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Best practice design of crates for livestock export by air

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Abstract

As a result of several incidents relating to stock crate failure before, during and after livestock transportation by air, the livestock export industry is facing pressure to improve livestock crate performance. This project was developed to provide two mechanisms to benefit the air export segment of the livestock export industry. Firstly, to develop a single best practice document for stock crate design and, secondly, to recommend a mechanism for self regulation. Government regulation is not a desirable outcome; therefore it is up to industry participants to ensure that the design and construction of stock crates for use in air transportation reaches a minimum standard. The industry would benefit immediately by reducing regulatory concerns about the safety and welfare of livestock being transported by air. Combined with improved design and construction techniques, a lower level of concern would ensure this segment of the livestock export industry continues to grow.

Executive summary

While stock crates to transport horses by air have been manufactured for an extended period, the growth in stock crates for general livestock such as cattle, sheep and goats has been a more recent development. Growth in export by air is particularly evident with Middle Eastern and Asian destinations. Within the last two years growth in livestock export to China has seen the most dramatic increase. This increase has forced manufacturers to design and construct an ever increasing number of stock crates.

Increasing production generally puts pressure on supply systems and the manufacture of stock crates has not been immune to incidents. Any incident in air travel has the potential for significant affect to human life. In addition, there is growing pressure from animal welfare organisations seeking to at least improve health and welfare during transportation. Incidents involving failure of transportation structures is not an issue Government regulators are prepared to accept.

As well as stock crate designers and manufacturers, exporters play a pivotal role in the economic considerations of stock crate design. Stock crates are manufactured to least cost principles and as a result there is significant variability in quality between manufacturers. The information required to design crates appears to be relatively disjointed and spread throughout industry documentation. This creates difficulties for new entrants to the supply chain and in some instances the whole stock crate manufacturing industry can be tarnished by a lack of information on the part of one designer. With ongoing pressure from AQIS to eliminate incidents of failure, the industry is seeking a solution to variability in quality throughout the industry and a method of regulating the industry to assure a quality outcome.

MLA together with LiveCorp instigated this project to achieve several objectives:

- minimise the risk of the contained animal's welfare being compromised
- minimise the risk of crate structural failure
- ensure the secure containment of livestock
- meet all existing IATA (International Air Transport Authority) guidelines for animal containment and space requirements
- protect any existing intellectual property rights developed by crate manufacturers
- deliver recommendations for a regulatory quality management system

To achieve these objectives two mechanisms were developed:

- a document detailing best practice in the design of stock crates for the transport of livestock by air
- recommendations for a system of self regulation of stock crate designs and manufacturers to assure the quality of stock crate supplied to exporters

The outcome of this project has been to develop both mechanisms in a manner no more onerous than that which should be in place in any quality conscious organisation.

The Best Practice Design Document is a compilation of existing industry specifications, standards and design methods. Its premise is to provide a source of primary design information and detail where to find supporting data.

While the document provides explanation and reasoning for various specifications and methods, there are a limited number of primary constraints as detailed below:

- the use of load tables provided as an appendix to determine forces on floors, walls and roofs of the structure
- the use of structural engineering design methods to calculate stresses involved in bending, tension, compression, torsion, shear and bearing and compare them to the specified material's mechanical properties
- instantaneous and permanent structural deflection limits of 38mm and 19mm respectively
- the inclusion of stress calculations for lift points and tie down points to assure against failure due to handling techniques
- recommendations for floor construction to withstand lifting forces
- minimum tier height specifications
- minimum solid wall height and solid panel specifications
- considerations for doors and doorway designs
- open area specifications to ensure both containment and adequate ventilation
- opening limits to reduce injury to animals
- effluent containment methods
- timber phytosanitary specifications
- markings for identification and traceability

In addition to the Best Practice Design Document this report details a mechanism for self regulation. This involves two mechanisms to assure quality to the exporter and therefore the industry at large:

- Registration of approved stock crate manufacturers.
- Certification and registration of stock crate designs.

Stock crates would be certified as meeting the minimum specifications found in the Best Practice Design Document. This certification would be provided by a competent person, an engineer with training in structural design. Design registration would occur on the basis of certification.

Manufacturers may achieve registration independent of design registration in order that they may manufacture under licence or contract to the designer. Manufacturers will have to submit to an audit of their quality system in order to be registered. The production of a HACCP plan, standard operating procedures and work instructions will be required prior to an audit.

It is recommended that self regulation of the industry be undertaken by the Australian Livestock Export Council with delegated responsibility for registration to LiveCorp. ALEC would appoint an auditor and direct that auditor in regard to initial registration audits and any subsequent corrective action audits of manufacturers.

The net result of implementing both the Best Practice Design Document and the self regulation system would be to assure exporters and AQIS of the quality of the supply chain. The intent would be to eliminate structural issues and reduce incidents in relation to non structural considerations. The results of any ongoing corrective action processes could be incorporated into later editions of the Best Practice Design Document.

There are costs associated with the implementation and ongoing control of this process. For a least cost industry the economic consideration may be viewed as a burden. However a greater burden would be action by AQIS to restrict export licences by air. With quality assurance in place it is expected that the air transportation segment of livestock export could grow without significant hindrance from Government regulation.

Contents

1 Background

In comparison to transportation of livestock by sea, air transportation has some significant advantages: short shipment times ensure animals arrive in basically the same condition as they are sent. Both sea and air transportation generate stressful experiences and their effect on livestock is not dissimilar. Air freight, at least, ensures that these experiences are relatively short-lived.

Air freight is almost an order of magnitude more expensive than sea freight on a per head basis. Whilst this is so, the control, timeliness, speed of transaction and animal welfare issues appear to outweigh the cost advantages of sea freight. In addition, at the discharge port, animals arrive in a ‘ready’ condition restricted only by the importing country’s bio-security measures.

Similarly to sea freight, air transportation has some inherent risks. However, with the concentration of effort directed toward the protection of human life in the air industry, the transportation of animals is far less problematic. Most issues arise primarily as a result of animal placement in the cargo holds of aircraft. Ventilation, heating and lighting are of primary concern to animal health while structural integrity of stock crates, effluent and animal escape provide the most significant dangers to the aircraft, its flight crew and passengers.

Structural integrity of crates for livestock transportation by air is therefore one of the most important issues facing the livestock export industry. Of potentially equal importance are non-structural, animal welfare constraints on those designs. In several cases these animal welfare constraints have a bearing on the structural capacity of a stock crate.

Air transportation of livestock has, over recent years, increased significantly. This has generated a need for more stock crates. Whilst manufacturers have enthusiastically met this need, they have had to do so at ‘least cost’ in alignment with the exporter’s need to minimise total transportation costs. They have also done this within what appears to be a difficult and sometimes conflicting information environment.

It is potentially due to least cost design processes and a lack of thorough understanding, that there have been ongoing instances of stock crate failure. While many of these instances can be isolated to particular issues, they damage the credibility of air transportation of livestock in general due to human safety and animal health concerns. In particular the Australian Quarantine Inspection Service (AQIS) in Australia is delegated with the responsibility of ensuring animal health and the regulation of imports and exports. AQIS has the capacity to restrict this transportation methodology but has, over many years, sought to work with industry to ensure there are procedures, specifications, standards and, where necessary, regulations in place which reduce the risk of failure and maintain high standards of animal health.

As a result of regulatory pressure and industry concern, Meat and Livestock Australia (MLA), in conjunction with LiveCorp, instigated a research and development project with a view to ensuring there is a consistent and coherent standard in place for the design of stock crates. This document would draw together all relevant industry information into one place to provide manufacturers and exports an assurance that a design standard exists which adequately addresses the issues raised by all industry participants. In addition, MLA sought to develop a mechanism to regulate the design and supply of stock crates to ensure that these crates are designed and constructed to reduce or eliminate the set of issues facing the industry. The preferred mechanism would be industry regulation.

2 Project objectives

To develop a set of best practice minimum design specifications and standards for the manufacture of livestock crates for air transport. These specifications and standards will:

- Minimise the risk of the contained animal's welfare being compromised. This will involve considerations for space, lighting, airflow, and the minimisation of risk of injury.
- Minimise the risk of crate structural failure, by including standards for the selection of structural materials, best practice design methodology, best practice construction methods for structural strength, and the quality assurance of finished products.
- Ensure the secure containment of livestock and minimise the chances of escape during all sectors of transport, including trucking, transfer from truck to aircraft, during the air flight and handling at transit ports and the port of destination.
- Meet all existing IATA guidelines for animal containment and space requirements, national and international statutory body requirements for export, transportation and handling.
- Protect any existing intellectual property rights developed by crate manufacturers.
- To deliver recommendations for a regulatory quality management system for ensuring that only air crates meeting the best practice design document will be used in the process of air transport from Australia of cattle, sheep, goats, deer and camelids.

3 Methodology

3.1 Initial audit and review of industry practices

A preliminary audit was conducted of existing Australian stock crate manufacturers, located in Sydney, Melbourne, Perth and Brisbane. This was achieved by visiting and/or communicating with operators by phone and e-mail.

Exporters were contacted in an attempt to ensure that all stock crate manufacturers were involved in the process of identifying issues of both a general nature and of particular concern to the business. Where issues were connected to intellectual property they were noted and addressed accordingly in the later development of the best practice design documentation.

The sensitive area of stock crate failure was addressed with many surveyed participants, including manufactures, exporters, air freight handlers and airlines. The survey sought to determine the nature of failure in order to assist in determining what measures should be taken to address this. The discussion of failure was not restricted purely to structural integrity but included non-structural elements and their effect on human and equipment interactions.

An extensive literature review was conducted to locate Australian and International Standards and related air industry regulations for the transportation of livestock by air. In addition, a significant search of all Australian Standards relating to timber framed design was undertaken. Due to the reliance on low cost timber in the construction of air freighted stock crates in Australia, it was expected that the latter standards would be highly applicable as the basis for good engineering design practice.

A final component of this review was an internet search to locate any construction guidelines existing for the manufacture of air crates in other key livestock air transporting countries, such as New Zealand, the USA, Canada, the EU and Brazil.

3.2 Development of a best practice design document for the manufacture of livestock air crates in Australia

As a result of the literature search and discussions with manufactures, all published specifications were collated. Similarities and differences were noted and any cross referencing investigated. Several instances of conflicting industry information were investigated and a decision taken as to the most appropriate inclusion or exclusion based on the published material.

Material specifications, designs and construction methods were investigated and compared. While there were similarities across the industry, any differences were related back to published literature and a common specification or standard sought, that allowed for the necessary customisation and differences in design philosophy across the manufacturing industry.

The development of a Best Practice Design Document sought to ensure that designers and manufacturers had access to all relevant industry knowledge in one location. It also sought to provide an understanding of the most appropriate design methodology which has been developed over time by the engineering profession.

In addition, the development process collated base data on issues not always apparent to the designer due to their physical isolation to external effects, such as handling techniques in foreign countries.

Following the release of the draft document, several successful stock crate manufacturers were approached and asked to provide detailed drawings and material specifications for at least one of their most common designs. This request, although necessary, was met with some reservation and required the issue of confidentiality agreements to a majority of participants.

Four relatively complete packages were obtained and analysed. These designs were analysed against the standard to determine if these successful designs met all the constraints within the Best Practice Design Document. The intent was to determine if the document unintentionally excluded successful designs rather than identified examples of non compliance. Due to the confidential nature of the information supplied by stock crate manufacturers, minor changes were incorporated into the Best Practice Design Document in a manner in which no participant could be identified nor their intellectual property infringed. A range of issues resulting from the analysis of crate designs is discussed in section 4.4.

3.3 Development of recommendations for a regulatory system

Industry regulation is a desired outcome but this must occur through a transparent system which ensures that stock crate failure is eliminated, or at the very least minimised to non-structural issues which can be easily addressed and rectified.

The processes of both design and construction were taken into account. These processes are relatively independent but not mutually exclusive. In addition to design criteria related to the use of the stock crate, the designer must take construction methods into account. The manufacturer in turn, must ensure that the stock crate is built to the agreed design.

Existing regulatory and non regulatory systems and the bodies within the industry were considered. Through discussions with manufacturers and exporters a preliminary control system was presented for industry appraisal at a meeting of industry representatives.

Recommendations were designed with the intention of ensuring that only air crates meeting the best practice design document will be used by the Australian livestock industry for the air freighting of cattle, sheep, goats, deer and camelids out of the country.

While the foundation of the recommended system was based on sound quality assurance principles, the detailed mechanism and physical operation of the system were open for discussion. As a result of the industry meeting several modifications were made which were subsequently incorporated into Section 4 of this report.

4 Results and discussion

4.1 Initial audit and review of industry practices

There appear to be between five and seven manufacturers who consistently supply stock crates for air transportation of livestock. These manufacturers are based in Brisbane, Sydney, Melbourne, Adelaide and Perth. In general, crate manufacturers expressed a willingness to be involved in the process of developing a design standard for stock crates.

Without exception, stock crate manufacturers hold and utilise intellectual property specific to stock crate design. That information has been garnered through research and experience over several years. It became apparent through discussions that general crate manufacturers would require a significant amount of livestock related industry information to enable them to design and construct adequate products.

Discussions regarding failures were somewhat problematic. However various manufacturers, exporters, ground handling organisations and air freight companies did offer unsupported evidence of failure. There was no attempt made to trace failures back to their source, nor conduct an engineering audit as this would have been counterproductive. As a result of discussions, a list of the more common issues was developed and is presented in no particular order below. It must be understood that this list may not be exhaustive:

- damage to base floors by inappropriate lifting equipment and handling techniques
- damage to upper tiers by lifting equipment
- weakness in door construction
- difficulty with door mechanisms during loading and unloading
- unsupported joints in structural and non-structural members
- excessive openings which allow body parts to protrude from the stock crate
- absorbent flooring material insufficient attached causing leakage of effluent
- insufficient joint strength and/or bracing allowing excessive racking
- insufficient fasteners or fastener strength allowing cladding to come free
- weakness in strapping positions leading to failure under load
- insufficient roof strength
- damage by tie down straps during domestic transportation
- insufficient specification of floor and wall materials leading to bearing failure
- insufficient strength of door top plate
- lack of reinforcement of low grade timber in structural positions
- poor quality assurance processes which do not isolate construction errors

A literature review targeted publicly available specifications, standards and regulations. In doing so, much of the public information known to current manufacturers is now more available and potentially more comprehensible to others in the crate manufacturing industry. It is hoped that the plethora of information discovered in this process is also more comprehensible to existing stock crate manufacturers and will assist them in correcting any new issues and improving their current designs.

The literature review included more documents than those included in the referenced document list in Section 4.2.1.3. Many of these were discounted on the basis that they did not specifically relate to stock crate manufacture such as Civil Aviation Safety Authority regulations for aircraft, aircraft maintenance and ground handling facilities.

The results of the search confirmed that the primary starting points for livestock transportation by air from Australia, are the IATA Live Animal Regulations (LARs), the IATA ULD (Unit Load Device) Technical Manual and the *Australian Standards for the Export of Livestock Version 2.2.* The IATA documents link to various International Organisation for Standardisation (ISO) and National Aerospace Standards (NAS) standards, both directly and indirectly.

The international search to determine other countries' requirements yielded several references to certified stock crates made from metal but very little or no reference to timber construction. It did confirm that most countries reference the IATA regulations in exactly the same manner as Australia. While we are aware that other countries export in one way timber crates there does not appear to be any additional regulation on which the Australian export industry may draw.

The literature search was subsequently expanded to include relevant ISO and NAS standards and all Australian Standards relating to timber framed construction. The study of Timber Standards provided data, specifications, standards and methodology which will assist in the resolution of failure issues noted by industry players.

From the detailed study of the literature EA Systems developed a stand-alone document which is specifically written to ensure best practice design of stock crates for air transport of livestock.

4.2 Best Practice Design of Stock Crates for the Transport of Livestock by Air

4.2.1 Introduction

4.2.1.1 Background

This specification document provides best practice methodology for the design of stock crates for the export of livestock by air and is written in a similar format to the many standards and reference documents on which it is based. It is compiled from many sources of information available throughout the air transportation industry, timber industry, engineering services, building services and related industry and Australian Standards applicable to design and construction of primarily timber structures.

Although a relatively large quantity of standards and related literature has been reviewed in the compilation of this document, the referenced document list should not be considered conclusive. That is to say, valid new methods and materials should not be discounted on the basis of non-inclusion in this document.

The International Air Transport Authority (IATA) is the principle body which provides regulation to the air industry worldwide. Within IATA's scope is the regulation of livestock transportation. IATA provides two primary documents which form the basis of the regulation of livestock transportation by air. These are the IATA "Live Animal Regulations (LAR)" and the IATA "ULD Technical Manual" both published each year.

In the IATA regulations, stock crates fit within the definition of containers and are referred to as such in the LARs. Containers, pallets, straps, nets, covers and restraint systems are collectively referred to throughout air industry literature as Unit Load Devices (ULDs). In contrast all certified types of ULDs, containers may be certified or uncertified. Certification is a process whereby ULD designs are tested against relevant standards, which for containers include the IATA ULD Technical Manual – Standard Specification 50/6 and ISO 10327:1995 Aircraft – Certified container for air cargo – Specification and testing. There are various National Airworthiness Authorities throughout the world which either undertake or manage the testing process. These include organisations such as the Civil Aviation Safety Authority (CASA) in Australia, the Federal Aviation Administration (FAA) in the United States and Luftfahrt-Bundesamt in Germany. Testing is an expensive and time consuming process generally costing upwards of USD 20,000 and takes several months per design. Any design changes must be re-tested; therefore modification is generally not contemplated. In conjunction with testing, application must be made to IATA in order that the ULD design is registered. If registered, the design is provided with a designation code which must appear on each unit in a specific location.

