	-0.002103	0.000000
2	0.002512	0.001586	0.017161	0.001323	-0.002093	-0.000000
3	-0.000000	-0.000002	0.013739	0.001324	-0.002041	-0.000000
4	0.000000	-0.000002	0.004345	0.001322	-0.000986	-0.000000
5	0.000000	-0.000001	0.002841	0.000869	-0.000975	-0.000000
6	0.000000	-0.000001	0.004237	0.000870	-0.001221	-0.000000
7	0.000000	-0.000000	-0.000009	0.000000	-0.000959	-0.000000
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.000000	-0.000001	0.007651	0.000871	-0.001794	0.000000
10	-0.000000	-0.000001	0.009049	0.000872	-0.002040	-0.000000
11	-0.000000	-0.000000	0.000046	-0.000002	-0.002020	-0.000000
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.007326	0.004652	0.036276	0.001333	-0.002101	0.000007
14	0.007342	0.004652	0.029676	0.001330	-0.002098	0.000001
15	0.002619	0.001271	0.007651	0.000871	-0.001794	0.000000
16	-0.002620	-0.001273	0.007651	0.000871	-0.001794	0.000000
17	0.001783	0.001269	0.004237	0.000870	-0.001221	-0.000000
18	-0.001782	-0.001271	0.004237	0.000870	-0.001221	-0.000000
19	-0.000000	-0.000002	0.029676	0.001330	-0.002098	0.000001
20	-0.000000	-0.000002	0.025283	0.001323	-0.002093	-0.000000
21	0.007326	0.004628	0.027883	0.001345	-0.002103	0.000000
22	0.007327	0.004628	0.023841	0.001323	-0.002093	-0.000000
23	-0.000000	-0.000002	0.015175	0.001323	-0.002093	-0.000000
24	-0.000000	-0.000002	0.002938	0.001323	-0.002093	-0.000000

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

JOINT	. . .DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	-0.000581	0.004436	0.006091	0.000494	-0.000000	0.000054
2	-0.000009	0.003302	0.000097	0.000495	0.000000	0.000042
3	0.000076	0.002545	0.001758	0.000495	-0.000197	0.000371
4	-0.000076	0.002545	-0.001759	0.000495	0.000196	0.000371
5	-0.000094	0.001689	-0.001163	0.000326	0.000199	0.000406
6	-0.000395	0.001689	-0.000640	0.000326	0.000108	0.000014
7	-0.000129	0.000006	-0.000010	-0.000000	0.000199	0.000368
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.000395	0.001689	0.000638	0.000326	-0.000107	0.000014
10	0.000094	0.001689	0.001162	0.000326	-0.000199	0.000406
11	0.000129	0.000006	0.000010	-0.000000	-0.000199	0.000368
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.000373	0.004610	0.004180	0.000496	-0.000000	0.000037
14	-0.000165	0.004608	0.001731	0.000496	0.000003	0.000045
15	0.000551	0.002165	0.000638	0.000326	-0.000107	0.000014
16	0.000238	0.001213	0.000638	0.000326	-0.000107	0.000014
17	-0.000552	0.002165	-0.000640	0.000326	0.000108	0.000014
18	-0.000238	0.001213	-0.000640	0.000326	0.000108	0.000014
19	-0.000154	0.002872	0.001731	0.000496	0.000003	0.000045
20	-0.000008	0.002871	0.000096	0.000495	0.000000	0.000042
21	-0.000373	0.004445	0.004178	0.000494	-0.000000	0.000054
22	-0.000230	0.004436	0.002693	0.000495	0.000000	0.000042
23	-0.000195	0.002550	0.002290	0.000495	0.000000	0.000042
24	0.000195	0.002550	-0.002292	0.000495	0.000000	0.000042

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

JOINT	. . . DEFLECTION	. . .		. . . ROTATION	. . .	
NO.	X	Y	Z	X	Y	Z
1	-0.003145	0.000430	-0.006209	0.000000	0.000657	0.000074
2	-0.001066	0.000237	-0.004528	0.000000	0.000658	0.000045
3	-0.000347	0.000064	-0.002061	0.000000	0.000351	0.000031
4	-0.000118	0.000069	-0.002063	0.000000	0.000351	0.000041
5	-0.000121	0.000021	-0.001353	0.000000	0.000348	0.000048
6	-0.003394	0.000018	-0.001352	0.000000	0.000348	0.002598
7	-0.000092	-0.000004	0.000000	0.000000	0.000343	0.000028
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.003519	0.000003	-0.001352	0.000000	0.000348	-0.002543
10	-0.000323	0.000000	-0.001351	0.000000	0.000348	-0.000009
11	-0.000241	0.000004	0.000000	-0.000000	0.000343	-0.000056
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.003063	0.000417	-0.007075	0.000001	0.000657	0.000034
14	-0.002835	0.000416	-0.007080	0.000001	0.000675	0.000062
15	-0.004028	0.000004	-0.001352	0.000000	0.000348	-0.002543
16	-0.003011	0.000003	-0.001352	0.000000	0.000348	-0.002543
17	-0.003902	0.000018	-0.001352	0.000000	0.000348	0.002598
18	-0.002885	0.000017	-0.001352	0.000000	0.000348	0.002598
19	-0.000474	0.000413	-0.007080	0.000001	0.000675	0.000062
20	-0.000275	0.000412	-0.007082	0.000000	0.000658	0.000045
21	-0.003062	0.000232	-0.004447	0.000000	0.000657	0.000074
22	-0.002818	0.000232	-0.004447	0.000000	0.000658	0.000045
23	-0.000476	0.000066	-0.002060	0.000000	0.000658	0.000045
24	-0.000057	0.000066	-0.002063	0.000000	0.000658	0.000045

DEFORMATION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.000527	0.007093	0.026064	0.002202	0.000111	0.000012
2	-0.000179	0.002679	-0.000323	0.002202	0.000111	0.000008
3	-0.000058	0.000008	0.007470	0.002202	-0.000819	0.000005
4	-0.000020	0.000009	-0.008166	0.002202	0.000938	0.000006
5	-0.000020	0.000002	-0.005395	0.001449	0.000944	0.000007
6	-0.000565	0.000001	-0.003069	0.001449	0.000536	0.000433
7	-0.000015	-0.000001	-0.000046	-0.000002	0.000941	0.000004
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.000587	-0.000001	0.002613	0.001449	-0.000419	-0.000424
10	-0.000054	-0.000002	0.004939	0.001449	-0.000827	-0.000002
11	-0.000040	0.000001	0.000046	-0.000002	-0.000825	-0.000010
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.000514	0.007773	0.017392	0.002202	0.000111	0.000005
14	-0.000477	0.007773	0.006514	0.002202	0.000114	0.000010
15	0.000024	0.002114	0.002613	0.001449	-0.000419	-0.000424
16	-0.001198	-0.002117	0.002613	0.001449	-0.000419	-0.000424
17	-0.001348	0.002117	-0.003069	0.001449	0.000536	0.000433
18	0.000217	-0.002115	-0.003069	0.001449	0.000536	0.000433
19	-0.000079	0.000066	0.006514	0.002202	0.000114	0.000010
20	-0.000046	0.000066	-0.000753	0.002202	0.000111	0.000008
21	-0.000514	0.007743	0.017835	0.002202	0.000111	0.000012
22	-0.000473	0.007743	0.011229	0.002202	0.000111	0.000008
23	-0.000079	0.000008	0.009837	0.002202	0.000111	0.000008
24	-0.000010	0.000008	-0.010532	0.002202	0.000111	0.000008

E V A L U A T I O N O F V A L V E

DEFORMATION RESPONSE OF COMBINED STATIC SEISMIC AND OPERATIONAL LOADS

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	-0.007928	0.013225	0.065766	0.003635	0.002314	0.000104
2	-0.002908	0.006349	-0.018071	0.003615	0.002305	0.000069
3	-0.000413	0.002554	0.021-73	0.003615	-0.002900	0.000378
4	-0.000160	0.002555	-0.013287	0.003613	0.002003	0.000380
5	-0.000174	0.001691	-0.008749	0.002378	0.001999	0.000416
6	-0.003982	0.001691	-0.007563	0.002378	0.001810	0.003031
7	-0.000174	-0.000008	-0.000059	-0.000002	0.001979	0.000374
8	0.0	0.0	0.0	0.0	0.0	0.0
9	-0.004129	-0.001691	0.010408	0.002379	-0.002249	-0.002967
10	-0.000390	-0.001691	0.014162	0.002380	-0.002905	-0.000408
11	-0.000313	0.000008	0.000093	-0.000004	-0.002884	-0.000382
12	0.0	0.0	0.0	0.0	0.0	0.0
13	-0.008464	0.014335	0.054587	0.003625	0.002312	0.000056
14	-0.008348	0.014334	0.037071	0.003621	0.002317	0.000087
15	0.004860	0.004625	0.010408	0.002379	-0.002249	-0.002967
16	-0.005196	-0.003876	0.010408	0.002379	-0.002249	-0.002967
17	-0.005673	0.004627	-0.007563	0.002378	0.001810	0.003031
18	0.003617	-0.003872	-0.007563	0.002378	0.001810	0.003031
19	-0.000577	0.002967	0.037071	0.003621	0.002317	0.000087
20	-0.000322	0.002966	-0.027010	0.003615	0.002305	0.000069
21	-0.008463	0.014164	0.046378	0.003635	0.002314	0.000104
22	-0.008327	0.014158	0.035631	0.003615	0.002305	0.000069
23	-0.000594	0.002559	0.025321	0.003615	0.002305	0.000069
24	-0.000212	0.002559	-0.014791	0.003615	0.002305	0.000069

BEAM STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS .

ELM NO.	JNT NO.	STRESS NO.	C1	C3/2	C	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE	FI JN
2	23	5	0.0	0.28	0.56	11.5	27.0	STEEL	0.43		2
3	3	7	-0.05	3.49	0.77	3.4	27.0	STEEL	0.13		1
4	3	5	0.0	0.28	0.56	4.5	27.0	STEEL	0.17		
5	24	5	0.0	0.28	0.56	14.8	27.0	STEEL	0.55		2
6	4	10	-0.05	-3.49	0.77	2.7	27.0	STEEL	0.10		
7	5	6	0.0	-0.19	0.37	25.9	27.0	STEEL	0.96		
8	7	4	1.92	-4.00	0.0	2.8	27.0	STEEL	0.10		
9	7	5	0.0	0.28	0.56	14.3	27.0	STEEL	0.53		
10	17	6	0.0	-0.19	0.35	12.5	27.0	STEEL	0.46		1
11	16	6	0.0	-0.19	0.35	12.3	27.0	STEEL	0.45		1
12	10	5	0.0	0.19	0.37	25.8	27.0	STEEL	0.95		1
13	11	4	1.92	-4.00	0.0	3.8	27.0	STEEL	0.14		1
14	11	6	0.0	-0.28	0.56	20.6	27.0	STEEL	0.76		1

BOLTED JOINT STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS
(N=NUMBER OF BOLTS. AREA=AREA PER BOLT)

BOLT JNT	JOINT LOC.	DESCRIPTION TYPE	N	AREA	BOLT NO.	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE	DI-
12	A	LEG	2	0.31	2	20.1	82.8	BOLTING	0.24		•
8	B	LEG	2	0.31	2	11.5	82.8	BOLTING	0.14		•
23	C	PAD	4	0.21	1	8.7	82.8	BOLTING	0.10		-

THIS EQUIPMENT IS ACCEPTABLE FOR THE SPECIFIED SEISMIC DISTURBANCE

THIS REPORT HAS BEEN PREPARED BY /

DAVE POPOVICH

Dave Popovich

FISHER CONTROLS COMPANY

CONTINENTAL CONTROL NO. 5A094 & 5A095
REPRESENTATIVE ORDER NO. 14-62496-A and
14-62496-B
CUSTOMER ORDER NO. 181104
ENGINEERING PROJECT NO. CD75-46

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

SEISMIC ANALYSIS OF 8", 20" AND 24" BUTTERFLY VALVE ASSEMBLIES FOR COMMONWEALTH EDISON COMPANY

DATE: December 19, 1978

PREPARED BY: Dennis M Hazel
Dennis M. Hazel, Engineering Associate

REVIEWED BY: Kanu Patel
Kanu Patel, Project Engineer

APPROVED BY: Richard Hoober
Richard E. Hoober, Manager of Engineering

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CUSTOMER REQUIREMENTS AND SUMMARY OF RESULTS

Based on the calculations shown in this report, we have demonstrated that the primary steady-state stresses, when combined with the inertial loading resulting from the response to a ground acceleration in both horizontal directions and in the vertical direction as specified in Scope of Analysis, acting simultaneously produce combined stresses which are safely within the yield stresses of the construction materials, both in tension and in shear.

Also, the calculations predict that the extended parts of each valve assembly have a first natural frequency of vibration greater than 33 Hertz.

In summary, this analysis demonstrates mathematically that the equipment supplied by Fisher Controls Company meets the requirements of the Sargent and Lundy Specification J2940 for Commonwealth Edison Company, LaSalle County Station, Units 1 and 2.

SCOPE OF ANALYSIS

The butterfly valve assemblies analyzed in this report apply to the following item and tag numbers:

CONTINENTAL CONTROL NO. 5A094

APPENDIX	CONTINENTAL ITEM NO.	CUSTOMER TAG NO.	VALVE SIZE	TYPE	ACTUATOR	GROUND ACCELERATION "g" HORIZ.	VERT.
B	34	1PC138	20"	9270	FISHER 1073	5	6
	24	1PC002A					
	25	1PC002B					
	26	1PC002C					
C	27	1PC002D	24"	9270	FISHER 1073	5	6
	28	1PC003A					
	29	1PC003B					
	30	1PC003C					
	31	1PC003D					
D	35	1FC54A	8"	9270	FISHER 1073	5	6
	36	1FC54B					
	32	1VQ042					
	33	1VQ043					
E	38	1VP113A	8"	9270	LIMITORQUE	7	6
	39	1VP113B			SMB-000/2-HOBC		
	40	1VP114A					
	41	1VP114B					

SEISMIC ANALYSIS

CONTINENTAL CONTROL NO. 5A095

APPENDIX	CONTINENTAL ITEM NO.	CUSTOMER TAG NO.	VALVE SIZE	TYPE	ACTUATOR	GROUND ACCELERATION "g" HORIZ.	VERT.
B	29	2FC138	20"	9270	FISHER 1073	5	6
	19	2PC002A					
	20	2PC002B					
	21	2PC002C					
C	22	2PC002D	24"	9270	FISHER 1073	5	6
	23	2PC003A					
	24	2PC003B					
	25	2PC003C					
	26	2PC003D					
D	30	2FC054A	8"	9270	FISHER 1073	5	6
	31	2FC054B					
	27	2VQ042					
	28	2VQ043					
	33	2VP113A					
E	34	2VP113B	8"	9220	LIMITORQUE	6	7
	35	2VP114A			SMB-000/2-HOBC		
	36	2VP114B					

APPENDIX A

FISHER Controls
MARSHALLTOWN, IOWA

STANDARDS AND SPECIFICATIONS COVER SHEET

SEISMIC ANALYSIS OF ROTARY VALVE ASSEMBLIES FOR NUCLEAR SERVICE

NO. ES 117 C

BY [illegible]

APVD R. Z. 12-12-77

PAGE 0.1 OF

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6	A
7	A
8	A
9	A
10	A
11	A
12	A
13	A
14	A

Specification Revision	Date	Approved by
B	4-7-78	R. Zeigler
C	6-20-78	Bob Roberts

FISHER Controls HALLTOWN, IOWA	STANDARDS AND SPECIFICATIONS COVER SHEET	NO. ES 117
	SEISMIC ANALYSIS OF ROTARY VALVE ASSEMBLIES FOR NUCLEAR SERVICE	BY R.M. 12/8/77
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SECTION PAGE

I. PURPOSE:

The purpose of this engineering standard is to establish a standard method of three dimensional seismic analysis of actuator-valve assemblies subjected to triaxial seismic loading.

II. PROCEDURE

II.A The Order Engineer is assigned the responsibility for performing a seismic analysis. The format for the seismic analysis is outlined in this standard.

II.A.1 The seismic analysis will normally consist of a copy of this standard; a cover letter summarizing the results along with a listing of the applicable order numbers, and tag numbers; a set of assembly drawings depicting the constructions analyzed; a sketch of the analytical models; copies of the computer output sheets listing the input and output data along with the acceptable values; and copies of seismic tests of the valve mounted accessories (if required).

II.A.2 Unless the customer's specification states otherwise, the following will be assumed:

(1) The valve is installed in a horizontal pipeline with the valve shaft mounted horizontal (Figure III-1).

(2) The stresses due to seismic loads are to be combined by square root of the sum of the squares (SRSS).

(3) The acceptance criteria contained in Section VIII of this standard are to be used.

(4) The resonant frequency is not required.

II.A.3 An Engineer (Senior Design Engineer, Design Engineer, or Engineering Associate) other than the one performing the original calculations is responsible for reviewing the seismic analysis and signing the cover letter along with the originator of the report.

II.B The Engineering Coordinator is assigned the responsibility for maintaining and distributing the seismic analyses.

II.B.1 The analyses are to be reproduced and the originals filed in a permanent area in a systematic manner.

II.B.2 The analyses are not to be revised. In the event that the valve construction changes after the analysis is performed, a new analysis shall be performed superseding the old analysis.

III. NOMENCLATURE

III.A Equation Symbols

All variables will be defined near the equations or figures in which they appear.

III.B Special Symbols

(1) ● - Joint
(2) ⊙ - Vector out of the plane of the paper.
(3) ⊗ - Vector into the plane of the paper.
(4) (•) - Concentrated mass at a model joint.
(5) [5] - Element number.
(6) ⑥ - Joint number.
(7) ●——● - Element neutral axis.
(8) ▬ - Rigid Link.
(9) ↗—/—↙ - Moment about an axis normal to plane of paper.
(10) ⊙—+—⊗ - Moment about an axis in the plane of the paper.
(11) [ ] - Matrix
(12) { } - Vector

III.C Coordinate System of the Actuator-Valve Assembly

All rectangular coordinate systems used are right-handed. The primary coordinate system is illustrated for a typical assembly in Figure III-1. The primary coordinate system will be referred to as the <u>system coordinates</u>.

III.D Geometric Variables

The geometric variables listed in Tables III-1 the III-4 are used to provide cross-section and bolt joint input data to the computer program (SEISMIC 4) that performs the seismic analysis. In addition, the system coordinates for each joint of the finite element model, the interconnection between the elements and rigid links, the constraint conditions between elements and boundaries, the lumped inertia properties of the accessories and the seismic and operating loads must be specified

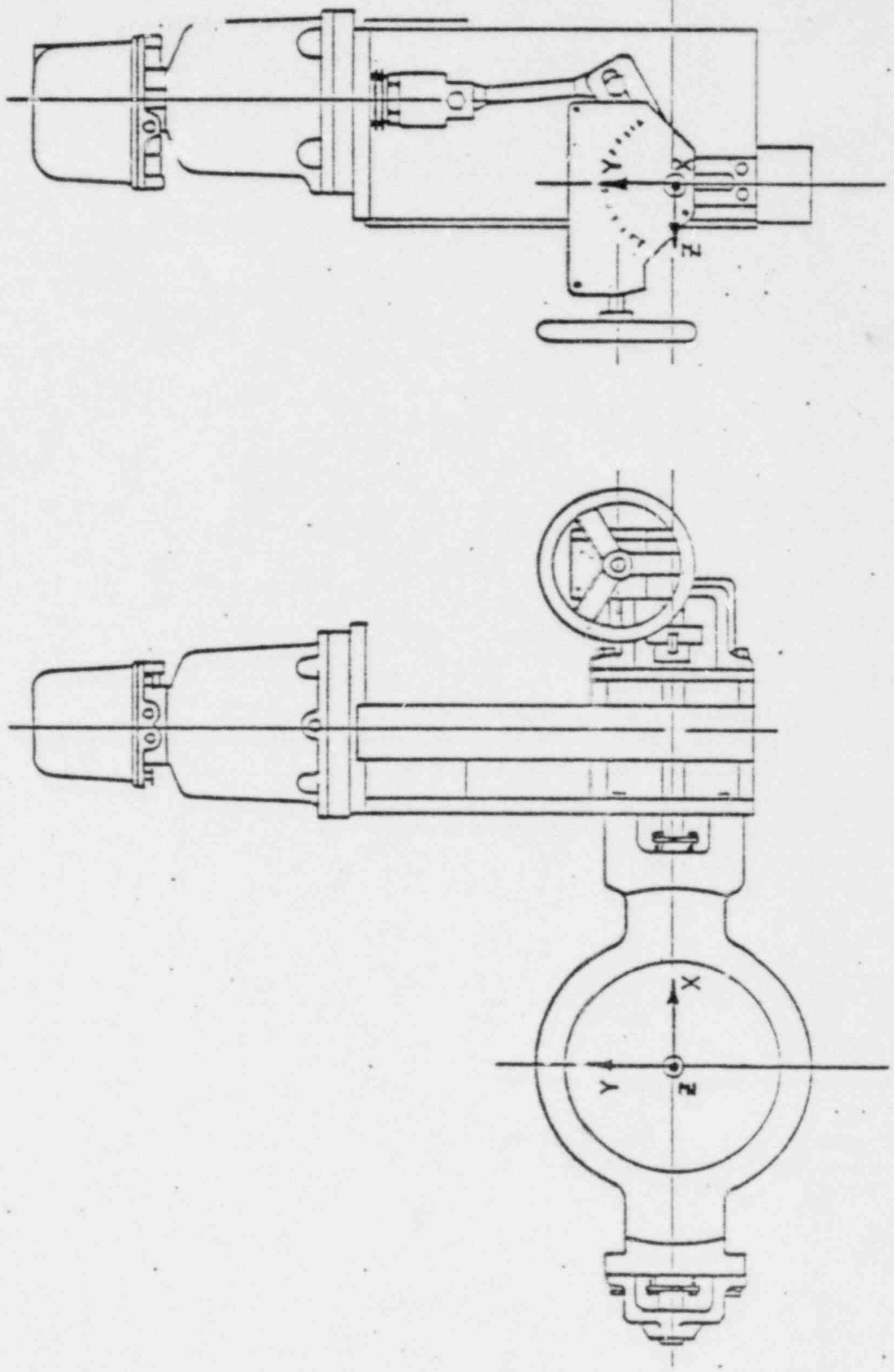
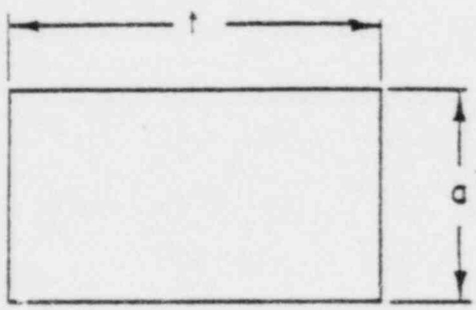


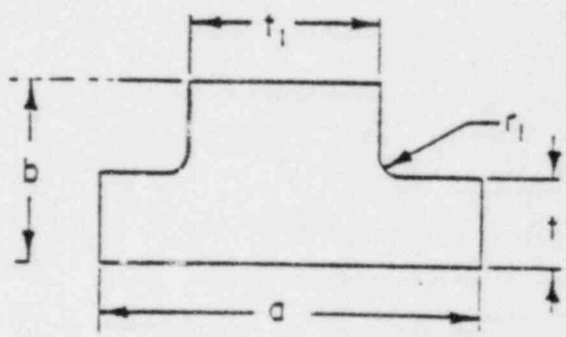
FIGURE III-1

TABLE III-1
STANDARD ELEMENT CROSS-SECTIONAL PARAMETERS

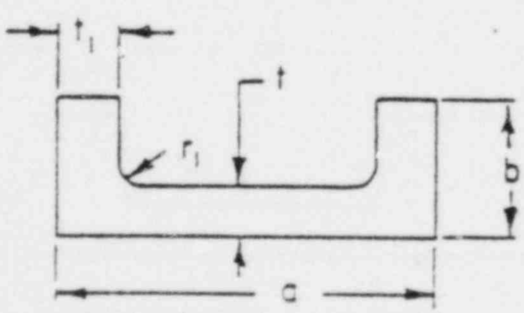
GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
a	III-2	Diameter or Length	inches
b	III-2 except (i)	Length	inches
	III-2 (i)	Angle	degrees
c	III-2 (e)(h)	Length	inches
t, t_1, t_2	III-2	Thickness	inches
r_1, r_2	III-2	Fillet Radius	inches



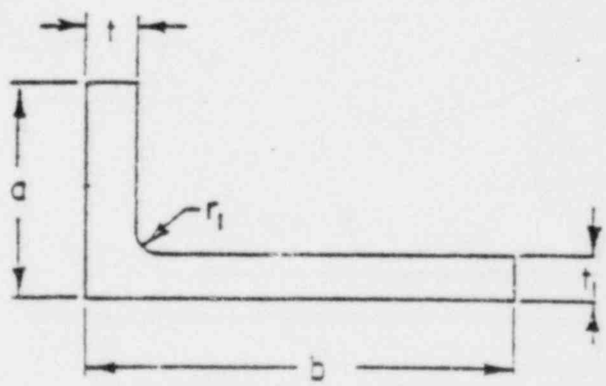
RECTANGLE
Figure III-2(a)



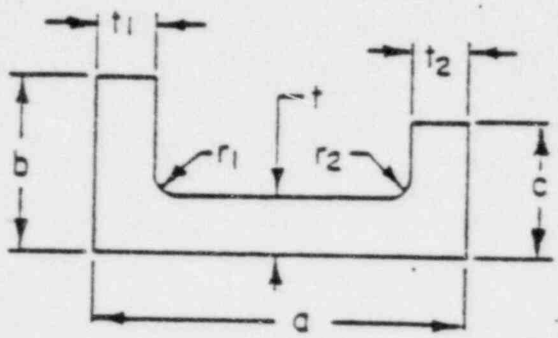
TEE
Figure III-2(b)



CHANNEL
Figure III-2(c)

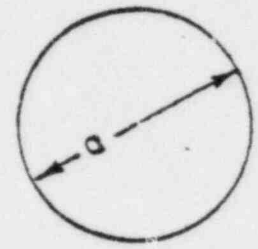


ANGLE
Figure III-2(d)



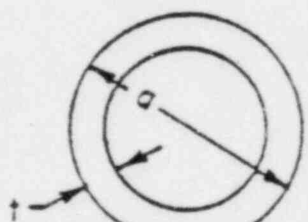
UNEQUAL LEG CHANNEL

Figure III-2(e)



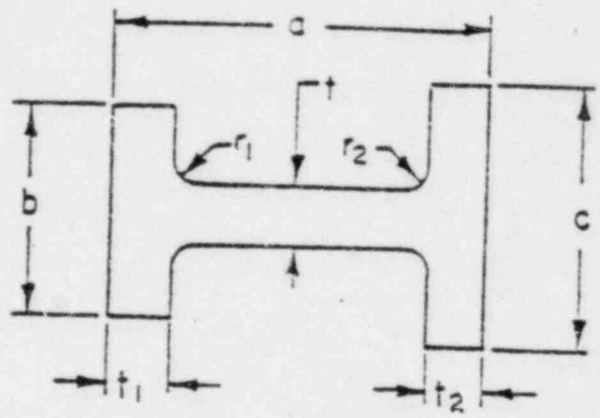
CYLINDER

Figure III-2(f)



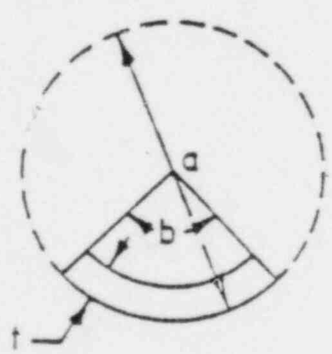
HOLLOW CYLINDER

Figure III-2(g)



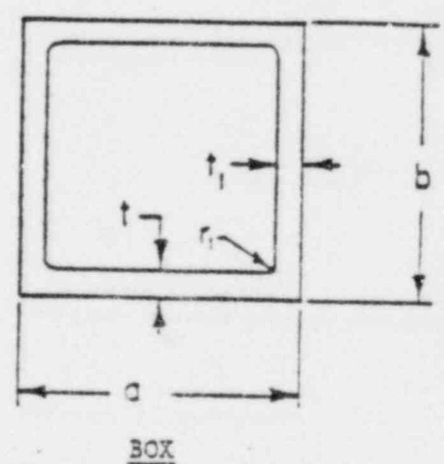
I or H

Figure III-2(h)



HOLLOW CIRCULAR SEGMENT

Figure III-2(i)



BOX

Figure III-2(j)

FIGURES III-2 STANDARD CROSS SECTIONS

TABLE III-2

NONSTANDARD CROSS-SECTIONAL PARAMETERS (STRAIGHT ELEMENT)

GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
A	III-3	Area - $\iint dx_1 dx_3$	$(inch)^2$
I_1	III-3	Bending Moment of Inertia = $\iint (x_3)^2\, dx_1 dx_3$	$(inches)^4$
I_2	III-3	Twisting Moment of Inertia.[1]	$(inches)^4$
I_3	III-3	Bending Moment of Inertia = $\iint (x_1)^2\, dx_1 dx_3$	$(inches)^4$
κ_1, κ_3	III-3	Shear deflection factors associated with x_1 and x_3 directions, respectively.[2]	
X_S, Z_S	III-3	Distance from centroid to shear center in x_1 and x_3 directions, respectively.[3]	inches
γ	III-3	Angle from reference direction to x_1 principal direction.	degrees
x_1, x_3	III-3	Coordinates in cross section	inches
x_1', x_3'	III-3	Reference directions	
C_1, C_3		$C_1 = x_1$, $C_3 = x_3$ coefficients for bending stress computation	inches
C		Coefficient for torsional shear stress computation at stress point.[4]	inches

1, 2, 3, 4 - Refer to references in Section X.

TABLE III-3

NONSTANDARD CROSS-SECTIONAL PARAMETERS (CURVED ELEMENT)

GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
A	III-4	Area $= \iint dx_1 dx_2$	$(\text{inches})^2$
I_1	III-4	Inplane Bending Moment of Inertia $= \iint (x_2)^2 \, dx_1 dx_3$	$(\text{inches})^4$
I_2	III-4	Second Moment of Area $= \iint (x_1)^2 \, dx_1 dx_2$	$(\text{inches})^4$
I_3	III-4	Twisting Moment of Inertia.[1]	$(\text{inches})^4$
κ_1, κ_2	III-4	Shear deflection factors associated with x_1 and x_2 directions, respectively.[2]	
Z	III-4	Bending Modulus[5] $= R^2 \iint (x_1/[R-x_1]) \, dx_1 dx_2$ $= I_2 (1 + c_1/R^2 + c_2/R^4)$	$(\text{inches})^4$
c_1, c_2	III-4	Coefficients to define bending Modulus Z.[6]	$(\text{inches})^2$, $(\text{inches})^4$
R	III-4	Radius to Centroid of Area	inches
x_1, x_3	III-4	Coordinates in cross section	inches
C_1, C_2		$C_1 = x_1$ and $C_2 = x_3$ coefficients for bending stress computation	inches
C		Coefficient for torsional shear stress computation at stress point.[4]	

1, 2, 4, 5, 6 - Refer to References in Section X.

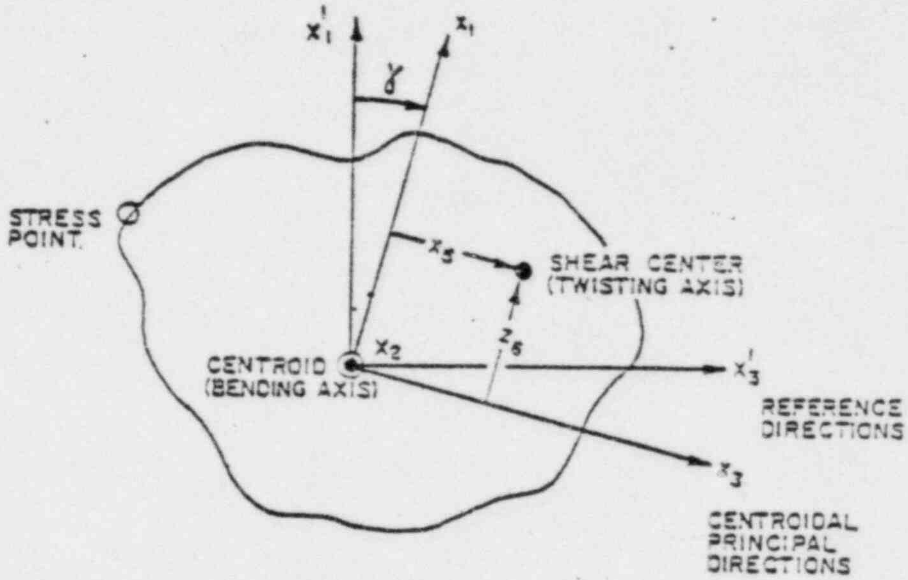


Figure III-3 Cross-Section for Straight Element

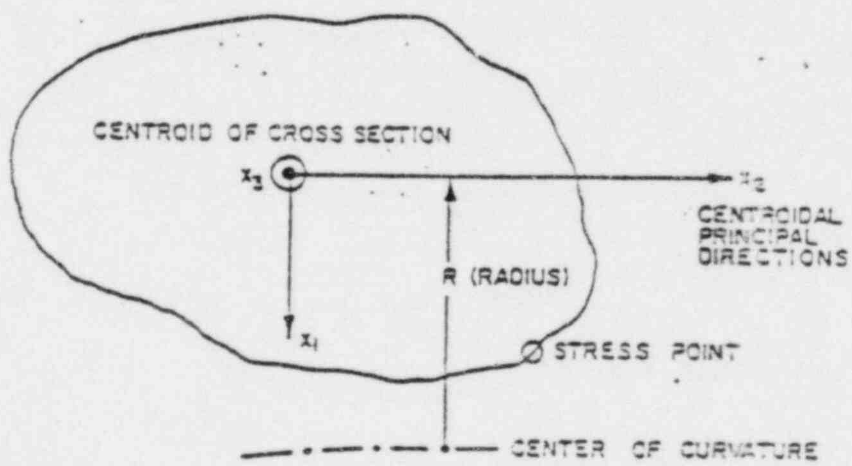


Figure III-4 Cross-Section for Curved Element

TABLE III-4
BOLT JOINT PARAMETERS

GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
NBI	III-5	Joint Number at which bolt reaction is referenced.	
V_1	III-5	Vector parallel to bolt axis	
V_2, V_3	III-5	Vectors (which are orthogonal to V_1) in bolt joint plane.	
D_b	III-5 (a)	Nominal Bolt Diameter	inches
n		Number of threads per inch	$(inch)^{-1}$
A_b		Root Area[7] = $\pi/4\ (D_b - 1.22687/n)^2$ for all Unified American Threads.	$(inches)^2$
N	III-5 (b)(c) III-5 (d)	Number of bolts, or Number of bolts in line.	
YSH, ZSH	III-5	Coordinates in V_2 and V_3 direction, respectively, from reference joint NBI to center of bolt joint pattern.	inches
D	III-5 (b)	Diameter of Bolt Circle.	inches
ϕ_o	III-5 (b)	Angle from V_2 direction to Bolt No. 1. Only 0 or 180/N permitted.	degrees
S	III-5 (c)(d)	Spacing between bolts on line = S/(N-1)	inches
YO	III-5 (c)	Distance from pivot edge to bolt line for leg pattern. or	inches
	III-5 (d)	Spacing between bolt lines for pad pattern.	inches
YE, ZT, ZB	III-5	Distances from pivot edges to bolts.	inches

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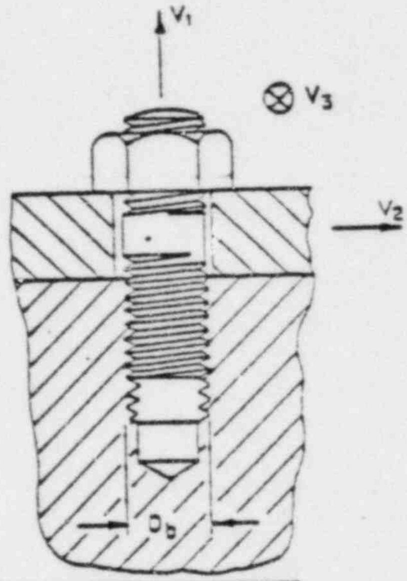
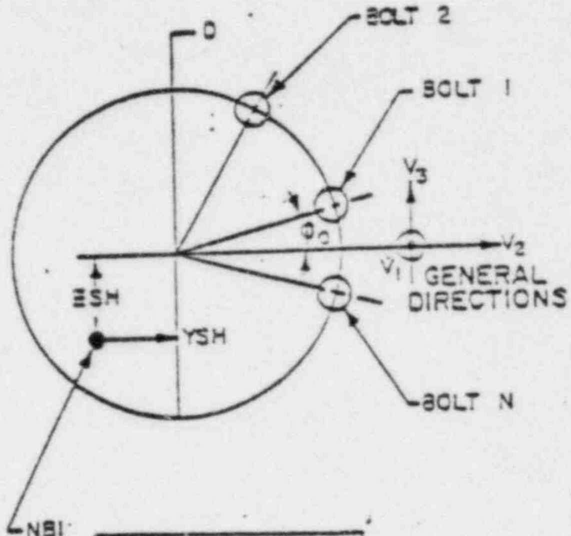
[7] - Refer to References in Section X.



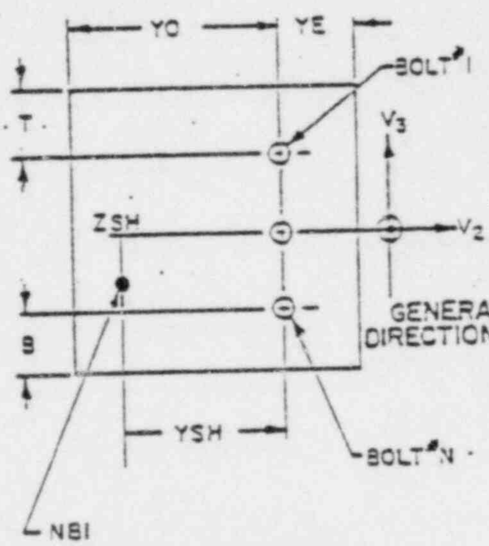
BOLT VECTORS

Figure III-5(a)



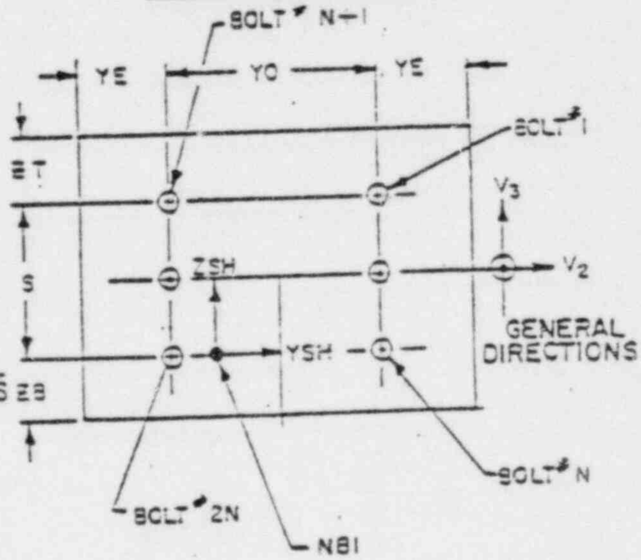
BOLT CIRCLE

Figure III-5(b)



LEG

Figure III-5(c)



PAD

Figure III-5(d)

FIGURES III-5 BOLTED JOINT INPUT PARAMETERS

IV. MODELING OF THE ACTUATOR-VALVE ASSEMBLY

IV.A Mathematical Model Components and Features

The model for the actuator-valve assembly is constructed from two basic types of beam elements each with distributed masses. These elements are referred to as a thick straight beam and a thick curved beam.[5] The ends of these beam elements are referred to as joints in the model. The joints can have as many as six degrees of freedom or as few as zero degrees of freedom (complete fixity). There are five types of joints: an equilibrium joint with independent displacements and rotations; an auxiliary joint with dependent displacements and rotations; a boundary joint with at least one degree of fixity; a spring boundary joint with at least one degree of elastic constraint; and a reference joint (which may be one of the above) at which bolting forces and moments are computed or the center of a curved element is defined.[8]

IV.A.1 Thick Straight Beam

The Element Coordinate System in which forces and moments are computed for the straight beam element is illustrated in Figure IV-1. The 2-axis lies along the centroidal axis of the beam from the joint at end two to end one. Positive directions of rotation about the 1, 2, and 3-axis obey the right-hand rule. The coordinates in the cross-section, x_1, x_3, are in the direction of the 1 and 3 axes (Figure III-3). The twisting axis[3] of the beam is parallel to but need not coincide with the centroidal axis. Shear deflection[2] is considered in the derivation of the stiffness and mass matrices.

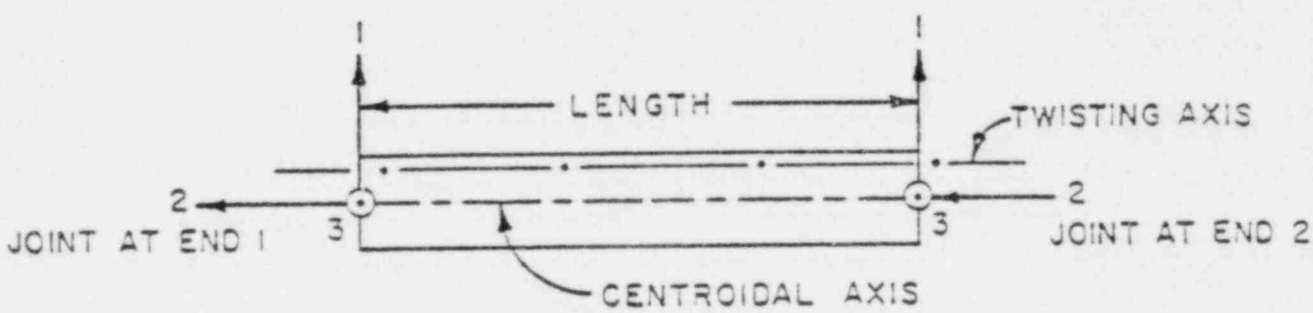


FIGURE IV-1

ELEMENT COORDINATE SYSTEM FOR A THICK STRAIGHT BEAM

2, 3, 5, 8 - Refer to References in Section X.

IV.A.2 Thick Curved Beam

The element coordinate system in which forces and moments are computed for each end of the curved beam element is illustrated in Figure IV-2. The positive direction of the 1-axis always is towards the center of curvature. The 3-axis is tangent to the centroidal axis. The radius of curvature is the distance from the center of curvature to the centroidal axis of the curved beam element. Positive directions of rotation about the 1, 2, and 3-axis obey the right-hand rule. The coordinates in the cross-section, x_1, x_2 are in the direction of the 1 and 2 axes (Figure III-4). The shift of bending axis from centroidal axis[5] and shear deflection[2] is considered in the derivation of the stiffness and mass matrices.

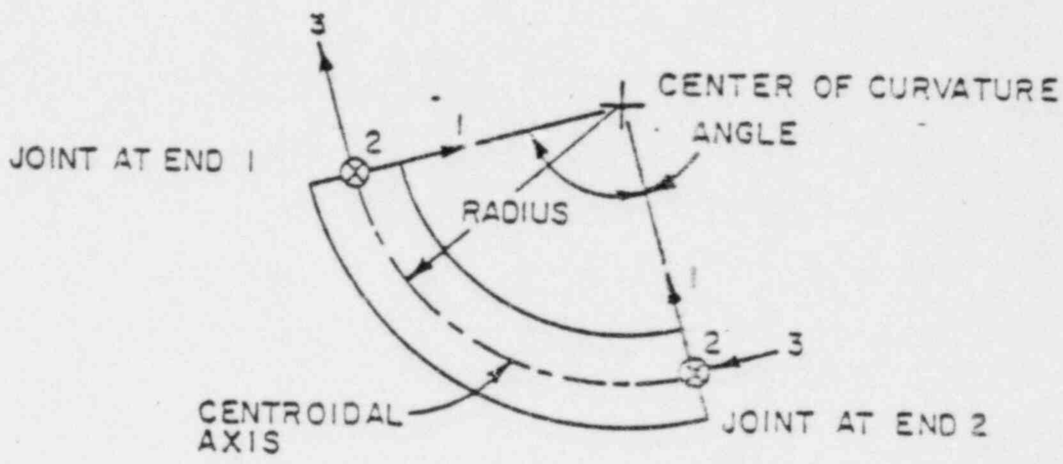


FIGURE IV-2

ELEMENT COORDINATE SYSTEM FOR A THICK CURVED BEAM

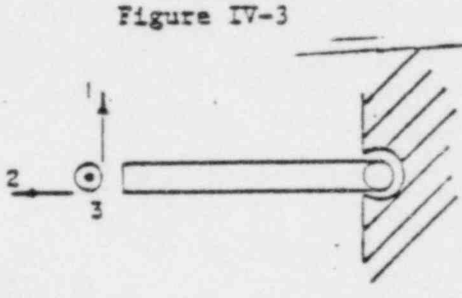
2, 5 - Refer to References in Section X.

IV.A.3 Element End Releases[9]

There are normally six degrees of freedom considered (three displacements and three rotations) at each joint. Any of these degrees of freedom may be specified as constrained or unconstrained, or as having an elastic connection to the adjacent elements. Figures IV-3 thru IV-6 describe typical release mechanisms. In Figure IV-3 end two of a straight element is released for degree of freedom six (rotation about 3-axis) representing a pin joint. In Figure IV-4 degree of freedom two (displacement along 2-axis) is released representing a slide connection. In Figure IV-5, a ball joint is modeled by releasing all rotations (degrees of freedom 4, 5, and 6). Figure IV-6 has an elastic connection to adjacent elements at end two in the axial and transverse directions.

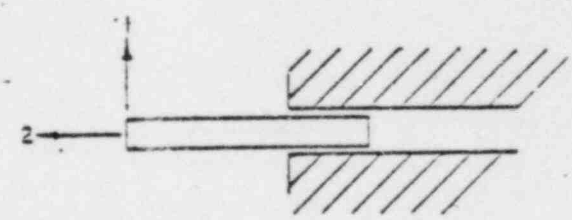
PIN CONNECTION

Figure IV-3



SLIDE CONNECTION

Figure IV-4



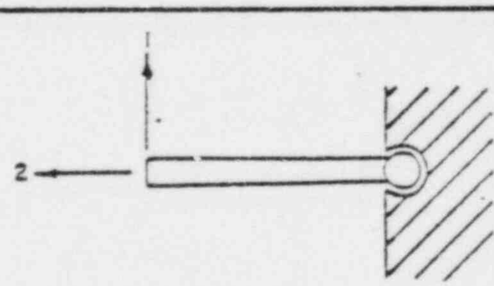


Figure IV-5

BALL CONNECTION

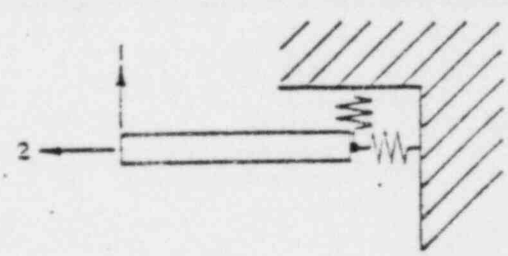


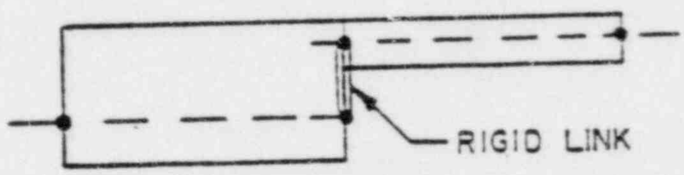
Figure IV-6

BI-AXIAL SPRING CONNECTION

9 - Refer to References in Section X.

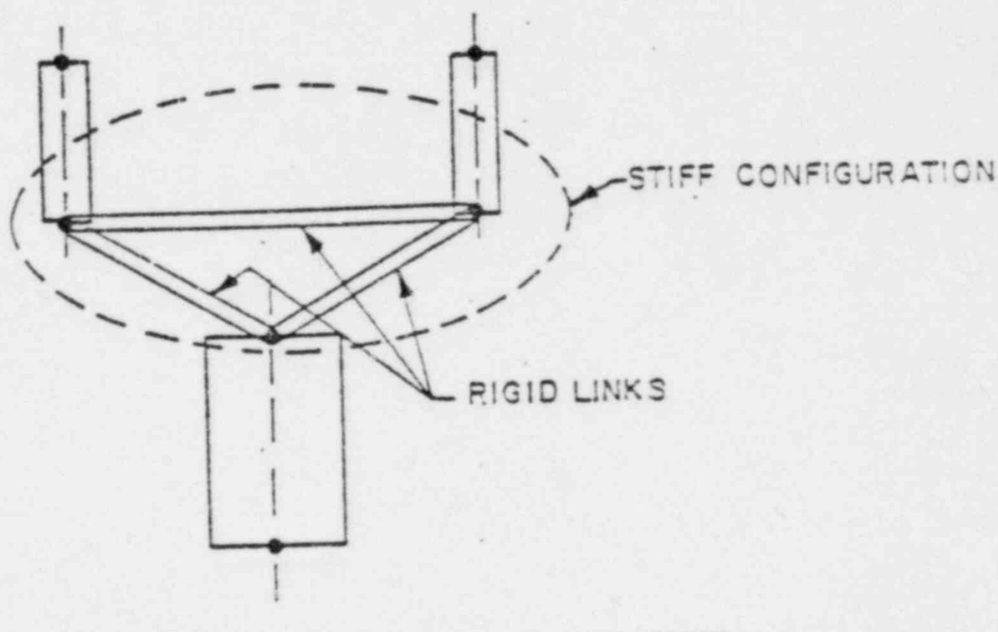
IV.A.4 Rigid Link[10]

A rigid link between any auxiliary joint and any equilibrium joint can be modeled exactly. A kinematic transformation of the element's stiffness and mass matrices is used for this purpose. Rigid links ensure that the rotation of all joints so connected are the same and that the displacements of all joints are related through the vector distances from each other. The rigid link mechanism may be used to accurately model elements joined off their centroidal axes, Figure IV-7, or extremely inelastic members of a physical structure as shown in Figure IV-8. In the latter example, any two of the three indicated rigid links may be specified.



ELEMENTS WITH CENTROIDAL AXES NOT ALIGNED

Figure IV-7



ELEMENTS JOINED THROUGH INELASTIC MEMBER

FIGURE IV-8

10 - Refer to References in Section X.

IV.A.5 Lumped Inertia Properties

Each elastic element in the mathematical model has an associated consistent mass matrix which accounts for a uniform distribution of mass.[5] Inertia other than this may be defined for accessories, rigid portions that were not modeled elastically (e.g., Figure IV-8) and shaft-disc assemblies. The inertia properties may be specified as lumped masses acting at any joint or at any coordinate from any joint. The lumped mass may act in all or only in some of the system coordinate directions. For example, a mass attached to a shaft supported by a journal and thrust bearing may be specified to act in the transverse directions of the journal and in the axial direction of the thrust bearing. Centroidal principal moments of inertia aligned to the system coordinates may be specified at any joint.

IV.A.6 Spring Boundaries and Constraints[8]

Boundary joints of the model may be attached to the external boundary with either complete or elastic fixity in any of the six system degrees of freedom (three translational and three rotational). Thus, a hanger may be modeled by means of uniaxial spring, and the piping or body (assumed rigid) may be modeled by specifying complete fixity.

IV.A.7 Cross section Properties[11]

The built-in standard cross sections in SEISMIC 4 as depicted in Figures III-2 may be used to define the properties of any straight or curved element. For special constructions, the Order Engineer may input nonstandard properties as described in Table III-1 and Figures III-3 and Figures III-4 to fit the modeling need.

V. MATHEMATICAL ANALYSIS

The SEISMIC 4 computer program employs the modeling features as described in Section IV.A to yield response to seismic excitation and operational loads and to compute system resonant frequency.

V.A Synthesis of Stiffness, Mass and Load Matrices[12]

The exact stiffness and consistent mass matrices are derived for each element (Section IV.A.1 and IV.A.2). A three column load matrix is

5, 8, 11, 12 - Refer to References in Section X.

determined from the mass matrix for unit gravitational loads in each of the system directions. Any required release (Section IV.A.3) or kinematic transformation (Section IV.A.4) is performed. The resulting matrices are then transformed from their element to the system coordinates and accumulated forming the system stiffness and mass matrices and three columns of the system load matrix. Lumped inertia properties (Section IV.A.5) are added to the system mass matrix and appropriate forces are added to the three unit gravitational load columns. Operational loads other than deadweight, consisting of concentrated forces and moments at any joint, comprise a fourth column of the system load matrix. Prescribed boundary conditions (Section IV.A.6) are then imposed on the system matrices, yielding:

[K] System Stiffness Matrix, symmetric (usually banded),

[M] System Mass Matrix, symmetric (usually banded),

[F] System Load Matrix, composed of three unit gravitational load columns and one operational load column.

V.B Gravitational and Operational Load Solution

The deformation due to the static unit gravitational and operational loads derives from the solution of the matrix equation:

$$[K]\,[X] = [F] \qquad (V.3\text{-}1)$$

where [K] and [F] were defined in Section V.A, and [X] is a four column deformation matrix; the first three are responses to the unit graviational loads in each of the system coordinates and the fourth the response to the operational loading condition not including deadweight. Each column of [X] consists of deflections in the system X, Y, Z directions, rotations about the system X, Y, Z directions for each equilibrium joint. The corresponding deformations for auxiliary joints are computed by employment of the kinematic transformations (Section IV.A.4).

V.C Determination of the Fundamental Resonant Frequency

A complete seismic analysis of any structural system includes the structural analysis for the dynamic loads caused by the vibratory earthquake motion of its supports. There are two general methods of analysis for dynamic loading depending upon the characteristics of the system. The equivalent static analysis, which is employed here, is applicable and conservative for actuator systems that can be shown to have no natural frequencies less than a specified amount. Thus, the lowest or fundamental frequency must be computed.

The fundamental resonant frequency is found by determining the smallest eigenvalue, λ, and corresponding eigenvector {u} from the undamped free vibration equation:[13]

$$([K] - \lambda [M]) \{u\} = \{0\} \quad \text{(V.C-1)}$$

where [K] and [M] are the system stiffness and mass matrices (Section V.A), {u} is the eigenvector corresponding to the smallest eigenvalue λ, and is normalized in the SEISMIC 4 computer program so that the largest displacement or rotation at any equilibrium joint is plus or minus one, {0} is a null vector.

The fundamental resonant frequency, f, is then determined by:

$$f = \sqrt{\lambda}/(2\pi) \quad \text{(V.C-2)}$$

the algorithm[14] used to determine values for λ is based on an iteration procedure on equation V.C-1 using as starting values the unit gravitational deformations (Section V.B).

V.D Calculation of Element Forces and Moments[15]

The force and moment response of the ends of the elements due to the four column load matrix [F] (Section V.A) are determined from:

$$[p] = [k] [S] - [m] [g] \quad \text{(V.D-1)}$$

where [p] is a four column matrix consisting of the element forces and moments at each end (thus, twelve rows),

[k] is the element stiffness matrix,

[m] is the element mass matrix, both described in Section IV.A.1 and Section IV.A.2,

[g] is a four column matrix; the first three consist of unit gravitational loads, the fourth a null column, and

[S] is a four column matrix consisting of the deformation response to unit gravitational and operational loads extracted from the system solution matrix [X] (Section V.B). The extraction of [S] from [X] involves transformation from system to element end coordinates (Sections IV.A.1 and IV.A.2) and accounting for any kinematic transformations (IV.A.4) or releases (IV.A.3).

13, 14, 15 - Refer to References in Section X.

V.E Calculation of Junction Reactions

The resultant reactions [P] due to the four basic loading conditions (Section V.B) is determined at all boundary joints and at any specified cut in the model. The element forces and moments [p] (Section V.D) for all elements joining at a boundary or on one side of the cut are employed to determine the junction reaction. The rigid link transformation (Section IV.A.4) is performed on [p] prior to transformation from the element coordinates (A.1 and A.2) to the system coordinate (Section III.C) and adding to [P].

VI. DETERMINATION OF SEISMIC AND OPERATIONAL FORCES AND MOMENTS

The resultant element end [p] (Section V.D) and junction [P] (Section V.E) reactions (forces and moments) for each of the unit loading conditions may be superimposed, because of the linear nature of elastic, small deformation systems,[12] to yield the reactions for any magnitude and direction of seismic excitation and any actuator orientation with respect to gravitational and seismic acceleration.

In this seismic analysis computer program, the capability is provided for the specification of any vertical gravitational direction with an associated G-level and two different G-levels for each of the two mutually perpendicular horizontal directions.

The Order Engineer may define the vertical gravitational direction by specifying to the SEISMIC 4 computer program a clue; either X-UP, Y-UP, Z-UP, or SKEW (along with the vertically downward vector, {V}). Another clue may be used to define one horizontal direction, {H1}, (the other horizontal direction {H2} is mutually perpendicular).

The corresponding seismic directions and their vector components with respect to the system coordinates for typical specifications are shown in Figure VI-1.

The resultant reactions on the element ends or junctions for the operational load is a superposition of the fourth column of [p] or [P] with some linear combination of the first three rows corresponding to the acceleration of gravity in the {V} direction, to account for deadweight.

12 - Refer to References to Section X.

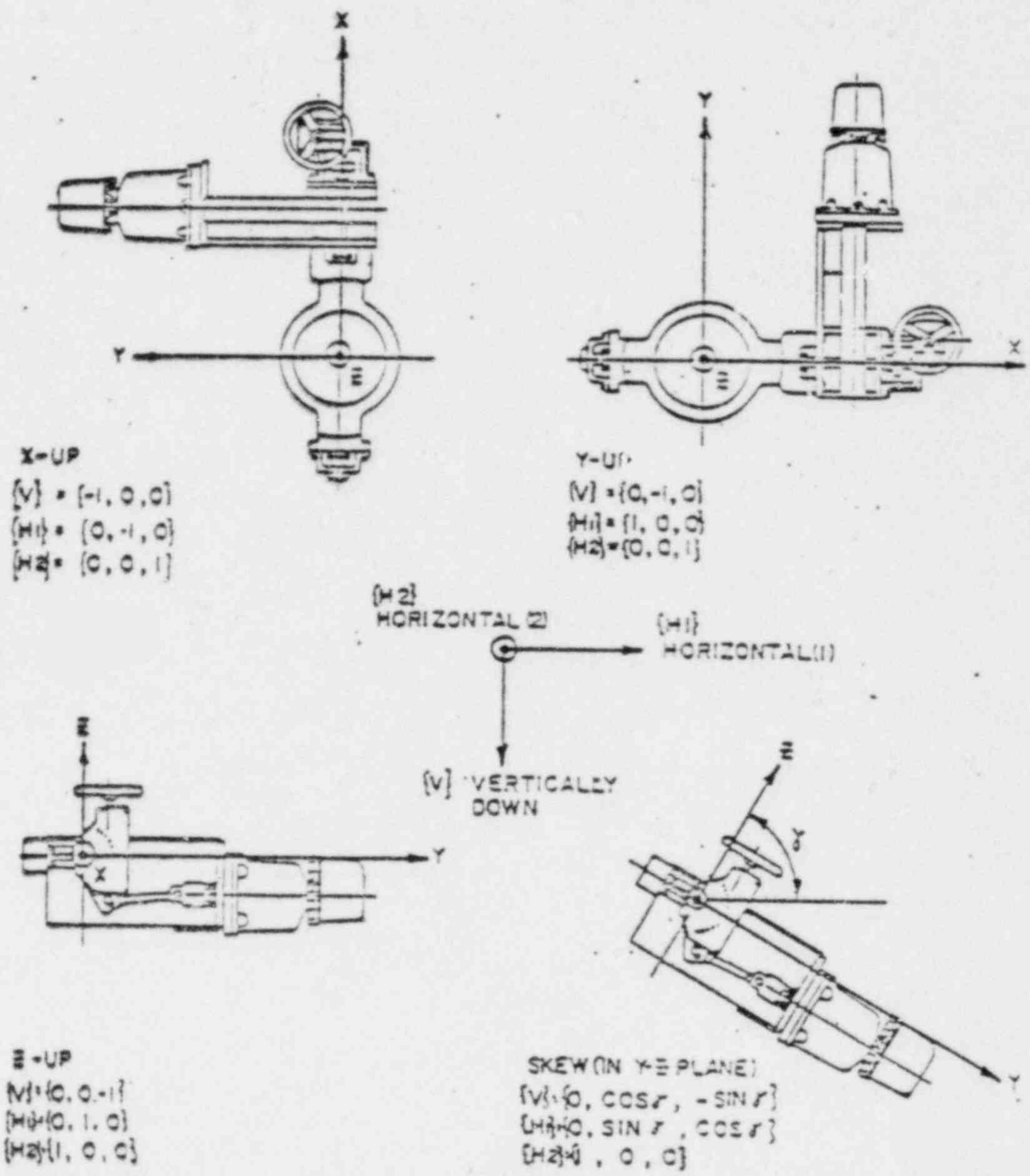


FIGURE VI-1 Typical Seismic Directions

VII. DETERMINATION OF STRESSES

The stress analysis of the actuator-valve assembly is carried out for the locations specified by the engineer. All straight and curved beam element ends may be selected. All bolted joints connecting one section to another or to the body may be selected. The portion of the structure on either side of a bolted joint is represented by a plane designation. The plane being defined for the ends of the elements that load the joint (refer to Figure VII-1 for typical locations where stresses are computed). The numerical designations refer to subsections in Section VII that follow. A detailed explanation of the methods for determining the stress components is presented in each particular section.

In general, the stresses at these locations are arrived at in the following manner. The element end and junction reactions for the seismic and operational loads were calculated as described in Section VI.

Normal and shear stress components for each of these four independent loading conditions are computed in accordance with the procedures in the following subsections. The seismic normal and shear stress components depending upon specifications are combined in any of three ways: direct sum, SRSS[16] (Square Root of the Sum of the Squares), or the sum of the absolute values. Each combined seismic normal and shear stress component is either added to, or subtracted from, the operational stress component, whichever yields the combined component with the larger magnitude. Either the maximum absolute principal stress, P_{max}, or the maximum stress intensity, S_{max},[17] is then computed (Equations VII-1 through 5) in accordance to specifications.

$$\tau_{max} = \sqrt{(\sigma/2)^2 + (\tau)^2} \quad \text{(VII-1)}$$

$$\sigma_{P_{max}} = (\sigma/2) + \tau_{max} \quad \text{(VII-2)}$$

$$\sigma_{P_{min}} = (\sigma/2) - \tau_{max} \quad \text{(VII-3)}$$

$$S_{max} = \text{Largest of } 2\,\tau_{max}\text{, or } (\sigma_{P_{max}} - \sigma_{P_{min}}) \quad \text{(VII-4)}$$

$$P_{max} = \text{largest of } \sigma_{P_{max}}\text{, or } |\sigma_{P_{min}}| \quad \text{(VII-5)}$$

16, 17 - Refer to References in Section X.

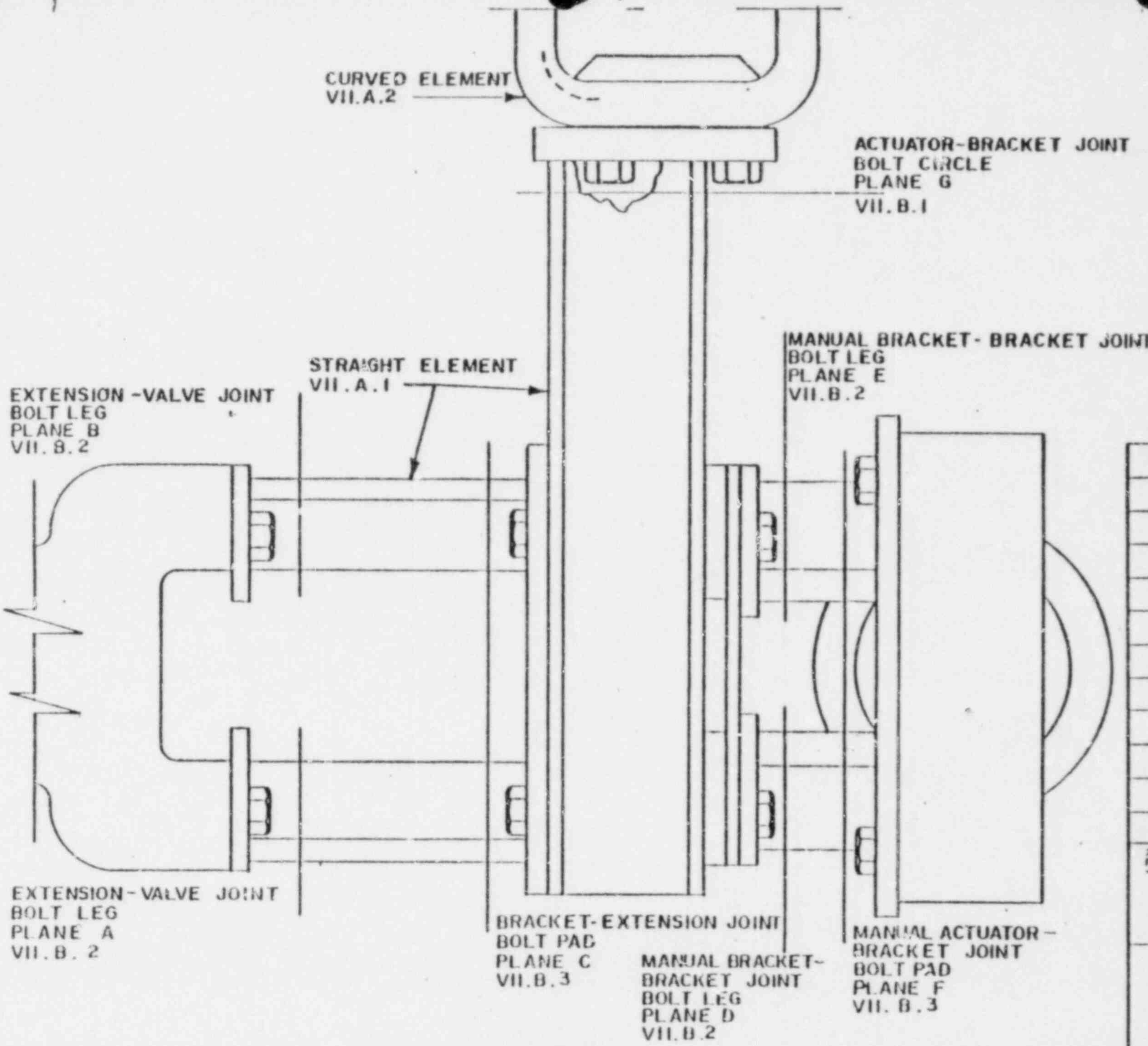


FIGURE VII-1
SECTIONS WHERE STRESSES ARE COMPUTED

Fisher Controls
MARSHALLTOWN, IOWA

ENGINEERING STANDARD

SEISMIC ANALYSIS OF ROTARY VALVE ASSEMBLIES FOR NUCLEAR SERVICE

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where σ is the surface fiber stress at a point on beam or the average axial stress in a bolt,

τ is a shear stress at a point on a beam or the average shear stress in a bolt,

τ_{max} is the maximum shear stress,

$\sigma_{P_{max}}$ is the maximum principal stress,

$\sigma_{P_{min}}$ is the minimum principal stress, with the third principal stress assumed zero (beam surface point or average through bolt).

