Report of Investigation
into the Sinking of
M.V. Hui Long
on 20 May 2005

The Hong Kong Special Administrative Region
Marine Department
Marine Accident Investigation Section
Preliminary Inquiry No. 2 of 2005

In accordance with Section 51 (1) of the Merchant Shipping Ordinance (Chapter 281), on 24 May 2005, the Director of Marine appointed Mr. LI Yiu-kwong, Acting Senior Surveyor of Ships to carry out a Preliminary Inquiry into the circumstances attending the casualty.
Purpose of Investigation

This incident is investigated, and published in accordance with the IMO Code for the Investigation of Marine Casualties and Incidents promulgated under IMO Assembly Resolution A.849(20). The purpose of this investigation conducted by the Marine Accident Investigation and Shipping Security Policy Branch (MAISSPB) of Marine Department is to determine the circumstances and the causes of the incident with the aim of improving the safety of life at sea and avoiding similar incidents in future.

The conclusions drawn in this report aim to identify the different factors contributing to the incident. They are not intended to apportion blame or liability towards any particular organization or individual except so far as necessary to achieve the said purpose.

The MAISSPB has no involvement in any prosecution or disciplinary action that may be taken by the Marine Department or others resulting from this accident.
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1. **Summary**

1.1 On 18 May 2005, the Hong Kong registered ship ‘*Hui Long*’ (the Vessel) was sailing from Sungei Pakning of Indonesia to India. The vessel was loaded with 11,245 tonnes of mixed general cargoes including 5,185 tonnes of fluorspar mineral in bulk. At around 1535 ship’s time (UTC+5), whilst the Vessel was 173 nautical miles from Sri Lanka, position at 5° 55.5’N 84° 20.7’E, the ship suddenly developed a list of 15 degrees to port. The list continued to be worsening and the Master abandoned the Vessel at 1602 after the port weather deck has been immersed into water at a list of 40 degrees. All 23 crew were rescued by a passing container vessel ‘*P&O Nedlloyd Asia*’. A salvage tug was called in the following day trying to rescue the vessel without success and the Vessel finally sank on 20 May 2005.
2. **Description of the Vessel**

2.1 M.V. *Hui Long* (Fig. 1)

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMO No.</td>
<td>9037032</td>
</tr>
<tr>
<td>Call Sign</td>
<td>9HDT6</td>
</tr>
<tr>
<td>Type</td>
<td>General Cargo</td>
</tr>
<tr>
<td>Length</td>
<td>158.0 m</td>
</tr>
<tr>
<td>Breadth</td>
<td>22.8 m</td>
</tr>
<tr>
<td>Gross Tonnage:</td>
<td>12,233</td>
</tr>
<tr>
<td>Deadweight</td>
<td>16,113</td>
</tr>
<tr>
<td>Engine Power</td>
<td>13,092 kW</td>
</tr>
<tr>
<td>Year of Built</td>
<td>1999</td>
</tr>
<tr>
<td>Classification Society</td>
<td>Germanischer Lloyds</td>
</tr>
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</table>

2.2 *Hui Long* was a general cargo carrier with four cargo holds. The Vessel was fitted with cranes and tween decks at No. 2, 3 and 4 holds. At the time of the accident, the Vessel was carrying mixed general cargoes including 5,000 tonnes of fluorspar in bulk in No. 3 lower and No. 1 holds. The survey record from its classification society indicated that the vessel had no major structural problem before the accident.

Fig. 1 M.V. *Hui Long*
3. **Sources of Evidences**

3.1 Statement provided by the Master of the Vessel;

3.2 Statement provided by the Chief Officer of the Vessel;

3.3 The ship’s management company – Tianjin Centrans Ship Management Co. Ltd;

3.4 The ship's file provided by the Hong Kong Shipping Registry;

3.5 SGS verification, testing and certification company, as the cargo survey agent in Hong Kong

3.6 Tak Hing Enterprises Development Ltd. as the shipper of the fluorspar cargo

3.7 Minton, Treharne & Davies Group, consulting scientists analytical and test laboratory in the United Kingdom
Outline of Events

