
**The Final Report on the Safety Investigation of
Air-conditioner Compressor Explosion on Board
Tanker Zhong Ran 53
off Jeju Island, Republic of Korea
21 May 2014**

Maritime Safety Administration of the People's Republic of China

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1. Summary of the accident and investigation.

1.1 Summary of the accident.

At 2040 on 21 May 2014, the Chinese tanker Zhong Ran 53, owned by Zhongran Shipping (Dalian) co., Ltd., occurred an air-conditioner compressor explosion on board on her way from Zhangjiagang, China, to Yosu, Korea, in light ship at position (33°30' .57N/126°03' .68E) close to Jeju Island South Korea , 2 crews died as a result. This was a very serious casualty according to IMO Casualty Investigation Code.



Figure 1.: Tanker Zhong Ran 53

1.2 The investigation.

1.2.1 Requirement of investigation.

According to Article 21, Chapter I and Article 6, Chapter XI-1 of *the Convention of Safety of Life at Sea 1974*, and the *Regulation of Safety Investigation of Marine Casualties and Incidents* enacted by China Maritime Safety Administration (MSA), China MSA carried out safety investigation into this accident.

1.2.2 Purpose of investigation.

The purpose of this investigation is to improve the maritime transportation safety management level, to prevent similar accidents from occurring in the future; it shall not be the purpose of this investigation to determine liability or to apportion blame.

1.2.3 Main evidences.

1. On-spot inspection report of tanker Zhong Ran 53;
2. Interview records and statements given by Zhong Ran 53's crews and relevant witnesses;
3. Operating records and documents of the ship's and company's Safety Management System;
4. Analysis and Testing Report into the cylinder by Dalian Institute of Chemicals and Physics;
5. Proof of death issued by S-Jungang Hospital, Republic of Korea.

2. Factual Information.

2.1 Particulars of the ship.

2.1.1 Technical parameters of the accident ship

Vessel's name: Zhong Ran 53

Flag: China

IMO number: 8879885

Construction: steel

Type: tanker

Length overall: 104.6 meters

Breadth: 16.4 meters

Depth: 8.15 meters

Gross tonnage: 3785

Net tonnage: 1598

Draft: 6.7 meters

Main engine power: 2206 KW

Built on: 1 Jan. 1993

Place of built: Jinling Shipyard, Nanjing, China

Owner and operator: Zhongran Shipping (Dalian) co., Ltd.

2.1.2 Ship's surveying state

The accident ship Zhong Ran 53 was classed by China Classification Society, ship was fully certificated with various statutory certificates.

2.1.3 Ship air-conditioner refrigeration systems

(1) System configuration

The ship air-conditioner refrigeration systems are single-stage compression refrigeration cycle system. The main components include compressor, condenser, thermostatic expansion valve, evaporator, forming a closed system with connecting pipelines. (See Figure 2)

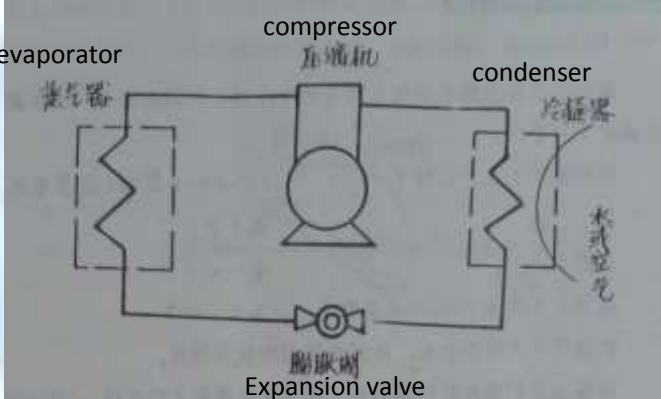


Figure 2: refrigeration system construction diagram

(2) Working principle.

The vapor is inhaled into the compressor and compressed into high-pressure steam, lubricating oil is separated through the oil separator. The high-pressure vapor is condensed into liquid through the condenser, then released into the evaporator through thermostatic expansion valve, and evaporated into low-pressure steam with the help of external heat, so that the surrounding medium is cooled. Low -pressure steam is inhaled into the compressor again. This cycle produces continuous cooling effect.

(3) Air- conditioner compressor

The ship air-conditioning compressor was produced by Shanghai Refrigerating Machine Manufacture, it was a 70 series Freon refrigeration compressor (8FS7 type, eight-cylinder, four fan-shaped arrangements), refrigerant is Freon R-22, and compressor lubricant oil is 25# refrigeration oil.

