Title: **Testing of components on the shaking table facilities of AEP and contribution to full scale dynamic testing of Kozloduy NPP**

Contributor: **Y. Ambriashvili**

Date: **December 1995**

IAEA BENCHMARK SEISMIC SAFETY NPP KOZLODUY

Final Report

Testing of components on the shaking table facilities of AEP and contribution to full scale dynamic testing of Kozloduy NPP

Research Contract No. 7447/R1/EN

Prof.Dr.Y.Ambriashvili

ATOMENERGOPROJECT
December 1995
Moscow

Introduction

According to the working plan of Atomenergoproject the following activities have been foreseen:

I.

- Analysis of calculated floor response spectra used by Atomenergoporject (AEP) during the designing of NPP in Kozloduy and comparison with other spectra recommended for this NPP.

- Analysis of floor response spectrum for the most important systems (reactor, main coolant loop, electrical systems and etc.).

II.

- Test of some main electrotechnical systems on NPP "Kozloduy" and comparison with the results of testing on the platform of AEP.

- Analysis of the results and conclusion on the seismic stability of those systems.

In the present report the results of the response spectra analysis are given, as well as the method and some results of the tests of the electrotechnical equipment which has been identified by the authorities of NPP "Kozloduy" and which will be analyzed in future according to the results of the test on seismic platform.

DESIGN FLOOR RESPONSE SPECTRUM FOR UNITS 5 & 6 KOZLODUY NPP.

Units 5 and 6 of KOZLODUY NPP were designed as a standard NPP WWER-1000, which has been built in the USSR for the last 15 years, on the basis of standard scheme designs, including the building structures and reactor building. Designed model was developed on the basis of the working drawings, the main dimensions are given on Fig.1.

In view of the fact that this type of NPP was planned to be built in various regions of the USSR and in other countries, calculations have been made of the set of accelerograms which includes artificial and already known recordings of earthquakes as Nish, Bucharest, Helena, Santa Barbara etc . Envelope response spectra of the set of accelerograms are shown on Fig.2. and in Table 1.

The accelerograms and response spectra were adopted on the basis of the analysis of the seismological, geological, geophysical and others conditions in the regions where the NPP is to be probability located, in order to obtain the wider coverage of the amplitude-frequency characteristics of weak and strong earthquakes, of different epicentral distances for various ground geological conditions.

The maximum acceleration amplitude of the horizontal oscillations for all accelerograms were assumed to be 4.0 m/s2 and those of the vertical oscillations of 2.0 m/s2.

It was assumed that for the calculation of the specific structures the maximum amplitudes and accelerograms could be standardized and adopted as follows:

Intensity level	9	8	7	6	5
Max. acceleration m/sec2	4.0	2.0	1.0	0.5	0.25

With this approach, and subject to allowance for a wide range of dynamic characteristics of earthquakes, it is possible, with some degree of error, to dispense with taking separate account of the influence of the special ground properties of the sites and of amplitude and phase shift frequency characteristics in case of weak and strong earthquake. The vertical component in this case is assumed to be equal to the half the horizontal.

Material properties.

The following material properties were employed for the soil and reinforced-concrete structures:

SOIL

-Velocity of longitudinal wave - 1500m/sec;
-Velocity of transverse wave - 600m/sec;

STRUCTURES

-Module of elasticity	E= 3 10/7 kN/m3
-Poissons ratio	- 0.2
-Specific gravity	- 25 kN/m3
-Damping	
(percent of critical)	D = 5 %

On Figure 2 you can see the envelope response spectra for 3 sets of accelerograms calculated on the maximum acceleration of 0.2 g.

1. Calculated envelope response spectrum from 10 sets accelerograms were defined by the Academy of science in 1984. It was used in AEP's and Siemens's works for the dynamic analysis of interaction of the reactor buildings for 5 types of soil: soft, medium, hard, soft-rock and medium-rock (curve 1).

2. Calculated envelope response spectra used by Siemens for calculations of the 5th and 6th NPP's block in Kozloduy in the frame of benchmark project for soft and hard soils (curve 2).

3. Standard envelope response spectra unified NPP WWER-1000 recalculated to 0.2 g for medium soil (curve 3).

As it follows from the diagrams, if those spectra are used for the analysis of the 5th and 6th blocks of NPP "Kozloduy", we can make a conclusion on seismic stability of NPP "Kozloduy", taking into consideration that the whole project was fulfilled for 0.1 g, but now the seismicity of the site is determined as 0.2 g. It is reasonable to say that many of technological and electrotechnical systems were calculated for interactions considerable exceeding 0.1 g and it is confirmed by our analysis of main coolant loops and electrotechnical systems tests on NPP "Kozloduy". It will be mentioned below.

On Figures 3 and 4 you can see the envelope floor response spectrum received by using the standard set of accelerograms in calculations of unified NPP WWER-1000 (Maximum acceleration is 0.4 g).

The values of the envelope floor response spectra for standard set of accelerograms (a= 0.1g) for the elevations of 24.6, 36.6 and 45.6 m , i.e. the level of concentrations of the most important equipment, are listed in tables 2, 3, 4, 5, 6 and 7.

On Figure 5 there are the horizontal envelope floor response spectra for the elevation 36.6m (damping = 2%) for accelerorgams (see Fig.2) and response spectrum implemented for the design of the reactor and main coolant loops.

Analyzing the data on Figures 3, 5 and Tables 3 and 4 it should be said the following:

Supports of the reactor is on the elevation of 24.6 m and formally should be projected onto the spectrum according Table 4 for NPP "Kozloduy" , i.e. peak of spectrum is 1.0 g.

In this case, according to our data, forces on snubbers of the steam generator is about 180 t, and on main pump is 80 t. But it is known that on steam generator there are 8 snubbers of 450 t each, and on the main pump there are 5 snubbers of 170 t each.
Consequently, that the reactor unit is designed for more than 0.2 g, and it is confirmed by diagram 3 on Fig.5. It is well to bear in mind that the load on snubbers was design of damping 1%, and diagram 4 on Fig. 5 is for 2 %. Therefore our calculations shows that the reactor unit has high level of protection.

In case of using of SIEMENS's data for the hard soil of Diagram 1 of Fig. 5, the reactor unit requests the enforcement (Benchmark Report. Article 16).

According to the calculations fulfilled by the software programs STRUDYN, and SASSI for the soft soil (the diagrams 4 and 5) some units of the reactor also should be checked, because eigenfrequences main coolant loops with snubbers and without it are as follows:

Without snubbers:

0.80	2.20	2.50	8.25	8.60
11.00	15.00	17.00	18.00	22.00

With snubbers:

8.80	9.70	11.70	12.60	13.40
14.00	17.00	18.00	18.40	22.00

Conclusions on the first part of the present report:

1. For NPP" Kozloduy" the similar analysis should be done for all main systems before the development of the new seismic safety systems.

2. For the detailed analysis of the seismic stability of NPP "Kozloduy" the data of calculations and testing NPPs which are available in AEP, VNIIAM and in other Russian Institutions should be used.

II.

The purpose of the second part of the report is the implementation of the works of investigations of seismic stability of electrotechecnical and technological equipment.

The work includes two tasks:

- Carrying out the test of some main equipment on NPP "Kozloduy" and fulfillment analysis of the analogous test on the seismic platform with the purpose to evaluate the seismic stability of the equipment under conditions of the expected earthquake for NPP "Kozloduy".

- To evaluate and make analysis of the difference in the results of the tests carried under natural conditions and on the seismic platform.

By nowadays the test of the equipment in NPP "Kozloduy" has been completed and the results are processing.

On the agreement with the authorities of NPP "Kozloduy" within the period from April 17 till 23, 1995 the team of specialists of AEP fulfilled the test of the main electrotechnical fire protection equipment and diesel-generator.
A number of cabinets were selected for the tests: 3 cabinets RT30, 2 cabinets ABP, 2 cabinets TKEP and Diesel generator cabinet. Organization of the test is shown below.

It is necessary to emphasize that all tested cabinets had good quality of assembling and design decision in respect of seismic safety: the cabinets are connected in the rows with each other and with the wall of the department by the metal joints
Elevation of the cabinets of fire protection unit is 20.4 m.

Test method and the analysis of the results are based on static and impulse effects.

1. Review of all cabinets are carried out and the list of equipment which, to

our opinion, should be tested, will be drawn up.

2. Preparation of the measurement instruments , including:
 - 4-channel magnitograph for signals record
 - 2-channel amplifier
 - three high sensitive accelerometers.

3. Preparation of the cabinet for the tests:
 - assembling the measurement instruments: accelerator - magnitograph - microphone (for record of sound information of the tests);
 - determination of the effect levels for qualitative record of the signal.

4. Carrying out the trial tests by static and impulsive methods.

5. Performance of the analysis of the results with application of special digital-to-analogue converter, set of soft-ware for PC-386.
If the results are positive, the tests will be carried out as follows:
 - one sensor records the vibration of the foundation of the cabinet, the second one is moved in the cabinet in the areas of the instruments of it which, to our opinion, is most important.
 - vibration is excited by static loads or by impulsive loads (impact of the special hammer in the foundation of the model)

6. In the results of the tests and processing of the PC's records we obtain the following graphic and digital data:

 - vibrations of each effect in the foundation of the cabinet and of the instrument in the cabinet;

 - amplitude-frequency characteristics of the points;

 - transfer functions of the points.

7. If there are floor response spectra, the calculated sintetic accelerogram and accelerograms as a reaction on the floor response spectrum by the transfer function of the cabinet in the zone of the instrument setting.

8. The level of seismic stability of the instruments and the cabinet is determined by accelerogram or response spectrum using the results of vibrations testing of instruments

9. Such method is a standard one. The use of the light tests equipment and instruments and PC allows to obtain graph and digital data operationally for creation of the conclusion on seismic stability.

Some test results for unit 5 of NPP "Kozloduy" are presented on Fig.6,7,8.

Such method was used for the test of electrical and technological equipment of NPP Kozloduy as well as for some other NPPs. The test results of electotechnical fire protection systems, diesel generator, transformer and etc. are shown on Fig. 10 - 39.

Maximum acceleration of the equipment which could be during the expected earthquake on NPP Kozloduy is compared with the maximum level of acceleration during normal operation of the same type of the equipment. It is known that all main components have been designed on maximum acceleration equal 0.15 g within the range of frequencies 2 - 20 Hz on the support of the components.

Data analysis shown on Fig. 5, 10 - 39 indicates that all systems tested by our Company on NPP Kozloduy have high level of seismic stability.

CONCLUSIONS

1. NPP Kozloduy was designed on 0.1 g (see Tables 2, 3, 4);

2. Maximum acceleration of the designed spectrum and new spectrum which are recommended now within the range of frequencies 2.5 - 20 Hz are equal (see Tables 3, 4, 5 and Fig.5 curve 5).

3. Acting reactor and primary loop are seismic stable.

4. All tested by our Company equipment of NPP Kozloduy is seismic stable.

Y.K.Ambriashvili

List of References

1.GOST 175161-90 "Electrical engineering products".Publishing House "Standards" 1990.

2.RD 25 818-87 "General requirement and test methods of the seismic loads of instruments and automation devices for NPPs"

3.Y.Ambriashvili "Seismic stability of NPPs" Publishers: Energoatomizdat, Moscow,1985.

Table of acceleration

Table 1

f(Hz)	0	3.0	7.0	30.0
a m/sec2	0	13.0	13.0	4.0

Table of acceleration (Horizontal Direction)

Table 2

Elevation 45.6m.

f(Hz)	0	3	4	6	12	30
a m/sec2 ST NPP*	0	32	120	120	42	18
Kozloduy NPP	0	8	30	30	10.5	4.5

ST NPP-standard NPP

Elevation 36.6m. **Table 3**

f(Hz)	**0**	**4**	**6**	**12**	**16**	**30**
a m/sec2						
ST NPP	**0**	**15**	**55**	**55**	**20**	**7**
Kozloduy NPP	**0**	**4**	**14**	**14**	**5**	**2**

Elevation 24.6m Table 4

f(Hz)	0	1.5	2	10	16	30
a m/sec2 ST NPP	0	13	40	40	16	5
Kozloduy NPP	0	3	10	10	4	1

Table of acceleration

(Vertical Direction)

Elevation 45.6m. Table 5

f(Hz)	0	2	4	8	12	30
a m/sec2 ST NPP	0	10	50	50	10	6.0
Kozloduy NPP	0	2.5	12.5	12.5	2.5	1.5

