Response of Equipments to High Frequency Excitations

L. Lazzeri, M. Scala, F. Vannucci, M. Olivieri, W. Ciucchi
Ansaldo Impianti S.p.A., Via G. D'Annunzio 113, I-16121 Genova, Italy

Summary

High frequency excitations are becoming more and more important as some hypothetical accidents (e.g.the aircraft impact load or SRVD load in BWR) are characterized by a strong contribution in the high frequency range. A typical characteristic of these loads is the large values of accelerations with comparatively low values of the displacements. For ductile equipments which have some energy dissipation capabilities these loads do not present a large danger if proper design is performed. Some typical cases concerning a piping system are shown: the computations are performed in the non linear case using PAULA 82 computer program (see section L). The case of aircraft impact is considered: the resulting FRS is characterized by very large accelerations (some twenty gs) at 30-40 cycles per second.

It is shown that the restraints of the piping have a very large importance in assessing the resulting loads on the piping. if the restraints are able to take the input displacements with acceptable deformations the loads on the piping are quite little, on the other hand substantial deformations are found on the piping (and very large loads on the restraints) if the restraints are designed in the elastic range. The case is quite different for fragile equipments such as electronics instruments, in this case energy dissipation is to take place somewhere else. The case of electronics inside pnales is considered; the case of panels with significative eigenfrequency higher than 20 cps (i.e.outside the earthquake range)is analized. CYRANO computer program (see section K) is used to compute FRS inside the panels at the equipment locations. It is shown that in the case effective filtering of the signal takes place, so that no large accelerations for the equipments are found in the significative range (higher than thirty cycles per second). It is recognized that even a better filtering action can be obtained if the significative eigenfrequency in the panel is lower however in this case trouble would result in the case of seismic excitations. In conclusion it can be stated that :

a) for ductile structures the application of ductility factors (to the structure itself or its supports) of around 2. -3. is sufficient to keep loads within allowable limits.

b) for fragile structures the same apply but the energy dissipation and decoupling (combined low frequencies) have to take place within the supports.

1. Introduction

High frequency excitations are becoming of greater and greater interest in the structural analysis as an effect of the study of the consequences of high frequency loads such as "pool dynamic loads" in BWR or aircraft impact loads. These loads are generally characterized by very high acceleration peaks and obviously by very small displacements, as the resonance frequencies are generally around 20 ÷ 40 cps. A research program was initiated to assess the significance of these loads with the sponsorship of the "Agreement between ENEA and AI for the Development of Light Water Reactors".

It is recognized that the behaviour of ductile structures (i.e. having large energy dissipation capabilities) is completely different from the one of fragile structures, which cannot dissipate energy. Both the behaviours have been investigated; a piping structure has been chosen as representative of a ductile structure, while a panel for electronics has been analyzed as a fragile one.

2. Methods of Analysis

2.1 Ductile Structure

For ductile structures the non linear behaviour is important, as energy dissipation takes place in the plastic range. The analyses have been performed by means of PAULA 82 code /1/.

2.2 Fragile Structures

For fragile structures it has been assumed that the behaviour is elastic, however it should be mentioned that fragile equipments are generally located inside metallic structures (panels), so that the loads, at the equipment level, are basically dominated by the dynamic characteristics of the panel structure. Consequently a typical problem of the computation of FRS under transient conditions is found; the computer code CYRANO /2/ has been used for the computation of FRS while computer code ASDIC /5/ has been selected for the dynamic analysis.

3. Input Data

In the case of ductile structures the input load is given under the form of a time history, which represents an extreme case of aircraft impact loads, with very high accelerations in the medium-high frequency range /3/ . The time history is shown in fig.2 .

For the case of fragile structures two input spectra have been used, they are typical of :

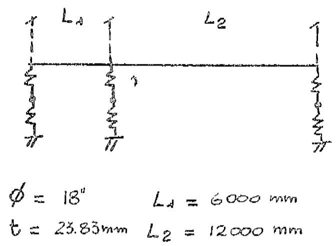
a) seismic response

b) aircraft impact response

The data for aircraft impact are typical of a medium- high level response, taking into account some effect of the ductility of the panel structure as suggested in ref./3/. The input data are shown in fig.3.

4. Analysis of Ductile Structures

The present analysis represents an extension of the one already reported in ref./4/;a very simple structure (a 2 span piping) has been used, typical data are shown in fig.1.