P_{max} or S_{max}, designated the "total" stress is compared against the appropriate stress limit in Section VIII of this standard.

VII.A Beam Stress Computation

The end force and moment reactions for each of the four independent load conditions comprise each column of [p], derived in Section V.D and transformed in Section VI.

$$\begin{Bmatrix} F_1^{(1)} \\ F_2^{(1)} \\ F_3^{(1)} \\ M_1^{(1)} \\ M_2^{(1)} \\ M_3^{(1)} \\ F_1^{(2)} \\ F_2^{(2)} \\ F_3^{(2)} \\ M_1^{(2)} \\ M_2^{(2)} \\ M_3^{(2)} \end{Bmatrix} = \{P\} \qquad \text{(VII.A-1)}$$

where $F_i^{(j)}$ $i = 1, 2, 3$ and $j = 1, 2$ are the reaction forces in the element, i direction for end j of the beam, and

$M_i^{(j)}$ are the reaction moments.

{p} represents any column of [P].

In the following subsections, the beam stress-reaction relations are presented with a sketch of the reaction sign conventions (Figures VII-2 and VII-4).

At both ends of the beam, at several selected points on the cross-section, a surface fiber stress, σ, and a shear stress, τ, is computed. σ and τ are then introduced into equations VII-1 to 5 for the computation of the "total" stress at each point.

VII.A.1 Straight Beam Stress

The end reactions as described in Section VII.A are aligned with the element coordinates as shown in Figure VII-2.

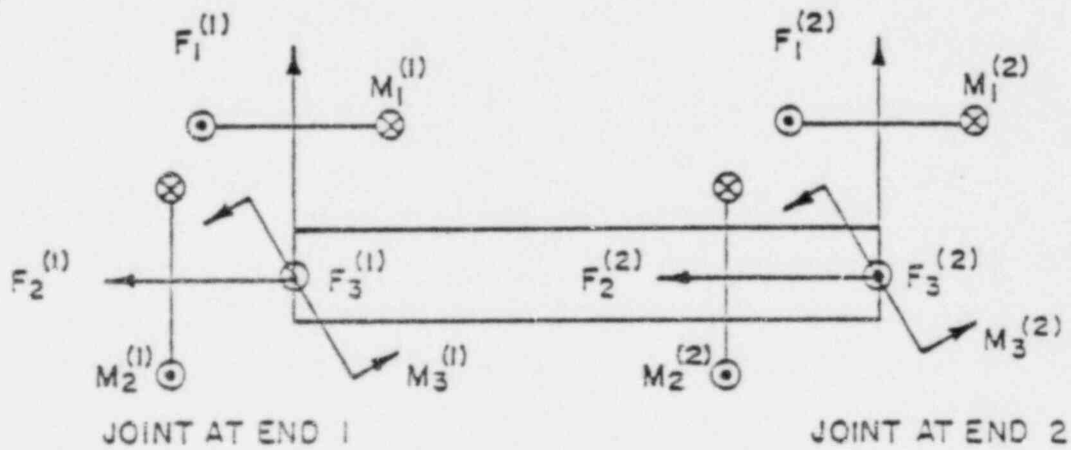


Figure VII-2

The stress at any point on the cross section, at either end, may be determined from the forces, F_1, F_2, F_3, and the moments, M_1, M_2, M_3, (superscript (1) or (2) denoting end, will be omitted in the following text), the cross-sectional properties for the end, A, I_1, I_2, I_3, the bending stress coefficients, C_1, C_3, and the torsional shear stress coefficients, C, as described in Table III-2 and Figure III-3.

Thus, the fiber stress[15] is

$$\sigma = \pm (F_2/A - C_3M_1/I_1 + C_1M_3/I_3) \qquad \text{(VII.A.1-1)}$$

15 - Refer to References in Section X.

The shear stress may be written, conservatively, assuming that the torsional shear[1] acts in the same direction as the transverse component of shear and the transverse component, which is zero on the outer surfaces, is taken as an average across the section:

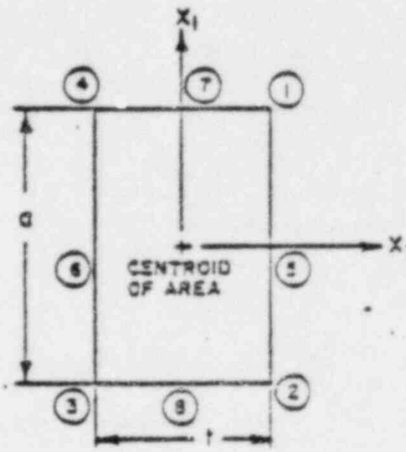
$$\tau = \pm [|(CM_2/I_2)| + \sqrt{(F_1)^2 + (F_3)^2}/A] \qquad \text{(VII.A.1-2)}$$

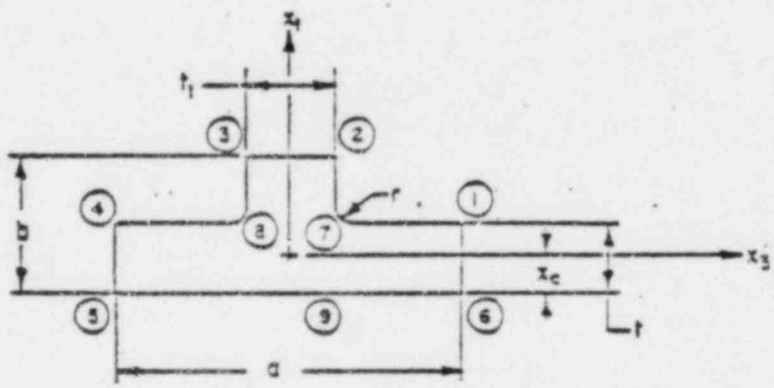
In the above equations, the + sign is employed for end one of the element and the - sign for end 2.

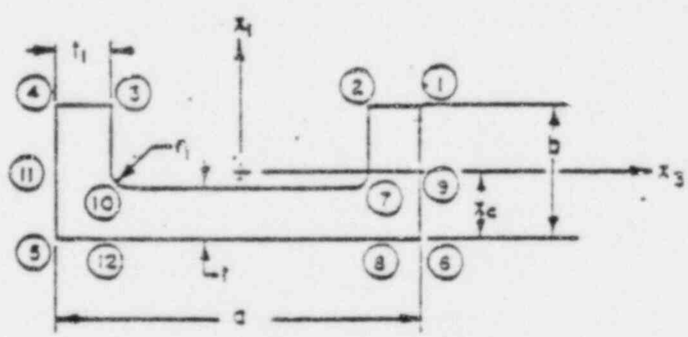
For standard sections (Figures III-2) A, I_1, I_2, I_3, and sets of C_1, C_3, and C are determined in the SEISMIC 4 computer program from the input parameters described in Table III-1.[11] The coefficients for the stress points are chosen at extreme fibers and near points at which the largest inscribed circle touches the boundary. For the standard sections, points, indicated by encircled numbers, are shown on Figures VII-3. Note that $C_1 = x_1$ and $C_3 = x_3$.

For nonstandard cross-sections C, C_1 and C_3 are entered directly along with the other section properties (Table III-2).

1, 11 - Refer to References in Section X.

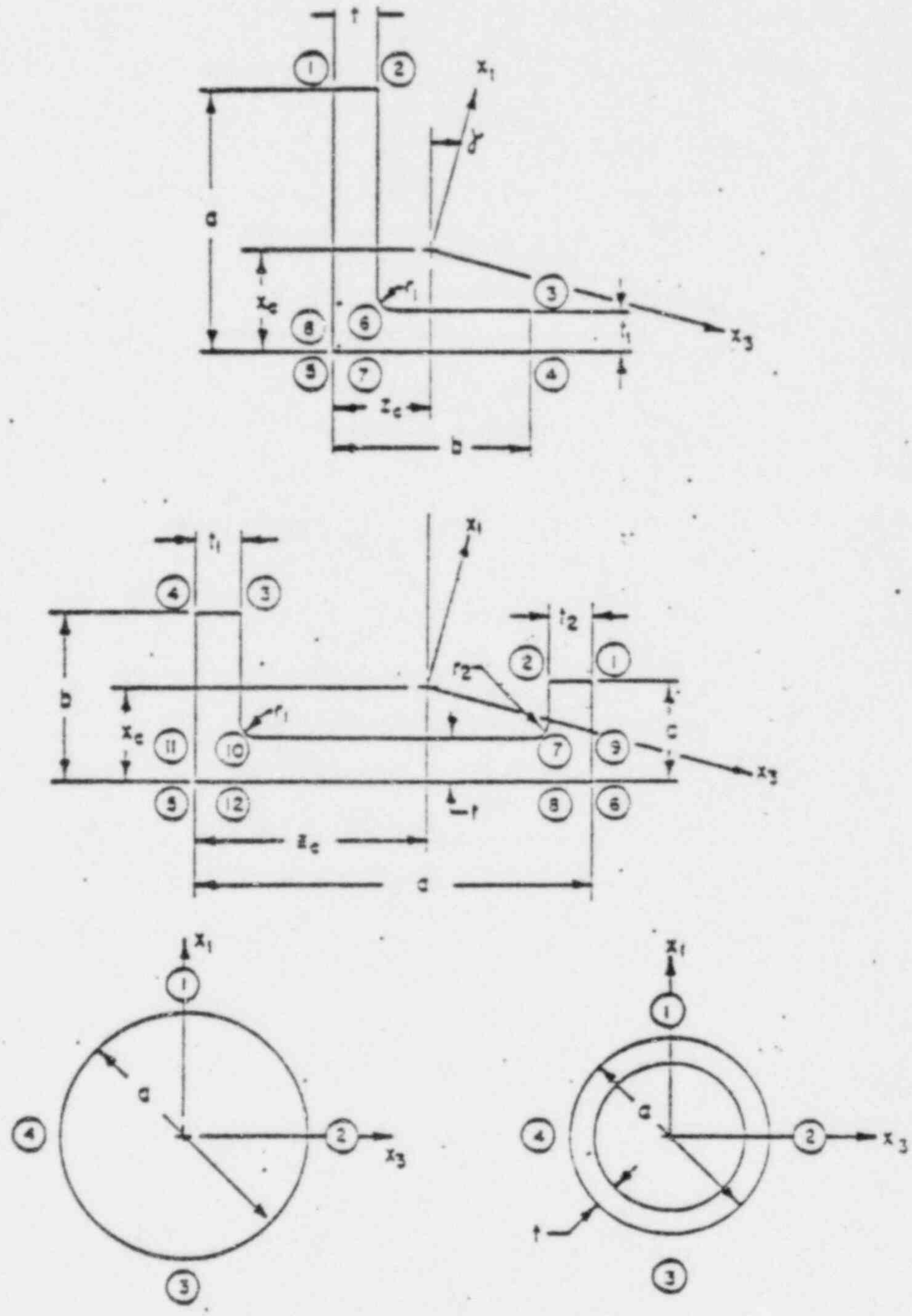






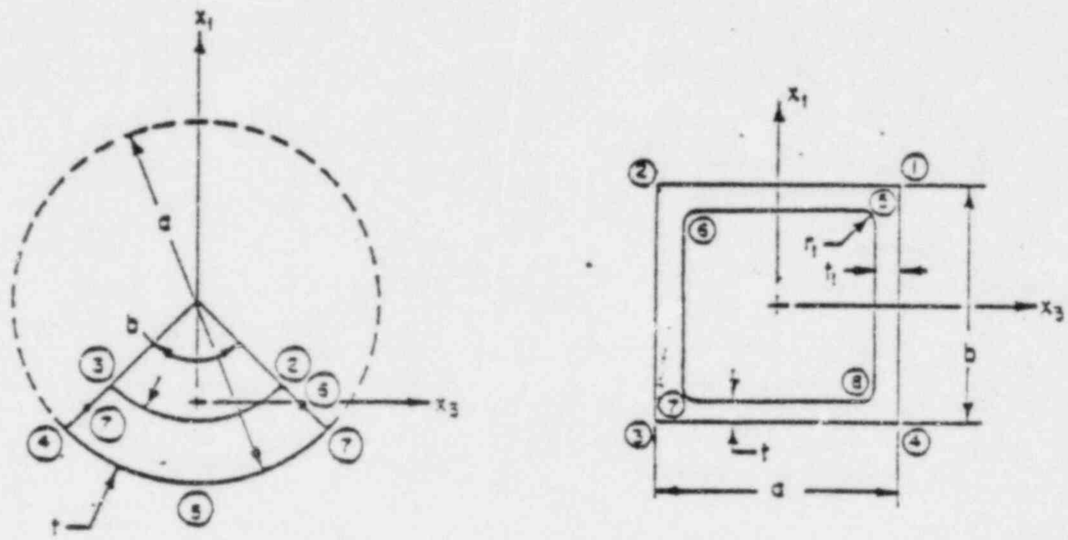
STRESS LOCATIONS STANDARD CROSS SECTIONS

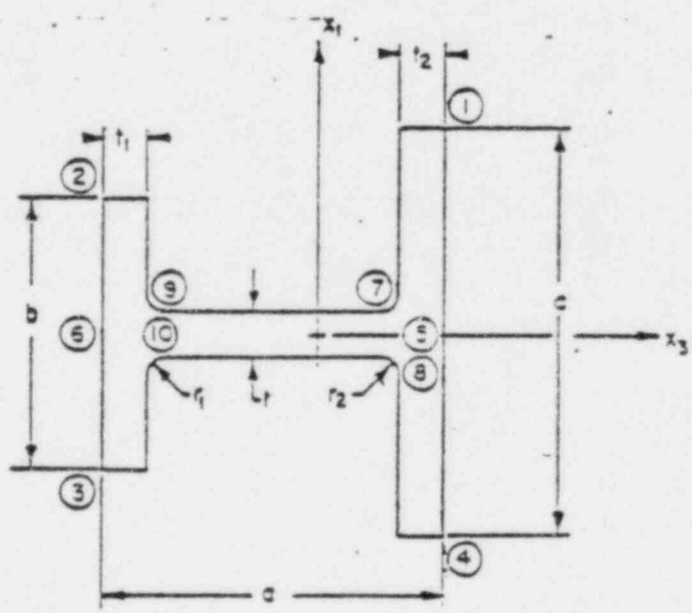
FIGURES VII-3



STRESS LOCATIONS STANDARD CROSS SECTIONS

FIGURES VII-3





STRESS LOCATIONS STANDARD CROSS SECTIONS

FIGURES VII-3

VII.A.2 Curved Beam Stress

The end reactions as described in Section VII.A are aligned with the element end coordinates as shown in Figure VII-4.

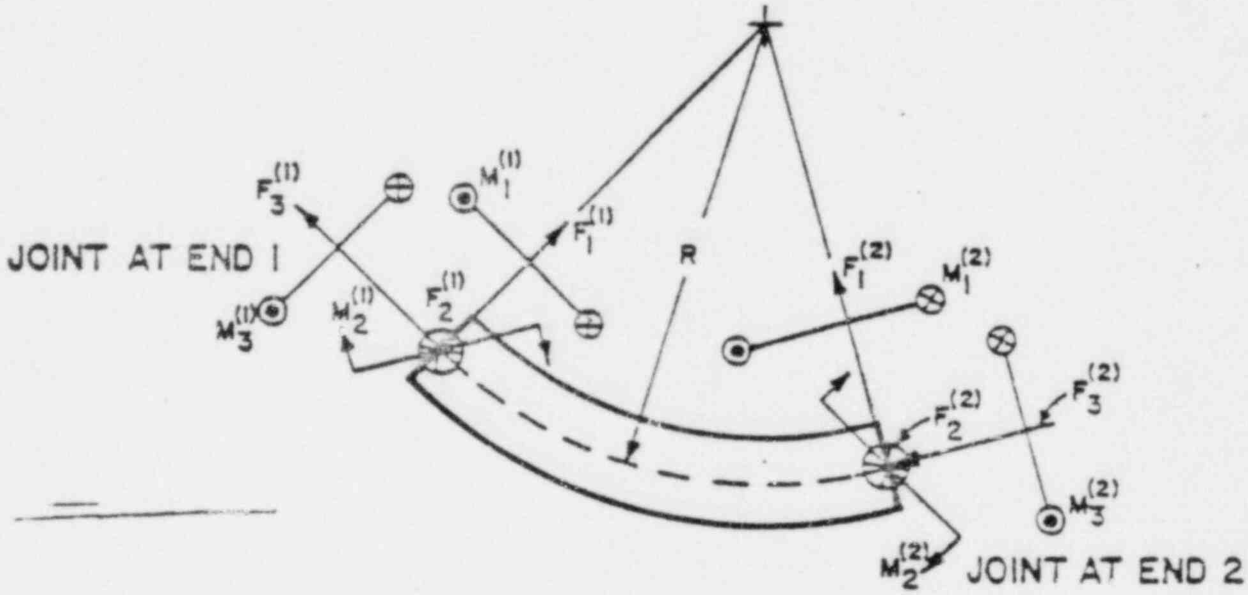


Figure VII-4

The stress at any point on the cross-section, at either end, may be determined from the forces, F_1, F_2, F_3, and the moments, M_1, M_2, M_3, the cross-section properties for the end, A, Z, I_1 and I_3, the bending stress coefficients, C_1, C_2, the torsional shear stress coefficient, C, and the radius to the centroid, R, as described in Table III-3 and Figure III-4.

The fiber stress[5] is:

$$\sigma = \pm \{(F_3 + M_2/R)/A - C_1 R M_2/[Z(R - C_1)] + C_2 M_1/I_1\} \qquad \text{(VII.A.2-1)}$$

The shear stress may be written, using the same conservative assumptions as in the development of equation VII.A.1-2.

$$\tau = \pm [\,|(CM_3/I_3)| + \sqrt{(F_1)^2 + (F_2)^2}/A] \qquad \text{(VII.A.2-2)}$$

5 - Refer to References in Section X.

where the + sign is employed for end one of the element and the - sign for end 2.

For standard sections (Figures III-2), A, Z, I_1, I_3 and sets of C_1, C_2 and C are determined in the SEISMIC 4 computer program in the same manner as for the straight standard cross-sections,[11] Figures VII-3.

Because of the difference in coordinate systems, (x_1, x_2, x_3) for a curved element corresponds to $(x_1, -x_3, -x_2)$ for a straight element (compare Figures IV-1 and IV-2). Therefore, for a curved element $C_1 = x_1$ and $C_2 = x_3$ in Figures VII-3. For nonstandard cross sections, C, C_1 and C_2 are entered directly with the other section properties (Table III-3).

VII.B Bolted Joint Stresses[18]

The junction reactions, [P], described in Section V.E and transformed to yield three independent seismic loads and the operational load including deadweight as described in Section VI, are the basis for computation of bolt joint loads and stresses. Each of the four independent columns of [P], designated {P}, has force and moment components in the system coordinate directions X, Y and Z.

$$\{P\} = \begin{Bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{Bmatrix} \qquad \text{(VII.B-1)}$$

{P} is transformed to the bolt configuration coordinate system defined by specified vectors, $\{V_1\}$, $\{V_2\}$ and $\{V_3\}$, and then shifted to the reference center of the configuration by the specified coordinates YSH and ZSH, described in Table III.D-4 and Figures III.D-4.

$\{V_1\}$ is parallel to the bolt axes in the direction toward the elements used to define the junction reactions (Section V.E).

The transformed load in the bolt configuration coordinate system is designated {B}:

11, 18 - Refer to References in Section X.

$$\{B\} = \begin{Bmatrix} f_1 \\ f_2 \\ f_3 \\ m_1 \\ m_2 \\ m_3 \end{Bmatrix} \qquad \text{(VII.B-2)}$$

where f_i ($i = 1, 2, 3$) are the forces acting at the reference center of the configuration in the V_i direction, and m_i are the moments.

f_2, f_3, m_1 will be used to compute two average shear stress components τ_2 and τ_3, and f_1, m_2, m_3 will be used to compute average axial stress, σ.

τ_2 and τ_3 are shear stress components in the V_2 and V_3 directions. These shear components for each independent seismic load and the operational load will be combined in the specified manner (Section VII). After combination, a single shear stress, τ, will be computed, which, along with σ, will be introduced into equations VII-1 to 5 for computation of "total" stress in each bolt:

$$\tau = \sqrt{(\tau_2)^2 + (\tau_3)^2} \qquad \text{(VII.B-3)}$$

Implicit in the computation of τ_2 and τ_3 is the conservative assumption that the shearing forces are resisted by the bolts and not by friction between the flanges.

In the following Sections VII.B.1 and VII.B.2, the stresses σ and τ for each bolt in the configuration will be computed so that there is equilibrium with the load {B} and flange reactions.

VII.3.1 Bolt Circle

The forces and moments on the bolt circle configuration consisting of N bolts may be depicted as in Figure VII-5.

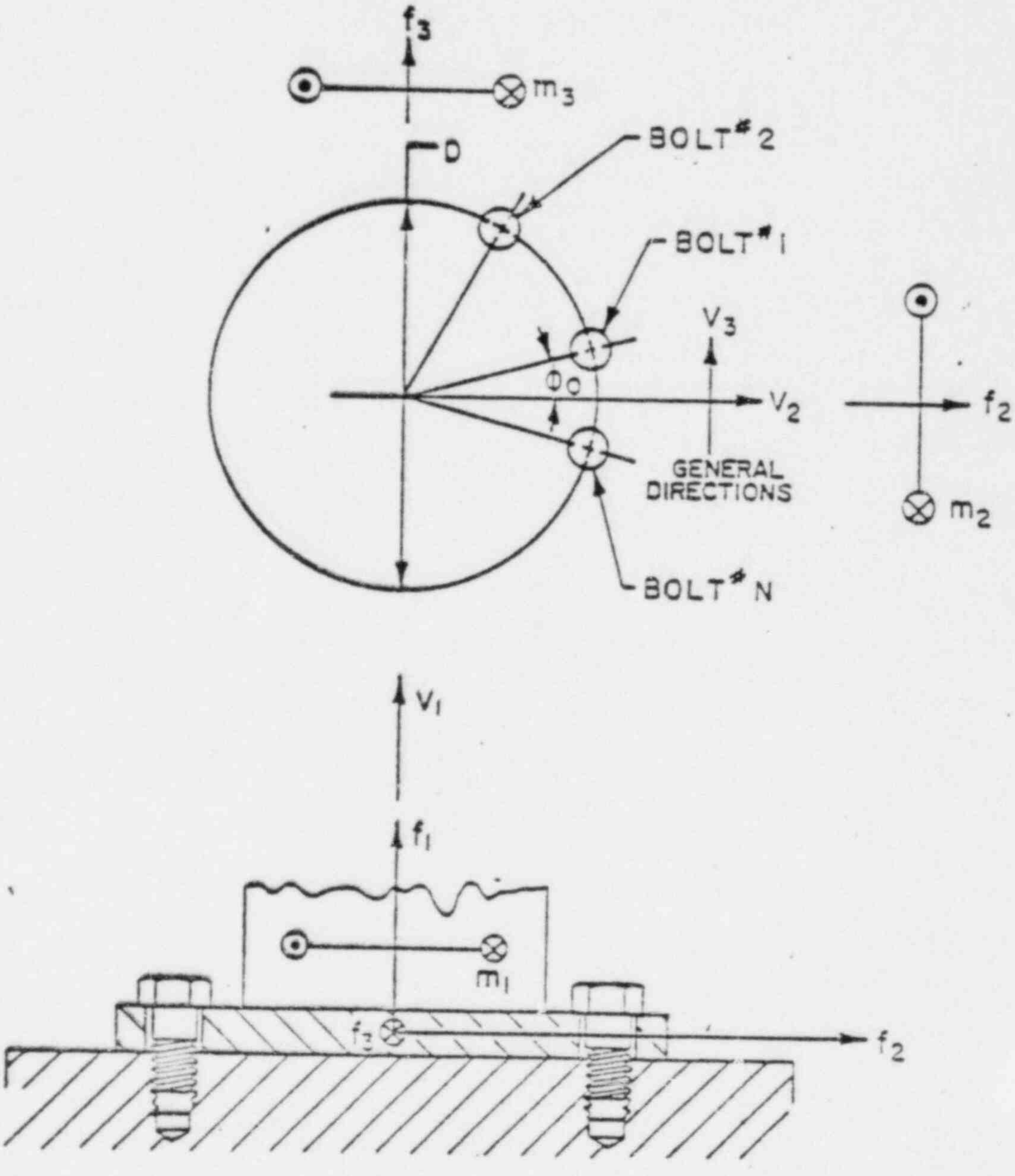


Figure VII-5
BOLT CIRCLE

The specified parameters for the bolt circle, N, ϕ_o, D and A_b are described in Table III-4 and Figure III-5(b).

The angular location, ϕ_i, in degrees, for the ith bolt, (i = 1, 2, 3, ...N), is:

$$\phi_i = 360(i - 1)/N + \phi_o \qquad \text{(VII.B.1-1)}$$

The inplane forces, f_2, f_3, will be assumed to be distributed uniformly to each bolt. In addition, the twisting moment, m_1, will be equilibrated by equal tangential shear forces with components in the $\{V_2\}$ and $\{V_3\}$ directions.

Thus,

$$V_{f_2}^{(i)} = (f_2 - \sin\phi_i(2m_1)/D)/N \qquad \text{(VII.B.1-2)}$$

$$V_{f_3}^{(i)} = (f_3 + \cos\phi_i(2m_1)/D)/N \qquad \text{(VII.B.1-3)}$$

The average total shear stress components on the ith bolt are thus,

$$\tau_1 = V_{f_2}^{(i)}/A_b \qquad \text{(VII.B.1-4)}$$

$$\tau_2 = V_{f_3}^{(i)}/A_b \qquad \text{(VII.B.1-5)}$$

where D is the bolt circle diameter, and

A_b is the root area of each bolt.

The axial force, f_1, and bending moments, m_2, m_3, will be assumed to be in equilibrium with the bolt axial forces, thus, the axial force in the ith bolt is:

$$A^{(i)} = [f_1 + (4/D)(m_2 \sin\phi_i - m_3 \cos\phi_i)]/N \qquad \text{(VII.B.1-6)}$$

It can be shown that for at least three evenly spaced bolts (i.e., N = 3),

$$\sum_{i=1}^{N} A^{(i)} = f_1 \qquad \text{(VII.B.1-7)}$$

$$\sum_{i=1}^{N} A^{(i)} \left(\frac{D}{2} \sin \phi_i\right) = m_2 \qquad \text{(VII.B.1-8)}$$

$$\sum_{i=1}^{N} A^{(i)} \left(\frac{D}{2} \cos \phi_i\right) = m_3 \qquad \text{(VII.B.1-9)}$$

The average axial stress for the ith bolt is, thus,

$$\sigma = A^{(i)}/A_b \qquad \text{(VII.B.1-10)}$$

For the operational loading condition a gasket force, F_g, may be specified which adds to the axial force. This total, if positive, is used to compute the axial stress for each bolt under operational conditions; if negative, it is assumed that the flanges react in compression and σ for those bolts with $A^{(i)} + F_g/N < 0$ is assumed zero.

$$\sigma_{\text{operational}} = A^{(i)} + (F_g/N)/A_b \qquad \text{(VII.B.1-11)}$$

VII.B.2 Bolted Joint Leg Configuration

A commonly used bolted connection between components in an actuator-valve assembly is designated a Leg Configuration with a single line of N evenly spaced bolts on a rectangular, nearly inelastic pad. Figure VII-6 depicts a typical configuration with the forces and moments acting.

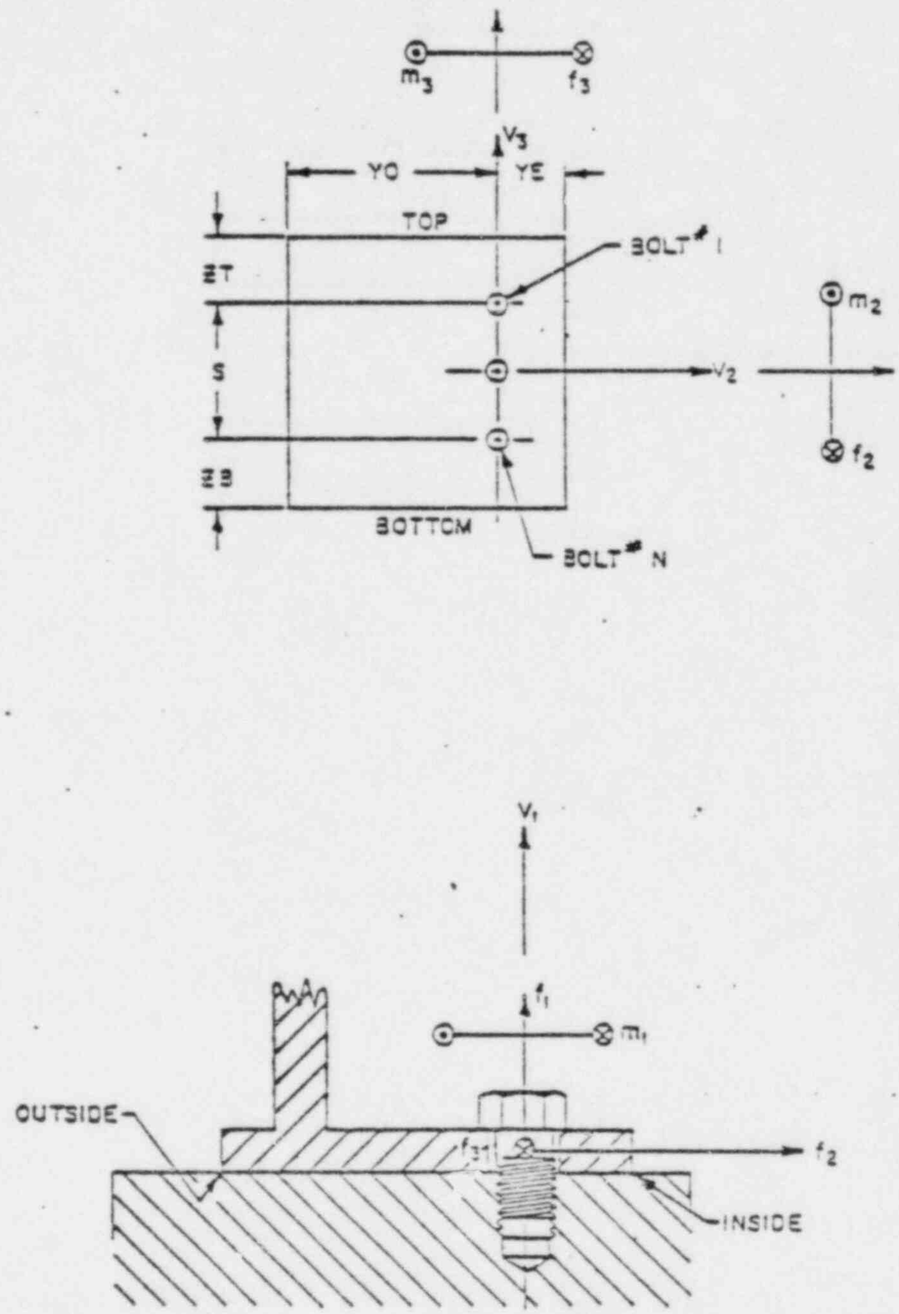
The specified parameters for this configuration, N, S, ZB, ZT, YO, YE and A_b are described in Table III-4 and Figure III-5(c).

The distance, V, from the reference center to the ith bolt ($i = 1, 2, \ldots N$) in the V_3 direction is:

$$V_3^{(i)} = S(N + 1 - 1 - 2i)/(2(N - 1)) \qquad \text{(VII.B.2-1)}$$

The inplane forces, f_2, f_3, are assumed to be distributed uniformly to each bolt. In addition, the twisting moment, m_1, is assumed to be distributed as shear forces, $V_m^{(i)}$, in the V_2 direction on each bolt, which are proportional to $V_3^{(i)}$.

$$V_m^{(i)} = m_1 (N + 1 - 2i) C_M \qquad \text{(VII.B.2-2)}$$



LEG CONFIGURATION

FIGURE VII-6

with,

$$C_M = 6/(S \cdot N \cdot (N+1)) \qquad \text{(VII.B.2-3)}$$

It can be shown that these shear forces do indeed equilibrate with the twisting moment.

$$\sum_{i=1}^{N} V_m^{(i)} \, V_3^{(i)} = m_1 \qquad \text{(VII.B.2-4)}$$

Thus, the shear forces on the ith bolt in the V_2 and V_3 directions are:

$$V_{f_2}^{(i)} = f_2/N - V_m^{(i)} \qquad \text{(VII.B.2-5)}$$

$$V_{f_3}^{(i)} = f_3/N \qquad \text{(VII.B.2-6)}$$

and the average total shear stress components on the ith bolt is:

$$\tau_2 = V_{f_2}^{(i)}/A_b \qquad \text{(VII.B.2-7)}$$

$$\tau_3 = V_{f_3}^{(i)}/A_b \qquad \text{(VII.B.2-8)}$$

where A_b is the root area of each bolt.

The axial force, f_1, and bending moment, m_3, is assumed to be reacted by a total load, f_1', for all the bolts and a contact reaction at either the inside or outside pivot edges (Figure VII-6). Both possible pivot edges are postulated; the one that yields tension for the bolt load and the smallest compression through the pivot reaction is selected.

For contact on inside edge

$$f_1' = f_1 + m_3/YI \qquad \text{(VII.B.2-8)}$$

For contact on outside edge

$$f_1' = f_1 - m_3/YO \qquad \text{(VII.B.2-9)}$$

For no contact which implies $m_3 = 0$

$$f_1' = f_1 \qquad \text{(VII.B.2-10)}$$

For the condition that neither postulated contact edge yields bolt tension

$$f_1' = 0 \qquad \text{(VII.B.2-11)}$$

Next, f_1' and m_2 will be assumed to be reacted by individual axial loads in each bolt, $A^{(i)}$, and a pivot reaction about either the top or bottom edges (Figure VII-6) depending upon the sense of m_2.

If $m_2 = 0$

$$A^{(i)} = f_1'/N \qquad \text{(VII.B.2-12)}$$

If $m_2 < 0$ (Pivot about top edge)

$$A^{(i)} = [f_1' (S/2 + ZB) + m_2][S(N - i)/(N-1) + ZB]/C_B \qquad \text{(VII.B.2-13)}$$

where

$$C_B = N \left[\frac{S^2 (N + 1)}{12(N - 1)} + (S/2 + ZB)^2\right] \qquad \text{(VII.B.2-14)}$$

If $m_2 > 0$ (Pivot about bottom edge)

$$A^{(i)} = [f_1'(S/2 + ZT) - m_2][S(i - 1)/(N - 1) + ZT]/C_T \qquad \text{(VII.B.2-15)}$$

where

$$C_T = N \left[\frac{S^2 (N + 1)}{12(N - 1)} + (S/2 + ZT)^2\right] \qquad \text{(VII.B.2-16)}$$

For the seismic loads, for which f_1, m_2, m_3, may reverse all together in sign, equations VII.B.2-8 through 2-16 are reevaluated yielding another set of axial loads, $A^{(i)}{}_k$ for each bolt; the largest value for each bolt is retained and then the average axial bolt stress is taken as:

$$\sigma = A^{(i)}/A_b \qquad \text{(VII.B.2-17)}$$

VII.B.3 Bolted Joint Pad Configuration

The bolted connection between components in an actuator-valve assembly that consists of a nearly inelastic rec-

tangular pad with two parallel lines, each with N evenly spaced, bolts, is designated a pad configuration. Figure VII-7 depicts such a configuration with forces and moments acting.

The specified parameters for this configuration, N, S, ZB, ZT, YO, YE and A_b are described in Table III-4 and Figure III-5(d).

The location of the ith bolt may be written in terms of the coordinates, $V_2^{(i)}$, $V_3^{(i)}$, in the plane parallel to vectors, $\{V_2\}$, $\{V_3\}$, respectively.

For $1 \leq i \leq N$

$$V_2^{(i)} = YO/2 \quad \text{(VII.B.3-1)}$$

$$V_3^{(i)} = S(N + 1 - 2i)/(2(N - 1)) \quad \text{(VII.B.3-2)}$$

For $N + 1 \leq i \leq 2N$

$$V_2^{(i)} = -YO/2 \quad \text{(VII.B.3-3)}$$

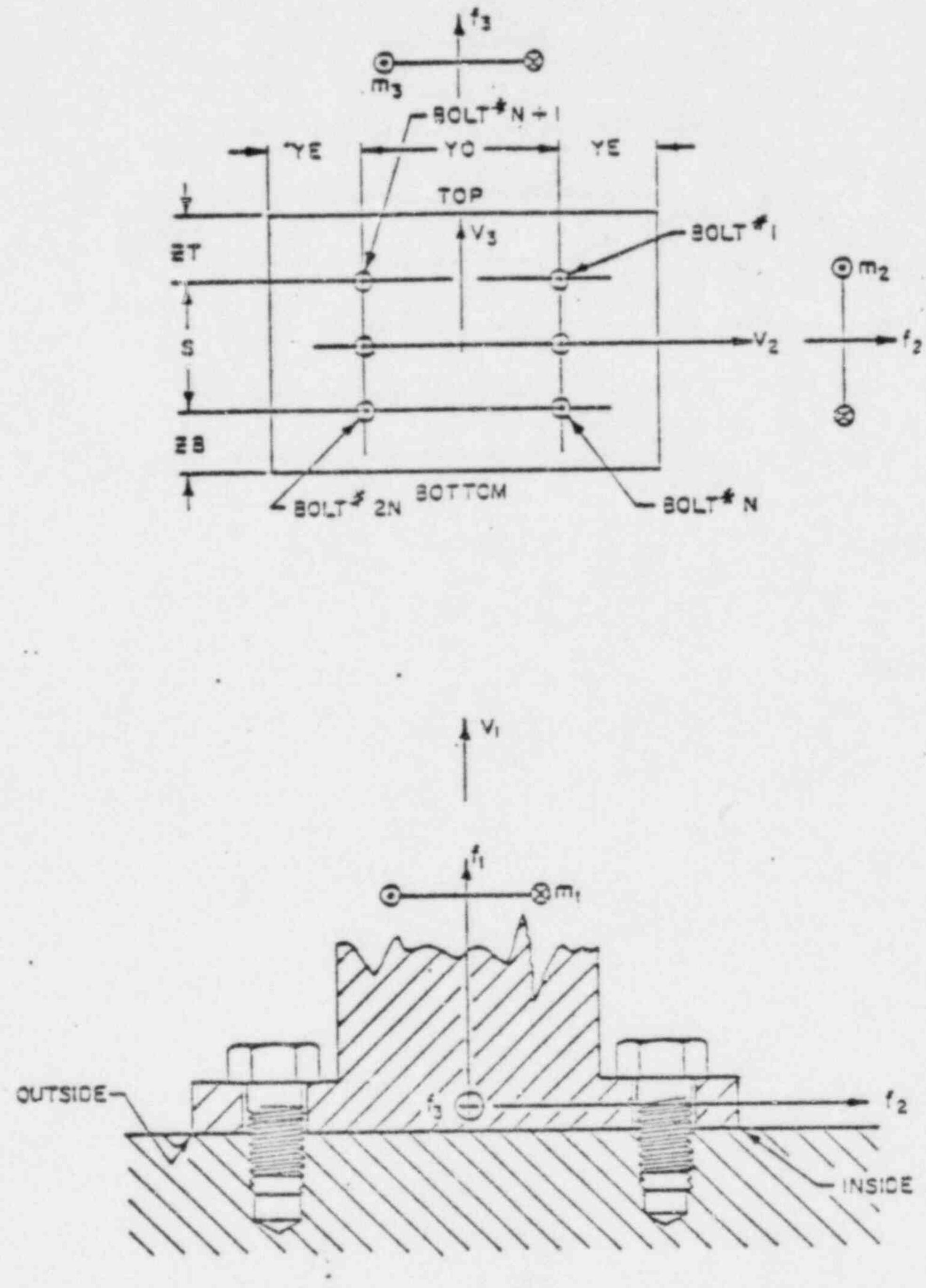
$$V_3^{(i)} = S(3N + 1 - 2i)/(2(N-1)) \quad \text{(VII.B.3-4)}$$

and the distance is:

$$d_i = \sqrt{(V_2^{(i)})^2 + (V_3^{(i)})^2} \quad \text{(VII.B.3-5)}$$

The inplane forces, f_2, f_3, are assumed to be distributed uniformly on each of the 2N bolts. In addition, the twisting moment, m_1, is assumed to be distributed as tangentially acting shear forces, $V_m^{(i)}$, proportional to the distance, d_i, from the reference center of the bolt pattern.

$$V_m^{(i)} = m_1\, d_i/(2N\, C_M) \quad \text{(VII.B.3-6)}$$



PAD CONFIGURATION

FIGURE VII-7

where:

$$C_M = 1/[(YO/2)^2 + S^2(N + 1)/(12(N - 1))] \quad \text{(VII.B.3-7)}$$

It can be shown that these shear forces do equilibrate with the twisting moment:

$$\sum_{i=1}^{2N} V_m^{(i)} d_i = m_1 \quad \text{(VII.B.3-8)}$$

Taking the components of $V_m^{(i)}$ in the V_2 and V_3 directions and adding to the shear developed by f_2 and f_3 yields the two shear force components on each of the i bolts.

$$V_{f_2}^{(i)} = (f_2 - C_M V_3^{(i)} m_1)/(2N) \quad \text{(VII.B.3-9)}$$

$$V_{f_3}^{(i)} = (f_3 + C_M V_2^{(i)} m_1)/(2N) \quad \text{(VII.B.3-10)}$$

and the average total shear stress components on the ith bolt are:

$$\tau_2 = V_{f_2}^{(i)}/A_b \quad \text{(VII.B.3-11)}$$

$$\tau_3 = V_{f_3}^{(i)}/A_b \quad \text{(VII.B.3-12)}$$

where A_b is the root area of each bolt.

The axial force, f_1, and the bending moment, m_3, is assumed to be reacted by total loads on the inside row of bolts (1 to N), $f_1^{(I)}$, the outside row of bolts (N + 1 to 2N), $f_1^{(o)}$, and either a reaction on the inside or outside pivot edges (Figure VII-7).

Various pivoting mechanisms may be postulated. For $f_1 \geq 0$ and $m_3 = 0$, no pivoting about the V_3 axis occurs.

$$f_1^{(I)} = f_1^{(o)} = f_1/2 \quad \text{(VII.B.3-13)}$$

For $m_3 > 0$, pivoting is on the inside edge

$$f_1^{(I)} = YE \cdot T_I \quad \text{(VII.B.3-14)}$$

$$f_1^{(o)} = (YE + YO) \cdot T_I \quad \text{(VII.B.3-15)}$$

where:

$$T_I = [(f_1/2)(YO + 2 \cdot YE) + m_3]/[(YE)^2 + (YE + YO)^2] \quad \text{(VII.B.3-16)}$$

For $m_3 < 0$, pivoting is on the outside edge:

$$f_1^{(I)} = (YE + YO) \cdot T_O \quad \text{(VII.B.3-17)}$$

$$f_1^{(o)} = YE \cdot T_O$$

where:

$$T_O = [(f_1/2)(YO + 2 \cdot YE) - m_3]/[(YE)^2 + (YE + YO)^2] \quad \text{(VII.B.3-18)}$$

For $f_1 \leq o$ and $m_3 = 0$, then f_1 is assumed reacted entirely by the two contact edges:

$$F_1^{(I)} = f_1^{(o)} = 0 \quad \text{(VII.B.3-19)}$$

$f_1^{(I)}$ and $f_1^{(o)}$ are assumed to uniformly load in the axial direction each bolt in the respective rows, thus,

$$\bar{A}^{(i)} = f_1^{(I)}/N \quad 1 \leq i \leq N$$

$$= f_1^{(o)}/N \quad N + 1 \leq i \leq 2N \quad \text{(VII.B.3-20)}$$

Next, an additional load, $\bar{\bar{A}}^{(i)}$, on each bolt caused by m_2 is computed based on the assumption of pivoting about either the top or bottom edge (Figure VII-7) depending upon the sense of m_2.

If $m_2 = 0$

$$\bar{\bar{A}}^{(i)} = \bar{\bar{A}}^{(i+N)} = 0 \quad 1 \leq i \leq N \quad \text{(VII.B.3-21)}$$

If $m_2 > 0$ (Pivot about bottom edge)

$$\bar{\bar{A}}^{(i)} = \bar{\bar{A}}^{(i+N)} = (m_2/2)[(S(N - i)/(N - 1) + ZB]/C_B \quad 1 \leq i \leq N \quad \text{(VII.B.3-22)}$$

where:

$$C_B = N[(S/2 + ZB)^2 + S^2 (N + 1)/(12(N - 1))] \quad \text{(VII.B.3-23)}$$

If $m_2 < 0$ (Pivot about top edge)

$$\bar{A}^{(i)} = \bar{A}^{(i+N)} + (m_2/2)[S(i-1)/(N-1) + ZT]/C_T \qquad \text{(VII.B.3-24)}$$

where:

$$C_T = N[(S/2 + ZT)^2 + S^2 (N+1)/(12(N-1))] \qquad \text{(VII.B.3-25)}$$

The total axial load on the ith bolt is then:

$$A^{(i)} = \bar{A}^{(i)} + \bar{A}^{(i)} \text{ for } 1 \le i \le 2N \qquad \text{(VII.B.3-26)}$$

For seismic loads for which f_1, m_2, m_3, may reverse all together in sign, equations VII.B.3-13 through 3-26, are reevaluated yielding another set of axial loads, $A^{(i)}$, for each bolt; the largest value for each bolt is retained, then the average bolt stress may be taken as:

$$\sigma = A^{(i)}/A_b \qquad \text{(VII.B.3-27)}$$

VIII. ACCEPTANCE CRITERIA

If the purchaser's design specification does not include acceptance criteria or if the acceptance criteria are incomplete, this section will be used to determine the acceptability of the equipment.

VIII.A. Pressure Retaining Structures

Table VIII.A.-1

Valve Classification	Section Analyzed	Stress Limits[1,2,3,4,5,6]
Active	Bonnet	$(\sigma_m \text{ or } \sigma_L) + \sigma_b \le 1.5S$ $\sigma_s \le 0.6S$
	Bolting	$\sigma_m \le 2S$
Non-active	Bonnet	$(\sigma_m \text{ or } \sigma_L) + \sigma_b \le S_y$ $\sigma_s \le 0.6S_y$
	Bolting	$\sigma_m \le 2S$

VIII.A. Pressure Retaining Structures (continued)

Notes to Table VIII.A.-1

1. The symbols are defined as follows:

   σ_m - general membrane stress. This stress is equal to the average stress across the solid section under consideration, excludes discontinuities and concentrations and is produced only by mechanical loads.

   σ_L - local membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.

   σ_b - bending stress. This stress is equal to the linear varying portion of the stress across the solid section under consideration, excludes discontinuities and concentrations, and is produced only by mechanical loads.

   σ_s - shear stress. This stress is the average primary shear stress across a section loaded in pure shear.

   S_y - yield strength.

   S - stress intensity for Class 1 valves or the allowable stress for Class 2 and 3 valves taken from Appendix 1 to Section III.

2. The stress limit for cast iron, ASTM A48 Class 30, is 15000 psi for all cases.

3. For the purposes of selecting the appropriate material properties and stress limits the actuator yoke, the yoke locknut or actuator-to-bonnet bolting shall be assumed to be at ambient temperature while the bonnet and the bonnet-to-body bolting shall be assumed to be at the service temperature.

4. The value for S for materials not listed in Appendix I to Section III shall be determined in the following manner:

   For Class 1 valves the lesser of:

   1/3 of the minimum specified tensile strength
   or
   2/3 of the minimum specified yield strength.

   For Class 2 and 3 valves the lesser of:

   1/4 of the minimum specified tensile strength
   or
   5/8 of the minimum specified yield strength.

   These values shall be selected for the appropriate temperature as specified in note 4.

5. A casting quality factor of 1.0 shall be assumed in satisfying these limits for Class 2 and 3 valves.

6. For bolted joints the bolt prestress is assumed to be equal to 2S. The bolt will not be considered overstressed until the bolt stress exceeds the bolt prestress.

VIII.B. Non-pressure Retaining Structures

For non-pressure retaining structures the stress limit will not exceed 90% of the specified minimum yield strength of the material.

IX. REVISION TO THIS STANDARD

Revisions to this standard must be approved by the Director of Evaluation & Analysis

X. REFERENCES

(1) Roark and Young, "Formulas for Stress and Strain," Chapter 9 (corresponds to K).

(2) Ibid, Article 7.10 (corresponds to F).

(3) Ibid, Article 7.14, Table 14 and Paz, et al., "Computer Determination of the Shear Center of Open and Closed Sections".

(4) Roark and Young, "Formulations for Stress and Strain", Chapter 9, Table 20, and Den Hartog "Advanced Strength of Materials," Chapter 1.

(5) Zudans, "Consistent Mass Matrix for Thick Beams," Section 2.

(6) Fishman, "Computation of Bending Modulus for Curved Beams."

(7) Rothbart, H.A., Mechanical Design and Systems Handbook, Section 20.

(8) Zudans, et al., "FELAP$_{TM}$, Finite Element Computer Program Input Description and User's Guide," Section III.2.

(9) Fishman, "Joint Release for Consistent Mass Elements," and Zudans, et al., "FELAP$_{TM}$, Finite Element Computer Program Theory Manual," Section 2.6.

(10) Ibid, Section 2.7.

(11) Roark and Young, "Formulas for Stress and Strain," Tables 1, 14, 20 and Fishman, Tung, Lin and Tsai, "Computation of Cross-Section Properties."

(12) Przemienicki, "Theory of Matrix Structural Analysis," Section 3.4; Zudans, "Survey of Advanced Structural Design Analysis Techniques", Section 2; and Archer, "Consistent Matrix Formulations for Structural Analysis Using Finite-Element Techniques."

(13) Harris and Crede, "Shock and Vibration Handbook," Volume 1, Section 2.

(14) "Theory for Real Eigenvalue Analysis," Nastran Theoretical Manual, Section 10.4.2.

(15) Zudans, et al., "FELAP™ Finite Element Computer Program Input Description and User's Guide," pp. 5-35, 38.

(16) Chu, et al., "Spectral Treatment of Actions of Three Earthquake Components on Structures."

(17) Timoshenko and Goodier, "Theory of Elasticity," Section 9; and ASME Boiler and Pressure Vessel Code, Section III, Article NB-3215.

(18) Fishman, "Analysis of Bolted Joint Configurations".

(19) ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components," Appendix I.

XI. BIBLIOGRAPHY

Archer, John S., "Consistent Matrix Formulations for Structural Analysis Using Finite-Element Techniques," AIAA Journal, Vol. 3, October, 1965, pp. 1910-1918.

ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components," Subsections NA and NB, American Society of Mechanical Engineers, 1974.

Chu, S.L., Amin, M. and Singh, S., "Spectral Treatment of Actions of Three Earthquake Components on Structures," Nuclear Engineering and Design 21 (1972), pp. 126-136.

Den Hartog, J.P., "Advanced Strength of Materials," McGraw Hill, 1952.

Fishman, Howard M., "Analysis of [illegible]lted Joint Configurations," Franklin Institute Research Laborator[illegible] [illegible]rical Note, 1977.

Fishman, Howard M., "Computation of Bending [illegible]ulus for Curved Beams," Franklin Institute Research Laborator[illegible] [illegible]chnical Note, 1977.

Fishman, Howard M., "Joint Release for Cons[illegible]t Mass Matrix," Franklin Institute Research Laboratories Techn[illegible] [illegible]ote, 1977.

Fishman, H.M.; Tung, C.; Lin, Y.L.; and Tsa[illegible] [illegible].; "Computation of Cross-Section Properties," Franklin Institut[illegible] [illegible]earch Laboratories Technical Note, 1977.

Harris, Cyril M. and Crede, Charles E., ed[illegible] "Shock and Vibration Handbook," Volume 1, McGraw-Hill, 19[illegible]

"NASTRAN, Theoretical Manual," National Ae[illegible]ics and Space Administration, 1972.

Paz, M.; Strehl, C.P.; and Schrader, P.; "[illegible] [illegible]r Determination of the Shear Center of Open and Closed Secti[illegible] [illegible]mputers & Structures, Vol. 6, 1976, pp. 117-125.

Przemienicki, J.S., "Theory of Matrix Stru[illegible] [illegible]nalysis," McGraw-Hill, 1968.

Rothbart, H.A., editor, "Mechanical Design [illegible]ystems Handbook," McGraw-Hill, 1964.

Roark, Raymond J. and Young, Warren C., "[illegible] [illegible] for Stress and Strain," Fifth Edition, McGraw-Hill, 1975.

Timoshenko, S. and Goodier, J.N., "Theory [illegible] [illegible]sticity," McGraw-Hill, 1951.

Zudans, Zenons, "Consistent Mass Matrix f[illegible] [illegible] Beams," ASME Publication 76-WA/PVP-13, July, 1976.

Zudans, Zenons, "Survey of Advanced Struct[illegible] [illegible]sign Analysis Techniques," ASME Publication 69-DE-13, January, 1[illegible]

Zudans, Z.; Fishman, H.M.; and Reddi, M.M.[illegible] [illegible]P$_{TM}$, Finite Element Computer Program Input Description and U[illegible] [illegible]uide," Franklin Institute Research Laboratories Technical Report[illegible] [illegible]th Revision, May, 1976.

Zudans, Z.; Fishman, H.M.; and Reddi, M.M.: [illegible]P$_{TM}$, Finite Element Computer Program, Theory Manual," Frankl[illegible] [illegible]itute Research Laboratories Technical Report, October, 1974.

APPENDIX B

FISHER CONTROLS COMPANY

SEISMIC-4

SEISMIC ANALYSIS

OF

ROTARY VALVES

MATERIAL PROPERTY INPUT DATA

MAT. NO.	DESCRIPTION	YOUNG'S MOD/10(6)	POISSON'S RATIO	MASS DENS/10(-4)	ALLOWABLE STRESS/10(3)
1	STEEL	30.000	0.283	7.240	27.000
2	BOLTING SAE	30.000	0.283	7.240	82.800

CUSTOMER NAME COMMONWEALTH EDISON CO.

CC NO 5A094
5A095

REPRESENTATIVE ORDER NO 14-52496

VALVE SIZE 8" VALVE TYPE 9270

ACTUATOR FISHER 1073 MANUAL

CUSTOMER ORDER NO 181104

CUSTOMER TAG NO 1FC054A 2FC054A
1FC054B 2FC054B

CERTIFIED DRAWING NO G269278

CROSS SECTION DRAWING NO F43430A

BRACKET DRAWING NO. G337248

DATE OF THIS REPORT / DECEMBER 15, 1978

C O N T R O L   I N P U T   D A T A

MANUAL INPUT GENERATION FOR VALVE ANALYSIS

SEISMIC STRESSES ARE SUPERIMPOSED BY SQUARE ROOT OF SUM OF SQUARES

STRESS ALLOWABLES ARE COMPARED TO MAXIMUM PRINCIPAL STRESS

MASS, STIFFNESS, LOAD AND STRESS MATRICES ARE NOT PRINTED

STATIC SEISMIC ANALYSIS TO BE PERFORMED

OPERATIONAL LOAD ANALYSIS TO BE PERFORMED

DYNAMIC MODAL ANALYSIS TO BE PERFORMED WITH EVALUATION

C R O S S - S E C T I O N   D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS		
1	RECTANGULAR	A = 4.000 ,	T = .6870 ,	
2	RECTANGULAR	A = 4.000 ,	T = .6870 ,	
3	RECTANGULAR	A = 4.000 ,	T = .6870 ,	
4	CHANNEL	A = 4.000 ,	T = .3120 ,	B = 1.721 ,
		T1= .2960 ,	R1= .2800 ,	

C R O S S - S E C T I O N   D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS			
5	CHANNEL	A = 4.000 ,	T = .3120 ,	B = 1.721 ,	
		T1= .2960 ,	R1= .2800 ,		
6	RECTANGULAR	A = 4.000 ,	T = .5000 ,		
7	CHANNEL	A = 4.000 ,	T = .3120 ,	B = 1.721 ,	
		T1= .2960 ,	R1= .2800 ,		
8	CHANNEL	A = 4.000 ,	T = .3120 ,	B = 1.721 ,	
		T1= .2960 ,	R1= .2800 ,		
9	RECTANGULAR	A = 4.000 ,	T = .6870 ,		
10	RECTANGULAR	A = 4.000 ,	T = .6870 ,		

J O I N T   C O O R D I N A T E   D A T A

JOINT NO.	X	Y	Z
1	8.983000	-1.810000	3.950000
2	7.300000	2.210000	0.0
3	7.300000	-2.210000	0.0
4	3.970000	2.210000	0.0
5	3.970000	-2.210000	0.0
6	0.0	2.875000	0.0
7	0.0	2.210000	0.0
8	0.0	-2.210000	0.0
9	0.0	-2.875000	0.0
10	7.300000	1.437000	0.0
11	7.300000	-1.437000	0.0

B O U N D A R Y ,   S P R I N G   &   B O L T   J O I N T   D A T A

JOINT NO.	TYPE-MAT /FIXITY		PLANE-DIRECTION OR DESCRIPTION		SPRING & BOLT JOINT PARAMETERS		
6	111111		BODY				
9	111111		BODY				
6	LEG	2	A	+X -Y	N.T= 2.16 ,	D/A= 0.3750,	YE= 0.8750
					YO= 0.8750,	YSH= 0.0 ,	S= 1.2500
					ZT= 1.0000,	ZB= 1.0000,	ZSH= 0.0
9	LEG	2	C	+X +Y	N.T= 2.16 ,	D/A= 0.3750,	YE= 0.8750
					YO= 0.8750,	YSH= 0.0 ,	S= 1.2500
					ZT= 1.0000,	ZB= 1.0000,	ZSH= 0.0
10	CIRC	2	B	-X -Y	N.T= 4.16 ,	D/A= 0.3750,	D= 2.8740
					YSH= 0.0 ,	ZSH= 0.0 ,	STD= 45.0000
					FG= 0.		

C O N C E N T R A T E D   M A S S   D A T A

JOINT NO.	LUMPED MASS	FOR DIR.	SHIFT DISTANCE OR MOMENT OF INERTIA X	Y	Z
1	0.067288	XYZ	0.0	0.0	0.0

C O N C E N T R A T E D   L O A D   D A T A

JOINT NO.	. . . . FORCES. . . . X	Y	Z	. . . .MOMENTS. . . . X	Y	Z
1	0.0	0.0	0.0	1735.0	0.0	0.0

E L E M E N T   I N P U T   D A T A

EL. NO.	JOINTS		LENGTH /RADIUS	ANGLE	AREA	MOMENTS OF INERTIA I-11	I-22	I-33	MATERIAL DESCRIPTION
1	2	10	0.773		2.7480	0.1081	0.3855	3.6640	STEEL
2	10	11	2.874		2.7480	0.1081	0.3855	3.6640	STEEL
3	11	3	0.773		2.7480	0.1081	0.3855	3.6640	STEEL
4	2	4	3.330		2.0821	4.5311	0.0702	0.5170	STEEL
5	3	5	3.330		2.0821	4.5311	0.0702	0.5170	STEEL
6	4	5	4.420		2.0000	0.0417	0.1535	2.6667	STEEL
7	4	7	3.970		2.0821	4.5311	0.0702	0.5170	STEEL
8	8	5	3.970		2.0821	4.5311	0.0702	0.5170	STEEL
9	6	7	0.665		2.7480	0.1081	0.3855	3.6640	STEEL
10	8	9	0.665		2.7480	0.1081	0.3855	3.6640	STEEL
	10	1			RIGID LINK				
	11	1			RIGID LINK				

S T A T I C   A N A L Y S I S

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM X DIR.

JOINT NO.	. . .DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.000081	0.000001	-0.000098	-0.000000	0.000019	0.000001
2	0.000001	-0.000001	-0.000065	-0.000000	0.000010	0.000000
3	0.000005	-0.000001	-0.000065	-0.000000	0.000010	-0.000000
4	0.000001	-0.000001	-0.000033	-0.000000	0.000009	-0.000000
5	0.000003	-0.000001	-0.000033	-0.000000	0.000009	-0.000000
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.000000	-0.000000	0.000000	-0.000000	0.000008	0.000000
8	0.000001	0.000000	0.000000	0.000000	0.000008	-0.000001
9	0.0	0.0	0.0	0.0	0.0	0.0
10	0.000002	-0.000001	-0.000065	-0.000000	0.000019	0.000001
11	0.000005	-0.000001	-0.000065	-0.000000	0.000019	0.000001

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Y DIR.

JOINT NO.	. . .DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.000001	0.000519	0.000191	-0.000105	0.000000	0.000000
2	-0.000003	0.000103	-0.000232	-0.000105	0.000016	0.000009
3	0.000003	0.000103	0.000232	-0.000105	-0.000016	0.000009
4	-0.000001	0.000058	-0.000126	-0.000057	0.000017	0.000014
5	0.000001	0.000058	0.000126	-0.000057	-0.000017	0.000014
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.000002	0.000000	-0.000001	0.000000	0.000016	0.000009
8	-0.000002	0.000000	0.000001	0.000000	-0.000016	0.000009
9	0.0	0.0	0.0	0.0	0.0	0.0
10	-0.000000	0.000103	-0.000151	-0.000105	0.000000	0.000000
11	0.000000	0.000103	0.000151	-0.000105	0.000000	0.000000

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Z DIR.

JOINT NO.	. . .DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.000119	0.000191	0.000329	-0.000048	-0.000030	-0.000000
2	0.000000	-0.000000	0.000084	-0.000048	-0.000019	-0.000000
3	-0.000000	-0.000000	0.000297	-0.000048	-0.000034	-0.000000
4	0.000000	-0.000000	0.000043	-0.000026	-0.000017	-0.000000
5	-0.000000	-0.000000	0.000159	-0.000026	-0.000033	-0.000000
6	0.0	0.0	0.0	0.0	0.0	0.0
7	-0.000000	-0.000000	0.000000	-0.000000	-0.000015	-0.000000
8	0.000000	-0.000000	0.000001	0.000000	-0.000029	-0.000000
9	0.0	0.0	0.0	0.0	0.0	0.0
10	0.000000	-0.000000	0.000122	-0.000048	-0.000030	-0.000000
11	-0.000000	-0.000000	0.000261	-0.000048	-0.000030	-0.000000

DEFORMATION RESPONSE TO OPERATIONAL LOADS (NOT INCLUDING DEADWEIGHT)

JOINT NO.	. . .DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.000001	-0.007030	-0.003224	0.001782	-0.000000	0.000000
2	-0.000000	0.000008	0.003924	0.001782	-0.000273	0.000001
3	0.000000	0.000008	-0.003922	0.001782	0.000272	0.000001
4	-0.000000	0.000004	0.002137	0.000967	-0.000291	0.000001
5	0.000000	0.000004	-0.002136	0.000967	0.000291	0.000001
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.000000	0.000000	0.000013	-0.000002	-0.000267	0.000001
8	-0.000000	0.000000	-0.000013	-0.000002	0.000267	0.000001
9	0.0	0.0	0.0	0.0	0.0	0.0
10	-0.000000	0.000008	0.002562	0.001782	-0.000000	0.000000
11	0.000000	0.000008	-0.002559	0.001782	-0.000000	0.000000

DYNAMIC ANALYSIS

RESONANT FREQUENCY = 123.5 HERTZ (IN Y-DIRECTION OR X-ROTATION)

* * * * NORMALIZED EIGENVECTOR * * * *

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.109507	1.000000	0.610492	-0.221860	-0.027894	0.000628
2	-0.004123	0.122405	-0.326957	-0.221860	0.011050	0.010989
3	0.003427	0.122408	0.650208	-0.221953	-0.056681	0.011109
4	-0.001358	0.066804	-0.182519	-0.120895	0.014675	0.016457
5	0.001396	0.066801	0.351413	-0.120909	-0.057798	0.016442
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.001581	0.000170	-0.001319	0.000214	0.014658	0.010025
8	-0.001759	0.000168	0.002059	0.000412	-0.051959	0.010128
9	0.0	0.0	0.0	0.0	0.0	0.0
10	-0.001364	0.122596	-0.156834	-0.221860	-0.027894	0.000628
11	0.000441	0.122596	0.480792	-0.221860	-0.027894	0.000628

STATIC SEISMIC ANALYSIS

THE VALVE AXIS IS POSITIONED Y-UP

ACCELERATION OF GRAVITY, G = 386.400

DIRECTION OF SEISMIC ACCELERATION	NO. OF G'S	COMPONENTS OF UNIT ACCELERATION IN VALVE COORDINATE SYSTEM X-COMP.	Y-COMP.	Z-COMP.
HORIZONTAL(1)	5.000	0.0	0.0	-1.0000
HORIZONTAL(2)	5.000	1.0000	0.0	0.0
VERTICAL	6.000	0.0	-1.0000	0.0

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	2	6.	-0.	-0.	1.	-325.	37.
	10	-3.	0.	0.	-0.	325.	-33.
2	10	6.	0.	0.	-0.	0.	3.
	11	6.	0.	-0.	-0.	0.	-3.
3	11	-138.	0.	-0.	-0.	-106.	-6.
	3	141.	-0.	0.	1.	106.	-102.
4	2	0.	-0.	6.	325.	37.	1.
	4	-0.	0.	-16.	-361.	-37.	0.
5	3	-0.	0.	-141.	106.	-102.	-1.
	5	0.	-0.	151.	379.	102.	-0.
6	4	6.	-0.	-0.	0.	-32.	15.
	5	6.	0.	0.	0.	32.	-15.
7	4	0.	-1.	22.	393.	51.	0.
	7	-0.	1.	-33.	-502.	-51.	1.
8	8	0.	1.	-168.	993.	-117.	1.
	5	-0.	-1.	157.	-347.	117.	0.
9	6	36.	-0.	-1.	-0.	-502.	74.
	7	-33.	0.	1.	1.	502.	-51.
10	8	-168.	0.	-1.	1.	993.	117.
	9	171.	-0.	1.	-0.	-993.	-230.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	6	1.	-0.	36.	-74.	-502.	-0.
BODY	9	-1.	-0.	171.	230.	-993.	-0.
A +X-Y	6	1.	-0.	33.	-74.	-502.	-0.
C +X+Y	9	-1.	-0.	168.	229.	-993.	-0.
B -X-Y	10	-0.	0.	-147.	444.	219.	1.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	2	0.	6.	21.	-22.	-257.	-0.
	10	-0.	-6.	-18.	7.	257.	0.
2	10	0.	0.	6.	-3.	0.	0.
	11	-0.	0.	6.	3.	0.	0.
3	11	0.	6.	-123.	78.	257.	-0.
	3	-0.	-6.	126.	18.	-257.	0.
4	2	-6.	21.	-0.	257.	-0.	-22.
	4	6.	-31.	0.	-257.	0.	1.
5	3	-6.	126.	0.	-257.	0.	-18.
	5	6.	-135.	-0.	257.	-0.	-3.
6	4	0.	0.	8.	-9.	0.	0.
	5	-0.	-0.	4.	0.	-0.	0.
7	4	-7.	39.	-0.	257.	-0.	-10.
	7	7.	-51.	0.	-257.	0.	-16.
8	8	7.	151.	0.	257.	0.	29.
	5	-7.	-140.	-0.	-257.	-0.	-3.
9	6	-0.	7.	53.	-19.	-257.	-0.
	7	0.	-7.	-51.	-16.	257.	0.
10	8	0.	7.	-151.	29.	257.	-0.
	9	-0.	-7.	154.	72.	-257.	0.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	6	-53.	7.	-0.	0.	-257.	-19.
BODY	9	-154.	-7.	-0.	-0.	-257.	72.
A +X-Y	6	-51.	7.	-0.	0.	-257.	-18.
C +X+Y	9	-151.	-7.	-0.	-0.	-257.	71.
B -X-Y	10	147.	-0.	0.	-0.	514.	447.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	2	-176.	87.	190.	-289.	-563.	-85.
	10	176.	-84.	-190.	142.	563.	-51.
2	10	-0.	7.	0.	-0.	0.	-0.
	11	0.	7.	-0.	-0.	0.	-0.
3	11	-176.	-84.	190.	142.	-563.	-51.
	3	176.	87.	-190.	-289.	563.	-85.
4	2	-88.	190.	-176.	563.	-85.	-289.
	4	99.	-190.	176.	25.	85.	-22.
5	3	88.	-190.	-176.	563.	-85.	289.
	5	-99.	190.	176.	24.	85.	22.
6	4	-0.	7.	59.	-130.	-84.	-0.
	5	0.	7.	-59.	-130.	84.	-0.
7	4	-107.	248.	-177.	59.	-86.	-108.
	7	121.	-248.	177.	642.	86.	-343.
8	8	-121.	-248.	-177.	642.	-86.	-343.
	5	107.	248.	177.	60.	86.	-108.
9	6	-177.	124.	248.	178.	642.	-203.
	7	177.	-121.	-248.	-343.	-642.	86.
10	8	-177.	-121.	248.	-343.	642.	86.
	9	177.	124.	-248.	178.	-642.	-203.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
BODY	6	-248.	124.	-177.	203.	642.	178.
BODY	9	248.	124.	177.	203.	-642.	178.
A +X-Y	6	-248.	121.	-177.	203.	642.	178.
C +X+Y	9	248.	121.	177.	203.	-642.	178.
B -X-Y	10	-0.	-175.	0.	609.	-0.	-260.

