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A New Pipe Routing Specification for Small Sized Piping Systems Based on Experimental Data

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SUMMARY

In nuclear power plants there is a large number of small bore pipes (inch nominal size 1/4, 1/2, 1 , 2) classified as ASME III Class 1 or 2 lines. Due to the large amount of small piping systems (up to 75 % of the whole piping network) a fully dynamic calculation would need a lot of software activities.

To limit the effort of this activities it would be helpful to have a procedure to qualify these piping systems using a simple design.

The procedure is based on a test program carried out on a shake table.

For this purpose nine small piping systems which are representative models of the large majority of piping systems in KWU nuclear power plants were tested to determine their capability of surviving extreme low-frequency and high-frequency excitation (corresponding to seismic and aircraft impact loads respectively).

The fundamental result of this program was that the piping systems survived the extreme load cases without collapse, leaks or loss of pressure. Responses were high with some accelerations in excess of 50 g ,displacements in excess of 50 cm and some plastic strains in excess of about 0.6 %.

For a comparison a calculation was carried out with the linear elastic finite element program KWUROHR and by the modal analysis method using multiple-support-excitation. The stress analysis is based on the ASME-Code Section III.

The results showed overstresses up to 300 % of the code allowable stress levels for the high-frequency load case and up to 400 % for the low-frequency load case.

The experimental investigation established that such piping systems have significant capacity beyond their elastic capacity and are adequate to meet their design loads. The results and the comparison with the calculations are helpful to create a simplified method to qualify small piping systems.

1. INTRODUCTION

In nuclear power plants there is a large number of small bore pipes (inch nominal size 1/4, 1/2, 1, 2 classified as ASME III Class 1 or 2 lines. Due to the large amount of small piping systems (up to 75 % of the whole piping network) a fully dynamic calculation would need a lot of software activities.

To limit the effort of this activities it is helpful to have a routing specification to qualify these piping systems.

The aim of this pipe routing specification is to show how piping systems can be designed to withstand static and dynamic loading using a simple method.

Based on the isometric drawings, system sketches and piping drawings and with pipe support spacing tables, which fix the maximum allowable spans between supports depending on the dead weight of piping, it is possible to determine the appropriate support locations.

Tables and diagrams will be used to verify that the necessary degree of flexibility will be provided and to determine reaction forces at supports.

The main emphasis will be laid on the loads caused by normal operation, i. e. :

- Dead weight
- Restrained thermal expansion
- Terminal movement

The design takes dynamic effects sufficiently into consideration. Care must be taken that adquate flexibility is ensured with respect to all three of the abovementioned load conditions.

Following the completion of erection work, the piping in question will be inspected for correctness of routing and design at the site.

2. PROCEDURE

The following procedure is shown diagrammatically in Figure 1.

All work shall be based on the isometric drawings, system sketches and piping drawings prepared by the pipe manufacturer. These show how individual pipes are routed as well as all terminal equipment.

Pipe support spacing tables (see Table I), which state the maximum allowable spans between supports depending on the dead weight of piping, can be used together with the isometric drawings, system sketches and piping drawings to determine the appropriate support locations.

The following criteria shall be taken into consideration when determining support locations :

- Pipe supports shall take the form not only of fixed supports but also of guide bearings or other similar types of supports.

  Where guide bearings and similar supports are used, they shall be designed such that all movements normal to the pipe centerline are restrained.

- An axial stop must be provided if straight pipe sections of a length equal to or greater than three times the allowable span are supported only by guide bearings.

- Valves and other piping components or attachments shall be supported either directly at the valve casing or at the connecting pipe.

  If this type of support is a guide bearing and not a fixed support, axial movement shall be restrained by a stop at another point in the connecting pipe.

  Valves with electric drives shall be supported by means of fixed supports. Furthermore, the appurtenances shall be supported by guide bearings or other similar types of supports.

- Free ends of piping which are longer than one half the maximum allowable span shall be provided with additional guiding.

- For pipes branching off in a vertical direction, the single-point load from the dead weight of the branching pipe on the continious pipe shall be kept sufficiently small, if necessary by using an axial support.

It shall be ensured that the thermal expansion occuring during normal operation can be taken into account. This can be achieved by modifying the routing of the pipes or by providing sufficiently large minimum distances (see sketch Fig.2). The axial expansion and the necessary minimum distance can be determined with the aid of Figures 2, 3a and 3b.

