



BRITANNIA LOSS PREVENTION

B GUIDANCE

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UNDERSTANDING LIQUEFACTION AND DYNAMIC SEPARATION IN SOLID BULK CARGOES

A RECENT INTERCARGO REPORT HIGHLIGHTED CARGO LIQUEFACTION AS THE GREATEST CONTRIBUTOR TO LOSS OF LIFE AT SEA IN THE PRECEDING DECADE.

Despite improved safety, cargo liquefaction incidents continued to occur. Although ship losses due to cargo liquefaction accounted for less than 20% of all vessel casualties during that period, they resulted in the loss of 70 lives, representing over 60% of the total fatalities¹. In other words, if cargo liquefaction occurs on a bulk carrier, it is more likely to result in loss of life than any other type of incident.

Cargo liquefaction is so dangerous because in certain cases it occurs without warning leading to a rapid loss of stability, hampering the crew's ability to evacuate and survive.

Safe carriage of cargoes is at the very foundation of ship safety. Stakeholders in the cargo distribution chain are required to know the cargo hazards, but also correctly declare the cargo and comply at all times with the requirements of the International Maritime Solid Bulk Cargoes (IMSBC) Code.

Stakeholder compliance with regulatory requirements may be affected by a lack of appreciation of the risks involved. Investigations into high-profile incidents have shown that many non-compliant cargoes had been shipped before an incident ultimately occurred². Potentially creating a false sense of safety between the involved parties. The understanding of moisture-related bulk cargo failures and the necessary risk mitigation practices is continually evolving. Amendments 06-21 of the IMSBC Code, effective from 1 December 2023, introduced the term "dynamic separation" as a new mechanism that can lead to moisture-related bulk cargo failure. While it is similar to cargo liquefaction, it differs in its specific physical process and impact on ship safety.

GROUP A CARGOES ACCORDING TO THE IMSBC CODE

THE IMSBC CODE NOW DESCRIBES TWO MECHANISMS WHICH MAY RESULT IN CARGO INSTABILITY DUE TO MOISTURE CONTENT, CLASSIFIED AS GROUP A CARGOES. THESE ARE **LIQUEFACTION** OR **DYNAMIC SEPARATION**.

To understand the difference between them, it is necessary to consider the physical properties of solid bulk cargoes.

Many mineral cargoes offered for shipment contain a significant amount of moisture due to production processes and exposure to rain during storage.

Solid bulk cargoes comprise of individual particles in contact with each other. The contact forces between these particles allow the cargo to retain shape and remain stable. Most cargoes are shipped partially saturated, meaning the voids between solid particles contain both air and moisture. When the cargo is subject to vibration and movement of the ship, it compacts and consolidates. Consolidation of the cargo ultimately results in reduction of the volume of the void spaces between the solid particles.

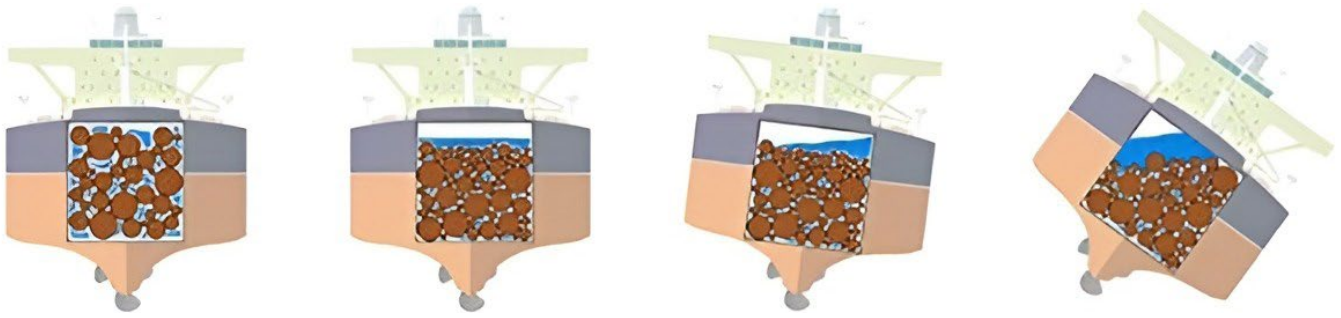
If the cargo predominantly consists of lumps (larger particles), the moisture may freely drain to the bottom of the cargo hold and be pumped out via the bilge system. In this case, cargo particles remain in contact with each other, and the cargo retains its strength.