[illegible]CTION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

[illegible] NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	2	-527.	13.	29.	-44.	-1682.	-255.
	10	527.	-12.	-29.	22.	1682.	-153.
2	10	-0.	1.	0.	-0.	0.	0.
	11	0.	1.	-0.	-0.	0.	-0.
3	11	-527.	-12.	29.	22.	-1683.	-153.
	3	527.	13.	-29.	-44.	1683.	-255.
4	2	-13.	29.	-527.	1682.	-255.	-44.
	4	15.	-29.	527.	73.	255.	-3.
5	3	13.	-29.	-527.	1683.	-255.	44.
	5	-15.	29.	527.	72.	255.	3.
6	4	-1.	1.	9.	-20.	-250.	-1.
	5	1.	1.	-9.	-20.	250.	-1.
7	4	-16.	38.	-528.	177.	-256.	-17.
	7	19.	-38.	528.	1918.	256.	-53.
8	8	-19.	-38.	-527.	1916.	-256.	-53.
	5	16.	38.	527.	178.	256.	-17.
9	6	-528.	19.	38.	28.	1918.	-607.
	7	528.	-19.	-38.	-53.	-1918.	256.
10	8	-528.	-19.	38.	-53.	1916.	256.
	9	528.	19.	-38.	28.	-1916.	-607.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
[illegible]	6	-38.	19.	-528.	607.	1918.	28.
[illegible]	9	38.	19.	528.	607.	-1916.	28.
A +X-Y	6	-38.	19.	-528.	607.	1918.	28.
C +X+Y	9	38.	19.	527.	607.	-1916.	28.
E -X-Y	10	-0.	-26.	0.	1819.	-1.	-39.

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

JOINT NO.	. . .DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.000597	-0.000953	-0.001647	0.000242	0.000151	0.000000
2	-0.000000	0.000001	-0.000422	0.000241	0.000095	0.000000
3	0.000000	0.000001	-0.001486	0.000242	0.000169	0.000000
4	-0.000000	0.000001	-0.000214	0.000131	0.000087	0.000000
5	0.000000	0.000001	-0.000793	0.000131	0.000166	0.000000
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.000000	0.000000	-0.000001	0.000000	0.000074	0.000000
8	-0.000000	0.000000	-0.000005	-0.000001	0.000146	0.000000
9	0.0	0.0	0.0	0.0	0.0	0.0
10	-0.000000	0.000001	-0.000609	0.000242	0.000151	0.000000
11	0.000000	0.000001	-0.001303	0.000242	0.000151	0.000000

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.000406	0.000005	-0.000488	-0.000000	0.000096	0.000006
2	0.000006	-0.000004	-0.000327	-0.000000	0.000052	0.000002
3	0.000023	-0.000005	-0.000327	-0.000000	0.000052	-0.000002
4	0.000005	-0.000004	-0.000165	-0.000000	0.000045	-0.000000
5	0.000016	-0.000005	-0.000165	-0.000000	0.000045	-0.000000
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.000002	-0.000000	0.000000	-0.000000	0.000038	0.000000
8	0.000006	0.000000	0.000000	0.000000	0.000038	-0.000004
9	0.0	0.0	0.0	0.0	0.0	0.0
10	0.000010	-0.000004	-0.000327	-0.000000	0.000096	0.000006
11	0.000026	-0.000004	-0.000327	-0.000000	0.000096	0.000006

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.000004	-0.003117	-0.001143	0.000632	-0.000000	-0.000002
2	0.000016	-0.000617	0.001392	0.000632	-0.000097	-0.000053
3	-0.000016	-0.000617	-0.001391	0.000632	0.000097	-0.000053
4	0.000006	-0.000347	0.000758	0.000343	-0.000103	-0.000082
5	-0.000006	-0.000347	-0.000757	0.000343	0.000103	-0.000082
6	0.0	0.0	0.0	0.0	0.0	0.0
7	-0.000010	-0.000001	0.000005	-0.000001	-0.000095	-0.000053
8	0.000010	-0.000001	-0.000005	-0.000001	0.000095	-0.000053
9	0.0	0.0	0.0	0.0	0.0	0.0
10	0.000003	-0.000618	0.000908	0.000632	-0.000000	-0.000002
11	-0.000003	-0.000618	-0.000908	0.000632	-0.000000	-0.000002

DEFORMATION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.000001	-0.007549	-0.003414	0.001887	-0.000000	-0.000000
2	0.000002	-0.000095	0.004156	0.001887	-0.000289	-0.000008
3	-0.000002	-0.000095	-0.004154	0.001887	0.000288	-0.000008
4	0.000001	-0.000053	0.002263	0.001024	-0.000308	-0.000013
5	-0.000001	-0.000053	-0.002262	0.001024	0.000308	-0.000013
6	0.0	0.0	0.0	0.0	0.0	0.0
7	-0.000002	-0.000000	0.000014	-0.000003	-0.000283	-0.000008
8	0.000002	-0.000000	-0.000014	-0.000003	0.000283	-0.000008
9	0.0	0.0	0.0	0.0	0.0	0.0
10	0.000000	-0.000095	0.002713	0.001887	-0.000000	-0.000000
11	-0.000000	-0.000095	-0.002711	0.001887	-0.000000	-0.000000

E V A L U A T I O N   O F   V A L V E

DEFORMATION RESPONSE OF COMBINED STATIC SEISMIC AND OPERATIONAL LOADS

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.000723	-0.010809	-0.005477	0.002564	-0.000179	-0.000006
2	0.000020	-0.000712	0.005647	0.002564	-0.000434	-0.000061
3	-0.000030	-0.000712	-0.006215	0.002564	0.000490	-0.000061
4	0.000009	-0.000400	0.003068	0.001391	-0.000451	-0.000095
5	-0.000018	-0.000400	-0.003371	0.001391	0.000509	-0.000095
6	0.0	0.0	0.0	0.0	0.0	0.0
7	-0.000011	-0.000001	0.000019	-0.000004	-0.000409	-0.000062
8	0.000013	-0.000001	-0.000021	-0.000004	0.000461	-0.000062
9	0.0	0.0	0.0	0.0	0.0	0.0
10	0.000011	-0.000713	0.003854	0.002564	-0.000179	-0.000006
11	-0.000027	-0.000713	-0.004332	0.002564	-0.000179	-0.000006

BEAM STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS

ELM NO.	JNT NO.	STRESS NO.	COORDINATES C1	C3/2	C	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE
1	2	5	0.0	0.34	0.68	5.0	27.0	STEEL	0.19	
2	11	2	-2.00	0.34	0.0	0.0	27.0	STEEL	0.00	
3	3	5	0.0	0.34	0.68	4.9	27.0	STEEL	0.18	
4	2	10	-0.11	-1.62	0.54	3.6	27.0	STEEL	0.13	
5	3	7	-0.11	1.62	0.54	3.9	27.0	STEEL	0.14	
6	4	5	0.0	0.25	0.50	1.7	27.0	STEEL	0.06	
7	7	7	-0.11	1.62	0.54	3.6	27.0	STEEL	0.13	
8	8	7	-0.11	1.62	0.54	4.1	27.0	STEEL	0.15	
9	7	6	0.0	-0.34	0.68	5.8	27.0	STEEL	0.22	
10	8	6	0.0	-0.34	0.68	6.5	27.0	STEEL	0.24	

BOLTED JOINT STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS
(N=NUMBER OF BOLTS, AREA=AREA PER BOLT)

BOLT JNT	JOINT DESCRIPTION LOC.	TYPE	N	AREA	BOLT NO.	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE
6	A	LEG	2	0.07	1	24.2	82.8	BOLTING SAE	0.29	
9	C	LEG	2	0.07	1	22.9	82.8	BOLTING SAE	0.28	
10	B	CIRC	4	0.07	1	9.4	82.8	BOLTING SAE	0.11	

THIS EQUIPMENT IS ACCEPTABLE FOR THE SPECIFIED SEISMIC DISTURBANCE

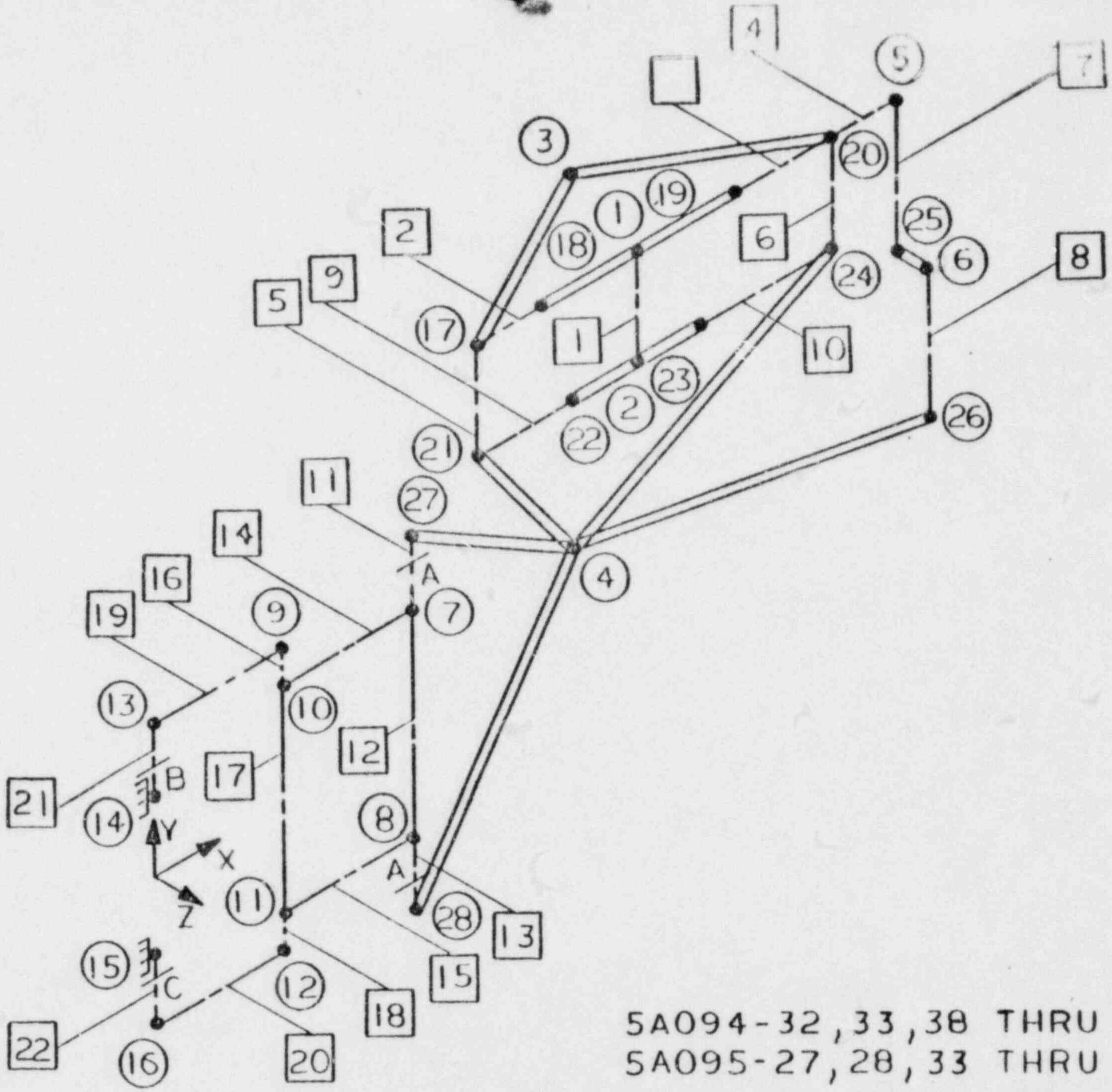
THIS REPORT HAS BEEN PREPARED BY /

ROBERT F.GONDA

FISHER CONTROLS COMPANY

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

APPENDIX E



5A094-32,33,38 THRU 41
5A095-27,28,33 THRU 36

FISHER CONTROLS COMPANY

SEISMIC-4

SEISMIC ANALYSIS

OF

ROTARY VALVES

ERIAL PROPERTY INPUT DATA

ESCRIPTION	YOUNG'S MOD/10(6)	POISSON'S RATIO	MASS DENS/10(-4)	ALLOWABLE STRESS/10(3)
STEEL	30.000	0.283	7.240	27.000
CAST IRON	15.000	0.230	6.750	15.000
BOLTING	30.000	0.283	7.240	117.000

COMMONWEALTH EDISON CO.
STATION CONSTRUCTION DEPT.

CC NO 5A094-32,33 & 38-41
5A095-27,28 & 33-36

REPRESENTATIVE ORDER NO 14-62496-A
14-62496-B

VALVE SIZE 8 VALVE TYPE 9220

ACTUATOR LIMITORQUE SMB000/2-H0BC

CUSTOMER ORDER NO 181104

CUSTOMER TAG NO	1VQ042	2VQ042
	1VQ043	2VQ043
	1VP113A	2VP113A
	1VP113B	2VP113B
	1VP114A	2VP114A
	1VP114B	2VP114B

CERTIFIED DRAWING NO G26925C

CROSS SECTION DRAWING NO F43428A

BRACKET DRAWING NO G34217A

DATE OF THIS REPORT / DECEMBER 15, 1978

C O N T R O L I N P U T D A T A

MANUAL INPUT GENERATION FOR VALVE ANALYSIS

SEISMIC STRESSES ARE SUPERIMPOSED BY SQUARE ROOT OF SUM OF SQUARES

STRESS ALLOWABLES ARE COMPARED TO MAXIMUM PRINCIPAL STRESS

MASS, STIFFNESS, LOAD AND STRESS MATRICES ARE NOT PRINTED

STATIC SEISMIC ANALYSIS TO BE PERFORMED

OPERATIONAL LOAD ANALYSIS TO BE PERFORMED

DYNAMIC MODAL ANALYSIS TO BE PERFORMED WITH EVALUATION

C R O S S - S E C T I O N   D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS								
1	TUBE	A =	2.250	, T =	.2500	,				
2	RECTANGULAR	A =	4.875	, T =	.6200	,				
3	RECTANGULAR	A =	4.120	, T =	.6200	,				
4	RECTANGULAR	A =	4.120	, T =	.6200	,				
5	RECTANGULAR	A =	.8750	, T =	.3750	,				
6	RECTANGULAR	A =	1.750	, T =	.7500	,				
7	RECTANGULAR	A =	4.100	, T =	.6200	,				
8	RECTANGULAR	A =	7.000	, T =	.6200	,				
9	RECTANGULAR	A =	4.000	, T =	.3130	,				
10	RECTANGULAR	A =	4.000	, T =	.3130	,				
11	RECTANGULAR	A =	9.000	, T =	.9370	,				
12	RECTANGULAR	A =	9.000	, T =	.9370	,				
13	RECTANGULAR	A =	9.000	, T =	.9370	,				
14	CHANNEL	A =	8.000	, T =	.4270	,	B =	3.502	,	
		T1=	.5250	, R1=	.0	,				
15	CHANNEL	A =	8.000	, T =	.4270	,	B =	3.502	,	
		T1=	.5250	, R1=	.0	,				
16	RECTANGULAR	A =	9.000	, T =	1.000	,				
17	RECTANGULAR	A =	9.000	, T =	1.000	,				
18	RECTANGULAR	A =	9.000	, T =	1.000	,				
19	CHANNEL	A =	6.000	, T =	.3790	,	B =	3.504	,	
		T1=	.4750	, R1=	.0	,				
20	CHANNEL	A =	6.000	, T =	.3790	,	B =	3.504	,	
		T1=	.4750	, R1=	.0	,				
21	RECTANGULAR	A =	7.000	, T =	.9370	,				
22	RECTANGULAR	A =	7.000	, T =	.9370	,				

J O I N T   C O O R D I N A T E   D A T A

JOINT NO.	X	Y	Z
1	10.531000	6.380000	-2.500000
2	10.531000	3.710000	-2.500000
3	14.281000	10.942000	-1.875000
4	10.961000	0.430000	-0.930000
5	13.716000	6.380000	-2.500000
6	13.716000	3.500000	0.0
7	7.062000	3.260000	0.0
8	7.062000	-3.260000	0.0
9	3.531000	5.120000	0.0
10	3.531000	3.260000	0.0
11	3.531000	-3.260000	0.0
12	3.531000	-5.120000	0.0
13	0.0	5.120000	0.0
14	0.0	2.875000	0.0
15	0.0	-2.875000	0.0
16	0.0	-5.120000	0.0
17	8.968000	6.380000	-2.500000
18	9.374000	6.380000	-2.500000
19	11.688000	6.380000	-2.500000
20	12.531000	6.380000	-2.500000
21	8.968000	3.710000	-2.500000
22	9.965000	3.710000	-2.500000
23	11.097000	3.710000	-2.500000
24	12.531000	3.710000	-2.500000
25	13.716000	3.500000	-2.500000
26	13.716000	0.0	0.0
27	7.062000	3.812000	0.0
28	7.062000	-3.812000	0.0

B O U N D A R Y ,   S P R I N G   &   B O L T   J O I N T   D A T A

JOINT NO.	TYPE-MAT /FIXITY	PLANE-DIRECTION OR DESCRIPTION		SPRING & BOLT JOINT PARAMETERS					
14	111111	BODY							
15	111111	BODY							
28	PAD 3	A	+X +Y	N.T=	2.13	,D/A=	0.5000,	YE=	0.6250
				YO=	7.6240,	YSH=	3.8120,	S=	3.0780
				ZT=	0.6250,	ZB=	0.6250,	ZSH=	0.0
14	LEG 3	B	+X +Y	N.T=	2.16	,D/A=	0.3750,	YE=	0.6250
				YO=	0.8750,	YSH=	0.0 ,	S=	1.2500
				ZT=	1.0000,	ZB=	1.0000,	ZSH=	0.0
15	LEG 3	C	+X -Y	N.T=	2.16	,D/A=	0.3750,	YE=	0.6250
				YO=	0.8750,	YSH=	0.0 ,	S=	1.2500
				ZT=	1.0000,	ZB=	1.0000,	ZSH=	0.0

C O N C E N T R A T E D   M A S S   D A T A

JOINT NO.	LUMPED MASS	FOR DIR.	SHIFT DISTANCE OR MOMENT OF INERTIA X	Y	Z
3	0.370083	XYZ	0.0	0.0	0.0
4	0.181159	XYZ	0.0	0.0	0.0

C O N C E N T R A T E D   L O A D   D A T A

JOINT NO.	FORCES X	FORCES Y	FORCES Z	MOMENTS X	MOMENTS Y	MOMENTS Z
4	0.0	0.0	0.0	761.0	0.0	0.0

ELEMENT INPUT DATA

EL. NO.	JOINTS		LENGTH /RADIUS	ANGLE	AREA	MOMENTS OF INERTIA I-11	I-22	I-33	MATERIAL DESCRIPTION
1	1	2	2.670		1.5708	0.7977	1.5953	0.7977	CAST IRON
2	17	18	0.406		3.0225	0.0968	0.3563	5.9860	CAST IRON
3	19	20	0.843		2.5544	0.0818	0.2963	3.6133	CAST IRON
4	20	5	1.185		2.5544	0.0818	0.2963	3.6133	CAST IRON
5	17	21	2.670		0.3281	0.0038	0.0112	0.0209	CAST IRON
6	20	24	2.670		1.3125	0.0615	0.1798	0.3350	CAST IRON
7	5	25	2.880		2.5420	0.08.4	0.2947	3.5609	STEEL
8	6	26	3.500		4.3400	0.1390	0.5251	17.7217	STEEL
9	21	22	0.997		1.2520	0.0102	0.0389	1.6693	CAST IRON
10	23	24	1.434		1.2520	0.0102	0.0389	1.6693	CAST IRON
11	27	7	0.552		8.4330	0.6170	2.3061	56.9227	STEEL
12	7	8	6.520		8.4330	0.6170	2.3061	56.9227	STEEL
13	8	28	0.552		8.4330	0.6170	2.3061	56.9227	STEEL
14	10	7	3.531		6.6447	63.3949	0.4909	7.5946	STEEL
15	11	8	3.531		6.6447	63.3949	0.4909	7.5946	STEEL
16	9	10	1.860		9.0000	0.7500	2.7900	60.7500	STEEL
17	10	11	6.520		9.0000	0.7500	2.7900	60.7500	STEEL
18	11	12	1.860		9.0000	0.7500	2.7900	60.7500	STEEL
19	13	9	3.531		5.2427	29.5336	0.3237	6.2320	STEEL
20	16	12	3.531		5.2427	29.5336	0.3237	6.2320	STEEL
21	13	14	2.245		6.5590	0.4799	1.7577	26.7826	STEEL
22	15	16	2.245		6.5590	0.4799	1.7577	26.7826	STEEL
	17	3			RIGID LINK				
	18	1			RIGID LINK				
	19	1			RIGID LINK				
	20	3			RIGID LINK				
	21	4			RIGID LINK				
	22	2			RIGID LINK				
	23	2			RIGID LINK				
	24	4			RIGID LINK				
	25	6			RIGID LINK				
	26	4			RIGID LINK				
	27	4			RIGID LINK				
	28	4			RIGID LINK				

S T A T I C   A N A L Y S I S

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM X DIR.

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.000282	-0.000054	0.000320	0.000008	-0.000022	-0.000039
2	0.000158	-0.000062	0.000294	0.000009	-0.000033	-0.000033
3	0.000439	-0.000196	0.000430	0.000006	-0.000022	-0.000038
4	0.000068	-0.000094	0.000308	0.000000	-0.000034	-0.000011
5	0.000281	-0.000134	0.000392	-0.000002	-0.000023	-0.000010
6	0.000115	-0.000126	0.000398	-0.000002	-0.000039	-0.000030
7	0.000065	-0.000052	0.000176	0.000000	-0.000030	-0.000009
8	-0.000003	-0.000052	0.000176	0.000000	-0.000030	-0.000009
9	0.000053	-0.000025	0.000069	0.000000	-0.000020	-0.000004
10	0.000059	-0.000025	0.000069	0.000000	-0.000030	-0.000005
11	-0.000002	-0.000024	0.000069	0.000000	-0.000030	-0.000008
12	-0.000013	-0.000024	0.000069	0.000000	-0.000020	-0.000006
13	0.000045	0.000000	0.000000	-0.000000	-0.000019	-0.000010
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	-0.000012	-0.000000	0.000000	0.000000	-0.000019	-0.000007
17	0.000282	0.000007	0.000286	0.000006	-0.000022	-0.000038
18	0.000282	-0.000009	0.000294	0.000008	-0.000022	-0.000039
19	0.000282	-0.000099	0.000346	0.000008	-0.000022	-0.000039
20	0.000282	-0.000127	0.000365	0.000006	-0.000022	-0.000038
21	0.000156	-0.000072	0.000241	0.000000	-0.000034	-0.000011
22	0.000158	-0.000044	0.000275	0.000009	-0.000033	-0.000033
23	0.000158	-0.000081	0.000313	0.000009	-0.000033	-0.000033
24	0.000156	-0.000111	0.000361	0.000000	-0.000034	-0.000011
25	0.000214	-0.000131	0.000398	-0.000002	-0.000039	-0.000030
26	0.000031	-0.000124	0.000402	0.000000	-0.000034	-0.000011
27	0.000073	-0.000052	0.000176	0.000000	-0.000034	-0.000011
28	-0.000010	-0.000052	0.000176	0.000000	-0.000034	-0.000011

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Y DIR.

JOINT NO.	. . . DEFLECTION X	Y	Z . . .	. . . ROTATION X	Y	Z . . .
1	-0.000126	0.000461	0.000289	0.000032	-0.000008	0.000027
2	-0.000064	0.000462	0.000189	0.000037	-0.000001	0.000022
3	-0.000256	0.000548	0.000443	0.000027	-0.000009	0.000027
4	-0.000007	0.000393	0.000022	0.000051	-0.000000	0.000017
5	-0.000125	0.000525	0.000318	0.000049	-0.000009	0.000009
6	-0.000074	0.000395	0.000176	0.000051	0.000001	0.000022
7	-0.000053	0.000277	0.000164	0.000051	-0.000007	0.000023
8	0.000053	0.000277	-0.000164	0.000051	0.000007	0.000023
9	-0.000096	0.000183	0.000096	0.000019	-0.000012	0.000044
10	-0.000049	0.000184	0.000063	0.000019	-0.000007	0.000023
11	0.000049	0.000184	-0.000063	0.000019	0.000007	0.000023
12	0.000096	0.000183	-0.000096	0.000019	0.000012	0.000044
13	-0.000089	0.000002	0.000002	-0.000000	-0.000012	0.000050
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	0.000089	0.000002	-0.000002	-0.000000	0.000012	0.000050
17	-0.000125	0.000419	0.000275	0.000027	-0.000009	0.000027
18	-0.000126	0.000430	0.000279	0.000032	-0.000008	0.000027
19	-0.000126	0.000493	0.000298	0.000032	-0.000008	0.000027
20	-0.000125	0.000516	0.000306	0.000027	-0.000009	0.000027
21	-0.000065	0.000437	0.000188	0.000051	-0.000000	0.000017
22	-0.000064	0.000450	0.000189	0.000037	-0.000001	0.000022
23	-0.000064	0.000475	0.000189	0.000037	-0.000001	0.000022
24	-0.000065	0.000499	0.000188	0.000051	-0.000000	0.000017
25	-0.000076	0.000523	0.000176	0.000051	0.000001	0.000022
26	-0.000000	0.000394	0.000000	0.000051	-0.000000	0.000017
27	-0.000066	0.000278	0.000193	0.000051	-0.000000	0.000017
28	0.000066	0.000278	-0.000193	0.000051	-0.000000	0.000017

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Z DIR.

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.000655	0.000593	0.004299	0.000396	-0.000218	0.000003
2	0.000662	0.000593	0.003355	0.000358	-0.000262	0.000002
3	0.000506	0.000332	0.007092	0.000434	-0.000217	0.000003
4	0.000246	0.000220	0.002700	0.000237	-0.000265	-0.000000
5	0.000655	0.000612	0.004964	0.000263	-0.000215	0.000006
6	0.000020	-0.000001	0.004196	0.000246	-0.000250	-0.000008
7	0.000000	-0.000000	0.002334	0.000237	-0.000283	-0.000000
8	-0.000000	-0.000000	0.000796	0.000237	-0.000219	-0.000000
9	0.000000	-0.000000	0.001117	0.000087	-0.000241	-0.000000
10	0.000000	-0.000000	0.000964	0.000087	-0.000283	-0.000000
11	-0.000000	-0.000000	0.000377	0.000087	-0.000215	-0.000000
12	-0.000000	-0.000000	0.000217	0.000087	-0.000128	-0.000000
13	0.000000	-0.000000	0.000014	-0.000001	-0.000236	-0.000000
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	-0.000000	-0.000000	-0.000004	-0.000000	-0.000122	-0.000000
17	0.000655	0.000588	0.003957	0.000434	-0.000217	0.000003
18	0.000655	0.000589	0.004047	0.000396	-0.000218	0.000003
19	0.000655	0.000596	0.004551	0.000396	-0.000218	0.000003
20	0.000655	0.000598	0.004732	0.000434	-0.000217	0.000003
21	0.000662	0.000592	0.002950	0.000237	-0.000265	-0.000000
22	0.000662	0.000592	0.003206	0.000358	-0.000262	0.000002
23	0.000662	0.000594	0.003503	0.000358	-0.000262	0.000002
24	0.000662	0.000592	0.003893	0.000237	-0.000265	-0.000000
25	0.000645	0.000613	0.004196	0.000246	-0.000250	-0.000008
26	0.000000	-0.000000	0.003328	0.000237	-0.000265	-0.000000
27	0.000000	-0.000000	0.002469	0.000237	-0.000265	-0.000000
28	-0.000000	-0.000000	0.000663	0.000237	-0.000265	-0.000000

DEFORMATION RESPONSE TO OPERATIONAL LOADS (NOT INCLUDING DEADWEIGHT)

JOINT	. . .DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.000000	0.000275	0.000702	0.000110	-0.000000	-0.000000
2	0.000000	0.000275	0.000409	0.000110	-0.000000	-0.000000
3	0.000000	0.000206	0.001205	0.000110	-0.000000	-0.000000
4	0.000000	0.000102	0.000048	0.000110	-0.000000	-0.000000
5	0.000000	0.000275	0.000703	0.000110	-0.000000	-0.000000
6	0.000000	-0.000000	0.000386	0.000110	-0.000000	-0.000000
7	0.000000	-0.000000	0.000358	0.000110	-0.000015	-0.000000
8	-0.000000	-0.000000	-0.000357	0.000110	0.000015	-0.000000
9	0.000000	-0.000000	0.000209	0.000041	-0.000026	-0.000000
10	0.000000	-0.000000	0.000137	0.000040	-0.000016	-0.000000
11	-0.000000	-0.000000	-0.000136	0.000040	0.000016	-0.000000
12	-0.000000	-0.000000	-0.000209	0.000041	0.000026	-0.000000
13	0.000000	-0.000000	0.000004	-0.000000	-0.000026	-0.000000
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	-0.000000	-0.000000	-0.000004	-0.000000	0.000026	-0.000000
17	0.000000	0.000275	0.000702	0.000110	-0.000000	-0.000000
18	0.000000	0.000275	0.000702	0.000110	-0.000000	-0.000000
19	0.000000	0.000275	0.000702	0.000110	-0.000000	-0.000000
20	0.000000	0.000275	0.000702	0.000110	-0.000000	-0.000000
21	0.000000	0.000275	0.000409	0.000110	-0.000000	-0.000000
22	0.000000	0.000275	0.000409	0.000110	-0.000000	-0.000000
23	0.000000	0.000275	0.000409	0.000110	-0.000000	-0.000000
24	0.000000	0.000275	0.000409	0.000110	-0.000000	-0.000000
25	0.000000	0.000275	0.000386	0.000110	-0.000000	-0.000000
26	-0.000000	-0.000000	0.000000	0.000110	-0.000000	-0.000000
27	0.000000	-0.000000	0.000420	0.000110	-0.000000	-0.000000
28	-0.000000	-0.000000	-0.000419	0.000110	-0.000000	-0.000000

D Y N A M I C   A N A L Y S I S

RESONANT FREQUENCY = 39.5 HERTZ (IN Z-DIRECTION OR X-ROTATION)

* * * * NORMALIZED EIGENVECTOR * * * *

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.081429	0.096103	0.591608	0.062895	-0.025172	0.000271
2	0.081788	0.096034	0.441372	0.056956	-0.032172	0.000159
3	0.064429	0.054112	1.000000	0.068969	-0.025085	0.000290
4	0.030571	0.036444	0.333074	0.037724	-0.032652	0.000017
5	0.081397	0.098801	0.667133	0.041839	-0.024705	0.000864
6	0.003642	0.001224	0.545003	0.039135	-0.030395	-0.001376
7	0.000162	0.001293	0.311970	0.037767	-0.035796	0.000071
8	0.000248	0.001292	0.066928	0.037749	-0.025631	0.000070
9	-0.000167	0.000916	0.151538	0.013918	-0.031256	0.000233
10	0.000145	0.000922	0.126920	0.013852	-0.035853	0.000099
11	0.000232	0.000926	0.033095	0.013934	-0.025128	0.000081
12	0.000447	0.000920	0.007745	0.013958	-0.013113	0.000218
13	-0.000199	0.000010	0.001876	-0.000149	-0.030539	0.000224
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	0.000416	0.000010	-0.000937	-0.000051	-0.012466	0.000246
17	0.081431	0.095677	0.552087	0.068969	-0.025085	0.000290
18	0.081429	0.095789	0.562484	0.062895	-0.025172	0.000271
19	0.081429	0.096416	0.620731	0.062895	-0.025172	0.000271
20	0.081431	0.096710	0.641464	0.068969	-0.025085	0.000290
21	0.081778	0.095636	0.391733	0.037724	-0.032652	0.000017
22	0.081788	0.095944	0.423162	0.056956	-0.032172	0.000159
23	0.081788	0.096124	0.459581	0.056956	-0.032172	0.000159
24	0.081778	0.095697	0.508070	0.037724	-0.032652	0.000017
25	0.079630	0.099061	0.545003	0.039135	-0.030395	-0.001376
26	0.000212	0.001408	0.406808	0.037724	-0.032652	0.000017
27	0.000147	0.001294	0.333347	0.037724	-0.032652	0.000017
28	0.000277	0.001294	0.045743	0.037724	-0.032652	0.000017

S T A T I C   S E I S M I C   A N A L Y S I S

THE VALVE AXIS IS POSITIONED Y-UP

ACCELERATION OF GRAVITY, G = 386.400

DIRECTION OF SEISMIC ACCELERATION	NO. OF G'S	COMPONENTS OF UNIT ACCELERATION IN VALVE COORDINATE SYSTEM X-COMP.	Y-COMP.	Z-COMP.
HORIZONTAL(1)	6.000	0.0	0.0	-1.0000
HORIZONTAL(2)	6.000	1.0000	0.0	0.0
VERTICAL	7.000	0.0	-1.0000	0.0

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

MEMB. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	-540.	2.	7.	13.	-959.	-1727.
	2	534.	-2.	-7.	-31.	959.	293.
2	17	-283.	-4.	5.	-0.	1233.	-781.
	18	281.	4.	-5.	-2.	-1233.	666.
3	19	257.	2.	3.	-2.	-494.	319.
	20	-260.	-2.	-3.	-1.	494.	-101.
4	20	1544.	39.	242.	-161.	1565.	1580.
	5	-1549.	-39.	-242.	-126.	-1565.	252.
5	17	3.	43.	-22.	5.	-7.	2.
	21	-3.	-43.	24.	57.	7.	6.
6	20	30.	-287.	163.	-625.	-117.	7.
	24	-30.	287.	-158.	195.	117.	72.
7	5	1548.	242.	-39.	126.	-252.	-1566.
	25	-1560.	-242.	39.	-13.	252.	6041.
8	6	1562.	242.	-39.	13.	-154.	-5437.
	26	-1587.	-242.	39.	125.	154.	10947.
9	21	208.	4.	-13.	5.	-173.	557.
	22	-210.	-4.	13.	8.	173.	-348.
10	23	-324.	-3.	-11.	9.	120.	-546.
	24	321.	3.	11.	7.	-120.	84.
11	27	3197.	1.	0.	1.	-5225.	6315.
	7	-3205.	-1.	-0.	-1.	5225.	-4548.
12	7	-509.	-0.	0.	-0.	1585.	-1807.
	8	417.	0.	-0.	-0.	-1585.	-1213.
13	8	1837.	-1.	-1.	-1.	-13495.	-2006.
	28	-1845.	1.	1.	1.	13495.	3023.
14	10	-1.	-1.	3753.	-6374.	6360.	-1.
	7	1.	1.	-3714.	-6809.	-6360.	-1.
15	11	0.	0.	2213.	7197.	3222.	0.
	8	-0.	-0.	-2253.	-15082.	-3222.	1.
16	9	-2417.	-1.	1.	-2.	-4351.	-5115.
	10	2389.	1.	-1.	-0.	4351.	645.
17	10	1364.	0.	0.	-1.	2023.	5714.
	11	-1463.	-0.	-0.	-1.	-2023.	3504.
18	11	-751.	1.	1.	0.	9219.	-281.
	12	722.	-1.	-1.	-2.	-9219.	-1088.
19	13	-1.	-1.	2448.	-12941.	5115.	0.
	9	1.	1.	-2417.	4352.	-5115.	-2.
20	16	1.	1.	691.	6724.	1088.	0.
	12	-1.	-1.	-722.	-9219.	-1088.	2.
21	13	2448.	1.	-1.	0.	12942.	5115.
	14	-2473.	-1.	1.	3.	-12942.	408.
22	15	665.	-1.	-1.	2.	-6724.	436.
	16	-691.	1.	1.	-0.	6724.	1088.

TYPE	JNT. NO.	FX	FY	FZ	MX	MY	MZ
		. . . . . BOUNDARY OR JUNCTION REACTION					
BODY	14	1.	-1.	2473.	408.	-12942.	-3.
BODY	15	-1.	-1.	-666.	436.	-6724.	-2.
A +X+Y	28	1.	2.	-1352.	-15034.	8270.	-3.
B +X+Y	14	1.	-1.	2473.	408.	-12942.	-3.
C +X-Y	15	-1.	-1.	-666.	436.	-6724.	-2.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
		=40.	430.	247.	-168.	237.	-85.
1		40.	=430.	=253.	-499.	-237.	-21.
		=47.	=173.	185.	-62.	60.	117.
2		47.	175.	-185.	-13.	-60.	-136.
		=7.	72.	=244.	113.	-24.	-40.
3		7.	=69.	244.	93.	24.	34.
		36.	=54.	=604.	527.	-67.	162.
4		=36.	58.	604.	189.	67.	-119.
		54.	878.	8.	-10.	2.	54.
5		=56.	-878.	=8.	-11.	-2.	93.
		508.	=704.	=11.	27.	29.	379.
6		=514.	704.	11.	3.	-29.	986.
		36.	=604.	58.	-189.	119.	67.
7		=36.	604.	=71.	3.	-119.	37.
		36.	-604.	71.	-3.	-57.	-1547.
8		=36.	604.	=96.	-289.	57.	1672.
		48.	152.	=433.	196.	12.	-80.
9		=48.	-150.	433.	236.	-12.	127.
		8.	=103.	-3.	16.	-9.	78.
10		=8.	106.	3.	-12.	9.	-66.
		=6.	=131.	1957.	-126.	-1053.	-1.
11		0.	131.	-1965.	-957.	1053.	1.
		0.	22.	=2.	-101.	-0.	0.
12		=0.	=22.	=90.	-186.	0.	-0.
		0.	=131.	606.	-489.	1055.	-1.
13		=0.	131.	=613.	152.	-1055.	1.
		153.	2007.	=1.	1056.	-1.	1600.
14		=153.	=1967.	1.	-1053.	1.	-1058.
		153.	=476.	0.	-1056.	1.	-134.
15		=153.	515.	=0.	1055.	-1.	674.
		1.	=34.	=1991.	1771.	1056.	2.
16		=1.	34.	1963.	1907.	-1056.	-0.
		=0.	=188.	43.	-307.	-0.	-1.
17		0.	188.	=142.	-296.	0.	0.
		=0.	=35.	-334.	430.	-1056.	0.
18		0.	35.	306.	165.	1056.	-1.
		=34.	2022.	=1.	1058.	-2.	-1893.
19		34.	=1991.	1.	-1056.	2.	1771.
		=35.	=275.	0.	-1058.	1.	41.
20		35.	306.	=0.	1056.	-1.	-165.
		=1.	[illegible]	2022.	-1893.	-1058.	-2.
21		1.	=34.	=2047.	-2676.	1058.	0.
		0.	35.	250.	-548.	1058.	-0.
22		=0.	=35.	=275.	-41.	-1058.	1.

TYPE		JNT. NO.	FX	FY	FZ	MX	MY	MZ
			. . . . . BOUNDARY OR JUNCTION REACTION					
BODY		14	-2047.	-34.	-1.	0.	1058.	2676.
BODY		15	250.	35.	-0.	-0.	1058.	548.
A	+X+Y	28	1344.	0.	1.	3.	-2108.	-14948.
B	+X+Y	14	-2047.	-34.	-1.	0.	1058.	2676.
C	+X-Y	15	250.	35.	-0.	-0.	1058.	548.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	84.	66.	-45.	222.	202.	264.
	2	-84.	-58.	45.	-100.	-202.	-40.
2	17	39.	32.	109.	-13.	-188.	151.
	18	-39.	-32.	-107.	-31.	188.	-135.
3	19	-45.	-13.	41.	-20.	75.	-61.
	20	45.	13.	-37.	-13.	-75.	23.
4	20	-129.	-36.	-441.	396.	-240.	-74.
	5	129.	36.	446.	129.	240.	-79.
5	17	1.	243.	4.	-1.	2.	-7.
	21	-1.	-241	-4.	-9.	-2.	9.
6	20	8.	-875.	-49.	123.	25.	-121.
	24	-8.	881.	49.	8.	-25.	144.
7	5	-129.	-446.	36.	-129.	79.	240.
	25	129.	460.	-36.	25.	-79.	-613.
8	6	-129.	-461.	36.	-25.	-11.	-539.
	26	129.	490.	-36.	-101.	11.	86.
9	21	-28.	-27.	-69.	30.	23.	-108.
	22	28.	27.	71.	40.	-23.	80.
10	23	56.	19.	-13.	13.	-16.	106.
	24	-56.	-19.	16.	7.	16.	-25.
11	27	628.	-782.	1725.	-1789.	-2333.	1165.
	7	-628.	791.	-1725.	837.	2333.	-819.
12	7	-115.	54.	-228.	743.	395.	-376.
	8	115.	54.	228.	743.	-395.	-376.
13	8	628.	790.	1725.	837.	-2334.	-818.
	28	-628.	-781.	-1725.	-1789.	2334.	1166.
14	10	895.	1953.	744.	102.	1194.	1497.
	7	-849.	-1953.	-744.	-2728.	-1194.	1580.
15	11	-895.	-1953.	744.	103.	1194.	-1497.
	8	849.	1953.	-744.	-2729.	-1194.	-1580.
16	9	-391.	985.	-2296.	3890.	606.	-773.
	10	391.	-952.	2296.	380.	-606.	45.
17	10	352.	58.	-343.	1117.	504.	1149.
	11	-352.	57.	343.	1117.	-504.	1149.
18	11	-391.	-952.	-2296.	360.	607.	46.
	12	391.	985.	2296.	3890.	-607.	-773.
19	13	1021.	2296.	391.	-775.	773.	-349.
	9	-985.	-2296.	391.	-606.	-773.	3890.
20	16	-1021.	-2296.	391.	-774.	773.	349.
	12	985.	2296.	-391.	-607.	- 73.	-3890.
21	13	391.	-1021.	2296.	-350.	776.	773.
	14	-391.	1050.	-2296.	-4805.	-776.	105.
22	15	391.	1050.	2296.	-4805.	774.	105.
	16	-391.	-1021.	-2296.	-349.	-774.	773.

TYPE		JNT. NO.	FX	FY	FZ	MX	MY	MZ
			. . . . . BOUNDARY OR JUNCTION REACTION					
BODY		14	-2296.	1050.	391.	105.	-776.	4805.
BODY		15	2296.	1050.	-391.	105.	774.	4805.
A	+X+Y	28	-0.	-1563.	0.	-2459.	1.	-9572.
B	+X+Y	14	-2296.	1050.	391.	105.	-776.	4805.
C	+X-Y	15	2296.	1050.	-391.	105.	774.	4805.

RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

	JNT. NO.	. . ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	12.	9.	-6.	32.	29.	38.
	2	-12.	-8.	6.	-14.	-29.	-6.
2	17	6.	5.	16.	-2.	-27.	22.
	18	-6.	-5.	-15.	-4.	27.	-19.
3	19	-6.	-2.	6.	-3.	11.	-9.
	20	6.	2.	-5.	-2.	-11.	3.
4	20	-18.	-5.	-63.	57.	-34.	-11.
	5	18.	5.	64.	18.	34.	-11.
5	17	0.	35.	1.	-0.	0.	-1.
	21	-0.	-34.	-1.	-1.	-0.	1.
6	20	1.	-125.	-7.	18.	4.	-17.
	24	-1.	126.	7.	1.	-4.	21.
7	5	-18.	-64.	5.	-18.	11.	3[illegible].
	25	18.	66.	-5.	4.	-11.	-87.
8	6	-18.	-66.	5.	-4.	-2.	-77.
	26	18.	70.	-5.	-14.	2.	13.
9	21	-4.	-4.	-10.	4.	3.	-15.
	22	4.	4.	10.	6.	-3.	11.
10	23	8.	3.	-2.	2.	-2.	15.
	24	-8.	-3.	2.	1.	2.	-4.
11	27	-106.	-112.	246.	-256.	392.	-196.
	7	106.	113.	-246.	120.	-392.	137.
12	7	19.	8.	-33.	106.	-66.	63.
	8	-19.	8.	33.	106.	66.	63.
13	8	-105.	113.	246.	120.	392.	137.
	28	105.	-112.	-246.	-256.	-392.	-196.
14	10	128.	279.	-125.	-17.	-200.	214.
	7	-121.	-279.	125.	458.	200.	226.
15	11	-128.	-279.	-125.	-17.	-200.	-214.
	8	121.	279.	125.	458.	200.	-226.
16	9	66.	141.	-328.	556.	-102.	130.
	10	-66.	-136.	328.	54.	102.	-8.
17	10	-59.	8.	-49.	160.	-85.	-193.
	11	59.	8.	49.	160.	85.	-193.
18	11	66.	-136.	-328.	54.	-102.	-8.
	12	-66.	141.	328.	556.	102.	130.
19	13	146.	328.	-66.	130.	-130.	-50.
	9	-141.	-328.	66.	102.	130.	556.
20	16	-146.	-328.	-66.	130.	-130.	50.
	12	141.	328.	66.	102.	130.	-556.
21	13	-66.	-146.	328.	-50.	-130.	-130.
	14	66.	150.	-328.	-687.	130.	-18.
22	15	-66.	150.	328.	-687.	-130.	-18.
	16	66.	-146.	-328.	-50.	130.	-130.

TYPE	JNT. NO.	FX	FY	FZ	MX	MY	MZ
BODY	14	-328.	150.	-66.	-18.	130.	687.
BODY	15	328.	150.	66.	-18.	-130.	687.
A +X+Y	28	-0.	-223.	0.	414.	-0.	-1368.
B +X+Y	14	-328.	150.	-66.	-18.	130.	687.
C +X-Y	15	328.	150.	66.	-18.	-130.	687.

. . . . . BOUNDARY OR JUNCTION REACTION . . . . .

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.003928	-0.003556	-0.025794	-0.002373	0.001308	-0.000017
2	-0.003972	-0.003556	-0.020128	-0.002148	0.001571	-0.000012
3	-0.003034	-0.001994	-0.042554	-0.002604	0.001305	-0.000017
4	-0.001478	-0.001321	-0.016202	-0.001421	0.001589	0.000000
5	-0.003927	-0.003671	-0.029784	-0.001578	0.001290	-0.000034
6	-0.000120	0.000008	-0.025178	-0.001475	0.001501	0.000047
7	-0.000000	0.000001	-0.014007	-0.001423	0.001696	0.000000
8	0.000000	0.000001	-0.004775	-0.001422	0.001313	0.000000
9	-0.000000	0.000001	-0.006705	-0.000523	0.001448	0.000000
10	-0.000000	0.000001	-0.005787	-0.000520	0.001696	0.000000
11	0.000000	0.000001	-0.002262	-0.000524	0.001292	0.000000
12	0.000000	0.000001	-0.001303	-0.000524	0.000766	0.000000
13	-0.000000	0.000000	-0.000082	0.000007	0.001414	0.000000
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	0.000000	0.000000	0.000024	0.000001	0.000735	0.000000
17	-0.003928	-0.003529	-0.023743	-0.002604	0.001305	-0.000017
18	-0.003928	-0.003536	-0.024281	-0.002373	0.001308	-0.000017
19	-0.003928	-0.003576	-0.027308	-0.002373	0.001308	-0.000017
20	-0.003928	-0.003591	-0.028392	-0.002604	0.001305	-0.000017
21	-0.003973	-0.003552	-0.017697	-0.001421	0.001589	0.000000
22	-0.003972	-0.003549	-0.019239	-0.002148	0.001571	-0.000012
23	-0.003972	-0.003563	-0.021017	-0.002148	0.001571	-0.000012
24	-0.003973	-0.003552	-0.023359	-0.001421	0.001589	0.000000
25	-0.003872	-0.003680	-0.025178	-0.001475	0.001501	0.000047
26	-0.000000	0.000001	-0.019969	-0.001421	0.001589	0.000000
27	-0.000000	0.000001	-0.014814	-0.001421	0.001589	0.000000
28	0.000000	0.000001	-0.003978	-0.001421	0.001589	0.000000

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

JOINT NO.	. . . DEFLECTION X	. . . Y	. . . Z	. . . ROTATION X	. . . Y	. . . Z
1	0.001689	-0.000325	0.001922	0.000045	-0.000134	-0.000232
2	0.000946	-0.000374	0.001765	0.000052	-0.000199	-0.000196
3	0.002635	-0.001176	0.002578	0.000034	-0.000134	-0.000225
4	0.000406	-0.000563	0.001849	0.000000	-0.000204	-0.000065
5	0.001689	-0.000507	0.002354	-0.000010	-0.000137	-0.000062
6	0.000692	-0.000758	0.002388	-0.000010	-0.000236	-0.000178
7	0.000388	-0.000311	0.001055	0.000000	-0.000182	-0.000052
8	-0.000020	-0.000312	0.001055	0.000000	-0.000182	-0.000055
9	0.000318	-0.000148	0.000416	0.000000	-0.000120	-0.000026
10	0.000353	-0.000148	0.000416	0.000000	-0.000180	-0.000032
11	-0.000011	-0.000143	0.000416	0.000000	-0.000180	-0.000049
12	-0.000078	-0.000143	0.000415	0.000000	-0.000120	-0.000036
13	0.000272	0.000000	0.000000	-0.000000	-0.000116	-0.000060
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	-0.000072	-0.000000	0.000000	0.000000	-0.000116	-0.000040
17	0.001691	0.000042	0.001713	0.000034	-0.000134	-0.000225
18	0.001689	-0.000056	0.001767	0.000045	-0.000134	-0.000232
19	0.001689	-0.000593	0.002077	0.000045	-0.000134	-0.000232
20	0.001691	-0.000760	0.002190	0.000034	-0.000134	-0.000225
21	0.000938	-0.000434	0.001443	0.000000	-0.000204	-0.000065
22	0.000946	-0.000263	0.001652	0.000052	-0.000199	-0.000196
23	0.000946	-0.000484	0.001878	0.000052	-0.000199	-0.000196
24	0.000938	-0.000665	0.002169	0.000000	-0.000204	-0.000065
25	0.001283	-0.000784	0.002388	-0.000010	-0.000236	-0.000178
26	0.000189	-0.000742	0.002409	0.000000	-0.000204	-0.000065
27	0.000435	-0.000311	0.001055	0.000000	-0.000204	-0.000065
28	-0.000058	-0.000311	0.001054	0.000000	-0.000204	-0.000065

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

JOINT	. . . DEFLECTION . . .			. . . ROTATION . . .		
NO.	X	Y	Z	X	Y	Z
1	0.000879	-0.003230	-0.002020	-0.000222	0.000059	-0.000190
2	0.000451	-0.003237	-0.001324	-0.000256	0.000004	-0.000154
3	0.001793	-0.003835	-0.003101	-0.000187	0.000060	-0.000192
4	0.000052	-0.002748	-0.000153	-0.000354	0.000000	-0.000122
5	0.000877	-0.003675	-0.002225	-0.000345	0.000060	-0.000063
6	0.000516	-0.002768	-0.001233	-0.000356	-0.000006	-0.000154
7	0.000374	-0.001941	-0.001151	-0.000355	0.000048	-0.000161
8	-0.000374	-0.001941	0.001150	-0.000355	-0.000048	-0.000161
9	0.000672	-0.001278	-0.000673	-0.000130	0.000085	-0.000307
10	0.000340	-0.001285	-0.000440	-0.000130	0.000051	-0.000162
11	-0.000340	-0.001285	0.000439	-0.000130	-0.000050	-0.0001[illegible]2
12	-0.000672	-0.001278	0.000673	-0.000130	-0.000085	-0.000307
13	0.000621	-0.000012	-0.000013	0.000001	0.000085	-0.000347
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	-0.000621	-0.000012	0.000013	0.000001	-0.000085	-0.000347
17	0.000878	-0.002930	-0.001928	-0.000187	0.000060	-0.000192
18	0.000879	-0.003010	-0.001951	-0.000222	0.000059	-0.000190
19	0.000879	-0.003450	-0.002089	-0.000222	0.000059	-0.000190
20	0.000878	-0.003615	-0.002142	-0.000187	0.000060	-0.000192
21	0.000452	-0.003061	-0.001315	-0.000354	0.000000	-0.000122
22	0.000451	-0.003150	-0.001321	-0.000256	0.000004	-0.000154
23	0.000451	-0.003324	-0.001326	-0.000256	0.000004	-0.000154
24	0.000452	-0.003496	-0.001316	-0.000354	0.000000	-0.000122
25	0.000532	-0.003658	-0.001233	-0.000356	-0.000006	-0.000154
26	0.000000	-0.002755	-0.000001	-0.000354	0.000000	-0.000122
27	0.000465	-0.001943	-0.001351	-0.000354	0.000000	-0.000122
28	-0.000465	-0.001943	0.001350	-0.000354	0.000000	-0.000122

DEFORMATION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

JOINT NO.	. . .DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.000126	-0.000186	0.000414	0.000078	0.000008	-0.000027
2	0.000065	-0.000187	0.000219	0.000073	0.000001	-0.000022
3	0.000256	-0.000341	0.000762	0.000083	0.000009	-0.000027
4	0.000008	-0.000290	0.000026	0.000059	-0.000000	-0.000017
5	[illegible]	-0.000250	0.000385	0.000061	0.000009	-0.000009
6	0.000074	-0.000395	0.000209	0.000059	-0.000001	-0.000022
7	0.000053	-0.000277	0.000193	0.000060	-0.000008	-0.000023
8	-0.000053	-0.000277	-0.000193	0.000060	0.000008	-0.000023
9	0.000096	-0.000183	0.000113	0.000022	-0.000014	-0.000044
10	0.000049	-0.000184	0.000074	0.000022	-0.000008	-0.000023
11	-0.000049	-0.000184	-0.000074	0.000022	0.000008	-0.000023
12	-0.000096	-0.000183	-0.000113	0.000022	0.000014	-0.000044
13	0.000089	-0.000002	0.000002	-0.000000	-0.000014	-0.000050
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	-0.000089	-0.000002	-0.000002	-0.000000	0.000014	-0.000050
17	0.000126	-0.000143	0.000427	0.000083	0.000009	-0.000027
18	0.000126	-0.000155	0.000424	0.000078	0.000008	-0.000027
19	0.000126	-0.000218	0.000404	0.000078	0.000008	-0.000027
20	0.000126	-0.000241	0.000396	0.000083	0.000009	-0.000027
21	0.000065	-0.000162	0.000221	0.000059	-0.000000	-0.000017
22	0.000065	-0.000175	0.000220	0.000073	0.000001	-0.000022
23	0.000065	-0.000200	0.000219	0.000073	0.000001	-0.000022
24	0.000065	-0.000224	0.000221	0.000059	-0.000000	-0.000017
25	0.000076	-0.000248	0.000209	0.000059	-0.000001	-0.000022
26	0.000000	-0.000394	0.000000	0.000059	-0.000000	-0.000017
27	0.000066	-0.000278	0.000227	0.000059	-0.000000	-0.000017
28	-0.000066	-0.000278	-0.000227	0.000059	-0.000000	-0.000017

EVALUATION OF VALVE

DEFORMATION RESPONSE OF COMBINED STATIC SEISMIC AND OPERATIONAL LOADS

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.004491	-0.005001	0.026358	0.002463	0.001324	-0.000327
2	0.004173	-0.005011	0.020468	0.002238	0.001584	-0.000271
3	0.004656	-0.004820	0.043506	0.002694	0.001321	-0.000324
4	0.001541	-0.003391	0.016334	0.001524	-0.001602	-0.000156
5	0.004489	-0.005507	0.030344	0.001676	0.001307	-0.000104
6	0.000946	-0.003265	0.025531	0.001577	-0.001520	-0.000262
7	0.000593	-0.002243	0.014287	0.001526	-0.001714	-0.000193
8	-0.000428	-0.002243	-0.005217	0.001525	0.001334	-0.000193
9	0.000840	-0.001469	0.006864	0.000561	-0.001470	-0.000352
10	0.000538	-0.001477	0.005892	0.000558	-0.001715	-0.000188
11	-0.000388	-0.001476	-0.002415	0.000562	0.001314	-0.000192
12	-0.000773	-0.001469	-0.001637	0.000562	0.000795	-0.000353
13	0.000767	-0.000014	0.000085	-0.000007	-0.001435	-0.000402
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	-0.000714	-0.000014	-0.000029	-0.000001	0.000763	-0.000399
17	0.004491	-0.004730	0.024310	0.002694	0.001321	-0.000324
18	0.004491	-0.004799	0.024847	0.002463	0.001324	-0.000327
19	0.004491	-0.005222	0.027670	0.002463	0.001324	-0.000327
20	0.004491	-0.005393	0.028953	0.002694	0.001321	-0.000324
21	0.004172	-0.004871	0.018025	0.001524	-0.001602	-0.000156
22	0.004173	-0.004927	0.019575	0.002238	0.001584	-0.000271
23	0.004173	-0.005097	0.021362	0.002238	0.001584	-0.000271
24	0.004172	-0.005252	0.023717	0.001524	-0.001602	-0.000156
25	0.004190	-0.005495	0.025571	0.001577	-0.001520	-0.000262
26	0.000189	-0.003247	0.020114	0.001524	-0.001602	-0.000156
27	0.000704	-0.002245	0.015139	0.001524	-0.001602	-0.000156
28	-0.000535	-0.002245	-0.004558	0.001524	-0.001602	-0.000156

[illegible] STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS

[illegible]	JNT NO.	STRESS NO.	COORDINATES C1	C3/Z	C	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE
[illegible]	27	6	0.0	-0.47	0.93	4.0	27.0	STEEL	0.15	
12	7	6	0.0	-0.47	0.93	1.2	27.0	STEEL	0.04	
13	28	6	0.0	-0.47	0.93	6.9	27.0	STEEL	0.25	
14	7	12	-1.06	-3.72	0.56	8.7	27.0	STEEL	0.32	
15	8	9	-0.78	4.00	0.56	5.2	27.0	STEEL	0.19	
16	9	6	0.0	0.50	0.99	4.3	27.0	STEEL	0.16	
17	11	6	0.0	-0.50	0.99	1.5	27.0	STEEL	0.06	
18	12	6	0.0	-0.50	0.99	5.4	27.0	STEEL	0.20	
19	9	12	-1.18	-2.75	0.51	9.7	27.0	STEEL	0.36	
20	12	8	-1.18	2.75	0.51	3.5	27.0	STEEL	0.13	
21	14	5	0.0	0.47	0.93	11.1	27.0	STEEL	0.41	
24	15	5	0.0	0.47	0.93	7.6	27.0	STEEL	0.28	

BOLTED JOINT STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS
(N=NUMBER OF BOLTS. AREA=AREA PER BOLT)

BOLT JNT	JOINT DESCRIPTION LOC:	TYPE	N	AREA	BOLT NO.	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE
26	A	PAD	4	0.13	2	17.5	117.0	BOLTING	0.15	
14	B	LEG	2	0.07	2	113.1	117.0	BOLTING	0.97	
15	C	LEG	2	0.07	2	89.5	117.0	BOLTING	0.77	

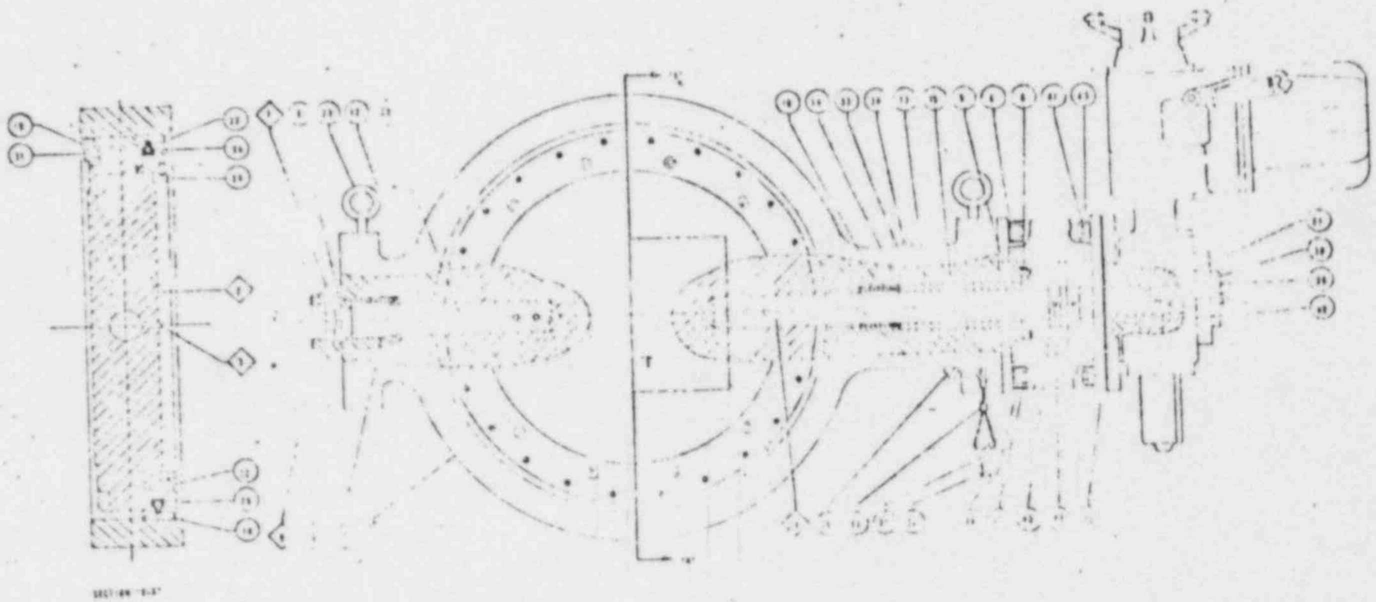
THIS EQUIPMENT IS ACCEPTABLE FOR THE SPECIFIED SEISMIC DISTURBANCE

THIS REPORT HAS BEEN PREPARED BY /

SAMUEL E. DUFF

FISHER CONTROLS COMPANY

Attachment 7 - Bill of Material Drawing



SECTION "B-B"

ITEM	QTY	DESCRIPTION	MATERIAL SPEC	PART NO.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

◇ PRESSURE RETAINING ITEM

RECOMMENDED SPARE PART

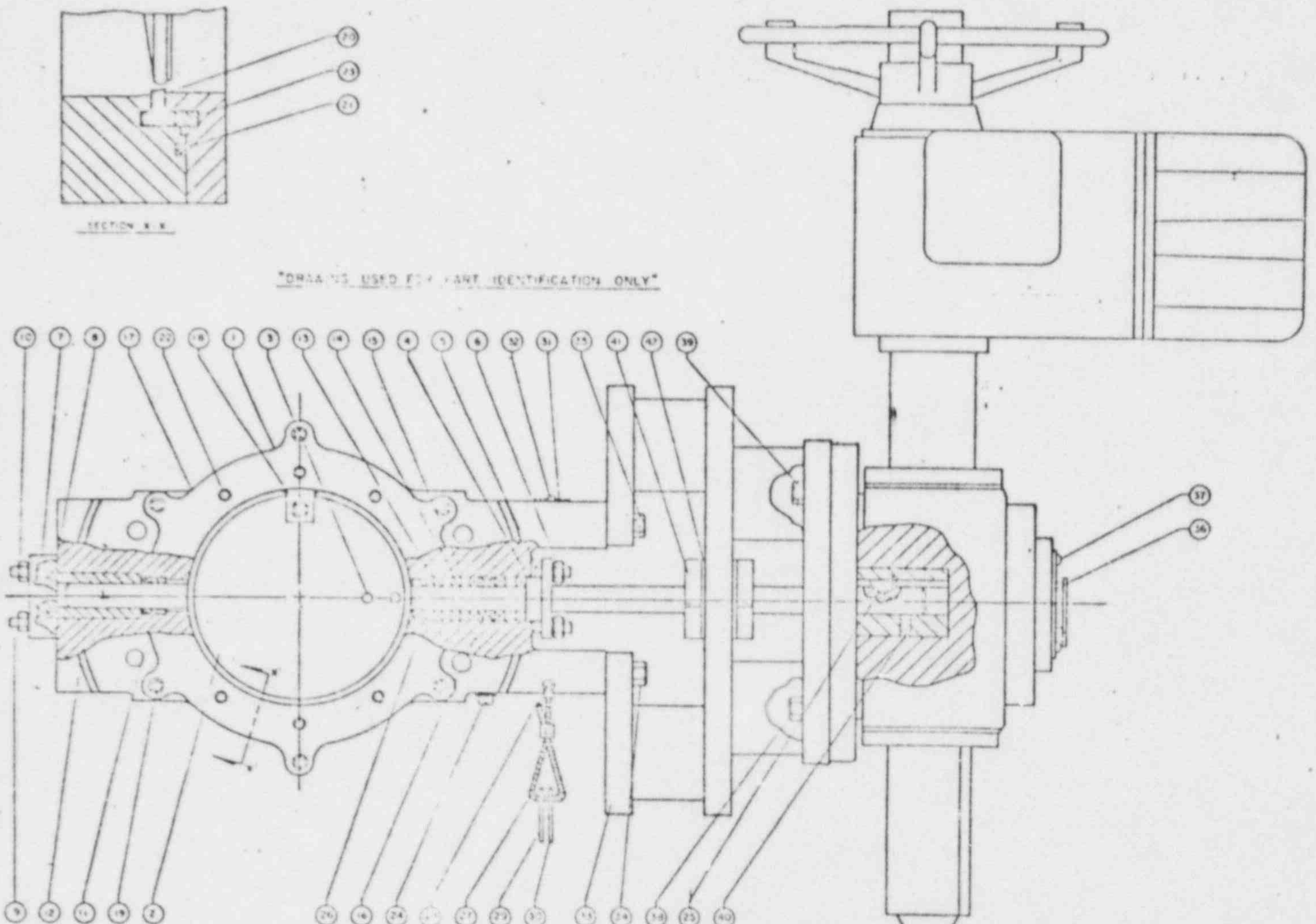
COMMONWEALTH EDISON COMPANY
SARGENT & LUNDY ENGINEERS S & L SPEC. J-2548
LASALLE COUNTY STATION – UNITS 1 & 2
[illegible]
CUST. ORDER NO. [illegible]

C.C. NO.	SERIAL NO.	CUSTOMER TAG	C.C. NO.	SERIAL NO.	CUSTOMER TAG
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION
Coraopolis, Pennsylvania 15108

DWN [illegible] | CHKD [illegible] | B



"DRAWING USED FOR PART IDENTIFICATION ONLY"

FIND NO.	Q	PART NO.	DESCRIPTION	MATERIAL SPEC.
1	1	[illegible]	BODY, VALVE	ASME SA-515 GR 70
2	1	[illegible]	DISC, VALVE, 3-RING*	[illegible]
3	2	[illegible]	PIN, TAPER	[illegible]
4	1	[illegible]	[illegible] FOLLOWER	[illegible]
5	2	[illegible]	STUD	CARBON STEEL
6	2	[illegible]	NUT, HEX	CARBON STEEL
7	1	[illegible]	[illegible]	[illegible]
8	1	[illegible]	[illegible], SPIRAL WOUND	[illegible]
9	4	[illegible]	[illegible]	[illegible]
10	4	[illegible]	NUT, HEX	[illegible]
11	2	[illegible]	BEARING	[illegible] GRAPHITE
12	1	[illegible]	[illegible] RETAINER	[illegible]
13	1	[illegible]	[illegible] PACKING	[illegible]
14	1	[illegible]	[illegible] RING	[illegible]
15	1	[illegible]	[illegible] RING	[illegible]
16	1	[illegible]	[illegible]	[illegible]
17	1	[illegible]	[illegible]	[illegible]
18	1	[illegible]	SCREW, SET, HEX SOCKET	ALLOY STEEL
19	4	[illegible]	SCREW, CAP, HEX SOCKET	ALLOY STEEL
20	1	[illegible]	[illegible]	EPDM
21	1	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	SCREW, SET, HEX SOCKET	[illegible] STEEL
23	1	[illegible]	[illegible]	[illegible] STEEL
24	[illegible]	[illegible]	[illegible]	[illegible] STEEL
25	1	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]
27	1	[illegible]	[illegible]	[illegible]
28	1	[illegible]	[illegible]	[illegible]
29	1	[illegible]	[illegible]	[illegible]
30	1	[illegible]	[illegible]	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]
32	[illegible]	[illegible]	[illegible]	CARBON STEEL
33	[illegible]	[illegible]	[illegible]	CARBON STEEL
34	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	CARBON STEEL
36	[illegible]	[illegible]	[illegible]	[illegible]
37	[illegible]	[illegible]	[illegible]	CARBON STEEL
38	[illegible]	[illegible]	[illegible]	[illegible]
39	[illegible]	[illegible]	[illegible]	CARBON STEEL
40	[illegible]	[illegible]	[illegible]	[illegible] STEEL
41	[illegible]	[illegible]	[illegible]	CARBON STEEL
42	2	[illegible]	[illegible]	[illegible]

◇ PRESSURE RETAINING ITEM

* RECOMMENDED SPARE PART

COMMONWEALTH EDISON COMPANY
LA SALLE COUNTY STATION UNITS 1 & 2
CUSTOMER ORDER NO. 181104
AGENT ORDER NO. [illegible]
SARGENT & LUNDY ENGINEERS SPEC. J-2940

[illegible]		
5A094-32	1VG042	BF246733
5A094-33	1VG043	BF246734
5A094-38	1VP113A	BF262136
5A094-39	1VP113B	BF262137
5A094-40	1VP114A	BF262138
5A094-41	1VP114B	BF262139
5A095-27	2VG042	BF246713
5A095-28	2VG043	BF246714
5A095-33	2VP113A	BF262140
5A095-34	2VP113B	BF262141
5A095-35	2VP114A	BF262142
5A095-36	2VP114B	BF262143

8" TYPE 9220 VALVE ASSEMBLY
W/LIMITORQUE [illegible] ACTUATOR

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

Attachment 8 - "Guidelines for Demonstration of Operability Purge and Vent Valves" and Later Clarification.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

RECEIVED
OCT 15 1979
WILLIAM J. CAHILL, JR.

