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May 29, 1980

NS-TMA-2250

Mr. James R. Miller, Chief
Special Projects Branch
Division of Project Management
U. S. Nuclear Regulatory Commission
7920 Norfolk Avenue
Bethesda, Maryland 20014

Dear Mr. Miller:

Subject: WECAN Verification

Reference: (1) NS-CE-1450, 5/26/77, Eicheldinger to Stolz
(2) Telecon, 4/11/80, Vashi (W) and Hartzman (NRC)

Per the referenced telecon on the subject of WECAN verification, the NRC informed Westinghouse that review of WCAP-8929, "Benchmark Problem Solutions Employed for Verification of the WECAN Computer Program," was not yet complete. In addition, the NRC noted that the verification related to modal response spectrum analysis was insufficient. To satisfy the requirement for benchmark problem solutions for WECAN response spectrum analysis, Westinghouse agreed to submit the solutions to three additional benchmark problems in order that the NRC may expedite their review of WCAP-8929.

Enclosed are the Westinghouse solutions to NRC benchmark problems 1, 323A, and 4.

Please note during review of these solutions that WECAN provides results with the same high degree of accuracy as the WESTDYN computer code which has been previously reviewed and approved by the NRC.

It is understood that the NRC approach to code verification consists of both benchmark problem solutions and confirmatory analyses.

It is expected that Staff approval of WCAP-8929, along with supplemental confirmatory analyses as the Staff may request, will result in generic approval of the WECAN computer code.

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If you have any questions on this submittal, please contact Ms. M. A. Haley (412-373-4091) or Mr. R. J. Sero (412-373-4189) of my staff.

Very truly yours,

T. M. Anderson, Manager
Nuclear Safety Department

MAH/TMA/jaw

Enclosure

cc: Mark Hartzman, w/enclosure

ATTACHMENT 1

WECAN SOLUTIONS TO THE NRC BENCHMARK
PROBLEMS 1, 323A and 4

This attachment provides the modal seismic response spectra solutions to the NRC Benchmark problems described below. These solutions were obtained using the Westinghouse computer program WECAN.

PROBLEM NO.	DESCRIPTION	W RUN NO.	DATE
1	Hovgaard Bend	Y6WG1CS	5/12/80
323A	Steam Line	Y6WG2RI	5/9/80
4	Reactor Coolant Loop	Y6WG4PR	5/13/80

Sketches and the WECAN solution outputs for these problems are attached. The four types of WECAN elements used in the Benchmark problems are described in Attachment 2. Also, a description of the stress and element force output is included. The WECAN post-processor to combine the modal responses is described in Attachment 3. Information in Attachments 2 and 3 is provided as an aid in your review of the computer output for the benchmark problems.

The WECAN modes are normalized to a maximum component of 1.0 for the mass degrees of freedom, while the NRC modes are normalized with respect to the mass matrix. The WECAN modes can be made equivalent to the NRC modes by dividing the WECAN modes by the square root of the quantity labeled "generalized mass" in the WECAN output. Similarly, the WECAN participation factors and mode coefficients should be multiplied by the square root of the generalized mass before comparison with NRC results.

The WECAN output format will be described, followed by a description of the WECAN post-processor output. First of all, a listing of the WECAN input cards is given . An interpretation of each of the WECAN card series is then printed. A table of frequencies, generalized mass, and generalized stiffness is then given. This is followed by a table of participation factors and mode coefficients for the first shock direction (X-direction in the Benchmark problems). Then for each mode for the X-direction, the mode shapes expanded to include massless degrees of freedom is printed. If the mode coefficient for that mode is significant (not less than .001 times the maximum mode coefficient for that direction), then the spectral displacements, stresses, forces and reaction forces are printed for that mode. After all of the modes have been processed, the displacements, stresses and reaction forces for the significant modes are combined by the SRSS method. The tape 10 format for each type of element is given in Attachment 2. The table of participation factors, etc., is then printed for the Y-direction, then the Z-direction, with the same format as the X-direction but without the expanded mode shapes.

The WECAN post-processor output begins with an input listing. The input for each direction is then processed in sequence. Modal responses can be combined by any of the procedures given in NRC Regulatory Guide 1.92. Combined displacements for the X, Y, and Z directions are given, e.g., using the ten percent method, then the square root of the sum of the squares of the three directional responses is printed. The same process is repeated for the element stresses and forces, then reaction forces are processed in the same manner.