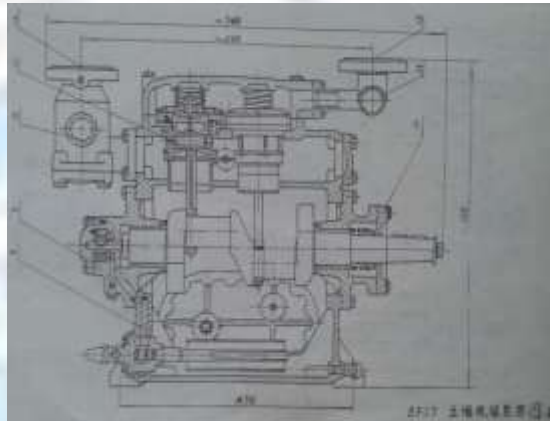
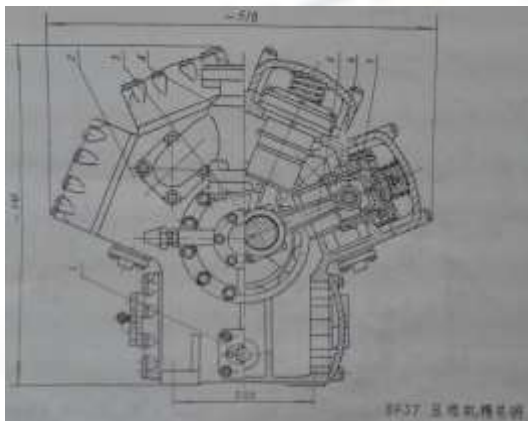


Figure 3: transverse view of the compressor Figure 4: compressor fore-and-aft view

2.1.4 Manning.

Zhong Ran 53's crews were recruited by Dalian Furen Seafarers Service Company, they were sent onboard to work after being evaluated and received pre-job training arranged by Zhongran Shipping (Dalian) co., Ltd. During the accident voyage, the manning consisted of 22 crews, all were Chinese. It was in compliance with ship's *Minimum Safety Manning Certificate*.

1. The chief engineer was born in 1970, posted on Zhong Ran 53 from 6 April 2014.
2. The second engineer was born in 1968, worked on aboard ships of Zhongran Shipping (Dalian) co., Ltd. as second engineer or chief engineer from 2009 to 2013, joined Zhong Ran 53 on 8 August 2013 as second engineer.

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3. The Zhang-surnamed motor man was born in 1992, joined Zhong Ran 53 as cadet on 26 March 2014.

At the time of accident, the second engineer was working in the air-conditioner room with the Zhang-surnamed motor man.

2.1.5 Ship company's profile

At the time of accident, Zhong Ran 53 was owned and managed by the same company- Zhongran Shipping (Dalian) co., Ltd. (Referred to as Zhongran Shipping hereinafter). This company owns, operates and manages two 5000-tonnage tankers, mainly provides domestic and international oil product transportation service for those companies within the Zhongran Group, which is the mother-company of Zhong Ran Shipping.

Zhongran Shipping was established on 28 December 2007, registered in Dalian. The company was issued with Document of Compliance in according with ISM code on 20 November 2008; the company has 7 internal departments, i.e. shipping department, safety supervision department and human resource department, 33 staff in total, 13 of them had experience of marine officers or engineers.

In May 2008, MT Pu You 10 was acquired by Zhongran Shipping and renamed as Zhong Ran 53; Zhong Ran 53 was issued with her SMC on 11 September 2013 by China Classification Society.

3. Evidence Analysis and facts determination.

3.1 On-spot survey.

On 29 May 2014, investigators carried out on-spot survey on board Zhong Ran 53 in anchorage of Dalian port, and found:

1. There was no apparent trace of flame burning on the explosion scene.
2. Several fire safety doors within the accommodation corridor area where the air-conditioner room was located were severely impacted and deformed, ceiling outfitting panel in corridors fell off; the inside of air-conditioner room was damaged seriously, the control panel on four walls, the on-top vent pipe and front wall all sustained strong impact from the fragments created by the explosion, were deformed, damaged or out of position.
3. The air-conditioner compressor was disintegrated, the fragments were projected outwards all around. Among the 4 compressing cylinder covers, only two were intact, one was totally shattered, the other one was with half left; the crankcase disintegrated completely; the 8 pistons and connecting rods are basically intact.
4. A gas cylinder was lying down close to the refilling valve of air-conditioning system. The Surface of the gas cylinder is rusty and without any mark; its outlet valve is open, and the connecting pipe of bottle valve is ruptured. A damaged oxygen decompression meter is found at the scene, and no other gas cylinders were

found.

