

Guidelines for managing ignition risk by inspection of Ex electrical equipment in hazardous areas (including support of IEC 60079-17)

EEMUA Publication 246



GUIDELINES FOR MANAGING IGNITION RISK BY INSPECTION
OF Ex ELECTRICAL EQUIPMENT IN HAZARDOUS AREAS
(INCLUDING SUPPORT OF IEC 60079-17)

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FOREWORD

Inspection of Ex electrical equipment is critical to assuring the continuing integrity of the types of protection that enable its use in potentially flammable atmospheres, hence management of the major accident hazard ignition control boundary. However, such inspections are sometimes not carried out adequately both with regard to frequency of inspection, grade of inspection and completeness of the portfolio of Ex electrical equipment installed. This is due in part to the onerous requirements of IEC 60079-17 with respect to close inspection, in three years, of the several thousand pieces of Ex electrical equipment at a typical installation handling flammable fluids in major hazard industries (both onshore and offshore) or allied process industries. In addition, inspection of Ex electrical equipment is often carried out at the same level of inspection (frequency of inspection, grade of inspection, etc.) without adjustment for the different ignition risks that might apply. Furthermore, there is a lack of clarity in IEC 60079-17 regarding carrying out sample inspections, particularly with respect to detailed inspections.

These *Guidelines for managing ignition risk by inspection of Ex electrical equipment in hazardous areas (including support of IEC 60079-17)* provide guidance on managing the ignition risks of Ex electrical equipment located in hazardous areas arising from flammable vapours and gases. This is mapped against a safety management system (SMS) framework which should be applied throughout its life cycle.

These guidelines further develop the risk-based inspection (RBI) concept by providing an RBI sampling methodology which will compliment an RBI inspection process that takes into account as low as reasonably practicable (ALARP) principles. The RBI methodology is intended for application to sampling of electrical equipment as defined within IEC 60079-17. The methodology applies random sampling to lots. Applying the RBI sampling methodology to the inspection of Ex electrical equipment should:

- Apportion level of inspection according to risk of ignition.
- Assure the continuing safety integrity of its types of protection.
- Reduce the possibility of introducing maintenance induced human failure due to intrusive inspection.
- Be cost beneficial compared to the additional requirements on managing the process.

These guidelines are based primarily on the UK legislative and regulatory framework and international standards; yet its guidance is globally applicable, provided it is read, interpreted and applied in conjunction with relevant national and local statutory legislation and standards. Where the requirements differ, the more rigorous should be adopted.

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PREFACE

These guidelines were commissioned and partly developed by the EI Electrical Committee, which comprises senior electrical engineers from companies operating in the offshore and onshore major hazard industries, consultants and the Health and Safety Executive (HSE). They set out what is generally regarded in the industry as good practice and should assist those with responsibilities to meet the requirements of pertinent legislation, regulations and standards. They are not mandatory, and different standards may be adopted in a particular situation where to do so would maintain an equivalent, or better, level of safety. They are now reissued in a second revision having been amended in an attempt to clarify and simplify the overall methodology taking account of industry user feedback.

Currently, many inspections of Ex electrical equipment are carried out at the same level of inspection (frequency of inspection, grade of inspection etc.) without adjustment for the different ignition risks that might apply. Yet the inventory of Ex electrical equipment is typically located in different hazardous areas (where the probability of a flammable atmosphere being present differs) and the various Ex electrical equipment type of protection concepts present different ignition risks. In addition, the equipment may be located where the environmental conditions differ.

Detailed inspections are typically carried out as part of initial inspections, and not always as part of routine inspections. Such intrusive inspections are very resource intensive and might lead to maintenance-induced human failure (e.g. damage to gaskets and seals, or leaving out bolts on reinstatement). However, in order to ensure that the internal parts are fit for purpose and safe, users should carry out Ex detailed (intrusive) inspections.

In addition to meeting requirements of relevant legislation, regulations and standards, there is a significant business driver to install and maintain Ex electrical equipment such that it does not provide a potential source of ignition. The impact on businesses of fires or explosions due to a failure to control sources of ignition in terms of personnel injury or fatality, repairs, loss margin or revenue, reputational damage and fines or other penalties, can be such as to pose a significant threat to the survival or profitability of the business. As all potentially explosive product installations contain large numbers of sources of ignition such as instruments, lights, motors, junction boxes etc., any such business should ensure that they are installed and maintained properly so as to limit the risk of uncontrolled sources of ignition.

These *Guidelines for managing ignition risk by inspection of Ex electrical equipment in hazardous areas (including support of IEC 60079-17)* promote adoption of risk-based inspection (RBI) principles to inspection of Ex electrical equipment. This should result in high risk Ex electrical equipment being inspected to a more rigorous level of inspection (e.g. frequency of inspection) than lower risk items.

These guidelines set out an approach for establishing an RBI strategy which should be targeted, balanced and effective. Guidance is provided on implementing the strategy and ensuring that it is effective on a continuing basis. Therefore, these guidelines constitute a benchmark of good practice.

The RBI sampling methodology draws from and bridges ISO 2859-1 and IEC 60079-17. It provides an audit trail to the established general sampling methodology of ISO 2859-1 and meets the Ex electrical equipment inspection requirements of IEC 60079-17 by applying statistical techniques to the sampling methodology such that the overall condition of the certified equipment population can be determined to a defined probability. In order to adapt the general sampling methodology to the specific application of inspection of Ex electrical equipment, additional management, sampling methodology and Ex electrical equipment requirements have been added to the criteria considered in ISO 2859-1. Application of RBI has the advantage of more efficient use and targeting of inspection resources.

OVERVIEW

Section 1 provides an introduction to the management of Ex electrical equipment ignition risks, defines the scope of these guidelines, and describes how they should be applied.

Section 2 sets out the requirements of legislation, regulations and international standards pertinent to the inspection of Ex electrical equipment.

Section 3 sets out the general framework for the implementation of an Ex inspection methodology.

Section 4 sets out the steps in developing and applying an RBI sampling strategy.

Annex A provides a gap analysis checklist for managing inspection of Ex electrical equipment ignition risk that aims to determine whether current practices and processes comply with pertinent legislation, regulations and standards.

Annex B illustrates the implementation of the RBI Ex inspection methodology with a case study on an operated facility.

Annex C provides a technical basis of the RBI methodology.

Annex D provides inspection schedules for various Ex electrical equipment types of protection.

Annex E.1–E.4 provides glossaries of terms, abbreviations, and publications referenced

1 INTRODUCTION, SCOPE AND APPLICATION

1.1 INTRODUCTION

The Ex sampling strategy set out in these guidelines is based on the following international standards:

- ISO 2859-1 (which is technically identical to BS 6001-1) provides a recognised sampling standard for general inspection requirements for manufacturing. This standard alone is not suitable for its direct application to inspection of Ex electrical equipment.
- IEC 60079-17 (which is technically identical to BS EN 60079-17) defines and states the requirements for the following types of Ex inspections: initial inspection (commissioning); periodic inspection (visual, close or detailed), and continuous supervision. The standard refers to Ex sample inspections; however, it does not provide specific guidance on what is required of a sampling strategy.

These guidelines provide a method of applying the sampling schemes set out in ISO 2859-1 (which then provides an audit trail to an established sampling method), together with the Ex electrical equipment inspection requirements set out in IEC 60079-17; therefore, these guidelines bridge those standards. In order to achieve this, the following management, sampling methodology and Ex electrical equipment requirements have been added to the criteria considered in ISO 2859-1 so as to develop an RBI Ex electrical equipment sampling methodology:

- Management requirements:
 - Having a high quality SMS with a systematic approach and high quality of audit and review.
 - Having a complete equipment register and records.
 - Developing an RBI strategy.
- Sampling methodology requirements:
 - Defining lots, sample size and rejection criterion.
 - Defining grade of inspection.
 - Defining frequency of inspection.
 - Reviewing category of inspection when the rejection criterion is exceeded.
- Ex electrical equipment requirements:
 - The probability of a flammable atmosphere being present, as indicated by the hazardous area classification (i.e. zones 0, 1 and 2 (and non-hazardous)).
 - The effect of severity of the environment.
 - The effect of equipment age (note: EI Research report *Investigation into the ignition risks due to the ageing effects of Ex electrical equipment* did not reveal a direct correlation between the equipment age and Ex failures, however the intention of including the equipment age as one of the criterias is to account for a cumulative exposure of equipment to such elements such as maintenance, inspection, modifications etc. over time.

The sampling methodology detailed in ISO 2859-1 provides an opportunity to utilise qualitative and/or quantitative analytical techniques within a defined strategy. A risk-based approach to inspection of Ex electrical equipment assesses the ignition risk by considering the probabilities of both a flammable atmosphere and a source of ignition (due to Ex integrity

failure) being present. This should result in high risk Ex electrical equipment being inspected to a more rigorous level of inspection than lower risk items. For detailed Ex inspections it prevents the need for the routine opening of all Ex enclosures.

