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ISOLATION OF I&C CABINETS AGAINST SHOCKS, VIBRATIONS AND SEISMIC MOVEMENTS

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This paper is presenting SERB-SITON solution to isolate the I & C cabinets against shocks, vibrations and seismic movements.

The seismic qualification is required because the I & C components installed inside the cabinets are generally sensitive to shocks, vibrations and seismic movements and many times, the manufacturer does not guarantee them for a level of shocks, vibrations and seismic movements higher and equal to the level in the location they are installed.

The document also presents the solution to isolate such I & C cabinets associated to the sulphur hydrogen compressors located in ROMAG-PROD Drobeta Turnu-Severin.

Keywords: shocks, vibrations, seismic movements, SERB-devices, isolation method.

1. Introduction

As a rule, the I&C equipment components have a thin structure and many times they cannot takeover in safety conditions the accidental dynamic loads given by shocks, vibrations and seismic movements that can affect their life span. The strengthening of I&C component structure is not usually possible because their constructive and operational requests do not allow this aspect.

An efficient solution in order to increase the reliability and the safety of I&C components in the situation in which they are subject to shocks, vibrations and seismic movements, is to isolate the equipment containing these I&C components.

The solution SERB-SITON to isolate the electrical cabinets applied for the seismic qualification of the cabinets with programmable self-actuated devices for the protection and the operation of the H_2S centrifugal components in the ROMAG-PROD GS1 installation, is a good solution in order to decrease or eliminate the effects of shocks, vibrations and seismic loads on I&C components.

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Considering the high diversity of I&C cabinets, their seismic qualification is performed usually through combined methods, numerical analyses and experimental tests on models or prototypes. For the programmable self-actuated device cabinets to ensure the protection and the operation of the H_2S centrifugal compressors from the installation GS1 from ROMAG-PROD were performed detailed nominal analysis for the 5 cabinets and experimental tests on a physical model. Following the analysis and the experimental tests were established the features of the SERB-SITON isolation devices so that a better isolation to be ensured against the possible seismic movements in ROMAG-PROD location and against the possible vibrations of the building in which they are installed.

The SERB-SITON isolation devices for the above-mentioned cabinets were designed by SITON and performed by QATRO-PROD SRL under the license of SC SIGMA STAR SERVICE SRL.

According to the numerical analysis performed by SITON and the experimental tests performed by IMS of the Romanian Academy under the control of SC SIGMA STAR SERVICE SRL, the maximum seismic acceleration which can be transmitted through the cabinet isolation systems for the components and the equipment installed in the cabinets is usually of 0.05 g. If there is an important cabinet oscillation phenomenon (this phenomenon is in fact, excluded because of the quality of the real isolation system) at its upper side, the maximum seismic acceleration of 0.12 g can be reached.

2. Cabinet and isolation devices construction description

The cabinets in which are installed the I&C equipment are parallelepiped-shaped with the base a rectangle with the sides of 1000 x 800 mm and the height of 2200 mm for 4 cabinets and of 2100 mm for 1 cabinet (see fig. 1).

Their resistance structure is identical and it is composed of an inferior and a superior frame made up of 2-mm thick metal corrugated sheet profiles, in which 4 piles are installed by welding.

The components (equipment) are installed on two central panels made of 2-mm thick plate that each one are installed with screws by two vertical piles which are as well tightened with screws to the resistance structure profiles (metal frames) from the superior and inferior sides.

The SERB 1000/800 (fig. 2) mechanical device of seismic isolation is rectangular shaped with the design sizes of 1000 x 800 and the height of 76 mm.

In the central area, the device is provided with a 600 x 400-mm rectangular cavity. The mechanical device is made of two 10-mm thick plate frames and between them are installed 6 X-shaped elements for the elastic take-up with cabinet weight damping and for the “cutting” of the seismic movement which is transmitted from the base structure to the cabinet. The X-shaped elements with elasticity and controlled damping are symmetrically installed by 2 on the long side of the device at a distance of 2 mm from the median plane and one on the short side, in the central area.

For the elastic control of the seismic loads take-ups from the horizontal plane between the superior and inferior frames, 4 pre-stressed spiral springs are installed between two catch members on the superior as well as inferior frames on the device diagonals.

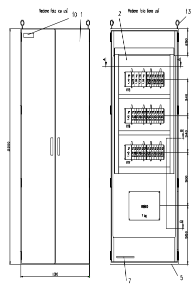

Fig. 1. I&C cabinet – AP-K1101A.

