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Risk Analysis in Stations of Pumping and Compression

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Abstract

There are three models of analyze of risk in pumping and compression stations: matrix, probabilistic, and indexing models. The most popular station and surface facilities risk assessment technique in current use is the index model. In this approach, numerical values are assigned to important conditions and activities on the pumping station that contribute to the risk picture. Each compression/pumping station is scored based on all of its attributes. The article presents the achievement of a model for analyze of risk finalized in a Matlab program, which calculates the relative risk for a pumping/compression station.

Key words: *noise, vibration, compressor, attenuator, numerical simulation.*

Introduction

Reliability engineering have two major objectives: preventing catastrophic failures of critical plant production systems and avoiding deviations from acceptable performance levels that result in personal injury, environmental impact, capacity loss, or poor product quality. For the risk assessment of a station of gas compression or pumping, there are known three general types of models: matrix, probabilistic, and indexing models.

One of the simplest risk assessment structures is a decision analysis matrix. It ranks station risks according to the likelihood and the potential consequences of an event by a simple scale, such as inacceptable, high, medium, low, or insignificant, or a numerical scale. Each threat is assigned to a cell of the matrix based on its perceived likelihood and perceived consequence. This approach cannot consider all important factors and their relationships.

The most rigorous and complex risk assessment model is a modeling approach commonly referred to as probabilistic risk assessment (PRA). This technique is used in the nuclear, chemical, and aerospace industries and in the petrochemical industry [2-5]. PRA is a rigorous mathematical technique that relies heavily on historical failure data and event-tree fault-tree analyses. Initiating events such as equipment failure and safety system malfunction are flowcharted forward to all possible concluding events, with probabilities being assigned to each branch along the way. Final accident probabilities are achieved by chaining the estimated probabilities of individual events. The disadvantages of that model are: more costly than other risk assessments; it requires trained operators; it had to use a computer and specialized programs; it needs extensive data, and in rare-event occurrences, the method is hard to apply [7,8].

The most spread technique of stations of pumping risk assessment in current use is the index model [6]. In this approach, numerical values are assigned to important conditions and activities on the station that contribute to the risk image. Among station operators today, this technique is widely used and ranges from a few factors model to models with hundreds of factors [2,4]. The indexing approach is especially used for several reasons:

- Provides immediate answers;
- Is a low-cost analysis;
- Is an intuitive approach using available data;
- Its comprehensive allows for incomplete knowledge;
- Acts as a decision support tool for resource allocation;
- Identifies and places values on risk mitigation opportunities.

An indexing-type model for station risk assessment is an important feature of a pipeline risk management program.

The quantification with the index method

The basic components of the risk score for any station facility could have the items showed in table 1. The external forces index assesses risks from possible outside forces related to: traffic; weather; successive reactions. The potential for damage by outside force increases with increasing activity levels, which include the type, frequency, intensity, complexity, and urgency of station activities. This also includes the qualifications of personnel who are active in the station, weather conditions, lighting, third-party access, traffic barriers, security, and a third-party awareness/damage prevention program.

Table 1. The basic components of the risk score for pumping and compression stations

External Forces Index	**Corrosion Index**	**Design Index**	**Incorrect Operations Index**	**Leak Impact Factor (LIF)**
A. Traffic	A. Atmospheric Corrosion	A. Safety Factor	A. Design	A. Product Hazard
B. Weather	B. Internal Corrosion	B. Fatigue	B. Construction	B. Spill Size
C. Successive Reactions	C. Subsurface Corrosion	C. Surge Potential	C. Operations	C. Dispersion
		D. Integrity Verification	D. Maintenance	D. Receptors
		E. Land Movements		
[Index Sum] = [External Forces] + [Corrosion] +[Design] + [Incorrect Operations]				
[Relative Risk] = [Index Sum] / [LIF]				
Observation: an additional adjustment factor, to take into account the relative size and complexity of a station, is recommended to adjust the index sum.				

Vehicle impact against some facility component is a threat. The type of vehicular traffic, the frequency, and the speed of those vehicles determine the level of threat. Use of signs, curbs, barriers, supervising personnel, operations by personnel unfamiliar with the station, lighting, etc. are included in the evaluation [2,4]. With closer facility spacing, larger surface areas, and poor traffic control, the potential for damage increases. The threat associated with meteorological events is the second factor of external forces index. Events such as a wind, storm, tornado, hurricane, lightning, freezing, hail, wave action, snow, and ice loadings should be considered. The earth movements such as earthquakes and landslides are considered in the design index. The third factor of external forces index is the threat associated with one portion of the facility or a neighboring facility, causing damage to another portion of the facility. Examples include vessels containing flammable materials that, on accidental release and ignition, can cause flame impingement or explosion overpressure damages to adjacent components of the facility [4].

