IMPACT LIMITER RETENTION USING A TAPE JOINT

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ABSTRACT

Sandia National Laboratories has developed the Beneficial Uses Shipping System (BUSS) cask [1] for the transportation of up to a megacurie of radiation source capsules. This work was done under contract to the Department of Energy. The BUSS cask (Fig. 1) employs polyurethane foam impact limiters that fit onto the ends of the cask. A foam impact limiter takes energy out of the system during a hypothetical accident condition by allowing foam crush and large deformations to occur. This, in turn, precludes high stresses or deformations from occurring in the cask. Depending on the nature of the impact limiters and large deformations experienced, retaining the limiters on a cask during a 9 meter regulatory drop poses a design challenge. Impact limiter retention becomes a concern to ensure the cask does not experience higher decelerations during secondary impacts without impact limiters in place. During the 9 meter drop, the impact limiters absorb the energy required to confine the cask deceleration to acceptable levels. However, if the impact limiters were removed from the cask due to initial impact, higher cask stress levels could occur during any secondary or rebound effects. A tape joint has been designed to solve the problem of retaining impact limiters onto the BUSS cask during impact loadings.

INTRODUCTION

The Beneficial Uses Shipping System (BUSS) cask, developed at Sandia National Laboratories, will transport Cesium Chloride (CsCl) and Strontium Fluoride (SrFl) radioactive source capsules. Figure 1 shows an exploded view of the BUSS cask components. Rigid polyurethane foam impact limiters fit over each end of the stainless steel cask. A thin stainless steel skin encapsulates the foam. Two independent systems fasten these impact limiters to the cask. For normal operations and handling, four turnbuckles provide all the load carrying capabilities required to keep the impact limiters fastened to the cask. The turnbuckles, located every 90° around the cask circumference, connect the

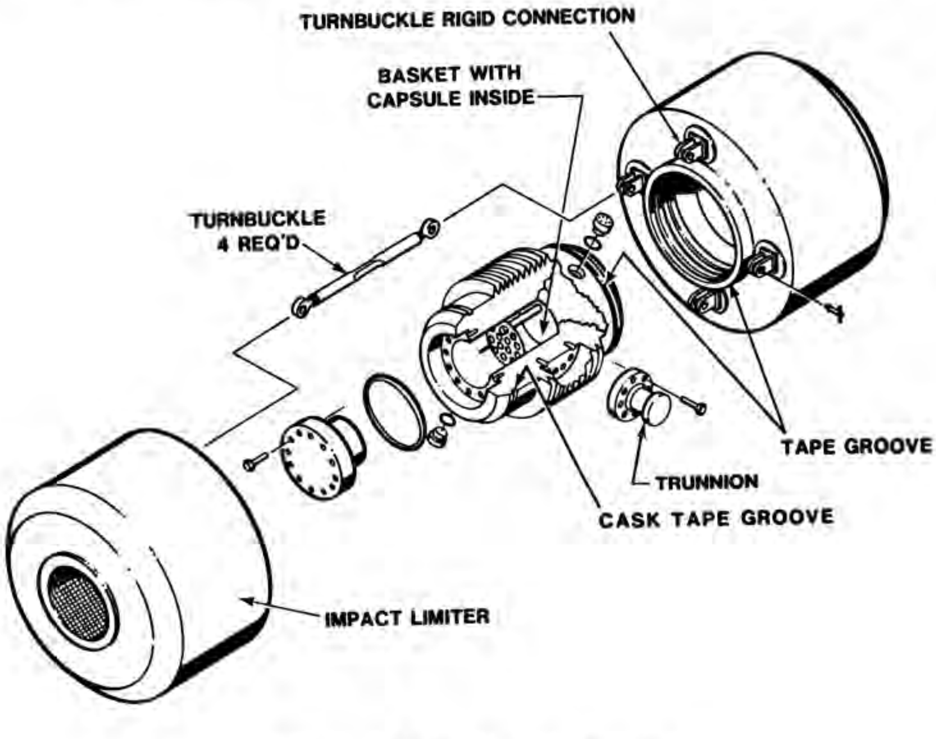

Fig. 1. Exploded View of BUSS Cask.