September 27, 1979

ALL LIGHT WATER REACTORS

Gentlemen:

RE: Containment Purging and Venting During Normal Operation - Guidelines For Valve Operability

By letter dated November 28, 1978, the Commission (NRC) requested all licensees of operating reactors to respond to generic concerns about containment purging and venting during normal plant operation. We are continuing our review of responses to those letters.

As a result of our reviews, we have learned from several licensees that at least three valve vendors have reported that their valves may not close against the ascending differential pressure and the resulting dynamic loading of the design basis LOCA. All identified licensees who are affected have proposed to maintain the valves in the closed position or to restrict the angular opening of the valves whenever primary containment integrity is required pending a re-evaluation which shows satisfactory valve performance under the Design Basis Accident - Loss of Coolant Accident (DBA-LOCA) condition can be provided.

We have developed the enclosed guidelines with the aid of our consultants, Brookhaven National Laboratory. Valve manufacturers have also been contacted and are cognizant of these guidelines. You are requested to initiate action on an expedited basis to ensure that containment vent and purge valves at your facility meet these guidelines.

Please inform us within 30 days that you commit to implement a valve qualification program on an expedited basis.

Sincerely,

Darrell G. Eisenhut, Acting Director
Division of Operating Reactors

Enclosure:
Guidelines for Demonstration of Operability of Purge and Vent Valves

cc: w/enclosure
See next page

ENCLOSURE

GUIDELINES FOR DEMONSTRATION OF OPERABILITY OF PURGE AND VENT VALVES

OPERABILITY

In order to establish operability it must be shown that the valve actuator's torque capability has sufficient margin to overcome or resist the torques and/or forces (i.e., fluid dynamic, bearing, seating, friction) that resist closure when stroking from the initial open position to full seated (bubble tight) in the time limit specified. This should be predicted on the pressure(s) established in the containment following a design basis LOCA. Considerations which should be addressed in assuring valve design adequacy include:

1. Valve closure rate versus time - i.e., constant rate or other.
2. Flow direction through valve; ΔP across valve.
3. Single valve closure (inside containment or outside containment valve) or simultaneous closure. Establish worst case.
4. Containment back pressure effect on closing torque margins of air operated valve which vent pilot air inside containment. (47 PSIG BACK PRESSURE)
5. Adequacy of accumulator (when used) sizing and initial charge for valve closure requirements.
6. For valve operators using torque limiting devices - are the settings of the devices compatible with the torques required to operate the valve during the design basis condition.
7. The effect of the piping system (turns, branches) upstream and downstream of all valve installations.
8. The effect of butterfly valve disc and shaft orientation to the fluid mixture egressing from the containment.

DEMONSTRATION

Demonstration of the various aspects of operability of purge and vent valves may be by analysis, bench testing, insitu testing or a combination of these means.

Purge and vent valve structural elements (valve/actuator assembly) must be evaluated to have sufficient stress margins to withstand loads imposed while valve closes during a design basis accident. Torsional shear, shear, bending, tension and compression loads/stresses should be considered. Seismic loading should be addressed.

Once valve closure and structural integrity are assured by analysis, testing or a suitable combination, a determination of the sealing integrity after closure and long term exposure to the containment environment should be evaluated. Emphasis should be directed at the effect of radiation and of the containment spray chemical solutions on seal material. Other aspects such as the effect on sealing from outside ambient temperatures and debris should be considered.

The following considerations apply when testing is [illegible] as a means for demonstrating valve operability:

Bench Testing

A. Bench testing can be used to demonstrate suitability of the in-service valve by reason of its tracibility in design to a test valve. The following factors should be considered when qualifying valves through bench testing.

   1. Whether a valve was qualified by testing of an identical valve assembly or by extrapolation of data from a similarly designed valve.

   2. Whether measures were taken to assure that piping upstream and downstream and valve orientation are simulated.

   3. Whether the following load and environmental factors were considered

      a. Simulation of LOCA
      b. Seismic loading
      c. Temperature soak
      d. Radiation exposure
      e. Chemical exposure
      d. Debris

B. Bench testing of installed valves to demonstrate the suitability of the specific valve to perform its required function during the postulated design basis accident is acceptable.

   1. The factors listed in items A.2 and A.3 should be considered when taking this approach.

In-Situ Testing

In-situ testing of purge and vent valves may be performed to confirm the suitability of the valve under actual conditions. When performing such tests, the conditions (loading, environment) to which the valve(s) will be subjected during the test should simulate the design basis accident.

NOTE: Post test valve examination should be performed to establish structural integrity of the key valve/actuator components.

CLARIFICATION OF SEPT. 27 LETTER TO LICENSEES REGARDING DEMONSTRATION OF OPERABILITY OF PURGE AND VENT VALVES

1. The ΔP across the valve is in part predicated on the containment pressure and gas density conditions. What were the containment conditions used to determine the ΔP's across the valve at the incremental angle positions during the closure cycle?

2. Were the dynamic torque coefficients used for the determination of torques developed based on data resulting from actual flow tests conducted on the particular disc shape/design/size? What was the basis used to predict torques developed in valve sizes different (especially larger valves) than the sizes known to have undergone flow tests?

3. Were installation effects accounted for in the determination of dynamic torques developed? Dynamic torques are known to be affected for example, by flow direction through valves with off-set discs, by downstream piping backpressure, by shaft orientation relative to elbows, etc. What was the basis (test data or other) used to predict dynamic torques for the particular valve installation?

4. When comparing the containment pressure response profile against the valve position at a given instant of time, was the valve closure rate vs. time (i.e. constant or other) taken into account? For air operated valves equipped with spring return operators, has the lag time from the time the valve receives a signal to the time the valve starts to stroke been accounted for?

   <u>NOTE:</u> Where a butterfly valve assembly is equipped with spring to close air operators (cylinder, diaphragm, etc.), there typically is a lag time from the time the isolation signal is received (solenoid valve usually deenergized) to the time the operator starts to move the valve. In the case of an air cylinder, the pilot air on the opening side of the cylinder is approximately 90 psig when the valve is open, and the spring force available may not start to move the piston until the air on this opening side is vented (solenoid valve de-energizes) below about 65 psig, thus the lag time.

5. Provide the necessary information for the table shown below for valve positions from the initial open position to the seated position (10° increments if practicle).

Valve Position (in degrees - 90° = full open)	Predicted ΔP (across valve)	Maximum ΔP (capability)

6. What Code, standards or other criteria, was the valve designed to? What are the stress allowables (tension, shear, torsion, etc.) used for critical elements such as disc, pins, shaft yoke, etc. in the valve assembly.? What load combinations were used?

9. For those valve assemblies (with air operators) inside containment, has the containment pressure rise (backpressure) been considered as to its effect on torque margins available (to close and seat the valve) from the actuator? During the closure period, air must be vented from the actuators opening side through the solenoid valve into this backpressure. Discuss the installed actuator bleed configuration and provide basis for not considering this backpressure effect a problem on torque margin. Valve assembly using 4 way solenoid valve should especially be reviewed.

10. Where air operated valve assemblies use accumulators as the fail-safe feature, describe the accumulator air system configuration and its operation. Provide necessary information to show the adequacy of the accumulator to stroke the valve i.e. sizing and operation starting from lower limits of initial air pressure charge. Discuss active electrical components in the accumulator system, and the basis used to determine their qualification for the environmental conditions experienced. Is the accumulator system seismically designed?

11. For valve assemblies requiring a seal pressurization system (inflatable main seal) describe the air pressurization system configuration and operation including means used to determine that valve closure and seal pressurization have taken place. Discuss active electrical components in this system, and the basis used to determine their qualification for the environmental condition experienced. Is this system seismically designed.

For this type valve, has it been determined that the "valve travel stops" (closed position) are capable of withstanding the loads imposed at closure during the DBA-LOCA conditions.

12. Describe the modification made to the valve assembly to limit the opening angle. With this modification, is there sufficient torque margin available from the operator to overcome any dynamic torques developed that tend to oppose valve closure, starting from the valve's initial open position? Is there sufficient torque margin available from the operator to fully seat the valve? Consider seating torques required with seats that have been at low ambient temperatures.

13. Does the maximum torque developed by the valve during closure exceed the maximum torque rating of the operators? Could this affect operability?

14. Has the maximum torque value determined in #13 been found to be compatible with torque limiting settings where applicable?

15. Where electric motor operators are used, has the minimum available voltage to the electric operator under both normal or emergency modes been determined and specified to the operator manufacturer, to assure the adequacy of the operator to stroke the valve at DBA conditions with these lower limit voltages available. Does this reduced voltage operation result in any significant change in stroke timing? Describe the emergency mode power source used.

16. Where electric operator units are equipped with handwheels, does their design provide for automatic re-engagement of the motor operator following the handwheel mode of operation? If not, what steps are taken to preclude the possibility of the valve being left in the handwheel mode following some maintenance, test etc. type operation.

17. Describe the tests and/or analysis performed to establish the qualification of the valve to perform its intended function under the environmental conditions exposed to during and after the DBA following its long term exposure to the normal plant environment.

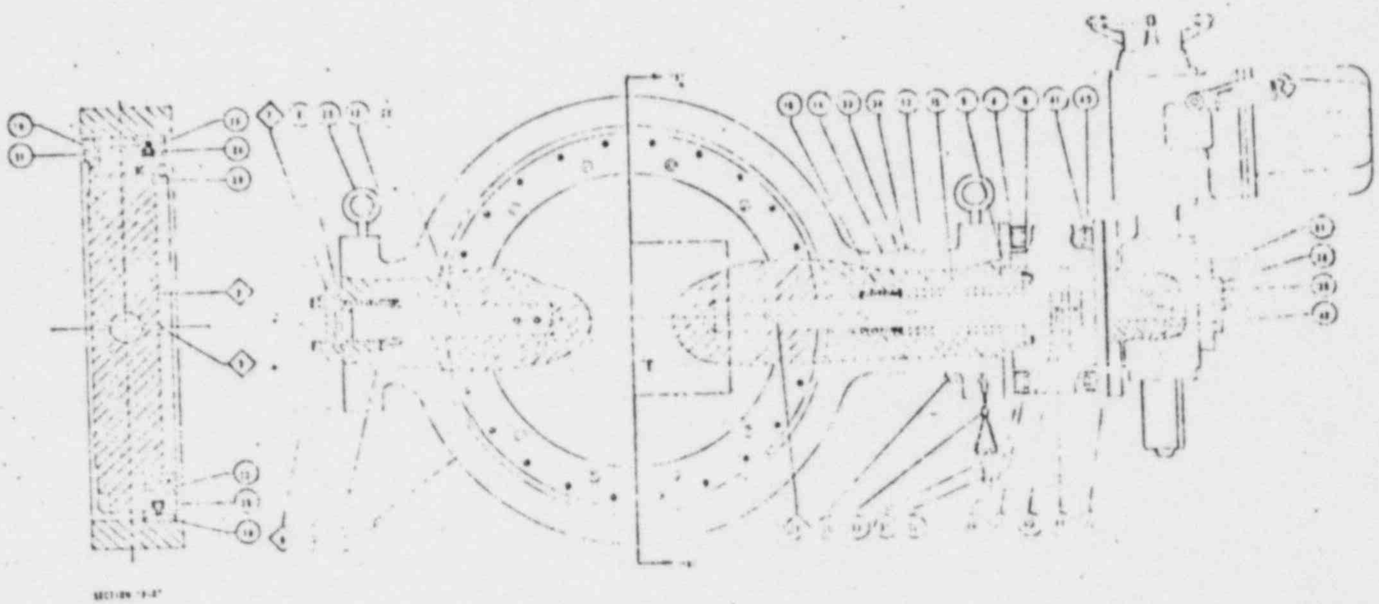
18.. What basis is used to establish the qualification of the valve, operators, solenoids, valves? How was the valve assembly (valve/operators) seismically qualified (test, analysis, etc.)?

19. Where testing was accomplished, describe the type tests performed conditions used etc. Tests (where applicable) such as flow tests, aging simulation (thermal, radiation, wear, vibration endurance, seismic) LOCA-DBA environment (radiation, steam, chemicals) should be pointed out.

20. Where analysis was used, provide the rationale used to reach the decision that analysis could be used in lieu of testing. Discuss conditions, assumptions, other test data, handbook data, handbook data, and classical problems as they may apply.

21. Have the preventive maintenance instructions (part replacement, lubrication, periodic cycling, etc.) established by the manufacturer been reviewed, and are they being followed? Consideration should especially be given to elastomeric components in valve body, operators, solenoids, etc. where this hardware is installed inside containment.

Attachment 9 - 9200 Butterfly Valve
Instruction Manual



ITEM	QTY	DESCRIPTION	MATERIAL SPEC	PART NO.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

◇ PRESSURE RETAINING ITEM

* RECOMMENDED SPARE PART

COMMONWEALTH EDISON COMPANY
SARGENT & LUNDY ENGINEERS S & L SPEC. [illegible]
[illegible] STATION – UNITS 1 & 2

C.C. NO.	SERIAL NO.	CUSTOMER TAG	C.C. NO.	SERIAL NO.	CUSTOMER TAG
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

B

Type 9200

Instruction Manual

Type 9200 T-Ring Butterfly Valve Bodies

Form 2432, March 1974

Introduction

The Type 9200, shown in figure 1, is a heavy-duty butterfly valve body designed for stringent shutoff requirements. An elastomer or TFE T-ring seat is used to obtain shutoff. The available construction variations of the Type 9200 are described below. The method of effecting the T-ring seal varies with the type of construction.

Specification A—The pressure-activated T-ring is contained in the body as shown in figure 2. External sealing pressure forces the T-ring against the disc periphery only when the disc is closed. There is no contact between the disc and T-ring when the disc is opening or closing. Specification A valves are available with elastomer T-rings only.

Specification B-1—The adjustable elastomer T-ring seat is contained between the body and retaining flange as shown in figure 3. The adjusting set screws and compression ring force the T-ring against the disc periphery to provide interference between the T-ring and disc.

Specification B-2—Similar to Specification B-1 except with TFE T-ring

Specification C-1—The adjustable elastomer T-ring seat is contained in the valve disc as shown in figure 4. The adjusting set screws and compression ring force the T-ring against the body bore to provide interference between the T-ring and body bore seating surface.

Specification C-2—Similar to Specification C-1 except with TFE T-ring

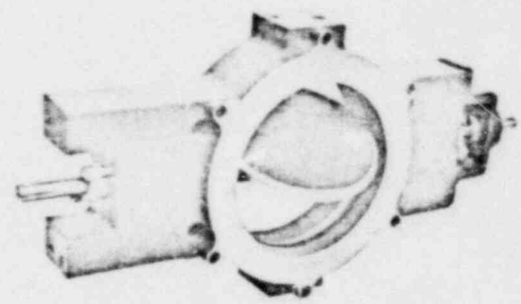


Figure 1. Type 9200 Butterfly Control Valve Body

Installation

WARNING

Do not install the valve in systems where the service conditions exceed those for which the valve was designed, or damage to the valve and personal injury may result.

1. Inspect the valve for shipping damage and be certain that the body cavity is free of foreign materials.

2. Clean out adjoining pipelines to remove all foreign material that could damage the valve seat.

3. In those cases where a flow direction arrow is attached to the valve body, install the body so that the flow through the valve will be in the direction indicated. (Although some seat materials and service conditions require flow in one direction only, the Type 9200 is normally capable of flow in either direction and will have no flow arrow attached.)

4. Be certain that the pipeline flanges are in line with each other and that the disc is fully closed before inserting the valve into the pipeline.

Type 9200

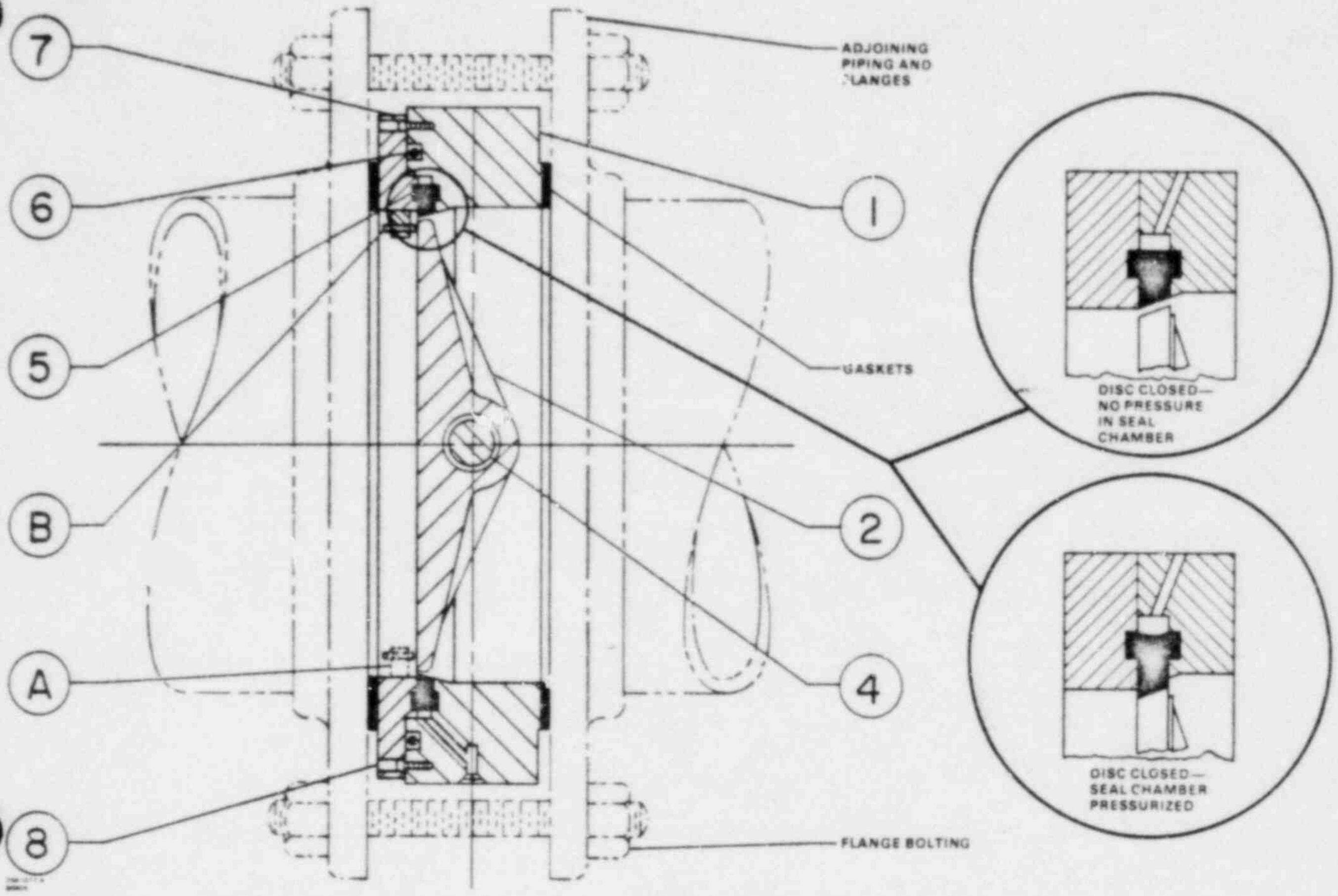


Figure 2. Type 9200 Specification A

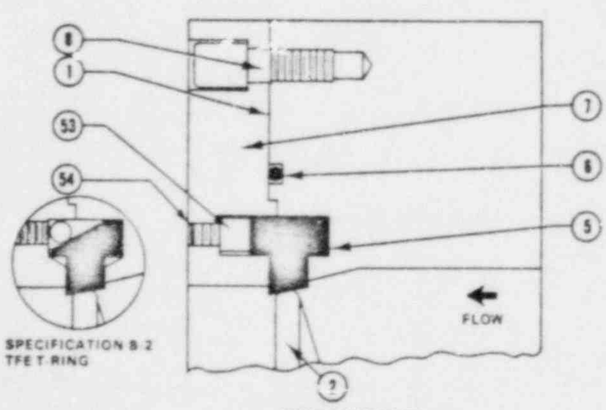


Figure 3. Type 9200 Specifications B-1 and B-2

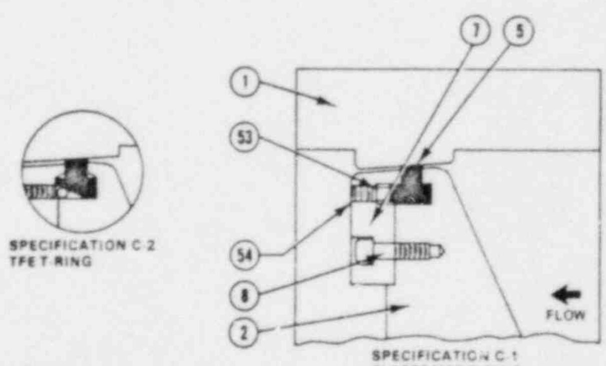


Figure 4. Type 9200 Specifications C-1 and C-2

CAUTION

If the flanges are out of alignment or if the disc is open, difficulties in installation and/or damage to the valve may occur. Be certain that flanges and adjacent piping will not interfere with the opening of the valve disc. Review the dimension drawings to ensure that the inside diameters of the adjacent flanges and piping are large enough to allow disc rotation without interference.

5. Center the valve between the pipe flanges. Although the valve may be installed in any position, the normal position is with the valve shaft horizontal and the actuator vertical above the valve body.

6. Follow accepted piping practices when installing the valve. Provide suitable flange bolting and flange gaskets.

7. If a power actuator is furnished with the valve body, refer to the appropriate actuator instruction manual for information regarding installation and operation of the actuator.

8. If a sealing system is supplied for Specification A constructions, refer to the seal system instructions for operation information.

Specification A Sealing Pressure

Required sealing pressure for Specification A valves is equal to (a) 50 psig or (b) the valve inlet pressure plus one-half the outlet pressure, whichever is greater. Maximum allowable sealing pressure is equal to (a) the maximum allowable pressure of the sealing system being used or (b) 2.5 times the inlet pressure, whichever is lower.

Operation

Specification A

On power-actuated valves when the disc is in the fully closed position, the seal pressure is applied to the back of the elastomer T-ring, forcing the T-ring against the disc periphery. Immediately upon activation of the actuator to open the valve, the seal pressure is released, allowing the disc to leave the seat without any force being exerted on the elastomer T-ring by the disc. The disc is then positioned at the required angle of operation.

When the disc is brought from its open position to its closed position, there is a delay before seal pressure is applied. The sealing system is tripped just as the disc is entering the seal and allows the disc to close fully (completely in the seat) before the seal pressure is applied. This operation is factory adjusted on each valve; if problems arise, the system can be re-adjusted per the seal system instructions.

On valves without power actuators, the sealing pressure must be released with the manually operated loading valve before the valve is opened and re-applied after the valve is closed.

CAUTION

Never apply pressure to the sealing system unless the valve disc is fully closed, or damage to the T-ring may result.

Specifications B-1, B-2, C-1, and C-2

For Specification B-1 and B-2 valves, the valve disc rotates into contact with the T-ring seat on closing. For Specification C-1 and C-2 valves, the valve disc rotates the T-ring into contact with the body bore seating surface on closing. No sealing pressure is required.

Maintenance

WARNING

To avoid personal injury and damage to the process system, isolate the control valve from all pressure and release pressure from the valve body and actuator before disassembling.

Outboard Roller Bearings

If the valve is equipped with outboard roller bearings, lubricate the bearings periodically with a good quality roller bearing grease.

Packing

Key numbers used in this section are shown in figure 5. For valves with lubricating-type packing boxes, lubricate the packing periodically. The frequency of lubrication required depends upon the severity of service conditions.

Type 9200

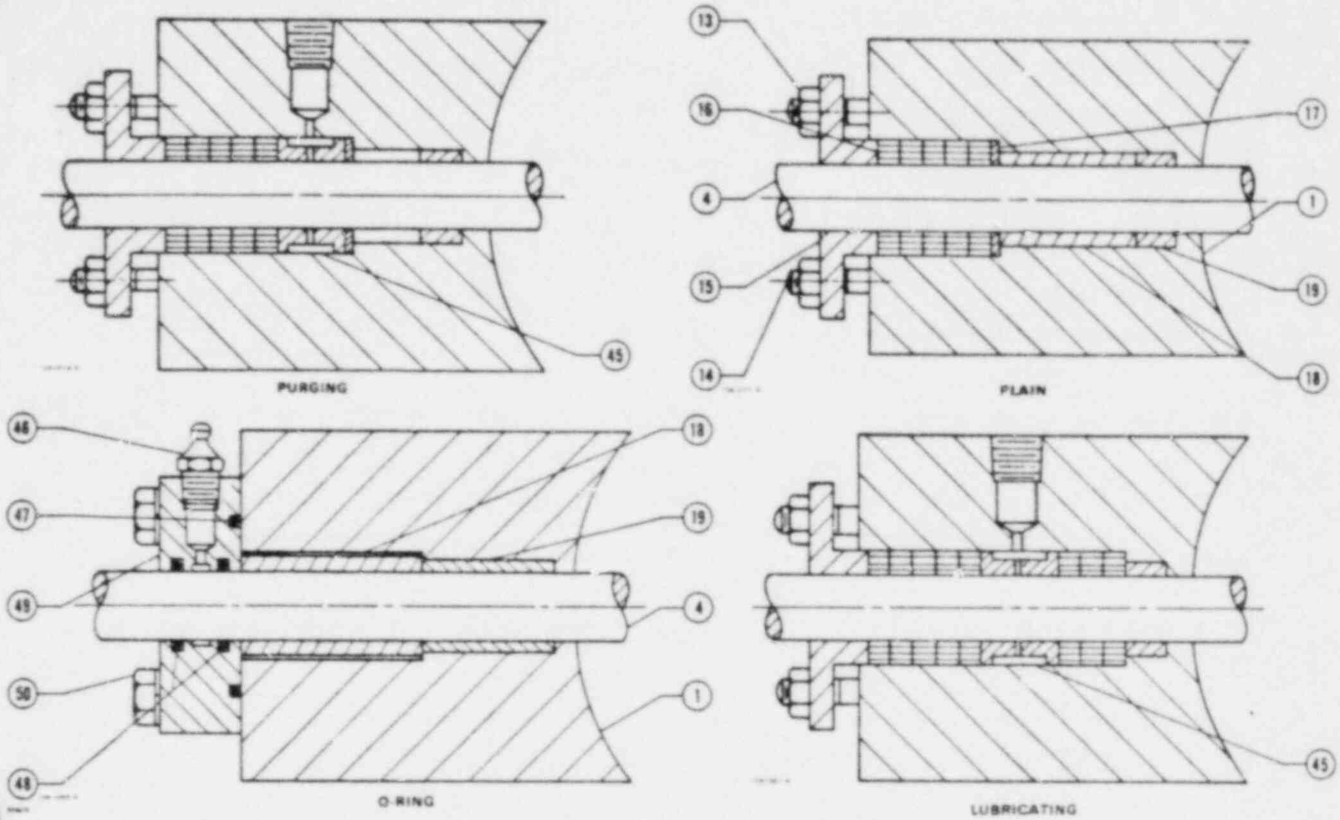


Figure 5. Packing Box Types

It may be necessary to tighten the packing follower nuts (key 13) to stop leakage. If leakage cannot be stopped in this manner, replace the packing per the instructions below.

For split-ring packing, unscrew packing follower nuts (key 13) and slide packing follower (key 15) away from the valve. Remo old packing rings (key 16).

For lubricating packing boxes, remove actuator mounting bracket. Remove lantern ring (key 45) to gain access to the packing rings behind the lantern ring. Place new rings over the valve shaft. When inserting the rings into the packing box, be certain that the split in each ring is positioned 90° from the split in the adjacent ring.

For ring-type packing, remove the actuator and all accessories. Unscrew packing follower nuts (key 13). Remove packing follower and packing rings (keys 15 and 16). For lubricating packing boxes, also remove lantern ring (key 45) to gain access to the packing rings behind the lantern ring. Install new packing rings on the shaft and insert them into the packing box.

For O-ring packing boxes, disassemble the components of the control valve assembly as far as is required to remove the O-ring follower (key 49). Replace O-rings (keys 47 and 48) in the follower as required.

Replacing T-Ring

Specification A

Key numbers used in the following steps are shown in figure 2 except where indicated.

1. Making certain that the valve disc (key 2) is fully closed, remove valve body from pipeline.

2. Note the location of travel stop (key 9, figure 6) on retaining ring (key 7) in respect to the body. This travel stop will be in either location A or B as shown in figure 2 and must be replaced in the same location during reassembly.

3. Unscrew Allen-head cap screws (key 8) and remove retaining ring and T-ring (key 5).

4. Inspect O-ring (key 6). If O-ring requires replacement, remove it from the body.

5. Clean T-ring and O-ring grooves, and coat the new T-ring with a good quality silicone grease.

6. Making certain that the T-ring seat angle matches the disc seat angle (as shown in the inset in figure 2), install the T-ring in the body. Insert the new O-ring if replacement is required.

7. Place retaining ring on the body. Using care to avoid damaging the O-ring (key 6), rotate the retaining ring slightly clockwise and counterclockwise to ensure proper alignment on the T-ring. Be certain the travel stop is positioned in the location noted during disassembly.

8. Replace and tighten Allen-head cap screws (key 8).

9. Replace valve in pipeline per the "Installation" section.

Specifications B-1 and B-2

Key numbers used in the following steps are shown in figure 3 except where indicated.

1. Making certain that the valve disc (key 2) is fully closed, remove valve body from pipeline.

2. Note the location of travel stop (key 9, figure 6) on retaining ring (key 7) in respect to the body. This travel stop will be in either location A or B as shown in figure 2 and must be replaced in the same location during reassembly.

3. Completely loosen adjusting set screws (key 54).

4. Unscrew Allen-head cap screws (key 8) and remove retaining ring, compression ring (key 53), and T-ring (key 5).

5. Inspect O-ring (key 6). If O-ring requires replacement, remove it from the body.

6. Clean T-ring and O-ring grooves. For elastomer T-rings, coat the new T-ring with a good quality silicone grease.

7. Making certain that the T-ring seat angle matches the disc seat angle (as shown in the inset on figure 2), install the T-ring in the body. Insert the new O-ring if replacement is required.

8. Place retaining ring on the body. Using care to avoid damaging O-ring (key 6), rotate the retaining ring slightly clockwise and counterclockwise to ensure proper alignment on the T-ring. Be certain the travel stop is positioned in the location noted during disassembly.

9. Replace and tighten Allen-head cap screws (key 8).

10. Adjust the T-ring per instructions in the "Adjustments" section.

11. Replace valve in pipeline per the "Installation" section.

Specifications C-1 and C-2

Key numbers used in the following steps are shown in figure 4 except where indicated.

1. Making certain that the valve disc (key 2) is fully closed, remove valve body from pipeline.

2. Specification C-1 and C-2 valves may be furnished with a travel stop on the body. This travel stop, if furnished, is not removable.

3. Completely loosen adjusting set screws (key 54).

4. Unscrew Allen-head cap screws (key 8) and remove retaining ring, compression ring, and T-ring (keys 7, 53, and 5).

5. Clean the T-ring groove. For elastomer T-rings, coat the new T-ring with a good quality silicone grease.

6. Making certain that the T-ring seat angle matches the body seat angle, install the T-ring in the disc.

7. Place retaining ring on the disc and rotate the retaining ring slightly clockwise and counterclockwise to ensure proper alignment on the T-ring.

8. Replace and tighten Allen-head cap screws (key 8).

9. Adjust the T-ring per instructions in the "Adjustments" section.

10. Replace valve in pipeline per the "Installation" section.

Replacing Valve Disc

If replacement of the valve disc is required, follow the "Replacing T-Ring" instructions to the point at which the retaining ring and T-ring have been removed. Then proceed with the instructions below. Key numbers used in the following steps are shown in figure 6.

1. Remove actuator, mounting bracket, packing followers (key 15) and packing.

2. If the ends of the taper pins (key 3) are peened, grind off the peened portion. Drive out taper pins.

3. If there is one set of taper pins in the disc, pull shaft (key 4) out of body and remove disc (key 2). Two sets of taper pins indicate that stub shafts are used. Each shaft portion must be pulled out of the body; do not attempt to drive the shaft portions through the disc.

CAUTION

When installing a new disc, also install a new shaft and taper pins. Attempting to use a new disc and old shaft will require drilling new taper pin holes in the shaft, thereby weakening the shaft. The weakened shaft may fail in service. A new shaft may be used with an old disc, using the taper pin holes in the old disc as guides for drilling taper pin holes in the shaft.

4. With inboard bushings (key 19) installed, place valve disc in the body. For large valves, block the body in the horizontal position. Be certain the clearance under the body is equal to at least one-half the disc diameter. With the disc vertical, use a hoist of suitable capacity to place the disc in the body. Be cerain the taper pin holes are on the actuator side of the body.

5. Align the disc shaft hole with the packing box holes in the body.

6. Insert the shaft through the body and disc. Make certain the key seat in the shaft is on the actuator side of the body.

7. Replace bushing retainers and packing box parts (keys 18, 17, 16, 15, and 13).

8. Install taper pins. The disc should be centered in the body bore.

9. Re-install T-ring and retaining ring per instructions in the "Replacing T-Ring" section. For Specifications B-1, B-2, C-1, and C-2, adjust the T-ring per instructions in the "Adjustments" section.

10. Install the valve in the pipeline per instructions in the "Installation" section.

Adjustments

Specifications B-1, B-2, C-1, and C-2 T-Ring

Adjust the T-ring as required to compensate for wear and to retain satisfactory shutoff capability.

1. Rotate valve disc to the fully closed position.

2. Loosen all adjusting set screws (key 54, figure 3 or 4) so that there is clearance between the T-ring and its seating surface at all points around the T-ring.

3. Select one adjusting set screw (key 54) as a starting point and tighten that screw 1/4 turn (clockwise rotation).

4. Moving clockwise around the retaining ring (key 7, figure 3 or 4), tighten each set screw 1/4 turn. Continue until the T-ring contacts its seat at one point.

5. When contact at one point has been made, return to the set screw selected as the starting point. Move around the retaining ring in a clockwise pattern, and wherever there is clearance between the T-ring and its seat, tighten the set screw at that point 1/4 turn. Bypass any screws where the T-ring is in contact with its seat.

6. When contact has been made at all points on the T-ring, tighten each set screw on Specifications B-1 and C-1 an additional 1/4 turn. No further tightening is required on Specifications B-2 and C-2.

7. Replace the valve in the pipeline per instructions given in the "Installation" section.

Double-Thrust Bearings

It is unlikely that the thrust bearings will require adjustment. If it does become necessary to adjust the bearings, proceed as follows. Key numbers used in the following steps are shown in figure 6.

1. Making certain the valve disc is in the closed position, remove valve from pipeline.

2. Loosen the screws found in each clamp-type collar (key 27).

3. With the valve disc closed, center the disc in the body bore.

4. With the valve disc centered, position one clamp-type collar against each end of the bearing bracket (key 21) hub. Then, tighten the screw in each collar.

5. For Specifications B-1, B-2, C-1, and C-2 valves, adjust T-ring per the procedure above if the adjustment was disturbed in centering the disc.

6. Replace the valve in the pipeline per the "Installation" section.

Actuator Linkage

Due to the large number of different types of actuators that can be used with the Type 9200, it is not practical to present detailed instructions for the various types. However, to simplify this adjustment and to ensure proper valve disc closure, an internal travel stop is normally furnished with the valve. When checking or adjusting the linkage, the disc may be closed until contact is made with this travel stop. Adjust linkage to close the disc to this point.

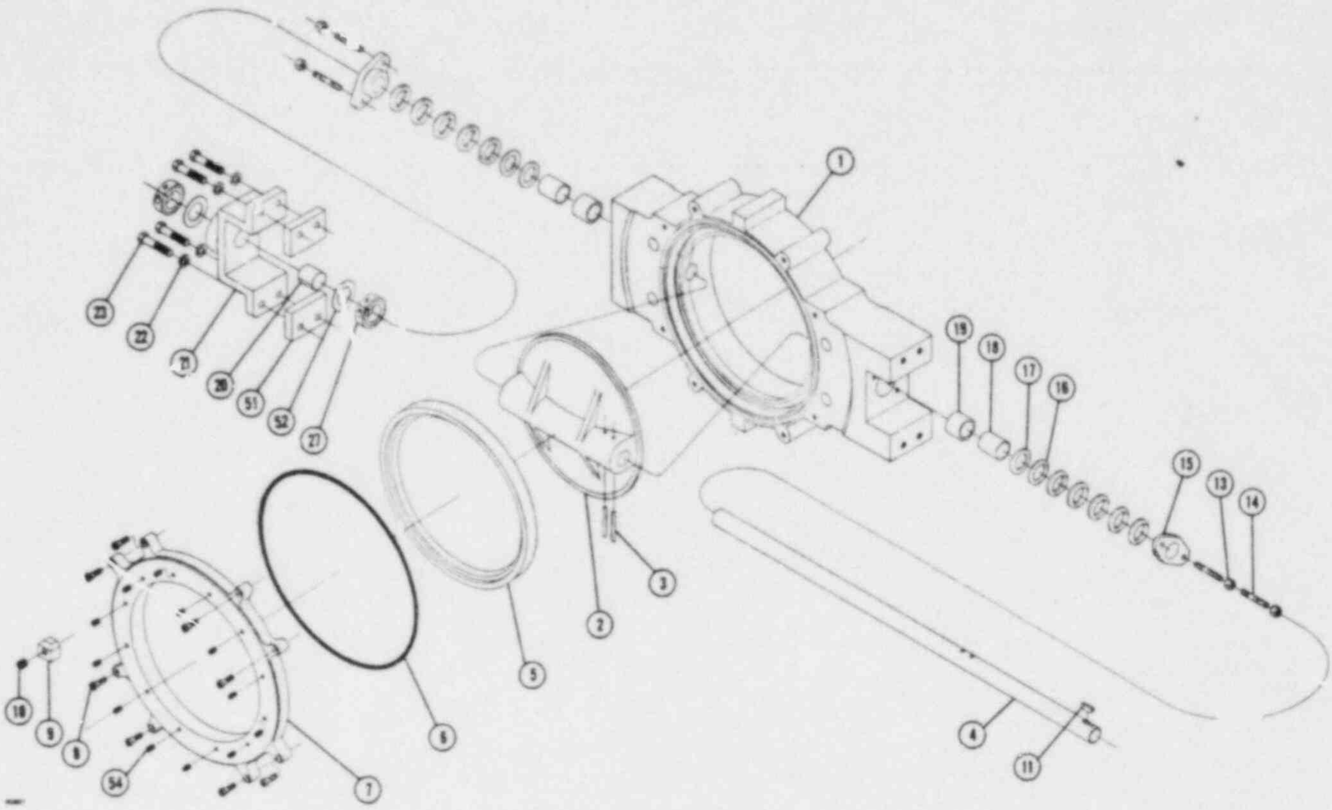


Figure 6. Typ^ 9200

Ordering Replacement Parts

To order replacement parts, specify the key number and name of each part required from the "Parts Reference" section. Also state the original material of the part, if known, the desired quantity, valve type number, size, serial number, and all other pertinent nameplate informat'-n. The correct part will be selected based on this information.

In all correspondence with the sales representative, mention the serial number of the valve.

Parts Reference

Key	Part Name
1	Body
2	Valve Disc
3*	Taper Pin
4	Valve Shaft
5*	T-Ring
6*	O-Ring (Specifications A, B-1, and B-2 only)
7	Retaining Ring
8	Allen-Head Cap Screw
9	Travel Stop
10	Set Screw
11*	Key
13	Packing Follower Nut
14	Packing Follower Stud
15	Packing Follower
16*	Packing Ring
17*	Packing Washer
18	Retainer Bushing
19	Inboard Bushing
20	Bushing
21	Bearing Bracket
22	Lock Washer
23	Hex Head Screw
27	Clamp-Type Collar
45	Lantern Ring (Lubricating and purging packing boxes only)
46	Fitting (O-ring packing boxes only)
47*	O-Ring (O-ring packing boxes only)
48*	O-Ring (O-ring packing boxes only)
49	O-Ring Follower (O-ring packing boxes only)
50	Hex Head Bolt (O-ring packing boxes only)
51	Spacer Block
52	Washer
53	Compression Ring (Specifications B-1, B-2, C-1, and C-2 only)
54	Adjusting Set Screw Specifications B-1, B-2, C-1, and C-2 only)

*Recommended Spare Part

Type 9200

WORLDWIDE MANUFACTURING SALES SERVICE

Fisher Controls Company

Printed in U.S.A.

Fisher Controls Company, Marshalltown, Iowa 50158

7

Attachment 10 - "Seismic 4 Verification Program for Commonwealth Edison."

ENGINEERING PROJECT NO. CD75-46
CUSTOMER ORDER NO. 181104
CONTINENTAL CONTROL NO. 5A094 AND 5A095
REPRESENTATIVE ORDER NO. 14-62496-A AND 14-62496-B

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

SEISMIC 4 VERIFICATION PROGRAM

FOR

COMMONWEALTH EDISON COMPANY

DATE: AUGUST 20, 1978

PREPARED BY: Kanu Patel
Kanu Patel, Project Engineer

APPROVED BY: Carl D. Wilson
Carl D. Wilson, Manager, Testing and Analysis

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PURPOSE:

The purpose of this report is to develop closed form solutions to a specific geometry which verify the computer solution using Seismic 4.

PROCEDURE:

A specific geometry is first defined, to be analyzed by conventional techniques and Seismic 4. For ease of hand solution, the model used is a single cantilever beam with two eccentric masses rigidly connected to the free end of the beam.

The cross-sectional properties of the beam are then varied to incite various vibrational modes of the cantilever beam, EG axial, simple bending, bending plus torsional and torsional.

Included in Appendix B is the development of the equations for frequency for the various modes.

The reactions and stresses are verified by a conventional summation of forces and moments taking into account the seismic and gravitational loads. The seismic loads in this report are summed by the square root of the sum of squares (SRSS) method.

Each appendix is then presented as a complete system including computer printout, closed form solution for frequency, and stress verification calculations for each of the aforementioned modes.

APPENDIX A

FISHER Controls MARSHALLTOWN, IOWA	STANDARDS AND SPECIFICATIONS COVER SHEET	NO. ES 117
	SEISMIC ANALYSIS OF ROTARY VALVE ASSEMBLIES FOR NUCLEAR SERVICE	BY
		APVD R.Z. 12-12-77
		PAGE 0.1 OF
		REV C 6-20-78

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THE TABLE BELOW SHOWS THE REVISION LEVEL OF EACH PAGE OF THIS DOCUMENT. A REVISION OF THIS PAGE WILL BE MADE WHEN ANY PAGE OF THIS DOCUMENT IS REVISED.

WHEN REFERRING TO THIS DOCUMENT SPECIFY THE REVISION LEVEL OF THIS PAGE.

PAGE NUMBER	REVISION LEVEL
0.1	C
0.2	C
1	A
2	A
3	A
4	A
5	A
6	A
7	A
8	A
9	A
10	A
11	A
12	A
13	A
14	A

Specification Revision	Date	Approved by
B	4-7-78	R. Zeigler
C	6-20-78	[illegible signature]

FISHER Controls
MARSHALLTOWN, IOWA

STANDARDS AND SPECIFICATIONS COVER SHEET

SEISMIC ANALYSIS OF ROTARY VALVE ASSEMBLIES FOR NUCLEAR SERVICE

NO. ES 117	C
BY	
APVD R.B.	12-12-77
PAGE 0.2 OF	
REV	3-10-78

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16	A	32	A		
17	A	33	A		
18	A	34	A		
19	A	35	A		
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22	A	38	B		
23	A	39	A		
24	A	40	A		
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26	A	42	B		
27	A	43	A		
28	A	44	A		
29	A	45	B		
30	A	46	A		

TABLE OF CONTENTS

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I. PURPOSE:

The purpose of this engineering standard is to establish a standard method of three dimensional seismic analysis of actuator-valve assemblies subjected to triaxial seismic loading.

II. PROCEDURE

II.A The Order Engineer is assigned the responsibility for performing a seismic analysis. The format for the seismic analysis is outlined in this standard.

II.A.1 The seismic analysis will normally consist of a copy of this standard; a cover letter summarizing the results along with a listing of the applicable order numbers, and tag numbers; a set of assembly drawings depicting the constructions analyzed; a sketch of the analytical models; copies of the computer output sheets listing the input and output data along with the acceptable values; and copies of seismic tests of the valve mounted accessories (if required).

II.A.2 Unless the customer's specification states otherwise, the following will be assumed:

(1) The valve is installed in a horizontal pipeline with the valve shaft mounted horizontal (Figure III-1).

(2) The stresses due to seismic loads are to be combined by square root of the sum of the squares (SRSS).

(3) The acceptance criteria contained in Section VIII of this standard are to be used.

(4) The resonant frequency is not required.

II.A.3 An Engineer (Senior Design Engineer, Design Engineer, or Engineering Associate) other than the one performing the original calculations is responsible for reviewing the seismic analysis and signing the cover letter along with the originator of the report.

II.B The Engineering Coordinator is assigned the responsibility for maintaining and distributing the seismic analyses.

II.B.1 The analyses are to be reproduced and the originals filed in a permanent area in a systematic manner.

II.B.2 The analyses are not to be revised. In the event that the valve construction changes after the analysis is performed, a new analysis shall be performed superseding the old analysis.

III. NOMENCLATURE

III.A Equation Symbols

All variables will be defined near the equations or figures in which they appear.

III.B Special Symbols

(1) ◐ - Joint
(2) ⊙ - Vector out of the plane of the paper.
(3) ⊗ - Vector into the plane of the paper.
(4) (•) - Concentrated mass at a model joint.
(5) [5] - Element number.
(6) (6) - Joint number.
(7) •——• - Element neutral axis.
(8) ▬ - Rigid link.
(9) ↶—+—↷ - Moment about an axis normal to plane of paper.
(10) ⊙—+—⊗ - Moment about an axis in the plane of the paper.
(11) [ ] - Matrix
(12) { } - Vector

III.C Coordinate System of the Actuator-Valve Assembly

All rectangular coordinate systems used are right-handed. The primary coordinate system is illustrated for a typical assembly in Figure III-1. The primary coordinate system will be referred to as the <u>system coordinates</u>.

III.D Geometric Variables

The geometric variables listed in Tables III-1 the III-4 are used to provide cross-section and bolt joint input data to the computer program (SEISMIC 4) that performs the seismic analysis. In addition, the system coordinates for each joint of the finite element model, the interconnection between the elements and rigid links, the constraint conditions between elements and boundaries, the lumped inertia properties of the accessories and the seismic and operating loads must be specified.

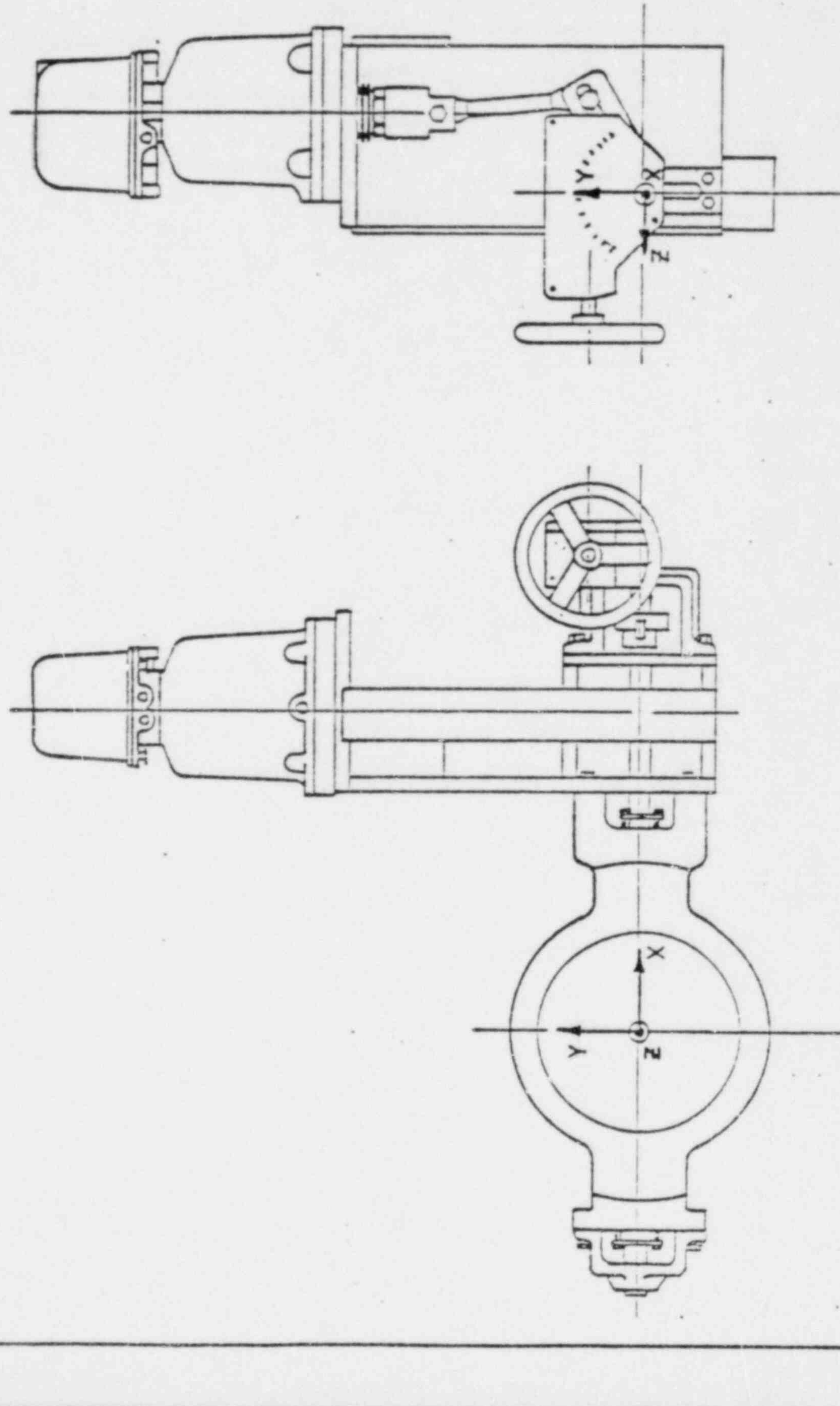
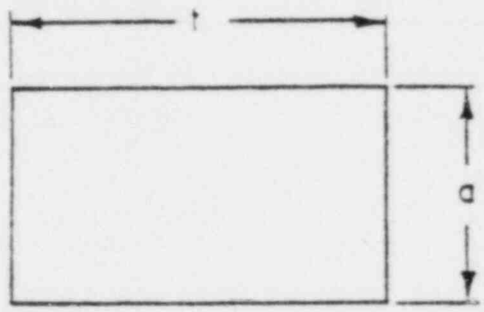


FIGURE III-1

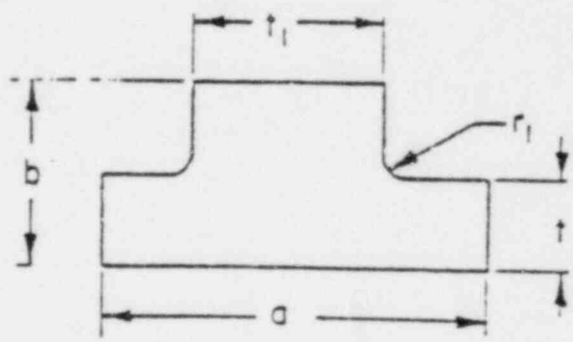
TABLE III-1
STANDARD ELEMENT CROSS-SECTIONAL PARAMETERS

GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
a	III-2	Diameter or Length	inches
b	III-2 except (i)	Length	inches
	III-2 (i)	Angle	degrees
c	III-2 (e)(h)	Length	inches
t, t_1, t_2	III-2	Thickness	inches
r_1, r_2	III-2	Fillet Radius	inches



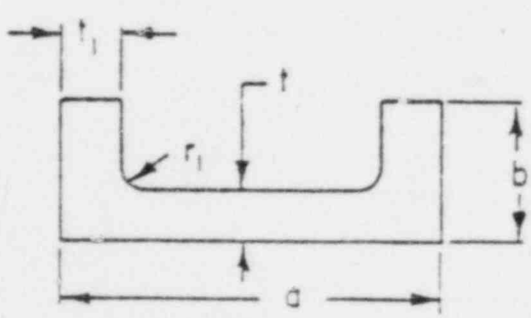
RECTANGLE

Figure III-2(a)



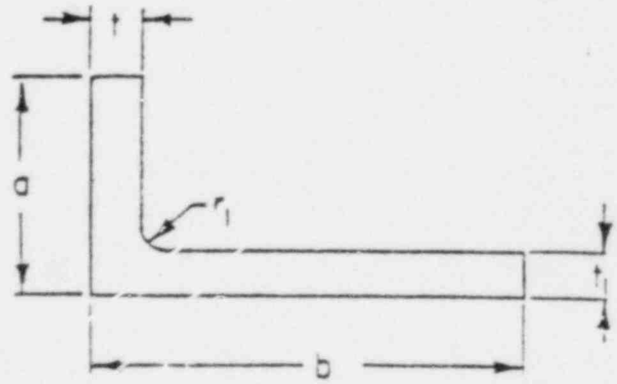
TEE

Figure III-2(b)



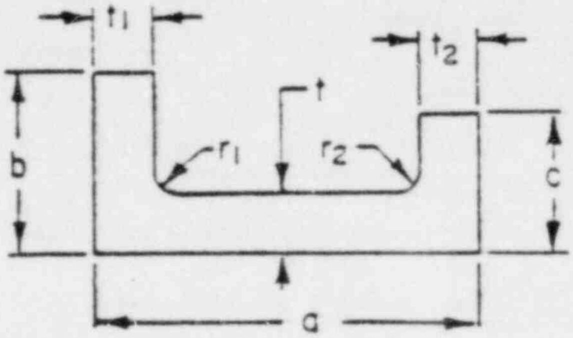
CHANNEL

Figure III-2(c)



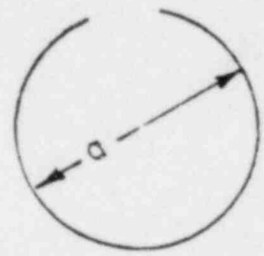
ANGLE

Figure III-2(d)



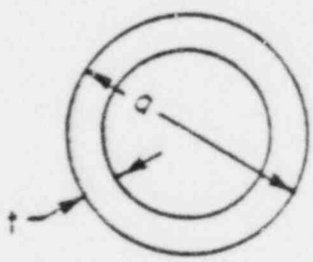
UNEQUAL LEG CHANNEL

Figure III-2(e)



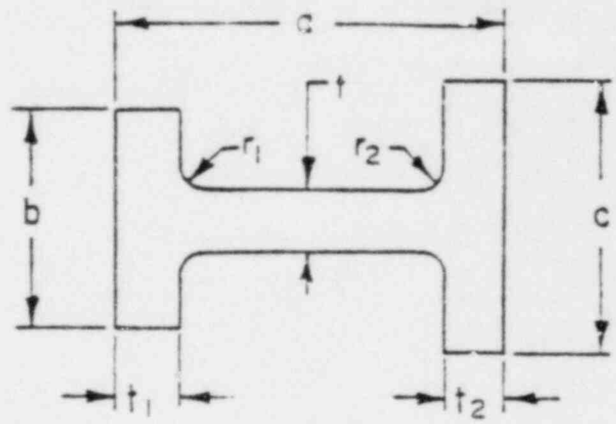
CYLINDER

Figure III-2(f)



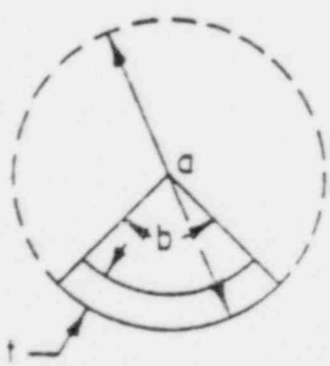
HOLLOW CYLINDER

Figure III-2(g)



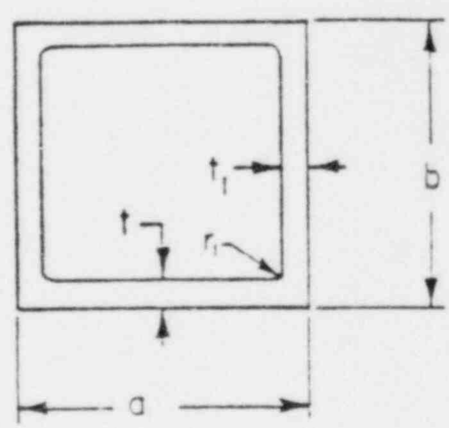
I or H

Figure III-2(h)



HOLLOW CIRCULAR SEGMENT

Figure III-2(i)



BOX

Figure III-2(j)

FIGURES III-2 STANDARD CROSS SECTIONS

TABLE III-2

NONSTANDARD CROSS-SECTIONAL PARAMETERS (STRAIGHT ELEMENT)

GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
A	III-3	Area - $\iint dx_1 dx_3$	$(inch)^2$
I_1	III-3	Bending Moment of Inertia = $\iint (x_3)^2 \, dx_1 dx_3$	$(inches)^4$
I_2	III-3	Twisting Moment of Inertia.[1]	$(inches)^4$
I_3	III-3	Bending Moment of Inertia = $\iint (x_1)^2 \, dx_1 dx_3$	$(inches)^4$
κ_1, κ_3	III-3	Shear deflection factors associated with x_1 and x_3 directions, respectively.[2]	
Z_S, Z_5	III-3	Distance from centroid to shear center in x_1 and x_3 directions, respectively.[3]	inches
[illegible]	III-3	Angle from reference direction to x_1 principal direction.	degrees
x_1, x_3	III-3	Coordinates in cross section	inches
x_1', x_3'	III-3	Reference directions	
C_1, C_3		$C_1 = x_1$, $C_3 = x_3$ coefficients for bending stress computation	inches
C_2		Coefficient for torsional shear stress computation at stress point.[4]	inches

1, 2, 3, 4 - Refer to references in Section X.

TABLE III-3

NONSTANDARD CROSS-SECTIONAL PARAMETERS (CURVED ELEMENT)

GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
A	III-4	Area = $\iint dx_1 dx_2$	$(\text{inches})^2$
I_1	III-4	Inplane Bending Moment of Inertia = $\iint (x_2)^2\, dx_1 dx_3$	$(\text{inches})^4$
I_2	III-4	Second Moment of Area = $\iint (x_1)^2\, dx_1 dx_2$	$(\text{inches})^4$
I_3	III-4	Twisting Moment of Inertia.[1]	$(\text{inches})^4$
κ_1, κ_2	III-4	Shear deflection factors associated with x_1 and x_2 directions, respectively.[2]	
Z	III-4	Bending Modulus[5] $= R^2 \iint (x_1/[R-x_1])\, dx_1 dx_2$ $= I_2 (1 + c_1/R^2 + c_2/R^4)$	$(\text{inches})^4$
c_1, c_2	III-4	Coefficients to define bending Modulus Z.[6]	$(\text{inches})^2$, $(\text{inches})^4$
R	III-4	Radius to Centroid of Area	inches
x_1, x_3	III-4	Coordinates in cross section	inches
C_1, C_2		$C_1 = x_1$ and $C_2 = x_3$ coefficients for bending stress computation	inches
C		Coefficient for torsional shear stress computation at stress point.[4]	

1, 2, 4, 5, 6 - Refer to References in Section X.

