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3.4. Condition measurement

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Condition measurement involves at least two measurements: the measurement of physical conditions and the measurement of risk.

The measurement of physical conditions is done through visual observation using checklists describing the items to be observed. The observation provides a numerical value indicating the hardware conditions found to be in good order.

The measurement of risk follows the risk ranking method used with DNV's risk-based inspection activities. Risks are calculated per equipment item and expressed as a combination of damage area (consequence) and likelihood of occurrence. Cumulative figures can be arrived at to indicate the “risk level” of a plant or a part thereof.

3.4.1 A conceptual view on condition measurement

Hardware conditions are the end results of many activities in the organization, which are part of the management system. Such activities include:

- hazard analysis;
- design of workplace and installations;
- maintenance and inspection;
- management of change;
- review of legislation, industry codes and standards;
- employee training;
- management leadership and supervision;
- purchasing of goods and materials.

Condition measurement is a means to:

- uncover initial design oversights;
- find deviations from original design specifications which may have been introduced through modifications;
- establish conformance with codes, standards and industry practices.

The measurement of (hardware) conditions and risks is mainly focused on the determination of the effectiveness of management system activities. As these activities are directed at eliminating and controlling substandard hardware conditions and related risks (so that losses will be controlled at a desired level), the measurement of those conditions and their risks can be seen as an indicator for the effectiveness of the “upstream” control system.

There is also a secondary purpose associated with the measurement of (hardware) conditions and risks, namely the determination of substandard conditions for correction. Although condition measurement is not really intended to be an “inspection” in order to generate items for correction, it is only natural that at least part of the non-conformities noted during the evaluation are corrected.

In this section, two methods for condition measurement are discussed: evaluation of physical conditions and risk-based measurement (risk-based inspection).

3.4.2 Evaluation of physical conditions

The evaluation of physical conditions is based on the process of carrying out observations, which are directed at hardware conditions and intended to determine whether or not the items observed comply with established criteria. The result is a comparison between the total number of observations and the number found to be in compliance. The end result is a ratio indicating the effectiveness of the upstream control activities. Under ideal circumstances all items observed should be in compliance and a 100/100 ratio will exist.

In order to rank the items observed relative to each other, they are normally grouped together in categories and provided with a value factor depending on the possible consequences of non-compliance. This is indicated in Table 3.5. The “risk score” is calculated per category, using the compliance ratio and the category value factor.

Measurement of physical conditions

Measurement in the context of physical conditions evaluation is done using a form such as that shown in Table 3.5. On this form the items to be observed are listed, whereas “what to look for” is provided through more extensive checklists. Compliance requirements IR included in those checklists and can be as detailed as deemed necessary. This type of observation can be carried out by people with varying experience and qualifications, depending on the purpose of the evaluation as well as on the issues/items being observed. The frequency of these evaluations depends on the purpose. More general aspects may be evaluated more frequently (as part of regular management system effectiveness evaluation), whereas detailed compliance evaluations (comparing conditions with codes, standards, etc) may be done less of ten.

Table 3.5 *Form for physical conditions evaluation*

CATEGORY/ITEM	NUMBER OBSERVED	NUMBER NOT IN COMPLIANCE	VALUE FACTOR	RISK SCORE
A. *General workplace conditions*			10	
3. Platforms/scaffolding				
8. Ventilation				
C. *Materials*			20	
12. Stacking and storage				
15. Waste disposal				
D. *Equipment*			25	
19. Lifting gear and equipment				
24. Hydraulic power systems				
F. *Emergency systems*			15	
34. Fire protection systems				
TOTAL			100	68

Analysis of physical conditions measurement results

The results of the condition measurements can be used as follows:

- as a measurement of the upstream (management system) activity effectiveness;
- over a period of time to compare an entire site or units on the site with itself or with each other. Progress as well as deterioration can be measured;
- as an indication of the level of compliance with codes, standards, etc, depending on the purpose for which the evaluation was made.