Since the three Benchmark problems had been set up on WESTDYN, a computer program was used to convert the WESTDYN input into WECAN input. This process generated node numbers different from the NRC node numbers, so node number correspondence tables are given below for the three Benchmark problems. Also, the WECAN input for Benchmark Problem 4 was modified to delete the additional nodes introduced in the WESTDYN input. Finally, the WECAN response spectra input is taken to be a tabular function of acceleration versus frequency, so such tables were derived from the NRC acceleration versus period tables.

It should be noted that the ten percent method for closely spaced modes was used in each shock direction for Problem Nos. 1 and 4, while SRSS was used for Problem No. 323A.

PROBLEM NUMBER 1: HOVGAARD BEND

The WECAN node points corresponding to the NRC node points are as follows:

NRC NODE	WECAN NODE
2	4
3	6
4	8
5	10
6	12
7	14
8	16
9	18
10	20

The WECAN and NRC results are in good agreement. For example, the maximum combined displacements and rotations are:

	WECAN	NRC
UX	.0079	.0078
NODE	10(5)*	5
UY	.0025	.0025
NODE	14(7)	7
UZ	.0176	.0174
NODE	8(4)	4
RX	.000186	.000184
NODE	6(3)	3
RY	.000214	.000212
NODE	14(7)	7
RZ	.000071	.000070
NODE	6(3)	3

*WECAN NODE (NRC NODE)

PROBLEM NUMBER 323A: STEAM LINE

The WECAN node points corresponding to the NRC node points are as follows:

NRC NODE	WECAN NODE	NRC NODE	WECAN NODE
2	202	22	226
3	206	23	28
4	4	24	228
5	6	25	30
6	8	26	230
7	10	27	32
8	208	28	232
9	12	29	34
10	210	30	234
11	14	31	36
12	16	32	236
13	18	33	38
14	218	34	238
15	20	35	40
16	220	36	42
17	22	37	44
18	222	38	46
19	24	39	246
20	224	40	250
21	26	41	48

The WECAN and NRC results are in good agreement. For example, the maximum combined displacements are:

	WECAN	NRC
UX	.0235	.0235
NODE	36(31)*	31
UY	.0779	.0779
NODE	40(35)	35
UZ	.0150	.0150
NODE	42(36)	36
RX	.000320	.000320
NODE	40(35)	35
RY	.000096	.000096
NODE	40(35)	35
RZ	.000311	.000311
NODE	46(38)	38

*WECAN NODE (NRC NODE)

PROBLEM NUMBER 4: REACTOR COOLANT LOOP

The WECAN node points corresponding to the NRC node points are as follows:

NRC NODE	WECAN NODE	NRC NODE	WECAN NODE
1	4	40	228
2	6	47	34
3	8	48	36
4	10	49	38
9	12	50	40
11	226	51	42
12	314	58	254
13	252	59	316
14	222	60	280
15	310	61	258
16	248	62	284
17	220	63	260
18	246	64	318
19	216	65	286
20	242	66	262
21	18	67	288
22	20	68	44
23	212	69	46
24	238	72	52
25	22	73	54
26	24	74	264
29	30	75	290
30	32	76	56
31	210	77	58
32	236	78	268
33	208	79	294
34	308	80	272
35	234	81	298
36	206	82	274
37	232	83	320
38	202	84	300
39	306	85	278

(Problem 4 continued)

NRC NODE	WECAN NODE
86	304
87	324
89	64
90	66
95	68
96	70
97	72

Additional WECAN node points are used to specify elbow planes and for anchors, but the nodes in the above table are the only nodes at which spectral displacements are calculated in the WECAN model.

The significant WECAN participation factors were adjusted by multiplying by the square root of the generalized mass and compared to the corresponding NRC participation factors. Tables for the three different directions are given. The WECAN and NRC results are in good agreement.

X - DIRECTION

SIGNIFICANT PARTICIPATION FACTORS

MODE	ADJUSTED WECAN	NRC
3*	16.37	16.57
7*	8.7	8.75
9*	94.55	94.70
17	39.97	39.98
18	.99	.98
22	1.28	1.37
27	1.55	1.91
29	5.29	5.56

*Modes 3, 7 and 9 are the dominant modes.