4.1 The loading voyage (Appendix 1) commenced on 22 April 2005 at Huangpu, China. ‘Hui Long’ (the Vessel) arrived Hong Kong on 1 May 2005 after loading in Huangpu. The Vessel would be loaded with a cargo of acid grade fluorspar in bulk to ship’s No. 3 lower and No. 1 holds in Hong Kong. Loading was carried out by grabs from the barges that were moored alongside the Vessel. On completion of loading, a pile of about 4 metres height of bulk fluorspar was stowed inside the No. 3 lower hold. There was no trimming of cargo after loading. The vessel sailed to Singapore on the next day.

4.2 According to the weather report there had been slight showers on the day of loading. The crew stated that showers did not impair the loading of the cargo. After loading, a cargo survey firm took cargo sample from the two holds and a Certificate of Moisture Content was issued to the Vessel (Appendix 2). The Certificate indicated that the moisture content of the fluorspar cargo was at 9.8%. The Certificate has not provided the details of the Transportable Moisture Limit (TML) of the fluorspar.

4.3 The voyage from Hong Kong to Singapore was uneventful. It arrived at Singapore on 7 May 2005 for unloading a cargo of aluminum ingot and steel angle bar. According to the ship’s officers that there had been intermittent rain showers during the cargo operation. The crew would close the No. 2, 3 & 4 hatch covers when raining.

4.4 The Vessel departed from Singapore on 11 May 2005 for Sei Pakning in Indonesia for loading wood pulp. During loading, it was reported that there had been occasional rain showers and the ship’s crew had to close the No. 2, 3 & 4 hatch covers during rain, as the wood pulp cargo is susceptible to rainwater.

4.5 On completion of cargo loading on 14 May 2005, the Vessel departed from Sei Pakning for India loaded with total deadweight of 11,244 tonnes, as shown in fig. 2. Draft on departure was at 7.6 metres forward and 9.8 metres aft. The maximum loading capacity at summer draft of the vessel was at 9.934 metres. The stability on departure was adequate with a rolling period of about 13 seconds. The Vessel was upright and in normal working condition on its departure.
During the passage in the Malacca Strait and west of Sumatra from 14 May 2005 to 18 May 2005, the voyage was uneventful. On 18 May 2005, the Vessel was proceeding on a westerly course at the speed of about 13.5 knots. Weather on scene was fine with moderate sea and southwesterly wind at force 5 of Beaufort wind scale. Occasional moderate rolling of vessel movement was experienced. According to the Master, normal ship movement was encountered in the moderate sea, there was no severe ship rolling movement during the passage. Routine checks on the cargo securing were recorded in the ship’s logbook that the lashings were in order.

At about 1535 (UTC+5) on 18 May 2005 whilst in position 5° 55.5N 84° 20.7E, the Vessel suddenly developed a 15° list to port. The bridge navigating officer stated that the vessel was navigating in normal order and rolled moderately at about 10 degrees to both sides in seaway before the list. There was no irregularity such as collision with other object during the watch and in the voyage. The sudden listing was immediately reported.
to the Master.

4.8 After acknowledging the situation, the Master informed the engineers to upright the Vessel by filling the starboard double bottom tanks. However due to severe listing, the ballast pump could not be started. Thus the crews were not able to upright the Vessel with ballasting.

4.9 The listing continued to be worsening to about 40º list to port. The port deck edge was immersed into the sea. Due to the dangerous situation, at 1602 the Master decided to abandon the Vessel. He sent out a distress message on Immarsat C Satellite System and a Mayday message via VHF Radio Channel 16. Within a short moment, there was response from a nearby container vessel M.V. ‘P&O Nedlloyd Asia’ and replied that it was proceeding to the scene. At 1545 the Master also informed the incident to the management company in China. The Master abandoned the Vessel in position of 5º 55N 84º 20.7E.

