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INTERNATIONAL STANDARD

Binary power generation systems –
Part 3-1: Safety requirements – System with less than 500 kW in capacity

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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BINARY POWER GENERATION SYSTEMS –

Part 3-1: Safety requirements – System with less than 500 kW in capacity

FOREWORD

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IEC 63277-3-1 has been prepared by IEC project committee 126: Binary power generation systems. It is an International Standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
126/68/FDIS	126/74/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 63277 series, published under the general title *Binary power generation systems*, can be found on the IEC website.

Future documents in this series will carry the new general title as cited above. Titles of existing documents in this series will be updated at the time of the next edition.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

While the world's binary power generation systems are growing, the IEC 63277 series specifies the performance test methods of binary power generation systems and acknowledges the fair and standardized competition of binary power generation systems.

It is very important to ensure that the binary power generation systems will be operated safely during the operation. Safety requirements are an important theme that should be internationally standardized as well as the performance test methods.

By adding an objective evaluation of safety based on international standards, it is expected that the selection criteria will become more appropriate and that it will have the effect of promoting it worldwide.

This document addresses the safety considerations unique to binary power generation systems and is intended to be one in a series of international standards addressing this new technology.

BINARY POWER GENERATION SYSTEMS –

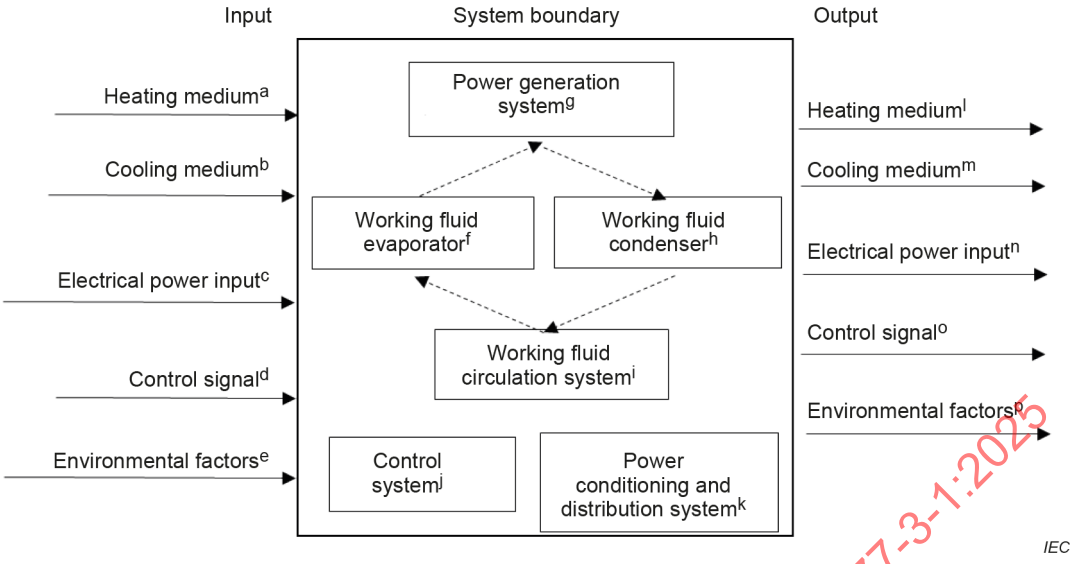
Part 3-1: Safety requirement – System with less than 500 kW in capacity

1 Scope

This part of IEC 63277 describes the safety requirements of binary power generation systems based on organic Rankine cycle (ORC) with less than 500 kW in output capacity.

This document covers significant hazards, hazardous situations, and events, with the exception of those associated with environmental compatibility (installation conditions), relevant to binary power generation systems (ORC), when they are used as intended and under the conditions foreseen by the manufacturer.

A typical binary power generation system is shown in Figure 1.



a	Heat transport medium for working fluid heating, commonly steam or hot water	f	Heat exchanger for evaporating the working fluid using of heating medium	l	Emission of heating medium from the system after heat exchanged
b	Heat transport medium for working fluid cooling, commonly air or water.	g	The system consists from a turbine or expander and a generator, it converts thermal energy of working fluid to electric energy	m	Emission of cooling medium from the system after heat exchanged
c	Electrical input specified by the manufacturer, for controls and other supporting functions	h	Heat exchanger for condensing the working fluid using a cooling medium	n	The power produced from the system and provided to an external load or grid
d	Includes the providing of control signals, setpoint and operation instructions as well as remote access, parameter, software, and firmware updates	i	Pressurization equipment for circulating the working fluid in a closed system	o	The transmission of operational state and other data collected or generated by the system
e	Factors from the surrounding impacting the binary power generation system, such as earthquake, rain, wind, snow, temperature, humidity, and atmospheric condition but also electromagnetic disturbances	j	System(s) that is composed of sensors, actuators, switches, and logic components that maintain the binary power generation system parameters within the manufacturer's specified limits including moving to safe states	p	Factors from the surrounding impacting the binary power generation system, such as emission of noise, vibrations, polluted water and gas, and electromagnetic disturbance
		k	System(s) that adjusts the power generated by the power generation system for transmitting to the outside of boundaries, and System(s) that distributes the power to the load inside of boundaries		