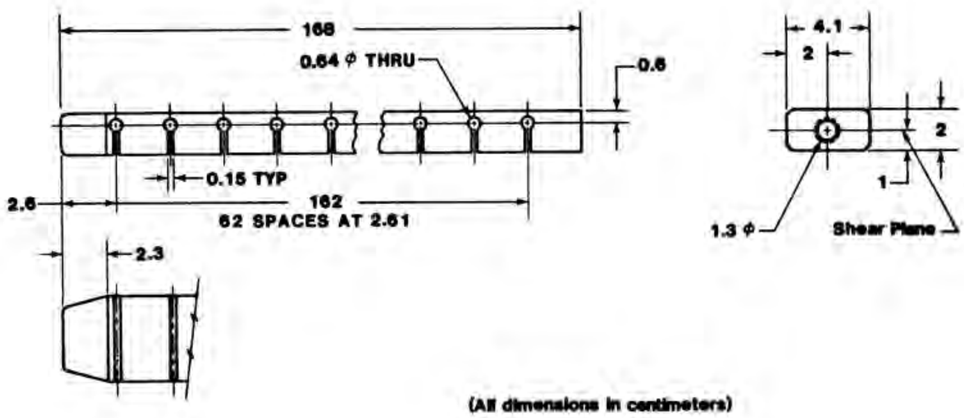

Fig. 2. Tape Section.

impact limiters without having the turnbuckles come in direct contact with the cask body. Fastening the turnbuckle to the impact limiters is a ball lock pin which allows only axial loading of the turnbuckle. The turnbuckles are continuously loaded in tension to securely fasten the impact limiters onto the cask. This is done to avoid any impact limiter movement during normal operations and handling. During a hypothetical accident sequence a loose fitting tape joint securely connects the impact limiters to the cask (Fig. 2). This tape joint connects the impact limiters directly to the cask by means of a rectangular key that fits into a groove (Fig. 3). This is to ensure the impact limiters remain on the cask avoiding any additional damage subsequent to the initial impact. In addition, this fastening method provides ease in assembly and handling without prolonged personnel exposure to the cask surface.

In the development of the BUSS cask system, the use of four turnbuckles easily satisfies the design criteria of 10 CFR 71[2] for normal operations and handling. However, because of the high impact loads generated by the regulatory hypothetical accident

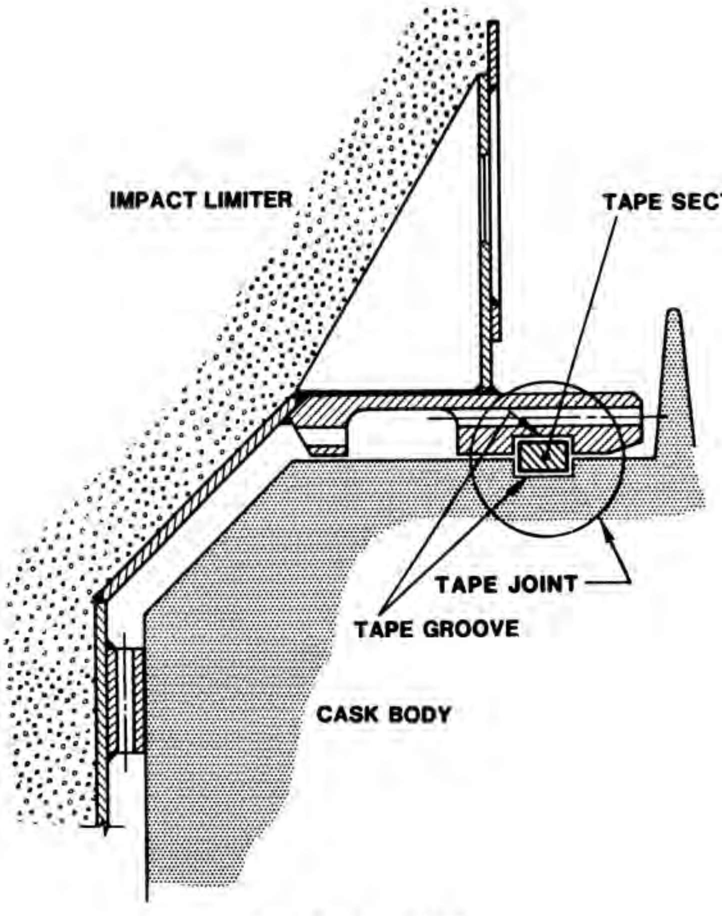

Fig. 3. Tape Joint.