The designs of all baggage containers are certified. They are constructed with fully integrated bases and each unit can be fastened into position in the cargo hold of an aircraft then netted. In comparison, certified stock crates such as horse containers supplied by several air freight companies worldwide are used in conjunction with certified pallets. This document does not detail the requirements for the carriage of horses, mules and larger camels. In general, a certified stock crate for the transportation of these species is owned and supplied by the aircraft cargo company. Certified stock crates for the carriage of these species are dealt with in considerable detail in standards including ISO 9469:1991 Air Cargo equipment – Unit load devices for the transport of horses. The requirements for the carriage of pets (principally cats and dogs), reptiles, birds and specialised requirements for other zoological animals are similarly excluded.

If constructed in a manner and of materials which allow for reuse, it may be economically feasible to certify general stock crate designs. However, certification is more economically feasible for very high use or specialised ULDs which can be moved from country to country transporting the same or similar product as is the case for baggage and similarly for horses attending racing and equestrian events which need to return to their home country.

In general, stock crates for what are considered lower value livestock, tend to be used in only one direction. Lower value livestock are often delivered to destinations at the lowest possible cost. As a result there is little incentive for exporters to use certified systems which have incurred expensive certifying costs in addition to further transportation costs for return, and cleaning costs to meet Australian bio-security measures. There is also anecdotal evidence that in some countries, uncertified, lower cost (timber) stock crates are broken down and used for internal stock transportation or other purposes, so additional incentive exists for one way use by the importer.

The IATA LARs allow uncertified containers to be used to transport; however, they also specify that these uncertified stock crates (containers) must be used in conjunction with certified ULDs. The commonly specified, certified ULDs used with stock crates are:

- pallets
- nets
- straps

There are several references to restraint systems in air industry regulations and standards. Restraint systems include locking devices used to secure certified pallets and containers into the floor of aircraft cargo holds (principally locking bolt devices) and ball races built into the floor of aircraft cargo holds for manoeuvring loads. These restraint systems are also considered ULDs and must be certified.

When stock crates are used the IATA LARs specify additional containment methods to protect the aircraft from escaping effluent which can damage electrical and control systems. These containment systems, usually additional plastic sheeting, are applied by ground loading staff during the strapping and netting process.

4.2.1.2 Application and Use of this Document in the Design of Stock Crates

This document is specifically applicable to the best practice design of uncertified stock crates for:

- cattle and buffalo
- sheep
- goats
- deer
- camelids (camels, llama, alpaca and vicunas other than trained camels and camels over 300kg)

The specifications, methodology and loading information contained within this document may be applied to materials other than timber; however other standards will have to be referenced that relate to the material used. That is, while the methodology may be similar, capacity factors, stress tables and other data contained in the timber series such as AS1720 and AS1684 (detailed in the Referenced Document list below) bear no relationship to design in steel.

Currently, no stock crate manufacturer in Australia has attempted to have a design certified. Where it is desirable to certify a particular design, for instance, a reusable material in a knock down design, we recommend that the manufacturer contact CASA for guidance in the testing and certification process.

There are significant points of difference in the design of stock crates from various manufacturers in Australia. While this document is reasonably comprehensive it is not intended to be totally prescriptive. It draws together much of the information available throughout the industry and places known resources in easy reach of the stock crate designer. This document also attempts to resolve some of the conflicts between several differing standards and industry practices. In their design process, manufacturers are bound by industry best practice and regulation to meet the specifications and design limits contained herein (being drawn from regulations and standards that may change from time to time).

This document does not place any limitation on the grade of material, size of members, position or spacing of structural members. However, it does place a responsibility on the manufacturer to design in such a manner that issues, such as the use of lower grade materials, do not place the stock crate outside the specifications and design limits detailed below. If a manufactured stock crate falls outside of the specifications and design limits detailed in this document it should be isolated by the manufacturer and corrected before being released to the customer.

Stock crates must be designed to maintain serviceability throughout several processes. These include:

- transportation to the port of origin
- handling by forklift or crane while empty
- strapping and netting
- loading of stock into the crate
- handling of the crate while full
- aircraft loading
- air transportation
- unloading and reloading at transit ports
- unloading at discharge ports

It is the responsibility of the manufacturer to ensure that the design and manufacture of a stock crate is carried out such that it is fit for its intended purpose as required in the *Trade Practices Act – 1974 Section 71 – Implied undertakings as to quality or fitness*. As is the case in any supply contract, failing to ensure that a stock crate carries the intended load to its destination without failure may leave the manufacturer open to legal recourse by the exporter, particularly if any failure results in financial loss or, worse, the loss of the customer's licence to export. A reasonable defence is to be able to prove that the design meets a recognised industry standard and that construction procedures are supported by reliable documentation.

4.2.1.3 Referenced documents

Australian Quarantine and Inspection Services, (2006), *Australian Wood Packaging Certification Scheme.* Department of Agriculture, Fisheries and Forestry, Canberra.

Australian Quarantine and Inspection Services, (2008), *Australian Standards for the Export of Livestock Version 2.2*, Department of Agriculture, Fisheries and Forestry, Canberra.

Forest and Wood Products Australia (2001) "Timber Joint Design 2, Nails, Staples and Screws", Forest and Wood Products Australia, Sydney NSW

Forest and Wood Products Australia (2001) "Timber Joint Design 3, Bolts, Coach Screws and Timber Connectors" Forest and Wood Products Australia, Sydney NSW

IATA "Live Animal Regulations (LAR)" (Published each year) International Air Transport Association, Geneva Switzerland.

IATA "ULD Technical Manual" (Published each year) International Air Transport Association, Geneva Switzerland.

International Organisation for Standardisation (1991) ISO 9469 "Air Cargo equipment – Unit load devices for the transport of horses" International Organisation for Standardisation Geneva, Switzerland.

International Organisation for Standardisation (1992) ISO 6517 "Air Cargo Equipment – Base-restrained certified containers exclusively for the lower deck of high-capacity aircraft" International Organisation for Standardisation Geneva, Switzerland.

International Organisation for Standardisation (1995) ISO 10327 "Aircraft – Certified container for air cargo – Specification and testing" International Organisation for Standardisation Geneva, Switzerland.

International Standards for Phytosanitary Measures (2002) "Guidelines for Regulating Wood Packaging Material in International Trade" Secretariat of the International Plant Protection Convention, Food and Agriculture Organisation of the United Nations, Rome Italy.

National Aerospace Standard (1990) NAS 3610 "Specification for cargo unit load devices" Aerospace Industries Association of America, Washington DC

Standards Australia (1997) AS 1720.1 "Timber structures Part 1: Design methods" Standards Australia, Homebush NSW

Standards Australia (1998) SAA HB108 "Timber design handbook" Standards Australia, Homebush NSW

Standards Australia (1999) AS 1648.1 "Residential timber-framed construction" Standards Australia, Homebush NSW

Standards Australia (1999) AS 4446 "Manufacture of nail plate-joined timber products" Standards Australia, Homebush NSW

Standards Australia (2000) AS 2878 "Timber – Classification into strength groups" Standards Australia, Homebush NSW

Standards Australia (2001) AS 1649 "Timber – Methods of test for mechanical fasteners and connectors – Basic working loads and characteristic strengths" Standards Australia, Homebush NSW.

Standards Australia (2002) AS 1170.0 "Structural design actions Part 0: General principles" Standards Australia, Homebush NSW

Standards Australia (2002) AS 1170.1 "Structural design actions Part 1: Permanent,

imposed and other actions" Standards Australia, Homebush NSW
Standards Australia (2003) HB 2.2 "Australian Standards for civil engineering students Part 2: Structural engineering" Standards Australia, Homebush NSW
Standards Australia (2006) AS 1720.2 "Timber structures Part 2: Timber properties" Standards Australia, Homebush NSW
Standards Australia (2007) AS 2082 "Timber – Hardwood – Visually stress graded for structural purposes" Standards Australia, Homebush NSW
Standards Australia (2008) AS 2269.0 "Plywood – Structural Part 0: Specification" Standards Australia, Homebush NSW
Standards Australia (2008) AS 2858 "Timber – Softwood – Visually stress graded for structural purposes" Standards Australia, Homebush NSW
Terrestrial Animal Health Standards (2008) "Guidelines for transport of animals by air" World Organisation for Animal Health (formally Office International des Epizooties), Paris France

Designers of stock crates are advised that they should hold and use many of the referenced documents in the list above, in particular IATA regulations and timber design standards. We also recommend, due to the importance of inwards goods inspection, that manufacturers hold and use, in particular, copies of AS 2082 "Timber – Hardwood – Visually stress graded for structural purposes" and Standards Australia (2008) AS 2858 "Timber – Softwood – Visually stress graded for structural purposes".

Copyright subsists over all regulations and standards in the referenced document list and to obtain a licensed copy, many must be purchased from the appropriate organisation. IATA manuals must be purchased directly from IATA's head office in Montreal, Canada (see IATA's website). Both ISO and AS standards must be purchased directly through SAI Global, Sydney Australia, either by phone or Internet. AQIS and the World Organisation for Animal Health provide documentation free on the Internet. The International Standards for Phytosanitary Measures are also available freely on the Internet and can be found by typing ISPM into an internet search engine.

4.2.1.4 New materials and methods

While this document makes particular reference to the use of timber in the construction of uncertified stock crates, it has done so on the basis of current practice within the industry and the economic considerations driving one way usage. These guidelines do not prevent the use of other materials or methods of design or construction whose inclusion is based on "analytical or engineering principles, or reliable test data, or both, that demonstrate the safety and serviceability of the resulting structure for the intended purpose"[1]. That is, providing the design uses the loading data and meets the specifications and design limits within this document, the materials and methodology shall not be prescriptive. Similarly this document does not preclude the design, manufacture and certification of reusable stock crates.

4.2.1.5 Useful definitions for terms within this Best Practice Design document[2]

Capacity
A structural member has an ability to withstand forces in particular directions i.e. in tension, compression, bending shear or torsion. Capacity is generally defined as the maximum force

[1] Adapted from AS 1720.1:1997, Section 1.3, New Materials and Methods
[2] These definitions have either been developed specifically for this document or are adaptations of those found in various industry standards.

a member can withstand before failure. Capacity may be presented in several difference units e.g. weight, Newtons and Pascals.

Capacity Utilisation
The load as a percentage of the maximum capacity of a structural member. Where the capacity utilisation exceeds 100% the structural member would fail under the subjected load. No member should exceed 100% and in general there should be some factor of safety involved.

Certified Design
A design which has been certified by a competent person as meeting the best practice for the design of a stock crate.

Competent Person
An engineer competent in the design of timber-framed construction.

Contour (airframe)
The continuous shape as listed in the IATA ULD Technical Manual of the inner most surface of a cargo bay in an aircraft. The contour accounts for any protrusions of parts of the air frame throughout the length of the cargo bay. The contour may vary in bulkhead positions.

Contour (stock crate)
The shape of a stock crate that ensures it does not encroach any closer than 50mm to the airframe contour.

Factor of Safety
The reciprocal of capacity utilisation. Factor of safety is often used to describe how times the capacity of the member exceeds the design load. The factor of safety would generally vary between 1.0 and 3.0 however the aircraft industry designs up to 12.0 for various applications. Where the factor of safety is less than 1.0, the member will likely fail under the design load.

Limit State Design
Engineering design methodology which utilise stress and deflection calculations to determine if material stress states have been exceeded in the design process.

Maximum Gross Weight
The maximum load case for a stock crate which is also to be marked on the stock crate. The maximum gross weight is the combined weight of the empty crate plus the maximum load it is designed to carry.

Modification Factors (capacity)
Constants used in engineering calculations to determine member capacities. Factors such as load duration, moisture content, temperature, length and position of bearing, load sharing, size, and stability have varying effects on

Restraint Systems
Ball races and restraining bolts fitted to air cargo compartment floors to restrain pallets and

other certified ULD during flights.

Structural Member
A member within a structure which serves a load bearing purpose, i.e. it is positioned to carry a load within the structure. This load may be as a result of a force in any direction.

Structural ULD
For the purpose of this specification, all stock crates are considered structural.

Unit Load Devices (ULD)
Unit Load Device including containers, pallets, nets, straps and covers. ULDs may be certified or uncertified, however uncertified ULDs are always used in conjunction with certified restraint devices i.e. pallet, nets, covers and straps.

4.2.2 Structural design considerations

4.2.2.1 Building Code of Australia and Australian Standards

Stock crates are not permanent structures as defined in the Building Code of Australia (BCA); therefore they are not regulated in any way. The BCA is however, a useful reference for the design of these structures. Stock crates provide a function which may be likened to a Class 10 Building (10a – A private garage, carport, shed or the like).

While the BCA provides useful guidance on design for Class 10 Buildings, stock crates have additional constraints and design considerations not found in the BCA. Live loads such as wind, snow and earthquake are inconsequential compared to the live animal load and other live loads generated from handling fully loaded stock crates. Designers are therefore advised that the use of standards and handbooks such as the AS 1170 "Structural design actions" (or loading data) series, the AS1720 "Timber Structures" (design) series and SAA HB 108 "Timber Design Handbook" and the development of live load data, as can be found in 9.1 of this document, may be more useful in developing good engineering design practice.

The BCA relies on accepted engineering practice in the design of residential, commercial and farming structures. Accepted engineering practice is to utilise limit state design to investigate the outcomes of the structure under three principle conditions:

- serviceability
- stability
- strength

Under Limit State Design, limits are set for the outcome of engineering calculations under the three conditions above. These are discussed in more detail below.

4.2.2.2 Structural Design Methodology - Limit State Design

Limit state design is the term used to describe a series of processes which form a structural design methodology. Limit state design is considered best practice by the engineering profession and forms the basis of many of the standards associated with timber framed construction.

Structures fail due to excessive forces. These excessive forces are generally live loads (as opposed to the dead load – the weight of the structure itself). Live loads can originate from inside the structure such as people, equipment or animals. Examples of external live loads are wind forces, earthquakes and snow. Where the combined effect of live and dead loads exceed the capacity of the structure failure will occur. In order to design a structure, best engineering practice determines that three primary design states require analysis:

- serviceability
- stability
- strength

4.2.2.2.1 Serviceability limit state design

In residential buildings, serviceability is defined by the maximum allowable deflections of floors, walls and roofs. The limits applied are generally far below the ultimate deflection encountered prior to failure. In residential and commercial construction these limits are applied in such a way that the average person will not notice the minor bowing or buckling of surfaces such as floors, walls or ceilings, therefore serviceability can be closely aligned with visual appearance. That is, the average person may become concerned about their personal safety if they observed significant deflection in a structure. For reference purposes, deflection limits can be found in AS 1648.1 “Residential timber-framed construction”. As an example, for wall studs in a residential building, the maximum deflection under wind load is defined as “stud height/150 but not greater than 20mm”.

Deflection can be determined for a structural member or group of members using standard engineering calculations. These calculations use defined loads acting against members of defined size and having nominated engineering properties in order to generate a measure of deflection.

Both the IATA ULD Technical Manual (Standard Specification 50/4 Certified Aircraft Container at Clause 7.3 and Attachment ‘B’) and ISO 10327 “Aircraft – Certified container for air cargo – Specification and testing” define the maximum serviceability limit (or maximum deflection) of the upper corners of a fully loaded, base restrained container to be 38mm at 1G. This limit is not concerned with safety of the structure. It has been put in place to protect the air craft in which the container will travel and potentially to reduce interference with adjacent containers. The specified maximum deflection works in combination with the airframe contour clearance discussed in Section 4.2.2.6 of this document to ensure that containers do not come in contact with the airframe at any time during a flight.

Standard Specification 50/7 – General Specification for Non-Certified Aircraft Container in the IATA ULD Technical Manual does not specify a maximum deflection. It does however state that, following test load conditions “the permanent set of the loaded container shall not exceed 19mm. Interestingly Standard Specification 50/4 states that under various load conditions “the container shall show neither detrimental permanent deformation nor abnormality which will render it unsuitable for use; and the dimensional requirements affecting handling, securing and interchange shall be satisfied”. Dimensional requirements appear in Standard Specification 50/6 Air/Surface (Intermodal) Container as are generally +0.0mm -25.4mm.

Design for serviceability limits would normally be carried out on a base restrained structure. With the base restrained, deflection of other parts of the structure would be investigated. When considering a stock crate, roofs, walls and corner joints should be investigated however the designer must be particularly concerned with deflection of the structure as a whole. That is, to ensure the whole crate does not deflect more than a specified limit. Deflection of the whole structure is referred generally to as racking.

Stock crates are base restrained. They are strapped to a certified pallet, usually through horizontal members approximately 500mm or more from the base of the crate. While this may provide positive restraint at higher levels within the stock crate it can also restrict the stock crate from returning to its dimensional constraints. Several ground loading staff have commented that doors are sometimes difficult to slide open and close following strapping and during loading. Some of this may be attributed to the racking effect due to what is termed racking loads.