Two Span Geometry

Fig.1

The double set of springs has been introduced to simulate the displacement pattern due to Aircraft Impact and the behaviour of non linear supports. Some difficulties have been found in having the structure loaded even if the input signal is an extreme one (see fig. 2), due to the fact that the model eigenfrequencies are much lower than the one of the input (typically around 10-15 cps). In order to have reasonance between the input signal and the structure, its properties have been artificially modified. As one can see an amplification factor of roughly 2 is present, so that the piping peak accelerations in this case are larger than 100 gs, with reactions on the restraints large than 100 tons. If plastic yielding of the pipe takes place (less than 1% of peak deformation) large reductions in the restraint loads are present.

However the most effective way of reducing the loads and the deformations on the piping has been found to allow plastic deformations on the restraints. Typically if one allows yielding of the support at 10 tons the data are :

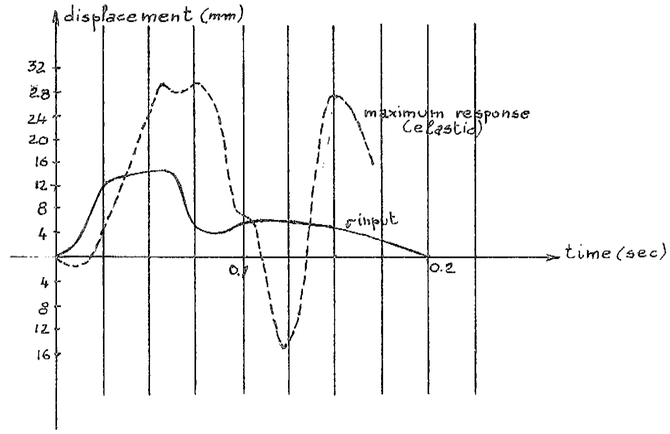
maximum displacement of input signal	9 mm
maximum piping deflection	10 mm
maximum restraint elongation	16 mm

From these data one should conclude that :

a) pipings are low frequency structures, which are not prone to high frequency excitations typical of AI input spectra; consequently both pipes and piping mounted equipment should be reasonably safe due to the effective filtering of the piping

b) if resonance would result the most effective way to reduce the response would be to limit the load capability of the restraints; in this way the differential displacement on the restraint should roughly double the input displacement. As typical displacements are less than 5 mm an allowable differential displacement of 1 cm should be enough.

Consequently the following rules should apply: if large loads are encountered on some stiff portions of the piping then the restraints should have the possibility of a controlled yielding (at values higher than seismic, which is not extremely difficult, as seismic accelerations are generally lower than 2 gs at important frequencies) and to have differential displacement of roughly 1 cm within allowable limits (typically, assuming an allowable strain of 5% that means a free length of about 20 cm).



AI Input Signal and Amplified Response of Model in Fig.1

Fig.2.

5. Analysis of Fragile Structures

The analyses have been performed on the mathematical model of panel structure,as shown in Fig.4; the structure is representative of a typical real situation. The basic problem of these panels should be found in the fact that they contribute strongly to the response of the equipment mounted on it as a function of the dynamic characteristics of the panel. Three types of structure have been analyzed as follows :

aa) stiff structure (i.e. with frequencies higher than the resonance seismic values)

bb) filtered structure (i.e. the aa structure under which special supports are placed)

cc) self filtering structure (i.e. a structure with a strict control of the dynamic characteristics so that they fall in the optimum range.

The main eigenfrequencies are shown in table 5.1.

Table 5.1

Basic Eigenfrequencies (cps) Structure

Mode	aa	bb	cc
1	19.11	8.98	18.42
2	42.84	9.64	21.74
3	46.14	16.94	24.37
4	-	20.00	24.61
5			24.71
6			25.34

The responses at the top of the panel have been computed (node 31 in fig.4), note that the following durations have been used :

Seismic 30 secs Aircraft Impact 0.12 secs

Typical responses have been reported in fig.5. It is shown that :

a) structure aa gives reasonable responses for the case of seismic excitation, for which it was originally designed however very high response peaks for the case of aircraft impact are found

b) structure bb is acceptable for the case of aircraft impact excitations however the supports induce rocking modes which can give a problem; they might be eliminated with a proper suspension system, even if this solution might be somewhat complicated

c) structure cc gives the best results in terms of peaks responses, even if it may require an accurate and somewhat cumbersome design.

