

## Shelving Cart Design and Manufacturing Safety Analysis

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**Abstract:** A South Carolina retail store employee was injured when the top shelf of a shelving cart fell and hit her on the head. The U.S. Consumer Product Safety Commission (CPSC) has received reports of 51 similar incidents associated with the subject model-shelving cart involving the upper shelf or latch. A deviation analysis was performed comparing the dimensions of the cart involved in the accident obtained by a FaroArm scan with the Computer Aided Design (CAD) drawings for the cart, which indicated several manufacturing defects. Alternative shelving cart top shelf securing designs are explored to prevent this well-documented injury mechanism.

**Keywords:** Shelving Cart Design, Manufacturing, Safety Analysis

### 1. Shelving Cart Accident History

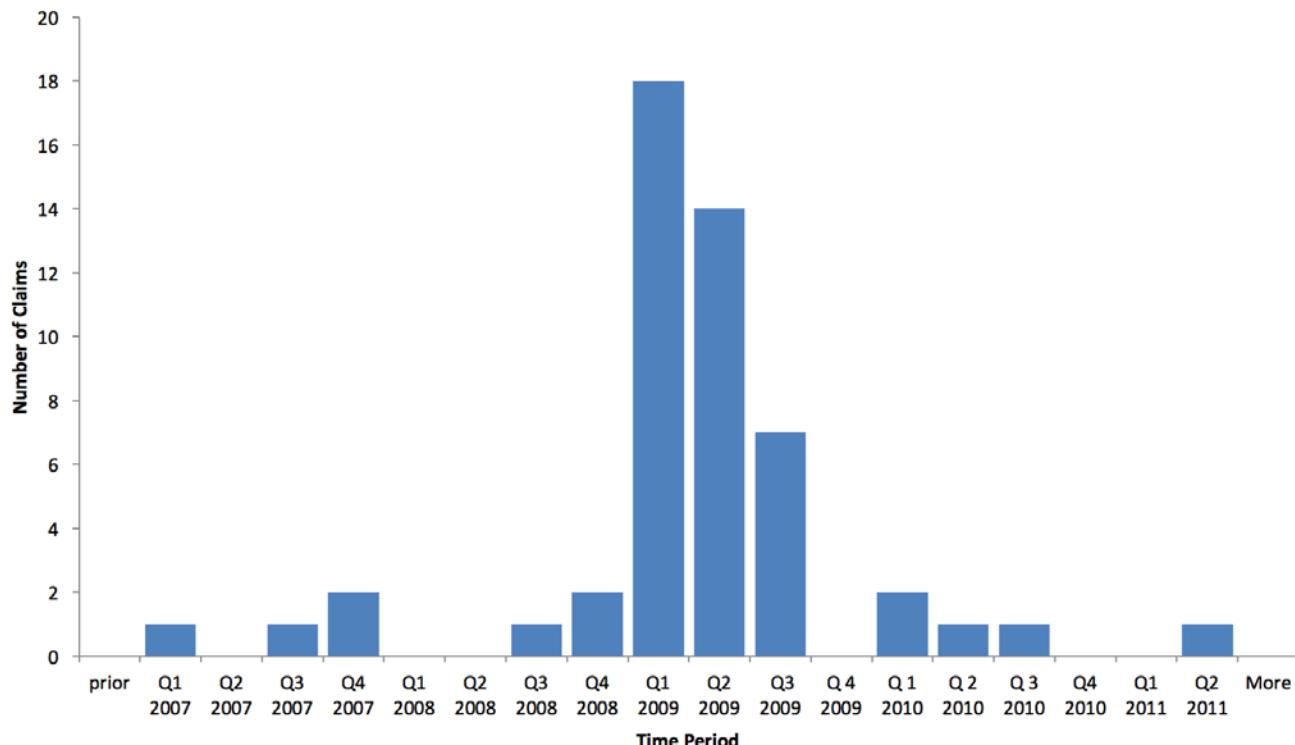


Figure 1. Shelving Cart Reported Injury History – Involving Top Shelf or Latch.

