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FILE

December 11, 1984

Mr. James G. Keppler
Regional Administrator
U.S. Nuclear Regulatory Commission
799 Roosevelt Road
Glen Ellyn, IL 60137

Subject: Byron Generating Station Units 1 and 2
Braidwood Generating Station Units 1 and 2
Design Concerns
NRC Docket Nos. 50-454/455 and 50-456/457

Reference (a): November 26, 1984 letter from T. R. Tramm to J. G. Keppler.

Dear Mr. Keppler:

This letter provides supplemental information to address items of concern regarding the design and construction of Byron and Braidwood stations. This additional information was requested by the Region III Staff during their review of the responses provided in reference (a).

Please address further questions regarding this matter to this office.

Very truly yours,

T. R. Tramm

T. R. Tramm
Nuclear Licensing Administrator

lm

cc: J. Streeter
J. Muffett

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ADDITIONAL INFORMATION REQUESTED BY THE NRC IN RESPONSE TO CONCERNS B.1.ii THROUGH B.1.vv

On December 1, 1984, calculations were reconstructed to substantiate the "Ø" factors used in the simplified design process as described in the Project Design Criteria - DC-ST-03-BY/BR, Rev. 8, Section 37.0.

What follows is a discussion of:

a. What the "Ø" factor is.

b. How the "Ø" factor was numerically quantified.

c. The bounding parameters involved in the selection of the "Ø" factors.

d. Tables 15.1 and 15.2 which summarize the "O" factors used and the sample calculations performed to substantiate them.

e. Attachment 15.5 which is a reproduction of one of the calculations performed highlighted to show the elements of design required by the project design criteria.

WHAT THE Ø FACTOR IS

The project design criteria enumerates all the design requirements for auxiliary steel supports. In addition to the major contribution of the actual applied pipe load, the effects of the following additive minor tolerances, eccentricities and member self-weight seismic excitation must be considered as specified in the Byron project design criteria section and further clarified by reference to Figures 15.1, 15.2, 15.3A and 15.3B.

37.1.1 Item e

10% lateral structural steel misalignment for simply supported W-shaped beams and double channels, and a 1% lateral structural steel misalignment for W-shaped cantilever and knee brace brackets. (see Figure 15.1)

37.1.1 Item f

0.5% vertical structural steel misalignment for simply supported W-shaped members subject to an axial load. (see Figure 15.1)

37.1.1 Item h

6" tolerance for the location of the hanger component along the longitudinal axis of the support steel. (see Figure 15.1)

37.1.1 Item i

1/4" location tolerance for the attachment of a lug on W-shaped member flanges with respect to the center line of the web. (see Figure 15.1)

37.1.1 Item g

2% hanger component displacement from its design position for all loading cases. (see Figure 15.2)

37.1.1. Item b

Self weight OBE and SSE excitation of the auxiliary steel and component hardware in the three principal orthogonal directions. The governing peak seismic excitation values, 2.0 g horizontal and 4.0 g vertical, have been used for all cases. (see Figures 15.3A and 15.3B)

Item b is a design requirement conservatively calculated by using the peak acceleration values (2.0 g horizontal and 4.0 g vertical).

Items e, f, h, i and g are installation tolerances. That is, they do not change the applied piping load but are effects on stress in auxiliary steel due to variation in support installation. Their main effect is to introduce torsional stresses in the auxiliary support steel.

Prior to 1980, detailed design was manually performed to account for the major applied loads and the minor tolerances listed above. This was a time consuming and laborious process. Therefore, a need arose to conservatively remove some of the tedious elements of the hand calculation effort without neglecting their effect on the member design. Thus, the "Ø" factor was developed. Minor tolerances and load effects which result in relatively low member stress were lumped together and were accounted for in the design by the use of the Ø factor.

This "Ø" factor is an allowable stress reduction factor introduced into the design process to account only for minor load effects. Stresses due to major load effects such as the actual applied load are directly calculated and are not included in the Ø factor. This Ø factor is only intended for certain support configurations and member types as shown in Table 15.1.

All the tolerances, items e, f, h, i and g are accounted for by this factor and in item b the effect of auxiliary steel self weight acceleration and component hardware acceleration in the longitudinal direction of the member is included in the "Ø" factor.

This longitudinal effect was chosen since its contribution is very minor when compared to all the other loadings since it amounts to a small percentage of loads compared to the member allowable load.

