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EVALUATION OF SIMPLE CRITERIA FOR SUPPORTING AND TESTING OF INSTRUMENTATION TUBING AND TUBE FITTINGS

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ABSTRACT

Instrumentation tubing and tube fittings constitute a very critical system in an NPP which run hundreds of kilometers of length throughout the plant. Analysis of such a large system of tubing for various loading conditions is rather a formidable task. Presented here in this paper is a way to combat this situation by evolving a general criteria for their supporting. Similarly, in order to avoid shake table testing of instrumentation tube fittings, a simple static testing criteria has been evolved for the testing of tube-fittings for leak tightness during a seismic event.

1.INTRODUCTION:

Instrumentation tubing and tube fittings serve as a link between the various processing systems and the control room in a nuclear power plant. Therefore, it is desirable that they should survive under all postulated loading conditions to which the plant is likely to be subjected. In general , the tubings are smaller in size , but they run in hundreds of kilometers of length across the plant with wide variations in their layouts from one place to other place within the same plant. This is mainly because in the project installation work this is the least priority job which is carried out towards the end of installation work and that the tubing layout is mostly governed by the available space left for routing the tubing after the completion of other installation works.The other factor which governs the tubing layouts is the need to support them with some structure,piping or concrete walls. Analysis of such a large system of tubing for various loading conditions is a very laborious and time consuming job and it is rather unwise to attempt to qualify each and every tubing layout based on the analysis. An attempt has been , therefore, made to evolve a simple generic criteria for supporting the tubing based on the analysis of a few typical layouts.

Based on the results of the above study, a simple static test has been suggested for the seismic testing of tube-fittings in place of shake table testing. The testing criteria is based on the fact that the leakage at the tube-tube fitting junction is a function of the relative deformation at the junction. An emperical formula has been evolved based on this study for the static seismic testing of the tube fittings. The paper outlines the methodology involved and the conclusions arrived at.

2. EVALUATION OF SUPPORTING CRITERIA FOR TUBING:

Instrumentation tubing layouts in PHWR system are subjected to various types of loadings such as dead weight, pressure, thermal and seismic loading. A flexible tubing layout is warranted to accomodate the thermal stresses while the same gives rise to high seismic stresses.Therefore ,the exercise shall be carried out to find out a trade-off between the two conflicting requirements.Three typical site installed tubing layouts (Fig-1,2,3) are used for the purpose of study.These layouts would normally qualify for the thermal loading without requiring any intermediate supports on account of flexible nature of layouts. The thermal loading considered was from 25°c to 310° c. Analysis for seismic loading was carried out by the Response Spectrum Technique using upper bound envelope spectra of various floor levels so that the tubing layouts qualified thus can be adopted at any floor level (Fig- 5).

The normal procedure for seismic analysis would require dynamic response calculation upto flat spectral region and the rigid body mode response calculation for taking care of missing mass effect.In all the cases analysed ,it was observed that the mass participation for all the modes upto 33 Hz is much less than 90% requiring rigid body mode response calculation. As an alternative,a conservative approach was addopted here wherein the seismic stresses were calculated in a static manner based on the acceleration corresponding to the fundamental frequency of the layout(Ref.1).It is believed that this conservatism in analysis would account for the diversity in the tubing layouts.

Intially ,supports were located on the tubing layouts near the fittings which are heavy in mass and at the null points where there is practically very little amount of thermal expansion.In addition, the supports were located in such a way that the fundamental frequency shifts away from the spectral peaks(Fig-6). It was observed that providing supports at either ends of fittings was good for accomodating seismic loading but the same was giving rise to high thermal stresses. Thus supports were removed near the fitting ends in a planned manner such that the layouts qualify for all loadings as per provisions of ASME code section-III-NC(Ref.2).However,a close look at the supporting conditions so evolved was not giving any definite pattern and thus it was difficult to suggest a generic supporting criteria at this stage.

