Veterinaria Italiana, **44** (1), 247-258

Engineering and design of vessels for sea transport of animals: the Australian design regulations for livestock carriers

Alexander G.T. Schultz-Altmann

Summary

The author outlines the principles underlying the standards employed by the Australian Marine Safety Authority to regulate live animal carriers, vessels used for sea transport of livestock, that operate from Australia. The standards are contained in regulations adopted by the Australian Maritime Safety Authority known as Marine Orders. The Cargo and Cargo Handling – Livestock Marine Order has evolved over time with subsequent 'issues' of the order as a consequence of operational experience and specific research. Recent changes have focused on the need to have adequate redundancy in systems and equipment of ships. A history of the development of these regulations is given and is followed by a description of the principles employed to develop the provisions contained in the regulations.

Keywords

Animal, Australia, Marine, Maritime safety, Regulation, Ship, Transport, Welfare.

Progettazione e design di navi per il trasporto mercantile di animali: la normativa australiana sul design per i trasportatori di bestiame

Riassunto

L'autore delinea i principi basilari utilizzati per creare gli standard con cui la Australian Marine Safety Authority disciplina la progettazione dei mezzi di trasporto per gli animali vivi, navi utilizzate per il trasporto marittimo di bestiame in Australia. Gli standard sono contenuti nella normativa adottata dalla Australian Maritime Safety Authority nota come Marine Orders. Successivamente sono stati promulgati emendamenti al Cargo e Cargo Handling Livestock Marine Order in conseguenza dell'esperienza acquisita sul campo e sulla base di ricerche specifiche. Alcuni cambiamenti recenti sono focalizzati sulla necessità di avere sistemi ed attrezzature adeguate sulle navi. Questo studio si occupa della storia dell'evoluzione di queste norme; segue l'esposizione delle teorie utilizzate per sviluppare i provvedimenti contenuti nella normativa stessa.

Parole chiave

Animale, Australia, Benessere, Guardia marittima, Marina, Nave, Normativa, Trasporto.

Principal Marine Surveyor, Ship Inspection Group, Australian Maritime Safety Authority, GPO Box 2181, Canberra, ACT 2601, Australia
Alex.Schultz-Altmann@amsa.gov.au

Introduction

Most vessels plying international trade routes are required to comply with a range of international conventions adopted to ensure the safety of the crew and any passengers and to protect the environment. The two that are directly relevant to Marine Order 43 (MO43) (3) are the International Convention for the Safety of Lives at Sea (SOLAS) (4) and the International Maritime Organization's *International Convention for the Prevention of Pollution from Ships* (MARPOL) (2). These two conventions only make allowance for the cargo in so far as safety of the crew and passengers and protection of the environment are concerned; they do not address any requirements of the sea transport of live animals on ships. In fact, there is no universally adopted international convention or code for this purpose and most states produce their own requirements where they deem it necessary.

Unlike passengers or crew who can abandon the ship if necessary, when live animals are carried on a vessel they are completely dependent on the vessel and its systems to ensure their well-being until such stage as they are disembarked. Because of this, the welfare, or proper carriage of live animals during sea transport, can only be sustained if the arrangements are such that the vessel can continue to provide the services the animals rely upon, even under adverse conditions or during breakdowns. In this regard, the SOLAS convention, while not being designed to address live animal issues, does provide a range of mechanism that have been extended by MO43 to cover livestock carriers in respect of power supplies and minimum structural fire protection standards.

In addition, Issue 5, and subsequently Issue 6 of MO43 have adopted a requirement that all systems be provided with 'adequate redundancy' in order that livestock system can be maintained in most foreseeable circumstances, including during shipboard incidents, such as fire or breakdowns. These requirements are in excess of the SOLAS convention and the mechanisms used to achieve this are discussed here. Issue 6 of MO43 is not an animal welfare standard but the engineering requirements it contains are critical to ensuring the welfare of live animals when carried by sea. It is one of the most comprehensive regulatory packages of its type as it provides an important case study on the design of vessels engaged in the transport of livestock by sea to facilitate the delivery of good animal care.

This paper is not designed as a comprehensive guide on compliance with the regulations covering the design and approval of carriers that may carry livestock from Australia by sea. Instead, the intention is to provide an explanation of the principles behind some of the requirements contained in Australia's guiding legislation, MO43 (Marine Orders Part 43 – Issue 6) (3) and how these principles translate into practice. It is emphasised at the outset that readers must consult MO43 to determine what the Australian requirements actually are, particularly when compliance is being sought.

Background history

Australia has a long involvement in regulating the design of livestock carriers because of its active export trade in live animals. The origins of the current design standards can be found in the Navigation (Deck Cargo and Livestock) Regulations introduced in Australia in 1926. The physical requirements for pen sizes and structure were subsequently detailed in Australian Department of Transport specifications which date back to 1952.