5. The air conditioner refrigeration system refilling valve, compressor suction valve and exhaust valve, inlet/outlet valve of cooler and the inlet valve of reservoir are fully open; the outlet valve of reservoir is shut; the control button of compressor is located at manually start position.
6. There was an Air-conditioner System Operating Procedure on the wall inside air-conditioning room, the procedure does not explain about the sequence of operating and precautions for refrigerant filling.

Based on the above on-spot survey and examination, it is determined that the air-conditioner compressor exploded, at the time of accident, the air-conditioner system was being refilled with refrigerants.

3.2 Crews' statements and work records of SMS

3.2.1 The cylinders in air-conditioning room.

1. According to the chief motor man and Dai-surnamed motor man, the cylinder found on the explosion scene were placed there by Dai-surnamed motor man and Zhang-surnamed motor man two days prior to accident from the Ice Room, at the instruction given by second engineer.
2. According to several crew members on board, this cylinder had long been stored in Ice Room, it was ignored in the past engineer's watch-keeping handovers, no one knows what was inside the cylinder. According to the chief engineer's statement,

the current second engineer once heard from the ex-second-engineer said that there was one big cylinder of refrigerants on board ship.

3. The ship and company's supply log records show there are 3 oxygen cylinders, 2 ethylene cylinder, and 1 R22 refrigerant cylinder (small). However the cylinder at the explosion scene was not recorded on the supply log.
4. According to Mr.Chen, the management staffmember of Zhongran Shipping, the refrigerants supplied by shore to ships are all in small sized R22 cylinders (net weight 22.7 KW); no big sized refrigerants cylinders were supplied.



Figure 5: cylinder found at scene



Figure 6: cylinder of R22

3.2.2 The air-conditioner system refrigerant refilling operations on board ship.

1. All crews onboard have no refrigerant refilling experience.
2. At about 2000 on 19 May, second engineer led chief motorman, Dai-surnamed motorman and Zhang-surname motorman and carried out one refrigerant refilling

operation. At the beginning of the operation, they chose to use refrigerants from the big cylinder in Ice Room. Because the outlet valve of the cylinder was incompatible with the refilling valve, they had to use the oxygen de-compression gauge. During the refilling operation, the chief motorman noticed the refilling pipeline was not cold and the cylinder was over-pressuring (about 10 Mpa), he at once reminded second engineer if it was oxygen they were refilling. Second engineer stopped the operation which had started for about 5 minutes after he felt the refilling pipeline. After that, second engineer instructed Zhang-surnamed motorman to fetch the small R22 cylinder from the storage in steerage room, restarted the refilling, the operation lasted for 30 minutes. Zhang-surnamed motorman put back the small R22 cylinder afterwards.

3. Before the refilling operation on 19 May, second engineer was given permission by chief engineer. Before ship's departure on 20 May, second engineer reported to chief engineer that half a cylinder of refrigerants has been refilled, the other half of the cylinder was saved for ice-machine; the liquid level was unreadable, the air-conditioner system is still not working, and ask for refrigerant supply next voyage. Chief engineer expressed his consent.

3.2.3 Accident scene.

The Third Engineer was the first arrival on scene right after the explosion, while the air-conditioner room was filling with white smoke. No flame was observed. The Second Engineer and Zhang-surnamed motorman were lying on the floor unable of moving, no visible external wounds, breathing difficultly, and spitting phlegm continuously, still able

of verbal communication, kept saying “feeling hot, uncomfortable and thirsty”.

3.2.4 The state in air-conditioner room at time of accident.

1. At the time of explosion, both the second engineer and Zhang were in the air-conditioner room. No one was on scene or informed of the operation beforehand.
2. At about 1930 on the day of accident, the Second Engineer took away Zhang to do some job, but did not specified what was the job.
3. Judging from the opening condition of the top valve of the cylinder and the valves in air-conditioning pipes on the scene, the Second Engineer and Zhang were operating refrigerant-refilling with the air-condition system.

3.2.5 The operation procedure of air-condition system.

1. According to company’s SMS, the Second Engineer is responsible for the onboard air-condition system maintenance.
2. On board Zhong Ran 53 there was *Air-conditioning System Operation Procedure* included in ship’s manual, however the procedure has no content and safety requirements about refrigerant-refilling operation.
3. The Air-conditioning System Operation Procedure was already posted on wall within the system room.

