 


# PRELIMINARY RISK ANALYSIS APPLIED TO THE CONSTRUCTION AND ASSEMBLY OF CHEMICAL PLANTS

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***Abstract***. *This paper, presents the results of a study where the Preliminary Risk Analysis (PRA) technique was used to identify associated hazards concerning construction, working at heights and in confined spaces, assembly, transport and unloading of heavy loads, during the construction and assembly phase of a large petrochemical plant. This is a non-traditional application of PRA whose results were considered as being efficient for risk identification. PRA is a qualitative technique for the identification of possible accident scenarios in a given facility, with their classification in pre-established categories of "frequency of occurrence" and "magnitude" and recommendations of measures to improve the safety of the facility. In activities related to construction, the movement of heavy loads and large vehicles, drilling and excavation, operations with equipment that generates excessive vibration, operation of large vehicles close to the fire combat water system and hauling of materials and partially assembled pieces of equipment were analyzed. In the cases of works at heights and in confined spaces the operations of assembly of scaffolds, crane use for lifting and assembling of parts and structures, works near hot pipes and electricity cables, the occurrence of unexpected storms, emission of gases or toxic vapors and exposure to soot emission or combustion products were analyzed. Regarding the assembly of large and complex pieces of equipment, transport of vehicles, great movement of heavy loads, welding processes, gammagraphy, cutting, trimming and grinding, large pipe coupling (stail) operations, hydrostatic testing of tubes and other pieces of equipment, storage of pipes and spool handling were considered. In relation to the transportation and unloading of heavy equipment, excessive load on the road, width and/or excessive height of the parts being transported and hauling heavy parts operations were evaluated. The consequences of an emergency situation in the facility with evacuation of the area needed were also analyzed. The main findings of these analyses were the identification of 265 accident scenarios and 397 recommendations. The identification of hazards is an important tool in the prevention, elimination, mitigation and other associated improvements, such as planning for emergencies, which can contribute significantly to the safety of normal activities in industrial plants as well as to other operations such as the ones described in this paper.*

**Keywords**. *risk analysis, hazard identification*

## 1. Introduction

The Preliminary Risk Analysis technique has traditionally been used for hazard identification in industrial processes, see Lees (1996), Wells (1996) and AIChE (1992). In this study, the technique was used to identify risks associated to activities regarding construction, working at heights and in confined spaces, assembly, transport and unloading of heavy loads, during the construction and assembly phase of a large scale operation. The operation in question is the expansion of a petroleum refinery. As this meant expanding without interrupting production, even normally routine jobs required special attention concerning safety. Given the size of this operation, the study was carried out by taking into account that there would be heavy on-site traffic of practically all types of vehicles, from bicycles to the moving of heavy hauling cranes, with intense traffic of trucks, cranes, buses, machines, cars and bicycles, which significantly increased the risk of accidents.

Since the plant would be operating, it was necessary to take into account the simultaneousness of the expansion works and an emergency in the refinery. This is important, because there would be many more people in the facility than under normal circumstances. It has been estimated that at the peak period of the work, around 8000 people will be on the site.

## 2. Preliminary Risk Analysis

Preliminary Risk Analysis (PRA) is a technique that allows existing hazards in a given facility to be systematically identified. Through PRA, events that could cause accidents in the assessed installations are identified, a.k.a. "initiating events". Basic causes and respective consequences are identified for each initiating event. Consequences of each initiating event depend on how the accident evolved after the initiating event occurred. The set made up of the initiating event, its causes and consequences, is named "accident scenario".

The technique is applied through the filling in of worksheets by a team of experts. The facility should be divided into modules to make processes easier to understand, use of minimum number of documents is recommended, as well as being able to count on a reasonable number (between five to eight) of specialist experts who will be part of the group carrying out the study.

