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ANALYSIS OF THE VIBRATIONS IN REFRIGERATING COMPRESSORS. DEVELOPMENT OF PRACTICAL CASE

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ABSTRACT

In the present communication it is presented the measurement protocol and the obtained results from a relative study to the existent vibrations in refrigerating compressors. 11 machines rooms have been analyzed with a total of 98 compressors, studying for all them in each one of the three normalized axes the acceleration in support structure and in floor of the room. The considered parameters included the maximum values, minima and equivalent. They were related these results with the antiquity of the compressors, as well as with their installation characteristics. The conclusions allow to deepen in the knowledge of the situation of these compressors, broadly extended at industrial level and in possible repercussions in their life useful and possible incidents in their operation.

1 INTRODUCCIÓN

The greater percentage of failures produced in the rotating and alternative machines can be caused by an excessive level of vibrations. These vibrations are consequence of the transmission of the forces by the machine that causes its wearing down and accelerate their breakage. When the machine is under perfect conditions, it presents a typical vibracional pattern and their phantoms of frequency are of a characteristic form. When it begins to arise a failure, they change the dynamic processes of the machine and change some of the forces that act on their pieces, which as well affects at the levels and the form of the phantom of vibrations.

By means of the measurements and analysis of the vibrations considering the phantom of frequencies, typical of this type of machines, important goals can be persecuted from the mechanical and economic point of view, like which next they are exposed:

- To reduce the costs produced by failures.
- To improve the planning of the works.
- To increase to the availability of the lines of production, reducing the run-down time.
- To improve the security and hygiene.
- To improve the quality of the end item.

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- To redesign the equipment to improve the productivity.
- To control the run-down times.
- To control the life utility of the components.
- To anticipate us to the purchase of spare parts.
- To use statistical controls at the time of making a decision.
- To know with exactitude the time limit performance that does not imply the development of an unexpected failure.

At the moment most of refrigerating plants use absorbent elements of the vibration that seek to insulate the generating source of vibrations of the receiver, through any way of transmission. The mission of these devices is to protect the support structure and adjacent systems of the alterations of vibration and impact to part to protect the sensible equipment of impacts and vibrations that are originated of the structure on which it is installed. Sometimes the election of these devices is not correct or simply they settle without considering as important factors as the frequency of excitation (fixed or variable) of the machine that is tried to insulation among other factors. Analyzing the results, we can determine the grade of adaptation of these devices to the refrigerating plants.

2 METHODOLOGY

2.1 Collaborating companies

To carry out the present study it was of vital importance to capture collaborating companies since it was indispensable to consent to machines rooms and compressors, and given the high number of measurements that sought to be carried out. They stayed contacts with diverse companies of the sector of the feeding and of the industrial cold located in the city of Leon (Spain). The entirety of the measurements was made in two big companies; one of them company leader in the sector of the industrial cold dedicated to the refrigerating storage and elaboration of ice in cubes and in flakes. The second of the companies are the ninth supermarkets of Spain for surface of sales; they have 20 supermarkets in Leon.

2.2 Collection of data

After planning the visit to the refrigerating plants, it lacked to elaborate the data sheet where to reflect the characteristics of each machines room.

Made the first visit it was come to the design of the data sheets:

- *Machines room*
- *Characteristic of the machines - Measurements*
  Individual support structure.
  Combined support structure.

2.2.1 Description of the leaf of collection of data: Room of machines

The information that will be reflected will be the following one:

- Name from the subjected company to study, address and it dates of the measurements.
- Plane of the machines room without scale in which will be reflected the disposition of the compressors. Next to the plane it will be indicated the surface, volume and the ventilation type.
- Type of supports structure in case that it arranges of the same one and in affirmative case, the material used for its construction.
- Number and type of compressors as well as the location of the same ones.

- Number and type of absorbent elements of the vibration.

2.2.2 Description of the leaf of collection of data: Characteristic of the equipment - Measurements

The information that will be reflected will be the following one:

- Files: Previous to this section, it is necessary to determine the concrete points where they will be carried out the measurements and based on this, to measure in oneself point the whole body vibration and the lineal vibrations. The file number will be indicated where we will store the results of a certain point.
- The following section makes reference to the characteristics of the compressors, coolant employee, temperatures and operation pressures, etc.