Coupling an Ex inspection sampling strategy with a risk-based approach provides a targeted, balanced and effective Ex inspection approach.

While the approach offers clear benefits as described above, it is important to note that there are certain strict prerequisites that must be satisfied for an effective adoption of Ex RBI strategy, such as full equipment data, good quality of historical data and a robust maintenance management system. Users may choose to continue with the conventional strategies until such time that all pre-requisites are satisfied. 3.5 gives an overview of those prerequisites including other available strategies.

Use of robust statistical data derived from ISO 2859-1, in conjunction with a complete equipment register and competent personnel, should optimise the potential of the methodology.

1.1.1 Objective

The objective of these guidelines is to provide guidance on establishing an Ex electrical equipment inspection strategy which accounts for ALARP principles. This should help in improving continuing major accident hazard (MAH) management through effective management of ignition risk by assuring the continuing integrity of Ex electrical equipment type of protection as inspection should identify faults such as corrosion, vibration, inadequate equipment selection etc. It should also improve the quality of inspections of Ex electrical equipment and, over time, improve the in- service performance of Ex electrical equipment. These guidelines should help to clarify the concepts and should facilitate compliance with the requirements of relevant legislation, regulations and standards.

Users are likely to seek answers to the following questions regarding managing the inspection of Ex electrical equipment:

- What legislation, regulations and standards do I have to comply with and are there other business benefits that might be accrued?
- What do these requirements imply in practice and how can I tell if what I already have is sufficient?
- How can I meet the requirements effectively (both in terms of cost and compliance) while at the same time leveraging the activity to provide added value/reduce risk for my business?

These guidelines provide guidance on answering those questions. They provide a pragmatic approach to achieving this by promoting a risk-based Ex inspection strategy. Furthermore, they offer the option of adopting a robust sampling methodology derived from IEC 60079-17 and ISO 2859-1 which is balanced and should meet ALARP requirements.

The success of an Ex electrical equipment inspection strategy is dependent on the complete life cycle of Ex electrical equipment being appropriately managed and inspected, having appropriate records, and being audited and reviewed (in accordance with the SMS principles of HSE managing for health and safety) so as to ensure that all such Ex electrical equipment is fit for purpose, safe, and can be demonstrated as being so.

These guidelines should encourage appropriate management of the complete Ex requirements of initial, visual, close and detailed inspections, as set out in IEC 60079-17, Figure A.1. In doing so, they should encourage a consistent approach in the petroleum and allied industries and consistency in its regulation and verification (where appropriate).

1.1.2 Methodology

Acceptance sampling is a statistical term, which uses statistical sampling to determine whether to accept or reject a production lot of material. It has been a common quality control technique in the manufacturing industry and was developed primarily for the inspection of a continuing series of lots all originating from the same production or servicing process as detailed in ISO 2859-1. Refer to 2.7 for further definition on ISO 2859-1 approach.

It is important to note that the sampling methodology presented in ISO 2859-1 is based on the assumption that items under consideration are homogenous. As a result, the adoption of the sampling methodology into Ex inspection presents several challenges:

- Variety of Ex protection concepts used on each plant or installation.
- Wide range of environmental factors that Ex equipment are exposed to.
- Various risk levels emerging from the hazardous area that an Ex item is located in, as well as the energy levels available within Ex items.

All these factors need to be taken into consideration for an effective adoption of sampling methodology. Therefore, equipment in a lot should be similar for one or more of the following:

- be used in the same hazardous area classification;
- have the same type of protection, and
- be used in the same environmental conditions, including the same installation area.

The methodology presented in these guidelines can be split into two major components:

- Sampling: defined in 3.4.3. In addition, Annex C provides a comprehensive technical basis of the methodology based on ISO 2859-1.
- Risk-based approach: detailed in 3.4.5.

A high level overview of the Ex RBI process detailed in these guidelines is given below (also refer to Figure 3):

- **Equipment register** (4.1): it is a fundamental assumption that a comprehensive and accurate equipment register is available: the lack of such an equipment register will make demonstration of compliance with legislation, regulations and standards very difficult, if not impossible, and will similarly dramatically affect the ability to properly inspect, maintain and operate parts of the installation.
- Defining **lots** (4.2): all Ex electrical equipment in the equipment register is divided into different lots as defined by various factors.
- Defining **grade of inspection** (4.3): once lots have been identified, grading is defined for each lot, which depends on various factors as detailed in 4.3.
- Defining **sample size** (4.4): the sample size should be determined for each lot (refer to sampling tables 6,7 and 8). Applying the principles of ISO 2859-1, the sample size is determined by four criteria:
 - Lot size: number of equipment in a lot.

- Global failure rate: statistical term, referring to the observed failure rate of a lot, which is highly dependent on the quality of the historical records. As part of this revision of the guidelines, this parameter has been fixed to a predetermined value, hence it is no longer a variable that needs to be determined separately. See note 1.
- Category of inspection (normal, reduced or increased): statistical term, referring to the degree of effort required to carry out an inspection.
- Acceptance safety level (ASL): statistical term, defined as the number of faulty equipment that is declared as being unacceptable on average, expressed as percentage. This parameter is required to define rejection criteria (Re), which is critical for the sampling process as detailed in Annex C. As part of this revision of the guidelines, this parameter has been fixed to a predetermined value, hence it is no longer a variable that needs to be determined separately. It has been derived from the sampling table at the ALARP ASL determined for each lot size in Table C.14, with a global failure rate level of II. See note 1.
- **Defining rejection criterion** (4.4.4): this is a statistical term defined by Re – if the number of faulty equipment found in the sample is less than Re, the safety level of the lot should be considered acceptable. Re is determined from the pertinent sampling table for a particular sample size; refer to sampling tables 6, 7 and 8.

Note 1: The simplified approach, summarised in sampling tables 6, 7 and 8, should be considered as a starting point to enter the RBI Ex inspection process. Users are free to then further refine their inspection strategy, taking into account the whole set of parameters of the method presented in Annex C.

- Defining **frequency of inspection**: see 4.5.

At this point the sampling plan is ready for implementation in an inspection. This completes the 'pre-inspection' part of the flowchart provided in Figure 3.

- Carrying out **inspection**: choose a random sample (see 4.6), inspecting the sample (see 4.7) and record inspection date (see 4.8).
- Defining **scoring** for faulty equipment: following an inspection, some faulty equipment may be identified: each fault may have a different criticality. An approach is provided in 4.9 for scoring the faults based on ignition risk. The score is then compared against the pertinent Re. This process includes determination of the causes of faults and consideration of the possibility of common mode faults.
- Defining rules for faulty equipment: rules are provided for the repair of faulty equipment and its prioritisation, as well as for carrying out remedial actions (see 4.10).
- Reviewing **category of inspection** by applying change rules (see 4.11).

1.2 SCOPE

These guidelines cover the inspection of Ex electrical equipment located in hazardous areas (other than mines) where the risk arises from flammable atmospheres. They are worded for direct application to Ex electrical equipment used in hazardous areas arising from liquids, vapours or gases, but could be easily transposed to Ex electrical equipment used in hazardous areas arising from combustible dusts. It is applicable to petroleum production, storage and processing installations, both onshore and offshore e.g. offshore production installations, petroleum refineries, bulk storage installations, etc. Whilst it covers maintenance as part of the life cycle of Ex electrical equipment, these guidelines are not a maintenance guide.

These guidelines have been developed for implementation on electrical, instrumentation and communication equipment only; hereafter referred to as 'Ex electrical equipment'. Risks due to process and human failure (except maintenance induced human failure) are excluded from these guidelines. They do not cover the details of inspection and testing requirements of BS 7671 and BS 6626 of associated LV and HV electrical systems respectively (e.g. earthing, cabling and overload protection devices); however, they recognise the possibility of efficiencies in carrying out such inspections as for any UK electrical installation, alongside Ex inspections.

These guidelines do not specifically cover the competency of personnel inspecting and maintaining certified electrical equipment, UK Health and Safety Legislation requires this work to be carried out by competent persons. Competency requirements are detailed within IEC 60079-17.

The principles of these guidelines could also be applied to other types of Ex equipment e.g. the inspection of mechanical equipment in hazardous areas (other than mines).

1.3 APPLICATION

These guidelines are intended to be used by those who manage the inspection of Ex electrical equipment and should include electrical engineers, especially those at the technical person with executive function/responsible person level working in the petroleum and allied industries. They should also be of use to those needing to improve their understanding of the concepts, those who want to keep in touch with the development of good practice or those who have outsourced inspection of Ex electrical equipment but need to remain an 'intelligent customer'.

These guidelines are based primarily on the UK legislative and regulatory framework and international standards; yet they are globally applicable provided they are read, interpreted and applied in conjunction with relevant national and local statutory legislation and standards. Where the requirements differ, the more rigorous should be adopted.

The legislation, regulations and standards to be complied with, and the SMS do not prescribe how compliance should be achieved: they are goal setting an approach. A key element in such an approach is the concept of ALARP. Installation duty holders should be able to demonstrate that their practices and procedures lead to any residual risk levels being ALARP.