Amendments to the Navigation (Deck Cargo and Livestock) Regulations covered the carriage of livestock by sea for many years. However, the introduction in the 1970s of larger and permanently fitted ships dedicated to the live export trade necessitated a more comprehensive regulatory approach. As a result, a Livestock Advisory Committee was established in the mid 1970s by the Australian Commonwealth Department of Transport (DoT). The Livestock Advisory Committee included participation from agencies of Australia's two tiers of government (Commonwealth and State Governments) and

from livestock ship owners and operators, exporters' representatives and animal welfare interests, specifically the Royal Society for the Prevention of Cruelty to Animals (RSPCA Australia). The task of the Livestock Advisory Committee was to frame new regulatory requirements for the specialised ships servicing a rapidly growing trade.

Deliberations by the Livestock Advisory Committee led to the introduction of design and equipment requirements for sea vessels: the *DoT Marine Standards Division (MSD) specifications for the carriage of livestock*. These specifications introduced the concepts of the 'livestock capacity plan' and 'livestock services'. Through the Livestock Advisory Committee, specifications were amended as necessary in light of operational experience, mainly derived from government marine surveyors and scrutiny of voyage outcomes.

In 1982, the MSD specifications were further refined as a result of operational experience with trade and recognition of the need for better regulatory oversight. The result was that the Australian Maritime Safety Authority (AMSA) promulgated Issue 1 of Marine Orders Part 43 (MO43) Cargo and Cargo Handling – Livestock. This came into effect in July 1983 and included most of the previous MSD specifications. The new Marine Orders were designed to be easier to amend and keep up to date than the previous Navigation Regulations which had to be tabled in the Australian Parliament.

The history and development of Marine Orders 43

During 1985, an Australian Government Senate Select Committee conducted hearings on the welfare of livestock carried by sea. This was followed by a joint government and industry workshop in 1988 and, as a result, in 1991 Issue 2 of Marine Orders 43 was adopted to address further changes deemed necessary for the proper and effective carriage of livestock.

Even with such a comprehensive development process, AMSA, in conjunction with the Livestock Advisory Committee, continued to assess incidents and voyage outcomes. As a consequence, the adoption of Issue 3 of MO43 in September 1997 saw significant changes to the minimum standard of structural fire protection for 'new' vessels and a focus on the safe and effective management of vessels. Issue 4 of January 2000 further refined these requirements and adopted a more rigorous design assessment and certification regime with the Australian certificate for the carriage of livestock (ACCL) replacing the livestock capacity plan. The ACCL is issued and endorsed in the same manner as other statutory certification and becomes invalid if other statutory certification lapses or the required inspections are not conducted.

Despite the changes adopted through Issues 1 to 4 of MO43, evaluations of incidents by AMSA found that the design philosophy of many livestock carriers still entailed a foreseeable risk that some or all services on vessels could be lost in particular circumstances. It was also found that many vessels were operating at close to their maximum generation capacity meaning the only effective reserve was the emergency power source. As a result, Issue 5 of MO43 focused on improving the arrangements on livestock carriers for adequate redundancy in systems and equipment. The design philosophy was that no service should be lost or severely degraded due to a failure in any part of the system and that normal maintenance could be performed on generators without having to rely upon the emergency system. Issue 5 of MO43 was adopted in January 2002 and was amended in May 2004.

In recognition of the fact that the primary concern to AMSA is safety at sea, protection of the environment and, in so far as live animal export is concerned, the material aspect of livestock carrier design, it was determined that the animal care aspects of animal welfare were outside AMSA's jurisdiction. These are now covered by the Australian Standards for the Export of Livestock, which are managed by the Australian Quarantine Inspection Service. For this reason, reference to animal welfare was deleted from Issue 6 of MO43 as adopted in December 2006. Issue 6 of MO43 also

introduced additional structural fire protection requirements and mandated the carriage of a humane killing device suitable for the species of livestock a vessel is certified to carry.

General provisions of Marine Orders 43

The requirements contained in all iterations of Marine Orders Part 43 have included a range of standing requirements governing the following:

- the design and size of pens for each species
- the design and size of stalls
- the design of rails and gates
- the strength of rails, gates and decks in the livestock area
- the strength of stalls
- the design of passageways and access arrangements
- the design of ramps, both internal and external
- the provision of hospital pens
- the design and arrangement of fodder storage and handling facilities and prevention of fires in bulk fodder storage
- the design of fresh water systems
- fire fighting equipment in the livestock space
- lighting arrangements, main and emergency
- documented maintenance plans
- certification and Inspection of vessels
- the method of seeking approval and documentation requirements
- mechanism for undertaking investigations and enforcing requirements
- the need for a record of equipment and arrangements.

Some explanation of why some of these provisions have been adopted may assist in understanding their application.