Typically, in PRA, after identifying the accident scenarios, a qualitative evaluation is carried out of the frequency of the scenario and its severity (or magnitude) and their respective consequences. This qualitative evaluation is carried out by establishing frequency categories and magnitude categories. Then, taking into account that risk is a combination of frequency and consequence, a qualitative evaluation of risks of the assessed facility can also be obtained, by combing the frequency and consequence categories obtained for each accident scenario. In this way, identified accident scenarios at a given facility can be ranked, both in terms of their respective frequency or consequences, as well as in terms of their risk levels. Therefore, results obtained though applying PRA are qualitative and do not supply numerical estimates of risks, but only their classification in qualitative ranges of frequency, magnitude or risk. From the results, mitigating measures can be proposed or recommendations can be made regarding the need of further analysis, for example, carrying out a vulnerability analysis or even a quantitative risk analysis.

PRA phases include setting the goals and scope of the analysis, defining the boundaries of the assessed facility, information gathering regarding the region, installations, hazardous substances involved and processes, carrying out the PRA (filling in the worksheet), including any suggestions of risk mitigating measures, working out the statistics of the identified scenarios by frequency and magnitude categories and, lastly, analysis of results and report writing. The scope of the PRA should cover all hazardous events, whose causes begin in the assessed facility, including both intrinsic component or system failures, as well as incidental operational errors (human errors).

In chemical/petrochemical type installations, hazards are basically caused by the loss of confinement of hazardous products (flammable and/or toxic) that are stored or handled there, either by accidental release due to intrinsic ruptures in equipment, pipelines and valves, or operating errors. Therefore, in a PRA the undesirable events that should be taken into account are accidental releases (small and big) of each of the dangerous products under analysis. The actual PRA is carried out through the filling in of a PRA worksheet for each of the facility's assessed modules (subdivisions of the plant in order to simplify and organize the work). The worksheet that was used in the PRA, shown in Tab. (1), contains nine columns, the description of each one follows.

Table 1. Preliminary risk analysis worksheet

<table>
<tr><th colspan="9">Preliminary Risk Analysis</th></tr>
<tr><td colspan="3">Unit:</td><td colspan="3">System:</td><td colspan="3">Date:</td></tr>
<tr><td colspan="3">Prepared by:</td><td colspan="3">Documentation:</td><td colspan="3">Reviewed by:</td></tr>
<tr><td>Hazard</td><td>Causes</td><td>Detection Method</td><td>Effect</td><td>Frequency Category</td><td>Magnitude Category</td><td>Risk Category</td><td>Observations/ Recommendations</td><td>Scenario N#</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

**1st column: Hazard**

This column contains the identified hazards for the analysis of the module under study. In general, hazards are accidental events that could potentially damage the facility, harm operators, the public or environment. Therefore, hazards refer to events such as small flammable gas leaks, big toxic liquid leaks, big toxic and flammable liquefied gas leaks, etc.

**2nd column: Cause**

The causes of each hazard should be described in this column. These causes could include both intrinsic equipment failure (leaks, ruptures, instrument failures, etc) as well as human errors in operations and maintenance.

**3rd column: Detection Method**

The methods that are available in the facility to detect the hazard identified in the first column should be listed in this column. Detection of a hazardous occurrence can be done through both instruments (pressure, temperature alarms, etc.) as well as through human perception (visual, smell, etc.).

**4th column: Effect**

Possible harmful effects of each identified hazard should be listed in this column. Main effects of accidents involving flammable products are: jet fire, cloud fire, cloud explosion, BLEVE (Boiling Liquid Expanding Vapor Explosion), fireball, environmental damage. While accidental release of toxic products generates toxic clouds and/or environmental damage.

**5th column: Scenario Frequency Category**

Within the scope of PRA, an accident scenario is defined as a set made up of the identified hazard, its causes and each of its effects. Example of an accident scenario: a big release of a flammable substance due to a pipeline rupture that could lead to the forming of a flammable cloud and cloud fire or explosion. According to PRA methodology, accident scenarios should be classified into frequency categories, which supply a qualitative indication of the expected frequency of each identified scenario, as shown in Tab. (2).

