Design Standards for an Airborne Rescue Valise for Infants and Small Children

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Helicopter rescue operations involving airborne extraction of infants and small children are particularly difficult due to the size of the child, the unpredictable behavior of the child during the extraction process and the lack of a suitable extraction device. Through a consultation process with Search and Rescue helicopter operators, flight crew and rescue paramedics, suggestion has been made for development of a certified Child Rescue Valise (CRV) to assist with the extraction of infants and/or small children. The CRV construction resembles a sturdy outdoor camping bag that has been specifically designed, tested and certified for aviation use. Currently, there is no recognized safety standard has been set to provide the minimum safety requirements for the CRV design and consequently no products in the market are certified for helicopter winch rescue missions that involved child or infants. For this reason, a minimum safety requirement standard has been developed based on AS/NZS 1891.1:1995 (Amdt 4) and the applicable section of FAA FAR Part 29 for Personnel Carrying Device System (PCDS). This standard provides certain design guidelines and requires the manufacturer to demonstrate the capability as well as reliability of the CRV through various safety tests set out by this standard.

I. Introduction

Helicopter operations are increasingly used in emergency rescue missions due to their versatility and ability to quickly access difficult-to-reach locations. In a typical helicopter rescue operation, a rescue crew person, fitted with an approved rescue harness, is lowered by a hoist system to the ground to assist or extract people who have been trapped or injured. For scenarios which require winch extraction, the rescued person is typically fitted with either a rescue harness or rescue strop, or secured to a rescue litter and lifted into the helicopter along with the air crew person.

This type of operation works particularly well for extraction of adolescents and adults, however, for extraction operations involving infants and small children, the retrieval mission is often more difficult. Children and infants generally do not fit the minimum physical limitation for a winch rescue operation, such as size requirements necessary for safe restraint by a harness or litter fittings. In addition, it is not reasonable to expect an infant to “hold on” and support their own weight during the winching operation.

Consequently, there are risks that they might slide up and down the litter. In an effort to provide a safer and more user friendly method of infant/small child rescue hoist extraction, it has been suggested that a rescue valise (similar in size and shape to a large sports bag) be developed. The rescue valise would provide protection for the infant/small child and would fully contain the child so that the possibility of unintentional release from the valise is eliminated.

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Such a rescue valise would provide means of rescue which is more reliable and efficient than improvised alternatives.

There are a number of commercial products available on the market today which could be used as a CRV (Figure 1). These products have been designed, manufactured and marketed for outdoor activities, such as bushwalking, camping, hiking, and other activities where a sturdy carry bag is required. However, there is currently no recognized safety standard being set by Australian Aviation Safety Authorities, thus, these existing products cannot be designed and manufactured to ensure safety during helicopter rescue operation. As a result, a minimum standard was developed based on industry best practice such as AS/NZS 1891.1:1995 (Amdt 4), FAA TSO C167 and the applicable sections of FAA FAR Part 29 for Personnel Carrying Device System.

Based on the standards and accompanying compliance tests and analysis procedures, a CRV design was proposed that meets the specified safety requirements. Essentially, this design offers a high structural integrity as well as the flexibility which allows it to be operated under extreme weather conditions. This CRV is also extendable allowing it to accommodate different child and infant’s sizes. Also, the material used in the CRV allows it to be used as a floatation device for over-water rescue missions. However, the design and testing results of the CRV are not included in this paper.

Figure 1: Child Rescue Valise (CRV).

Figure 2: Typical Installation of CRV to Hoist.
II. CRV design and construction requirement

CRV can be defined as an item of equipment that provides a means by which a small child can be winch-lifted into a helicopter when that child does not fit the minimum physical limitation of a typical winch rescue operation using a helicopter rescue harness. The shape of the CRV is required to be container-like which comprise some means to restrain the child occupant and to attach the CRV to a winch/hoist system (Figure 2).

Under the above description, the CRV can be defined as a Personnel Carrying Device System and it is therefore classified as a Rotorcraft Load Combination (RLD) class D under Advisory Circular 29-2C of FAR Part 29.865. Furthermore, as the sole purpose of the CRV is for helicopter rescue mission of children and infants therefore CRV is also classified as a Helicopter External Cargo (HEC) carrying device under Australian Technical Standard Order (ATSO-C1003). These standards was developed mainly to describe the minimum safety requirement for harness and fall arrest system as well as its related device which must be suitable for fall-arrest performance including free fall and restrained fall (AS/NZS 1981.1 1999). Since the CRV is also used to as a helicopter external personnel carrying device, hence certain components of the CRV such as material strength, stitching patterns is similar to the harness.

