Report on the investigation

of a major LPG leak from the gas carrier

Ennerdale

while alongside Fawley Marine Terminal

17 October 2006

Marine Accident Investigation Branch
Carlton House
Carlton Place
Southampton
United Kingdom
SO15 2DZ

Report No 10/2007
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Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2005 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

2/O	-	Second Officer
3/O	-	Third Officer
ASTM	-	American Society for Testing and Materials
Bar absolute	-	Pressure in bar including atmospheric pressure
Bar gauge	-	Pressure in bar registered on content gauge (excludes atmospheric pressure)
BSI	-	British Standards Institute
BST	-	British Summer Time
CDI	-	Chemical Distribution Institute
ESD	-	Emergency shut down (valve)
FMT	-	Fawley Marine Terminal
HFRS	-	Hampshire Fire and Rescue Service
HS&E	-	Health, Safety & Environment
IACS	-	International Association of Classification Societies
ICS	-	International Chamber of Shipping
ICSM	-	Indo China Ship Management
IGC Code	-	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, 1993 Edition
IMO	-	International Maritime Organization
IMT	-	International Maritime Transport Ltd
ISGOTT	-	International Safety Guide for Oil Tankers and Terminals
LPG	-	Liquefied petroleum gas
MARVS	-	Maximum allowable relief valve setting of cargo tank
MCA	-	Maritime and Coastguard Agency
NKK	-	Nippon Kaiji Kyokai (Classification Society)
NRV	-	Non return valve
OCIMF	-	Oil Companies International Marine Forum

PMS	-	Planned maintenance system
PTFE	-	Polytetrafluoroethylene
SIGTTO	-	Society of International Gas Tanker and Terminal Operators
SIR	-	Ship inspection report (CDI Inspection)
SIRE	-	Ship Inspection Report Programme (OCIMF inspection)
SMS	-	Safety Management System
SOLFIRE	-	Solent and Southampton Water marine emergency plan
UK	-	United Kingdom
URs	-	Unified requirements
UTC	-	Universal Time Constant
Vapour pressure	-	Equilibrium pressure of saturated vapour above the liquid gas expressed in bars absolute at a specific temperature
VLC	-	Very Large Crude (Carrier)
VTS	-	Vessel Traffic Services

SYNOPSIS

(All times are BST, UTC+1)

On 17 October 2006, the Hong Kong registered gas carrier *Ennerdale* experienced a major leak of liquefied propane, while cargo sampling operations were taking place, alongside Fawley Marine Terminal (FMT). The leak was sealed 29 hours later, after an estimated 66 tonnes of propane had been lost to atmosphere.

The fully pressurised gas carrier *Ennerdale* arrived at FMT's No. 2 berth at 2300 on 15 October 2006, to load liquefied propane. Preloading checks were conducted and loading commenced shortly after. At 1830 on 17 October the loading operation was halted, approximately 2 hours before cargo loading was due to be completed, to allow a 'freeze' test to be conducted. A cargo surveyor came aboard and attached his cargo sampling equipment to the sampling point of tank No. 1. The cargo was then circulated for 2-3 minutes. The process was repeated for tank No. 2. With the test results satisfactory, cargo loading continued and completed at 2100.

The cargo surveyor returned to the ship and went straight to the sampling point of tank No. 1, where the chief officer was already preparing. The cargo surveyor used a thread adapter to connect the sampling device to the ship's sampling connection. The chief officer then circulated the cargo, using the deep well pump, to ensure a good representative sample was obtained. The cargo surveyor flushed the sampling device through three times before filling it. He repeated the process, taking four samples in total, before moving aft to the sampling point of tank No. 2. While the chief officer secured tank No. 1, the cargo surveyor prepared to fit his equipment to the sampling point of tank No. 2. As he turned the sampling connection towards himself, the sampling valve assembly came off in his hand.

The chief officer saw and heard a leak and activated the emergency shut down (ESD) valves. Attempts were made to refit the sampling valve but the 11 bar pressure of the cargo, and the formation of ice on the connection, made it impossible. It soon became apparent that the ESD valve adjacent to the tank on the same line as the sampling connection was not completely shut.

The emergency services were alerted soon after the accident and the ship was doused in water sprays to disperse the gas cloud. At 2200, the port of Southampton was closed to all traffic. All ships at FMT were evacuated at 0000. At 0530 on 18 October, with the situation stabilised, traffic restrictions were reduced to a 400 m exclusion zone around *Ennerdale*, which allowed the port to reopen to traffic.

After several options to stop the leak had been considered, it was decided to hot tap the cargo pipework and inject a sealing compound to stop the leak of gas. Furmanite, a company regularly used at Fawley refinery, successfully drilled into the pipework at 1408 on 18 October. The sealing compound was then slowly injected into the pipework, enabling the leak to be sealed and capped at 0240 the next morning.

Ennerdale then sailed and anchored in the Solent, awaiting clearance to sail which was contingent upon class approval of the repair and the discharge port agreeing to accept the vessel. This completed, she sailed at 1814 the same day.

The assembly used for gas sampling was designed as a drain point for the cargo pipework system, but had come to be used for cargo sampling when the original arrangement provided for this was deemed unsuitable. The regulatory requirements for gas carriers include very little guidance on cargo sampling, with no unified standard employed. Industry guidance on sampling was also lacking. Guidance, published in 1989 by the Society of International Gas Tanker and Terminal Operators (SIGTTO), appeared to have been overlooked as industry inspections of *Ennerdale* had not highlighted any concerns with the sampling arrangement.

Inspection of the ESD valve, which failed to close and contain the leak of liquefied propane, revealed that it had been jammed open by a small burr. Although ESD valves onboard *Ennerdale* were tested to ensure their closure rates were acceptable, there was a false assumption that the valves were indicating that they were closed. Although some ESD valves appeared to have been pressure tested by ship's staff, those on the cargo discharge lines were not, as there was no readily available method to do so. There were no records of when the faulty ESD valve was last inspected, tested or overhauled. Furthermore, there is no clear regulatory requirement for ESD valves to be tested or internally examined at periodic intervals, or industry standard for regularly testing of ESD valves in service.

Due to the nature of the leak, the ship's crew were unable to secure the leak themselves. Although the emergency response by the ship, FMT, and local emergency services was good, liaison between ship's staff and the FMT was not ideal.

Recommendations have been made to SIGTTO, Chemical Distribution Institute (CDI) and Oil Companies International Marine Forum (OCIMF) with regard to providing industry guidance on sampling arrangements and procedures. Lloyd's Register has been recommended to take two proposals to IACS regarding the standard of sampling connections, and ESD valve design and periodic testing.

Figure 1

SECTION 1 - FACTUAL INFORMATION

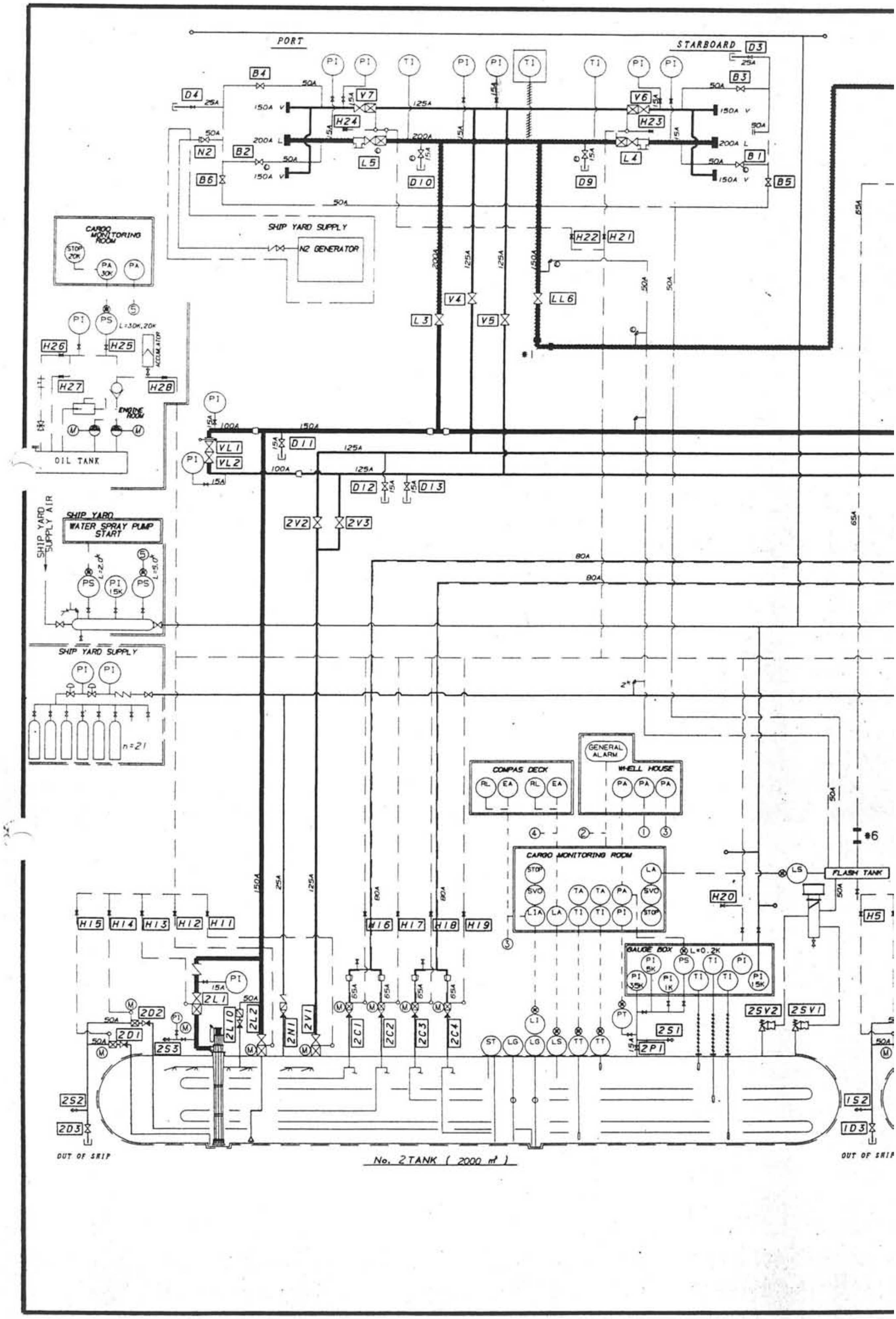
1.1 PARTICULARS OF *ENNERDALE* AND ACCIDENT

Vessel details (Figure 1)

Registered owner	:	Everjoy City Ltd, Hong Kong
Manager	:	ICSM Pte Ltd
Commercial Operator		Petredec Services Asia
Port of registry	:	Hong Kong
Flag	:	Hong Kong
Type	:	Fully pressurised liquefied gas tanker
Built	:	1997, Shin Kochi-Jyuko Co. Ltd, Japan
Classification society	:	Nipon Kaiji Kyokai (NKK)
Construction	:	Steel
Length overall	:	99.92 m
Gross tonnage	:	4227
Engine power and/or type	:	3089 kW, Akasaka 6UEC37LA
Service speed	:	12 knots
Other relevant info	:	Single fixed pitch propeller, no bow thruster

Accident details

Time and date	:	2142 17/10/2006
Location of incident	:	Alongside No. 2 berth, Fawley Marine Terminal
Persons on board	:	19 crew + 1 cargo surveyor
Injuries/fatalities	:	1, minor cold burn
Outcome	:	66 tonnes of LPG lost to atmosphere



