Cruise liner accident highlights many problems including with emergency power generation

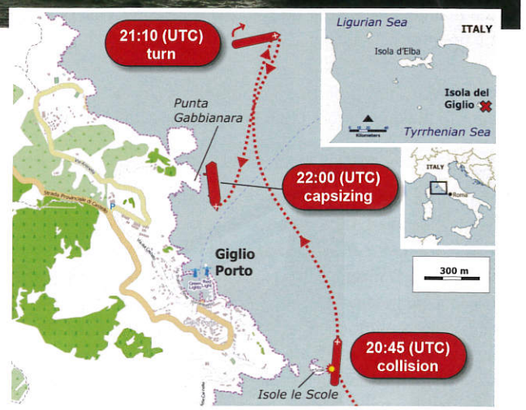
The *Costa Concordia*

Costa Concordia capsize

On the evening of 13 January 2012, whilst the cruise liner 112,000grt *Costa Concordia* was sailing in the Mediterranean off the Italian coastline with a total of 4,229 persons on board (3,206 passengers and 1,023 crew) it hit the Scole Rocks of Giglio Island. The resulting capsize led to the death of 32 people (27 passengers and 5 crew) but fortunately 4,197 people survived, although 157 were injured. Now the Italian Ministry of Infrastructures and Transports' Marine Casualties Investigative Body has published a report on its safety technical investigation into the accident.

It has been concluded that the ship was sailing too close to the coastline, in a poorly lit shore area, under the master's command who had planned to pass at an unsafe distance at night and at high speed (15.5kts). The danger this entailed was recognised too late to avoid the impact which was so severe that the ship heeled over and its speed rapidly decreased – from 15.3kts at the moment of impact on the rocks down to just 3.9kts in a little over six minutes.

The vessel immediately lost all propulsion and was thus affected by a blackout. Although the emergency genset cut in as expected, it was unable to supply the utilities to handle the emergency and only operated on and off. The rudder remained jammed to starboard, turning the vessel in that direction and resulting in it finally grounding on Giglio Island at around 23.00 with a heel of approximately 15°.



A map showing the track of the vessel from hitting the rocks till it capsized

Although the prime cause of the accident has been determined as human error, there are a number of issued raised by the report that concern the vessel's operational procedures and the functionality of some equipment.

Damage sustained

Damage assessment under the direct coordination of the master revealed the seriousness of the situation after just 16 minutes. After about 40 minutes (22.27) water reached the bulkhead deck aft.

Damage was found to affect watertight compartments (WTC) 4, 5, 6, 7 and 8 which contained machinery and equipment vital for the propulsion and steering of the ship as follows:

- WTC 4 - main thrust bearing and hydraulic units, machinery space air conditioning compressors


The capsized vessel with some of its lifeboats in the foreground

- WTC 5 - propulsion electric motors (PEM), fire and bilge pumps, propulsion and engine room ventilation transformers, propulsion transformers
- WTC 6 - three main diesel generators (aft)
- WTC 7 - three main diesel generators (fwd)
- WTC 8 - ballast and bilge pumps.

Days later it was discovered that the breach in the hull was around 53m long. The hole on the port side extended approximately from frame 52 to 124, and being located above the double bottom (some 2m above the keel), was crucial for the severity of the accident as, rather than the better protected double bottom of the ship being affected, flooding was directly into the operating compartments. In particular, the testimonies of the second and third engineers, as well as the second chief engineer, combined with audio recordings of communications between the VDR and bridge - have established that in just a few minutes (about 3 for the PEM and 7 for the aft diesel generators room) the ship has lost WTCs 5 and 6, while the adjacent WTC 4 and 7 were initially partially flooded, resulting in a dangerous liquid free surface, and then completely filled after about 40m.

The water appears to have also affected the adjacent WTCs 3 and 8 (local stores and local evaporators respectively). The first information about three WTCs being completely flooded reached the bridge 15 minutes after the contact. In total the flooding amounted to over 20,000t.

Watertight doors

One area of concern that emerged from the investigation involved the keeping open of watertight doors. The ship's owner, Costa Crociere (part of the Carnival Corporation) had set up a procedure establishing guidelines for the use of watertight doors during navigation. This shows that the procedure allowed the master the possibility, if deemed necessary, of keeping open some watertight doors while sailing, specifically doors 7, 8, 12, 13 and 24.

These included the automatic doors 7 between compartments 6 and 7, and 8 between compartments 5 and 6. This procedure does not comply with the requirements of SOLAS as it is not allowed to open these watertight doors while sailing.

Following the investigation, the difficulties were brought to the attention of the flag state administration (Italian Coast Guard Headquarters) which has modified the procedure, aligning it with the applicable legislation which may allow temporary openings supervised in case of need. The procedure applied on the *Costa Concordia*, and provided by the company for all its vessels, could create a hazard to the safety of navigation and the protection of persons onboard the other ships operated by Costa. Nevertheless, from the evidence obtained during the investigation, at the time of the contact the watertight doors were all closed.