In cargoes containing more fine particles, there may be insufficient drainage channels for excess moisture to escape. As the volume of the voids decreases due to consolidation/compaction, the water which cannot escape from the void spaces will ultimately push the solid particles apart. When the solid particles lose contact with each other, the cargo will lose strength and will behave as a liquid, affecting the ship's stability. This phenomenon is called **liquefaction**.

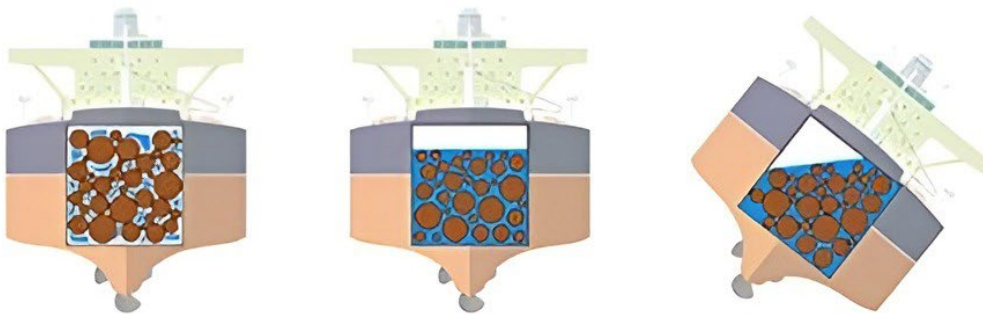
If the water can escape from some of the void spaces but cannot drain completely, it may migrate upwards from the area of high pressure to the area of low pressure, ultimately collecting on the surface of the cargo forming a liquid slurry (consisting of water and fine solids). This slurry, moving with the motion of the vessel, can impair the ship's stability. This phenomenon is called **dynamic separation**.

The following comparison published by AMSA³ highlights the differences between liquefaction and dynamic separation:

DYNAMIC SEPARATION



LIQUEFACTION



SOURCE: Australian Maritime Safety Authority (AMSA)³

KEY POINTS

- Although liquefaction and dynamic separation are different phenomena, they present similar hazards
- Moisture content and particle size of the cargo determine whether it may become unstable and liquefy/undergo dynamic separation
- In dynamic separation, the bottom part of the cargo may remain stable whilst the top is covered with the liquid slurry

HAZARDS ASSOCIATED WITH LIQUEFACTION AND DYNAMIC SEPARATION OF CARGOES

FOR A SHIP EXPERIENCING LIQUEFACTION OR DYNAMIC SEPARATION, THE MAIN HAZARD IS THE UNCONTROLLABLE SHIFTING OF CARGO.