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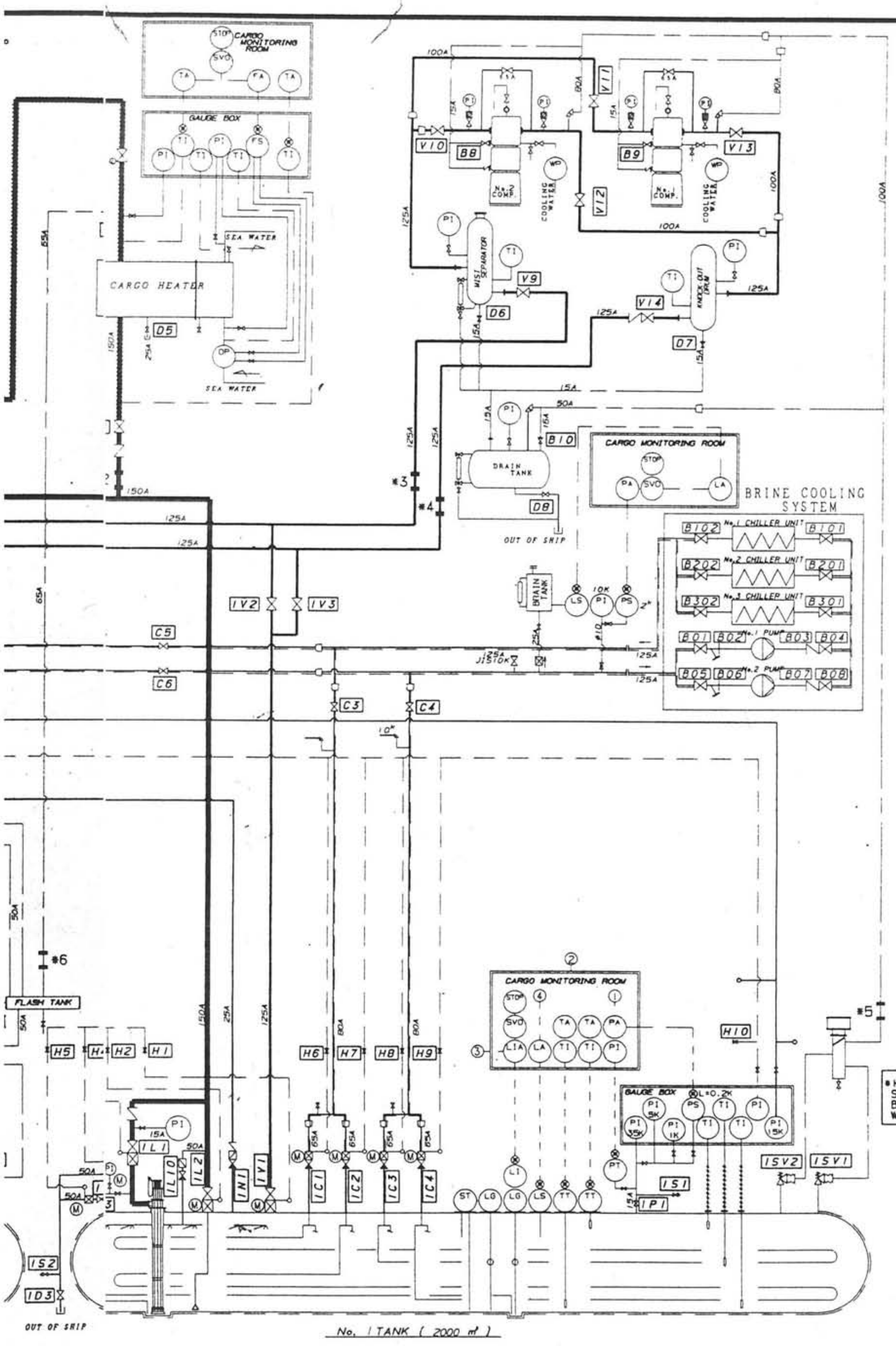


PRINCIPAL DESIGN CONDITIONS		
CLASSIFICATION	NK	
RULES AND REGULATION	NK RULE	
	IGC CODE	
	USCG(COC)	
CARGO TANK		
DESIGN VAPOUR PRESS.	NK 18.0	kg/cm^2
DESIGN TEMPERATURE	0	°C
SET PRESSURE OF SAFETY VALVE	18.0/7.0/2.0	kg/cm^2
HYDROSTATIC TEST PRESSURE	27.0	kg/cm^2
TIGHTNESS TEST PRESSURE	18.0	kg/cm^2
CARGO PIPING		
DESIGN PRESSURE	20.0	kg/cm^2
DESIGN TEMPERATURE	0 / -45	°C
SET PRESSURE OF SAFETY VALVE	20.0	kg/cm^2
HYDROSTATIC TEST PRESSURE	30.0	kg/cm^2
AIRLEAK TEST PRESSURE	18.0	kg/cm^2

SYMBOLS			
	GLOBE VALVE(TEFLON)	PI	PRESSURE GAUGE
	EMERGENCY SHUT-DOWN VALVE	TI	TEMPERATURE GAUGE
	BALL VALVE	ST	SLIP-TUBE GAUGE
	SWING CHECK VALVE	LG	FLOAT GAUGE
	T-TYPE STRAINER	LS	LEVEL SWITCH
	STRAINER	LI	LEVEL INDICATOR
	NEEDLE VALVE	LA	LEVEL ALARM
	SOLENOID VALVE	PS	PRESSURE SWITCH
	SAMPLING VALVE	PA	PRESSURE ALARM
	3-WAY VALVE	SVO	OPENING OF SOLENOID VALVE
	SAFETY VALVE	STOP	SYSTEM STOP
	TRANSMITTER	LIA	LEVEL INDICATOR ALARM
	THROTTLE JOINT		EXCESS FLOW VALVE
	FUSIBLE PLUG	WP	WATER PUMP
	SIGHT FLOW	FS	FLOW SWITCH
L	LOW TEMPERTURE VALVE		PILOT TYPE SAFETY VALVE
	LOW TEMPERTURE LINE (-45°)		BREATHER VALVE
	ANGLE VALVE	PT	PRESS. TRANSMITTER
	BLANK-OPEN FLANGE	TT	TEMP. TRANSMITTER
	SPOOL PIECE	OP	ORIFICE PLATE
M	METAL SEAT	EA	ELECTRIC ALARM
		RL	ROTALLY LIGHT

*6: BEFORE LOADING OF PROPYLENEOXIDE, SPOOL PIECES SHALL BE REMOVED AND INSTALL BLANK FLANGES AT THESE LOCATION WITH A WIRE AND SEAL.

4000m³ POX/LPG CARRIER

ENNERDALE

FLOW DIAGRAM

IZUMI STEEL WORKS, LTD.

1.2 BACKGROUND

1.2.1 Ship description

Ennerdale was built in 1997 as a chemical and gas carrier. She had operated under the managers, ICSM Pte Ltd, since March 2005, predominately transporting liquefied petroleum gas (LPG). ICSM Pte Ltd managed nine ships at the time of accident, the ships being a mixture of LPG, product and VLC carriers.

Ennerdale was a fully pressurised gas tanker, and transported her cargo at ambient temperature in horizontal cylindrical pressure vessels rated for no greater than 18 bar gauge and at temperatures no lower than 0°C. Unlike semi pressurised or fully refrigerated gas carriers, her tanks were not heavily insulated and there was no cargo refrigeration plant onboard. A cargo cooling facility was provided, but this was only used when carrying propylene oxide.

Figure 2 shows the cargo containment layout. The two 2000m^3 tanks were mirror images of each other and were loaded and discharged through either the port or starboard manifold **(Figure 3)**. If the cargo to be loaded was refrigerated, it could be directed through a heater to ensure the cargo temperature was above 0°C. Each tank had a vapour line to allow gas vapour to be returned ashore when loading and also to enable cargo vapour to be pressurised with the ship's two compressors for its return to the tanks.

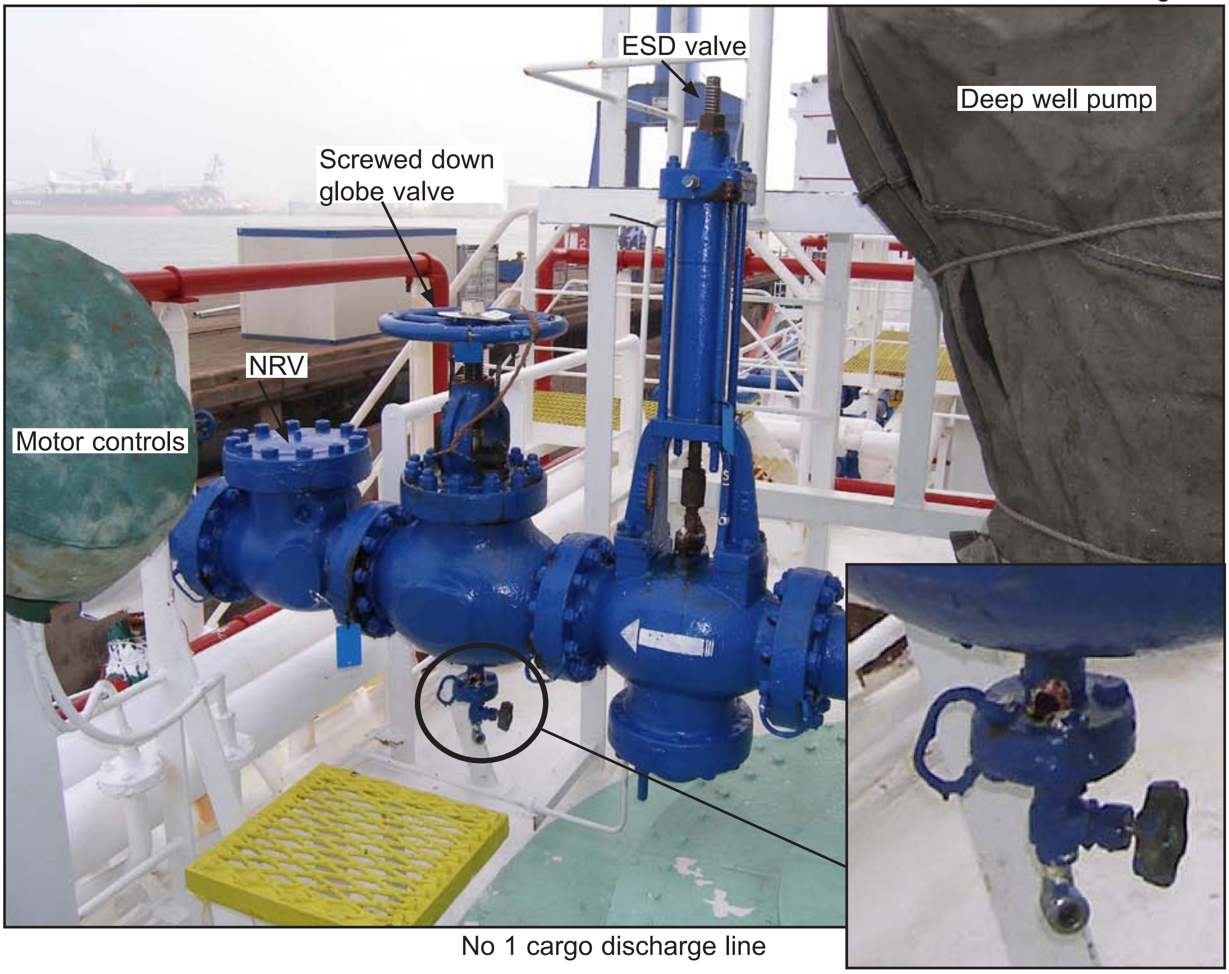
Figure 3

Port cargo manifold

At the tank domes, the loading lines were fitted with emergency shut down (ESD) valves immediately next to the tank, and then a manual screw down globe valve in series. On the discharge line, a deep well pump was used to remove the cargo via an ESD valve, manual globe valve and non return valve **(Figure 4)** to the manifold. The cargo manifolds were fitted with ESD valves and manual globe valves. The vapour lines were also fitted with ESD valves and manual valves at the tank dome and manifold. The 10 ESD valves all operated on the same hydraulic system, closing automatically under spring pressure when the hydraulic pressure was removed.

The sampling points used in this accident were situated beneath the manual globe valves on the discharge lines of the tanks **(Figure 4)**. To obtain a representative sample, the cargo was circulated from the tank using the deep well pump, via the discharge line, and back into the tank, via the loading line.

Figure 4



No 1 cargo discharge line

1.2.2 Liquefied petroleum gas

LPG comprises propane, butane and mixtures of the two. LPG is an important fuel that has a wide range of uses including power generation and other industrial purposes, such as metal cutting. LPG has been carried by sea since 1934, and significant quantities of LPG continue to be transported by sea.

Propane, the gas carried in this case, has a boiling point at atmospheric pressure of -42°C and a vapour pressure at 37.8°C of 12.9 bars absolute. This requires the gas to be either refrigerated, pressurised or a combination of the two, to allow its transportation as a liquid.

