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Forensic Engineering Investigation of a Fall from a Construction Machine

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Abstract

Each construction machine design presents unique challenges for mounting and dismounting by workers. A forensic case involved a worker's fall from around the turret platform of a new digger derrick truck, parked on level concrete. The case involved analysis of OSHA, ANSI, FMVSS, SAE, and ISO standards, and their scopes, relevance and interpretations. The analysis also focused on operator instructions, the design and fabrication of the access systems, the worker's proportions, feasible competitor designs, and feasible fabrication options for the subject digger derrick.

Keywords

Forensic Engineering, Access, Standard, Handrail, Handhold, Derrick, J185, J1116, A10.31.

Introduction

Digger derricks are machines used to install utility poles. At a minimum, they typically are comprised of a heavy truck chassis and body with a turret-mounted telescoping boom and articulated auger. This is used to drill a hole sized to accept a utility pole. The operating station for control of this boom and auger may be designed as a stationary console located on the side of the truck, or may be turret-mounted and swivel along with the main boom, as on the subject machine. The intended route of entry to the turret control platform and the layout of handholds, controls and foot step features all combine into what is called the "access system". The design of an access system has a significant influence on machine ingress and egress. The subject machine's access system design will be compared to known standards.

Background

The client Plaintiff was an experienced digger derrick operator who had been employed for 18 years by a utility company. He was notified on a Friday that the following Monday he would begin using a new digger derrick truck that had just been delivered. The Plaintiff boarded the truck (shown in Figure 1) to familiarize himself with it. The truck was located on a covered, level concrete pad and the weather had been dry. During the course of his examining the turret-mounted controls and warnings, the operator, who was 6'-5" tall and weighed 380 pounds, fell from the vehicle, landing prone behind it. He sustained significant injuries consistent with a fall from elevation. Injuries included a fractured wrist, elbow, patella and orbital. The actual fall was not witnessed; the Plaintiff was observed only as he was

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striking the ground. The Plaintiff does not remember what specific motions he was engaged in near the turret control platform.

Figure 1
Subject Digger Derrick Truck

Figure 2
Sole boarding route for entering turret control platform

Observations made of subject digger derrick truck

An inspection was conducted of the subject machine, several months post-incident, with the machine in the same general location as at the time of the incident:

1. The manufacturer-designed route to be taken by operators when they climb to use the digger derrick controls is shown in Figure 2. Enroute to the turret control platform, the operator must climb atop the right-side cabinets of the truck body and stand on an expanded metal walkway. This walkway was approximately 72 inches above the ground and was 18 inches wide as shown in Figure 3.

Figure 3
Walkway and access route to turret control platform, looking rearward

Figure 4
Access system features of subject turret control platform

2. Referring to the labels in Figure 4 depicting the digger derrick turret, Handrail **A** was a tubular loop approximately 1.5 inches in diameter, welded to the front of the dashboard support frame. Handhold **B** was a rounded-rectangular hole cut in the right-side dashboard end panel, which was made of 3/16-inch thick steel plate. Handrail **C** was a tubular loop approximately 1.5 inches in diameter, welded to the seat

support behind the seat. Also present in the access system for the turret control position was a fabricated metal platform step **D**. It was attached to the top of the walkway by 4 bolts, and reportedly had originally been mounted approximately 9 inches forward on the walkway using an alternate set of mounting holes still visible.

3. The viewing perspective of one author (6'3" in height) when standing on the walkway to mount the control position is shown in Figure 5. It can be observed that handholds **A** and **B** were both near the viewer, and past them was the actual entry area onto the platform and seat of the turret control position. Beyond the seat, and not generally visible to the viewer, was handhold **C**.

Figure 5
View prior to boarding turret control platform

Summary of Analysis of Access System

It is well-known that three robust structural points for human body contact are necessary for safe climbing to and from user positions on equipment. Though the subject vehicle had steps, a handhold, and two handrails, the positions of those components did not allow the user to readily establish a stable 3-point base of support when boarding or dismounting the turret control platform.

As will be discussed, there are well-known and relevant standards regarding the proper design of access systems for this type of machine, and the subject vehicle did not comply with these standards. There was nothing unique about the subject vehicle that would have precluded it from conforming to these standards. These standards were available to the manufacturer.