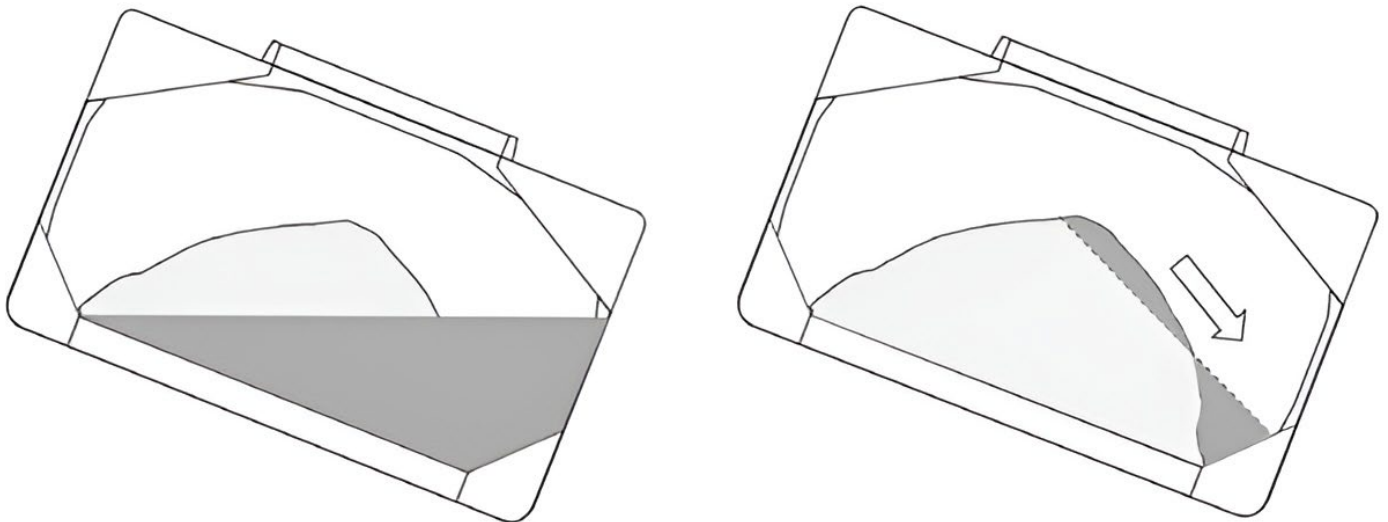
Cargo shifting may result in listing, capsizing and/or structural damage to the ship⁴. When cargo behaves like a dense fluid, the free surface effect can further impair the ship's stability.

CARGO SHIFTING

Most mineral cargoes are relatively heavy; therefore, cargo holds are likely to be only part filled, leaving space for cargo movement. If the cargo liquefies or undergoes dynamic separation, the cargo can flow across the hold whilst the ship is rolling. However, the liquefied cargo (or dynamically separated slurry) has certain inertia and after flowing to one side, it may not return when the ship rolls back. Consequently, the ship may develop a new equilibrium with a large, permanent list. This list may worsen as the liquefied cargo shifts more toward the heeling side than the opposite side⁴.

THE FREE SURFACE EFFECT of the liquefied cargo (or dynamically separated cargo slurry) reduces the ship's dynamic stability, decreasing its ability to absorb energy from external heeling forces and increasing the risk of capsizing.

CARGO SLIDING is a phenomenon related to, but different from, liquefaction or dynamic separation. Normally, a cohesive, untrimmed bulk cargo will maintain its shape during ship rolling due to cohesion forces, or the cargo particles "locking" against each other. However, the cohesion in many mineral cargoes depends on moisture content. If it is too low or too high, the cargo may be prone to sliding. Therefore, moisture migration within the cargo may prompt cargo sliding. This highlights the IMSBC Code requirements related to cargo trimming (7.1.2 and section 5).



SOURCE: DNV⁴

KEY POINTS

- Cargo liquefaction or dynamic separation may lead to ship listing heavily and capsizing or sinking
- Cargo shifting combined with free surface effect may result in a rapid loss of stability
- The risk of cargo becoming unstable increases when the ship is rolling heavily.

CARGO MOISTURE CONTENT AND LIQUEFACTION/DYNAMIC SEPARATION

THE IMSBC CODE ASSIGNS GROUP A TO CARGOES WHICH MAY “POSSESS A HAZARD DUE TO MOISTURE THAT MAY RESULT IN LIQUEFACTION OR DYNAMIC SEPARATION” IF SHIPPED AT A MOISTURE CONTENT EXCEEDING THEIR TRANSPORTABLE MOISTURE LIMIT.