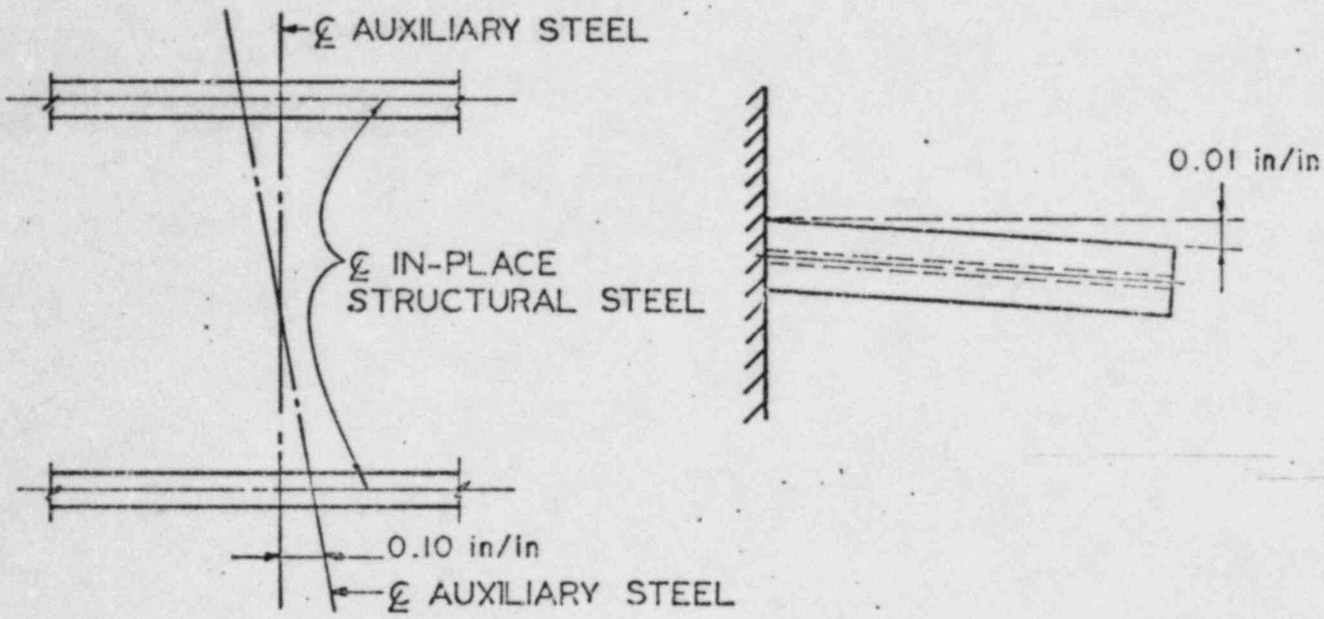
For detailed analysis as shown in the idealized support on Figure 15.3A, the loads other than piping applied load (PA) act as follows:

a. Auxiliary Steel member weight (WS) - excited seismically in 3 directions, applied at the center of beam and midspan.

b. Hanger hardware (WH) - excited seismically in 3 directions, applied at the hardware pin point, eH from the centerline of the beam.

For simplified analysis as shown in the idealized support on Figure 15.3B, all the loads are applied at the shear center of the beam. (Note: no seismic excitation in the longitudinal direction).

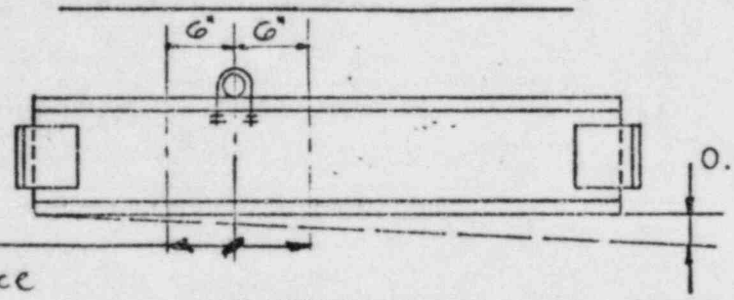
FIGURE 15.1



PLAN VIEW
Simply Supported

PLAN VIEW
Cantilever

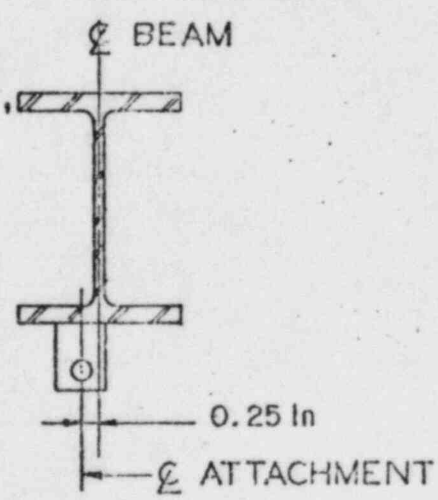
LATERAL MISALIGNMENT (*Item e*)