Y - DIRECTION

SIGNIFICANT PARTICIPATION FACTORS

MODE	ADJUSTED WECAN	NRC
4	1.17	1.23
8	1.78	1.75
12*	26.75	28.79
14*	65.04	64.58
21	79.45	78.51
23	42.82	44.46
26	9.22	9.77

*Modes 12 and 14 are the dominant modes

Z - DIRECTION

SIGNIFICANT PARTICIPATION FACTORS

MODE	ADJUSTED WECAN	NRC
2	.41	.29
5**	61.56	61.61
10**	70.50	70.61
15	35.48	35.12
16	10.04	9.94
20	22.63	23.18
25	6.82	8.17

**Modes 5 and 10 are the dominant modes.

The WECAN and NRC results are in reasonable agreement. The maximum combined displacements and rotations are:

	WECAN	NRC
UX	.454	.467
NODE	32(30)*	30
UY	.076	.086
NOD#	4(1)	1
UZ	.955	.972
NODE	32(30)	30
RX	.00411	.00419
NODE	32(30)	30
RY	.00252	.00257
NODE	208(33)	33
RZ	.00213	.00220
NODE	32(30)	30

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*WECAN NODE (NRC NODE)

ATTACHMENT 2

DESCRIPTIONS OF THE WECAN
PIPE AND ELBOW ELEMENTS

5.7 Element 7 - Three-Dimensional Straight Pipe

The three-dimensional straight pipe is a uniaxial element with tension-compression, torsion, and bending capabilities. The displacement functions are linear polynomials in the axial displacement and torsional rotation, and cubic polynomials in the two transverse displacements. No coupling between the axial and transverse components is included. The effect of shear deformation is available as an option. The mass matrix of the element is a consistent mass matrix with the displacement functions as shown on page 5.7-3. The effect of rotatory inertia* is also included in the mass matrix.

The element is defined by its two nodal points, outer diameter, wall thickness, and material properties. The pipe must not have zero values for length, wall thickness, or elastic modulus. The thermal gradient is assumed linear through the thickness and uniform along the length.

The straight pipe element is applicable to static, modal, harmonic response, and transient dynamic analyses. It does not have plastic or creep capabilities. Plasticity is included in elements 22 and 28. Creep is available in elements 22, 25, and 41.

The computed output for each end includes the direct** (axial) stress, maximum bending stress, torsional shear stress, hoop stress due to internal pressure, and shear stress due to the lateral shear force. Also included for each end are the following quantities computed at the outer surface: axial thermal stress, maximum and minimum principal stresses, and twice the maximum shear stress, which may or may not occur at the same location around the pipe circumference.

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*Ref., Przemieniecki, J. S., "Theory of Matrix Structural Analysis," McGraw-Hill, New York, N.Y., 1968, p. 294.

**Includes stress due to internal pressure.

THREE-DIMENSIONAL STRAIGHT PIPE
ELEMENT CHARACTERISTICS

Subroutine name	STIF7
Nodes per element	2
Degrees of freedom per node	6 (U_X, U_Y, U_Z, R_X, R_Y, R_Z)
Real constants	2 (D_o, t_{wall})
Temperatures	2 (T_{ave}, T_{out})
Pressures	1 ($P_{internal}$)
Material properties (b,c)	EX, ALPX, NUXY, DENS, MDAM, KDAM
Matrices calculated (a)	Stiffness, Mass
Valid for analysis types (K20)	0 Static 2 Modal 3 Harmonic response 4 Nonlinear transient dynamic 5 Linear transient dynamic
Additional capabilities	Storage and retrieval available for K20=4
KEYSUB(1) (d)	0 Include shear deformation 1 Omit shear deformation
KEYSUB(2)	No meaning
Data stored on TAPE10 (42) (f)	DIR(1), DIR(2), 2MXSR(1), 2MXSR(2), BEND(1), BEND(2), SMAX(1), SMAX(2), SMIN(1), SMIN(2), ST(1), ST(2), SP(1), SP(2), SF(1), SF(2), TH(1), TH(2), $[FX(1), FY(1), FZ(1), MX(1), MY(1), MZ(1)]_{LOCAL}$ $[FX(2), FY(2), FZ(2), MX(2), MY(2), MZ(2)]_{LOCAL}$ $[FX(1), FY(1), FZ(1), MX(1), MY(1), MZ(1)]_{GLOBAL}$ $[FX(2), FY(2), FZ(2), MX(2), MY(2), MZ(2)]_{GLOBAL}$

Modeling considerations

(Letters in above parentheses refer to corresponding modeling considerations)

a) The mass matrix is a consistent mass matrix that includes rotary inertia.