There are many ways to demonstrate ALARP. The methodology chosen to do so will be specific to individual assets and based on relevant pertinent factors including, plant size, complexity and anticipated service life. Inspection strategies may take many forms and could include 100 % inspection or period periodic inspection or a combination of both. The guidance offered within this document is intended to provide a methodology which will optimise inspection activity based on sound understanding of equipment condition. It must be recognised that establishing the process as recommended will require allocation of resources for initial set up and monitoring thereafter and may not therefore offer significant benefit to small assets or those in late life. The guidance provided here is not prescriptive, and should be considered as one possible methodology to achieve ALARP (or in meeting similar national or local criteria) for managing the inspection of Ex electrical equipment.

These guidelines should be applied to the inspection of both new and existing Ex electrical equipment, at both new and existing facilities.

Application of these guidelines is likely to increase the demands on management, but should result in greater confidence in the continuing integrity of Ex equipment through more targeted application of inspection resources.

For the purpose of these guidelines, the interpretations of terms in Annex E.2 and abbreviations in Annex E.3 apply, irrespective of the meaning they may have in other connections. However, many replicate or are based on the interpretations in IEC 60079-17, ISO 2859-1, *EI Model code of safe practice Part 1: The selection, installation, inspection and maintenance of electrical and non-electrical apparatus in hazardous areas* and *EI Model code of safe practice Part 15: Area classification for installations handling flammable fluids*.

Users of these guidelines should first read and understand IEC 60079-17 before attempting to follow these guidelines.

1.3.1 Managing inspection of Ex electrical equipment ignition risk by applying gap analysis

In order to illustrate the practical implications of compliance with legislation, regulations and standards, Annex A provides a gap analysis checklist for managing inspection of Ex electrical equipment ignition risk, that enables users to compare their current practices with those that should be in place if fully compliant. The questions in the checklist (see Table A.1) derive from information given in these guidelines and IEC 60079-17.

The gap analysis should help users seeking answers to the following questions regarding managing inspection of Ex electrical equipment ignition risk:

- Where is my organisation now?
- Where is it trying to get to?
- How can it get there by planning and making improvements?

The gap analysis is set around the following SMS principles:

- policy;
- organisation;
- planning and implementation;
- measuring performance;
- audit, and
- review.

throughout the Ex electrical equipment life cycle phases of:

- design and construction;
- installation/commissioning/handover;
- operation;
- maintenance and inspection;
- modification, and
- decommissioning.

It should be noted from the gap analysis checklist (see Table A.1) that the continuous improvement model set out in HSE guidance HSG65 *Managing for health and safety* implies that a significant number of reviews should take place (see Figure 1).

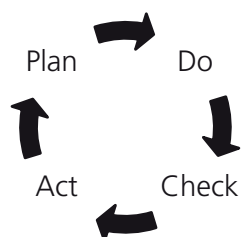


Figure 1: Continuous improvement model

2 LEGISLATION, REGULATIONS AND STANDARDS

2.1 INTRODUCTION

This section sets out the Ex requirements of pertinent UK legislation, UK regulations (some of which are based on European Community directives) and international standards as they apply to the inspection of Ex electrical equipment. It should be noted that some aspects of the regulations apply differently to onshore and offshore installations.

The objective of the legislation, regulations and standards is to allow installations to safely use electricity (which has the potential to readily provide a source of ignition) in potentially flammable atmospheres, e.g. whether arising from vapours, gases or liquids.

While the origin and focus of the guidelines are in the UK, it is recognised that users operating outside the UK regulatory regime may wish to apply this guideline in other jurisdictions, or international companies with assets in both UK and abroad may wish to incorporate the approaches in these guidelines into their international standards. In these cases, the methodology will likely remain valid, however it may need to be adapted somewhat to align with local requirements (e.g. the definition of ATEX equipment may not be relevant in some regions).

2.2 THE UKCA

The UK Conformity Assessed (UKCA) marking is a new UK product marking that is used for goods being placed on the market in Great Britain (England, Wales and Scotland). It covers most goods which previously required the CE marking, known as 'new approach' goods.

The UKCA marking came into effect on 1 January 2021. However, to allow businesses time to adjust to the new requirements, you will still be able to use the CE marking until 1 January 2023 in most cases.

The technical requirements (essential requirements) that must be met – and the conformity assessment processes and standards that can be used to demonstrate conformity – are largely the same as they were for the CE marking.

For all intents and purposes the methodology described within this document remains unchanged at this time, therefore references to ATEX remain throughout the document.

2.3 THE EQUIPMENT AND PROTECTIVE SYSTEMS FOR USE IN POTENTIALLY EXPLOSIVE ATMOSPHERES REGULATIONS AND THE DANGEROUS SUBSTANCES AND EXPLOSIVE ATMOSPHERES REGULATIONS

The ATEX Directives introduced specific legal requirements aimed at specifying the necessary properties of electrical and non-electrical equipment for use in potentially explosive atmospheres, and protecting personnel from the potential hazards of explosive atmospheres, respectively.

In the UK the requirements of the ATEX 'Equipment Directive' (2014/34/EU) (harmonisation of the laws of the member states relating to equipment and protective systems intended for use in potentially explosive atmospheres) are embodied in the Equipment and Protective Systems for use in Potentially Explosive Atmospheres Regulations (EPSR). ATEX equipment should be assessed against the essential health and safety requirements of the directive and if it conforms, it should be CE marked and a certificate of conformity should be prepared. The marking also comprises other information as may be required by the European Union directives applying to a particular product.

In the UK the requirements of the ATEX 'Workplace Directive' (ATEX 153, 99/92/EC) (directive on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres) are embodied in the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) which set out minimum requirements for the protection of workers from fire and explosion risks arising from dangerous substances, and potentially flammable atmospheres arising from work with them. They require the classification of areas where flammable atmospheres may occur into zones.

As noted in 1.2, this document applies to all Ex electrical equipment, whether pre- or post-ATEX. Pre-ATEX Ex electrical equipment typically will not have an ATEX technical file/certification, which is one way of demonstrating that it is fit for purpose and safe at the time of installation. In the absence of any ATEX technical file/certification, the Ex electrical equipment should comply with relevant standards at the time of design and construction.

This document while written as guidance to aid the management of ignition risk through inspection of electrical equipment certified for use in areas classed as hazardous in the UK under ATEX can equally be applied to installations classed under NEC Articles 500 and 505.

2.4 THE CONTROL OF MAJOR ACCIDENT HAZARD REGULATIONS 2015 (COMAH)

The Control of Major Accident Hazards Regulations 2015 (COMAH) are the enforcing regulations within the UK based on the SEVESO III Directive (2012/18/EU) devised in Brussels following the SEVESO disaster. They are applicable to any establishment storing or otherwise handling large quantities of industrial chemicals of a hazardous nature. Types of establishment include chemical warehousing, chemical production facilities and some distributors.

The principal aim of the regulations is to reduce the risks of potential major accidents that are associated with the handling of hazardous substances. The regulations operate on two levels depending on the establishment's status which is divided into two categories, 'lower tier' and 'upper tier' determined by inventory.

2.5 THE ELECTRICITY AT WORK REGULATIONS

The Electricity at Work Regulations (EAWR) cover the requirements of electrical systems, work activities, protective equipment and the effects of adverse or hazardous environments (i.e. the use of Ex equipment).

Employers have duties under EAWR. In addition, employees have a duty to co-operate with employers to enable compliance with duties placed on their employers: this should ensure the safety of the installation and those who work on or near it. EAWR require any person working on all electrical equipment to be competent so as to prevent danger and injury or to be under such degree of supervision as appropriate to the nature of the work.

Owners, operators and contractors and those self-employed are deemed to be employers and therefore have duties in relation to electrical activities and equipment associated with installations. Contractors include companies who provide intermittent or infrequent electrical services as well as main contractor companies providing continuous or more regular services.

2.6 IEC 60079-17

The IEC 60079 series of international standards provides the basis for designing Ex electrical equipment (and that those designing the installations are competent), but also contains in IEC 60079-17 information on its maintenance and inspection.

2.6.1 Maintenance

Regardless of the Ex inspection strategy chosen (see section 3), Ex equipment should be maintained in accordance with its functional requirements (which could be based on the manufacturer's guidance and factors governing its deterioration) and the ignition risks associated with faults for the various types of protection.

Where functional maintenance of equipment is being carried out by a skilled person, the opportunity should be taken to inspect its Ex integrity at the same time and all findings (including faults) should be recorded. Doing so should maximise equipment availability. For example, with lamp replacement the opportunity should be taken to inspect the Ex integrity of the luminaire at the same time.

Where appropriate, and on an opportunistic basis, suitable preservation techniques should be applied to mitigate against corrosion.

If a skilled person has performed work on Ex electrical equipment, before the work is completed they should inspect it so as to ensure that the integrity of the type of protection has not been compromised. The grade of inspection should be proportionate to the work carried out.