Elevation 36.6m. Table 6

f(Hz)	0	10	16	30
a m/sec2 ST NPP	0	40	40	4.0
Kozloduy NPP	0	10	10	1.0

Elevation 24.6 Table 7

f(Hz)	0	4	14	20	30
a m/sec2	0	25	25	10	2.0
Kozloduy NPP	0	6.25	6.25	2.5	0.5

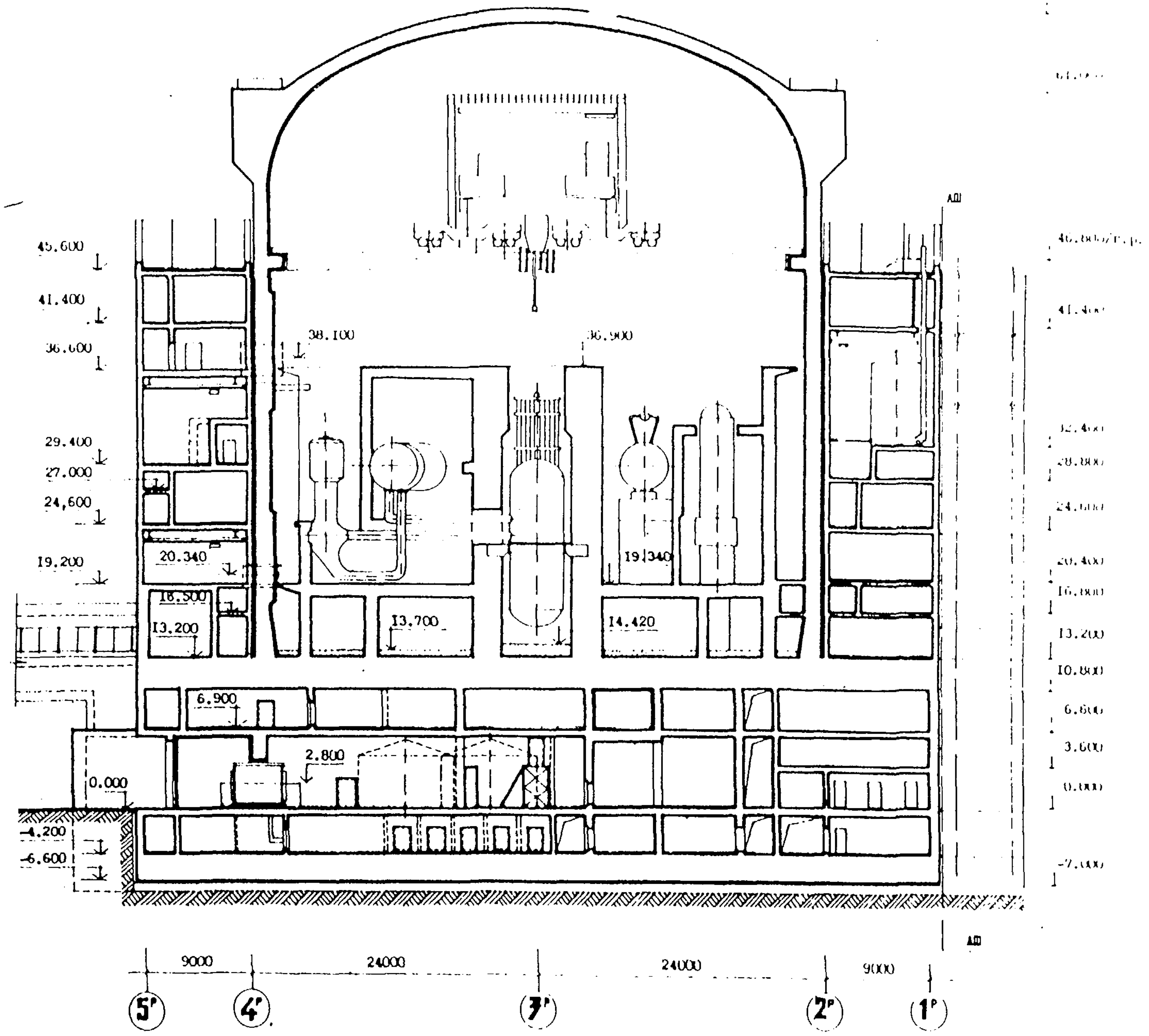

Figure 1 : Section of Building

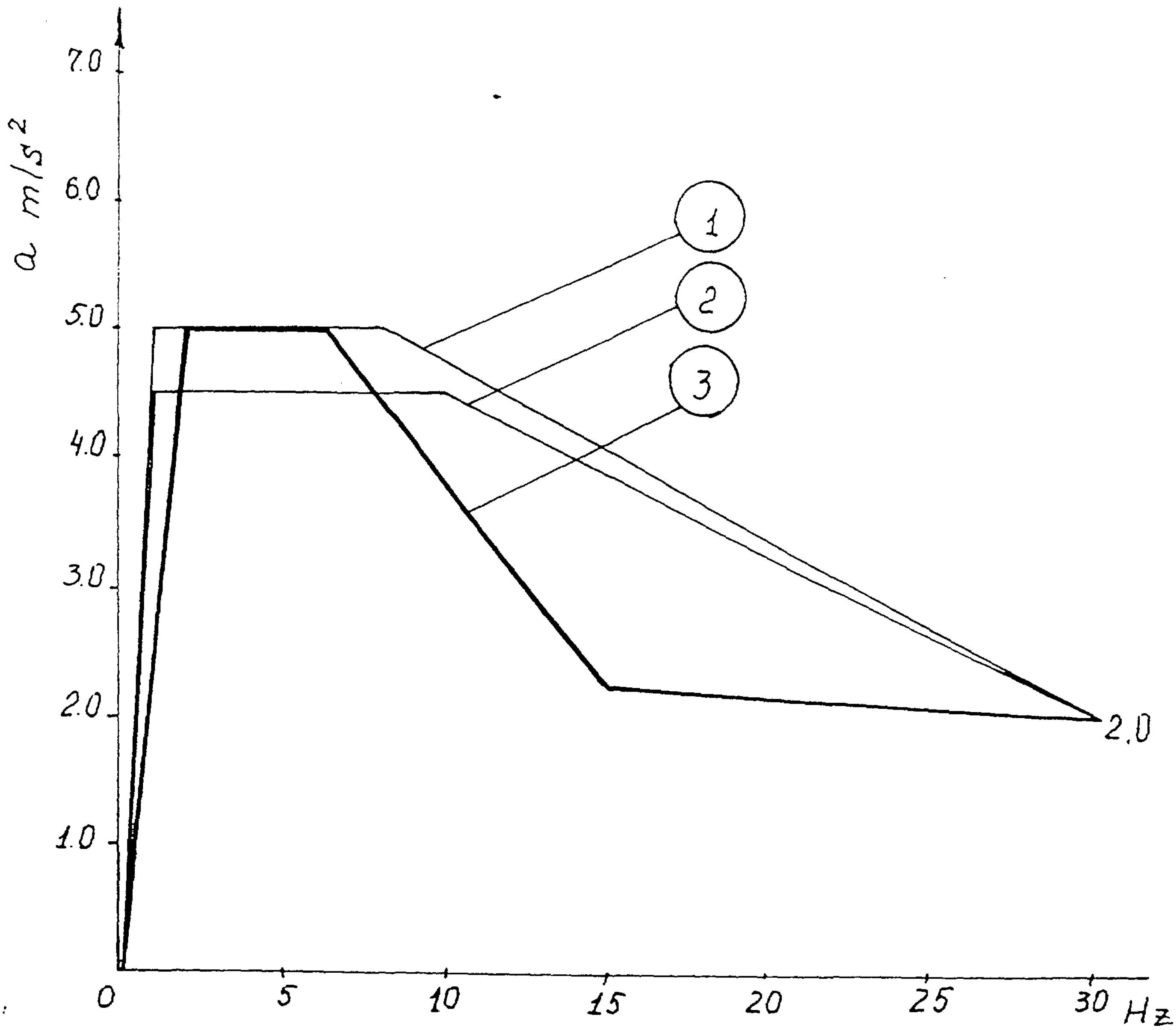

Figure 2. Envelope response spectrum (maximum acceleration 0.2g, damping factor- 5%)

1- from 10 sets of accelerograms defined by the Academy of sciense in 1984.

2- for Units 5 and 6 Kozloduy NPP

3- for Unified NPP WWER-1000

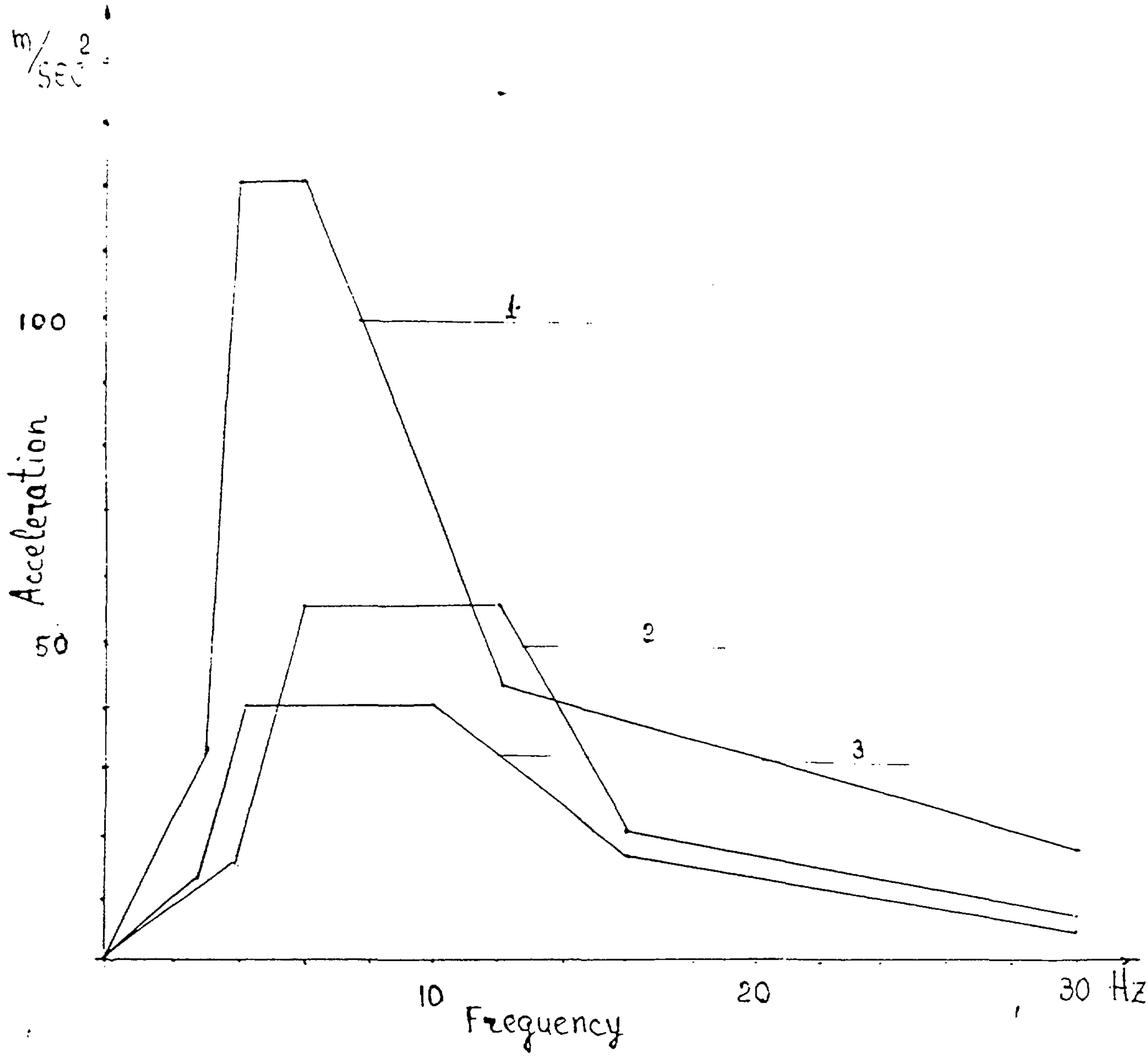

Figure 3. Envelope designed floor response spectrum for Unified NPP WWER-1000 (maximum acceleration 0.4, damping-2%) (Horizontal Direction)

Points:
1- Elevation ----45.6 m.
2- Elevation ----36.6 m.
3- Elevation ----24.6 m.

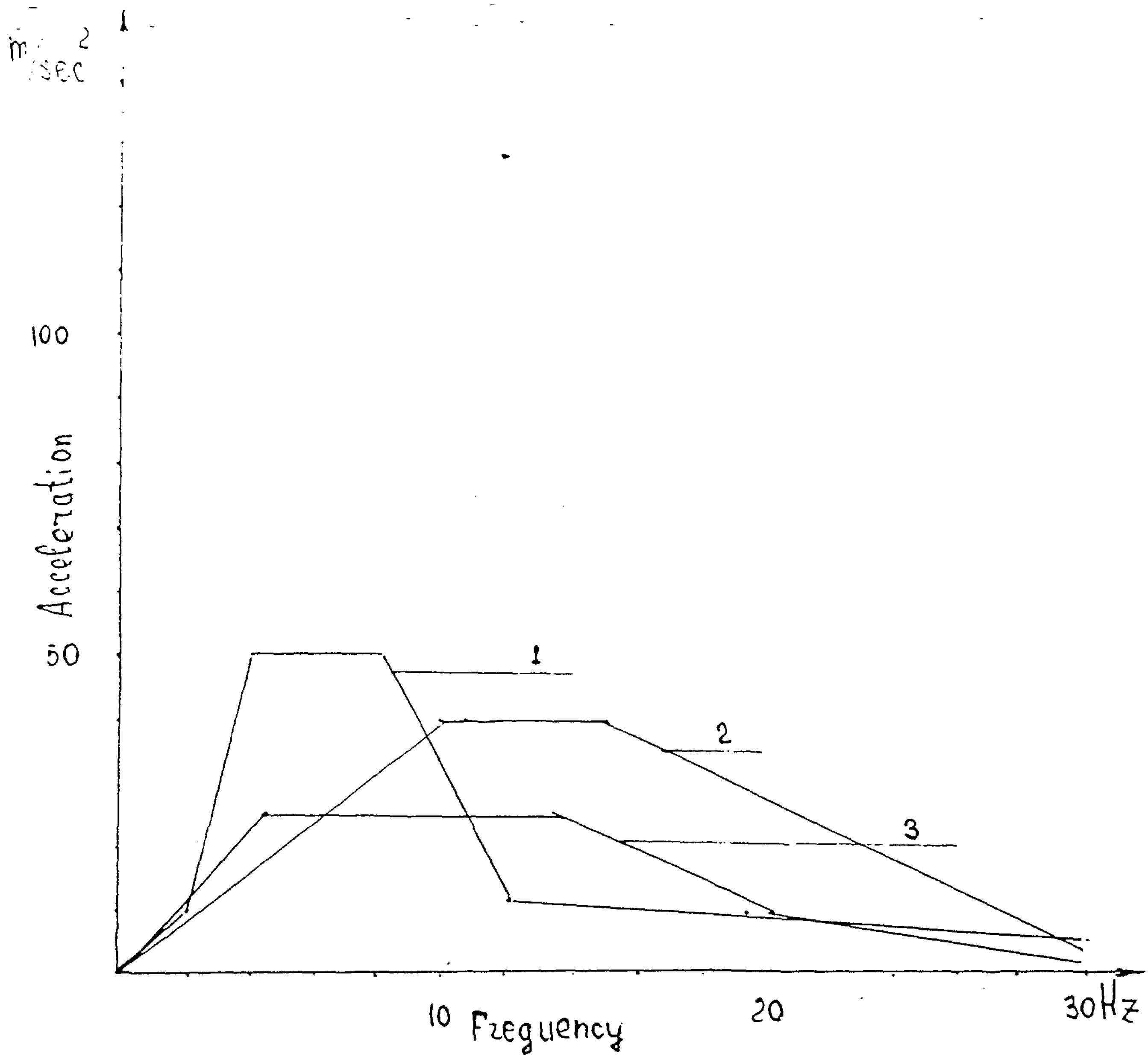

Figure 4. **Envelope design floor respons spectrum for Unified NPP WWER-1000(maximum acceleration 0.2g, damping-2%) (Vertical Direction)**

Points:
1- Elevation ----45.6 m.
2- Elevation ----36.6 m.
3- Elevation ----24.6 m.

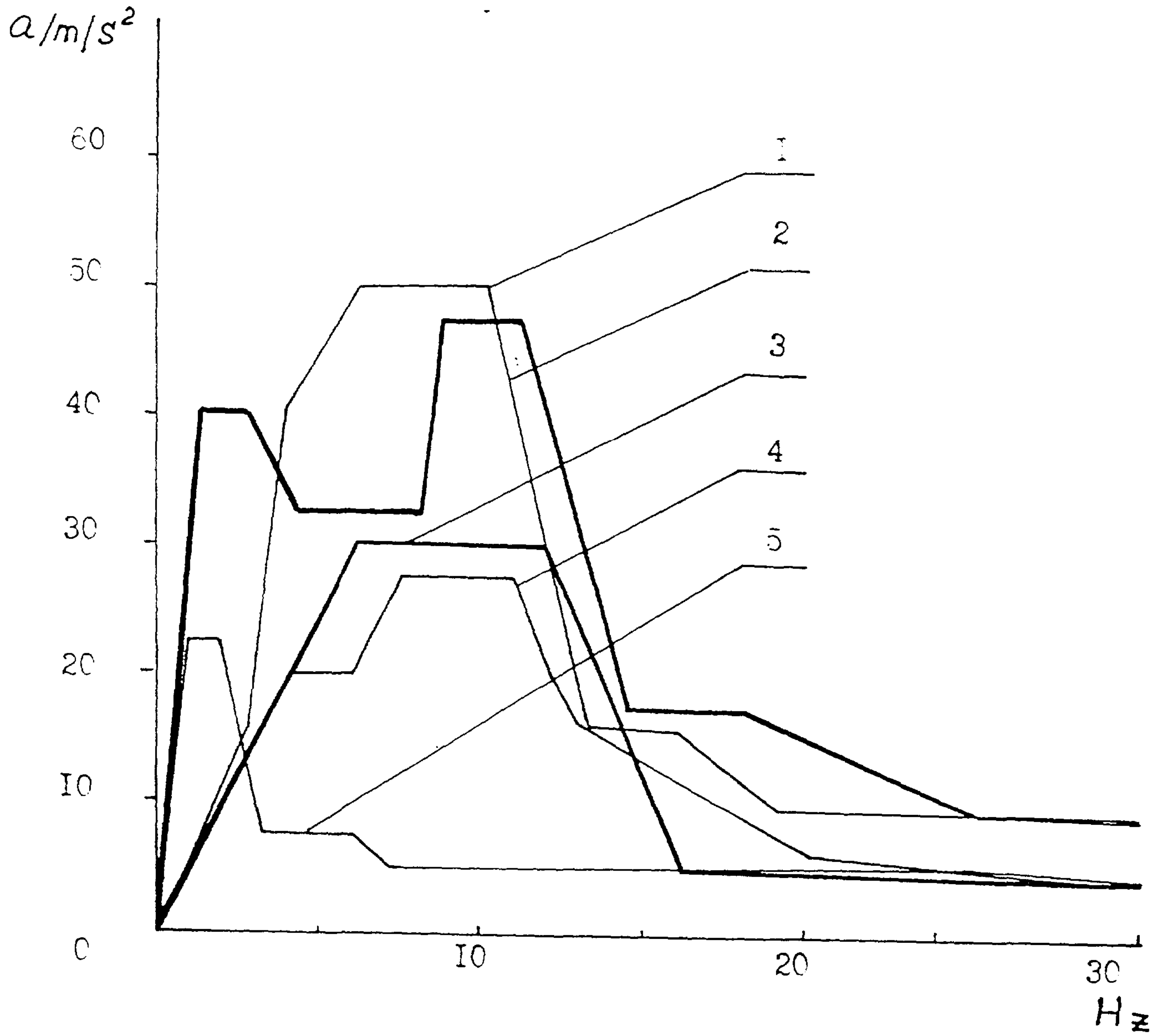

Fig. 5 Envelope floor response spectra. Reactor section. Elevation 36.6 m. Maximum acceleration 0.2g. D=2%. Unified NPP WWER-1000.