For evolving such a criteria, the distances between various supports of these three layouts were found out at all locations which was between 1.0m to 1.5m. It was felt that 1.0m support spacing may be adequate and with this in aim , supports were relocated on all the three layouts in such a way that the maximum unsupported span is 1.0m(Fig-6). This analysis revealed that the stresses in all the three layouts for various kind of loadings are within the allowable limits.At this point of time, it was felt necessary to check this new supporting criteria with respect to the point of start for locating the supports. This was studied by first locating the supports on a typical layout at 1.0m distance starting from any fixed end and later on trying the same by starting from other fixed end. From all these studies, it was observed that 1.0m support spacing criteria is a unique one i.e. in a sense that the tubing always gets qualified under all loading conditions(Table-1). Therefore, based on this study, it is reccomended to use 1.0m support spacing for all tubing layouts.

3. EVALUATION OF TESTING CRITERIA FOR TUBE FITTINGS:

For the fittings it can be safely assumed that the leakage will begin at the point of maximum stress and is a function of relative deformation between the tube and tube fitting. This maximum stress , evaluated from the seismic analysis of the representative layouts can be developed in the test model at the tube and tube fitting junction by static deformation of tube while holding the fitting rigidly as shown in Fig-4 . The displacement at the free end of the tube can be decided in such a way that stress developed at the tube and tube-fitting junction is same as the one developed in the representative layout. The value of displacement at the top of the cantilever for a given value of stress at the fixed end, i.e. the junction of tube and fitting ,is given as follows:

$$d = \frac{f * L ** 2}{3 * Y * E} \qquad - - - - (1)$$

Where,

f = stress (kgf/mm **2),L = length of the tube (mm) ,Y = Outer radius of the tube section, E = Modulus of elasticity of tube material(kgf/mm**2),d= Displacement at the top of tube (mm)

A simple test procedure for the seismic qualification of Ferul type tube fittings can be thus developed.The test can be performed on the simple tube- tube fitting model avoiding the need for the shake table testing of the full layout. The displacement at the top of tube while holding the fitting rigidly , can be given cyclically to simulate the cyclic nature of seismic event. From the analysis of the three layouts, the maximum stress comes out to be 15.00 kgf/mm***2 for the layout-3 which comprises of 10 mm tubing. It is , therefore, recommended to test the fittings using the test setup as shown in Fig.4 with a free end displacement amplitude corresponding to this maximum stress value. This criteria developed so for the 10mm tubings can then be applied to tubings of higher sizes also because under similar conditions of supportings and layouts, the induced stresses in the higher size tubings will be on lower side. Therefore, equation-(1) gets modified as follows for the purpose of seismic testing.

$$d = (15.00 \times L^{2}) / 3 * Y * E \quad - - - - - (2)$$

Using this formula , the deflection values to be imposed for the test setup of Fig-4 (L =300 mm) are given in Table-2. For example for 10 mm size , it is recommended to use 4.3 mm deflection at free end for the setup shown in Fig-4 .The displacement amplitude of4.3 mm at the free end of tube shall be repeated 60 times (considering 5 OBE and one SSE events with ten cycles per event) to qualify the tube- tube fitting junction for leak tightness under pressurised condition.

4.0 CONCLUSIONS:

Based on the studies carried out for 10mm size tubing, it is recommended to use supports at a distance of 1.0m span in the tubing run. This criteria can be extended to tubings of higher size also as it will be conservative. In addition ,a simple static test has been suggested for the testing of tube fittings which avoids the need of shake table facility.

5. REFERENCES:

1. USNRC SRP- 3.7.3,SEISMIC SUBSYSTEM ANALYSIS.
2.ASME CODE SECTION III,DIV.1, SUBSECTION NC AND APPENDICES

TABLE-1

FUNDAMENTAL FREQUENCY AND STRESSES DUE TO DIFFERENT LOADING CONDITIONS FOR ALL LAYOUTS

LAYOUT NO	FUNDAMENTAL FREQUENCY(Hz)	THERMAL STRESS (<16.0Kgf/mm**2)	STRESS(Pr.+Gr.+Eq.) (<16.8Kgf/mm**2)
1	42.88	15.41	2.51
2	12.81	8.33	6.37
3	6.41	11.66	14.29

