

DEP SPECIFICATION

SAFEGUARDING AND INSTRUMENTED PROTECTIVE FUNCTIONS FOR ROTATING EQUIPMENT

DEP 32.29.20.10-Gen.

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DESIGN AND ENGINEERING PRACTICE

DEM1



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for safeguarding and instrumented protective functions (IPFs) for rotating equipment. For guidance on condition monitoring of rotating equipment, refer to DEP 31.29.00.11-Gen. This standard covers the minimum safeguarding requirements for rotating equipment in vital and essential services used in petroleum, chemical, and gas industry process services and is intended for use in conjunction with the machinery DEPs.

Protecting and safeguarding rotating equipment prevents or limits the possible damage to rotating equipment in the event of a malfunction. It avoids, or significantly limits consequential damage to the environment, minimizes potential hazards for people, prevents damage to adjacent equipment and minimizes significant lost revenue for the facility.

This DEP provides functional safeguarding requirements for vital and essential rotating equipment, either spared or unspared, in continuous operation, but does not provide safeguarding requirements beyond rotating equipment protection. For safeguarding other plant equipment and processes (e.g., reactors, heaters, vessels, etc.) where tripping the rotating equipment is considered critical to the success of the safeguard, there may be additional requirements on the rotating equipment IPF beyond those specified herein.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

This is a revision of the DEP dated February 2013; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

The word **may** indicates a permitted option.

1.3.2 Specific definitions

Term	Definition
alarm	Audible and/or visible means of indicating to the operator an equipment malfunction, process deviation, or abnormal condition requiring a response. (ANSI/ISA-18.2) Warning of the presence of a hazard to life, property or the environment. (IEC 62642-1)
essential	Service in which failure of equipment renders a plant inoperable or reduces performance to an unacceptable level.
high energy pumps	Pumps with head greater than 200 m (650 ft) per stage and with power more than 225 kW (300 bhp) per stage.
IPF	Instrumented Protective Function, now known as SIF (Safety Instrumented Function)
NFPA	National Fire Protection Association (USA)
OEM	Original Equipment Manufacturer
Process Safety Time	Period of time in which the process can be operated without protection and with a demand present without entering a dangerous condition. The Process Safety Time determines the dynamic response requirements of an IPF.
pre-alarm	Alarm that, if not responded to, may result in a demand on an IPF, i.e., a machine trip.
SIFPro	Shell developed RRM software tool and Work Process that optimally designs Safety Instrumented Function
SIL	Safety Integrity Level
SIL Assessment	Team activity, whereby the SIL of one or more IPFs is established and the rationale documented using a defined methodology. In the same activity, related safety integrity system requirements are defined and documented.
trip	Automatic shutdown of a machine upon reaching a pre-set trip value.
Vital Service	A service which, when failing in operation or when failing if called upon, may cause an unsafe condition of the process and/or electrical installation, jeopardise life, or cause major damage to the installation.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets (). Other documents referenced by this DEP are listed in (5).

1.5 SUMMARY OF MAIN CHANGES

This is a revision of the DEP dated February 2013. The changes followed a requirements quality review and were not a full technical update. The following are the main, non-editorial changes:

Section/Clause	Change
All	Restructured and clarified requirements, enforced use of shall/should/may for normative statements.
4	Separated the tables into specific SHALL [PS], shall, should, may statements and tables converted to informative summaries. Non-normative text removed

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://swwww.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

2. GENERAL

2.1 OBJECTIVES

The type of protection to be applied depends largely on the type of rotating equipment. The main strategy for any machinery is to protect against operating the equipment outside its integrity and performance design envelope. For several types of equipment, this protection is defined according to International and API standards, particularly API 670.

1. A project specific Safety Integrity Level (SIL) assessment shall be carried out on hazardous processes and associated equipment in accordance with DEP 32.80.10.10-Gen.
2. If a machinery system is defined as a hazard per section 4 of DEP 32.80.10.10-Gen., then this DEP 32.29.20.10-Gen. shall be applied to the design and implementation of instrumented protective functions (IPFs) for the machinery.