1.3 NARRATIVE

(All times are BST, UTC+1)

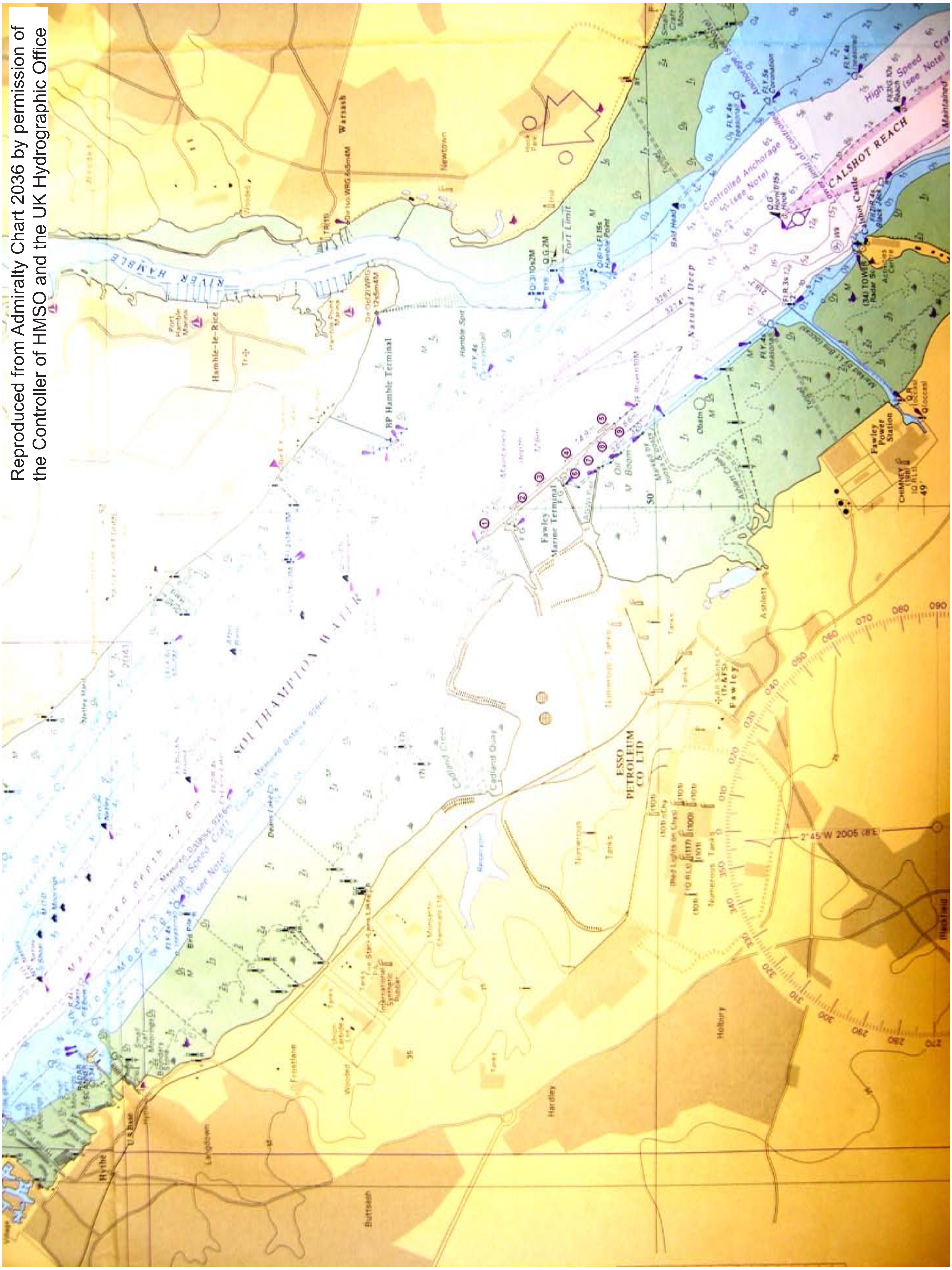
1.3.1 Events leading up to the cargo leak

The gas carrier *Ennerdale* arrived, for her first ever visit, at Fawley Marine Terminal (FMT) on 7 October 2006. She loaded with liquefied propane and sailed for Portugal, where she unloaded in Leixoes and Lisbon before returning to the UK in ballast. She arrived at FMT at 2300 on 15 October, mooring port side to on berth 2 **(Chart 1)**. The intention was to load one more cargo of liquefied propane, destined for Portugal, before the ship entered dry dock for a scheduled survey and repair period.

After completion of mooring, the terminal marine superintendent went aboard *Ennerdale* and the ship/shore safety checklist was completed. A cargo surveyor, from Intertek Caleb-Brett, also went onboard the vessel to complete a residual cargo calculation with the chief officer, because, as usual, vapour from the previous cargo was still onboard. After that, the chief officer opened the ESD valve system and aligned the manual valves to permit cargo loading. At 0006 on 16 October, liquefied propane began to flow into No. 1 and No. 2 cargo tanks.

At 1830 on 17 October, with roughly 2 hours of loading remaining, cargo operations were stopped and the manual manifold valve was closed. A cargo surveyor came aboard to conduct a freeze test, which checked the water content of the cargo. He was shown to the sampling point for No. 1 cargo tank **(Figure 4)**, by the chief officer. The cargo surveyor then attached his freeze test equipment to the end of the elbow piece of the sampling point. The chief officer opened the necessary valves and started the deep well pump to circulate the cargo for 2-3 minutes until the cargo surveyor indicated he was content. The chief officer and cargo surveyor then moved to No. 2 cargo tank, which had an identical sampling arrangement, and repeated the process, with no apparent problems. After the cargo surveyor had confirmed the freeze test had been successful, cargo loading resumed.

At 2100, the ship completed loading, having roughly 900 tonnes of liquefied propane in each tank. Both the liquid and vapour line manual manifold valves were closed, as well as the No. 1 and No. 2 manual loading valves. The cargo surveyor re-boarded the ship to obtain cargo samples and determine the cargo quantity onboard. He went straight to No.1 sampling point. The cargo surveyor could see the manual globe valve, to which the sampling point was attached, was screwed down and, therefore, shut. He also assumed that the ESD valve between the sampling point and the tank was closed. Happy that it was safe to continue, he found the appropriate screw adapter that would fit between the threaded elbow piece of the sampling arrangement and the sampling device **(Figures 5 and 6)**. He attached the sampling device and tightened the connection by hand. The chief officer meanwhile had opened the manual cargo loading valve and, once the cargo surveyor was ready, the deep well pump of No. 1 tank was started. The chief officer then cracked open the discharge line manual valve and continued to open this valve slowly to start the cargo circulating. The cargo surveyor opened the sampling valve and the two valves on either end of the sampling device. He flushed the sampling device by filling and venting it to atmosphere three times before filling it. He closed the ship's sampling valve and removed the sampling device. He fitted another sampling device and repeated the process, eventually taking four samples in total. The last sampling device was slightly



Fawley Marine Terminal

Figure 5

Sampling bomb

Figure 6

Thread adapter

different as this was to be used for a copper corrosion test. Once the ship's sampling valve had been closed for the last time, the chief officer closed the discharge valve and stopped the deep well pump. He moved to close the manual loading valve. The cargo surveyor removed his equipment and started to walk aft along the flying bridge to the sampling point for tank No. 2. The chief officer meanwhile noticed that some vapour was still emitting from the end of the sampling point, even though the capping plug had been inserted. He called the deck cadet to bring a wrench and tighten the plug. This did not stop the vapour, so the chief officer told the cadet to retrieve some PTFE tape from the cargo control room to wrap around the screw thread of the plug to make it gas tight. When the cadet had returned, the chief officer left him and headed aft as he was conscious that the cargo surveyor was already making preparations at the sampling point for No. 2 tank.

The cargo surveyor, happy again that the manual globe was closed and assuming the ESD valve was shut, reached down to grasp the sampling point with his right hand while holding a thread adapter in his left. Unlike No. 1 sampling point, he then had to rotate, by hand, the sampling valve towards him. The valve was rotated through no more than 90 degrees to enable him to attach the thread adapter. As the cargo surveyor rotated the valve, the valve and elbow piece came off in his hand, in one piece, and liquefied propane started to gush out of the threaded stud piece. The pressure in the line at the time was approximately 11 bar gauge.

1.3.2 Weather

The weather conditions at the time of the accident consisted of a light south easterly, 8 knot breeze, and it was overcast with occasional drizzle.

1.3.3 Emergency response

A little after 2140, the chief officer saw a cloud of vapour and could hear a loud hissing noise as he was walking aft on the flying bridge. He ran to the sampling point for No. 2 cargo tank and asked the cargo surveyor what had happened. In reply, the cargo surveyor held out the gas sampling valve and said that the valve had come off. The chief officer ran back to the midships position on the flying bridge and pressed the emergency shut down button **(Figure 7)** to activate an emergency shut down. The cargo surveyor attempted to refit the valve but was unsuccessful, dropping the valve on the deck in the vapour cloud in the process. The chief officer recovered the valve using his feet, as he could not see it, and then instructed his crew to get some rags as he intended to try and refit the valve himself. He believed now the ESD valve had been activated that it was only the pressure in the line causing the leak. The chief officer, using an equipment cover as a shield, tried to reconnect the valve but was forced back by the escaping gas.

The master of *Ennerdale* was on the bridge when he heard a hissing noise and then heard over the portable radios there had been a leak. He sounded the general alarm and made an announcement on the public address system that there had been a cargo leak. The crew mustered, and an emergency team formed up preparing hoses and donning protective equipment. At 2150, the master also started the ship's deck water spray system to dissipate the leaking gas.

The chief officer arranged for the gas sampling valve to be given to the chief engineer, so that the elbow piece could be removed from the bottom of the valve. Having removed the elbow piece and, with the sampling valve open, it was hoped it could be replaced more easily. One of the emergency team, wearing breathing apparatus and a chemical suit, tried to refit the valve once the elbow had been removed, but he was unable to do so as he found some ice had already accumulated on the threaded stud piece that projected from the underside of the globe valve. The sampling valve was handed back to another officer for safe keeping. It was now becoming increasingly obvious that the ESD valve was not holding and that No. 2 cargo tank was venting to atmosphere.

The master notified the ship managers of the incident at 2200. As the incident developed, the company formed up their emergency management team at their offices to support the emergency response.

Ashore, a member of FMT staff saw the incident unfold and raised the alarm. Cargo work was stopped, and at 2145 the emergency services and Southampton Vessel Traffic Services (VTS) were notified of the accident. As a precaution, VTS closed the port of Southampton at 2200. At 2220 Hampshire Fire and Rescue Service (HFRS) personnel arrived at FMT's jetty and took overall control of the accident site.

At 2225, in response to the incident, Southampton harbourmaster activated SOLFIRE 'B'. The marine response centre was set up at the VTS Centre at Southampton Docks. Representatives from the emergency services and FMT then reported to the marine response centre.

FMT shore monitors and further fire-fighting hoses were employed to increase the water spray on to *Ennerdale* and disperse the gas cloud **(Figure 8)**. One of the two tugs which were permanently based at FMT was also continuously employed spraying additional water.

Just before midnight, HFRS ordered the evacuation of all non essential personnel from the ships moored at FMT. The master, chief engineer and second engineer remained onboard *Ennerdale*.

Prior to the evacuation, the chief engineer and chief officer went to the cargo manifold and had started discharging overboard the cargo that was in the lines. The pressure in the lines was slowly reducing when the chief officer was evacuated ashore with all the other crew.