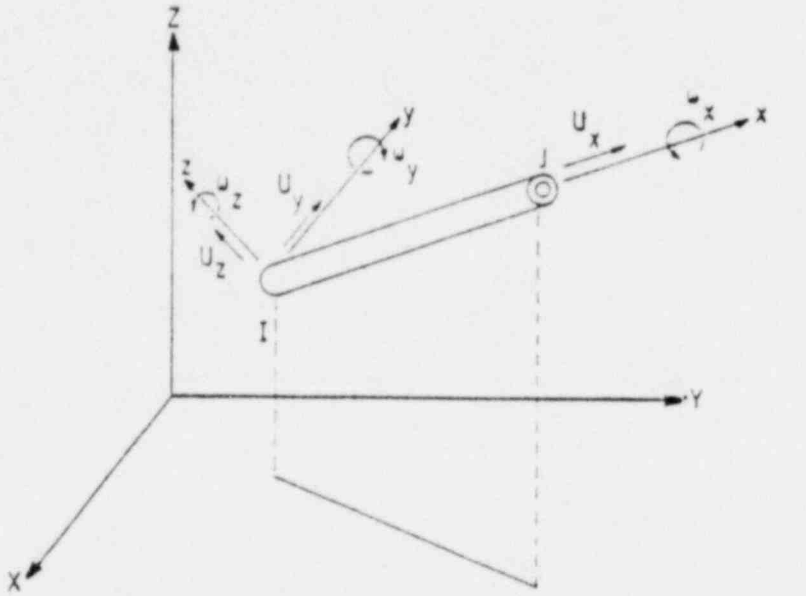
b) DENS is required only for dynamic analyses (K20=2,3,4,5) and for K20=0 with acceleration or centrifugal force field.

c) MDAM and KDAM are required only for K20=3 or 4.

d) See Section 3.14.1 for a discussion of shear shape factors. STIF7 uses a built-in value of 2.0.

e) Nodal point forces are calculated for this element. Reaction forces include the effects for this element.

f) The orientation of local axes of an element is such that when its local x axis is made parallel to global X axis without being rotated about the local x axis, its local y and z axes will become parallel to global Y and Z axes, respectively.



Three-dimensional straight pipe

Displacement functions:

$$U_x(x) = \alpha_1 + \alpha_2 x \quad \text{(linear)}$$

$$U_y(x) = \alpha_3 + \alpha_4 x + \alpha_5 x^2 + \alpha_6 x^3 \quad \text{(cubic)}$$

$$U_z(x) = \alpha_7 + \alpha_8 x + \alpha_9 x^2 + \alpha_{10} x^3 \quad \text{(cubic)}$$

$$\omega_x(x) = \alpha_{11} + \alpha_{12} x \quad \text{(linear)}$$

$$\omega_y(x) = dU_z/dx = -\alpha_8 - 2\alpha_9 x - 3\alpha_{10} x^2 \quad \text{(quadratic)}$$

$$\omega_z(x) = dU_y/dx = \alpha_4 + 2\alpha_5 x + 3\alpha_6 x^2 \quad \text{(quadratic)}$$

Output definitions:

- DIR = direct (axial) stress
- BEND = maximum bending stress
- ST = torsional shear stress
- SP = hoop stress due to internal pressure
- SF = shear stress
- TH = axial thermal stress at outer surface
- SMAX = maximum principal stress at outer surface
- SMIN = minimum principal stress at outer surface
- SINT = 2MXSR = twice the maximum shear stress at outer surface

* The element local coordinate system is used internally and is defined in similar manner to that of STIF4. No input is expressed in terms of the y or z element directions. Node forces in terms of the x, y and z element directions may be placed on TAPE 10