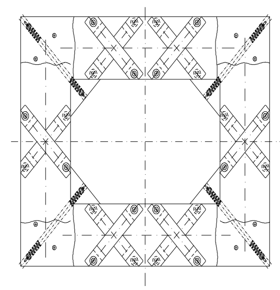

Fig. 2. SERB 1000/800 seismic isolation mechanical device.

3. Analysis and results

The cabinet seismic qualification by their isolation with SERB 1000/800 devices was performed through experimental tests on physical models and numerical analysis on mathematical models.

STEP 1 – the dynamic analysis of the cabinet embedded in the base structure (without seismic isolation device) from which resulted if the cabinet structure is able to takeover high amplifications of the seismic movement and if may appear local amplification effects of this one.

STEP 2 –the preliminary analysis of the cabinets with isolation systems from which resulted the stiffness of the isolation devices so that these ones to accomplish a much longer distance of the first vibration eigen period of the cabinet eigen vibration from the Tc corner period in the response spectrum of the seismic movement stipulated in the Code P100 [2] for Drobeta Turnu-Severin area.

STEP 3 – the execution and the testing of a cabinet seismic isolation physical model made of an X-shaped elastic element with elasticity and damping having the same sizes as the X-shaped elastic elements that will be used for the cabinet seismic isolation devices.

STEP 4 – the final detailed numerical analysis of the cabinet seismic behavior with SERB 1000/800 isolation systems. The results were performed with

SAP2000 software from which it resulted the safety margins for the components installed in the isolated cabinets.

Comparing the classical seismic qualification method - stiff connection to the base structure (no isolation) - with SERB-SITON method (with isolation), it is obvious the advantage to apply the base seismic isolation solution, especially if the cabinet has a non-homogenous structure from the stiffness point of view or if it may contain equipment which are not seismically qualified.

The fig. 3 gives the design acceleration time-history used in the analysis, according to the seismic design requirements in the Code P100/2006 [2], and the fig. 4 gives the seismic response spectrum associated to that acceleration time-history.

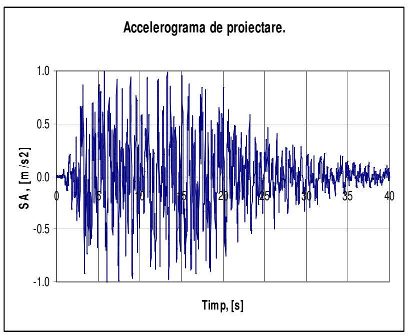

Fig. 3. Seismic design acceleration time-history.

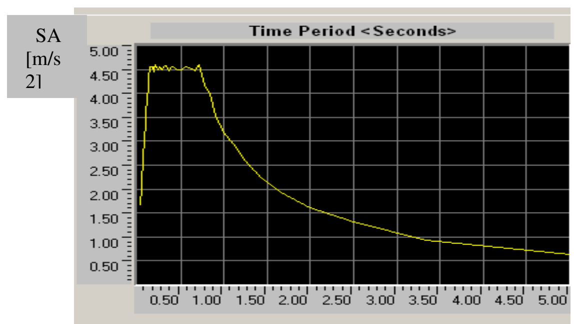

Fig. 4. The response spectrum of the location corresponding to the design acceleration time-history.

The design acceleration time-history has the corner period $Tc = 0.7$ s and it is compatible with the response spectrum from the Code P100/2006 and it covers the entire interest period field for the dynamic behavior of the seismically isolated cabinets. In the calculations, the acceleration time-history is scaled at the acceleration maximum value of 1.6 m/s^2 on both horizontal directions, as well as 1.1 m/s^2 on the vertical. These values are one level higher than those specific for Drobeta Turnu-Severin area for the Romanian territory.

The fig. 5 and 6 present the complete model with or without stiffening bars together with the first own mode of vibration.

The tables 1 and 2 give the results of the modal analysis for the models with and without stiffening bars (*Uy* means the back-front displacement and *Ay* means back-front acceleration). The results present the effect of the seismic behavior improvement of the cabinet pointed out by the vibration periods, the participation factors and the modal masses for the first 15 proper modes. It is observed that both cabinet versions, with or without supplementary stiffening bars, present not a too high stiffness required by the anti-seismic protection. The introduction of the side strengthening bars leads, nevertheless, to a supplementary strengthening from 3.3 Hz to 4 Hz which indicate an improvement of the cabinet total behavior and especially the panels on which are fixed the equipment following its strain corresponding to the first level of vibration.

