Risk-Based Asset Condition Monitoring Using World Best Practice Sampling Methods

By Peter Mills: February 2015

An international best-practice trend among large scale asset owners/operators is to adopt a risk-based approach to maintenance activities. This article describes how internationally published acceptance-sampling-by-attributes methods (ISO 2859.1) can be used to design a highly effective and efficient risk-based asset condition monitoring system.

Asset Condition Auditing

Asset condition monitoring auditing provides asset owners/operators reliable information on the condition of complex assets, without having to undertake costly and time-consuming 100% inspection.

According to the Australian Asset Management Collaborative Group (AAMCoG);

> *"An audit of a complex asset is normally carried out by assessing an asset's individual elements. Elements are inspected and their actual condition relative to the desired condition standards is then reported in detail. Any deficiencies in asset condition, together with the associated risks, can then be evaluated".* [1]

When matched with an effective preventative maintenance program, asset auditing can substantially reduce condition monitoring costs and lead to a significant reductions in long-term OPEX and CAPEX.

Risk-Based Inspection

One of the most significant advancements in asset condition auditing over recent years is the move to risk-based inspection (RBI).[2] The purpose of RBI is to optimise the asset management process by prioritising asset inspections in accordance with assessed risk levels.

RBI normally involves an initial risk analysis of potential degradation mechanisms and threats to the integrity of the asset. Risk rankings are then used to develop a prioritised audit plan that targets individual asset components within appropriate inspection intervals.

The American Petroleum Institute (API) is at the forefront of RBI and recommends that an effective RBI should provide one of the following: [3]

a) *overall reduction in risk for the facilities and equipment assessed,*
b) *acceptance/understanding of the current risk.*

It also points out that an effective RBI;

> *"Often results in a significant reduction in the amount of inspection data that is collected. This focus on a smaller set of data should result in more accurate information. In some cases, in addition to risk reductions and process safety improvements, RBI plans may result in cost reductions".*

[1] AAMCoG Best Practice in Integrated Engineering Asset Management (Draft) 2008
[2] Inspection is sometimes used as a synonym for audit and is used interchangeably in this article
[3] American Petroleum Institute, Risk-Based Inspection, Recommended Practice, Second Edition, 2009

And that;

"Compared with a typical inspection program a risk-based approach should lead to a reduction in overall risk levels with increases in inspection frequency"; refer Figure 1.

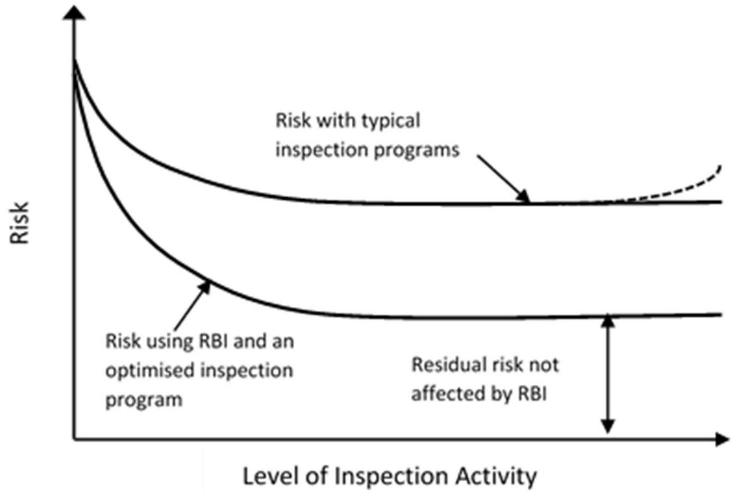

Figure 1: Management of Risk Using RBI [3]

Common Weaknesses

While risk-based inspection can be a very powerful asset condition monitoring tool many systems fail to operate at maximum efficiency because of problems with the timeliness and reliability of generated data.[4]

To effectively predict the likelihood of asset failure a risk-based inspection system needs some form of quantitative or semi-quantitative analysis capability. Without it, the accuracy of the audit result remains unknown, and can vary from inspection to inspection. A situation which can often lead to suboptimal decision making or worse still, no decision making at all.

This lack of scientific rigor also significantly diminishes management's ability to reliably assess and compare asset performance across different asset elements, plants and geographic locations.

There is a proven scientific inspection methodology that can help asset owners/operators significantly optimise the efficiency and effectiveness of their current risk-based inspection systems. It can also make RBI more affordable for organisations looking to establish a system for the first time. This is called acceptance sampling.

Acceptance Sampling

There are many types of acceptance sampling but arguably the most popular and easiest to understand is the International Organisation of Standardisation ISO 2859.1: Sampling procedures for inspection by attributes.[5]

Initially developed as a quality control tool, the statistical methods and tables outlined in the Standard are suited to a wide range of other risk monitoring and control applications, including the continuous monitoring and control of asset risks e.g. safety, environment, economic, security, etc.