3.2.6 Fatigue elements.

In the 24 hours prior to accident, the Second Engineer had 8 hours on duty, 2 hours of ship maintenance and 14 hours of rest. No evidence showed he was fatigued.

3.2.7 Emergency response.

After being reported of the accident, the ship's company responded in timely manner according to the Emergency Response Procedure of its SMS documents. The response record was in proper place. Meanwhile, ship's company has carried out accident investigation and cause analysis, relevant corrective measure were determined and implemented consequently.

3.3 Lab test and hospital report.

1. According to the test report issued by Dalian Chemicals and Physicals Research Institute, the content from the cylinder at the explosion scene on board Zhong Ran 53 was oxygen, not Freon R22 or acetylene.
2. According to the proof of death issued by Korea S-JUNGANG hospital, the Second Engineer and Zhang's death was accidental. Zhang died of respiratory tract burning, The Second Engineer died of pulmonary edema from respiratory tract burning.

4. Sequence of events.

At 1606 on 20 May 2014, Chinese tanker Zhongran53 departed Zhangjiagang, China, bound for Yosu, Korea, without cargo.

At 2040 on 21 May, when ship arrived location 33°32' .3N/126°05' .9E close off Jeju Island, loud explosion was heard on board. The bridge fire alarm was activated subsequently.

At 2041, captain arrived bridge, sounded the general fire alarm. After preliminary investigation, it was found the explosion happened in air-conditioner room, there were two people in the room. On board search and rescue was immediately started.

At 2044, the Second Engineer and Zhang-surnamed motorman were found severely injured and moved to open space in starboard main deck. The first aid measures were immediately applied.

At 2045, the captain reported the accident to ship's company, local agency in Korea, Korean Navy and Jeju MRCC respectively, and requested emergency medical aid.

At 2050, the company reported the accident to Liaoning MRCC.

At 2205, Korean Navy rescue ship arrived at Zhong Ran 53.

At 2300, the two injured were transported to Jeju Island Central Hospital for further treatment.

At 2345, the two injured crew members were declared dead by the hospital.

5. Losses.

As a result of the explosion, the Second Engineer and Zhang-surnamed motor man of Zhong Ran 53 died.

As a result of the explosion, the compressor of the air-conditioner system disintegrated, the equipments in air-condition room and parts of neighboring accommodation corridor were damaged.

6. Cause analysis.

6.1 Analysis of explosion element.

6.1.1 The principles of explosion.

The three elements for gas explosion include flammable gas, oxygen and ignition. The mixture of flammable gas and oxygen, when confined in a closed container, will emit enormous combustion heat after being ignited, expands rapidly and create high pressure, until the container bursts and gas explosion occurs.

6.1.2 Mixture of explosive gas.

Usually inside the compressor contains refrigerant R22 and small amount of #25 refrigerating lubricant oil. Due to the fact that R22 is not flammable, not explosive and not supportive of combustion, the mixture of R22 and oil vapor does not burn or explode.

When oxygen was mis-regarded as refrigerant and refilled into the system, as a strong oxidizer and combustion supporting agent, together with R22 and lubricant oil vapor created flammable mixture of gas. When the content of flammable mixture of gas reached the explosive limit, the presence of ignition led to explosion.

6.1.3 The ignition source.

According to the evidences available, the ignition source could be:

1. Sparks from friction between pistol bearing and cylinder, or percussion of the air valve of the compressor,

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2. Due to oxygen enters into the refrigeration system, the compressor crankcase and cylinder were incapable of cooling, resulting in the continued rise of exhaust pressure and temperature. Eventually the temperature rises to oil mist ignition point, igniting the explosive gas mixture and causing explosion.

6.2 Causal factors of the accident.

6.2.1 Human factors.

(1) Analysis of unsafe acts.

When the Second Engineer and Zhang-surnamed motor were refilling refrigerants for the air-condition system, they mistook oxygen cylinder as the R22, injecting large amount of oxygen into the cooling system, forming a flammable mixture of oxygen, R22 refrigerants and lubricant oil vapor inside the compressor.

(2) the precondition of unsafe acts.

Due to the death of both crew members on spot as a result of the explosion, it is impossible to determine accurately why the mistakes happened. However the unsafe act probably resulted from the following factors:

1. Most parts of China are appearing hot weather from the middle of May, especially the south coastal area, the temperature staying above 30 Celsius degrees. As the responsible person for air-condition system onboard the ship, the Second Engineer was eager to repair and test the system in hurry. Therefore he carried out two refilling operation within two days.