There were feasible (and superior) alternate access system designs that could have been implemented on the subject vehicle's basic structure without loss of functionality. Manufacturers of competing models already present in the stream of commerce created superior alternate access system designs to that of the subject vehicle.

Case-related analysis of Standards

ANSI-ASSE A10.31

The data plate on the boom of the subject vehicle states that it conformed to ANSI A10.31, which is a shortened reference to ANSI-ASSE (American Society of Safety Engineers) A10.31 "Safety Requirements, Definitions and Specifications for Digger Derricks"[1]. Like other ASSE A10 standards, A10.31 does not include design requirements for access systems. Consequently, an enquiry was made of the A10.31 committee to determine what should be referenced as a safety standard for this aspect of the equipment. A response was provided by the committee's Technical Liaison (a licensed Professional Engineer) who cited SAE (Society of Automotive Engineers) Recommended Practice J185 "Access Systems for Off-Road Machines"[2] as the appropriate reference.

SAE J185

The J185 standard is a known practice document that was released in 1970. While not specifically codified by OSHA for digger derricks, it is listed in the OSHA "Incorporated by Reference" section 29CFR1910.6[3]. It recommends dimensional criteria for steps, platforms, walkways, handrails, handholds and entrance openings of access systems on off-road construction vehicles. The criteria contained therein apply to a list of off-road self-propelled work machines defined in another SAE standard, J1116[4]. While digger derricks are not explicitly listed in this equipment list, the verbiage is not exclusive and these machines could (in the authors' opinions) reasonably be placed into either the "earthmoving" or "road building and maintenance" categories. A footnote in the standard acknowledges that the list is not exhaustive and states, "the lists are not intended to include all machines in current production". Examining the list's occasionally-generic equipment names, the list appears to include most common off-road machines. The digger derrick truck is indeed a heavy-duty off-road vehicle, as manifested by its four-wheel drive, steep hill approach angle, bumper winch, and elevated ground clearance. It was on this basis, as well as the response from the ANSI A10.31 Technical Liaison, that SAE J185 was determined to be applicable. Specific requirements include those in Section 4.5 which state that "Access systems shall":

a. (item g): "Permit and, by proper placement of components, promote achievement of three point support while ascending or descending the access system when more than one meter above the ground."

b. (item e): "Accommodate dimensionally a 95th percentile male through a 5th percentile female as defined in SAE J/ISO 3411."

c. (item f): "Be obvious as to proper usage without special training."

Federal Regulations

Research into Federal regulations revealed a Federal Motor Vehicle Safety Standard entitled "Step, Handhold, and Deck Requirements for Commercial Motor Vehicles"[5]. However, this regulation (and its apparent intent[6]) only pertains to cab-over commercial trucks and is therefore irrelevant. Another document examined in the Federal Register was one proposing rules related to crane and derricks used in construction[7]. Though not enacted, this did recommend codifying SAE J185 for equipment generically classified as "derricks".

Legal Challenges made by Defendant

The manufacturer of the subject digger derrick claimed several points in defense, as follows:

1. The machine was compliant with ANSI/ASSE A10.31 and the digger derrick had appropriate labeling advertising this compliance.

2. Compliance with SAE J185 was not required since digger derricks are not specifically listed in SAE J1116.

3. The Plaintiff, at 6'-5" and 380 pounds, was "bigger" than the 95th percentile design maximum in J185.

4. Only someone experienced with digger derrick design could testify as an expert in this type of case.

Analysis of subject digger derrick access system

Operator Instructions

To the left side of the operator's seat are a series of operator warning labels – see Figure 6. While various operational hazards are identified, no instructions for boarding/dismounting the turret control platform are given. Additionally, these warning labels are generally obscured from the operator's view by the dashboard when the control platform is approached from the walkway as previously illustrated in Figure 5.

Figure 6
Warning labels

Design & Fabrication of Access Systems

The access system of the turret consisted of 6 components; the fixed walkway and step, two handrails, a handhold, and the turret platform. Each of these components is described below – see Figure 7.

Fixed walkway: This was a horizontal surface that extended along the top of the right-side tool cabinets, and it was fabricated from expanded metal. The walkway extended from several feet in front to several feet past a point immediately adjacent to the turret platform.

