Evolution of Offshore Safety in Brazil – Comparison with International Data

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Abstract: Offshore oil E&P activities in Brazil are undergoing a very fast expansion with the development of the pre-salt oil province announced in 2007 together with other offshore oil fields in various parts of the Brazilian coast. Under such situation it is of paramount importance that safety conditions are given very high priority and that operational safety be conducted at par with the most advanced recommended practices exercised in other countries.
The main objectives of this paper are to generate a picture of the evolution of safety in offshore exploration and production in Brazilian waters since its beginnings in the 70s to present day, and to compare the evolution of offshore safety in Brazil with that of other parts of the world.
Results indicate that offshore safety conditions in Brazil have experienced a significant improvement within the last 15 years. Among other reasons, the creation of ANP and its effects as offshore safety regulators represent one of the most important factors for such improvement. Some measures are proposed to further improve the offshore safety situation especially in light of the predicted even faster expansion of offshore activities in the upcoming years.

Keywords: Offshore safety, FAR, individual risk, risk tolerability.

1. INTRODUCTION AND OBJECTIVES

Offshore oil and gas exploration in Brazilian waters started in 1968 in shallow waters off the coast some Northeastern states. In 1972 Petrobras started exploration activities at Campos Basin off the coast of the state of Rio de Janeiro and in 1974 the Brazilian Government announced the first large discovery at Campos Basin where oil production started in 1977. This can be considered the beginning of large scale offshore oil and gas activities in Brazil. Until the year 2000, Campos Basin was responsible for more than 90% of the offshore production in Brazil and since then its relative contribution has decrease a bit with the beginning of production in Espirito Santo and Santos Basins but it still represents about 85% of all offshore oil and gas production in Brazil.

Petrobras, the state owned company created in 1953, was until 1997 the only company with rights to explore and produce oil and gas in Brazil. This was the era of the Petrobras monopoly which lasted until 1997 when the Petroleum Law was signed ending it, creating the National Petroleum Agency (ANP) and instituting a regime of concessions of areas for exploration and production by any company established in Brazil.

The main objectives of this paper are: 1) to generate a picture of the evolution of safety in offshore exploration and production in Brazilian waters since its beginnings in the 70s to present day, 2) to investigate the main causes behind the changes in different periods and the influence of ANP in recent years, 3) to compare the evolution of offshore safety in Brazil with that of other parts of the world, 4) to explore the implications of the current state of offshore safety indicators to the formulation of risk tolerability criteria to be applied in offshore activities in Brazilian waters, and 5) to propose a few measures to further improve the situation especially in light of the predicted fast expansion of this area in the upcoming years.

2. A BRIEF HISTORY OF OFFSHORE ACTIVITIES IN BRAZIL

Offshore oil and gas exploration in Brazilian waters started in 1968 in shallow waters off the coast some Northeastern states. In 1972 Petrobras started exploration activities at Campos Basin off the coast of the state of Rio de Janeiro and in 1974 the Brazilian Government announced the first large discovery at Campos Basin where oil production started in 1977. This can be considered as the beginning of large scale offshore oil and gas activities in Brazil. Until the year 2000, Campos Basin was responsible for more than 95% of the offshore production in Brazil and since then its relative contribution has decreased a bit with the beginning of production in Espirito Santos and Santos Basins but it still represents more than 80% of all offshore oil and gas production in Brazil as indicated in Figure 1.

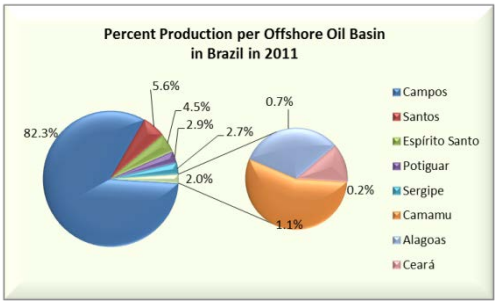

Figure 1 - Distribution of oil production among the various basins in Brazil

By that period Petrobras - the state-owned company created in 1953 - was the only company with rights to explore and produce oil and gas in Brazil. This was the era of Petrobras monopoly which lasted until 1997 when the Petroleum Law [1] was passed ending the monopoly, creating the National Petroleum Agency (ANP) and instituting a regime of concessions of areas for exploration and production by any company established in Brazil.