1- SIEMENS-Kozloduy-hard soil.

2- AEP-SIEMENS-12 set of accelerogram for soft,soft layered, medium, medium layered and hard soil.

3- AEP-10 set of accelerogams defined by the Academy of Science in 1984-medium soil.

4- For calculation of the reactor and main coolant loops.

5- SIEMENS-Kozloduy-soft soil

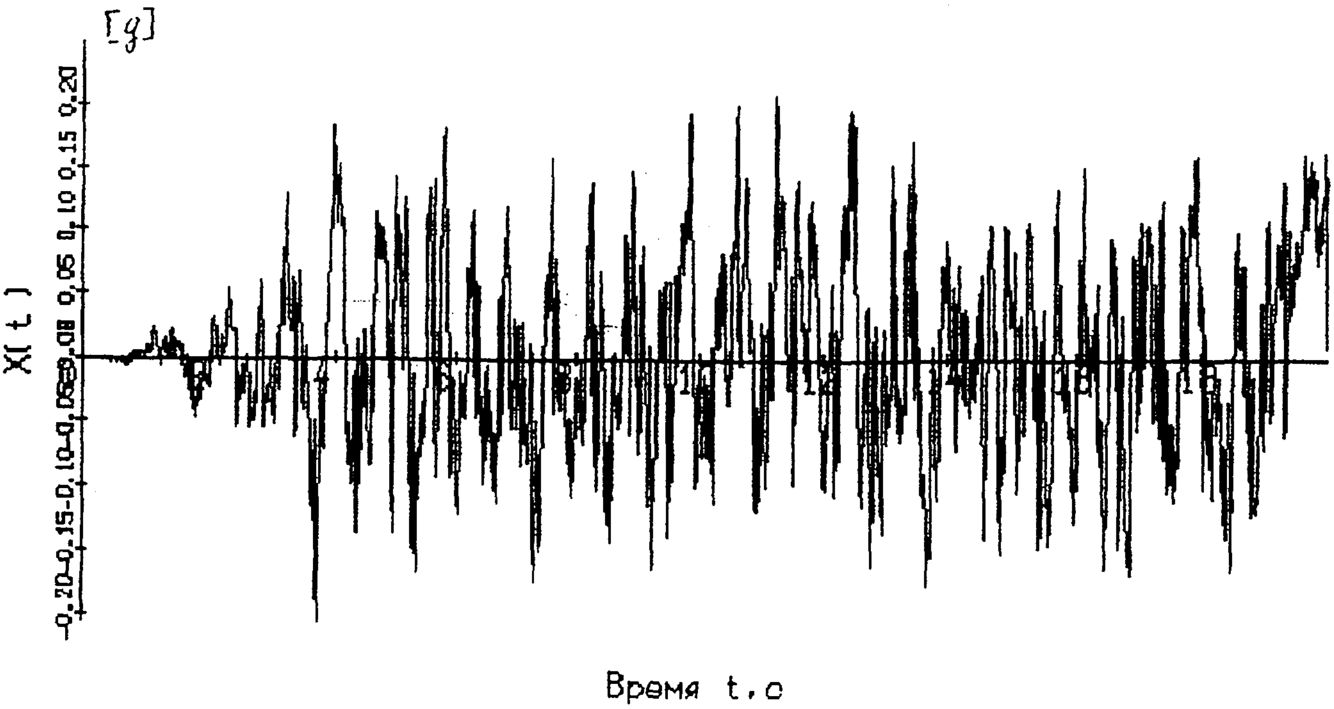

Fig.6 Free field design seismic excitation.

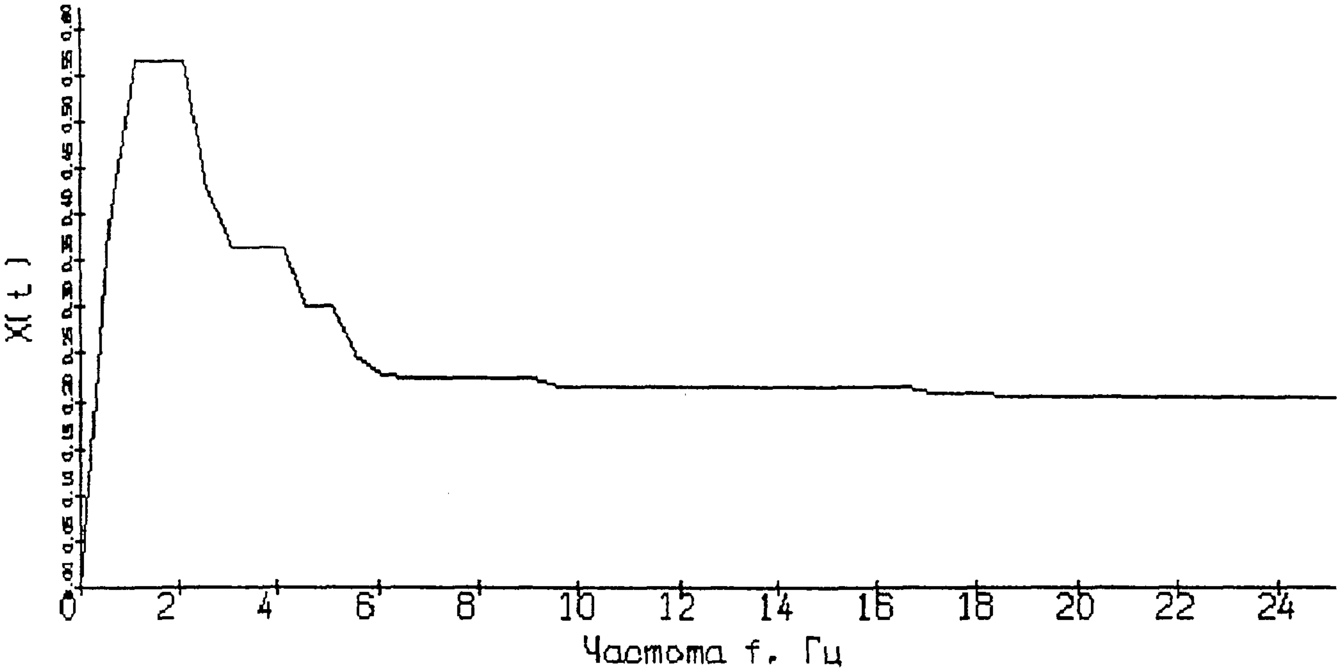

Fig.7 Free field design respons spectrum.

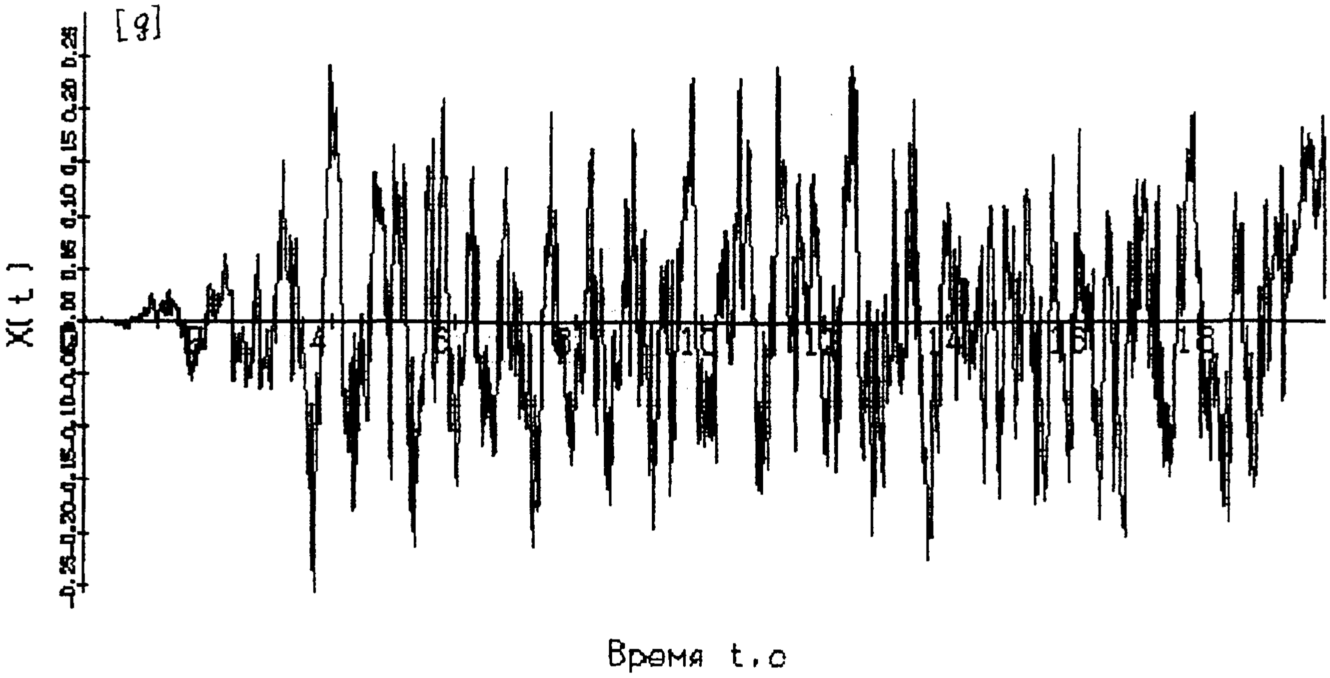

Fig.8 Floor accelerogram.Elevation 20.4m.

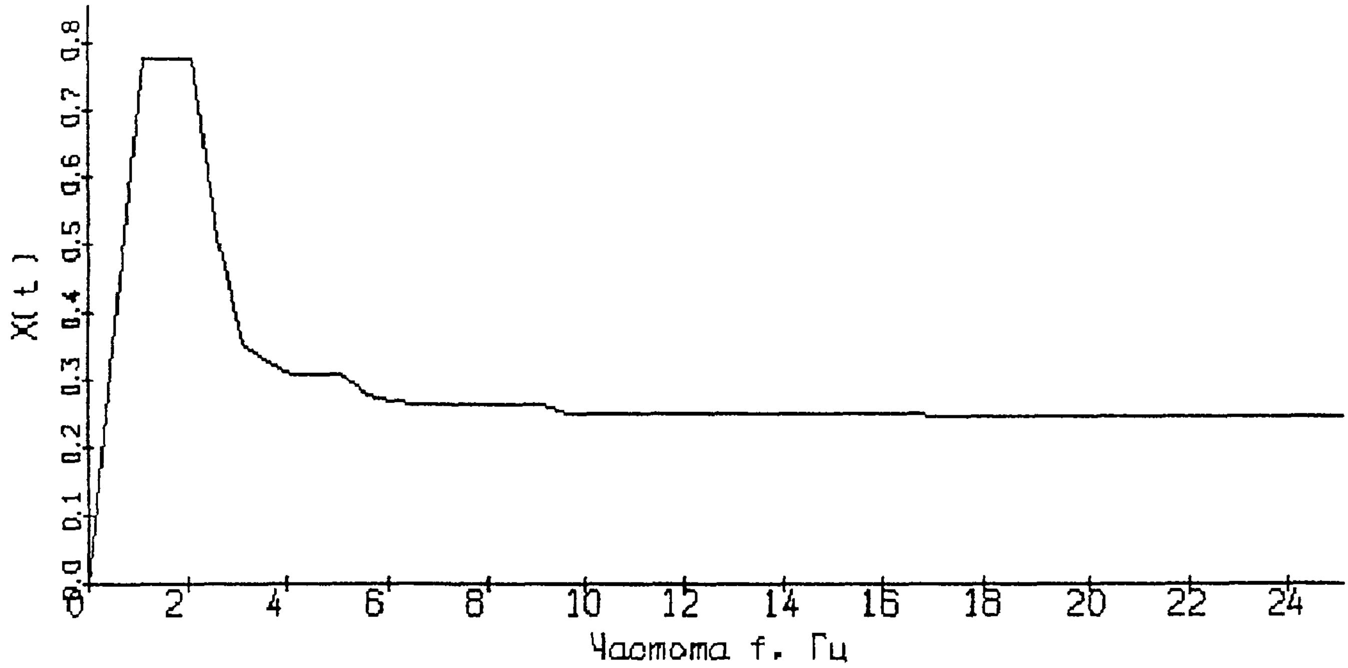

Fig.9 Floor respons spectrum. Eleyation 20.4m.

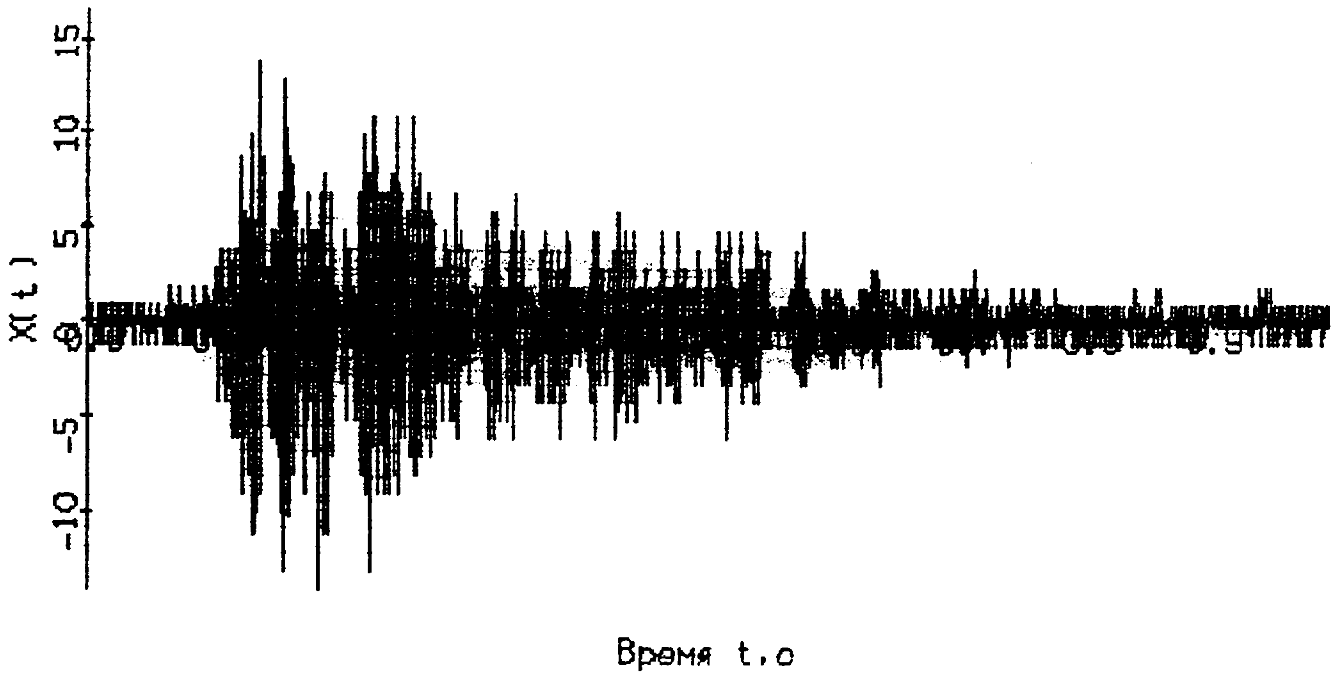

Fig.10 Reaction of Control Cabinets RT to the
impact load.