Pen design, sizes and strengths

Current requirements for pens sizes and proportional dimensions predate the first issue of MO43 and strength requirements for decks and rails were adopted with Issue 1 of MO43. The minimum strength of fittings and maximum allowable size of pens is unambiguous but it is important to understand why these limits were set.

Pen size

MO43 stipulates a maximum pen size for cattle (21 m^2) and sheep (40.5 m^2), as well as the maximum proportional dimensions of pens. The intent of the pen size and proportion limitation is to reduce the risk of crushing animals and to ensure that individual animals have adequate access to feed and water. Some variation of length to breadth ratio has been permitted when variations have been judged to improve access to feed rails. There is, however, limited scope to allow increases in the overall size of pens.

The reasoning that led to the adoption of these pen dimensions was that the average total weight or mass of animals that may be housed in a given pen would determine the maximum pen floor area and size of the pen. The intention is that the aggregate mass of the animals in the pen would not be enough to crush any animals trapped against the pen rails because of bad weather or other contingencies. Likewise, the maximum allowable pen breadth has also been limited to reduce the risk of animals being crushed against pen rails in such circumstances.

Rail and deck strengths

The requirements for the strength of decks and rails are designed to ensure these structures can support a dynamic load catering for the movement of the ship, combined with the movement of animals and the fact that animals will tend to bunch. The issue of bunching is particularly critical to deck strength and the requirements take into account the fact that the load will not be applied evenly over the entire area of the deck. Rather, the load will be applied as a series of point loads combined with greater localised loads when the animals bunch. Because of this, the deck structure must support the calculated load for the entire pen when applied to any two thirds of the pen area. In other words, any part of the deck must be capable of supporting 1.5 times the calculated floor load per square metre.

Pen rails must also be able to withstand the load applied by the aggregate weight of livestock along a single set of longitudinal rails, rather than on the basis that this same weight

be distributed evenly around the total perimeter of a pen. Hinges and securing pins must be strong enough to support the same load. To ensure that arrangements have adequate strength, MO43 provides a set of formulae to calculate the minimum load that any deck or rail should be able to withstand.

Design of the outer perimeter for sheep

One area where weaknesses have been recognised in some shipboard designs is the outer perimeter of open decks where sheep are carried. These requirements are often missed or not understood. Their purpose is to limit the risk of animals escaping over the side of the ship from open decks. Table 3 in MO43 allows a rail spacing of 200 mm and 300 mm for sheep pens, depending on rail location. However, in open structures above the weather deck where pen rails form the outer perimeter, the containment provisions in 20.1.2 of Issue 6 of MO43 reduce these rail spacings as follows:

'(a) a maximum clear vertical space below the bottom edge of the lowest rail and the top of a deck boundary angle or fashion plate, must be 100 millimetres; and

(b) a maximum clear vertical space between rails must be 200 millimetres except that the maximum clear vertical space between the uppermost rail and the next lower rail may be 250 millimetres'.

Depending on the design of the vessel, the outer boundary may be permitted as a separate enclosure located outside the line of the pens rails. In all cases, the outer boundary must be complete to satisfy compliance with MO43. The rail spacing in gates fitted to any opening in the outer perimeter must also comply with provision 20.1.2 of MO43.

Passage widths and heights

MO43 stipulates minimum passage widths for both sheep and cattle. Those for sheep are the minimum required for effective access, whereas those for cattle have a specific safety function. It should be noted that these are minimum requirements and more space is recommended where practical. Passage widths for cattle are measured between fixed obstructions. Those for sheep are measured between removable receptacles since passage widths are generally quite narrow where a ship is designed purely for sheep.

For sheep, a minimum space of 550 mm is required clear of all receptacles and fittings. For cattle, the minimum passage widths are as follows:

- 1 000 mm between the rails with pens on both sides of the passageway
- 750 mm between the rails and adjacent structure when pens are on one side of the passageway.

These clearances are designed to limit the risk to crew from animals kicking or butting through the rails. Whether this 'required clear space' is measured between fixed obstructions, or the pen rails themselves, depends on whether the animals will be loaded through the passageways or through pens. As more room is required when animals are loaded via passageways, the clear width is measured between all fixed obstructions.

Clear heights for animals have remained unchanged in MO43 since the beginning. To provide safe access for crew attending to animals, however, the clear height requirements in passageways have been modified in Issue 6 of MO43. Passageways and walkways in livestock areas must now be:

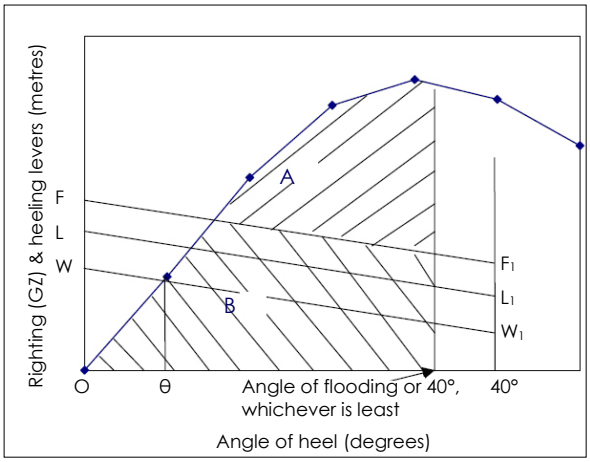
'(a) in a ship that was engaged in carrying livestock from Australia before 1 July 1983 – have a minimum clear height of 1.8 metres; or

(b) in any other ship – have a minimum clear height of 2.0 m'.