Measurements.

- Representación gráfica de los puntos exactos donde se llevaron a cabo las mediciones tanto en la bancada como a nivel estructural (suelo, etc.).
- Graphic representation of the exact points where they were carried out the measurements as much in the support structure as to structural level (floor, etc.).

2.3 Performances protocol

One of the most important steps to reach the success of the present study, depended on designing a performance protocol for the realization of the measurements. The followed steps are those that next are detailed:

1º/ Inspection of the machines room.
2º/ Measurements.

2.3.1 Inspection of the machines room

To be able to execute the data sheet of the machines room, it is necessary to make an exhaustive visual inspection of the same one.

Once carried out the inspection, it is come to fill up the data sheets, with the intention of having a wide database that facilitates us the study during the treatment of the data in the laboratory.

2.3.2 Measurements

- Location of measurement points

One of the premises to keep in mind before carrying out the measurements on the support structure is to know the support type (from the structural point of view) of the compressors with those that we can be during the realization of the study. Two are the support structures types: Individual and Combined. The first of them serves from supportive element to an only compressor, while the second serve as support to more than a compressor.

In the case of an **individual support structure**, we will position the next accelerometer to each point of support of the compressor, such and like sample the *Figure 1*:

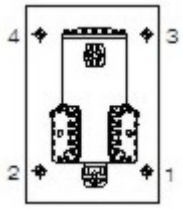

Figure 1: Distribution of the measurement points in an individual support structure.

In the case of a **combined support structure**, the elected approach when distributing the measurement points has settled down based on the obtaining of an uniform number of measurements and that the allotment of the same ones is homogeneous *(Figure 2).*

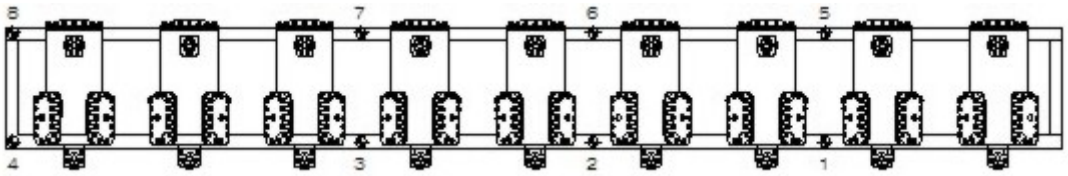

Figure 2: Distribution of the measurement points in an combined support structure.

With regard to the measurements carried out on constructive elements of the machines room these they were executed in the floor, in order to determining the vibration levels to those that it is subjected the maintenance personnel. In this case we locate the measurement points in completely random areas around the support structure as well as at different distances of the same one.

- Duration of the measurements

The factors to keep in mind when selecting the time of measurement, are those that next are described:

1. **Cycle of operation of the refrigerating compressors.** It is to determine the times of outburst and stop of the compressors.
2. **Type of compressors.** Each maker should contribute us the declared value of emission of vibrations *"a"* (m/s^2) as well as the level of uncertainty *"K"* (m/s^2).
3. **Operation temperature.** Closely related with speed of turn of the compressor.
4. **Station of the year.** Variations in the relationship of compression of the compressors caused by the variations of external temperatures.

A duration of *2 minutes* for point is enough to consider that the results have been obtained under the possible more demanding conditions.

2.4 Instrumentation

The necessary equipment for the realization of the relative tasks to this phase of the study is detailed next:

- *Monitor of vibrations:* Larson Davis; Model: IHVM 100.
- *Triaxial ICP accelerometer:* PCB Piezotronics; Model: 356A02.

Monitor of vibrations: Simultaneous 3-channel Measurements: X, Y and Z axes, plus Sum (S). Conforms to ISO Standards 8041:1990, ISO 2631 de 1997 (parts 1 and 2), ISO 5349 (parts 1 and 2), ISO 8622 and ISO 10819 *(Table 1).*

Table 1: Technical specifications: Monitor of vibrations.