The evolution of annual total and offshore oil production in Brazil is shown in Figure 2, where it can be seen that from the seventies on, offshore oil production is the dominant contributor to oil production in Brazil.

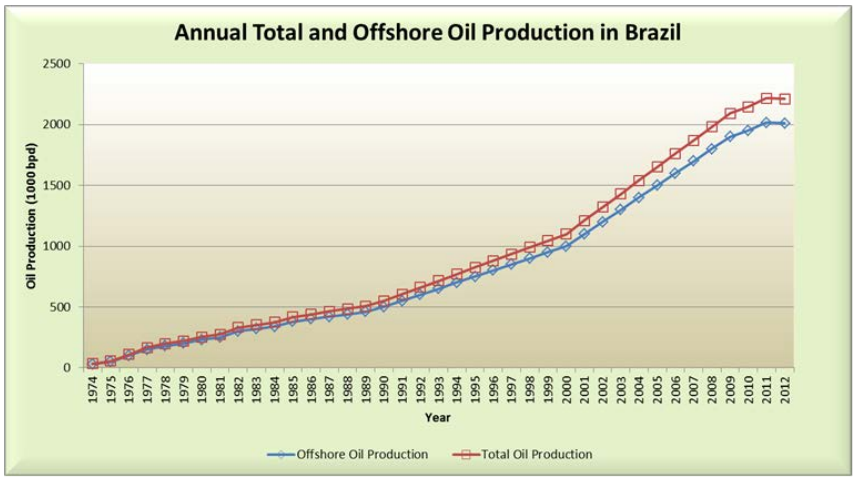

Figure 2 - Evolution of Annual Total and Offshore Oil Production in Brazil

3. SAFETY AND ENVIRONMENTAL REGULATIONS OF OFFSHORE ACTIVITIES IN BRAZIL

The key milestones of the evolution of Brazilian oil and gas safety and environmental regulations of offshore activities are illustrated in Figure 1. This evolution closely reflects the historical development of such activities in our country. During the initial phase of offshore oil development in the 70´s there was not really any applicable regulation. Petrobras had the monopoly of exploration and production and effectively had the control of all operations with very little interference from any governmental regulatory agency. That was the period of safety and environmental self-regulation by Petrobras.

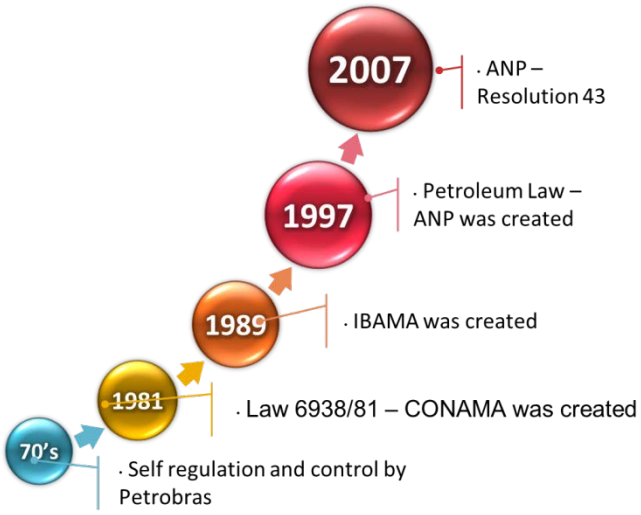

Figure 3 - Key milestones of evolution of oil and gas Brazilian safety and environmental regulations