6. Conclusions

The case of the response of ductile structures (typically a piping system) and fragile structures has been examined; it is shown that :

a) ductile structures are not prone to be largely damaged by high frequency excitations; even very large acceleration peaks can be accomodated provided that sufficient deformation capability is kept in the weakest structural member (which should never be a fragile items).

b) in the case of fragile equipments the support system is obviously the key item, consequently it may happen that a relatively unexpensive and unimportant item such as a panel structure can play a major role in the design loads of the panel mounted equipments. It is shown that a careful design of the panels (via a control of the frequencies) can be very effective,otherwise external filtering might be used.

References

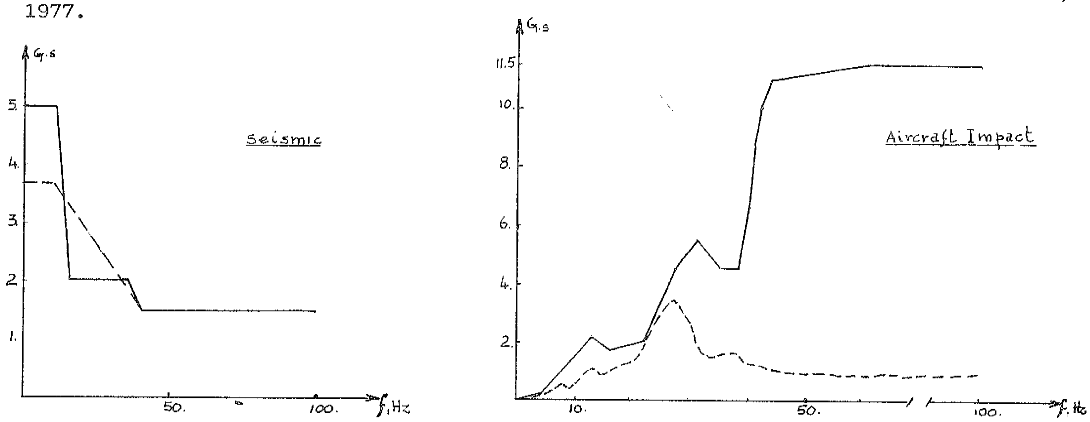
/1/ LAZZERI L. "PAULA 82 : A Code for Non Linear Analysis of Pipes and Shells" 7 SMIRT, L6/7, Chicago 1983.

/2/ CIUCCHI W., LAZZERI L., OLIVIERI M. "On the Computation of FRS" 7 SMIRT, K/6/3, Chicago 1983.

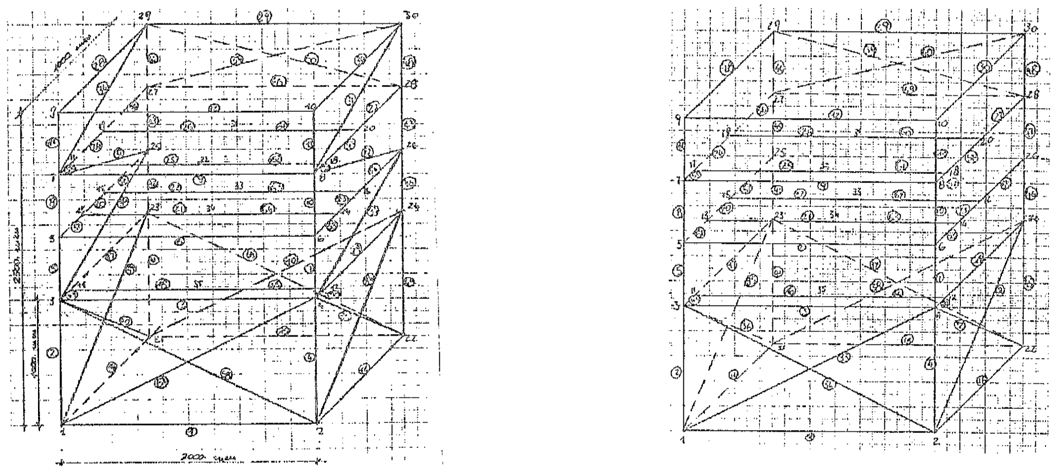
/3/ LAZZERI L., OLIVIERI M., TRAVI S. "On the Analysis of the Consequences of Aircraft Impact for the Design of Structures and Components" 6 SMIRT, J9/1, Paris 1981.

/4 GIULIANO V., LAZZERI L., SCALA M. "3D analysis of Piping in the Non Linear Field Under Extreme Conditions " 6 SMIRT, K10/11, Paris 1981.

/5/ LAZZERI L., STRONA P.P. "ASDIC : Theoretical Manual" Ansaldo Impianti Rep 0226 Z 001, 1977.

