PETROBRAS'S ACOUSTIC EMISSION DATABASE – ANALYSYS AND OBTAINED RESULTS

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Abstract: During the last years, PETROBRAS has trying to use acoustic emission technique as a inspection toll. In this period, acoustic emission concept was changed from a revolutionary technique to a global inspection technique with the aim of indicate areas to complimentary inspection.

In the last years more than 600 acoustic emission exams was done in equipments like pressure vessels, reactors, tanks, spheres and etc. In 2002 the results of acoustic emission exams and nondestructive tests done in this equipments was collected to build a database of PETROBRAS environment.

This paper shows the analysis done to obtain a relationship between acoustic emission and life assessment of industrial equipments.

Introduction: Brazilians engineers and researchers have been studied acoustic emission phenomena since 1979. PETROBRAS R&D Center (CENPES) is an important player in this scenario. During the last 25 years, PETROBRAS has trying to use Acoustic Emission technique as an inspection toll. In this period, the concept of Acoustic Emission was changed from revolutionary technique to global inspection technique with the aim of select areas for complementary inspection.

PETROBRAS has a big amount of pressure vessel and other equipments inspected by acoustic emission to establish a relationship with Non Destructive Testing, in the last five years more than 600 equipments were inspected.

Acoustic emission is a global inspection and could be applied to a large variety of structures, including spheres, piping systems, storage tanks, pressure vessels and etc. An extend range of materials and thickness could be inspected by acoustic emission. The test component could be at room temperature or at high temperature. Access to structure is required to install the sensors. Acoustic emission detects discontinuities that generated energy during the deformation of structure when it is stressed. Typical events detected during acoustic emission inspection include fatigue crack growing, hydrogen induced damage, stress corrosion cracking, and etc.

This paper presents the analysis did with the collected data of complimentary non destructive testing and acoustic emission to obtain a probable relationship between of acoustic emission and life assessment of industrial equipments.

Results: The following materials were used in this study:
- data base in Microsoft Access (Aguiar, 2002);
- PETROBRAS acoustic emission results.

Data base allowed the use of the same information that are used by inspection team to make decisions related to operational continuity of inspected equipments in a refinery. Beyond of geometrical and fabrication characteristics, the data base has NDT results after acoustic emission test. NDT results were used to establish relationship between acoustic emission and fracture mechanics.

Acoustic emission tests in the Brazil market are made with MONPAC criteria. This criterion developed by MONSANTO and Physical Acoustics Corporation – PAC involves data collection, data analysis in controlled condition of pressurization and set-up of instrumentation. During the data analysis, two parameters are determined: historic index and severity. Historic index parameter is related with the activity during the acoustic emission test and the severity parameter is related with the acoustic emission signal intensity. Results interpretation are make easy by means of charts with five distinct areas that represents the action that the owner of component in test should do. Figure 1 shows a typical acoustic emission data analysis with MONPAC criteria. In this chart the values obtained for historic index and severity in each sensor are plotted. The chart is divided in six regions: no significant emissions, A, B, C, D and E. The actions are described in table 1. Results classified, as D or E requires NDT to discontinuities sizing that could be exist.

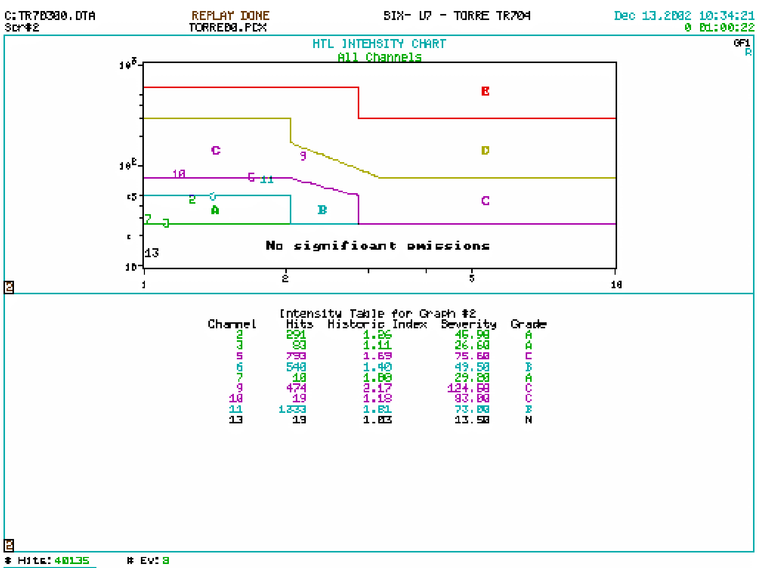


Fig. 1 – Exemplo típico de gráfico do critério MONPAC.

