MEMBER ALERT

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DECEMBER 16, 2010

DANGERS WITH RESPECT TO THE CARRIAGE OF NICKEL ORE AND OTHER BULK CARGOES PRONE TO LIQUIFACTION:

The hazards associated with the carriage of bulk mineral cargoes with a relatively high moisture content and small particle size are well known and publicized. Recent catastrophic casualties involving nickel ore shipped from Indonesia have once more brought this problem to the forefront of industry concern. INTERCARGO has released two safety alerts over the last few weeks warning 03/10 and warning 04/10 which are intended to remind owners and operators of the very serious risks involved.

Formal investigations with respect to the recent casualties continue. However, nickel ore is a cargo which may liquefy if the moisture content of the material reaches or exceeds its transportable moisture limit (TML). This cargo liquefaction may then lead to a cargo shift and subsequent loss of stability, to the extent that the vessel may capsize.

As the global economy continues to emerge from recession, shipments of nickel laterite ore from the principal exporters in Indonesia, New Caledonia and the Philippines are expected to rise. Accordingly, there will likely be an increase in the number of nickel ore cargoes offered for shipment.

Why are these problems occurring?

Many mines in the regions mentioned above are very basic and are situated in very remote locations, making it hard for surveyors and experts to attend them. Moreover, it is not easy to arrange for cargo samples to be tested independently due to the lack of reliable laboratories in such countries.

The nickel ore is mined from open quarries and stored in open areas where stockpiles are susceptible to heavy rainfall and high humidity prior to shipment. In some cases, the ore is transported directly from the mine to the vessel.

The “solar drying” of stockpiles has limited effect and rarely does more than dry the surface area of the ore. No other processing is involved. The ore is typically loaded into barges and transshipped to bulk carriers waiting at anchor. Although the cargo presented for shipment may appear to be dry, this is not a guide as to whether the cargo is actually safe to carry.

Nickel ore is non-homogenous cargo and particle sizes vary considerably. This creates problems for laboratories when trying to ascertain the flow moisture point (FMP) from which the TML is calculated. Local test facilities in these problem areas are not able to complete the testing required by the new IMSBC Code (see below). The required shipping documentation, actual moisture content and TML may therefore be very inaccurate.

The non-homogenous nature of nickel ore means that cargo loaded in different holds may be inconsistent from one hold to the next with respect to the FMP of cargo in such different holds.

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International Maritime Solid Bulk Cargoes (IMSBC) Code

This Code will become mandatory on January 1, 2011 and will supersede the guidance provided by the Bulk Cargo (BC) Code. Its purpose is to facilitate the safe stowage and shipment of solid bulk cargoes. The Code provides information on the dangers associated with the shipment of certain types of solid bulk cargo, and on the procedures to be adopted when shipment is contemplated.

As with many other fine particulate minerals including mineral ore concentrates, nickel ore may liquefy and shift if its inherent moisture level is too great. Because of this risk of liquefaction, nickel ore is subject to the provisions of SOLAS and the IMSBC Code regarding the testing and certification of cargoes that are liable to liquefy which are identified as "Group A" hazards.

Members contemplating carriage of nickel ore are therefore advised to study SOLAS Ch.VI, Reg.2 and Sections 4, 7 and 8 of the IMSBC Code.

Practical assessment of moisture content

Members should remember that the "can test" as described in the IMSBC Code is a very useful way to check if the cargo may be unsuitable for shipment. It is a practical test that can be completed by a competent crew member.

In brief, it involves filling a can with a cargo sample and banging it sharply on a hard surface from a height of about two feet. This should be repeated twenty five times. If moisture is seen on the surface of the sample, then this indicates that the cargo may be unsafe for shipment and should be made the subject of laboratory testing.

Advice to Members

Members who plan to fix or charter a vessel to load nickel ore from ports in Indonesia, New Caledonia or the Philippines should contact the Managers at the earliest opportunity.

Many shippers of nickel ore provide certificates issued by the mines' in-house laboratories, which are based on their own sampling and testing. Prior audits of the sampling and testing methods used by such mines have revealed serious deficiencies which have rendered the cargo properties certified by many shippers effectively meaningless.