Table 2. Frequency categories used in PRA.

| Category | Definition | Description |
|---|---|---|
| *A* | Extremely Remote | Scenarios that depend on multiple failures of protection systems or rupture of pressure vessels through mechanical failure. Conceivably possible, but extremely unlikely to occur during the facility lifetime. There is total redundancy. |
| *B* | Remote | Multiple errors in the system (human and/or equipment) or large-scale equipment ruptures. Not expected to occur during the facility lifetime. An occurrence has never been registered before at the facility. |
| *C* | Occasional | This scenario depends on just one error (human or equipment). |
| *D* | Probable | One occurrence is expected during the system lifetime. Control and protection measures need to be improved.<br>At least one occurrence of the scenario has already been recorded in the actual system. |
| *E* | Frequent | Expected to occur several times during facility lifetime. |

**6th column: Magnitude Category**

According to PRA methodology, accident scenarios should be classified into magnitude categories, which supply a qualitative indication of the expected magnitude of consequences of each identified scenario. Magnitude categories that are usually used are shown in Tab. (3).

Table 3. Magnitude categories of the consequences of accident scenarios.

| Category | Definition | Description / Characteristics |
|---|---|---|
| I | Negligible | Operational incidents that could cause personnel to feel unwell or uncomfortable and insignificant damage to the environment and equipment (easily repaired and low costs). Insignificant production losses. No environmental impacts. |
| II | Minor | Potentially able to wound personnel and cause little damage to environment or equipment/instruments. Significant reduction in production. Environmental impacts restricted to the facility site, controllable. No significant effect on population. |
| III | Critical | Potentially able to cause one or more fatal victims or great damage to the environment or facility. Serious damage to equipment. Temporary/partial halt in production (weeks or months). Demands immediate corrective actions to stop it turning into a catastrophe. |
| IV | Catastrophic | Potentially able to cause several fatal victims among workers and population. Irreparable or impossible (cost/time) damage to environment and/or installations. |

***Observation:*** *To classify a scenario into a given magnitude category it is not necessary for all the foreseen aspects in the category to be included in the possible effects of this accident.*

**7th column: Risk Category**

It is possible to define risk categories by combining frequency and magnitude categories, as shown in Tab. (4). The risk category supplies a qualitative risk level for each scenario identified in the analysis.

Table 4. Risk classification matrix.

| | | **Magnitude** | | | |
|---|---|---|---|---|---|
| | | **I** | **II** | **III** | **IV** |
| **Frequency** | **E** | **3** | **4** | **5** | **5** |
| | **D** | **2** | **3** | **4** | **5** |
| | **C** | **1** | **2** | **3** | **4** |
| | **B** | **1** | **1** | **2** | **3** |
| | **A** | **1** | **1** | **1** | **2** |
| Criteria used for frequency category:<br>A - Extremely remote<br>B - Remote<br>C - Occasional<br>D - Probable<br>E - Frequent | | Criteria used for magnitude category:<br><br>I - Negligible<br>II - Minor<br>III - Critical<br>IV - Catastrophic | | Criteria used for risk classification:<br>1 - Negligible<br>2 - Minor<br>3 - Moderate<br>4 - Serious<br>5 -Critical | |

**8th column: Recommendations/Observations**

This column contains recommendations or any observations regarding the accident scenario under study. Observations that can help to explain how the scenario was identified and, very important, recommendations for the reduction or possible elimination of risks.

**9th column: Accident Scenario Identification**

This column contains the accident scenario identification number. It is sequentially filled in to make any scenario of interest easy to access.

After the worksheet has been filled in, it is possible to assess how many scenarios have been identified for each of the combinations of frequency and magnitude categories. A table is drawn up like the one in table 3, which is used to demonstrate the classification of risk classes or categories, and each space is filled in with the number of scenarios identified with the combination of frequency and magnitude categories previously mentioned. This matrix enables the visualization of how risk scenarios are distributed throughout the facility.