WECAN ELEMENT 7

THREE-DIMENSIONAL STRAIGHT PIPE

Sample of printed output

```
3-D PIPE   8   NODES  13  14   MATERIAL  2 A.TEMP=    0.  O.TEMP=   0.0  I.TEMP=   0.0
1 DIR= -1478. BEND=   635. ST=  4662. SP=     0. SF=    64. TH=    -0. SMAX=  4259. SMIN= -5637. 2MXSR=  9561.
2 DIR= -1478. BEND=  3171. ST=  4662. SP=     0. SF=    64. TH=    -0. SMAX=  5585. SMIN= -7534. 2MXSR= 10419.

FORCES ON NODE    13  -.793247E+03  -.940500E+05   .185467E+04   .418073E+05   .667325E+06   .179241E+05
FORCES ON NODE    14   .793247E+03   .940500E+05  -.185467E+04   .208842E+05  -.667325E+06   .538042E+05
```

Definition of printed output parameters

DIR	=	Direct stress
BEND	=	Maximum bending stress
ST	=	Torsional shear stress
SP	=	Hoop stress due to internal pressure
SF	=	Shear stress due to lateral shear force
TH	=	Axial thermal stress due to thermal gradient thru thickness
SMAX	=	Maximum principal stress
SMIN	=	Minimum principal stress
2MXSR	=	Twice the maximum shear stress

5.29 Element 29 - Three-Dimensional Curved Pipe

The three-dimensional curved pipe is a circularly uniaxial element with tension-compression, bending and torsion capabilities. The element is limited to having an axis with a single curvature. The shear deformation term is always included.* The displacement functions are described in the referenced paper (p. 5.29-3), in which the in-plane and out-of-plane flexibility factors of the curved pipe are computed as those given in the ASME Boiler and Pressure Vessel Code, Sect. III, NB-3687.2 and NB-3682, in 1974. If the ASME requirements of NB-3687.2 are not met, the user should input an appropriate flexibility factor.

The element is defined by three nodal points, an outer diameter, the wall thickness, and the radius of curvature in the plane of the element. Although the pipe element has only two endpoints, the third nodal point K is required to define the plane in which the element lies. It may be a nodal point which is specially defined in space and belongs to no other elements or it may belong to another element. In either case, nodal point K must lie in the plane of the curved pipe. The angle subtended by the element must be no greater than 90 degrees. For larger angles, two or more elements are required.

The curved pipe element is applicable to static, modal, harmonic response, and transient dynamic analyses. This element does not have plastic or creep capabilities. (See Element 42.)

The computed output for each end consists of the following quantities: axial stress**, maximum bending stress on the outer surface, torsional shear stress, hoop stress due to internal pressure, lateral shear stress, axial thermal stress at the outer surface, the principal stresses at the outer surface, twice the maximum shear stress at the outer surface, and the forces at the two ends of the member. The stress output includes the stress intensification factor given in ASME Boiler and Pressure Vessel Code, Section III, Figure NC-3673.2 (b)-1, 1977, which applies for elbows with the ratio of outside diameter to nominal wall thickness being less than or equal to 100.

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*See Section 3.14.1 for a discussion of shear deformation.

**Includes stress due to internal pressure.

THREE-DIMENSIONAL CURVED PIPE
ELEMENT CHARACTERISTICS

Subroutine name	STIF29
Nodes per element (b)	3
Degrees of freedom per node (e)	6 (U_X, U_Y, U_Z, R_X, R_Y, R_Z)
Real constants (a)	4 (D_o, t_{wall}, R_{curve}, K_{flex})
Temperatures	2 (T_{ave}, T_{out})
Pressures	1 ($P_{internal}$)
Material properties (c,d)	EX, ALPX, NUXY, DENS, MDAM, KDAM
Matrices calculated (g,i)	Stiffness, Mass
Valid for analysis types (K20)	0 Static 2 Modal 3 Harmonic response 4 Nonlinear transient dynamic 5 Linear transient dynamic
Additional capabilities (f)	Storage and retrieval available for K20=4.
KEYSUB(1)	No meaning
KEYSUB(2)	No meaning
Data stored on TAPE10 (30)	DIR(1), DIR(2), 2MXSR(1), 2MXSR(2), BEND-(1), BEND(2), SMAX(1), SMAX(2), SMIN(1), SMIN(2), ST(1), ST(2), SP(1), SP(2), SF(1), SF(2), TH(1), TH(2), FX(1), FY(1), FZ(1), MX(1), MY(1), MZ(1), FX(2), FY(2), FZ(2), MX(2), MY(2), MZ(2)