Figure 1 displays 51 reported similar incidents associated with the subject model-shelving cart involving the top shelf or latch as reported to the U.S. Consumer Product Safety Commission (U.S. CPSC, 2015). The injuries occurred from 2007 to 2011 with a peak of 39 incidents reported in 2009. Of the 51 reported injuries, 49 involved the head, one involved the arm, and one was unknown. Fifty store employees sustained injuries and one injury involved a store customer. Nine incidents happened in Texas and eight incidents occurred in Michigan.

## 2. South Carolina Shelving Cart Accident Description

On December 7, 2009, a South Carolina retail store employee was injured when the top shelf of a shelving cart fell and hit her on the head. A surveillance camera in the store as shown in frames A and B of Figure 2 captured this accident. Figure 2 frames C and D show the relative position of the cart top shelf during the accident sequence with frame C displayed in the vertical stowage position and frame D displayed in the horizontal unsecured position. At the time of the accident, the injured worker was standing in front of the cart attempting to lift the bottom shelf. She touched the cart side door with her left hand, which initiated the top shelf falling onto her head from the false latched vertical stowage position.

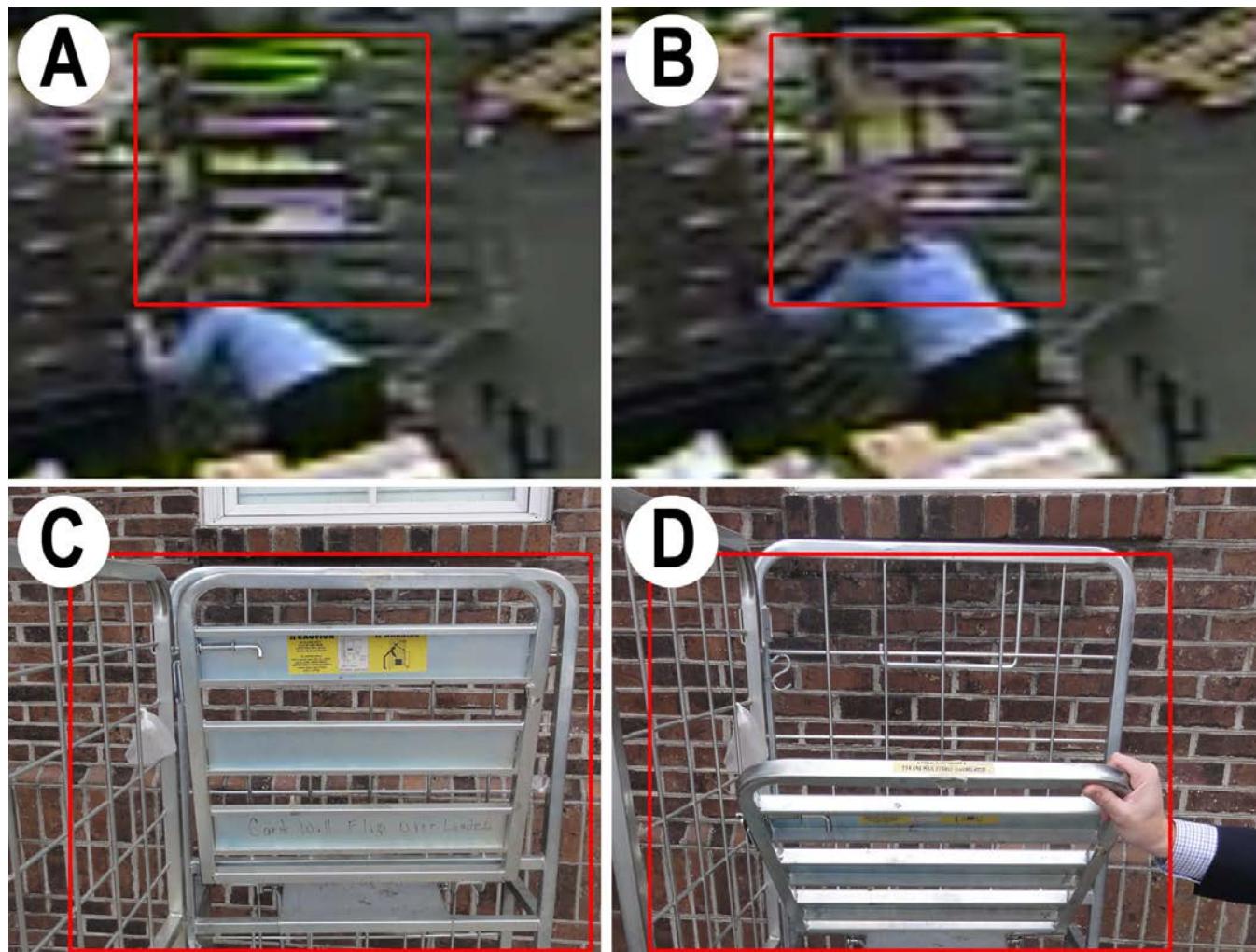


Figure 2. South Carolina Shelving Cart Accident Sequence.