[4] R.P.Y. Mehairjan, Q. Zhuang, D. Djairam, J.J Smit; Conference Paper, Upcoming Role of Condition Monitoring in Risk-Based Asset Management for the Power Sector, 8th World Congress on Engineering Asset Management ,2013, (WCEAM), Hong Kong

[5] ISO 2859.1:199 (E) Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection. Duplicate versions of these methods are published by standards bodies worldwide; e.g. AS 1199.1

The Standard's most powerful feature is its ability to assess whether large batches of items have exceeded a user-specified maximum non-compliance limit by examining a much smaller sample.   This maximum non-compliance limit is referred to as the Acceptance Quality Limit (AQL).

This simple yes/no approach to compliance assessment is ideally suited to asset condition monitoring; especially when deciding when best to schedule remedial maintenance and replacement activities.

Another key feature of the Standard is its ability to calculate the optimum sample-size for each audit by taking into consideration, among other things, an asset's recent compliance performance.

In other words, an asset with a "good" compliance history is subjected to a lower level of sampling than an asset which with a "poor" compliance history.

The Standard achieves this functionality by "switching" an asset between three levels of audit severity (i.e. Reduced, Normal and Tightened) based on its capacity to achieve or do better than a specified AQL over previous audits; Refer to Figure 2.

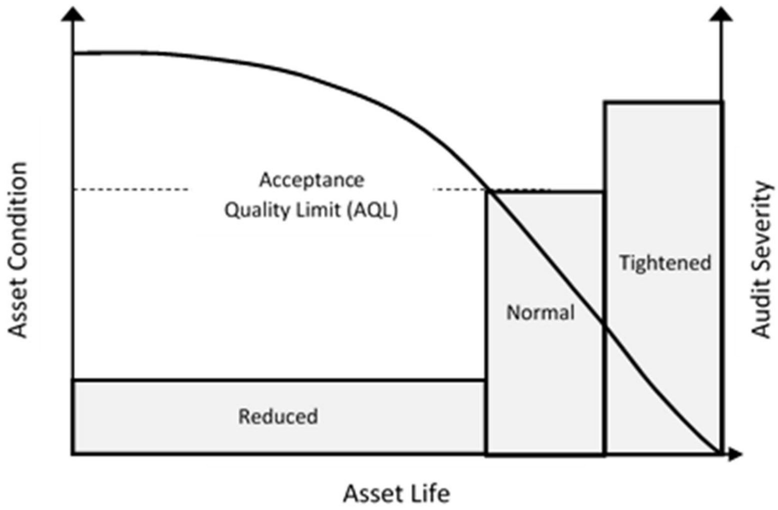

Figure 2: ISO 2859.1 Audit Severity "Switching" Feature [6]

This dynamic, risk-based approach to asset auditing is far more efficient than static non-scientific methods and can deliver significant inspection savings over the life of an asset.

An asset's audit severity rating can also be used to quickly assess and benchmark its performance against other assets, and to trigger maintenance and replacement activities and changes in audit frequency - refer to Defining Action Protocols below.

How it Works for Asset Owners/Operators

This section describes how the acceptance sampling methods outlined in ISO 2859.1 can be used to create a highly efficient and effective risk-based asset condition auditing system.

Defining Condition Metrics

Most asset failure-modes have measurable characteristics that develop over time. Acceptance sampling quantitatively assesses these metrics to systematically evaluate changes in an asset's condition – thereby enabling remedial action to be planned in a cost effective manner.

To undertake acceptance sampling it is important that what is considered normal for individual asset components is clearly defined.

Conduct Risk Assessment

Each failure mode is categorised according to its impact (consequences) on asset performance i.e. High, Medium and Low.

Risks normally considered as part of this assessment process include workplace health and safety, security, functionality, financial impacts (including cost of consequential damage), regulatory and legal exposure.

Defining Risk Category Thresholds

Each risk category is assigned a maximum failure or non-compliance limit i.e. AQL. This limit represents the tolerable non-compliance limit where remedial action is needed to mitigate risks and/or improve asset performance.

The High risk category is normally assigned a smaller AQL that the Medium risk category, which in turn is assigned a smaller AQL than the Low risk category..

Defining Action Protocols

As outlined below in Table 1, action protocols are developed for each possible audit outcome. Protocols might include a range of mitigation measures and/or changes in audit frequency.