## 3. Description of expansion works and hazard identification

The aim of this work was to identify the hazards associated to expansion works carried out in a petroleum refinery without the interruption of normal operational activities. New units will be constructed as part of the expansion: Atmospheric Residue Catalytic Cracking Unit - with processing capacity of 7.000 $m^3$/day, Petroleum Retarded Coking

Unit - with processing capacity of 2.000 $m^3$/day and Unstable Substances Treatment Unit - with processing capacity of 4.000 $m^3$/day. This is a large-scale operation.

Expansion works like any other activity necessarily imply in the possibility of accidents harming workers, the population, the environment and financial losses for the entrepreneur. Works inside a refinery require tasks to be carried out in places that are very close to the sources of danger where there are big inventories of several flammable and toxic materials, making safety issues even more important. Accidents that in other types of installations represent relatively low losses, in a refinery an accident that leads to an unscheduled stop could represent losses of around US$ 2 million per day. Therefore, efforts made towards identifying potential hazards and seeking ways of avoiding them or minimizing their expected frequency or reducing possible damage are highly justifiable.

Next, some of the actions that were analyzed and some of the serious hazards that were identified will be described.

Within the civil engineering works the following were evaluated; movement of vehicles and cargo, drilling, excavation and exploration processes, equipment that generates excessive vibration, movement of equipment near the fire combat water systems, and hauling of materials and pre-molded parts. For piledriving with metal or concrete piles that are driven into the soil to guarantee support for the load, the following were used:

- ➔ piledriving by driving: the pre-molded concrete pile is driven into the soil by a piledriver;
- ➔ piledriving by excavation: a pile-shaped mold is dug into the ground and then cemented “in loco”.

Given that approximately 8600 piles will be used in the works, one may get a notion of how many times the piling operation will be carried out. The main precaution that must be taken in the piling operation is to guarantee that there are no electric cables, optical fiber cables and live subterranean lines where the operation will be carried out. When it is suspected that there are electric cables, optical fiber cables and live subterranean lines that have not been properly identified a manual survey should be carried out. One way of detecting these lines is by using equipment that generates magnetic fields covering depths varying from 1 to 1,5 meters. The trench method is used to analyze deeper layers. First, a 1,5-meter layer is analyzed and then a 1-meter trench is dug and the equipment is used again.

Before excavation works begin, it is important to check for site interference, and guidelines about the possibility of unidentified site interference should be given to all machine operators and personnel involved in the operation. This interference refers both to electric cables, optical fiber cables and subterranean lines as well as finding contaminated soil. When there is suspicion that the soil is contaminated, an analysis of this soil should be carried out and the excavation works on this site should be interrupted. During the analysis period, the site should be cordoned off and the material that has already been removed should be stored in an appropriate place.

In the piledriving operation, one possible interference comes from the influence pile driving equipment will have on equipment instrumentation systems and electrical systems (pumps, compressors, generators, etc.), due to vibrations caused by the piledriving equipment.

The armed concrete structures to be used in the works should be built according to norms established by the company and may be molded on-site or be pre-molded, according to executive project specifications. Bases for equipment should be molded on-site. The pre-molded structures will be transported by munck cranes and will be assembled with the aid of cranes. Hazards in this operation are the same as in any hauling operation using cranes like, for example, equipment falling on people, structures and pipelines. Regarding parts that will be molded on site, the main risk is cementing in the wrong place and affecting people. Given the complexity of this operation, the company demands that all contracted companies submit operation procedures and an analysis of the risks involved in the expansion works.

Works at heights in the expansion works demand a safety system that is efficient for both the actual work and possible rescues at heights, as there will be over 100-meter high scaffolding.