TABLE - 2

RECOMMENDED VALUES OF DEFLECTIONS AT THE FREE END OF TUBING OF TEST SET-UP(FIG - 4) FOR STATIC SEISMIC TEST

TUBING SIZE(mm)	SUGGESTED DEFLECTION FOR 300 MM LENGTH (mm)
10	4.3
12	3.57
16	2.67
18	2.38

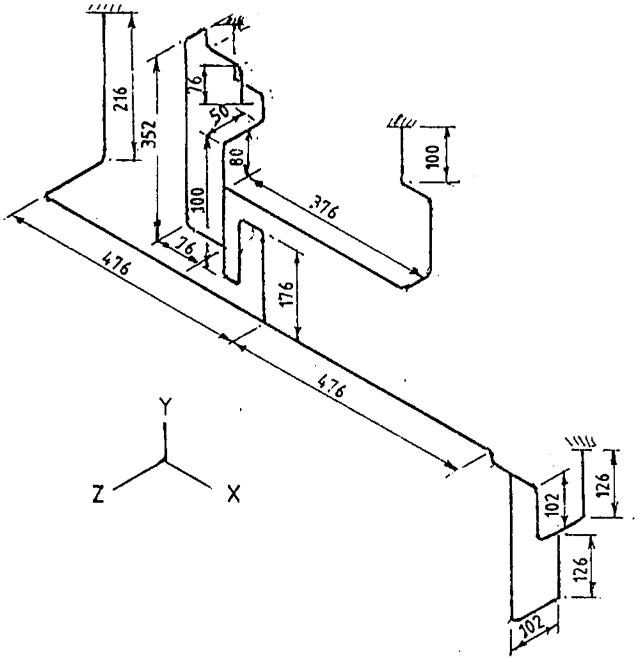


FIG. 1 CHANNEL FLOW MONITORING TUBING LAYOUT-1

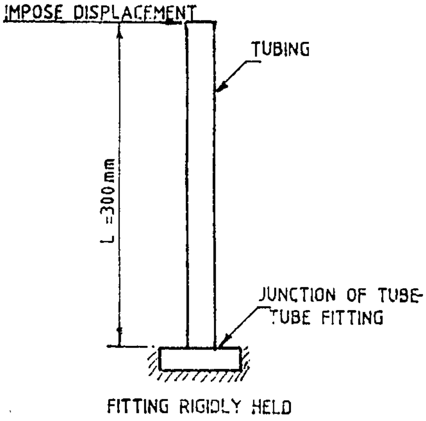


FIG. 4 SIMPLIFIED MODEL FOR TESTING TUBE-FITTING

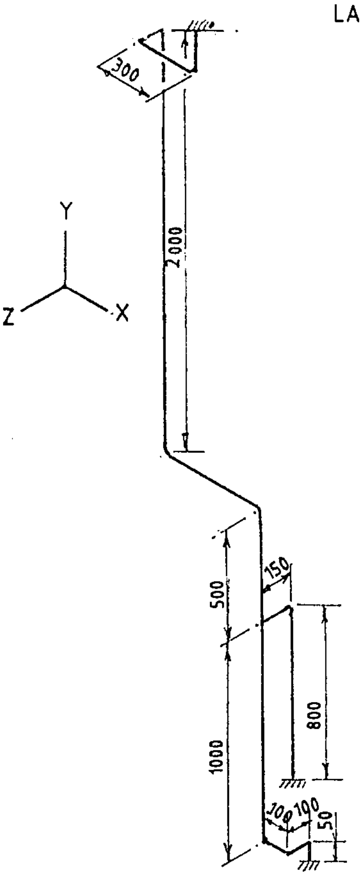


FIG. 2 HEADER PRESSURE CONTROL TUBING. LAYOUT -2