Pipes branching off larger pipes or connected to components must be provided with sufficient flexibility to be able to allow all terminal movements resulting from thermal expansion, earthquake and aircraft impact loads.
Adequate flexibility shall be demonstrated by a procedure similar to that for the thermal expansion of hot pipes on the basis of Figures 3a and 3b.

<u>Snubbers shall not be used here</u>

The movements of the supports resulting from earthquake and aircraft impact loads are, under normal circumstances accounted by the minimum distance as in Figures 3a and 3b.
However, care should be taken to ensure that the pipes cannot be torn off by the relative movements of fixed supports which are located closely together and which are anchored in structures with different vibration characteristics (e.g.concrete

wall/platform).

If the support concept decided upon cannot be put into practice for reasons related to these flexibility criteria, it shall be examined whether the concept can be modified at certain locations.

In this case, the support which impairs pipe flexibility shall be replaced by a vertical pipe support, spring hanger or similar type of support.

If it is not possible to modify the support concept, the routing of the piping shall be changed by, for example, installing expansion bends so that the requisite degree of flexibility is achieved.

Reaction forces at supports shall be determined using the data given in Table II.

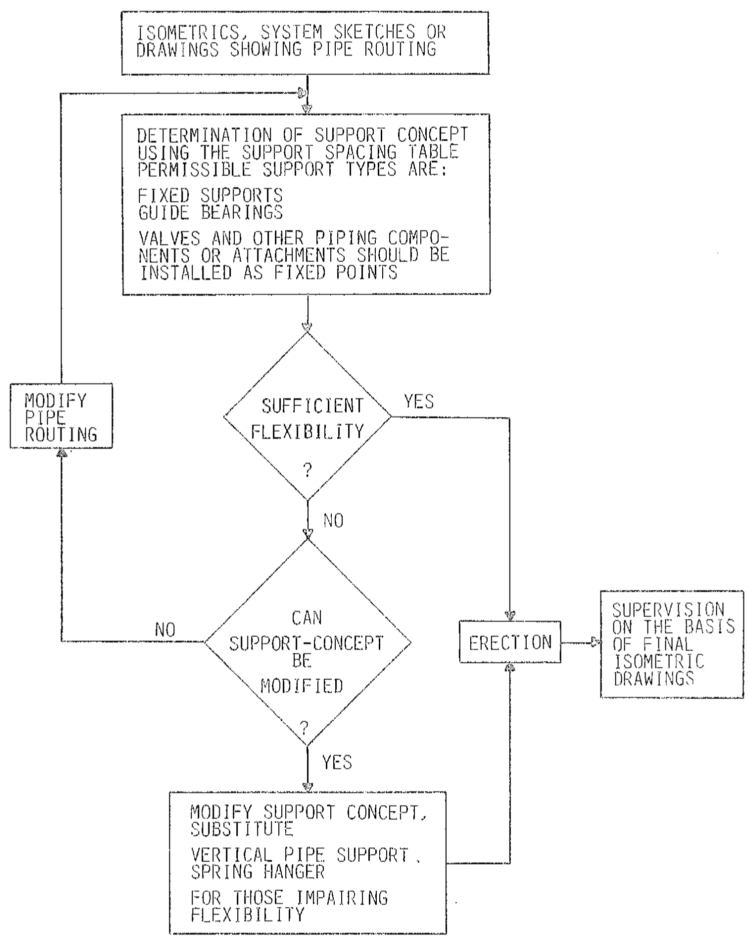


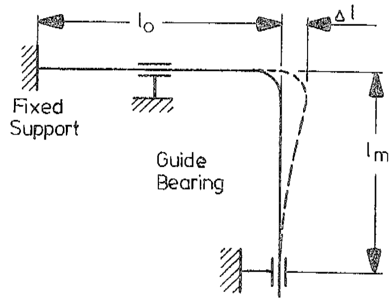
Figure 1 : Flow Chart

Figure 2 Longitudinal Expansion in Ferritic and Austenitic Steels

Calculation of Axial Thermal Expansion

To calculate the axial thermal expansion :