Proper engineering analysis of deflection of the stock crate can indicate where structural members or bracing are inadequate and can also recommend a range of changes required to correct the situation.

For the purpose of best design practice the specification of serviceability limits shall be that:

- deflection as a result of full load to a base restrained stock crate of no more than 38mm
- no permanent deformation of the structure which exceeds 19mm when the load is removed

While not a requirement for uncertified containers, manufacturers may wish to test their stock crate designs (in addition to engineering analysis) to ensure they meet the serviceability criteria above. Although primarily related to the testing of certified ULDs, a good source of information regarding testing procedures can be found in Standard Specification 50/6 in the IATA ULD Technical Manual and ISO 10327 “Aircraft – Certified container for air cargo – Specification and testing”. Due to the load states involved in stock crate design, it is expected that serviceability constraints would be subservient to strength limit state design.

4.2.2.2.2 Stability limit state design

Stability limit state design ensures that a structure will not overturn or become unstable as a result of load or uplift on a structure. This generally relates to wind loads and loads resulting from earthquakes.

In the case of stock crates, stability is not generally considered to be a limiting issue. A stock crate is only fully base restrained when it is loaded and restrained in the cargo bay of an aircraft where there is no requirement to design for high wind loads. Given the serviceability limits and strength to weigh ratios of stock crates it would be expected that a stock crate would not be damaged if it overturned when empty. The same could not be said if it overturned when it was fully loaded; however overturning when fully loaded would likely have a far greater negative impact on the livestock than on the stock crate.

The highest risk of overturning would be during handling manoeuvres. All stock crates must be designed to be lifted and carried while empty with a forklift or crane. Stock crates may also be required to be lifted by forklift when fully loaded. In either case overturning is more a function of the operator in control of the manoeuvre and the equipment used.

It should be noted that the pallet, strapping, netting and restraining systems have far greater capacity than the dead and live loads attributed to the fully loaded stock crate. When fully restrained in an aircraft cargo hold overturning of the stock crate is almost impossible and is therefore ignored in the design calculations.

4.2.2.2.3 Strength limit state design

Failure of a stock crate in service has the possibility of catastrophic consequences. Air transport of live animals can create distress not normally experienced in road transportation and distress can create unusual live load conditions. It is therefore vital that the designer take a conservative approach in designing a stock crate. In addition, there are several load cases to be considered when designing for strength in floors, walls and roofs of stock crates including:

- the dead load of the crate

- the static load of animals loaded into the crate
- the dynamic load of animal movement due to loading, handling and air transport
- the applied load of materials handling equipment in both loaded and unloaded conditions

Members within any structure are subject to forces which generate bending, tension, compression, torsion and bearing stresses. It is the responsibility of the designer to compare the force or stress values calculated through the design process with the capacity of the structural member under consideration.

AS 1720.1 “Timber structures Part 1: Design methods” applies a conservative approach to timber properties through the use of factors, the product of which is applied to the ultimate limit state capacity of the member. These factors include:

- load factors
- capacity factors
- various modification factors such as duration of load, partial seasoning, length of bearing, stability, size and strength sharing

In good design practice, each of the strength limit states (bending, tension, compression, torsion, shear and bearing stress) are calculated in turn to determine whether the structural member will fail in any of these states. The designer should note that not all strength limit states are critical to the design process for every member. AS 1684.1 “Residential timber-framed construction” is a good reference for determining applicable limit states for floor, wall and roof members.

An experienced designer may have already tabulated the strength limit state outcomes for various member sizes in standard positions and loading conditions within the structure so that minor modification of any given design is a relatively simple process.

Other useful software tools based on both the AS 1648 and AS 1720 series’ are available to assist with strength limit state design. These are provided free in some instances to promote the use of various timber products, such as Hyne Design V6[3].

In undertaking strength limit state design, member capacity utilisation of 50 to 75% (or factor of safety of 1.5 to 2.0) is a recommended outcome for stock crate design. Higher capacity utilisation (close to 100%) may result in failure regardless of the modification factors incorporated in engineering calculations.[4]

4.2.2.3 Information which should be provided by the exporter

The following information must be provided by the exporter in order for the stock crate manufacturer to determine the most appropriate dimensions, configuration, contour and special requirements to suit the animals and aircraft on which they will be transported:

- species of animal and requirements for multi-tier stock crates;

[3] Hyne & Son “Hyne Design V6” Hyne & Son Pty Limited, Maryborough Queensland
[4] See definitions in Section 4.2.1.5 for further explanation of terms used.

- average liveweight and expected number of animals per tier (for each tier);
- wither height of each group of animals
- total number of crates required including the pallet positions and any need for contour modification throughout the cargo compartment
- type of aircraft and configuration including details of any transhipping aircraft
- pallet prefix – which provides the type, size and restraint system (see section 4.2.2.5)
- deadline for delivery to port of origin (i.e. 48 hours prior to loading)
- port of origin
- any special design requirements as a result of the port of destination

4.2.2.4 Load capacities of certified ULDs used in conjunction with stock crates

Certified ULDs have designated maximum load capacities detailed in Table 1 below.

Table 1: ULD Maximum Load Capacities

Type of ULD	Ultimate Load (kg)	Ultimate Load (lbs)
Pallet – downward for 224 x 318 cm (88 x 125 in)*	19,220 to 34,280	42,400 to 75,600
Pallet – downward for 244 x 318 cm (96 x 125 in)*	20,810 to 34,680	45,900 to 76,500
Tie down studs and track type tie down receptacles**	900	2000
Strap**	900 to 1700	1980 to 3750
Net**	3700	8160

*See NAS 3610 Table I and Table II for details of other load criteria such as other pallet sizes and the variants of downward, upward, forward and aft ultimate load criteria within a pallet size.
**Minimum Load Capacities defined in ISO 16049-1:2001 Air Cargo equipment – Restraint straps – Part 1: Design criteria and testing methods and ISO 4170:1995 “Air cargo equipment – Interline pallet nets to be used in engineering design calculations.
Note that loads range due to manufacturing design variations within the same sized pallet. In addition strap loads vary due to the use of single or double connectors. The strap itself is designed for the maximum load.

While stock crates could be designed in conjunction with the use of certified ULDs listed above, it has not been common practice to do so. The designer of a stock crate should take account of tie down positions and ensure that they can withstand the full load capacity of the strapping system, i.e. tie down points are not damaged in the process of pre-load tie down by ground handling staff.

Where manufacturers take full account of the tie down system within the design (both straps and nets) it may be argued that lowest cost design could incorporate the strap in particular, as an integral structural member in the design. However, straps are not a fixed length, solid member in the structure and in some cases may increase racking effects. Although they are designed to restrain an uncertified container in transit their practical application cannot be guaranteed in the design process due to the requirement for human interaction.

4.2.2.5 Base dimensions of stock crates

The base of stock crates must conform to the internal dimensions of a standard pallet to be used in the aircraft that is designated to transport the animals. The most common sizes are 224 x 318 cm (88 x 125 in) and 244 x 318 cm (96 x 125 in). As detailed in both NAS 3610 and the IATA ULD Technical Manual, pallets are coded to assist with identification of type, size and owner; therefore the common sizes mentioned above have a generic prefix of PAX and PMX respectively, where P signifies pallet and A and M define the respective pallet sizes. The final alpha code varies and assists to separate different restraint systems in the same pallet size. NAS 3610 contains drawings of the various pallet configurations. The relationship between the pallet codes and NAS 3610 drawings can be found in the IATA ULD Technical Manual Standard Specification 40/1 – Appendix ‘C’ - ID Code – Pallets. For example, PAJ is equivalent to configuration number 2A6 in NAS 3610.

The maximum allowable dimensions of stock crates to be used in conjunction with pallets are restrained by the positioning of the net and strap fixing systems and internal curvatures of the various pallet designs. It is important to completely verify the pallet configurations so that important features such as net fixing points, internal curvatures and required clearances are accounted for. While NAS3610 provides indication of the pallet configurations used throughout the air industry it does not always provide edge distances and internal curvatures to allow the designer to determine the maximum base dimensions of a stock crate.

In general, maximum base dimensions should allow for an internal clearance of **at least 30mm from the centreline of the strap and net fixing device**. As some pallets have “sunken” bases it is recommended that additional pallet configuration advice be sought from ground handling and engineering staff at the various ports of origin. The manufacturer may also need to inspect pallets and take measurements to determine accurate dimensions and configurations.

4.2.2.6 Airframe Contours

The cargo bay of each aircraft has a designated internal shape defined by the internal shape of the airframe and any service requirements. These shapes or contours are listed in the IATA ULD Technical Manual. With the development of new aircraft, new contour information becomes available. The IATA ULD Technical Manual is updated each year to include any newly released information. The contour diagrams include the maximum allowable contours for cargo. In all cases “a minimum of 50mm (2in) clearance must exist between the minimum aircraft contours specified in Chapter 2 of the IATA ULD Technical Manual and the maximum contour of the cargo unless otherwise specified by the appropriate airframe manufacturer”[5].

The exporter must provide details of the aircraft and configuration as required in Section 4.2.2.3 so that the manufacturer can provide externally contoured stock crates which will meet the requirements of the IATA ULD Technical Manual and any aircraft in which the goods will be transported.

The manufacturer should note that contours presented in the IATA ULD Technical Manual represent sections of the cargo compartment that have a **constant cross section**. The position within the cargo bay is often important to the external contour of the stock crate and modification may be required near bulkheads and rearward compartments.

[5] Adapted from IATA ULD Technical Manual, 35th Edition, Chapter 2, Section 2, p 11.

While exporters may generally book space in positions with constant contour cross sections, manufacturers can expect exporters to provide additional detail regarding contour modifications. Alternatively air freight staff at the various ports of origin or, in particular, airline companies are able to provide detail necessary to ensure stock crate contours fit the appropriate positions.

4.2.2.7 Structural ULDs

The term, structural ULD (container) is used in the IATA LARs. IATA define that a container as structural if it is stackable or it is multi-tiered. This means that any multi-tiered stock crate is considered structural.

Stock crates for the transport of larger livestock such as cattle in excess of 300kg are often single tiered and constructed with open tops. In terms of the IATA LARs, these types of containers are not considered structural.

It is recommended that regardless of the definition found in the IATA LARs all stock crates should be considered structural due to the live loads able to be applied during loading and transit. Due to similar levels of live load per tier, the same design methodology should be applied to single tier, open top stock crates as the top tier of multi-deck stock crates.

Stock crates for young cattle, sheep and goats are designed in integrated, two or three tier configurations. Each tier must be capable of supporting the live weight of the animals on that tier and any tiers above it. As a result the structural strength requirements for wall members will be highest in the bottom tier. The total load per tier will vary depending on the average liveweight of the group of animals. In the case of sheep the total liveweight will vary from 960 to 1500 kg. Further detail regarding floor loads (live loads) will be addressed in Section 4.2.2.9.

Not all components of a stock crate need to be considered structural members. Slats and other cladding would not generally be considered structural. Other members such as bearers, joists, studs, top and bottom plates and lintels are all structural members. The designer must nominate the structural and non structural members within a design. All structural members should be noted as such on detailed design drawings.

4.2.2.8 The specifications of structural timbers and plywood

Design principles contained within this document are drawn primarily from the AS 1684 and AS 1720 series' of standards with additional guidance found in SAA HB 108. Due to the reliance on timber strength and load capacities it is deemed necessary to make reference to the various systems of structural timber grading referenced in this document.

Many species have been classified into strength groups through general usage and mechanical testing. Strength groups define species with similar material properties. The "S" series refers to unseasoned timber while "SD" to seasoned. Seasoned timber has lower moisture content, higher density and higher material properties than its unseasoned counterpart. In addition, timber classified as S1 or SD1 will have much higher material properties than timber classified as S6 and SD8.

Timber within a strength group can be further stress graded. Stress grading of structural timber has been carried out for many years using visual techniques found in AS 2082 and AS 2858 for hardwood and softwood respectively. A resultant Structural Grade 1 indicates that the length of timber is relatively free of knots and other inconsistencies and therefore has higher material properties than Structural Grade 4. Table 2 is drawn from SAA HB 108 and provides further detail to assist in understanding the interrelationships between various groupings and grades.

Table 2: Relationship between Strength Groups, Structural Grades (through Visual Stress Grading) and Stress Grades (F Grades).

Strength Group		**Stress Grades**			
		Structural Grade 1	**Structural Grade 2**	**Structural Grade 3**	**Structural Grade 4**
	SD1		F34	F27	F22
	SD2	F34	F27	F22	F17
S1	**SD3**	F27	F22	F17	F14
S2	**SD4**	F22	F17	F14	F11
S3	**SD5**	F17	F14	F11	F8
S4	**SD6**	F14	F11	F8	F7
S5	**SD7**	F11	F8	F7	F5
S6	**SD8**	F8	F7	F5	F4
S7		F7	F5	F4	

The F-Grade designation in Table 2 above is still in current usage. The higher the F-Grade number, the higher the material properties. The typical material for the construction of stock crates is Radiata pine due to its low density. Low density also means low strength which leads it to be classified in strength group S7. You will note that structural grades of this species are limited to the lowest F-Grades (F7 to F4). Tables which detail characteristic properties for F-Graded hardwood and softwood timbers can be found in Table 2.4 in AS 1720.1. F-graded plywood characteristic properties can be found in Table 5.1 in AS 1720.1. These tables provide characteristic properties such as strength limit data used to compare against calculated data to validate the design for strength limit states e.g. bending, tension and compression of members.

There has been considerable research carried out over many years on pine species. As a result other methods of grading have become popular due to higher reliability. Machine Graded Pine (MGP) is now in common use. The MGP system grades pine via mechanical means into three categories MGP15, MGP12 and MGP10. These grades have properties that are similar to but certainly not identical to grades varying from F14 to F5.

The IATA LARs state that timber may be used in the construction of containers for livestock (stock crates). However in Container Requirement 3 of Section 8.3 in the LARs which applies to all species referred to in this document, the following statement can be found regarding the materials of construction “Metal, **hardwood**, fibreglass and polythene sheeting”.

Much of the material used in construction of stock crates in Australia is softwood, particularly Australian pine and plywoods. This practice has now been in place for several years without objection being placed by any air transport company. The specification of only hardwood appears erroneous when the density and resultant additional weight of these materials is taken into account. With good design practice there is no reason why softwoods cannot continue to be successfully used in the design of stock crates.

All plywood supplied in Australia is F-Graded or in grade tested. In contrast manufacturers chose to use significant quantities of non graded pine in the construction of stock crates. This decision is primarily driven by the cost of timber. Pine supplied under the MGP system, which provides reasonable guarantees of soundness, is far more expensive than ungraded “fall down” timber.

Whilst manufacturers may purchase least cost materials they generally are quite selective about the quality of timber used in structural members. Inwards goods inspection is carried out in most manufacturing facilities resulting in some form of visually stress graded timber. Manufacturers are in fact carrying out very similar processes to those found in AS 2858 “Timber – Softwood – Visually stress graded for structural purposes”. It is very likely that visual stress grading is resulting in upgrading lengths of timber destined to be used as structural members to at least F4 grade. At the very least inwards goods inspection is isolating lengths which provide little or no strength for use in non structural positions.

Where a manufacturer is cautious about the quality of a structural member they would generally reinforce that position with other similar timber. It should be pointed out that least cost design and production methodologies do not by necessity infer least cost materials. Least cost materials can have a place but generally only where good design methodology and construction techniques are practiced. Even under least cost manufacturing principles it is always beneficial to consider the use of a higher grade material as opposed to reinforcing with poorer grades. This should be done in light of both weight and cost considerations.

Regardless of grade or structural status, the full specification of all members of a stock crate (size and grade) shall be specified on detailed design drawings.

4.2.2.8.1 Timber and plywood material properties for comparison in limit state design

Where graded timber or plywood has been used within a stock crate, results of limit state design calculations shall be compared with the material properties of the designated grade.

For all non graded timber it is assumed that structural members have been visually graded to a minimum of F4. The material properties of F4 are defined as follows:

Table 3: Material Properties for F4 graded timber

Grade	Characteristic Strength (MPa)				Modulus of Elasticity (MPa)	Modulus of Rigidity (MPa)
	Bending f'_b	Tension f'_t	Shear f'_s	Compression f'_c		
F4	13	6.5	1.5	9.7	6100	410

In order to simplify the design process, the results of all limits state design calculations for structural members shall be compared to F4 graded timber material properties where ungraded Radiata pine has been used in the design. The primary assumption being that the design results should not exceed F4 stress values, therefore retaining some additional capacity over and above F4 graded timber. In practice this can achieved in low grade timber supplies, through good timber selection at inwards goods inspection and additional strengthening (duplication or reinforcement) of structural members where the manufacturer is concerned about the structural strength of particular lengths of timber. Where graded timber is used in particular positions, the properties of the grade of that member will be used in any analysis.

All calculations of limit states will be based on un-reinforced structural members.

4.2.2.9 Flooring specifications

The range of floor loading for various species is listed in Table 4 below.