2.6.2 Inspection

The intention of inspection is to ensure that the Ex electrical equipment continues to comply with its original Ex certification requirements both externally and internally. To achieve this result, a verification dossier is prepared for every installation.

The results of all inspections (initial, visual, close and detailed), maintenance, repair and faults found must be recorded, audited and reviewed to provide an auditable trail for each Ex electrical equipment installed. During Ex inspections the opportunity should be taken to apply some form of identification to each Ex electrical equipment e.g. a coloured tag identifying the year of inspection provides a visual indication to what equipment has been inspected and that equipment which has not been inspected. All Ex electrical equipment must be recorded in an equipment register. Definitions for the types of inspection (initial inspection, periodic inspection, sample inspection and continuous supervision) and grades of inspection (visual, close and detailed) are given in IEC 60079-17. The following provides clarification on the requirements of IEC 60079-17:

- The interval between periodic inspections shall not exceed three years without seeking expert advice.

- Inspection strategies must ensure that both the internal and external parts of the Ex electrical equipment comply with its Ex certification throughout its life cycle (e.g. the condition of the flame path of Ex 'd' enclosures must be inspected to ensure that the flange faces are clean and undamaged, and gaskets, if any, are satisfactory; whereas, for Ex 'e' enclosures the condition of terminations should be checked for tightness and a check made to ensure that there is no undue ingress of water). These guidelines provided in Annex B detail an RBI sampling methodology to manage Ex electrical equipment ignition risks which should meet these requirements both for internal and external Ex integrity so as to ensure that Ex electrical equipment is fit for purpose and safe throughout its life cycle.

2.6.3 Skilled personnel (electrical technicians)

Skilled personnel are generally electrical technicians, responsible electrical persons (REPs) and nominated electrical persons (NEPs), whether they are in-house or contractors (see Annex E.2). They should be supported by senior management and the technical person with executive function (see 2.6.4). They should be competent on:

- The various types of Ex protection and installation practices.
- The relevant rules and regulations.
- The general principles of hazardous area classification.

2.6.4 Responsible person/technical person with executive function

Standards 60079 parts 14 and 17 use the terms Technical Person with executive function (TPEF) and Responsible Person (RP). In practice this has been found to be the same person and for purpose of this guidance the terms are interchangeable. The position is generally delegated by senior management to a senior competent person who is responsible for ensuring the integrity of Ex equipment. They should be supported by senior management and other skilled persons as defined in 2.6.3.

2.6.5 Expert advice

Standard 60079-17 uses the term 'expert advice'. For purpose of this guidance expert advice is considered as the collection of intelligence the responsible person will use as the basis for making decisions related to an inspection strategy. The level and quantity of intelligence required will depend on the significance of the decision and could by example include:

Quantitative assessment of

- defect performance;
- strategy coverage, and
- historical trends.

By means of example any decision to extend an inspection strategy beyond a three-year period would be based on all of the above factors taken over multiple successive rounds of inspection, the results of which then documented and held within the verification dossier.

2.7 ISO 2859-1

ISO 2859-1 provides an acceptance sampling system for inspection by attributes. It is indexed in terms of the acceptance quality limit (AQL). Its purpose is to seek and maintain a process average at least as good as the specified AQL, while at the same time providing an upper limit for the risk to the client of accepting the occasional poor lot.

Whilst primarily developed for manufacturing applications, the scope of the standard states that it is applicable to inspection of:

- end items;
- components and raw materials;
- operations;
- materials in process;
- supplies in storage;
- maintenance operations;
- data or records, and
- administrative procedures.

These schemes are intended primarily to be used for a continuing series of lots, that is a series long enough to allow change rules to be applied, which provide:

- Protection to the client (by means of switching to increased inspection using change rules or discontinuation of sample inspection) should a deterioration in quality be detected.
- An incentive (at the discretion of the responsible authority) to reduce inspection costs (by means of switching to reduced inspection using change rules) should consistently good quality be achieved.

Sampling plans in ISO 2859-1 may also be used for the inspection of lots in isolation where the operating characteristic curves are used to find a plan that will yield the desired protection.

3 EX INSPECTION GENERAL FRAMEWORK

This section outlines the necessary components required for a successful Ex electrical equipment inspection strategy, and provides guidance on suitable strategies for organisations at various stages of asset life cycle, inspection maturity and facility size.

3.1 POLICY

An appropriate policy for managing inspection of Ex electrical equipment, i.e. an Ex inspection strategy, should be defined, implemented, audited and reviewed and where necessary, modified so as to ensure the satisfactory integrity of Ex equipment throughout its life cycle phases. It should cover the general intentions, approaches and objectives of the organisation in managing inspection of Ex electrical equipment, together with the criteria and principles on which actions and responses are based. The Ex inspection strategy should be effective and should be supported by an effective management system to ensure the safe operation, maintenance, inspection and work on Ex electrical equipment.

3.2 PERSONNEL COMPETENCE

3.2.1 Roles and responsibilities

Employers, employees and contractors have responsibilities under EAWR (see 2.5). Regardless of this; many of these fall on the duty holder; pertinent ones include:

- Appointing nominated electrical persons (NEPs) to be responsible for managing aspects of the electrical function, which are under their control. With regard to Ex electrical equipment the petroleum industry generally nominates a TPEF (see 2.6.4).
- Ensuring that regular audits are performed so that all pertinent personnel are fully aware of their responsibilities and accountabilities in relation to Ex electrical equipment.

Typical examples of Ex inspection activities that should be carried out by duty holders include:

- Reviewing maintenance and inspection completion and backlog reports to check that the correct information has been recorded and that deferred maintenance will not result in unsatisfactory safety risks. An example is a supervisor being made responsible for weekly reviews and the TPEF carrying out regular audits to determine if the relevant procedures are being implemented. All audits and review should be documented and recorded, outlining:
 - which sections have been audited and reviewed;
 - what Ex findings/faults have been revealed;
 - whether there are generic faults;
 - recommended actions e.g. further inspections required on Ex electrical equipment, and
 - changes to the Ex inspection strategy.
- Performing ongoing competence assessments of personnel involved in electrical work e.g. checking the quality of Ex electrical equipment inspections and associated Ex records.

Periodically reviewing approvals of change requests, subsequent modifications and changes to operational constraints that might impact the integrity of Ex electrical equipment.

3.2.2 Qualifications of skilled personnel

A competence assurance system should be in place to ensure the competence of all personnel involved with Ex electrical equipment. As part of achieving competence, Ex electrical technicians should be adequately trained and experienced. For other roles (e.g. REP, TPEF/RP, ICP) additional competence requirements apply.

Competence with Ex electrical equipment requires thorough knowledge of its construction, type of protection, operation and failure mechanisms to determine whether they are fit for purpose and safe.

3.2.2.1 *Inspector competence*

The inspection of electrical equipment installed within hazardous areas should be carried out by personnel who have been trained and assessed as competent, typically Ex electrical technicians. This should be achieved by the personnel meeting the requirements of a competency based scheme. In the UK, a recognised training, assessment and certification scheme for electrical technicians is the CompEx national training and assessment scheme. Competency should be refreshed regularly (every five years for CompEx) and there should be satisfactory performance on training course and workplace assessments to ensure that current good practice is applied.

The minimum training requirements of IEC 60079-17 for Ex electrical technicians are described in 2.5.3. The competency level of personnel lies within the responsibility of the TPEF. This responsibility should be endorsed by the duty holder or equivalent, and should be supported by the relevant competency assurance processes.

To be qualified for the inspection of electrical equipment installed within hazardous areas, a person should justify initial competences in electrical equipment and have successfully been assessed on:

- a training course with the minimum content required by the standard and several years of practical experience of working with Ex equipment, or
- a training course with the minimum content described above and a mentoring period implemented and validated by experienced inspectors.

Evidence of the relevant experience and training should be available. Audits are necessary to ensure that the inspectors do their tasks in accordance with site procedures. All audits and reviews should be formally recorded together with actions taken.

The knowledge of Ex electrical technicians should be regularly refreshed (for example to comply with the requirements of CompEx) due to changes in regulations, standards, new types of protection and development of good practice.

In addition to electrical technicians carrying out Ex inspections, other competent personnel will also inspect Ex electrical equipment, e.g. TPEF, ICP, REPs and NEPs.

3.2.2.2 *Competence of employers using contractor resources*

As noted in 1.3, employers should be 'intelligent customers' and so should be able to competently select contractors, and specify, audit and review their work. Where employers do not possess in house Ex electrical equipment competence, they should consider delegating

this responsibility to a consultant so as to ensure that the requirements for inspection of Ex electrical equipment are complied with; if this is the case, these roles and responsibilities should be clearly defined and documented.

