Linked Ship/Shore Emergency Shutdown Systems for Oil and Chemical Transfers

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Glossary

The following are agreed definitions for terms used within this paper.

At sea Indicates waters away from a terminal.

Barge There is no universally recognised definition of a barge. Barges can be self-propelled, towed or pushed, and may be used to carry or store liquid hydrocarbons, chemicals or liquefied gases in bulk. They may be employed in inland waterways or at sea outside port limits.

Cargo transfer Operation when crude oil, LPG or other hydrocarbon products are moved from a ship to a terminal, or vice versa, by means of pumping.

Emergency Release System (ERS) A system for quickly and safely disconnecting a loading arm from a ship with minimal product spillage. It consists of an emergency release coupler between two interlocked block valves.

Emergency Shutdown (ESD) system ESD systems execute a sequential shutdown of ship or terminal pumps and valves in an emergency. ESD systems shut down the cargo transfer operation in a quick and controlled manner by closing the shutdown valves and stopping the transfer pumps and other relevant equipment.

Flow rate The linear velocity of flow of liquid in a pipeline, usually measured in metres per second (m/s). The determination of the flow rates at locations within cargo pipeline systems is essential when handling static accumulator cargoes.

Loading arm The articulated metal loading arm system used for transferring product(s) to or from ships with the capability of accommodating differences in tides and freeboard and ship motions.

Manifold The flanged pipe assembly onboard ship to which the presentation flange of the loading arm or spool piece connects.

Pendant ESD unit A hand-held portable unit for controlling the ESD.

Powered Emergency Release Coupling (PERC) An emergency release coupling that uses stored energy to ensure breakout through any ice build-up.

Pressure surge A sudden increase in the pressure of the liquid in a pipeline brought about by an abrupt change in flow rate.

Recommendations OCIMF supports and endorses a particular method of working or procedure.

Ship Any vessel, including barges, that is designed to carry oil, liquefied gases or chemicals in bulk.

Ship blackout Operating in the event of loss of power.

Terminal A place where ships are berthed or moored for the purpose of loading or discharging hydrocarbon cargo.

Abbreviations

CCR	Cargo Control Room
ERS	Emergency Release System
ESD	Emergency Shutdown
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MAOP	Maximum Allowable Operating Pressure
MAWP	Maximum Allowable Working Pressure
MLA	Marine Loading Arm
PERC	Powered Emergency Release Coupling
ROSOV	Remotely Operated Shut-off Valve
SSL	Ship/Shore Link

1 Introduction

Linked ship/shore ESD systems have been a standard safety feature of LNG transfer operations for many years. Similar safety issues exist with oil and chemical transfer operations, but the provision of linked ESD systems between ships and terminals has been hampered by the lack of an accepted industry standard for equipment to achieve the required connection.

This paper gives details of a recommended connection for industry that will enable ship and terminal ESD systems to be linked so that manual activation by the terminal or ship will stop cargo transfer operations. The minimum requirement of any linked ESD system is:

- All cargo transfer pumps will be stopped when an ESD is activated on the ship or terminal.
- The ship's cargo transfer pumps will be stopped when a terminal tank high level alarm is activated.

In this paper, ship is used to describe any vessel that carries oil and chemicals, including barges, and terminal is used to describe both onshore and offshore terminals.

It is recommended that ships and terminals involved in oil and chemical transfer operations are provided with the necessary equipment to enable inter-connection of ESD systems. An electrical umbilical incorporating 5-pin twist connectors is recommended for universal adoption. These connectors have been used for several years within segments of the LPG industry and have a proven record of reliable service. A terminal may adopt other forms of ESD system, e.g. incorporating a wireless connection or a different connector. If another form of ESD system is used, the terminal is responsible for making sure it is compatible with visiting ships.

The minimum recommendations are aimed at linking manual ESD activation functions. Once ship and terminal systems are connected, a limited number of additional activators and actions may be included. Any expansion of system functionality beyond the minimum requirements should be thoroughly assessed to make sure they add real safety benefits.

For recommendations on linked ship/shore ESD systems for LNG and LPG vessels, see *ESD arrangements and linked ship/shore systems for liquefied gas carriers* (SIGTTO).

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2 ESD philosophy and general recommendations

2.1 Introduction

ESD systems for cargo transfers are used to stop the flow of cargo liquid and vapour in an emergency and to bring the cargo handling system to a safe, static condition.

It is recommended that linked ESD systems are installed so that an ESD trip activated on the ship will send an ESD signal to the terminal and vice versa.

A core recommendation of this paper is that, as a minimum, ESD is manually activated. Some ship and terminal systems will include the provision for automatic shutdown of cargo transfers in abnormal operating conditions, e.g. high tank levels, high or low tank pressures, excessive pressure in the cargo transfer system, fire or gas detection and excessive ship movement or break-out.