In the station of compression model, corrosion potential is assessed in the three categories of atmospheric, internal, and subsurface. Atmospheric corrosion potential is a function of facility design, environment, coating systems, and preventive maintenance practices. Industrial and marine environments are considered to be the most severe for atmospheric corrosion, whereas inland dry climates are often the least severe [5]. During normal operations, station facilities are generally exposed to the internal corrosion potential. Certain facilities can be exposed to corrosive materials in higher concentrations and for longer durations. Sections of station piping, equipment, and vessels can be isolated for weeks or even years. The lack of product flow through these isolated sections can allow internal corrosion cells to remain active [1]. Also, certain product additive and waste collection systems can also concentrate corrosion promoting compounds in station systems designed to transport products within line pipe specifications. In some older buried metal station facility designs, little or no corrosion prevention provisions were included. If the station facilities were constructed during a time when corrosion prevention was not undertaken, or added after several years, then one would expect a history of corrosion-caused leaks.

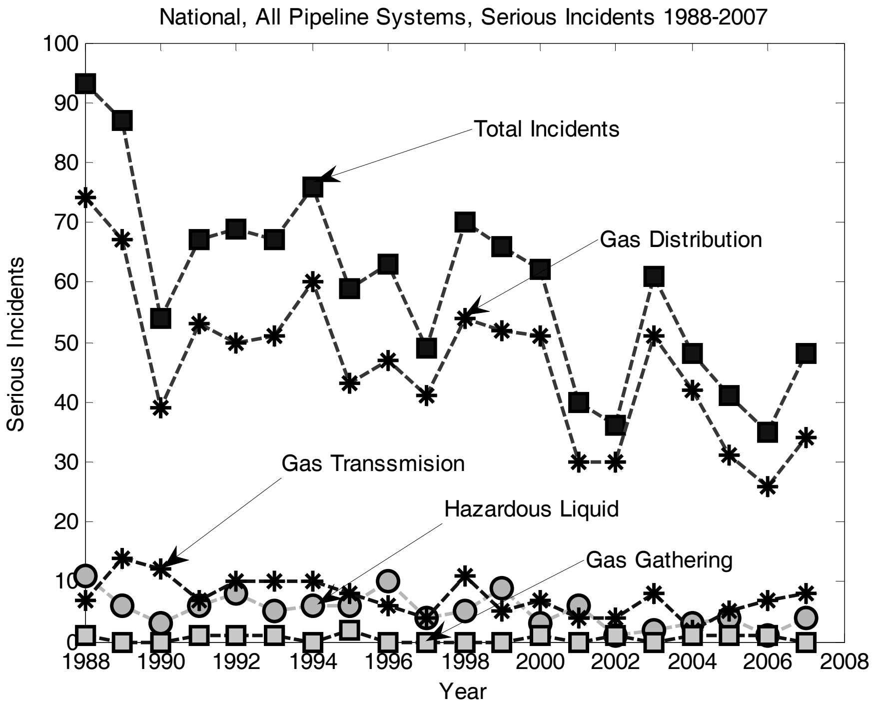

Fig. 1. Serious incident in U.S.A. pipeline system, between 1988 – 2007.

The design index is a collection of failure mechanisms and mitigations related to original design conditions. The main variables included into the design index are showed also in table 1. In scoring the safe factor, the evaluator should take into account material differences and other pipe design factors peculiar to station facilities. The stress level of a component, measured as a percentage of maximum allowable stress or pressure, shows how much margin exists between normal operating levels and component maximum stress levels. At stress levels close to absolute tolerances, unknown material defects or unanticipated additional stresses can easily result in component failure. Fatigue is one of the most common failure mechanisms in steel [7]. The threat is reduced as cycle frequency or magnitude is reduced. Common causes of fatigue on equipment include loading cycles from traffic, wind loadings, harmonics in piping, rotating equipment, pressure cycles, temperature cycles, and ground freezing. As further measure of potential fatigue loadings, sources of vibration can be assessed. Common practices to minimize vibration effects include careful attention to equipment supports, pulsation dampers, and the use of high ductility materials operating far from their maximum stress levels [1].