### 3. Shelving Cart Top Shelf Latching Mechanism Description

Figure 3 displays the shelving cart design top shelf in three separate positions. In Figure 3A, the top shelf is secured in the latched vertical position by a spring-latch pin, which is inserted into a strike plate opening. Figure 3B shows the spring-latch pin moved to the right out of the strike plate opening, which allows the top shelf to fall by gravity. The top shelf has initiated its downward descent in Figure 3C where the left top shelf catch freely passes by the cart side door tubing.

Figure 4 shows an overlay comparison of the as-designed CAD configuration of the top shelf latching mechanism (displayed in green) with the as-manufactured configuration of the same top shelf latching mechanism (displayed in orange) as obtained by a scan of the cart involved in the South Carolina accident using a FaroArm (Faro, 2016). In Figure 4A, the top shelf has sufficient clearance from the shelving cart side door to freely move without interference. Figure 4B illustrates the dimensional deviation between the green as-designed configuration and the orange as-manufactured condition where there is physical interference between the spring-latch pin tip and the side door and between the top shelf catch and the cart side door. This mechanical interference contributes to the false latching condition of the top shelf in the vertical stowage position shown in Figures 2A and 2C, which is not readily apparent to the shelving cart user in her position in front of the cart. The false latch condition occurs when the top shelf makes contact with the side door and provides a temporary frictional support for the raised top shelf without complete and proper spring-latch pin engagement in the strike plate.

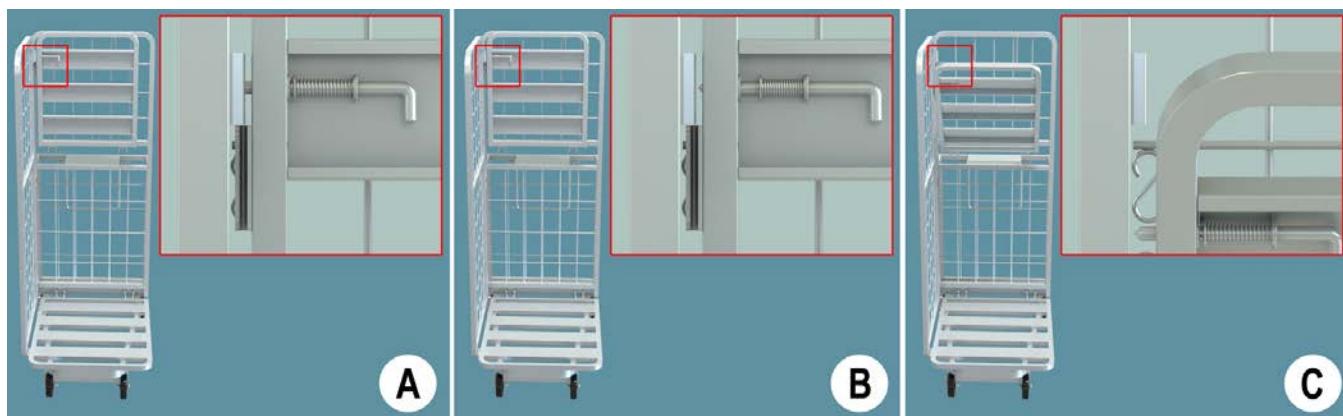


Figure 3. Shelving Cart Top Shelf Latching Mechanism (As-Designed Configuration).