$\Delta l = l_o . \alpha . \Delta t$ is applicable



where

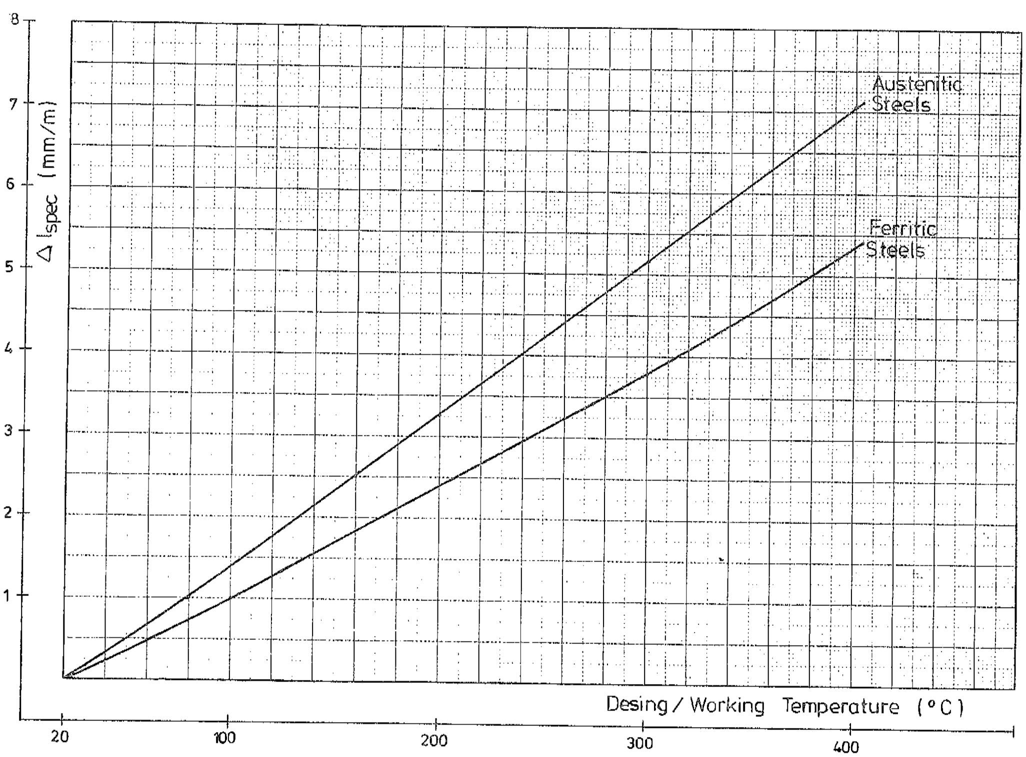
l_o = free length of thermal expansion (see sketch)

α = coefficient of expansion

Δt = temperature span related to 20 °C

The following figure is used to determine, as a function of temperature the specific expansion in mm/m for the materials concerned.