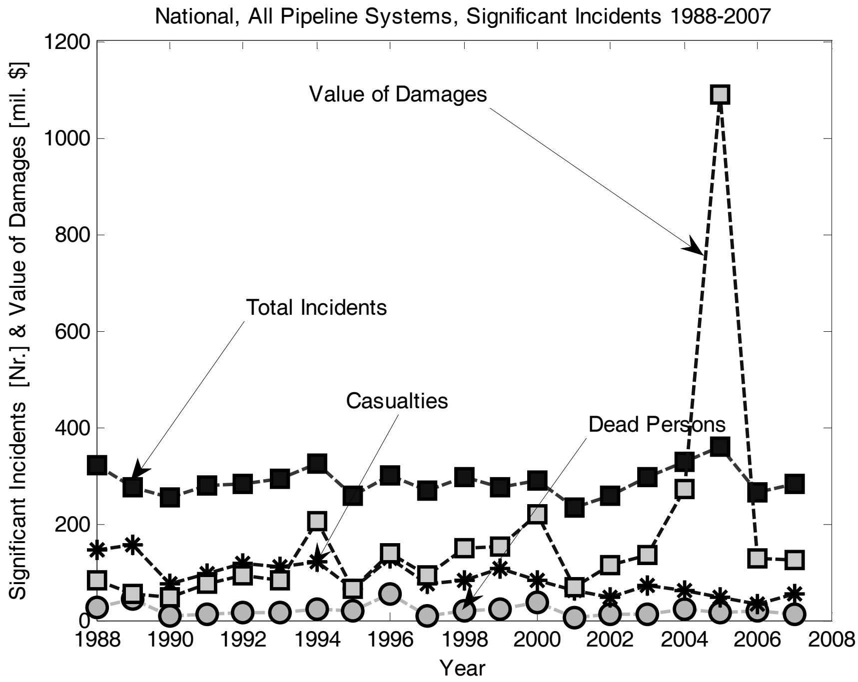

Fig. 2. Significant incident in U.S.A. pipeline system, between 1988 – 2007.

Human error is a significant factor to consider when scoring risk at a pipeline station [2,3]. Human error is often the true root cause of facility failures when one considers that proper design, construction, testing, operations, inspection, and maintenance should prevent almost all equipment and product containment integrity failures. A station environment provides many more opportunities for human error but also provides more chances to interrupt an accident sequence through mitigation measures to avoid human error. With safety systems the risk is reduced as safety systems are able to reliably take independent action-without human intervention to prevent or minimize releases. Safety systems which close valves, stop pumps, and/or isolate equipment automatically in extreme conditions are very efficient. Modern safety systems include warning alarms which are sent to a monitored control center. Also valuable is the ability of a manned control center to remotely activate isolation and shutdowns to minimize damages. Safety system actions that provide increasing station facility overpressure protection include equipment shutdown, equipment isolation, equipment lock-out, station isolation, station lock-out, and full capacity relief. A SCADA system allows remote monitoring and some control functions, normally from a central location, such as a control center. Standard industry practice seems to be 24-hours-per-day monitoring of critical data with audible and visible indicators set for abnormal conditions [6]. At a minimum, control center operators should have the ability to safely shut down critical equipment remotely when abnormal conditions are seen. A comprehensive and effective "procedures program" effort should capture all current station facility design, construction, maintenance, operations, testing, emergency response, and management related procedures.

The potential consequences from a station spill or release are included in leak impact factor. A spill or leak size in any scenario is a function of many factors such as the failure mechanism, facility design, product characteristics, and surrounding environment. Smaller leak rates tend to occur due to corrosion (pinholes) or design (mechanical connections) failure modes. The most damaging leaks at station facilities may be small leaks persisting below detection levels for long periods of time. Larger leak rates tend to occur under catastrophic failures such as external force equipment impact, ground movement, and avalanche crack failures [4].

The achievement of a program based on the index model

The model described shortly above, includes many variables. For example the design factor might include: safety system utilization; safety system adequate review; material cyclic stress; pressure test stress; vibration monitoring; safety system duplication; safety system actions; housekeeping; anti-freeze-program [1]. Some of these variables include also elements which have to be count. A program that uses the index model is useful to appreciate the relative risk into a compression/pumping station. A release of a program of risk assessment was achieved in Matlab. It was tested during the postgraduate courses with TRANSGAZ S.A. Romania personal. Some positive results indicated by: the difference between a new (modern) station and a old one; the importance of safety system in relative risk score; the influence of complexity of station; close results of relative risk coefficient for similar stations. There are too many negative aspects: the overlapping of variables; a lack of variables; the absence of many data to realize a trust evaluation. However, the evaluation of relative risk in pumping/compression station is an important aspect of a pipeline management. The objective is the continuous reduction of accidents, in a system which grows annually. A good element of comparison is the statistic situation in U.S.A. showed in figures 1 and 2, which indicates a slowdown of frequency of incidents, due the technical means and adequate procedures used in gas and liquid transport.

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Analiza riscului în staţiile de pompare şi comprimare

Rezumat

Sunt trei modele de analiză a riscului în staţiile de pompare şi comprimare: matricial, probabilistic şi al coeficienţilor de importanţă. Cel mai cunoscut model este cel al coeficienţilor de importanţă. Potrivit acestui model sunt atribuite valori numerice celor mai importante condiţii şi activităţi din staţia de pompare, ce contribuie la imaginea de risc. Fiecare staţie de comprimare - pompare este clasificată printr-un punctaj care ţine seama de toate atributele sale. Articolul prezintă realizarea unui model de evaluare a riscului finalizat într-un program în mediul de programare Matlab, care calculează riscul relativ pentru o staţie de pompare/comprimare.