Modeling considerations

(Letters in above parentheses refer to corresponding modeling considerations)

a) If $K_{flex} > 0$, the value is used in place of the ASME formula for in-plane and out-of-plane flexibility factors. If $K_{flex} \leq 0$, the ASME formula is used. A value for K_{flex} should be input if: 1) the ratio of the bend radius to the elbow radius is less than 1.7, 2) the centerline length is less than the elbow mean diameter, or 3) there are flanges or other similar stiffeners within an elbow mean radius distance from the curved section of pipe.

b) The third point, K, should be constrained if it is not connected to the structure. K must be in the plane of the curved pipe on the concave side of the straight line connecting I and J.

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c) DENS is required only for dynamic analyses (K20=2,3,4,5) and for K20=0 with acceleration or centrifugal force field.

d) MDAM and KDAM are required only for K20=3 or 4.

e) Tension, compression, bending, torsion and shear deformation are considered by this element.

f) Plasticity is not considered by this element. Use STIF42 if you want to consider plasticity.

g) A mass matrix is generated for dynamic analyses.

h) Nodal point forces are calculated for this element. Reaction forces include the effects for this element.

i) The stiffness matrix for this element is derived from a flexibility matrix. W. Van Buren, S. K. Chan, and C. Visser, "Derivation of the Elastic Stiffness Matrix and Plastic Load Vector for the Three-Dimensional Curved Pipe Element," Westinghouse Research Report 77-1E7-NESPD-R1, May 25, 1977, performs this derivation.

j) The elemental x and z axes lie in the plane of the curved pipe.

Dwg. 6363A99

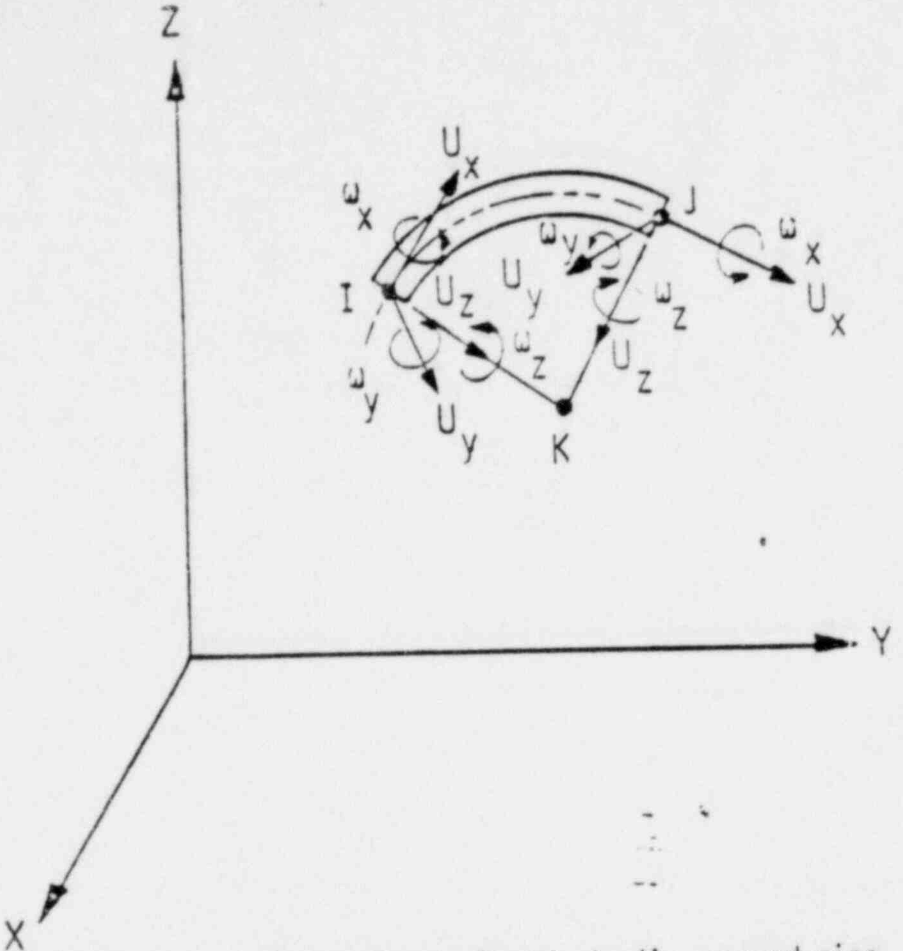

Fig. 5.29-1 — Three-dimensional elastic curved pipe

Displacement functions: see Chen, L.H., "Piping Flexibility Analysis by Stiffness Matrix," J. of Applied Mechanics, Paper No. 59-APM-24