Setting up scaffolding is an activity that requires countless safeguards, as there are lots of associated hazards. Among which, people falling, scaffolding collapse and falling of pipes or other objects that could injure people or damage structure should be highlighted and, besides sudden illness or accident with scaffolding builder requiring rescue at heights. It is important to point out that legislation concerning works with the use of scaffolding is well documented and set out within Brazilian norms. Two Brazilian norms within which these works are regulated are NBR 6494 and NBR 7678 may be cited.

Another concern that the contracted companies will have to observe are some typical jobs, forbidden by norms, that are carried out during scaffold mounting, known in Brazil as "Chita Monkey" and "Ant Work". The "Chita Monkey" work consists of the builders climbing up the scaffolding without following safety procedures recommended by the norms, while the "Ant Work" consists of equipment or parts for the work fronts being taken up without using elevators, parts are taken up by passing from hand to hand until reaching the desired height.

The contracted companies will have to take special care with work at heights inside units that are operating. Some of the difficulties the workers will face are the hot pipelines that will make the work much harder. Apart from the pipelines, there are cables that supply energy for the units electrical systems.

As we are dealing with great heights, other preventive safeguards will have to be taken, wind and weather variables have a big influence when scaffolding works are being carried out. During works carried out at the refinery previously, one of the measures adopted, which was suggested by the workers, was that the use of a safety harness with two straps should be adopted as a norm by the scaffolding workers.

Among accidents that have been recorded at the refinery, the crash between a crane and high-voltage cables stands out. Taking this incident into account special care should be taken when working with cranes, as there are several points inside the refinery where high-voltage cables cross roads and avenues.

Regarding cargo hauling, hauling using munck cranes as well as non-retractable jib cranes were taken into account. In the operation using munck cranes, special attention should be given to training workers and signs, as the most frequent accident was caused by the fact that the operating assistant has not been adequately trained to carry out the operation.

Usually, the greatest difficulty in handling spools is the lack of storage space. This leads to having big stacks of spools in the storage area which could cause accidents when they are moved. The same problem occurs when storing pipes. Given that this is a large-scale work, there will be a great number of pipe sections, which will interfere with storage. A measure that is normally taken in works of this size is not to store spools and pipes on the work fronts.

Safety requirements for welding depend on three factors: the inherent conditions of welding operations, the peculiarities of the materials to be welded and the characteristics of the equipment or structure, whose making or assembling require welding. In welding and gammagraphy operations, canisters of acetylene and radioactive sources are present and this requires extra special safeguards as they are materials that could cause serious accidents. The internal norm of the refinery referring to radioactive sources says that the maximum source allowed to enter the refinery is 20 Ci. In cutting and grinding jobs, the main concern will be small fragments that could come loose from equipment normally used for this purpose, such as sanding machines, manual or portable machines, etc.

Among ambient conditions required to carry out safe welding operations are: they should not be carried out when the surface of the part is damp or if the surface temperature is below +15°C, the dampness should be removed from the parts by drying with a flame: if the temperature of the part is below +15, the operation may be carried out as long as the region to be welded is heated to at least +50°C; welding should not be done in the rain, when there are strong winds or dust from abrasive sprays, except when the joint is protected and for all welding operations, protection measures should be used to avoid gusts of wind that could alter welding conditions.

During assembly, provisional supports should be foreseen, so that the line does not undergo any exaggerated tension, and does not transmit big efforts that were unforeseen in the project for the equipment, even for short periods. Anchoring should only be done after finishing assembling, aligning and leveling works and, before the pressure test.

Many workers are necessary for the coupling of large pipes ("stail") operation to be carried out, thereby, increasing the effects of an accident. Another relevant factor in the coupling of large pipes operation is the placing of support frames under the pipeline. There are two types of support frames: normal, where the support frame is built and afterwards the piping is laid; bipartite, where the pipes are coupled first and only then is the support frame built so that it eases tensions.