4.10 At time of abandoning, the ‘P&O Nedlloyd Asia’ was about one nautical mile from the Vessel. Due to the severe listing, the crews were not able to lower the lifeboats. However, some of the crew managed to inflate and boarded the inflatable liferafts. As the ‘P&O Nedlloyd Asia’ was closing in, other remaining crewmembers jumped into the sea after donning their lifejacket and swam towards the container ship.

4.11 The crew of ‘P&O Nedlloyd Asia’ successfully rescued all survivors from the water and the liferafts. There was no casualty in the incident.

4.12 A salvage tug arrived at scene in the following day. Crews from the salvage tug boarded the Vessel and they tried to carry out the salvage without success. As the listing deteriorated, on 20 May 2005 at 1650 (UTC+5), about 49 hours from the time of initial listing, the Vessel finally sank in position 06º 30N 084º 45.7E at 43 nautical miles northeast of the initial listing position. There was no apparent oil pollution in the sea area.
5. **Analysis of Evidences**

5.1 **Certification and Experience of the Crews**

5.1.1 The certification and experience of crews on the Vessel have been verified to be appropriate for their capacity. All officers and crew were Chinese nationals. The Master was holding a Class A1 Certificate of Competency issued by the Maritime Safety Administration of the People’s Republic of China and a Class 1 Deck Officer Licence issued by the Marine Department, Hong Kong SAR. He had been serving as Master on board various bulk carriers for over 5 years.

5.2 **The Voyages of ‘Hui Long’**

5.2.1 ‘Hui Long’ was a general cargo vessel and it carried a variety of cargoes including 5,185 tonnes of fluorspar mineral in bulk. The voyage from Hong Kong to Singapore took about 5 days which is the longest sea passage during the first leg of the voyage. The stability of the vessel was in good condition and the voyage was uneventful.

5.2.2 After unloading the ingots and steel angle bars in Singapore and Sei Pakning, the Vessel was reloaded with machinery and wood pulp. On the commencement of the voyage to India, the stability was in good condition.

5.2.3 The navigation and stability condition of the vessel were reported to be normal after the departure from Sei Pakning. The rolling period was observed to be about 13 seconds which indicated that the vessel was in a stable condition. There was also no report of collision with other vessel or floating object before the accident occurred.

5.3 **Condition of Vessel**

5.3.1 The Vessel was operating in good condition before the accident. According to the ship management company, the maintenance record of the Vessel was in good condition. The survey record from its classification society has also indicated that the Vessel had no major structural problem. The ship’s safety and trading certificates were inspected to be in order. During interview, the crews stated that the Vessel had been operating in good condition.
5.4 **Weather Condition**

5.4.1 The weather enroute after departure from Sei Pakning was moderate. According to the weather report of the sea area there was no adverse weather condition prevailing in the area. The picture of the listed Vessel taken from the rescued vessel showed that the on scene weather was not severe (fig. 3).

![Fig. 3 M.V. ‘Hui Long’ after the initial listing](image)

5.5 **The Cargo of Fluorspar**

5.5.1 The Master and crews of the Vessel did not know what had caused the sudden listing. The Second Officer who was on duty at time of listing said that the Vessel all of a sudden listed to port side and could not return to upright position.

5.5.2 One of the possibilities that could cause the sudden listing of ship would be the shift of large quantity of cargo. However, as the wood pulp cargo was in bale and they had been stowed in close pack, the bales of wood pulp at the side of vessel were also stowed against the ship’s frame, therefore they should not be shifted easily under normal ship movement. Other cargo such as machinery and the remaining zinc ingots were also properly lashed in position and their quantity should not be sufficient to cause the ship to
5.5.3 The remaining possibility would be the 5,135 tonnes of fluorspar cargo which was stowed at No. 3 lower hold (4,685 tonnes) and No. 1 hold (450 tonnes). Calculation on the cargo shift moment revealed that due to the large width of No. 3 lower hold, a transverse shift of approximate 800 tonnes of liquefied fluorspar cargo would cause an initial heel of 21° to the Vessel (appendix 3).