Stability requirements

Marine Orders Part 43 contains additional stability assessment criteria, in addition to that required by the SOLAS convention which is intended to ensure that the ships motion is such that, in most situations, the animals will not lose their footing. This recognised that a roll period that is too fast (i.e. the ship is very stiff) or too slow (the ship is tender and may have inadequate stability) is likely to cause the animals difficulty through the animals being thrown off their feet, or bunching to one side, exacerbating the roll of the ship.

Some effects on vessel stability are peculiar to livestock vessels and are not considered when preparing stability information for a typical cargo vessel. Figure 1 shows the additional criteria that take into account the effects on vessel stability that are peculiar to livestock vessels. To enable the ship to perform the additional calculations, MO43 requires additional information to be incorporated in the stability book. This necessitates approval of the ships stability information by both AMSA and the vessels national administration or its recognised organisation.



OW heeling lever at 0° due to wind
WW_1 heeling lever curve due to wind
WL heeling lever at 0° due to the shift of livestock
LL_1 heeling lever curve due to the combined effects of the wind and the shift of livestock
LF heeling lever curve at 0° due to the effect of shift of fodder
FF_1 heeling lever curve due to the combined effects of the wind and the shift of livestock and fodder
θ angle of heel due to wind

Figure 1
Theoretical considerations underlying the stability requirements in Australia's Marine Order 43 for vessels carrying livestock

Australian certificate for the carriage of livestock

To carry livestock from an Australian port a vessel must issued with an ACCL. The ACCL will only be issued after the vessel design and arrangements have been assessed to ensure compliance with MO43. This process involves a combination of plan assessment and inspection.

Generally, the ACCL will be harmonised with the vessel's Safety Construction Certificate (SAFCON) issued in accordance with the SOLAS convention and, as a result, will only have a maximum period of validity of five years. In some cases, a short-term ACCL is issued where a vessel may not fully comply or some outstanding documentation issues need to be resolved. To ensure the vessel's overall condition remains satisfactory, not just the livestock arrangements, it is a condition of every ACCL that all statutory trading certificates must remain valid. If these are allowed to lapse, the ACCL will automatically become invalid. The SOLAS convention can be viewed at the Internet site of the International Maritime Organization (4).

In addition, the ACCL will become invalid if a range of other conditions or events described in the current MO43 occur. A change in operator is particularly critical as it has implications for transitional arrangements currently allowed in respect of structural fire protection which lapse under such circumstances. In addition, each livestock vessel must undergo an inspection for the endorsement of the ACCL within three months of the anniversary date of the certificate. Failure to complete this inspection again leads to the certificate becoming invalid. It should be reiterated that no vessel can load livestock in Australia unless the ACCL is valid.

Finally, the ACCL may be withdrawn if it becomes apparent that a livestock vessel has not been adequately maintained or managed and this has the potential to compromise the proper carriage of livestock.

Record of equipment and arrangements

The record of equipment and arrangements is a critical part of a ship's certification for the carriage of livestock and is considered part of the ACCL, although it is a separate document. The record of equipment and arrangements is assessed and approved as part of the initial certification process and cannot be amended without specific approval by AMSA.

When a livestock vessel is inspected for compliance, the record of equipment and arrangements is used as the reference document in the same way that attachments to statutory certification are used when a ship is being surveyed for compliance with international conventions. The record of

equipment and arrangements provides comprehensive information on the space available for each species of animal on a pen by pen basis and is critical to the planning of each load of livestock for sea transport.

Adequate redundancy in systems and equipment (Issues 5 and 6 of MO43)

Changes adopted in Issue 5 and carried over to Issue 6 of MO43 were focused on ensuring that a minimum level of redundancy is inherent in the design of each livestock vessel. Adequate redundancy is important for the carriage of live animals as it is critical to the ability of a system, or systems, to keep functioning normally in the event of a component failure or incident, by having back-up components that perform duplicate functions.

This is a change to the traditional design philosophy previously employed where the secondary source of power and starters for livestock services were often located in the same compartment. While the secondary source of power is a separate power supply designed to provide a 3-day emergency power supply in the event of any failure in the primary source of power co-locations with starters for livestock services meant that an incident in this compartment had the potential to disable all livestock services. The secondary source of power should not be confused with emergency power supply required by the SOLAS convention, which is still required, rather this is a source of power specifically designed as a back-up livestock services alone.