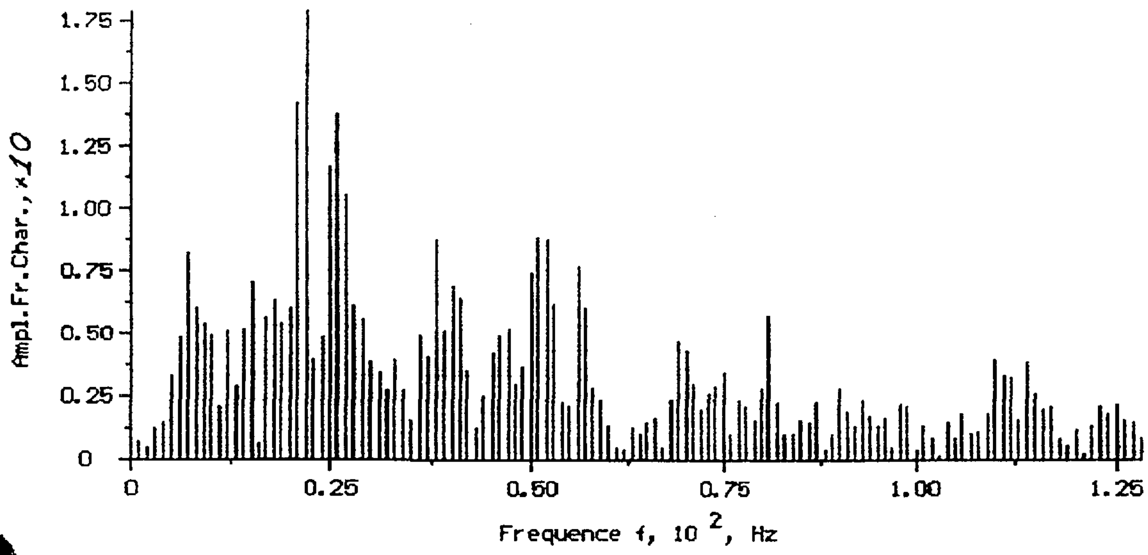

Fig. 11 Amplitude-frequence characteristic Control Cabinets RT. Upper part.

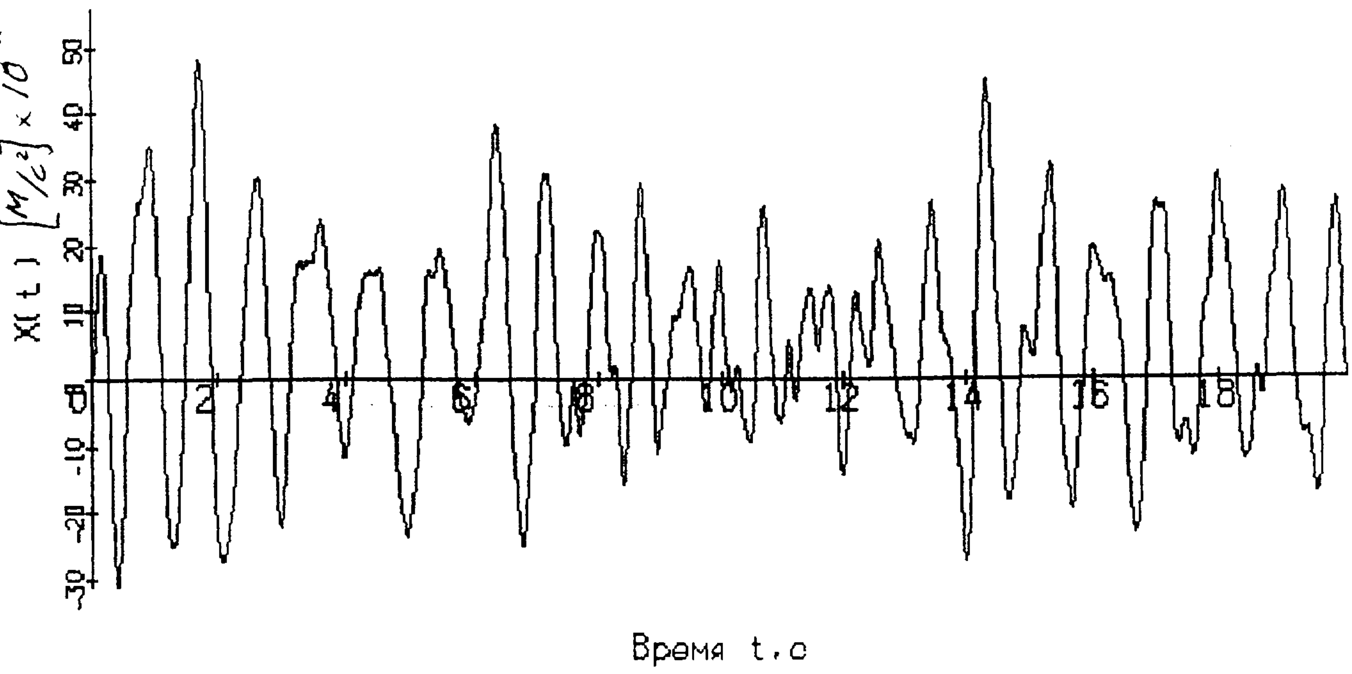

Fig. 12 Reaction of Control Cabinets to the floor accelerogram.

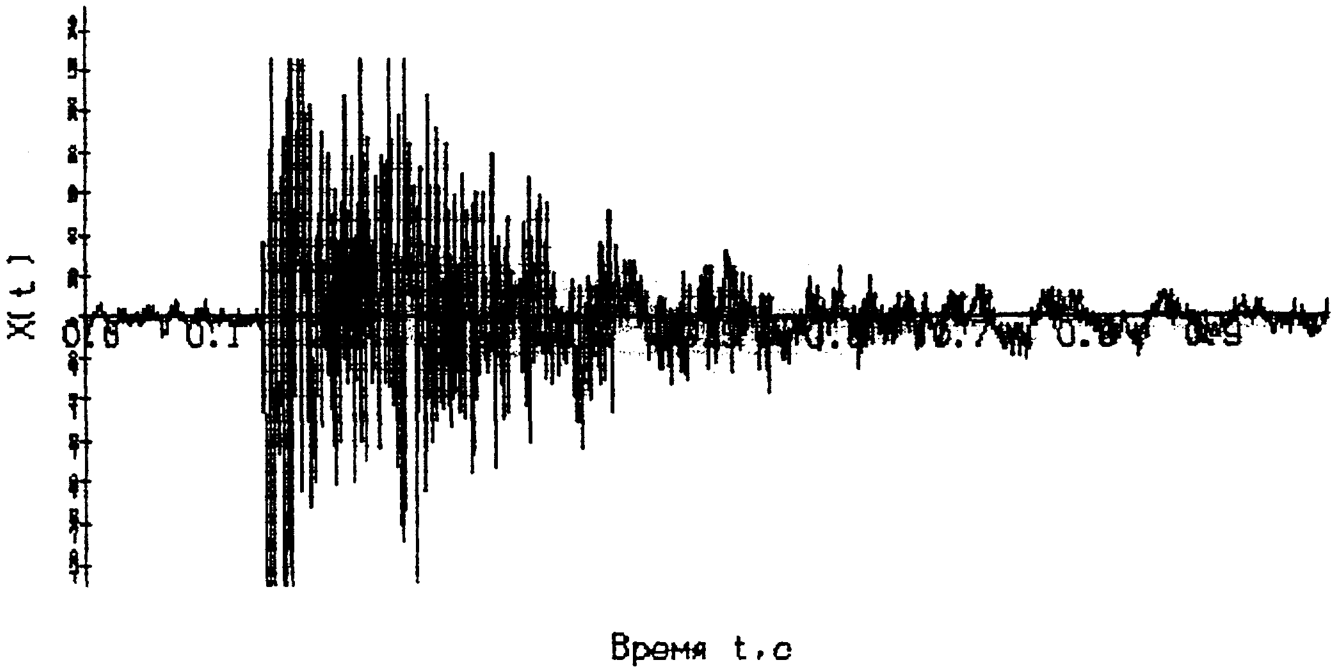

Fig. 13 Reaction of transformer TC3A to the impact load.

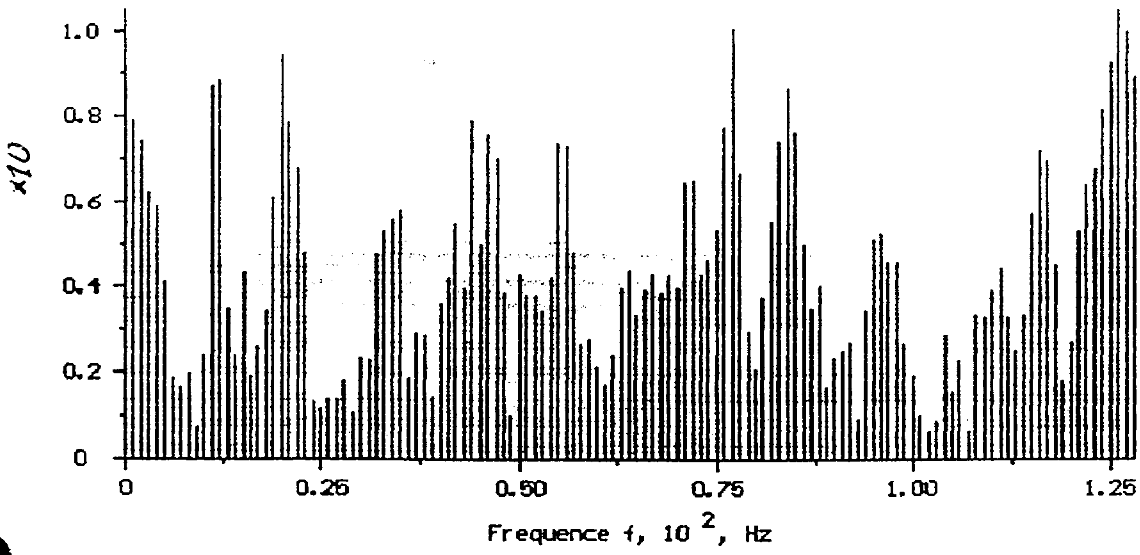

Fig. 14 Amplitude-freguece characteristic of transformer TC3A. Upper part.

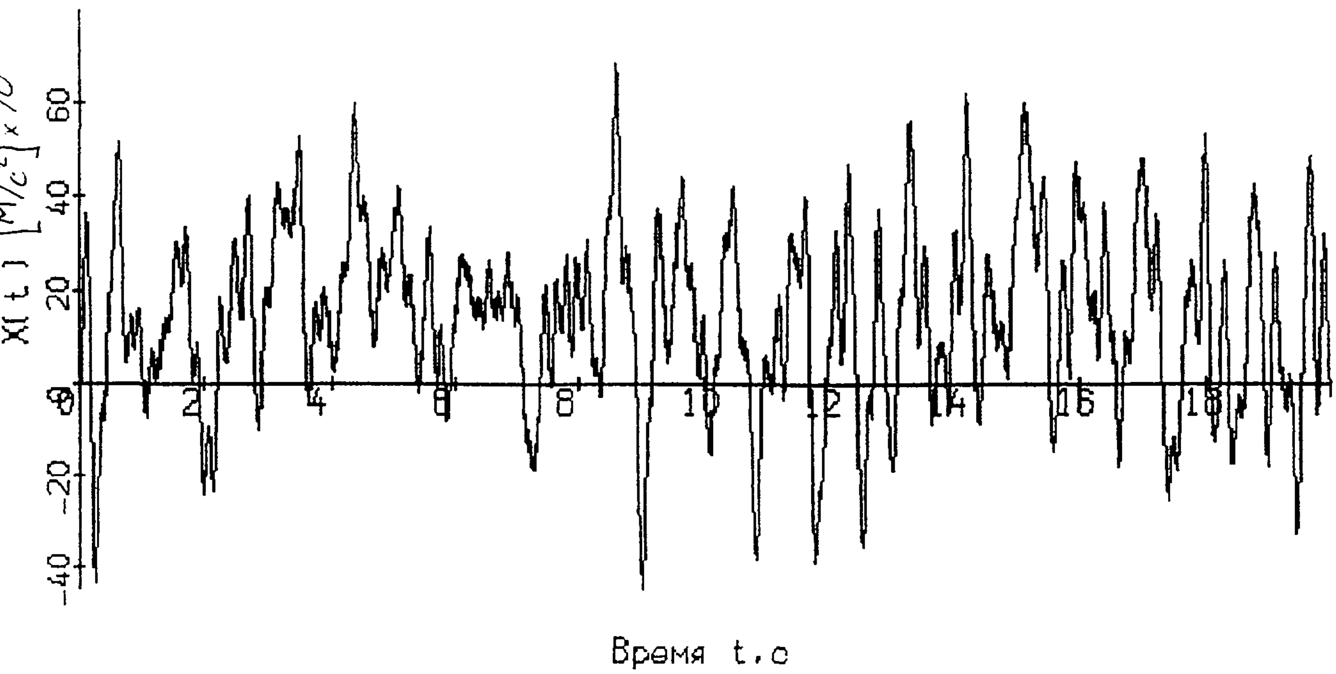

Fig.15 Reaction of transformer TC3A to the floor accelerogram.