Despite the passing of the Law 6938/81 in 1981 [2] that created the National Council for the Environment (CONAMA), it was only with the creation of the Brazilian Institute for the Environment (IBAMA) in 1989 that it can be said that the offshore activities of Petrobras started to experience some degree of regulation. IBAMA started to enforce the requirement of environmental impact assessment (EIA) for the granting of licenses for construction and operation of offshore installations. Initially this involved only the classical requirements of environmental protection, following the guidelines established in CONAMA 001 regulation of January 23th, 1986 [3]. Later, some aspects of environmental damages caused by operational accidents and a mitigation plan (emergency plan) started to be required as part of the EIA. By the end of the 90´s and beginnings of 2000, IBAMA started to include requirements related to safety assessments (preliminary risk analysis – qualitative) which were then followed by requirements of a limited safety management system (SMS). The latter was actually not very effective as it was only a report indicating that the company intended to implement an SMS but there was not any real auditing activity by IBAMA after the installation was in operation to verify that the SMS was really implemented and to measure its efficacy.

With the passing of the Petroleum Law [1] which ended with Petrobras monopoly and created the National Petroleum Agency (ANP) things started to change towards a more effective safety regulation of offshore activities in Brazil. The new regulatory safety regime put in force by ANP through Resolution ANP nº 43 from 6th December, 2007 [4], related to the requirement for implementation of an Operational Safety Management System in all offshore installations, brought important changes to the offshore safety situation in Brazil. But contrary to the situation in some of the analyzed European countries, offshore pipelines are not considered as an offshore installation and are therefore excluded from the referred regulation.

The current situation in Brazil regarding safety regulation of offshore installations involves the action of the two referred agencies, IBAMA and ANP. The former acts by granting license permits for construction and operation, and therefore is the agency that has the possibility of interfering at the design stage which is fundamental for the establishment of effective safety systems which will be most

important for the safety of the operations later on. Because of its traditional actuation in the environmental issues, the strength of IBAMA continues to reside mostly on its recognized competence relative to environmental protection.

On the other hand, ANP activities come on only during the operational phase and focus on the production and drilling activities. It is widely recognized that the introduction of the requirements of an effective operational safety management system by ANP is bringing important changes with respect to the safety of offshore activities in Brazil (see next section). Unfortunately it seems that we are still missing a decisive safety regulatory action at the level of the design stage. Although ANP Resolution 43 [4], in its "management practice 10", establishes that risks must be identified, assessed and minimized during the design phase, verification of this practice is only done after the installation is operating. This means that if it were not adequately done during the design phase (when it was still easy to attain significant design improvements), then it is really difficult to require any significant hardware retrofits during the operational phase. This means that an important opportunity is being missed to significantly improve safety at the design phase of the new offshore production installations.

4. FAR FOR OFFSHORE ACTIVITIES IN BRAZIL AND COMPARISON WITH AVERAGE INTERNATIONAL VALUES

An important safety indicator of an activity which is widely used in the world is the fatal accident rate (FAR). It is formally defined as the number of fatalities per 100 million worked-hours in the referred activity. Therefore the FAR of an activity in a given period is given by:

$$FAR = \frac{No.of\ fatalities}{No.of\ worked-hours\ in\ the\ period} \times 10^8 \quad (1)$$

FAR values for offshore activities in Brazil for various periods until 2002 have been previously calculated by some authors. In the pioneering work of Faertes [5], average FAR values were obtained for the period between 1974 and 1992. In that work the number of fatalities was obtained from Petrobras records and therefore has low uncertainty. On the other hand there was no reliable value for the corresponding number of worked-hours in the period. That number had to be estimated from an estimate of the number of workers (both from Petrobras and from contractors). Since the offshore working regime is different for Petrobras employees (14 x 21) and for contractors (14 x 14) an average value of annual worked-hours had to be used to take into account the two regimes. This introduced a significant degree of uncertainty to the resulting FAR value.