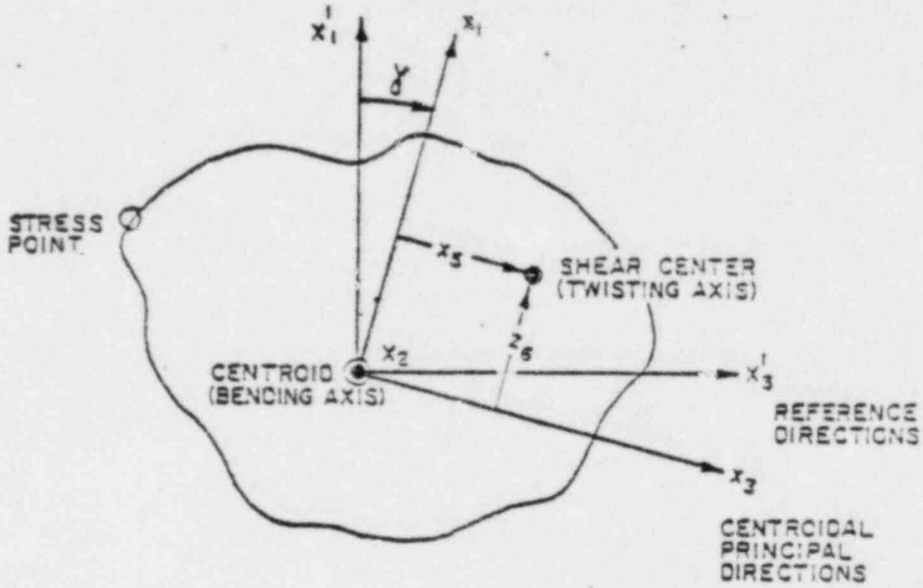


Figure III-3 Cross-Section for Straight Element

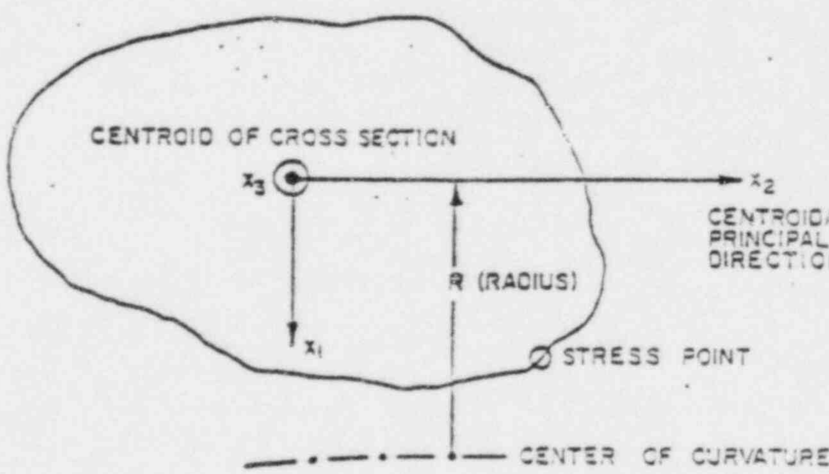
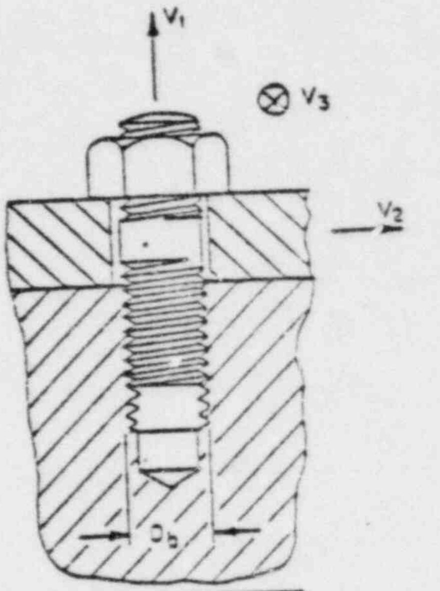


Figure III-4 Cross-Section for Curved Element

TABLE III-4
BOLT JOINT PARAMETERS

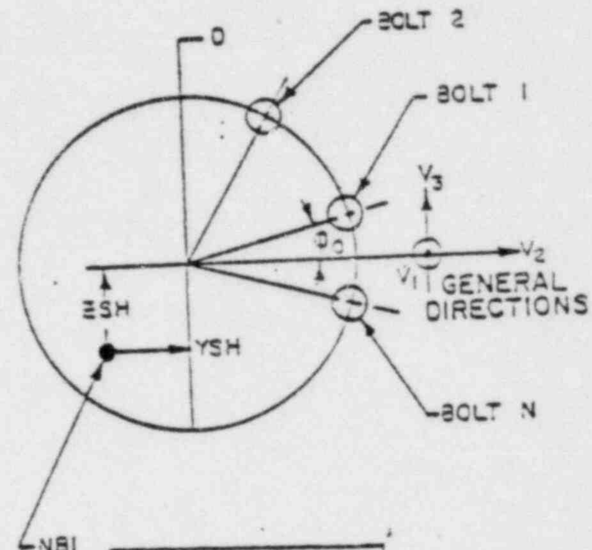
GEOMETRIC VARIABLES	FIGURE NUMBERS	DESCRIPTION	UNITS
NBI	III-5	Joint Number at which bolt reaction is referenced.	
V_1	III-5	Vector parallel to bolt axis	
V_2, V_3	III-5	Vectors (which are orthogonal to V_1) in bolt joint plane.	
D_b	III-5 (a)	Nominal Bolt Diameter	inches
n		Number of threads per inch	$(inch)^{-1}$
A_b		Root Area[7] = $\pi/4\ (D_b - 1.22687/n)^2$ for all Unified American Threads.	$(inches)^2$
N	III-5 (b)(c) III-5 (d)	Number of bolts, or Number of bolts in line.	
YSH, ZSH	III-5	Coordinates in V_2 and V_3 direction, respectively, from reference joint NBI to center of bolt joint pattern.	inches
D	III-5 (b)	Diameter of Bolt Circle.	inches
θ_o	III-5 (b)	Angle from V_2 direction to Bolt No. 1. Only 0 or 180/N permitted.	degrees
S	III-5 (c)(d)	Spacing between bolts on line = S/(N-1)	inches
YO	III-5 (c)	Distance from pivot edge to bolt line for leg pattern, or	inches
	III-5 (d)	Spacing between bolt lines for pad pattern.	inches
YE, ZT, ZB	III-5	Distances from pivot edges to bolts.	inches

[7] - Refer to References in Section X.



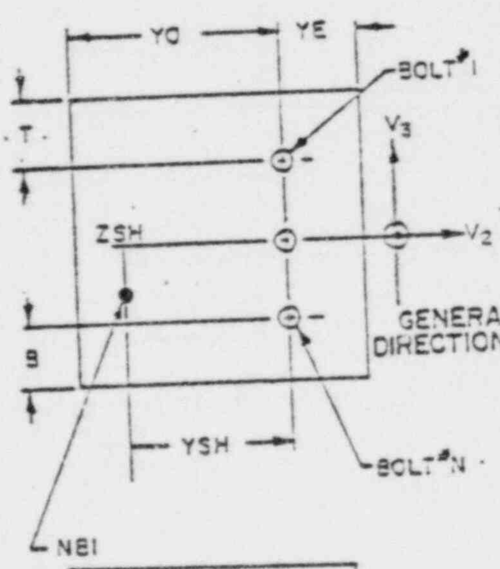
BOLT VECTORS

Figure III-5(a)



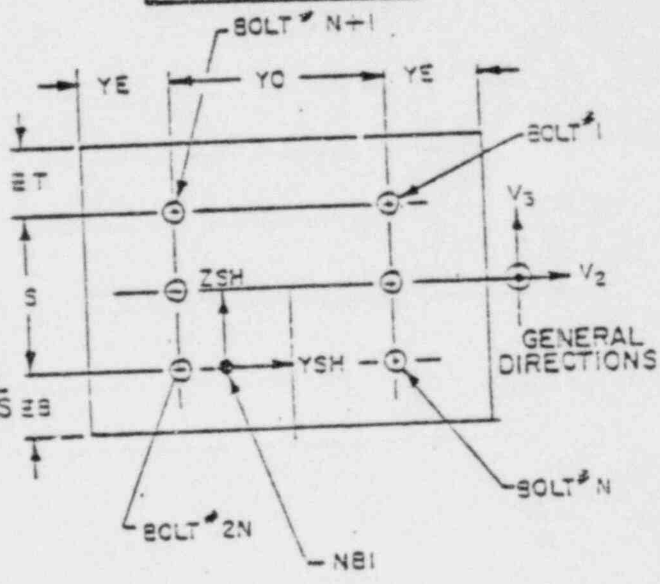
BOLT CIRCLE

Figure III-5(b)



LEG

Figure III-5(c)



PAD

Figure III-5(d)

FIGURES III-5 BOLTED JOINT INPUT PARAMETERS

IV. MODELING OF THE ACTUATOR-VALVE ASSEMBLY

IV.A Mathematical Model Components and Features

The model for the actuator-valve assembly is constructed from two basic types of beam elements each with distributed masses. These elements are referred to as a thick straight beam and a thick curved beam.[5] The ends of these beam elements are referred to as joints in the model. The joints can have as many as six degrees of freedom or as few as zero degrees of freedom (complete fixity). There are five types of joints: an equilibrium joint with independent displacements and rotations; an auxiliary joint with dependent displacements and rotations; a boundary joint with at least one degree of fixity; a spring boundary joint with at least one degree of elastic constraint; and a reference joint (which may be one of the above) at which bolting forces and moments are computed or the center of a curved element is defined.[8]

IV.A.1 Thick Straight Beam

The Element Coordinate System in which forces and moments are computed for the straight beam element is illustrated in Figure IV-1. The 2-axis lies along the centroidal axis of the beam from the joint at end two to end one. Positive directions of rotation about the 1, 2, and 3-axis obey the right-hand rule. The coordinates in the cross-section, x_1, x_3, are in the direction of the 1 and 3 axes (Figure III-3). The twisting axis[3] of the beam is parallel to but need not coincide with the centroidal axis. Shear deflection[2] is considered in the derivation of the stiffness and mass matrices.

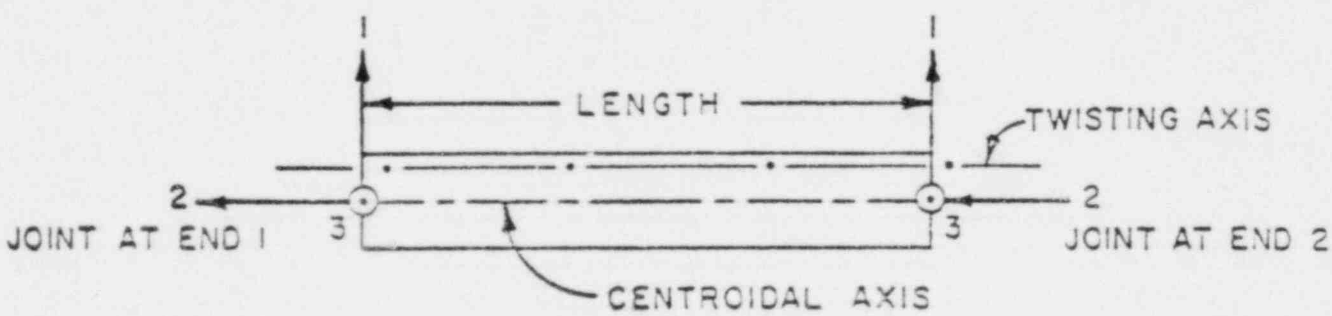


FIGURE IV-1

ELEMENT COORDINATE SYSTEM FOR A THICK STRAIGHT BEAM

2, 3, 5, 8 - Refer to References in Section X.

IV.A.2 Thick Curved Beam

The element coordinate system in which forces and moments are computed for each end of the curved beam element is illustrated in Figure IV-2. The positive direction of the 1-axis always is towards the center of curvature. The 3-axis is tangent to the centroidal axis. The radius of curvature is the distance from the center of curvature to the centroidal axis of the curved beam element. Positive directions of rotation about the 1, 2, and 3-axis obey the right-hand rule. The coordinates in the cross-section, x_1, x_2 are in the direction of the 1 and 2 axes (Figure III-4). The shift of bending axis from centroidal axis[5] and shear deflection[2] is considered in the derivation of the stiffness and mass matrices.

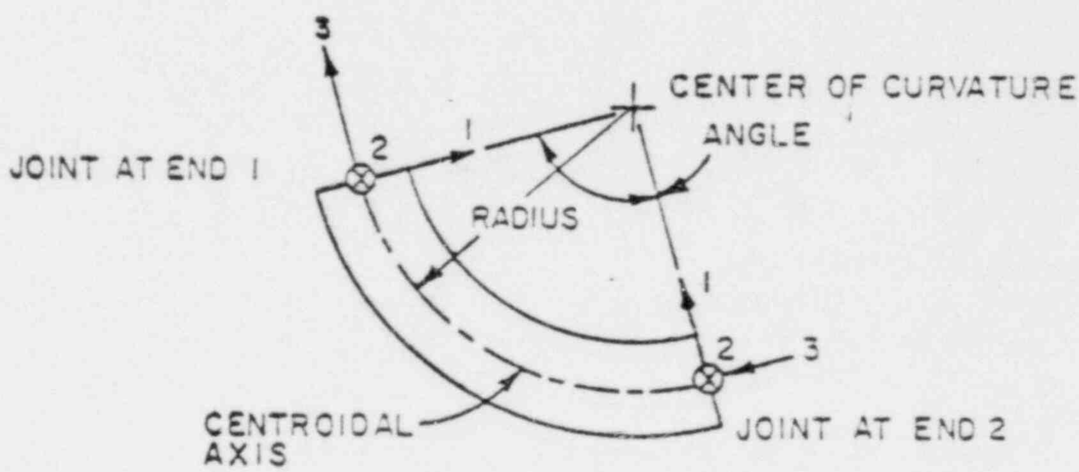


FIGURE IV-2

ELEMENT COORDINATE SYSTEM FOR A THICK CURVED BEAM

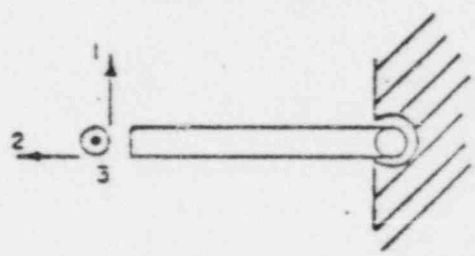
2, 5 - Refer to References in Section X.

IV.A.3 Element End Releases[9]

There are normally six degrees of freedom considered (three displacements and three rotations) at each joint. Any of these degrees of freedom may be specified as constrained or unconstrained, or as having an elastic connection to the adjacent elements. Figures IV-3 thru IV-6 describe typical release mechanisms. In Figure IV-3 end two of a straight element is released for degree of freedom six (rotation about 3-axis) representing a pin joint. In Figure IV-4 degree of freedom two (displacement along 2-axis) is released representing a slide connection. In Figure IV-5, a ball joint is modeled by releasing all rotations (degrees of freedom 4, 5, and 6). Figure IV-6 has an elastic connection to adjacent elements at end two in the axial and transverse directions.

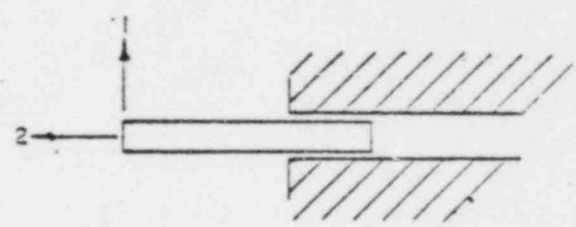
PIN CONNECTION

Figure IV-3



SLIDE CONNECTION

Figure IV-4



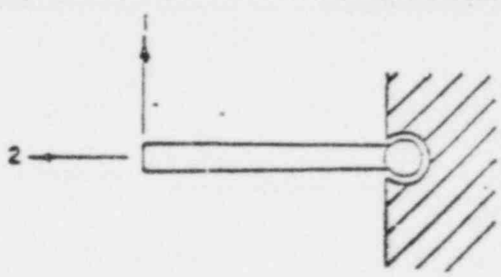


Figure IV-5

BALL CONNECTION

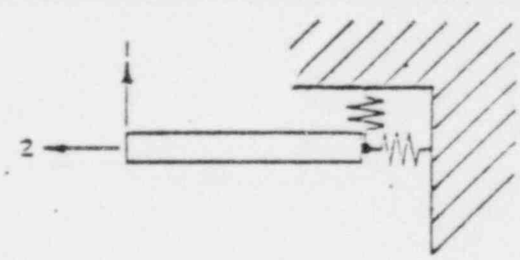


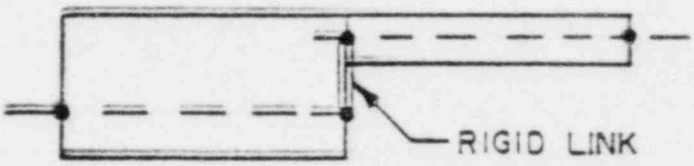
Figure IV-6

BI-AXIAL SPRING CONNECTION

9 - Refer to References in Section X.

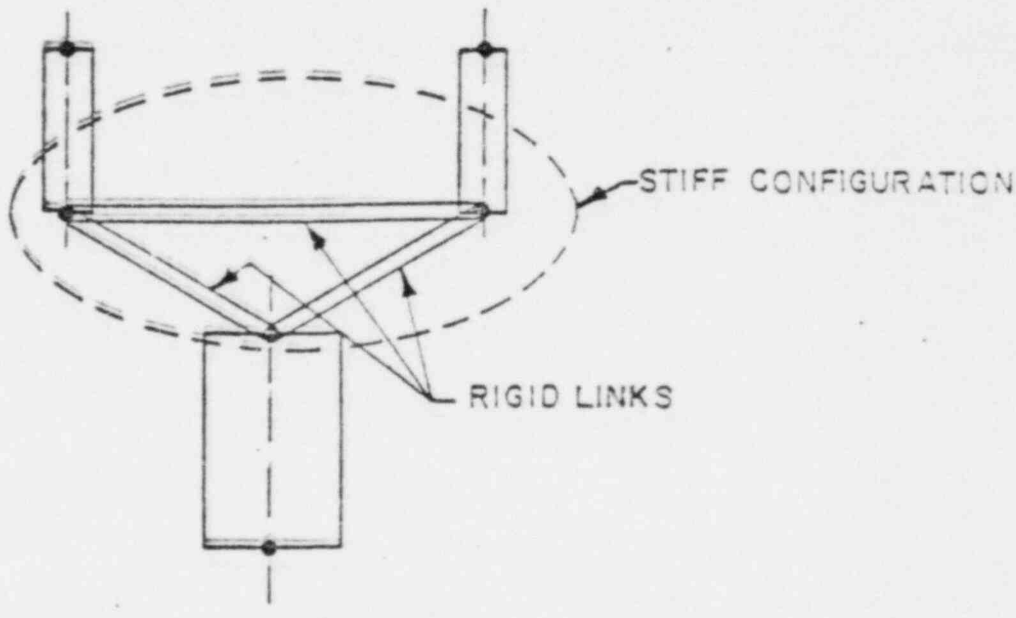
IV.A.4 Rigid Link[10]

A rigid link between any auxiliary joint and any equilibrium joint can be modeled exactly. A kinematic transformation of the element's stiffness and mass matrices is used for this purpose. Rigid links ensure that the rotation of all joints so connected are the same and that the displacements of all joints are related through the vector distances from each other. The rigid link mechanism may be used to accurately model elements joined off their centroidal axes, Figure IV-7, or extremely inelastic members of a physical structure as shown in Figure IV-8. In the latter example, any two of the three indicated rigid links may be specified.



ELEMENTS WITH CENTROIDAL AXES NOT ALIGNED

Figure IV-7



ELEMENTS JOINED THROUGH INELASTIC MEMBER
FIGURE IV-8

[10] = Refer to References in Section X.

IV.A.5 Lumped Inertia Properties

Each elastic element in the mathematical model has an associated consistent mass matrix which accounts for a uniform distribution of mass.[5] Inertia other than this may be defined for accessories, rigid portions that were not modeled elastically (e.g., Figure IV-8) and shaft-disc assemblies. The inertia properties may be specified as lumped masses acting at any joint or at any coordinate from any joint. The lumped mass may act in all or only in some of the system coordinate directions. For example, a mass attached to a shaft supported by a journal and thrust bearing may be specified to act in the transverse directions of the journal and in the axial direction of the thrust bearing. Centroidal principal moments of inertia aligned to the system coordinates may be specified at any joint.

IV.A.6 Spring Boundaries and Constraints[8]

Boundary joints of the model may be attached to the external boundary with either complete or elastic fixity in any of the six system degrees of freedom (three translational and three rotational). Thus, a hanger may be modeled by means of uniaxial spring, and the piping or body (assumed rigid) may be modeled by specifying complete fixity.

IV.A.7 Cross section Properties[11]

The built-in standard cross sections in SEISMIC 4 as depicted in Figures III-2 may be used to define the properties of any straight or curved element. For special constructions, the Order Engineer may input nonstandard properties as described in Table III-1 and Figures III-3 and Figures III-4 to fit the modeling need.

V. MATHEMATICAL ANALYSIS

The SEISMIC 4 computer program employs the modeling features as described in Section IV.A to yield response to seismic excitation and operational loads and to compute system resonant frequency.

V.A Synthesis of Stiffness, Mass and Load Matrices[12]

The exact stiffness and consistent mass matrices are derived for each element (Section IV.A.1 and IV.A.2). A three column load matrix is

5, 8, 11, 12 - Refer to References in Section X.

determined from the mass matrix for unit gravitational loads in each of the system directions. Any required release (Section IV.A.3) or kinematic transformation (Section IV.A.4) is performed. The resulting matrices are then transformed from their element to the system coordinates and accumulated forming the system stiffness and mass matrices and three columns of the system load matrix. Lumped inertia properties (Section IV.A.5) are added to the system mass matrix and appropriate forces are added to the three unit gravitational load columns. Operational loads other than deadweight, consisting of concentrated forces and moments at any joint, comprise a fourth column of the system load matrix. Prescribed boundary conditions (Section IV.A.6) are then imposed on the system matrices, yielding:

[K] System Stiffness Matrix, symmetric (usually banded),

[M] System Mass Matrix, symmetric (usually banded),

[F] System Load Matrix, composed of three unit gravitational load columns and one operational load column.

V.B Gravitational and Operational Load Solution

The deformation due to the static unit gravitational and operational loads derives from the solution of the matrix equation:

$$[K]\ [X] = [F] \qquad (V.B-1)$$

where [K] and [F] were defined in Section V.A, and [X] is a four column deformation matrix; the first three are responses to the unit graviational loads in each of the system coordinates and the fourth the response to the operational loading condition not including deadweight. Each column of [X] consists of deflections in the system X, Y, Z directions, rotations about the system X, Y, Z directions for each equilibrium joint. The corresponding deformations for auxiliary joints are computed by employment of the kinematic transformations (Section IV.A.4).

V.C Determination of the Fundamental Resonant Frequency

A complete seismic analysis of any structural system includes the structural analysis for the dynamic loads caused by the vibratory earthquake motion of its supports. There are two general methods of analysis for dynamic loading depending upon the characteristics of the system. The equivalent static analysis, which is employed here, is applicable and conservative for actuator systems that can be shown to have no natural frequencies less than a specified amount. Thus, the lowest or fundamental frequency must be computed.

The fundamental resonant frequency is found by determining the smallest eigenvalue, λ, and corresponding eigenvector {u} from the undamped free vibration equation:[13]

$$([K] - \lambda [M]) \{u\} = \{0\} \qquad (V.C-1)$$

where [K] and [M] are the system stiffness and mass matrices (Section V.A), {u} is the eigenvector corresponding to the smallest eigenvalue λ, and is normalized in the SEISMIC 4 computer program so that the largest displacement or rotation at any equilibrium joint is plus or minus one, {0} is a null vector.

The fundamental resonant frequency, f, is then determined by:

$$f = \sqrt{\lambda}/(2\pi) \qquad (V.C-2)$$

the algorithm[14] used to determine values for λ is based on an iteration procedure on equation V.C-1 using as starting values the unit gravitational deformations (Section V.B).

V.D Calculation of Element Forces and Moments[15]

The force and moment response of the ends of the elements due to the four column load matrix [F] (Section V.A) are determined from:

$$[p] = [k] [S] - [m] [g] \qquad (V.D-1)$$

where [p] is a four column matrix consisting of the element forces and moments at each end (thus, twelve rows),

[k] is the element stiffness matrix,

[m] is the element mass matrix, both described in Section IV.A.1 and Section IV.A.2,

[g] is a four column matrix; the first three consist of unit gravitational loads, the fourth a null column, and

[S] is a four column matrix consisting of the deformation response to unit gravitational and operational loads extracted from the system solution matrix [X] (Section V.B). The extraction of [S] from [X] involves transformation from system to element end coordinates (Sections IV.A.1 and IV.A.2) and accounting for any kinematic transformations (IV.A.4) or releases (IV.A.3).

13, 14, 15 - Refer to References in Section X.

V.E Calculation of Junction Reactions

The resultant reactions [P] due to the four basic loading conditions (Section V.B) is determined at all boundary joints and at any specified cut in the model. The element forces and moments [p] (Section V.D) for all elements joining at a boundary or on one side of the cut are employed to determine the junction reaction. The rigid link transformation (Section IV.A.4) is performed on [p] prior to transformation from the element coordinates (A.1 and A.2) to the system coordinate (Section III.C) and adding to [P].

VI. DETERMINATION OF SEISMIC AND OPERATIONAL FORCES AND MOMENTS

The resultant element end [p] (Section V.D) and junction [P] (Section V.E) reactions (forces and moments) for each of the unit loading conditions may be superimposed, because of the linear nature of elastic, small deformation systems,[12] to yield the reactions for any magnitude and direction of seismic excitation and any actuator orientation with respect to gravitational and seismic acceleration.

In this seismic analysis computer program, the capability is provided for the specification of any vertical gravitational direction with an associated G-level and two different G-levels for each of the two mutually perpendicular horizontal directions.

The Order Engineer may define the vertical gravitational direction by specifying to the SEISMIC 4 computer program a clue; either X-UP, Y-UP, Z-UP, or SKEW (along with the vertically downward vector, {V}). Another clue may be used to define one horizontal direction, {H1}, (the other horizontal direction {H2} is mutually perpendicular).

The corresponding seismic directions and their vector components with respect to the system coordinates for typical specifications are shown in Figure VI-1.

The resultant reactions on the element ends or junctions for the operational load is a superposition of the fourth column of [p] or [P] with some linear combination of the first three rows corresponding to the acceleration of gravity in the {V} direction, to account for deadweight.

12 - Refer to References to Section X.

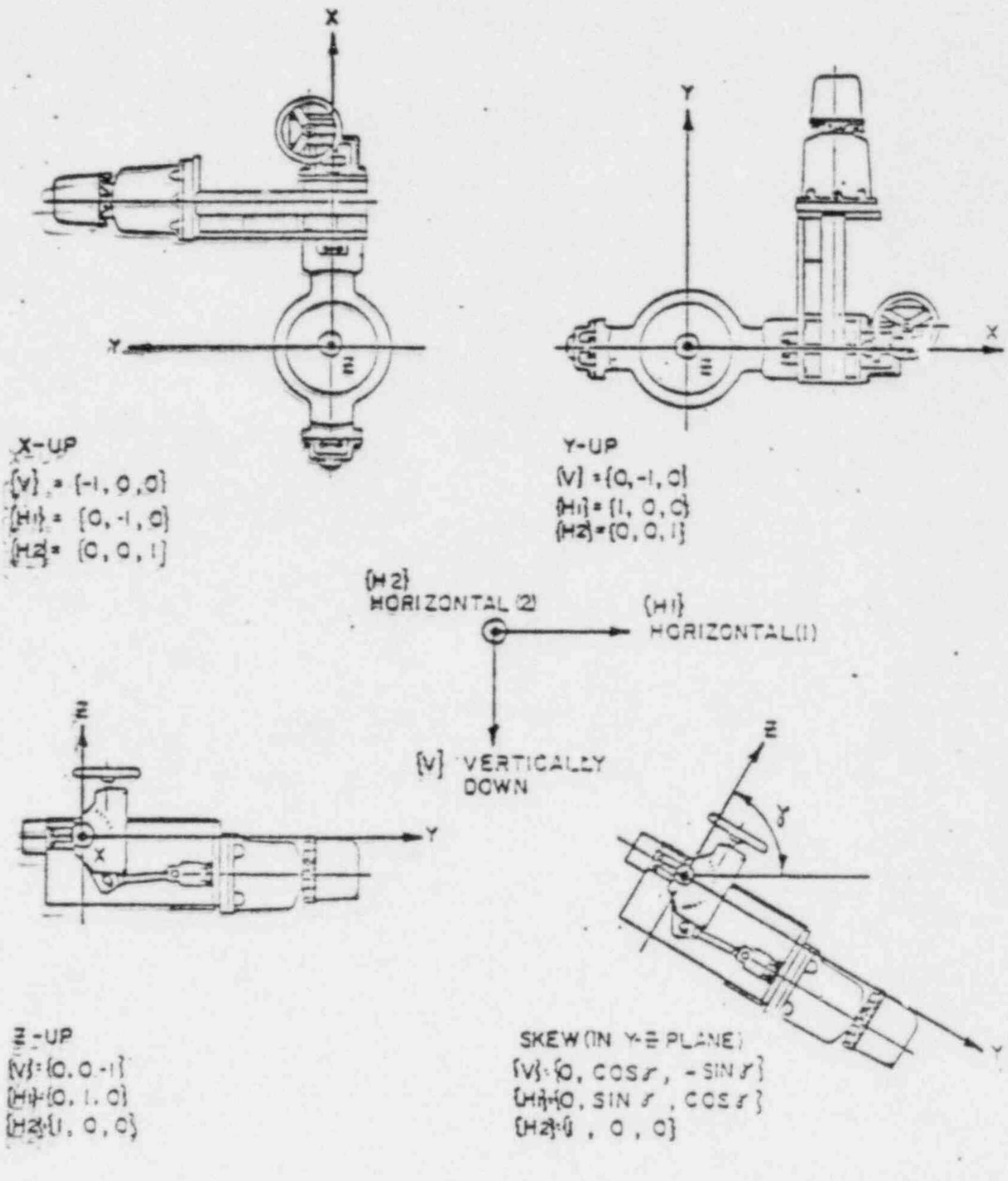


FIGURE VI-1 Typical Seismic Directions

VII. DETERMINATION OF STRESSES

The stress analysis of the actuator-valve assembly is carried out for the locations specified by the engineer. All straight and curved beam element ends may be selected. All bolted joints connecting one section to another or to the body may be selected. The portion of the structure on either side of a bolted joint is represented by a plane designation. The plane being defi ed for the ends of the elements that load the joint (refer to Figure VII-1 for typical locations where stresses are computed). The numerical designations refer to subsections in Section VII that follow. A detailed explanation of the methods for determining the stress components is presented in each particular section.

In general, the stresses at these locations are arrived at in the following manner. The element end and junction reactions for the seismic and operational loads were calculated as described in Section VI.

Normal and shear stress components for each of these four independent loading conditions are computed in accordance with the procedures in the following subsections. The seismic normal and shear stress components depending upon specifications are combined in any of three ways: direct sum, SRSS[16] (Square Root of the Sum of the Squares), or the sum of the absolute values. Each combined seismic normal and shear stress component is either added to, or subtracted from, the operational stress component, whichever yields the combined component with the larger magnitude. Either the maximum absolute principal stress, P_{max}, or the maximum stress intensity, S_{max},[17] is then computed (Equations VII-1 through 5) in accordance to specifications.

$$\tau_{max} = \sqrt{(\sigma/2)^2 + (\tau)^2} \qquad \text{(VII-1)}$$

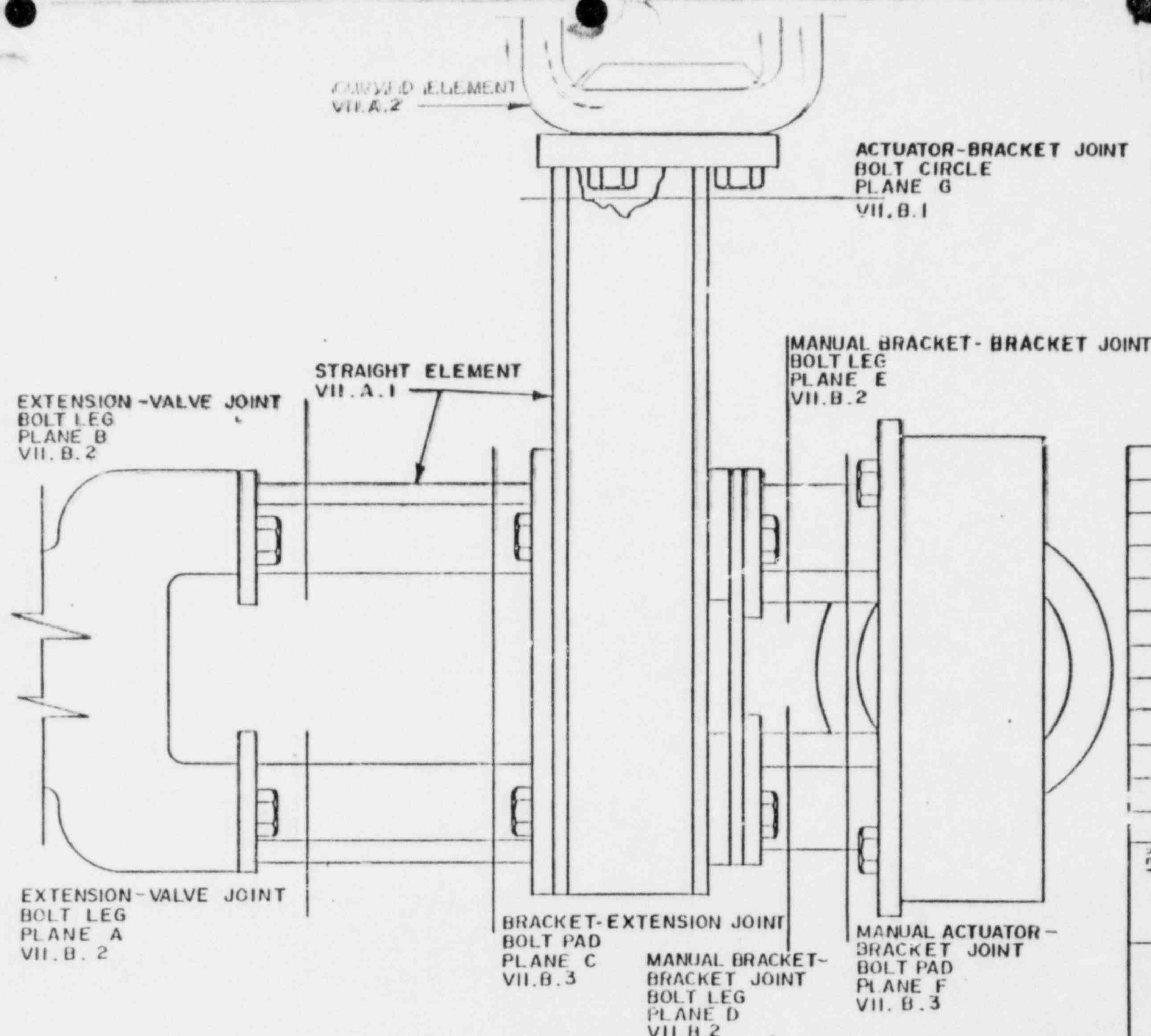
$$\sigma_{P_{max}} = (\sigma/2) + \tau_{max} \qquad \text{(VII-2)}$$

$$\sigma_{P_{min}} = (\sigma/2) - \tau_{max} \qquad \text{(VII-3)}$$

$$S_{max} = \text{largest of } 2\,\tau_{max}, \text{ or } (\sigma_{P_{max}} - \sigma_{P_{min}}) \qquad \text{(VII-4)}$$

$$P_{max} = \text{largest of } \sigma_{P_{max}}, \text{ or } |\sigma_{P_{min}}| \qquad \text{(VII-5)}$$

16, 17 - Refer to References in Section X.



SECTIONS WHERE STRESSES ARE COMPUTED
FIGURE VII-1

OWN IOWA

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SEISMIC ANALYSIS OF ROTARY VALVE ASSEMBLIES FOR NUCLEAR SERVICE

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where σ is the surface fiber stress at a point on beam or the average axial stress in a bolt,

τ is a shear stress at a point on a beam or the average shear stress in a bolt,

τ_{max} is the maximum shear stress,

$\sigma_{P_{max}}$ is the maximum principal stress,

$\sigma_{P_{min}}$ is the minimum principal stress, with the third principal stress assumed zero (beam surface point or average through bolt).

P_{max} or S_{max}, designated the "total" stress is compared against the appropriate stress limit in Section VIII of this standard.

VII.A Beam Stress Computation

The end force and moment reactions for each of the four independent load conditions comprise each column of [p], derived in Section V.D and transformed in Section VI.

$$\begin{Bmatrix} F_1^{(1)} \\ F_2^{(1)} \\ F_3^{(1)} \\ M_1^{(1)} \\ M_2^{(1)} \\ M_3^{(1)} \\ F_1^{(2)} \\ F_2^{(2)} \\ F_3^{(2)} \\ M_1^{(2)} \\ M_2^{(2)} \\ M_3^{(2)} \end{Bmatrix} = \{P\} \qquad \text{(VII.A-1)}$$

where $F_i^{(j)}$ $i = 1, 2, 3$ and $j = 1, 2$ are the reaction forces in the element, i direction for end j of the beam, and

$M_i^{(j)}$ are the reaction moments.

{p} represents any column of [P].

In the following subsections, the beam stress-reaction relations are presented with a sketch of the reaction sign conventions (Figures VII-2 and VII-4).

At both ends of the beam, at several selected points on the cross-section, a surface fiber stress, σ, and a shear stress, τ, is computed. σ and τ are then introduced into equations VII-1 to 5 for the computation of the "total" stress at each point.

VII.A.1 Straight Beam Stress

The end reactions as described in Section VII.A are aligned with the element coordinates as shown in Figure VII-2.

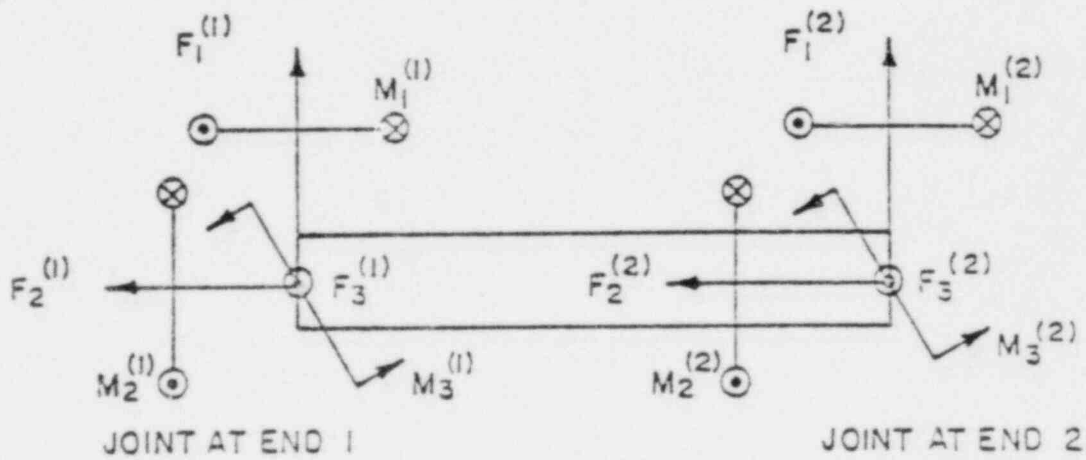


Figure VII-2

The stress at any point on the cross section, at either end, may be determined from the forces, F_1, F_2, F_3, and the moments, M_1, M_2, M_3, (superscript (1) or (2) denoting end, will be omitted in the following text), the cross-sectional properties for the end, A, I_1, I_2, I_3, the bending stress coefficients, C_1, C_3, and the torsional shear stress coefficients, C, as described in Table III-2 and Figure III-3.

Thus, the fiber stress[15] is

$$\sigma = \pm (F_2/A - C_3M_1/I_1 + C_1M_3/I_3) \qquad \text{(VII.A.1-1)}$$

[15] - Refer to References in Section X.

The shear stress may be written, conservatively, assuming that the torsional shear[I] acts in the same direction as the transverse component of shear and the transverse component, which is zero on the outer surfaces, is taken as an average across the section:

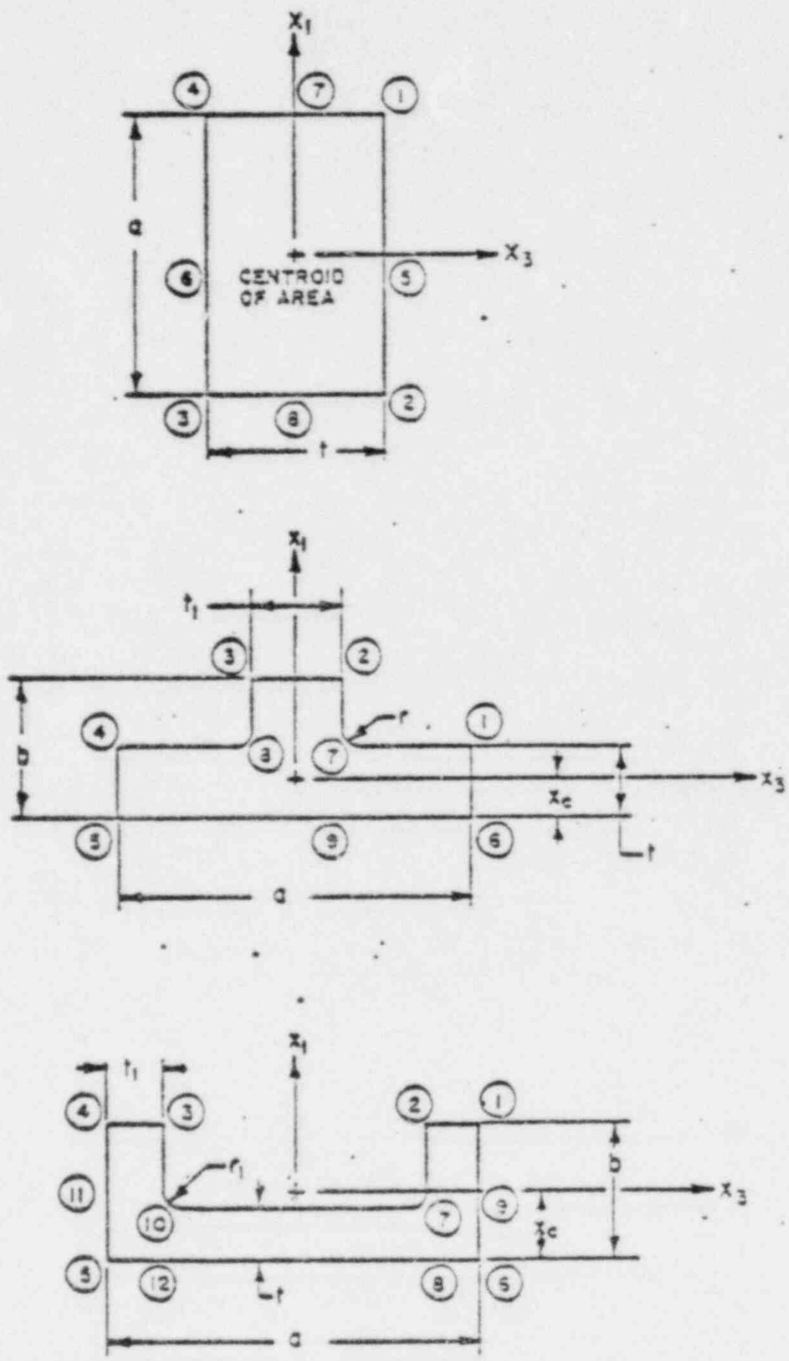
$$\tau = \pm [|(CM_2/I_2)| + \sqrt{(F_1)^2 + (F_3)^2}/A] \qquad \text{(VII.A.1-2)}$$

In the above equations, the + sign is employed for end one of the element and the - sign for end 2.

For standard sections (Figures III-2) A, I_1, I_2, I_3, and sets of C_1, C_3, and C are determined in the SEISMIC 4 computer program from the input parameters described in Table III-1.[II] The coefficients for the stress points are chosen at extreme fibers and near points at which the largest inscribed circle touches the boundary. For the standard sections, points, indicated by encircled numbers, are shown on Figures VII-3. Note that $C_1 = x_1$ and $C_3 = x_3$.

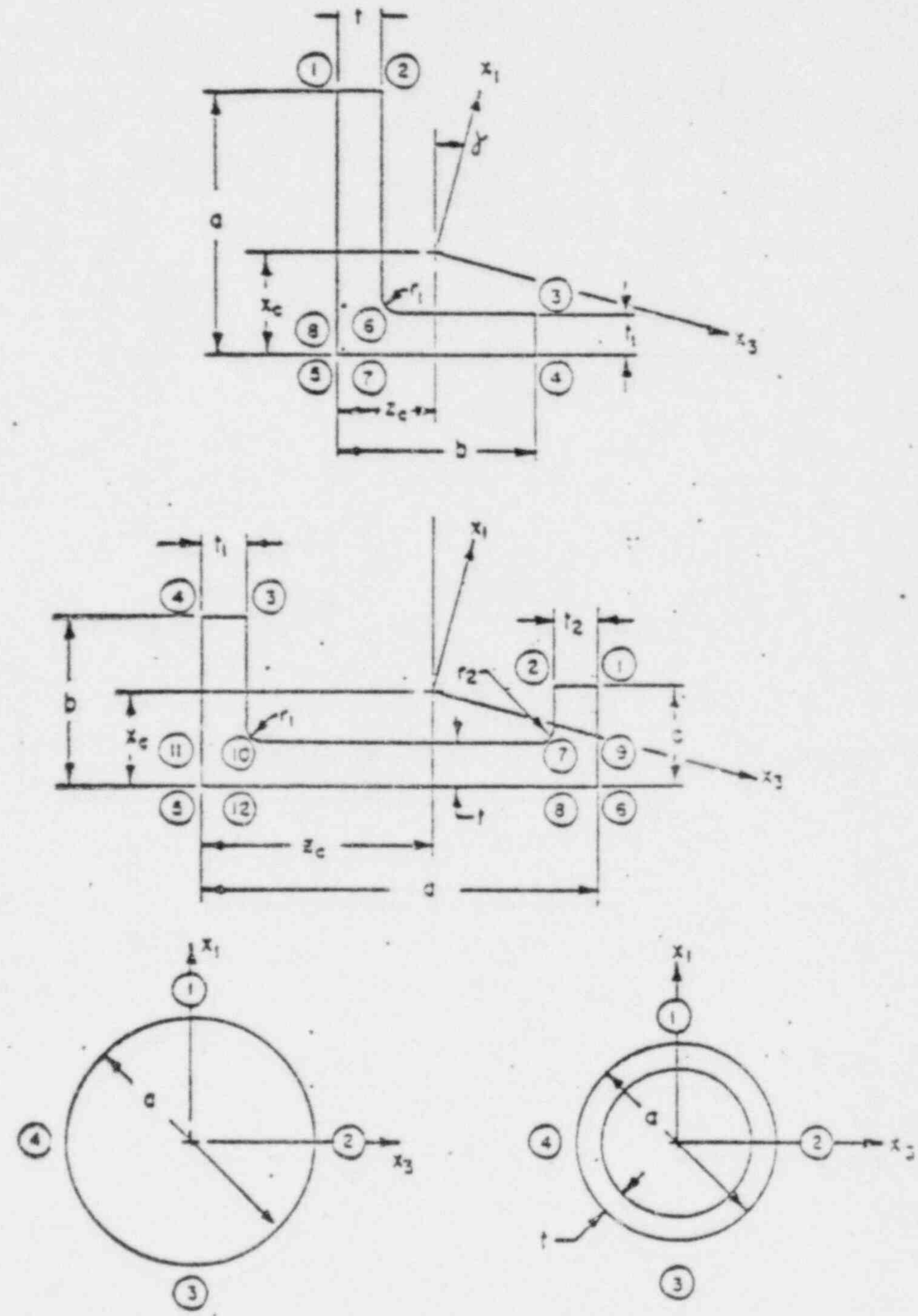
For nonstandard cross-sections C, C_1 and C_3 are entered directly along with the other section properties (Table III-2).

I; II = Refer to References in Section X.



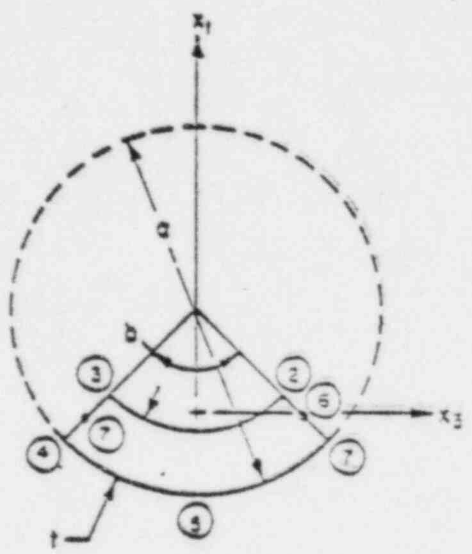
STRESS LOCATIONS STANDARD CROSS SECTIONS

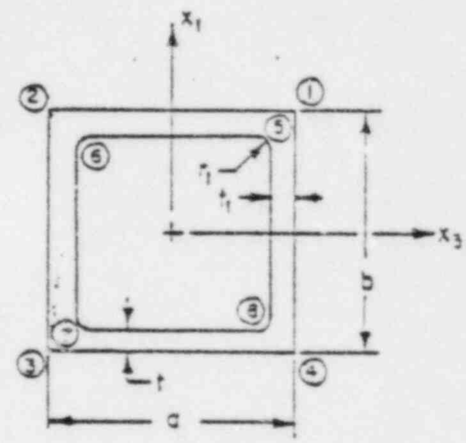
FIGURES VII-3

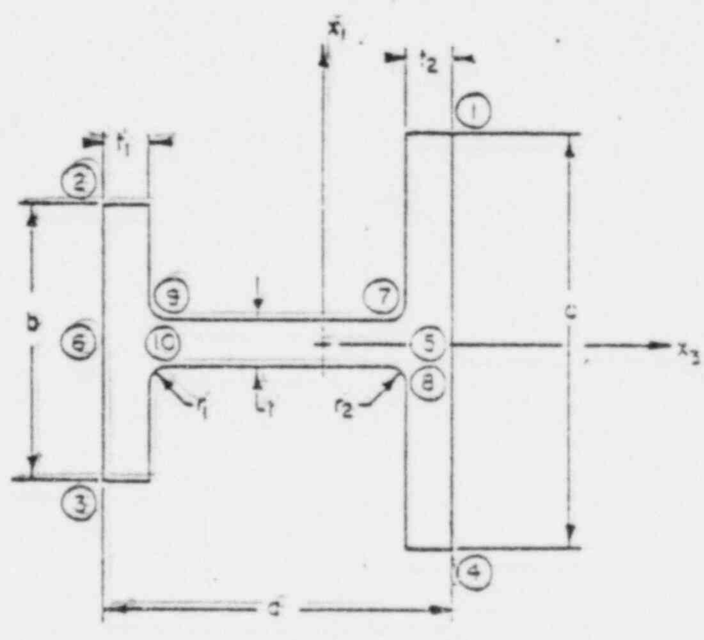


STRESS LOCATIONS STANDARD CROSS SECTIONS

FIGURES VII-3







STRESS LOCATIONS STANDARD CROSS SECTIONS

FIGURES VII-3

VII.A.2 Curved Beam Stress

The end reactions as described in Section VII.A are aligned with the element end coordinates as shown in Figure VII-4.

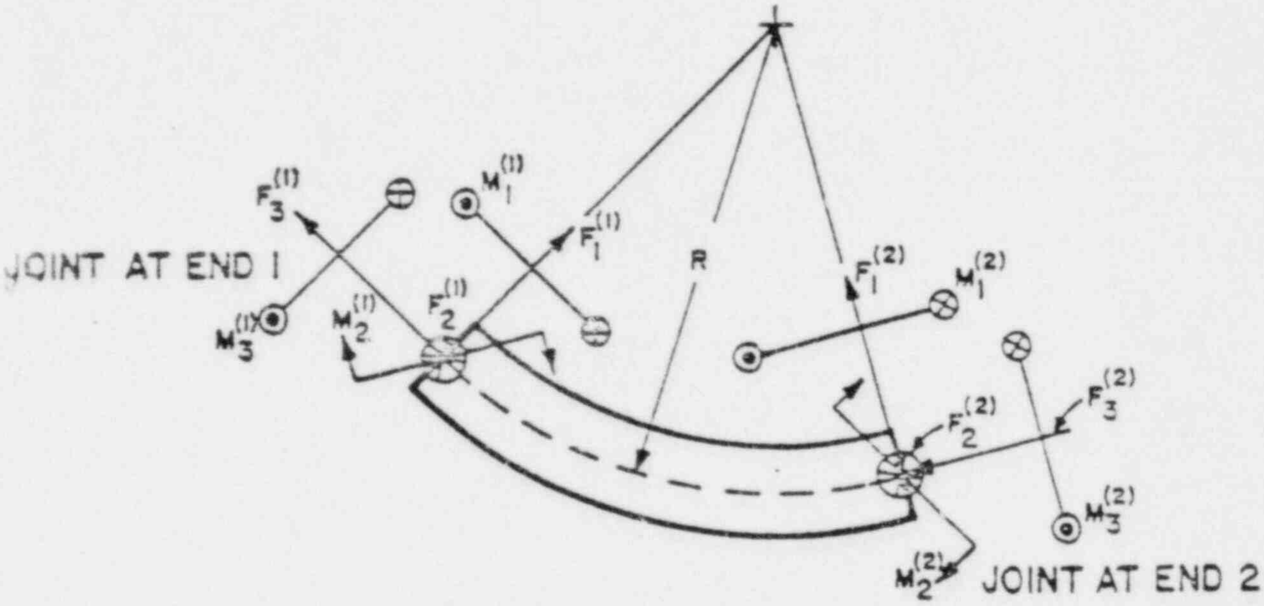


Figure VII-4

The stress at any point on the cross-section, at either end, may be determined from the forces, F_1, F_2, F_3, and the moments, M_1, M_2, M_3, the cross-section properties for the end, A, Z, I_1 and I_3, the bending stress coefficients, C_1, C_2, the torsional shear stress coefficient, C, and the radius to the centroid, R, as described in Table III-3 and Figure III-4.

The fiber stress[5] is:

$$\sigma = \pm \{(F_3 + M_2/R)/A - C_1RM_2/[Z(R - C_1)] + C_2M_1/I_1\} \qquad \text{(VII.A.2-1)}$$

The shear stress may be written, using the same conservative assumptions as in the development of equation VII.A.1-2.

$$\tau = \pm [|(CM_3/I_3)| + \sqrt{(F_1)^2 + (F_2)^2}/A] \qquad \text{(VII.A.2-2)}$$

5 - Refer to References in Section X.

where the + sign is employed for end one of the element and the - sign for end 2.

For standard sections (Figures III-2), A, Z, I_1, I_3 and sets of C_1, C_2 and C are determined in the SEISMIC 4 computer program in the same manner as for the straight standard cross-sections,[11] Figures VII-3.

Because of the difference in coordinate systems, (x_1, x_2, x_3) for a curved element corresponds to (x_1, $-x_3$, $-x_2$) for a straight element (compare Figures IV-1 and IV-2). Therefore, for a curved element $C_1 = x_1$ and $C_2 = x_3$ in Figures VII-3. For nonstandard cross sections, C, C_1 and C_2 are entered directly with the other section properties (Table III-3).

VII.B Bolted Joint Stresses[18]

The junction reactions, [P], described in Section V.E and transformed to yield three independent seismic loads and the operational load including deadweight as described in Section VI, are the basis for computation of bolt joint loads and stresses. Each of the four independent columns of [P], designated {P}, has force and moment components in the system coordinate directions X, Y and Z.

$$\{P\} = \begin{Bmatrix} F_x \\ F_y \\ F_z \\ M_x \\ M_y \\ M_z \end{Bmatrix} \qquad \text{(VII.B-1)}$$

{P} is transformed to the bolt configuration coordinate system defined by specified vectors, $\{V_1\}$, $\{V_2\}$ and $\{V_3\}$, and then shifted to the reference center of the configuration by the specified coordinates YSH and ZSH, described in Table III.D-4 and Figures III.D-4.

$\{V_1\}$ is parallel to the bolt axes in the direction toward the elements used to define the junction reactions (Section V.E).

The transformed load in the bolt configuration coordinate system is designated {B}:

11, 18 - Refer to References in Section X.

$$\{B\} = \begin{Bmatrix} f_1 \\ f_2 \\ f_3 \\ m_1 \\ m_2 \\ m_3 \end{Bmatrix} \qquad \text{(VII.B-2)}$$

where f_i ($i = 1, 2, 3$) are the forces acting at the reference center of the configuration in the V_i direction, and m_i are the moments.

f_2, f_3, m_1 will be used to compute two average shear stress components τ_2 and τ_3, and f_1, m_2, m_3 will be used to compute average axial stress, σ.

τ_2 and τ_3 are shear stress components in the V_2 and V_3 directions. These shear components for each independent seismic load and the operational load will be combined in the specified manner (Section VII). After combination, a single shear stress, τ, will be computed, which, along with σ, will be introduced into equations VII-1 to 5 for computation of "total" stress in each bolt:

$$\tau = \sqrt{(\tau_2)^2 + (\tau_3)^2} \qquad \text{(VII.B-3)}$$

Implicit in the computation of τ_2 and τ_3 is the conservative assumption that the shearing forces are resisted by the bolts and not by friction between the flanges.

In the following Sections VII.B.1 and VII.B.2, the stresses σ and τ for each bolt in the configuration will be computed so that there is equilibrium with the load {B} and flange reactions.

VII.B.1 Bolt Circle

The forces and moments on the bolt circle configuration consisting of N bolts may be depicted as in Figure VII-5.

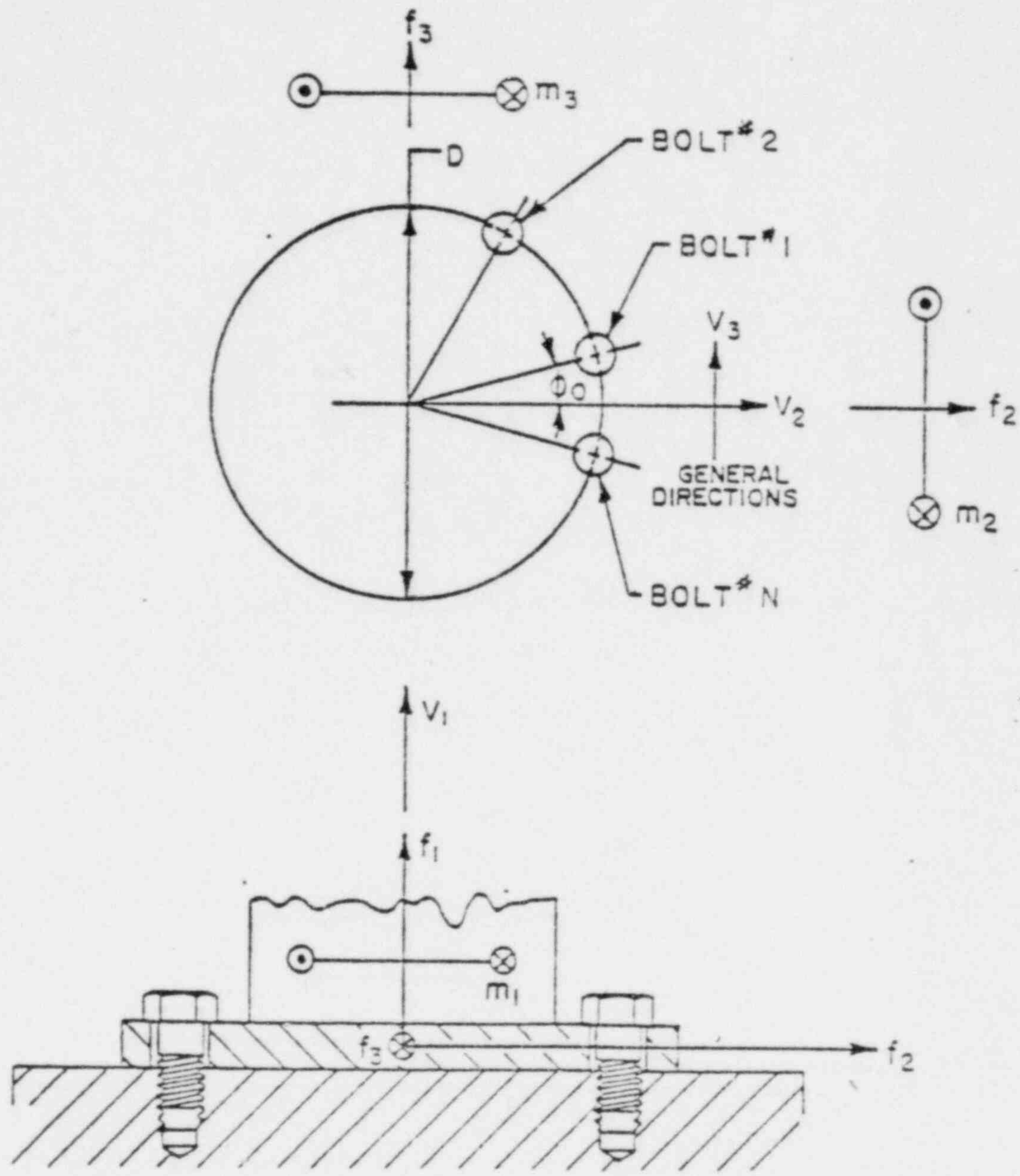


Figure VII-5
BOLT CIRCLE

The specified parameters for the bolt circle, N, ϕ_o, D and A_b are described in Table III-4 and Figure III-5(b).

The angular location, ϕ_i, in degrees, for the ith bolt, (i = 1, 2, 3, ...N), is:

$$\phi_i = 360(i - 1)/N + \phi_o \qquad \text{(VII.B.1-1)}$$

The inplane forces, f_2, f_3, will be assumed to be distributed uniformly to each bolt. In addition, the twisting moment, m_1, will be equilibrated by equal tangential shear forces with components in the $\{V_2\}$ and $\{V_3\}$ directions.

Thus,

$$V_{f_2}^{(i)} = (f_2 - \sin\phi_i(2m_1)/D)/N \qquad \text{(VII.B.1-2)}$$

$$V_{f_3}^{(i)} = (f_3 + \cos\phi_i(2m_1)/D)/N \qquad \text{(VII.B.1-3)}$$

The average total shear stress components on the ith bolt are thus,

$$\tau_1 = V_{f_2}^{(i)}/A_b \qquad \text{(VII.B.1-4)}$$

$$\tau_2 = V_{f_3}^{(i)}/A_b \qquad \text{(VII.B.1-5)}$$

where D is the bolt circle diameter, and

A_b is the root area of each bolt.

The axial force, f_1, and bending moments, m_2, m_3, will be assumed to be in equilibrium with the bolt axial forces, thus, the axial force in the ith bolt is:

$$A^{(i)} = [f_1 + (4/D)(m_2 \sin\phi_i - m_3 \cos\phi_i)]/N \qquad \text{(VII.B.1-6)}$$

It can be shown that for at least three evenly spaced bolts (i.e., N = 3),

$$\sum_{i=1}^{N} A^{(i)} = f_1 \qquad \text{(VII.B.1-7)}$$

$$\sum_{i=1}^{N} A^{(i)} \left(\frac{D}{2} \sin \phi_i\right) = m_2 \qquad \text{(VII.B.1-8)}$$

$$\sum_{i=1}^{N} A^{(i)} \left(\frac{D}{2} \cos \phi_i\right) = m_3 \qquad \text{(VII.B.1-9)}$$

The average axial stress for the ith bolt is, thus,

$$\sigma = A^{(i)}/A_b \qquad \text{(VII.B.1-10)}$$

For the operational loading condition a gasket force, F_g, may be specified which adds to the axial force. This total, if positive, is used to compute the axial stress for each bolt under operational conditions; if negative, it is assumed that the flanges react in compression and σ for those bolts with $A^{(i)} + F_g/N < 0$ is assumed zero.

$$\sigma_{\text{operational}} = A^{(i)} + (F_g/N)/A_b \qquad \text{(VII.B.1-11)}$$

VII.B.2 Bolted Joint Leg Configuration

A commonly used bolted connection between components in an actuator-valve assembly is designated a Leg Configuration with a single line of N evenly spaced bolts on a rectangular, nearly inelastic pad. Figure VII-6 depicts a typical configuration with the forces and moments acting.

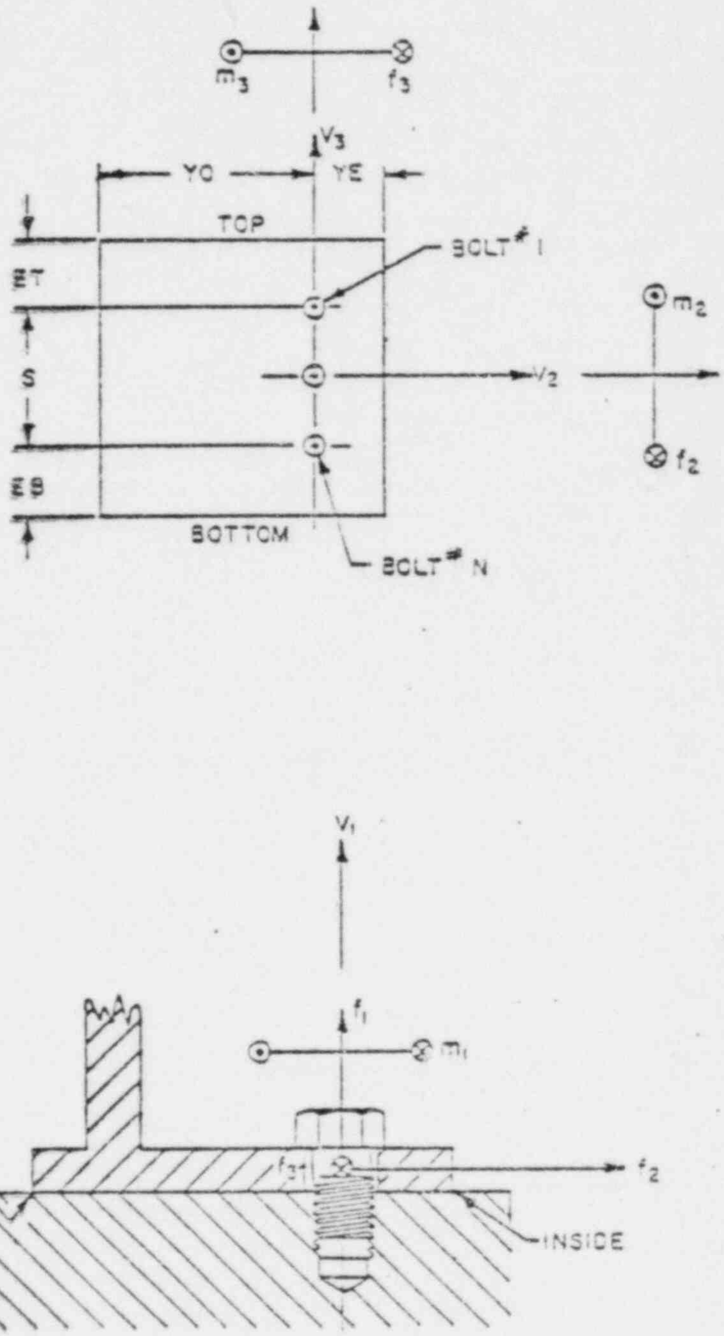
The specified parameters for this configuration, N, S, ZB, ZT, YO, YE and A_b are described in Table III-4 and Figure III-5(c).