It is therefore important that a surveyor with the requisite knowledge and experience attends the loading facility, prior to loading, in order to evaluate the risk and collect test samples as required by the IMSBC Code.

In addition:

- Vessels should not accept the cargo if the right documentation is not provided by the Shipper in advance of loading.

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- Loading should not be commenced if the documentation provided appears to be incorrect or incomplete.
- Nickel ore and all other "Group A" hazardous cargoes must be loaded in accordance with the provisions of the IMSBC Code.
- The IMSBC Code requires that the interval between sampling/testing for moisture content and loading should never exceed seven days.
- The required certificates must be issued by a recognized test facility.
- Regular "can tests" should be conducted during loading which should cease if moisture problems are suspected.
- Loading should be ceased and the hatches closed during periods of rainfall.
- Cargo hold bilge suctions should be functional, clean and well prepared prior to loading.
- Regular hold bilge soundings should be taken and hold bilges should be pumped out as necessary.

Members who plan to fix or charter a vessel to load nickel ore from ports in Indonesia, New Caledonia or the Philippines must take care to ensure that express terms are included within the charter party, contract of affreightment or other contract (as applicable) so as to safeguard their position. Members should contact the Club's claims and loss prevention departments for further advice before entering into such a fixture or charter.

Failure to take the above precautions could result in cover being prejudiced.

For additional information on the liquefaction of unprocessed mineral ores, please refer to the attached information presented by Brookes Bell. Your Managers therefore recommend that Members follow this guidance accordingly and that all relevant "M" Notices should be consulted for further information.

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Liquefaction of unprocessed mineral ores - Iron ore fines and nickel ore

By Dr Martin Jonas,
Brookes Bell, Liverpool.

Dr Martin Jonas considers some of the technical issues behind the casualties involving the carriage of unprocessed natural ores from India and nickel ore from Indonesia, the Philippines and New Caledonia.

Introduction

Liquefaction of mineral ores, resulting in cargo shift and loss of stability, has been a major cause of marine casualties for many decades. Recent problems, already leading to several total losses this year, have primarily involved the carriage of unprocessed natural ores such as iron ore fines from India and nickel ore from Indonesia, the Philippines and New Caledonia. The main cause of casualties and near misses is the poor compliance of shippers with the testing and certification requirements that are designed to ensure that cargoes are loaded only if the moisture content is sufficiently low to avoid liquefaction occurring during the voyage.[1]

Principles of liquefaction

Cargoes that are at risk of liquefaction are those containing at least some fine particles and some moisture, although they need not be visibly wet in appearance. The most widely-known cargoes with this hazard are mineral concentrates, although many other cargoes can also liquefy, such as fluorspar, certain grades of coal, pyrites, millscale, sinter/pellet feed, etc.

Although they often look dry in appearance at the time of loading, these cargoes contain moisture in between the particles. At the time of loading, the cargoes are usually in their solid state, where the particles are in direct contact with each other and, therefore, there is physical strength of resistance to shear strains. During ocean transport, cargoes are exposed to agitation in the form of engine vibrations, ship's motions and wave impact, resulting in compaction of the cargo. This leads to a reduction of the spaces between the particles. If compaction is such that there is more water inside the cargo than there are spaces between the particles, the water pressure inside the cargo can rise sharply and press the particles apart (see Figure 1). This suddenly reduces the friction between particles, and thus the shear strength of the cargo.

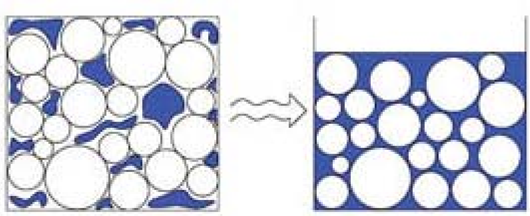

Figure 1: Liquefaction as a result of cargo compaction. In the solid state (left), the shear strength of the cargo is provided by the direct contact between the cargo particles. There are sufficient interstitial spaces to accommodate the inherent moisture and a proportion of interstitial air. As the cargo compacts under the influence of the ship's motions, the volume between the particles reduces and interstitial air is expelled. Eventually, the water pressure resulting from compaction presses the particles apart, potentially leading to them losing direct contact and a resulting sudden loss of shear strength, i.e., a fluid state (right).