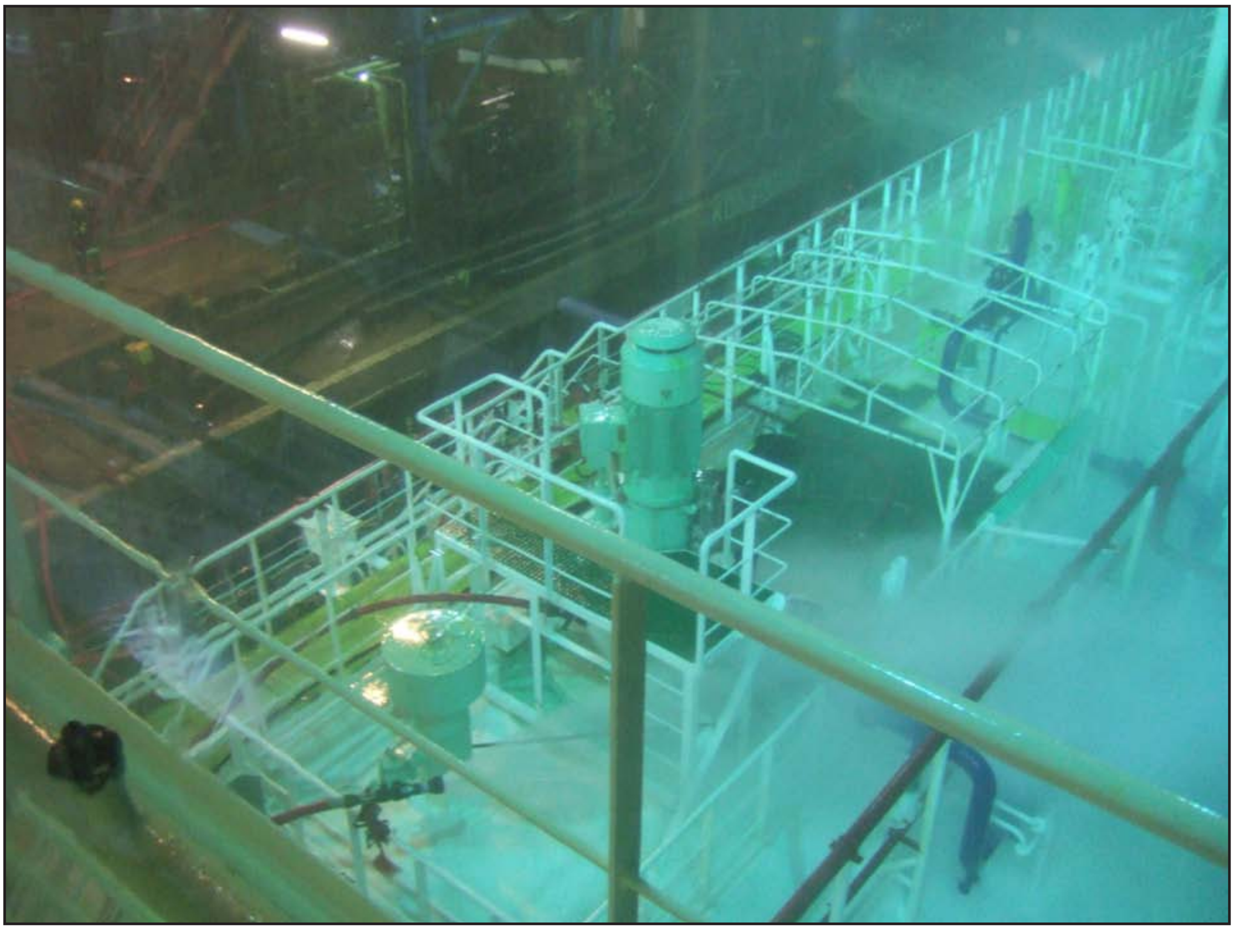
During the night, with consultation between HFRS, FMT, ship's staff and the ship managers, different plans were considered and steps taken. Attempts were made to refit the valve, but the ice ball which had formed prevented this. There was an attempt to jack shut the actuator valve stem to try and close the ESD valve, as well as manually opening and closing it to try and get the valve to seat.

Gas monitoring was regularly carried out by FMT staff. The water sprays were found to be fully effective in dissipating the leaking gas, and there was minimal danger of a flammable gas cloud forming. With the situation stabilised, at 0530 on 18 October the port of Southampton was reopened but with a 400m exclusion zone imposed around *Ennerdale*. Crews were permitted to return to their ships, and normal operations were resumed outside of the exclusion zone. A tanker moored at FMT No. 1 berth was the only other ship unable to resume normal operations.

Figure 7

ESD button on flying bridge

Figure 8



Water spray dispersion of LPG gas

1.3.4 Main options for securing the LPG leak

During the morning, the options for stopping the gas leak became clearer. Ship's staff suggested pumping No. 1 cargo tank ashore and then transferring the contents of No. 2 tank into No. 1 tank. It was estimated this would take 12 hours. However, FMT staff considered this to be an option of last resort because there was no spare storage ashore to receive the cargo. Also, FMT staff were confident they could cure the leak in less than 12 hours.

Ship's staff also suggested that a thick piece of wood could be jacked up under the globe valve to try and temporarily seal the leak. FMT considered this to be impractical, due to the size of the ice ball and because of the risk of further damage to the pipework. This repair would also have been of a very temporary nature and would not have enabled the ship to sail to a discharge port.

The next plan, for which adapters and connectors were already being constructed throughout the night, was to fit a sea water hose to the No. 2 tank drain sump and then inject sea water into the tank. It was hoped that the water would then be pushed through the deep well pump and out of the tank through the leaking orifice. With water flowing through the leak, the ice ball could then be removed, and it would be possible to fit an open ball valve on to the stud piece with water at 11 bar still flowing through. Once fitted, the ball valve could then be shut. This option was not particularly favoured due to the unpredictability of the water flow, ice formation within the pipework and potential contamination problems.

The last considered option was to hot-tap the pipework between the ESD and manual globe valve and then inject a compound into the pipework that would seal the leak. This work would be carried out by Furmanite, a sub contractor with whom Fawley refinery had a 24 hour call-out contract. Although Furmanite had been employed regularly on the Fawley refinery site, they had never been used to fix a live leak onboard a tanker such as was the case onboard *Ennerdale*.

At approximately 1000 on 18 October, the decision was made that the hot-tap injection method represented the best chance of sealing the leak. At 1340, preparations were complete and the contractors started to drill a hole into the flange of the globe valve. By 1425, the hot-tap was in place and they started injecting the sealing compound, which was delivered in 16 cc packets. It was initially estimated that 40-60 packets would be required. However, it was not until 93 packets had been inserted, at 0240 on 19 October, that the flow of cargo was sufficiently reduced to enable the ice ball to be removed and the leak capped. A new ½" ball valve, fitted with a thread adapter to screw on to the ⅜" stud piece, was fitted to close off the pipework **(Figure 9)**.

1.3.5 Post accident action

With *Ennerdale* gas tight, preparations were made to clear berth No. 2 at FMT. The manifold cargo hose was drained and the loading arm was disconnected. Tank quantities were measured and, from the ship's figures, it was estimated that 66 tonnes of propane had been lost during the leak.

The MCA gave permission for the ship to sail to the Saltmead anchorage in the Solent. *Ennerdale* left the FMT berth at 0905, and by 1030 was at anchor. Before she could leave the anchorage, the MCA stipulated the leak repair must be approved by class, the destination port must have agreed to receive the cargo, and the master must have had at least 6 hours rest.

Figure 9

No 2 sampling point repair

Once written confirmation had arrived that the cargo would be received in Lisbon, and having obtained a condition of class from NKK, *Ennerdale* weighed anchor at 1814. The master confirmed to the MCA he had managed 5 hours rest.

After some delays due to lack of tankage, *Ennerdale* unloaded her cargo in Lisbon before sailing for Vlissigen, Holland, for repairs.

1.4 CREW AND CARGO SURVEYOR

All of the crew onboard *Ennerdale* were Filipinos who were employed through a manning company which was a subsidiary of the management company.

The 51 year old master held a class II/2, with gas endorsement and had served as master on LPG carriers for 17 years. During this time, he had sailed on fully refrigerated and semi pressurised LPG tankers, but the majority of his time had been spent on fully pressurised gas carriers like *Ennerdale*. At the time of the accident, the master had served 5 months of his 6 month contract, his first onboard *Ennerdale*.

The 33 year old chief officer obtained class II/3 in 1995 and served five contracts as 3/O on LPG carriers. He then served a further four contracts as 2/O before obtaining his class II/2, with gas endorsement and being promoted to chief officer 9 months prior to the accident. *Ennerdale* was his second contract as chief officer, and he had been onboard for half his 6 month contract. Although it was his first time onboard *Ennerdale*, he had previously served on a sister vessel as 3/O.

The 41 year old chief engineer had held his class III/2, with gas endorsement since September 2004, and had served two contracts as a chief engineer, both on LPG carriers. He had begun his career as a seagoing engineer in 1994. For the last 8 years he had sailed only on LPG tankers, predominately semi pressurised. At the time of the accident, the chief engineer had been onboard *Ennerdale* for 5 months of his 6 month contract.

The 51 year old cargo surveyor had joined Intertek Caleb-Brett as a cargo surveyor in August 2006. He had undergone a company training programme since then to allow him to operate as a cargo sampler. Previously he had been in the Merchant Navy for 17 years, the last 5 years as a master on LPG carriers. He switched to a non maritime career in 1990, before his return as a cargo surveyor in August 2006.

1.5 CARGO SAMPLING

1.5.1 General

Sampling of cargo is required to verify the quality of the product that has been transported. It is carried out regularly on departure and arrival at tanker terminals. At FMT, Intertek Caleb-Brett was contracted to collect samples on behalf of the terminal and the cargo charterers, both ashore and onboard ships. Once collected, the samples were taken to the laboratory at Fawley refinery for analysis.

For a sample to be taken, it is necessary to breach the containment system of the cargo in a controlled and safe manner. In this case, an open-loop system of sampling was employed as a small release of LPG to the atmosphere was acceptable. For more hazardous products, a closed-loop sampling system is required such that any product released, that is not required as a sample, is returned to the tank.

1.5.2 Sampling arrangement on *Ennerdale*

The original design intent **(Annex A)** for the drawing of liquid samples from the tanks of *Ennerdale* was via the sump drain **(Figure 10)**, or by the use of the slip tubes **(Figure 11)**. Samples of cargo vapour could be taken from the sampling valve on the tank dome.

The sump drain was not a preferred sampling point as the bottom of the tank might well be contaminated, with water or previously carried cargoes.

The slip tubes were installed as a back up system if the tank level float gauge failed. They consisted of two graduated tubes which penetrated the cargo tank, one in the lower half of the tank, the other into the upper half. An ullage measure of the tank contents could be taken by raising the tube out of the tank; opening the slip tube vent, releasing gas, lowering the slip tube until liquid was seen emitting from the vent instead of gas; this indicated the liquid level in the tank. The graduations on the slip tube could then be read to provide the ullage reading. When used for sampling, the slip tube would be positioned such that liquid would emit from the vent into a sample container.

During the last 10 years, changes to industry best practice have effectively stopped the regular use of slip tubes for sampling. There were many hazards inherent with this practice, including the fact it was not a closed loop sampling system. There was reliance on one small vent valve between the tank contents and the atmosphere. There have also been accidents where slip tubes have been ejected from tank domes under pressure, leaving an opening into the tank that was difficult to seal.

Figure 10

Sump drain line

Figure 11

Slip tubes on tank dome

Onboard *Ennerdale,* with slip tubes no longer an option and the tank sump drain unable to provide a good representative cargo sample, another method of obtaining samples was needed. On the bottom of all the screw down globe valves in series with the ESD valves, was a drain cock. The simple solution was then to adopt the drain cocks of the manual globe valves on the discharge lines **(Figure 4)**, as open loop sampling points. The cargo could then be circulated using the deep well pumps to provide a good, representative, sample of the tank's contents.

1.5.3 Sampling valve assembly examination

Both sampling point assemblies were removed from the ship for detailed examination. A copy of the examination report is included at **(Annex B)**.

The drain point consisted of a flange, threaded stud piece, needle valve and elbow piece. A cap was also screwed into the end of the elbow piece when not in use. It was confirmed that all threads were compatible ⅜" BSP tapered threads. All threads were in good condition and showed no signs of damage. Fully tightened, the drain point should produce an adequate seal up to 18 bar gauge, the design limit for the cargo tank. However, no means of mechanically locking the threads was provided to prevent the assembly from unscrewing. It was also observed that there were several layers of paint on one of the valves, which would hamper seeing the depth of thread engagement.

1.5.4 Onboard sampling procedure

The company's gas carrier safety management system (SMS) manual included a section on cargo sampling **(Annex C)**. It required that a competent officer accompanied the cargo surveyor at all times. The danger of accidentally loosening the sampling connection was also highlighted and preventative measures detailed.

The crew was aware of the possibility of the sampling points unscrewing, and had tightened the assemblies in the past. Checks were made to ensure the sampling point fittings were tight as part of the shipboard procedures for securing for sea.

1.5.5 Cargo surveyor sampling procedure

The sampling process adhered to by Intertek Caleb-Brett cargo surveyors followed the Gas Ship Measurement Guidelines, which were developed in 1998/99 for Exxon Chemical Europe Inc. ASTM D1265-97 was the specific standard employed for sampling LPG. To ensure that cargo surveyors were able to take samples of the various cargoes safely, they were trained and supervised internally until signed off as fit to sample a specific type of cargo.