SPECIFICATIONS	UNITS
Input types	Acelerómetros ICP, carga y directo
Input range	>100 dB
Metric for vibration	Arms, Amin, Amax, Aeq, Amp, Pico
Metric for Whole body	Arms, Amin, Amax, Aeq, Amp, Pico, VDV
Frequency weightings: Vibration	Ws, Fa (0,4-100Hz), Fb(0,4 a 1250Hz)
Frequency weightings: Whole body	Wc, Wd, We, Wj, Wk, WB

Accelerometer: Triaxial ICP accelerometer 10 mV/g (*Table 2).*

Table 2: Technical specifications: Accelerometer

SPECIFICATIONS	UNITS	ACELERÓMETER ISEN021F
Sensitivity	mV/g	10
Frequency range (+/-5%)	Hz	0,5 a 3.000
Frequency range (+/-10%)	Hz	0,3 a 5.000
Resonant frequency	kHz	≥25
Measurement range	+/- g pk	500
Excitation voltage	VDC	20 a 30

The indicated instrumentation allows to obtain detailed and precise results relative to each one of the analyzed equipment. In annexed I and II models of data sheets can be seen, as much for whole body vibration for vibrations in machines.

3. RESULTS

As it was commented previously, 11 machines rooms were studied, with a total of 98 compressors and a final group of 330 measurements, on support structure of machines and floor. It suits to separate when considering the results the different aspects:

A) Machine vibration.
B) Whole body vibration.

3.1. Machine vibration

In the annexed charts a graphic summary of the obtained results can be observed, distributed for each machines room or establishment.

In the Figure 3 the corresponding values are detailed in support structure. Of the results it can be deduced that, with the exception of the room nº 6, the rest shows uniform numbers enough. The reason for the disparity of nº 6 already mentioned is based in a clear deficiency in the installation of the absorbent elements of the vibration, considering that is an engine room of recent installation.

On the other hand, in it Figures it 4 they are reflected the values in the floor of the room. The correspondence between the support structure figures and machine would allow to analyze the vibration decrease originated by the structural relationship between the support structure and the floor of the room, as well as for the subduing elements characteristic of the support structure.

To this respect it is worthy of mention the concerning thing to the room nº 4. In spite of presenting some similar values to those of the rest as for the vibrations in support structure, it offers an excellent value on floor. It could be proven, indeed that the elements of subduing of the support structure were extremely faulty.

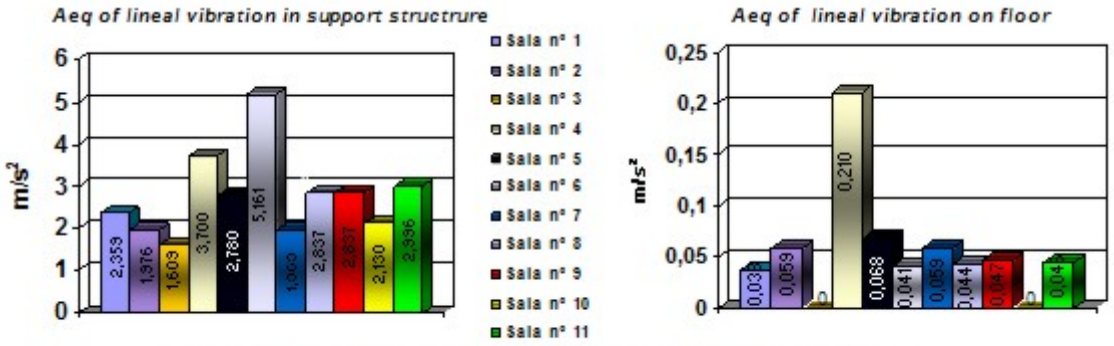

Figure 3: Values of lineal vibration in support structure and on floor

3.2. Whole body vibration

Of equal it forms, in the Figure 4 the values are detailed obtained in the measurements corresponding to whole body, of interest to the object of being able to check if the vibration values can be dangerous for workers that remain in the machines rooms.

They highlight the relating values again to the machines room nº 4, already commented previously. Nevertheless, the values are not elevated in any case.