Of note, some cargoes like coal may be assigned Group A and B (as they may liquefy/undergo dynamic separation and possess a chemical hazard).

Be aware that cargoes may seem dry and granular during loading, but they can still contain enough moisture to become fluid or unstable when subjected to compaction and vibration during the voyage.

Liquefaction or dynamic separation may occur in cargo when two conditions are met:

- The cargo has **particle size distribution (PSD)** which does not enable free draining and in result makes it prone to liquefaction or dynamic separation
- There is enough **moisture** in the cargo to enable liquefaction/dynamic separation.

Moisture content (MC) is defined as the portion of a representative sample of cargo consisting of water, ice or other liquid, expressed as a percentage of the total wet mass of that sample.

Transportable moisture limit (TML) of a Group A cargo means the maximum MC of the cargo which is considered safe for carriage in ships (unless they are specially constructed/fitted). TML is determined by test procedures, approved by a competent authority, such as those specified in Appendix 2 of the IMSBC Code, paragraph 1.

KEY POINTS

- For a Group A cargo to be compliant with IMSBC Code and acceptable for carriage, the MC must be below the TML
- Cargo declaration, testing and certification must fulfil the requirements of IMSBC Code (Section 4, also 7, 8)
- For cargoes like bauxite or coal, the PSD will determine whether they are liable to liquefy/ dynamically separate and should be carried under Group A requirements.

WHICH CARGOES ARE SUBJECT TO LIQUEFACTION/DYNAMIC SEPARATION?

MOST GROUP A CARGOES ARE MINERAL CONCENTRATES; THESE ARE REFINED ORES THAT HAVE BEEN ENRICHED BY REMOVING MOST OF THE WASTE MATERIAL.

Refining the cargo may impact the PSD, potentially increasing the risk of liquefaction/dynamic separation.

Attention should be paid to the IMSBC Code general schedule for MINERAL CONCENTRATES, which, as stated in the schedule and in the IMSBC Code Appendix 4 (Index), should be read in conjunction with some of the specific cargo schedules (e.g. MANGANESE CONCENTRATE).

Group A includes several unprocessed or partly processed **ore cargoes**, such as **NICKEL ORE, BAUXITE FINES or IRON ORE FINES**. Liquefaction or dynamic separation of these cargoes has been attributed to several tragic incidents, in particular nickel ore and bauxite/bauxite fines.

Finally, Group A includes several cargoes of **other types** where the hazard of liquefaction/dynamic separation has been identified – such as COAL (Britannia Guidance on the [Carriage of Coal Cargo](#) may provide further reference).

The list of Group A cargoes is regularly updated, with new cargoes and new schedules. To establish whether a cargo offered for shipment is classed as Group A, the primary reference should always be the current edition of the IMSBC Code, Appendices 4 (Index) and 1 (individual schedules). In case of any doubt, it is recommended to seek guidance from the Flag State or Class and contact the Club.

It's important to recognise that the actual properties of the cargo offered for shipment may differ from those listed in the IMSBC schedule. Several IMSBC cargo schedules were developed only after tragic incidents involving cargoes that were not initially classified as Group A. Clay is an example of cargo which currently has a Group C schedule but has been known to present Group A hazards.

The IMSBC Code warns that *“schedules for individual cargoes are not exhaustive, and the properties attributed to the cargoes are given only for guidance. Consequently, before loading, it is essential to obtain current valid information from the shipper on the physical and chemical properties of the cargoes presented for shipment”* (section 1.2.1 of the Code).

Furthermore, Group A classification is not definitive, and some cargoes may still present such hazard: *“Many fine-particled cargoes if possessing a sufficiently high moisture content are liable to flow. Thus any damp or wet cargo containing a proportion of fine particles should be tested for flow characteristics prior to loading”*. (Appendix 3, section 2.1).

Special attention is required when cargoes not listed in the IMSBC Code are offered for shipment. These unlisted cargoes can be particularly dangerous, as their potential hazards when loaded in bulk remain uncertain until they undergo the proper procedures outlined in Section 1.3 of the Code.