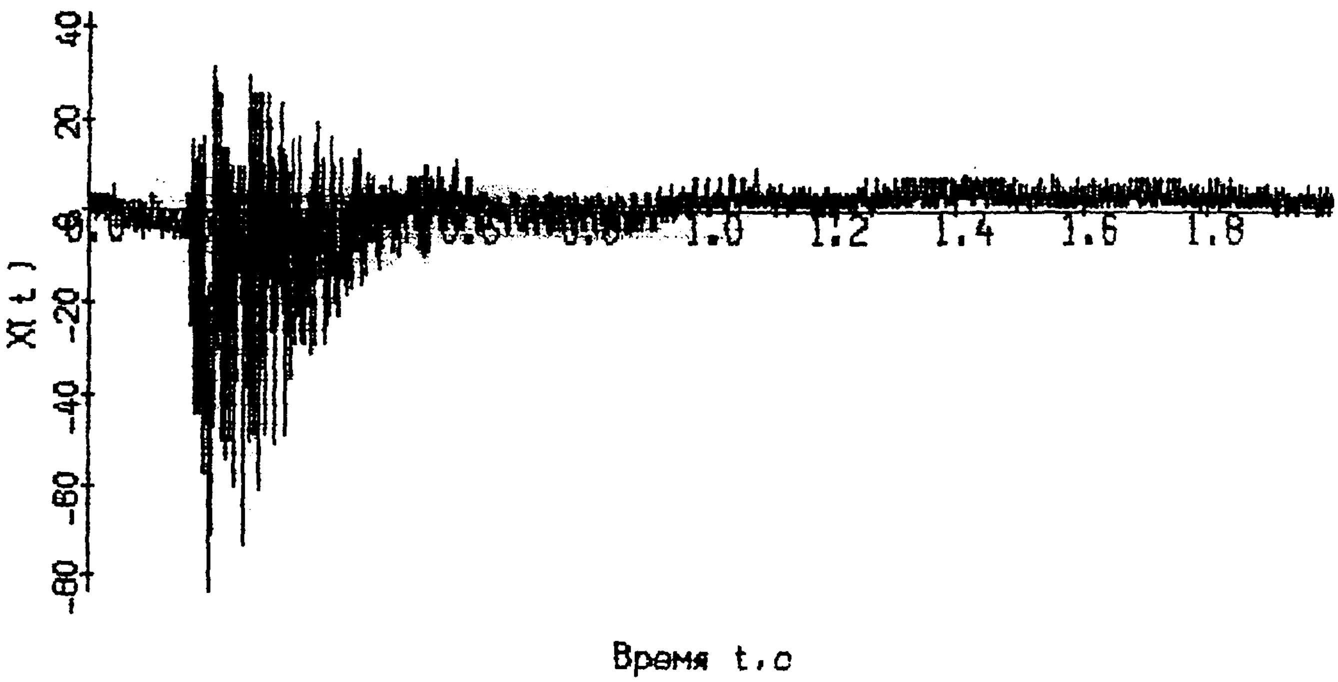

Fig.16 Reaction of Cabinets NC 11 to the impact load

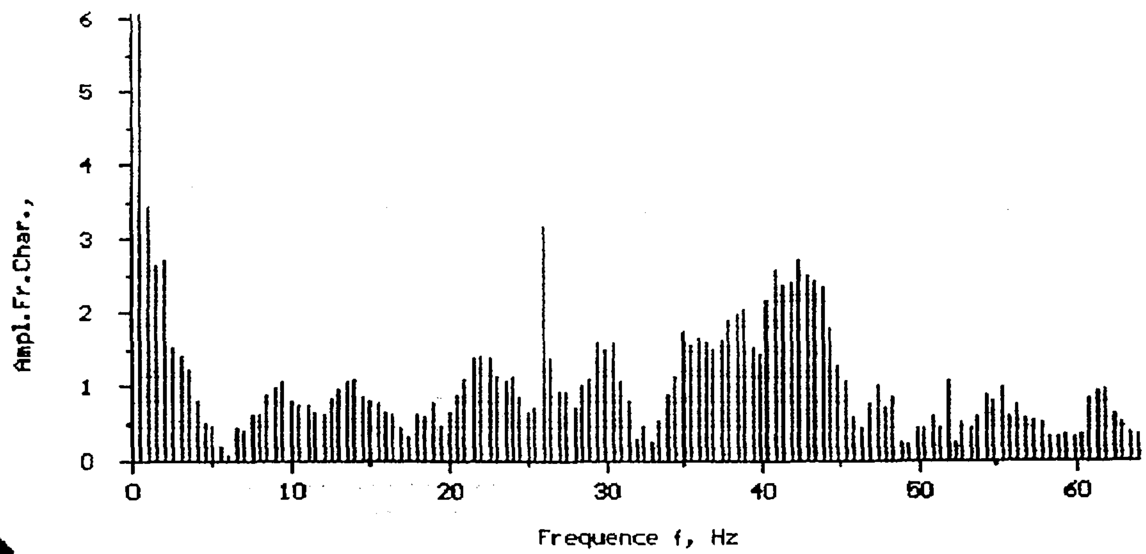

Fig.17 Amplitude-frequence characteristic of Cabinet NC 11.Upper part.

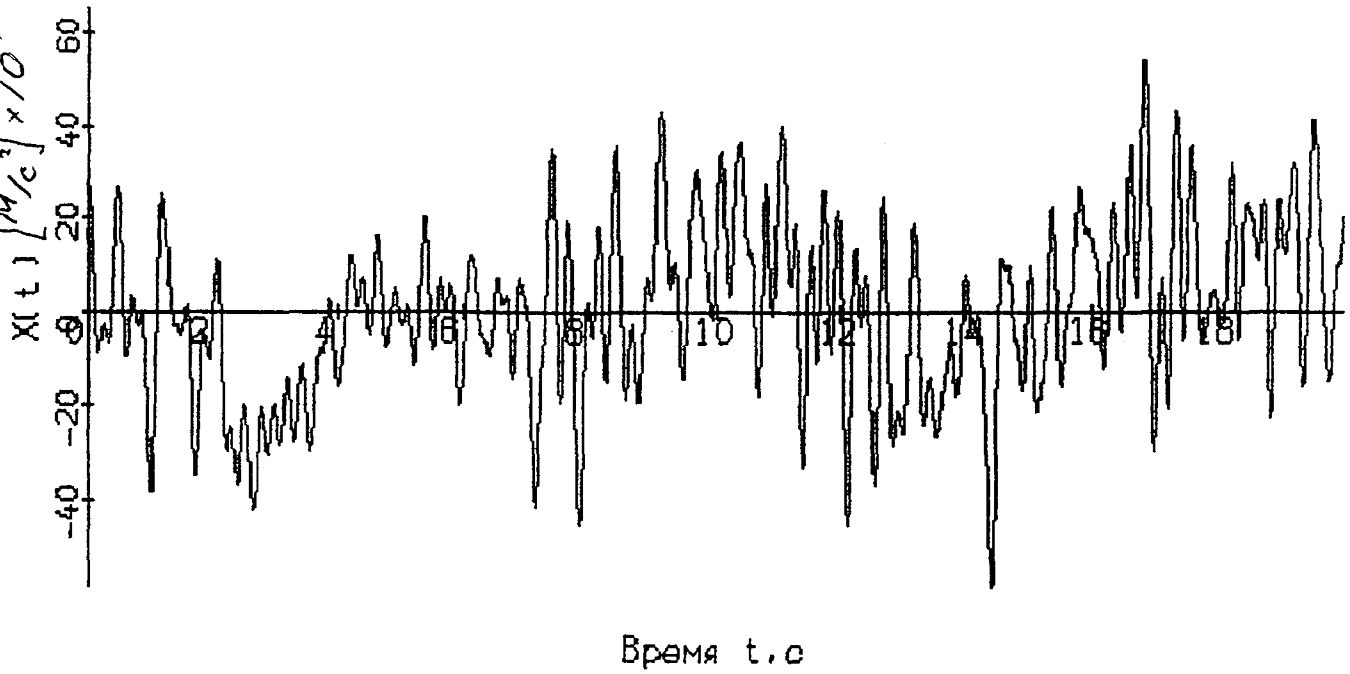

Fig.18 Reaction of Cabinet NC 11 to the floor accelerogram.

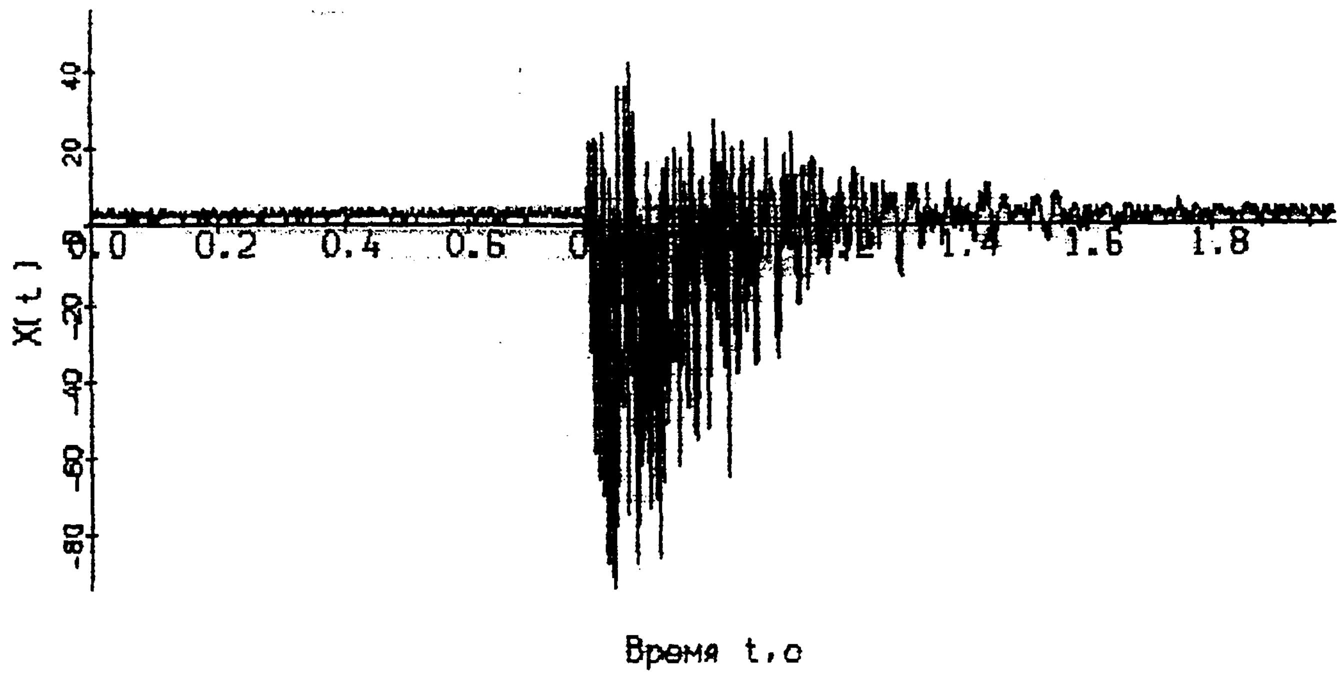

Fig.19 Reaction of Cabinets KRU KA6C to the impact load.

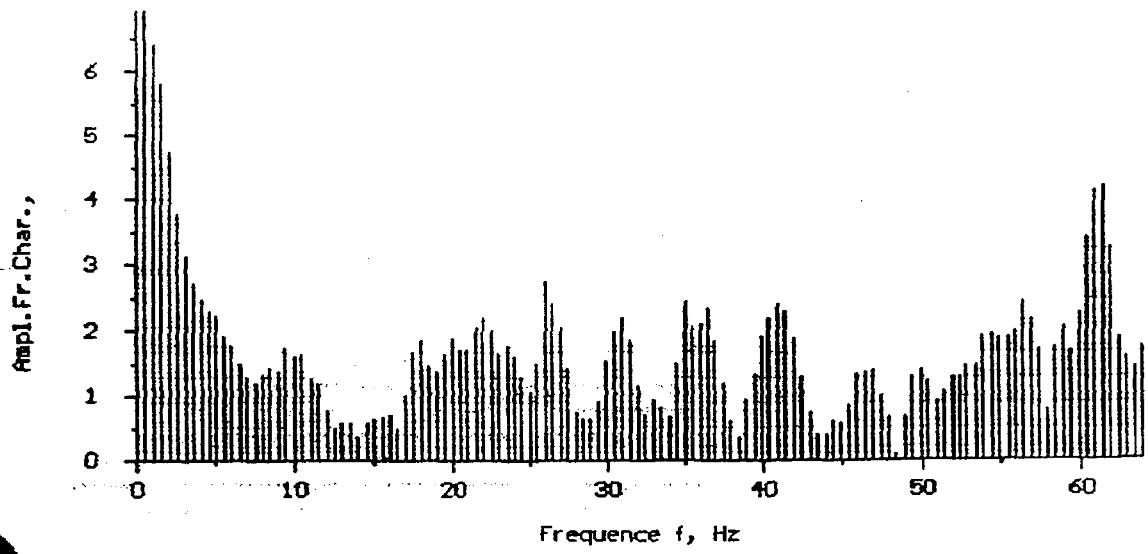

Fig.20 Amplitude-freguence characteristic of
Cabinets KRU KA6C on the switch AP-50MT

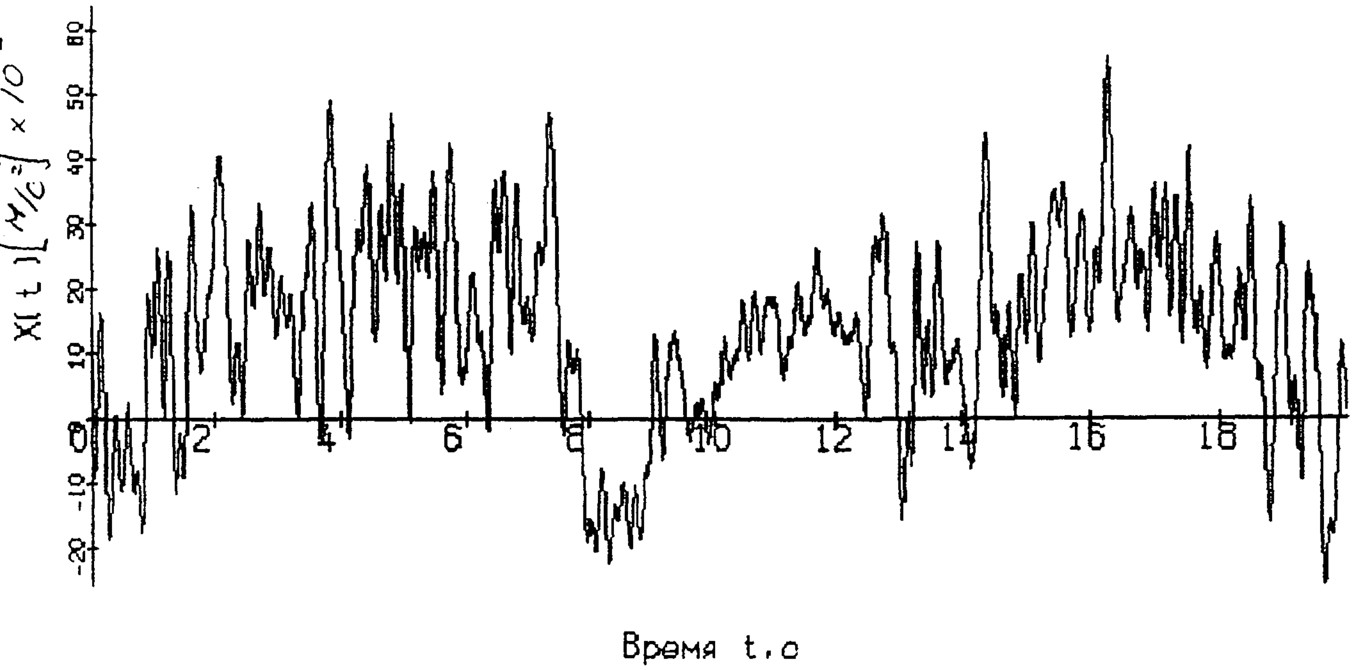

Fig.21 Reaction of Cabinet KRU KA6C to the floor accelerogram.

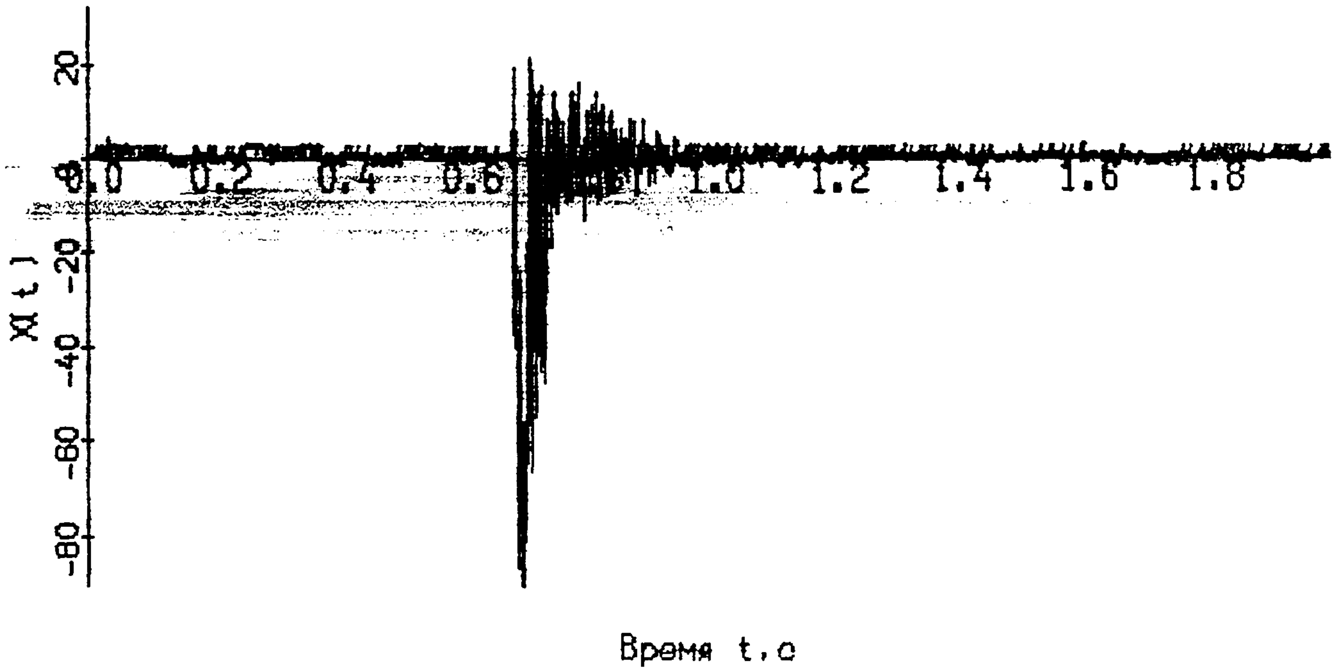

Fig.22 Reaction Relays of KRU KA6C to the impact load.