Power supplies are critical to livestock vessels and having sufficient redundancy in generation capacity (generators, support services and switchboards) and supporting infrastructure (cables, starters, distribution boards, etc.) is necessary to ensure that livestock services can be supported in all situations. However, the changes to Issues 5 and 6 of MO43 were not limited to power supplies alone but also addressed redundancy of livestock services (i.e. back-up for ventilation systems, drainage systems and water and feed systems), design of ventilation systems and their efficiency and design of drainage systems.

Issue 5 of MO43 ended the purely prescriptive approach to standards for livestock services. The requirements in the body of Issue 6 of MO43 remain prescriptive but many livestock services are now covered by provision 12. This provision requires vessels to have 'adequate redundancy' in systems and equipment but MO43 also provides a 'deemed to comply' standard. This approach offers the ship owner/operator the option of using a risk analysis approach in determining how to provide the services not covered in the body of MO43 and is intended to facilitate the use of alternate or innovative solutions without the need to change the regulations.

Risk assessment

Where the risk assessment option is chosen, it must result in a system that can withstand an assessment based on contemporary risk assessment methodology; for example, Australian and New Zealand Standard AS/NZS 3931:1998 (5) or other similar assessment tools. The idea is that the proposed arrangement should provide a level of effectiveness equivalent to that prescribed in appendix 4 of MO43. Key elements of the risk assessment are the identification of risks/possible failures/events, the likelihood of their occurrence and the impact if the identified possible failures or events were to occur.

Sources of electrical power

All versions of MO43 have required two independent sources of electrical power, referred to as the primary and secondary sources of power. However, experience showed that these sources of power were sometimes not completely independent of each other because of the shared support and distribution systems. MO43 now requires that no service or system supporting one of the power sources can be vital for the operation of the other power source. The idea is that no single failure of any type on either power supply should result in the loss of both power supplies.

For the purpose of applying this requirement, power sources are deemed to constitute all parts of the system used to provide electrical

power, including cables to switchboards and the switchboards themselves. The usual method of compliance is to separate the power sources and distribution systems. It may be necessary to divide or duplicate electricity distribution boards to ensure that an incident involving any one of them will not result in the complete loss of electrical power to a service and that the required minimum livestock service levels can be maintained.

Secondary source of power

While the secondary source of power is not required by SOLAS, the requirements contained in MO43 have adopted the relevant SOLAS requirements, where appropriate, to ensure the system is fitted and maintained in a safe manner. In addition, MO43 also requires that the secondary source of power should be 'readily started' and the starting arrangement should be capable of being 'recharged' within 30 minutes. No time is specified for 'readily started'. However, power supplies must be restorable as rapidly as possible because even a limited period without ventilation can have a detrimental effect on livestock. Experience has shown that a loss of power for as little as ten minutes can result in significant mortality in certain conditions and the ability to start the secondary source of power is considered in light of this potential outcome.

Primary source of power

In previous versions of MO43, the capacity of the primary source of power was often just sufficient to provide power to ship and livestock services. This situation occurred because the approval of the generators in SOLAS did not take into account cargo demands. Rather, they were simply focused on ensuring adequate power for ship services. As a result, Issue 5 of MO43 required that SOLAS requirements be extended to address livestock services as well. As a result, the primary source of power must have sufficient capacity to provide power to all ship and livestock services with any one generator forming part of that source of power being out of service for maintenance, or on standby.

The purpose of this requirement was to ensure that electrical power could be maintained to all livestock and ship services during normal operations, including routine maintenance, without recourse to the secondary source of power. Where generators of varying capacity are the source of power, the arrangement is assessed on the basis that if the largest capacity unit is shut down, the remaining units are able to support the full theoretical sea load. SOLAS requirements stipulate that these electrical services should be maintained, regardless of the speed and direction of rotation of ship's propulsion machinery. Consequently, some arrangements for generating electricity from a ship's propulsion machinery may not comply.

Redundancies for livestock systems

The requirement for 'adequate redundancy' in MO43 applies to all livestock services. Livestock services have to be arranged in such a way to ensure that no single failure will result in the complete loss or unacceptable degradation of a system in the ship as a whole or in any part of the ship. The systems involved are those for ventilation, drinking water, fodder supplies, lighting (including emergency lighting) and drainage.

It is not always necessary to completely duplicate a system to meet the objectives for livestock systems; duplication can be limited to critical elements. For other elements of the system (i.e. pipe work, bilge pumps, fodder systems), alternative measures can be employed, such as interchangeable units, an isolation and repair approach (provided the necessary materials are available), an emergency back-up in lieu of complete duplication of the system or a combination of these approaches.

Design and efficiency of ventilation systems

MO43 requires that ventilation systems on livestock vessels:

- meet standards for minimum air changes when operating on either the primary or secondary electrical power supply
- continue to supply ventilation to the livestock space in the event of a failure of some part of the system
- ensure that the whole livestock space is effectively ventilated.