5.5.4 Fluorspar is a commercial term for the mineral fluorite i.e. calcium fluoride which when pure contains 51.1% calcium and 48.9% fluoride. The acid grade fluorspar, which carried on board the Vessel, is a critical raw material for fluor-chemicals industry. Under the Code of Safe Practice for Solid Bulk Cargoes, 2004 (BC Code) published by the International Maritime Organization, fluorspar is categorized as Groups A and B cargoes. The characteristic of Group A cargo may liquefy during a voyage whilst Group B cargo possess a chemical hazard which could give rise to a dangerous situation.

5.5.5 Fluorspar is a material that may liquefy if shipped at moisture content in excess of the Transportable Moisture Limit (TML). TML is regarded as the maximum amount of moisture within a mineral cargo in bulk suitable to be transported by ships. Liquefaction of fluorspar cargo largely depends on its moisture content. The moisture content of cargo determines the amount of moisture within the cargo. When moisture limit exceeds its TML, it can cause the cargo, or part of the cargo to change from solid to liquid form due to vibration, rolling and pitching during voyage. Moisture can then become trapped between cargo particles and if there is sufficient saturation, the cargo may shift to one side inside the cargo hold.

5.5.6 Once liquefaction occurs, the fluorspar cargo would become liable to shift in a liquid state. When the cargo is in viscous fluid state, it may flow to one side of the ship but not completely return to the other side during ship rolling at sea. The shifting of the bulk cargo can cause potentially disastrous consequence to vessel through listing and may progressively reach a dangerous heel and capsize. However, the process of liquefaction of the fluorspar cargo may take several days from the time of loading for the moisture to separate from the bulk mineral.

5.5.7 Section 7 of the Code states that it is extremely important to mariners who carry the cargo that they are provided with accurate TML and moisture content values of the cargo. Such cargoes should also be trimmed reasonable level and loaded as deeply as practicable. These measures will minimize the potential shifting of the cargo. To prevent hazardous liquefaction occurring, the BC Code also requires the flow properties of subject cargoes
to be tested (TML and moisture content) and subsequently certified by shippers prior to loading. Cargoes should not be loaded if their moisture content exceeds the TML. In particular, these types of cargoes should not be loaded if water is observed escaping from the cargo during loading.

5.5.8 Section 3 of the Merchant Shipping (Safety) (Carriage of Cargoes) Regulation (Cap. 369) stipulates that the owner or master of a ship shall not accept for carriage any cargo unless the shipper has furnished with information on the TML and moisture content of the cargo. The master or owner of a ship shall not accept for carriage by the ship any cargo that may liquefy when carried by sea unless the actual moisture content of such cargo is less than its TML.

5.6 Moisture Content of the Fluorspar Cargo on Board the Vessel

5.6.1 The fluorspar cargo on board the Vessel was originated from a nearby port in Pearl River Delta. The cargo was shipped to Hong Kong by coastal barges for loading to the Vessel. After loading on board, cargo sample was taken by a cargo surveyor for testing of the moisture content. A moisture content was tested to be 9.8% by the survey firm and a certificate was issued to this effect (appendix 2).

5.6.2 However there was no certification regarding the TML of the fluorspar cargo from the shipper or the cargo survey firm. The cargo surveyor did not measure the TML of the fluorspar cargo because test of TML was not requested by the shipper. The survey firm was asked by the shipper to certify whether the moisture content of the fluorspar cargo was below the 10% moisture limit.

5.6.3 There was no laboratory test certificate or documentary proof in verifying the actual TML of fluorspar loaded in Hong Kong. As such the actual TML of the fluorspar cargo remained unknown before the shipment. The Master appeared to have misbelieved that the TML was at 10%, which was informed by the shipper. He therefore accepted the cargo on the basis that the moisture content at 9.8% was below the said 10%. In the absence of the TML of the fluorspar cargo, there is a possibility that the moisture content of 9.8% could have already exceeded the TML and the cargo would be liable to liquefy.
5.7 **Sampling Procedures for The Fluorspar Cargo on Board**

5.7.1 Section 4.6 of the BC code has recommended the sample size as a minimum for determining the TML and moisture content:

‘The number of sample size required should be given by the cargo surveyor with the following scale: Consignments of less than 15,000 tonnes: one 200 g sub-sample should be taken for each 125 tonnes to be shipped.’