Follow-up on physical conditions measurement

The results of an evaluation of physical conditions may be seen as an “end-of-pipe” indicator. Depending on the levels set by management, the results may trigger further analysis of the causes of deterioration and initiate further upstream problem solving and action. The results of the evaluation can also lead to corrective actions.

3.4.3 Risk-based inspection

The performance indicator here is based on the risk calculation and ranking method that is part of the risk-based inspection (RBI) approach of DNV. This approach uses risk assessment techniques in decision management concerning asset integrity. DNV has been active in this field for several years and has developed a method for the American Petroleum Institute, shortly to be issued as the Recommended Practice on Risk-Based Inspection. DNV has also developed RBI software to assist in the process, and allow “what-if” studies to be carried out. These studies can be carried out not only on existing plants (in order to optimize inspection and maintenance activities), but also for major modifications and when designing new plants. In the latter case the software is being used to arrive at a best “risk picture”, looking at a variety of mitigating measures.

The RBI process comprises an assessment of the hazards and risks involved with each piece of process equipment, leading to a specification of appropriate inspection methods and frequencies as well as other risk-reduction actions.

The risk calculation and ranking activities inc1ude the following factors:

- generic failure data of the equipment type under consideration;
- an equipment modification factor.

In addition to these two factors, a third aspect may be added:

- a management system modification factor.

RBl risk measurement

For the risk calculation and ranking, the likelihood and consequence are calculated and expressed in matrix form.

Assessment of the likelihood of failure is carried out by using a maximum of three aspects:

- generic failure data, obtained from data bases for equipment/installation items like centrifugal pumps, columns, filters, heat exchangers, piping, pressure vessels and storage tanks.

- an equipment modification factor in which aspects as listed in Table 3.6 are considered;
- a management system modification factor, based on API 750 and in which elements as listed in Table 3.7 are considered.

Table 3.6 *RBI equipment modification factor: elements/aspects to be considered*

TECHNICAL MODULE SUBFACTOR	MECHANICAL SUBFACTOR
Damage rate	Equipment complexity
Inspection effectiveness	Construction code
UNIVERSAL SUBFACTOR	Life cycle
Plant condition	Safety factors
Cold weather	Vibration monitoring
Seismic activity	**PROCESS SUBFACTOR**
	Continuity
	Stability
	Relief valves

The consequence of failure is determined from an estimation of the potential inventory release rate and the effects of mitigating systems. In principle, four consequence areas may be considered: flammability/explosion, toxicity, environmental damage and business interruption. From these, a consequence category is determined per equipment type or item and ranked from low (A) to high (E), as indicated in Figure 3.10.

Table 3.7 *RBl management system modification factor: elements to be considered*

1. Leadership and administration
2. Process safety information
3. Process hazard analysis
4. Management of change
5. Operating procedures
6. Safe work practices
7. Training
8. Mechanical integrity
9. Pre-startup safety review
10. Emergency response
11. Incident investigation
12. Contractors
13. Assessments

On the basis of the likelihood and consequence factors, the risk level for each equipment item can be determined from the matrix and items can be ranked according to their risk. Using this method, inspection extent and frequency can be optimized by directing attention to those items requiring it, and inspection techniques may be selected on the basis of the damage mechanism established. This usually results in reduced inspection time and increased inspection intervals, which leads to increased plant availability.

Plant safety and risk management can be improved by using the results of the risk assessment and ranking method. The risk assessment per equipment item may reveal those items requiring attention, whereas other, low-risk items may be “ignored”.

Analysis of RBI risk measurement results

The matrix presented in Figure 3.11 provides the results of an RBI study in a petro-chemical unit with more than 450 equipment items. The matrix is a risk indicator: the greater the number of items found in the upper right-hand corner, the greater the risk within the installation.

The results of the risk calculation and ranking can be used:

- as an indicator of the risk level of the installation;
- to establish the effects of risk mitigation measures;
- to compare units and processes on the basis of risk;
- to trend the risk development of a unit over time and during its life cycle.