Issues 5 and 6 of MO43 also contain additional requirements for newly converted or constructed livestock vessels that add to or modify previous requirements.

Air exchange capacity

Mechanical ventilation is not currently required on existing vessels fitted with open decks of 20 m or less in breadth. Where the deck had a breadth of more than 20 m, or is partially enclosed, existing vessels are required to have a mechanical ventilation system that can provide 75% of the capacity of that necessary for enclosed decks. The introduction of Issue 5 of MO43 saw this requirement altered with mechanical ventilation fitted to opens decks on all livestock vessels built on or after 27 May 2004 was required to be the same as that required for closed decks. This change was adopted in response to a high number of mortalities in animals on open decks while ships were in port or still air in very hot/humid conditions.

The air exchange requirements remain the same for existing and new vessels in the current version of MO43. The minimum clear height within a space is used to calculate the air changes required to ventilate the entire volume of a space as shown in Table I. Spaces can be individual decks or decks separated by a partial or full bulkhead.

The minimum clear height within each space or area is measured from the deck to the lowest obstruction to air flow (structural beams or frames, pipe work, horizontal vent ducting or fodder/water systems etc.). Objects that do not significantly interfere with airflow (such as light fittings or high mounted fire hydrants) are not considered as obstructions, as shown in Figure 2.

Table I
Air changes required for a given clear height within a ventilated space on livestock vessels

Minimum clear height	Air changes per hour
2.3 m and above	20
2.2 m	22
2.1 m	24
2.0 m	26
1.9 m	28
1.8 m and below	30

The number of air changes specified in MO43 is considered for all modes of operation. However, a higher air exchange rate may be necessary for new vessels to comply with the air distribution requirements. There is evidence that a higher number of effective air changes improves the provision of oxygen into the livestock space and reduces heat levels. It is

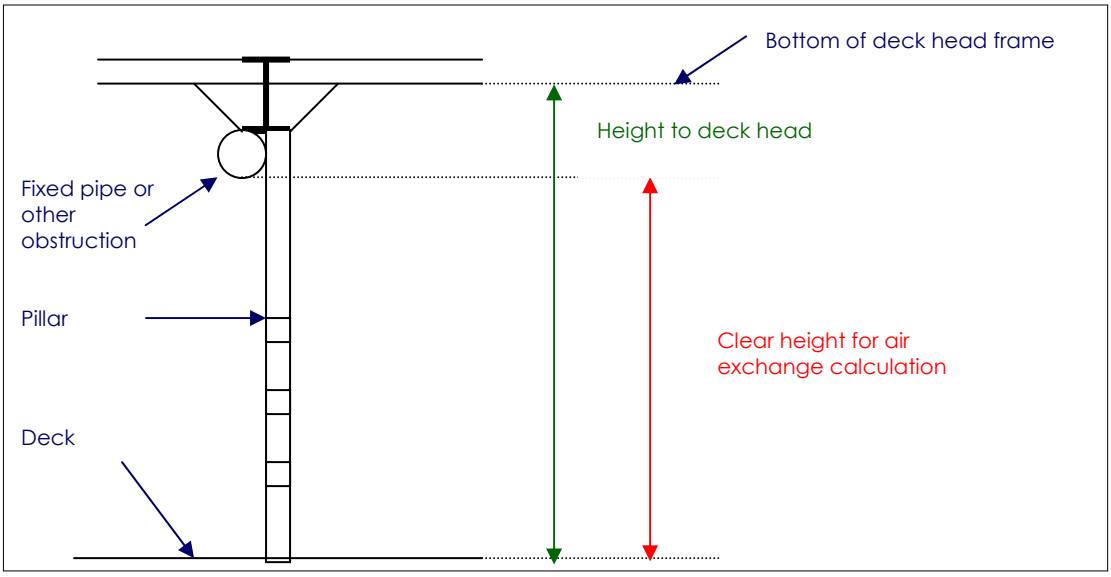


Figure 2
Determination of clear height used for calculating ventilation air changes on livestock vessels

important that the design of the system provides sufficient air changes to effectively prevent excessive pressure in the livestock space. Excessive pressure can result in stalled flows of air or short-circuiting of flows across pens, or both, as air exhausts by the most direct route.

The advantage of having a system with a high air exchange capability is demonstrated in Table II. This shows the theoretical benefit on air temperature and relative humidity from increasing the number of air exchanges over and above the minimum shown in Table I. The comparison uses a psychrometric chart for a hypothetical space of 15 000 m^3 containing 20 000 sheep and with 20 and 40 air changes per hour (1).

Air distribution requirements for new and existing livestock vessels

For any livestock vessel and regardless of the date of construction, the air distribution system must be arranged in such a way that the livestock space is effectively ventilated and the recirculation of exhaust air is avoided. This can only be achieved through the effective separation of supply inlets and exhaust outlets.