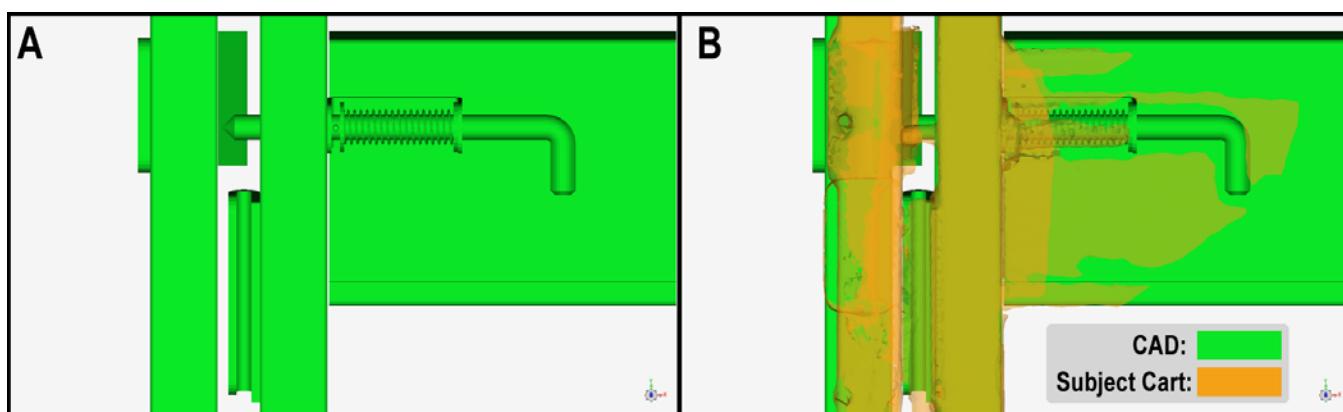


Figure 4. Top Shelf Latching Mechanism Overlay Comparison of As-Designed (Green) with As-Manufactured (Orange).

#### 4. Subject Cart Dimensional Deviation Analysis

A dimensional deviation analysis has been performed comparing the geometry of the shelving cart involved in the South Carolina accident obtained by a FaroArm scan with the Computer Aided Design (CAD) drawings for the cart. Figure 5 displays a mapping of the dimensional deviations of the shelving cart where green represents within 1/16 inch tolerance. The red and blue scales in Figure 5 represent dimensions exceeding 1/16 inch tolerance specifications. The CAD for the shelving cart indicates a clearance between the top shelf catch and the side door tubing of 0.1567 inches whereas the subject cart top shelf catch contacts the side door tubing. The dimensional deviations exhibited by the shelving cart are due to manufacturing defects and not due to cart damage. The dimensional deviations are gradual and the overall appearance of the shelving cart does not exhibit any significant impact damage. Specifically, the as-manufactured condition of the shelving cart deviates from the as-designed CAD for the subject shelving cart with respect to the rear upright tubing, rear horizontal rods, towel rod, strike plate, S-hook, top shelf hinges, top side door hinge pin, top door hinge base, side door tubing, side door horizontal rods, door hinge top, side door catch, top shelf catch, top shelf, and spring-latch pin. These manufacturing defects caused the false latching condition of the shelving cart top shelf, which led to the top shelf falling onto the worker's head.