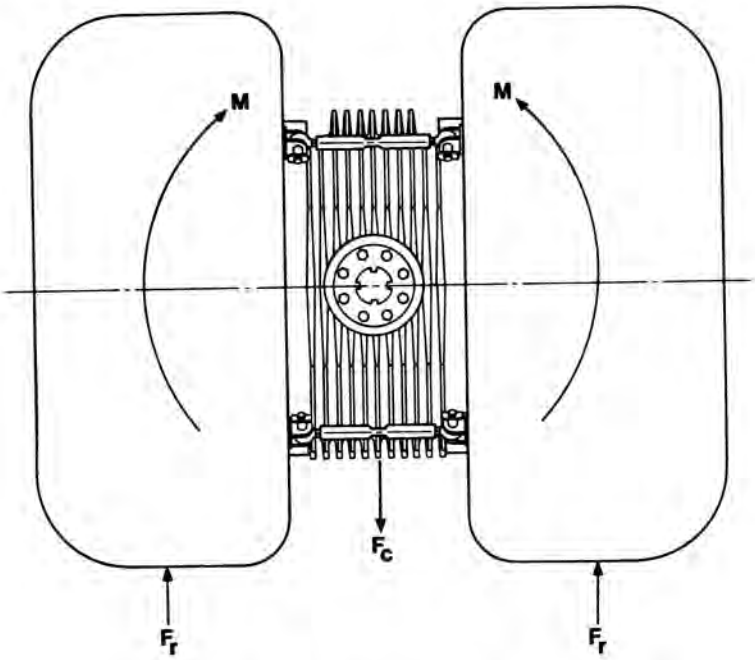

Fig. 4. Moment Applied to Cask Due to Regulatory Side Drop.

conditions, use of an additional connection between the cask and impact limiters became necessary. The design precluded the impact limiters from covering a large amount of the actual cask in order to provide a large surface area for heat dissipation. This produced an inherent problem of maintaining impact limiter retention while working with little available cask surface area.

DESIGN CONSIDERATIONS

Of the potential drop orientations for the package, the side drop presents the worst case with respect to impact limiter retention. Corner and end drops cause the impact limiter to be pushed onto the cask, thus reducing the problem with impact limiter retention. Design development tests show the impact limiters do crush to absorb energy, however, the side drop results in a large moment. This moment causes the impact limiters to try rotating about the cask (Fig. 4). Since the common surface area between the cask and impact limiter is small and the turnbuckle connection system is designed to carry only normal service loads, the rotation of the impact limiters onto the cask must be achieved by a device which retains contact between the impact limiter and the cask. Hence, this criteria results in utilizing a tape joint to provide the required strength during an accident condition.

With the cask and impact limiter dimensions given and resisting the moment due to impact as a design goal, a reference, "Guidelines for Designing Tape Joints" [3], was used to size the tape joint. Ensuring the tape section could be inserted and removed by hand was a design priority from a user's standpoint. The tape has two sections as shown in Fig. 2. First, a cross section of 4.1 cm x 2 cm was designed to withstand the applied load generated by the side impact. However, in order to easily bend the tape to insert into the tape groove a thin section is required. A 4 cm x 0.3 cm section is ductile enough to allow bending by hand to easily insert the tape into the groove. Some concern existed with regard to the ease of the tape insertion and removal. A full scale laboratory test setup demonstrated that one person by hand could insert and remove the tape (Fig. 5). This laboratory test demonstrated the tape cross section's ability to withstand repeated bending during insertion and removal. Applying a lubricant to the tape made insertion easier and helped prevent material galling. Performing this procedure over 200 times without failure illustrated the durability of the tape during normal service operations.

To house the tape section a groove is required. The tape groove provides a clearance for a loose fit but is adequate to guard against tape roll-over when

Fig. 5. Tape Joint Durability Test.

subjected to a direct shear. The tape groove consists of two mating sections. The cask wall has a machined groove on each end (Fig. 1 and 3). The other half of the tape groove is a lip protruding from the impact limiter which when fitted onto the cask matches the respective grooves. The tape is inserted through a slot in the impact limiter groove. Two tapes, each encircling one-half of the cask circumference, form the tape joint for each impact limiter.