In a subsequent work, Faertes [6] calculated FAR values for the period 1993-95 also using data from Petrobras and estimated values for the corresponding working-hours. Oliveira et al [7] further extended the evaluation to the period 1996-2002 using data from the open literature found in Brazil. The results of those first three works are summarized in Table 1. While in the platform, the workers are subjected to 12 shifts, that is, they spend 12 hours in their working stations and rest for the other 12 hours of the day. FAR values in references [5-7] were calculated considering that workers in an offshore installation are exposed to the platform risks during the whole time they spend in the platform, that is, 24 out of 24 hours, and not only during the true working hours (12 out of 24 hours). Therefore, in accordance with Vinnen [8], the FAR values for the offshore workers in references [5-7] were obtained taking into account the risk-exposure-hours (workers in an offshore platform are exposed to risks even when they are resting in the accommodation module). Since OGP FAR values are based on true worked-hours, the FAR values from references [5-7] are here converted to the worked-hour basis by multiplying its value by two, as indicated in the fourth column of Table 1. Therefore the values in column 4 of Table 1 are directly comparable to those evaluated in this paper and those from OGP.

Table 1 - Average FAR values for offshore activities in Brazil obtained for three periods from 1982 to 2002

Reference	Period	FAR offshore (from the references)*	FAR Offshore (expressed on worked-hours)
Faertes [5]	1982-1993	26.0	52.0
Faertes [6]	1994-1998	10.3	20.6
Oliveira et al [7]	1999-2002	38.6	77.2

* Calculated on the basis of risk-exposed-hours

In reference [7] the large variation in FAR values obtained for the three periods in Table 1 are explained by the following reasoning: 1) the first period encompasses the blowout accident of Enchova Platform which caused the death of 37 workers, 2) the second period is a short one during which no large accident occurred, and 3) the accident with the P-36 Platform which caused the death of 11 people is included in the third period. Therefore it is thought that the effects of the two cited large process accidents are the main cause for the large FAR values obtained for the first and third periods. It is also indicated in that reference that the number of fatalities in the second period seems to be somewhat under-reported. In addition the fatality data for the last of the three referred periods was collected from a variety of scattered public sources such as newspapers and internet sites and they were not considered very reliable.
Since 2006 ANP started collecting accident related data from offshore activities in Brazil and publicizing them in annual reports [9-11]. Several kinds of data are published including the annual number of worked-hours in offshore activities. The present work takes advantage of those much more reliable data to calculate FAR values for offshore activities in Brazil and compare them with average international values published by OGP. A new source of offshore fatality data has been found and it is also used to complete a larger period of FAR values for offshore activities in Brazil during the last 15 years. The latter reference is a paper published by Alvarez et al [12] in the Brazilian Journal of Occupation Health in 2010. Annual fatality values from 1998 to 2008 given in [12] were obtained from fatal accidental data collected by the North-Fluminense Union of Oil Workers.

The worked-hours for the period 2007 to 2012 are given given by ANP [9-11] and therefore for this period the precision of the FAR values is higher than on the other period where those data were not available in an official and comprehensive report. The worked-hour values for the period 1998-2006 were obtained from an interpolation between the values given by ANP and one value for the number of offshore workers estimated in reference [7] for the year 1998 (estimated at 6600 workers).
Combining the fatality data given in [12] from 1998 to 2005 with those provided by ANP from 2006 to 2012 [9-11] and the worked-hours for the period, we obtain the evolution of FAR values for offshore activities in Brazil during the last 15 years. The calculated results are plotted in Figure 4 together with the corresponding values FAR values given by OGP [13]. The latter are obtained from data provided by a large number of international operators of offshore exploration and production units. To facilitate the comparative analysis of the two sets of data, they are plotted in both linear and exponential scales.

The very high FAR value for 2001 in Brazil can be explained by the P-36 accident which caused 11 fatalities. On the other hand we cannot find any specific reason for the almost equally high value found for 1998. The oil workers unions in Brazil claim that the high accident rates found in the period from 1998 to 2001 resulted from the significant increase in the number of contractors hired by Petrobras for offshore work. They claim that the contractor labor force was much less trained than Petrobras own employees and were put to work in the riskier tasks. Indeed data shown in reference [12] indicate that, except for the year 2001 (year of the P-36 accident), the number of fatalities among the contractor workforce is much higher than that among Petrobras employees. In particular, this disparity during the years 1998 to 2000 is strikingly high.