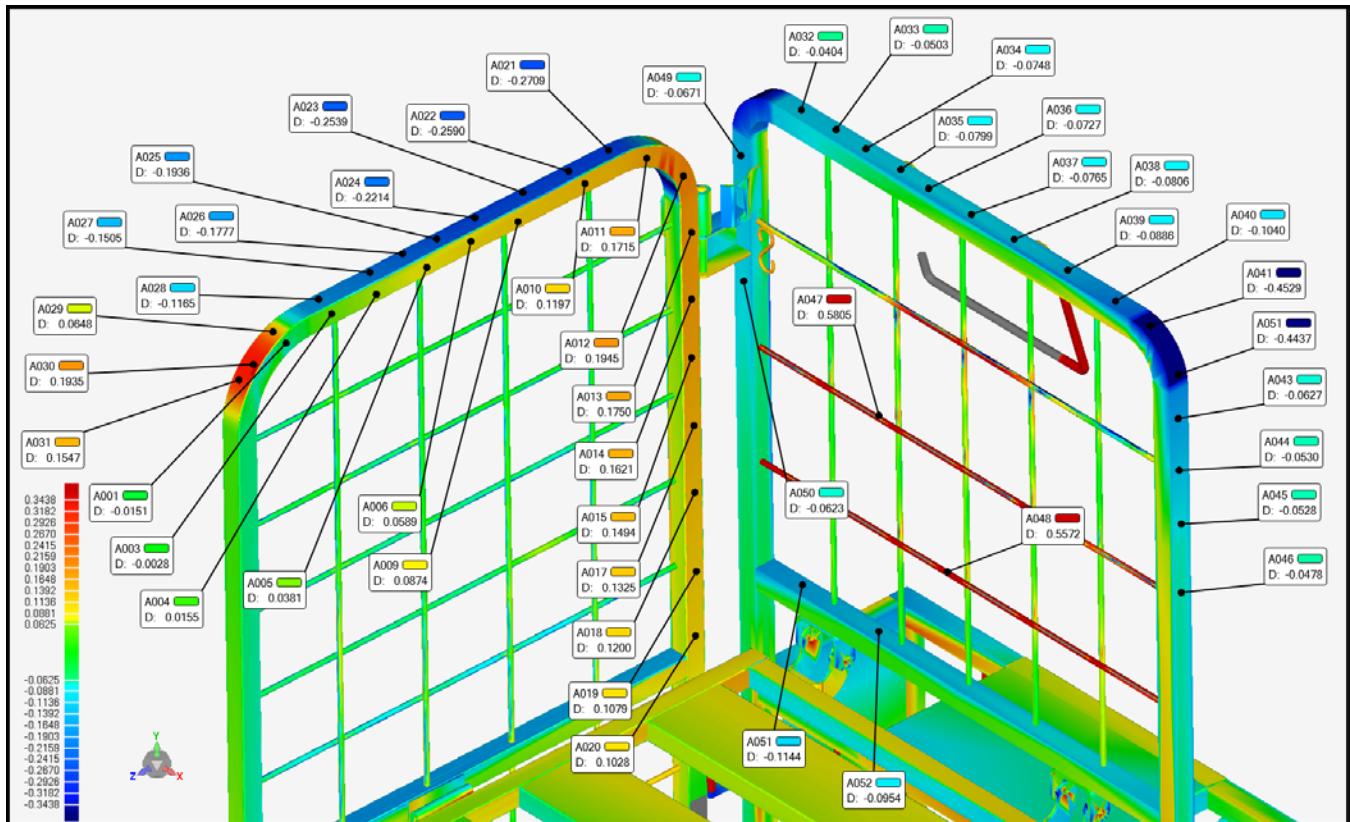


Figure 5. Subject Cart Dimensional Deviation Analysis.