Table 4: Floor Load Ranges for Applicable Species

Species	**Pallet Size**			
	PAX		**PMX**	
	Minimum floor load (kg)	**Maximum floor load (kg)**	**Minimum floor load (kg)**	**Maximum floor load (kg)**
Sheep	860	1300	960	1400
Goats	1050	1300	1155	1400
Deer	1015	2575	1110	2505
Cattle	1800	2250	1950	3000

Floors will be designed with a series of bearers, joists and flooring to account for the loads indicated above and the uniformly distributed loads detailed in 9.1 for various liveweights per species being transported.

4.2.2.9.1 Design loads for floors

In order to analyse the limits states of a structure the design forces or loads need to be determined. In addition, the position of these loads in important. In designing floors we are interested in both uniformly distributed and concentrated loads. Uniform distribution assumes that weight is evenly distributed across the floor as is the case with the dead weight of the floor itself. The live load of animals is generally considered a uniformly distributed load. Concentrated loads are points where significant load may occur such as the legs of machinery or in this case the transference of significant weight onto a single leg of an animal or groupings of animals.

Possibly the most difficult aspect of specifying timber and plywood for use in the construction of stock crates, is related to the determination of design loads. It is noted that Appendix B in AS 1170.1 makes no mention of concentrated loads for animals (refer to AS 1170.1, Table B1 Other Imposed Actions). As a result information extracted from the Australian Standards for the Export of Livestock Ver. 2.2 (AQIS) has been used to calculate design loads for both uniformly distributed and concentrated loads. This expanded information can be found in 9.1.

AQIS regulations specify stocking densities which provide livestock with both room to move within a stock crate and space for air movement. The ability of stock to move is limited, therefore live loads may still be considered to be uniformly distributed but potentially distributed over a lesser area than the full floor area. Physical observation suggests that livestock are able to temporarily pack more tightly over two thirds of the floor area. Best practice design would suggest that there are several Loading Cases to be analysed as follows:

- Load Case 1: Full load uniformly distributed over two thirds of the floor area closest to the long side;
- Load Case 2: Full load uniformly distributed over two thirds of the floor area closest to the short side; and,
- Load Case 3: Full load uniformly distributed over the central two thirds of the floor;

The Loading Cases above should be utilised in the calculation of different stresses in strength limit state design of floors. It should be noted that for floors, the highest shear stress will result from either Loading Case 1 or 2 and the highest bending stress will result from Loading Case 3.

For the purpose of stock crate design, concentrated loads are generally used in calculating bearing (or punch through) stresses in flooring materials. This is discussed in more detail in the following section. As previously mentioned, concentrated loads have been calculated from data in AQIS regulations. Explanation of the methodology which has been used to calculate concentrated loads can be found in Sections 4.2.2.9.2 and 4.2.2.11.3.

Concentrated loads can also come about as a result of internal posts or partitions which form supporting walls for upper tiers. Where these are used it would be considered best practice to analyse their effect on floor members for bending and bearing and where applicable shear stresses.

The design loads for uniformly distributed loads and extended concentrated loads found in 9.1, are used throughout the remainder of this document to determine specific design features and analyse stress conditions.

In multi-tiered stock crates, the floor loads on the various tiers may be equal except where contours vary on the top layer. The available floor area for stock is reduced where the head room is inadequate and therefore the number of stock on uppermost tiers is generally less than lower tiers. Designers of multi-tiered stock crates may utilise this information to recalculate the uniformly distributed load required to be supported if this leads to reduced materials and cost of manufacture.

4.2.2.9.2 Bearing capacity in flooring using plywood as the primary example

Where plywood is used in flooring systems for the construction of stock crates, the design action for bearing capacity has been determined to be the extended concentrated load found in the species tables detailing species, density and floor load in 9.1. The normalised loads are based on an animal having all four legs in contact with the floor. In practice an animal may place more than half its weight on one leg. This may occur more regularly and to a greater extent during takeoff, landing and during turbulence. As a result extended concentrated loads have been calculated, based on 2.5 times the normalised load. Where significant G forces are encountered it is more likely that animals would collapse than place more than 2.5 times the normalised load on one leg, thus distributing the concentrated load.

The design capacity of plywood in bearing for strength limit state has been calculated using methodology and modification factors found in AS 1720.1:1997, Section 5.4.4 Bearing Strength. The factors used and the results are presented in Table 5 below.

Table 5: Liveweight Bearing Capacity of Plywood

	F-Grades							
Bearing Strength Factors	**F7**	**F8**	**F11**	**F14**	**F17**	**F22**	**F27**	**F34**
Φ^1	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
$\mathbf{k_1}^1$	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
$\mathbf{k_7}^1$	1	1	1	1	1	1	1	1
$\mathbf{k_{19}}^1$	1	1	1	1	1	1	1	1
$\mathbf{g_{19}}^1$	1	1	1	1	1	1	1	1
$\mathbf{f'_p}$**(MPa)**	7.7	9.7	12	15	20	23	27	31
$\mathbf{A_p}$ **(m^2)**	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035	0.00035
$\phi \mathbf{N_p}$ **(kN)**	1.62	2.04	2.52	3.15	4.20	4.83	5.67	6.51
Maximum Liveweight Capacity (kg)	**260**	**330**	**410**	**500**	**680**	**N/A**[2]	**N/A**[2]	**N/A**[2]

1 Capacity and modification factors used in stress analysis of timber members
2 Resultant values exceed the maximum liveweights listed in 9.1

The results obtained in Table 5 indicate that under the circumstances of extended concentrated load, maximum animal liveweight limits should apply. The calculations show that for F7 plywood, the maximum allowable animal liveweight for bearing stress is 260 kg. F7 plywood would be applicable to all sheep and goat shipments but higher grades would be required to support cattle, deer and camelids.

This data may be extended to the use of specific timber species in flooring, however, strength groups and structural grade as detailed in Section 4.2.2.8 must be taken into account. Table 5 above should not be viewed in isolation to the results of strength limit state design of the flooring system. It is more likely that the strength limit state for bending will determine that a higher grade of plywood is required for flooring (refer to Section 4.2.2.2.3).

4.2.2.9.3 External load conditions - Handling by forklift or crane

Designers should be aware that empty and fully loaded crates will be handled by forklifts or cranes at ports of origin, transit or discharge and that the procedures used may differ from those in Australia. Care should be taken in the design process to account for potential damage which may occur at any step in the transportation process. The manufacturer should address handling issues with the exporter and ensure the designer has taken care of any handling issues within the design. Any design must either eliminate the possibility of failure, or at the very least, minimise its adverse effects. Anecdotal evidence suggests that designs which have not taken account of poor handling procedures do lead to failure of floor structures in multi-deck stock crates in particular.

The stock crate designer should place bearers and floor joists to ensure that forklift access is adequately addressed; that is, provide forklift openings on the long side of the base floor of the stock crate and crane lifting points where applicable. In Australia, regulations ensure that forklifts with extended tines are used to move over-depth stock crates. Stock Crates designed for both PAX and PMX pallets are too deep for standard forklifts tines. A standard tine will only extend approximately 1m into the side of the stock crate. An extended tine will generally reach to a minimum or 1.6m. There is no guarantee that materials handling equipment and procedures in other countries address the safety issue.

It is recommended that designers make careful consideration of the placement of floor joists to ensure materials handling equipment does not damage the stock crate and result in injury or escape of livestock. As a minimum, designers should specify at least two floor joists in each side of the base or upper deck floor spaced no more than 900mm (centre to centre) apart to allow a standard forklift tine to adequately lift an empty stock crate without damage even though safety regulations should restrict the load being carried in this condition. Lifting points should be adequately marked with “LIFT POINT” or similar.

Another issue mentioned in discussions with industry participants is the practice of skidding loads across handling areas. This has been observed in destination ports where forklifts fitted with standard tines are used. The skidding of empty stock crates reduces the danger of overturning but can do considerable damage to the stock crate. The manufacturer may consider bearer or joist edge protection if made aware of the potential for this practice and the designer should address the additional loads in the design of the base floor.

While handling systems in Australia generally exclude lifting stock crates while fully loaded there are instances where crates are delivered already loaded by truck. Fork lift operators are required to lift fully loaded stock crates and place them onto aircraft pallets for strapping and netting. **Where it is known that a stock crate is to be lifted fully loaded the base floor or an appropriately marked upper floor must be designed to be capable of supporting the maximum gross weight of the stock crate**. See Section 4.2.2.9.6 for methods of achieving increased floor capacity.

The designer shall not rely on handling staff lifting stock crates only from the base floor. There are several examples of second and third tier floors failing due to being lifted by forklift while full. Where this is a known practice the designer should make provision in the design of upper floors for lifting points. Where a low cost design does not address this issue, the floor and walls may require strengthening and duplicating specific structural members such as upper bearers and floor joists may adequately resolve this issue.

Where a designated stock crate floor is designed to be lifted fully loaded it will generally have a load capacity in excess of the maximum gross weight.

In any event it is recommended that the manufacture mark areas of the stock crate to identify “LIFT POINT” and “NO-LIFT POINT” in an attempt to safeguard the structure from inappropriate handling procedures. Where a stock crate is not designed to be lifted fully loaded from any level it should be appropriately marked with the words “DO NOT LIFT FULLY LOADED”

4.2.2.9.4 Strength limit states design

Bearers and floor joists shall be designed for the strength limit states of:

- bending
- shear
- bearing

As a result of the discussion in Section 4.2.2.9.2, bearing capacity of properly supported plywood flooring is unlikely to be the constraining strength limit state; however, plywood flooring may fail in bending. Therefore, all flooring material (whether plywood or slats), shall be designed principally for the strength limit state of bending.

All base floor component design shall incorporate the live and dead loads associated with handling a fully loaded stock crate by forklift **where specified by the exporter** as discussed in Section 4.2.2.9.3. Where specified by the exporter, mid tier floors will also be designed to be handled by forklift at this level in a fully loaded condition. See Section 4.2.2.9.6 for a more in depth discussion on floor construction. The manufacturer should specifically enquire about handling procedures during the ordering process to ensure that this design criterion is catered for. For design purposes, lifting points must be notated on drawings. It is also recommended that all nominated lifting points be identified (marked) on the finished stock crate.

4.2.2.9.5 Serviceability limit state design

The base floor of the stock crate in service is additionally supported by the pallet and the floor of the aircraft. As a result, deflection of the base floor during transit is unlikely to create an issue to the safety of the structure. Other loading conditions such as the upward force of forklift tines during handling manoeuvres may have a far greater impact on the serviceability (deflection) of floors within the structure.

If the previously defined maximum deflection limit of 38mm is applied to base or upper floors in a stock crate it will undoubtedly not be the constraining factor in floor design. Limits of deflection applying to residential timber-framed construction for floors can be found in Table 4.2.8 in AS 1648.1:1999 “Limits of deflection”. This table will yield much lower absolute values for the purpose of comparison i.e. **9mm maximum floor deflection.** A stock crate is not subject to deflection limits in AS1684.1 but it is recommended that the designer take this limit into account in the design process particularly in regard to the effect significant deflection of the floor(s) may have on other structural members within the stock crate.

4.2.2.9.6 Floor construction

The majority of crate manufactures limit their floor designs to a cladding and bearer construction spanning the shorter pallet dimension. This is generally adequate for bearing and bending capacity for both dead and live loads in a downward direction. In addition, nailed joints in cladding materials adequately support the downward load. The primary concern is the likely damage which can result from stock crates being lifted when both empty and loaded as alluded to in Sections 4.2.2.9.3 and 4.2.2.9.4 above. While some manufacturers have attempted to improve the capacity of the floor they have done so by increasing the thickness or load capacities of the cladding material which may not be the most efficient design nor the most economic way to achieve the desired improvement.

The full load lifting capacity of floors (during materials handling manoeuvres) is often not adequately considered in the design phase. Where designers need to account for this load condition they can achieve dramatic improvements in load capacity (in excess of 100%) if they consider a combination of the following changes to designs:

- Altering cladding layout to span the longer dimension of the pallet to fully utilise the stiffness capacity of the material.
- Modifying joint positions and fastening procedures to utilise the full capacity of the system e.g. shifting cladding joints away from lifting positions and reverting to vertical nailing in flooring to fully utilise withdrawal capacity.
- The addition of joists spanning the long dimension rather than simply bearers across the short span of the pallet to improve load sharing of floor components.
- Limit the spacing of (long span) floor joists to increase load sharing.

To incorporate the above changes, designers may need to decrease bearer heights or, where no bearers are used, to modify the construction of long span floor joists to incorporate lift access points. In the latter case, cut-in areas in the base of floor joists may require additional support such as nail or bolt plates.

4.2.2.10 Ventilation

The following information has been extracted and adapted from both the IATA LARs and the Terrestrial Animal Health Standards (TAHS).

- There are no requirements for an open top stock crates (see other guidelines following).
- The design should ensure there is no ventilation dead (still-air) space within the stock crate.
- Ventilation openings must be provided and distributed over all four sides. For each tier, two sides may have a reduced ventilation capacity provided the overall open area is maintained.
- The openings in the walls and roof must be equivalent to not less than 20% of the floor area per tier for all stock.
- For cattle the openings in the walls and roof must be equivalent to not less than 33% of the floor area per tier.
- For sheep (and pigs) the openings in the walls and roof must be equivalent to not less than 40% of the floor area per tier.
- When holes and slots are used for ventilation purposes, attention must be given to allow noxious gases such as CO_2 to be able to escape from the stock crate. Therefore openings must be provided in the lower half of the four walls, as well as higher up and on each and every tier.
- The maximum height of any opening for cattle shall be 13cm. This maximum opening height should be reduced according to the species (see Table 6 below) so that it cannot cause injury to feet.
- Internal floor supports and partitions must not restrict air flow through the stock crate.

The following (similar) constraints found in the Terrestrial Animal Health Standards “Guidelines for transport of animals by air” and the IATA LARs conflict with the practice of many stock crate manufacturers in regard to solid walls and although not a requirement, should be considered in any attempt to improve animal health issues during air transportation:

- All stock crates should have a sufficiently large ventilation opening at a height of 25 to 30cm above floor level on all four sides to allow for circulation.
- For cattle the stock crate should have one ventilation opening 20-25cm above the floor limited in width so it cannot cause injury to the feet.

Additional support in regard to the necessity for mostly solid walls can be found in Section 4.2.2.11.2.

Maximum opening heights recommended above relate to areas of walls where injury to feet may occur but should be extended to higher levels to eliminate the ability of animals to place their head outside of the stock crate. The TAHS guidelines do not provide definitive openings for other animals so a more comprehensive list of openings is recommended in Table 6 below.

Table 6: Maximum Openings by Species

Species	Maximum Opening (cm)	Minimum Open Area as a % of floor area (for each tier) TAHS/Recommended
Cattle	13	33%
Camelids	11	20% / 33%
Deer	10	20% / 33%
Sheep	8	40%
Goats	8	20% / 40%

It should be noted that Section 4.2.2.11.2 specifies a partial solid wall according to species in order that effluent is retained in the crate. This may obviate some of the opening requirements at levels below the urination height of the species.

4.2.2.11 Wall specifications

Walls may be formed of any combination of posts, load bearing and non load bearing wall studs, load bearing and non load bearing wall plates and cladding. Load bearing members are only required in multi-tier stock crates.

In the case of stock crates, cladding has a far higher requirement for specification in the design process than in residential timber-frame construction. The walls of a stock crate may receive impacts from animals which have the possibility of exceeding bearing capacity of the cladding material. A discussion of bearing strength for plywood can be found in Section 4.2.2.11.3. The use of other timber members are analysed in Sections 4.2.2.11.4 and 4.2.2.11.5.

The designer shall incorporate cross members and/or corner bracing into the design of all stock crates to reduce the incidence of racking. The use of plywood panels would meet this criterion where the specification of the plywood provides for adequate bracing in the design. Corner bracing may also be provided by additional timber supports or metal brackets.

4.2.2.11.1 Design loads for walls

Table II in NAS 3610 provides a guide to the relationship between directional load capacities of pallets. In 24 out of 32 load conditions the relationship can be described as follows:

Table 7: Summary of load ratios

Load Direction	Load ratio (fraction of downward load)
Forward	0.25-0.30
Aft	0.25-0.30
Side	0.20-0.30
Up	~0.50
Down	1.0

Adapted from NAS 3610:1990, Table II

Load conditions for PAX and PMX pallets fall within the load ratio's listed above. The side, forward and aft load conditions appear to be limited to 30% of the downward load. Considering the ability of live animals to shift their weight during take-off, landing and flight manoeuvres it is reasonable to consider that much of the weight on each tier could be transferred to the walls. The IATA ULD Technical Manual (Standard Specification 50/6 – Air/Surface (Intermodal) Container) and ISO 10327 define the test condition as the net load (live load) of the ULD (stock crate) applied against the wall.

The designer shall therefore use the total live load of each tier applied at mid-wall height. This load should be considered uniformly distributed along the length of the wall (at the mid-wall height) in calculations for lateral deformation and bending. In addition to the horizontal weight of shifting animals the designer must allow for the live and dead loads from upper tiers and the wall itself. Combined loads may severely affect structural members in walls, and engineering design calculations must be carried out to ensure the structural wall members will not fail. For walls, the highest buckling stress will result from the live load transferred to walls from upper tiers in Loading Cases 2 and 3 in Section 4.2.2.9.1 on top of existing dead loads of the structure itself.