3.3 GRADES OF INSPECTION

Three different grades of inspection are defined in IEC 60079-17:

- **Visual inspection:** inspection which identifies, without the use of access equipment or tools, those defects, such as missing bolts, which will be apparent to the eye. Visual checks may be supplemented by the use of binoculars or thermal imaging equipment.
- **Close inspection:** inspection that identifies faults which may compromise the protection concept of equipment. A close inspection is visual but encompasses identification of defects that will also be apparent by accessing the equipment, e.g. physical checks on enclosures, bolts, cable glands etc. This inspection does not require the equipment to be de-energised and isolated or the enclosure to be opened.
- **Detailed inspection:** grade of inspection which encompasses those aspects covered by a close inspection and, in addition, identifies those faults, such as loose terminations, which will only be apparent by opening the enclosure, and/or using, where necessary, tools and test equipment. Such inspections are intrusive inspections and require the enclosure to be opened and the equipment to be de-energised. Such intrusive inspections are very resource intensive and might lead to maintenance-induced human failure (e.g. damage to gaskets and seals, or leaving out bolts on reinstatement). However, in order to ensure that the internal parts are fit for purpose and safe users should carry out Ex detailed (intrusive) inspections.

3.4 INSPECTION TYPES

IEC 60079-17 is fundamental in determining an Ex inspection strategy for all grades of inspection of Ex electrical equipment; however, these guidelines further develop the concept of sample inspections by adopting the sampling methodology set out in section 4.

Inspections should be completed to optimise resource and access requirements. Where appropriate, functional maintenance should be aligned with Ex integrity inspections and a grade of inspection appropriate to the maintenance carried out may be claimed. However, the functional maintenance frequency should not exceed the frequency required to maintain the Ex integrity of the equipment.

The scope of Ex inspections should include inspecting the integrity of the whole system and should also include any special requirements as per the Ex certification which are normally identified on the Ex certificate of conformity number by the suffix 'X'.

All inspections or repair and maintenance should be recorded together with the details of Ex faults found. The assignment of fault codes should assist in the process of reliability and trend analysis. A robust system of audit and review together with actions taken resulting from these findings should be recorded. The results of this should demonstrate whether the strategy is effective and whether personnel competence is adequate.

3.4.1 Initial inspections for new installations

New installations are required to have an initial inspection. The initial inspection will be an exhaustive inspection, i.e. all equipment including assemblies (this includes self-certified assemblies) must be inspected. Sample inspections during initial inspection are for quality assurance, validation and progress check only. The detailed initial inspection to be carried out as set out in Annex A of IEC 60079-17. Once this initial Ex detailed inspection has been carried out (i.e. a baseline has been achieved for the electrical installation) then periodic (visual or close) and sample inspections (visual, close or detailed) are applied for subsequent inspections.

The duty holder should have confidence in the completeness and accuracy of Ex inspection data as a pre-requisite to adopting an RBI strategy.

Initial inspection might be considered as the first and most important step to protect against potential ignition risks: it is key to continuing integrity of Ex electrical equipment. However, it is not always carried out as well as it should be due to pressure at the back end of projects.

Duty holders are responsible for ensuring that their Ex electrical equipment is fit for purpose and safe. Where Ex electrical equipment has been installed and had an Ex initial inspection by third parties, e.g. fabricators supplying assemblies or installation contractors, duty holders should audit and review: the competence of those personnel; the quality of their work (by validating some of these inspections); associated Ex initial inspection records, and the equipment register. If an unreasonable percentage of faults are found in such a validation then further validation should be carried out. These inspections should be representative of the overall installation and should be a combination of visual, close and detailed grades of inspection.

The initial (together with periodic, sample, functional and breakdown) Ex electrical equipment inspection records and associated equipment register (i.e. electrical equipment data e.g. apparatus group, temperature class, manufacturer, certification data, identification number (tag), etc) should be kept by the duty holder as part of the Ex inspection strategy. In order to meet the requirements of the EAWR duty holders should ensure that the results of an inspection are recorded and kept throughout the life of the equipment.

The initial Ex electrical equipment inspection should include a check of installation against certification requirements. Particular care should be taken when the certification specifies conditions on how the equipment can be utilised and installed.

3.4.2 Periodic inspections

As noted in 3.3., IEC 60079-17 requires periodic inspections comprising visual, close and detailed inspections, which should be carried out at a frequency of inspection that should not normally exceed three years without seeking expert advice; however, IEC 60079-17 provides flexibility over what grade of periodic inspection should normally be carried out in a particular inspection and how much equipment should be inspected at each grade. This flexibility has led in practice to a wide range of Ex electrical equipment inspection strategies being adopted ranging from 100 % visual inspections with close inspections only for faulty equipment, through to some nominal percentage of visual, close and detailed inspections.

Practical experience shows that intervening in detailed inspections, i.e. removing equipment covers, carries with the action the risk of introducing faults. If the probability of faults being present before inspection is low then the act of inspection may introduce more faults and reduce rather than improve safety. IEC 60079-17 recognises this effect and carries a warning that care must be taken that reassembly restores original design integrity.

Following SMS principles, users should be able to justify their Ex electrical equipment inspection strategy and demonstrate that their strategy remains robust over time. In periodic inspection this is achieved through sample inspections and ongoing review of key performance indicators (KPI). In a periodic methodology all equipment will be inspected over the inspection period, the grade dependent on the confidence of the integrity in the equipment, by default close or visual inspection as a minimum. The appropriate grade of inspection must be determined by the duty holder. More onerous (higher proportions of close) or less onerous (lower proportions of close) would be more justified based on historical failure rates. An asset able to demonstrate limited static defect levels may be able to justify high levels of visual vs close periodic inspections although levels should remain under constant review, with escalation (or reduction) applied where measured defect performance proves to be favourable (or unfavourable) when compared with company/industry norms. Escalation may, for example, constitute a doubling of the higher grade inspection percentages.

In developing an Ex electrical equipment inspection strategy, there should be a robust consideration as to what grades of inspection should be carried out on a continuing basis and at what frequency of inspection.

Close inspection of Ex electrical equipment provides a more comprehensive indication than visual inspections of external Ex integrity of the electrical equipment. Where not readily accessible, this might require the use of access equipment (e.g. scaffolding) or the use of electrical technicians with appropriate qualification and competency in rope access techniques.

Both visual and close inspections check whether the external components of Ex electrical equipment comply with its original Ex certification; for example, that enclosures are not damaged or bolts are not missing.

Note: periodic inspection is always augmented by sampling ref. 3.4.3.

Although not subject of RBI methodology movable electrical equipment (hand-held, portable and transportable) should be subject to a close or detailed inspection carried out by personnel competent to do so as determined by the use and nature of the equipment, at a frequency of typically every 12 months, and visually inspected before each use to check for obvious damage.

Temporary or third party owned Ex electrical equipment should be supplied with appropriate Ex records or Ex inspection test certificates; in addition, ATEX marking and certificate of conformity documentation should be supplied in the case of temporary or third party supplied assemblies. Duty holders should consider carrying out a complete Ex visual inspection prior to its installation or use, together with a sample inspection of Ex close and detailed inspections so as to ensure that the Ex equipment is fit for purpose and safe. The duration installed or used should be used to determine whether third party or temporary Ex electrical equipment should be included in the duty holder's normal inspection strategy.

Where a visual or close inspection indicates a need to investigate further to fully ascertain the causes of faults, a more rigorous grade of inspection should be applied (e.g. changing from close to detailed inspection).

3.4.3 Sample inspections

Sample inspections always compliment other types of inspection;

- Sample inspections may be used for assurance during initial inspection to determine adequacy and coverage.
- For periodic inspection IEC 60079-17 4.4.2 states '*Once an interval has been fixed, the installation should be subjected to additional interim sample inspections to support or modify the proposed interval and grade of inspection.*'
- Continuous supervision by skilled personnel: IEC 60079-17 3.4.4 states '*The use of continuous supervision by skilled personnel does not remove the requirement for initial and sample inspections.*'

Although the severity of the environment and service will have an effect on performance, the critical aspect is the original selection of Ex electrical equipment. If Ex electrical equipment is installed that has a known good performance in the intended application then the Ex electrical equipment inspection strategy can utilise this knowledge in determining the level of inspection if the initial inspection proves that the original installation is to a high standard. If the Ex electrical equipment is new to the installation and has no proven performance record, then the Ex electrical equipment inspection strategy should consider potential early life failure modes.

Users should consider classifying their Ex electrical equipment according to their experience and knowledge of performance (e.g. fluorescent fittings by manufacturer); such assessments should be recorded together with the evidence supporting the assessments.

Where appropriate Ex history/records exist together with Ex fault records and trend analysis, the duty holder should be in a position to robustly justify their Ex inspection strategy.

100 % detailed inspection of equipment population is arguably the Ex inspection strategy which would give the greatest confidence in the equipment continuing to meet its Ex integrity, but it is grossly time consuming and carries the risk of introducing maintenance induced human failures; whereas a periodic Ex inspection strategy which applies a proportion of lower grades of inspection augmented by a robust sampling methodology provides a better balance between the cost of inspection and confidence in the Ex integrity of the equipment. The demonstration of ALARP within a risk management framework can be achieved through various methods; periodic inspection augmented by RBI sampling methodology is an effective way of doing so.