In a linked ESD system, the party receiving cargo, i.e. the ship in the loading port and the terminal in the discharge port, can stop cargo flow by shutting down the transfer pumps in a controlled way. The receiving party should never have to shut valves against a full flow of incoming liquid. A linked system also allows either party to activate a controlled shutdown of the transfer process if a leakage or fire is discovered, without generating unacceptable surge pressures in the pipework that would make the situation worse. Once the ESD has been activated, further action may need to be taken to secure ship and terminal systems.

2.2 Ship/Shore Link

The purpose of the SSL is to transmit, without delay, a signal from ship to terminal or vice versa. For oil and chemical transfers, the minimum recommendation is to use an electric SSL that incorporates a 5-pin twist connector, as described in Appendix A.

Figure 2.1: *5-pin twist connectors*

2.3 Recommended minimum functional requirements

Appendix B gives an example of the components and circuitry needed to effectively and safely link independent ship and terminal ESD systems. Complete systems are available from instrumentation suppliers and manufacturers, but it may also be possible for ships and terminals to develop compatible systems using readily-available components.

The following minimum requirements should be met to achieve a functional and safe ESD system:

- Ability for either party to manually activate the other's ESD.
- On activation of own ESD, the other party's ESD is automatically activated.
- Electrical classification is appropriate for the working environment.
- Uses an electrical umbilical that has recommended male 5-pin twist connectors at each end (see detail in Appendix A), for connection to female 5-pin twist connectors on the ship and jetty.
- Can be de-energised during connection.
- Interfaces electrically with existing ship and terminal ESD systems.
- When connected, includes an indication of the system's health.
- Is automatically activated if electrical power is lost or the circuitry is damaged.
- Raises an audible and visual alarm when activated.
- Indicates system re-set status.
- Can be tested; for ships, both at sea and in port.

An indication of the activating party may be included as an enhancement.

Programmable electronic equipment, including operating systems and configuration software, should be proven for use in safety applications.

2.4 Emergency operation of normally linked systems

Linked ship and terminal ESD systems reduce the risk of hose or pipeline failure causing cargo spills in two ways. Excessive pressure surges caused by a unilateral shutdown can cause hose rupture and mechanical damage to valves, pipelines and supporting structures. Excessive vessel movement alongside the berth or vessel breakout from the berth may result in hose or MLA failure. The linked system should therefore be considered a critical safety system for cargo transfer operations.

Pre-arrival testing of the linked ESD system will reduce the risk of a failure during operation, but contingency plans should be made for any failure of the linked system. It is recommended that the terminal and ship discuss contingency plans before operations begin. The terminal's emergency response procedures should also address failure of the linked system.

A pendant ESD unit may be used as a mitigation measure, if available.

2.5 Summary of recommendations

The key recommendations in this paper are:

- For transfer operations involving oil and chemicals, including ship to ship transfers, linked ESD systems should be provided and used.
- Ship and terminal ESD systems should be linked via an electrical umbilical, provided by the terminal, that uses recommended 5-pin twist connectors.
- The ESD link should be capable of being manually activated, as a minimum.
- The linked ESD system must be tested regularly. Contingency plans should be in place in case of failure of the linked ESD system.
- Any modifications to the system should follow strict procedures and be documented in full.
- A functional flowchart of the linked ESD and related systems should be available in the terminal control room and in the Terminal Information Book provided to visiting ships.
- Linked ESD systems should pass ESD signals in both directions, e.g. from terminal to ship and from ship to terminal.
- Terminals should arrange for surge calculations to be made as part of the hydraulic analysis of their specific pipeline and cargo transfer systems to establish the maximum safe flow rate. The output from hydraulic analysis should be considered when deciding the appropriate ESD options for each berth.

3 ESD activations and associated safety systems

3.1 General

The linked ESD system improves operational safety during the transfer of oil and chemicals between ship and terminal. It provides a quick and safe way of stopping the transfer of cargo and, where applicable, isolating ship and terminal cargo systems in a controlled manner. The ESD can be activated either manually or automatically under abnormal operating conditions. Some terminals also have a second level of protection that enables rapid disconnection of the loading arms from the ship.

The ship or terminal receiving tanks are often some distance from the transfer pumps and the kinetic energy in the moving liquid can be considerable. The potential hazards of surge pressure should therefore be considered. The ship and terminal ESD systems need to be connected using a suitable cable or wireless communications link to allow ESD actions to be coordinated.

3.2 Typical ESD actions

3.2.1 Terminal to ship transfers

Activation of ESD should trip visual and audible alarms on the ship and terminal and the following actions.

Ship		Terminal
Transmits ESD trip signal to terminal via SSL.	→	Receives ESD trip signal from ship.
	or	
Receives ESD trip signal from terminal.	←	Transmits ESD trip signal to ship via SSL.
		Stops cargo flow, either by tripping terminal's cargo transfer pumps or by other safe means.
Optional		
Closes ship's manifold valves in a safe manner, taking account of potential surge issues.		Closes terminal's ESD valves in a safe manner, taking account of potential surge issues.

