

QUANTIFYING THE TOLERABILITY OF POTENTIAL IGNITION SOURCES FROM UNCERTIFIED MECHANICAL EQUIPMENT INSTALLED IN HAZARDOUS AREAS†

Steve Sherwen
Senior Consultant, ABB Engineering Services, Daresbury Park, Warrington, Cheshire WA4 4BT, UK

The Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) place a requirement on the operators of equipment located in hazardous areas to ensure that equipment cannot produce an ignition source. Certified electrical equipment has been widely available for a number of years but certified mechanical equipment has only been produced for the last 10 years. The DSEAR ACOP states, "Equipment/protective systems at the workplace can continue to be used provided that the assessment indicates it is safe to do so." Guidance on how to carry out this assessment can be taken from BS 13463-1:2009 [2], "Non-electrical equipment for potentially explosive atmospheres — Part 1: Basic method and requirements".

This standard states that the tolerability of the potential ignition source is proportional to the hazardous zone where the machine is installed. What the standard does not do, is fully define what is meant by a rare failure or an expected failure with respect to existing equipment.

ABB has developed a methodology that defines the tolerability of these failure rates and then determines the suitability of equipment using a semi quantified risk assessment. This process uses failure data and potential mitigating measures to either justify the continued use of the equipment or specify extra safeguards that need to be implemented in order to assure the continued use of the machines.

This paper discusses the practical experience gained in carrying out studies using this methodology and gives real worked examples from a study carried out at SRM Ltd., Sunderland Ocean Terminal site.

KEYWORDS: DSEAR, ATEX, mechanical risk assessment

INTRODUCTION

DSEAR, for the first time, legislated and laid out requirements for operators to follow to demonstrate that they were identifying and addressing the risks of using flammable substances in the workplace.

For the diligent employer; particularly in the chemical, oil and gas and pharmaceutical industries, many of the requirements were already being met. These requirements included:

- Carrying out Area Classification
- Having risk assessments for working with flammable substances
- Having emergency response plans
- Identifying and labelling containers and pipes
- Selecting electrical equipment appropriate to the identified zone
- Maintenance and inspection electrical equipment as per the requirements of EN 60079 part 17

One area that was new to all operators was the requirement to select mechanical equipment, constructed to the requirements of the "Equipment and Protective Systems for Use in Potentially Explosive Atmospheres Regulations 1996" (EPS) [3]. Put simply, any new mechanical equipment would now need to be certified and any existing equipment, assessed to determine if it is suitable for ongoing use.

Regulation 17 of DSEAR states in Table 1, that for plants in use on or before 30th June 2003, the user must "Review equipment/protective systems against risk assessment requirements in regulation 5 of DSEAR. Equipment/protective systems at the workplace can continue to be used provided that the assessment indicates it is safe to do so."

The methodology for carrying out this assessment and indeed identifying the suitability of the equipment was not expanded upon further.

This paper looks at how ABB have carried out these assessments and decided upon criteria to establish the suitability of equipment using a semi quantified analysis.

THE ASSESSMENT PROCESS

MECHANICAL IGNITION SOURCES

Mechanical equipment can produce an ignition source for a number of reasons. Considering fluid handling equipment, a typical centrifugal pump can create ignition sources as a result of the following reasons, shown in Figure 1.

As can be seen, the ignition sources can be as a result of normal operating conditions, expected failures or rare failures.

THE TOLERABILITY OF IGNITION SOURCES

EN 13463-1:2009 outlines the process and recording format that the manufacturers of new equipment should adopt to