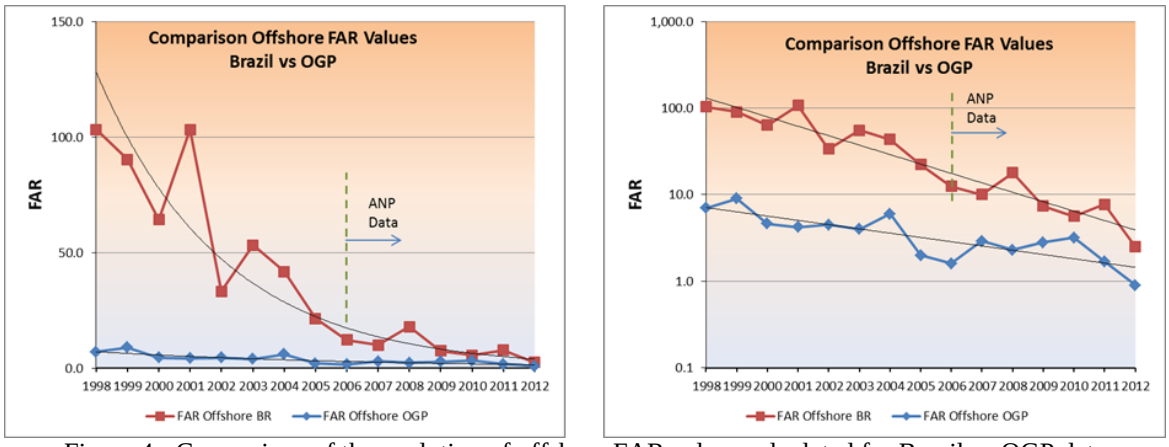

Figure 4 - Comparison of the evolution of offshore FAR values calculated for Brazil vs OGP data

From the time evolution point of view, it can be seen from Figure 4 that the FAR values for offshore activities in Brazil have been reduced by a factor of 40 during the 15-year period from 1998 to 2012 (from a value of 100 in 2001 to 2.5 in 2012). Such a large reduction coincides with the period of existence of ANP and undoubtedly the work of the regulatory agency has had a significant impact in the reduction of the FAR values, especially after 2007 when ANP Resolution 43 (contains the offshore Operational Safety Management System) [4] was published and started to be enforced by the agency. In our opinion, other factors that can also be credited as important contributors for the FAR reduction for offshore activities in Brazil shown in Figure 4 are:

- The intensification by Petrobras of the use of various techniques of risk analysis in the design of the new floating production units which started in the second half of the nineties;

- The launching of the PEGASO (Program of Excellence in Environmental and Operational Safety Management) by Petrobras in 2000 after the oil spill accident in the Bay of Guanabara and its implementation in subsequent years; and

- The implementation of the Petrobras HSE Management System with its 15 directives in all offshore units of the company (equally implemented in onshore units) starting in 2005.

In addition to the above it is worth mentioning that after 2000 several international oil companies have started operating offshore units in Brazil and this may also have been a contributing factor to the large reduction of FAR indicated in Figure 4.

From Figure 4 it can be seen that the average FAR values reported by OGP (average values from various international oil companies) also show a significant reduction during the referred period, going from a value of 10 in 1999 to a value of 0.9 in 2012, a reduction by a factor of 10. Therefore, despite the very large reduction in the period, the FAR for offshore activities in Brazil in 2012 remains a factor of 2.5 higher than the average international value reported by OGP. This is an indication that there is still room for further improvement in safety conditions of offshore operations in Brazil. Some suggestions in that direction are proposed in Section 8 of this paper.