4.2.2.11.2 Wall height

The total height of the wall shall be:

- 10cm above the head in normal resting position for sheep and goats; and,
- 20cm above the head in normal resting position for deer and cattle.

Solid walls conflict with other requirements for animal health; however in practice solid walls are used. An excerpt from the IATA LARs makes the following comment,

"Solid up to a height that will prevent the escape of urine depending on the species and sex of the animals being carried. Above this height louvered or slatted sides are suitable but they must be constructed in such a manner that the animals cannot harm themselves and excreta cannot escape".

This may be interpreted to mean that walls shall be solid up to 25cm (see Section 4.2.2.10) and may be slatted above this height provided there is adequate containment at the normal height of urination and defecation.

This document does not restrict nor recommend the use of solid plywood walls but in any event solid walls should not exceed the height of the animals head in normal resting position. The designer should be mindful of comments regarding ventilation in Section 4.2.2.10.

Regardless of any conflict, it has been determined by industry participants that walls shall have a solid "wither panel" in all designs to redirect urine and manure to the floor of the stock crate. Table 8 below details the requirements adapted from comments by industry participants as at August 2009. The top of the panel should be positioned to match the wither height of the animal and its position will therefore vary with the age of the animal being transported. The requirement for solid panels in walls does not restrict the use of solid walls from the floor to the wither height of the animal being transported.

Table 8: Solid Wall heights for various species

Species	Minimum Solid Wither Panel (cm)	Average Mature Wither Height (cm)	Recommended Top Position of Panel (cm)[1]
Alpaca	50	90	Not defined
Llama	50	110	Not defined
Camel	50	170	Not defined
Cattle	60	150	130[2]
Deer	40	110	Not defined
Sheep	40	80	Not defined
Goats	40	90	Not defined

1 While the correct height of the top of the wither panel can be easily audited at the point of loading, it is advised that the Exporter should discuss the panel height with the Manufacturer before construction is completed to reduce incidents of non compliance at loading.
2 The recommended height will generally be lower than the mature height as most often animals are transported at a lower age.

Table 8 above does not alter the requirement to place a solid wall up to 25cm to contain effluent at floor level but does allow for some ventilation to occur between 25cm and the bottom of the wither panel.

4.2.2.11.3 Bearing capacity in plywood walls

The variation in liveweight data shown in Table 5 is primarily applicable to deer or cattle. Cattle in particular have a tendency to strike out if disturbed. As an estimate of the force which can be applied to walls, it would be considered appropriate to use the data as presented when specifying materials for wall construction where bearing capacity needs to be considered.

"The concentrated load has been applied over an area of $350mm^2$ for the calculation of punching and crushing forces" (Note 1 of Table B1 in AS 1170.1). This may be somewhat less than the total hoof area of older animals of various species but does provide a good basis for comparison. It also accounts for instantaneous loads from the tips of hooves, generally over-estimating the effect.

4.2.2.11.4 Strength limit states design

Calculations for strength limit states shall use floor live loads defined in Sections 4.2.2.9.1 and 4.2.2.11.1.

Upper tiers must transfer load to the walls and the progressive load increases in the walls of lower floors must be accounted for in design calculations.

Internal floor supports may be used in conjunction with load transfer to the walls but these must also be accounted for in design calculations.

Posts shall be designed for the strength limit states of:

- tension
- compression

Load bearing wall studs shall be designed for the strength limit states of:

- tension
- compression
- bending

Wall plates for load bearing walls shall be designed for the strength limit states of:

- minor axis bending
- shear

Wall cladding (or slats) shall be designed for the strength limit states of:

- bending;
- shear
- bearing (refer to Section 4.2.2.11.3).

4.2.2.11.5 Serviceability limit state design

The absolute deflection limit of the completed structure is defined in Section 4.2.2.2.1 as 38mm. This limit takes into account deflection of wall members and joint (corner) stability. In all cases this limit is higher than that allowed for any member in AS 1684.1.

This level of flexibility allows the designer to rely on strength limit state design for the wall structures. The issue of deflection should not be unnecessarily confused with instability or failure. Failure in this case may occur but generally only if strength limit states are exceeded. Deflection may be a more significant issue as a result of failure of fastening systems and joint structures which is discussed in sections 4.2.2.14 and 4.2.2.15.

Due to the relaxed deflection limits, non structural member sizes may be reduced. In turn the capacity of the structure will generally be reduced. The designer must therefore use good engineering principles to ensure the structure remains both strong and serviceable.

Reducing the size and possibly the number of members and cladding will require the analysis of lateral deformation of load bearing wall studs and deflection due to bending of members and cladding materials.

Any calculations for serviceability limit state shall use live loads defined in Sections 4.2.2.9.1 and 4.2.2.11.1.

4.2.2.12 Doors

Doors may be open or solid but they are part of the wall structure and must therefore be designed to meet the same strength and serviceability criteria as walls (see Section 4.2.2.11).

In addition doors shall be designed to take account of the following loading procedures:

- must be able to be slid or placed into the closed position easily by loading staff without obstruction
- must have secure fastenings that can be opened and closed easily
- must not create safety issues for loading staff
- must allow access to animals (on each tier) during transit where government regulations require it

Where doors are designed to slide in relatively closely contained restraints, racking can cause significant problems particularly if straps restrict the ability of the structure to return to its dimensional constraints after deflection. It is therefore important that the side of the stock crate containing the door is either corner braced or has some form of cross member support.

Designers should note the safety concerns of transport operators and loading staff regarding the opening and closing doors at height. This is an issue of particular concern in multi-tiered stock crates where operators may climb above two metres in order to open or close doors. Horizontal sliding doors are difficult to reach when loading is complete due to the proximity of transportation vehicles. Vertical sliding doors create additional problems in loading by obstructing entry to upper tiers. Doors which slide through to the outside of the crate may assist the closing operation but still create height safety issues at upper tier levels. Sliding doors are not the only mechanism available; however the “placement” of doors in any case still creates safety concerns.

Top plates at doorways are of particular concern. There are many instances of damage to top plates from livestock during loading. Designers must take account of the dynamic load of an animal, particularly cattle, striking the top plate at speed when exiting the truck. Load calculations on top plates are generally carried out in a vertical direction, the top plate in this instance should be designed in bending as a result of a horizontal impact load. The load to be used in the calculation shall be two and a half times (2.5) the average liveweight of the animals being loaded.

The resultant stress may restrict the use of ungraded softwood timber in this position. The alternatives are to duplicate the member for additional strength, use structural grade softwood, replace softwood with an ungraded or graded hardwood or use another material such as structural RHS (steel). In any case the manufacturer should not use a poor quality softwood member in this position.

4.2.2.13 Roof specifications

While open top stock crates are manufactured they are generally used for the air transport of large livestock such as cattle over 300kg. Multi-tiered stock crates provide a better use of expensive floor space on aircraft. Smaller livestock such as goats and sheep are transported in triple-tiered stock crates in which the upper tier is contoured to fit the airframe. It is considered best practice that all multi-tiered stock crates be fitted with roofs. Where roofs are required the height will be as specified for walls in Section 4.2.2.11.2.

4.2.2.13.1 Strength limit states design

In Table 7 above the roof load ratio is defined as 0.5 times (50% of) the downward load. Only animals on the top tier of a multi-tiered stock crate will have any effect on the roof structure. As previous discussed in Section 4.2.2.9.1, the available floor area and therefore the load is reduced by contours affecting head space. Standard Specification 50/6 of the IATA ULD Technical Manual specifies that container shall be capable of withstand 100% of the net load applied to the weakest part of the roof (the central area). The IATA standard is somewhat more onerous and is the same test condition found in ISO 10327 for certified containers. Given that the stock crate is an uncertified container used in conjunction with a certified net, it would appear satisfactory to relax this design load specification to a lower standard of 50% of the resultant upper tier live load uniformly distributed over the non contoured area of the roof.

Ceiling joists (or slats) shall be designed for the strength limit state of:

- bending
- shear (adjacent to the external joints)

Roof cladding (or slats) shall be designed for the strength limit state of:

- bending
- shear (adjacent to the ceiling joists)

4.2.2.13.2 Serviceability limit state design

As in Section 4.2.2.11.5, the absolute deflection limit of the completed structure is defined in Section 4.2.2.2.1 as 38mm. This limit also applies to the roof structure. Members designed to satisfy strength limit states may ensure that this deflection limit is not exceeded but it would be wise to calculate the total deflection to verify that the roof itself meets the serviceability criteria.

4.2.2.14 Fastening systems

AS 1649 defines fasteners into four groups:

- Category A — Nails, staples and screws — Tension (withdrawal) and shear
- Category B — Fasteners acting as dowels — Shear only
- Category C — Gussets and splice plates — Tension, compression and shear
- Category D — Brackets — Tension, compression and shear

AS 1720.1:1997, Section 4 provides withdrawal and shear capacities for both nails and screws in various timber joint groups. Joints groups are a convenient way of summarising timber characteristics and operate in a similar manner to strength groups. Joint Group classifications for various timber species can be found in AS 1720.2: 2006 Table 1. As an example, unseasoned Radiata Pine has a J4 joint group classification which provides a shear capacity of 575 N for a 3.15 mm nail and a withdrawal capacity (in tension) of 14 N per mm of penetration for a 3.15 mm nail.

The designer shall compare withdrawal and shear capacities for the manufacturer's preferred fastening systems with the forces resulting from the structures dead load and the live load data found in 9.1 and dead load estimates for floors, walls and roofs above, to ensure that the capacity of fastening systems are not exceeded. The collective capacity of fastening systems is the sum of the individual capacities of each of the fasteners. However the manufacturer must ensure that fasteners, neither individually nor collectively weaken structural members during construction.

AS 1720.1:1997, Section 4 provides minimum spacing, edge and end distances for nails and screws which will help eliminate timber splitting and other negative interactions between individual fasteners. To further minimise splitting in more dense and drier timbers it is recommend to pre-bore nail and screw holes to 80% of the shank diameter.

To assist the designer further, Forest and Wood Products Australia have produced two documents entitled Timber Joint Design 2 & 3 which will assist in both design and construction methods for fastening systems. These documents are available at www.timber.org.au.

Where a designer makes use of new materials such as serrated nails, advice on withdrawal and shear capacity in various joint groups and plywood should be sort from the manufacturer. The withdrawal capacity of serrated nails lies between plain shank steel nails and screws.

Other than for screw heads and bolted joints (Category B fasteners) fasteners shall not protrude from the timber members within the structure.

4.2.2.15 Joints and joint structures

In general all materials should be continuous for the full span. Where cladding or slats are required to be joined, the joint shall either be fully supported by another structural member or be joined in a manner that the join is stronger than the base material in shear. The latter can be achieved by the use of Category C fasteners such as nail plates (see AS 4446-1999 Manufacture of nail plate-joined timber products)

Cladding or slats joined over another structural member must be nailed or screwed in place in accordance with fastening system guidelines in Section 4.2.2.14.

The strength of wall joints shall be greater than that of the wall structure. It is recommended that wall joints be designed in both tension (withdrawal) and shear (Type 1 and Type 2 Joints – AS 1720.1) where possible. Strong wall joints will ensure that total deflection of the structure is maintained below the serviceability limit of 38mm.

The use of metal brackets (Category D fasteners) to strengthen wall joints is allowable. There is no restriction on the use of steel in the construction of stock crates; however, steel has significant weight considerations so its use will likely be restricted to nail plates, brackets and special structural members.

Since live load forces apply from the inside, stronger joints are achieved where cladding or slats are fixed to the inside of the structural members. This will reduce the reliance on the withdrawal capacity of Category A fasteners.

Where the designer intends to place cladding or slats to the outside of structural members of walls, the capacity of the joints and fastening systems should be compared to the extended concentrated loads found in 9.1 to ensure the joints and fastening systems will not fail in service.

4.2.2.15.1 Serviceability limit state design

Racking of the structure is a design consideration. As detailed in Section 4.2.2.2.1 the serviceability limits of the structure are:

- Deflection as a result of full load to a base restrained stock crate of no more than 38mm.
- No permanent deformation of the structure which exceeds 19mm when the load is removed.

Whilst the collective deflection due to bending of structural members can be estimated, the strength of joints must not be exceeded otherwise permanent racking will result. Load conditions for the structure as a whole should be investigated to ensure the structure remains within the maximum deflection limit and that collective fastening systems shear and withdrawal forces are not exceeded.

The primary load case occurs where all horizontal tier loads are applied at their respective heights to one wall of the structure at the same time, as would be the case during takeoff, landing and during a very steeply banking flight manoeuvre. This effect of this load case should be investigated on both the long and short sides of the structure.

When design calculations indicate that the joint structures have sufficient capacity in excess of the design loads (sufficient capacity is recommended as 2.5 times the stress on the joint structure), the joint structures may be considered as fixed. In this case the deflection of the combined structure in bending shall be calculated. The resultant deflection shall be below the serviceability limit.

4.2.3 Other non-structural design considerations

4.2.3.1 Livestock injury

The designer shall eliminate the necessity for any internal protrusions in a stock crate so that there is little possibility of injury to the livestock.

Openings for ventilation shall be positioned and sized to restrict the ability of animals to place appendages through the gaps. This includes walls and roofs in enclosed stock crates.

Following manufacture, there shall be no protruding fasteners inside the stock crate. This includes nails, screws, bolts, plates and brackets. Where internal fasteners are required in the design they shall be flush with the surface and have no sharp edges.

4.2.3.2 Effluent containment

IATA LARs state that "the floor of each tier shall be solid and leak-proof. Polyethylene sheet may be used as a leak proof barrier. Footholds and rubber bedding appropriate to the species must be provided".

In addition "effluent must not be able to leak between tiers. In the event that a leak occurs from an upper tier any effluent must be collected by the next tier".

The most common method of achieving the above is to staple a polyethylene sheet to each of the floors which continues up the side wall (either inside of outside the crate) to a height of approximately 25 cm. In addition, an absorbent material made up of carpet underlay and carpet is laid on top and also stapled to the floor. It is recommended that the absorbent material also extend up the side wall to a height of 25cm in order to protect the polyethylene sheet from being pierced and to ensure the lining is not dislodged by animals during transport**.** This method appears to provide adequate foothold for animals as there is little or no complaint from the air cargo industry. **This is the recommended practice in this document.**

The IATA LARs also state that, "strong polyethylene sheeting or similar shall be placed between aircraft pallet and container. The sheeting must extend approximately 25 cm (10 in) up the sides of the container, endeavouring not to occlude the ventilation openings". This final effluent capture system is applied by ground handling staff at the port of origin. Some exporters specify an optional fitted tarpaulin in an attempt to make this final feature more effective. The fitting of external systems is a secondary capture system. It appears to be necessary only because the primary system fails to contain effluent within the stock crate.

Where complaint has been received it appears to relate to the failure of internal effluent containment systems. In some cases the internal absorbent material and plastic lining have either come away from, or been scraped away from, the floor of the stock crate. In any event the manufacturer must ensure that the lining survives the period of transport, this may include additional stapling, larger staples or improved fastening systems. This negates much of the needs for the secondary containment system.

In addition to floor containment, there is specific concern from the aircraft industry in regard to effluent escaping at height during urination and defecation through openings in the side wall. Section 4.2.2.11.2 provides recommendations to designers to restrict or eliminate escape of effluent at height by placing solid barriers on side walls. **This is a recommended practice in this document.**

4.2.3.3 Timber phytosanitary specifications

All timber used in the production of stock crates shall meet the International Standards for Phytosanitary Measures – Guidelines for Regulating Wood Packaging Material in International Trade (ISPM 15). Debarked timber shall undergo heat treatment and methyl bromide fumigation as directed by AQIS for any transit ports and the destination port.

Treatment shall be carried out by an AQIS certified timber treatment provider. Appropriate markings shall be applied to the stock crate to indicate the timber treatments undertaken. These markings shall include where necessary; DB, HT and MB and the certification number of the treatment facility in two prominent locations on the outside of the crate.

Further detail regarding certification can be found in:

Australian Quarantine and Inspection Services, (2006), *Australian Wood Packaging Certification Scheme.* Department of Agriculture, Fisheries and Forestry, Canberra.

4.2.3.4 Labelling and markings

4.2.3.4.1 Manufacturers' labels and markings

A combination of AQIS and IATA regulations together with the need for good record keeping either require or endorse the following markings on all stock crates:

- name and address of the manufacturer
- tare weight
- maximum gross weight
- serial number or date of manufacture or both to ensure full stock crate traceability;
- iata live animal label (see iata lars section 9.3.2.1)
- iata directional label (see iata lars section 9.3.2.2)
- ispm-15 markings for treatment as appropriate to the transit port and the port of destination

In addition to the above markings it is recommended that, following certification of the manufacturer, the stock crate be marked with:

- The manufacturer's certification number displayed in the lower right hand corner of one side of the stock crate.

In practice, manufacturer's details, weights, serial numbers and IATA label are generally absent for the markings on stock crates. It is recommended that all marking be included. The manufacturer and serial number markings ensure traceability in the event of failure while the weight markings provide valuable information to the exporter, ground handling staff and AQIS. IATA labelling appears to be superfluous given the nature of the livestock involved and the obvious orientation of the stock crates. ISPM markings are a strict requirement.