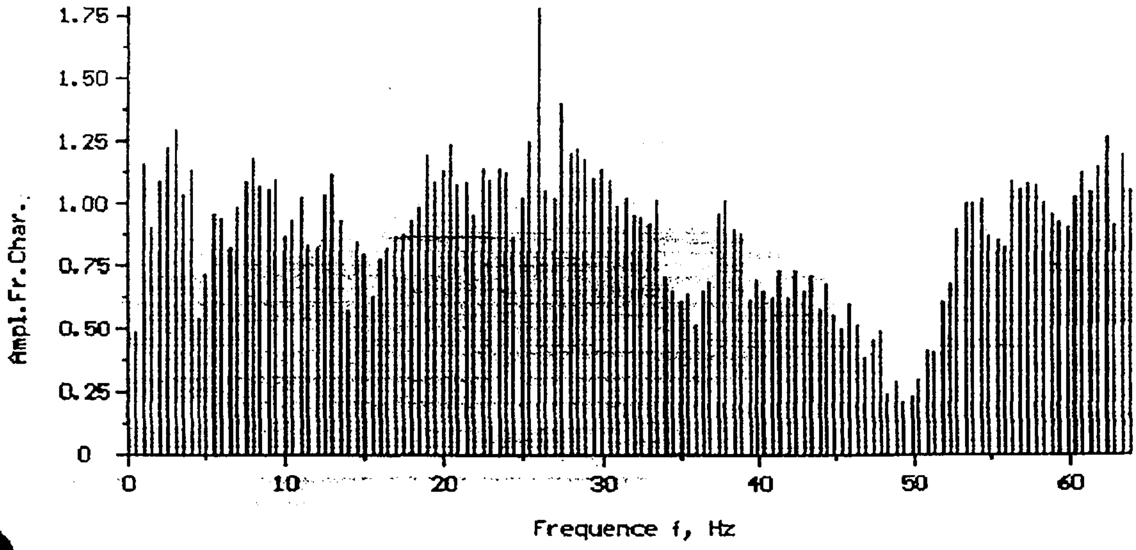

Fig 23 Amplitude-freguence characteristic
KRU KA6C

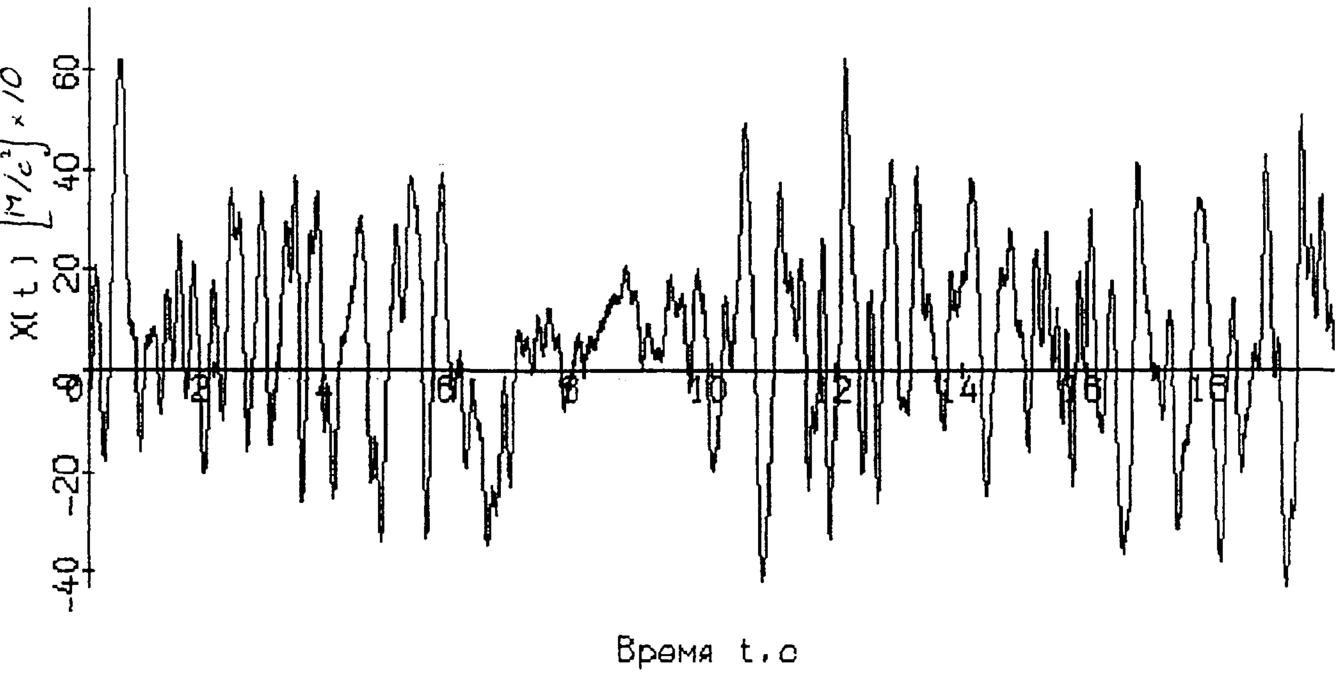

Fig 24 Reaction of Relays of KRU KA6C to the floor accelerogram.

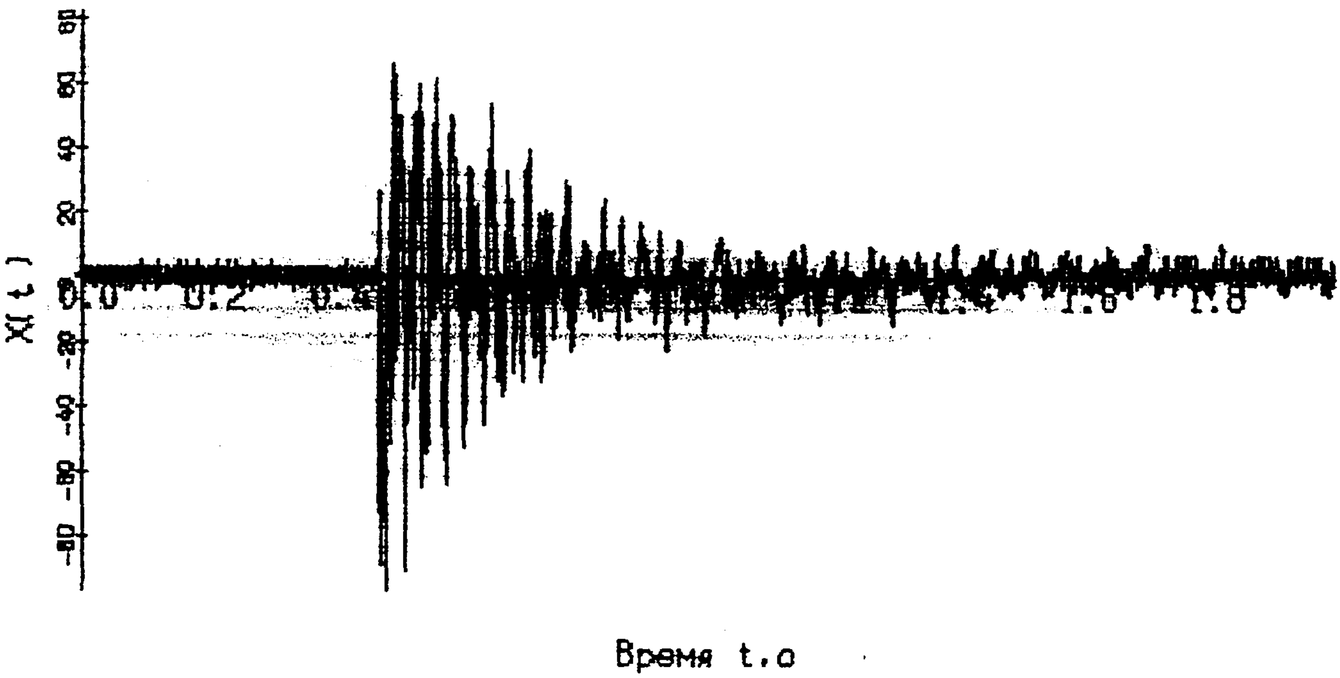

Fig.25 Diesel generator. Reaction of Cabinets SHA-1400 to the impact load.

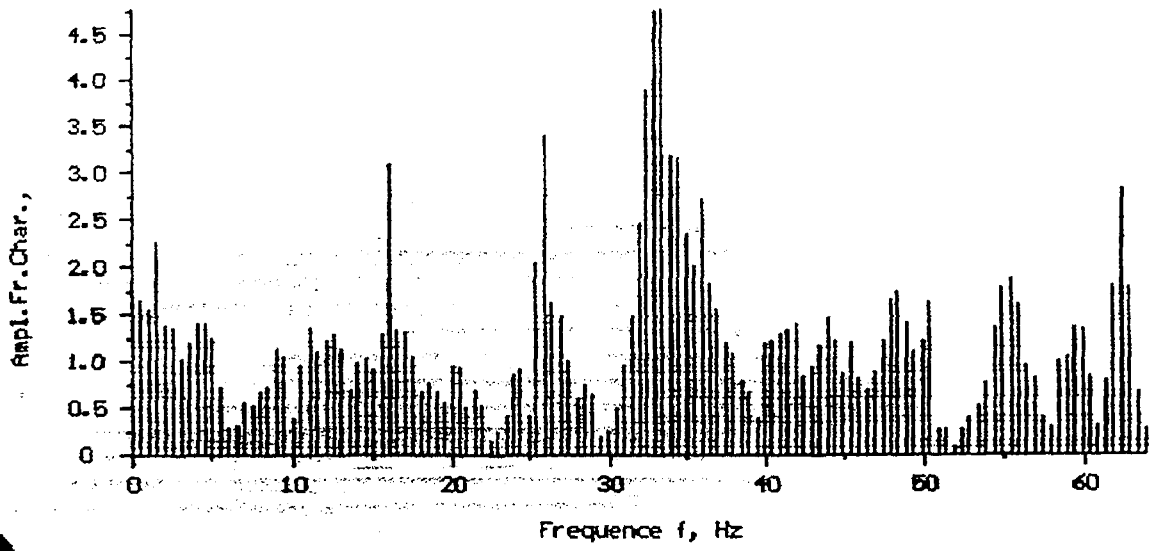

Fig.26 Diesel generator. A-F CH of Cabinets SHA-1400 N580 PPC on the relays RPU-2U36.

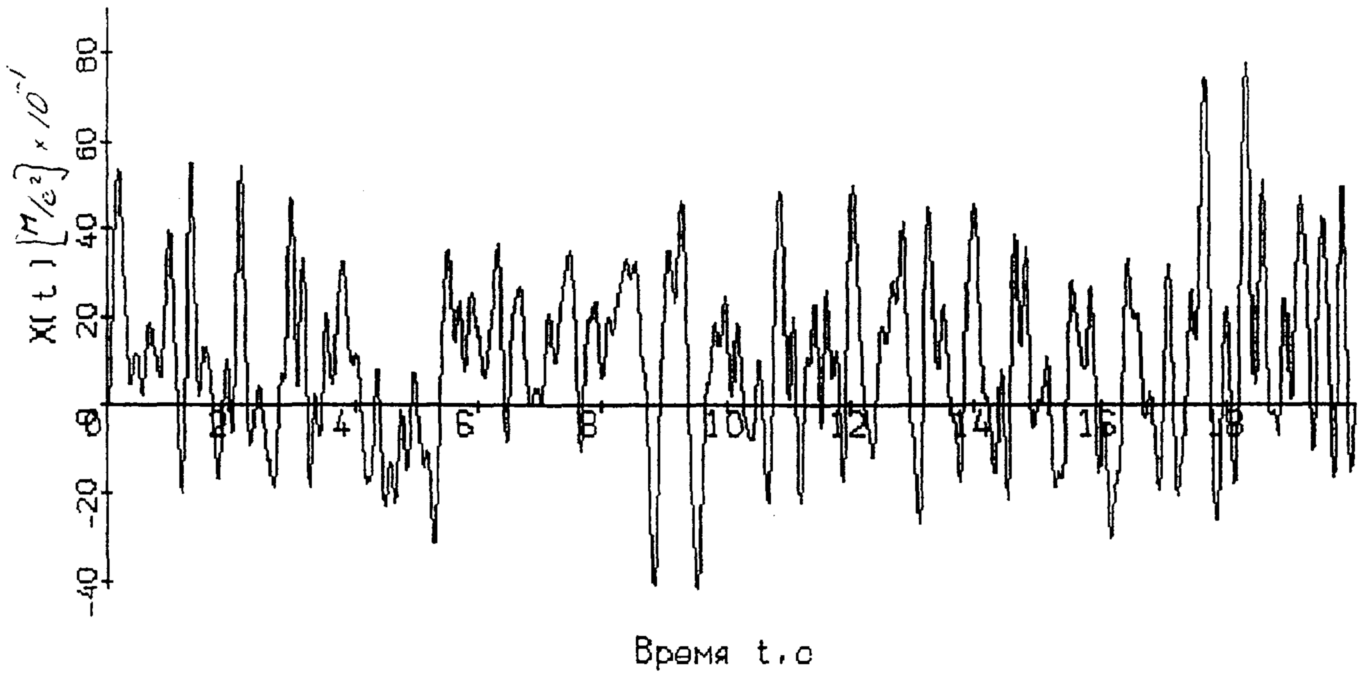

Fig.27 Reaction of relays RPU-2U36 SHA-1400
to the floor accelerogram.