Table 3.1: *ESD actions for terminal to ship transfers*

The terminal actions above are typical for export facilities and may vary to suit the design of the plant. If loading by gravity, the terminal ESD system should stop the cargo flow safely and quickly, taking into account pressure surges.

3.2.2 Ship to terminal transfers

Activation of ESD should trip visual and audible alarms on the ship and terminal and the following actions.

Ship		Terminal
Transmits ESD trip signal to terminal via SSL.	→	Receives ESD trip signal from ship.
	or	
Receives ESD trip signal from terminal.	←	Transmits ESD trip signal to ship via SSL.
Stops cargo flow by tripping ship's cargo transfer pumps.		
Optional		
Closes ship's manifold valves in a safe manner, taking account of potential surge issues.		Closes terminal's ESD valves in a safe manner, taking account of potential surge issues.

Table 3.2: *ESD actions for ship to terminal transfers*

3.3 ESD activation

As a minimum, ESD should be activated by either:

- Manual operation of an ESD trip.
- An automatic trip on loss of electrical power to the ESD circuit.

3.3.1 Manual operation of an ESD trip (minimum requirements)

Ship	Terminal
Activates ESD by manually operating trips, e.g. switches or push buttons, one of which should be in the CCR (or equivalent).	Activates ESD by manually operating trips, e.g. switches or push buttons, one of which should be in the terminal's control room (or equivalent).
Manual trips should be located in accordance with the ship's design so they can be reached quickly by anyone who has identified a serious hazard.	Manual trips should be located so they can be reached quickly by anyone who has identified a serious hazard.
The manual ESD should not form part of any other shutdown system.	The manual ESD should not form part of any other shutdown system.

Table 3.3: *Manual operation of an ESD trip (minimum requirements)*

3.3.2 Loss of electrical power to the ESD circuit (minimum requirements)

Ship	Terminal
The ship's cargo pumps will typically trip automatically without any intervention from the ESD system.	The terminal's transfer pumps will typically trip automatically without any intervention from the ESD system.
The activation of ESD on the ship will trip the terminal's transfer pumps under ship blackout conditions.	The activation of ESD on the terminal will trip the ship's transfer pumps under terminal blackout conditions.

Table 3.4: *Loss of electrical power to the ESD circuit (minimum requirements)*

3.3.3 Optional activators

Table 3.5 gives some optional activators for ESD. Any expansion of system functionality beyond the minimum requirements described above should be thoroughly assessed to ensure that positive safety benefits will be achieved.

Hazard	Ship	Terminal
Fire detection	ESD will be activated when fusible links installed in the cargo area are tripped, typically between 98–104°C.	ESD will be activated by the terminal's fire detection system.
Overfilling of tanks	ESD will be activated when the higher of two 'spot' level sensors in each of the ship's cargo tanks is tripped. This high-high level sensor will be independent from the main level measuring system and arranged so that the operation of any one sensor will activate ESD.	At an import terminal, ESD will be activated at a level defined by terminal procedures.
Loss of pressure in cargo valve remote control system	The trip for the ESD will depend on the type of valve actuators used. The trip should be a low-low pressure switch installed in the common supply line downstream of any isolating valve. Pre-alarms should also be fitted and signals should have suitable time delays.	
Excessive pressure in cargo transfer system	Pressure sensors in the tanker's discharge pipelines may be pre-set to activate an ESD if they register a pressure in excess of the nominal operating pressure for the cargo transfer system but less than its MAWP.	Pressure sensors in the terminal's cargo transfer system may be pre-set to activate an ESD if they register a pressure in excess of the nominal operating pressure for the cargo transfer system but less than its MAOP. The optimum siting and setting for these pressure sensors would be determined by hydraulic analysis which includes consideration of surge.
Movement of monitored critical valve in cargo transfer system	ESD is activated when a cargo transfer valve closes, that hydraulic analysis has determined needs to be open for the duration of a transfer operation, e.g. a ROSOV.	ESD is activated when a cargo transfer valve closes, that hydraulic analysis has determined needs to be left in open for the duration of a specific transfer operation.
High level of liquid in surge drum		In terminal cargo transfer systems fitted with surge drums, detection of high liquid levels could activate an ESD.

Hazard	Ship, continued	Terminal, continued
Exceeding MLA operating limits		MLAs may be designed to activate an ESD when operating envelope limit switches are tripped. Sensors or other trips may be placed at the vertical and horizontal limits of the MLA and may be triggered by sway and surge excursions of the ship at the berth. MLAs may also have ESD activators associated with loss of actuating power to the arms or ancillary equipment.
Activation of MLA PERC		ESD activation should precede PERC activation. PERCs may be activated either manually or when MLA operating envelope limit switches have been tripped.

Table 3.5: *Optional activators for ESD*

3.4 Associated safety systems

3.4.1 Emergency disconnection of loading arms

For a terminal to be able to disconnect loading arms from the ship in an emergency, an ERS should be provided with a PERC incorporated into each arm. This allows disconnection with minimum spillage, known as the dry-break concept.