Output definitions:

DIR = direct (axial) stress
BEND = maximum bending stress on outer surface
ST = torsional shear stress
SP = hoop stress due to pressure (Pr/t)
SF = stress due to shear force
TH = axial thermal stress at outer surface (assumed constant)
SMAX, SMIN = principal stresses at outer surface
2MXSHR = twice maximum shear stress at outer surface

WECAN ELEMENT 29

THREE-DIMENSIONAL CURVED PIPE

Sample of printed output

```
ELBOW    66   NODES   86  87   MATERIAL  1 A.TEMP=  115.  O.TEMP= 115.0  I.TEMP= 115.0
1 DIR=    -0. BEND=     41. ST=      2. SP=      0. SF=      7. TH=     -0. SMAX=     41. SMIN=    -41. 2MXSR=     41.
2 DIR=     3. BEND=     22. ST=      1. SP=      0. SF=      3. TH=     -0. SMAX=     25. SMIN=    -19. 2MXSR=     25.

FORCES ON NODE   86   .138903E+01   .420112E+01  -.854043E+01  -.403348E+01  -.411551E+02  -.235229E+02
FORCES ON NODE   87  -.138903E+01  -.420112E+01   .854043E+01   .231360E+02   .610916E+01   .939035E+01
FORCES ON NODE  113  0.            0.            0.            0.            0.            0.
```

For definition of printed output see page 5.29-4.

ATTACHMENT 3

DESCRIPTION OF THE WECAN POST-PROCESSOR COMSPC

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3.14 COMSPC

3.14.1 Input Instructions

The response of structures to seismic load may be studied by using the WECAN response spectrum capability. The maximum modal displacements, forces, stresses, and other responses are computed for each mode in WECAN. Since these maximum modal responses do not necessarily occur at the same time, the resulting structural response has to be determined by combining the modal responses empirically. The method used in WECAN for combining modal responses is the square root of the sum of the squares method (SRSS) which gives satisfactory results if there are no closely spaced modes. However, if some or all of the significant modes are closely spaced, one of the methods described in the U.S. Nuclear Regulatory Guide 1.92 or the Westinghouse Method should be used. They include the following:

- Grouping Method
- Ten Percent Method
- Double Sum Method
- Westinghouse Method *

The WECAN post-processor COMSPC is designed to combine responses with closely spaced modes. COMSPC also computes and combines the modal velocity and acceleration responses in addition to the displacement, node force, stress, and reaction force responses. After combining modal responses for each shock, the three dimensional effects of an earthquake are also computed in COMSPC.

The methods for combining modal and spatial components in seismic response can be categorized as falling into one of two groups. They are

1. Methods which involve the summation of the absolute value of the maximum responses (e.g., absolute sum of the maximum responses).

2. Methods which involve the summation of the absolute value of the quadratic terms of the maximum responses (e.g., SRSS method, grouping method, ten percent method, double sum method, Westinghouse method).

*RESAR 41, Section 3.7, "Aseismic Design", December 1973.

To allow for all of the above and for possible changes of the NRC regulatory guides, the program allows the user to define each term in the summation through a summation instruction card. The format of this card, as well as other input cards, will be described in this section. However, COMSPC provides an option that the program will determine the closely spaced modes and calculate the coupling factors between closely spaced modes internally for the Westinghouse method.

One characteristic of a general purpose program is that it should be able to do simple problems simply and it should also be able to solve complex problems. The complex part of COMSPC is that it must be able to handle large amounts of data when large sized problems are encountered. For the absolute sum method or SRSS method, data can be handled sequentially, and only two working areas in computer memory are needed. However, for other more general methods, due to the presence of cross terms, data cannot be handled sequentially. This means that three instead of two working areas need to be used. In COMSPC, if the three working areas of the problem can be fit into the core, each term of the summation will be calculated in one pass; otherwise, each term will be calculated during multiple passes. Thus, problems of all sizes can be handled effectively.