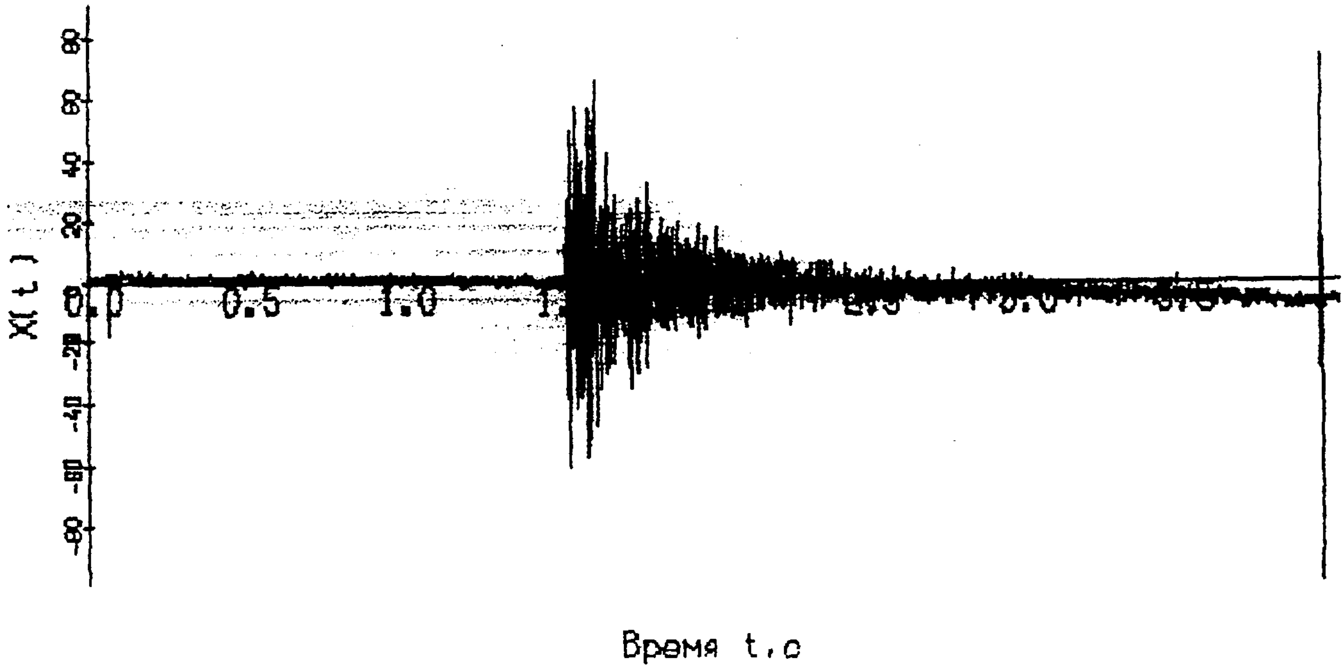

Fig.28 Reaction of upper part of Stabilizer STS-2M
to the impact load.

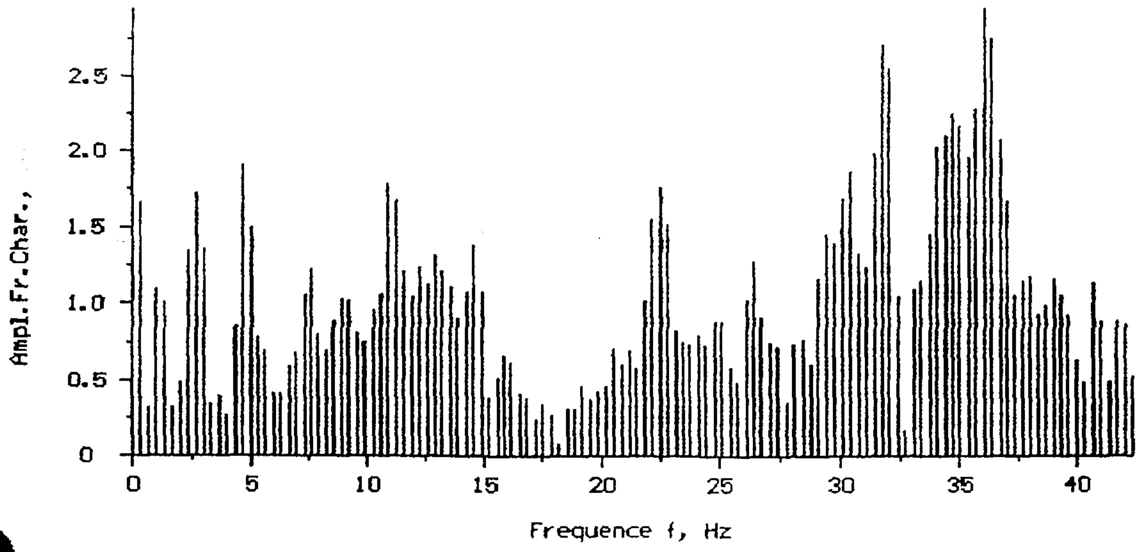

Fig.29 A-F CH of Stabilizer STS-2M

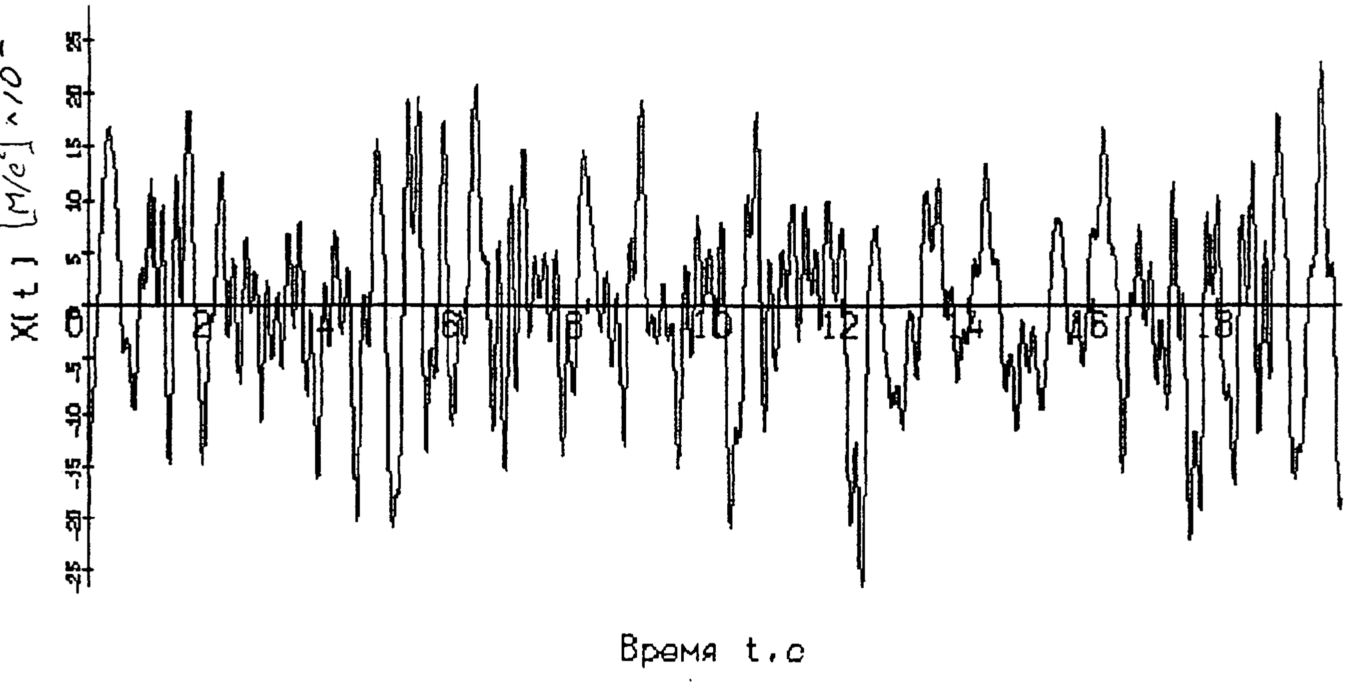

Fig 30 Reaction of upper part of Stabilizer STS-2M

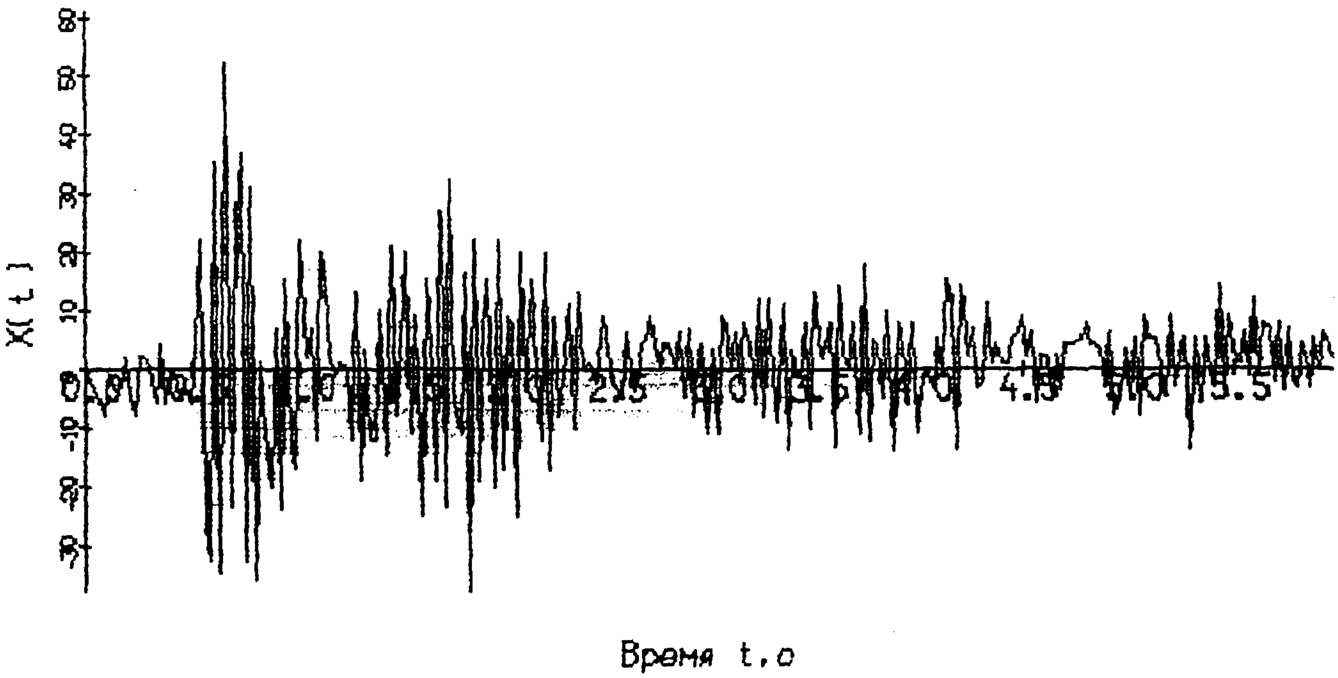

Fig.31 Diesel generetor. Reaction of upper part vessels to the impact load.

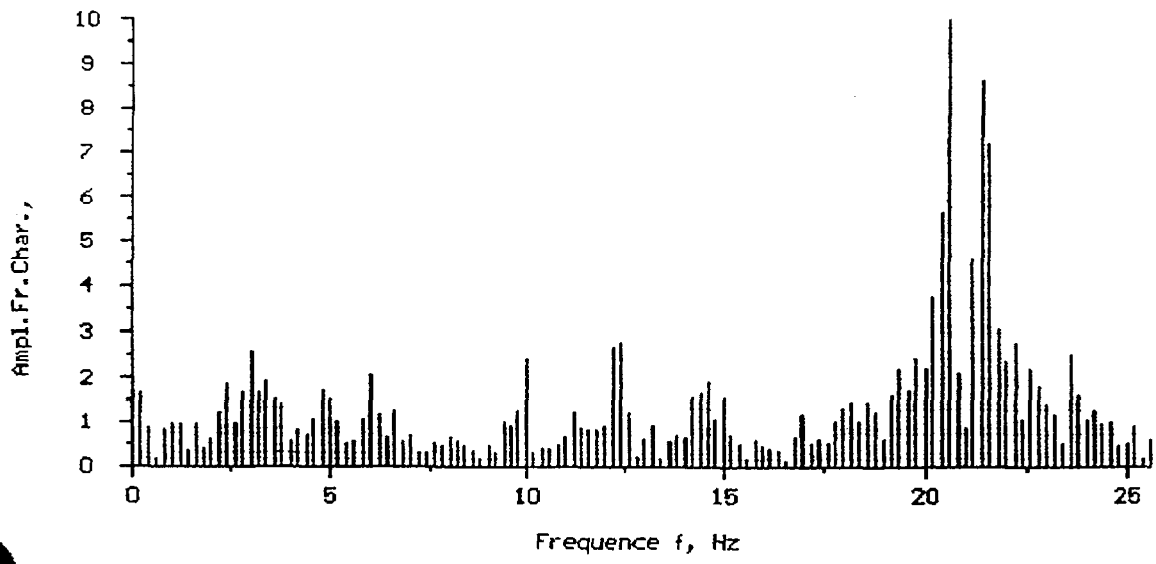

Fig. 32 Amplitude-freguence characteristic of upper part vessels.

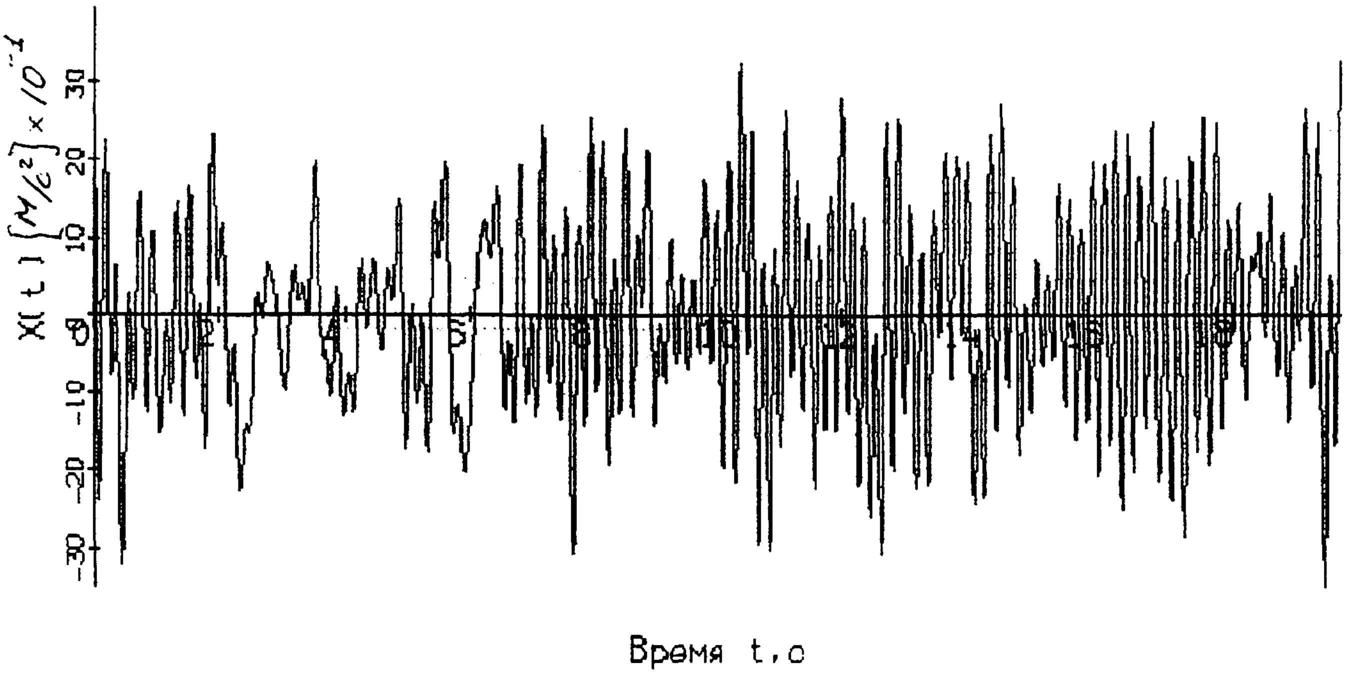

Fig.33 Reaction of vessels to the floor accelerogram.