5.7.2 For the approximate 5,000 tonnes of fluorspar loaded on board the Vessel, a total of 40 samples of 200 gram each should have been taken for analysis. According to the certificate of moisture (appendix 2), only one individual sample was drawn from each cargo hold for analysis purposes.

5.7.3 Under the circumstances, the sampling size taken by the cargo surveyor would not be sufficient for a proper determination of moisture content as far as the BC Code is concerned.

5.8 **Rules Governing the Carriage of Bulk Cargo**

5.8.1 In the BC Code, the value of TML for fluorspar cargo is not specified, as different grades of fluorspar mineral may have different value of TML. The BC Code however, requires the flow properties of relevant cargoes, i.e. the TML and moisture content to be tested and subsequently certified by shippers prior to loading in order to prevent hazardous liquefaction.

5.8.2 The BC Code also stipulates that a test to determine the TML of solid bulk cargoes which may liquefy should be conducted at regular intervals. In the case of materials of consistent composition a test should be conducted at least once every six months. Where the composition or characteristics are variable for any reasons, more frequent testing is necessary.

5.8.3 Section 2.3.12 of the ship management company safety manual “Safety on Bulk Cargo Carriage” (散雜貨安全操作須知) on board the Vessel has explicitly expressed that if the moisture content of the bulk cargo is over 8%, the master should not accept the carriage.

5.8.4 The instructions in the company safety manual applies to general condition of all bulk cargo including fluorspar. If the moisture content is found to be higher than 8% the master should cast doubt as to whether he should accept the cargo. At least the master
should attempt to verify the TML of the cargo through documentation from shipper and to seek instruction from the management company as to the situation before accepting the cargo or to conduct a simplified sample test as described in the BC Code.

5.8.5 Section 8 of the BC Code stipulates that if the master has doubts in regard to the appearance or condition of the material, a simplified in-situ testing method for providing a rough idea on the possibility of flow may be carried out, i.e. by half filled a cargo sample inside a cylindrical vessel of about 1 litre capacity and strike it against a hard surface for 25 times, if free moisture appears on the surface of the sample, additional laboratory tests should be conducted.

5.8.6 Apparently, both the shippers and the Master had failed to follow the requirements as stipulated in the Merchant Shipping (Safety) (Carriage of Cargoes) Regulation, before the loading of the fluorspar cargo.

5.8.7 After the accident, the remaining sample left in the cargo survey firm was taken to a reputable laboratory in the UK for testing the TML. However, the UK laboratory responded that the quantity of the sample was not sufficient for the test of TML, thus the TML of the remaining sample was not able to ascertain.

5.9 **Effect of Rain**

5.9.1 Apart from the possibility of moisture content within the cargo itself, the possibility of aggregation of water due to rain was considered. Under the BC Code, the fluorspar cargo can be loaded and discharged in rain, unless the moisture content is very close to the TML.

5.9.2 While loading the fluorspar cargo in Hong Kong, there was report of slight local rain but not affecting the normal loading of the cargo. On arrival to Singapore and Sei Pakning, the hatch cover of No. 3 upper hold had been opened for cargo operation. In case of raining the crews would close the hatch covers and ceased loading. The record on the time of closing of hatch covers during intermittent rain showers was found in the deck logbook. Therefore, it is believed that the effect of rain that might contribute to the moisture content of the fluorspar cargo would not be significant.
5.10 Similar Occurrences

5.10.1 It has been aware that other similar casualties have occurred in mid 2005 on two non Hong Kong registered vessels. Both vessels were carrying fluorspar cargoes originated from China and loaded in Hong Kong. Each of the two vessels developed a severe list due to what is possibly a liquefaction of the cargo. In one of these vessels, free water was observed to have developed on the cargo surface during carriage (fig. 4). Given the prevalence of the instances in a short period of time and their similar nature, it seems some common grounds might have prevalent among the three accidents that:

a) the vessel was loaded with the fluorspar cargo from the same origin and shipper;
b) the moisture content of the cargo were close to but less than the ‘10%’ limit;
c) the shipper, via the local survey firm, was providing only cargo moisture contents and no information is provided regarding the flow properties of the cargo or the TML; and
d) there was no trimming after completion of cargo