Possible Audit Outcomes	Action Protocols (Examples)
1. AQLs not achieved	• Improve maintenance performance
2. AQLs achieved	• No action
3. Severity switch "Reduced-to-Normal"	• Full asset refurbishment • Increase audit frequency 48 to 24 months
4. Severity switch "Normal-to-Tightened"	• Increase audit frequency 24 to 12 months • Asset replacement
5. Severity switch "Normal-to-Reduced"	• Reduce audit frequency 24 to 48 months
6. Severity switch "Tightened-to-Normal"	• Reduce audit frequency 12 to 24 months

Table 1: Example: Linking ISO2859.1 Audit Outcomes to Action Protocols

Defining Audit Frequency

To further optimise monitoring costs an asset's audit frequency can also be tied to its recent compliance performance via its audit-severity-rating i.e. Normal, Tightened or Reduced. In other words, an asset with a "Reduced" audit-severity-rating is audited at a lower frequency than an asset with a "Tightened" audit-severity-rating. Newly constructed or remediated assets are initially assigned a "Reduced" audit-severity-rating.

Over subsequent audits the "switching" rules in the Standard are used to assess the asset's condition and to increase its audit frequency as it approaches and exceeds one or more of the specified AQLs; refer to Figure 2 and Table 1.

Determining Sample-Size

When planning individual audits the total number of asset components being assessed is estimated and used in conjunction with the tables in the Standard (ISO 2859.1) to determine the optimum sample-size i.e. total number of asset components to be audited.

Collecting Audit Data

The required sample-size is randomly selected from the asset population and individually assessed for compliance against defined normal asset conditions. This task normally involves a physical inspection of the asset equipment, sub-systems, assemblies and components - in many cases using specialised tools and equipment.

Any non-compliances are recorded against their respective compliance requirements and associated risk-category.

The audit is concluded once the total number of inspected asset components equals the specified sample-size; no more or no less.

Analysing Results

At the completion of an audit the total number of non-compliances identified against each risk-category is summated and used in conjunction with the tables in the Standard to determine whether its specified non-compliance limit has been exceed; or not. This evaluation is accomplished by comparing the total number of observed non-compliances with the applicable Acceptance Number (Ac); refer to Table 2 for an example.

The “switching” rules in the Standard are then applied to determine whether the asset’s severity rating should be adjusted for the next audit.

Asset Audit Plan			**Audit Outcomes**	
Audit Population (N) = 5,000	Sample Size (n) = 200			
Risk Category	**Max Failure Limit (AQL)**	**Acceptance No. (Ac)**	**Total Recorded Non-Compliances**	**Assessment Result**
High	AQL_H = 0.01%	0	0	Pass
Moderate	AQL_M = 0.40 %	1	1	Pass
Low	AQL_L = 1.50 %	3	4	Fail

Table 2: Example, Single Acceptance Sampling by Attributes Audit Plan (ISO 2859.1) and Results

Actioning Audit Outcomes

The protocols associated with each audit outcome are implemented; refer to Table 1. Possible protocols might include an increase in existing maintenance activities, the implementation of a bulk maintenance program or a complete asset replacement, etc.

In Practice

An electricity utility uses a combination of reactive and routine replacement methods to ensure its public lighting assets provide an acceptable level of public safety and amenity. All public lighting assets are treated the same regardless of their function e.g. security lighting, main road lighting, minor road lighting, public space lighting, etc.

Unfortunately, this one-size-fits-all approach often means a large proportion of assets and asset components (e.g. globes, starters, switches, etc.) are replaced unnecessarily due to the variable nature of their deterioration (e.g. weather conditions, voltage variation, operating hours, manufacturer, etc.).

An acceptance sampling system reduces unnecessary replacement waste and lowers maintenance costs by accurately identifying when asset conditions have exceeded a user-specified maximum risk limit (i.e. AQL); refer to Figure 2.

This risk limit represents the point where existing replacement activities are no longer capable of maintaining the asset’s performance within acceptable levels. It is at this point some type of intervention is needed to ensure risks don’t increase further i.e. intensified maintenance, asset replacement, refurbishment, etc.

Further efficiency gains can be achieved by separating public lighting assets into different risk classes; with separate risk limits. For example, assets with a high failure consequence (e.g. security lights) would be subject to more frequent and larger sample inspections than assets with a lower failure consequence (e.g. minor road lights).

Conclusion

Best practice risk-based auditing based on ISO 2859.1 acceptance-sampling methods has a number of significant advantages over conventional static non-scientific auditing methods. These include:

- Provides reliable information for assessing the adequacy of existing maintenance activities,

- Provides reliable information for the analysis of physical condition trends;
- Reports on asset physical performance in a consistent format;
- Assists asset owners/operators target and prioritise asset management strategies;
- Provides information for quantifying maintenance, renewal and replacement requirements;
- Contributes as a warning for timely made decisions for preventing failures;
- Contributes to obtaining predictive information about degradation of assets.

Once only the province of large manufacturing companies with highly centralised production processes, recent advancements in cloud-based software and technology have made Best Practice risk-based Inspection possible for all organisations, including asset owners and operators.

For further information on how your organisation can take advantage of the very latest in acceptance sampling technology please visit www.compliance-master.com.

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