Item h
6" location tolerance along a member

ELEVATION

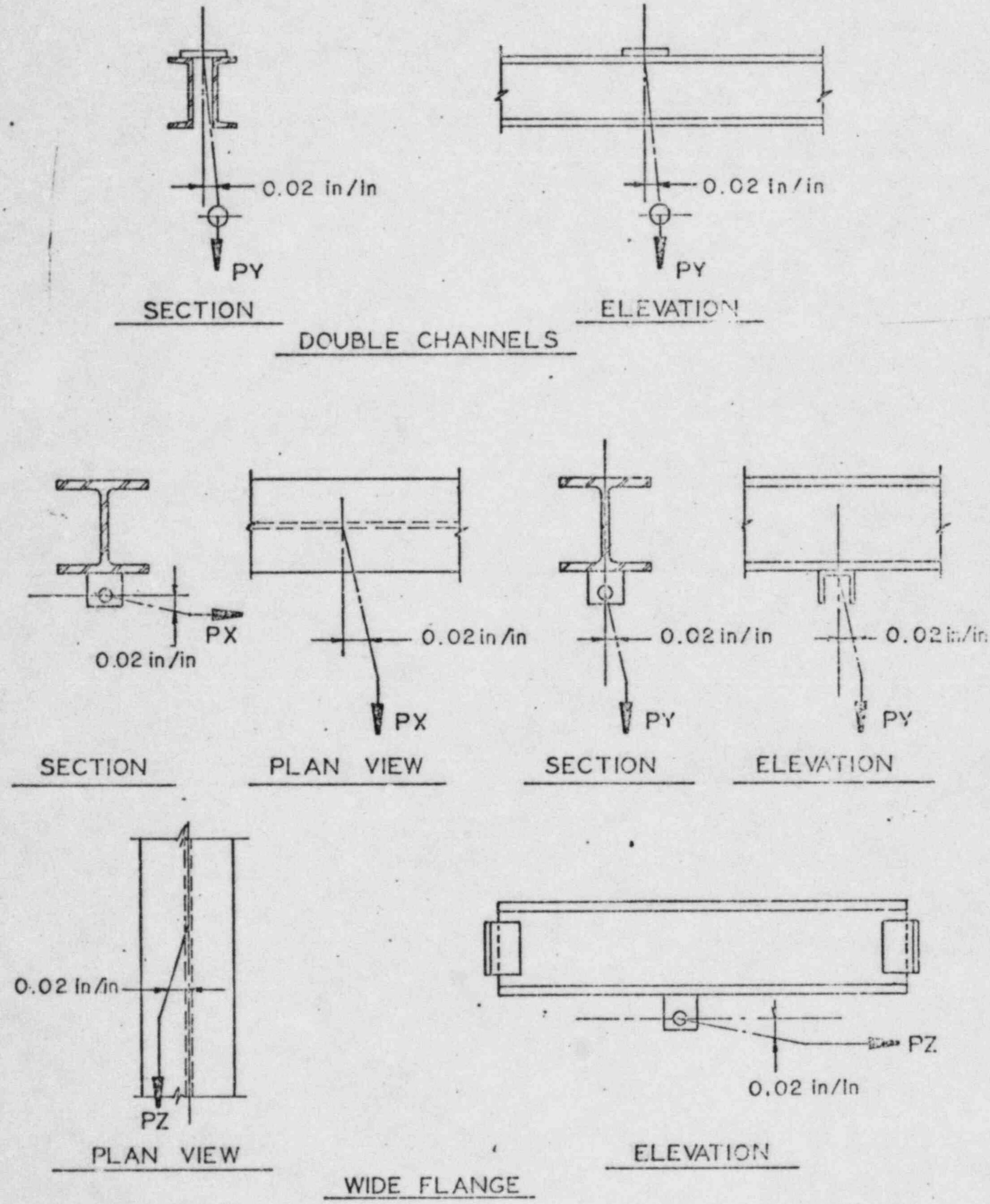
VERTICAL MISALIGNMENT (*Item f*)



SECTION

ATTACHMENT MISALIGNMENT (*Item i*)