Fig. 4 Condition of fluorspar cargo taken from one of the wrecked vessels
6. Conclusions

The following conclusions are drawn based on the evidences obtained and the analysis described above:

6.1 On 18 May 2005, the Hong Kong registered ship ‘Hui Long’ suddenly developed a list of 15 degrees to port in position about 173 nautical miles east of from Sri Lanka. The list continued to be worsening and the Master abandoned the Vessel at 1602 after the port weather deck was immersed into water at a list of 40 degrees. All 23 crews were rescued by a passing container vessel ‘P&O Nedlloyd Asia’. A salvage tug was called in the following day trying to rescue the Vessel. However, the Vessel was finally sunk on 20 May 2005.

6.2 The exact cause of the sinking of ‘Hui Long’ could not be established.

6.3 After investigation the probable causes of the accident, it is believed to be the liquefaction of the fluorspar cargo inside the No.1 and No. 3 holds. The flow state of the fluorspar cargo might have developed a list to the Vessel and caused it to capsize and sink.

6.4 The Master appeared to have not followed the company’s cargo safety manual for loading bulk cargo that may liquefy by accepting on board for shipment of fluorspar cargo with the moisture content higher than the stipulated 8%.

6.5 The shipper has failed to provide the TML of the fluorspar cargo before the shipment as required by the Merchant Shipping (Safety) (Carriage of Cargoes) Regulation and the BC Code. While a norm of 10% TML for bulk fluorspar was used by the shipper without documentation support of any laboratory test. As such it is possible that the fluorspar cargo at moisture content of 9.8% had exceeded the actual TML.

6.6 The amount of sample taken by the survey firm would not be sufficient for a proper determination of moisture content as far as the BC Code is concerned.
7. **Recommendations**

7.1 A copy of the report should be sent respectively to the shipper, ship management company of the Vessel and the Master advising the findings of the incident in particular, the tragic consequences that could result when loading fluorspar or other similar bulk cargo with high moisture content. The attention of the shipper should be drawn to the requirements of providing the Transportable Moisture Limit certification when loading the fluorspar or other bulk cargo that may liquefy at high moisture content.

7.2 A Merchant Shipping Information Note and a Marine Department Notice should be issued to promulgate the lessons learnt from this incident, drawing the industry’s attention on the safety precautions in loading bulk cargo that may liquefy.
8. **Submissions**

8.1 In the event that the conduct of any person or organization is commented in an accident investigation report, it is the policy of the Marine Department to send a copy of the relevant part of the draft report to that person or organization for their comment.

8.2 The draft report was sent to the Master of the ‘Hui Long’ (at time of the incident), the ship's management company, the shipper and the cargo survey firm in Hong Kong.

8.3 Submissions on the report were received from the lawyer representing the management company of ‘Hui Long’. The Investigating Officer has taken into account some of the views from the submissions and the draft report has been amended where appropriate. Other submissions that have not been incorporated into the report were responded separately to the party concerned.

19 April 2006
## Cargo loading sequences of ‘Hui Long’

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<th>Port</th>
<th>Date</th>
<th>Cargo</th>
<th>Loaded</th>
<th>Discharged</th>
<th>Tonnes</th>
<th>Discharge port</th>
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<td>Fluorspar</td>
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<tr>
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CERTIFICATE OF MOISTURE

In pursuance of an order received from Messrs. TAK HING ENTERPRISES DEVELOPMENT LTD., requesting us to carry out the instructions summarized as under:

Sampling from ship's cargo hold (in bulk) and submission of sample to our laboratory.