Table 1
Active area classification

Intensity	Color	Action
No significant emissions	Black	No action
A	Green	No action
B	Blue	Record as a reference to future inspection.
C	Pink	Attention level, recommendation to decrease inspection interval.

D	Yellow	Presence of defects, apply NDT.
E	Red	Presençe of significative defects, apply NDT.

When discontinuities are detected, fracture mechanics algorithms are used to evaluated the discontinuities criticality to make a decision of keep or not the operation of component.

This study evaluates the existence of relationship between acoustic emission exam, non destructive testing and fracture mechanics for metallic equipments submitted to internal pressure, at oil industry.

Discussion: Database has 210 tests. Table 1 shows that equipment classifies as "E" are the most critical to safety operation. Database analysis selected 21 equipments with "E" classification. Table 2 shows summarize the data collected in 18 equipments.

Table 2
Equipments classifieds as "E" by acoustic emission testing

<table>
<tr><th>Type and equipment code</th><th>NDT</th><th colspan="3">Discontinuity sizing</th></tr>
<tr><td>Sphere (008)</td><td>VT, PT, MT e UT</td><td colspan="3">380 mm superficial, LF, DL</td></tr>
<tr><td>Column (030)</td><td>UT</td><td colspan="3">SI, LP</td></tr>
<tr><td>Column (032)</td><td>UT</td><td colspan="3">LF</td></tr>
<tr><td>Column (035)</td><td>MT</td><td colspan="3">0 (zero)</td></tr>
<tr><td>Column (038)</td><td>VT, MT</td><td colspan="3">Leakings, 0 (zero)</td></tr>
<tr><td>Column (039)</td><td>UT</td><td colspan="3">LP</td></tr>
<tr><td>Column (046)</td><td>MT, UT</td><td colspan="3">LP</td></tr>
<tr><td>Pressure vessel (050)</td><td>MT, UT</td><td colspan="3">SI</td></tr>
<tr><td>Pressure vessel (061)</td><td>MT, UT</td><td colspan="3">10 mm</td></tr>
<tr><td>Pressure vessel (132)</td><td>MT, UT</td><td colspan="3">TC, LC, HIC</td></tr>
<tr><td>Pressure vessel (133)</td><td>MT, UT</td><td colspan="3">TC, LC</td></tr>
<tr><td>Pressure vessel (134)</td><td>MT</td><td colspan="3">TC, LC</td></tr>
<tr><td>Reactor (155)</td><td>None</td><td colspan="3">None</td></tr>
<tr><td>Reactor(166)</td><td>UT, VT, MT</td><td colspan="3">Crack</td></tr>
<tr><td rowspan="5">Pressure vessel (1203)</td><td rowspan="5">PT, UT, MT</td><td>Type</td><td>Lenght</td><td>Depth</td></tr>
<tr><td>Cracks</td><td>60, 5 and 11 mm</td><td>> 2 mm</td></tr>
<tr><td>Cracks</td><td>20 mm</td><td>3,2 mm</td></tr>
<tr><td>Cracks</td><td>60 mm</td><td></td></tr>
<tr><td>LF</td><td>210, 280 and 45 mm</td><td></td></tr>
<tr><td>Pressure vessel (1206)</td><td>None</td><td colspan="3">None</td></tr>
<tr><td>Heat exchanger (1207)</td><td>RT</td><td colspan="3">LP, PO, LF</td></tr>
<tr><td>Piping (1219)</td><td>VT</td><td colspan="3">0 (zero)</td></tr>
</table>

Note: DL (delamination), HIC (hydrogen induced cracking), LF (lack of fusion), LC (longitudinal crack), LP (lack of penetration), MT (magnetic particle), PO (porosity), PT (penetrant testing), RT (radiographic testing), SI (slag inclusion), TC (transversal crack), UT (ultrasonic testing), VT (visual testing).

Table 2 presents that 81% of equipments classified as “E” has discontinuities. Spheres, pressure vessels, reactors and heat exchanger when inspected shown discontinuities. Piping system did not shown discontinuities.