In a sampling strategy, the quality of the entire population is not precisely known but a statistically valid estimation of that quality can be made. This estimation can then be analysed to update/modify the strategy through audits and reviews. Confidence in the Ex integrity of the population should therefore increase. In effect, sample inspections should allow the user to have sufficient confidence in the Ex integrity of the entire population without having to carry out detailed inspection of all the items.

Two types of sampling methodology exist: progressive and random, the two and their application within an inspection strategy should not be confused;

1. Progressive inspection considers a population of equipment and takes a random selection of that whole population. Inspection is then carried out on that subset (e.g. 10 %), and the remaining items that had not been selected on the first inspection noted. The reduced population of previously unselected items is then used as the

population from which the next random selection is taken on the second inspection. The remaining population after this second selection is then used for the third; this continues until the entire population has been selected. Thereafter, inspection recommences on the whole population.

This methodology may be employed in a periodic inspection strategy where the duty holder has elected to apply more than one grade of inspection.

2. Random sampling considers the whole population at each inspection, and then takes a purely random subset of that whole population. Random sampling can lead to the same equipment being inspected on two or more consecutive inspections, even though the sample size may be relatively small. This may seem to be a disadvantage of random sampling; yet it is the key advantage that random sampling has over progressive sampling in inspection of equipment. By having the possibility of revisiting previously inspected items before the entire population has been inspected (i.e. potentially more frequently than would be the case for progressive sampling), it is significantly superior in highlighting maintenance-induced human failures due to poor reassembly or human failure by the inspector on the last inspection. This allows greater confidence in the ability of the inspection strategy to cover not only randomly occurring faults and wear out faults, but damage and other human intervention related failures. Where possible repeat inspections will be carried out by a different inspector.

Random samples within a periodic inspection strategy serve to augment the periodic inspection activity and give assurance of the strategy effectiveness.

For sample inspections, the level of inspection should be determined; usually, its parameters should be varied based on inspection performance but could also be influenced by other business reasons. The findings of Ex sample inspections should be used in audits and reviews to support or modify the level of inspection.

An Ex sampling strategy is not carried out in isolation but augments other levels of inspection.

3.4.4 Continuous supervision and opportunistic inspections

Some equipment requires frequent attendance, inspection, service, care and maintenance in order to maintain its type of protections in a satisfactory condition. It is acceptable to take credit for equipment which has been subject to inspection by personnel who are competent to do so as part of its regular functional maintenance and inspection regime where this activity is completed at a frequency which is aligned with the periodic inspection regime. Where the intention is to take credit for these inspections as part of an periodic inspection strategy they should be recorded and fed into the equipment register as if they were part of the normal inspection strategy.

Equally, breakdowns of equipment requiring maintenance intervention should be regarded as opportunities to generate and record additional inspection data. For instance, results of such opportunistic inspections could be used as results of periodic inspections, if the opportunistic inspection took place at a time less remote than the periodic inspection period. Results of opportunistic inspections can be recorded in the same equipment register as other inspection results, emphasizing the grade of inspection that was performed and its date.

3.4.5 Risk-based inspection

Current Ex inspection strategies tend to inspect a nominal percentage of the total Ex electrical equipment inventory per annum, which for some installations might be 50 000 items; however, not all the equipment is exposed to the same potential risk of a flammable atmosphere (i.e. Zone 0, 1, and 2 and non hazardous) being present or the same risk of ignition owing to the different Ex protection types. Therefore, such an approach does not best target inspection resources on high risk equipment.

A risk-based approach to inspection of Ex electrical equipment should assess the ignition risk by considering the probability of a flammable atmosphere being present, as indicated by the hazardous area classification, and the probability of a source of ignition being present due to Ex integrity failure. Equipment with similar characteristics can be allocated to lots (specifically defined and identifiable collections of equipment with similar characteristics) and inspected by sampling according to the risk associated with the lot.

In an RBI Ex inspection strategy, high risk Ex electrical equipment should be inspected to a more rigorous level of inspection (e.g. frequency of inspection, etc.) than low risk Ex electrical equipment. This should provide more balanced, effective and targeted inspections, with resources deployed to higher risk areas in a more concentrated fashion.

The RBI Ex inspection concept is presented in these guidelines taking into account as low as reasonably practicable (ALARP) principles. The cost of such an inspection strategy should however always be monitored and compared to the cost of conventional inspection strategies.

Section 4 provides further guidance on the implementation of a risk-based inspection strategy.

3.5 CONSIDERATIONS FOR CHOOSING AN APPROPRIATE INSPECTION STRATEGY

Ex inspection strategies are a key part in MAH management and a fundamental component of an operator's ignition control barrier. The Ex inspection strategy will for every asset be bespoke and very likely to change over the asset lifetime. There are several different options of inspection strategy (inspection type) available to duty holders, and the choice of strategy will typically depend on factors such as:

- Facility life cycle stage: the period of elapsed time of operation and remaining plant life.
- Asset register size: the number of Ex electrical equipment items present at the facility.
- Maturity of inspection data: the confidence the duty holder has in the completeness and accuracy of Ex electrical inspection data currently recorded.

The following sections provide guidance on which inspection strategy is the most appropriate based on these criteria, and a route map for moving from simple periodic inspections towards a risk-based strategy. This is broadly illustrated in Figure 2.

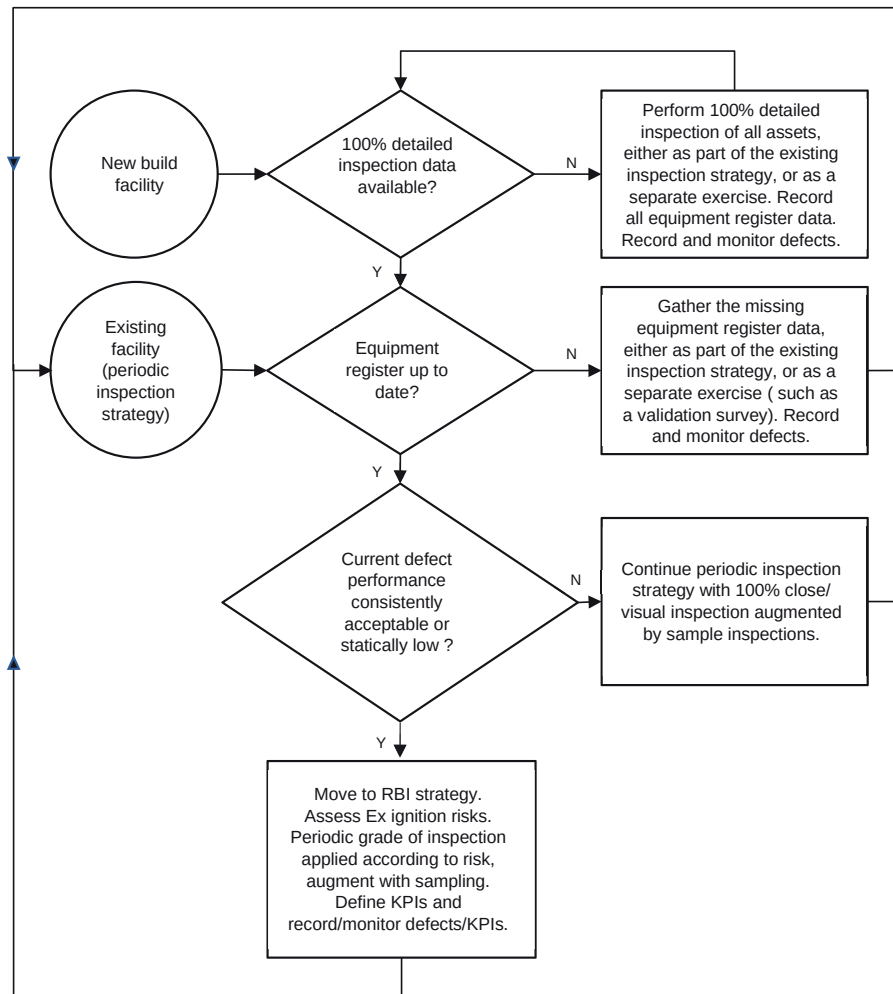


Figure 2: : Inspection strategy options

It is worth noting that different inspection strategies may be chosen to apply to different parts of an installation. For example, if a new process unit is installed at an existing facility, then the duty holder may wish to continue applying an RBI strategy on the existing plant and apply a standard periodic inspection strategy for the new plant until sufficient confidence in inspection data and defect rates is gained. In any case, all strategies must be based on a firm foundation, the inspection records must be accurate, fully populated and the equipment condition well understood.

3.5.1.1 Asset life cycle stage

For all assets, it is a requirement that a full detailed initial inspection is carried out during construction and is handed over to the operations team as a project deliverable. It is a fundamental requirement within these guidelines that the full detailed initial inspection has been carried out and is available.