The effect of this process is a transition from a solid state to a viscous fluid state in which all or part of the cargo can flatten out to form a fluid surface. In this condition, cargo may flow to one side of the ship with a roll one way but not completely return with a roll the other way, progressively leading to a dangerous list and potentially the sudden capsizing of the vessel.

Cargo liquefaction will not occur if the cargo contains a sufficiently low inherent moisture content and sufficiently high interstitial air that, even in its most compacted state, there are still sufficient interstitial spaces to accommodate all of the moisture so that the increase in water pressure is inhibited.

The lowest moisture content at which liquefaction can occur is called the Flow Moisture Point (commonly abbreviated FMP). Its numerical value can vary widely even for cargoes with the same description. It is not possible to predict the FMP of a given cargo from its description, particle size distribution or chemical composition and the FMP therefore needs to be determined by laboratory testing separately for each cargo provided by each shipper.

In cargoes loaded with a moisture content in excess of the FMP, liquefaction may occur unpredictably at any time during the voyage. Some cargoes have liquefied and caused catastrophic cargo shift almost immediately on departure from the load port, some only after several weeks of apparently uneventful sailing. While the risk of liquefaction is greater during heavy weather, in high seas, and while under full power, there are no safe sailing conditions for a cargo with unsafe moisture content. Liquefaction can occur unpredictably even in relatively calm conditions on a vessel at anchorage or proceeding at low speed.

It is for these reasons that SOLAS and the IMSBC Code incorporate provisions intended to ensure that only cargoes with sufficiently low inherent moisture content to avoid liquefaction are loaded. Strict adherence to these provisions is the only safe way of carrying these types of cargoes.

SOLAS/IMSBC Code Regulations
SOLAS requires that the shippers of bulk cargoes provide the Master in writing sufficiently in advance of loading with information on any special properties of the cargo, including the likelihood of shifting, and for concentrates or other cargoes which may liquefy additional information in the form of a certificate on the moisture content of the cargo and its Transportable Moisture Limit (commonly abbreviated to TML).[2] Cargoes which may liquefy shall only be accepted when the actual moisture content is less than the TML.[3]

Unlike the FMP, which can be determined in the laboratory, the TML is a parameter that is calculated, rather than measured, as 0.9 times the FMP. Thus, for example, a cargo with an FMP of, say, 10 per cent (as determined in the laboratory) has a corresponding TML of 9 per cent, this being 0.9 times 10 per cent.

Thus, the maximum allowed moisture content of a cargo at the time of loading (the TML) is lower than the moisture content at which liquefaction actually occurs (the FMP). This difference between the TML and the FMP is intended to provide a safety margin to protect against variations in moisture or FMP throughout the cargo and to allow for measurement uncertainties in the laboratory determination of moisture and FMP. It is essential that this safety margin is always preserved and thus cargoes should never be accepted if the moisture content exceeds the TML, regardless of by how much.[4]

Full details on the underlying testing and sampling procedures for shippers' certification obligations under SOLAS are given in the IMSBC Code 2009 (and previously in effectively identical form in its predecessor, the BC Code 2004)[5]. In brief, the IMSBC Code specifies the following:

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1) Identification of hazard
Prior to start of loading, the shipper must declare to the Master in writing whether or not the cargo offered for loading is a cargo that may liquefy.[6] This is a very important part of the shippers' obligation to provide appropriate cargo information, as it is not necessarily obvious from the cargo name or from a visual inspection of the cargo whether the cargo may liquefy, and thus whether the Master should insist on a declaration of moisture and TML prior to allowing the cargo to be loaded. In principle, any bulk cargo that contains at least some moisture and at least some fine particles is at risk of liquefaction. The IMSBC Code specifies that all such cargoes should be submitted for laboratory testing to establish whether or not they possess flow properties.[7] If such testing shows that the cargo possesses a flow moisture point, then shippers must provide a certificate of moisture and of TML prior to loading, regardless of whether or not the cargo is specifically listed by name in the IMSBC Code as a cargo that may liquefy.