#### 5. Shelving Cart Design History

The first version of the shelving cart was produced in 2007. The purpose of the shelving cart is to facilitate moving products from the storeroom onto store shelves. The nestable cart design includes a second shelf for sorting loads, a cardboard holder, a paper towel holder, a pull handle, and a flat work surface. A United States patent for the shelving cart was filed on June 23, 2004 and was issued on May 8, 2007 (Gregory, 2007). The shelving cart associated with the South Carolina store worker was manufactured in late February of 2008. The inspection sticker on this shelving cart actually states February 30, 2008. It was determined that shorter people had a more difficult time reaching the spring-latch pin on the top shelf of the shelving cart. A safety latch shown in Figure 6B had been proposed by the shelving cart manufacturer as of

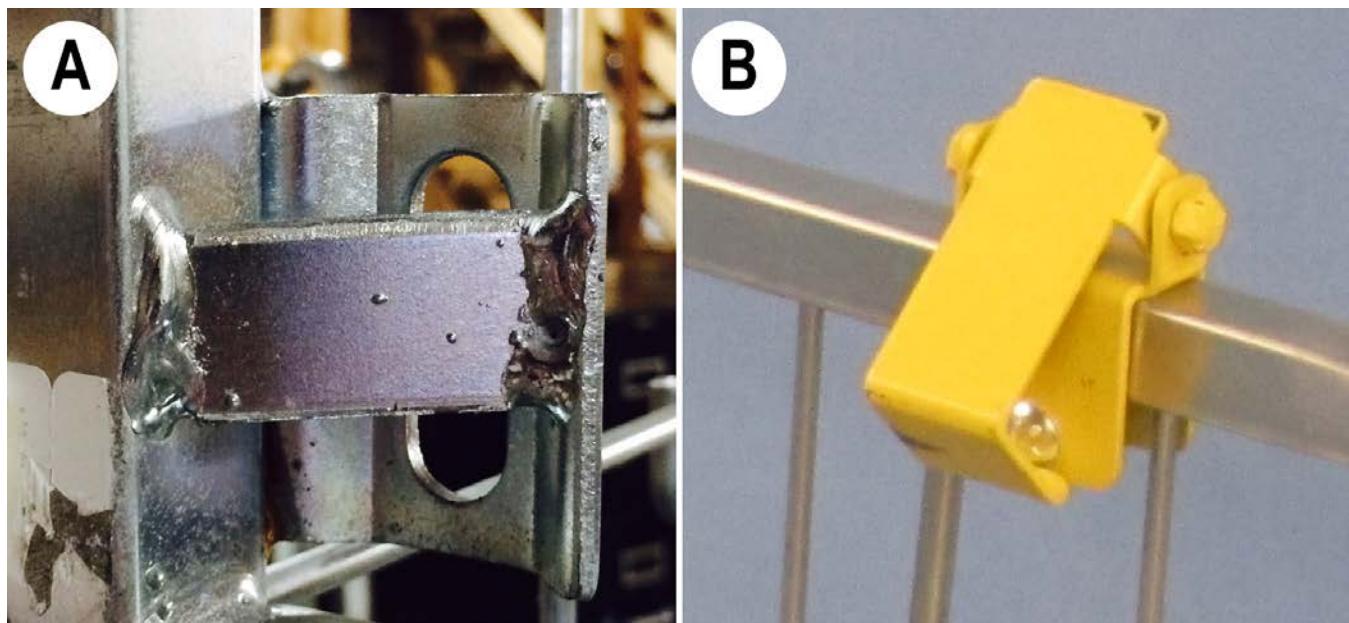


Figure 6. Shelving Cart Strike Plate Gusset (A) and Top Shelf Secondary Safety Latch (B).

August of 2009 as a retrofit safety measure to be installed on carts marked February 2008. The safety latch is an active device that requires the shelving cart user to latch the top shelf in the vertical stowage position to ensure the top shelf would be secure if the spring-latch pin did not lock properly. The shelving cart manufacturer alleges that the secondary safety latch could not have been put on the shelving carts without permission from the retail store shelving cart owner. Therefore, the subject-shelving cart had not been retrofitted with the secondary safety latch prior to the South Carolina worker's accident.