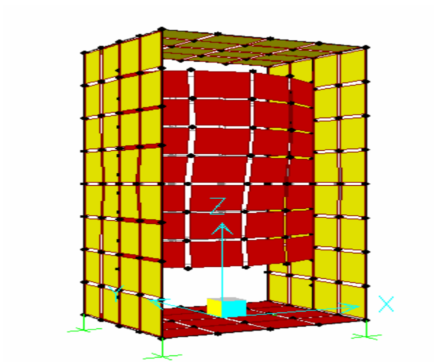

Fig. 5. Model of embedded cabinet. Cabinet without included strengthening bars. Mode 1 of vibration with $T = 0.3$s belongs to panels on which the equipment is installed.

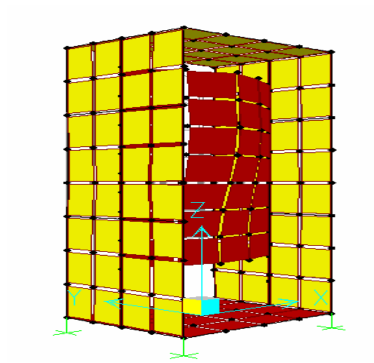

Fig. 6. Model of embedded cabinet. Cabinet with included strengthening bars. Mode 1 of vibration with $T = 0.23$s belong to panels on which the equipment is installed.

Table 1

Maximum displacements. Embedded model.

Node	Without horizontal strengthening bars		With horizontal strengthening bars	
	Uy, cm	*Ay*, m/s2	*Uy*, cm	*Ay*, m/s2
176	1.3	6.0	0.6	5.0
157	1.5	6.3	0.8	5.9

Table 2

The strengthening and seismically isolated cabinet. The modal analysis, eigen vibration modes, period, participation factors and modal masses.

MODE	PERIOD	INDIVIDUAL MODE (PERCENT)			CUMULATIVE SUM (PERCENT)		
		UX	*UY*	*UZ*	*UX*	*UY*	*UZ*
1	1.502179	0.0000	99.7471	0.0000	0.0000	99.7471	0.0000
2	1.483593	99.8825	0.0000	0.0000	99.8825	99.7471	0.0000
3	1.136011	0.0000	0.0000	0.0000	99.8825	99.7471	0.0000
4	0.291298	0.0000	0.2456	0.0000	99.8825	99.9927	0.0000
5	0.248667	0.1175	0.0000	0.0000	99.9999	99.9927	0.0000
6	0.205649	0.0000	0.0001	0.0000	99.9999	99.9928	0.0000
7	0.205176	0.0000	0.0000	24.6417	99.9999	99.9928	24.6417
8	0.185857	0.0000	0.0071	0.0000	99.9999	99.9999	24.6417
9	0.146565	0.0000	0.0001	0.0000	99.9999	100.0000	24.6417
10	0.137590	0.0000	0.0000	71.6038	99.9999	100.0000	96.2455

The left-right movements for a cabinet with or without strengthening side bars are very little and the differences are not significant. For the two models with or without rails, there are not big differences for the accelerations left-right.

The back-front movements are reduced with 50% in case of cabinet with rails included in the model, and the accelerations are reduced with about 20%. The reduction implies lower stress in the anchoring points and in the installed equipment.

The analysis model from step 2 comprises the cabinet and SERB 1000/800 seismic isolation device.

The fig. 7 gives the vibration mode 1 which represents a rigid front-back movement with a vibration period of 1.5s and the fig. 8 gives the vibration mode 2 which represents a rigid left-right movement with an eigen vibration period of 1.49s.

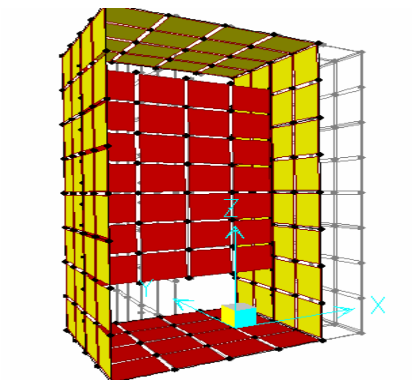

Fig. 7. Model of seismically isolated cabinet. Vibration mode 1. Back-front movement.