ANALYSIS

Analysis of the tape joint concentrated on its ability to withstand shear as a result of the moment applied during impact. For the impact limiter to separate from the cask, the entire tape must shear through its cross section or the impact limiter groove must tear from the impact limiter. With such a large effective shear area supplied by the tape joint, 304 stainless steel provides the proper amount of material strength to withstand the given loads. Upon impact, the impact limiters crush and deform. This deformation produces a large turnbuckle stress due to the rigid connection onto the impact limiter skin (Fig. 1). By design, the connection pads will pull out, before the turnbuckles yield, and allow differential movement between the impact limiters. This movement of the impact limiters loads the tape.

Newton's second law determines the amount of force trying to remove the impact limiters during side drop impact. With a total cask assembly mass of 15,000 kg and a calculated deceleration force of approximately 97 g's [1] gives a total impact force, F_c, of 14.3 MN upon the cask system. This results in an approximate load of 7.2 MN, Fr, per impact limiter to cause a moment about the cask (Fig. 4). Using a moment arm of 49.5 cm shown in Fig. 6 results in a moment of 3.6 MN·m applied to each impact limiter.

Using the ultimate strength failure of the tape joint material as the design criteria, the tape must be sheared through its cross section to remove the impact limiters. This is a limit load calculation as opposed to a progressive failure. Because of the geometry and intimate connection between the cask and impact limiter, the entire tape cross section is effective. The proximity of the tape joint to the 143°C cask body warrants using a lower material ultimate strength (75% of that at normal operating temperature [4] to compensate for reduced material strength from temperature effects. Using a von Mises shear stress criteria, the ultimate shear stress is 149 MPa. With the length of two tape sections (324 cm, Fig. 2) and tape thickness of 4.1 cm results in a tape shear strength of 20 MN·m. Encircling the cask circumference, the tape joint resists the applied moment. The tape moment arm [5] is equal to:

$$\text{Moment arm} = 2\,\frac{2r}{\pi}$$

where:

r = radius of tape circumference (58 cm)

gives a value of 74 cm. Using half the tape shear strength of 10 MN and moment arm of 74 cm gives an allowable moment of 7.4 MN·m which is greater than the 3.6 MN·m applied moment. Thus, the tape will not shear in impact.

Because of the confined space of the groove, tape roll-over is not a problem. In fact, if roll-over were to occur, the tape would need to be compressed then sheared in order for the impact limiters to be removed from the cask. This illustrates the conservatism associated with analysis of failure by pure shear.

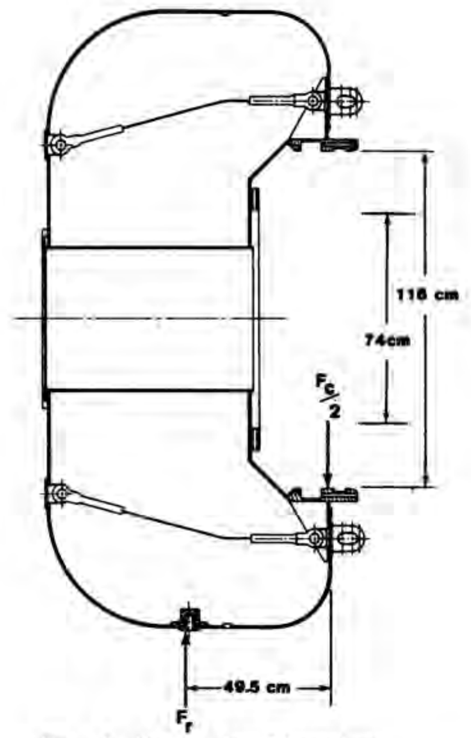

Fig. 6. Moment Arm Dimensions.

SUMMARY

Given the small area available to withstand large loads due to impact, a tape joint system proved valuable. A tape joint provides a large surface and shear area without using exotic high strength material. In the special case of the BUSS cask, the tape joint will not go into effect unless an accident condition were to occur. If the impact limiters were loaded in such a way as to try removing them from the cask, the tape section would absorb the load through its cross section in shear. The amount of shear strength provided by the tape joint results in a load carrying capability to ensure impact limiter retention subsequent to an accident scenario.

SUMMARY

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