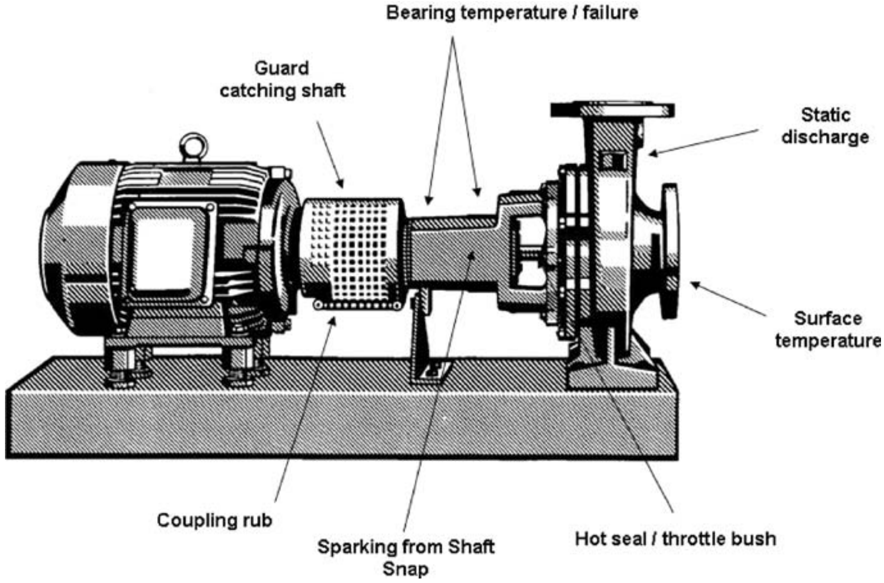

Figure 1. Ignition sources from a centrifugal pump

comply with the requirements of the EPS. ABB ES have adopted this approach in the retrospective assessment of existing equipment, as there was little guidance.

This standard lays out the tolerability of the ignition sources versus the hazardous area zone where it is installed. In essence it says that:

- Category 1 equipment, installed in a zone 0/20 must not produce an ignition source through normal operation, as a result of an expected failure and as a result of a rare failure.
- Category 2 equipment, installed in a zone 1/21 must not produce an ignition source through normal operation and as a result of an expected failure.
- Category 3 equipment, installed in a zone 2/22 must not produce an ignition source through normal operation.

The definition of the hazardous zones are taken from the DSEQAR ACOP, L138 and outlined in Table 1.

There is no further expansion of what is meant by an expected failure or a rare failure.

ABB wanted to define these failures further so that it would be possible to identify a threshold to identify if an item of equipment was suitable for ongoing use.

To this end, the following failure rates were derived, taking guidance from the 3rd edition of IP15 (Area Classification Code – Part 15 of the Model Code of Safe Practice) and in particular Annex C – Part 2. This section of the standard outlines the risk acceptability criteria used in this edition of IP15.

The boundary between an expected failure and a rare failure has been taken to be once every 25 years or a probability of 0.04 i.e. the failure rate of a component must be les than 0.04 to be allowable in a zone 1 area.

Expected ignition sources are not tolerable in a zone 1 area but rare failures are allowable.

For this equipment, rare failures are not tolerable and so the failure rate must be extremely rare or less than 0.004 (1 in 250 years).

It should be noted that BS EN 13463-1 in its part qualitative part quantitative approach implies a zero limit for equipment in zone 0. This is physically impossible as all means of mitigation and control can fail and the residual likelihood of an active ignition source is linked to the combined "failure on demand rate" of the measures employed. These can never get to zero however much redundancy is employed.

No failure rate data are given for equipment installed in a zone 2 area as failures that produce an ignition source are tolerable. This equipment must not produce an ignition source under normal operating conditions.

DETERMINING THE PROBABILITY OF IGNITION SOURCES

In order to establish if an item of equipment is suitable for the hazardous zone in which it is installed, the probability of that item failing and producing an ignition source, must be established.

ABB ES use fault trees to carry out this semi quantitative assessment. This example is from an agitated vessel used by SRM Ltd. at its Ocean Terminal site in Sunderland.

This vessel is used to mix a blend of solvents, used as alternative fuel in the cement industry. It is a tall, cylindrical vessel fitted with an agitator and was classified as having an internal zone 0 with a T4 temperature classification.

Table 1. Definition of hazardous zones

Zone	Definition
0	A place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas vapour or mist is present continuously or for long periods or frequently.
1	A place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.
2	A place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.
20	A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequently.
21	A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.
22	A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

As can be seen, the failure rates of each sub assembly or process conditions are listed. These are base failure rates i.e. where no ignition source protection is present.

Each failure case is derived from identifying all the causes of that failure. For example, a bearing could fail due to poor assembly, overloading, inadequate lubrication or through wear out.