The ERS should only be activated after the ESD has been activated. The sequence of actions on the terminal is as follows:

1. ESD activated (either on the terminal or ship, manually or automatically).
2. ERS activated (either manually or automatically).
3. ERS valves close (automatically).
4. PERC activated (automatically).
5. Loading arms disconnected (automatically).

It is recommended that when an ERS is activated a loud audible and highly visible alarm is triggered on the jetty. This will warn personnel to stand clear of the ship's manifold area and the jetty working platform.

3.4.2 Surge relief

Some terminal arrangements incorporate a surge relief system. At loading terminals, this may comprise a fast opening fail-safe dump valve that diverts liquid flow to a surge drum while the ESD and ERS valves are closing, minimising surge.

4 Recommendations for linked ESD systems for oil and chemical transfers

Recommended minimum system capability	
Actions to stop cargo flow	Enables ship to stop the terminal's cargo transfer pumps or prompts shutdown of terminal system. Enables terminal to stop ship's cargo transfer pumps.
Activation	Manual push button. Automatic shutdown of ship's pumps on terminal tank high level alarm. Automatic activation if signal is lost, e.g. in event of power failure on ship or in terminal.
ESD linkage achieved by	Ship/shore electrical umbilical fitted with recommended 5-pin twist connectors.

Table 4.1: *Recommended minimum capability for linked ESD systems*

In addition to the minimum requirements, automatic activators may be considered as described in section 3.3.3.

It is recommended that, as a minimum, ship and terminal ESD systems are linked by an electrical umbilical that terminates in recommended 5-pin twist connectors (see Appendix A). The linked ESD systems should enable either ship or terminal personnel to manually activate the remote shutdown of either the ship or terminal's cargo transfer pumps.

Oil and chemical tankers should present a female 5-pin twist connector at each manifold location. The connector should be linked to the ship's cargo shutdown system which, as a minimum, should include the provision to trip the ship's cargo transfer pumps.

Terminals handling oil and chemical tankers should present an ESD link to ships that comprises an electrical umbilical with a male 5-pin twist connector for connecting to the ship's female connector at the ship's manifold. The terminal end of the umbilical should be linked to the terminal's ESD system which, as a minimum, should include the provision to stop the cargo flow, typically by tripping the terminal's cargo transfer pumps.

Some terminals have developed ESD systems that use wireless technology. The terminal will provide the ship with a wireless transmitter/receiver if using a wireless system. To provide an interface for these wireless systems, it is recommended an additional female 5-pin twist connector is provided in the ship's CCR. This should connect to the ship's ESD circuit including an on board power source. The terminal-supplied wireless transmitter/receiver module should be fitted with a male 5-pin twist connector to enable connection to the CCR mounted standard female 5-pin twist connector.

Terminal supplied wireless technology may also be used to provide an ESD link at offshore terminals, in which case the additional 5-pin twist connector in the CCR will be used to connect the terminal's ESD system to the ship's ESD system.

Figure B3 provides a simplified diagram showing how a wireless ESD link on the terminal may be connected to the ship's ESD system using the recommended 5-pin twist connector located in the CCR.

In addition to manual activation, it is recommended that terminals include an automatic shutdown function that trips the ship's cargo transfer pumps on activation of a terminal receiving tank high level alarm.