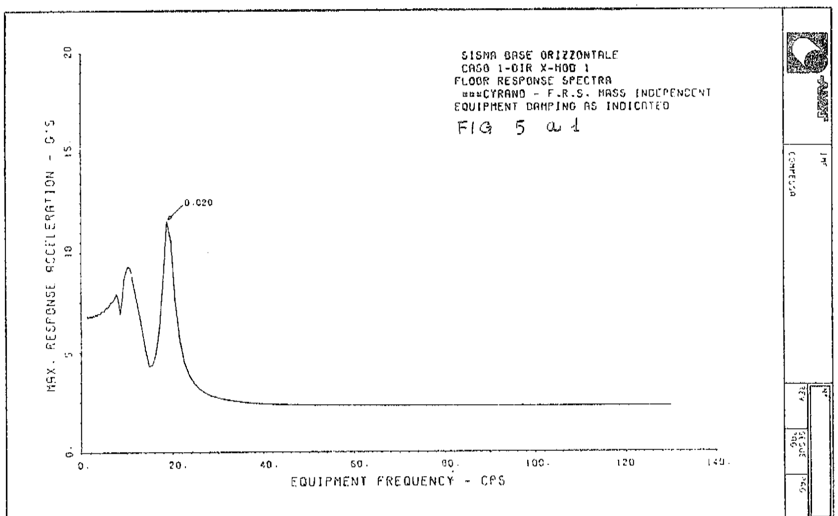


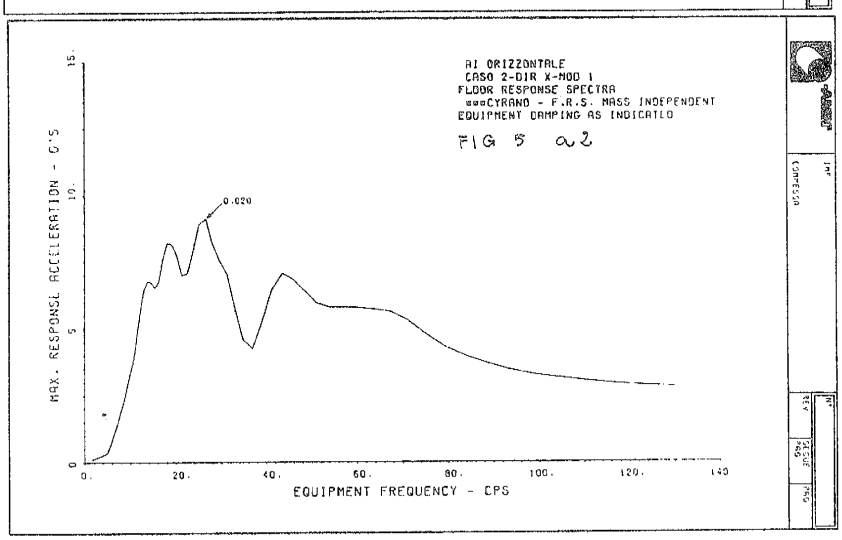
Input Spectra
Fig.3

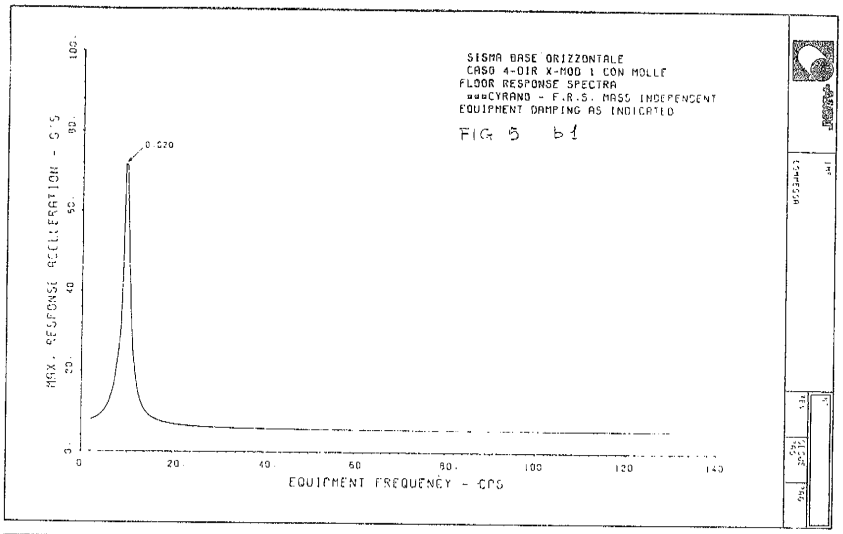


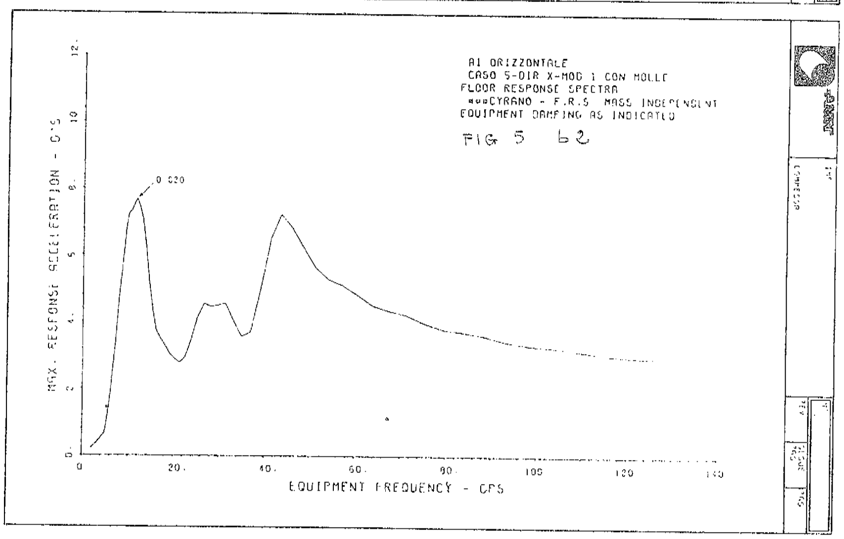
"aa" "bb" "cc"

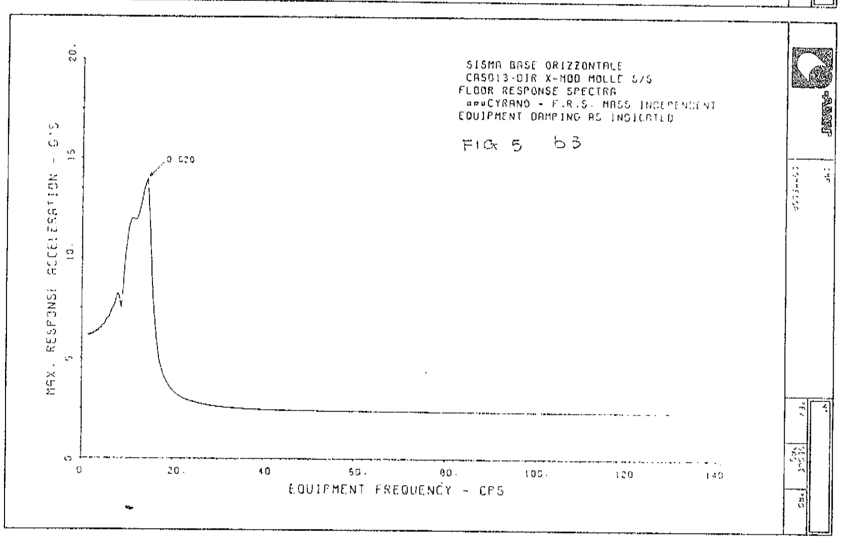
FIG.4- Models of Panel Structure






SISMA BASE ORIZZONTALE
CASO 4-DIR X-MOD 1 CON MOLLE
FLOOR RESPONSE SPECTRA
***CYRANO - F.R.S. MASS INDEPENDENT
EQUIPMENT DAMPING AS INDICATED
FIG 5 b1
0.020
MAX. RESPONSE ACCELERATION - G'S
EQUIPMENT FREQUENCY - CPS


AI ORIZZONTALE
CASO 5-DIR X-MOD 1 CON MOLLE
FLOOR RESPONSE SPECTRA
***CYRANO - F.R.S. MASS INDEPENDENT
EQUIPMENT DAMPING AS INDICATED
FIG 5 b2
0.020
MAX. RESPONSE ACCELERATION - G'S
EQUIPMENT FREQUENCY - CPS


SISMA BASE ORIZZONTALE
CASO13-DIR X-MOD MOLLE 6/5
FLOOR RESPONSE SPECTRA
***CYRANO - F.R.S. MASS INDEPENDENT
EQUIPMENT DAMPING AS INDICATED
FIG 5 b3
0.020
MAX. RESPONSE ACCELERATION - G'S
EQUIPMENT FREQUENCY - CPS