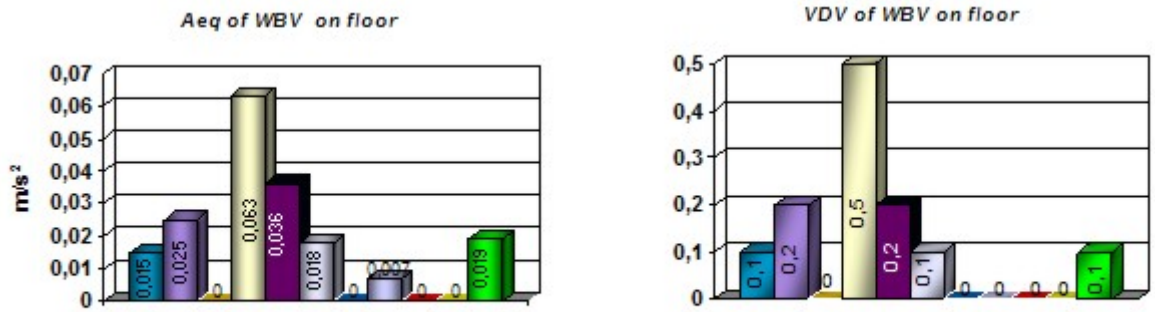

Figure 4: Values of whole body vibration on floor

4 CONCLUSIONS

The results offer some values of a similar order for all the machines rooms and analyzed compressors, although in some case standing out above the stocking, caused by a so much faulty installation of the own compressor like of the absorbents elements of the vibration.

The most decisive factor is, therefore, the not well state of the compressors and of its installation, not being an outstanding element the antiquity of the compressors, without direct relationship exists parameters between both.

The figures obtained as for the possible repercussion from the vibrations to the workers are low, for what is not necessary to wait undesirable effects on those.

A next continuation and deepening of the present study will allow to create a vibracional model for this type of machines, that we thought would have special importance in the installation and beginning of systems of predictive maintenance.

5 ACKNOWLEDGEMENTS

We want to express our most sincere gratefulness to the collaborating companies without whose collaboration would not have been possible to make the study.

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[13] *ISO 10816-3:1998* "Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts – Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15000 r/min when measured *in situ*"

[14] *ISO 10816-4:1998* "Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts – Part 4: Gas turbine driven sets excluding aircraft derivates"

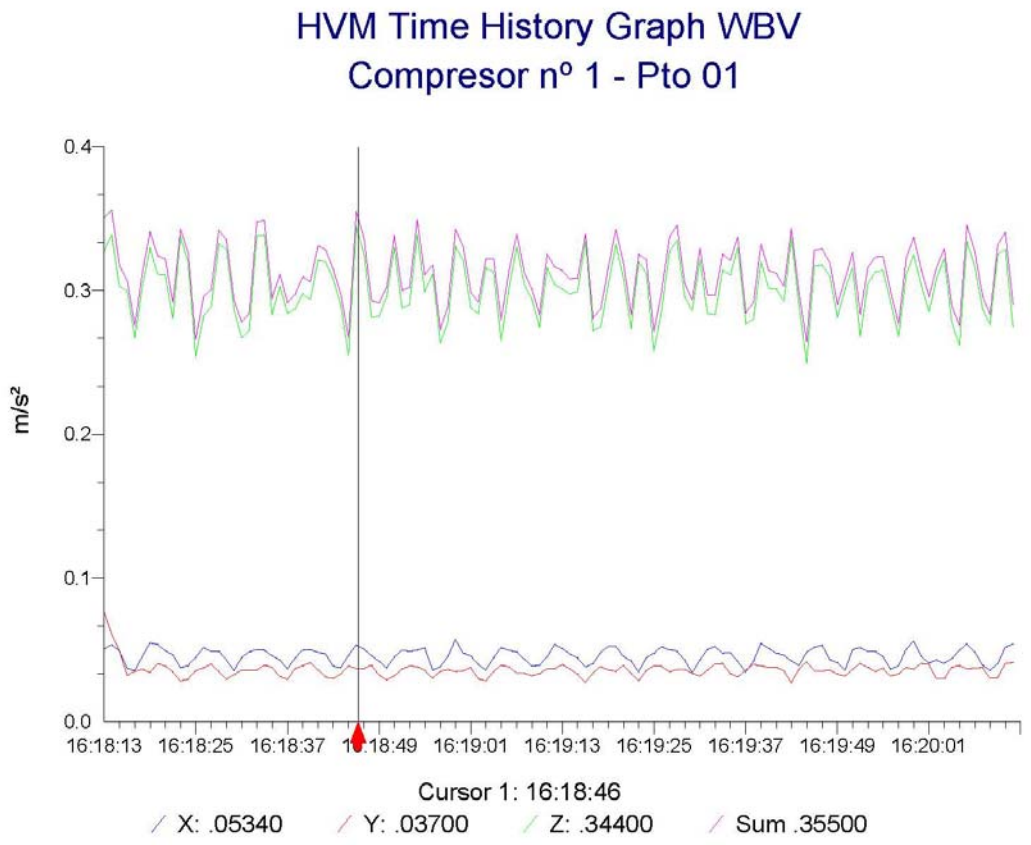
Annexed I.- Results sheet Whole Body Vibration