The next fault tree focuses on agitator faults that lead to an ignition source. These faults are the shaft failing and either snapping or bending, allowing the impeller to contact the internal baffles or tank wall. This could create a hot spot or incendive spark.

It was established that as the tank internals were a zone 0, the agitator should not produce a potential ignition source, except if the chance of such a failure was extremely rare i.e. less often than 1 in 250 years.

Table 2. Tolerability of ignition sources

Zone	Upper limit of duration of flammable atmosphere (hours/year)	Upper limit of ignition source tolerability–cumulative for each equipment item (events/year)	Tolerable overall failure rate for all ignition sources for each equipment item
0	8760	0.004	1 in 250 years
1	1000	0.04	1 in 25 years

Calculations suggested that for one of the 5 units, the running speed was close to the critical speed of the agitator. This meant that if the agitator was operated inside an empty vessel, the shaft could bend, allowing the impeller to strike the vessel wall, spark and potentially ignite the flammable vapour contained inside the vessel.

Given the geometry of the agitator and vessel, a shaft deflection of only 5 degrees would be needed for the blades to catch the baffles – something easily achievable. The linear speed of the blades is 2.5 m/s, fast enough to produce a spark or friction.

The only protection prior to the assessment was an operating procedure that required the agitator to be turned off when the level in the tank was below a certain value.

$$\text{Failure Rate}\quad F_{current} = \text{Base Failure Rate} \times \text{Mitigating Factors}\,(M_1 \times M_2 \ldots M_x)$$
$$F_{current} = 0.05 \times 0.5$$
$$F_{current} = 0.025$$

As can be seen this is greater than the target failure rate of 0.004 failures per year.

$$F_{current} > F_{target}$$

Had the running speed been below the critical speed, this would have been a safeguard as well, as it was on other agitated vessels (a mitigation of $M = 0.1$ is awarded when this design criteria is used).

MITIGATING THE FREQUENCY OF IGNITION SOURCES

There are a number of mitigations or protection layers that can be employed to reduce the probability of a failure occurring and therefore an ignition source happening.

These mitigating actions can be grouped into one of the following generic categories:

- Operating & Maintenance Instructions
- Operating & Maintenance documented checks
- Periodic Condition monitoring
- Alarms requiring operator action
- Instrumented trips
- Hardware protective devices
- SIL 1 rated instrument loops

These mitigations each lower the chance of a failure occurring by between a factor of 0.5 and a factor of 0.05. They can be used together and credit claimed providing they are mutually exclusive e.g. a maintenance action and a hardware protective item but not two actions by the same person – if they miss one action, they are likely to miss the second.