Figure 1 – Typical binary power generation system

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60079-29-1, *Explosive atmospheres – Part 29-1: Gas detectors – Performance requirements of detectors for flammable gases*

IEC 60204-1, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60335-1, *Household and similar electrical appliances – Safety – Part 1: General requirements*

IEC 60417, *Graphical symbols for use on equipment, available at http://www.graphical-symbols.info/equipment*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60730-1, *Automatic electrical controls – Part 1: General requirements*

IEC 60730-2-6, *Automatic electrical controls – Part 2-6: Particular requirements for automatic electrical pressure sensing controls including mechanical requirements*

IEC 60730-2-9, *Automatic electrical controls – Part 2-9: Particular requirements for temperature sensing controls*

IEC 60730-2-15, *Automatic electrical controls – Part 2-15: Particular requirements for automatic electrical air flow, water flow and water level sensing controls*

IEC 60950-1, *Information technology equipment – Safety – Part 1: General requirements*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61511-1, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and application programming requirements*

IEC 61557-1, *Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC – Equipment for testing, measuring or monitoring of protective measures – Part 1: General requirements*

IEC 61557-2, *Electrical safety in low voltage distribution systems up to 1 000 V AC and 1 500 V DC – Equipment for testing, measuring or monitoring of protective measures – Part 2: Insulation resistance*

IEC 62040-1, *Uninterruptible power systems (UPS) – Part 1: Safety requirements*

IEC 62061, *Safety of machinery – Functional safety of safety-related control systems*

IEC 62477-1, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

IEC 62477-2, *Safety requirements for power electronic converter systems and equipment – Part 2: Power electronic converters from 1 000 V AC or 1 500 V DC up to 36 kV AC or 54 kV DC*

ISO 3864-2, *Graphical symbols – Safety colours and safety signs – Part 2: Design principles for product safety labels*

ISO 4413, *Hydraulic fluid power – General rules and safety requirements for systems and their components*

ISO 4414, *Pneumatic fluid power – General rules and safety requirements for systems and their components*

ISO 7000, *Graphical symbols for use on equipment, available at http://www.graphical-symbols.info/equipment*

ISO 12100, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13709, *Centrifugal pumps for petroleum, petrochemical and natural gas industries*

ISO 13849-1, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

ISO 13849-2, *Safety of machinery – Safety-related parts of control systems – Part 2: Validation*

ISO 13850, *Safety of machinery – Emergency stop function – Principles for design*

ISO 14847, *Rotary positive displacement pumps – Technical requirements*

ISO 15649, *Petroleum and natural gas industries – Piping*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1 Terms and definitions

3.1.1
binary power generation system
set of components that consists of five main components and a system in which a working fluid having a low boiling point is heated and evaporated by hot water, and the expander is driven by the working fluid gas to generate electricity

Note 1 to entry: The five main components are an evaporator, a condenser, a working fluid pump, an expander and a generator.

3.1.2
working fluid
medium used within the thermodynamic cycle that receives heat from the heat source via a heat transport medium and produces power by fluid expansion

3.1.3
heat source
component that supplies heat to drive the system

Note 1 to entry: This power generation system utilizes factory waste heat, hot spring water, geothermal heat and solar heat as heat sources from which it extracts heat with hot water (heat transfer medium) and thereby heats the working fluid through an evaporator to generate vapour.

3.1.4
evaporator
heat exchanger that heats and evaporates working fluid liquid by using hot water

3.1.5
condenser
heat exchanger that cools and condenses working fluid gas by using cold water or ambient air

3.1.6
working fluid pump
fluid machine that pressurize and circulate the liquid from the condenser to the evaporator

3.1.7
expander
machine that generates power by expanding a high-pressure working medium (working fluid vapour) thereby driving a generator

Note 1 to entry: More specifically, high-pressure medium vapour taken in from the expander's inlet internally expands and then is discharged from the outlet port as low-pressure medium vapour; this process converts fluid energy into mechanical power.

Note 2 to entry: Generally, expanders are categorized according to their expansion mechanism into kinetic type (centrifugal, axial, etc.) and displacement type (reciprocating, rotary, scroll, screw, etc.), and are selected depending on operating conditions and capacity range.

3.1.8
design pressure
highest pressure that can occur under any and all operating modes, including steady state and transient

3.1.9
electromagnetic disturbance
electromagnetic phenomenon that can degrade the performance of a device, piece of equipment or system, or adversely affect living or inert matter

3.1.10
electrical equipment
material, fittings, devices, appliances, fixtures, apparatus and the like used as part of, or in connection with, an electrical installation

3.1.11
emergency shutdown
control system actions (based on process parameters) taken to shutdown immediately the binary power generation system and all its reactions, to avoid equipment damage, or personnel hazards or both

[SOURCE: IEC 60050-485:2020, 485-19-02, modified – The words "fuel cell power system" have been replaced with "binary power generation system".]