Description of Goods: Acid Grade Flourmper in bulk as per sales Contract No. TS31125F dated 13.01.2005.
Load Port: Hongkong Sea Port
Destination: Kandla Seaport India
L/C Number: 50732051M00005399

WE REPORT AS FOLLOWS:

Stowage: Ship's Cargo Hold Nos.1 Hold & No.2 Lower Hold
Sampling: During loading of the above mentioned parcel one individual sample was drawn by us from each cargo hold for analysis purposes.
Analysis: On consignee's order one individual sample was drawn by us from each ship's cargo hold and mixed with one composite sample was submitted to our Laboratory in order to test the following items.

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Unit</th>
<th>Test Method</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>wt. %</td>
<td>In-House Method</td>
<td>9.80</td>
</tr>
</tbody>
</table>

The sample will be retained for 90 days at our SGS Hong Kong Ltd. Laboratory for reference.

Precision parameters apply in the determination of above test results. Also refer to ASTM D244-90 IP-367 and Appendix E of IP Standard Methods for Analysis and Testing for utilization of test data of determine conformance with specifications.

This test document can not be reproduced in any way except in full context without the prior approval in writing from SGS Hong Kong Ltd. The above reflects our findings at time, date and place of inspection only.

Our intervention as above has been carried out to the best of our knowledge and ability and our responsibility is limited to the exercise of reasonable care.

For and on behalf of
S.G.S. Hong Kong Ltd.

Authorized Signature

ISSUED AT HONG KONG PORT
Appendix 3

Angle of heel due to transverse shift of Fluorspar cargo

Displacement = 19574.78 mt
KG = 7.938 m
(Trans. shift of cg) \( Y_d = 0.625 \) m

\[
GZ = KN-KG*\sin\theta
\]

(Vert. shift of cg) \( Z_d = 0.084 \) m

\[
G_1Z_1 = GZ-Y_d^*\cos\theta-Z_d^*\sin\theta
\]

<table>
<thead>
<tr>
<th>( \theta )</th>
<th>( \sin\theta )</th>
<th>( KN )</th>
<th>( GZ )</th>
<th>( Z_d^* \sin\theta )</th>
<th>( \cos\theta )</th>
<th>( Y_d^*\cos\theta )</th>
<th>( G_1Z_1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>1.000</td>
<td>0.625</td>
<td>-0.625</td>
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<tr>
<td>10</td>
<td>0.174</td>
<td>1.631</td>
<td>0.253</td>
<td>0.015</td>
<td>0.985</td>
<td>0.616</td>
<td>-0.378</td>
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<td>12</td>
<td>0.208</td>
<td>1.960</td>
<td>0.310</td>
<td>0.017</td>
<td>0.978</td>
<td>0.612</td>
<td>-0.319</td>
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<tr>
<td>20</td>
<td>0.342</td>
<td>3.299</td>
<td>0.584</td>
<td>0.029</td>
<td>0.940</td>
<td>0.587</td>
<td>-0.032</td>
</tr>
<tr>
<td>30</td>
<td>0.500</td>
<td>4.889</td>
<td>0.920</td>
<td>0.042</td>
<td>0.866</td>
<td>0.541</td>
<td>0.337</td>
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<tr>
<td>40</td>
<td>0.643</td>
<td>6.264</td>
<td>1.162</td>
<td>0.054</td>
<td>0.766</td>
<td>0.479</td>
<td>0.629</td>
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<tr>
<td>50</td>
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<td>7.347</td>
<td>1.266</td>
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<td>0.643</td>
<td>0.402</td>
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<tr>
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<td>1.150</td>
<td>0.073</td>
<td>0.500</td>
<td>0.313</td>
<td>0.764</td>
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<tr>
<td>70</td>
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<td>8.370</td>
<td>0.911</td>
<td>0.079</td>
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<td>0.214</td>
<td>0.618</td>
</tr>
<tr>
<td>80</td>
<td>0.985</td>
<td>8.401</td>
<td>0.584</td>
<td>0.083</td>
<td>0.174</td>
<td>0.109</td>
<td>0.393</td>
</tr>
</tbody>
</table>

Angle of heel (Deg.)

Note:
Assuming a transverse shift of 800 tonnes of Fluorspar cargo in No. 3 lower cargo hold, there would be a heeling moment to cause the ship to heel at a list of about 21°.