Quantitative analysis needs information about: material, thickness, geometry, heat treatment, hydrostatic test pressure, maximum work pressure and temperature. This information was obtained from database.

Only three equipments showed in table 2 has discontinuities sizing. The total of discontinuities with sizing in “E” classification were six. From six discontinuities only two has height sizing. Height sizing, when not provided, were set-up to 2 mm for superficial discontinuities and the value of ultrasonic reference reflector (according to ASME) for internal discontinuities.

Table 3 shows the equipments evaluated by fracture mechanics and parameters used in fracture mechanics algorithms. The equipments were evaluated in static condition according to BS 7910 level 2.

Table 3
Equipments evaluated by fracture mechanics

Type and equipment code	Parameters						
	Material	Height (mm)	Length (mm)	Thickness (mm)	Section dimension (mm)	Membrane Stress (MPa)	Heat treatment condition
Sphere (008)	ASTM A515 Gr70	2	380	64,6	4000	126	Treated
Pressure vessel (061)	ASTM A515 Gr70	2	10	44,5	5000	157	Treated
Pressure vessel (1203)	ASTM A516 Gr70	3,8	60,5	111	10868	141	treated
		2	11				
		3,2	20				
		2	60				
		2	210				
		3,9	280				
		2	45				

Table 4 shows the mechanical property values used for perform the analysis.

Table 4

Mechanical properties

Material	Mechanical properties		
	Yield stress limit (MPa)	Strength stress limit (MPa)	Toughness fracture K (MPa.m0,5)
ASTM A515 Gr70	256	483	80
ASTM A516 Gr70	256	483	80
ASTM A204 Gr.A	255	448	80
ASTM A285 Gr.C	205	380	80

Parameters showed in table 3 and 4 are inputs for build a FAD (Failure Assessment Diagram) diagram showed in figure 2. Table 5 shows FAD results for analyzed equipments. Geometrical place for Kr e Lr provide information about the probable failure mode. The left side of diagram represents collapse mode, and the right side of diagram represents catastrophic mode. Discontinuities that, after calculus, were into the figure (Kr < 1,0 and Lr < 1,55, figure 2) are acceptable, instead of it are unacceptable. Parameter "safety margin" show us the distance between geometrical place and FAD curve. Values below 1 identify critical situations where the failure could happen, value close to 1 identify situation close to failure and values higher and far from 1 identify comfortable structural situations.

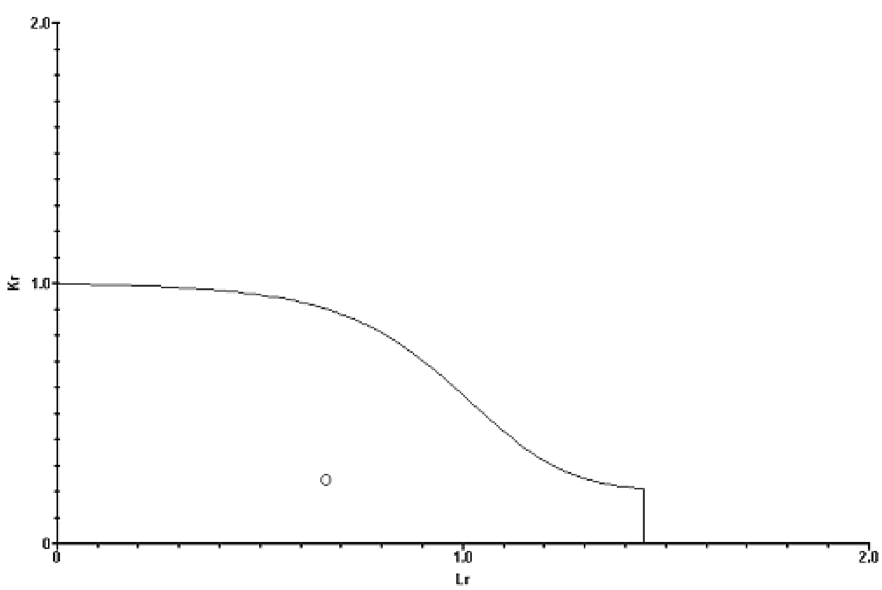


Fig. 2 – Typical FAD diagram.