Engineers' response

It is worth pointing out that all the engine staff and the electricians' department responded promptly to the emergency situation, transferring all the information necessary to allow the bridge staff to continually assess the flooding, and propulsion and emergency powering conditions. These crewmembers, coordinated by the chief engineer, tried in vain to start the vital equipment in the flooded WTCs, thus putting their own lives at risk. They remained for some time in the area of the bulkhead deck, even when flooding reached it, despite being aware that the ship was lost. They left the deck only when the bridge gave clearance. The electricians also, and in particular the head of this staff, did an exceptional job in making the connection between the emergency diesel generator (EDG) and the related switchboard.

EDG functionality

The ship suffered an immediate 'shut down' due to the violent entry of water in uncontrollable quantities that in less than a minute affected the stern DG Room (WTC 6, where three main generators were sited) and the PEM room (WTC 5). The blackout, in fact, is recorded 51sec after hitting the rocks. The consequences of the violent water entry had irreversible effects - the ship lost propulsion immediately, and all services.

The cross connection/isolation between the two main electrical panels and the emergency one (switches 902 and 905) which link the main electrical panel (QEP) with the emergency panel (limited to users of 220V and 440V supplied by that system), prevented, as designed, serious and widespread short-circuits to the emergency electrical network (through the automatic opening of switches 902 or 905, or both).

It should be noted that the plant is always on stand-by and once the EDG engine starts, because there is no power from the main units, the link between the DG and the electrical emergency panel (EEQ) is automatically connected (except that there is no protection against a short circuit in the emergency power network) by a large thermo switch (901, equipped with a hand-wound spring). It was necessary, however, for the electrician officer to manually engage (or re-engage) switch 901.

When at 21.52.32 (7 minutes after the impact) the chief engineer asked the electrician officer to start the EDG, it is likely that it didn't start automatically and this is the probable cause of the immediate blackout (21.46.44) together with the violence of the water on the electrical production and distribution system and the consequent shorts circuits.

It should be noted that the primary switches powered either by the QEP or the EEQ, are switched to the emergency network

Looking through WTCs 6 and 7 from WTC 5 (actually aboard sistership, the *Costa Serena*)

through individual switches located the in Local EDG on the EEQ.

Screwdriver 'stop-gap'

The EEQ was engaged at 22.10.52, after the arrival of the electrician officer in the EDG room. He immediately identified the problem, gave manual winding with the handle to the spring of the switch 901. Then, noting that the system did not, nevertheless, allow the engagement of the EDG to the related electrical network, used a screwdriver, relying on the blade to make mechanical interconnection inside the switch, to connect and engage the EDG to the emergency power grid.

The operation, says the electrician officer, was repeated three times, and that is when the EDG stopped because of excessive cooling water temperature (110°C) due to the locking of the corresponding fan on the alternator.

Finally, the electrician officer made a sort of chock with a cloth to avoid standing still with his hand on the screwdriver blocking the connection of switch 901.

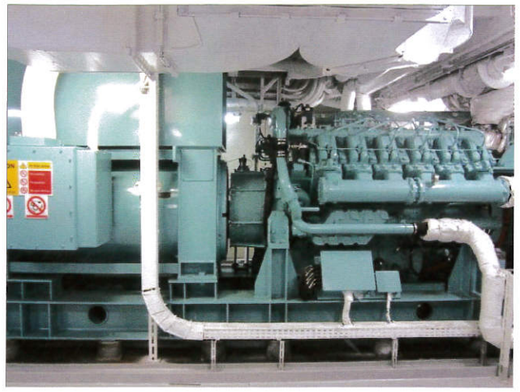
According the testimonies of the three crew members who intervened in the EDG room, it appears that this precarious operation, which began at 22.11, lasted up to 22.55 when the ship continued to list increasingly to starboard, after the abandon ship signal was given. At that time they had to leave the compartment. The first engineer, before leaving the room, said he had turned off the EDG to prevent the excessive engine temperature leading to a fire that nobody could then control.

Subsequently, a specific investigation has been carried out to study in depth the working of the emergency electric power system, analysing each aspect which could be significant:

- evidence related to the condition of the system at the time of leaving from Civitavecchia; - why the blackout occurred
- if after the blackout the EDG automatically engaged the emergency switchboard
- if during each forced attempt to engage the EDG with the ES, some supplied utility was actually working.

Requirements

In compliance with Rule 42 of Chapter II-1 of SOLAS 74 (amendments 96-98), apart from the main electric power, the



The emergency genset aboard the *Costa Favolosa*

ship must be equipped with an emergency power supply provided either by batteries or a diesel generator (*Costa Concordia* was equipped with the latter). These sources must be sufficient to provide power to the ship's essential safety services in an emergency, and be located so that a fire or any other accident in the spaces containing the main electric power supply, do not interfere with the supply, control and distribution of emergency electric power.

The emergency power supply must guarantee emergency lighting, the GMDSS equipment, means of internal communications, the emergency bilge pump and primary machinery with relevant valves for a period of 36h; and all electrically-driven watertight doors and the lifts for 30h.