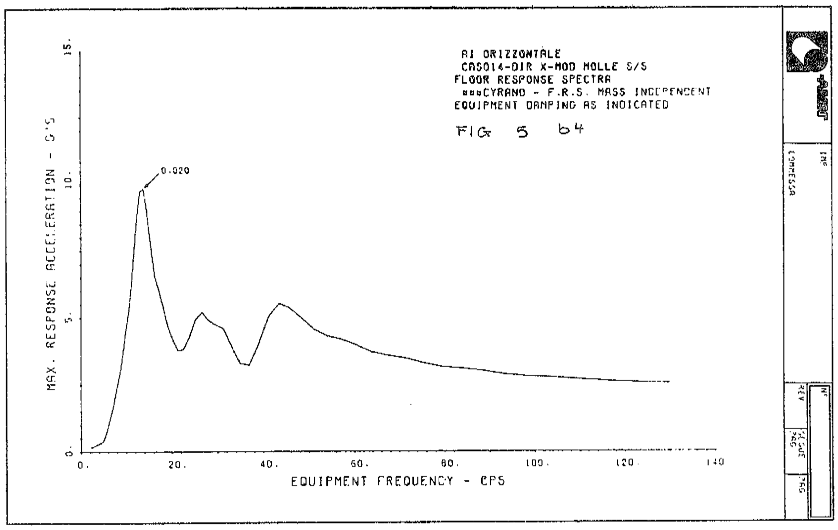


FIG 5 b4

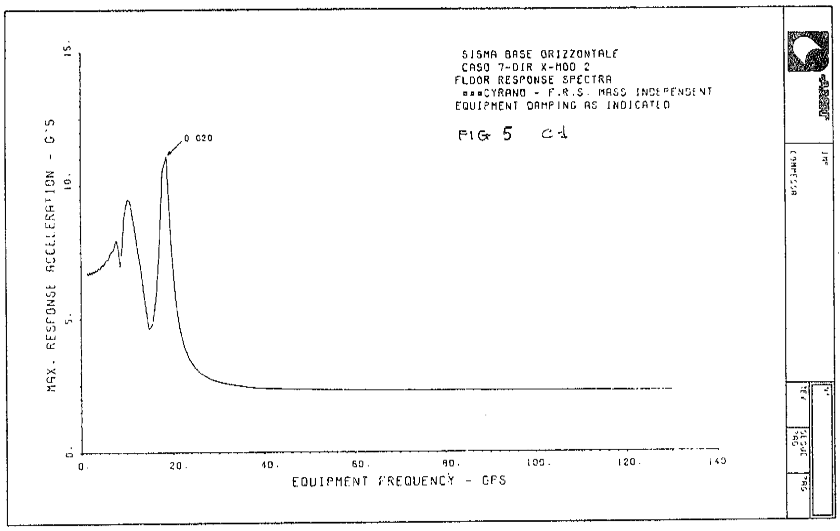


FIG 5 c1

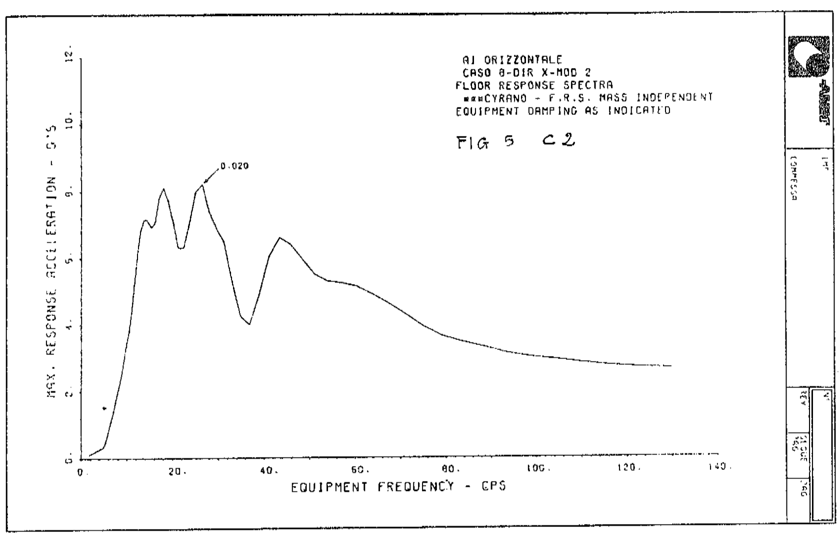


FIG 5 c2