FIGURE 15.2

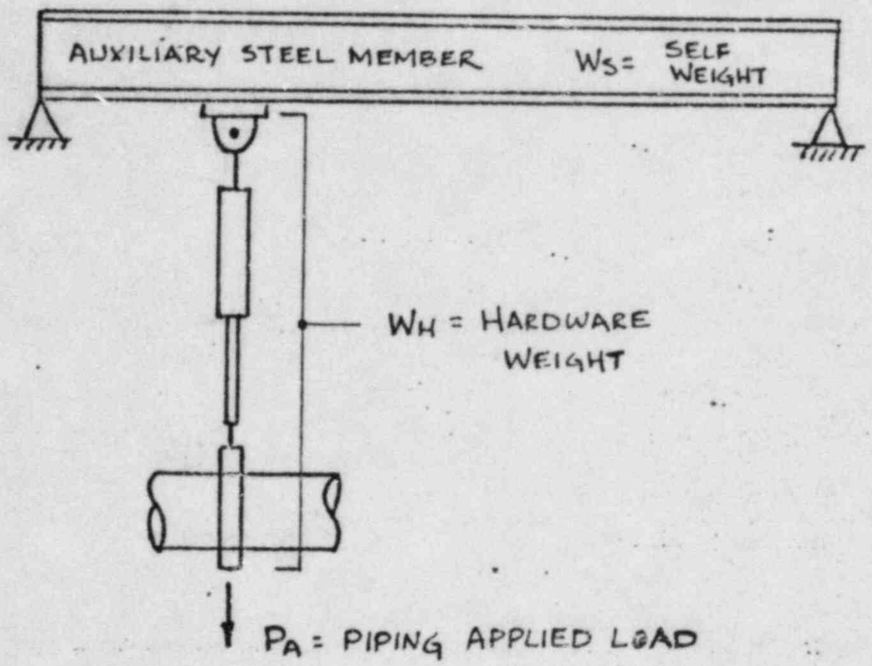


HANGER COMPONENT MISALIGNMENT (Item g)

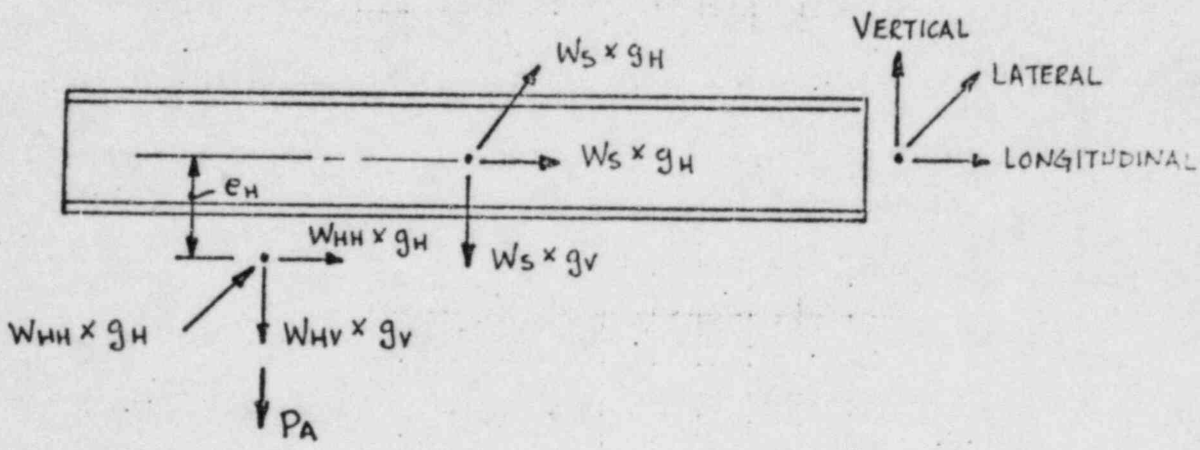
FIGURE 15.3A

SUPPORT DESIGN REQUIREMENTS

DETAILED ANALYSIS



ACTUAL SUPPORT



IDEALIZED SUPPORT

W_{HH} = WEIGHT OF HARDWARE IN THE HORIZONTAL DIRECTION

W_{HV} = WEIGHT OF HARDWARE IN THE VERTICAL DIRECTION

g = SEISMIC ACCELERTION VALUE

g_H = 2.0 (HORIZONTAL)