2) Certification of moisture content
The declaration of moisture content must contain a statement from shippers that this is the average moisture content of the cargo at the time the declaration is handed to the Master prior to start of loading.[8] One important consequence of this is that the entire cargo must already be available at the load port to be sampled prior to start of loading, rather than be delivered piecemeal throughout a protracted loading process. The moisture content determination must be carried out on truly representative test samples of the entire cargo.[9] This is an elaborate process requiring full access to the cargo and careful planning to ensure the moisture content of the test sample is truly the average moisture content of the entire consignment.[10]

Sampling for moisture content must take place not more than seven days prior to loading. Additional check tests should be conducted if there is significant rainfall between sampling and loading.[11]

Iron ore fines before and after liquefaction.

Shippers must declare the moisture content separately for each cargo hold of the vessel, unless sampling has shown that the moisture content is uniform throughout the entire consignment.[12] In concentrates, the moisture content is often sufficiently uniform, but in unprocessed ores such as iron ore fines and nickel ore, the moisture content can vary significantly throughout the consignment and thus separate hold-by-hold moisture declaration is required. In actual shipping practice, few if any shippers do declare a hold-wise moisture content even in highly non-uniform cargoes, and this is a cause for concern.

If more than one distinct type of cargo is loaded commingled in the same cargo hold, e.g., if loading is from different stockpiles from a different source of supply or with different exposure to rain, then shippers must provide separate certificates for each type of cargo in each cargo hold. Similarly, shippers must carry out separate sampling and certification for each substantial portion of material which appears to be different in characteristics or moisture content from the bulk of the consignment. The moisture content must be below the respective TML separately for each distinct parcel of cargo. Any portions that are shown to have a moisture content above the TML should be rejected as unfit for shipment.[13] Thus, if cargo is loaded from

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more than one source, it is not sufficient for the average moisture content of all of the cargo in each hold to be below the TML. One important consequence of this is that it is not possible to compensate for the loading of a batch of excessively wet cargo by then loading additional drier cargo into the same cargo hold.

3) Certification of TML

As discussed above, the TML is derived mathematically from a laboratory determination of the FMP. In principle, there are several different alternative test methods to determine the FMP: three of them are described in full detail in Appendix 2 of the IMSBC Code and the competent authority of the exporting county may approve additional test procedures.[14] In actual shipping practice, the only test method that is in widespread use is the flow table method, as described in paragraphs 1.1.1 to 1.1.4 of Appendix 2. While the test method is not difficult, it contains a subjective element and needs to be carried out by an experienced analyst who is familiar with the early signs of liquefaction in a test sample. The critical part is the ability to reliably identify a flow state in the test sample using the criteria given in the Code.[15] It is a matter of some concern that laboratories testing iron ore fines in India and nickel ore in Indonesia and the Philippines depart in many important respects from the IMSBC Code test procedure without approval from the respective competent authorities and without conducting systematic inter-laboratory comparisons to establish consistency of their results with laboratories using the unmodified IMSBC Code method.

For most processed ores, such as concentrates, the TML depends mainly on the technical details of the concentration process and does not vary significantly between shipments. For these cargoes, it is sufficient if shippers carry out a TML test once every six months. However, if the composition or characteristics of the cargo are variable between successive shipments for any reason, then a new TML test is required each time.[16] Unprocessed ores such as iron ore fines and nickel ore vary greatly in composition not only from shipment to shipment but also within each individual shipment. Thus, for these cargoes, shippers must carry out a new TML test for every single cargo being loaded.