$$\Delta l = l_o . \Delta l_{spec}$$



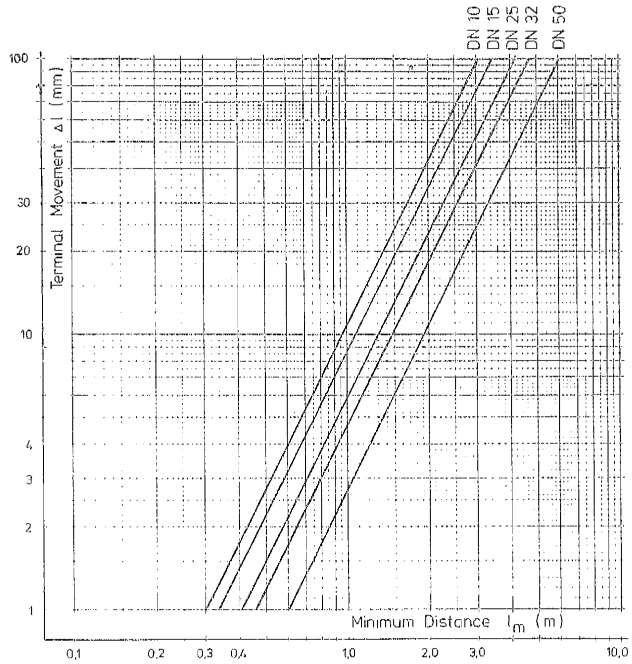


Figure 3a : Necessary Minimum Distance l_m as a Function of Terminal Movement

Material : Austenitic Steel

Bend radius : 5 x DN

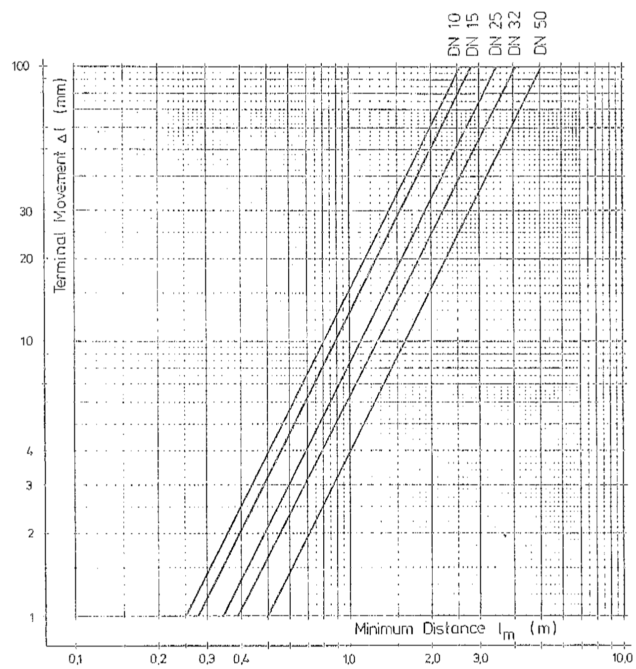


Figure 3b : Necessary Minimum Distance l_m as a Function of Terminal Movement

Material : Ferritic Steel

Bend radius : 5 x DN

Table II Pipe Support Loading

Nominal Diameter	Dimensions (mm) Outer Diameter / Wall Thickness	Pipe Support Loading: Austenic Steels Fx=Fy=Fz (N)	Austenic Steels Mx=My=Mz (Nm)	Ferritic Steels Fx=Fy=Fz (N)	Ferritic Steels Mx=My=Mz (Nm)
10	(12,0 x 2,2)	219	20	133	12
	(14,0 x 2,5)	294	31	178	19
	(14,0 x 2,8)	308	39	186	23
	(17,2 x 2,6)	407	48	246	28
	(18,7 x 2,6)	459	57	278	33
15	(21,3 x 2,0)	452	56	273	33
	(21,3 x 2,2)	486	62	294	36
	(21,3 x 2,6)	549	73	332	43
	(21,3 x 2,9)	591	82	357	48
	(21,3 x 3,2)	624	91	378	53
	(21,3 x 3,6)	664	102	401	60
	(26,9 x 7,1)	1181	322	714	189
25	(33,7 x 2,6)	969	180	587	106
	(33,7 x 2,9)	1060	201	641	118
	(33,7 x 3,6)	1247	252	754	148
	(33,7 x 4,4)	1434	311	867	183
	(33,7 x 5,0)	1551	354	939	208
	(33,7 x 5,5)	1634	391	988	230
32	(42,4 x 4,0)	1802	441	1090	259
	(42,4 x 4,5)	1967	499	1190	293
	(42,4 x 5;6)	2285	625	1382	368
50	(60,3 x 2,6)	1873	566	1133	332
	(60,3 x 2,9)	2068	633	1251	372
	(60,3 x 3,2)	2257	700	1365	411
	(60,3 x 3,4)	2380	747	1440	439
	(60,3 x 4,0)	2735	882	1655	518
	(60,3 x 4,5)	3021	992	1828	583
	(60,3 x 5,0)	3292	1111	1992	653
	(60,3 x 6,9)	4198	1550	2540	911
	(60,3 x 7,1)	4295	1601	2599	941

Table I Maximum Allowable Pipe Support Spacing Depending on Pipe Nominal Diameter

	ALLOWABLE SPAN (m) *)				
Nominal Diameter	DN 10	DN 15	DN 25	DN 32	DN 50
Dimensions (mm) (Outer diameter/ wall thickness)	(12,0x2,2) (14,0x2,5) (14,0x2,8) (17,2x2,6) (17,2x2,9) (18,7x2,6)	(21,3x2,0) (21,3x2,2) (21,3x2,6) (21,3x2,9) (21,3x3,2) (21,3x3,6) (26,9x7,1)	(33,7x2,6) (33,7x2,9) (33,7x3,6) (33,7x4,4) (33,7x5,0) (33,7x5,5)	(42,4x4,0) (42,4x4,5) (42,4x5,6)	(60,3x2,6) (60,3x2,9) (60,3x3,2) (60,3x3,4) (60,3x4,0) (60,3x4,5) (60,3x5,0) (60,3x6,9) (60,3x7,1)
with Insulations	1,0	1,6	2,4	2,8	3,6
without Insulation	1,6	2,3	3,1	3,7	4,5

*) These spans apply for all ASME classes, temperatures and pressures present.