KEY POINTS

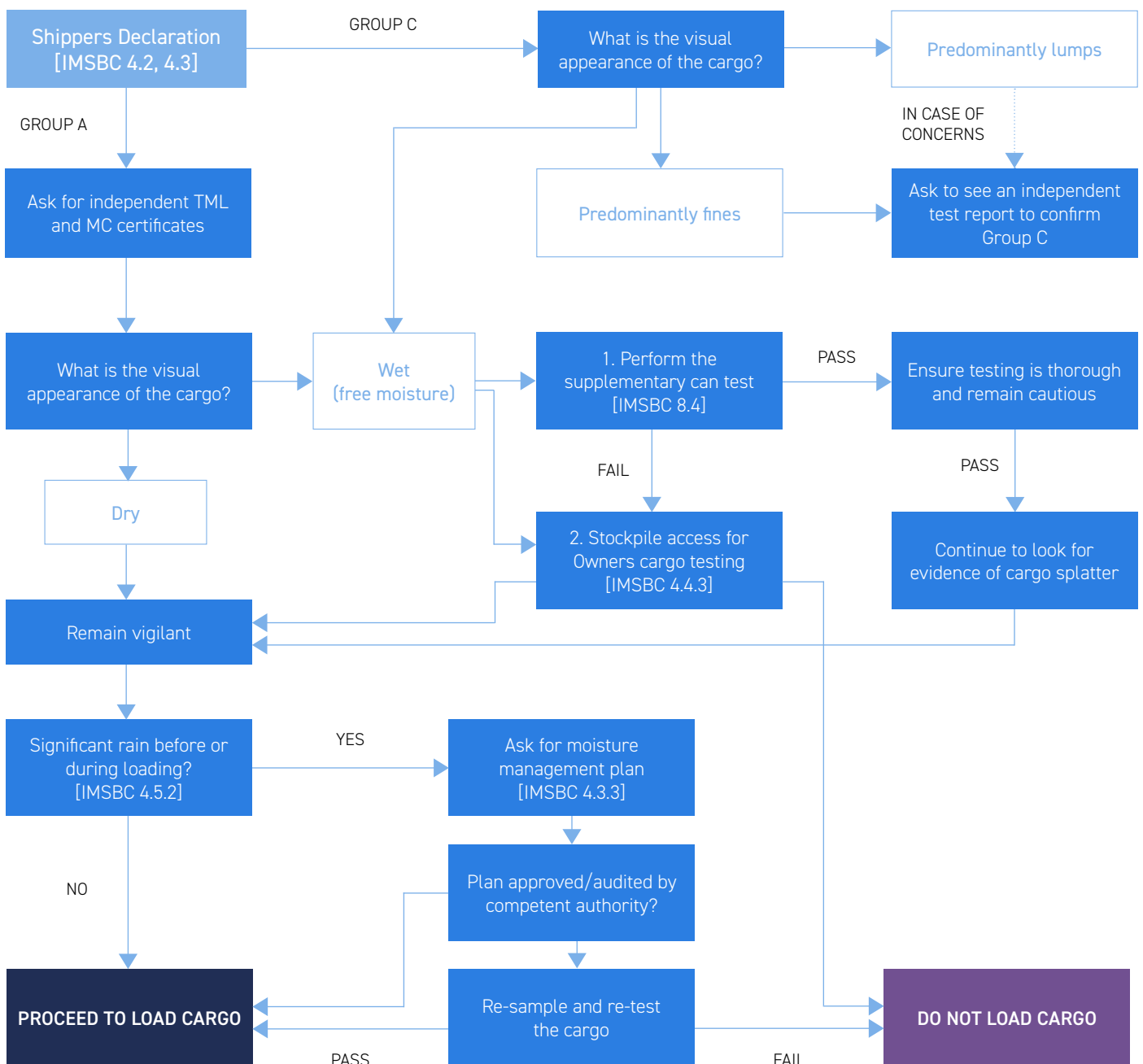
- All solid bulk cargoes must be shipped under their correct Bulk Cargo Shipping Name (BCSN), which identifies the schedule and the relevant requirements of the IMSBC Code
- The cargo declaration must be complete and fulfil the IMSBC Code requirements
- Actual properties of a cargo may differ from those in its IMSBC schedule, and it may require sampling/testing (for example, to confirm it is not liable to liquefy)
- Unlisted cargoes are only acceptable for shipment if they fulfil the requirements of IMSBC Code section 1.3. This applies also to cargoes where there is no complete BCSN match with an existing cargo schedule.