3.1.12
interlock
component that prevents other operations from occurring unless certain conditions are met and provides that proof to the related safety control device which performs the safety shutdown

3.1.13
enclosure
housing affording the type and degree of protection suitable for the intended application

3.2 Abbreviated terms

EMC electromagnetic compatibility

FMEA failure mode and effects analysis

FTA fault tree analysis

ORC organic Rankine cycle

UPS uninterruptible power systems

4 Safety requirements and protective measurements

4.1 General safety strategy

The manufacturer shall perform risk assessment in written form, in accordance with ISO 12100, to ensure the following.

a) All reasonably foreseeable hazards, hazardous situations and events, and foreseeable misuse throughout the anticipated binary power generation system's lifetime have been identified. Annex A lists the hazards covered in this document.

b) The risk to these hazards is estimated from a combination of the probability of occurrence of the hazard and the projected severity.

c) The two factors which determine each one of the estimated risks (probability and severity) have been eliminated or reduced to a level not exceeding the acceptable risk level through the application of

   1) intrinsically safe structural design and its methods, or

   2) guards and protective devices provided

      i) by passive control of energy release without endangering the surrounding environment (e.g. rupture disc, discharge valve, heat shut-off device), or

      ii) by active control of energy that is released through safety-related control functions.

      EXAMPLE An electronic control device installed in a binary power generation system evaluates sensor signals and implements appropriate measures with safety-related control functions.

d) For residual risks that could not be mitigated by the measures referred to in c), labels, warnings or special training requirements shall be presented so that persons entering the hazardous area understand the need for countermeasures.

e) For functional safety, the required severity level, performance level or grade of control function shall be determined and designed in accordance with the following:

   1) for systems covered by IEC 60204-1, IEC 61511-1, ISO 13849-1, ISO 13849-2, the IEC 61508 series or IEC 62061 shall apply;

   2) IEC 60730-1 shall apply to equipment based on IEC 60335-1 or IEC 62040-1;

   3) for other systems, both the IEC 61508 series and IEC 61511-1 shall apply.

f) For failure mode and effects analysis (FMEA) and fault free analysis (FTA), the following standards can be used as guidance:

   - IEC 60812;
   - SAE J1739;
   - IEC 61025.

4.2 Physical environment and operating conditions

4.2.1 General requirements

The protection system of the binary power generation systems shall be designed and constructed to perform the intended functions under the physical environment and operating conditions specified in 4.2.2 to 4.2.6.

4.2.2 Electrical power input

Binary power generation systems shall be designed to operate correctly with the electrical power input conditions specified in the relevant electrical product standards listed in 4.7 or specified by the manufacturer.

4.2.3 Physical environment

The manufacturer shall define the physical environmental conditions suitable for the binary power generation systems, considering the following:

- use indoors or outdoors;
- temperature, humidity, altitude;
- the possibility of earthquake in the area where it will be installed.

4.2.4 Water input

The manufacturer shall specify the water quality and supply the characteristics of the water used for the binary power generation systems.

4.2.5 Vibrations, shocks and bumps

Adverse effects of vibrations, shocks and bumps (including those generated by machinery and related equipment, and those caused by the physical environment) shall be avoided by selecting the suitable equipment, by mounting away from the binary power generation systems or by mounted on anti-vibration mounts. This does not include the impact of earthquake shocks which shall be dealt with separately if the manufacturer determines that the effects of earthquakes shall be considered (see 4.2.3).

4.2.6 Handling, transportation and storage

Binary power generation systems and its components shall be designed or packed so that they can be safely handled and transported. They shall also, if applicable, provide a means suitable for handling by crane or similar equipment, and be designed to be stored safely and without damage (e.g. proper stability, special support, etc.).

4.3 Selection of materials

All materials shall be suitable for their intended use.

a) Mechanical stability with respect to strength (fatigue properties, endurance limit, creep strength) shall be maintained under the entire range of use conditions during the service life specified by the manufacturer.

b) The fluids used in binary power generation systems (e.g. working fluids, lubricants, cooling water) shall not be adversely affected by chemical and physical effects, and their environmental degradation shall be ensured.

c) Unless replacement is foreseen, the chemical and physical properties of the materials required for operational safety shall not be affected during the planned life of the equipment.

d) When selecting materials and production methods, the corrosion resistance, wear resistance, electrical conductivity, impact strength, aging resistance, temperature change effects, effects of combining materials (e.g. electrolytic corrosion), ultraviolet rays, and the effects on the mechanical performance of materials shall be fully considered.

e) If the materials used to build a binary power generation system are known to be hazardous under certain circumstances, the manufacturer shall implement the necessary measures to fully minimize the risks that threaten the safety or health of persons and provide the necessary information.

f) Asbestos or asbestos-containing materials shall not be used in the manufacture of binary power generation systems. The use of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl, polybrominated diphenyl ether and other hazardous substances, such as polychlorinated biphenyls, can be subject to regulatory requirements.

g) In the event of the possibility of erosion, wear, corrosion or other chemical adverse effects, the following measures shall be taken:

   1) minimize such impacts through appropriate design or appropriate protection (e.g. use of cladding materials or surface coatings), giving due consideration to the intended and reasonably foreseeable use;

   2) make the most affected parts replaceable.

h) The maintenance manual presented in 6.4.4 describes the content and frequency of inspection and maintenance measures necessary for continued safe use. In addition, if necessary, criteria for parts replacement shall be indicated.