Introduction of an RBI strategy will introduce additional resource demands in the first instance to set the program up and thereafter in the monitoring, review and adjustment of level and grades of inspection to ensure ignition risk is managed to ALARP. In a new-build asset or an asset with significant life remaining it should be easy to justify the additional demand against the prospective efficiencies and confidence in ongoing equipment integrity gained over time. It may not be possible to make the same justification for a mature asset, one with a limited production life or an asset which is by design in use only for short transient periods and varying locations.

3.5.1.2 Population size and other characteristics

The numbers, types and locations of Ex electrical equipment items present at a facility are the principal factors determining the effort – and thereby cost – required to achieve a robust and defensible inspection programme.

Installations with low populations of Ex electrical equipment may find that the benefits afforded by RBI are disproportionately low when compared with the administrative effort of implementing an RBI strategy. Conversely, larger installations are likely to find that the reduced inspection burden of an RBI approach outweighs the effort required to implement and administer the strategy.

Where access to equipment to facilitate close or detailed inspection is not straightforward (e.g. where rope access or scaffolding is required), the use of sampling and risk-based inspection strategies can yield cost savings.

3.5.1.3 Maturity of inspection data

The confidence the duty holder has in the completeness and accuracy of their current Ex electrical inspection data will determine their readiness to enter into an RBI approach. Duty holders for existing assets where a full record of detailed inspection data is not available must first seek to update their inspection dossier. This may range from a repeat of the 100 % detailed inspection, to a proportion of close and detailed inspection determined by the technically responsible person.

The outcomes of inspection are reviewed by the TPEF. If the results are acceptable, there is a strong understanding of the equipment condition and the risk factors are well known and documented, entry into a risk based inspection strategy could be considered.

3.6 DEFINING KPI TO MONITOR THE EFFECTIVENESS OF THE INSPECTION STRATEGY

Used correctly, a KPI should be a good method of providing an overview of the health of a system and early warning of a decline in standards: it can be used to trigger action before risk levels rise above what is acceptable. KPIs comprise leading and lagging indicators: the former indicate what will happen in the future; whereas, the latter show what happened in the past. Good practice is to have a balance of both types of KPIs.

It is possible to conceive many other KPIs that could be used. However, KPIs should be used sparingly and there should be a clear identifiable reason for collecting and reviewing the information. It is not uncommon for KPIs to be established to monitor specific areas of under-performance and for such KPIs to be discontinued once there is confidence that good performance exists and has become a normal part of the business processes. A good test for the need for a KPI is to ask what action will be taken if the value moves adversely from the target value, such as that defined in performance standards.

Where it is determined that an inspection schedule or sample number will not be met, a further risk assessment should be undertaken, or the electrical equipment concerned should be electrically isolated.

If there is more than one group or contractor responsible for different parts of the installation it is useful to have the results arranged per contractor so any difference in performance of the various workgroups can be identified.

Typical examples of KPIs that may be used for performance of Ex equipment, performance of Ex strategy and new installation audits are:

Performance of Ex equipment:

- Failure rate for the period = number of faults found during the period ÷ (period of evaluation (days) x number of Ex electrical equipment inspected for the period). (This KPI is typically used as part of a performance standard for reliability of SCEs for offshore installations.)
- Total number of action items resulting from an inspection, which can be subdivided by severity into:
 - Number of safety items: these are faults where corrective action should be taken in the short term (e.g. <one week).
 - Number of integrity items: these are faults where corrective action should be taken in the medium term (e.g. <three months).
 - Number of housekeeping items: these are faults that do not affect level of risk but represent a non-compliance with standards (e.g. missing or damaged labelling) where action should be taken in the long term (e.g. <12 months, such as during the next planned maintenance).
- Number of action items resulting from an inspection for each lot, which can be subdivided by severity into safety, integrity and housekeeping items (as above) and could be further subdivided by fault code.

Performance of Ex strategy:

- % Ex detailed inspections carried out (e.g. in a particular year) = $\frac{\text{number of Ex detailed inspections carried out} \times 100}{\text{total number of Ex electrical equipment installed}}$
- % Ex close inspections carried out (e.g. in a particular year) = $\frac{\text{number of Ex close inspections carried out} \times 100}{\text{total number of Ex electrical equipment installed}}$
- % Ex visual inspections carried out (e.g. in a particular year) = $\frac{\text{number of Ex visual inspections carried out} \times 100}{\text{total number of Ex electrical equipment installed}}$
- % Ex electrical with no recorded Ex inspection (e.g. in a particular year) = $\frac{\text{number of equipment with no recorded Ex inspection} \times 100}{\text{total number of Ex electrical equipment installed}}$
- Inspection backlog = $\frac{\text{number of overdue inspections} \times 100}{\text{total number of Ex electrical equipment installed}}$

(This KPI may be part of a broader KPI for all types of SCE.)

Where a duty holder has determined an audit of a new installation is necessary the following KPIs are suggested:

- Total number of faults found during a new installation audit after initial inspection has been completed, which can be subdivided by severity into:
 - Number of major items: faults where corrective action should be taken in the short term (e.g. <one week).
 - Number of minor 'B' integrity items: faults where corrective action should be taken in the medium term (e.g. <three months).
 - Number of minor 'C' housekeeping items: faults that do not affect level of risk but represent a non-compliance with standards (e.g. missing or damaged labelling) where action should be taken in the long term (e.g. <12 months such as during the next planned maintenance).

Note: the terms major, minor 'B' and minor 'C' are used to categorise faults based on their risk ranking. Examples of fault categories are given in Table 11, 4.10.2.

Note: additional parameters calculated within the scope of RBI Ex inspection may also be used as KPIs : for instance the number of lots deemed unacceptable as their faults weighted score exceeds their rejection criterion (see 4.10.1) or the number of lots whose category of inspection must be increased (see 4.11).

4 IMPLEMENTING RBI EX SAMPLING STRATEGY

This section sets out the steps in developing an inspection plan by applying the RBI sampling methodology. It defines key parameters and provides guidance on determining suitable values with an initial sample inspection in mind. In order to present an easily implementable approach, some parameters of the method have been frozen (ASL, global failure rate). This has no impact on the risk level characterising an asset which the method converges towards, but only on the number of inspection cycles needed for the method to converge. Yet, the extensive technical basis of the method can be referred to in Annex C.

To help users, the sampling methodology is illustrated with examples (see also Annex B) and includes rules for applying a sampling plan.

The flowchart on the next page will help users differentiate the successive steps in implementing the RBI Ex inspection strategy. These steps and their prerequisites are detailed in 4.1 to 4.11.

Note: sampling should be separate from the periodic inspection. Where sampling and periodic inspection are set up separately there will be instances of inspection activity duplicated. In these cases, the TPEF may elect to take credit for the sample inspection results, provided that:

- a. the grade of the inspection is the same or greater than that selected under the periodic strategy, and
- b. the time elapsed is not such that would significantly affect the results.