After the subject-shelving cart was manufactured, a latch gusset plate was added to the shelving cart design in approximately May of 2009 as shown in Figure 6A. The latch gusset plate assists in maintaining the structural rigidity and geometry of the strike plate, which contains the opening that the spring-latch pin enters to secure the top shelf. The shelving cart involved in the South Carolina accident displayed wear marks on the strike plate, which is evidence of physical interference with the spring-latch pin on the top shelf.

## 6. Alternative Shelving Cart Top Shelf Securing Designs

Figure 7 displays two alternative shelving cart top shelf securing designs. Figure 7A depicts a passive latching mechanism that secures the top shelf in the vertical stowage position by pushing the top shelf up into place without having to actively manipulate a spring-latch pin for proper top shelf latching. This passive top shelf latching mechanism is offered on a Matco 3-sided, 2-shelf, foldable stocking cart (Matco, 2016). Figure 7B shows a vertical hinge, which allows the top shelf to be secured in a vertical stowage orientation without the use of a latching mechanism. This shelving cart top shelf vertical hinge design is available on Matco dairy product multi-use carts utilized in dairy, manufacturing, retail, snack food, and many other industries (Matco, 2015).

## 7. Conclusions

The deviation analysis results indicate that the subject-shelving cart possesses several manufacturing defects that result in dimensions that exceed the 1/16 inch tolerance specified in the cart drawings. In an as-manufactured condition, the cart top shelf is capable of producing a false latch condition in the vertical stowage position, which can lead to the top shelf falling unexpectedly onto the cart user, especially 5th percentile height females (SAE, 2007). In fact, a brand new exemplar-shelving cart was observed to possess the same manufacturing defect as the subject cart involved in the South Carolina

worker's accident, which contributed to the false latch condition of the top shelf. Alternative shelving cart designs possessing passive top shelf latching mechanisms and vertical hinges can prevent this well-documented injury mechanism.

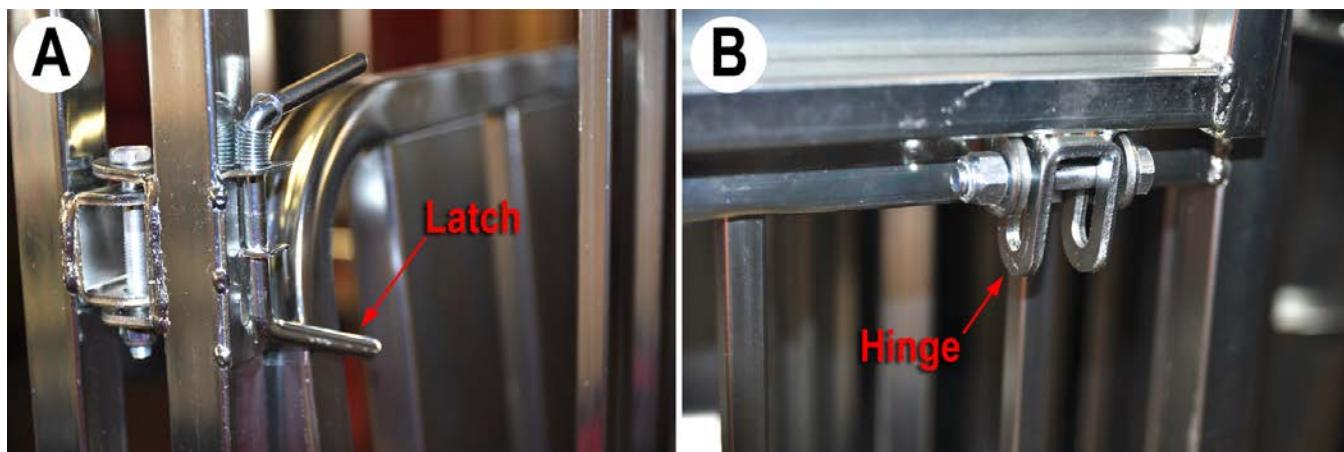


Figure 7. Alternative Shelving Cart Top Shelf Securing Designs - Passive Latch (A) and Vertical Hinge (B).

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