Appendix A Recommended 5-pin twist connector

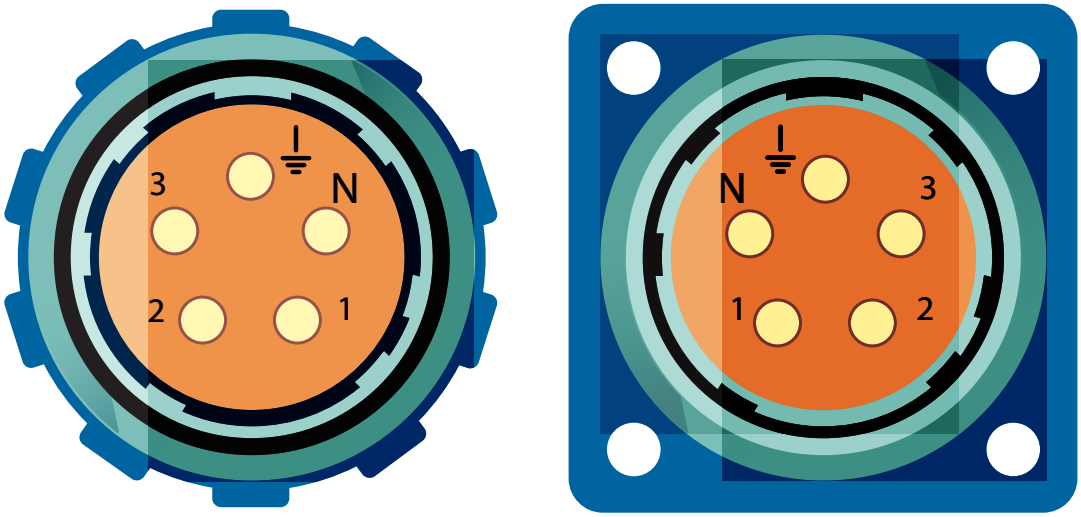
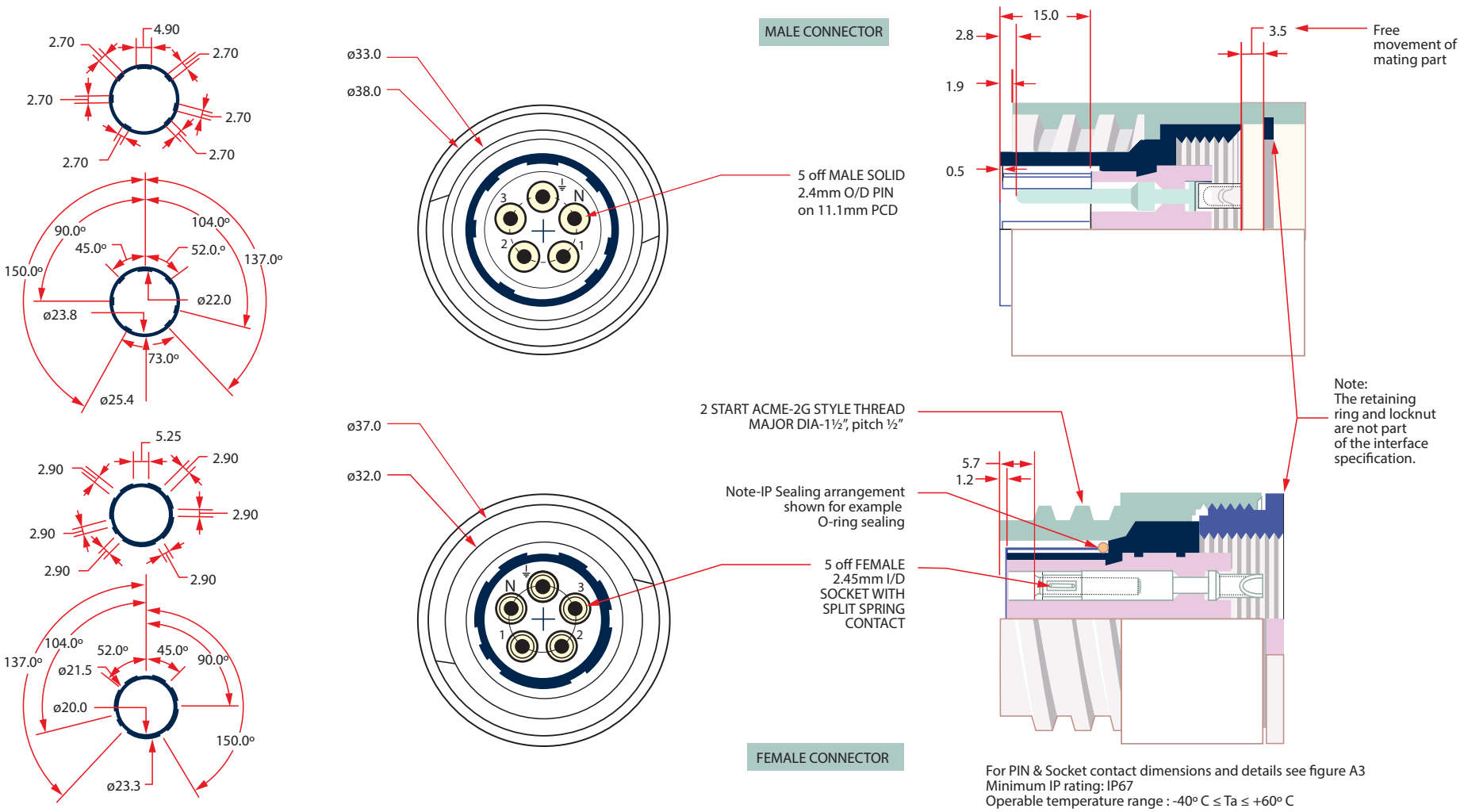


Figure A1: *Pin designation*

The ship/shore electrical umbilical should comprise twisted pairs of wires without armour or screen, to avoid the hazard of a potentially incendive spark if the insulating sheath is cut by an earthed object on the jetty. The pin designations are as follows:

1	+	Intrinsically safe circuit, nominal 24v DC, 20mA
2	−	Intrinsically safe circuit, nominal 24v DC, 20mA
3	+	Spare
N	−	Spare
E		Not connected

Figures A2 and A3 give more details of the male and female connectors.