Close adherence to the above requirements of the IMSBC Code is essential in order to ensure that only cargoes that are safe for ocean transport are loaded. The IMSBC Code places the burden of certification on shippers, not on the Master. Without accurate information and certification being provided by shippers, the Master can not independently assess whether or not the cargo offered for loading is safe to carry. This is because it is impossible to determine from a visual inspection or from ad hoc sampling of cargo being delivered to the vessel whether or not the moisture content of a cargo is below the TML. Cargoes with moisture above the TML typically look much the same as cargoes with moisture below the TML. Clearly discernible alarm signals, such as separation of free water on the cargo surface or muddy appearance of the cargo, are only visible during loading when cargoes have a grossly excessive moisture content.

Unprocessed ores - Iron ore fines and nickel ore

There is a wide range of mineral cargoes that may liquefy, and they vary in their appearance and physical properties. One sub-group of cargoes has a particularly dangerous combination of risk factors, and accounts for a large proportion of recent casualties, near misses and contentious load port disputes during carriage of cargoes that may liquefy.

The cargoes in question are unprocessed ores, the most widely-encountered of which are iron ore fines, mainly exported from India, and nickel ore, mainly exported from Indonesia, the Philippines and New Caledonia. Unlike concentrates, these are simply dug out of the ground in open-cast mines in mineral-rich, and often remote, locations and are presented for ocean transport with little or no processing. Thus, where concentrates have a highly uniform particle size and physical consistency, unprocessed ores are very heterogeneous, consisting of a mixture of fine-grained ore, clay-like material, pebble-sized stones and the occasional larger lump.

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Flow table test.

For shipowners contemplating carriage of these cargoes, and for Masters instructed to load them, a major difficulty is that neither iron ore fines nor nickel ore have a specific listing in the IMSBC Code and thus it is not immediately obvious from consulting the Code that these are indeed cargoes that may liquefy. Unless he is already aware of the potential hazards from other sources, the Master is dependent on shippers correctly declaring the cargo as a liquefaction hazard. Although most shippers do indeed acknowledge that the cargo is a liquefaction hazard by supplying a moisture and TML certificate, albeit frequently flawed, some shippers do not, and without expert knowledge it is difficult for the Master to know that he should insist on a declaration of moisture and TML before allowing loading to commence.

Implementing a sampling and testing regime that complies with the provisions of SOLAS and the IMSBC Code, as summarised above, is a technically much more demanding task for unprocessed ores than it is for concentrate cargoes. The IMSBC procedures were designed with concentrates in mind and therefore have an implicit assumption of uniform particle size and reasonably uniform moisture distribution throughout the entire cargo. Neither of these applies to unprocessed ores.

It is an unfortunate combination that although sampling and testing cargoes of unprocessed ores is a technically more demanding task than for concentrate cargoes, the shippers of these cargoes are typically relatively small operators often lacking in the knowledge, expertise and technical infrastructure, and sometimes the will, to comply with their SOLAS and IMSBC Code obligations. Because of the unprocessed nature of the cargo, shippers have only very limited control over moisture content and some shippers may not actually be able to supply cargoes that meet the SOLAS requirements.

Following are some of the technical issues that need to be considered by shippers when designing their certification procedures.

The physical composition of unprocessed ores varies significantly even within a single open cast pit, and even more so as most cargoes are mixtures of material dug out from several, and sometimes very many, individual pits, which may be distributed over a wide geographical area. As a result, the TML may vary

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greatly from one part of the cargo to another, but in an unsystematic and unpredictable manner, which does not allow to simply test each source of material separately.

The moisture distribution throughout each cargo is typically highly non-uniform. The material is already variable in moisture at the time it is dug out of the ground. Most mining locations are in tropical countries with frequent heavy rainfall and the cargoes are typically transported in open lorries/wagons and stored in open stockpiles leading to unpredictable increases in moisture.

The IMSBC Code specifically states that the ubiquitous test method for TML determination, the flow table method, is unsuitable for materials containing particles above 7mm in size.[17] This creates a dilemma for laboratories testing unprocessed cargoes, which frequently contain pebble-like stones above that size. Nickel ore, in particular, often has a very high proportion of lumps above 7mm. Iron ore fines are generally somewhat finer, but some cargoes also have a significant proportion of lumps above 7mm. The most frequent workaround to avoid this problem is to screen out all particles above 7mm prior to analysis and to conduct the TML test only on the proportion that is below 7mm in size. When doing so, it is essential that the particles above 7mm are removed from both the sample submitted for TML testing and the samples used to certify the moisture content of the cargo. Failure to do so will systematically overstate the safety of the cargo and may therefore lead to cargoes being accepted for loading that are actually unsafe.