The arrangement must also ensure that air supplied to the livestock space is as clean and fresh as practical. In order to achieve this:

- supply inlets must also be located in such a way that fouled air being expelled from the livestock space, from sources other than exhaust vents and contaminated air from other sources (engine room outlets, fuel tank vents etc) cannot be drawn into the air supply system

ventilate the livestock space. At the same time, there must be sufficient exhaust capacity to

- the livestock space must be protected from contaminated air being vented or blown into the space through other means apart from the supply air system.

The latter is particularly relevant to the engine room, auxiliary machinery space and tank vents or exhaust systems.

Additional requirements for air distribution in new vessels

The current version of MO43 specifies changes to air distribution requirements for all livestock vessels built on or after 27 May 2004. These changes were adopted in the light of two separate sources of evidence showing that air flows of at least 0.5 m per second and the jetting of air across a significant proportion of animal pens had a potential to improve survival rates during thermal stress. The evidence comes from sheep but the findings are applicable to other species of livestock. As a result, the requirements for new vessels are that the ventilation system should provide a minimum air velocity of not less than 0.5 m/s across the area of the pen from an air supply and, where practical, provide an air supply for each pen, ensuring that air passing across a pen is directed to the exhaust system and not into another pen. This means the airflow needs to travel from the supply vents across the entire area of the pen to the exhaust system without significant 'dead areas', where the airflow has stalled or there are no direct flows.

Redundancy in ventilation systems

MO43 provides advice on the means for ensuring redundancy of ventilation systems on

Table II
Effect of heat loss by sheep on the air exchange ventilation

Inlet air		Heat generated			Exit air			
Air temperature	RH (%)	Sensible heat MW	Evaporative heat MW	Total MW	20 AC/h Exit air temperature	R.H. (%)	40 AC/h Exit air temperature	RH (%)
20°C	50	1.36	–	1.36	34.0°C	35	27.0°C	25
30°C	70	0.91	0.45	1.36	38.0°C	48	34.0°C	58
35°C	70	0.45	0.91	1.36	40.0°C	60	37.5°C	65

AC/h air changes per hour
RH relative humidity
MW mega watts

livestock vessels and recommends that the starter control panels for groups of ventilation fans are situated in at least two locations and that the operation of fans from either panel can effectively ventilate the livestock spaces.

Starter panels for the ventilation system should be supplied by both the main and the secondary sources of electrical power with power cables routed in such a manner that neither one passes through a space containing any part of the other source of power. Under this arrangement, the fitting of interlocks or other similar failsafe devices is necessary to prevent simultaneous supply from both sources of power. If one group of starter panels is lost, the other starter panels should be able to support enough fans to ensure that air change requirements are met.

For existing vessels, redundancy for ventilation can be achieved by distributing fans between group starter panels in a manner that the loss of one panel will not result in the complete loss or serious degradation of ventilation in an area of the vessel. Figure 3 provides an example of how distribution of individual group starters between two panels may be employed on ships to comply with the redundancy requirements. This solution is often not practical for new vessels given the need to provide an air movement of 0.5 m/s over the area of the pen. As a result, all starters are often duplicated in new vessels.

Drainage

The adoption of Annex IV of the MARPOL convention necessitated changes to MO43 for the handling and storage of effluent flows from livestock spaces. Previously, wastes such as washings and effluent could be discharged directly over the side from bilge well or open decks once the ship was outside harbour limits. However, Annex IV of MARPOL defines livestock effluent as sewage and all flows from livestock spaces now need to be connected to a sewage system complying with regulation 9 of MARPOL Annex IV and discharged in accordance with regulation 11. The convention can be accessed on the Internet site of the International Maritime Organization (4).

The need for existing vessels to comply with Annex IV of MARPOL by 23 September 2008 was incorporated the current version of MO43,