Hydrostatic tests are carried out in pipelines and large equipment to test the resistance of the installation under project conditions. The great danger of this test is pipeline or equipment rupture, which could cause catastrophic effects. The decompression phase of pipelines and equipment could also represent an accident scenario. The internal norm of the refinery for this type of operation contains an item referring to the pressure tests containing relevant observations and recommendations which should be strictly followed. It ought also to be highlighted that before testing all necessary safety measures should be taken, mainly in places that due to their location represent in case of failure, danger for personnel or in adjacent installations.

The last phase to be considered refers to painting and finishing services whose main hazards are the generation of flammable clouds that could cause fires or even explosions.

It is important to highlight that the transportation and unloading of heavy equipment should be done very carefully, and done by a team that is specialized in performing this type of operation. For the operation to be carried out, it is necessary to have, for example, an engineer with at least 10 years experience in cargo hauling, a supervisor with at least 10 years experience in assembling equipment in industrial plants and safety technicians with at least five years experience.

The main risks involved in transporting heavy equipment are the sinking of the road surface, interrupting traffic, and excessive width or height of the part with regards to the road that is being used. Concerning unloading of heavy equipment, the risks are inherent to the cargo hauling process with jib crashes against the structure, crane toppling, among others. On routes that have been mapped out for the heavy equipment to go along there are some risks like overpasses above pipeline carrying products, passing near a liquid petroleum gas (LPG) sending source. An important recommendation is to check in the Cargo Transporting Plan if it foresees any difficulties regarding the presence of agents that could impede passage, such as: lampposts, electric cables, lookouts, fire escapes and fire combating equipment.

The PRA was applied to different activities and worksheets were filled in for: a) construction and assembly, b) areas/activities involving building works (land leveling, piledriving, foundations, etc,) c) pipelines/boilers, d) works at heights, and e) transporting and unloading heavy equipment. Different worksheets were filled in for works to be carried outside the area the refinery is currently operating in and works that have been foreseen to be carried out in the actual processing area.

The focus was more on accidents that are not typically dealt with in the Regulation Norms (RNs defined in the Ministry of Labor's Directive n# 3.214, of 8/6/1978) and the work resulted in the identification of 265 accident scenarios and 397 recommendations. In the following preliminary analysis worksheets are examples of worksheets that were filled in.

| Preliminary Risk Analysis (PRA) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **System: Pipelines and Boilers - On-Site** | | | **Supervisor: César Leal** | | | **Date: 06/11/01** | | **6/22** |
| **APP Team: NORTES – UFRGS and Refinery** | | | | | | | **Review: 0** | |
| ***Hazard*** | ***Causes*** | ***Detection methods*** | ***Effects*** | ***Frequency Category*** | ***Magnitude Category*** | ***Risk Cat.*** | ***Recommendations/Observations*** | ***Scenario*** |
| Hauling heavy equipment with cranes | - Human error<br>- Operating error<br>- Low ground resistance to haul weight<br>- Underestimating steel cable and/or machine<br>- Rupture due to lack of maintenance and inspection of steel cables, joints, support points (lifting hooks) and articulations in the jib.<br>- Inadequate joints<br>- Rigging plan error. | Visual | Damage or death of people through fall of parts | **B** | **III** | **2** | R25) Hauling with cranes operations should be accompanied by trained riggers who are capable of carrying out such operations.<br>R26) Hauling with cranes operations require rigging plans to be drawn up.<br>R27) Check whether rigging plan requires the area to be cordoning off.<br>R28) Guarantee quality of assembly and appropriate sign posting for hauling of parts operation.<br>R29) All hauling with cranes operations should be carried out extremely carefully.<br>R30) Check if the WRC (Works' Risk Checklist) is adequate for the work to be carried out.<br>R31) A visual inspection should be made of crane parts such as hooks, joints and, mainly, parts' supports.<br>R32) Check if sign posting is right for the crane.<br>R33) Demand experience, foreseen in the contract, of operators for crane operations.<br>R34) It is recommended that crane transport is adequately planned so as not to allow unforeseen movements. | 12 |