Because of the non-uniform nature of unprocessed ore cargoes, samples from every single cargo need to be submitted for laboratory TML testing. Shippers therefore need to have a suitably equipped and qualified laboratory close at hand for TML testing to achieve acceptable turnaround times between sampling and certification. This differs from shippers of concentrate cargoes, who only need to submit one sample every six months, and therefore do not find it onerous to courier samples to reputable laboratories overseas. TML testing is a specialised task, and there are few laboratories worldwide who have a track record of obtaining reproducible results and participating in inter-laboratory comparisons over many years. None of these are in the main exporting countries of unprocessed ores.

In India, shippers of iron ore fines used to ignore their SOLAS obligations to provide a TML certificate until quite recently. Independent laboratories offering TML testing have only started to operate in the country after the 2007 monsoons. Although there are now many laboratories in India, all of them were started quite recently and therefore there is little or no experience data available to assess their reproducibility and consistency with leading international laboratories. To date, there has been no centralised accreditation or inter-laboratory testing effort to establish the soundness of the test procedures used by Indian laboratories.

In Indonesia, the Philippines and New Caledonia, mining locations are typically very remote indeed, and loading takes place at natural anchorages close to the mines, well away from any sophisticated infrastructure. The mines therefore generally operate their own flow table for TML testing in their in-house laboratories rather than using independent laboratories. On closer scrutiny, many of these in-house laboratories have been found to be poorly equipped and to depart significantly, and sometimes grossly, from the test procedures set out in the IMSBC Code.

Footnotes:

1 See article "Carriage of dangerous cargo - Questions to ask before you say yes" elsewhere in this issue of Gard News.

2 SOLAS, Chapter VI, Regulation 2, Para. 2.2.

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3 SOLAS, Chapter VI, Regulation 6, Para. 2.

4 The difference between moisture content and TML is a frequent source of confusion, leading to nonsensical statements such as "The TML of the cargo increased because of rainfall". The TML of a cargo depends on the type and composition of the cargo, but is not affected by whether the cargo is wet or dry. The TML is similar to, say, a speed limit on a road. The speed limit does not depend on how fast you drive, but you break the law if you drive faster than the speed limit.

5 The IMSBC Code may be applied voluntarily from 1st January 2009 and will become mandatory under the provisions of SOLAS from 1st January 2011.

6 IMSBC Code, Para. 4.2.2.2. The IMSBC Code classifies cargoes that may liquefy in cargo group A and requires shipper to declare the cargo group.

7 IMSBC Code, Appendix 3, Para. 2.1.

8 IMSBC Code, Para. 4.3.2.

9 IMSBC Code, Para. 4.4.1 to 4.4.4.

10 IMSBC Code, Para. 4.4.4. Paras. 4.6.1 to 4.6.6 give a set of recommendations for concentrate stockpiles that specify the minimum number of sub-samples to be taken to make up the representative sample. For a cargo of (say) 40,000 MT a minimum of 160 sub-samples is required. For cargoes that are more inhomogeneous than concentrates, including iron ore fines and nickel ore, collecting a sufficiently large number of sub-samples is even more important than for concentrates.

11 IMSBC Code, Para. 4.5.2.

12 IMSBC Code, Para. 4.3.3.

13 IMSBC Code, Paras. 4.3.3 and 4.4.3.

14 IMSBC Code, Paras. 4.1.4 and 8.3. Appendix 2 contains the actual test procedures to determine the FMP and TML, including the flow table method in Paras. 1.1.1 to 1.1.4.

15 IMSBC Code, Appendix 2, Paras. 1.1.4.2.3 and 1.1.4.3.

16 IMSBC Code, Para. 4.5.1.

17 IMSBC Code, Appendix 2, Para. 1.1.1.