PRECAUTIONS FOR LOADING AND CARRIAGE OF GROUP A CARGOES

Britannia's article on [Liquefaction – Caution Remains the Watchword](#) provides the basic operational guidance for loading Group A cargoes, summarising the process and documentary requirements to be followed.

It should be noted that mandatory P&I Club notification requirements remain in place for nickel ore cargoes from ports in Indonesia and the Philippines – see [circular dated May 2012](#).

The flowchart below offers guidance on actions the crew may need to take upon loading if there are concerns about the accuracy of the cargo declaration or the actual condition of the cargo. Full expert commentary has been provided in Britannia webinar recording²:



KEY POINTS

- The shipper is responsible for correct declaration, certification and testing of the cargo. Masters and officers should be conversant with the IMSBC Code requirements in this regard and immediately report any discrepancies
- The crew should be vigilant for any signs indicating excessive moisture content, such as cargo splatter
- Can tests are supplementary – they are not formal evidence that the cargo is compliant but may provide a warning
- It is recommended to seek support if there is any suspicion that the cargo has been incorrectly declared or certified, or that it is in an unsuitable condition for transport.

ACTIONS IF LIQUEFACTION OR DYNAMIC SEPARATION IS DETECTED DURING THE VOYAGE

THE SAFETY MANAGEMENT SYSTEM (SMS) ON SHIPS CARRYING SOLID BULK CARGOES SHOULD INCLUDE PROCEDURES FOR MANAGING CARGO LIQUEFACTION AND DYNAMIC SEPARATION.

These issues can develop rapidly, particularly in adverse weather conditions. The SMS procedures, as well as the training provided to officers and crew should consider the following points^{4,3}:

- When a ship is loaded with cargo presenting the risk of liquefaction or dynamic separation, rolling should be kept to a minimum as far as possible
- The ship's rolling period in its current loading condition should be known, recorded, and monitored. Resonance with the sea or swell frequency can promote liquefaction and should be avoided whenever possible
- In cases of dynamic separation, the sloshing of slurry on top of the cargo may result in an uncharacteristic motion, disrupting the regular rolling rhythm due to different wave periods of the slurry in each hold. Any irregular rolling should be investigated
- Any indication of the ship developing a list should be noted, reported and recorded together with details of the rolling period and its characteristics (irregular, asymmetric, etc.)
- Route planning and weather avoidance should be executed to avoid heavy weather and excessive rolling
- If safe and permitted by weather, the cargo surface should be regularly examined for change, such as accumulation of water, collapse, or shifting. Keeping a photographic record will assist in detecting changes between examinations
- Where abnormalities or indications of liquefaction dynamic separation are detected, the appropriate crisis response should be triggered and assistance from shore based experts sought.

If liquefaction/dynamic separation of the cargo is occurring:

- The master/shipowner should immediately follow the emergency notification procedure
- The crew should prepare for immediate evacuation and remain in readiness until the situation is under control
- The SMS should assist the master in evaluating whether it is safe to remain on board
- Speed and course should be adjusted to minimise the ship's rolling movement as far as possible
- If possible, the ship should proceed to a sheltered area or a port of refuge.

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FOR FURTHER INFORMATION

For further information, please do not hesitate to email lossprevention@tindallriley.com.

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