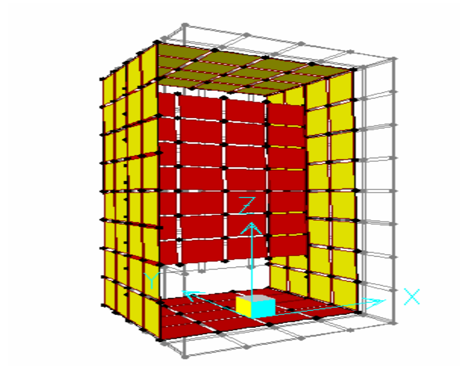

Fig. 8. Model of seismically isolated cabinet. Vibration mode 2. Left-right movement.

It can be observed that the first two vibration modes belong to the seismic isolation device on 2 horizontal directions and the seismic movement is almost totally consumed in this device. The relative internal movements of the cabinet are almost eliminated.

The modal damping is of 5% for the cabinet elements and of 30% for the seismic isolation device. This value was evaluated from the tests on device and is enclosed in the seismic design code, [2].

3.1. Cabinet placed on a ground embedded structure or at the ground level of a construction

In this case, the seismic movement is defined by the design acceleration chart of the ground and it is compatible with the seismic design data imposed by the code P100/2000 [2] for Drobeta Turnu-Severin area.

The table 3 presents the obtained displacement and the maximum accelerations as well as a comparison between the seismically isolated model and the embedded (classical) model for the same nodes as in the model of the strengthening bars cabinet. The variables from table 3 are: *Uy* – total front-back displacement; *Ay* – absolute front-back acceleration; *Dy* – relative front-back displacement to the isolation point.

Table 3

Maximum displacements and accelerations. Seismically isolated cabinet and embedded cabinet (classical solution) for two nodes of the panel.

	Seismically isolated model			Classical embedded model	
Node	*Uy*, cm	*Dy*, cm	*Ay*, m/s2	*Dy*, cm	*Ay*, m/s2
176	5.0	0.3	1.2	0.6	5.0
157	5.5	0.8	1.3	0.8	5.9
4	4.7				

Comparing with the classical embedded model, for the seismically isolated model with SERB 1000/800 devices can be noticed a significant reduction of the front-back movement for some of the panel points on which the equipment is installed and a very important reduction of the accelerations on this direction, of about 4 times.

3.2. Cabinet placed at superior floors of a construction

In case the cabinet is placed at superior floors of a construction, it was used a tape type filter on an eigen period of 0.3 s (the most frequent natural vibration period for a construction) and it was determined the new filtered acceleration diagram. The filtered acceleration time-history was applied to the cabinet through the intermediary of the SERB 1000/800 isolation device. Because the seismic action from different floors of the construction is amplified regarding the base seismic movement, much higher values of seismic accelerations were obtained for the seismically qualified cabinets by classical solution (cabinet steadily stiff installed on the base structure). In case of cabinet seismic isolation with SERB 1000/800 devices, its maximum accelerations are much lower than those of the classical solution.

The fig. 9 presents the two response spectra associated to the acceleration time-history used for equipment installed at the ground and superior floors.

It is observed that the equipment placed at the superior level is associated to a response spectrum superior to that of the ground floors for the entire field of frequencies/periods. The maximum acceleration on building floors floor becomes 4.6 m/s^2, comparing 1,6 m/s^2 as it is at the base of the construction, which is, in fact, the maximum acceleration of the floor on which the cabinet is placed.

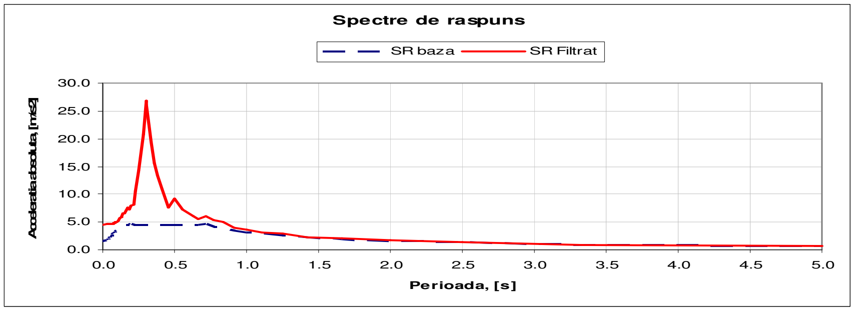

Fig. 9. Response spectra associated to the acceleration time-history used for equipment placed at ground and superior floors.

The table 4 presents the maximum displacements and accelerations obtained in the nodes on upper part of cabinet, as well as a comparison between the model with seismic isolation and the embedded model (classical) for the same nodes in the model with strengthening rails for the cabinet that is installed at the superior floor.