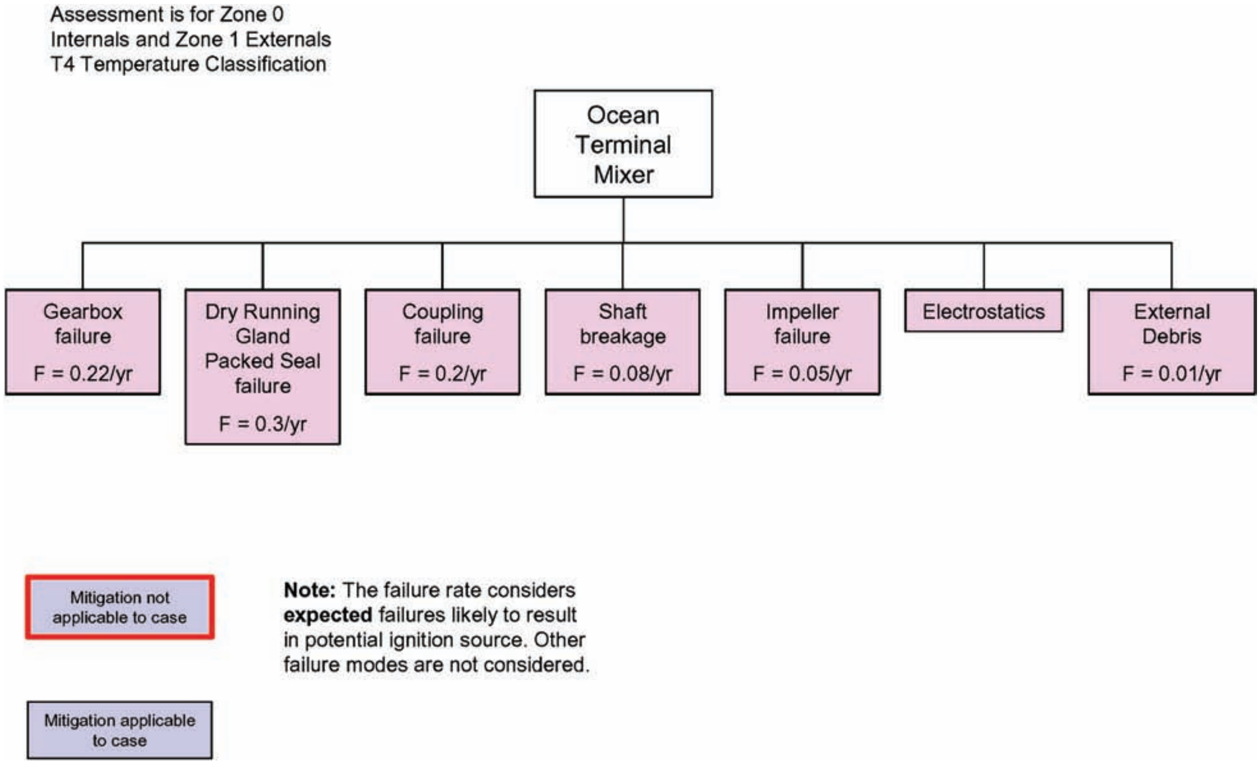

Figure 2. Fault tree

Using this semi-quantitative approach allows us to judge how much mitigation is required to demonstrate if a machine is suitable for ongoing use.

APPLYING THE MITIGATION

It was decided that in the above case study, an extra layer of protection was required. It was agreed with SRM Ltd. that an instrumented interlock would be used to prevent the agitator running when the liquid level was below the level of the impeller. A mitigation of 0.1 can be given to a non-SIL rated instrument protection loop, providing it is adequately tested and designed.

$$F_{new} = \text{Base Failure Rate} \times \text{Mitigating Factors}$$
$$(M_1 \times M_2 \ \ldots M_x)$$
$$F_{new} = 0.05 \times 0.5 \times 0.1$$
$$F_{new} = 0.0025$$

As can be seen this is now less than the target failure rate of 0.004 failures per year.

$$F_{current} > F_{target} > F_{new}$$

This added enough mitigation so that the chance of there being a spark as a result of the shaft bending, striking the vessel wall in a vapour/air mixture was low enough to be tolerable.

SOURCES OF DATA

In carrying out these assessments, use is made of the experience of ABB Engineering Services' machinery engineers. This amounts to well over a hundred years collective experience of the operation of a wide range of machinery in process industry applications.

Other published sources of data and internal reports produced by ICI Engineering's machinery section provide further failure rate data.

The sources give representative data for the major rotating equipment types and static equipment such as valves. A conservative approach was taken in assessing and quantifying the likelihood of and consequences of active ignition sources. For example, the higher end of a likely frequency range of an event was taken together with maximum likely temperature potentially caused by that event.

In some cases there is no data available for specific equipment types. In these instances we compare the equipment sub-assemblies and relate these to similar assemblies in equipment for which we have data. Figures for the relative reliability are derived in this manner.

The mitigation factors are also derived from a number of sources. For activities involving operators and