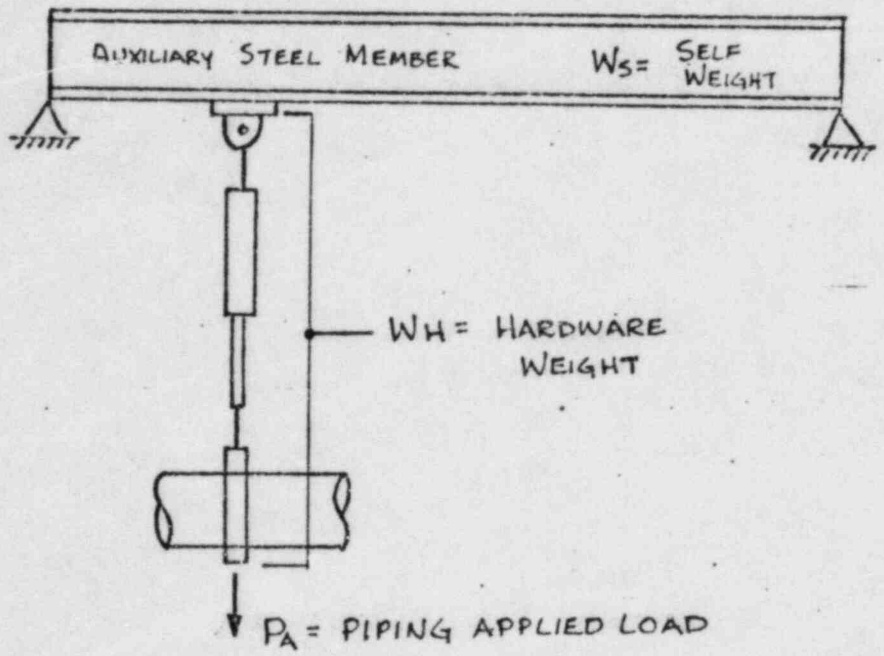
g_V = 4.0 (VERTICAL)

e_H = ECCENTRICITY OF THE HARDWARE WEIGHT FROM THE ℄ OF MEMBER

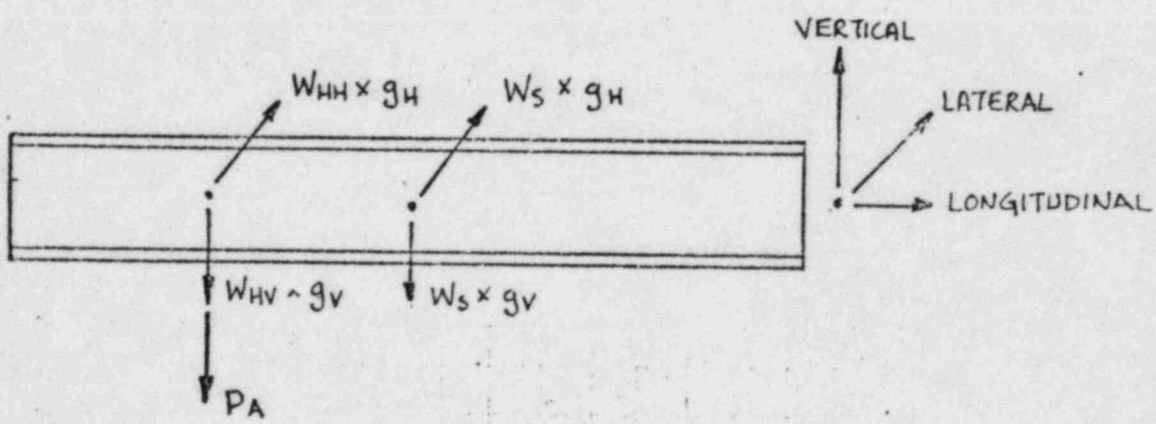
FIGURE 15.3B

SUPPORT DESIGN REQUIREMENTS

SIMPLIFIED ANALYSIS



ACTUAL SUPPORT



IDEALIZED SUPPORT

FOR DEFINITIONS SEE FIG. 15.3A

It is important to note that even for these minor load effects this "simplified" approach which uses a reduction factor yields conservative designs compared to the detailed hand calculation procedure.

HOW THE Ø FACTOR WAS NUMERICALLY QUANTIFIED

The Ø factor is defined as the ratio of the design interaction ratio obtained by the simplified calculation to the design interaction ratio obtained by a detailed calculation. In the form of an equation:

$$\phi = \frac{I_S}{I_D} = \frac{\text{Simplified Interaction Ratio}}{\text{Detailed Interaction Ratio}}$$

The design interaction ratio, I, is the ratio of the actual member stress divided by the allowable member stress. Before the advent of the computerization of the design parameters, the simplified and detailed analyses were performed manually. The "Aux-Steel" program was developed in 1980 to aid in the preliminary selection of mechanical componentsupport steel members. This program considers <u>all</u> of the design requirements of the detailed analysis as specified in the Byron Project Design Criteria. To expedite the reverification of the Ø factors, the "Auxiliary-Steel" program was used both for the simplified approach and the detailed approach.

Thus, for calculations performed on December 1, 1984 the ϕ factor can be quantified by the ratio:

$$\phi = \frac{\text{Design interaction obtained with the "Aux-Steel" program using the simplified design criteria and all applicable loads.}}{\text{Design interaction obtained with "Aux-Steel" program with each and every detailed requirement and all applicable loads.}}$$

The simplified and detailed calculation requirements are pictorially represented in Figures 15.3A and 15.3B. Both figures show the <u>actual</u> support configuration and the idealized design condition locating the loads and the direction of loads to be considered.