The distance, V, from the reference center to the ith bolt (i = 1, 2, ...N) in the V_3 direction is:

$$V_3^{(i)} = S(N + 1 - 1 - 2i)/(2(N - 1)) \qquad \text{(VII.B.2-1)}$$

The inplane forces, f_2, f_3, are assumed to be distributed uniformly to each bolt. In addition, the twisting moment, m_1, is assumed to be distributed as shear forces, $V_m^{(i)}$, in the V_2 direction on each bolt, which are proportional to $V_3^{(i)}$.

$$V_m^{(i)} = m_1 (N + 1 - 2i) C_M \qquad \text{(VII.B.2-2)}$$



LEG CONFIGURATION

FIGURE VII-6

with,

$$C_M = 6/(S \cdot N \cdot (N + 1)) \qquad \text{(VII.B.2-3)}$$

It can be shown that these shear forces do indeed equilibrate with the twisting moment.

$$\sum_{i=1}^{N} V_m^{(i)} \; V_3^{(i)} = m_1 \qquad \text{(VII.B.2-4)}$$

Thus, the shear forces on the ith bolt in the V_2 and V_3 directions are:

$$V_{f_2}^{(i)} = f_2/N - V_m^{(i)} \qquad \text{(VII.B.2-5)}$$

$$V_{f_3}^{(i)} = f_3/N \qquad \text{(VII.B.2-6)}$$

and the average total shear stress components on the ith bolt is:

$$\tau_2 = V_{f_2}^{(i)}/A_b \qquad \text{(VII.B.2-7)}$$

$$\tau_3 = V_{f_3}^{(i)}/A_b \qquad \text{(VII.B.2-8)}$$

where A_b is the root area of each bolt.

The axial force, f_1, and bending moment, m_3, is assumed to be reacted by a total load, f_1', for all the bolts and a contact reaction at either the inside or outside pivot edges (Figure VII-6). Both possible pivot edges are postulated; the one that yields tension for the bolt load and the smallest compression through the pivot reaction is selected.

For contact on inside edge

$$f_1' = f_1 + m_3/YE \qquad \text{(VII.B.2-8)}$$

For contact on outside edge

$$f_1' = f_1 - m_3/YO \qquad \text{(VII.B.2-9)}$$

For no contact which implies $m_3 = 0$

$$f_1' = f_1 \qquad \text{(VII.B.2-10)}$$

For the condition that neither postulated contact edge yields bolt tension

$$f_1' = 0 \qquad \text{(VII.B.2-11)}$$

Next, f_1' and m_2 will be assumed to be reacted by individual axial loads in each bolt, $A^{(i)}$, and a pivot reaction about either the top or bottom edges (Figure VII-6) depending upon the sense of m_2.

If $m_2 = 0$

$$A^{(i)} = f_1'/N \qquad \text{(VII.B.2-12)}$$

If $m_2 < 0$ (Pivot about top edge)

$$A^{(i)} = [f_1' (S/2 + ZB) + m_2][S(N - i)/(N-1) + ZB]/C_B \qquad \text{(VII.B.2-13)}$$

where

$$C_B = N \left[\frac{S^2(N + 1)}{12(N - 1)} + (S/2 + ZB)^2\right] \qquad \text{(VII.B.2-14)}$$

If $m_2 > 0$ (Pivot about bottom edge)

$$A^{(i)} = [f_1'(S/2 + ZT) - m_2][S(i - 1)/(N - 1) + ZT]/C_T \qquad \text{(VII.B.2-15)}$$

where

$$C_T = N \left[\frac{S^2(N + 1)}{12(N - 1)} + (S/2 + ZT)^2\right] \qquad \text{(VII.B.2-16)}$$

For the seismic loads, for which f_1, m_2, m_3, may reverse all together in sign, equations VII.B.2-8 through 2-16 are reevaluated yielding another set of axial loads, $A^{(i)}_k$ for each bolt; the largest value for each bolt is retained and then the average axial bolt stress is taken as:

$$\sigma = A^{(i)}/A_b \qquad \text{(VII.B.2-17)}$$

VII.B.3 Bolted Joint Pad Configuration

The bolted connection between components in an actuator-valve assembly that consists of a nearly inelastic rec-

tangular pad with two parallel lines, each with N evenly spaced, bolts, is designated a pad configuration. Figure VII-7 depicts such a configuration with forces and moments acting.

The specified parameters for this configuration, N, S, ZB, ZT, YO, YE and A_b are described in Table III-4 and Figure III-5(d).

The location of the ith bolt may be written in terms of the coordinates, $V_2^{(i)}$, $V_3^{(i)}$, in the plane parallel to vectors, $\{V_2\}$, $\{V_3\}$, respectively.

For $1 \le i \le N$

$$V_2^{(i)} = YO/2 \qquad \text{(VII.B.3-1)}$$

$$V_3^{(i)} = S(N + 1 - 2i)/(2(N - 1)) \qquad \text{(VII.B.3-2)}$$

For $N + 1 \le i \le 2N$

$$V_2^{(i)} = -YO/2 \qquad \text{(VII.B.3-3)}$$

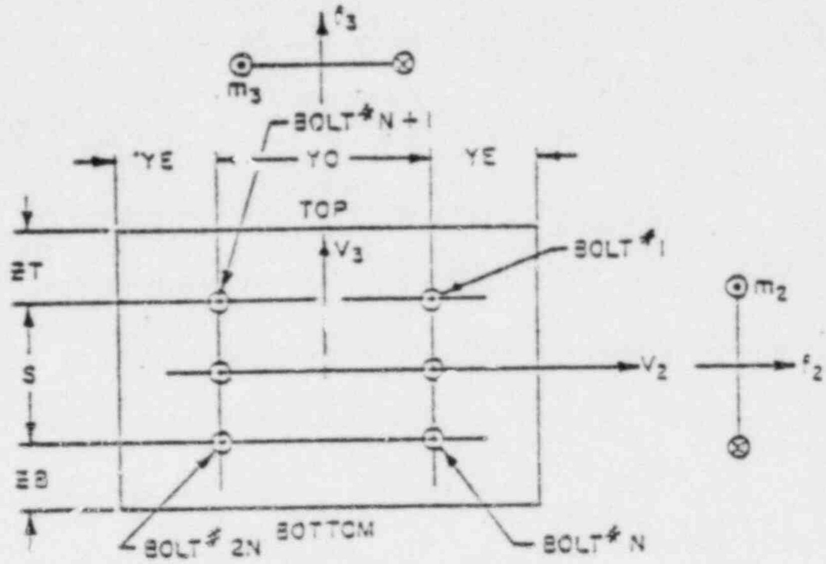
$$V_3^{(i)} = S(3N + 1 - 2i)/(2(N-1)) \qquad \text{(VII.B.3-4)}$$

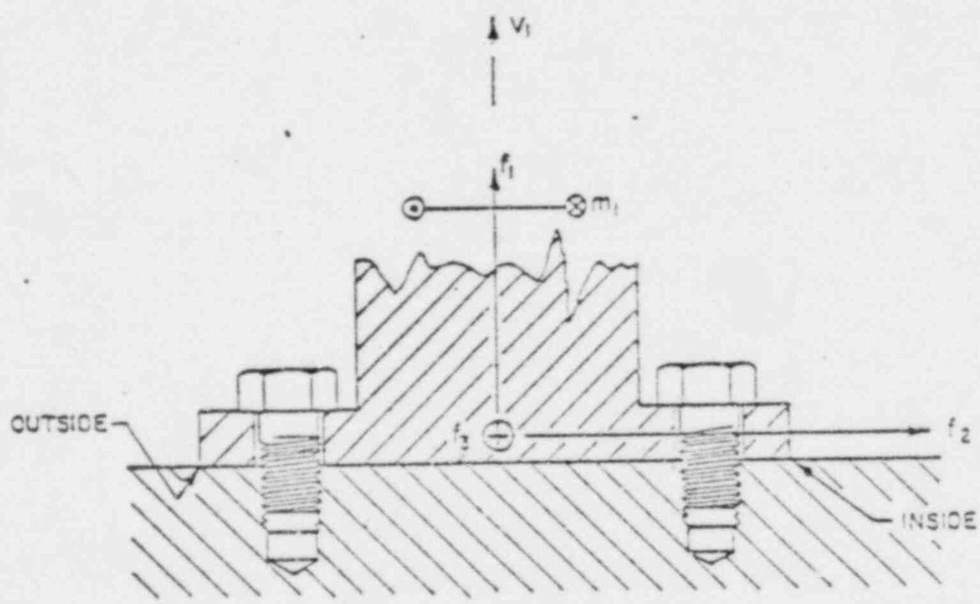
and the distance is:

$$d_i = \sqrt{(V_2^{(i)})^2 + (V_3^{(i)})^2} \qquad \text{(VII.B.3-5)}$$

The inplane forces, f_2, f_3, are assumed to be distributed uniformly on each of the 2N bolts. In addition, the twisting moment, m_1, is assumed to be distributed as tangentially acting shear forces, $V_m^{(i)}$, proportional to the distance, d_i, from the reference center of the bolt pattern.

$$V_m^{(i)} = m_1 \, d_i/(2N \, C_M) \qquad \text{(VII.B.3-6)}$$





PAD CONFIGURATION

FIGURE VII-7

where:

$$C_M = 1/[(YO/2)^2 + S^2(N+1)/(12(N-1))] \qquad \text{(VII.B.3-7)}$$

It can be shown that these shear forces do equilibrate with the twisting moment:

$$\sum_{i=1}^{2N} V_m^{(i)} d_i = m_1 \qquad \text{(VII.B.3-8)}$$

Taking the components of $V_m^{(i)}$ in the V_2 and V_3 directions and adding to the shear developed by f_2 and f_3 yields the two shear force components on each of the i bolts.

$$V_{f_2}^{(i)} = (f_2 - C_M V_3^{(i)} m_1)/(2N) \qquad \text{(VII.B.3-9)}$$

$$V_{f_3}^{(i)} = (f_3 + C_M V_2^{(i)} m_1)/(2N) \qquad \text{(VII.B.3-10)}$$

and the average total shear stress components on the ith bolt are:

$$\tau_2 = V_{f_2}^{(i)}/A_b \qquad \text{(VII.B.3-11)}$$

$$\tau_3 = V_{f_3}^{(i)}/A_b \qquad \text{(VII.B.3-12)}$$

where A_b is the root area of each bolt.

The axial force, f_1, and the bending moment, m_3, is assumed to be reacted by total loads on the inside row of bolts (1 to N), $f_1^{(I)}$, the outside row of bolts (N + 1 to 2N), $f_1^{(o)}$, and either a reaction on the inside or outside pivot edges (Figure VII-7).

Various pivoting mechanisms may be postulated. For $f_1 \geq 0$ and $m_3 = 0$, no pivoting about the V_3 axis occurs.

$$f_1^{(I)} = f_1^{(o)} = f_1/2 \qquad \text{(VII.B.3-13)}$$

For $m_3 > 0$, pivoting is on the inside edge

$$f_1^{(I)} = YE \cdot T_I \qquad \text{(VII.B.3-14)}$$

$$f_1^{(o)} = (YE + YO) \cdot T_I \qquad \text{(VII.B.3-15)}$$

where:

$$T_I = [(f_1/2)(YO + 2\cdot YE) + m_3]/[(YE)^2 + (YE + YO)^2] \quad \text{(VII.B.3-16)}$$

For $m_3 < 0$, pivoting is on the outside edge:

$$f_1^{(I)} = (YE + YO)\cdot T_O \quad \text{(VII.B.3-17)}$$

$$f_1^{(o)} = YE\cdot T_O$$

where:

$$T_O = [(f_1/2)(YO + 2\cdot YE) - m_3]/[(YE)^2 + (YE + YO)^2] \quad \text{(VII.B.3-18)}$$

For $f_1 \leq o$ and $m_3 = 0$, then f_1 is assumed reacted entirely by the two contact edges:

$$f_1^{(I)} = f_1^{(o)} = 0 \quad \text{(VII.B.3-19)}$$

$f_1^{(I)}$ and $f_1^{(o)}$ are assumed to uniformly load in the axial direction each bolt in the respective rows, thus,

$$\bar{A}^{(i)} = f_1^{(I)}/N \quad 1 \leq i \leq N$$

$$= f_1^{(o)}/N \quad N + 1 \leq i \leq 2N \quad \text{(VII.B.3-20)}$$

Next, an additional load, $\bar{\bar{A}}^{(i)}$, on each bolt caused by m_2 is computed based on the assumption of pivoting about either the top or bottom edge (Figure VII-7) depending upon the sense of m_2.

If $m_2 = 0$

$$\bar{\bar{A}}^{(i)} = \bar{\bar{A}}^{(i+N)} = 0 \quad 1 \leq i \leq N \quad \text{(VII.B.3-21)}$$

If $m_2 > 0$ (Pivot about bottom edge)

$$\bar{\bar{A}}^{(i)} = \bar{\bar{A}}^{(i+N)} = (m_2/2)[(S(N - i)/(N - 1) + ZB]/C_B \quad 1 \leq i \leq N \quad \text{(VII.B.3-22)}$$

where:

$$C_B = N[(S/2 + ZB)^2 + S^2 (N + 1)/(12(N - 1))] \quad \text{(VII.B.3-23)}$$

If $m_2 < 0$ (Pivot about top edge)

$$\bar{A}^{(i)} = \bar{A}^{(i + N)} + (m_2/2)[S(i - 1)/(N - 1) + ZT]/C_T \quad \text{(VII.B.3-24)}$$

where:

$$C_T = N[(S/2 + ZT)^2 + S^2 (N + 1)/(12(N - 1))] \quad \text{(VII.B.3-25)}$$

The total axial load on the ith bolt is then:

$$A^{(i)} = \bar{A}^{(i)} + \bar{\bar{A}}^{(i)} \text{ for } 1 \leq i \leq 2N \quad \text{(VII.B.3-26)}$$

For seismic loads for which f_1, m_2, m_3, may reverse all together in sign, equations VII.B.3-13 through 3-26, are reevaluated yielding another set of axial loads, $A^{(i)}$, for each bolt; the largest value for each bolt is retained, then the average bolt stress may be taken as:

$$\sigma = A^{(i)}/A_b \quad \text{(VII.B.3-27)}$$

VIII. ACCEPTANCE CRITERIA

If the purchaser's design specification does not include acceptance criteria or if the acceptance criteria are incomplete, this section will be used to determine the acceptability of the equipment.

VIII.A. Pressure Retaining Structures

Table VIII.A.-1

Valve Classification	Section Analyzed	Stress Limits[1,2,3,4,5,6]
Active	Bonnet	$(\sigma_m$ or $\sigma_L) + \sigma_b \leq 1.5S$ $\sigma_s \leq 0.6S$
	Bolting	$\sigma_m \leq 2S$
Non-active	Bonnet	$(\sigma_m$ or $\sigma_L) + \sigma_b \leq S_y$ $\sigma_s \leq 0.6S_y$
	Bolting	$\sigma_m \leq 2S$

VIII.A. Pressure Retaining ... ures (continued)

... Table VIII.A.-1

1. The symbols are defined as follows:

   σ_m - general membrane stress. This stress is equal to the average stress across the solid section under consideration, excludes discontinuities and concentrations and is produced only by mechanical loads.

   σ_L - local membrane stress. This stress is the same as σ_m except that it includes the effect of discontinuities.

   σ_b - bending stress. This stress is equal to the linear varying portion of the stress across the solid section under consideration, excludes discontinuities and concentrations, and is produced only by mechanical loads.

   σ_s - shear stress. This stress is the average primary shear stress across a section loaded in pure shear.

   S_y - yield strength.

   S - stress intensity for Class 1 valves or the allowable stress for Class 2 and 3 valves taken from Appendix 1 to Section III.

2. The stress limit for cast iron, ASTM A48 Class 30, is 15000 psi for all cases.

3. For the purposes of selecting the appropriate material properties and stress limits the actuator yoke, the yoke locknut or actuator-to-bonnet bolting shall be assumed to be at ambient temperature while the bonnet and the bonnet-to-body bolting shall be assumed to be at the service temperature.

4. The value for S for materials not listed in Appendix I to Section III shall be determined in the following manner:

   For Class 1 valves the lesser of:

   1/3 of the minimum specified tensile strength
   or
   2/3 of the minimum specified yield strength.

   For Class 2 and 3 valves the lesser of:

   1/4 of the minimum specified tensile strength
   or
   5/8 of the minimum specified yield strength.

   These values shall be selected for the appropriate temperature as specified in note 4.

5. A casting quality factor of 1.0 shall be assumed in satisfying these limits for Class 2 and 3 valves.

6. For bolted joints the bolt prestress is assumed to be equal to 2S. The bolt will not be considered overstressed until the bolt stress exceeds the bolt prestress.

VIII.3. Non-pressure Retaining Structures

For non-pressure retaining structures the stress limit will not exceed 90% of the specified minimum yield strength of the material.

IX. REVISION TO THIS STANDARD

Revisions to this standard must be approved by the Director of Evaluation & Analysis

X. REFERENCES

(1) Roark and Young, "Formulas for Stress and Strain," Chapter 9 (corresponds to K).

(2) Ibid, Article 7.10 (corresponds to F).

(3) Ibid, Article 7.14, Table 14 and Paz, et al., "Computer Determination of the Shear Center of Open and Closed Sections".

(4) Roark and Young, "Formulations for Stress and Strain", Chapter 9, Table 20, and Den Hartog "Advanced Strength of Materials," Chapter 1.

(5) Zudans, "Consistent Mass Matrix for Thick Beams," Section 2.

(6) Fishman, "Computation of Bending Modulus for Curved Beams."

(7) Rothbart, H.A., Mechanical Design and Systems Handbook, Section 20.

(8) Zudans, et al., "FELAP-TM, Finite Element Computer Program Input Description and User's Guide," Section III.2.

(9) Fishman, "Joint Release for Consistent Mass Elements," and Zudans, et al., "FELAP-TM, Finite Element Computer Program Theory Manual," Section 2.6.

(10) Ibid, Section 2.7.

(11) Roark and Young, "Formulas for Stress and Strain," Tables 1, 14, 20 and Fishman, Tung, Lin and Tsai, "Computation of Cross-Section Properties."

(12) Przemiencki, "Theory of Matrix Structural Analysis," Section 3.4; Zudans, "Survey of Advanced Structural Design Analysis Techniques", Section 2; and Archer, "Consistent Matrix Formulations for Structural Analysis Using Finite-Element Techniques."

(13) Harris and Crede, "Shock and Vibration Handbook," Volume 1, Section 2.

(14) "Theory for Real Eigenvalue Analysis," Nastran Theoretical Manual, Section 10.4.2.

(15) Zudans, et al., "FELAP$_{TM}$ Finite Element Computer Program Input Description and User's Guide," pp. 5-35, 38.

(16) Chu, et al., "Spectral Treatment of Actions of Three Earthquake Components on Structures."

(17) Timoshenko and Goodier, "Theory of Elasticity," Section 9; and ASME Boiler and Pressure Vessel Code, Section III, Article NB-3215.

(18) Fishman, "Analysis of Bolted Joint Configurations".

(19) ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components," Appendix I.

XI. BIBLIOGRAPHY

Archer, John S., "Consistent Matrix Formulations for Structural Analysis Using Finite-Element Techniques," AIAA Journal, Vol. 3, October, 1965, pp. 1910-1918.

ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components," Subsections NA and NB, American Society of Mechanical Engineers, 1974.

Chu, S.L., Amin, M. and Singh, S., "Spectral Treatment of Actions of Three Earthquake Components on Structures," Nuclear Engineering and Design 21 (1972), pp. 126-136.

Den Hartog, J.P., "Advanced Strength of Materials," McGraw Hill, 1952.

Fishman, Howard M., "Analysis of Bolted Joint Configurations," Franklin Institute Research Laboratories Technical Note, 1977.

Fishman, Howard M., "Computation of Bending Modulus for Curved Beams," Franklin Institute Research Laboratories Technical Note, 1977.

Fishman, Howard M., "Joint Release for Consistent Mass Matrix," Franklin Institute Research Laboratories Technical Note, 1977.

Fishman, H.M.; Tung, C.; Lin, Y.L.; and Tsai, H.C.; "Computation of Cross-Section Properties," Franklin Institute Research Laboratories Technical Note, 1977.

Harris, Cyril M. and Crede, Charles E., editors, "Shock and Vibration Handbook," Volume 1, McGraw-Hill, 1961.

"NASTRAN, Theoretical Manual," National Aeronautics and Space Administration, 1972.

Paz, M.; Strehl, C.P.; and Schrader, P.; "Computer Determination of the Shear Center of Open and Closed Sections," Computers & Structures, Vol. 6, 1976, pp. 117-125.

Przemiencki, J.S., "Theory of Matrix Structural Analysis," McGraw-Hill, 1968.

Rothbart, H.A., editor, "Mechanical Design and Systems Handbook," McGraw-Hill, 1964.

Roark, Raymond J. and Young, Warren C., "Formulas for Stress and Strain," Fifth Edition, McGraw-Hill, 1975.

Timoshenko, S. and Goodier, J.N., "Theory of Elasticity," McGraw-Hill, 1951.

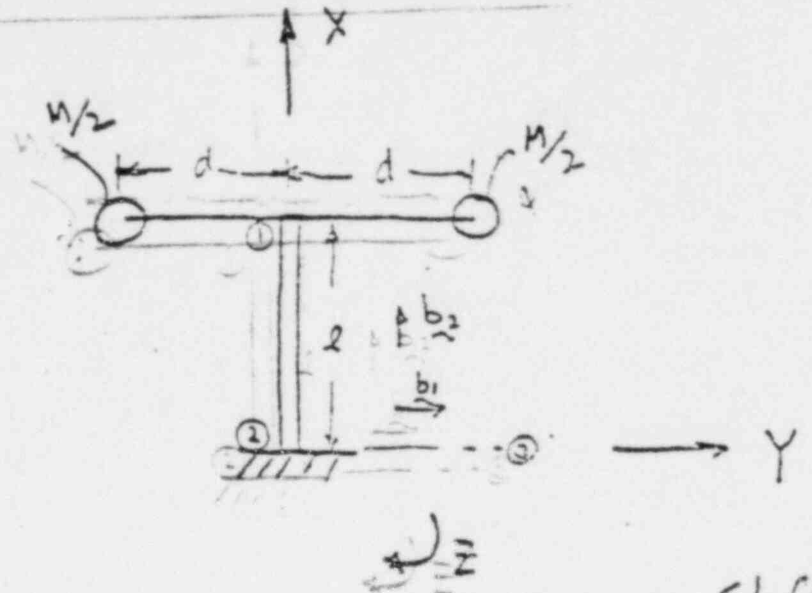
Zudans, Zenons, "Consistent Mass Matrix for Thick Beams," ASME Publication 76-WA/PVP-13, July, 1976.

Zudans, Zenons, "Survey of Advanced Structural Design Analysis Techniques," ASME Publication 69-DE-13, January, 1969.

Zudans, Z.; Fishman, H.M.; and Reddi, M.M., "FELAP$_{TM}$, Finite Element Computer Program Input Description and User's Guide," Franklin Institute Research Laboratories Technical Report, Fourth Revision, May, 1976.

Zudans, Z.; Fishman, H.M.; and Reddi, M.M.; "FELAP$_{TM}$, Finite Element Computer Program, Theory Manual," Franklin Institute Research Laboratories Technical Report, October, 1974.

APPENDIX B



$I_b = I_{11}$

$I_p = I_{22}$

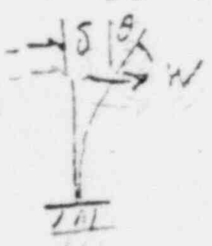
$I = I_{33}$

	Stiffness	Inertia
Axial Mode	$k_a = \dfrac{EA}{l}$	M
Bending Mode	$k_b = \dfrac{3EI_b}{l^3}$	M
Torsimal Mode	$k_t = \dfrac{I_p G}{l}$	Md^2

Bending + Rotation

$$k_r = \frac{2EI}{l^3}\begin{bmatrix} 6 & -3l \\ -3l & 2l^2 \end{bmatrix} \qquad \begin{bmatrix} M & 0 \\ 0 & Md^2 \end{bmatrix}$$

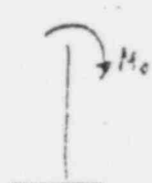
Derived from



$\delta = \dfrac{Wl^3}{3EI}$

$\theta = \dfrac{Wl^2}{2EI}$

&



$\delta = \dfrac{M_0 l^2}{2EI}$

$\theta = \dfrac{M_0 l}{EI}$

$$[M]\ddot{\underset{\sim}{X}} + [K]\underset{\sim}{X} = 0 \qquad \text{for} \quad \underset{\sim}{X} = \underset{\sim}{\bar{X}} e^{i\omega t}$$

$$\left[K - \omega^2 M\right]\underset{\sim}{\bar{X}} = 0$$

$$\left| K - \omega^2 M \right| = 0$$

Thus Axial mode $\omega_a = \sqrt{\frac{EA}{\ell M}}$

Simple Bending $\omega_b = \sqrt{\frac{3EI_b}{\ell^3 M}}$

Torsion Mode $\omega_t = \sqrt{\frac{I_p G}{\ell M d^2}}$

Bending + Rotation

$$\left| \frac{2EI}{\ell^3}\begin{bmatrix} 6 & -3\ell \\ -3\ell & 2\ell^2 \end{bmatrix} - \omega^2 M \begin{bmatrix} 1 & 0 \\ 0 & d^2 \end{bmatrix} \right| = 0$$

$$\begin{vmatrix} (6-\bar{\omega}^2) & -3\ell \\ -3\ell & \ell^2(2-\bar{\omega}^2\lambda) \end{vmatrix} = 0 \qquad \text{where} \quad \bar{\omega}^2 = \frac{M}{\left(\frac{2EI}{\ell^3}\right)}\omega^2$$

$$\lambda = (d/\ell)^2$$

$$(6-\bar{\omega}^2)\ell^2(2-\bar{\omega}^2\lambda) - 9\ell^2 = 0$$

$$\lambda\bar{\omega}^4 - 2(1+3\lambda)\bar{\omega}^2 + 3 = 0$$

$$\bar{\omega}^2 = \frac{(1+3\lambda) \pm \sqrt{1+3\lambda+9\lambda^2}}{\lambda}$$

It can be shown that negative sign may be taken for all $\lambda > 0$ (yielding smaller ω)

$$\omega_r = \sqrt{\frac{2EI}{M\ell d^2}\left[1 + 3\lambda - \sqrt{1 + 3\lambda + 9\lambda^2}\right]}$$

$$\lambda = \left(\frac{d}{\ell}\right)^2$$

Note for $d = \lambda = 0$ the limit becomes

$$\omega_r = \sqrt{\frac{3EI}{M\ell^3}}$$

Same as ω_b

Frequency in Hertz (or cps)

$$f = \frac{\omega}{2\pi}$$

AXIAL MODE

$$f_a = \frac{1}{2\pi}\sqrt{\frac{EA}{\ell M}}$$

SIMPLE BENDING MODE

$$f_b = f_a\sqrt{\frac{3 I_b}{\ell^2 A}}$$

TWISTING MODE

$$f_t = f_a\sqrt{\frac{G}{E}\frac{I_p}{d^2 A}}$$

BENDING + ROTATION MODE

$$f_r = f_a\sqrt{\frac{2I}{d^2A}\left(1+3\left(\frac{d}{\ell}\right)^2-\sqrt{1+3\left(\frac{d}{\ell}\right)^2+9\left(\frac{d}{\ell}\right)^4}\right)}$$

APPENDIX C

FISHER CONTROLS COMPANY

SEISMIC-4

SEISMIC ANALYSIS

OF

ROTARY VALVES

M A T E R I A L   P R O P E R T Y   I N P U T   D A T A

MAT. NO.	DESCRIPTION	YOUNG'S MOD/10(6)	POISSON'S RATIO	MASS DENS/10(-4)	ALLOWABLE STRESS/10(3)
1	SAMPLE MATERIAL	31.415	0.0	0.0	27.000

INPUT T[illegible]

CLOSED FORM SOLUTION [illegible]

DATE OF THIS REPORT / AUGUST 16, 1978

C O N T R O L I N P U T D A T A

MANUAL INPUT GENERATION FOR VALVE ANALYSIS

SEISMIC STRESSES ARE SUPERIMPOSED BY SQUARE ROOT OF SUM OF SQUARES

STRESS ALLOWABLES ARE COMPARED TO MAXIMUM PRINCIPAL STRESS

MASS, STIFFNESS, LOAD AND STRESS MATRICES ARE PRINTED

STATIC SEISMIC ANALYSIS TO BE PERFORMED

OPERATIONAL LOAD ANALYSIS TO BE PERFORMED

DYNAMIC MODAL ANALYSIS TO BE PERFORMED WITH EVALUATION

C R O S S - S E C T I O N D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS
1	MANUAL DATA	

JOINT COORDINATE DATA

JOINT NO.	X	Y	Z
1	10.000000	0.0	0.0
2	0.0	0.0	0.0
3	10.000000	-4.472000	0.0
4	10.000000	4.472000	0.0

BOUNDARY, SPRING & BOLT JOINT DATA

JOINT NO.	TYPE--REL /FIXITY	PLANE-DIRECTION OR DESCRIPTION	SPRING & BOLT JOINT PARAMETERS
2	111111	- OR	

CONCENTRATED MASS DATA

JOINT NO.	LUMPED MASS	FOR DIR.	SHIFT DISTANCE OR MOMENT OF INERTIA X	Y	Z
3	0.500000	XYZ	0.0	0.0	0.0
4	0.500000	XYZ	0.0	0.0	0.0

ELEMENT INPUT DATA

EL. NO.	JOINTS		LENGTH /RADIUS	ANGLE	AREA	MOMENTS OF INERTIA I-11	I-22	I-33	MATERIAL DESCRIPTION
1	1	2	10.0[illegible]		0.1250	30.0000	30.0000	30.0000	SAMPLE MATERIAL
	3	1			RIGID LINK				
	4	1			RIGID LINK				

S T A T I C   A N A L Y S I S

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM X DIR.

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.0000[illegible]	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0000[illegible]	0.0	0.0	0.0	0.0	0.0
4	0.0000[illegible]	0.0	0.0	0.0	0.0	0.0

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Y DIR.

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.0	0.000137	0.0	0.0	0.0	0.000020
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.000072	0.000137	0.0	0.0	0.0	0.000020
4	-0.000072	0.000137	0.0	0.0	0.0	0.000020

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Z DIR.

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.0	0.0	0.000137	0.0	-0.000020	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.000137	0.0	-0.000020	0.0
4	0.0	0.0	0.000137	0.0	-0.000020	0.0

DEFORMATION RESPONSE TO OPERATIONAL LOADS (NOT INCLUDING DEADWEIGHT)

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0

D Y N A M I C   A N A L Y S I S

RESONANT FREQUENCY = 94.7 HERTZ (IN X-DIRECTION OR Z-ROTATION)

* * * * NORMALIZED EIGENVECTOR * * * *

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	1.000000	0.000052	0.000002	0.000004	-0.000000	0.000009
2	0.0	0.0	0.0	0.0	0.0	0.0
3	1.000034	0.000052	-0.000017	0.000004	-0.000000	0.000009
4	0.999981	0.000052	0.000021	0.000004	-0.000000	0.000009

S T A T I C   S E I S M I C   A N A L Y S I S

THE VALVE AXIS IS POSITIONED X-UP

ACCELERATION OF GRAVITY, G = 386.400

DIRECTION OF SEISMIC ACCELERATION	NO. OF G'S	COMPONENTS OF UNIT ACCELERATION IN VALVE COORDINATE SYSTEM X-COMP.	Y-COMP.	Z-COMP.
HORIZONTAL(1)	2.000	0.0	0.0	1.0000
HORIZONTAL(2)	2.000	0.0	1.0000	0.0
VERTICAL	2.000	-1.0000	0.0	0.0

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

ELT. NO.	JNT. NO.	. ELEMENT FORCES . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	0.	0.	-773.	0.	0.	0.
	2	0.	0.	773.	7728.	0.	0.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	0.	0.	-773.	0.	7728.	0.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(Z) DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	773.	0.	0.	0.	0.	0.
	2	-773.	0.	0.	0.	0.	7726.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	0.	-773.	0.	0.	0.	-7726.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	0.	-773.	0.	0.	0.	0.
	2	0.	773.	0.	0.	0.	0.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	773.	0.	0.	0.	0.	0.

REACTION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

ELT. NO.	JNT. NO.	. .ELEMENT FORCES. . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	0.	-386.	0.	0.	0.	0.
	2	0.	386.	0.	0.	0.	0.

TYPE	JNT. NO.	. . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	386.	0.	0.	0.	0.	0.

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.0	0.000273	0.0	-0.000041	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.000273	0.0	-0.000041	0.0
4	0.0	0.0	0.000273	0.0	-0.000041	0.0

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.000273	0.0	0.0	0.0	0.000041
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.00018[illegible]	0.000273	0.0	0.0	0.0	0.000041
4	-0.00018[illegible]	0.000273	0.0	0.0	0.0	0.000041

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.001[illegible]	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.001[illegible]	0.0	0.0	0.0	0.0	0.0
4	-0.001[illegible]	0.0	0.0	0.0	0.0	0.0

DEFORMATION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-[illegible]	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-[illegible]	0.0	0.0	0.0	0.0	0.0
4	-[illegible]	0.0	0.0	0.0	0.0	0.0

[illegible] VALVE

DEFORMATION RESPONSE OF COMBINED STATIC SEISMIC AND OPERATIONAL LOADS

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.002454	[illegible]0273	0.000273	0.0	0.000041	0.000041
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.002454	[illegible]0273	0.000273	0.0	0.000041	0.000041
4	-0.002454	[illegible]0273	0.000273	0.0	0.000041	0.000041

BEAM STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS

ELM NO.	JNT NO.	STRESS NO.	COORDINATES C1	CS/2	C	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE
1	2	1	1.[illegible]	1.00	1.00	14.5	27.0	SAMPLE MATERIAL	0.54	

EDIT OF STRESS COMPONENTS ((FIBER.SHEAR).POINT

[illegible]	-0.	0.	0.	-[illegible].
[illegible]	0.	[illegible].	-[illegible].	-[illegible].
[illegible]	-0.	0.	-[illegible].	[illegible].
[illegible]	-3.	0.	-3.	[illegible].
[illegible]	-4.	4.	-4.	[illegible].

THIS EQUIPMENT IS ACCEPTABLE FOR THE SPECIFIED SEISMIC DISTURBANCE

THIS REPORT HAS BEEN PREPARED BY

KANU PATEL

Kanu Patel

FISHER CONTROLS COMPANY

SOLUTION FOR AXIAL MODE

LET $E = 10\pi \times 10^6$ $\quad G = E/2$

$A = 4\pi \times 10^{-2}$ $\quad d^2 = 20$

$l = 10$ $\quad I_b = I_p = I = 30$

$M = 1$

$$f_a = \frac{1}{2\pi}\sqrt{\frac{EA}{lM}} = \frac{1}{2\pi} \times \sqrt{\frac{10\pi \times 10^6 \times 4\pi \times 10^{-2}}{10 \times 1}} = 100$$

$$f_b = f_a \cdot \sqrt{\frac{3 I_b}{l^2 A}} = f_a \times \sqrt{\frac{3 \times 30}{(10)^2 \times 4\pi \times 10^{-2}}} = 2.67 f_a$$

$$f_t = f_a \sqrt{\frac{G}{E} \cdot \frac{I_p}{d^2 A}} = f_a \times \sqrt{\frac{1}{2} \times \frac{30}{20 \times 4\pi \times 10^{-2}}} = 2.44 f_a$$

$$f_r = f_a \sqrt{\frac{2I}{d^2 A}\left[1 + 3\left(\frac{d}{l}\right)^2 - \sqrt{1 + 3\left(\frac{d}{l}\right)^2 + 9\left(\frac{d}{l}\right)^4}\right]}$$

$$= f_a \sqrt{\frac{2 \times 30}{20 \times 4\pi \times 10^{-2}}\left[1 + 3\left(\frac{20}{100}\right) - \sqrt{1 + 3 \times \frac{20}{100} + 9 \times \left(\frac{1}{5}\right)^2}\right]}$$

$$= 2.18 f_a$$

IT IS OBSERVED FROM ABOVE THAT THE NATURAL FREQ. IS IN AXIAL MODE.

VERIFICATION PROBLEM 1.

REFER COMPUTER PRINTOUT.

STRUCTURE HAS ONE ELEMENT, ONE BOUNDARY JOINT, TWO MASSES.

$M_1 = M_2 = 193.2$ #

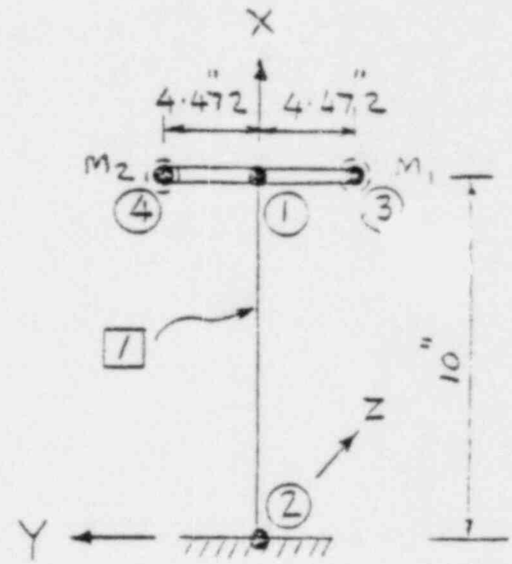
ELEMENT SECTION PROPERTIES:

$I_{11} = I_{22} = I_{33} = 30$ IN^4

$A = .125$ IN^2

$K_1 = K_3 = 0$

$C_1 = C_3 = C = 1$



MASS EQUIV. TO 2 G'S

$= 2(193.2 + 193.2)$

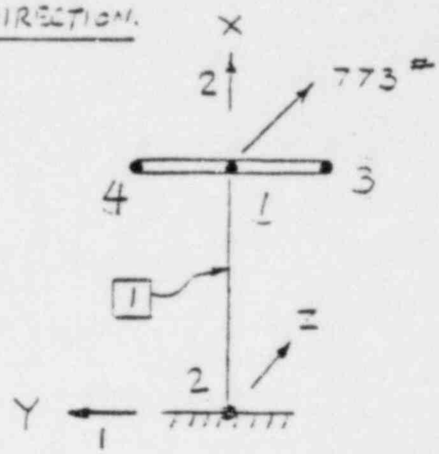
$= 772.8$ #

MOMENT @ 2

$= 772.8 \times 10 = 7728$ "#

MOMENT @ 1. $= 0$

CASE I. MASS ACTING IN HORIZONTAL (1) DIRECTION.



HORIZ. (1) DIRECTION IS +Z DIRECTION
(SEE PG. 4 COM. RUN)

+Z DIRECTION IS −3 DIRECTION
(SEE PG. 27, ES 117)

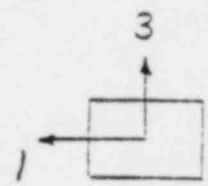
REACTION AT 1, $F_3 = -773^{\#}$

" AT 2, $F_3 = -773^{\#}$

MOMENT ABOUT Y-AXIS

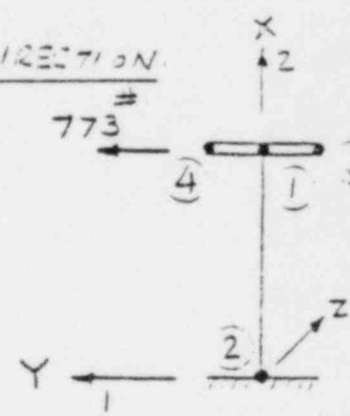
AT 1 $M_1 = 0$

AT 2 $M_1 = -7728''^{\#}$



TOP VIEW
ELEMENT SECTION

CASE II. MASS ACTING IN HORIZONTAL (2) DIRECTION.



REACTION AT 1, $F_1 = 773^{\#}$

" AT 2, $F_1 = -773^{\#}$

MOMENT ABOUT 3-AXIS

AT 2 $M_3 = 7728''^{\#}$

AT 1 $M_3 = 0$

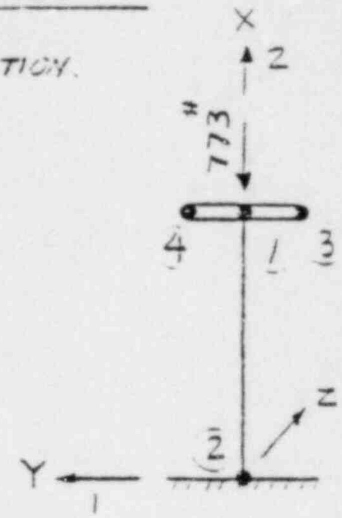
MOMENT ABOUT Z-AXIS

AT 2 $M_z = -7728''^{\#}$

SUBJECT VERIFICATION PROBLEM
BY V. PATEL DATE

CASE III MASS ACTING IN VERTICAL DIRECTION

IN THIS CASE MASS IS ACTING IN −X DIRECTION.



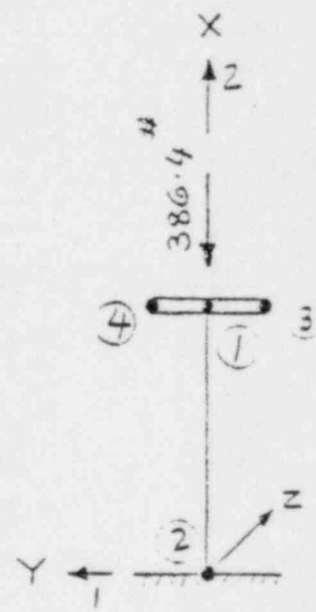
REACTION AT 1, $F_2 = -773^{\#}$

" AT 2, $F_2 = 773^{\#}$

MOMENT @ 1 = 0

" @ 2 = 0

CASE IV OPERATIONAL LOADS + DEADWEIGHT



REACTION AT 1, $F_2 = -386^{\#}$

" AT 2, $F_2 = 386^{\#}$

MOMENT @ 1 = 0

" @ 2 = 0

STRESS COMPUTATION

CASE I

FIBER STRESS — SHEAR STRESS

END 1.

$\sigma = 0$ — $\tau = \frac{.773}{.125} = 6.184$ ksi

END 2.

$\sigma = \frac{7.728 \times 1}{30} = .257$ KSI — $\tau = \frac{-0.773}{.125} = -6.184$ KSI

CASE II END 1. & 2.

SAME AS STRESSES IN CASE I.

CASE III.

AXIAL STRESS $= \frac{-.773}{.125} = -6.184$ ksi END 1 & 2

BENDING STRESS = 0 , SHEAR = 0

CASE IV.

AXIAL STRESS $= \frac{-.386}{.125} = -3.092$ ksi END 1 & 2

BENDING STRESS = 0 , SHEAR STRESS = 0

SUPERIMPOSED FIBER STRESS

END 1. $\sigma = -6.184 - 3.092 = -9.276$ KSI

END 2. $\sigma = \sqrt{(.257)^2 + (.257)^2 + (6.184)^2} - 3.092 = -9.28$ KSI

SUPERIMPOSED SHEAR STRESS

END 1. $\tau = \sqrt{(6.184)^2 + (6.184)^2} = 8.74$ KSI
(SAME FOR END 2)

MAX. STRESS

$$\tau_{MAX.} = \sqrt{\left(\frac{9.28}{2}\right)^2 + (8.74)^2} = 9.89 \text{ KSI}$$

$$\sigma_{P_{MAX.}} = \frac{9.28}{2} + 9.89 = 14.53 \text{ KSI}$$

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

APPENDIX D

MATERIAL PROPERTY INPUT DATA

MAT. NO.	DESCRIPTION	YOUNG'S MOD/10(6)	POISSON'S RATIO	MASS DENS/10(-4)	ALLOWABLE STRESS/10(3)
1	SAMPLE MATERIAL	31.415	0.0	0.0	27.000

INPUT [illegible]

CLOSE [illegible] 100 HZ

DATE OF THIS REPORT / AUGUST 15, 1978

C O N T R O L   I N P U T   D A T A

MANUAL INPUT GENERATION FOR VALVE ANALYSIS

SEISMIC STRESSES ARE SUPERIMPOSED BY SQUARE ROOT OF SUM OF SQUARES

STRESS ALLOWABLES ARE COMPARED TO MAXIMUM PRINCIPAL STRESS

MASS, STIFFNESS, LOAD AND STRESS MATRICES ARE PRINTED

STATIC SEISMIC ANALYSIS TO BE PERFORMED

OPERATIONAL LOAD ANALYSIS TO BE PERFORMED

DYNAMIC MODAL ANALYSIS TO BE PERFORMED WITH EVALUATION

C R O S S - S E C T I O N   D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS
1	MANUAL DATA	

JOINT COORDINATE DATA

JOINT NO.	X	Y	Z
1	10.000000	0.0	0.0
2	0.0	0.0	0.0
3	10.000000	-4.472000	0.0
4	10.000000	4.472000	0.0

BOUNDARY, SPRING & BOLT JOINT DATA

JOINT NO.	TYPE-FLEXIBILITY	PLANE-DIRECTION OR DESCRIPTION	SPRING & BOLT JOINT PARAMETERS
2	111111	4 CH	

CONCENTRATED MASS DATA

JOINT NO.	LUMPED MASS	FOR DIR.	SHIFT DISTANCE OR MOMENT OF INERTIA X	Y	Z
3	0.[illegible]00000	XYZ	0.0	0.0	0.0
4	0.[illegible]00000	XYZ	0.0	0.0	0.0

ELEMENT INPUT DATA

EL. NO.	JOINTS	LENGTH /RADIUS	ANGLE	AREA	MOMENTS OF INERTIA I-11	I-22	I-33	MATERIAL DESCRIPTION
1	1 2	10.000		12.5700	4.1-90	30.0000	30.0000	SAMPLE MATERIAL
	3 1			RIGID LINK				
	4 1			RIGID LINK				

S T A T I C   A N A L Y S I S

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM X DIR.

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.000001	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.000001	0.0	0.0	0.0	0.0	0.0
4	0.000001	0.0	0.0	0.0	0.0	0.0

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Y DIR.

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.0	0.000137	0.0	0.0	0.0	0.000020
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.000042	0.000137	0.0	0.0	0.0	0.000020
4	-0.000042	0.000137	0.0	0.0	0.0	0.000020

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Z DIR.

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.0	0.0	0.000979	0.0	-0.000147	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.000979	0.0	-0.000147	0.0
4	0.0	0.0	0.000979	0.0	-0.000147	0.0

DEFORMATION RESPONSE TO OPERATIONAL LOADS (NOT INCLUDING DEADWEIGHT)

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0

D Y N A M I C   A N A L Y S I S

RESONANT FREQUENCY = 100.0 HERTZ (IN Z-DIRECTION OR Y-ROTATION)

* * * * NORMALIZED EIGENVECTOR * * * *

JOINT NO.	. . . DEFLECTION X	Y	Z . . .	. . . ROTATION X	Y	Z . . .
1	[illegible]	[illegible]	1.000000	0.000003	-0.150000	0.000007
2	0.0	0.0	0.0	0.0	0.0	0.0
3	[illegible]	[illegible]	0.999997	0.000003	-0.150000	0.000007
4	-0.[illegible]	[illegible]	1.000012	0.000003	-0.150000	0.000007

S T A T I C   S E I S M I C   A N A L Y S I S

THE VALVE AXIS IS POSITIONED X-UP

ACCELERATION OF GRAVITY, G = 386.400

DIRECTION OF SEISMIC ACCELERATION	NO. OF G'S	COMPONENTS OF UNIT ACCELERATION IN VALVE COORDINATE SYSTEM X-COMP.	Y-COMP.	Z-COMP.
HORIZONTAL(1)	2.000	0.0	0.0	1.0000
HORIZONTAL(2)	2.000	0.0	1.0000	0.0
VERTICAL	2.000	-1.0000	0.0	0.0

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

ELT. NO.	JNT. NO.	. . ELEMENT FORCES . . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	0.	0.	-773.	-0.	0.	0.
	2	0.	0.	773.	7725.	0.	0.

TYPE	JNT. NO.	. . . . . . BOUNDARY OR JUNCTION REACTION . . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	0.	0.	-773.	0.	7725.	0.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(Z) DIRECTION

ELT. NO.	JNT. NO.	F1	F2	F3	M1	M2	M3
1	1	773.	0.	0.	0.	0.	0.
	2	-773.	0.	0.	0.	0.	7728.

. . ELEMENT FORCES . . / . ELEMENT MOMENTS .

TYPE	JNT. NO.	FX	FY	FZ	MX	MY	MZ
ANCH	2	0.	-773.	0.	0.	0.	-7728.

. . . . . BOUNDARY OR JUNCTION REACTION . . . . .

REACTION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

ELT. NO.	JNT. NO.	F1	F2	F3	M1	M2	M3
1	1	0.	-773.	0.	0.	0.	0.
	2	0.	773.	0.	0.	0.	0.

TYPE	JNT. NO.	FX	FY	FZ	MX	MY	MZ
ANCH	2	773.	0.	0.	0.	0.	0.

REACTION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

ELT. NO.	JNT. NO.	F1	F2	F3	M1	M2	M3
1	1	0.	-388.	0.	0.	0.	0.
	2	0.	388.	0.	0.	0.	0.

TYPE	JNT. NO.	FX	FY	FZ	MX	MY	MZ
ANCH	2	388.	0.	0.	0.	0.	0.

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.0	0.001957	0.0	-0.000294	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.001957	0.0	-0.000294	0.0
4	0.0	0.0	0.001957	0.0	-0.000294	0.0

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.000273	0.0	0.0	0.0	0.000041
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.000183	0.000273	0.0	0.0	0.0	0.000041
4	-0.000183	0.000273	0.0	0.0	0.0	0.000041

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.000020	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.000020	0.0	0.0	0.0	0.0	0.0
4	-0.000020	0.0	0.0	0.0	0.0	0.0

DEFORMATION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	[illegible]	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.000019	0.0	0.0	0.0	0.0	0.0
4	-0.000019	0.0	0.0	0.0	0.0	0.0

E V A L U A T I O N   O F   V A L V E

DEFORMATION RESPONSE OF COMBINED STATIC SEISMIC AND OPERATIONAL LOADS

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.000[illegible]	0.000273	0.001957	0.0	0.000244	0.000041
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.000[illegible]	0.000273	0.001957	0.0	0.000244	0.000041
4	-0.000[illegible]	0.000273	0.001957	0.0	0.000244	0.000041

BEAM STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS

ELM NO.	JNT NO.	STRESS NO.	COORDINATES CY	CZ/Z	C	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE
1	2	1	1.00	1.00	1.00	1.9	27.0	SAMPLE MATERIAL	0.07	

ELT OF STRESS COMPONENTS ((FIBER.SHEAR).POINT

NO				
1	0,	0,	2,	-[illegible],
2	0,	0,	-[illegible],	-[illegible],
3	-0,	0,	-[illegible],	[illegible],
4	-0,	0,	-[illegible],	[illegible],
SUM	-0,	0,	-2,	[illegible],

THIS EQUIPMENT IS ACCEPTABLE FOR THE SPECIFIED SEISMIC DISTURBANCE

THIS REPORT HAS BEEN PREPARED BY /

KANU PATEL

[signature]

FISHER CONTROLS COMPANY

SOLUTION FOR BENDING MODE

LET $E = 10\pi \times 10^6$ $\quad G = E/2$

$A = 4\pi$ $\quad d^2 = 20$

$l = 10$ $\quad I_b = \frac{4\pi}{3}$

$M = 1$ $\quad I_p = I = 30$

$$f_a = \frac{1}{2\pi} \cdot \sqrt{\frac{10\pi \times 10^6 \times 4\pi}{10 \times 1}} = 1000$$

$$f_b = f_a \cdot \sqrt{\frac{3 \times (4\pi/3)}{100 \times 4\pi}} = \cdot 1\, f_a$$

$$f_t = f_a \cdot \sqrt{\frac{1}{2} \times \frac{30}{20 \times 4\pi}} = \cdot 244\, f_a$$

$$f_r = f_a \sqrt{\frac{2 \times 30}{20 \times 4\pi} \left[1 + 3 \times \frac{1}{5} - \sqrt{1 + 3 \times \frac{1}{5} + 9 \times \frac{1}{25}}\right]} = \cdot 218\, f_a$$

IT IS OB[illegible]ED FROM ABOVE THAT THE NATURAL FREQ. [illegible] IN BENDING MODE.

VERIFICATION PROBLEM 2.

STRUCTURE HAS ONE ELEMENT, ONE BOUNDARY JOINT, TWO MASSES.

$M_1 = M_2 = 193.2$ #

ELEMENT SECTION PROPERTIES

$I_{11} = 4.189$

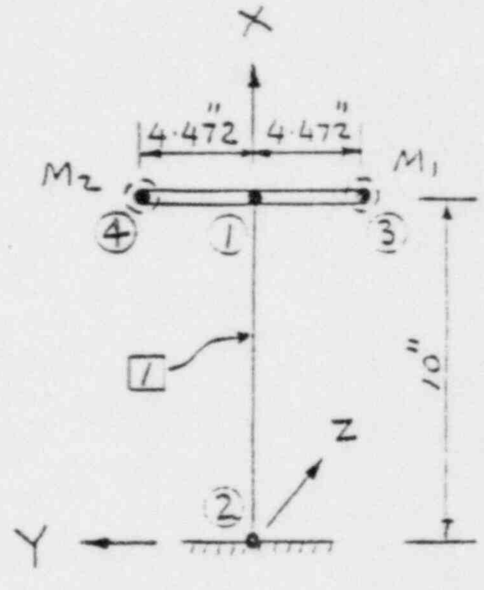
$I_{22} = 30$

$I_{33} = 30$

$A = 12.57$ in^2

$K_1 = K_3 = 0$

$C_1 = C_3 = C = 1$



MASS EQUIV TO 2 G's

= 2 (193.2 + 193.2)

= 772.8 #

MOMENT @ 2 = 772.8 × 10

= 7728 "#

MOMENT @ 1 = 0

CASE I. MASS ACTING IN HORIZONTAL (1) DIRECTION.

HORIZ. (1) DIRECTION IS +Z DIRECTION
(SEE PG. 4. COMP. RUN)

+Z DIRECTION IS −3 DIRECTION
(SEE PG. 27, ES 117)

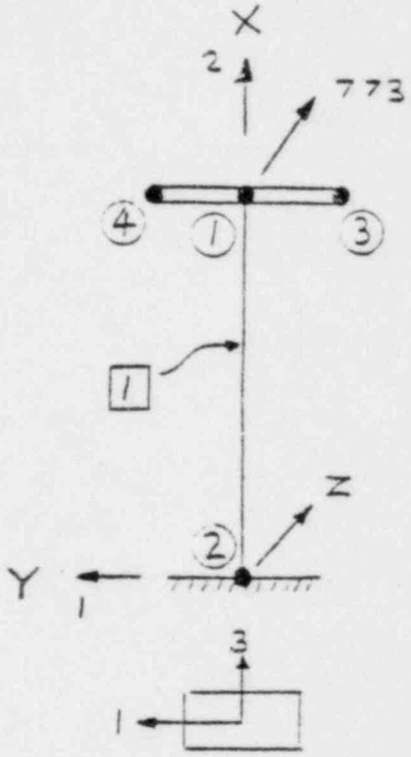
REACTION AT 1. $F_3 = -773^{\#}$

" AT 2. $F_3 = 773^{\#}$

MOMENT ABOUT Y-AXIS

AT 1. $M_1 = 0$

AT 2. $M_1 = 7728^{\#''}$



TOP VIEW
ELEMENT SECTION

CASE II. MASS ACTING IN HORIZ. (2) DIRECTION.

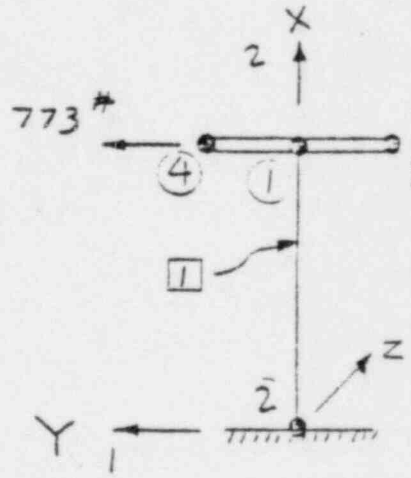
REACTION AT 1 $F_1 = 773^{\#}$

" AT 2 $F_1 = -773^{\#}$

MOMENT ABOUT Z-AXIS.

AT 2 $M_3 = -7728^{''\#}$

AT 1. $M_3 = 0$



FISHER CONTROLS COMPANY
CONTINENTAL DIVISION
Coraopolis, Pennsylvania 15108

ENGINEERING DATA

CASE III. MASS ACTING IN VERTICAL DIRECTION.

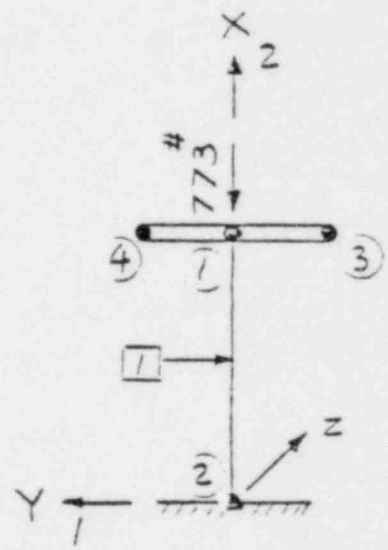
MASS IS ACTING IN (−)X DIRECTION.

REACTION AT 1. $F_2 = -773^{\#}$

" AT 2. $F_2 = -773^{\#}$

MOMENT @ 1 = 0

" @ 2 = 0



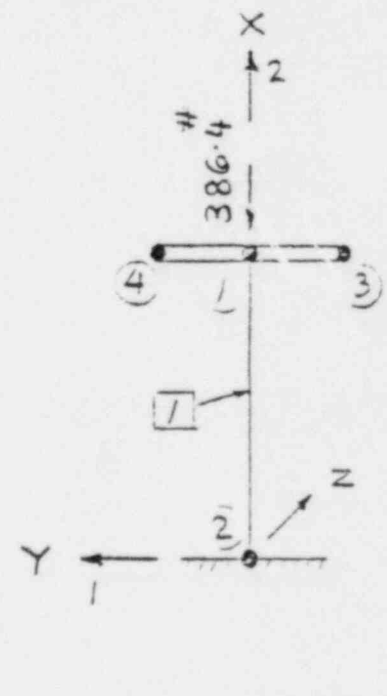
CASE IV OPERATIONAL LOADS + DEADWEIGHT.

REACTION AT 1. $F_2 = -386^{\#}$

" AT 2. $F_2 = 386^{\#}$

MOMENT @ 1. = 0

MOMENT @ 2. = 0



SUBJECT VERIFICATION PROBLEMS

BY K. PATEL DATE

STRESS COMPUTATION

CASE I.

FIBER STRESS

END 1. $M=0$

END 2. $\sigma = \frac{7.728 \times 1}{4.189} = 1.845$ ksi

SHEAR STRESS

$\tau = \frac{.773}{12.57} = .061$ ksi

$\tau = \frac{-.773}{12.57} = -.061$ ksi

CASE II.

END 1. SAME AS CASE I.

END 2. $\sigma = \frac{-7.728 \times 1}{30} = -.257$ ksi., $\tau = -.061$ ksi

CASE III

END 1 & 2 SHEAR STRESS IS ZERO AS ONLY AXIAL STRESS EXISTS.

AXIAL STRESS $= \frac{-.773}{12.57} = -.061$ ksi

BENDING STRESS = 0

FIBER STRESS = $-.061 + 0 = -.061$ ksi END 1 & 2

CASE IV.

AXIAL STRESS $= \frac{-.336}{12.57} = -.031$ ksi END 1 & 2

BENDING STRESS = 0

SHEAR STRESS = 0

SUPERIMPOSED FIBER STRESS

END 1. $-.061 - .031 = -.092$ ksi

END 2. $\sigma = \sqrt{(1.845)^2 + (.257)^2 + (.061)^2} - .031 = -1.877$ ksi

SUPERIMPOSED SHEAR STRESS.

END 1 & 2.

$$\tau = \sqrt{(.061)^2 + (.061)^2} = \pm .086 \text{ ksi}$$

MAXIMUM STRESS

$$\tau_{(MAX.)} = \sqrt{\left(\frac{1.877}{2}\right)^2 + (.086)^2} = \pm .942 \text{ ksi}$$

$$\sigma_{P(MAX.)} = \frac{1.877}{2} + .942 = 1.88 \text{ ksi}$$

APPENDIX E

MATERIAL PROPERTY INPUT DATA

MAT. NO.	DESCRIPTION	YOUNG'S MOD/10(6)	POISSON'S RATIO	MASS DENS/10(-4)	ALLOWABLE STRESS/10(3)
1	SAMPLE MATERIAL	31.415	0.0	0.0	27.000

INPUT [illegible]

CLOSED [illegible]

[illegible] THIS REPORT / AUGUST 16, 1978

C O N T R O L   I N P U T   D A T A

MANUAL INPUT GENERATION FOR VALVE ANALYSIS

SEISMIC STRESSES ARE SUPERIMPOSED BY SQUARE ROOT OF SUM OF SQUARES

STRESS ALLOWABLES ARE COMPARED TO MAXIMUM PRINCIPAL STRESS

MASS, STIFFNESS, LOAD AND STRESS MATRICES ARE PRINTED

STATIC SEISMIC ANALYSIS TO BE PERFORMED

OPERATIONAL LOAD ANALYSIS TO BE PERFORMED

DYNAMIC MODAL ANALYSIS TO BE PERFORMED WITH EVALUATION

C R O S S - S E C T I O N   D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS
1	[illegible]	

JOINT COORDINATE DATA

JOINT NO.	X	Y	Z
1	10.000000	0.0	0.0
2	0.0	0.0	0.0
3	10.000000	-4.472000	0.0
4	10.000000	4.472000	0.0

S P R I N G   A N D   B O L T   J O I N T   D A T A

JOINT NO.	TYPE-DIR XYZXYZ	FOR DIRECTION OR DESCRIPTION	SPRING & BOLT JOINT PARAMETERS
2	111111	C-	

C O N C E N T R A T E D   M A S S   D A T A

JOINT NO.	LUMPED MASS	FOR DIR.	SHIFT DISTANCE OR MOMENT OF INERTIA X	Y	Z
3	[illegible].5000	XYZ	0.0	0.0	0.0
4	[illegible].5000	XYZ	0.0	0.0	0.0

E L E M E N T   I N P U T   D A T A

EL. NO.	JOINTS		LENGTH	ANGLE Z-AXIS	AREA	MOMENTS OF INERTIA I-11	I-22	I-33	MATERIAL DESCRIPTION
1	1	2	1[illegible]		12.5700	30.0000	[illegible].0270	30.0000	SAMPLE MATERIAL
	3	1			RIGID LINK				
	4	1			RIGID LINK				

S T A T I C   A N A L Y S I S

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM X DIR.

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.000011	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.000014	0.0	0.0	0.0	0.0	0.0
4	0.000012	0.0	0.0	0.0	0.0	0.0

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Y DIR.

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.000137	0.0	0.0	0.0	0.000020
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.000054	0.000137	0.0	0.0	0.0	0.000020
4	-0.000054	0.000137	0.0	0.0	0.0	0.000020

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Z DIR.

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.0	0.000137	0.0	-0.000020	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.000137	0.0	-0.000020	0.0
4	0.0	0.0	0.000137	0.0	-0.000020	0.0

DEFORMATION RESPONSE TO OPERATIONAL LOADS (NOT INCLUDING DEADWEIGHT)

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0

D Y N A M I C   A N A L Y S I S

RESONANT FREQUENCY OF [illegible] HZ [illegible] HORIZ (IN Y-DIRECTION OR X-ROTATION)

* * * * NORMALIZED EIGENVECTOR * * * *

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	[illegible]	0.00[illegible]	0.0[illegible]	1.000000	-0.000001	0.000045
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0[illegible]	0.00[illegible]	-0.[illegible]	1.000000	-0.000001	0.000045
4	-[illegible]	[illegible]	-0.[illegible]	1.000000	-0.000001	0.000045

S T A T I C   S E I S M I C   A N A L Y S I S

THE VALVE AXIS IS POSITIONED [illegible]

ACCELERATION OF GRAVITY, G = 386.400

DIRECTION OF SEISMIC ACCELERATION	NO. OF G'S	COMPONENTS OF UNIT ACCELERATION IN VALVE COORDINATE SYSTEM X-COMP.	Y-COMP.	Z-COMP.
HORIZONTAL(1)	[illegible]	0.0	0.0	1.0000
HORIZONTAL(2)	[illegible]	0.0	1.0000	0.0
VERTICAL	[illegible]	-1.0000	0.0	0.0

REACTIONS [illegible] TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

ELT. NO.	JT. NO.	. ELEMENT FORCES . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	[illegible]	[illegible]	-773.	0.	0.	0.
	2	[illegible]	[illegible]	773.	7725.	0.	0.

TYPE	JT. NO.	. . . . . SUMMARY OF JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
[illegible]	2	[illegible]	[illegible]	-773.	0.	7725.	0.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(X) DIRECTION

ELT. NO.	JNT. NO.	. . ELEMENT FORCES . . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	773.	0.	0.	0.	0.	0.
	2	-773.	0.	0.	0.	0.	7720.

TYPE	JNT. NO.	. . . . . . SUMMARY OF JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	0.	-773.	0.	0.	0.	-7720.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

ELT. NO.	JNT. NO.	. . ELEMENT FORCES . . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	0.	-773.	0.	0.	0.	0.
	2	0.	773.	0.	0.	0.	0.

TYPE	JNT. NO.	. . . . . . SUMMARY OF JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	773.	0.	0.	0.	0.	0.

REACTION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

ELT. NO.	JNT. NO.	. . ELEMENT FORCES . . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	0.	-367.	0.	0.	0.	0.
	2	0.	367.	0.	0.	0.	0.

TYPE	JNT. NO.	. . . . . . SUMMARY OF JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	367.	0.	0.	0.	0.	0.