4.2.3.4.2 Suggested exporters labels and markings

At the port of origin the IATA regulations require the exporter to add the following details:

- full name and address of the exporter
- full name and address of the consignee including 24 hour contact
- full scientific name of the animals
- quantity of animals
- flight number
- time and date of departure

In practice not all of these marking are applied. This may be the result of improved record keeping on the part of exporters, AQIS and air cargo companies. Since these are applied after despatch of the stock crate from the manufacturer’s facility they do not form part of the requirements of this document.

4.2.3.4.3 Other Recommended Markings

- road transportation strapping indicators
- certified strap tie down points
- forklift and crane lifting points
- no lift markings (or positive exclusion zones)

4.3 Development of recommendations for a regulatory system

4.3.1 Background

Regulation is a function generally carried out by government or semi-government bodies. Regulations are developed to ensure the operation of a law is controlled and applied consistently. Governments will delegate the responsibility of regulation to various departments under their control. In the case of livestock export, regulation is carried out by the Australian Quarantine Inspection Service (AQIS).

AQIS are generally concerned with bio-security. One of their main purposes is to assure the quality of products leaving Australia. As are many other products, livestock exports are regulated and scrutinised by officers of AQIS in various locations throughout Australia.

The key focus of AQIS, in regard to livestock export, is animal health and wellbeing, such that animals arrive at their destination without disease and with the minimum of stress. As such, AQIS has developed standards for the export of livestock which provide for inspection and a level of protection of the animals in transit (see *Australian Standards for the Export of Livestock Version 2.2)*. In the export of livestock, AQIS primarily has a veterinary role. It does not generally concern itself with mechanical safety unless it has a direct effect on the safety of food or animals as is the case in livestock transport. Where there is a significant threat, for example in food safety, AQIS will instigate quality assurance measures.

The key process utilised in quality assurance is the development of a Hazard Analysis and Critical Control Point (HACCP) plan. The principles and development of a plan is detailed more thoroughly in 9.2. HACCP plans are essential in food production for export and for domestic consumption. However, they are not as prevalent in the supply chain.

While AQIS are concerned with food and animal quality and safety, it is not their only focus. Of note to livestock export by air, they also regulate the export of timber products to ensure they meet the bio-security requirements of the transit and destination countries. AQIS therefore regulate facilities which provide services to ensure timber products meet ISPM standards.

Failure of stock crates in operation, generate significant danger to animal health and human safety. As a result, it would not seem unreasonable to suggest that while AQIS regulate the supply of timber products for export and the shipment of animals in stock crates produced from those timber products that they also be responsible for regulating the design and construction of the stock crates. In contrast, AQIS has primarily a bio-security function. There are few if any instances where this function extends to an engineering capacity. While AQIS determine some criteria in many export products they are limited to the interactions with bio-security measures.

Stock crates are an engineered product. Generally, there are adequate published standards available to ensure that engineered products are designed in a safe manner. In addition, other systems of quality assurance have been developed to assure the general public that a product meets the required standards. The primary examples are AS 9001 and 2 Third Party Accreditation and the Standards Mark system. These systems are quite onerous, expensive to maintain and require some political or legal intervention to instigate. While these avenues may be available, the cost involved would effectively restrict the growth of the livestock air freight industry. The manufacture of stock crates is a least cost operation. In order to ensure its survival, a least cost but effective system of regulation is required. The primary delivery of this mechanism should commence through industry self regulation. Additional processes and regulation are usually only sort where industry self regulation fails.

4.3.2 Quality assurance delivery through industry self regulation

Quality can be defined in many ways. In the supply and operation of stock crates, quality can be defined as structural integrity, good animal health measures and effective bio-security. A review of general failure issues in Section 4.1 clearly indicates that there are two mechanisms required to assure quality in the delivery and operation of stock crates for transportation of livestock by air:

- Quality Assurance in design; and,
- Quality Assurance in construction.

4.3.2.1 Quality assurance in design

The basic premise of this research project was to develop a best practice design document which drew together specifications, standards and methodology existing in many locations. This document (in Section 4.2 and 9.1) details the recommended minimum (and sometimes maximum) specifications, standards and methodology as well as guidance on how to apply these to stock crate design.

It is a recommendation of this report that stock crate designs be **Certified** by a **Competent Person**. In light of the best practice methodology presented a competent person is one who has had professional training in engineering design practices. Self regulation mechanisms would lead us to believe that a manufacturer could utilise the services of an engineer either internal or external to the company. Where considered appropriate and more cost effective, it may be that the engineering certification services be supplied by one organisation appointed by the **Regulating Body**.

The certification process would utilise the best practice methodology to validate that the stock crate design meets the minimum specifications presented in the best practice design document. A **Competent Person** would then provide the **Regulating Body** with a short written report in support of the design.

4.3.2.2 Quality assurance in construction

While good design is vital to ensure structural integrity, it is also vital that the construction process carries the design to a finished product. As a result of the importance of this part of the process it is recommended that the stock crate manufacturing industry instigate HACCP plans as a basis of their quality assurance programs. HACCP plans identify hazards, prioritise them and designate critical points throughout the process where actions can be controlled to achieve appropriate outcomes.

There are several processes in each manufacturing operation. Only some of them are critical to the final product. Of particular note is inwards goods inspection. Section 4.2.2.8 describes how timber selection is vital to ensuring the construction has the desired structural integrity. Other points in the process may ensure that the constructed stock crate physically matches the design. Manufacturers are able to define other critical parts of their respective processes. Some generic suggestions are listed below:

- inward goods inspection/material selection
- floor construction
- wall construction
- floor installation
- roof construction
- post production inspection
- loading for delivery

A basic HACCP plan has been provided in 9.2 as an example which relates directly to the construction of stock crates which should assist a manufacturer in developing a new plan or reviewing their existing control procedures.

Following the development of a HACCP plan, the manufacturer should generate **Standard Operating Procedures** (SOP) and **Work Instructions** necessary to control hazards identified within the process. The SOPs and Work Instructions should be presented as simply as possible while still maintaining effective control of the outcome. An SOP provides an overview of the process indicating how certain tasks are linked. A **Work Instruction** is more detailed but may be as simple as a **Routing Sheet, Jigging Layout** or **Process Check-sheet**. This collection of documents would be referred to as the **Manufacturing QA Manual.** In most cases much of this documentation already exists and possibly only needs to be collated in an appropriate manner. Where written information is absent, it is often simply a matter of putting in writing, the current verbal mechanisms in operation.

Manufacturers would be expected to assure the quality of the goods that they have manufactured. It would be expected that the goods are made in accordance with a certified design and are suitable for their intended purpose. It is therefore vital that manufacturers carry out finished goods or post production inspection and document their findings.

4.3.2.3 Self regulating process

Despite assuring quality in both design and construction the industry needs to ensure that the industry regulator, AQIS, can have confidence that participants in the process can competently meet their respective commitments.

AQIS regulate the issue of export licences to various entities and individuals. Attached to these licences are enforceable conditions which provide AQIS with the ability to withdraw and in some cases, cancel these licences. It is recommended that AQIS consider additional conditions on export licences which ensure that industry self regulation works. In order to determine the nature of these conditions it is appropriate to detail the recommended process of certification and self regulation.

Regulation of the livestock air crate manufacturing industry in Australia should be based on a two part process:

- registration of qualified manufacturers
- certification and registration of new and existing designs

It is recommended that responsibility for regulation of the livestock air crate manufacturing industry in Australia be vested with the **Australian Live Export Council** (ALEC), who report to the Commonwealth government regulator, **Australian Quarantine and Inspection Service** (AQIS). ALEC would be referred to as the **Regulating Body**.

The **Regulating Body** may delegate the responsibility of maintaining a register of qualified manufacturers and certified designs to an industry group such as LiveCorp or an industry association. However it is important that reporting to and feedback from AQIS is as direct as possible. The delegated party would be referred to as the **Registrar**.

4.3.2.3.1 Registration of Qualified Manufacturers

It is appropriate that manufacturers may be qualified and registered in the absence of certified designs particularly where stock crates are manufactured under licence or contract to the owner of the designs. The following process is recommended for qualification of manufacturers:

- All livestock air crate manufacturers wishing to become registered would need to nominate a **QA Manager**. This person would not necessarily need building or engineering qualifications, but must have a minimum of 5 years demonstrable experience in a similar supervisory, quality assurance or factory foreman position in the timber frame construction industry.

- The **QA Manager** will be responsible for ensuring adherence to a **Manufacturing QA Manual** and for issuing a **Certificate of Soundness** or similar for all batches of stock crates dispatched from the factory. The **Certificate of Soundness** would be considered a declaration that assures the goods are manufactured to the design. The **Manufacturing QA Manual** would be prepared by each stock crate manufacturer to document procedures in place to ensure compliance with a **Certified Design** (discussed later).

- The **Regulating Body** would appoint an **Auditor** to act on their behalf. This person would be expected to have had extensive experience in the assessment of manufacturing processes and preferably have experience in timber frame construction and the air freight industry. It is anticipated that **LiveAir Australia Inc** may advise the **Regulating Body** in the selection of this Auditor.

- The **Regulating Body** appointed Auditor would undertake **Registration Audits** of manufacturers wishing to become registered. Registration audits would examine raw material selection processes, factory construction processes and pre-dispatch quality checks. Documentation, including HACCP plans, quality check sheets, and other record keeping would also be audited. The primary objective would be to ensure compliance with the manufacturer's self developed SOPs and Work Instructions.

- Compliance at a **Registration Audit** would result in the workplace being placed on a register of approved manufacturers. Each approved workplace (manufacturing site) would be issued with a **Workplace Registration Number**. The registration number would be used as a prefix to a serial number appearing on all stock crates and be included on the **Certificate of Soundness**.

4.3.2.3.2 Certification and registration of designs:

Section 4.3.2.1 describes the recommended certification method whereby a **Competent Person** certifies that the design meets the minimum specifications set out in the Best Practice Design Document. As well as certifying the design as meeting the specification, the **Competent Person** would recommend that the design be **Registered**.

- The certification report and recommendation should be sent to the **Registrar**.
- The certification and recommendation would also nominate the **Design Owner** of the design allowing the design to be registered by the **Registrar**.
- The **Design Owner** would be provided with a **Registered Design Number** to be included as a secondary prefix in a serial number on each stock crate.
- Where the **Design Owner** undertakes structural modification to a design it would require a **Competent Person** to certify the modified design and submit a new report to the **Registrar**.

4.3.2.4 Industry compliance

In order that compliance is achieved several parties must agree and ensure that only registered designs and manufacturer's products are used in the air transportation.

- **The Regluating Body** would advise all **Exporters** that it is a requirement that they use registered manufacturers and designs.
- It is recommended that a list of registered manufacturers and designs be provided (or made available) and updated on a regular basis. The **Registration List** should be made available to all interested parties. In the first instance we recommend **Exporters** and AQIS.
- Manufacturers would place a serial number on each stock crate. As an example the serial number would be as follows:

  03/015/090513-1

  Where:

  03 = Manufacturer's **Workplace Registration Number**
  015 = Design Owner's **Registered Design Number**
  090513-1 = Reverse date of manufacture and stock crate production number (unique to each stock crate)

- **Exporters** would take receipt of a **Certificate of Soundness** from the Manufacturer together with physical receipt of the stock crates. At that point they are in a position to validate the serial numbers on each stock crate against both the **Certificate of Soundness** and the **Registration List**.

- With the registration system in place AQIS are also in a position to validate stock crates in the same manner as the **Exporter** with a much greater level of assurance than previously. With that level of assurance in place, AQIS would also be in a position to place additional conditions on **Exporters** restricting them to use of the **Registered List** of manufacturers and designs.

4.3.2.5 Subsequent audits

We do not believe that regular **Compliance Audits** of manufacturers would generally be required. However, in the event of reported problems of either structural or non structural inadequacy (most commonly via feedback from AQIS officers and Exporters), the **Regulating Body** may order that a **Compliance Audit** be conducted with the manufacturer. Manufacturers with areas of non-compliance would be issued with corrective action requests (CARs) and re-audited on a basis to be determined by the **Regulating Body**. Manufacturers failing second audits would be asked to show cause as to why they should not be removed from the (proposed) Register of Stock Crate Manufacturers.

Where a compliance audit determines that the fault lies in the design, a CAR would be issued to the **Design Owner**. The **Design Owner** would make any necessary corrections and show cause as to why the design should not be removed from the Register of Stock Crate Designs. A subsequent report from a **Competent Person** would be required to validate that the design meets the minimum specifications set out in the Best Practice Design Document and recommend continuance on the **Registration List**.

Where significant structural failure is apparent the **Regulating Body** may seek a second independent report on the structural integrity of the design or its modifications. The **Design Owner** would be responsible for the costs associated with this report.

4.3.2.6 Supply of livestock air crates by non-certified manufacturers

It is recommended that only **Registered** manufacturers be permitted to supply stock crates to **Exporters**. In the first instance **Exporters** would be responsible for ensuring that only registered products are used in the air transport of livestock. Fair advance notice of any change in protocol must be given to all industry participants to allow manufactures time to complete registration processes.

AQIS would continue to have the ability to add conditions to the “Licence to Export Livestock”. In the event that Exporters cannot self-regulate, it is recommended that AQIS take affirmative action. In the case that export licences are modified, it would become the responsibility of AQIS officers to check all documentation presented with stock crates at the loading port and to reject those not on the **Registration List**.

Owners of non-registered designs and non-registered manufacturers seeking to become registered would contact the **Regulating Body** in order to get advice regarding the required registration procedure and to obtain a copy of the Best Practice Design Document. Design Owners and manufacturers should be provided with fair notice of the registration process and not be unduly excluded from participation in the export process.

4.4 Results of detailed analysis of stock crate designs

A total of four relatively complete drawing sets were received from a request to six manufacturers. These were analysed against the Best Practice Design Document as it stood in June 2009. This analysis resulted in general comments back to the industry in July 2009. A list of the major issues arising from the analysis is presented in general terms below:

1. The types of materials used in crate construction were generally Pine (radiate, hoop, etc) and structural plywood. Hardwood is used in some specific locations to increase strength. The materials were generally classed as F4, F5, MPG10, Merch and F14 (plywood). Most of the materials used were visually graded and unseasoned – all visually graded timber was analysed as F4 grade and S6 strength group unless otherwise marked.

2. Based on the assumption that joints were adequate and fixed, calculated deflections ranged from 0.003mm – 15mm max. Therefore serviceability design (deflection and creep) was not critical and the structures were more likely to fail due to strength issues than to exceed the maximum deflection limits. Permanent deflection would more commonly result in material failure and in turn overall structural failure. Key areas that will commonly be exposed to permanent deflection in these cases are:

   - joints (both corner and side wall attachments)
   - side wall panels
   - side wall columns (due to takeoff and landing 9.81*w)

   This is due to the nature of the composite connections. In addition, timber generally suffers minor deflection and returns to original state or it fails.

3. Strength limit state was found to be the critical design test. Crates were analysed using medium term load duration. Being timber structures, any exposure to altering environmental conditions needs to be considered (i.e. moisture content, sun exposure, shrinkage, cracks, etc). Weather conditions, particularly seasonal changes are important factors to consider and in some cases may change the properties of timber quite markedly. Storage of the raw materials and the finished structures need to be considered by both manufacturers and exporters.

4. Crates need to be designed to a maximum gross weight not just based on floor area and average animal weights. Crates must also be designed for worse case loading (e.g. maximum weight during takeoff). If crates are to be used for various types of animals, consideration needs to be given to the worse case loading of all species not loads based on the average animal carried in the crate. This leads to a decision of either a one fits all structure or the potential of several load classes within a particular design (usually based on floor alterations and joint structure changes in end walls).

5. Few if any of the crates were designed to be lifted fully loaded. There were no visible markings to indicate that the crate should not be lifted while fully loaded or where to lift the crate when empty. Floor assemblies that use a cladding and bearer system need to have designated lifting (and NO LIFT) points due to the possibility of withdrawal of nails, punch through and excessive bending loads from forklift tynes. Lift points and floor strength should be determined based on safe lifting practises outlined for forklift users. Some designs were likely to fail when lifted by improper materials handling equipment or methods, principally standard tyne forklifts, without any live load being present.

6. Stock crate structural members need to be designed for bending moment, shear force and bearing capacity. It is important to consider the governing force and its direction then size members accordingly e.g. making your member wider does not necessary provide more strength against a bending moment force. Increasing the height of a joist or bearer will have more impact on resistance to bending moment.

7. Door frames that are exposed to impact loading during animal loading need to be designed to withstand a very short term point load (e.g. the average width of animals nose and animals crown) equal to 9.81W. In most cases the door frames proved to be adequate based on F4 grade properties. Where lower grade timber (below F4 grade) is used in door way lintels, particularly if it contains knots, impact will inevitably lead to failure. Based on F4 grade timber, the worst case involved a capacity utilisation of 87% (or factor of safety of only 1.2).

8. Doors need to be strong enough to withstand impact load cases. The stiffness capacity of some materials specified in doors was considered to be low and may fail in an emergency situation by being punched out of its restraining structures. Where plywood is used as the door, this situation may be resolved by reorientation or by bracing to increase its horizontal stiffness capacity.

9. Joints need to be designed for both Type 1 and Type 2 joint grades. The joints in these structures are exposed to shear forces (in side and in end grain, double/multiple shear), in-plane moment and axial forces (withdrawal from side and end grain). While the joints used in most stock crates meet the design criteria, more focus needs to be applied to meeting the axial force demands and attempting to combine shear and withdrawal in joint structures to improve performance.