1.6 EMERGENCY SHUT DOWN VALVES

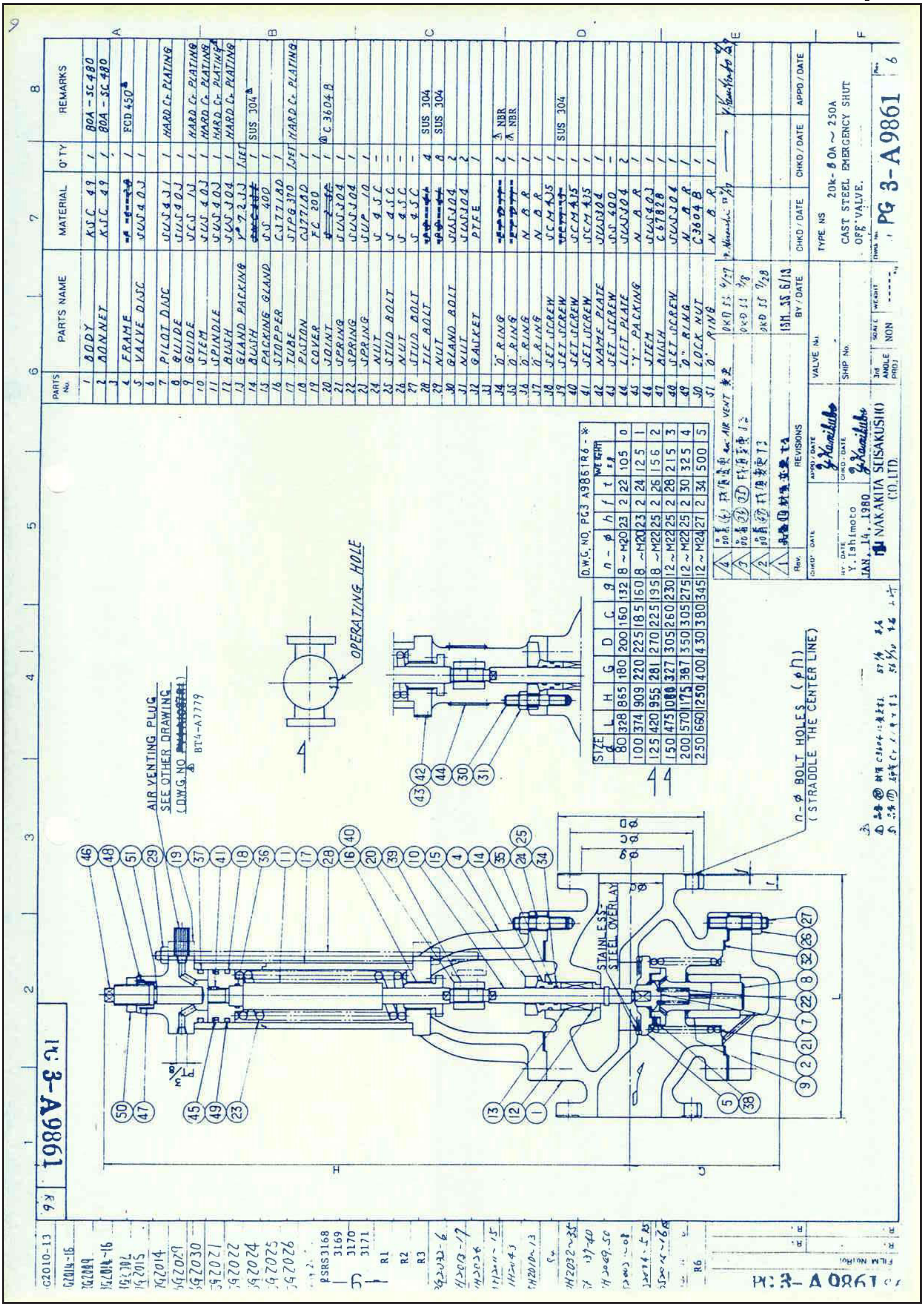
1.6.1 General

The ESD valve is intended to seal the cargo tank in an emergency. The IGC Code requires ESD valves to be capable of remote operation and that they close at a set steady rate to prevent damaging back pressure surges.

1.6.2 *Ennerdale* ESD valve description

A drawing of the ESD valves fitted to *Ennerdale* is included at **(Figure 12)**. As **(Figure 2)** indicates, there were 10 ESD valves on the cargo containment system, all of the same design, but three different sizes: 125mm nominal bore on the vapour lines; 150mm nominal bore on the loading and discharge lines; and 200mm nominal bore on the port and starboard liquid loading manifolds.

Figure 12



ESD valve drawing

A single hydraulic system supplied all 10 ESD valve actuators which, when the valves needed to be opened, pushed the valve spindles down into the valve body. In this design of valve, the spindle was not attached to the valve disc as it had first to contact with a pilot valve on the centre of the valve disc **(Figure 13)**. The pilot valve assembly allowed the initial pressure differential either side of the valve disc to be reduced. This enabled the valve disc to be opened with less force and, therefore, required a smaller hydraulic actuator.

Figure 13

ESD valve disc with pilot valve

When a shut down was carried out, the correct closure rate for the ESD valve was determined by the rate of relief of the hydraulic oil pressure and the force of the two springs in the system; one in the actuator, the other below the valve disc. The closure rate for the ESD valves was tested and logged by ship's crew regularly. Only a sample of ESD valves was timed on each occasion. Although the last logged ESD test on *Ennerdale* recorded 28 seconds on 12 October 2006, it is unclear which ESD valve was tested. This test and the previous ESD valve tests, all recorded acceptable closure times **(Annex D)**. The timing of the ESD closure was one of the items required in the terminal ship/shore safety checklists, as the terminal staff wanted to ensure their pipework systems were protected from any back pressure surge.

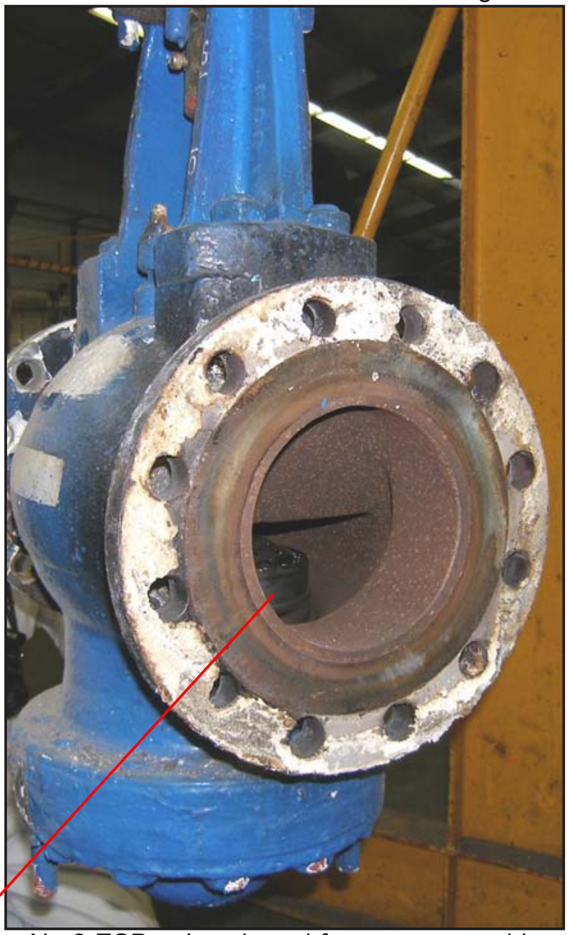
1.6.3 Valve manufacturer

The ESD valves on *Ennerdale* were manufactured by Nakakita Seisakusho Co Ltd. This type of valve has been in construction since 1979 and was still available in 2006. Over 800 ESD valves of this type and varying sizes have been produced. A basic 'Instruction Booklet' and 'Check and Maintenance Manual' **(Annex E)** were produced by the manufacturers for this type of valve, but no copies of these documents were found onboard *Ennerdale*.

1.6.4 Examination of the faulty ESD valve

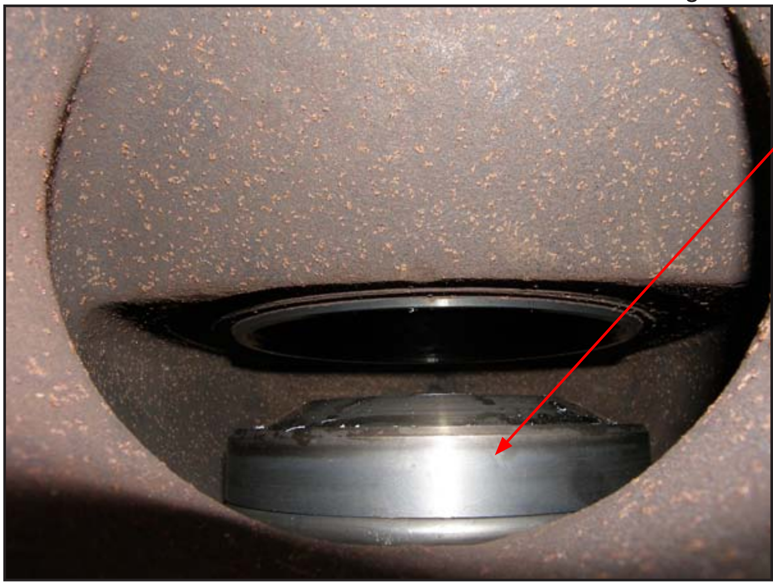
Once in dry dock, all the ESD valves onboard *Ennerdale* were removed and examined. No problems were found except with the ESD valve on the No. 2 discharge line. It was found to be jammed open, and obviously accounted for why the ESD valve had not contained the leak **(Figures 14 & 15)**. The bottom of the valve, which contained the valve disc and spring assembly, was removed **(Figure 16)**. It was discovered that a small burr in the valve guide was preventing the valve disc from rising, under the force of the spring, on to the valve seat **(Figures 17 & 18)**. The burr was adjacent to one of two tack welds that held the guide in position in the bottom of the valve body.

Figure 14



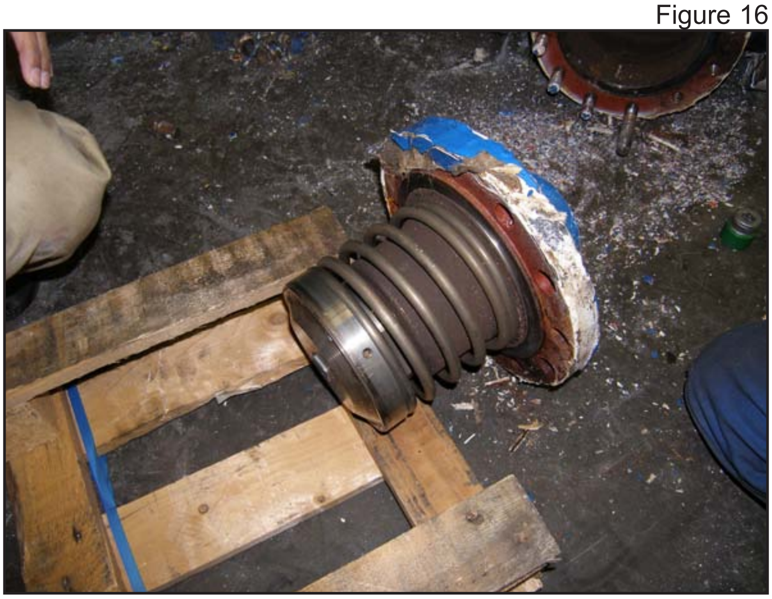
No 2 ESD valve viewed from pressure side

Figure 15



Inside No 2 ESD valve- seat at top and valve disc at bottom

Figure 16



Valve bottom assembly

Figure 17

Burr on valve guide

Figure 18

Scoring damage on valve disc body

1.7 IGC CODE

The purpose of the IGC Code is to provide an international standard for the safe transportation by sea of bulk liquefied gases and certain other substances. The 1993 edition of the IGC Code applied to gas carriers constructed after 1 October 1994, which included *Ennerdale*. A supplement to the IGC Code has been published since 1994, but this entered into force on 1 July 1998, after *Ennerdale* was constructed. The predecessor to the IGC Code was the Gas Carrier Code, whose requirements applied to vessels with build contracts placed after 1976, or delivered after 1980.

The IGC Code details numerous requirements including stability, ship arrangement, cargo containment, pressure piping systems and fire protection. Classification societies assess vessels against the requirements of the IGC Code and any additional class rules they may have for gas carriers.