To obtain the design interaction necessary to compute the "ϕ" factors, certain parameters were considered in determining the bounding conditions used to select the piping support configurations. What follows is an identification of how those parameters were used in the selection process. A more detailed description will be discussed further with the introduction of Tables 15.1 and 15.2 which summarize the results of the calculations performed on December 1, 1984.

BOUNDING PARAMETERS IN THE SELECTION OF THE Ø FACTORS

The bounding parameters are:

a. Auxiliary-steel configuration and support conditions.

Support conditions can be said to bound a selection process if they are more critical, that is, produce greater stress levels than other support conditions. When the simplified design process was used manually, a frame was conservatively considered as being composed of simply supported and cantilevered members without considering the continuity of the members. Thus, simply supported members and cantilevered members are bounding support conditions over frame assemblies since the redundancy of a frame allows redistribution of stresses over its multiple members. A simply supported or cantilevered member has no other members to share its stresses. Frame assemblies are bounded by other conditions since it can be said that a frame is an extension of a simply supported condition and two cantilevered conditions. Therefore, the "Ø" factor of 0.75 is conservative when compared to the factors for simply supported and cantilevered members.

b. Auxiliary steel size and shape.

1. The auxiliary steel sizes and shapes must be representative of actual field requirements. The selection process involved choosing the most commonly used sizes and shapes.

2. A size and shape selection can be said to bound a selection process if the more critically stressed size and shape is chosen. For example, once it has been determined what "Ø" factor is required for a wide flange shape, a determination of a factor for an angle shape is not required. Warping normal torsional stress added to the bending stresses is the primary reason for the factor used and this effect occurs in wide-flange shapes but not in angle shapes. The consideration of the same tolerances produce torsional shear stresses in angle shapes that are not added to the bending stresses.

In addition, the wide variety of members selected are bounding torsional strength comparisons. Since the effect of the design requirements that the Ø factor replaces is primarily one of torsion, by comparing the strong axis strength to the torsional strength, one can determine bounding conditions on members. Thus, a W8x31 strong axis strength to torsional strength has a ratio of about 19. A W4x13 strong axis strength to torsional strength has a ratio of approximately 12. Therefore, the W8x31 is bounding over the W4x13.

c. Span length

Representative lengths were selected. Auxiliary steel members span between in-place main-steel or embedded plates. Based on this, spans ranging from 5'-0 to 8'-0 encompass lengths for simply-supported cases and therefore, were selected. However, since the detailed interaction values are fully stressed, the length variation has very little effect on the Ø factor.

d. Load location along the span

Various locations along the spans of simply supported members were selected. For cantilevers, the load was placed at the end of the member where its placement would have the most critical effect. For simply supported cases, the position of the load was placed close to the center of the center where its location would have the most conservative effect.

e. Load direction

The most critical applied piping load is a load creating torsion on a member. The Ø factor does not account for this effect and thus, separate hand calculations must be performed to account for this effect.

An applied vertical piping load on a member produces no torsion and thus, a load from any tolerance creating torsion changes a torsional stress from 0% to some finite number which theoretically is an infinite percentage increase; whereas, a load from any tolerance causing torsion on a member already designed for an applied piping load that produces torsion will have a substantially lower percentage increase than one with a vertically applied loading producing no torsion. All Ø factor calculations were performed with the most conservative direction of the applied piping load - the direction vertical to the member. In an actual calculation where the actual applied piping load is at an angle to the member, the components of this loading are considered in a manually performed detailed analysis.

f. Load magnitude

Various magnitudes of loadings were selected to assure I_D = 1.0 or as close as possible to ensure that the stress cally stressed condition. Tables 15.1 and 15.2 summarizes the calculations performed, and a detailed discussion on the results obtained follows.

Table 15.1 is a summary of the commonly used member sizes with the corresponding appropriate configurations. Representative configurations are shown in Figure 15.3c.

Table 15.2 is a recreation of a table available in Calculation Book 13.3.15 completed December 1, 1984, with the problem "I.D." numbers renumbered for the convenience of grouping the auxiliary steel configuration. Therefore, a one-to-one correspondence between the "I.D." number in Table 15.2 and the summary table provided in Calculation Book 13.3.15 is not appropriate. However, when reviewing Calculation Book 13.3.15, all problem "I.D." numbers were identified correspondingly with the calculation page numbering sequential to what is listed in the summary table provided in Calculation Book 13.3.15.

For simply supported cases from Table 15.1, the most commonly used shapes with appropriate load ranges and spans are shown.

A total of 15 sample problems were selected and summarized in Table 15.2 and a review of Table 15.2 when compared to Table 15.1 will show a member size correspondence; loading ranging from 503 pounds to 7,723 pounds compared to 500 to 4,000 pounds; span ranging from 5'0" to 8'-0" compared to spans ranging from 5'0" to 9'-0".