Table 4

The maximum of displacements and accelerations. Seismically isolated cabinet and embedded (classical) cabinet for the most stressed points.

	Solution	*Ux*	*Dx*	*Uy*	*Dy*	*Uz*	*Dz*	*Ax*	*Ay*	*Az*
1	Classical		0.0		0.0		0.0	4.6	4.6	3.2
1	Isolation	5.3	0.0	5.1	0.0	0.2	0.0	1.4	1.4	3.0
5	Classical		0.0		0.0		0.0	4.7	4.6	3.2
5	Isolation	5.7	0.4	5.9	0.8	0.1	0.1	1.5	1.6	3.1
157	Classical		0.3		2.2		0.0	4.7	13.6	3.2
157	Isolation	5.7	0.4	6.0	0.9	0.0	0.2	1.4	1.4	3.2
164	Classical		0.0		2.1		0.0	4.7	14.0	3.2
164	Isolation	5.5	0.2	5.7	0.6	0.0	0.2	1.5	1.5	3.2
176	Classical		0.0		1.7		0.0	4.7	13.6	3.2
176	Isolation	5.4	0.1	5.4	0.3	0.0	0.2	1.4	1.4	3.2
4	Classical		0.0							
4	Isolation	5.3	0.0	5.1	0.0	0.1	0.1	1.4	1.4	3.1

We can notice in the an acceleration reduction report for the equipment installed at a superior floor and seismically isolated with SERB 1000/800 devices, 3 times on the direction left-right and about 10 times on the direction front-back compared to the classical situation of location (embedded situation).

The maximum accelerations of the equipment installed in a seismically isolated cabinet with SERB 1000/800 devices, during an earthquake, are subject to inferior accelerations to those at which the operation during shocks and vibrations is guaranteed.

4. Experimental Results

In order to demonstrate the performances of SERB 1000/800 mechanical devices to seismically isolate the cabinets, physical models were performed on which were tested experimental quasi-static and dynamic determinations by SC SIGMA STAR SERVICE SRL in collaboration with the Institute for Solid Mechanics of the Romanian Academy.

On this models were determined the elasticity and damping properties as well as the maximum acceleration at which the "cutting" phenomenon takes place at SERB device. A cabinet seismic isolation physical model is constituted of an X-shaped elastic element, with elasticity and damping having the same sizes as the X-shaped elastic elements that will be used for the cabinet seismic isolation devices. For the tests, the cabinet seismic isolation mechanical device with additional masses, which are part of the seismically isolated cabinet mass, was installed in a vertical position on the testing platform (figs 10-11).

Fig. 10. Model of SERB 1000/800 device. Dynamic tests on the horizontal plane for the determination of the "cutting" capacity of the seismic acceleration.

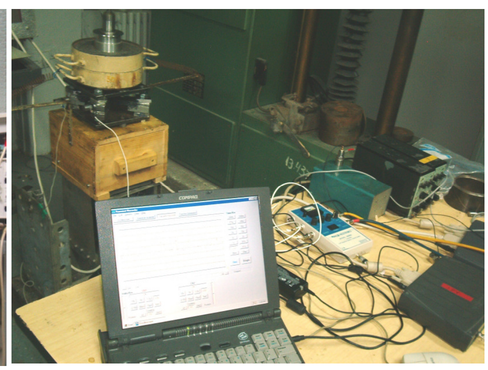

Fig. 11. Model of SERB 1000/800. Dynamic tests on the vertical direction for the determination the dynamic response of the device – additional mass and stiffness.

For the dynamic tests on the horizontal plane, the input accelerations (of the excitation) and output acceleration were measured (the accelerations of the dynamic system response performed from the device model and the additional mass. The dynamic tests for the model of SERB 1000/800 isolation mechanical device were performed with two additional masses of 20 and 40 kg.

The figures 12 and 13 give the experimental result input and output for the dynamic tests and fig. 14 gives the acceleration-frequency spectrum for input and output.

The fraction of the critical damping for the seismic isolation device has values of 40-60%. The damping coefficient *c* proportional to the speed, calculated for the proper period of the electrically isolated cabinet has a value of 0.38 x 10^6 Ns/m for the vertical direction, and for the horizontal direction it has much higher values. From the quasi-static experimental determinations performed over the model charged with masses of 20 kg and 40 kg, a “cutting” force results that is equivalent to a 0.04 ÷ 0.05 g seismic acceleration.

The figure 15 presents two pictures of SERB 1000/800 isolation mechanical device of cabinet.