However, due to the fundamental differences in construction design, supported weight and certain medical issues, thus additional requirements will be imposed on the CRV design to ensure its structural integrity for it to be operated safely without catastrophic failure under all likely service scenarios. These additional requirements are established from the study of AS/NZS 1891.1:1995 (Amdt 4) and Advisory Circular (AC) 29.865. Compliance with the AC 29.865 will automatically lead to compliance with FAA FAR Part 29.865.

III. Materials requirement

This new CRV standard categorizes all materials used for its construction into metallic and non-metallic components.

A. Non-metallic component

All components which are used to distribute load directly to the body of the CRV and are in contact with it are required to be made from webbing or materials that have been demonstrated to be equivalent to webbing in respect of strength, durability and load transfer characteristics. In addition, load-bearing webbing that are used to distribute and transfer the load directly to the body of the CRV is further required to not be less than 40 mm wide and remain flat in regular use (AS/NZS 1981.1 1999). Moreover, to increase the visibility level during rescue missions in dark area, the color of the CRV’s webbing is also required to be an approved international standard orange-yellow (TSO-C13f 1992). The finished CRV product is to be clean and free from any defects that might affect its function.

B. Metallic component

The metallic components of the CRV construction comprise of connecting and attachment hardware such as attachment rings and hook. To reduce the probability of inadvertently opening, hook is required to be capable of being opened only be at least 2 consecutive deliberate actions. If there are multiple attachment fittings which connect the CRV to the hoist system, each of the attachment fittings is also required to be capable of supporting the weight of the occupant and the CRV during operation. This requirement ensures the safety of the occupant in case of any failure or inadvertent release of one of the attachment fittings.

IV. Strength requirement

Through the study of TSO-C13f, Life Preservers under Section 4.1.8: Buoyancy for Child, the minimum weight of a child occupant carried as a Human External Cargo (HEC) is specified as 16 kg (35 pounds). In order to support the weight of the child occupant, the following strength requirement for both metallic and non-metallic components is proposed.

A. Non-metallic components

Although the weight of the child occupant is relatively low of 16 kg, however, as mentioned above, during an event of inadvertently fallout from the helicopter, assuming an 8g downward loading (FAR 25.561), the generated dynamic loading can be up to 4000 N which is sufficient to cause slipping or even breakage of the webbing material. For this reason, the minimum breaking strength requirement for webbing material was specified not to be less than 15 kN (AS/NZS 1981.1 1999). This strength requirement was based on AS/NZS 1891.1:1995.
Similar to harnesses, CRV will be operated under extreme weather conditions and thus the ability to resist degradation by daylight of the webbing material is also required. In order to demonstrate this ability, the webbing material must at least retain 70% of the breaking strength after being exposure to daylight for 100 hours and 24 hours in the laboratory conditions (TSO-C167 2005). Besides, the ability to resist loading and degradation by daylight, the webbing material is also required to withstand degradation by temperature and certain solvents in order to provide safe operation under all likely service/rescuing scenarios.

To achieve such strength requirements described above, the sewing of webbing is required to be carried out on a lockstitch machine and must not be less than 2 mm from the edge of the webbing (AS/NZS 1981.1 1999). The threads that are used for sewing load-carrying webbing material needs to also have similar physical and chemical properties to the materials being sewn. Threads that contain fibers are not allowed to sew load-carrying components (AS/NZS 1981.1 1999). Furthermore, holes, rivets or eyelets cannot be installed in load-bearing webbing as it introduce stress concentration while increasing shear stress which may cause the breakage the stitching leading the detachment of the webbing.

**B. Metallic components**

Due to the unpredicted rescue situation, the CRV and its related device will be subjected certain fatigue loading due to the fact that it will be winched up and down numerous number of times during its service time. Thus, all metallic components of the CRV are required to be substantiated under fatigue loading in accordance with AC 29.865, Section 15: Fatigue substantiation for Human External Cargo application and will be subjected to proof loaded to 7.5 kN at which load the metallic hardware components should be free from defects on visual inspection (AS/NZS 1981.1 1999).

Furthermore, each individual of the attachment fitting/rings are required to resist the entire force generated from dynamic loading. In order to achieve this level of safety, all metallic attachment hardware is required to withstand a load of 15kN without permanent distortion (AS/NZS 1981.1 1999). In addition, the surface of the attachment hardware must also be free from manufacturing defects in order to minimize damage to the webbing.

As CRV is intended to be used for various rescue situation under extreme weather conditions, all metallic components must be adequately protected against corrosion. To verify the ability of metallic components to withstand degradation due to corrosion, all metallic components will be subjected to 24 hours exposure to salt spray followed by 1 hour drying. The salt water will be removed from metallic hardware and corrosion level can be inspected.

Webbing or metallic components which had been previously approved to meet the strength requirement and that no new design changes have been made which would adversely affect the reliability or functional ability of the material shall be reused.