5. CONVERSION OF FAR TO INDIVIDUAL RISK VALUES

A key risk indicator used in quantitative risk assessment is the average individual risk (AIR), defined as the “expected annual frequency of fatality to an individual (in this case, a worker of an offshore installation) due to accidents in the reference installation”. The quantitative relation between FAR and AIR values is given by the following equation:

$$AIR = \frac{FAR}{10^8} \times NH \qquad (2)$$

where NH is the number of hours per year that an individual spends working on the referred activity. This definition is consistent with that given in Eq.(1) as the number of worked-hours is used on both equations. An offshore worker in a 14 x 14 day regime in Brazil accumulates 2000 hours of work per year (by law all workers in Brazil have 30 days of vacation per year) and 1600 hours in the 14 x 21 day regime used by Petrobras. Considering an average value between these two limits, then NH is equal to 1800 hours of work per year in this paper.

An average FAR value of 8.2 for offshore activities in Brazil in the period 2006-2012 can be obtained from the ANP data for the period (30 fatalities in a total of 365 million worked-hours). This FAR value is equivalent to an AIR value of 1.5 x 10-4/yr for the period. It is worth mentioning that the FAR in 2012 was only 2.5 which is equal to an AIR of only 4.5 x 10-5/yr. Since these values were calculated from real field data for offshore activities in Brazil, we can say that this is the actual level of average individual risk that is being currently practiced by Petrobras and all other oil companies working in Brazilian waters. Such AIR values derived from current practice have implications for the establishment of risk tolerability criteria as indicated below.

6. IMPLICATIONS TO RISK TOLERABILITY CRITERIA FOR OFFSHORE INSTALLATIONS IN BRAZIL

The issue of setting risk tolerability criteria for offshore activities in Brazil has long been discussed but was never really implemented neither by Petrobras or the ANP. This is not the case of the state-based regulatory agencies for onshore activities (CETESB-SP, INEA-RJ, others) which have implemented risk analysis during the licensing process for hazardous installations and set their own quantitative risk tolerability criteria (individual and societal risks).

Many risk studies have already been conducted and important risk-related decisions have been taken by Petrobras in the offshore area. In the absence of a company defined (or ANP defined) risk tolerability criteria, decisions were made by using criteria from other countries (mainly UK and Norway) which are not the same between themselves and this introduces inconsistencies in the decision making process, with the use of different criteria depending on the situation at hand. It would be much better if clear definition and guidance were given on the issue of risk tolerability criteria to the safety of workers in offshore activities in Brazil.

The AIR value of 1.5×10^{-4}/yr obtained from the last seven years of ANP collected data gives a clear indication that, if so desired, ALARP risk tolerability criteria could very well be set with a maximum accepted individual risk for offshore worker equal to 1.0×10^{-4}/yr for all accidental loads. In fact the results shown in Section 5 indicate that already a lower value AIR value (4.5×10^{-5}/yr) has already been attained in 2012.

Starting in 2006 Petrobras has changed the way it was conducting quantitative risk assessments during the design phase of its offshore production units and began restricting the objectives of the studies only to fire and explosion protection of the installations themselves: deciding where to locate gas detectors, passive fire protection and blast protection. For such studies, risk criteria are defined by Petrobras with respect to the lowest expected frequency for which protection should be provided. Collision risks have also been conducted but again with the aim of protecting the installations. While such studies have given and continue to give important contributions to improving safety of the installations, a much more complete risk picture could be obtained (with very little additional effort) if the risks to the offshore workers (AIR and LSIR[*]) were also quantitatively assessed and the ALARA principle were used to continuously drive the workers risks to lower values. For that matter, the AIR values derived from the current practiced risk levels in offshore activities in Brazil could be used to establishing quantitative risk tolerability criteria as indicated in the preceding paragraph.

[*] LSIR = Location Specific Individual Risk

As a result of the accident involving the rupture of the riser which was being used for the long duration testing of well 3-SPS-74 (in the Carioca Field) in January 31 2012, ANP [11] has recommended that Petrobras establishes "clear and auditable criteria aligned with the best engineering practices for the definition of risk acceptability criteria to be used on both qualitative and quantitative risk analyses". To our knowledge, Petrobras has not yet implemented this recommendation.