**Preliminary Risk Analysis (PRA)**

**System: Pipelines and Boilers - On-Site** **Supervisor: César Leal** **Date: 06/11/01** 

**APP Team: NORTES – UFRGS and Refinery** **Review: 0**

| *Hazard* | *Causes* | *Detection methods* | *Effects* | *Frequency Category* | *Magnitude Category* | *Risk Category* | *Recommendations/Observations* | *Scenario* |
|---|---|---|---|---|---|---|---|---|
| | | | Damage to hauled part caused by crash or fall | **B** | **I** | **1** | R25) Hauling with cranes operations should be accompanied by trained riggers who are capable of carrying out such operations.<br>R26) Hauling with cranes operations require rigging plans to be drawn up.<br>R27) Check whether cordoning off the area is required in the rigging plan.<br>R32) Check if sign posting is right for the crane.<br>R33) Demand experience, foreseen in the contract, of operators for crane operations.<br>R34) It is recommended that crane transport is adequately planned so as not to allow unforeseen movements.<br>R35) It is recommended to draw up a Plan of Works to be Carried Out. | 13 |
| | | | Damage to equipment or structures caused by crash or fall | **B** | **II** | **1** | R25) Hauling with cranes operations should be accompanied by trained riggers who are capable of carrying out such operations.<br>R26) Hauling with cranes operations require rigging plans to be drawn up.<br>R27) Check whether cordoning off the area is required in the rigging plan.<br>R32) Check if sign posting is right for the crane.<br>R33) Demand experience, foreseen in the contract, of operators for crane operations.<br>R34) It is recommended that crane transport is adequately planned so as not to allow unforeseen movements.<br>R36) Use of cranes is restricted to hauling cargo and should not be used to transport it. | 14 |

| Preliminary Risk Analysis (PRA) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| System: Pipelines and Boilers - On-Site | | | | Supervisor: César Leal | | Date: 06/11/01 | | 8/22 |
| APP Team: NORTES – UFRGS and Refinery | | | | | | | Review: 0 | |
| ***Hazard*** | ***Causes*** | ***Detection methods*** | ***Effects*** | ***Frequency Category*** | ***Magnitude Category*** | ***Risk Category*** | ***Recommendations/Observations*** | ***Scenario*** |
| | | | Toppling of crane with cargo. | **C** | **II** | **2** | R25) Hauling with cranes operations should be accompanied by trained riggers who are capable of carrying out such operations.<br>R26) Hauling with cranes operations require rigging plans to be drawn up.<br>R27) Check whether cordoning off the area is required in the rigging plan.<br>R32) Check if sign posting is right for the crane.<br>R33) Demand experience, foreseen in the contract, of operators for crane operations.<br>R34) It is recommended that crane transport is adequately planned so as not to allow unforeseen movements.<br>R32) Check if sign posting is right for the rig.<br>R36) Use of cranes is restricted to hauling cargo and should not be used to transport it.<br>R37) Check whether to be used crane is suitable for cargo to be hauled. | 15 |

## 4. Conclusions

One of the most popular risk identification techniques - the Preliminary Risk Analysis, and its application to a set of activities that are part of expansion works in a refinery was described in this work. Traditionally PRA is used to identify accident scenarios in process industries, it is not often used in areas like civil construction, for example. But, in the case under study, given that the expansion works are being carried out while the refinery is operating, increased safety of the works through using a technique that naturally recommends these types of measures was sought.

This work has only covered part of the activities within which 265 accident scenarios were identified and 397 recommendations were made. The simple fact of carrying out this type of analysis, gathering specialists from several areas, with experience in the activities to be carried out, where accident scenarios are identified and suggestions are made to improve safety, could make a considerable difference. The cost of this type of analysis is much less than possible accident costs, even small-scale ones.

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