The IGC Code has several specific requirements for ESD valves detailed in section 5.6: The following extracts applied to *Ennerdale*:

> *5.6.1 Every cargo piping system and cargo tank should be provided with the following valves, as applicable:*
>
> *...*
>
> *.2 For cargo tanks with a MARVS exceeding 0.7 bar gauge, all liquid and vapour connections, except safety relief valves and liquid level gauging devices, should be equipped with a manually operated stop valve and a remotely controlled emergency shut down valve. These valves should be located as close to the tank as practicable…*
>
> *5.6.4 The control system for all required emergency shut down valves should be so arranged that all such valves may be operated by single controls situated in at least two remote locations on the ship. One of these locations should be the control position required by 13.1.3 or cargo control room. The control system should also be provided with fusible elements designed to melt at temperatures between 98°C and 104°C which will cause the emergency shut down valves to close in the event of a fire. Locations for such fusible elements should include the tank domes and loading stations. Emergency shutdown valves should be of the fail-closed (closed on loss of power) type and be capable of local manual closing operation. Emergency shutdown valves in liquid piping should fully close under all service conditions with 30 s of actuation. Information about the closing time of the valves and their operating characteristics should be available on board and the closing times should be verifiable and reproducible. Such valves should close smoothly.*

The requirements for ESD valves under the Gas Carrier Code did not differ significantly from the above. These were the regulations that were applicable in 1979 when the Nakakita Seisakusho Co Ltd first manufactured the type of ESD valve fitted to *Ennerdale*.

1.8 IACS

The International Association of Classification Societies (IACS) also holds unified interpretations of the IGC Code, approved by IMO (International Maritime Organization), to ensure areas of ambiguity in the code are covered consistently by the various classification societies. At the time of the accident, there were no IACS interpretations relevant to ESD valve requirements or cargo sampling.

IACS also holds unified requirements (UR) which represent a minimum standard for IACS members to adopt into their rules. Of particular interest was the requirement found in UR Z16, ‘Periodic Surveys of Cargo Installations on ships carrying liquefied gas in bulk’, which states under the Special Survey requirements for Piping Systems:

> *2.3.1 The cargo, liquid nitrogen and process piping systems, including valves, actuators, compensators etc. are to be opened for examination as deemed necessary. Insulation is to be removed as deemed necessary to ascertain the condition of the pipes. If the visual examination raises doubt as to the integrity of the pipelines, a pressure test at 1,25 times the MARVS for the pipeline is to be carried out. After reassembly the complete piping systems are to be tested for leaks.*

1.9 INDUSTRY GUIDANCE

1.9.1 SIGTTO

The Society of International Gas Tanker and Terminal Operators (SIGTTO), was created in 1979 to promote high standards and industry best practice worldwide, to maintain confidence in the safety of the liquefied gas industries. In 1982, SIGTTO was granted observer status at IMO, recognising its position as an impartial expert organisation, advising on safety matters.

SIGTTO has produced many publications providing guidelines to the industry and it maintains a library of information on the organisation’s website. In 1989, SIGTTO published a report of a working group on liquefied gas sampling procedures (a copy is included at **Annex F**). The key recommendation made was that a standardized sampling connection fitting should be adopted. Further recommendations were made for consideration and application as operational circumstances permitted, these included: sample containers, closed loop sampling and sampling procedures. The following extract applied specifically to the sample arrangement:

> *Pipework or tubing up to the sampling connection should be robust enough to withstand marine service and up to 3.5 kg weight of an attached sample cylinder. The sampling connection should be isolated by two standard ball valves fitted at least one metre apart as a precaution against hydrate formation at the primary valve. The sampling connection locked so that it cannot be unscrewed by the normal action of making and breaking connections….*

With regard to sampling, there was also one HS&E bulletin, 07/2004, published by BSI, which highlighted the dangers of over filling sampling devices.

1.9.2 ICS

The International Chamber of Shipping (ICS) has published a tanker safety guide for liquefied gas carriers, which provided best practice guidance and included a section on cargo sampling, an extract of which is included below:

> *The responsible officer should be present when any cargo sampling is carried out. He should be fully conversant with all aspects of the ship’s sampling system including the operational characteristics of all valves. He should clearly recognise that the responsibility rests entirely with him for ensuring that sampling operations are conducted in a safe and efficient manner which will preclude any escape of cargo liquid or vapours to the atmosphere beyond that required by the sampling process, whoever is performing the actual sampling operation.*

The responsible officer should satisfy himself that the sampling equipment is compatible with the ship's sampling points before starting any sampling operations.

1.10 SHIP INSPECTIONS

1.10.1 Background

The tanker industry is exposed to scrutiny beyond classification surveys and flag administration inspections. Industry bodies conduct further inspections to provide a measure of vessel material and operational quality. Inspections are conducted by Chemical Distribution Industry (CDI), the Oil Companies International Marine Forum (OCIMF) and by the LPG terminals themselves.

1.10.2 Chemical Distribution Industry

CDI is a non profit-making foundation, one of whose main aims is to improve the safety and quality of marine transportation in the chemical industry. A key element of this is the inspection of ships.

The CDI ship inspection report (SIR) provides a quality assessment of a ship and its operation, including safety aspects. Potential charterers can then view the reports for a nominal fee. The inspections are conducted by qualified and approved independent inspectors and can take up to 12 hours to complete. The request for an inspection is initiated by a ship owner or manager, at least once a year. *Ennerdale*'s last CDI inspection was dated 21 July 06.

The SIR questionnaire is comprehensive, covering:

- regulatory aspects- highlighted as statutory,
- industrial best practice- highlighted as recommended
- CDI requirements- highlighted as desirable.

SIR questions 5.1.56- 5.1.58 dealt specifically with sampling. In particular 5.1.57 asked whether:

5.1.57 Means for the connection of sampling equipment appears to be satisfactory

The CDI inspector's guidance notes expanded on this, incorporating some of the SIGTTO recommendations at **(Annex F)**:

Pipework to be of robust construction to withstand up to 3.5 kg weight of a sample cylinder. The sampling connection isolated by two ball valves. There should be a clearance of at least 250mm around the stub piece connection to allow spanner access

This question was categorised as 'recommended', and was completed in the affirmative at the last *Ennerdale* CDI inspection.

1.10.3 OCIMF SIRE

OCIMF is a voluntary association of oil companies having an interest in the shipment and terminals of crude oil and oil products. The purpose of this organisation is to promote continuous improvement in standards of design and operation of oil tankers and terminals. In support of this, OCIMF also conducts a Ship Inspection Report Programme (SIRE). This programme was launched in 1993 to address concerns over poor quality shipping in the oil industry.

SIRE inspections, unlike CDI inspections, are initiated by potential charterers. Inspections are carried out by appointed inspectors and the questioning is extensive. The results of the inspections are available to OCIMF members and other organisations, for a nominal charge, to assist in their vetting of potential shipping. *Ennerdale*'s previous two SIRE inspections were dated 23 April and 12 October 2006. Neither highlighted any particular concerns.

Pertinent questions in the SIRE questionnaire relevant to gas carrier cargo sampling included:

> *8.39 Are sample lines provided for both liquid and vapour and are they valved and capped?*

There were no further guidance notes associated with this question.

1.10.4 Terminal inspection

A further element to the vetting system occurs when a ship arrives at a terminal, such as FMT. There is often an inspection by terminal staff to ensure the vessel operates to the standards expected. *Ennerdale* was inspected on her first arrival at FMT, and was found acceptable.

1.11 SIMILAR ACCIDENTS

Coral Acropora had a major release of vinyl chloride monomer on 10 August 2004 while alongside at Runcorn, UK. A full investigation was conducted and a report produced by the MAIB.

The gas leak was caused by over pressurizing the forward cargo tank while taking samples from the aft tank. The cargo was circulated to obtain a sample in a similar fashion to the method employed on *Ennerdale*. However, cargo valves had been, routinely, left open causing the cargo to be transferred into the other cargo tank rather than back into the aft tank. At the same time shore side workers had started work at the manifold without any supervision from ship's staff. Although the cargo required a closed loop sampling system to be employed, there was no means of taking closed loop samples from the aft tank of *Coral Acropora*. Recommendations were made to the terminal and ship operators. A recommendation was also made to SIGTTO and OCIMF to review the then current guidelines and recommendations concerning gas carrier checklists and procedures, with respect to sample operations requiring the use of cargo pumps. The procedures and checklists were reviewed and amendments were included in the fifth edition of the International Safety Guide for Oil Tankers and Terminals (ISGOTT), published in 2006.

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 THE ACCIDENT

The initial leak of LPG gas was caused by the cargo surveyor unscrewing the gas sampling valve, by roughly ¼ of a turn, while he aligned the connection with his equipment. The sampling valve fell off in the cargo surveyor's hand, breaching the cargo containment system and LPG was released to the atmosphere.

The sample point in use had been originally fitted as a drain cock for the manual globe valve. When other fixed methods of sampling on board became unacceptable industrial practice, the drain cock was used instead, as it provided an easy and effective means of taking cargo samples.

Although the emergency shut down system was activated, it failed to contain the leak as the ESD valve in the cargo discharge line, from which the sample was being taken, failed to close. The ESD valve was later found to be jammed open. How long this valve was in this state is unknown.

Due to the nature of the leak, the ship's crew were unable to secure the leak themselves and assistance from FMT was provided. The leak took 29 hours to seal.

2.3 FATIGUE

Fatigue is not considered to be a contributory factor in this accident. The chief officer was well rested, and the cargo surveyor had come on duty only 3 hours before taking his samples on *Ennerdale*.

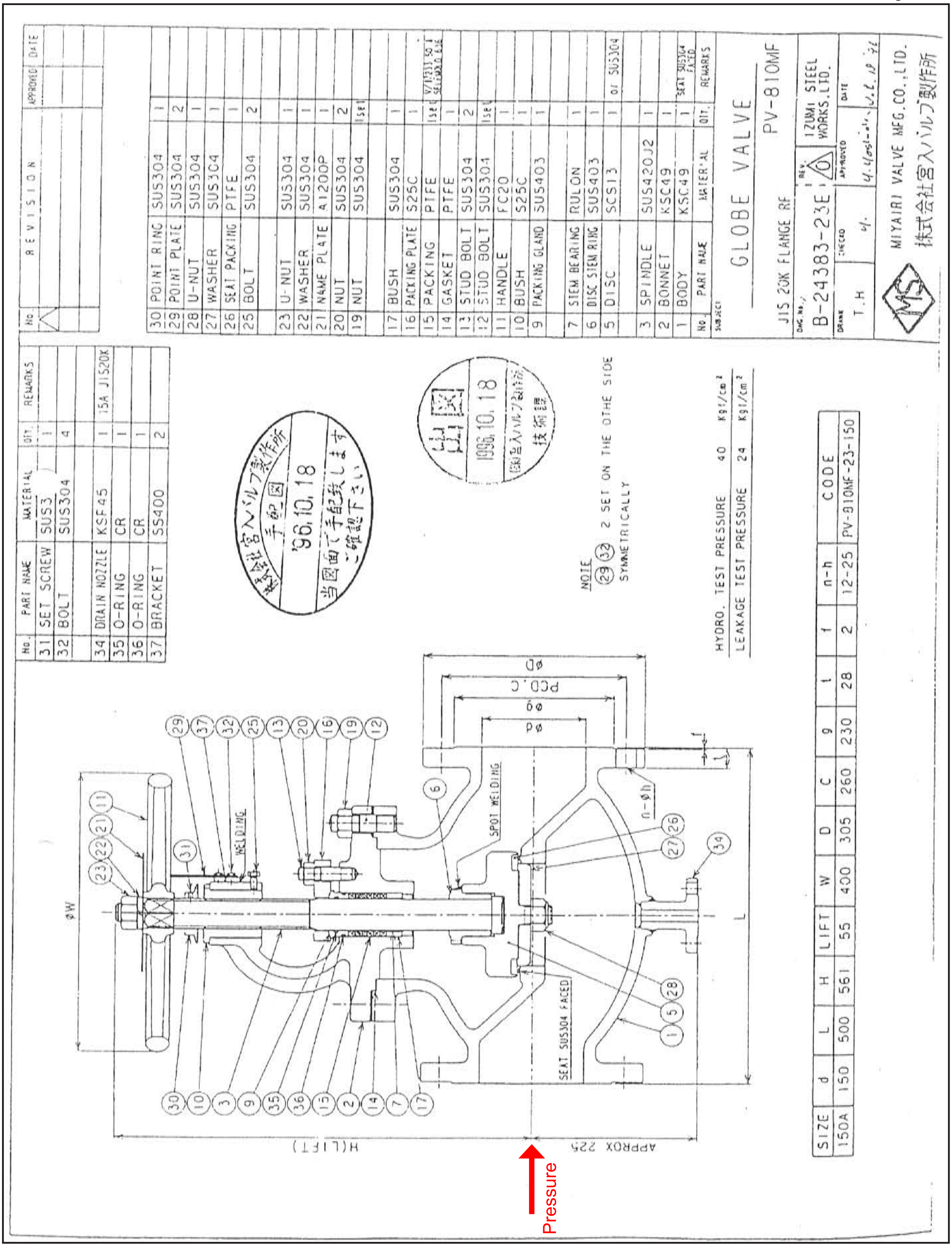
2.4 SAMPLING PROCEDURES

2.4.1 Relationship between ship's staff and cargo surveyor

Cargo surveyors, although frequently taking cargo samples, will not be familiar with the details of the numerous different cargo systems that they encounter. For this reason, cargo surveyors need to be closely supervised by a member of the ship's crew to ensure they are not endangering themselves or the ship.