4.4 Other requirements

a) To the extent permitted by the application, accessible parts of the binary power generation systems shall not have sharp edges, sharp angles, or rough surfaces that can cause personal injury.

b) Binary power generation systems and peripherals to which access is expected shall be designed and constructed to prevent people from slipping, tripping, or falling.

c) The moving parts of a binary power generation systems shall be designed, built, and arranged to avoid hazards. If hazards persist, the moving parts shall be guarded or secured with protective equipment to prevent all contact risks leading to accidents.

d) The components of binary power generation systems and their connections shall be constructed in such a way that they are free from damage and wear, as they are subject to instability and distortion, which can jeopardize safety during normal use.

e) Binary power generation systems shall be designed and built to avoid hazards from gases, liquids, dust or vapours emitted during operation or maintenance.

f) All components shall be securely installed and firmly supported.

g) Components of a safe shutdown system whose failure could cause a hazardous event shall be assessed in accordance with ISO 12100 for the intended use.

h) The manufacturer shall eliminate any risk of injury caused by contact with or proximity to hot external surfaces of the enclosure, handles, grips or knobs of the binary power generation systems.

i) Binary power generation systems shall be designed and constructed to reduce acoustic noise to an appropriate level which can be subject to relevant regional or national noise regulation standards.

j) If explosive, flammable or toxic fluids are contained in the pipes, precautions shall be taken with proper design and marking.

k) The power supply system shall not exceed its rated temperature.

l) Manufacturers shall not use pollutants (e.g. dust, salt, smoke) and consider the suitability for operation of binary power generation systems in the presence of corrosive gases.

m) Binary power generation systems shall be designed to safely contain leakage of any harmful liquids, such as oil.

4.5 Pressure equipment and piping systems

4.5.1 Pressure equipment

The construction and labelling of pressure vessels (heat exchangers, accumulators, or similar containers) and pressure relief mechanisms associated with pressure vessels (relief valves or similar equipment) can be subject to regulatory requirements.

Containers such as tanks and similar containers that are not subject to applicable local or national pressure equipment regulation standards shall be constructed of appropriate materials in accordance with 4.3 and shall satisfy the provisions of 4.4. Such containers, and their associated joints or fittings, shall be designed and constructed with appropriate strength with respect to functional tightness to prevent unintentional release.

4.5.2 Piping systems

Piping and associated joints shall meet the requirements of ISO 15649. The piping systems shall be constructed of appropriate materials in accordance with 4.3 and shall meet the applicable requirements of 4.4.

4.6 Electrical safety

Electrical systems shall meet the requirements of the relevant electrical product standards:

– IEC 60204-1 (e.g. large industrial);
– IEC 62477-1 and IEC 62477-2 (e.g. UPS, power electronic converter system).

Voltages above 600 V limit are permissible when separately evaluated in accordance with standards appropriate to the higher voltage. The selection of appropriate standards shall be presented in the technical specifications.

4.7 Control systems and protective components

4.7.1 General requirements

Control systems shall be designed in accordance with ISO 13849-1 and validated in accordance with ISO 13849-2.

a) The risk assessment as specified in 4.1 shall provide the basis for setting the protection parameters of the safety circuit.
b) Binary power generation systems shall be designed so that a single failure of a component does not result in a cascading hazardous condition. Means to prevent cascading failures include, but are not limited to
    1) protection devices for binary power generation systems (such as interlocks, trip devices),
    2) protective interlocks for electrical circuits,
    3) use of proven technologies and components, and
    4) partial or complete redundancy, diversification.

In the event of a failure, the evaluation of the measures necessary to avoid or control it shall be indicated in the criteria set out in 4.1.

4.7.2 Control systems

4.7.2.1 General requirements

Automatic electrical and electronic controls in power generation facilities shall be designed and constructed to be safe and reliable and shall include operation systems such as remote/local and manned/unmanned.

Manual controls shall be clearly marked and designed to prevent inadvertent adjustment or activation.

In particular, 4.7.2.2 to 4.7.2.5 apply.

4.7.2.2 Start

The start of operation should only be possible if all safety devices are installed and functioning.

Appropriate interlocks shall be provided to ensure proper startup procedures.

For automated systems functioning in automatic mode, restart after shutdown shall be possible only after safety conditions have been met. Binary power generation systems shall be able to be safely restarted by intentionally activating a controller provided for that purpose.

This requirement does not apply to normal sequencing restarts of binary power generation systems.

4.7.2.3 Shutdown

4.7.2.3.1 General

As determined by the risk assessment set out in 4.1, the functional requirements of binary power generation systems shall include the following shutdown functions.

- Emergency shutdown

Emergency shutdown is to provide the working fluid or stop the circulation of the working fluid as a result of detecting the failure of the operation or failure of the limiter or the internal failure of the system.

- Normal shutdown

Normal shutdown is used to stop the supply of the heating medium or the circulation of the working fluid depending on the result of the command of the control unit.

After shutdown, the system returns to the startup position.

4.7.2.3.2 Emergency shutdown

4.7.2.3.2.1 General

The emergency stop function shall be incorporated as part of the binary power generation systems to avoid an imminent crisis that cannot be controlled by control equipment alone.