Some program information is listed in the following table.

COMSPC Program Parameters

1.	Number of modal responses per shock	299
2.	Number of nodal points	No limit
3.	Number of elements	No limit
4.	Number of terms to be summed per shock	500
6.	Input files	TAPE 8, TAPE 10, TAPE 68
7.	Scratch files	
	a) Sequential file	TAPE 32, TAPE 33, TAPE 34, TAPE 35
	b) Random file	TAPE 31
8.	Output file	TAPE 16

Card 1.0 Code Name 3(3A4,8X)

This card is required to call COMSPC from the WAPPP library. This is done by entering the code name COMSPC on the card starting in Column 1 and ending in Column 6. Once the code has been entered, this card should not be respecified as long as data remains on the plot tape. Note WAPPP checks only the first four characters for spelling. The user may also specify his name, NAME, and location, LOCAT.

Prior to execution, WAPPP will automatically list and count all of your input data similar to WECAN. To omit printing of this data listing, a minus sign (-) should be punched in Column 80.

Card 2.0 Title Card (20A4)

This card is required and is used to specify any alphanumeric label for the job title.

TITLE(N) Any alphanumeric title for output.

Card 3.0 Keys and Parameters (8I3,2F12.0,2I3)

This card is required to select displacement and/or stress responses and the rules to be used in their combination.

KEYDIS=1 Combine displacement response

=0 No displacement calculation

KEYVEL=1 Combine velocity response

=0 No velocity calculation

KEYACC=1 Combine acceleration response

=0 No acceleration calculation

KEYSTR=1 Combine force/stress response

=0 No force/stress calculation

NUMSHK Number of shock (or spatial) components

MT1=2 (or 0) Combine shock (or spatial) responses by SRSS method

=1 Combine shock (or spatial) responses by absolute sum method

MT2=2 (or 0) Combine modal responses by group method, double sum, ten percent method, or SRSS

=1 Absolute sum for modal responses

(Note: For modal responses only significant modes from WECAN are considered.)

=-1 Sum modal responses using Westinghouse method, program calculates closely spaced modes and multiplier internally

ITTRP=0 Do not print contents of input tapes

=1 Print contents of input tapes

G Acceleration unit conversion factor, default=1

TD Duration of the earthquake, specify only if MT2=-1

KEYREA=1 Combine reaction force response

=0 No reaction force calculation

ITP16=1 Write combined force/stress response on TAPE16 (KEYSTR must be 1)

=0 No TAPE16 written

Card 4.0 Summation Instructions for Modal Responses (4I6,F12.0)

This card group is required, except for the Westinghouse method, to define the terms to be summed for each shock. Each group ends with a card which has a -1 on Columns 5 and 6. There should be as many Card 4.0 groups as the number of shocks to be summed. The summation instructions are defined as follows.

ID1 Modal response number on TAPE8 or TAPE10

ID2 Modal response number on TAPE8 or TAPE10

(Note: For ID1 and ID2 only the significant modes from WECAN are counted.)

INC Increment for the generation of additional terms

INUM Number of terms to be generated

FACTOR Multiplier

When MT2=0 or 2 (SRSS method, ten percent method, etc.), COMSPC makes the following summation:

(1) Initialize a vector SR=0.

(2) Sum into SR, i.e.,

$$SR = SR + FACTOR*(|R_{ID1}*R_{ID2}| + |R_{ID1+INC}*R_{ID2+INC}| + \ldots + |R_{ID1+INC*(INUM-1)}*R_{ID2+INC*(INUM-1)}|$$

(3) Repeat step (2) until a ID1=-1 card is reached.

(4) Combined response is R_S = SQRT(SR).

Or if MT2=1 (absolute sum method), step (2) would be

$$SR = SR + FACTOR*(|R_{ID1}| + |R_{ID1+INC}| + \ldots + |R_{ID1+ID1*(INUM-1)}|);$$

and step (4) would be simply

$$R_S = SR$$

Card 6.0 <u>ENDC Card</u> (A4)

This card is required to terminate COMSPC and return control to WAPPP.