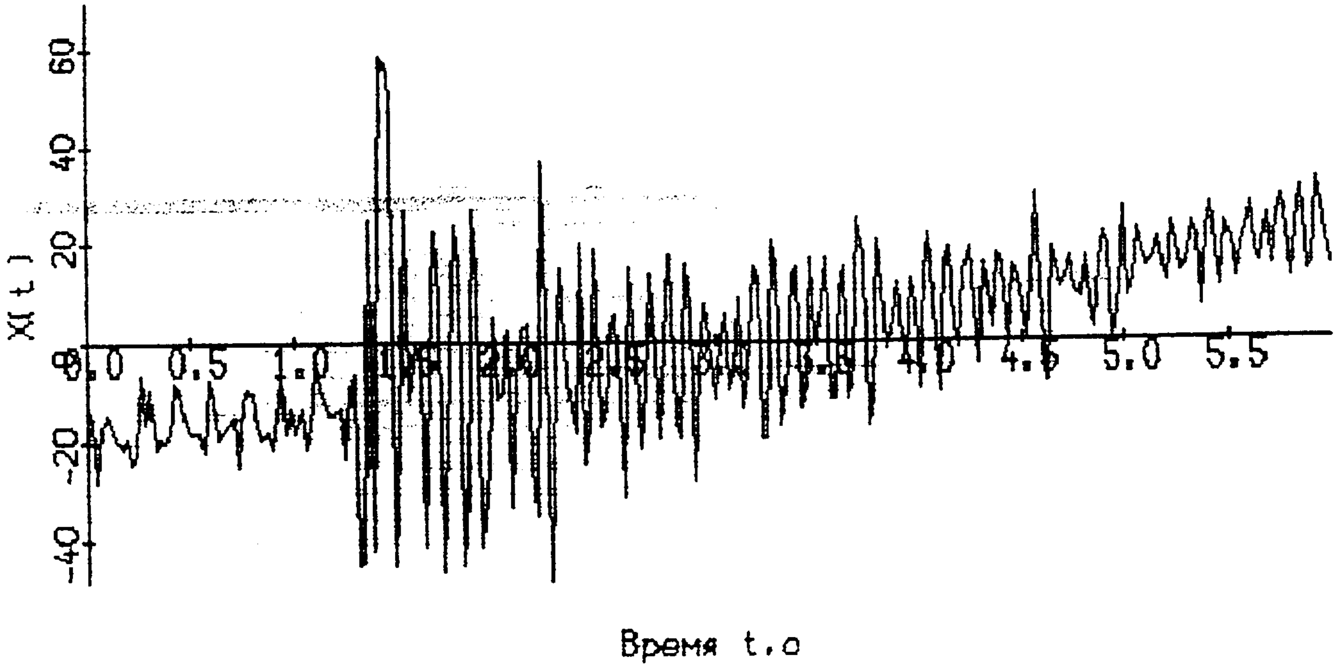

Fig.34 Cabinet RTSO-69. Reaction of Relay RP-256 ULCH
to the impact load.

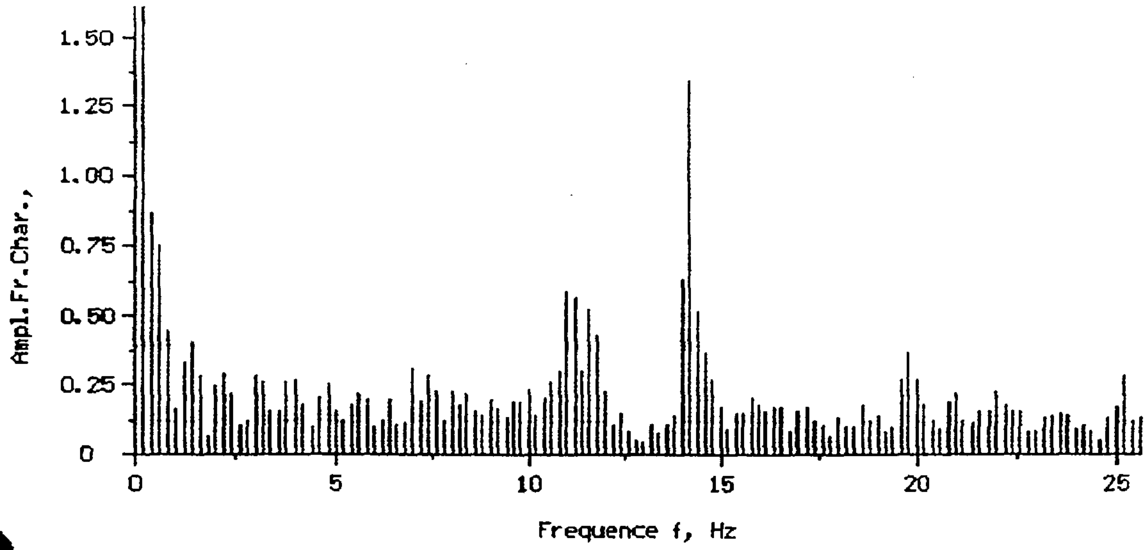

Fig 35 Cabinet RTSO-69. A-F CH Relay RP-256 ULCH.

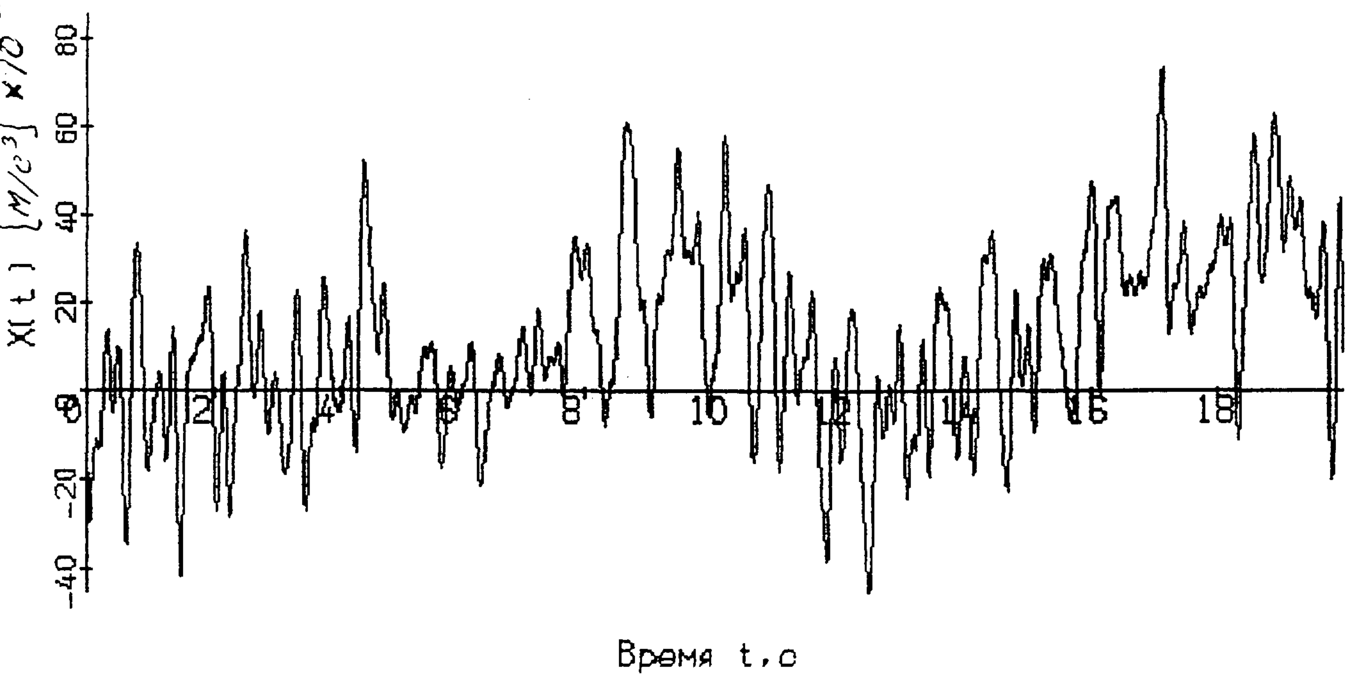

Fig.36 Cabinet RTSO-69. Reaction of Relay RP-256 ULCH to the floor accelerogram.

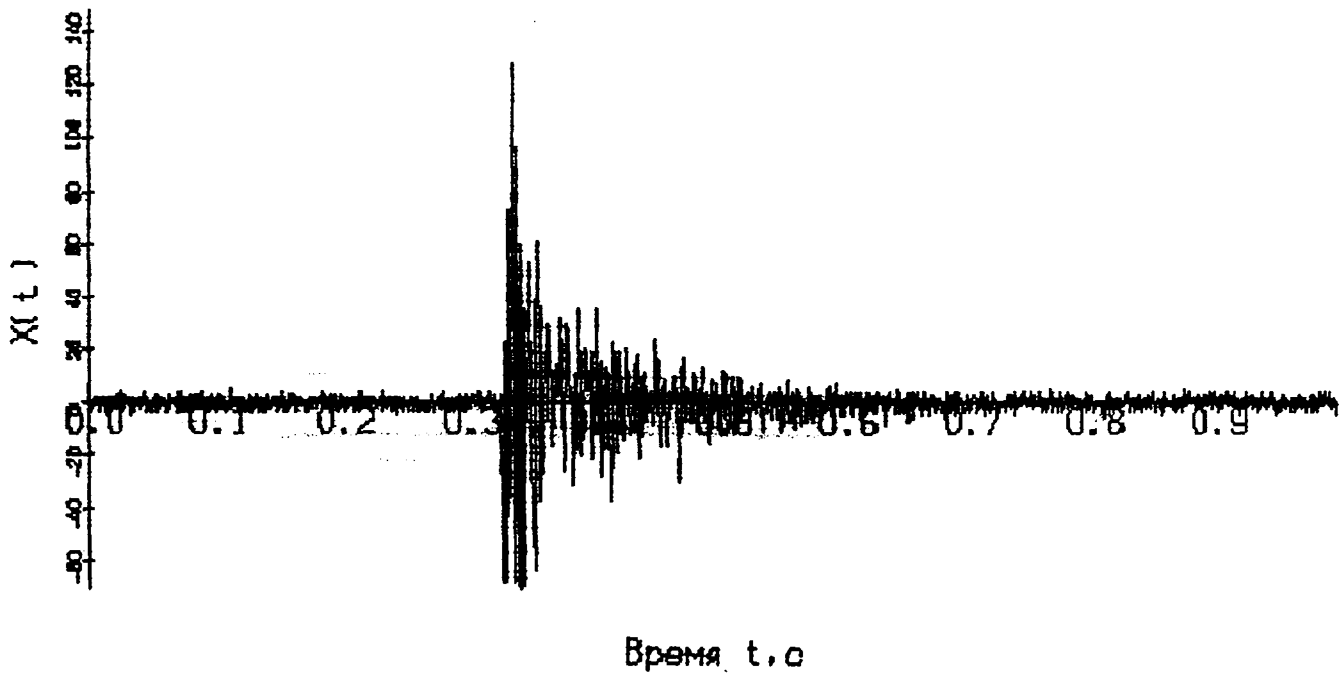

Fig 37 Cabinet TKEP SH-6. Reaction of upper part to the impact load.

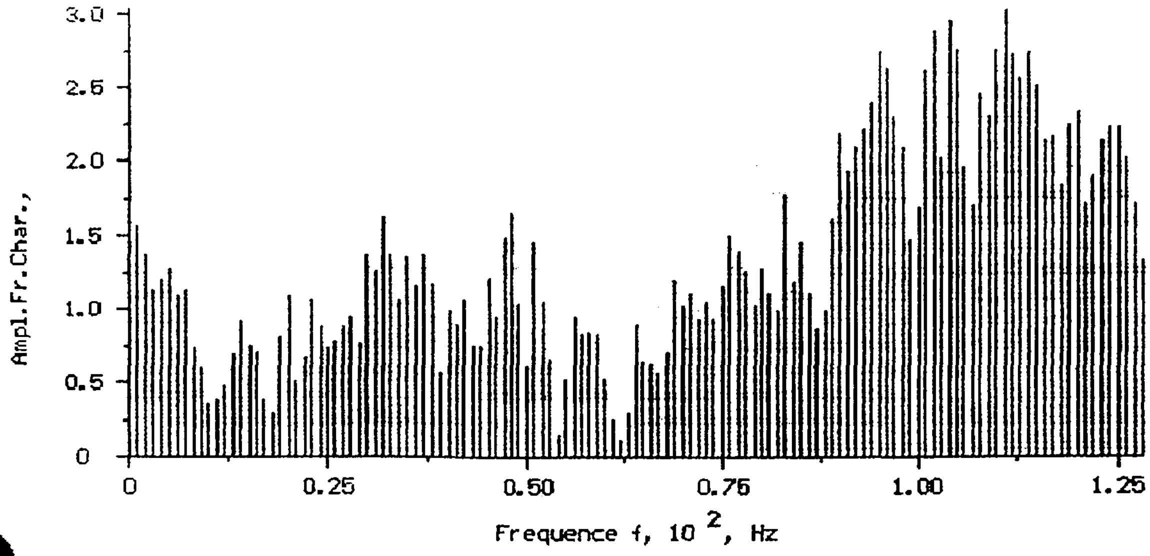

Fig 38 Cabinet TKEP SH-6. A-F CH of upper part.

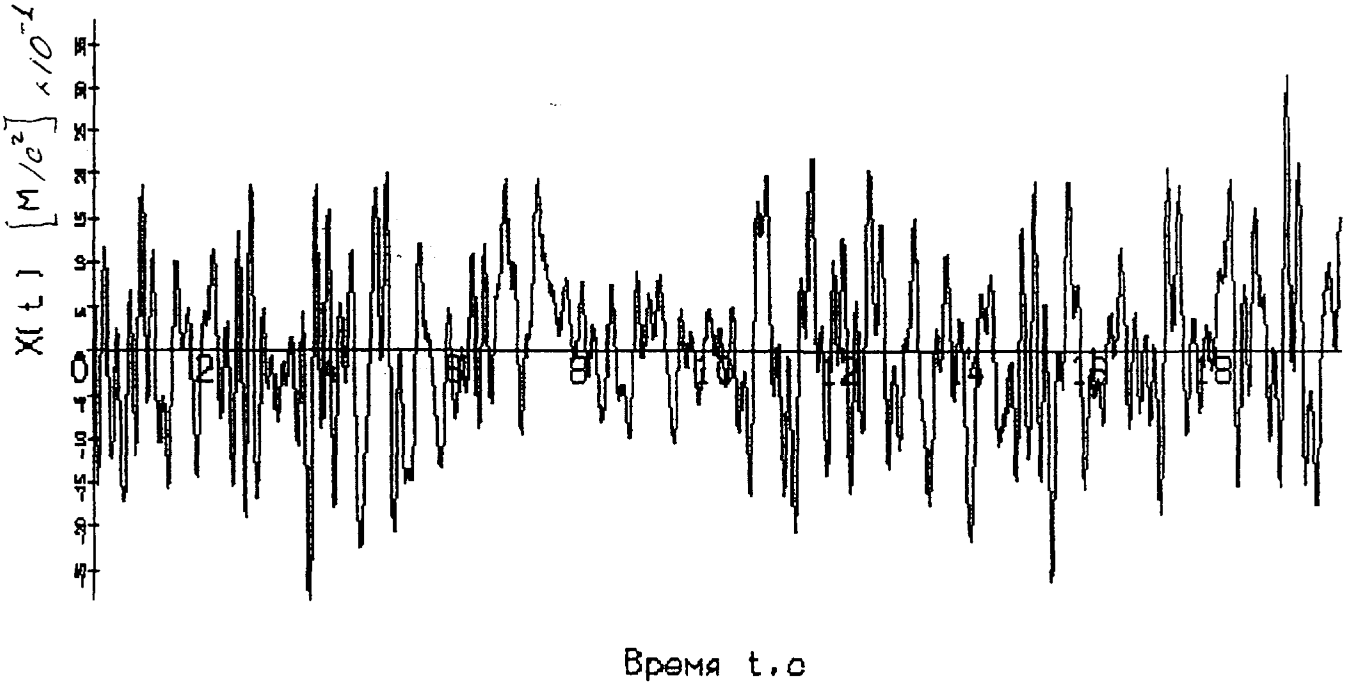

Fig 39 Cabinet TKEP SH-6. Reaction of upper part to the floor accelerogram.