7. RECENT EVOLUTION OF OTHER OFFSHORE SAFETY INDICATORS

In addition to the FAR, it is worthwhile looking at the recent evolution for other meaningful safety indicators. Unfortunately there are no data for such indicators for the period prior to the creation of ANP. Based on data from ANP [11] for the period 2007-2012, we examine the following offshore safety indicators:

1. Number of events of fire and/or explosions
2. Number of injuries
3. Total number of reported incidents
4. Number of oil spills or leaks

In Figure 5 the numbers of the four indicators per million hours of operation are plotted for the period 2007-2012. As can be seen, while the fourth indicator is showing a more stable evolution, the numbers for the first three indicators have shown a steady growth in the period. It is important to point out that some of this growth may be due to the increasing enforcement actions by ANP which is forcing the operators to report more than previously. Nevertheless, the number of fire/explosion events is showing an even faster increase than the number of total reported incidents. This may be an indication that process safety conditions in the platforms may be deteriorating in the last few years, although this conclusion is not properly corroborated by the evolution of the number of oil spills and leaks.

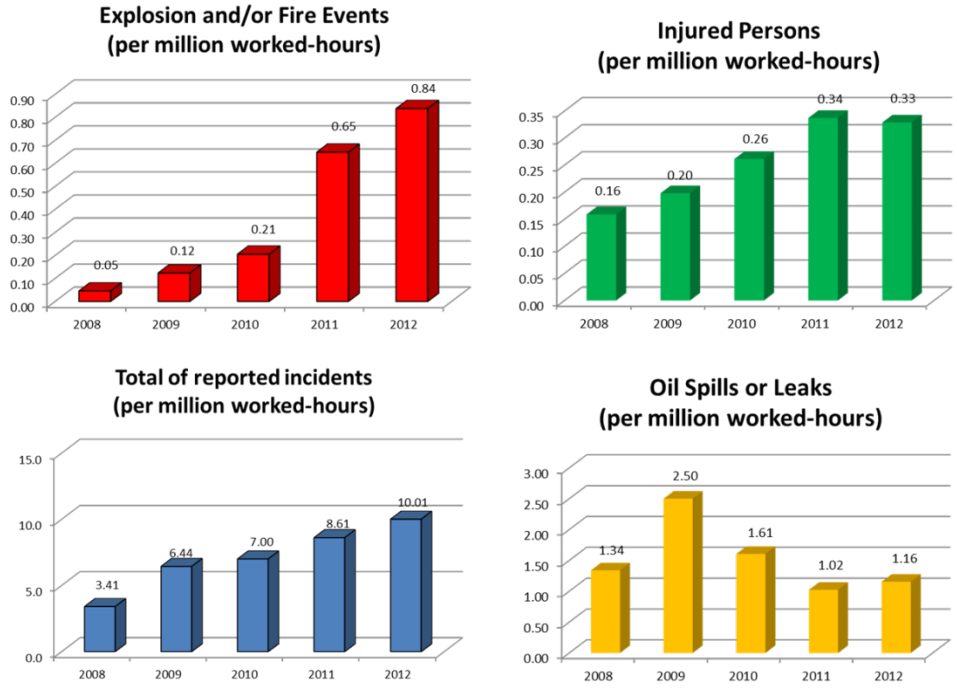

Figure 5 - Recent Evolution of Four Important Offshore Safety Indicators

8. FINAL COMMENTS

In this paper we attempted to draw a summarized overview of the evolution of safety in offshore exploration and production activities in Brazilian waters since its beginnings in the 70s to present day. We compared the situation of offshore safety in Brazil with that of other parts of the world.

As evidenced by the evolution of FAR values estimated here for offshore activities in Brazilian waters, fatal accident conditions have shown a very significant improvement during the last twelve years (from a value of 100 in 2001 to 2.5 in 2012). In our opinion this is most probably related to actions taken by both the ANP and Petrobras as explained in Section 4 of this paper. Other possible reasons for such an improvement are also presented in that section.