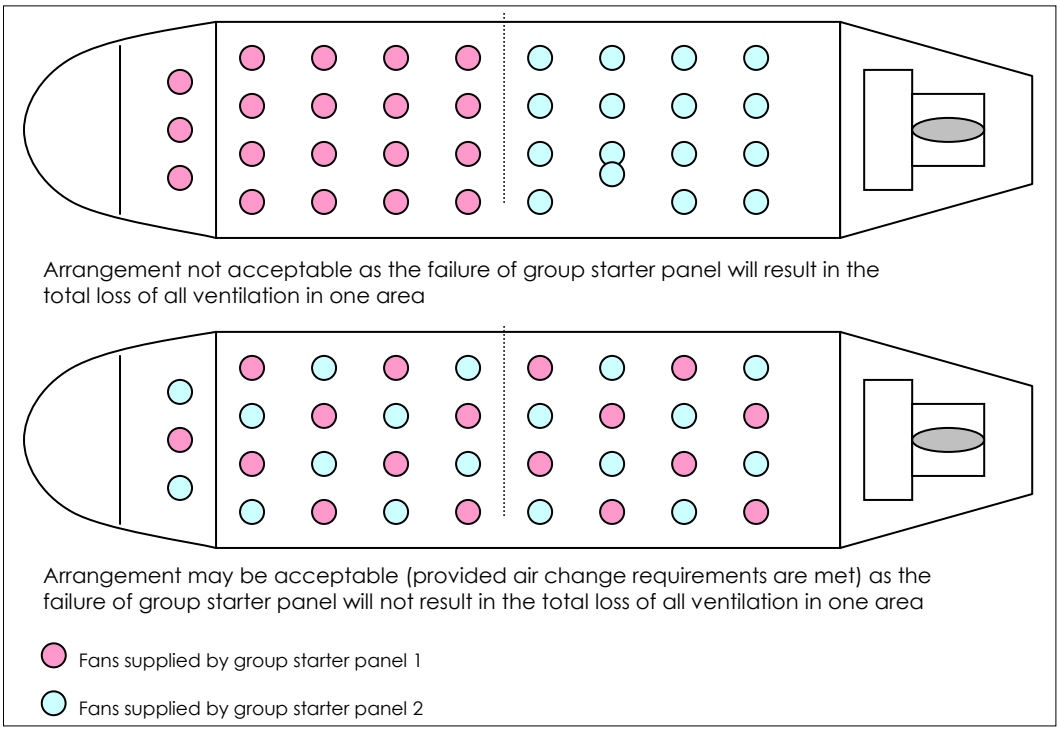


Figure 3
Examples of distribution requirements using two group starter panels for ventilation showing acceptable and unacceptable arrangements for achieving redundancy

but only for the interface between the livestock space drainage system and the storage and discharge system approved under MARPOL. The latter is approved by the ship's national administration or recognised organisation. Basically, drainage from all livestock spaces, both open and closed, needs to be connected to the approved sewage discharge arrangements. Additionally, pumping and transfer arrangements must have an adequate level of redundancy.

Structural fire protection

From Issue 3 of MO43, the minimum permissible standard for compliance with SOLAS was SOLAS 74, inclusive of the 1981 amendments. These amendments specified a range of requirements that applied only to newly constructed or converted vessels and had a significant focus on structural fire protection.

The changes adopted in Issue 3 of MO43 did not apply to existing vessels which were permitted to operate under a transitional arrangement that allowed these vessels to continue under an existing approval provided the vessel operator did not change. It was not envisaged that this would be a long-term arrangement. However, a number of vessels have continued to operate under this transitional arrangement despite clear evidence that the 1981 amendments improve structural fire protection on livestock vessels. The current version of MO43 ends the transitional arrangements in December 2011. After this date, all livestock vessels will be required to comply with SOLAS 74, inclusive of the 1981 amendments, as a minimum for retaining their ACCL.

All incidents involving livestock carriers are investigated and analysed as a matter of standard practice to determine if the MO43 requirements are adequate to ensure that certified vessels can carry livestock with the minimum of risk. Incidents involving fires in livestock spaces have raised concern about the use of combustible material in livestock spaces. In one case, a livestock ship was completely gutted by a fire that started in the livestock space while in a repair yard. Subsequent investigation determined that timber livestock decks contributed to this fire despite the fact it was initiated by welding operations.

As a result, Issue 6 of MO43 now requires that livestock structures, including livestock decks and containment structures, but excluding parts of livestock services such as water pipes and feed troughs, must be constructed of non-combustible materials. This does not exclude the use of wood or plastics provided this material has been tested to ensure it is non-combustible.

References

1. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) 1977. Handbook of fundamentals, Chapter 5. ASHRAE, New York.
2. Australian Government Department of Infrastructure, Transport, Regional Development and Local Government 2007. Prevention of pollution from ships. MARPOL (www.infrastructure.gov.au/maritime/environment/pollution.aspx accessed on 14 February 2008).
3. Australian Maritime Safety Authority (AMSA) 2006. Marine Orders – Part 43: Cargo and cargo handling – Livestock, Issue 6 (Order No. 13 of 2006). AMSA, Canberra, 70 pp (www.comlaw.gov.au/ComLaw/Legislation/LegislativeInstrument1.nsf/0/8CAB7FEAFF43267CCA25721E0010F082/$file/Mo43Issue613of2006.pdf accessed on 14 February 2008).
4. International Maritime Organization (IMO) 1980. International Convention for the Safety of Life at Sea (SOLAS), 1974 as amended. IMO, London (www.imo.org/Conventions/contents.asp?topic_id=257&doc_id=647 accessed on 14 February 2008).
5. Standards Australia 1998. AS/NZS 3931:1998 – Risk analysis of technological systems – Application guide. Standards Australia, Homebush, 30 pp.