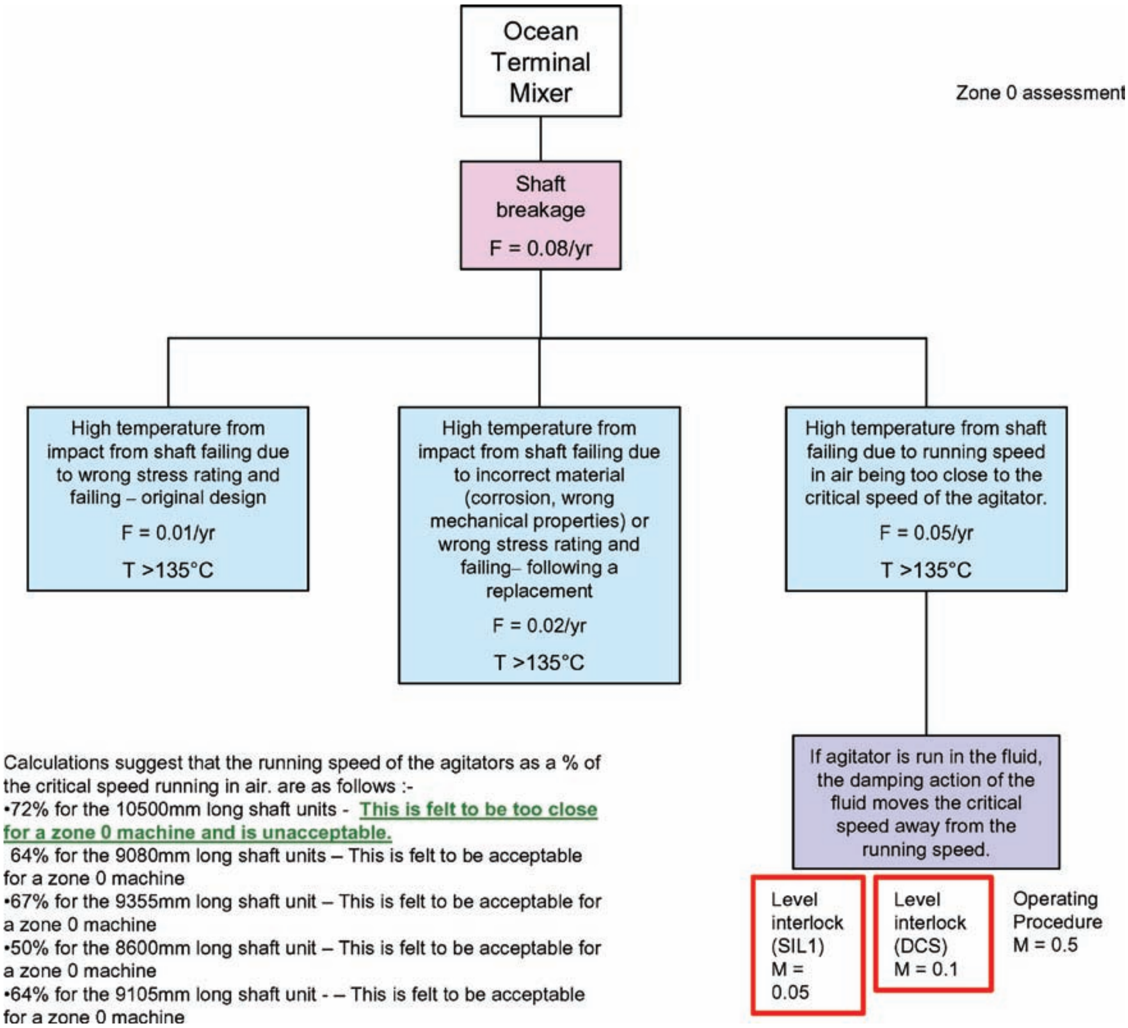

Figure 3. Fault tree detail

maintenance technicians the factors for human error are derived from those used in hazard study analysis. For instrumentation they are related to the failure on demand factors used in SIL determination.

CONCLUSIONS

The adoption of this technique allowed us to demonstrate that in the vast majority of cases, diligent employers with good initial specification, maintenance and operating policies can continue to use their installed equipment base with minimal extra work.

Where modifications or improvements have been required, the use of a semi-quantified risk assessment, known as Hazmec, has allowed the improvements to be targeted to address the risk without adding unnecessary complexity or costs.

REFERENCES

1. HSE, The Dangerous Substances and Explosive Atmospheres Regulations 2002, HSE Books.
2. British Standards, BS EN 13463-1 – Non-electrical equipment for potentially explosive atmospheres, Part 1: Basic method & requirements.
3. HSE, The Equipment and Protective Systems for Use in Potentially Explosive Atmospheres Regulations 1997, HSE Books.