In addition it is shown that average FAR values reported by OGP for international offshore activities also show a significant reduction during the referred period, going from a value of 10 in 1999 to a value of 0.9 in 2012, a reduction by a factor of 10. Comparing the two developments it can be seen that despite the very large reduction in the period, the FAR for offshore activities in Brazil in 2012 remains a factor of 2.5 higher than the average international value reported by OGP. This is an indication that, despite this very significant reduction, there is still room for further improvement in safety conditions of offshore operations in Brazil. We would like to propose some suggestions that we think will contribute in that direction.

- The first suggestion is the creation of a separate regulatory agency to deal exclusively with safety of oil and gas installations (separate the operational safety branch of ANP from the other branches), such as has been done in the most advanced oil producing countries: Australia, Netherlands, Norway, UK, and USA, for example. Also the recently published European Community Directive 2013/30/EU, "on safety of offshore oil and gas operation" [14] stipulates that "the new competent authority (integrating safety & environment) must be independent from economic regulation". The main advantage is the independence and avoidance of any possible conflict of interest with oil production and economic goals.

- It is very important that the safety regulatory agency have strong involvement during the design phase of new installations, especially during the licensing process. It is clear that many strong safety measures can be built into in the installation during its design phase when layouts can be changed and safety features introduced to optimize the safety conditions of the installation. After it is constructed and operating, it becomes much more difficult and costly to introduce important hardware safety features or to promote safety optimizing changes. In Brazil we are currently lacking this kind of intervention. ANP has had a very important role in the improvement of operational safety conditions (as indicated in Section 4) but the agency inspectors are exerting their impact only after the design is frozen and the installation is built.

- Echoing the common practices of the most advanced oil producing countries, Directive 2013/30/EU [14] explicitly requires the use of Safety Case Reports (SCR) as a safety management tool. An SCR must be submitted by the operator during the design phase and accepted by the regulator prior to operations commencing. This is not currently the case in Brazil. We propose an update the ANP operational safety regulation (SGSO – [4]) to include clear requirements for preparation of Safety Case Reports and their submission to the agency for approval during the licensing process.

- We propose an update of the ANP SGSO [4] to include clear requirements for performance standards for safety critical elements and safety barrier management, including provisions to the adoption of functional safety specifications such as those from IEC 61508 [15]. Again similarly to the European regulation [14], we propose an update of ANP operational safety regulation to require the inclusion of schemes for independent verification of safety critical elements within the required safety management systems of the operator companies.

It is well known that within the next decade, offshore oil and gas E&P activities in Brazil will accelerate to an even higher pace than that of the past period. To maintain a high safety level within such a tremendous growth period requires that the country safety authorities be equipped with the best possible regulatory practices and tools. We firmly believe that the implementation of the measures suggested above is a necessary action in the direction of safer offshore activities.

Nevertheless, as indicated by Jane Cuttler, the Chief Executive of NOPSEMA – the Australian regulatory agency for offshore oil and gas activities – in her speech at the Piper +25 Conference in Aberdeen last year [16], "Essential to progress is the recognition that responsibility for safety in offshore petroleum operations rests with the operators. Regulators cannot inspect safety into the operations; it must be integral to the way the industry does business."

Undeniably, after the four important accidents in the period 2000-2002, Petrobras has taken firm steps to improve safety but the current focus on fast increase of the production curve has led to some decisions that certainly do not go in the direction of increased offshore safety levels. Among them we can cite: not using quantitative risk analysis to evaluate risks to workers safety, not performing SIL analyses and not applying the safety lifecycle requirements of IEC 61508 [15], not developing a comprehensive Safety Case Report to each offshore installation, not defining/implementing performance standards for the safety-critical elements, and not applying a comprehensive integrity verification program of the safety barriers of the offshore installations. These are all modern process safety practices that are being conducted by most of the major international oil companies (they are part of their process safety management systems). If such "recommended practices" (since they are not yet required in Brazil) are not being followed by our most advanced company (Petrobras), it is not difficult to imagine that still much less is being done by the various other Brazilian companies that are newcomers to the offshore oil and gas business. We think that the use of such practices is essential to maintain the offshore safety level as high as it can be done with the existing technologies and consequently to maintain the level of risk "As Low As Reasonably Achievable or ALARA".

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