COMPRESOR Nº 1 - PTO 01
User:
Location:
Job Description:

07 July 2006 18:25:01
EL ARBOL - Eras de Renueva
LEÓN
SALA DE MÁQUINAS

Serial Number:	00150	Start:	06 Jul 2006 16:18:12
Model Number:	LARSON DAVIS IHVM100	Stop:	06 Jul 2006 16:20:12
Operating Mode:	Whole Body	Run Time:	00:02:00
Integration:	None	Averaging:	1 second
Weighting X:	Wd Horizontal-XY	Sum Factor X:	1.40
Weighting Y:	Wd Horizontal-XY	Sum Factor Y:	1.40
Weighting Z:	Wk Vertical-Z	Sum Factor Z:	1.00
Sensitivity X:	9.980 mV/g	Gain X:	40 dB
Sensitivity Y:	10.06 mV/g	Gain Y:	40 dB
Sensitivity Z:	10.93 mV/g	Gain Z:	40 dB
Number TH Samples:	120		

	Channel X	Channel Y	Channel Z	Sum	Units
Aeq	.04620	.03660	.30200	.31200	m/s²
Amax	.05720	.07660	.34400	.35600	m/s²
Amp	.13100	.16200	.90700	.89500	m/s²
Amin	.03430	.02710	.24900	.26400	m/s²
VDV	0.2	0.2	1.2	1.2	
CFmp	2.8	4.4	3.0	2.9	
CFmp (dB)	9.1	12.9	9.5	9.1	dB



Annexed II.- Results sheet Lineal Vibration

COMPRESOR Nº 1 - PTO 01
User:
Location:
Job Description:

07 July 2006 18:36:20
EL ARBOL - Eras de Renueva
LEÓN
SALA DE MÁQUINAS

Serial Number:	00150	Start:	06 Jul 2006 18:04:02
Model Number:	LARSON DAVIS IHVM100	Stop:	06 Jul 2006 18:06:02
Operating Mode:	Vibration	Run Time:	00:02:00
Integration:	None	Averaging:	1 second
Weighting X:	Fb 0.4-1250 Hz	Sum Factor X:	1.00
Weighting Y:	Fb 0.4-1250 Hz	Sum Factor Y:	1.00
Weighting Z:	Fb 0.4-1250 Hz	Sum Factor Z:	1.00
Sensitivity X:	9.980 mV/g	Gain X:	40 dB
Sensitivity Y:	10.06 mV/g	Gain Y:	40 dB
Sensitivity Z:	10.93 mV/g	Gain Z:	40 dB
Number TH Samples:	120		

	Channel X	Channel Y	Channel Z	Sum	Units
Aeq	2.0200	2.4300	2.8900	4.2700	m/s²
Amax	2.2200	2.8300	3.1100	4.6400	m/s²
Amp	8.9400	10.900	12.200	13.100	m/s²
Amin	1.7300	2.1800	2.7200	3.9900	m/s²