In this accident, the cargo surveyor, who appeared to be conversant with the normal routine, was simply shown the sampling point by the chief officer and he set to work attaching the necessary thread adapter to connect the sampling device. Rather than having a useful exchange of information between the two men, both made assumptions about the state of the cargo system and what was going to happen. The cargo surveyor believed he had a greater degree of valve separation between himself and the cargo than he actually had. This was because he could see the manual globe valve was shut, the sample cock was closed, and he believed the ESD valve was also shut. In reality, the sample point was on the pressure side of the valve **(Figure 19)**, and the ESD valve was open, meaning the only barrier between him and the cargo was the small needle valve on the sampling cock. The chief officer meanwhile was content for the cargo surveyor to attach the sampling equipment in this valve state, as it was normal practice.

Figure 19



Manual globe valve drawing

With no problems encountered with taking samples from No. 1 tank, the cargo surveyor moved aft to No. 2 tank. The chief officer was then not supervising the cargo surveyor as he was securing No. 1 tank. The cargo surveyor believed, as before, he was safe to connect his sampling equipment and, since he had no instructions to the contrary, continued to do so. However, in the case of No. 2 sampling point he needed to turn the elbow piece towards him to allow the sampling device to be connected. The cargo surveyor made his final flawed assumption that it would be safe to turn the sampling point towards him. The chief officer was not present at that time.

The manner in which samples were taken onboard *Ennerdale* was very casual and demonstrated a level of complacency often shown in routine operations such as this. Taking samples of the cargo required the cargo containment system to be breached in a controlled and safe manner. Both the cargo surveyor and chief officer appear to have overlooked the inherent dangers of the sampling arrangement. The cargo surveyor was not provided with adequate instructions or a briefing, and the chief officer assumed that the cargo surveyor knew what he was doing, a potentially dangerous assumption when a stranger is onboard.

2.4.2 Guidance provided

The section on cargo sampling in the ship's SMS manual, **Annex C**, highlights the need for cargo surveyors to always be accompanied, while onboard. The ICS Tanker Safety Guide - Liquefied Gas is more succinct and provides further guidance on cargo sampling. Section 4.18 states:

> *The responsible officer should be present when any cargo sampling is carried out. He should be fully conversant with all aspects of the ship's sampling system including the operational characteristics of all valves. He should clearly recognise that the responsibility rests entirely with him for ensuring that sampling operations are conducted in a safe and efficient manner which will preclude any escape of cargo liquid or vapours to the atmosphere beyond that required by the sampling process, whoever is performing the actual sampling operation.*
>
> *The responsible officer should satisfy himself that the sampling equipment is compatible with the ship's sampling points before starting any sampling operations.*

The cargo surveyor was not supervised closely in this case. However, it is by no means certain if the chief officer had been present at No. 2 sampling point whether he would have stopped the cargo surveyor from turning the sampling point, as there was evidence that these fittings had been tightened in the past. This practice was in contravention of the ship's SMS manual which highlighted the hazard of accidentally loosening the sampling connection. In order to prevent this, the manual requires temporary securing of the fitting using *'a length of rubber gasket and seizing wire'*. As shown in the preceding paragraphs, although there was some information on sampling procedures provided to ship's staff, it was by no means comprehensive and it was open to interpretation. Clearer guidance is required to ensure ship crews are aware of the proper steps to be taken when obtaining LPG cargo samples. Cargo surveyors must also be briefed to clarify what they should and should not do.

Cargo surveyors must also be provided with better guidance on ship specific safety aspects of taking cargo samples. The guidance and ASTM standard provided by Intertek Caleb-Brett are generic in nature and more concerned with obtaining a good sample. Clear instructions need to be provided to the cargo surveyors to ensure they are not conducting sampling operations based on their own assumptions.

2.5 PHYSICAL SAMPLING ARRANGEMENTS

2.5.1 Design

The means of taking cargo samples onboard *Ennerdale* had evolved during the vessel's life, prior to operating under the current managers. Of the three means of taking liquid samples, the drain point on the manual globe valve on the discharge line appeared the safest and simplest for taking a good representative cargo sample. However, the drain point was never intended as a regular sampling point. It was only present to provide a means of draining the section of pipework between the globe valve and the ESD valve. There was no record of when the drain cock became the 'normal' method of drawing samples, nor whether any risk assessment was carried out in support of the change by the previous managers of the vessel. The SMS now in place includes instructions on the management of change, which would have highlighted the alteration of the means of cargo sampling.

No drawings for the actual drain point were found, suggesting the drain points on the manual globe valves were a shipyard supplied item. This may account for the non metric standard of the fittings. As a drain point, the valve arrangement was adequate to withstand the design pressure, as long as the component pieces remained screwed together. The lack of a securing arrangement left the assembly liable to become unscrewed through vibration or human error.

Since the accident, FMT staff and the Intertek Caleb Brett cargo surveyors have studied the sampling points in use by the various ships visiting FMT. No examples of sampling from the drain cock of globe valves, as on *Ennerdale* have been found. This might indicate this arrangement was relatively unusual, although the ship's crew did not believe there was anything particularly strange about the sampling arrangement on their vessel.

2.5.2 Regulatory requirements

Chapter 5 of the IGC Code *'Process pressure vessels and liquid, vapour and pressure piping'*, contains the following two pertinent extracts:

> *5.2.1.6 All pipelines or components which may be isolated in a liquid-full condition should be provided with relief valves.*
>
> *5.4.2 The following direct connection of pipe lengths, without flanges, may be considered:*
>
> *...*
>
> *.3 Screwed couplings acceptable to the Administration should only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less*

These regulations account for the requirement for drain valves to be fitted on the manual globe valves, and also why screw connections were permitted, since the drain point assembly was less than 25 mm external diameter. The IGC Code contains no explicit requirements for cargo sampling.

NKK, the classification society responsible for assessing *Ennerdale* against the IGC Code and their own classification rules was content that the drain point arrangement was satisfactory. NKK did not examine or approve the sampling arrangement in isolation. However, other classification societies do not permit screw thread joints when piping systems convey toxic or flammable substances.

With no clear regulatory requirement for sampling arrangements, there is the opportunity for a wide range of differing standards to emerge, some potentially as dangerous as that fitted to *Ennerdale*. The IACS unified interpretations provide a mechanism for applying a consistent standard. However, sampling is not currently one of the areas covered under the interpretations.

It might be suggested that a higher standard of sampling points is unnecessary, since two valve separation was present in the form of the sampling valve and the ESD valve. Also, it could be argued that it was unreasonable to expect the failure of the ESD to be foreseen. However, even if the ESD valve had functioned correctly and shut off the cargo, a significant quantity of cargo from the cargo lines would still have been released. Depending on the cargo carried, serious injuries might still have resulted.

2.5.3 Industry best practice

In addition to regulation, there is a significant amount of guidance available to the oil, gas and chemical industries. Unfortunately, sampling is not an area that is covered in great depth and, in many ways, appears to have been overlooked. The key exception to this was the SIGTTO working group report on liquefied gas sampling procedures **(Annex F)**, which made several recommendations including sampling arrangements. This recommendation was included in the CDI inspection questionnaire but, in the case of *Ennerdale,* the arrangement fitted was marked as satisfactory at the last CDI inspection even though it in no way met the SIGTTO recommendations. The sampling arrangement was not noticed as being hazardous during any of the inspections to which the ship was subjected.

It is unclear how far the recommendations made by the SIGTTO working group have been adopted by the industry but, considering it was published in 1989, it may be prudent to revisit the advice on sampling arrangements for LPG and amend CDI and SIRE inspections accordingly. Indeed, given the apparent lack of information on sampling, the industry could benefit from further general guidance to ensure unsafe practices are avoided.

2.6 EMERGENCY SHUT DOWN VALVES

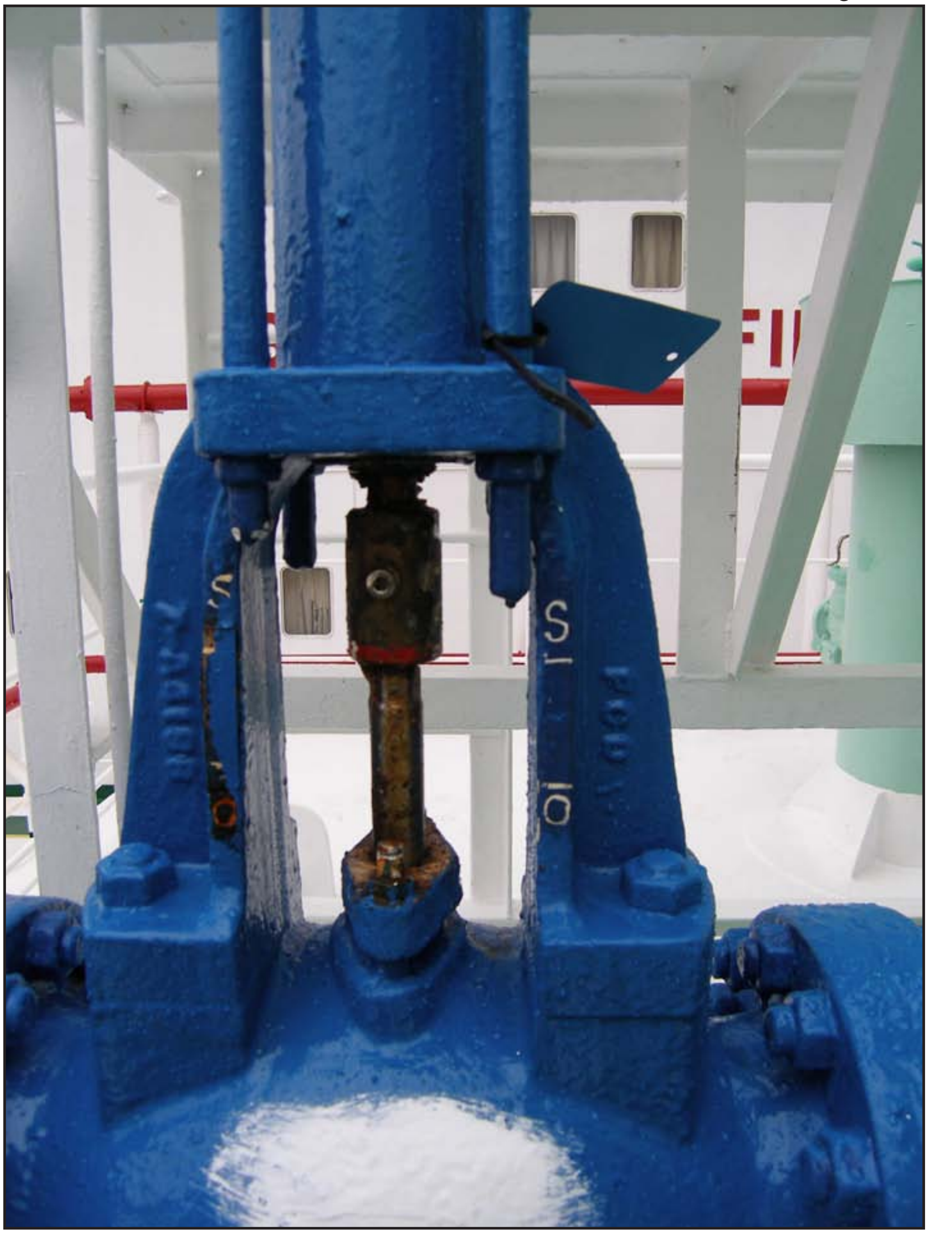
2.6.1 Design

One of the fundamental requirements from the IGC Code for ESD valves is that they fail closed. Therefore, the force applied to open the valve must act against an opposing force, which, if power is lost, closes the valve. The JIS 20 K ESD valves fitted to *Ennerdale* employ a spring to force the valve disc against the valve seat. Once closed, the pressure in the line will also force the valve disc on to its seat. The second important requirement is that the valve does not close too quickly. The JIS 20 K achieves this by another spring in the hydraulic actuator assembly, which controls the rate at which the valve spindle retreats once the hydraulic pressure is removed. The JIS 20 K would, therefore, appear to meet these two requirements of the IGC Code.