In addition to the member sizes being representative, they offer a wide cross section of various structural shpaes ranging from torsionally weaker to torsionally stronger, e.g., double channel C3x4.1 to TS3x3x1/4.

All types of mechanical component hardware were considered on the design process and the most conservative combinations were selected. For example, in problem I.D. No. 2 for the member W4x13 with a Ø calculation = 0.76, a variable spring hanger was used. This would have the effect of creating the most torsional stress in the member that the Ø factor must account for.

The commonly used cantilever configurations summarized in Table 15.1. When one compares the Table to Table 15.2 it will show a member size correspondence; loads ranging from 500 to 2,000 lbs. compared to loads ranging from 475 lbs. to 12,059 lbs.; spans ranging from 1'-6" to 3'-0" compared to spans ranging from 1'-6" to 3'-6".

For commonly used bracket configurations summarized in Table 15.1 when compared to Table 15.2 again shows a correspondence to size, loading, and spans.

For commonly used frames without hardware summarized in Table 15.1 when compared to Table 15.2 again show a correspondence to size, loading, and spans.

FIGURE 15.3.C.

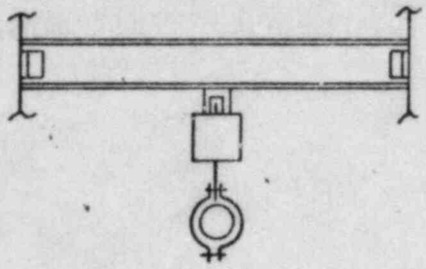
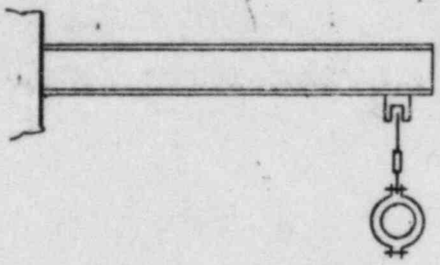
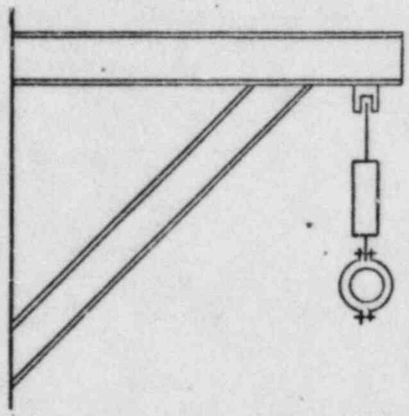
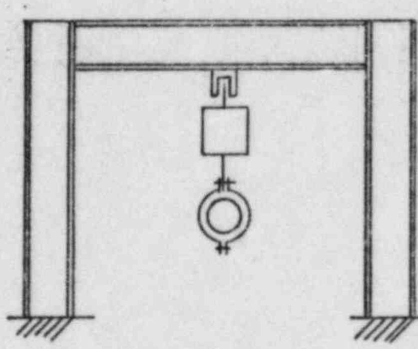
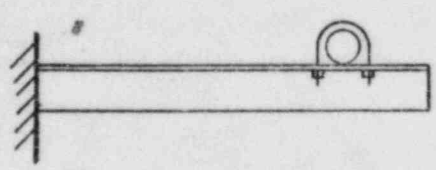
		¢
SIMPLY SUPPORTED		.75
CANTILEVER		.65
BRACKET		.65 OR .40
FRAME W/ HARDWARE		.75
FRAME W/O HARDWARE		.90

TABLE 15.1

Summary of ϕ Factor used for Design of Auxiliary Steel for Mechanical Component Supports

Configurations	Commonly Used on Byron/Braidwood Project				ϕ Factor Used
	Shapes	Sections	Load Range (lbs)	Spans	
Simply Supported	Wide Flange	W4x13, W6x25, W8x31 (Included in Ø Factor Derivation Prior to 1982, See Attach. A & B)	500 to 4000	5'-0" to 8'-0"	.75
	Double Channel	C3x4.1, C4x5.4, C5x .7, C6x8.2 (Included in Ø Factor Derivation Prior to 1982, See Attach. A & B)			
	Tube Section	TS3x3x1/4, TS4x4x1/4			
Cantilever	Wide Flange	W4x13, W5x16, W8x31 (Included in Ø Factor Derivation Prior to 1982, See Attach. A & B)	500 to 2000	1'-6" to 3'-0"	.65
	Double Channel	C12x20.7			
	Angle	L 3x3x3/8, L 4x4x1/4			
	Tube Section	TS4x4x1/4			
Bracket (Knee Brace)	Wide Flange	W4x13, W8x31 (Included in Ø Factor Derivation Prior to 1982, See Attachments A & B)	250 to 2000	3'-0" to 5'-0"	.40 or .65
Frame W/Hardware	Wide Flange	W4x13, W8x31 (Included in Ø Factor Derivation Prior to 1982, See Attachment B)	250 to 2000	4'-0" to 6'-0"	.75
Frame W/O Hardware	Wide Flange	W4x13	500 to 2000	1'-6" to 2'-0"	.90
	Angle	L 4x4x1/4			