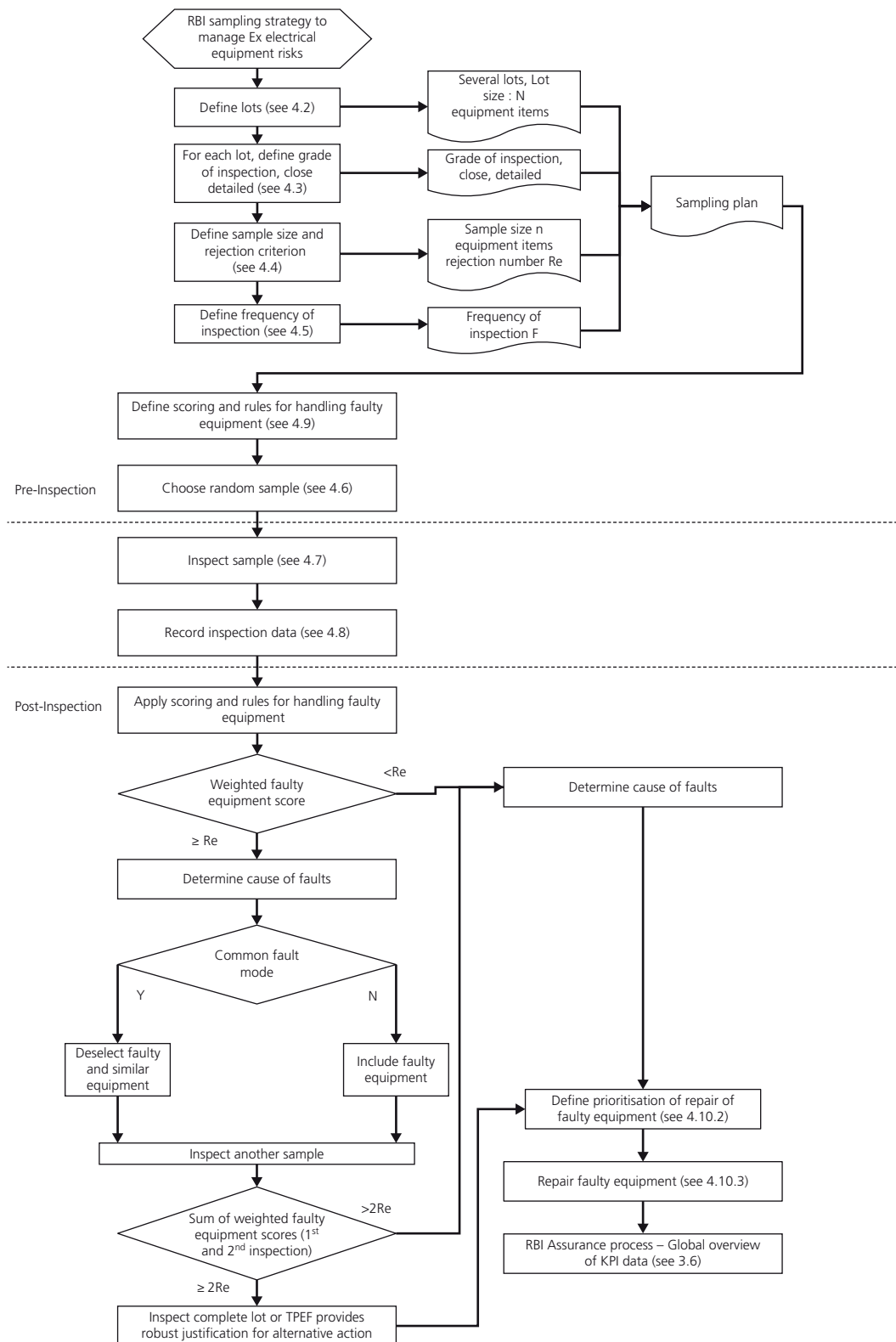


Figure 3: Steps in developing a sampling plan by applying a RBI Ex sampling strategy

4.1 EQUIPMENT REGISTER

The fundamental requirement of a risk-based approach to managing Ex electrical equipment inspection is the collection and analysis of equipment records in support of an equipment register.

It is a fundamental assumption that a comprehensive and accurate equipment register is available: the lack of such an equipment register will make demonstration of compliance with legislation, regulations and standards very difficult, if not impossible, and will similarly dramatically affect the ability to properly inspect, maintain and operate parts of the installation.

Whilst any new equipment register or modification to an equipment register is essentially part of the design group function, the verification of a new equipment register or modifications to an existing equipment register should form part of the installation and commissioning group's scope.

The accuracy of any equipment register is very dependent on the quality of data provided by the design and construction group. The installation and commissioning team have an important role in verifying that the data provided are correct by comparing these data with the installed Ex electrical equipment nameplates. Practical experience shows that, especially with late changes in design, some errors can often occur.

To be able to implement an RBI strategy, the Ex equipment register should, as a minimum, record the information in Table 1. Duty holders should find that most of the fields in Table 1 overlap with those already being recorded as part of existing ATEX asset registers.

Table 1: Suggested minimum content of an equipment register

Location definition		
1	Tag number	Unique identification number as externally marked on the item of equipment
2	Area	Asset defined to suit the installation
3	Sub-area	Asset defined to suit the installation
4	Hazardous area zone /gas group/ temperature class	Zone 0, Zone 1 or Zone 2 / e.g. IIC / e.g. T3
5	Required equipment category	
Equipment		
6	Designation/type	Asset defined description, for example junction box or temperature transmitter
7	Serial number	As marked on the equipment item
8	Loop number	From loop drawing to identify associated items in an I.S loop
9	IP rating	As marked on the equipment item
10	Manufacturer	As marked on the equipment item
11	Hazardous area marking	As marked on the equipment item
12	EU type certificate number	As marked on the equipment item
ATEX compliance		

Table 1: Suggested minimum content of an equipment register (contd.)

13	Ex marking compliance	Yes/no
14	Other non compliance (fault description: e.g. cable, earthing, enclosure etc.)	
15	Recommendations	
Additional information		
16	First use	≤5 years old; >5 years old but ≤20 years old, and >20 years old
17	Environmental conditions (exposure to weather: severe, moderate, benign)	Exposure to difficult conditions regarding exposure to one of the following factors: dust/sand, ultraviolet radiation, ambient temperature or temperature cycling
18	Corrosion rating	High: delamination, medium, low: no surface corrosion
19	Vibration exposure	High: turbine, medium: rotating equipment, low: fixed
20	Additional area information	

In this example four of the items recorded in such a register will be used to define the lots (specifically defined and identifiable collections of equipment with similar characteristics, see 4.2 or Annex E) of Ex equipment. They are further detailed in the following sections.

The following lots definition process is given as an example, and can be adapted to fit the specificities of each asset, at the duty holder's appreciation.

4.1.1 Hazardous area classification

Equipment should be divided according to the following four hazardous area classification zones for the purpose of defining lots:

- Zone 0;
- Zone 1;
- Zone 2, and
- non-hazardous.

Note: in the case of offshore installations, which are compact, it might be prudent to consider external non-hazardous areas as Zone 2 areas for the purpose of defining lots and inspecting Ex electrical equipment.

4.1.2 Type of protection

For the purpose of defining lots equipment should be divided according to common attributes such as their type of protection:

Note: some flexibility may be used in the defining of lots:

- Where an equipment item has more than one protection concept, the dominant concept may be used to categorise it.
- Where there is a small number of non incendive Ex 'n' equipment this may be grouped with increased safety Ex 'e' equipment.
- Other types of protection; oil filled Ex 'o', powder filled Ex 'q', encapsulated Ex 'm' may be grouped together
- Where there are large numbers of equipment which share the same multiple protection type these can be grouped together.

Where there are very small numbers of equipment with specific protection types these should not be grouped into lots, confidence in their ongoing suitability must come from periodic inspection alone which should be a factor when determining the applied grade of inspection.

4.1.3 Environmental conditions

Equipment in the same installation area can be divided according to the following six environmental conditions for the purpose of defining lots:

- water, corrosion (salt, humidity, SO₂, etc.), chemicals;
- dust/sand;
- ultraviolet (UV) radiation;
- ambient temperature or temperature cycling;
- mechanical damage, vibration, and
- hydrocarbon leaks and seeps.

Such environmental conditions have the potential to accelerate equipment ageing. 4.4.3.2 provides an example of grading the severity of the environment into categories 'severe', 'moderate' and 'benign'.

4.2 LOT IDENTIFICATION

Equipment lots should be defined by applying common factors to the contents of an equipment register of Ex electrical equipment used in hazardous areas, in this example:

- hazardous area classification;
- type of protection, and
- environmental conditions.

Therefore, equipment in a lot should be similar for one or more of the following reasons:

- used in the same hazardous area classification;
- have the same type of protection, and
- used in the same environmental conditions, including the same installation area.

Ex electrical equipment should be allocated to lots using the criteria in 4.1.2; to facilitate this, a matrix should be defined. The number of equipment items in each lot will vary. See 4.2.1 regarding exclusion of equipment from lots and assigning equipment to specific lots.

Note that as more of the factors in 4.1.2 are applied when determining lots, the equipment will tend to be more homogeneous (e.g. same hazardous area classification, same type of protection etc). However, this has the disadvantage of resulting in small lots except where the equipment is prevalent (e.g. junction boxes, luminaries, etc.). Users should carefully consider how to best define lots based on their portfolio of equipment, its location in installation areas, typical shutdown areas, etc.

When building lots, users need to be aware of the balance between practicality and methodology, large lots on a comparatively small installation are likely to lead to an effective sampling regime but which are impractical in terms of work management. It may be preferable to carry out separate maintenance builds for periodic inspection routes and sampling lots.

Some 80 % of Ex electrical equipment in a typical installation may be located in Zone 2 hazardous areas; with such numbers, it should be beneficial to apply the sampling methodology. However, the number of Ex electrical equipment located in Zone 0 and Zone 1 hazardous areas of a typical installation may preclude application of the sampling methodology since lot sizes may be small, and more so once the additional criteria of 4.1.2 are used to further subdivide the equipment into lots.

The case study presented in Annex B illustrates the definition of lots for an example asset register and proposes a matrix used for this purpose.

4.2.1 Exclusion of equipment from lots and assigning equipment to specific lots

Some circumstances may preclude equipment from being allocated to lots and including it in a sampling plan. For example, where:

- Specific grades and frequencies of inspection are required by overriding legislation, standards etc. (e.g. for fire and gas detection equipment).
- The equipment design life is relatively short compared to the frequency of inspection such that it is unlikely to be inspected whilst in service.

Other circumstances may necessitate equipment being allocated to specific lots and including it in a sampling plan. This may apply to:

- Equipment with a particular safety integrity level (SIL) requirement.
- SECEs, which will be energised during emergencies (e.g. fire and gas detection equipment, emergency lighting, public address (PA), general alarm (GA), etc.).

Having such specific lots may facilitate allocation of a particular level of inspection proportionate to the equipment specific requirements. In addition, it ensures that some higher risk equipment is inspected, rather than it possibly not being randomly selected if part of a lot of mixed equipment.