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.0	0.0	0.000273	0.0	-0.000041	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.000273	0.0	-0.000041	0.0
4	0.0	0.0	0.000273	0.0	-0.000041	0.0

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	0.0	0.000273	0.0	0.0	0.0	0.000041
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.000184	0.000273	0.0	0.0	0.0	0.000041
4	-0.000184	0.000273	0.0	0.0	0.0	0.000041

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.0000[illegible]	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.0000[illegible]	0.0	0.0	0.0	0.0	0.0
4	-0.0000[illegible]	0.0	0.0	0.0	0.0	0.0

DEFORMATION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

JOINT NO.	DEFLECTION X	DEFLECTION Y	DEFLECTION Z	ROTATION X	ROTATION Y	ROTATION Z
1	-0.0000[illegible]1	0.0	0.0	0.0	0.0	0.0
2	[illegible]	0.0	0.0	0.0	0.0	0.0
3	-0.0000[illegible]1	0.0	0.0	0.0	0.0	0.0
4	-0.0000[illegible]1	0.0	0.0	0.0	0.0	0.0

[illegible]

DEFORMATION [illegible] FOR COMBINED STATIC SEISMIC AND OPERATIONAL LOADS

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.[illegible]	[illegible].000273	0.000273	0.0	0.000041	0.000041
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.[illegible]	[illegible].000273	0.000273	0.0	0.000041	0.000041
4	-0.[illegible]	[illegible].000273	0.000273	0.0	0.000041	0.000041

BEAM STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS

ELM NO.	JNT NO.	STRESS NO.	COORDINATES C1	C3/2	C	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE
1	2	1	1.[illegible]	1.[illegible]	1.00	0.4	27.0	SAMPLE MATERIAL	0.02	

NO					EDIT OF STRESS COMPONENTS ((FIBER.SHEAR).POINT
1	-0.	0.	[illegible]	-[illegible]	
2	0.	0.	-0.	-[illegible]	
3	-0.	0.	-0.	[illegible]	
4	-0.	0.	-0.	[illegible]	
SUM	-0.	0.	-0.	[illegible]	

THIS EQUIPMENT IS ACCEPTABLE FOR THE SPECIFIED SEISMIC DISTURBANCE

THIS REPORT HAS BEEN PREPARED BY /

KANU PATEL

Kanu patel

FISHER CONTROLS COMPANY

SOLUTION FOR TWISTING MODE.

LET $E = 10\pi \times 10^6$ $\quad G = \frac{E}{2}$

$A = 4\pi$ $\quad d^2 = 20$

$l = 10$ $\quad I_b = I = 30$

$M = 1$ $\quad I_p = 1.6\pi$

$$f_a = \frac{1}{2\pi}\sqrt{\frac{10\pi \times 10^6 \times 4\pi}{10 \times 1}} = 1000$$

$$f_b = f_a \sqrt{\frac{3 \times 30}{100 \times 4\pi}} = .267\, f_a$$

$$f_t = f_a \sqrt{\frac{1}{2} \times \frac{1.6\pi}{20 \times 4\pi}} = .1\, f_a$$

$$f_r = f_a \sqrt{\frac{2 \times 30}{20 \times 4\pi}\left[1 + 3 \times \frac{1}{5} - \sqrt{1 + \frac{3}{5} + 9 \times \frac{1}{25}}\right]} = .218\, f_a$$

IT IS OBSERVED FROM ABOVE THAT THE NATURAL FREQ. IS IN TWISTING MODE.

VERIFICATION PROBLEM 3

STRUCTURE HAS ONE ELEMENT, ONE BOUNDARY JOINT, TWO MASSES

$M_1 = M_2 = 193.2^{\#}$

ELEMENT SECTION PROPERTIES.

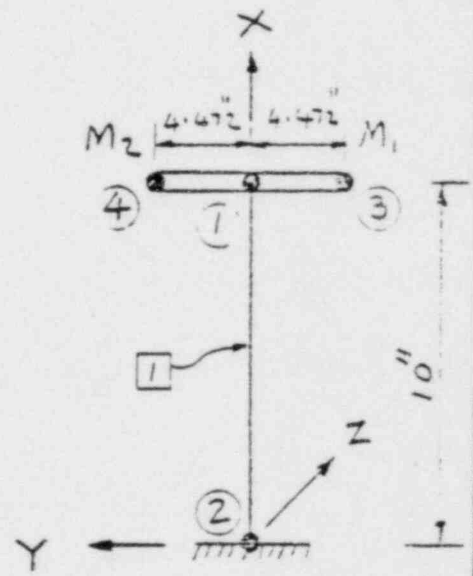
$I_{11} = I_{33} = 30$

$I_{22} = 5.027$

$A = 12.57 \ in^2$

$K_1 = K_3 = 0$

$C_1 = C_3 = C = 1$



MASS EQUIVALENT TO 2 G'S

$= 2(193.2 + 193.2)$

$= 772.8^{\#}$

MOMENT @ 2 $= 772.8 \times 10$

$= 7728 \ ''\#$

MOMENT @ 1 $= 0$

CASE I   MASS ACTING IN HORIZONTAL (1) DIRECTION.

HORIZ. (1) DIRECTION IS +Z DIRECTION
(SEE PG. 4. COMP. RUN)

+Z DIRECTION IS −3 DIRECTION
(PG. 27, ES 117)

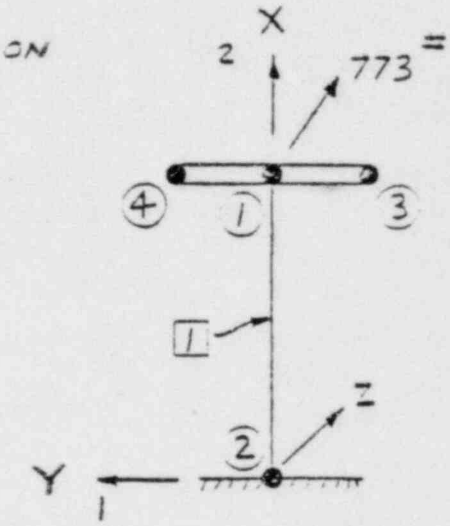
REACTION AT 1. $F_3 = -773^{\#}$

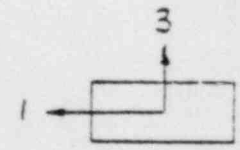
" AT 2. $F_3 = -773^{\#}$

MOMENT ABOUT Y-AXIS

AT 1 $M_1 = 0$

AT 2 $M_1 = 7728''^{\#}$





TOP VIEW
ELEMENT SECTION.

CASE II   HORIZONTAL (2) DIRECTION.

REACTION @ 1 $F_1 = 773^{\#}$

" @ 2 $F_1 = -773^{\#}$

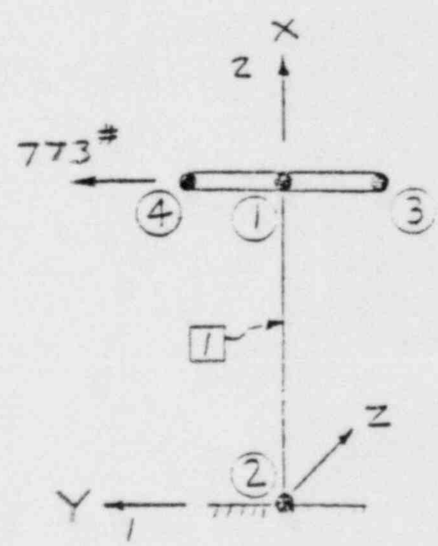
MOMENT @ 3-AXIS

AT 2 $M_3 = 7728''^{\#}$

AT 1 $M_3 = 0$

MOMENT ABOUT Z-AXIS

AT 2 $M_Z = = 7728''^{\#}$

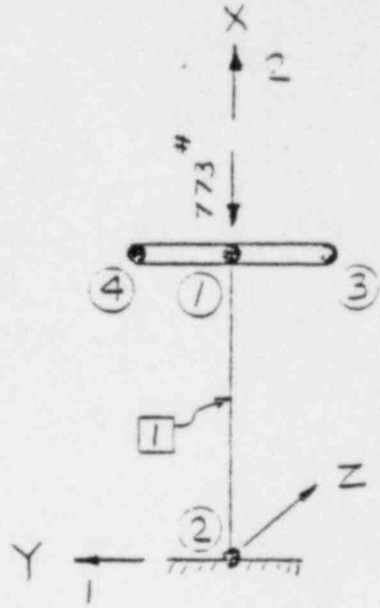


CASE III. VERTICAL DIRECTION

ACCELERATION ACTING IN (−) X DIRECTION.

REACTION AT 1 $F_2 = -773^{\#}$
AT 2 $F_2 = 773^{\#}$

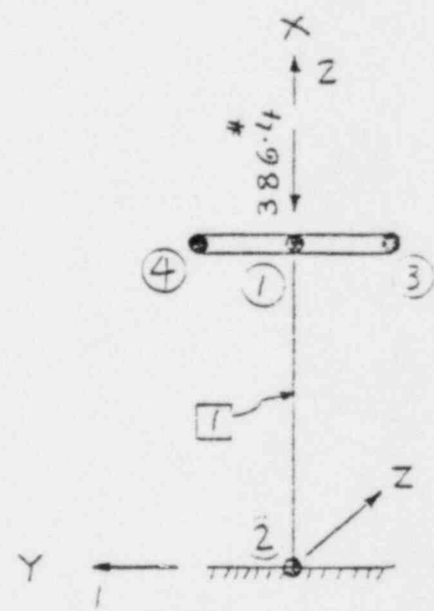
MOMENT @ 1 = 0
@ 2 = 0



CASE IV OPERATIONAL LOADS + DEADWEIGHT.

REACTION @ 1 $F_2 = -386^{\#}$
@ 2 $F_2 = 386^{\#}$

MOMENT @ 1 = 0
" @ 2 = 0



STRESS COMPUTATION.

CASE I

FIBER STRESS | SHEAR STRESS

END 1. $\sigma = 0$ $\tau = \frac{.773}{12.57} = .061$ KSI

END 2. $\sigma = \frac{7.728 \times 1}{30} = .257$ KSI $\tau = \frac{-.773}{12.57} = -.061$ KSI

CASE II.

END 1. $\sigma = 0$ $\tau = \frac{.773}{12.57} = .061$ KSI

END 2. $\sigma = \frac{-7.728 \times 1}{30} = -.257$ ksi $\tau = \frac{-.773}{12.57} = -.061$ KSI

CASE III

END 1. $\sigma = \underset{(BENDING)}{0} + \underset{(AXIAL)}{\left(\frac{-.773}{12.57}\right)}$ $\tau = 0$

$= -.061$ ksi

END 2. $\sigma = -.061$ ksi $\tau = 0$

CASE IV

END 1. $\sigma = \underset{(BENDING)}{0} + \underset{(AXIAL)}{\left(\frac{-.386}{12.57}\right)}$ $\tau = 0$

$= -.031$ ksi

END 2. $\sigma = -.031$ ksi $\tau = 0$

SUPERIMPOSED FIBER STRESS

END 1. $\sigma = -.061 - .031 = -.092$ ksi

END 2 $\sigma = \sqrt{(.257)^2 + (.257)^2 + (.061)^2} - .031 = -.4$ ksi

SUPERIMPOSED SHEAR STRESS

END 1 & 2 $\tau = \sqrt{(.061)^2 + (.061)^2} = 0.086$ ksi

MAXIMUM STRESS

$\tau_{MAX} = \sqrt{\left(\frac{.4}{2}\right)^2 + (.086)^2} = 0.217$ ksi

$\sigma_{p\,max} = \frac{.4}{2} + .217 = 0.417$ ksi

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

APPENDIX F

M A T E R I A L   P R O P E R T Y   I N P U T   D A T A

MAT. NO.	DESCRIPTION	YOUNG'S MOD/10(6)	POISSON'S RATIO	MASS DENS/10(-4)	ALLOWABLE STRESS/10(3)
1	SAMPLE MATERIAL	31.415	0.0	0.0	27.000

INPUT T[illegible] SOLUTION [illegible]

CLOSED FORM [illegible] HZ

DATE OF THIS REPORT / AUGUST 16, 1978

C O N T R O L   I N P U T   D A T A

MANUAL INPUT GENERATION FOR VALVE ANALYSIS

SEISMIC STRESSES ARE SUPERIMPOSED BY SQUARE ROOT OF SUM OF SQUARES

STRESS VALUES ARE COMPARED TO MAXIMUM PRINCIPAL STRESS

MASS, STIFFNESS, LOAD AND STRESS MATRICES ARE PRINTED

STATIC SEISMIC ANALYSIS TO BE PERFORMED

OPERATIONAL LOAD ANALYSIS TO BE PERFORMED

DYNAMIC MODAL ANALYSIS TO BE PERFORMED WITH EVALUATION

C R O S S - S E C T I O N   D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS
1	MANUAL INPUT.	

JOINT COORDINATE DATA

JOINT NO.	X	Y	Z
1	10.000000	0.0	0.0
2	0.0	0.0	0.0
3	10.000000	-4.472000	0.0
4	10.000000	4.472000	0.0

[illegible] SPRING & BOLT JOINT DATA

JOINT NO.	TYPE-[illegible] / FIXITY	[illegible] DESCRIPTION	SPRING & BOLT JOINT PARAMETERS
2	111111	[illegible]	

CONCENTRATED MASS DATA

JOINT NO.	LUMPED MASS	FOR. DIR.	SHIFT DISTANCE OR MOMENT OF INERTIA X	Y	Z
3	0.5000[illegible]	-12	0.0	0.0	0.0
4	0.500000[illegible]	-12	0.0	0.0	0.0

ELEMENT INPUT DATA

EL. NO.	JOINTS		LENGTH /RADIUS	ANGLE	AREA	MOMENTS OF INERTIA I-11	I-22	I-33	MATERIAL DESCRIPTION
1	1	2	10.0[illegible]		12.5700	30.0000	30.0000	[illegible].2800	SAMPLE MATERIAL
	3	1			RIGID LINK				
	4	1			RIGID LINK				

S T A T I C   A N A L Y S I S

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM X DIR.

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	[illegible]	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	[illegible]	0.0	0.0	0.0	0.0	0.0
4	[illegible]	0.0	0.0	0.0	0.0	0.0

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Y DIR.

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.000033	0.0	0.0	0.0	0.000096
2	0.0	0.0	0.0	0.0	0.0	0.0
3	[illegible]E-37	0.000033	0.0	0.0	0.0	0.000096
4	-[illegible]E-37	0.000033	0.0	0.0	0.0	0.000096

DEFORMATION RESPONSE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Z DIR.

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.0	0.000137	0.0	-0.000020	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.000137	0.0	-0.000020	0.0
4	0.0	0.0	0.000137	0.0	-0.000020	0.0

DEFORMATION RESPONSE TO OPERATIONAL LOADS (NOT INCLUDING DEADWEIGHT)

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0

[illegible] A N A L Y S I S

[illegible] HORIZ (1) DIRECTION OR Z-ROTATION)

* * * * NORMALIZED EIGENVECTOR * * * *

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	[illegible]	1.[illegible]	0.000150	0.000249	-0.000022	0.166665
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.745[illegible]	1.[illegible]	-0.000982	0.000249	-0.000022	0.166665
4	-0.745[illegible]	1.[illegible]	0.001262	0.000249	-0.000022	0.166665

S T A T I C   S E I S M I C   A N A L Y S I S

THE VALVE AXIS IS POSITIONED [illegible]

ACCELERATION OF GRAVITY, G = 386.400

DIRECTION OF SEISMIC ACCELERATION	NO. OF G'S	COMPONENTS OF UNIT ACCELERATION IN VALVE COORDINATE SYSTEM X-COMP.	Y-COMP.	Z-COMP.
HORIZONTAL(1)	2.000	0.0	0.0	1.0000
HORIZONTAL(2)	2.000	0.0	1.0000	0.0
VERTICAL	2.000	-1.0000	0.0	0.0

REACTIONS DUE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

ELT. NO.	JNT. NO.	. RESULTANT FORCES . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	0.	0.	-773.	0.	0.	0.
	2	0.	0.	773.	7726.	0.	0.

TYPE	JNT. NO.	. . . . . . BOUNDARY OR JUNCTION REACTION . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	0.	0.	-773.	0.	7724.	0.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(Z) DIRECTION

ELT. NO.	JNT. NO.	. . ELEMENT FORCES . . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	773.	0.	0.	0.	0.	-0.
	2	-773.	0.	0.	0.	0.	7726.

TYPE	JNT. NO.	. . . . . . BOUNDARY OR JUNCTION REACTION . . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	0.	-773.	0.	0.	0.	-7726.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

ELT. NO.	JNT. NO.	. . ELEMENT FORCES . . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	0.	-773.	0.	0.	0.	0.
	2	0.	773.	0.	0.	0.	0.

TYPE	JNT. NO.	. . . . . . BOUNDARY OR JUNCTION REACTION . . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	773.	0.	0.	0.	0.	0.

REACTION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

ELT. NO.	JNT. NO.	. . ELEMENT FORCES . . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	0.	[illegible]	0.	0.	0.	0.
	2	0.	[illegible]	0.	0.	0.	0.

TYPE	JNT. NO.	. . . . . . BOUNDARY OR JUNCTION REACTION . . . . . . FX	FY	FZ	MX	MY	MZ
ANCH	2	[illegible]	0.	0.	0.	0.	0.

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

JOINT	. . . DEFLECTION	. . .		. . . ROTATION	. . .	
NO.	X	Y	Z	X	Y	Z
1	0.0	0.0	0.000273	0.0	-0.000041	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.000273	0.0	-0.000041	0.0
4	0.0	0.0	0.000273	0.0	-0.000041	0.0

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

JOINT	. . . DEFLECTION	. . .		. . . ROTATION	. . .	
NO.	X	Y	Z	X	Y	Z
1	0.0	0.001308	0.0	0.0	0.0	0.000146
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.000276	0.001308	0.0	0.0	0.0	0.000146
4	-0.000276	0.001308	0.0	0.0	0.0	0.000146

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

JOINT	. . . DEFLECTION	. . .		. . . ROTATION	. . .	
NO.	X	Y	Z	X	Y	Z
1	-0.00002[illegible]	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.00002[illegible]	0.0	0.0	0.0	0.0	0.0
4	-0.00002[illegible]	0.0	0.0	0.0	0.0	0.0

DEFORMATION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

JOINT	. . . DEFLECTION	. . .		. . . ROTATION	. . .	
NO.	X	Y	Z	X	Y	Z
1	-0.000001	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.000001	0.0	0.0	0.0	0.0	0.0
4	-0.000001	0.0	0.0	0.0	0.0	0.0

E [illegible] F V [illegible] L V [illegible]

DEFORMATION RESPONSE OF COMBINED STATIC SEISMIC AND OPERATIONAL LOADS

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.00002[illegible]	0.001308	0.000273	0.0	0.000041	0.000146
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.[illegible]	0.001308	0.000273	0.0	0.000041	0.000146
4	-0.00002[illegible]	0.001308	0.000273	0.0	0.000041	0.000146

BEAM STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS

ELM NO.	JNT NO.	STRESS NO.	COORDINATES CI	D3/2	C	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE
1	2	1	1.[illegible]	1.00	1.08	1.3	27.0	SAMPLE MATERIAL	0.05	

EDIT OF STRESS COMPONENTS ((FIBER,SHEAR),POINT

NO				
1	-0.	0.	[illegible]	-0.
2	-0.	0.	-1.	-0.
3	-0.	0.	-0.	0.
4	-0.	0.	-0.	0.
SUM	-0.	0.	-1.	0.

THIS EQUIPMENT IS ACCEPTABLE FOR THE SPECIFIED SEISMIC DISTURBANCE

THIS REPORT HAS BEEN PREPARED BY /

RAMU PATEL

Kamu Patel

FISHER CONTROLS COMPANY

BENDING AND TWISTING MODE.

$E = 10\pi \times 10^6$ $\quad G = E/2$

$A = 4\pi$ $\quad d^2 = 20$

$l = 10$ $\quad I_b = I_p = 30$

$M = 1$ $\quad I = 2\pi$

$$f_a = 1000$$

$$f_b = .267\, f_a$$

$$f_t = f_a \sqrt{\frac{1}{2} \times \frac{30}{20 \times 4\pi}} = .244\, f_a$$

$$f_r = f_a \sqrt{\frac{2 \times 2\pi}{20 \times 4\pi} \left[.2 \right]} = .1\, f_a$$

IT IS OBSERVED FROM ABOVE THAT THE NATURAL FREQ. IS IN BENDING PLUS TWISTING MODE.

VERIFICATION PROBLEM 4

STRUCTURE HAS ONE ELEMENT, ONE BOUNDARY JOINT, TWO MASSES

$M_1 = M_2 = 193.2$ #

ELEMENT SECTION PROPERTIES

$I_{11} = 30 \quad I_{22} = 30$

$I_{33} = 6.28$

$A = 12.57 \text{ in}^2$

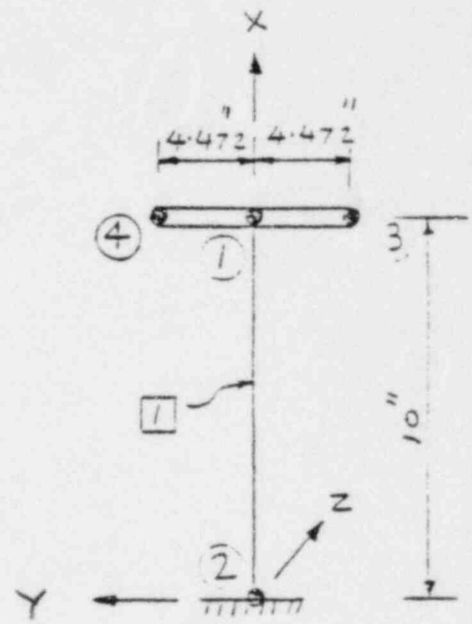
$K_1 = k_3 = 0$

$C_1 = C_3 = C = 1$

MASS EQUIVALENT TO 2G'S

$= 2(193.2 + 193.2)$

$= 772.8$ #



MOMENT AT 2 $= 772.8 \times 10$

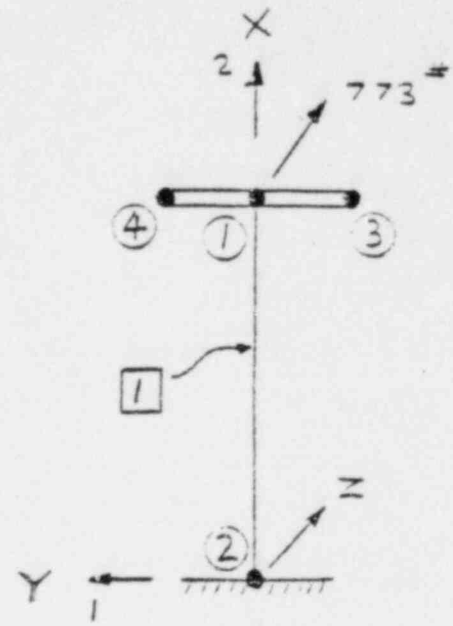
$= 7728$ "#

M AT 1 $= 0$

CASE I. MASS ACTING IN HORIZONTAL (1) DIRECTION.

HORIZ. (1) DIRECTION IS +Z DIRECTION
(SEE PG. 4. COMP. RUN)

+Z DIRECTION IS −3 DIRECTION
(SEE PG. 27, ES 117)



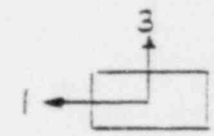
REACTION AT 1. $F_3 = -773^{\#}$

" AT 2. $F_3 = 773^{\#}$

MOMENT ABOUT Y-AXIS

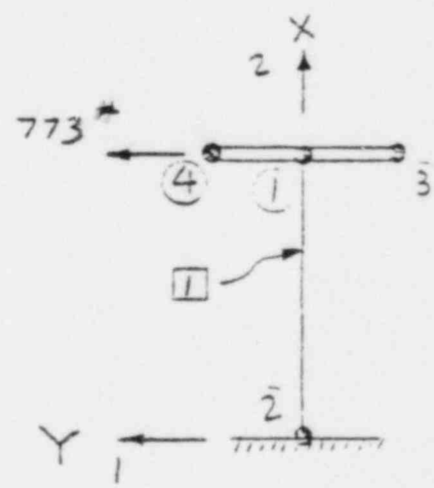
AT 1. $M_1 = 0$

AT 2. $M_1 = 7728^{\#''}$



TOP VIEW
ELEMENT SECTION

CASE II. MASS ACTING IN HORIZ. (2) DIRECTION.



REACTION AT 1 $F_1 = 773^{\#}$

" AT 2 $F_1 = -773^{\#}$

MOMENT ABOUT 3-AXIS.

AT 2 $M_3 = -7728^{''\#}$

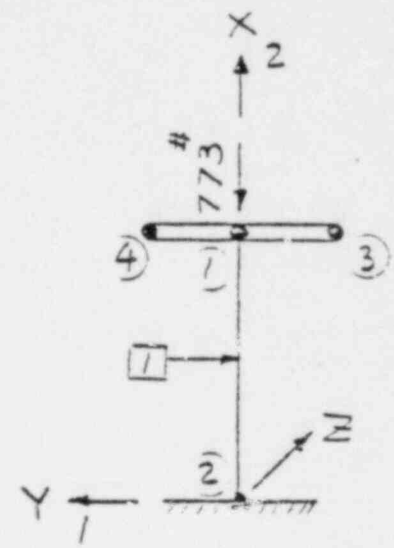
AT 1. $M_3 = 0$

MOMENT ABOUT Z-AXIS

AT 2 $M_Z = -7728^{\#''}$

CASE III. MASS ACTING IN VERTICAL DIRECTION.

MASS IS ACTING IN (−)X DIRECTION.



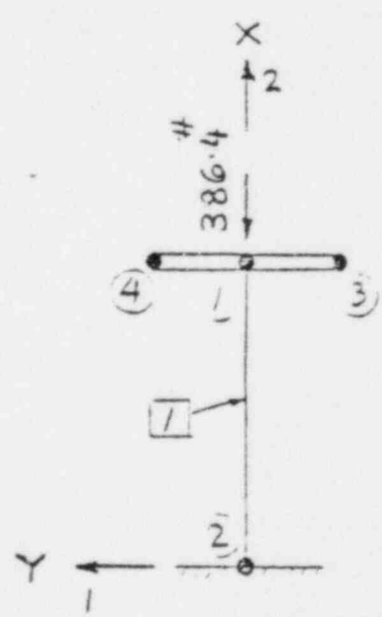
REACTION AT 1. $F_2 = -773^{\#}$

" AT 2. $F_2 = 773^{\#}$

MOMENT @ 1 = 0

" @ 2 = 0

CASE IV OPERATIONAL LOADS + DEADWEIGHT.



REACTION AT 1. $F_2 = -386^{\#}$

" AT 2. $F_2 = 386^{\#}$

MOMENT @ 1. = 0

MOMENT @ 2. = 0

STRESS COMPUTATION

CASE I

FIBER STRESS | SHEAR STRESS

END 1. $\sigma = 0$ $\quad \tau = \frac{.773}{12.57} = .061$ ksi

END 2. $\sigma = \frac{7.728 \times 1}{30} = .257$ ksi $\quad \tau = -.061$ ksi

CASE II

END 1. $\sigma = 0$ $\quad \tau = \frac{.773}{12.57} = .061$ ksi

END 2. $\sigma = \frac{-7.728 \times 1}{6.28} = -1.231$ ksi $\quad \tau = -.061$ ksi

CASE III

END 1. $\sigma = 0 + \left(-\frac{.773}{12.57}\right)$ $\quad \tau = 0$

$= -.061$ ksi

END 2. $\sigma = -.061$ ksi $\quad \tau = 0$

CASE IV

END 1. $\sigma = 0 + \left(-\frac{.386}{12.57}\right)$ $\quad \tau = 0$

$= -.031$ ksi

END 2. $\sigma = -.031$ ksi $\quad \tau = 0$

SUPERIMPOSED FIBER STRESS

END 1. $\sigma = 0 - .061 - .031 = -.092$ ksi

END 2 $\sigma = \sqrt{(.257)^2 + (1.231)^2 + (.061)^2} - .031 = -1.29$ ksi

SUPERIMPOSED SHEAR STRESS

END 1 & 2 $\tau = \sqrt{(.061)^2 + (.061)^2} = .086$ ksi

MAXIMUM STRESS

$\tau_{(MAX)} = \sqrt{\left(\frac{1.29}{2}\right)^2 + (.086)^2} = .65$ ksi

$\sigma_{(MAX)} = \frac{1.29}{2} + .65 = 1.295$ ksi

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

APPENDIX G

M A T E R I A L   P R O P E R T Y   I N P U T   D A T A

MAT. NO.	DESCRIPTION	YOUNG'S MOD/10(6)	POISSON'S RATIO	MASS DENS/10(-4)	ALLOWABLE STRESS/10(3)
1	SAMPLE MATERIAL	31.415	0.0	0.0	27.000

[illegible]

DATE OF THIS REPORT [illegible] AUGUST 15, 1978

C O N T R O L   I N P U T   D A T A

MANUAL I [illegible] GENERATION FOR VALVE ANALYSIS

SEISMIC STRESSES ARE SUPERIMPOSED BY SQUARE ROOT OF SUM OF SQUARES

STRESS ALLOWABLES ARE COMPARED TO MAXIMUM PRINCIPAL STRESS

MASS, STIFFNESS, LOAD AND STRESS MATRICES ARE [illegible] PRINTED

STATIC SEISMIC ANALYSIS TO BE PERFORMED

OPERATIONAL LOAD ANALYSIS TO BE PERFORMED

DYNAMIC MODAL ANALYSIS TO BE PERFORMED WITH EVALUATION

C R O S S - S E C T I O N   D A T A

EL. NO.	CROSS-SECTION DESCRIPTION	PARAMETERS
1	MANUAL DATA	

JOINT COORDINATE DATA

JOINT NO.	X	Y	Z
1	1[illegible]	0.0	0.0
2	[illegible]	0.0	0.0
3	1[illegible]	-4.472000	0.0
4	1[illegible]	4.472000	0.0

B O U N D A R Y   S P R I N G   &   B O L T   J O I N T   D A T A

JOINT NO.	TYPE - ACTIVITY	[illegible] OR DESCRIPTION	SPRING & BOLT JOINT PARAMETERS
2	111111	[illegible]	

[illegible] DATA

JOINT NO.	[illegible] MASS	[illegible]	X	Y	Z
3	[illegible] +12	0.0	0.0	0.0	
4	[illegible] +12	0.0	0.0	0.0	

E L E M E N T I N P U T D A T A

EL. NO.	JOINTS	LENGTH	ANGLE Z-AXIS	AREA	MOMENTS OF INERTIA I-11	I-22	I-33	MATERIAL DESCRIPTION
1	1 2	1[illegible]		12.5700	3.1400	47.3100	50.2700	SAMPLE MATERIAL
	3 1			RIGID LINK				
	4 1			RIGID LINK				

[illegible]

DEFORMATION RESPONSE DUE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM X DIR.

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	[illegible]	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	[illegible]	0.0	0.0	0.0	0.0	0.0
4	[illegible]	0.0	0.0	0.0	0.0	0.0

DEFORMATION RESPONSE DUE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Y DIR.

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	[illegible]	0.0	0.0	0.0	0.000012
2	0.0	0.0	0.0	0.0	0.0	0.0
3	[illegible]	[illegible]	0.0	0.0	0.0	0.000012
4	[illegible]	[illegible]	0.0	0.0	0.0	0.000012

DEFORMATION RESPONSE DUE TO 1 G GRAVITATIONAL LOAD IN VALVE SYSTEM Z DIR.

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.0	0.001305	0.0	-0.000146	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.001305	0.0	-0.000146	0.0
4	0.0	0.0	0.001305	0.0	-0.000146	0.0

DEFORMATION RESPONSE TO OPERATIONAL LOADS (NOT INCLUDING DEADWEIGHT)

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0

[illegible] ANALYSIS

RESPONSE [illegible] HORIZ (1) Z-DIRECTION OR Y-ROTATION)

* * * * NORMALIZED EIGENVECTOR * * * *

JOINT NO.	. . . DEFLECTION X	Y	Z . . .	. . . ROTATION X	Y	Z . . .
1	[illegible]	[illegible]	1.000000	0.000003	-0.150000	0.000003
2	[illegible]	0.0	0.0	0.0	0.0	0.0
3	[illegible]	[illegible]	0.999967	0.000003	-0.150000	0.000003
4	[illegible]	[illegible]	1.000011	0.000003	-0.150000	0.000003

S T A T I C S E I S M I C A N A L Y S I S

THE VALVE AXIS IS POSITIONED [illegible]

ACCELERATION OF GRAVITY, G = 386.400

DIRECTION OF SEISMIC ACCELERATION	NO. OF G'S	COMPONENTS OF UNIT ACCELERATION IN VALVE COORDINATE SYSTEM X-COMP.	Y-COMP.	Z-COMP.
HORIZONTAL(1)	2.000	0.0	0.0	1.0000
HORIZONTAL(2)	2.[illegible]	0.0	1.0000	0.0
VERTICAL	2.000	-1.0000	0.0	0.0

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

ELT. NO.	JNT. NO.	. . ELEMENT FORCES . . F1	F2	F3	. ELEMENT MOMENTS . M1	M2	M3
1	1	[illegible].	[illegible].	-773.	0.	0.	0.
	2	[illegible].	[illegible].	773.	7726.	[illegible].	0.

TYPE	JNT. NO.	. . . . . . BOUNDARY OR JUNCTION REACTION . . . . . . FX	FY	FZ	MX	MY	MZ
[illegible]	2	[illegible].	[illegible].	-773.	[illegible].	7726.	0.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN HORIZONTAL DIRECTION

ELT. NO.	JNT. NO.	F1	F2	F3	M1	M2	M3
		. . ELEMENT FORCES . .			. ELEMENT MOMENTS .		
1	1	773.	[illegible]	0.	0.	0.	0.
	2	-773.	0.	0.	0.	0.	7720.

TYPE	JNT. NO.	FX	FY	FZ	MX	MY	MZ
		. . . . . SUMMARY OF JUNCTION REACTION					
ANCH	2	[illegible]	-773.	0.	0.	0.	-7720.

REACTION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

ELT. NO.	JNT. NO.	F1	F2	F3	M1	M2	M3
		. . ELEMENT FORCES . .			. ELEMENT MOMENTS .		
1	1	0.	-773.	0.	0.	0.	0.
	2	0.	773.	0.	0.	0.	0.

TYPE	JNT. NO.	FX	FY	FZ	MX	MY	MZ
		. . . . . SUMMARY OF JUNCTION REACTION					
ANCH	2	773.	[illegible]	0.	0.	0.	0.

REACTION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

ELT. NO.	JNT. NO.	F1	F2	F3	M1	M2	M3
		. . ELEMENT FORCES . .			. ELEMENT MOMENTS .		
1	1	0.	-3[illegible].	0.	0.	0.	0.
	2	0.	3[illegible].	0.	0.	0.	0.

TYPE	JNT. NO.	FX	FY	FZ	MX	MY	MZ
		. . . . . SUMMARY OF JUNCTION REACTION					
ANCH	2	3[illegible].	[illegible]	0.	0.	0.	0.

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(1) DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.0	0.002511	0.0	-0.000342	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.002511	0.0	-0.000342	0.0
4	0.0	0.0	0.002511	0.0	-0.000342	0.0

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN HORIZ(2) DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	0.0	0.000163	0.0	0.0	0.0	0.000024
2	0.0	0.0	0.0	0.0	0.0	0.0
3	[illegible]	0.000163	0.0	0.0	0.0	0.000024
4	-0.000104	0.000153	0.0	0.0	0.0	0.000024

DEFORMATION RESPONSE TO STATIC SEISMIC LOAD IN VERTICAL DIRECTION

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.000026	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.000026	0.0	0.0	0.0	0.0	0.0
4	-0.000026	0.0	0.0	0.0	0.0	0.0

DEFORMATION RESPONSE TO OPERATIONAL LOADS (INCLUDING DEADWEIGHT)

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	[illegible]	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	[illegible]	0.0	0.0	0.0	0.0	0.0
4	[illegible]	0.0	0.0	0.0	0.0	0.0

[illegible]

DEFORMATION [illegible] FOR COMBINED STATIC SEISMIC AND OPERATIONAL LOADS

JOINT NO.	. . . DEFLECTION . . . X	Y	Z	. . . ROTATION . . . X	Y	Z
1	-0.[illegible]	0.000153	0.002511	0.0	0.000342	0.000024
2	0.0	0.0	0.0	0.0	0.0	0.0
3	-0.[illegible]121	0.000153	0.002511	0.0	0.000342	0.000024
4	-0.[illegible]121	0.000153	0.002511	0.0	0.000342	0.000024

BEAM STRESS FOR COMBINED STATIC AND OPERATIONAL LOADS

ELM NO.	JNT NO.	STRESS NO.	COORDINATES CY	CZ/2	C	STRESS/10(3) SMAX	SAL	MATERIAL DESCRIPTION	SMAX /SAL	NOTE
1	2	1	[illegible]	1.00	1.00	2.[illegible]	27.6	SAMPLE MATERIAL	0.0[illegible]	

EXIT OF STRESS COMPONENTS ((FIBER+SHEAR)+POINT

NO				
1	0.	0.	2.	-0.
2	0.	0.	-1.	-0.
3	-0.	0.	-1.	0.
4	-0.	0.	-1.	0.
SUM	-0.	0.	-2.	.

THIS [illegible] IS ACCEPTABLE FOR THE SPECIFIED SEISMIC DISTURBANCE

THIS REPORT HAS BEEN PREPARED BY /

KANU PATEL

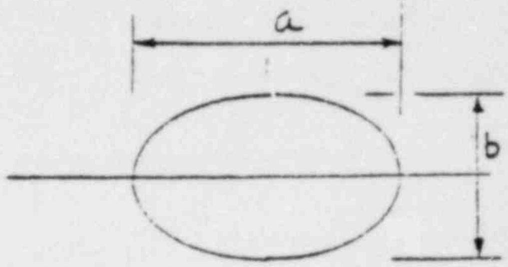
Kanu Patel

FISHER CONTROLS COMPANY

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION
Coraopolis, Pennsylvania 15108

ENGINEERING DATA

CONSIDER ELLIPTICAL CROSS-SECTION



$$A = \frac{\pi a b}{4}$$

$$I_b = \frac{\pi a b^3}{64} = \frac{b^2}{16} A$$

$$I_p = \frac{\pi a^3 b^3}{4(a^2+b^2)} = \frac{a^2 b^2}{(a^2+b^2)} \cdot A$$

$$I = \frac{\pi b a^3}{64} = \frac{a^2}{16} A$$

LET $a = 8$, $b = 2$

$A = 4\pi$, $I_b = \frac{1}{4} A = \pi$

$I_p = \frac{64}{17} A = \frac{256}{17} \pi$, $I = 4A = 16\pi$

LET $E = 10\pi \times 10^6$ $G = E/2$

$l = 10$ $d^2 = 20$

$M = 1$

$$f_a = \frac{1}{2\pi} \sqrt{\frac{10\pi \times 10^6 \times 4\pi}{10 \times 1}} = 1000$$

$$f_b = f_a \sqrt{\frac{3}{10^2} \times \frac{1}{4}} = 50\sqrt{3} = 86.602$$

$$f_t = f_a \sqrt{\frac{1}{2} \times \frac{64}{17} \times \frac{1}{20}} = 306.78$$

$$f_r = f_a \sqrt{\frac{2 \times 4}{20} \left[\cdot 2 \right]} = 282.84$$

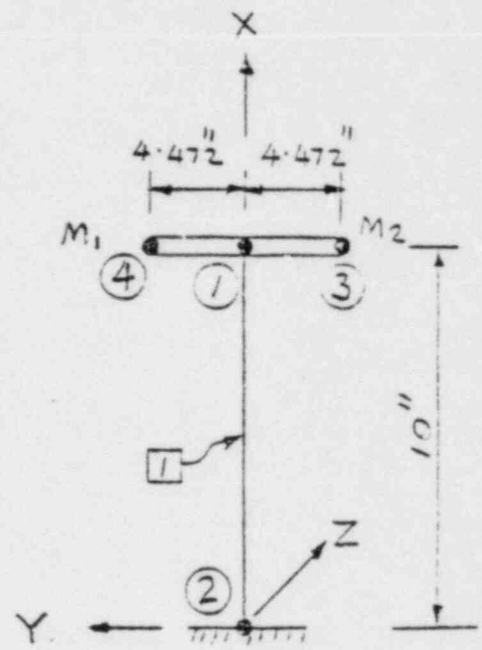
SUBJECT VERIFICATION PROBLEMS

BY K. PATEL DATE

VERIFICATION PROBLEM 5

STRUCTURE HAS ONE ELEMENT, ONE BOUNDARY JOINT AND TWO MASSES.

$M_1 = M_2 = 193.2$ #



ELEMENT SECTION PROPERTIES

$I_{11} = 3.14$

$I_{22} = 47.31$

$I_{33} = 50.27$

$A = 12.57$ in^2

$K_1 = k_3 = 0$

$C_1 = C_3 = C = 1$

MASS EQUIVALENT TO 2G's

$= 2(193.2 + 193.2) = 772.8$ #

MOMENT AT 2 $= 772.8 \times 10$

$= 7728$ "#

" AT 1 $= 0$

CASE I MASS ACTING IN HORIZONTAL (1) DIRECTION

HORIZ. (1) DIRECTION IS +Z DIRECTION
(SEE PG. 4 COMP RUN)

+Z DIRECTION IS -3 DIRECTION
(SEE PG. 27, ES ...T)

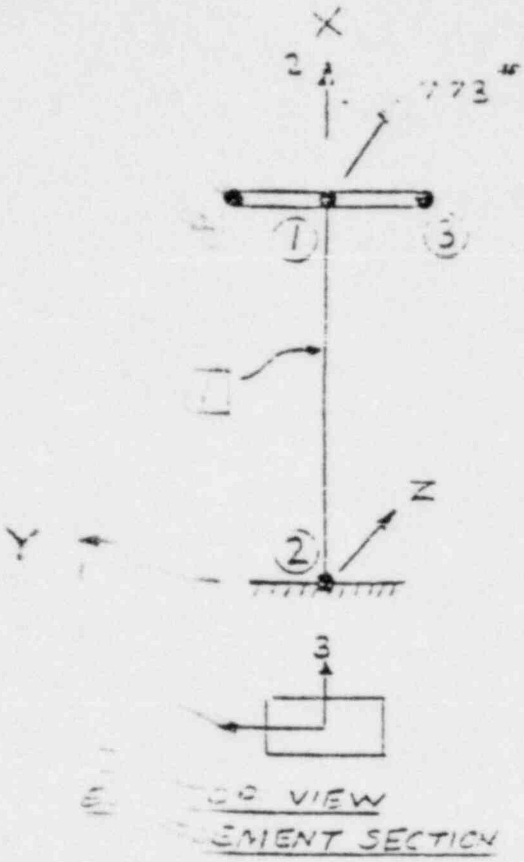
REACTION AT 1 $F_3 = -773$ #

" AT 2 $F_3 = 773$ #

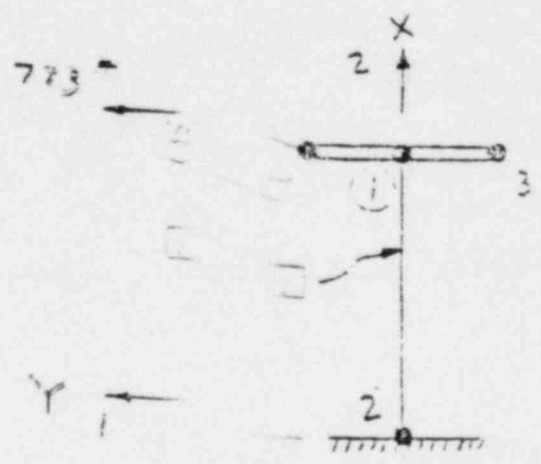
MOMENT ABOUT Y-AXIS

AT 1 $M_1 = 0$

AT 2 $M_1 = 7728$ #"



CASE II MASS ACTING IN HORIZ (2) DIRECTION



REACTION AT 1 $F_1 = 773$ #

" AT 2 $F_1 = -773$ #

MOMENT ABOUT 3-AXIS

AT 2 $M_3 = 7728$ "#

AT 1. $M_3 = 0$

MOMENT ABOUT Z-AXIS

AT 2. $M_Z = -7728$ #"

CASE III. MASS ACTING IN VERTICAL DIRECTION.

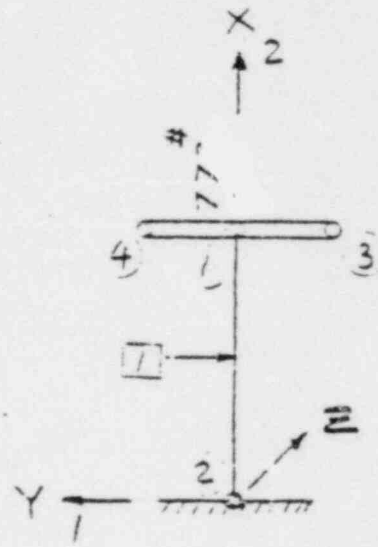
MASS IS ACTING IN (−)X DIRECTION.

REACTION AT 1. $F_2 = -773$ #

" AT 2. $F_2 = 773$ #

MOMENT @ 1 = 0

" @ 2 = 0



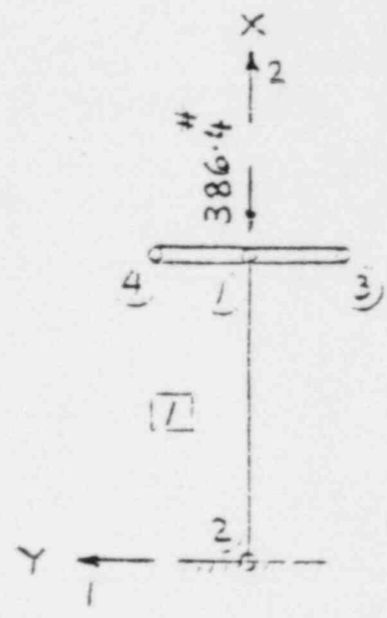
CASE IV OPERATIONAL LOADS + DEADWEIGHT

REACTION AT 1. $F_2 = -386$ #

" AT 2. $F_2 = 386$ #

MOMENT @ 1. = 0

MOMENT @ 2 = 0



STRESS COMPUTATION

CASE I

	FIBER STRESS	SHEAR STRESS
END 1	$\sigma = 0$	$\tau = \frac{.773}{12.57} = .061$ ksi
END 2.	$\sigma = \frac{7.728 \times 1}{3.14} = 2.461$ ksi	$\tau = -.061$ ksi

CASE II

END 1.	$\sigma = 0$	$\tau = .061$ ksi
END 2.	$\sigma = \frac{-7.728 \times 1}{50.27} = -.154$ ksi	$\tau = -.061$ ksi

CASE III

END 1.	$\sigma = 0 + \left(\frac{-.773}{12.57}\right) = -.061$ ksi	$\tau = 0$
END 2.	$\sigma = -.061$ ksi	$\tau = 0$

CASE IV

END 1.	$\sigma = 0 + \left(\frac{-.386}{12.57}\right) = -.031$ ksi	$\tau = 0$
END 2.	$\sigma = -.031$ ksi	$\tau = 0$

SUPERIMPOSED FIBER STRESS

END 1. $\sigma = -.061 - .031 = -.092$ ksi

END 2. $\sigma = \sqrt{(2.461)^2 + (.154)^2 + (.061)^2} - .031$

$= -2.497$ ksi

SUPERIMPOSED SHEAR STRESS

END 1 & 2. $\tau = \sqrt{(.061)^2 + (.061)^2} = .086$ ksi

MAXIMUM STRESS

$\tau_{(MAX)} = \sqrt{\left(\frac{2.497}{2}\right)^2 + (.086)^2} = 1.251$ ksi

$\sigma_{(MAX)} = \frac{2.497}{2} + 1.251 = 2.5$ ksi

11

Attachment 11 - Continental Order Write-Ups

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

PAGE 1 OF 3

FISHER Controls

NO. 5A094-01

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE			
181104		1-3-75	EXPORT BOX ☒ FINAL INSP. ☒	NUCLEAR CLASS 2	SERIAL NO. 3F225151
AGENT ORDER NO. 14-62496-A	ITEM # 1	REV. 3 REV. DATE 12/6/77	CUST. DATA ☒ HOLD FOR DWG. APP'L. ☐	CONTINENTAL QUALITY LEVEL 2	SCH'D. SHIP DATE

01141

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
BOX 240, ROUTE 1,
MARSEILLES, ILL. 61341
ATTN: A. W. KLEINRATH,
CONTRACT SECTION

SHIP TO: LATER

VIA.

ENGINEERING

A — VALVE DESCRIPTION

FLANGE DRILLING 150# RF — F/C CLASS 2 — EXTENSION ☐ TYPE

QTY.	SIZE	TYPE
1	26	9220

MATERIALS OF CONSTRUCTION:
BODY SA515 GR70 0.2 — DISC SA515 GR70 0.2
SHAFT SA564 GR630 H1075 — PINS SA564 GR630 H1075
INB'D. BUS'G. GA/GRL #2 — SEAT EPT
FOLLOWERS D/I — RET PLATE SA515 GR70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. — DISC. DIA.
FLOW L TO R (2)

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 187I CRANE
PACKING BOX – PLAIN ☐ LUB. ☒ * PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND – GRAPHITAR ☐ S/S TL ☒ ** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. — 50 MAX. DEG. (3)
SCHEMATIC DWG. NO.: PIPING — WIRING

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE — STROKE

QTY. 1 — ACTUATOR TYPE AND MODEL NUMBER: SMB-000-2 H1BC — NOMINAL SPRING RANGE ___ TO ___ — INITIAL SPRING COMPRESSION — FULL STROKE PRES. W/VALVE

QTY. — POSITIONER TYPE AND MODEL NUMBER — BYPASS VALVE ☐ — DIRECT ☐ REVERSE ☐ — GAUGES ☐ BYPASS ☐ — INST. SIGNAL ___ TO ___ — SUPPLY ___ PSI — AIRSET

D — MANUAL ACTUATOR DESCRIPTION

QTY. — TYPE — POS. — CHAIN ___ FT.

SERVICE CONDITIONS: FLUID AIR
TEMP. 340 °F — FLOW RATE 11,000 SCFM — STATIC PRES. ___ PSIG
ACTUAL Δ P FLOW ___ PSI — ACT. Δ P SHUTOFF 60 PSI — TORQUE REQ'D.

ACTUATOR MOUNTING INSTR.: CONT'L. FURN. & MT. ☒ CUST. FURN./CONT'L. MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F.

CUSTOMER TAG: 1VQ026 (1)

QTY.	BM/PART NO.	DESCR.
	BM-3F225151	Pg. 1
	BM-3F225151	Pg. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND.

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L-ASME SA479/316)

— PROVIDE QTY 6 TOOLS FOR REMOVING LANTERN GLAND

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED & WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.

— BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

— BRACKET AND ACTUATOR FITTING TO BE LOCK WIRED

— MACHINE SHAFT FOR 1¾" SPLINE ADAPTOR

CUSTOMER NO.	PRODUCT CODE
14723	121201
QUOTED SHIP DATE	REQUESTED SHIP DATE

CHECK LIST: W/UP AV? — ENG'R R.M.L. — Q.C.

Form No. C0207 - 8/73

FISHER Controls

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

PAGE 1 OF 3

NO. 5A094-02

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE				SERIAL NO.
181104		1-3-75	EXPORT BOX ☒ FINAL INSP. ☒	NUCLEAR CLASS	2	BF225152
AGENT ORDER NO. 14-62496-A	ITEM # 2	REV. 2 REV. DATE 2/6/77	CUST. DATA ☒ HOLD FOR DWG. APP'L. ☒	CONTINENTAL QUALITY LEVEL	2	SCH'D. SHIP DATE

0114

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
BOX 240, ROUTE 1.
MARSEILLES. ILL. 61341
ATTN: A. W. KLEINRATH,
CONTRACT SECTION

SHIP TO: LATER

VIA.

ENGINEERING

A VALVE DESCRIPTION

FLANGE DRILLING 150# RF — F/C CLASS 2 — EXTENSION ☐ TYPE

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET; DISC. EXP. -; DISC. DIA. -; FLOW R TO L

QTY.	SIZE	TYPE
1	26	9220

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 0.2 — DISC SA515 GR70 0.2
- SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H1075
- INB'D. BUS'G. GR/BRZ #2 — SEAT EPT
- FOLLOWERS D/I — RET PLATE SA515 GR 70

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐ — SEAL SUPPLY — PACK'G. TYPE: TEFLON ☐ OTHER 187I CRANE

PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒ ** ALEMITE ☐ PLUGGED ☒

B BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐ — PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐ — LINKAGE SET: 0 MIN. DEG. 50 MAX. DEG. (2) — SCHEMATIC DWG. NO.: PIPING, WIRING

C POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE — STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2 HIBC	TO		

QTY. POSITIONER TYPE AND MODEL NUMBER — BYPASS VALVE ☐ — DIRECT ☐ REVERSE ☐ — GAUGES ☐ BYPASS ☐ — INST. SIGNAL TO — SUPPLY PSI — AIRSET

D MANUAL ACTUATOR DESCRIPTION

QTY. TYPE POS. CHAIN FT.

SERVICE CONDITIONS: FLUID AIR; TEMP. 340 °F; FLOW RATE 11,000 SCFM; STATIC PRES. PSIG; ACTUAL Δ P FLOW PSI; ACT. Δ P SHUTOFF 60 PSI; TORQUE REQ'D. - #

ACTUATOR MOUNTING INSTR.: CONT'L. FURN. & MT. ☒ CUST. FURN./CONT'L. MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F.

CUSTOMER TAG: 1VQ040 (1)

QTY.	BM/PART NO.	DESCR.
	BM-BF225152	Pg. 1
	BM-BF225152	Pg. 2

ENGINEERING SPECS:
- * FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND.
- ** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L-ASME SA479/316)
- FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED & WELDED IN BODY BORE. ______ WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.
- — BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.
- — BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED
- — MACHINE SHAFT FOR 1 3/4" SPLINE ADAPTOR

CUSTOMER NO. 14723 — PRODUCT CODE 12201 — QUOTED SHIP DATE — REQUESTED SHIP DATE

CHECK LIST: W/UP OVL ENG'R R.M.L. Q.C.

Form No. C0207 - 8/73

FISHER Controls

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-735

C NO. 5A094-03

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE				
181104		1-3-75	EXPORT BOX ☒ FINAL INSP. ☒	NUCLEAR CLASS	2	SERIAL NO. BF 225153
AGENT ORDER NO. 14-62496-A	ITEM 3	REV. 3 REV. DATE 12/6/77	CUST. DATA ☒ HOLD FOR DWG. APP'L. ☒	CONTINENTAL QUALITY LEVEL	2	SCH'D. SHIP DATE

0 1 4

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
BOX 240, ROUTE 1.
MARSEILLES. ILL. 61341
ATTN: A. W. KLEINRATH,
CONTRACT SECTION

SHIP TO: LATER

VIA.

ENGINEERING

A — VALVE DESCRIPTION

FLANGE DRILLING 150# RF — F/C CLASS 2 — EXTENSION ☐ TYPE

QTY.	SIZE	TYPE
1	26	9220

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 | 012 — DISC SA515 GR70 | 012
- SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H1075
- INB'D. BUS'G. GR/BRZ #2 — SEAT EPT
- FOLLOWERS D/I — RET PLATE SA515 GR 70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET; DISC. EXP. "; DISC. DIA. "; FLOW L TO R (2)

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐ — SEAL SUPPLY — PACK'G. TYPE: TEFLON ☐ OTHER 187I CRANE

PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒ ** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐ — PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐ — LINKAGE SET: 0 MIN. DEG. 50 MAX. DEG. (3) — SCHEMATIC DWG. NO.: PIPING — WIRING —

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE — STROKE

QTY. 1 — ACTUATOR TYPE AND MODEL NUMBER: SMB-000-2 HIBC — NOMINAL SPRING RANGE TO — INITIAL SPRING COMPRESSION — FULL STROKE PRES. W/VALVE

QTY. — POSITIONER TYPE AND MODEL NUMBER — BYPASS VALVE ☐ — DIRECT ☐ REVERSE ☐ — GAUGES ☐ BYPASS ☐ — INST. SIGNAL TO — SUPPLY PSI — AIRSET

D — MANUAL ACTUATOR DESCRIPTION

QTY. — TYPE — POS. — CHAIN FT.

SERVICE CONDITIONS: FLUID AIR — TEMP. 340 °F — FLOW RATE 11,000 SCFM — STATIC PRES. PSIG — ACTUAL Δ P FLOW PSI — ACT. Δ P SHUTOFF 60 PSI — TORQUE REQ'D. "-LB.

ACTUATOR MOUNTING INSTR.: CONT'L. FURN. & MT. ☒ CUST. FURN./CONT'L. MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATION.

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F.

CUSTOMER TAG: 1VG027 (1)

QTY.	BM/PART NO.	DESCR.
	BM-BF225153	PG. 1
	BM-BF225153	PG. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND.

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L-ASME SA479/316)

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED & WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.

BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED

MACHINE SHAFT FOR 1 3/4" SPLINE ADAPTER

CUSTOMER NO 14723 — PRODUCT CODE 1 1 2 2 0 1

QUOTED SHIP DATE — REQUESTED SHIP DATE

CHECK LIST: W/UP AVL ENG'R R. M. L. Q.C.

Form No. C0207 - 8/73

FISHER Controls

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION
CORAOPOLIS, PENNSYLVANIA 15108
PHONE: (412) 264-3010—TWX: 710-793-3615—TELEX: 086-785

PAGE 1 OF 3

C NO. 5A094-04

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE				
131104		1-3-75	EXPORT BOX ☒ FINAL INSP. ☒	NUCLEAR CLASS 2	SERIAL NO. BF225154
AGENT ORDER NO. 19---62496-A	ITEM # 4	REV. 3 REV. DATE 12/6/77	CUST. DATA ☒ HOLD FOR DWG. APP'L. ☒	CONTINENTAL QUALITY LEVEL 2	SCH'D. SHIP DATE

0114

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
BOX 240, ROUTE 1.
MARSEILLES, ILL. 61341
ATTN: A. W. KLEINRATH,
CONTRACT SECTION

SHIP TO: LATER

VIA.

ENGINEERING

A VALVE DESCRIPTION

FLANGE DRILLING 150# RF | F/C CLASS 2 | EXTENSION ☐ TYPE

QTY.	SIZE	TYPE
1	26	9220

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 012 — DISC SA515 GR70 012
- SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H1075
- INB'D. BUS'G. GR/BFZ #2 — SEAT EPT
- FOLLOWERS D/T — RET PLATE SA515 GR. 70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. -
DISC. DIA. -
FLOW L TO R (2)

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 187I CRANE
PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒ ** ALEMITE ☐ PLUGGED ☒

B BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. 50 MAX. DEG. (3)
SCHEMATIC DWG. NO.: PIPING — WIRING —

C POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ | ROTARY ACT. CWTO ☐ CWTC ☒ | BORE | STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2 HIBC	TO		

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE	DIRECT / REVERSE	GAUGES / BYPASS	INST. SIGNAL	SUPPLY	AIRSET
	--	☐	☐ / ☐	☐ / ☐	TO	PSI	

D MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN
			FT.

SERVICE CONDITIONS: FLUID AIR; TEMP. 340 °F; FLOW RATE 11,000 SCFM; STATIC PRES. — PSIG; ACTUAL Δ P FLOW — PSI; ACT. Δ P SHUTOFF 60 PSI; TORQUE REQ'D. --

ACTUATOR MOUNTING INSTR.: CONT'L FURN. & MT. ☒ CUST. FURN./CONT'L MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F. (1)

CUSTOMER TAG: 1VG041

QTY.	BM/PART NO.	DESCR.
	BM-BF225154	Pg. 1
	BM-BF225154	Pg. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND.

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L - ASME SA479/316)

FURNISH S/S ASME SA-240 - GE 316 SEAT RING ROLLED & WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.

BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED. MACHINE SHAFT FOR 1 3/4" SPLINE ADAPTOR

CUSTOMER NO. 14723 | PRODUCT CODE 1121201
QUOTED SHIP DATE | REQUESTED SHIP DATE

CHECK LIST: W/UP CWB ENG'R R. M. A. Q.C.

Form No. C0207 - 8/73

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION
CORAOPOLIS, PENNSYLVANIA 15108
PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

PAGE 1 OF 3

ENGINEERING

NO. 5A094-05

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE				
181104		1-3-75	EXPORT BOX ☒ FINAL INSP. ☒	NUCLEAR CLASS 2	SERIAL NO. BF225155
AGENT ORDER NO.	ITEM #	REV. / REV. DATE	CUST. DATA ☒ HOLD FOR DWG. APP'L. ☒	CONTINENTAL QUALITY LEVEL 2	SCH'D. SHIP DATE
14-62496-A	5	2 / 12/6/77			0114

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
Box 240, Route 1.
MARSEILLES. ILL. 61341
ATTN: A. W. KLEINRATH,
CONTRACT SECTION

SHIP TO: LATER

VIA.

A — VALVE DESCRIPTION

FLANGE DRILLING 150# RF | F/C CLASS 2 | EXTENSION ☐ TYPE | DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET

QTY.	SIZE	TYPE
1	26	9220

MATERIALS OF CONSTRUCTION:
BODY SA515 GR 70 | 0.2 — DISC SA515 GR 70 | 0.2
SHAFT SA564 GR 630 H-1075 — PINS SA564 GR 630 H1075
INB'D. BUS'G. GR/BRZ #2 — SEAT EPT
FOLLOWERS D/I — RET PLATE SA515 GR 70
DISC. EXP. — DISC. DIA. — FLOW R TO L

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐ | SEAL SUPPLY | PACK'G. TYPE: TEFLON ☐ OTHER 187I CRANE

PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐ | PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐ | LINKAGE SET: 0 MIN. DEG. — 50 MAX. DEG. (2) | SCHEMATIC DWG. NO.: PIPING — WIRING

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ | ROTARY ACT. CWTO ☐ CWTC ☒ | BORE | STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE TO	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2 HIBC			

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE	DIRECT ☐ REVERSE ☐	GAUGES ☐ BYPASS ☐	INST. SIGNAL TO	SUPPLY PSI	AIRSET
	--	☐					

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN FT.

SERVICE CONDITIONS: FLUID AIR
TEMP. 340 °F — FLOW RATE 11,000 SCFM — STATIC PRES. PSIG
ACTUAL Δ P FLOW PSI — ACT. Δ P SHUTOFF 60 PSI — TORQUE REQ'D.

ACTUATOR MOUNTING INSTR.: CONT'L. FURN. & MT. ☒ CUST. FURN./CONT'L. MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS
Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F. (1)

CUSTOMER TAG: 1VQ029

QTY.	BM/PART NO.	DESCR.
	BM-BF225155	Pg. 1
	BM-BF225155	Pg. 2

ENGINEERING SPECS:
* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND.
** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L-ASME SA479/316)
FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED & WELDED IN BODY BORE. ______ WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.
BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.
BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED
MACHINE SHAFT FOR 1 3/4" SPLINE ADAPTOR

CUSTOMER NO. 14723 | PRODUCT CODE 112201
QUOTED SHIP DATE | REQUESTED SHIP DATE

CHECK LIST: W/UP OVS ENG'R R.M.S. Q.C.

Form No. C0207-8/73

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108
PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

ENGINEERING

NO. 5A094-06

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE		NUCLEAR CLASS	SERIAL NO.
181104		1-3-75	EXPORT BOX ☒ FINAL INSP. ☒	2	BF225156
AGENT ORDER NO.	ITEM #	REV. / REV. DATE	CUST. DATA ☒ HOLD FOR DWG. APP'L. ☒	CONTINENTAL QUALITY LEVEL	SCH'D. SHIP DATE
14-62496-A	6	3 12/6/77		2	

0114

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
BOX 240, ROUTE 1.
MARSEILLES, ILL. 61341
ATTN: A. W. KLEINRATH.
CONTRACT SECTION

SHIP TO: LATER.

VIA.

A — VALVE DESCRIPTION

QTY.	SIZE	TYPE
1	26	9220

FLANGE DRILLING 150# RF — F/C CLASS 2 — EXTENSION ☐ TYPE

MATERIALS OF CONSTRUCTION:
BODY SA515 GR70 0.2 — DISC SA515 GR70 0.2
SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H1075
INB'D. BUS'G. GR/BRZ #2 — SEAT EPT
FOLLOWERS D/I — RET PLATE SA515 GR 70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. — DISC. DIA. —
FLOW L TO R (2)

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 187I CRANE

PACKING BOX — PLAIN ☐ LUB. ☒ * PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒ ** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. — 50 MAX. DEG. (3)
SCHEMATIC DWG. NO.: PIPING — WIRING —

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE — STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2 H1BC	TO		

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE	DIRECT / REVERSE	GAUGES / BYPASS	INST. SIGNAL	SUPPLY	AIRSET
		☐	☐ / ☐	☐ / ☐	TO	PSI	

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN
			FT.

SERVICE CONDITIONS — FLUID AIR
TEMP. 340 °F — FLOW RATE 11,000 SCFM — STATIC PRES. PSIG
ACTUAL Δ P FLOW PSI — ACT. Δ P SHUTOFF 60 PSI — TORQUE REQ'D. —

ACTUATOR MOUNTING INSTR.: CONT'L. FURN. & MT. ☒ CUST. FURN./CONT'L. MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS
Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F. (1)

CUSTOMER TAG: IVQ030

QTY.	BM/PART NO.	DESCR.
	BM-BF225156	Pg.1
	BM-BF225156	Pg.2

ENGINEERING SPECS:
* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND.
** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L-ASME SA479/316)
FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED & WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.
BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.
BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED
MACHINE SHAFT FOR 1 3/4" SPLINE ADAPTOR

CUSTOMER NO.	PRODUCT CODE
14723	1121201
QUOTED SHIP DATE	REQUESTED SHIP DATE

CHECK LIST: W/UP OV8 ENG'R R.M.L. Q.C.

Form No. C0207 - 8/73

ENGINEERING

FISHER CONT OLS COMPANY
CONTINENTAL DIVISION

FISHER Controls

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

:NO. 5A094-07

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE				SERIAL NO.
181104		1-3-75	EXPORT BOX ☒ FINAL INSP. ☒	NUCLEAR CLASS	2	BF225157
AGENT ORDER NO.	ITEM #	REV. / REV. DATE	CUST. DATA ☒ HOLD FOR DWG. APP'L. ☒	CONTINENTAL QUALITY LEVEL	2	SCH'D. SHIP DATE
14-62496-A	7	3 / 12/0/77				

0114

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
Box 240, Route 1.
MARSEILLES. ILL. 61341
ATTN: A. W. KLEINRATH.
CONTRACT SECTION

SHIP TO: LATER

VIA.