TABLE 15.2

SUMMARY OF BACKUP CALCULATIONS FOR Ø FACTOR

PAGE 1

CONFIGURATION	PROBLEM I.D. NO.	MEMBER	SPAN ('-")	LOAD (lbs)	CALC. Ø FACTOR	DESIGN Ø FACTOR	COMPARISON OF Ø FACTOR REMARKS
Simply Supported	1	(2) C6x8.2	8'-0"	2694	0.80	0.75	Acceptable
"	2	W4x13	6'-0"	3229	0.76	0.75	Acceptable
"	3	W6x25	8'-0"	7723	0.77	0.75	Acceptable
"	4	(2) C3x4.1	6'-0"	1100	0.82	0.75	Acceptable
"	5	(2) C6x8.2	6'-0"	3600	0.78	0.75	Acceptable
"	6	TS 4x4x1/4	6'-0"	5130	0.97	0.75	Acceptable
"	7	TS 4x4x1/4	6'-0"	4900	1.00	0.75	Acceptable
"	8	TS 3x3x1/4	6'-0"	1475	1.00	0.75	Acceptable
"	9	(2) C3x4.1	5'-8"	587	1.00	0.75	Acceptable
"	10	(2) C5x6.7	7'-9"	2200	0.87	0.75	Acceptable
"	11	(2) C4x5.4	8'-0"	1143	1.03	0.75	Acceptable
"	12	W4x13	5'-8"	503	1.10	0.75	Acceptable

TABLE 15.2

SUMMARY OF BACKUP CALCULATIONS FOR Ø FACTOR

CONFIGURATION	PROBLEM I.D. NO.	MEMBER	SPAN ('-")	LOAD (lbs)	CALC. Ø FACTOR	DESIGN Ø FACTOR	COMPARISON OF Ø FACTOR REMARKS
Simply Supported	13	W8x31	7'-0"	.4750	0.80	0.75	Acceptable
"	14	W18x50	9'-0"	2500	1.63	0.75	Acceptable
"	15	W4x13	5'-0"	1300	0.76	0.75	Acceptable
Cantilever	16	W5x16	3'-0"	1609	0.74	0.65	Acceptable
"	17	W8x31	2'-0"	12059	0.66	0.65	Acceptable
"	18	(2) C12x20.7	2'-0"	12016	0.66	0.65	Acceptable
"	19	L 3x3x3/8	1'-6"	513	0.72	0.65	Acceptable
"	20	W4x13	2'-0"	1954	0.77	0.65	Acceptable
"	21	L 3x3x3/8	1'-6"	600	0.83	0.65	Acceptable
"	22	L 4x4x1/4	2'-0"	475	0.77	0.65	Acceptable
"	23	TS 4x4x1/4	3'-0"	2000	0.74	0.65	Acceptable
"	24	W4x13	2'-3-7/16"	2550	0.67	0.65	Acceptable

TABLE 15.2

SUMMARY OF BACKUP CALCULATIONS FOR Ø FACTOR

CONFIGURATION	PROBLEM I.D. NO.	MEMBER	SPAN ('-")	LOAD (lbs)	CALC. Ø FACTOR	DESIGN Ø FACTOR	COMPARISON OF Ø FACTOR REMARKS
Cantilever	25	W5x16	3'-6"	497	0.67	0.65	Acceptable
Bracket	26	W8x31	4'-0"	12645	0.52	0.40	Acceptable
"	27	W4x13	5'-0"	3000	0.71	0.65	Acceptable
"	28	W4x13	3'-6"	497	1.06	0.65	Acceptable
"	29	W4x13	3'-9-3/4"	266	1.01	0.65	Acceptable
"	30	W4x13	4'-3"	222	2.80	0.65	Acceptable
Frame	31	W4x13	1'-3"	10500	0.97	0.90	Acceptable
"	32	L 4x4x1/4	2'-0"	603	0.88	0.90	Acceptable

CONCLUSION

The calculation presented in this response demonstrates that the ϕ factors are correct and support the Byron/Braidwood project design criteria and the auxiliary steel support design for Byron Unit 1.