**V. Additional Requirements**

**A. Flame resistance requirement**

Under operation involving fire such as bush-fire rescue, the CRV is required to be capable of resisting fire. This ability of the CRV is to be demonstrated through flame resistance test of the webbing material which is used to construct the CRV. Details discussion of the flame resistance tested is showed in section 5.2.

**B. Medical Design Issues**

Helicopter rescue missions that involved fire or water such as bush-fires or flooded are the most popular type of rescuing. During these type of rescue situation, the injured occupant or water soaked occupant may be exposed to high body heat loss from sources such as rotor wash and the airstream. Therefore, the CRV is to be designed to the maximum practicable extent and placarded to maximize the HEC’s protection from medical considerations such as blocked air passages induced by improper body configuration and excessive loss of body heat during operations.

Cushioned rest is also required to be used to protect the occupant from head injuries in case of an impact event. The cushion rest is required to be 1 inch thick and is preferred to be made of Polyvinyl Chloride (PVC) or other material with equivalent energy absorbing characteristics (Advisory Circular 29-2C 2008).

In addition, in order to monitor the state of the injured child occupant, direct communication is required under all operation conditions between rescue crewmembers and the occupants. Voice or hand signals is acceptable, however, sophisticated devices such as two way radios or intercoms should be employed (Advisory Circular 29-2C 2008).
C. Optional floatation requirement

CRV that are intended to have dual role as PCDS and floatation devices or life preservers is required to be substantiated under the TSO-C13f Life Preservers. The TSO-C13f categorizes the life preservers into 2 types which are inflatable (type 1) and non-inflatable (type 2). In general, any CRV intended to be used in water should have a floatation kit which is required to support the weight of the occupant and the CRV in the water. The minimum buoyancy force of the floatation kit for a 35 pounds small child is required to be at least 20 pounds in fresh water (TSO-C13f 1992). Furthermore, the life preserver must prevent contact of the wearer’s upper torso (i.e., from the waist up) with the water. Additionally, light source and other supporting equipment should be incorporated into the design of the CRD and is ready for usage during rescue operation.

D. Quick Release Device requirement

Under certain operation conditions where the CRV must be quickly released from helicopter, a Quick Release Device (QRD) should be incorporated to strop or straps which are used to attach the CRV system to the winch hook. The QRD should be simple and obvious to action and is required to be easily released using one hand (ATSO 2003). The QRD should also be able to release the CRV in less than 5 seconds. At least two distinct and separate physical actions are needed to initiate release of the CRV from winch hook and consequently protecting the CRV against inadvertent release. In case of failure of the QRD, a backup manual quick release system should be available and readily accessible. The manual back up QRD should be able to release the valise in less than 30 seconds (Advisory Circular 29-2C 2008). A comprehensive requirement of the Quick Release Device and its operating conditions is discussed in the master AC 29-2C.

Hook Dynamic roll-out occurs during certain ground handling and flight conditions that may allow the CRV to unintentionally release from its attachment point. It typically occurs when the CRV is not properly attached to the hook, is blown by downdraft; or is otherwise placed into the dangerous hook-to-eye configuration.

While Dynamic Rollout or unintentional disengagement cannot be prevented by the design of the hook alone, consideration should be made within the design of the attachment components of the CRV to minimize the possibility of unintentional disengagement during all modes of operation. Similarly, personal energy absorbers can be connected in series with the lanyard and the CRV to reduce damage impose up on the CRV and the connecting lanyard generated from dynamic loading during an inadvertently disengagement.

E. CRV loading requirement

A previously mentioned, the CRV within this standard is intended to support a 16kg (35 pounds) child occupant. The loading condition of human external cargo specified from FAA FAR Part 29.865 Section 8: Personnel Carrying Device System required a safety factor of 3 is required to incorporate into the design weight of the CRV. In case where the CRV possess more than 1 shape, most critical configuration must be determined in which the structure will be examined based on the specified weight.

According to the FAA FAR Part 29.865 Section 8: Personnel Carrying Device System for human external cargo, the limit load of 3.5 should also be applied on the design load of the CRV. However, for the application of this CRV, the vertical limit load factor is not applicable and shall not be considered as a requirement for the design of the CRV. This is due to the operational procedure of the CRV where the CRV is attached to a hoist system from the ground and being winched up vertically. This process occur when the helicopter is hovering and therefore induce no limit load factor on the structure of the CRV.

F. CRV general construction requirement

The construction requirement of a human external cargo has been discussed in the FAA FAR Part 29.865 Section 8: Personnel Carrying Device System. In general, CRV should be capable of being opened and closed easily and readily by the rescuing winchman. Instruction on ingress and egress as well as the location/orientation for the child occupant should be placarded properly on the CRV. In addition, should the CRV be a close container and door latch is used, more than one fasteners or closure device should be integrated. The latch design should provide direct visual inspectability to assure it is fastened and secured (Advisory Circular 29-2C 2008).