A — VALVE DESCRIPTION

FLANGE DRILLING 150# RF — F/C CLASS 2 — EXTENSION ☐ TYPE

QTY.	SIZE	TYPE
1	26	9220

MATERIALS OF CONSTRUCTION:
BODY SA515 GR70 | 012 — DISC SA515 GR70 | 012
SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H1075
INB'D. BUS'G. GR/BRZ #2 — SEAT EPT
FOLLOWERS D/I — RET PLATE SA515 GR. 70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. "
DISC. DIA. "
FLOW B TO T (2)

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 187I CRANE

PACKING BOX — PLAIN ☐ LUB. ☒ PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒ * ** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☐ VERTICAL (2) ☒
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. 50 MAX DEG. (3)
SCHEMATIC DWG. NO.: PIPING — WIRING

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE — STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE TO	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2 HIBC			

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE	DIRECT ☐ REVERSE ☐	GAUGES ☐ BYPASS ☐	INST. SIGNAL TO	SUPPLY PSI	AIRSET
		☐					

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN FT.

SERVICE CONDITIONS — FLUID AIR
TEMP. 340 °F — FLOW RATE 11,000 SCFM — STATIC PRES. PSIG
ACTUAL Δ P FLOW PSI — ACT. Δ P SHUTOFF 60 PSI — TORQUE REQ'D.

ACTUATOR MOUNTING INSTR.: CONT'L. FURN. & MT. ☒ CUST. FURN./CONT'L. MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS
Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F. (1)

CUSTOMER TAG: 1VG031

QTY.	BM/PART NO.	DESCR.
	BM-BF225157	Pg.1
	BM-BF225157	Pg.2

ENGINEERING SPECS:
* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND.
** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L-ASME SA479/316)
FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED & WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.
BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.
BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED
MACHINE SHAFT FOR 1 3/4" SPLINE ADAPTOR

CUSTOMER NO. 14723 — PRODUCT CODE 1 2 2 0
QUOTED SHIP DATE — REQUESTED SHIP DATE

CHECK LIST: W/UP [illegible] ENG'R R.M.L. Q.C.

Form No. C0207 8/73

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 085-785

NO. 5A094-08

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE	EXPORT BOX / FINAL INSP. / CUST. DATA / HOLD FOR DWG. APP'L.	NUCLEAR CLASS	SERIAL NO.
181104		1-3-75	☒ ☒ ☒ ☒	2	BF225158
AGENT ORDER NO.	ITEM #	REV. / REV. DATE		CONTINENTAL QUALITY LEVEL	SCH'D. SHIP DATE
14-62496-A	8	3 / 12/6/77		2	

011141

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
Box 240, Route 1.
MARSEILLES. ILL. 61341
ATTN: A. W. KLEINRATH.
CONTRACT SECTION

SHIP TO: LATER

VIA.

ENGINEERING

A — VALVE DESCRIPTION

QTY.	SIZE	TYPE
1	26	9220

FLANGE DRILLING: 150# RF — F/C CLASS: 2 — EXTENSION ☐ TYPE

MATERIALS OF CONSTRUCTION:
BODY: SA515 GR70 |0|2| — DISC: SA515 GR70 |0|2|
SHAFT: SA564 GR630 H-1075 — PINS: SA564 GR630 H1075
INB'D. BUS'G.: GA/BRZ #2 — SEAT: EPT
FOLLOWERS: D/E — RET PLATE: SA515 GR 70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER: OFFSET
DISC. EXP. —
DISC. DIA. —
FLOW: L TO R (2)

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 187I CRANE

PACKING BOX—PLAIN ☐ LUB. ☒ * PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND—GRAPHITAR ☐ S/S TL ☒ ** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. — 50 MAX. DEG. (3)
SCHEMATIC DWG. NO.: PIPING — WIRING —

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT.: P.D.T.O. ☐ P.D.T.C. ☐
ROTARY ACT.: CWTO ☐ CWTC ☒
BORE — STROKE —

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2 HIBC	TO		

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE	DIRECT / REVERSE	GAUGES / BYPASS	INST. SIGNAL	SUPPLY	AIRSET
		☐	☐ / ☐	☐ / ☐	TO	PSI	

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN
			FT.

SERVICE CONDITIONS: FLUID: AIR
TEMP.: 340 °F — FLOW RATE: 11,000 SCFM — STATIC PRES.: PSIG
ACTUAL Δ P FLOW: PSI — ACT. Δ P SHUTOFF: 60 PSI — TORQUE REQ'D.:

ACTUATOR MOUNTING INSTR.:
CONT'L. FURN. & MT. ☒
CUST. FURN./CONT'L. MT. ☐
CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F.

CUSTOMER TAG: IVG034

QTY.	BM/PART NO.	DESCR.
	BM-BF225158	Pg. 1
	BM-BF225158	Pg. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND.

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L-ASME SA479/316)

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED & WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.

BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED
MACHINE SHAFT FOR 1 3/4" SPLINE ADAPTOR

CUSTOMER NO.: 14723 — PRODUCT CODE: 1|2|2|0|1
QUOTED SHIP DATE — REQUESTED SHIP DATE

CHECK LIST: W/UP: AVJ — ENG'R: R.M.L. — Q.C.

Form No. C0207 - 8/73

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

NO. 5A094-09

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE			
181104		1-3-75	EXPORT BOX ☒ FINAL INSP. ☒	NUCLEAR CLASS 2	SERIAL NO. BF225159
AGENT ORDER NO. 14-62496-A	ITEM # 9	REV. 2 REV. DATE 12/16/77	CUST. DATA ☒ HOLD FOR DWG. APP'L. ☒	CONTINENTAL QUALITY LEVEL 2	SCH'D. SHIP DATE

0114

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
Box 240, Route 1.
MARSEilles. Ill. 61341
ATTN: A. W. KLEINRATH, CONTRACT SECTION

SHIP TO: LATER

VIA.

ENGINEERING

A — VALVE DESCRIPTION

FLANGE DRILLING 150# RF — F/C CLASS 2 — EXTENSION TYPE ☐

QTY.	SIZE	TYPE
1	26	9220
		–

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 |0|2| — DISC SA515 GR70 |0|2|
- SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H1075
- INB'D. BUS'G. GR/BRZ =2 — SEAT EPT
- FOLLOWERS D/I — RET PLATE SA515 GR. 70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET; DISC. EXP. –; DISC. DIA. –; FLOW R TO L

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐ — SEAL SUPPLY — PACK'G. TYPE: TEFLON ☐ OTHER 187I CRANE

PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND—GRAPHITAR ☐ S/S TL ☒** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐ — PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐ — LINKAGE SET: 0 MIN. DEG. 50 MAX. DEG. (2) — SCHEMATIC DWG. NO.: PIPING ___ WIRING ___

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE — STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2 HIBC	TO		

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE	DIRECT / REVERSE	GAUGES / BYPASS	INST. SIGNAL	SUPPLY	AIRSET
		☐	☐ / ☐	☐ / ☐	TO	PSI	

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN
			FT.

SERVICE CONDITIONS: FLUID AIR; TEMP. 340 °F; FLOW RATE 11,000 SCFM; STATIC PRES. PSIG; ACTUAL Δ P FLOW PSI; ACT. Δ P SHUTOFF 60 PSI; TORQUE REQ'D. –

ACTUATOR MOUNTING INSTR.: CONT'L. FURN. & MT. ☒ CUST. FURN./CONT'L. MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F. (1)

CUSTOMER TAG: 1VQ036

QTY.	BM/PART NO.	DESCR.
	BM-BF225159	PG. 1
	BM-BF225159	PG. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND.

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L-ASME SA479/316)

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED & WELDED IN BODY BORE. ___ WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.

BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

BRACKET AND ACTUATOR FITTING TO BE LOCK WIRED
MACHINE SHAFT FOR 1 3/4" SPLINE ADAPTOR

CUSTOMER NO. 14723 — PRODUCT CODE 1|2|2|0|1 — QUOTED SHIP DATE — REQUESTED SHIP DATE

CHECK LIST: W/UP AVS ENG'R R.M.L. Q.C.

Form No. C0207 - 8/73

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108
PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

PAGE 1 OF 3

NO. 5A094 - 32

REPRESENTATIVE ORDER NO.	ITEM #	ENTRY DATE		EXPORT BOX / FINAL INSP. / CUST. DATA / HOLD FOR DWG. APPL.	NUCLEAR CLASS	SERIAL NO.
14-62496-A		12/74			2	246703
CUSTOMER ORDER NO.	**ITEM #**	**REV**	**REV. DATE**		**CONTINENTAL QUALITY LEVEL**	**SCH'D. SHIP DATE**
18114		1	9-5-78		2	3-2-79

CUSTOMER NO.: 1 4 7 2 1 3 | PRODUCT CODE: | TAX NO.:

SOLD TO:
Commonwealth Edison Company
Station Construction Department
Box 240, Route 1
Marseilles, Ill. 61341

SHIP TO: Later

ATTN: A. W. Kleinrath - Contract Section VIA.

ENGINEERING

VALVE DESCRIPTION —

COMP	QTY.	SIZE	TYPE
A	1	8	9220

FLANGE DRILLING 150 | F/C CLASS 3 | EXTENSION TYPE ☐

MATERIALS OF CONSTRUCTION:
- BODY SA515Gr70 012
- DISC SA351 CF8M 013
- SHAFT SA564Gr630
- PINS SA564Gr630
- INS'D. BUS'G. #2
- SEAT EPDM
- FOLLOWERS D/T
- Ret. ring SA515Gr70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER ____ DISC. EXP. ____ DISC. DIA. ____ FLOW ____ TO ____

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐ | SEAL SUPPLY | PACK'G. TYPE: TEFLON ☐ OTHER **

PACKING BOX — PLAIN ☐ & LUB. ☐ PURGED ☐ STICK LUB. ☐ SOL VALVES ☐
LANTERN GLAND — GRAPHITE ☐ SST ☐ LUB. FITTING ☐ PLUGGED ☐

BRACKET & LINKAGE

COMP	QTY.
B	1

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐ | PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐ | LINKAGE SET: 0 MIN. DEG. 90 MAX. DEG. | SCHEMATIC DWG. NO.: PIPING ____ WIRING ____

POWER/MANUAL ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ | ROTARY ACT. CWTO ☐ CWTC ☒ | BORE | STROKE

COMP	QTY.	ACTUATOR TYPE AND MODEL NUMBER
C	1	SMB 000/2-H0BC

NOMINAL SPRING RANGE ____ TO ____ | INITIAL SPRING COMPRESSION ____ | FULL STROKE PRES. W/VALVE ____

POSITIONER TYPE AND MODEL NUMBER | BYPASS VALVE ☐ | DIRECT ☐ REVERSE ☐ | GAUGES ☐ BYPASS ☐ | INST. SIGNAL ____ TO ____ | SUPPLY

AIRSET

MANUAL | POS. | CHAIN

SERVICE CONDITIONS: FLUID Air/Nitrogen | TEMP. 340 °F | FLOW RATE | STATIC PRES. 45 psig | ACTUAL Δ P FLOW | ACT. Δ P SHUTOFF 45 | TORQUE REQ'D. 545

ACTUATOR MOUNTING INSTR.: CONT'L FURN. & MT. ☐ CUST. FURN./CONT'L MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS
Body Design Pres. 275 PSI, Δ P 226 PSI Shutoff At 70° F.

CUSTOMER TAG: 1VQ 042

COMP	QTY.	EM/BM/PART NO.
A	1	BM*B-5A094 PG. 1
B	1	BM*B-5A094 PG. 2
C	1	BM*B-5A094 PG. 2

ENGINEERING SPECS:

*Packing to be 1871 & Grafoil
**Leakoff type packing
-Body to be drilled and tapped for 1/2" NPT leakoff connection.
-All acc. bolting to be lock wired.
-Build to 1974 edition, ASME Code, no addenda.

CHECK LIST: W/UP D.T.H. | ENG'G R.B. | Q.C.
QUOTED SHIP DATE | REQUESTED SHIP DATE | SP. INVOICING ☐ | NET PRICE

Form No. C0207 - 7/75

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 294-3010—TWX: 710-793-3616—TELEX: 086-785

PAGE 1 OF 1

NO. 5A094-33

REPRESENTATIVE ORDER NO.	ITEM #	ENTRY DATE		NUCLEAR CLASS	2	SERIAL NO.
14-62496-A		12/74	EXPORT BOX / FINAL INSP. / CUST. DATA / HOLD FOR DWG. APPR.			BF 246704
CUSTOMER ORDER NO.	**ITEM #**	**REV. / REV. DATE**		**CONTINENTAL QUALITY LEVEL**	2	**SCH'D. SHIP DATE**
18114		1 / 9-5-78				3-2-77

CUSTOMER NO. 1 1 4 7 1 2 1 3 PRODUCT CODE YEAR NO.

SOLD TO:
Commonwealth Edison Company
Station Construction Department
Box 240, Route 1
Marseilles, Ill. 61341

ATTN: A. W. Kleinrath - Contract Section

SHIP TO: Later

VIA

VALVE DESCRIPTION — FLANGE DRILLING 150 — F/C CLASS 3 — EXTENSION TYPE ☐

COMP	QTY.	SIZE	TYPE
A	1	8	9220

MATERIALS OF CONSTRUCTION:
BODY SA515Gr70 02 — DISC SA351 CF8M 013
SHAFT SA564Gr630 — PINS SA564Gr630
INB'D. BUS'G. #2 — SEAT EPDM
FOLLOWERS D/I — Ret. ring 515Gr70

DISC TYPE: CONV. ☒ FISHTAIL ☐ OTHER
DISC. EXP. — DISC. DIA. — FLOW TO

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER **

PACKING BOX — PLAIN ☐ *LUB. ☐ PURGED ☐ STICK LUB. ☐ ISOL VALVES ☐
LANTERN GLAND — GRAPHITE ☐ SST ☐ LUB. FITTING ☐ PLUGGED

BRACKET & LINKAGE

COMP	QTY.
B	1

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. 90 MAX. DEG.
SCHEMATIC DWG. NO.: PIPING — WIRING —

POWER/MANUAL ACTUATOR DESCRIPTION — LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE — STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB 000/2-HOBC	TO		

POSITIONER TYPE AND MODEL NUMBER — BYPASS VALVE ☐ — DIRECT ☐ REVERSE ☐ — GAUGES ☐ BYPASS ☐ — INST. SIGNAL TO — SUPPLY PSI

AIRSET

MANUAL — POS. — CHAIN

SERVICE CONDITIONS: FLUID Air/Nitrogen
TEMP. 340 °F — FLOW RATE — STATIC PRES. 45 PSIG
ACTUAL Δ P FLOW — ACT. Δ P SHUTOFF 45 PSI — TORQUE REQ'D. 545

ACTUATOR MOUNTING INSTR.: CONT'L FURN. & MT. ☒ CUST. FURN./CONT'L MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 224 PSI Shutoff At 70° F.

CUSTOMER TAG: 1VQ 043

COMP	QTY.	BM/SM/PART NO.
A	1	BM*B-5A094 PG. 1
B	1	BM*B-5A094 PG. 2
C	1	BM*B-5A094 PG. 2

ENGINEERING SPECS:

*Packing to be 1871 & Grafoil
**Leakoff type packing
-Body to be drilled and tapped for 1/2" NPT leakoff connection.
-All acc. bolting to be lock wired.
-Build to 1974 edition, ASME Code, no addenda.

CHECK LIST:
W/UP D. D. W.
ENG'R R. M. L.
C. C.

QUOTED SHIP DATE — REQUESTED SHIP DATE — SP. INVOICING ☐ — NET PRICE

Form No. C0207 - 7/75

FISHER Controls

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION
CORAOPOLIS, PENNSYLVANIA 15108
PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

C NO. 57015-01

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE			
181107		7-29-75	EXPORT BOX ☐ FINAL INSP. ☐	NUCLEAR CLASS 2	SERIAL NO. BF226465
AGENT ORDER NO. 14-62496-B	ITEM # 1	REV. 3 REV. DATE 12/6/77	CUST. DATA ☐ HOLD FOR DWG. APP'L. ☐	CONTINENTAL QUALITY LEVEL 2	SCH'D. SHIP DATE

0114

ENGINEERING

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
1319 S. 1ST AVENUE
MAYWOOD, ILLINOIS 60153

SHIP TO: LATER

VIA.

A VALVE DESCRIPTION

FLANGE DRILLING 150# — F/C CLASS 2 — EXTENSION ☐ TYPE

QTY.	SIZE	TYPE
26		9220

MATERIALS OF CONSTRUCTION:
BODY SA515 GR70 | 02 — DISC SA515 GR70 | 02
SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H-1075
INB'D. BUS'G. GR/BRZ #2 — SEAT EPT
FOLLOWERS D/I — RET PLATE - SA515 GR70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP.
DISC. DIA.
FLOW L TO 2 ②

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 182# CRANE
PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND—GRAPHITAR ☐ S/S TL ☒ ** ALEMITE ☐ PLUGGED ☒

B BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. — 50 MAX. DEG. ③
SCHEMATIC DWG. NO.: PIPING — WIRING

C POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE — STROKE

QTY. 1 — ACTUATOR TYPE AND MODEL NUMBER: SMB-000-2-H1BC — NOMINAL SPRING RANGE ___ TO ___ — INITIAL SPRING COMPRESSION — FULL STROKE PRES. W/VALVE

QTY. — POSITIONER TYPE AND MODEL NUMBER — BYPASS VALVE ☐ — DIRECT ☐ REVERSE ☐ — GAUGES ☐ BYPASS ☐ — INST. SIGNAL ___ TO ___ — SUPPLY ___ PSI — SET

D MANUAL ACTUATOR DESCRIPTION

QTY. — TYPE — POS. — CHAIN

SERVICE CONDITIONS: FLUID AIR
TEMP. 340 °F — FLOW RATE 11,000 SCFM — STATIC PRES. ___ PSIG
ACTUAL Δ P FLOW ___ PSI — ACT. Δ P SHUTOFF 60 PSI — TORQUE REQ'D. —

ACTUATOR MOUNTING INSTR.: CONT'L. FURN. & MT. ☒ — CUST. FURN./CONT'L. MT. ☐ — CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS
Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F. ①

CUSTOMER TAG: 2VQ026

QTY.	BM/PART NO.	DESCR.
	BM-BF226465	Pg.1
	BM-BF226465	Pg.2

ENGINEERING SPECS:
* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND
** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L ASME SA479 TYPE 316)
FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED AND WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.
BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.
BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED.

CUSTOMER NO. 14723 — PRODUCT CODE 11220
QUOTED SHIP DATE — REQUESTED SHIP DATE

CHECK LIST: W/UP (GW) ENG'R R.M.L. Q.C.

Form No. C0207

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

FISHER Controls

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

C NO. 5A095-02

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE		NUCLEAR CLASS	SERIAL NO.
181104		7-29-75	EXPORT BOX ☐ FINAL INSP. ☐	2	BF 226466
AGENT ORDER NO.	**ITEM #**	**REV. / REV. DATE**		**CONTINENTAL QUALITY LEVEL**	**SCH'D. SHIP DATE**
14-62496-B	2	2 / 1-16-77	CUST. DATA ☐ HOLD FOR DWG. APP'L. ☐	2	

0 | 1 | 4

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
1319 S. 1st AVENUE
MAYWOOD, ILLINOIS 60153

SHIP TO: LATER

VIA.

ENGINEERING

A — VALVE DESCRIPTION

QTY.	SIZE	TYPE
1	26	9220

FLANGE DRILLING 150# — F/C CLASS 2 — EXTENSION TYPE ☐

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 | 0 | 2 — DISC SA515 GR70 | 0 | 2
- SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H-1075
- INB'D. BUS'G. GR/BRZ #2 — SEAT EPT
- FOLLOWERS D/I — RET PLATE - SA515 GR70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. —
DISC. DIA. —
FLOW R TO L

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 1822 CRANE

PACKING BOX — PLAIN ☐ LUB. ☒ * PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒ ** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. — 50 MAX. DEG. (2)
SCHEMATIC DWG. NO.: PIPING — WIRING —

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT.: P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT.: CWTO ☐ CWTC ☒ — BORE — STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2-H1BC	TO		

POSITIONER TYPE AND MODEL NUMBER: — BYPASS VALVE ☐ DIRECT ☐ REVERSE ☐ GAUGES ☐ BYPASS ☐ INST. SIGNAL TO — SUPPLY PSI — AIRSET

D — MANUAL ACTUATOR DESCRIPTION

QTY. — TYPE — POS. — CHAIN FT.

SERVICE CONDITIONS: FLUID AIR
TEMP. 340 °F — FLOW RATE 11,000 SCFM — STATIC PRES. PSIG
ACTUAL Δ P FLOW PSI — ACT. Δ P SHUTOFF 60 PSI — TORQUE REQ'D.

ACTUATOR MOUNTING INSTR.: CONT'L FURN. & MT. ☒ CUST. FURN./CONT'L MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS (1)

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F.

CUSTOMER TAG: 2VG040

QTY.	BM/PART NO.	DESCR.
	BM-BF226466	Pg. 1
	BM-BF226466	Pg. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L ASME SA479 TYPE 316)

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED AND WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER C.I.S 1.4 REV 11.

BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED.

CUSTOMER NO. 14723 — PRODUCT CODE 1 2 2 0

QUOTED SHIP DATE — REQUESTED SHIP DATE

CHECK LIST: W/UP (initials) ENG'R R.M.L. Q.C.

Form No. C0207 - 8/73

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

FISHER Controls

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

C NO. 5A095-03

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE		NUCLEAR CLASS	SERIAL NO.
181104		7-29-75	EXPORT BOX ☐ FINAL INSP. ☐	2	BF 226467
AGENT ORDER NO.	ITEM #	REV. / REV. DATE	CUST. DATA ☐ HOLD FOR DWG. APP'L. ☐	CONTINENTAL QUALITY LEVEL	SCH'D. SHIP DATE
14-62496-B	3	3 / 12/6/77		2	

0 1 4

ENGINEERING

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
1319 S. 1st AVENUE
MAYWOOD, ILLINOIS 60153

SHIP TO: LATER

VIA.

A — VALVE DESCRIPTION

FLANGE DRILLING 150# — F/C CLASS 2 — EXTENSION ☐ TYPE ____

QTY.	SIZE	TYPE
	26	9220
		-

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 | 02
- DISC SA515 GR70 | 012
- SHAFT SA564 GR630 H-1075
- PINS SA564 GR630 H-1075
- INB'D. BUS'G. GR/BRZ #2
- SEAT EPT
- FOLLOWERS D/C
- RET PLATE - SA515 GR70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. -
DISC. DIA. -
FLOW L TO R ②

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 1877 CRANE

PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. / 50 MAX. DEG. ③
SCHEMATIC DWG. NO.: PIPING ____ WIRING ____

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT.: P.D.T.O. ☐ P.D.T.C. ☐
ROTARY ACT.: CWTO ☐ CWTC ☒
BORE ____ STROKE ____

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2-H1BC	TO		

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE			INST. SIGNAL	SUPPLY	AIRSET
		☐	DIRECT ☐ REVERSE ☐	GAUGES ☐ BYPASS ☐	TO	PSI	

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN
			FT.

SERVICE CONDITIONS — FLUID: AIR

TEMP.	FLOW RATE	STATIC PRES.
340 °F	11,000 SCFM	PSIG
ACTUAL Δ P FLOW	**ACT. Δ P SHUTOFF**	**TORQUE REQ'D.**
PSI	60 PSI	-

ACTUATOR MOUNTING INSTR.:
- CONT'L. FURN. & MT. ☒
- CUST. FURN./CONT'L. MT. ☐
- CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS ①

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F.

CUSTOMER TAG: 2VQ027

QTY.	BM/PART NO.	DESCR.
	BM-BF226467	PG. 1
	BM-BF226467	PG. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L ASME SA479 TYPE 316)

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED AND WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.

BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED.

CUSTOMER NO.	PRODUCT CODE
14723	1 2 2 0 1
QUOTED SHIP DATE	REQUESTED SHIP DATE

CHECK LIST: W/UP avl ENG'R R.M.L. Q.C. ____

Form No. C0207 8/73

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

FISHER Controls

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

C NO. 5A095-04

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE				SERIAL NO.
181104		7-29-75	EXPORT BOX ☐ FINAL INSP. ☐	NUCLEAR CLASS	2	BF 226468
AGENT ORDER NO.	ITEM #	REV. / REV. DATE	CUST. DATA ☐ HOLD FOR DWG. APP'L. ☐	CONTINENTAL QUALITY LEVEL	2	SCH'D. SHIP DATE
14-62496-B	4	3 / 12/6/77				0 1 4 1

ENGINEERING

SOLD TO:
COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
1319 S. 1ST AVENUE
MAYWOOD, ILLINOIS 60153

SHIP TO: LATER

VIA.

A — VALVE DESCRIPTION

FLANGE DRILLING 150# — F/C CLASS 2 — EXTENSION TYPE ☐

QTY.	SIZE	TYPE
	26	9220

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 | 0 2 |
- DISC SA515 GR70 | 0 2 |
- SHAFT SA564 GR630 H-1075
- PINS SA564 GR630 H-1075
- INB'D. BUS'G. GR/BRZ #2
- SEAT EPT
- FOLLOWERS D/I
- RET PLATE - SA515 GR70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. "
DISC. DIA. "
FLOW L TO R (2)

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 187I CRANE

PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. — 50 MAX. DEG. (3)
SCHEMATIC DWG. NO.: PIPING ____ WIRING ____

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE — STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2-H1BC	TO		

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE	DIRECT / REVERSE	GAUGES / BYPASS	INST. SIGNAL	SUPPLY	AIRSET
		☐	☐ / ☐	☐ / ☐	TO	PSI	

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN
			FT.

SERVICE CONDITIONS — FLUID: AIR

TEMP.	FLOW RATE	STATIC PRES.
340 °F	11,000 SCFM	PSIG
ACTUAL Δ P FLOW PSI	ACT. Δ P SHUTOFF 60 PSI	TORQUE REQ'D.

ACTUATOR MOUNTING INSTR.:
- CONT'L. FURN. & MT. ☒
- CUST. FURN./CONT'L. MT. ☐
- CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F. (1)

CUSTOMER TAG: 2VQ041

QTY.	BM/PART NO.	DESCR.
	BM-BF226468	PG. 1
	BM-BF226468	PG. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L ASME SA479 TYPE 316)

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED AND WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.

BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED.

CUSTOMER NO. 14723 — PRODUCT CODE 1 2 2 0 1

QUOTED SHIP DATE — REQUESTED SHIP DATE

CHECK LIST: W/UP avB ENG'R R.M.S. Q.C.

Form No. C0207 - 8/73

ENGINEERING

FISHER CONTROLS COMPANY

CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

C NO. 5A095-05

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE			
181104		7-29-75	EXPORT BOX ☐ FINAL INSP. ☐	NUCLEAR CLASS 2	SERIAL NO. BF 226469
AGENT ORDER NO. 14-62496-B	ITEM # 5	REV. 2 REV. DATE 12/6/77	CUST. DATA ☐ HOLD FOR DWG. APP'L. ☐	CONTINENTAL QUALITY LEVEL 2	SCH'D. SHIP DATE

0 1 4

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
1319 S. 1st AVENUE
MAYWOOD, ILLINOIS 60153

SHIP TO: LATER

VIA.

A — VALVE DESCRIPTION

FLANGE DRILLING 150# | F/C CLASS 2 | EXTENSION ☐ TYPE

QTY.	SIZE	TYPE
	26	9220

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 | 0 2
- DISC SA515 GR70 | 0 2
- SHAFT SA564 GR630 H-1075
- PINS SA564 GR630 H-1075
- INB'D. BUS'G. GR/BRZ #2
- SEAT EPT
- FOLLOWERS D/I
- RET PLATE - SA515 GR70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. "
DISC. DIA. "
FLOW R TO L

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 1877 CRANE

PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. 50 MAX. DEG. (2)
SCHEMATIC DWG. NO.: PIPING ____ WIRING ____

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ | ROTARY ACT. CWTO ☐ CWTC ☒ | BORE | STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2-H1BC	___ TO ___		

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE			INST. SIGNAL	SUPPLY	AIRSET
	--	☐	DIRECT ☐ REVERSE ☐	GAUGES ☐ BYPASS ☐	___ TO ___	___ PSI	

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN
			FT.

SERVICE CONDITIONS — FLUID AIR
TEMP. 340 °F | FLOW RATE 11,000 SCFM | STATIC PRES. ___ PSIG
ACTUAL Δ P FLOW ___ PSI | ACT. Δ P SHUTOFF 60 PSI | TORQUE REQ'D. ___

ACTUATOR MOUNTING INSTR.: CONT'L FURN. & MT. ☒ CUST. FURN/CONT'L MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F. (1)

CUSTOMER TAG: 2VQ029

QTY.	BM/PART NO.	DESCR.
	BM-BF226469	Pg. 1
	BM-BF226469	Pg. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L ASME SA479 TYPE 316)

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED AND WELDED IN BODY BORE.
WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.
BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.
BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED.

CUSTOMER NO.	PRODUCT CODE
14723	1 2 2 1 0
QUOTED SHIP DATE	REQUESTED SHIP DATE

CHECK LIST: W/UP OVS ENG'R R.M.L. Q.C.

Form No. C0201 - 8/73

FISHER Controls

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

FC NO. 5A095-06

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE				SERIAL NO.
181104		7-29-75	EXPORT BOX ☐ FINAL INSP. ☐	NUCLEAR CLASS	2	BF 226470
AGENT ORDER NO. 14-62496-B	ITEM # 6	REV. 3 REV. DATE 1-26-77	CUST. DATA ☐ HOLD FOR DWG. APP'L. ☐	CONTINENTAL QUALITY LEVEL	2	SCH'D. SHIP DATE

0114

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
1319 S. 1ST AVENUE
MAYWOOD, ILLINOIS 60153

SHIP TO: LATER

ENGINEERING

VIA.

A — VALVE DESCRIPTION

FLANGE DRILLING 150# — F/C CLASS 2 — EXTENSION ☐ TYPE ____

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET

QTY.	SIZE	TYPE
	26	9220

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 | 02 — DISC SA515 GR70 | 02
- SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H-1075
- INB'D. BUS'G. GR/BRZ #2 — SEAT EPT
- FOLLOWERS D/☐ — RET PLATE - SA515 GR70

DISC. EXP. ____" DISC. DIA. ____"

FLOW L TO R ②

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐ — SEAL SUPPLY ____ — PACK'G. TYPE: TEFLON ☐ OTHER 187= CRANE

PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐

LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐ — PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐ — LINKAGE SET: 0 MIN. DEG. 50 MAX. DEG. ③ — SCHEMATIC DWG. NO.: PIPING ____ WIRING ____

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE ____ STROKE ____

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2-H1BC	____ TO ____		

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE	DIRECT / REVERSE	GAUGES / BYPASS	INST. SIGNAL	SUPPLY	AIRSET
		☐	☐ / ☐	☐ / ☐	____ TO ____	____ PSI	

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN
			FT.

SERVICE CONDITIONS: FLUID AIR; TEMP. 340 °F; FLOW RATE 11,000 SCFM; STATIC PRES. ____ PSIG; ACTUAL Δ P FLOW ____ PSI; ACT. Δ P SHUTOFF 60 PSI; TORQUE REQ'D. ____

ACTUATOR MOUNTING INSTR.: CONT'L. FURN. & MT. ☒ CUST. FURN./CONT'L. MT. ☐ CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS ①

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F.

CUSTOMER TAG: 2VQ030

QTY.	BM/PART NO.	DESCR.
	BM-BF226470	Pg. 1
	BM-BF226470	Pg. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L ASME SA479 TYPE 316)

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED AND WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.

BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED.

CUSTOMER NO.	PRODUCT CODE
14723	12210
QUOTED SHIP DATE	REQUESTED SHIP DATE

CHECK LIST: W/UP QVL ENG'R R.M.S. Q.C. ____

Form No. C0207 - 8/73

FISHER Controls

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

ENGINEERING

C NO. SA095-07

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE		NUCLEAR CLASS	SERIAL NO.
181104		7-29-75	EXPORT BOX ☐ FINAL INSP. ☐	2	BF 226471
AGENT ORDER NO.	ITEM #	REV. / REV. DATE	CUST. DATA ☐ HOLD FOR DWG. APP'L. ☐	CONTINENTAL QUALITY LEVEL	SCH'D. SHIP DATE
14-62496-B	7	3 / 1-26-77		2	

0114

SOLD TO:
COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
1319 S. 1ST AVENUE
MAYWOOD, ILLINOIS 60153

SHIP TO: LATER

VIA.

A — VALVE DESCRIPTION

FLANGE DRILLING 150# | F/C CLASS 2 | EXTENSION ☐ TYPE

QTY.	SIZE	TYPE
26		9220

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 | 0.2
- DISC SA515 GR70 | 0.2
- SHAFT SA564 GR630 H-1075
- PINS SA564 GR630 H-1075
- INB'D. BUS'G. GR/BRZ #2
- SEAT EPT
- FOLLOWERS D/E
- RET PLATE - SA515 GR70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. ___ DISC. DIA. ___
FLOW B TO T (2)

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 187 CRANE
PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND — GRAPHITAR ☐ S/S TL ☒** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☐ VERTICAL (2) ☒
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. / 50 MAX. DEG. (3)
SCHEMATIC DWG. NO.: PIPING ___ WIRING ___

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.O.T.O. ☐ P.O.T.C. ☐ | ROTARY ACT. CWTO ☐ CWTC ☒ | BORE | STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2-H1BC	___ TO ___		

QTY. POSITIONER TYPE AND MODEL NUMBER | BYPASS VALVE ☐ | DIRECT ☐ REVERSE ☐ | GAUGES ☐ BYPASS ☐ | INST. SIGNAL ___ TO ___ | SUPPLY ___ PSI | AIRSET

D — MANUAL ACTUATOR DESCRIPTION

QTY. | TYPE | POS. | CHAIN

SERVICE CONDITIONS — FLUID: AIR
TEMP. 340 °F | FLOW RATE 11,000 SCFM | STATIC PRES. ___ PSIG
ACTUAL Δ P FLOW ___ PSI | ACT. Δ P SHUTOFF 60 PSI | TORQUE REQ'D. ___

ACTUATOR MOUNTING INSTR.:
- CONT'L. FURN. & MT. ☒
- CUST. FURN./CONT'L. MT. ☐
- CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F. (1)

CUSTOMER TAG: 2VQ031

QTY.	BM/PART NO.	DESCR.
	BM-BF226471	Pg. 1
	BM-BF226471	Pg. 2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L ASME SA479 TYPE 316)

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED AND WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.

BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED.

CUSTOMER NO. 14723 | PRODUCT CODE 1220
QUOTED SHIP DATE | REQUESTED SHIP DATE

CHECK LIST: W/UP CVS ENG'R R. M— Q.C. ___

Form No. C0207 - 8/73

FISHER Controls

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

CORAOPOLIS, PENNSYLVANIA 15108

PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

ENGINEERING

C NO. 5A095-08

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE				SERIAL NO.
181104		7-29-75	EXPORT BOX ☐ FINAL INSP. ☐	NUCLEAR CLASS	2	BF 226472
AGENT ORDER NO.	**ITEM #**	**REV. / REV. DATE**				**SCH'D. SHIP DATE**
14-62496-B	8	2 12/6/77	CUST. DATA ☐ HOLD FOR DWG. APP'L. ☐	CONTINENTAL QUALITY LEVEL	2	

0 1 1 4

SOLD TO: COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
1319 S. 1ST AVENUE
MAYWOOD, ILLINOIS 60153

SHIP TO: LATER

VIA.

A — VALVE DESCRIPTION

QTY.	SIZE	TYPE
	26	9220
		–

FLANGE DRILLING 150# — F/C CLASS 2 — EXTENSION ☐ TYPE

MATERIALS OF CONSTRUCTION:
- BODY SA515 GR70 | 0 2 — DISC SA515 GR70 | 0 2
- SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H-1075
- INB'D. BUS'G. GR/BRZ #2 — SEAT EPT
- FOLLOWERS D/E — RET PLATE - SA515 GR70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. –
DISC. DIA. –
FLOW: R TO L

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 182E CRANE

PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND—GRAPHITAR ☐ S/S TL ☒** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. — 53 MAX. DEG. (2)
SCHEMATIC DWG. NO.: PIPING — WIRING —

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT.: P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT.: CWTO ☐ CWTC ☒ — BORE — STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2-H1BC	TO		

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE			INST. SIGNAL	SUPPLY	AIRSET
		☐	DIRECT ☐ REVERSE ☐	GAUGES ☐ BYPASS ☐	TO	PSI	

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN
			FT.

SERVICE CONDITIONS: FLUID AIR
TEMP. 340 °F — FLOW RATE 11,000 SCFM — STATIC PRES. PSIG
ACTUAL Δ P FLOW PSI — ACT. Δ P SHUTOFF 60 PSI — TORQUE REQ'D. –

ACTUATOR MOUNTING INSTR.:
CONT'L. FURN. & MT. ☒
CUST. FURN./CONT'L MT. ☐
CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F.

CUSTOMER TAG: 2VQ034 (1)

QTY.	BM/PART NO.	DESCR.
	BM-BF226472	Pg.1
	BM-BF226472	Pg.2

ENGINEERING SPECS:

* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND

** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L ASME SA479 TYPE 316)

FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED AND WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER CIS 1.4 REV 11.

BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.

BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED.

CUSTOMER NO.	PRODUCT CODE
14723	1 2 2 0 1
QUOTED SHIP DATE	**REQUESTED SHIP DATE**

SP [illegible]

CHECK LIST: W/UP CVS ENG'R R.M.S. Q.C.

Form No. C0207 9/73

FISHER CONTROLS COMPANY
CONTINENTAL DIVISION

FISHER Controls

CORAOPOLIS, PENNSYLVANIA 15108
PHONE: (412) 264-3010—TWX: 710-793-3616—TELEX: 086-785

C NO. 5A095-09

CUSTOMER ORDER NO.	ITEM #	ENTRY DATE		NUCLEAR CLASS	SERIAL NO.
181104		7-29-75	EXPORT BOX ☐ FINAL INSP. ☐	2	BF 226473
AGENT ORDER NO.	ITEM #	REV. / REV. DATE	CUST. DATA ☐ HOLD FOR DWG. APP'L. ☐	CONTINENTAL QUALITY LEVEL	SCH'D. SHIP DATE
14-62496-B	9	2 / 12/6/77		2	

0114

ENGINEERING

SOLD TO:
COMMONWEALTH EDISON COMPANY
STA. CONSTRUCTION DEPT.
1319 S. 1st AVENUE
MAYWOOD, ILLINOIS 60153

SHIP TO: LATER

VIA.

A — VALVE DESCRIPTION

QTY.	SIZE	TYPE
	26	9220

FLANGE DRILLING 150# — F/C CLASS 2 — EXTENSION TYPE ☐

MATERIALS OF CONSTRUCTION:
BODY SA515 GR70 | 0.2 — DISC SA515 GR70 | 0.2
SHAFT SA564 GR630 H-1075 — PINS SA564 GR630 H-1075
INB'D. BUS'G. GR/BRZ #2 — SEAT EPT
FOLLOWERS D/I — RET PLATE - SA515 GR70

DISC. TYPE: CONV. ☒ FISHTAIL ☐ OTHER OFFSET
DISC. EXP. "
DISC. DIA. "
FLOW R TO L

SEAT TYPE: LINED ☐ ADJUST ☒ SEAL ☐
SEAL SUPPLY
PACK'G. TYPE: TEFLON ☐ OTHER 182* CRANE
PACKING BOX — PLAIN ☐ LUB. ☒* PURGED ☐ STICK LUB. ☐ ISOL. VALVES ☐
LANTERN GLAND—GRAPHITAR ☐ S/S TL ☒** ALEMITE ☐ PLUGGED ☒

B — BRACKET & LINKAGE

PIPE RUN: HORIZONTAL ☒ VERTICAL ☐
PUSHROD: PERPENDICULAR TO PIPE ☐ PARALLEL TO PIPE ☐
LINKAGE SET: 0 MIN. DEG. — 50 MAX. DEG. (2)
SCHEMATIC DWG. NO.: PIPING — WIRING —

C — POWER ACTUATOR DESCRIPTION

LINEAR ACT. P.D.T.O. ☐ P.D.T.C. ☐ — ROTARY ACT. CWTO ☐ CWTC ☒ — BORE — STROKE

QTY.	ACTUATOR TYPE AND MODEL NUMBER	NOMINAL SPRING RANGE	INITIAL SPRING COMPRESSION	FULL STROKE PRES. W/VALVE
1	SMB-000-2-H1BC	TO		

QTY.	POSITIONER TYPE AND MODEL NUMBER	BYPASS VALVE	DIRECT / REVERSE	GAUGES / BYPASS	INST. SIGNAL	SUPPLY	AIRSET
		☐	☐ / ☐	☐ / ☐	TO	PSI	

D — MANUAL ACTUATOR DESCRIPTION

QTY.	TYPE	POS.	CHAIN
			FT.

SERVICE CONDITIONS: FLUID AIR
TEMP. 340 °F — FLOW RATE 11,000 SCFM — STATIC PRES. PSIG
ACTUAL Δ P FLOW PSI — ACT. Δ P SHUTOFF 60 PSI — TORQUE REQ'D.

ACTUATOR MOUNTING INSTR.:
CONT'L. FURN. & MT. ☒
CUST. FURN./CONT'L. MT. ☐
CUST. FURN. & MT. ☐

S/N TAG INFORMATION: STRUCTURAL LIMITATIONS

Body Design Pres. 275 PSI, Δ P 68 PSI Shutoff At 70° F.

CUSTOMER TAG: 2VQ036 (1)

QTY.	BM/PART NO.	DESCR.
	BM-BF226473	Pg. 1
	BM-BF226473	Pg. 2

ENGINEERING SPECS:
* FURNISH 5 RINGS OF PACKING ON EACH SIDE OF LANTERN GLAND
** DRILL & TAP 2 HOLES (#10-24) 180° APART ON EACH END OF LANTERN GLAND. (MAT'L ASME SA479 TYPE 316)
FURNISH S/S ASME SA-240 TYPE 316 SEAT RING ROLLED AND WELDED IN BODY BORE. WELD TO BE LIQUID PENETRANT TESTED PER C.I.S 1.4 REV 11.
BODY TO BE DRILLED AND TAPPED FOR 1/2" NPT LEAK OFF CONNECTION. FURNISH CARBON STEEL PIPE PLUG IN LEAK OFF CONNECTION.
BRACKET AND ACTUATOR BOLTING TO BE LOCK WIRED.

CUSTOMER NO. 14723 — PRODUCT CODE 1220
QUOTED SHIP DATE — REQUESTED SHIP DATE

CHECK LIST: W/UP (OOB) ENG'R R.M.L. Q.C.

Form No. C0707 - 8/73

12

Attachment 12 - Material Properties Data for Ethylene-Propylene Elastomers

COMPARATIVE PROPERTIES of the Du Pont elastomers and natural rubber

Properties	Natural Rubber	ADIPRENE* polyurethane	HYPALON* chloro-sulfonated poly-ethylene	HYTREL* polyester elastomer 92A	55D	63D	72D	KALREZ* perfluoroelastomer	Neoprene chloroprene	NORDEL* ethylene-propylene-diene polymer	VAMAC* ethylene/acrylic elastomer	VITON* co-polymer of vinylidene fluoride and hexafluoro-propylene
HARDNESS RANGE (durometer A&D)	30-90A	60-99+A (up to 80D)	40-95A	92A	55D	63D	72D	65-95A	40-95A	40-90A	40-95A	55-95A
TENSILE STRENGTH, MPa(psi) Pure gum	Over 20.7 (3,000)	Over 27.6 (4,000)	Over 17.2 (2,500)	40.7 (5,900)	44.1 (6,400)	40.0 (5,800)	40.0 (5,800)	N.A.	Over 20.7 (3,000)	—	—	Over 12.4 (1,800)
Black loaded stocks	Over 20.7 (3,000)	—	Over 20.7 (3,000)	—	—	—	—	Over 13.8 (2,000)	Over 20.7 (3,000)	Over 20.7 (3,000)	Over 17.2 (2,500)	Over 13.8 (2,000)
SPECIFIC GRAVITY (Base Material)	0.93	1.06	1.12-1.28	1.17	1.20	1.22	1.25	2.01	1.23	0.86	1.08-1.12	1.85
VULCANIZING PROPERTIES	Excellent	Excellent	Excellent	Unnecessary to vulcanize				N.A.	Excellent	Excellent	Good to Excellent	Good
ADHESION TO METALS	Excellent	Excellent	Excellent	Good	Good	Good	Good	Fair	Excellent	Good to Excel	V.G. to Excellent	Good
ADHESION TO FABRICS	Excellent	Excellent	Good	Good	Good	Good	Good	Good	Excellent	Good	Good	Good to Excel
TEAR RESISTANCE	Good	Excellent	Fair	Excel	Outstng	Outstng	Outstng	Fair	Good	Good	Good	Fair
ABRASION RESISTANCE	Excellent	Outstanding	Excellent	Outstng	Very Outstng	Very Outstng	Very Outstng	Good	Excellent	Excellent	Good	Good
COMPRESSION SET	Good	Fair	Fair	Fair	Fair	Poor	Poor	Fair	Fair to Good	Good	Good	Fair to Good
REBOUND Cold	Excellent	Poor at V.L. temp.	Good	V. Good	Good	Fair	Fair	N.A.	Very Good	Very Good	Poor	Good
Hot	Excellent	Good at R.T.	Good	Excel	V. Good	Good	Good	N.A.	Very Good	Very Good	Fair	Excellent
DIELECTRIC STRENGTH	Excellent	Excellent	Excellent	Fair to Good	Fair to Good	Fair to Good	Good	Excellent	Good	Excellent	Good	Good
ELECTRICAL INSULATION	Good to Excellent	Fair to Good	Good	Fair to Good	Fair to Good	Fair to Good	Good	Excellent	Fair to Good	Excellent	Fair to Good	Fair to Good
PERMEABILITY TO GASES	Fair	Fair	Low - V.L.	Fair	Fair	Fair	Good	Fair	Low	Fair	Very Low	Very Low
ACID RESISTANCE Dilute	Fair to Good	Fair	Excellent	Fair	Fair	Fair	Fair	Excellent	Excellent	Excellent	Good	Excellent
Concentrated	Fair to Good	Poor	Very Good	Poor	Poor	Poor	Poor	Excellent	Good	Excellent	Poor	Excellent
SOLVENT RESISTANCE Aliphatic hydrocarbons	Poor	Excellent	Good	Excel	Excel	Excel	Excel	Excellent	Good	Poor	Good	Excellent
Aromatic hydrocarbons	Poor	Fair to Good	Fair	Good	Good	Good	Good	Excellent	Fair	Poor	Fair	Excellent
Oxygenated (ketones, etc.)	Fair to Good	Poor	Poor	Fair	Good	Good	Good	Excellent	Poor	Good	Poor	Poor
Lacquer solvents	Poor	Poor	Poor	Fair	Fair to Good	Good	Good	Excellent	Poor	Poor	Poor	Poor
RESISTANCE TO: Swelling in lubricating oil	Poor	Excellent	Good to Excel	Good	Excel	Excel	Excel	Excellent	Good	Poor	Good	Excellent
Oil and gasoline	Poor	Excellent	Good	Very Good	Excel	Excel	Excel	Excellent	Good	Poor	Good	Excellent
Animal and vegetable oils	Poor to Good	Excellent	Good	Very Good	Excel	Excel	Excel	Excellent	Good	Good	Good	Excellent
Water absorption	Very Good	Good at R.T. Poor at 100°C (212°F)	Very Good	V. Good up to 100°C (212°F)	V. Good up to 100°C (212°F)	V. Good up to 100°C (212°F)	V. Good up to 100°C (212°F)	Very Good	Good	Very Good	Very Good up to 100°C (212°F)	Very Good
Oxidation	Good	Excellent	Excellent	Excel	Excel	Excel	Excel	Outstanding	Excellent	Excellent	Outstanding	Outstanding
Ozone	Fair	Excellent	Outstanding	Excel	Excel	Excel	Excel	Outstanding	Excellent	Outstanding	Outstanding	Outstanding
Sunlight aging	Poor	Good	Outstanding	Very Good***	Very Good***	Very Good***	Very Good***	Outstanding	Very Good	Outstanding	Outstanding	Outstanding
Heat aging (upper limit cont. service)	85°C (185°F)	85°C (185°F)	135°C (275°F)	100°C (212°F)	110°C (230°F)	110°C (230°F)	110°C (230°F)	290°C (554°F)	95°C (203°F)	145°C (293°F)	165°C (329°F)	205°C (401°F)
Flame**	Poor	Fair (will melt)	Good	Good*** (will melt)				Excellent	Very Good	Poor	Poor	Excellent
Heat	Good	Good	Excellent	V. Good	Excel	Excel	Excel	Very Outstng	Very Good	Excellent	Excellent	Outstanding
Cold	Excellent	Excellent	Good	Excel	Excel	Excel	Excel	Good	Good	Excellent	Good	Good

Measuring Performance Characteristics.

Test methods have been established by the American Society for Testing Materials (ASTM) and the Society of Automotive Engineers (SAE) for measuring physical and chemical properties of products made from elastomers. Properly used and interpreted, these tests provide an excellent basis for specifying to the rubber supplier the performance characteristics you require in a rubber product. A complete description of testing procedures is contained in the publication, "ASTM Standards on Rubber Products", issued by the ASTM, 1916 Race Street, Philadelphia, Pennsylvania, 19103.

*Reg. U.S. Pat. & Tm. Off.

**These evaluations are qualitative and comparative only. They should not be construed as recommendations. Specific compounding is required to optimize performance. Elastomer choice should be based upon a practical consideration of the potential fire hazards involved in each individual case and, if applicable, the results of appropriate flame tests.

***With additives

Selecting elastomeric seals for nuclear service

Compression set tests have proved more reliable than tensile tests in the selection of elastomer compounds for use as seals in a nuclear environment

By ROBERT BARBARIN, Parker Hannifin Corp./Seal Group

In the early 1960s, the primary test used in selecting elastomers for reactor seals was a tensile test conducted on unstressed slabs of the compounds after they had been subjected to irradiation. These standard tests had the unfortunate ability to make compounds look very appealing to the nuclear engineer while completely failing the primary requirements of seal engineers. Today, a test has been developed which promises to satisfy the demands of both engineers. This is a test to determine the compression set of seals which are simultaneously squeezed (as they would be when installed) and irradiated (as they may be when in service) over prolonged periods. The new data provide criteria by which compounds may be selected for long life, normally requiring replacement only during conservatively scheduled five-year reactor overhauls.

Typical applications for elastomeric seals in and around nuclear reactors include the static seals in pressurized conduits containing radioactive fluids, and the dynamic seals in structural hydraulic snubbers.

Compression set

Compression set may be defined as the percent by which a seal fails to return to its original dimension after compression, expressed as a percent of its deflection. This loss of dimensional memory is due to changes in the elastomer's arrangement and density of molecular cross-links. As the change in cross-linking progresses, the seal will gradually take on the shape of the confining groove and relax the force that it exerts on the confining surfaces.

Since this normally occurs before tensile property changes, the tensile tests are frequently omitted as contemporary criteria for nuclear seal compound selection.

Of the three major types of radiation from nuclear fission, only gamma rays are normally considered a hazard to elastomer seals that are completely enclosed in conventional metal grooves. Alpha and beta rays are effectively stopped by thin metal barriers. Gamma rays, however, easily penetrate the typical elastomeric seal glands and cause cumulative changes in the compounds (see Table 1).

All elastomers tested to date have shown excessive compression set at 10^8 rads, yet a number of compounds showed acceptable compression set at 10^7 rads of gamma radiation dosage.

Therefore, no elastomer known today should be considered for

Table 1. Effects of gamma radiation on the principal properties of elastomeric compounds most often considered for seals in and around nuclear reactors. Compression set tests were conducted at room temperature and 25% deflection, for the number of days noted, while under radiation from cobalt strips in air.

Generic or Base Polymer (Compound No.)	Radiation Dosage in Rads	Hardness in Pts on Shore "A" Scale (Pts Change)	Tensile Strength in Psi @ Break (% Change)	Elongation in % @ Break (% Change)	Modulus in Psi @ 100% Stretch (% Change)	Tear Strength in lb/in. (% Change)	Compression Set Test: Days Deflected	Compression Set Test: CS in % of Original Deflection
Silicone	Original	69	807	117	668	63	93	7.6
(S455-70)	10^7	72 (+3)	733 (-9)	89 (-24)	--	63 (0)	93	31.4
	10^8	85 (+16)	--	--	--	--	93	90.5
Silicone	Original	66	1010	149	695	70	93	3.8
(S604-70)	10^7	69 (+3)	1020 (+1)	129 (-13)	833 (+25)	62 (-11)	93	20.0
	10^8	85 (+19)	939 (-7)	31 (-79)	--	29 (-59)	93	92.4
Ethylene	Original	78	1450	213	689	164	93	16.2
Propylene	10^7	78 (0)	1220 (-16)	176 (-17)	740 (+7)	148 (-10)	93	46.6
(E515-80)	10^8	84 (+6)	1030 (-29)	79 (-6[illegible]	--	71 (-57)	93	96.2
Ethylene	Original	70	2080	233	554	174	93	6.7
Propylene	10^7	73 (+3)	2140 (+3)	194 (-17)	808 (+46)	163 (-6)	93	28.6
(E740-70)	10^8	79 (+9)	1700 (-18)	96 (-59)	--	70 (-60)	93	90.5
Fluorocarbon	Original	75	1510	190	634	128	93	14.7
(V747-75)	10^7	76 (+1)	1580 (+5)	130 (-32)	1120 (+77)	87 (-32)	93	66.7
	10^8	88 (+15)	1180 (-22)	29 (-85)	--	82 (-36)	93	93.3
Polyurethane	Original	66	3560	582	342	306	56	17.1
([illegible]42-70)	10^7	67 (+1)	3570 (0)	491 (-16)	444 (+30)	374 (+22)	56	55.2
	10^8	66 (0)	1420 (-60)	201 (-65)	--	146 (-52)	56	91.4
Fluoro-	Original	68	1050	180	520	72	128	13.3
silicone	10^7	72 (+4)	668 (-36)	97 (-46)	--	--	128	67.6
(L677-70)	10^8	84 (+10)	--	--	--	--	128	97.1

application where 10^7 rads dosage will be exceeded between scheduled overhauls.

Table 1 documents several compounds frequently considered for nuclear seals, showing their original properties and those same properties after exposure to 10^7 rads. At this dosage, two silicones, two nitriles and one ethylene propylene compound exhibit acceptable compression set. A second ethylene propylene compound, as well as polyurethane, polyacrylate, fluorocarbon, and fluorosilicone, would not be recommended because they all tested out at marginal or excessive compression set. The results for polyurethane are particularly revealing; the tensile, tear and modulus tests were either unchanged or actually improved by 10^7 rads, but the compression set rose from approximately 17% to over 55%.

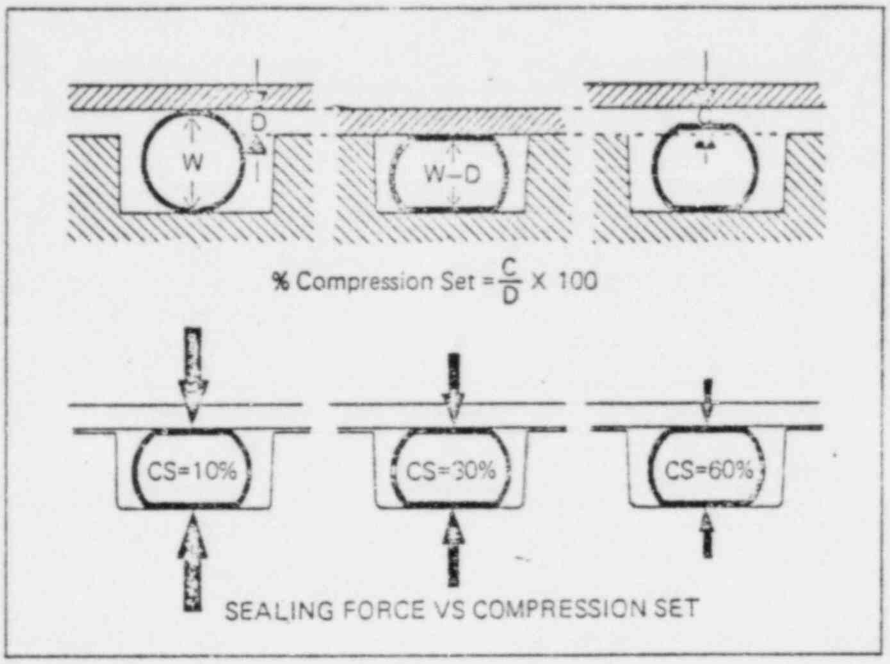


Figure 1. Compression set (the percentage of initial deflection which is unrecovered when a seal is released) directly affects the force that a compression seal can maintain on its sealing lines. This factor, which is increased by radiation, is a prime criterion for the selection of seals for reactors.

Temperatures and fluids

Service temperatures and/or fluids often degrade an elastomer faster and more severely than gamma radiation. This is illustrated clearly by comparisons between Tables 1 and 2. While Table 1 shows the effects of gamma radiation without fluid or temperature influences, Table 2 shows the effects of fluids and temperatures frequently encountered in nuclear reactor environments but without the gamma radiation. It is interesting to note that the polyurethane degradation documented in Table 2 was the result of temperature, but that it would doubtless have been attributed to radiation if it had occurred in a reactor.

The combined effects of radiation, temperature and fluid are seldom a simple addition of their individual effects, but are synergistic. However, knowledge of all three characteristics for each compound will help in the selection of the best compounds for testing.

Table 2. Effects of fluid immersion in principal reactor fluids on polyurethane and ethylene propylene elastomers considered for seals in and around nuclear reactors. Note severe effects of temperature excursions on properties of polyurethane compounds compared to the properties of most ethylene propylenes.

Generic or Base Polymer (Compound No.)	Immersion Test Fluid immersed 3 hrs @ 340F + 3 hrs @ 320F + 18 hrs @ 250F	Hardness in Pts on Shore "A" Scale (Pts Change)	Tensile Strength in Psi @ Break (% Change)	Elongation in % @ Break (% Change)	Modulus in Psi @ 100% Stretch (% Change)	Volume Change in %	Compression Set in % of Original Deflection
Polyurethane (P4611)	Original properties	95	7240	470	1590		
	GE SF 96 Silicone (200 c/s)	89 (-6)	4250 (-41)	537 (+14)	1370 (-14)	-0.8	119.2
	GE SF1154 Silicone	89 (-6)	3650 (-50)	550 (+17)	1400 (-12)	-0.3	cancelled
	Water	89 (-6)	4680 (-35)	576 (+23)	1180 (-26)	+2.3	96.5
Polyurethane (P642-70)	Original properties	66	3780	699	350		
	GE SF 96 Silicone (200 c/s)	Deteriorated	—	—	—	-1.7	cancelled
	GE SF1154 Silicone	Deteriorated	—	—	—	-2.2	cancelled
	Water	Deteriorated	—	—	—	—	—
Ethylene Propylene (E740-75)	Original properties	73	2390	177	991		
	GE SF 96 Silicone (200 c/s)	73 (0)	2800 (+17)	207 (+17)	865 (-13)	-1.5	19.9
	GE SF1154 Silicone	70 (-3)	2660 (+11)	198 (+12)	800 (-19)	+3.0	17.8
	Water	74 (+1)	2600 (+9)	182 (+3)	873 (-12)	0.0	14.4
Ethylene Propylene (E652-90)	Original properties	88	2330	146	1230		
	GE SF 96 Silicone (200 c/s)	91 (+3)	2330 (0)	146 (0)	1500 (+22)	-2.5	44.9
	GE SF1154 Silicone	89 (+1)	2430 (+4)	143 (-2)	1490 (+21)	+0.4	cancelled
	Water	90 (+2)	2450 (+5)	145 (-1)	1430 (+16)	-1.0	42.0
Ethylene Propylene (E529-65)	Original properties	61	1450	273	279		
	GE SF 96 Silicone (200 c/s)	61 (0)	1680 (+16)	317 (+16)	296 (+6)	-4.5	29.6
	GE SF1154 Silicone	60 (-1)	1520 (+5)	279 (+2)	290 (+4)	-2.1	28.4
	Water	61 (0)	1590 (+10)	298 (+9)	276 (-1)	-0.1	29.8
Ethylene Propylene (E692-75)	Original properties	74	1610	239	563		
	GE SF 96 Silicone (200 c/s)	72 (-2)	1350 (-16)	209 (-13)	578 (+3)	-3.4	25.4
	GE SF1154 Silicone	72 (-2)	1620 (+1)	219 (-8)	549 (-2)	+0.8	30.5
	Water	73 (-1)	1100 (-32)	171 (-28)	545 (-3)	+0.2	16.7

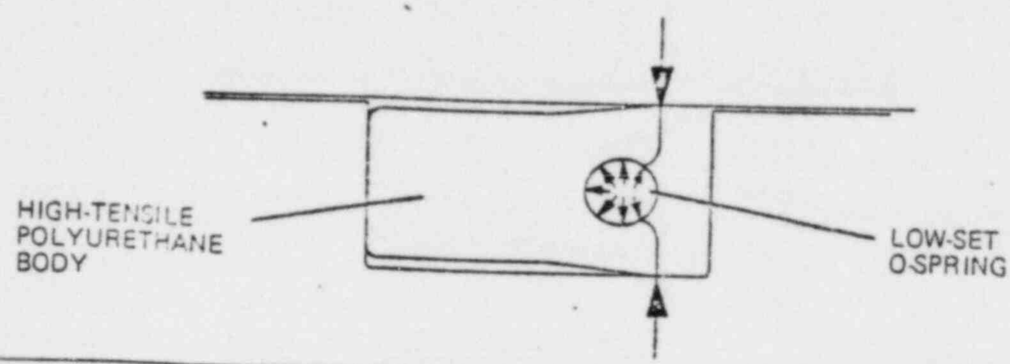


Figure 2. Excellent tensile, tear and modulus properties of polyurethane under radiation may be preserved by a design which compensates for poor compression set under radiation. An O-ring with superior compression set can be used as a spring to energize a polyurethane seal body with superior tensile properties.

Base polymers vs variations

It can be very misleading to ascribe either fluid, temperature or radiation resistant properties to a generic class of elastomers. Variations in compounding within the generic class can cause wide differences in properties. Early tests of nitriles, for example, discouraged their use in reactor environments for many years. However, later tests of other nitrile formulations showed that their compression set properties were among the best when subjected to gamma radiation.

Ethylene propylene is a case in point. The standard Parker E515-80 compound (see Tables 1 and 2) developed nearly twice the compression set and lost significantly more tensile and tear strength than E740-75—another ethylene propylene compound. The E740-75 material has compression set characteristics similar to the silicones and nitriles tested and also has much better resistance than the latter to water and silicone fluids commonly used in reactors.

Silicones are deceptive in that they show excellent compression set characteristics under radiation, but show poor resistance to water and the silicone fluids. This severely limits their usefulness in reactors.

Fluoroelastomers (fluorocarbons and fluorosilicones) have long been equated by many engineers with "the best available" primarily because of their outstanding temperature range. Not only do test results contradict this optimism, with neither recommended for more than 10^6 rads, but fluoroelastomers tend to degrade rapidly in water or steam. Also, some reactor specifications forbid the use of any materials containing fluorine or chlorine. Even if the fluid is compatible, and the radiation tolerance can be accepted at 10^6 rads, such specifications as the AEC's RDT M11-1T may prohibit their use.

Polyurethane takes a rather high compression set in radiation even though its unstressed physical properties hold up well at room temperature after 10^7 rads. It would not be a preferred material for O-rings or other compression type seals. It probably would serve well in an O-ring energized lip seal, however, if the O-ring is radiation-resistant (see Figure 2), or in lip type seals that are activated entirely by *continuous* fluid pressure.

While polyurethane compounds are not generally recommended for use in water fluids, it should be pointed out that the rapid deterioration of the P4611 and P642-70 compounds reported in Table 2 was due primarily to temperature.

Nitrile compounds' resistance to gamma radiation varies greatly, depending on the specific formulation. Thus far, N674-70 and N741-75 are unique in their ability to tolerate 10^7 rads with little compression set. These two formulations, therefore, may become quite useful in some nuclear applications. Even these formulations, however, could not be recommended for long-term use if the sealed fluid were hot air or other critical fluid/temperature combinations.

Polyacrylates are like polyurethanes in that they have a low tolerance for water, especially at higher temperatures, while being quite compatible with silicone fluids up to 350 F. Their compression set properties under radiation usually would suggest switching to the E740-75 ethylene propylene for reactor service.

Work to overhaul periods

Compounds that are recommended for service as seals in reactor environments should have ample remaining life at regularly scheduled overhaul intervals to permit routine replacement without stretching their projected life. Many engineers who inquire about seals ask for 20 to 40 years of service even though shutdown and overhaul is scheduled at 5- or 10-year intervals.

Designers working with elastomeric seals must learn to work to the overhaul periods and not to the reactor life. Even then, it is important to test elastomers under the combined degradation factors anticipated for each application to earn a high confidence factor.

No blanket recommendation can logically be made for the one best seal compound for nuclear reactors or non-nuclear applications. While the E740-75 ethylene propylene compound exhibits the best combination of radiation, fluid and temperature tolerance of all the known contenders for reactor seals, even this excellent compound should be evaluated under the combined conditions for the specific application. Tensile tests alone cannot predict elastomer's response to radiation environments. This may not only lead away from the optimum material, but may lead to a compound that develops excessive compression set early in its exposure to gamma radiation.

END

Attachment 13 - Environmental Conditions

TABLE M.4-4

HARSH ENVIRONMENT ZONE H4 - BOUNDING

ENVIRONMENTAL CONDITIONS IN THE REACTOR BUILDING

Temperature (°F)	145-134	134-128	128-115	115-111	111-110.5
Pressure (in. W.G.)	-0.25	-0.25	-0.25	-0.25	-0.25
Relative Humidity (%)	95	95-75	75-30	30	30
Duration (days)	0-1	1-3	3-13	13-38	38-100

Radiation (See Figure M.4-3):

Subzone H4A

More than 20 feet from outer edge of SGTS charcoal filter - 1×10^7 rads (gamma integrated)

[redacted]

[redacted]

Note:

Temperature and relative humidity change linearly over the time duration to the next value.

TABLE M.4-13

HARSH ENVIRONMENT ZONE H4 - SERVICE CONDITIONS

IN THE REACTOR BUILDING (GENERAL ACCESSIBLE AREAS)

TEMPERATURE (°F)	RELATIVE HUMIDITY (%)	DURATION NO. OF DAYS IN 40 YEARS PLANT LIFE
100	49	3
98	49	57
96	48	197
94	48	234
92	48	355
90	48	3291
85	42	1167
81	40	9306

Radiation: 2×10^6 rads gamma (integrated)

Pressure: -0.4 inch W.G.