These features include the following:

a) shutdown of the dangerous situation without creating further danger;
b) triggering or allowing triggers for specific safeguard actions as necessary;
c) taking precedence over all other features;
d) preventing the reset feature from initiating a reboot;
e) a reboot lockout function so that the new start command takes effect during normal operation only after the restart lockout has been intentionally reset.

4.7.2.3.2.2 Emergency shutdown

If deemed necessary in the risk assessment in 4.1, a manual emergency shutdown device shall be clearly identifiable, visible and readily accessible in accordance with ISO 13849-1 and ISO 13850.

4.7.2.3.2.3 Control functions in the event of control systems failure

If there is a failure of the control system logic or a failure or damage to the control equipment itself, the following shall apply.

a) After receiving a shutdown order, a power generation facility shall not be prevented from shutdown.

b) Automatic or manual shutdown of moving parts shall not be disturbed.

c) The protective device shall be in a completely valid state.

d) Power generation facilities shall not be restarted unexpectedly.

If a protective device or interlock causes a safety shutdown of the power generation equipment, the condition shall be notified to the logic of the control system.

Resetting the shutdown function shall not initiate a hazardous condition. Control or monitoring systems that can operate safely in hazardous situations shall remain energized to provide facility information.

4.7.2.3.3 Normal shutdown

Even in an unforeseen situation, if the situation can be safely controlled or does not pose an imminent danger, the system can be restored to a normal state by normal shutdown operation.

4.7.2.4 Complex installations

If the power generation systems are designed to work with other equipment and it is dangerous to continue the operation, the shutdown function of the power generation systems, including emergency shutdown, shall be able to work in cooperation with the upstream or downstream equipment by providing means such as signal interfaces.

4.7.2.5 Remote monitoring and control systems

Remotely controlled power generation facilities shall be equipped with a local labelled switch or other means to allow on-site operators to disconnect the equipment from the remote signal during inspection and maintenance.

Remote monitoring and remote-control systems shall

– not lead binary power generation systems to be in a dangerous condition, and

– not take precedence over the locally set protection safety control.

4.7.3 Protective components

4.7.3.1 General

Suitable protective devices and combinations thereof include appropriate monitoring devices such as indicators or alarms that allow appropriate measures to be taken automatically or manually to keep the binary power generation systems within acceptable limits.

Protective devices shall be

– designed and built to be reliable and suitable for their intended role, taking into account equipment maintenance and testing requirements, where applicable,

– independent from other functions, and

– designed appropriately to obtain adequate and reliable protection. These principles include, in particular, fail-safe mode and redundancy.

The dangerous state of the equipment shall be designed to be prevented by means such as monitoring devices.

Protective devices with measurement capabilities shall be designed and built to meet predictable operating requirements and special operating conditions.

If the protection control consists of electronic components, the control shall be designed according to the criteria specified in 4.1.

4.7.3.2 Types of components

The following components shall comply with the appropriate safety-related measures set out in the International Standards referred to below to ensure the results of 4.1.

a) The pressure limiting device of the pressure monitoring device shall comply with IEC 60730-2-6.

b) The temperature monitoring device shall have a sufficiently safe response time to meet the measurement function in accordance with IEC 60730-2-9.

c) The flow monitoring device shall have a sufficiently safe response time to meet the measurement function in accordance with IEC 60730-2-15.

d) The level monitoring device shall have a sufficiently safe response time to meet the measurement function in accordance with IEC 60730-2-15.

e) Binary power generation systems can use gas detectors as protective devices to reduce the possibility of working fluid leakage. When used in binary power generation systems, the gas detector shall comply with IEC 60079-29-1 and IEC 60730-1 based on the results of risk assessment in accordance with 4.1.

f) All components of binary power generation systems that are set up or adjusted during the manufacturing phase and are not intended to be operated by a user or installer shall be adequately protected.

g) Levers and other control and setting devices shall be clearly marked and indicated with appropriate instructions to prevent mishandling. Their design shall be such that accidental manipulation is excluded.

4.8 Pneumatic and hydraulic powered equipment

Each pneumatic hydraulic system used in a power generation facility shall be designed in accordance with ISO 4414 and ISO 4413.

4.9 Valves

4.9.1 Shut off valves

a) Gate valves shall be installed in all equipment systems where the flow of working fluid needs to be shut off and contained in the event of plant shutdown, testing, maintenance, or emergency.

b) The gate valve should be selected according to the working pressure, operating temperature, and fluid characteristics.

c) The actuator installed on the gate valve shall be designed to withstand the outside air temperature at the installation site and the heat transmitted from the valve body.

d) Electrically, hydraulically, or pneumatically driven gate valves shall move to the fail-safe position when the drive source is lost.

4.9.2 Safety valves

a) Pressure relief devices (safety valves, rupture discs, etc.) shall be installed in the high-pressure parts of the binary power generation system.

b) The set pressure of the pressure relief device shall be less than or equal to the design pressure of the component.

4.10 Rotating equipment

4.10.1 General requirements

a) Rotating equipment shall be designed in accordance with the pressure, temperature, and fluid properties to which it can be exposed under normal operating conditions.

b) Fluid inlets and outlets shall be adequately protected from vibration damage.

c) The shaft sealing device shall be suitable for the fluid characteristics and the temperature and pressure expected during normal and abnormal operation and during shutdown.

d) The shaft seal shall be designed to prevent the leakage of harmful fluids. To protect against health or safety risks in the event of leakage of harmful fluids, manufacturers shall provide containers for storing fluids and means of dilution as appropriate.

e) Electric motors, bearing and sealing devices shall be suitable for the expected load.