Follow-up on RBI risk measurement

The follow-up on the risk calculation and ranking (with the risk matrix as a “performance indicator”) obviously depends on the results as represented in the matrix. Depending on the risk level or distribution set by management, actions may be taken to reduce risk further.

Given a favourable picture, the RBI risk calculation and ranking may result in optimization of inspection and maintenance activities. Thus, attention may be given to equipment in need of it, while equipment with less risk gets less attention.

The risk of items with a high consequence factor and a low likelihood rating cannot be decreased by management systems but only by technical solutions - for example, by reducing the maximum inventory associated with one single loss-of-containment incident.

The risk matrix and related software allows further analysis to estimate risk development over time - for example, when nothing is done and the installation is run without any particular inspection or maintenance activity. At the same time the influence on risk of introducing certain risk-mitigating measures can be analyzed.

Besides providing a “risk indicator”, DNV risk-based inspection offers an auditable and transparent method developed for the process industries. It can lead to a reduced equipment failure rate, reduced inspection time and increased plant availability, and thus result in increased profitability.

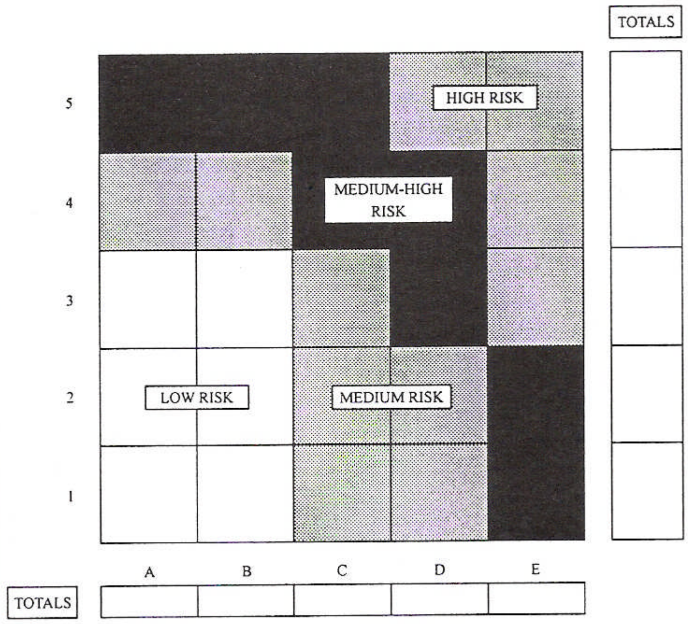

Figure 3.10 *Risk matrix*

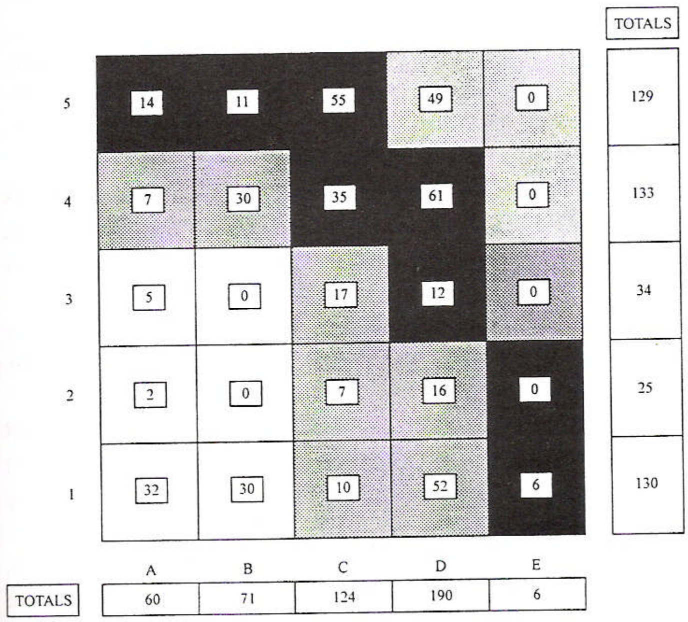

Figure 3.11 *Risk matrix — example from RBI study*