10. Fastening systems are often critical to the performance of jointing structures and therefore to failure instances in stock crates. Some important considerations that were sometimes over-looked in the design and in practice are:

    - spacing distances (fastener patterns)
    - edge distances
    - end distances
    - thickness of the materials
    - fastener penetrations (fastener lengths and timber thickness)
    - timber splitting (unseasoned timber shows a marked tendency to split – may use pre-bored holes)

11. In general the joints and fastening systems were the weakest section of the structure and require significantly more attention. Analysis has found limited cases of over capacity in joints. These cases do not lead to complete failure but do affect the integrity of the overall structure.

12. A defined capacity utilisation or factor of safety should be utilised throughout each design for both design and cost considerations. Members, joints and fastening systems range from being extremely over designed (only using 2% of the member capacity) to exceeding member capacity by 2 times (resulting in member failure). It should be noted that these figures refer to the governing load acting on that member alone. Where load sharing occurs members may not fail in practice but any structure is only as strong as its weakest element.

13. Drawing sets need to be of a standard which allow an engineer to analyse all aspects of the design for certification purposes and include:
    - details of member sizes, spacing and positions within the structure
    - detailed dimensions on floors, walls and roofs
    - enlarged details of joint structures
    - fastening types, patterns numbers and specific locations
    - all material specifications including timber types and grades, nail, screw, bolt and bracket capacities
    - details of lifting and strapping points
    - tare weight
    - maximum gross weight or design capacity of the whole structure
    - maximum gross weight for each floor

Detailed drawings would enable manufacturing staff and external parties to confirm that the constructed stock crates match an approved design. In some cases the drawings provided did not always fully represent what was constructed and illustrated in photographs, e.g. additional members, different nailing patterns and altered numbers were apparent. Auditing manufactured stock crates to an approved design (through in house quality assurance) could prove difficult in practice if adequate drawings are not available.

The analysis phase resulted in some minor alterations to the Best Practice Design Document in regard to:

- A stronger emphasis on strength rather than serviceability in limit state design.
- The need to nominate a maximum gross weight and provide an indication on each stock crate.
- More consideration of materials handling equipment and its impact on the structural integrity of stock crates.

5 Success in achieving objectives

To achieve the project objectives there were two primary mechanisms:

- Develop an industry best practice design document that details industry standards, specifications and design methodology suited to stock crate for air transportation.
- Recommend a control mechanism to ensure that stock crates are designed and manufactured to industry best practice.

5.1 Best Practice Design Document

It is believed that the document produced through a literature review and the application of well known engineering design methodology fulfils the objectives listed below:

- minimises the risk of the contained animal's welfare being compromised
- minimises the risk of crate structural failure
- ensures the secure containment of livestock and minimise the chances of escape during all sectors of transport
- meets all existing IATA guidelines for animal containment and space requirements; and
- meets national and international statutory body requirements for export, transportation and handling

This has been achieved by analysing the interrelationships between industry, national and international standards. These objectives above are met by observing industry specifications and applying recognised engineering design methodology during the design process. In practice design requirements are spread throughout a series of interrelated documents and standards. While recognised manufactures have undergone a very similar process of literature search and review the process undertaken in this project is potentially the first time all specifications have been gathered and recorded in one document.

Design methodology incorporated into the Best Practice Design Document to ensure structural integrity has been drawn from timber framed construction design methods found in various Australian Standards. This does not limit designers strictly to timber as a material of construction by the Best Practice Design Document but it does require the designer to use equivalent design methods in other materials.

Load cases used in the design process have also been developed independently of Australian Standards and relate directly to stocking densities found in AQIS export standards. Where load cases are correctly applied in the design of stock crates the outcome should ensure that the above objectives are met.

Where instances of conflicting standards exist, particularly in regard to animal welfare, a recommendation for best practice has been made.

5.2 Protection of Intellectual Property (IP)

While there have been several discussions with manufacturers and construction techniques have been analysed, no part of any design has been incorporated into the Best Practice Design Document. The process of literature review was driven by the need to find published material which would support design specifications, standards and methodology. Where comments received from one manufacturer conflicted with design principles of another, published data was sort to confirm or deny that the constraints were valid. As an example, the use of steel in a structure was not thought to be permissible yet there is no published information limiting its use.

In addition to intellectual property contained in designs and manufacturing techniques, copyright exists over all standards utilised within the Best Practice Design Document. Readers are advised that to protect copyright they should purchase the recommended standard from the appropriate supplier.

5.3 Industry regulation

While the recommendation made as a result of this project has been discussed be several industry representatives its success can only be gauged once it has been implemented. The success of the process will only be achieved by the commitment of industry participants.

The main force driving the success of implementation should be the desire to self-regulate rather than be regulated by a government department with associated constraints and costs. The development of user pays billing by government inspection services would place additional burden on the industry.

6 Impact on meat and livestock industry – Now and in five years time

6.1 Benefits to livestock exporters and the industry at large

The development of a set of outcomes-based minimum design standards for the manufacture of stock crates for air transport, together with a regulatory framework for the air crate manufacturing industry, would minimise the risk of structural failures of air crates. Other potential benefits would include:

- aircraft safety for freight handlers, animal attendants, flight crew and passengers
- animal health, safety and welfare during all loading and unloading procedures at airports, as well as pre and post airport transport networks, and during the flight itself
- national and international public perception of industry, safety, efficiency and animal welfare
- loss of downtime and repair costs associated with crate failures
- ultimately an improved profitability and economic viability of the live export air freighting industry

The development of a design standard and self regulation methods will go a long way to altering negative perceptions within the industry. Correct implementation of these strategies will assist with sustaining and improving the numbers of livestock transported by air.

Development of minimum design standards for the manufacture of livestock air crates, together with recommendations for a regulatory system, should lead to the rapid adoption of these new standards across Australian. The implementation of the outcomes of this project provides additional opportunity for Australia to establish a reputation as the world leader in the livestock air freight industry. With limited evidence of similar best practice design documents operating in other countries, it would seem appropriate that Australian exporters gain advantage over international competitors now and in the medium term.

6.2 Benefit to AQIS

Correctly implemented self regulation will reduce the concerns of AQIS as an inspection service devoted primarily to animal welfare. Reducing one of the main issues with air transportation would allow AQIS to concentrate on ensuring the welfare of livestock delivered through this mechanism.

7 Conclusions and recommendations

7.1 Conclusions

The best practice design specifications, standards and methodology compiled in this project will assist industry participants to ensure stock crates built for air transportation of livestock perform a satisfactory function in a safe manner. National and international bodies have devoted time and energy to animal welfare and aircraft safety. This single document attempts to place information from several sources into one place making it easier for stock crate designers to understand the constraints and improve their designs.

Recommendations for industry self regulation have been provided which we believe are capable of successful implementation. We believe that an important driver for self regulation will be manufacturer visibility, that is, the ability to identify stock crates by manufacturer. This alone is one mechanism to ensure improved design and construction outcomes. It is the combination of push-pull regulatory mechanisms which should achieve the desired outcome for all industry participants.

7.2 Recommendations

While this project can provide two mechanisms for improvement in the livestock export industry it has not at this stage been implemented. Proper implementation can be achieved by buy-in of the majority of industry players.

Decisions must be taken as to which entities will act as the Regulatory body and the Registrar. It is the recommendation of this project that the Regulating Body is ALEC and the Registrar is LiveCorp. This recommendation has been made based on the proximity of ALEC to AQIS, the government regulator.

ALEC has also been chosen as the Regulating Body due to its influence over livestock exporters. Where ALEC uses its influence to convince air freight exporters to buy into this system of regulation we believe it will provide the sort after benefits.

Design certification and quality assurance systems should provide mechanisms which will improve desired outcomes within the industry. The constraint will be the uptake by exporters. In any event self regulation may be assisted by pressure from AQIS as the issuer of Livestock Export Licences.

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9 Appendices

9.1 Stocking Density versus Live Load Tables

Floor Loads for Cattle & Buffalo

Adapted from AQIS Export Standards Ver. 2.2

Liveweight per animal	Minimum pen area (m^2/head)	Uniformly Distributed Load (kPa)	Normalised Concentrated Load based on 350 mm^2 (N)	Extended Concentrated Load based on 350 mm^2 (N)	Number of head per floor PAX	Total Liveweight per floor (Kg)	Number of head per floor PMX	Total Liveweight per floor (Kg)
150	0.54	2.7	368	920	12	1800	13	1950
160	0.56	2.8	392	981	11	1760	12	1920
170	0.58	2.9	417	1042	11	1870	12	2040
180	0.60	2.9	441	1104	10	1800	12	2160
190	0.62	3.0	466	1165	10	1900	11	2090
200	0.64	3.1	491	1226	10	2000	11	2200
210	0.66	3.1	515	1288	9	1890	10	2100
220	0.68	3.2	540	1349	9	1980	10	2200
230	0.70	3.2	564	1410	9	2070	10	2300
240	0.72	3.3	589	1472	9	2160	10	2400
250	0.74	3.3	613	1533	8	2000	9	2250
260	0.76	3.4	638	1594	8	2080	9	2340
270	0.78	3.4	662	1655	8	2160	9	2430
280	0.80	3.4	687	1717	8	2240	9	2520
290	0.82	3.5	711	1778	8	2320	8	2320
300	0.84	3.5	736	1839	7	2100	8	2400
310	0.87	3.5	760	1901	7	2170	8	2480
320	0.89	3.5	785	1962	7	2240	8	2560
330	0.91	3.6	809	2023	7	2310	7	2310
340	0.93	3.6	834	2085	7	2380	7	2380
350	0.95	3.6	858	2146	6	2100	7	2450
360	0.98	3.6	883	2207	6	2160	7	2520
370	1.00	3.6	907	2269	6	2220	7	2590
380	1.02	3.7	932	2330	6	2280	7	2660
390	1.04	3.7	956	2391	6	2340	6	2340
400	1.06	3.7	981	2453	6	2400	6	2400
410	1.08	3.7	1006	2514	6	2460	6	2460
420	1.10	3.7	1030	2575	5	2100	6	2520
430	1.12	3.8	1055	2636	5	2150	6	2580
440	1.15	3.8	1079	2698	5	2200	6	2640
450	1.17	3.8	1104	2759	5	2250	6	2700
460	1.19	3.8	1128	2820	5	2300	6	2760
470	1.21	3.8	1153	2882	5	2350	5	2350
480	1.23	3.8	1177	2943	5	2400	5	2400
490	1.25	3.8	1202	3004	5	2450	5	2450
500	1.27	3.9	1226	3066	5	2500	5	2500
510	1.29	3.9	1251	3127	5	2550	5	2550
520	1.31	3.9	1275	3188	5	2600	5	2600
530	1.34	3.9	1300	3250	4	2120	5	2650
540	1.36	3.9	1324	3311	4	2160	5	2700
550	1.38	3.9	1349	3372	4	2200	5	2750
560	1.40	3.9	1373	3434	4	2240	5	2800
570	1.42	3.9	1398	3495	4	2280	5	2850
580	1.44	4.0	1422	3556	4	2320	5	2900
590	1.46	4.0	1447	3617	4	2360	4	2360
600	1.48	4.0	1472	3679	4	2400	4	2400
610	1.50	4.0	1496	3740	4	2440	4	2440
620	1.53	4.0	1521	3801	4	2480	4	2480
630	1.55	4.0	1545	3863	4	2520	4	2520
640	1.57	4.0	1570	3924	4	2560	4	2560
650	1.59	4.0	1594	3985	4	2600	4	2600
660	1.61	4.0	1619	4047	4	2640	4	2640
670	1.64	4.0	1643	4108	4	2680	4	2680
680	1.66	4.0	1668	4169	3	2040	4	2720
690	1.68	4.0	1692	4231	3	2070	4	2760
700	1.70	4.0	1717	4292	3	2100	4	2800
710	1.72	4.0	1741	4353	3	2130	4	2840
720	1.74	4.1	1766	4415	3	2160	4	2880
730	1.76	4.1	1790	4476	3	2190	4	2920
740	1.78	4.1	1815	4537	3	2220	4	2960
750	1.80	4.1	1839	4598	3	2250	4	3000

Floor Loads for Sheep

Adapted from AQIS Export Standards Ver. 2.2

Liveweight per animal	Minimum pen area (m^2/head)	Uniformly Distributed Load (kPa)	Normalised Concentrated Load based on 350 mm^2 (N)	Extended Concentrated Load based on 350 mm^2 (N)	Number of head per floor PAX	Total Liveweight per floor (kg)	Number of head per floor PMX	Total Liveweight per floor (kg)
20	0.150	1.3	49	123	43	860	48	960
21	0.154	1.3	52	129	42	882	46	966
22	0.158	1.4	54	135	41	902	45	990
23	0.162	1.4	56	141	40	920	44	1012
24	0.166	1.4	59	147	39	936	43	1032
25	0.170	1.4	61	153	38	950	42	1050
26	0.174	1.5	64	159	37	962	41	1066
27	0.178	1.5	66	166	37	999	40	1080
28	0.182	1.5	69	172	36	1008	39	1092
29	0.186	1.5	71	178	35	1015	38	1102
30	0.190	1.5	74	184	34	1020	37	1110
31	0.194	1.6	76	190	33	1023	37	1147
32	0.198	1.6	78	196	33	1056	36	1152
33	0.202	1.6	81	202	32	1056	35	1155
34	0.206	1.6	83	208	31	1054	34	1156
35	0.210	1.6	86	215	31	1085	34	1190
36	0.214	1.7	88	221	30	1080	33	1188
37	0.218	1.7	91	227	30	1110	33	1221
38	0.222	1.7	93	233	29	1102	32	1216
39	0.226	1.7	96	239	29	1131	31	1209
40	0.230	1.7	98	245	28	1120	31	1240
41	0.234	1.7	101	251	28	1148	30	1230
42	0.238	1.7	103	258	27	1134	30	1260
43	0.242	1.7	105	264	27	1161	29	1247
44	0.246	1.8	108	270	26	1144	29	1276
45	0.250	1.8	110	276	26	1170	28	1260
46	0.254	1.8	113	282	25	1150	28	1288
47	0.258	1.8	115	288	25	1175	27	1269
48	0.262	1.8	118	294	25	1200	27	1296
49	0.266	1.8	120	300	24	1176	27	1323
50	0.270	1.8	123	307	24	1200	26	1300
51	0.274	1.8	125	313	24	1224	26	1326
52	0.279	1.8	128	319	23	1196	25	1300
53	0.283	1.8	130	325	23	1219	25	1325
54	0.288	1.8	132	331	22	1188	25	1350
55	0.293	1.8	135	337	22	1210	24	1320
56	0.297	1.8	137	343	22	1232	24	1344
57	0.302	1.9	140	349	21	1197	23	1311
58	0.306	1.9	142	356	21	1218	23	1334
59	0.311	1.9	145	362	21	1239	23	1357
60	0.315	1.9	147	368	20	1200	22	1320
61	0.320	1.9	150	374	20	1220	22	1342
62	0.324	1.9	152	380	20	1240	22	1364
63	0.329	1.9	155	386	20	1260	21	1323
64	0.333	1.9	157	392	19	1216	21	1344
65	0.338	1.9	159	399	19	1235	21	1365
66	0.342	1.9	162	405	19	1254	21	1386
67	0.347	1.9	164	411	18	1206	20	1340
68	0.352	1.9	167	417	18	1224	20	1360
69	0.356	1.9	169	423	18	1242	20	1380
70	0.360	1.9	172	429	18	1260	20	1400
75	0.383	1.9	184	460	17	1275	18	1350
76	0.374	2.0	186	466	17	1292	19	1444
77	0.378	2.0	189	472	17	1309	19	1463
78	0.382	2.0	191	478	17	1326	18	1404
79	0.386	2.0	194	484	17	1343	18	1422
80	0.405	1.9	196	491	16	1280	17	1360
85	0.428	1.9	208	521	15	1275	16	1360
90	0.450	2.0	221	552	14	1260	16	1440
95	0.473	2.0	233	582	13	1235	15	1425
100	0.495	2.0	245	613	13	1300	14	1400