4.10.2 Motors and generators

Rotating electrical machines shall comply with IEC 60034-1.

4.10.3 Expanders, turbines, and auxiliary equipment

4.10.3.1 Materials

The materials used for the pressure-resistant parts of the vessels and pipes belonging to the auxiliary equipment of the expander shall be safe, with chemical stability and mechanical strength capable of withstanding the chemical and physical effects on the material at the highest operating temperature.

4.10.3.2 Structure

a) The structural mechanical strength of the expanders, turbines and auxiliary equipment shall support the rotational speed that can be operated.

   The structural mechanical strength of the expanders, turbines and auxiliary equipment shall support the maximum vibration that can occur in the main bearing or shaft.

b) Main bearing shall be capable of stably supporting the load during operation and shall not cause abnormal wear, deformation, and overheating.

c) The critical speed of the rotor shaft shall not be between the minimum rotational speed that can be adjusted by the speed regulator and the rotational speed reached when the emergency speed regulator is activated. However, this does not apply if sufficient measures have been taken to prevent vibration at critical speeds from interfering with the operation.

d) The structure of the pressure-resistant part of the auxiliary equipment shall be safe against maximum stresses generated at the maximum working pressure or maximum operating temperature. In this case, the stress generated in the pressure-resistant part shall not exceed the allowable stress of the material used for the part.

4.10.3.3 Speed regulator

To prevent its output from continuously oscillating even when the load fluctuates, the turbine shall be provided with a speed regulator that automatically adjusts the amount of working fluid flowing into the turbine. In this case, the speed regulator should have the ability to ensure that the rotational speed reached when the rated load (or the maximum load when the turbine is operated in excess of the rated load) is interrupted does not exceed the rotational speed at which the emergency speed regulator operates.

4.10.3.4 Emergency shutdown devices

To prevent the occurrence of harm due to over rotation or other abnormalities that occur during operation, an emergency speed control device or other emergency shutdown device shall be installed to automatically and quickly shut off the flow of working fluid to the expander or turbine.

4.10.3.5 Overpressure prevention devices

Expanders, turbines, and their auxiliary equipment that can cause overpressure shall be equipped with appropriate overpressure protection devices to release the pressure.

4.10.4 Pumps

a) Packaged electric pumps for processing liquids shall conform to ISO 13709 or ISO 14847.

b) Pumps excluded from the scope of the International Standards referred to in 4.10.4 a) due to small capacity or low discharge pressure shall comply with the requirements specified in 4.7.

4.11 Enclosures

a) The strength and rigidity of the enclosures, if used, shall be able to support and protect components of binary power generation systems and piping, as well as to meet storage, transportation, installation, and final installation site requirements.

b) Enclosures of binary power generation systems intended for indoor or weather-independent outdoor use shall be designed and tested to meet a minimum IP20 rating in accordance with IEC 60529.

c) Binary power generation systems intended for outdoor use shall be designed and tested to meet at least IP23 rating.

d) Ventilation openings should be designed so that they are not blocked by dust, snow, or vegetation during normal operation, depending on the intended application.

e) All materials used to construct the enclosure, including joints, vents, and door gaskets, shall be capable of withstanding the physical, chemical, and thermal conditions reasonably anticipated throughout the life of the binary power generation systems.

f) Maintenance panels, covers, or insulation that need to be removed for normal maintenance and accessibility shall be designed so that repeated removal and replacement will not cause damage and the value of insulation will not be compromised.

g) Maintenance panels, covers, or insulation that need to be removed for normal maintenance and accessibility shall not be replaceable if replacement could render them unsafe.

h) Access panels, covers or doors that are intended to protect equipment from personnel entry shall have means for retaining it in place and shall require the use of a tool, key or similar mechanical means to open.

i) If personnel can fully access the enclosure, access instructions shall be specified in the product's technical documentation.

4.12 Insulation

Insulating systems used in the binary power generation system shall be designed with considerations to the following:

a) chemical compatibility with the metal to be heated, the outside air and temperature to which the equipment is exposed, and the components contained in the insulation material itself;

b) protection of heat insulating materials from possible thermal and mechanical abuse (including damage due to outside air conditions);

c) fire safety to limit the surface temperature of objects that generate heat to prevent nearby materials from Igniting;

d) future accessibility to piping, fittings, etc. for maintenance.

In particular, thermal insulating materials and their internal bonding or adhesive attachment means mounted on components of the binary power generation system shall

– be mechanically or adhesively retained in place and shall be protected against displacement or damage from anticipated loads and service operation, and

– withstand all air velocities, temperatures and fluids to which they may be subjected in normal operation.

If necessary, to avoid hazards to health and safety, the manufacturer shall specify in the maintenance manual the thermal insulation system inspection and safety requirements.

4.13 Utilities

4.13.1 General requirements

Equipment shall be designed and constructed in such a way that loss of utility does not cause

a) health, safety, and environmental hazards, and

b) permanent damage to equipment.