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2. Based on the insufficient information exchanged from his predecessors, the Second Engineer believed there was large cylinder of refrigerants on ship, and subjectively presumed it was the cylinder inside the ice-room. Therefore he used this cylinder to refill air-condition system on two occasions.
 3. The Second Engineer and the Zhang-surnamed motorman lacked of safety awareness. They failed to assess and understand the safety risks of refilling operation, take precautions, even be warned after one refilling operation. Meanwhile, the lack of refrigerant refilling experience before let them fail to check safety procedure before operation.
 4. The absence of label on the cylinder objectively contributes to the wrong judgment of the Second Engineer.

6.2.2 The organizational factors.

(1) Shipping management.

1. According to the Ship's Crews Sign on/off Procedure, when crews sign on or off the ship, they should exchange clearly the onboard material information, and enter into Sign on/off log. Reviewing the Second Engineer's sign on/off log shows it only records the general information of spare materials, stating the air-conditioners and auxiliary equipments are in good order, without mentioning the cylinder in ice-room that was unlogged. The insufficient clarity of the Second Engineer's exchange with his predecessor, contributes to his misjudgment about the cylinder later on.
2. According to the *Ship's Material Management Procedure*, based on the material in

stock on board and operation needs, supplies should be ordered annually, seasonally or temporarily. Even though the inadequate refrigerants on board, MT Zhongran 53 failed to order supply timely, leading to insufficient refrigerant supply on board ship. The procedure also requires the Second Engineer, as the responsible person for material in engine department, should establish supply log for each type of material, keep records of the receipt, use and amount left of materials, ensure the consistency between log book, records and material itself. By the end of each season, all types of material on board should be counted or measured and inform shore management office. However, the cylinder placed long in ice-room was neither counted, logged, nor labeled in any way. This mismanagement of materials onboard creates the potential possibility of mistakes about the cylinder's content.

3. According to company's *Reporting, Investigation and Correction Procedure of Unconformities, Near misses and Accidents* on board Ships, the master should be reported once any unconformity is observed. The unconformity should be corrected timely. Several crew members on board MT Zhongran 53 saw the unknown cylinder. At least the Second Engineer, Chief Motorman and other 2 crews knew of one refill operation with the wrong cylinder. The Second Engineer once mentioned to Chief Engineer about the unclearness of level mark of the liquid storage tank inside air-conditioner room. However none of those unconformities and abnormal phenomenon was reported or corrected.

(2) Company management.

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1. Company safety assessment of onboard operations is insufficient. Risks associated with refilling operation of air-conditioning system have not been identified, marked. No proper precaution is in place.
 2. Company's visits and inspections to ships by shore management officer are ineffective. The long-existing mismanagement of materials and other problems on board MT Zhongran 53 are not uncovered, not corrected.
 3. Crews' daily safety training is inadequate. Crews' safety awareness is poor. The two deceased crew members failed to further verify the content of the cylinder before refilling operation.

6.3 Conclusions.

1. On 21 May 2014, the Chinese tanker Zhongran 53, when she was navigating close off Jeju Island Korea, her onboard air-conditioner compressor exploded. As a result of the accident, second engineer and Zhang-surnamed motorman died.
2. The probable direct cause for the explosion is when the crews were carrying out refrigerants refilling operation for the air-conditioning system, they mistook the cylinder of oxygen for refrigerants, injecting large amount of oxygen into the air-conditioning system. It created a flammable and explosive mixture of refrigerant R22 vapor, lubricant oil vapor and oxygen, the mixture of gas was ignited by high temperature or sparks of friction, and finally exploded.

7. Safety recommendations

This explosion accident caused a severe loss of two deaths. The investigation reveals several safety lessons that deserve profound thinking.

7.1 Zhong Ran 53 is recommended to:

1. strictly implement SMS document requirements, especially requirements regarding crews sign on/off procedure, ship's material management and operational risks.
2. at once carry out a special operation to count, measure and log all materials on board ship, based on visual inspection of material itself to ensure consistency between paper record and real condition of materials, the log should indicate the storage place, put apparent labels on important items.

7.2 Zhongran Shipping (Dalian) Ltd. is recommended to:

1. further revise and improve company's safety management system, especially about documents of operational requirement. The *Air-conditioner System Operation Procedure* should clearly stipulate the operations steps and safety requirements for refrigerant refilling action.
2. strengthen the company shore offices' visit and inspection scheme of ships; supervise ship's management and crews' operation under the company's safety

management system.

3. disseminate this accident information and its investigation findings among company's fleet, crews, organize crew safety training course, and improve safety awareness.