Floor Loads for Goats

Adapted from AQIS Export Standards Ver. 2.2

Liveweight per animal	Minimum pen area (m^2/head)	Uniformly Distributed Load (kPa)	Normalised Concentrated Load based on 350 mm^2 (N)	Extended Concentrated Load based on 350 mm^2 (N)	Number of head per floor PAX	Total Liveweight per floor (Kg)	Number of head per floor PMX	Total Liveweight per floor (Kg)
15	0.093	1.6	37	92	70	1050	77	1155
16	0.098	1.6	39	98	67	1072	73	1168
17	0.103	1.6	42	104	63	1071	69	1173
18	0.107	1.7	44	110	61	1098	67	1206
19	0.112	1.7	47	116	58	1102	64	1216
20	0.117	1.7	49	123	56	1120	61	1220
21	0.121	1.7	52	129	54	1134	59	1239
22	0.127	1.7	54	135	51	1122	56	1232
23	0.131	1.7	56	141	50	1150	55	1265
24	0.136	1.7	59	147	48	1152	53	1272
25	0.141	1.7	61	153	46	1150	51	1275
26	0.146	1.7	64	159	45	1170	49	1274
27	0.151	1.8	66	166	43	1161	47	1269
28	0.155	1.8	69	172	42	1176	46	1288
29	0.160	1.8	71	178	41	1189	45	1305
30	0.165	1.8	74	184	39	1170	43	1290
31	0.170	1.8	76	190	38	1178	42	1302
32	0.175	1.8	78	196	37	1184	41	1312
33	0.179	1.8	81	202	36	1188	40	1320
34	0.184	1.8	83	208	35	1190	39	1326
35	0.189	1.8	86	215	34	1190	38	1330
36	0.194	1.8	88	221	33	1188	37	1332
37	0.199	1.8	91	227	33	1221	36	1332
38	0.203	1.8	93	233	32	1216	35	1330
39	0.208	1.8	96	239	31	1209	34	1326
40	0.213	1.8	98	245	30	1200	33	1320
41	0.218	1.8	101	251	30	1230	33	1353
42	0.223	1.8	103	258	29	1218	32	1344
43	0.227	1.9	105	264	29	1247	31	1333
44	0.232	1.9	108	270	28	1232	31	1364
45	0.237	1.9	110	276	27	1215	30	1350
46	0.242	1.9	113	282	27	1242	29	1334
47	0.247	1.9	115	288	26	1222	29	1363
48	0.251	1.9	118	294	26	1248	28	1344
49	0.256	1.9	120	300	25	1225	28	1372
50	0.261	1.9	123	307	25	1250	27	1350
51	0.266	1.9	125	313	24	1224	27	1377
52	0.271	1.9	128	319	24	1248	26	1352
53	0.275	1.9	130	325	23	1219	26	1378
54	0.280	1.9	132	331	23	1242	25	1350
55	0.285	1.9	135	337	23	1265	25	1375
60	0.309	1.9	147	368	21	1260	23	1380
65	0.333	1.9	159	399	19	1235	21	1365
70	0.357	1.9	172	429	18	1260	20	1400
75	0.381	1.9	184	460	17	1275	18	1350
80	0.405	1.9	196	491	16	1280	17	1360
85	0.429	1.9	208	521	15	1275	16	1360
90	0.453	1.9	221	552	14	1260	15	1350
95	0.477	2.0	233	582	13	1235	15	1425
100	0.501	2.0	245	613	13	1300	14	1400

Floor Loads for Deer

Adapted from AQIS Export Standards Ver. 2.2

Liveweight per animal	Minimum pen area (m^2/head)	Uniformly Distributed Load (kPa)	Normalised Concentrated Load based on 350 mm^2 (N)	Extended Concentrated Load based on 350 mm^2 (N)	Number of head per floor PAX	Total Liveweight per floor (Kg)	Number of head per floor PMX	Total Liveweight per floor (Kg)
20	0.13	1.5	49	123	51	1014	55	1109
22	0.14	1.5	54	135	47	1036	51	1133
24	0.15	1.6	59	147	44	1055	48	1153
26	0.16	1.6	64	159	41	1071	45	1171
28	0.17	1.6	69	172	39	1086	42	1187
30	0.32	0.9	74	184	21	618	23	676
32	0.33	1.0	78	196	20	639	22	699
34	0.33	1.0	83	208	20	679	22	743
36	0.34	1.0	88	221	19	698	21	763
38	0.34	1.1	93	233	19	737	21	806
40	0.35	1.1	98	245	19	753	21	824
42	0.36	1.1	103	258	18	769	20	841
44	0.36	1.2	108	270	18	806	20	881
46	0.37	1.2	113	282	18	819	19	896
48	0.38	1.2	118	294	17	833	19	910
50	0.38	1.3	123	307	17	867	19	948
55	0.41	1.3	135	337	16	884	18	967
60	0.44	1.3	147	368	15	899	16	983
65	0.48	1.3	159	399	14	893	15	976
70	0.52	1.3	172	429	13	887	14	970
75	0.56	1.3	184	460	12	883	13	965
80	0.61	1.3	196	491	11	864	12	945
85	0.61	1.4	208	521	11	918	12	1004
90	0.66	1.3	221	552	10	899	11	983
95	0.72	1.3	233	582	9	870	10	951
100	0.75	1.3	245	613	9	879	10	961
110	0.55	2.0	270	674	12	1318	13	1441
120	0.57	2.1	294	736	12	1388	13	1517
130	0.59	2.2	319	797	11	1452	12	1588
140	0.61	2.3	343	858	11	1513	12	1654
150	0.63	2.3	368	920	10	1569	11	1716
160	0.64	2.5	392	981	10	1648	11	1802
170	0.66	2.5	417	1042	10	1698	11	1856
180	0.68	2.6	441	1104	10	1745	11	1908
190	0.69	2.7	466	1165	10	1815	10	1985
200	0.70	2.8	491	1226	9	1883	10	2059
210	0.73	2.8	515	1288	9	1896	10	2073
220	0.75	2.9	540	1349	9	1933	10	2114
230	0.77	2.9	564	1410	9	1969	9	2153
240	0.79	3.0	589	1472	8	2002	9	2190
250	0.81	3.0	613	1533	8	2034	9	2224
260	0.84	3.0	638	1594	8	2040	9	2231
270	0.86	3.1	662	1655	8	2069	8	2263
280	0.88	3.1	687	1717	7	2097	8	2293
290	0.90	3.2	711	1778	7	2124	8	2322
300	0.92	3.2	736	1839	7	2149	8	2350
310	0.96	3.2	760	1901	7	2128	8	2327
320	0.98	3.2	785	1962	7	2152	7	2353
330	1.00	3.2	809	2023	7	2175	7	2378
340	1.02	3.3	834	2085	6	2197	7	2402
350	1.05	3.3	858	2146	6	2197	7	2402
360	1.08	3.3	883	2207	6	2197	7	2402
370	1.10	3.3	907	2269	6	2217	7	2424
380	1.12	3.3	932	2330	6	2236	6	2445
390	1.14	3.4	956	2391	6	2255	6	2466
400	1.17	3.4	981	2453	6	2253	6	2464
410	1.19	3.4	1006	2514	6	2271	6	2483
420	1.21	3.4	1030	2575	5	2288	6	2502

9.2 Hazard Analysis Critical Control Point (HACCP), as Applicable to the Manufacture of Stock Crates for the Transportation of Livestock by Air

Background

The “HACCP” procedure has evolved from a system originally used for the evaluation of human food processes for microbiological hazards. It has now become widely used as a logical and systematic approach to analyse many operational processes in any discipline in order to identify and control hazards that may prevent a product or service meeting physical, chemical, compositional, microbiological, sensory or even legal specifications.

Purpose of the HACCP Procedure

The purpose of the HACCP procedure is to establish a uniform method of applying specific techniques to build controls into the process of manufacturing stock crates in order to prevent the occurrence of a finished article not being suitable for purpose. This is achieved by identifying potential risks (or hazards) to the achievement of the desired product and linking the cause of the potential defect to a production line or raw material factor (Critical Control Point) which controls the potential hazard and prevents its occurrence.

Preliminary Steps In Conducting a HACCP Analysis

<u>Step 1 - Formation of HACCP Team.</u>
For Stock Crate manufacturing, this team should ideally consist of:

- Factory General Manager,
- Factory QA Manager,
- Factory Foreman (or other worker, if QA Manager is also Foreman),
- Consulting or Company Engineer.

<u>Step 2 - Description of Finished Product Specifications.</u>
Design specifications of all stock crate makes & models should be carefully documented.

<u>Step 3 - Identify Intended Use of Finished Product.</u>
All aspects of the purpose of finished products - all stock crate makes & models, for all relevant livestock species and sizes - should be documented.

<u>Step 4 - Flow Diagram of Manufacturing Procedures to be constructed.</u>
This should simply but clearly illustrate all key steps of the full manufacturing process, from “A to Z”. This should cover raw material selection, construction phases and dispatch of finished stock crates from the factory. However, the flow diagram should be extended to illustrate various steps and processes well beyond the factory door, e.g., loading onto & off trucks and transportation of crates.

<u>Step 5 - On-site Verification of Accuracy and Completeness of Flow Diagram.</u>
This is achieved by all members of the HACCP team stepping through all phases indicated on the flow diagram and collectively identifying potential hazards to the achievement of a high quality finished product with specifications as outlined during Step 2 above. Critical Control Points (CCPs) in the production process are also identified and documented, as are their control measures and corrective action protocols.

HACCP Principles

<u>Principle 1.</u>
Performance of a hazard analysis: Preparation of a list of process steps where significant hazards occur and description of their Control Measures.

At each step of the Flow Diagram, potential hazards with respect to targeted quality specifications are identified. It is then determined if **Control Measures** exist which prevent or eliminate these hazards. Hazards are rated and the risks assessed with respect to both the severity of consequences and likelihood of occurrence. The identified hazards and preventive measures are then listed in a HACCP Table. (A sample HACCP Table is given below)

<u>Principle 2.</u>
Identification of Critical Control Points in the Production Process.

If an unacceptable risk is identified at a particular step in the flow diagram, the control mechanism for that step is designated a **"Critical Control Point" (CCP)**. The control can either, prevent, eliminate or reduce the potential hazard to acceptable levels.

There may be more than one component task involved in a CCP. Where a CCP is a procedure, it may have application at a number of different stages in the processing sequence. CCPs are entered into a HACCP Table.

<u>Principle 3.</u>
Establishment of Critical Limits for preventive measures associated with each identified Critical Control Point.

Critical Limits are established to separate acceptability from non-acceptability for each preventive measure associated with each CCP. These are the boundaries of safe compliance.

Under Principle 7 below, it is necessary to verify that Critical Limits are adequate to control hazards that are likely to occur. Such verifications must be scientifically based. Where preventive measures are inherent in the design of procedures, Critical Limits will include the correct application of these preventive measures.

Critical Limits for each preventive measure will either:
(a) Eliminate the hazard; or
(b) Build greater control into the design of the process via:
- Product specifications;
- Procedure specifications;
- Worker responsibility specifications;
- Improved systems for Monitoring, Inspecting and Testing; and
- Statistical controls or record keeping.

Establishing Critical Limits involves formulating a written **Standard Operation Procedure (SOP)** and a more detailed **Work Instruction (WI)** for each "Critical Operation" – this being a process or procedure in the flow diagram that has an associated CCP. Professional training, clearly documented and understood procedures, work instructions and specifications are vital to achieve quality and profitability standards. It is important that the reasons for preventive measures are made clear to people who are responsible for making them work. While the HACCP procedure is the tool for identifying preventive measures and associated critical limits, documented SOPs and WIs are the vehicle for ensuring practical implementation.

Principle 4.
a.) Establishment of a Monitoring system for each Critical Control Point;
b.) Establishment of procedures for using the results of monitoring to adjust the process and maintain control.

Having established how an operation should be performed, control includes building in methods for early detection and correction of "Non-Conformity" by reference to the specified preventive measures and their documented Critical Limits. A "non-conformity" is defined as a deviation from specified preventive procedures or failure to meet Critical Limits.

The frequency of monitoring of a CCP is based on the assessed risk of deviation and the likely consequences if a deviation were to occur unchecked for a period of time. Monitoring records are kept to enable a recording of monitoring results at each CCP at the required frequency, the action taken and the results of follow-up checks. Mechanisms are made available for data analysis to detect trends and recurring problems and to provide feedback on process performance and the initiation of corrective actions.

Results of monitoring are collected in a form that enables timely analysis in order to adjust and maintain the process before product quality is compromised.

In-process monitoring of preventive measures built into CCPs should not be confused with finished product inspection activities, which aim at verifying the adequacy of those preventive measures after the fact. Verification activities are described in Principle 7.

Principle 5.
Establishment of Corrective Action to be taken when monitoring indicates there is a deviation from an established Critical Limit.

Documentation of corrective action guidelines occurs at two main levels:

- General principles of corrective action to be followed in all instances of deviation; and,
- Corrective action specific to deviation at a given CCP should also be developed and documented along with the SOP, WI and the HACCP Table.

Corrective action must always be accompanied by a follow-up check to determine if the action has been effective in resolving the problem and maintaining control of the system.

Principle 6.
Establishment of procedures for Verification that the HACCP plan is working correctly.

Verification procedures are directed towards two areas:

- Scientific and technical evidence of the adequacy of critical limits to control hazards; and,
- Production line verification, which includes:
  - The implementation and documentation of Inspection and Test procedures for the receipt and processing of raw materials, stock crate manufacturing process steps and finished product loading. Where required, statistically based sampling plans are implemented by suitably experienced personnel.
  - Subjecting the full HACCP plan to regular auditing. Under audit, the effectiveness of established control mechanisms for each CCP is continually reassessed. Monitoring systems that are based on past custom and habit are reviewed to ensure they are still necessary and appropriate.

Principle 7.
Establishment of an effective Record Keeping system that documents the full HACCP Plan.

Documentation kept should ideally include:

- Purpose and Scope statement;
- Members of the HACCP Team – names, qualifications, responsibilities;
- Finished Product description, including cost and profitability parameters;
- Flow Diagram of all operations;
- Hazard Analysis report;
- CCP Determination sheet;
- Full HACCP Table;
- SOPs and WIs for all operational tasks, monitoring and corrective actions, etc;
- Monitoring records;
- Corrective Action reports;
- Verification schedule;
- Validation information;
- Audit reports – both internal and external;
- Documentation schedule; and,
- HACCP meeting minutes.

CRITICAL CONTROL POINT (CCP) DETERMINATION

Manufacture of Stock Crates - Example only

OPERATIONAL STEP	Q 1. Does a hazard exist for this step?	Q 2. Do preventative measures exist for this step?	Q 3. Is this step specifically designed to reduce the occurrence of a hazard to an acceptable level?	Q 4. Could the problems caused by the hazard increase to unacceptable levels over time?	Q 5. Will a subsequent step eliminate the hazard or reduce its likely occurrence to an acceptable level?	CCP NUMBER
Raw Material Selection	YES	YES	YES	YES	NO	1
Design Plans	YES	YES	YES	YES	NO	2
Joint Construction	YES	NO	YES	YES	NO	3
Bracing & Support	YES	YES	YES	YES	NO	4
Tie-down Points	YES	NO	NO	YES	NO	5
Forklift Tyne Points	YES	NO	NO	YES	NO	6
Size & Head room	YES	YES	YES	YES	NO	7
Floor Construction	YES	YES	YES	YES	NO	8
Ventilation & Light	YES	NO	NO	YES	NO	9
Injury Prevention	YES	NO	NO	YES	NO	10

HACCP TABLE (completed for each CCP)

CCP - 8 - Floor Construction, part a.) - Example Only

POTENTIAL HAZARDS IDENTIFIED	CONTROL MEASURES TAKEN What? How? When? Who?	CRITICAL CONTROL POINTS What procedures are most important to control?	CRITICAL LIMITS FOR CONTROL MEASURES Max & Min Tolerances
1. Failure due to design	Engineering design plans; Every crate; Engineering consultant.	Professional drawing of design plans; Accurate following of plans.	Design plan accuracy to 2.0 mm
2. Failure due to materials	List of quality assured suppliers; Check that every incoming load up to spec.; Purchasing Mgr.	QA check of materials upon arrival at factory; Must conform to internal standards.	Meets design grade specification for component.
3. Failure due to construction	Factory QA manual, SOP's, WI's; Every day overseen by Foreman & QA Mgr.	Competency of workers; Accuracy against drawings & following of SOP's & WI's.	Minimum worker qualifications, Correct member and fastening positions.
4. Failure due to overloading	Check animals nos with exporters & freight forwarders; Nominated gross weights on crate.	Correct loading of crates with correct number of animals of the correct weight and type.	See AQIS Livestock Export Standards.

Floor Construction, part b.)

	MONITORING PROCEDURE, FREQUENCY, AND PERSONS RESPONSIBLE What? How? When? Who?	CORRECTIVE ACTION AND PERSONS RESPONSIBLE Action to take? Who? Who else should be notified?	VERIFICATION PROCEDURE, AND PERSONS RESPONSIBLE Inspection / Audit processes? How often? Who?	RECORD KEEPING AND DOCUMENTATION What records are kept? Where? Who is responsible?
1.	Checking of design plans by QA Mgr when new design submitted by Engineer.	Engineer to re-draw design plan if requested by QA Mgr; GM to be told.	Internal audits by QA Mgr every month.	All design plans, internal & external audit reports kept by QA Mgr; his office.
2.	Visual check of every incoming load against supplier's specs, by Purchasing Mgr.	Suppliers warned once of non-compliance by Purchasing Mgr then dumped; GM.	Internal audits by QA Mgr every month.	All purchase & supplier docs kept by Purchasing Mgr in his office.
3.	Worker competency & manufacturing stds checked using QA Checklist as crates leave factory, by QA Mgr.	Non-conforming crates to be re-worked by offending worker, then re-assessed; Foreman to re-train or dismiss worker.	Internal audits by QA Mgr every month.	All QA Checklists & staff performance records kept by QA Mgr in his office.
4.	Member/fastener size, position and specification checked by QA Mgr using QA Checklist as crates leave factory.	Non-conforming crates to be re-worked, then re-assessed by QA Mgr; GM.	Internal audits by QA Mgr every month.	All QA Checklists, internal & external audit reports kept by QA Mgr; his office.