4.13.2 Cold water supply

a) If water is required to operate the system, it shall be provided through a connection to an on-site water supply, which can be subject to regulatory requirements, or via a self-contained water source.

b) Process water should not contaminate drinking water sources. This can be subject to local regulations.

4.13.3 Hot water or steam supply

a) The heating medium supplied to the power generation system shall not exceed the maximum working pressure and maximum operating temperature in the supply system.

b) Heat sources should not be contaminated. This can be subject to local regulations.

4.13.4 Electrical connections – Disconnection from the mains supply

4.13.4.1 Lockout

A shut-off device provided to shut off power for the safety of service personnel shall have a means of physical lockout to prevent inadvertently reconnecting before the work is completed.

4.13.4.2 Circuit-breakers

The equipment shall be equipped with a shut-off device to disconnect from AC or DC power supply for maintenance. The shut-off means can be located outside the maintenance access area or equipment. The shut-off equipment shall be suitable for the overvoltage category of the target equipment.

4.13.4.3 Devices that remain in an energized state

Devices on the supply side of the shut-off device which remains energized even when the power isolator is turned off shall be protected and labelled to indicate that proper processing has been carried out and that the power supply is energized to prevent accidental contact by the operator.

4.13.4.4 Shut-off operation

When the operation direction of the shut-off device is vertical rather than rotating or horizontal, the position "up" of the operating means shall be in the "ON".

4.13.4.5 Three-phase equipment

In the case of equipment with a three-phase power supply, the shut-off device shuts off all lines of the AC mains power supply at the same time. For equipment that requires connection to the neutral point of the power distribution system, the shut-off device should be a 4-pole device and all conductors and neutral wires should be blocked. If a 4-pole device is not supplied with the equipment, the installation instructions shall clearly state that it shall be additionally installed outside the equipment. When the blocking device blocks the neutral conductor, cut off all conductors at the same time.

4.13.4.6 Single-phase DC equipment

If a shut-off device is installed in or as part of the device, both poles shall be shut off simultaneously. However, the following cases are excluded:

a) when the ground of the DC mains or the neutral ground of the AC mains can be identified, and the specification of a single-pole shut-off device is permitted;

b) when the ground of the DC mains or the neutral ground of the AC mains cannot be distinguished, and the bipolar shut-off device is not provided;

c) when the installation instructions clearly state that a bipolar blocking device shall be installed outside the equipment.

4.13.4.7 Emergency shutdown

Manual emergency shutdown (i.e., emergency shutdowns), if required by the risk assessment in 4.1, shall have clearly identifiable, clearly visible, and quickly accessible controls in accordance with ISO 13850.

If the equipment has an integrated emergency shutdown device or a terminal for connecting to the remote emergency shutdown device, no further external power shall be supplied to the circuit under any operating conditions.

4.14 Installation and fulfilment

4.14.1 Installation

The manufacturer shall provide instructions for the proper installation, adjustment, operation, and maintenance of power generation equipment.

Errors that occur during the installation or realignment of a particular part that might pose a risk shall be minimized by the design of the part or by the information that can be read from the part itself. In places where the direction of operation shall be indicated to avoid risk, indicate the direction of operation on moving parts or housings. Other information deemed necessary shall also be given in the instructions.

Where a faulty connection can be the source of risk, incorrect connections shall be minimized by design or eliminated by information contained in pipes, cables, connector blocks, etc.

4.14.2 Maintenance

a) Areas for maintenance, such as adjustment and refueling, shall be located outside the zone where there is a risk of injury or health hazards, or, to avoid health and safety risks, shall include maintenance instructions in the instruction manual of the product specified in 6.4.4 as necessary.

b) It shall be possible to adjust, maintain, repair and clean and perform maintenance work while the binary power generation systems are down. When performing these tasks during the operation of the binary power generation systems, design these tasks to be performed without any risk of injury.

c) Parts of power generation equipment that need to be replaced regularly shall be removed and replaced without risk of injury. Access to the parts shall be possible to perform these tasks using the necessary technical means (tools, measuring instruments, etc.) in accordance with the technical documentation of the product.

d) To protect health, safety instructions or diagrams installed in power generation facilities shall be displayed in a permanent manner that is resistant to the environment in which they are used or protected from environmental conditions.

5 Tests

5.1 General requirements

All product units shall be tested prior to shipment. However, if the shipping test is difficult, a site test (see 5.3.3) may be carried out instead.

In particular, the boundary interface of the test environment for the shipping test shall conform to the design application of the binary power generation systems. The delivery test shall be conducted in accordance with 5.6. When the initial start-up adjustment work of the binary power generation systems shall be followed by a shipping test, the binary power generation systems shall be connected to the adjustment equipment and performed under the operating conditions specified by the manufacturer.

Before the system is put into operation, the following tests shall be performed on all components or the entire system:

a) strength-pressure test;

b) tightness test;

c) electrical safety tests;

d) electromagnetic compatibility test.

During the strength pressure test tightness test, the connection shall be accessible and inspectable.

Functional tests of all electrical safety circuits shall be performed after pressure and tightness tests and before starting the system for the first time.

The results of these tests shall be recorded.