The underlying assumption is that adequate operational attention is paid to the rotating equipment in service that the correct pre-start checks are carried out prior to putting machines into operation, and that adequate start permissives are in place.

3. For rotating equipment packaged units that have dedicated safeguarding and control systems, the safeguarding system shall be SIL assessed to assure compliance with IPF classification and implementation methodology.

Some rotating equipment packaged units have dedicated safeguarding and control systems included in the package instead of being integrated in the overall plant safeguarding and DCS systems. Typically, gas turbine driver packages are equipped with their own dedicated systems, which often feature the "single start/stop button" design. The package safeguarding and control systems include start permissives, programmed operational logic, and alarm and shutdown functions.

4. Exceptions to IPF classification and implementation methodology for packaged equipment shall be subject to approval of the Principal.

3. ROTATING EQUIPMENT SAFEGUARDING BACKGROUND

3.1 MACHINE ALARM AND SHUTDOWN FUNCTIONS

Machine safeguarding shutdown functions ("trips") are required on rotating equipment to prevent serious failures resulting in potential hazards to personnel or the environment or in extended process unit downtime.

1. All machine trips shall be provided with a pre-alarm prior to a shutdown to allow Operations sufficient time (typically minimum 15 minutes) to take action to prevent a trip.
2. Shutdown function design shall be based on an SIL Assessment.
3. Shutdown function design shall incorporate the recommendations of the original equipment Manufacturer (OEM).
4. In cases where it is safer to keep the machine running to allow a process shutdown, the shutdown system should be sequenced to do so automatically so that the process is returned to a safe situation before the machine is shut down.

The IPF methodology specified in this DEP is intended to avoid unnecessary machine trips. In some processes it is safer to keep the machine running in order to carry out an orderly process shutdown.

3.2 INPUT TO THE IPS

API 670 has traditionally required relays be used as the output from the machinery protection rack to the IPS, and that voting be carried out in the machinery protection rack. This approach may limit flexibility in the IPS implementation for some applications.

1. As an alternative approach to API 670, 4 mA – 20 mA outputs on the machinery protection rack may be directed to the IPS, where voting and other logic can be implemented in that system:
 - a. either relays or 4 mA – 20 mA signals may input to the IPS;
 - b. if relays are used as input to the IPS, the most configurable relay system available should be selected in order that flexibility in the design of voting logic is available.
2. NOT OK and BYPASS conditions shall be included when voting in the IPS, either with relays or 4 mA – 20 mA outputs.
3. By choosing to vote in the IPS instead of in the machine protection rack, some desired functionality around OK and BYPASS conditions that are part of the machine protection rack design might be overridden in the IPS. This functionality shall be included in the design of the logic system in the IPS.
4. For systems where voting is implemented in the IPS, NOT OK condition should be configured as a vote to trip as one of the following:
 - a. in the instrument circuit;
 - b. in the cards in the machinery protection rack;
 - c. removing the NOT OK channel from the voting logic (i.e., 2oo3 voting reverts to 2oo2 in the presence of a NOT OK channel).
5. In all cases a NOT OK condition shall trigger a high priority operator alarm.
6. There are processes that are not tolerant to trips; in these cases tripping on NOT OK should be evaluated and other actions taken to prevent loss of machinery protection in the case of instrument or card faults.
7. Due to the impact of card failures, voting channels shall be segregated between cards.

This prevents a card failure causing a trip on NOT OK, and also prevents a card failure completely removing machinery protection.
8. For offshore applications where space and weight is a concern, monitoring systems may be utilized that are not 19 inch rack mounted (as required to be compliant to API 670), subject to approval by the Principal:
 - a. these systems may be modular on skid, or modular in an auxiliary room (din rail mounted as an example);
 - b. monitoring systems that are not 19 inch rack mounted shall have the necessary IPF functionality per the requirements of this DEP.