Furthermore, retention devices and its related design safety features should be incorporated within the CRV to restrain the child occupant during the winch extraction process. Once the CRV is winched up and located within the helicopter, appropriate means such as safety belts or straps must be used to secure the position of the CRV.
VI. Testing plan

The tested weight for the CRV is at least 48kg as a result of 16 kg child occupant multiply with a safety factor of 3. Both static and dynamic test is to be performed at 7 meters above the ground.

A child dummy is preferred to simulate the child occupant being restrained within the CRV, however, should other means of simulating the occupant be used, such as ballast or sand bag, the weight distribution shall be appropriately determined to represent that of a real occupant. The dimension of the child dummy is illustrated in the figure 3.

To perform the static and dynamic test, an anchorage structure is required such that application of a steady force of 20 kN does not cause a deflection greater than 1 mm. A testing lanyard of 4.5 m with no energy absorber capability, which meet the requirement of AS 4142.2, is to be used as a testing medium for the connection between the CRV and the anchor point.

A. Static test

In order to verify its structural integrity and reliability during a winch operation, the CRV system is required to be tested by subjecting it to the specified weight of the child occupant while it is hanging in midair. This test also includes strength substantiation of each attachment fittings to validate the ability to support the entire load when one of them failed.

The CRV attachment fittings is connected to the testing lanyard with the simulated weight being securely restrained and will be held in midair for 3 minutes. Furthermore, the capability of each of the attachment fittings to carry the entire static will also be performed. Under this static loading, no fracture of the webbing material and no failure of attachment hardware are allowed.

B. Dynamic test

The dynamic testing is subsequently carried out to assess the structural integrity of the CRV when subjected to impulse loading. The test is performed with all of the attachment fittings of the CRV attached. Each of the attachment fittings is required to be tested individually to verify that each one of them is able to withstand the generated load as well as preventing damage imposed on the CRV or the child occupants in the event of a fall.

All attachment fittings of the CRV are to be connected to the testing lanyard which will be rigidly fixed to the anchorage point. The original height above the gourd of the CRV is recorded. Simulated mass of the child occupant is restrained securely within the CRV. Subsequently, the CRV will be brought up to the same height as the anchorage point and will be released to simulate a free fall event. The position of the child occupant simulated mass and the state of the CRV is recorded. The process repeated for each of the CRVC attachment fittings.

Under this dynamic loading, the slippage the section of webbing which is used as a mean to connect the CRV to the attachment fittings is required not to be more than 50 mm. In addition, the child occupant simulated mass shall remain securely within the CRV. In general, there should be no complete breakage of webbing or complete failure of any one pattern of stitches at any webbing junction and no failure of any attachment hardware.

C. Flame resistance test

This test is carried out to access the flame resistance ability of the webbing material which must be tested either as a section cut from a final CRV product or as a specimen cut from a flat sheet of the webbing material that are used for construction of the CRV. Specimen thickness must not be thicker than the thickness of the actual webbing material. Both warp and fill direction of the weave must be tested to determine the most critical flammability condition.

In order to correctly determine the flame resistance ability of the webbing, at least three specimens is required to be tested and the results are to be averaged. Each specimen is supported horizontally while being exposed to a Bunsen Burner or Tirrill Burner which needs to give out a flame of 38 mm (1.5 in) in height. The minimum flame testing temperature is required not to be less than 840 °C (1550 °F). The flame is applied for 15 s and then removed.
A minimum of 250 mm (10 in) of the specimen must be used for timing purposes, approximately 38 mm (1.5 in) must burn before the burning front reaches the time zone, and the average burn rate must be recorded.

Burn length is the distance from the original edge to the farthest evidence of damage to the test specimen due to flame impingement. In this flame substantiation test, the minimum burnt length of the webbing material is required to not exceed 2.5 inches per minute.

**Conclusion**

Through suggestions from paramedics and helicopter rescue personnel, the Child Rescue Valise standard has been proposed to describe the minimum requirements that must be met by all new Child Rescue Valise equipment. This new standard is a modification to, or rather an extended version of the existing Australian standard for crew rescue harnesses (ATSO-C1003) which describes the minimum safety requirement for a helicopter external personnel lifting devices. The standard has been developed based on the analysis of AS/NZS 1891.1:1995 (Amdt 4), FAA FAR Part 29.853, FAA FAR Part 29.865 and other aforementioned additional standards to establish the appropriate information and requirements for the CRV design. Additional safety and design requirements have been added to further enhance the level of the safety for the occupants.

**References**