For PIN & Socket contact dimensions and details see figure A3
Minimum IP rating: IP67
Operable temperature range : -40° C ≤ Ta ≤ +60° C

Dimension	Tolerances	
Linear 0.00	+0.05	-0.05
Linear 0.0	+0.1	-0.1
Angular 0.0	+0.1°	-0.1°
Angular 0	+1°	-1°
All other tolerances as drawing		
Dimension unit	mm	

5-way connector pin designations		
1	+	Intrinsically safe circuit, nominal 24v dc, up to 20mA Healthy, <4mA ESD
2	-	Intrinsically safe circuit, nominal 24v dc, up to 20mA Healthy, <4mA ESD
3	+	Spare (used for pendant system when switched on)
N	-	Spare (used for pendant system when switched on)
E ⏚		Not connected

Figure A2: *Example of recommended 5-pin twist connector interface arrangement: male and female connectors*

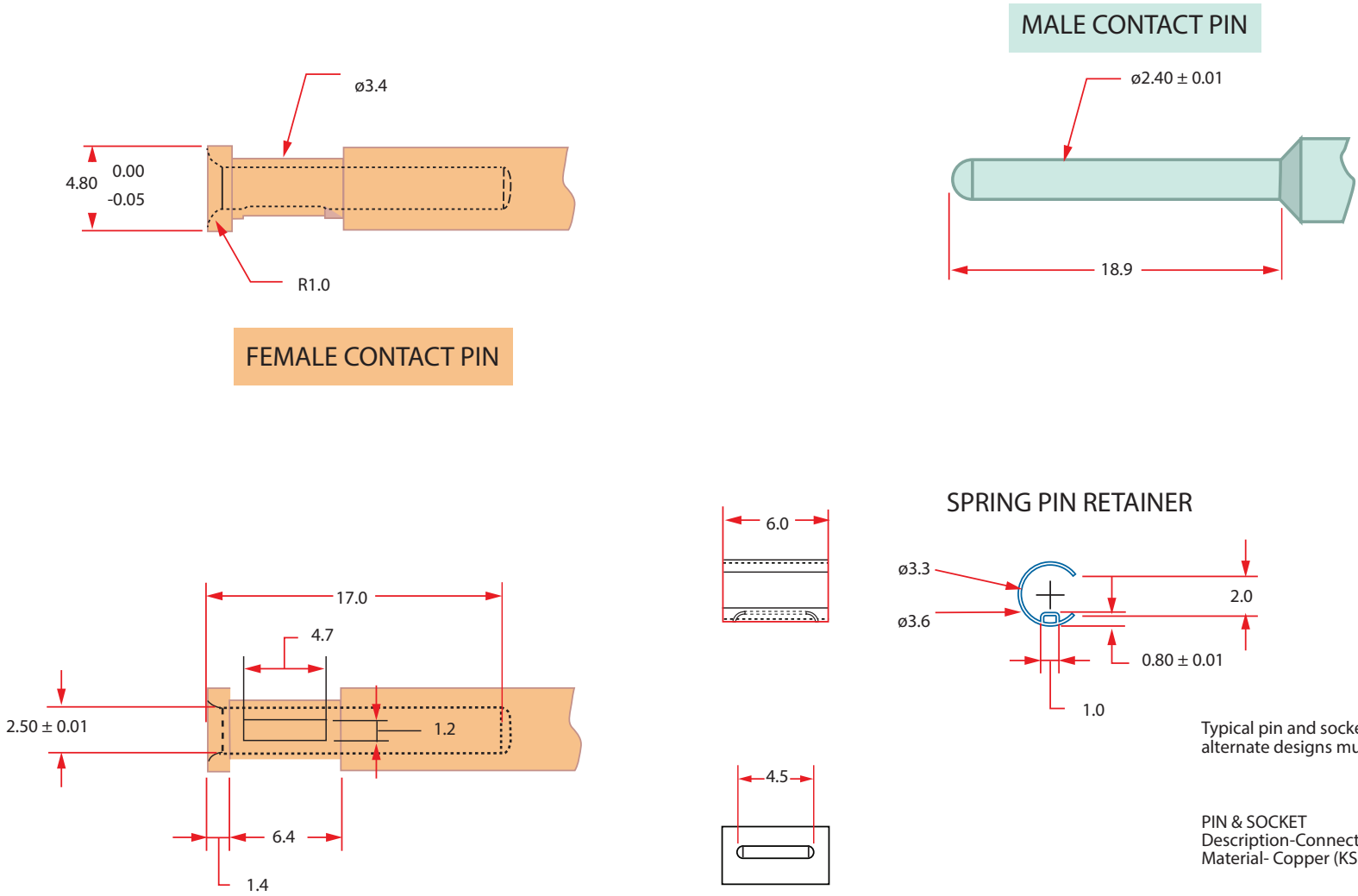


Figure A3: *Example of recommended 5-pin twist connector interface arrangement: male and female contact details*

Appendix B Configuration of a linked ship/shore ESD system

The standard terminal configuration comprises:

- a terminal control unit for installation in the terminal's control room; connected to
- a jetty control unit; connected to
- a ship/shore umbilical cable fitted with a recommended male 5-pin twist connector.

The standard ship configuration comprises:

- a ship control unit, for installation in the ship's control room; connected to
- a ship side box fitted with fixed recommended female 5-pin socket assemblies for installation in the ship's manifold area, port and starboard.