3.3 SHUTDOWN SETTINGS

1. There are three main safety/integrity barriers for rotating equipment:
 - a. process containment;
 - b. mechanical containment;
 - c. prevention of ignition sources.
2. Shutdown settings shall be established to protect against equipment failures, i.e., that could breach these barriers and lead to a process safety and/or asset integrity incident.
3. Once the shutdown level is reached, the equipment being protected by the safeguarding system shall shut down automatically.
4. The use of a trip multiplier shall be subject to the approval of the Principal.

In some cases, trip multipliers might be required for machine start-up.

In the case of a trip multiplier, the normal setting is multiplied by a factor 2 or 3 even up to 5 in some cases during start-up to prevent a trip during start-up whilst maintaining some protection rather than no protection as would be the case when applying a start-up override.

5. Shutdown settings shall be selected to prevent the following:
 - a. loss of containment in the machine through the seals or the main casing/bearing housings;
 - b. loss of containment from vibration induced fatigue failure of attachments to the machine, which generally occurs first at flanges or on small-bore piping, tubing and instruments;
 - c. secondary damage to the nearby facilities from failed machine components due to breaching mechanical containment;
 - d. failures that keep the machine down for extended periods, e.g., those entailing damage to the casing or stationary components. Bearing and rotor damage may result when a shutdown event occurs.

3.4 TIME DELAYS

1. In all cases to prevent significant equipment damage and plant exposure, overspeed trip functions, axial position trip functions, surge shutdown on axial compressors and manual trip buttons shall have no time delays in instrument system design.
2. All proposed time delays shall be subject to the approval of the Principal.
Typical package shutdown PLCs, vibration monitoring systems, surge control systems and other instrument package systems can have built-in time delays as a standard feature, usually intended to prevent spurious trips caused by signal noise or fast transients.
3. The default shutdown time delay settings from the instrument Manufacturer/Supplier shall ultimately be reviewed during system commissioning (usually the instrument Manufacturer/Supplier).
The default settings from the instrument Manufacturer/Supplier will likely include a few seconds of time delay. Often during the course of the design phases, individual time delays can add-up and can ultimately exceed the Process Safety Time.
4. Start-up overrides and temporary start-up time delays shall be subject to approval of the Principal.
There are some pieces of equipment where automatic start-up overrides (time and/or condition limited override during machine start-up) are necessary for equipment start up.
5. Depending on the plant site, time delays on selective trip points can be justified to prevent false trips from rough weather or other factors unrelated to equipment failure. In such cases, time delays should not be limited to just rotating equipment.
6. Before adding time delays to machine trip functions, it should be confirmed that the shutdown system design does not already include a system delay in the plant shutdown hardware.
7. If a machine trip time delay is necessary, the time delay plus the time to trip SHALL [PS] not exceed the calculated Process Safety Time.
8. Time delays should be evaluated in the HAZOP process.

3.5 SURGE CONTROL AND SHUTDOWN IN COMPRESSORS

1. Refer to DEP 31.29.40.10-Gen., section 6.7.3.1 for surge control and shutdown design alternatives.
2. The surge reference line and the surge control line should be chosen such that 80% plant throughput operating points in performance diagram for all normal operating conditions specified in requisition are located on right hand side of the surge control line and therefore the anti-surge control valves are still closed.

4. IPF CLASSIFICATION BY MACHINE TYPE

4.1 GENERAL

The required and recommended safeguarding for various types of rotating equipment, are shown in the following sections (4.2) through (4.15). DEM 1 requirements specified in the sections, apply only to the trip parameter.

The sections include typical IPF requirements and selective alarms for the subject equipment.

Other trips, alarms, and permissives might be necessary, depending on the particular equipment Manufacturer/Supplier's requirements, recommendations and local requirements. Project requirements could also dictate additional alarms or other IPF features over and above the requirements of this DEP.

1. Where typical SIL levels are mentioned, they may be used as a starting point for a project or machine specific SIL evaluation.
2. The instrumentation type, level of redundancy, and voting logic selection shall be based on the SIL analysis according to process safety, plant economics and environmental considerations as determined during the IPF design, as required per DEP 32.80.10.10-Gen.