5.2 Strength-pressure test

5.2.1 General

Certified components having a rated pressure equal to or greater than the design pressure of the system shall be deemed to conform to the provisions in 5.2.2.

5.2.2 Strength-pressure test

Strength pressure tests shall be performed on all assemblies or parts thereof the product as follows.

a) The test pressure shall be at least 1,5 times the design pressure of the product.

b) The article under test shall be filled with a liquid at room temperature, ensuring all air is completely eliminated. It shall then be gradually pressurized to the desired test pressure and held at that pressure for at least 10 min.

c) Ensure that the product under test is free from any damage, leakage or abnormal deformation. However, if a slight leak that does not impair the pressure resistance performance of the gasket or mechanical seal part occurs at or above the design pressure, it is not considered to be a leak in the strength pressure test.

d) If it is not possible to perform a strength pressure test using a liquid for technical reasons, it can be performed with gas.

Relevant local or national regulations and standards for high pressure equipment can also exist.

5.3 Tightness test

5.3.1 General

The completed system shall undergo a full or partial test in accordance to 5.3, if needed. This test shall be conducted at the factory for factory-assembled systems and on-site for systems assembled or filled with the working medium on-site.

5.3.2 Factory tests

a) The test pressure shall be equal to or greater than the design pressure of the system.

b) Depending on the manufacturing conditions, check that there is no leakage by several methods, such as pressurization with inert gas or traces of radioactive gas.

c) It is necessary to test with inert gases such as nitrogen, helium, and carbon dioxide to avoid the emission of harmful substances. Do not use oxygen, acetylene, or hydrocarbons for safety reasons. Avoid mixing air and gas, as some mixtures can be dangerous.

5.3.3 Site tests

All sections of the system constructed at the installation site shall undergo a tightness test before filling the system with working fluid. The field test procedure pass/fail criteria shall conform to the requirements of 5.3.1 and 5.3.2. Components (devices) that have already undergone tightness testing and can be safely separated from field testing do not need to be retested.

5.4 Electrical safety tests

5.4.1 General

The electrical safety of binary power generation systems shall be verified against the applicable standards set forth in 4.6.

5.4.2 Insulation resistance test

According to the insulation resistance meters stipulated in IEC 61557-1 and IEC 61557-2, the insulation resistance between the wire-to-line electrical circuit of a low-voltage electric circuit and the earth shall be equal to or greater than the respective insulation resistance value, according to the classification of the working voltage of the electric circuit in Table 1 for each electric circuit that can be separated by a switchgear or overcurrent circuit-breaker.

Table 1 – Insulation resistance

Classification of working voltage of electric circuit		Insulation resistance value MΩ
300 V or less	Ground voltage[a], if 150 V or less	0,1
	Otherwise	0,2
Over 300 V		0,4

[a] In the case of a grounded electric circuit, it refers to the voltage between the electric wire and the earth, and in the case of a non-grounded electric circuit, it refers to the voltage between the electric wire.

5.4.3 Protective device test

For each protective device, the contacts of the related relay or detector should be operated by simulated operation such as manually closing or actually operated, and it should be confirmed that the related fault indicators, alarm devices, etc. operate normally.

5.4.4 Comprehensive interlock test

When operating a binary power generation system, simulate an accident for each of the electrical and mechanical elements, actually operate the protective devices related to the accident, and confirm that the circuit-breaker, solenoid valve, etc. are opened and closed normally.

5.5 Electromagnetic compatibility (EMC) test

Binary power generation systems shall not generate electromagnetic interference beyond the level appropriate for the place of use. In addition, the equipment shall have an adequate level of immunity to electromagnetic disturbances so that it can operate correctly in its intended environment.

5.6 Delivery test

This is a test conducted after all installation work or installation work of the binary power generation systems is completed, and then handed over to the user. It shall be checked whether the binary power generation system maintains its normal function and whether the safety of the system is ensured in the installed state. In addition to the above, the delivery test shall be conducted for the following items. However, the part that has already been performed at the time of the shipping test may be excluded from the test object.

a) Conduct the airtightness test in accordance with 5.3.

b) Conduct a comprehensive interlock test in accordance with 5.4.4.

6 Marking, labeling and packaging

6.1 General requirements

Binary power generation systems shall be marked in accordance with the applicable provisions of ISO 3864-2. Marking and mounting methods shall be durable and suitable for the application.

6.2 Marking of binary power generation systems

The binary generation systems shall have a combination of data plates or adjacent labels arranged so that it can be easily read when the binary power generator systems are in its normal installation position.

The data plate or label shall contain the following information:

– manufacturer name (with trademark), and location;

– manufacturer's model number or trade name, the serial number and year of manufacture of the binary power generation systems;

– electrical input, if applicable: voltage, current, frequency, phase, power consumption;

– electrical output: voltage, current, frequency, phase, rated power, or kVA and power factor;

– outdoor or indoor use.

If binary power generation systems are evaluated based on the classification of hazardous locations according to IEC 60079-10-1, they should be marked accordingly to warn personnel of possible personal injury or equipment damage, and to emphasize the importance of following installation and operating instructions.

If binary power generation systems are evaluated based on the classification of hazardous locations in accordance with IEC 60079-10-1, the evaluation shall be marked accordingly.