Table 5
FAD results

Equipment	Values

	Activation (%)	Kr	Lr	Safety margin
Sphere (008)	10	0,235	0,591	1,994
Pressure vessel (061)	71	0,232	0,736	1,669
Pressure vessel (1203)	65	0,323	0,661	1,669
		0,221	0,661	1,850
		0,276	0,661	1,741
		0,248	0,661	1,790
		0,251	0,662	1,783
		0,337	0,664	1,644
		0,247	0,661	1,793

The same analysis showed in the previous pages were performed for the class no significant, A, B, C and D. The tables were not showed in function of the maximum number of pages of the article. Analysis could be done considering the amount of equipments with or without discontinuities, type of equipment or fracture mechanics results.

Figure 3 shows the general result by classification grade.

The inflexion noted in class "B" could be explained by small amount of complimentary inspection performed in this class of equipments.

Figure 4 shows the results of comparison between MONPAC criteria and fracture mechanics.

There isn't a clear separation between geometrical place of critical grades ("E" and "D") and the other grades ("A", "B" and "C"). This could be explained by small amount of available values for equipments classified as "A", "B" and "C".

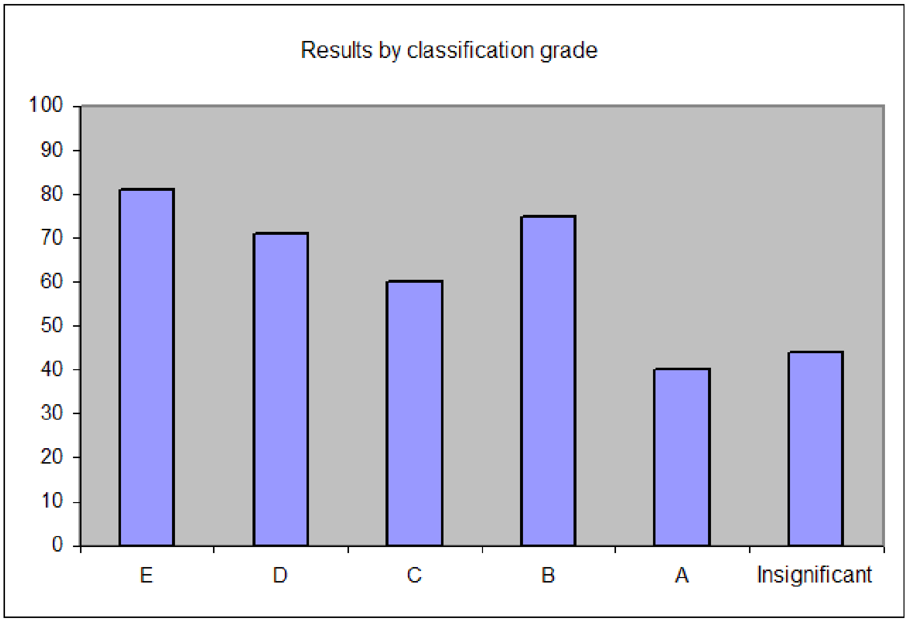


Fig. 3 – Results of inspected equipments by classification grade.

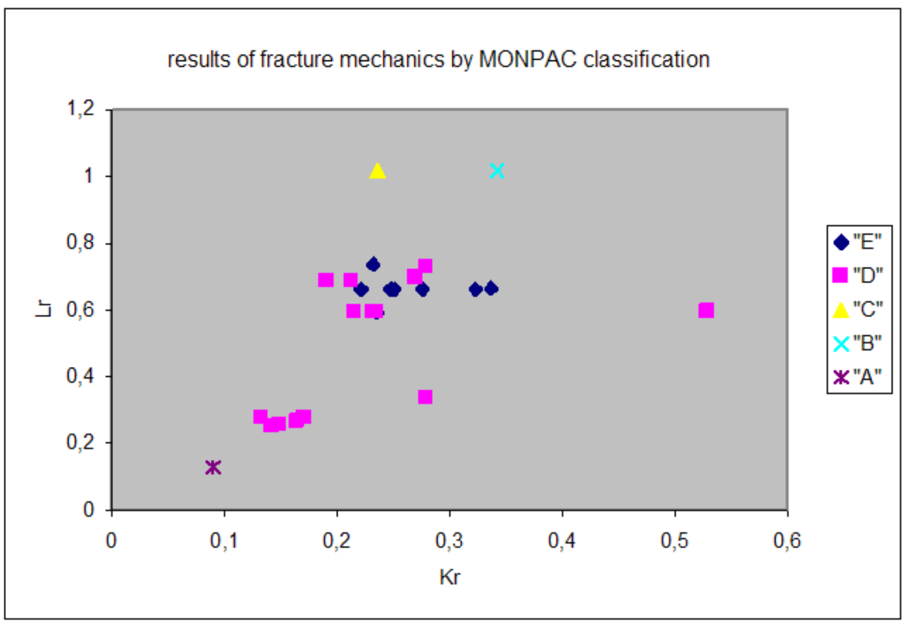


Fig. 4 – Comparison between MONPAC criteria and fracture mechanics.