However, what became clear during MAIB's investigation was that the operators, and many assessors, did not realise that the JIS 20 K ESD valve design does not provide a positive indication of the valve's position. The joint between the actuator spindle and the valve stem was used as an indicator of whether the valve was open or shut **(Figure 20)**. The fact that this indication method could only positively show when the valve was open, not shut, was overlooked. This fundamental omission in the design of the JIS 20 K compromised the ability of this valve to act as an ESD valve, since no confidence could ever be placed in the valve being shut under the current testing regime.

The IGC Code does not require ESD valves to have positive indication of the valve position. It does, however, require the valve to be capable of local manual closure. The JIS 20 K ESD valve was approved by class at build as meeting ESD requirements **(Annex A)**. It is assumed local manual closure of the valve was interpreted on the basis that the hydraulic pressure could be removed locally by disconnecting the hydraulic pipe to the actuator. The stem on top of the valve can be screwed down using a wrench, but this could only be used to push the valve open, not closed. A consistent interpretation of the IGC Code requirements for ESD valves is required to ensure there is no ambiguity about the need for the valve position to be indicated, or the ability to manually close the valve.

Figure 20



ESD valve position indicator

2.6.2 Testing and maintenance

A sample of the ESD valves onboard *Ennerdale*, was regularly tested before loading and unloading cargo to ensure the closure rate was satisfactory. Unfortunately, this test was only providing a definitive measure of how long it took for the hydraulic actuator to move from the open to the closed position. The lack of a full appreciation of the design of the ESD valve led to a false belief that these valves were functioning correctly.

Testing of sections of cargo lines was carried out by pressurising the system with the ship's compressors and then monitoring if the pressure was held. This testing could be extended to most of the ESD valves, simply by opening the manual valve ahead of the ESD valve. The ship's log appears to record such a test on the tank loading line ESD valves, which occurred on 18 August 2006 **(Annex D)**. Pressure tests were also recorded as having been conducted on the cargo manifold valves on 31 July 2006 and twice in August 2006. Whether these tests included testing the ESD valves, is unclear from the log. There was also no specified requirement to conduct ESD pressure testing in either the ship's SMS or planned maintenance system (PMS).

However, the two ESD valves on the discharge lines have a non-return valve in the line, which prevents testing by merely pressurising the cargo lines. One possible approach to testing these ESD valves would be when the tanks contain cargo, since pressurising the tanks when they were full of vapour, using the ship's compressors, would be unfeasible. Alternatively, the ESD valve could actually be operated while unloading cargo, to check it works correctly. Both these methods of testing require cargo to be either onboard or unloading, which, unfortunately, means if a valve problem is discovered the cargo has still to be unloaded before anything can be done to rectify the situation.

The instruction manual produced by the manufacturers provided some information on installing, servicing and reassembly of the ESD valves. The check and maintenance manual, however, included a brief list of checks and their suggested intervals, as well as a 'trouble shooting' guide **(Annex E)**. Although basic check points for overhauling the valve were provided, there was no suggested periodicity. Also, in light of the fact there was no positive valve indication, the manual did not suggest how often, and by what means, the valve should be tested in service to ensure it functioned correctly.

The IGC Code is primarily a design standard, however, section 18 does detail some operating requirements, in particular:

> *18.7 Systems and controls*
>
> *Cargo emergency shutdown and alarm systems involved in cargo transfer should be tested and checked before cargo handling operations begin. Essential cargo handling controls should also be tested and checked prior to transfer operations.*

The testing of the closure rates of the ESD valves is one example of applying this requirement. However, given the critical safety nature of the function of ESD valves, there appears to be no clear regulatory requirement for the periodic pressure testing and internal inspection of ESD valves. As shown in section 1.8, any internal inspection of ESO valves at periodic surveys is entirely at the discretion of the attending surveyor.

How long the ESD valve on No. 2 discharge line had been jammed open was impossible to determine. The burr was either present when the valve was constructed, or it had been caused by contamination from cargo that had been carried in the past. NNK could find no record of the ESD valves on *Ennerdale* ever being tested, internally inspected or overhauled.

The lack of a requirement to regularly internally inspect and/or pressure test ESD valves is of concern, since the ESD valve is a fundamental part of the vessel's safety system. The different classification societies might have individual requirements for inspection or testing at periodic intervals, but there is no consistent approach.

To ensure ESD valves fulfil the role for which they are intended, they must be regularly tested, at two levels. Firstly, ship operators must ensure that the ESD valves onboard their vessels function correctly, and industry guidance should be reviewed and amended to include this requirement. Secondly, classification societies should include a periodic requirement for pressure testing and/or internal inspection of ESD valves, as part of the verification that the cargo containment system is fit for purpose. In this manner, full confidence can be maintained in the ESD system.

2.7 ACTIONS FOLLOWING THE LEAK

The alarm was raised very quickly after the leak occurred, and emergency plans were put into action swiftly. The general alarm was sounded and an emergency team mustered, to tackle the cargo leak. Although the master of *Ennerdale* did not actually employ the check-off list in the SMS Emergency Procedures Manual, all the necessary basic actions were carried out, demonstrating the benefit of crew drills. The water sprays and additional hoses were used to good effect to disperse the leaking gas and prevent the creation of a flammable gas cloud.

The scenario of the ESD valve failing to close had not been considered by ship's staff nor included in the ship's SMS. Once it became clear that the leak could not be contained and was beyond the capability of the ship's crew, the management of the incident became slightly confused. The ship's crew was unsure who was actually in charge. The ship management company ICSM Pte Ltd was liaising with IMT Ltd and with FMT, who worked closely with the local emergency services. ICSM Pte Ltd was also in contact with the ship. Decisions then appeared to be hampered by the need for the ship to continuously consult with the ship managers.

FMT is a technologically advanced terminal compared with many around the world, and had a lot of expertise and experience to contribute to the problem of securing the leak on *Ennerdale*. During the management of the incident, ship's staff felt they were not fully integrated in the decision making process. At the same time, FMT staff believed they were not receiving full co-operation from ship's staff.

It will rarely be possible to drill or simulate a real emergency such as the LPG leak onboard *Ennerdale* and, in reality, difficulties in liaison between different authorities might occur. Establishing clear lines of authority, and providing basic information on what will happen in an emergency will ensure an emergency is tackled effectively. However, ultimately, the outcome of the emergency response was a success, and the difficulties in communications are unlikely to have delayed the securing of the leak to any significant degree.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT WHICH HAVE RESULTED IN RECOMMENDATIONS

1. The ESD valve on the discharge line of No. 2 cargo tank was jammed open, compromising the ship's emergency cargo shut down system. [2.2]

2. The IGC code permits unsecured screw fittings. [2.5.2]

3. There was no clear regulatory requirement for sampling arrangements. [2.5.2]

4. No concerns about the sampling point arrangement had been raised during any of the numerous recent ship surveys by class and other inspection authorities. [2.5.3]

5. There is a general lack of guidance on cargo sampling in the industry. [2.5.3]

6. The definition of *'local manual closing'* would appear to need clarification given the ESD valves onboard *Ennerdale* were approved by class. [2.6.2]

7. There was no clear regulatory requirement or industry requirement for ESD valves to be regularly pressure tested or inspected to ensure the valve was functioning correctly. [2.6.2]

3.2 SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION WHICH HAVE NOT RESULTED IN RECOMMENDATIONS BUT HAVE BEEN ADDRESSED (SEE SECTION 4)

1. The sampling valve was able to be unscrewed by hand and came apart after roughly a quarter of a turn. [2.2]

2. The briefing and supervision of the cargo surveyor did not provide an adequate means for ensuring cargo sampling could take place safely. [2.4.1]

3. The cargo surveyor was attaching his equipment assuming he had at least two valve separation from the cargo pressure, which was incorrect. [2.4.1]

4. The screw fitting of the sampling point was not secured as required in the ship's SMS, and the fact that it had become unscrewed went unnoticed. [2.4.2]

5. The use of the globe valve drain as a regular sampling point had evolved and the dangers of this practice had not been fully appreciated. [2.5.1]

6. The operators and many assessors did not realise that the JIS 20 K ESD valve design does not provide a positive indication of the valve's position. [2.6.1]

7. Although cargo lines and some valves were pressure tested, the ESD valves on the discharge line were not tested to ensure they were closing. [2.6.2]

8. Liaison between ship's staff and the marine terminal were not ideal, but the difficulties in communications are unlikely to have delayed the securing of the leak to any significant degree. [2.7]

SECTION 4 – ACTION TAKEN

4.1 ICSM PTE LTD

The ship managers, ICSM Pte Ltd, conducted their own investigation after the accident and have taken steps to prevent a reoccurrence.

Onboard *Ennerdale* the following modifications have taken place:

- The manual globe valve drain cocks on *Ennerdale* have been replaced with flanged ball valves to prevent them from being unscrewed, and the drain cocks will no longer be used for cargo sampling.
- A dedicated closed loop sampling system has been fitted, in position, after the NRV on the discharge line, with two valves between the cargo line and the sampling point **(Figure 21)**.

Figure 21

Modified No. 2 sampling point

- Ship procedures have been amended to ensure the ESD valves, including those in the discharge line, are pressure tested monthly.
- The ESD valves will also be removed, pressure tested, and overhauled where required at every dry dock period.

A company Safety Bulletin has also been issued which contains:

- Re-emphasis that ship's staff are responsible for the safety of cargo operations and, where shore contractors need to be involved, they must be closely supervised.
- Instructions to vessels to check sampling connections and secure any screw fittings, pending permanent design modifications.

- Instructions to all gas carriers in the fleet to put in place an in service ESD valve testing regime.
- A requirement to conduct a risk assessment on cargo systems to ensure single valve failure does not jeopardise the gas tight integrity of the system.
- Suggested amendments to drill scenarios to ensure coordination with shore based emergency response has been included.

4.2 INTERTEK CALEB-BRETT

Intertek Caleb-Brett at FMT has instructed its staff to:

- Employ ship's staff to connect the sampling equipment with the cargo surveyor in attendance.
- Wear a chemical suit when sampling gases.

4.3 SIGTTO

SIGTTO has:

- Published a safety alert on the inherent weaknesses of the type of ESD valve identified in this accident, highlighting the need to check their operational integrity.
- Reminded its members of the guidance already available from SIGTTO for LPG sampling.
- Presented and discussed the lessons learnt from this accident at regional meetings.
- Commenced development of LPG Training Guidelines, which are scheduled to be complete in 2008. Knowledge of correct LPG sampling procedures will be included in the underpinning knowledge section.

4.4 OCIMF

OCIMF has:

- Initiated the process to amend the wording in SIRE Vessel Particulars Questionnaire Section 8 for gas carriers to observe recommendations contained in SIGTTO's "Report of a Working Group on Liquefied Gas Sampling Procedures" at its next revision.
- An information notice has been issued to the SIRE inspection group regarding this incident and the details will be discussed at the forthcoming SIRE inspection group meetings.

SECTION 5 - RECOMMENDATIONS

SIGTTO, OCIMF and **CDI** are recommended to:

2007/149 Review and revise guidance provided to the industry on sampling arrangements, taking due account of any standard required by classification societies

Lloyd's Register is recommended to:

2007/150 Take forward a proposal to IACS on the development of unified requirements (URs) on sampling arrangements for liquefied gas carriers. The standards should, as a minimum, address the relevant shortfalls identified in this investigation, especially with regard to the provision of two valve separation from the cargo system and the avoidance of screw couplings.

2007/151 Take forward a proposal to IACS regarding the operation and design of ESD valves which:

- Stipulates a requirement for ESD valves to be tested and inspected during class surveys to verify effective closure.
- Ensures that the IGC Code requirement for local manual closure means the ESD valve can be positively closed by hand.
- Requires arrangements for the indication of the status of ESD valves to accurately mimic whether the valve is open or closed.

Marine Accident Investigation Branch
May 2007

Safety recommendations shall in no case create a presumption of blame or liability