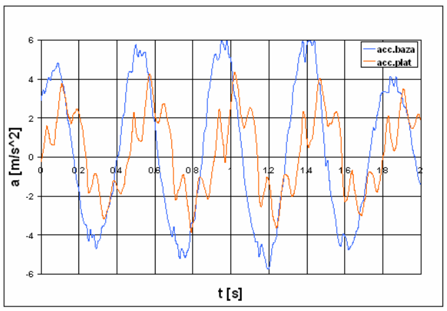

Fig. 12. Horizontal excitation and response accelerations of SERB mechanical device for a 20 kg mass.

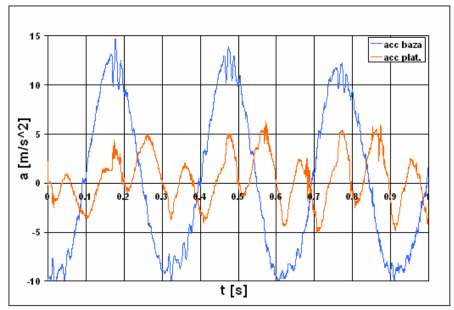

Fig. 13. Horizontal excitation and response accelerations for SERB mechanical device for a 40 kg mass.

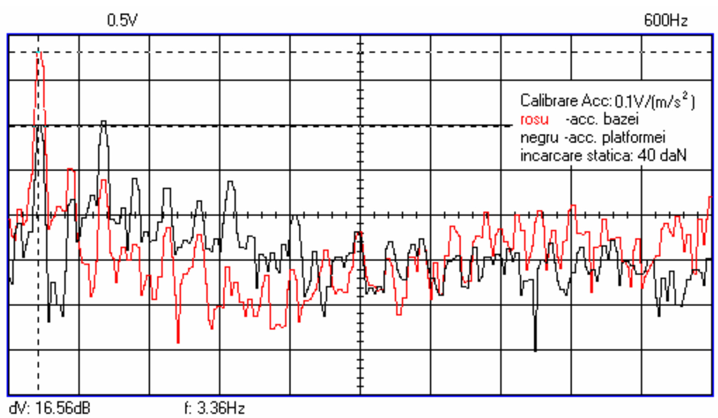

Fig. 14. Acceleration-frequency spectra model for input and output SERB device for a 40 kg attached mass.

5. Conclusions

Following the numerical and experimental analysis, it is shown that SERB 1000/800 seismic isolation devices made of stainless steel lamella spring produced by the company SANDVIK from Sweden ensuring the seismic isolation of the cabinets for the self-programmable systems for the protection and the operation of the H_2S compressors from the ROMAG-PROD Drobeta Turnu-Severin isotopic exchange equipment.

The maximum acceleration in a seismically isolated cabinet is much under values of 0.2g irrespective to the size of the maximum acceleration during an earthquake. All the components in the shock and vibration qualified cabinets at higher than 0.5g values, will be in operation according to the quality certificate transmitted by the equipment suppliers with a safety margin of over 0.3g.

The numerical analysis and the experimental determinations proved that the self-programmed equipment (the cabinets) for H_2S compensation will be operational during an earthquake that might take place in Drobeta Turnu-Severin area with a medium recurrence interval of 100 years, corresponding to a superior class of seismic limitation and ensuring the operation of the cabinet unit if other events, independent to the direct seismic action, which could damage the cabinet operation, do not occur.

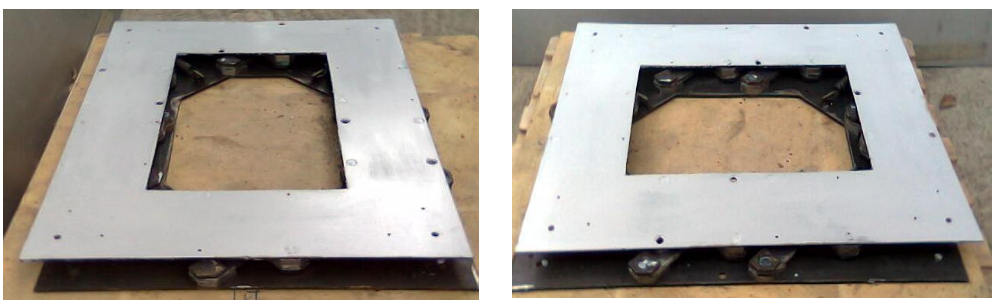

Fig. 15. SERB 1000/800 cabinet isolation device.

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