Table 6 shows the amount of equipment qualitatively analyzed. Only spheres and pressure vessels has results in all categories of MONPAC criteria. Table 7 shows the results of discontinuities presence or not.

Figures 5a and 5b shows the result by MONPAC criteria for spheres and pressure vessels, respectively. There is a relationship between MONPAC criteria and presence of discontinuities for pressure vessels.

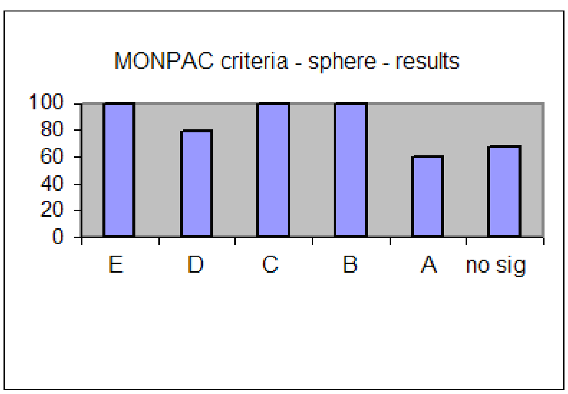
Figure 6 shows the result of comparison between MONPAC criteria and fracture mechanics for spheres. Figure 7 shows the result of comparison between MONPAC criteria and fracture mechanics for pressure vessels. There is a crescent gradation, in pressure vessels results, from “A” to “E” when fracture mechanics concepts are used.

Table 6
Equipments qualitatively analyzed

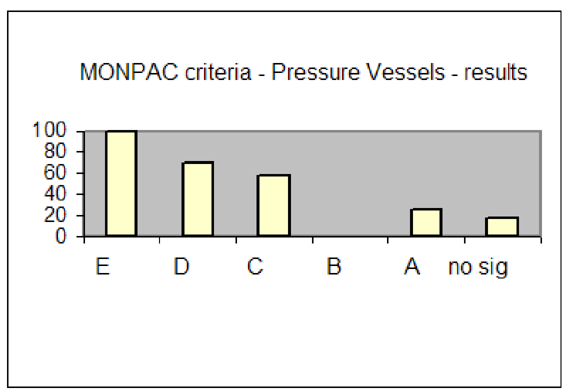
Grade	Sphere	Column	Pressure vessel	Reactor	Heat exchanger	Piping	Collector	Boiler
E	1	6	6	1	1	1		
D	5		10	7			1	
C	4	1	7	2	1			
B	3		1					
A	5	1	4					
No significant	6		6	2	1	3		1

Table 7
Percentage of discontinuity presence by equipment type and MONPAC criteria

Grade	Sphere	Column	Pressure vessel	Reactor	Heat exchanger	Piping	Collector	Boiler
E	100	67	100	100	100	0		
D	80		70	86			100	
C	100	0	57	50	0			
B	100		0					
A	60	0	25					
No significant	67		17	0	0	67		100



(a)



(b)

Fig. 5 – MONPAC criteria results of inspected equipments: (a) spheres; (b) pressure vessels.

Conclusions: The collected data in 210 equipments tested by acoustic emission into the PETROBRAS system analysed ans presented in this article allows the following conclusions.

There is a relationship between MONPAC criteria and presence of dicontinuities. Almost all equipments classified as “E” had discontinuities and less than 50% of equipments classified as “A” had.
There isn’t a clear separation between MONPAC classes. The small amount of data in class “B” and “C” could be the reason for this result.
There is a quasi-linear relationship between acoustic emission and fracture mechanics for inspections performed in pressure vessels.
Acoustic emission technique has better results when pressure vessels are been inspected.
Acoustic emission technique could be used as a screening technique to select areas for complimentary inspection.