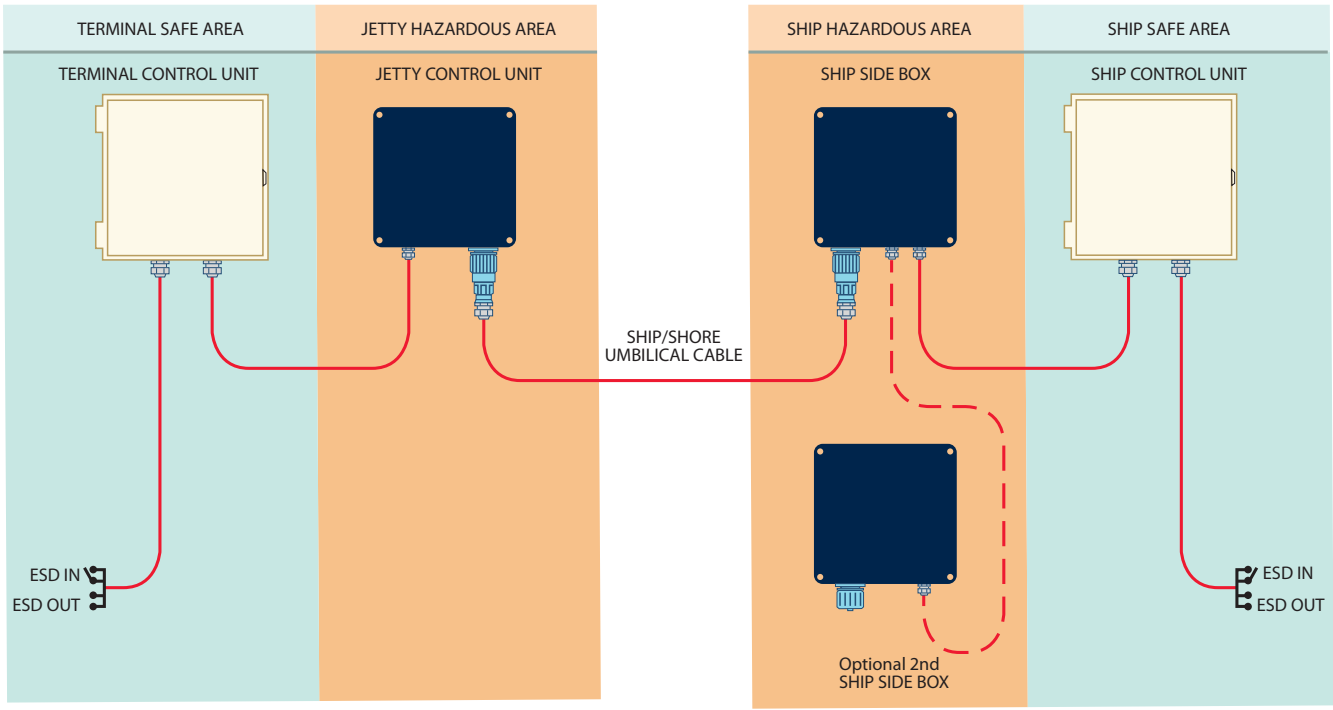


Figure B1: *Example of ship/shore ESD configuration*

In the jetty assembly two relay loops are connected back-to-back, isolating the ship and terminal ESD systems from each other as shown. When the ship ESD system is healthy, an intrinsically safe solenoid driver in the ship assembly is energised, making power available on the ship side loop of the jetty assembly via the ship/shore cable. If the terminal ESD system is also healthy, the shore side loop is similarly energised. Pressing the reset button in the jetty assembly will then energise the upper relay, closing its contact and energising the lower relay. The SSL is then armed. Breaking either ship side or shore side loops, either by breaking contacts or by physical disconnection, will cause both relays to drop out, ensuring a simultaneous linked trip.