Immediately after the impact a blackout occurred at 21.45.47 - the emergency generator started but supplied power for just 41secs.

According to the declarations of the first electronic officer, the first electrician and the first mate it has been concluded that the emergency diesel generator was not able to perform the designed service notwithstanding the crew's efforts to guarantee its working.

The emergency diesel generator should have supplied power to, among others, the emergency bilge pump and one of the "heeling system" pumps. Due to the blackout and the emergency diesel generator failure to supply power, the UPS batteries intervened guaranteeing the internal communication means and the emergency lighting.

It is not known when the batteries stopped supplying power or the technical reasons that determined the power supply stop. The consequences included loss of power supply for the emergency bilge pump and the heeling system emergency pump while the steering gear ceased to function.

Technical investigation of the EDG

Some investigations into the EDG were carried out aboard the sistership *Costa Favolosa* including:

- Study of historical data for the last year of service relevant to the EDG/EEP and to the low tension main electric switchboard aboard *Costa Concordia*, supplied by the fleet manager

Switch 901, also aboard the *Costa Favolosa*

and by the superintendent of the *Costa Concordia*. Such data included:

a) plant description and layout for the departure of *Costa Concordia* from Civitavecchia on 13 January 2012
b) periodical checks
c) working tests
d) ordinary overhaul
e) extraordinary overhaul/events
f) results of lube oil analysis
g) further additional information.

- Analysis of the EEP intermittent working, the latter taking place during a collective meeting that was attended by the chief electrician too: the latter, during an interview, has given a detailed technical account of the event occurring to the EDG
- Sharing of technical papers among the parties, necessary for drawing up a testing and simulation protocol that, in compliance with the ruling safety regulations for people and vessel, required another sistership of *Costa Concordia* (particularly because of the similarity of plant onboard) to perform a voyage without passengers (corresponding to the transfer to a drydock) as soon as it was feasible The *Costa Favolosa* was selected, as she was scheduled to depart from Savona bound for Palermo to drydock
- Sharing of above mentioned test protocol among the crew (master and officers).

Subsequent meetings resulted in a new schedule of tests so as to take into consideration the Chief Engineer's requirements. It was also pointed out, at first to the members of the team, and later on to the whole crew, the need to further check, during the full blackout, the time employed by the ship's lifts (totalling 29 and including the ones employed by the crew and by the passengers) to reach the deck, in accordance with the requirements of the relevant SOLAS regulation. This test has been required by the flag state representative as future support of the forthcoming investigations into the accident, as this is a test not easily repeatable within the short term. Anyway, the test was exclusively functional, as it is not possible to compare its results with what happened on the *Costa Concordia* as it is not known how many and which lifts were working at the beginning of the emergency and during the whole emergency phase.

Scope of activities

As previously described, the planned activities had the aim of assessing the possible causes of the intermittent working of *Costa Concordia*'s EEP.

According to the events chronology, until 22:36h the EDG was running with a starboard list of 10° to 15°. Sometime before, at about 22.10h, the port list had reached its maximum value ie 10°.The list never exceeded the maximum allowed value of 22.5° which could have led to its stopping due to loss of lube oil suction from the sump (SOLAS Rule II-1/42.6).

Each time the crew manually intervened on breaker 901, ie they succeeded in unlocking it, the latter actually closed on the ES because the current measuring instrument read, after an initial 1,000A, a running current of about 400A.

Results of tests

In total seven different test were carried out with the following results:

- Test no. 1 – it has been successfully checked that the EDG, when in manual mode and in OVERRIDE, does not shut down due to the action of water high-high temperature alarms and lube oil low-low pressure alarm
- Test no. 2 – it has been successfully checked that the EDG, when in manual mode and safety devices in ENABLE position, does stop due to the action of water high-high temperature alarms and lube oil low-low pressure
- Test no. 3 – it has been checked that, following a black-out, the EDG automatically starts, the electro ventilator louvers open, the electro ventilator starts and the breaker 901 closes
- Test no. 4 –the ship's lifts positioning sequence at deck level has been successfully checked
- Test no. 5 – it has been successfully checked that the "ship-to-shore" commutator, when in shore mode, induces the breaker 901 opening on ES
- Test no. 6 – it has been successfully checked that auxiliary power failure to the ES allows the manual closing of the breaker 901 through its mechanical push-buttons
- Test no. 7 – the opposite sequences in order to restore the ship's normal power supply after the emergency situation, has been carried out successfully.

Recommendations

Amongst the many recommendations made by the report is one concerning emergency generators. It is proposed that emergency generator capacity be increased to also feed the high capacity pump(s) which are also proposed in the report. In addition a second emergency diesel generator should be provided, located in a separate main vertical zone from the first emergency generator, and above the most continuous deck. This second generator could be dimensioned on the basis of selected services.

The related manufacturing and handling should be as follows:

- new emergency diesel generators to be made according to specific building techniques to guarantee reliable and long-lasting operation
- regulate function tests, planning them once a week, under a significant load (at least 50%) and of at least 2h duration for both emergency diesel generators. □