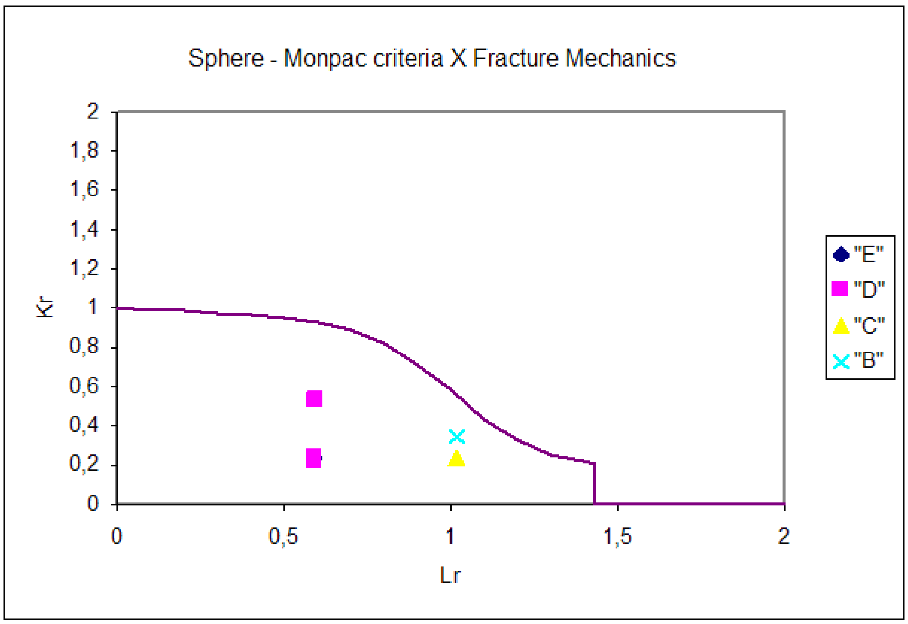


Fig. 6 – Comparison between MONPAC criteria and fracture mechanics for spheres

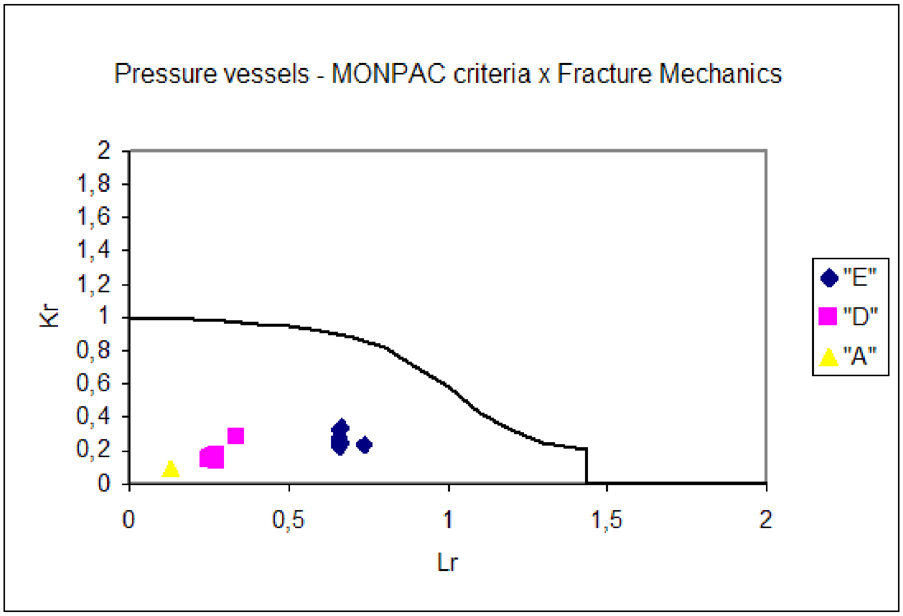


Fig. 7 – Comparison between MONPAC criteria and fracture mechanics for pressure vessels.

References: Aguiar, Juliano, Tesser, Juliano, Report of PETROBRAS database inquire, University Federal of Ceará, Center of Technology, Departament of Mechanical Engineer, 2002.

Soares, Sergio Damasceno, Database of Acoustic Emission Testing at PETROBRAS System – Analyses and obtained results, INSPEQ 2, PETROBRAS, São José dos Campos, Brazil, 2004.