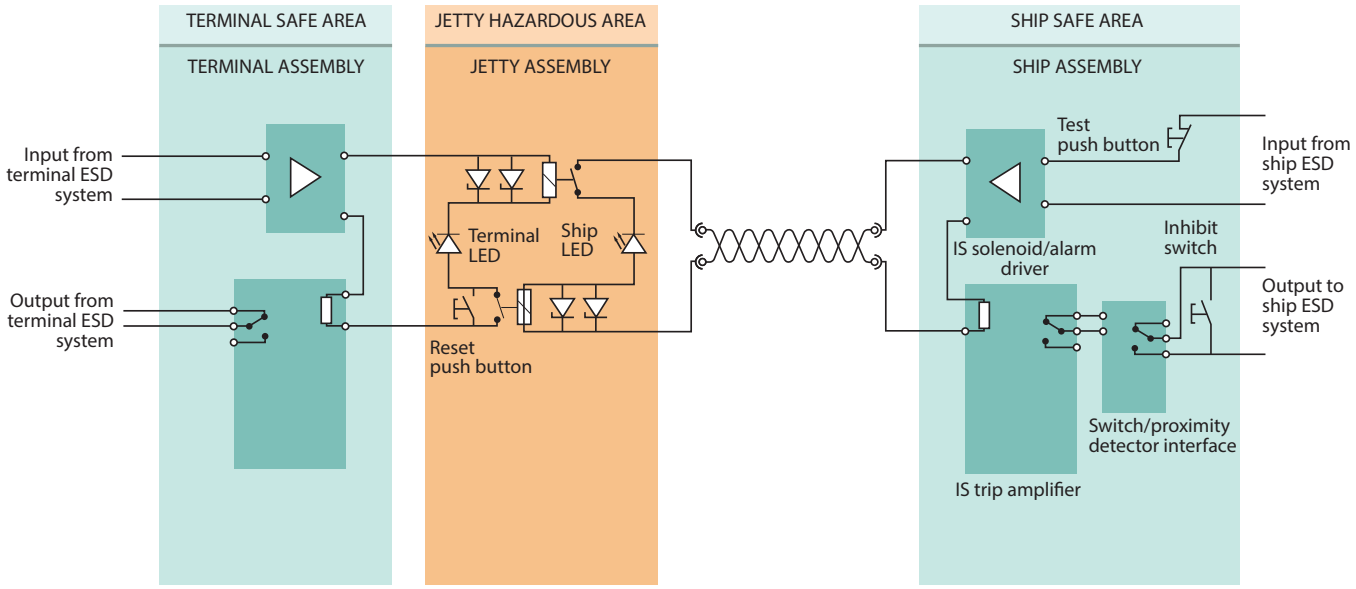


Figure B2: *Example of simplified circuit diagram*

Figure B2 has been simplified for clarity. In the actual system, the terminal assembly has a separate reset push button and indicators to show whether a trip was activated by the terminal/jetty or by the ship. There is also additional circuitry to allow connection of pendant ESD units and to facilitate testing.

Figure B3 shows how an existing wireless terminal ESD link may be connected to the ship's ESD system using the recommended 5-pin twist connector located in the CCR.

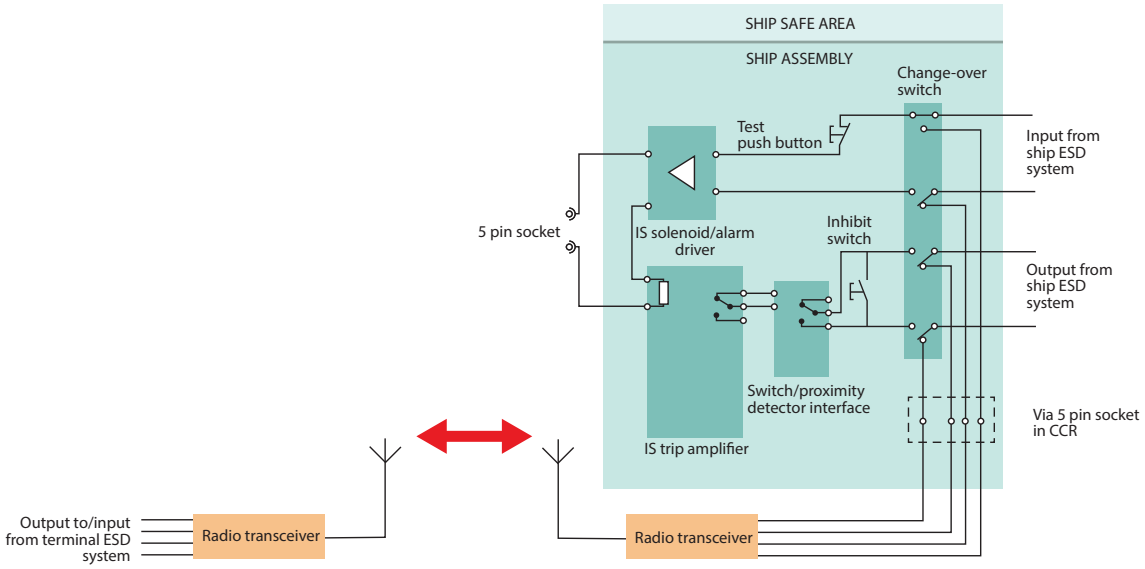


Figure B3: *Example of simplified circuit to accommodate an existing wireless ESD link*

The shore system presents interposing relays to the connecting ship system and the ship system provides the power to energise the ship side of the interposing relays. The electrical parameters for connecting to the interposing relays are as follows.

Parameter	Value	Units	Comments
Vin minimum	8	V	
Vin maximum	26.04	V	
I max (normal conditions)	30	mA	Connected to a similar system
I max (fault conditions)	168.61	mA	
P max	1.098	W	
Trip point rising current	4.6	mA	
Trip point falling current	3.6	mA	
Hysteresis	5	%	Based on 20mA working current
Recommended healthy working current	>10	mA	
Tripped current	0	mA	

Table B1: *Electrical parameters for connecting to the interposing relays*

A voice for safety

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