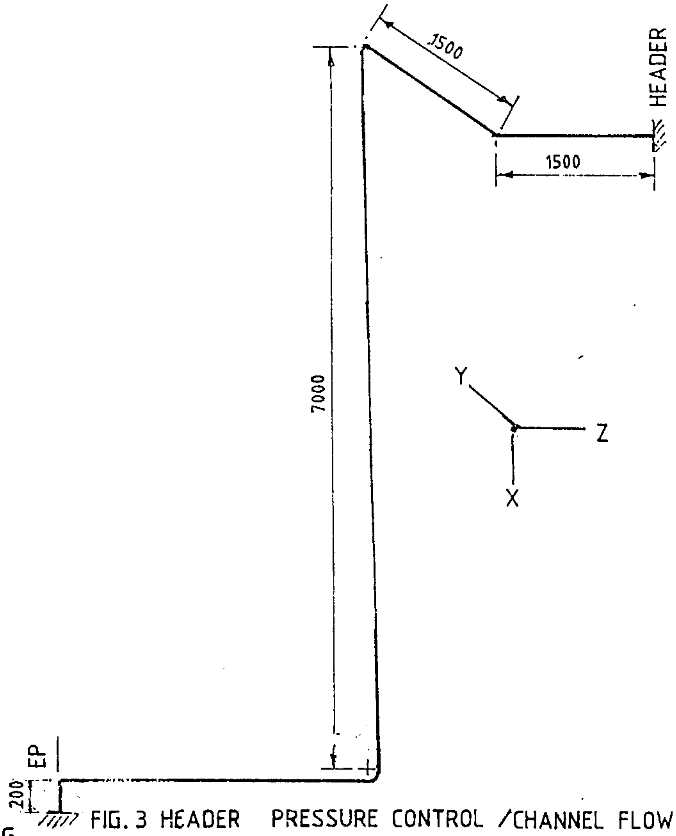


FIG. 3 HEADER PRESSURE CONTROL /CHANNEL FLOW MONITORING TUBE LAYOUT-3 (FROM HEADER TO EP)

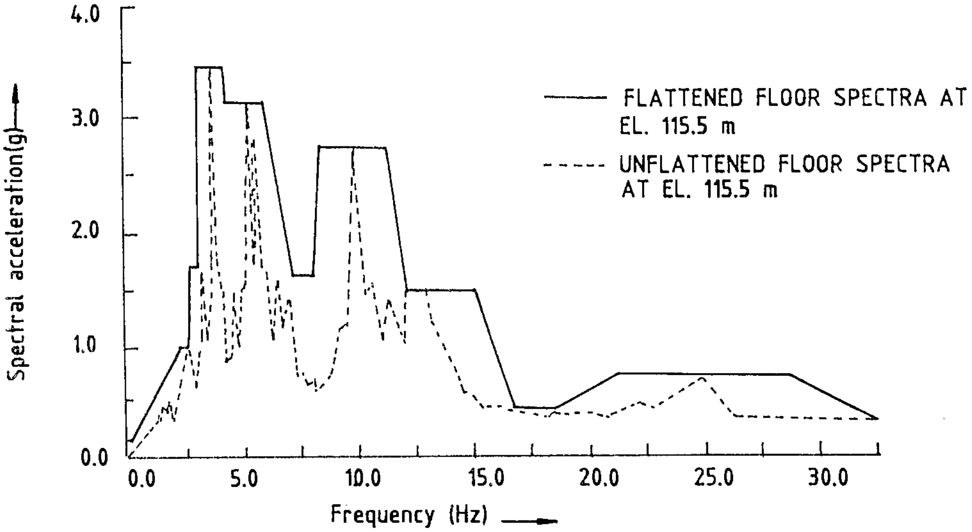
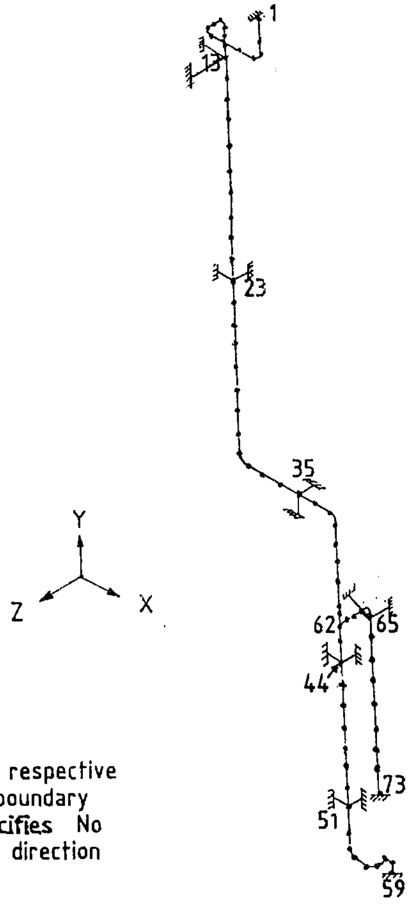


Fig. 5 TYPICAL FLATTENED FLOOR RESPONSE SPECTRA (OBE, NS)



Note:

Numbers denote the respective node positions and boundary element (spring) specifies No displacement in that direction

Fig. 6 FEM MODEL OF LAYOUT No. 2 SHOWING SUPPORT LOCATION