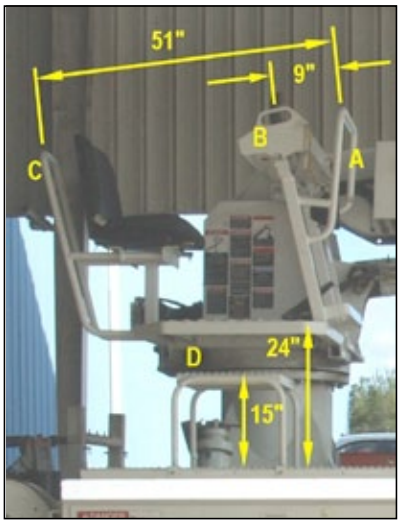


Figure 7
Access system features and dimensions

Fabricated bolt-on platform step **D**: As mentioned above, this appears to be have been relocated after the initial truck construction. Its design consisted of 2 pieces of bent steel tubing formed into inverted "U" profiles. These were then welded to a 13x16 inch platform made of expanded metal. To each of the free ends of the bent tubes (which formed the platform legs) were attached angle brackets that allowed for attaching the welded platform assembly to the edges of the fixed walkway. SAE J185 requires that such steps have side rails or other features that prevent lateral slipping of the operator's foot, and such features were not present - though the expanded metal platform itself would provide effective traction. Lacking this step, the operator would be required to step up over 24 inches in order to negotiate between walkway and the turret platform – though it is noted that J185 permits a step-up height of 27.56 inches. As is, the operator of this digger derrick must unevenly step up 15 inches and then 9 inches.

Handrails: The first handrail **A** was in front of the turret dashboard and consisted of bent steel tubing, which forms the initial handrail an operator would encounter on their right when approaching the turret control platform. The tubing was welded to the structure supporting the turret controls. The second handrail **C** was located behind the turret seat. It was fabricated also from tubular steel, and was attached to the turret platform, extending upwards behind the seatback. The spacing between Handrail **A** and Handrail **C** was measured as approximately 51 inches.

Handhold **B**: approximately 9 inches aft of Handrail **A** was a rounded rectangular handhold. This handhold was part of the plate forming the end of the turret control dashboard. The cutout slot of the 3/16-inch thick plate was measured to be approximately 5 inches wide by 2 inches tall. This left a handhold with a ½ x 3/16 inch cross-section. See Figure 8.

Figure 8
Handhold **B**

Turret Platform: This consisted of a square tubular framework and expanded metal floor, extending lengthwise from the front edge of the seat to underneath the control dashboard. The platform was positioned to the right of the turret such that when the boom was in the stored position the platform edge was inset approximately 4-5 inches from the outside edge of the walkway.

Discussion

As noted, one of the requirements in Section 4.5 of SAE J185 was that the access system should be able to "accommodate dimensionally a 95th percentile male through a 5th percentile female as defined in SAE J/ISO 3411". Per that ISO standard, a 95th percentile male is 6'-3", 237 pounds[8]. The client Plaintiff, at 6'-5" tall and 380 pounds, was outside the dimensional range described in the standard. However, in consideration of the dimensional requirements of J185, the design was not safe for anyone – even those individuals that fall within the dimensional range described in those standards. As an example, a 5th percentile female has an arm span of approximately 60 inches[9], only 9 inches wider than the span between Handrails **A** and **C**.

It can be seen that even if the vehicle's user wants to move to a position to attempt to use the existing handgrips and handhold, the platform step **D** basically blocks the user's way. The platform step must therefore either be carefully stepped around, over, or under, or straddled, before Handrail **C** can be grasped. If the feet are placed under the outboard side of the platform step, the tread of the

Figure 9
Shoe heel off walkway during frontal approach to turret control platform

step contacts the user's shins and prevents the user's heels from being able to rest on the walkway – thereby requiring the user to constantly hold onto handrails/handholds to avoid falling. See Figure 9. The user cannot climb the platform step **D** from the "starting position" shown in Figure 5 without relying on Handrail **A** and Handhold **B**, which both end up on the right side of the body during climbing, preventing the establishment of a stable 3-point-contact base of support. This is further complicated (as mentioned) by the general inability to see Handhold **C** when starting to board the turret control platform.

The primary J185 access system non-compliance issues noted were as follows: First, the measured handhold separations between handrail **A** and **C** (51 inches) as well as between handhold **B** and handrail **C** (42 inches) were wider than the maximum of 600mm (23.6 inches) recommended by J185. The standard specifically states "handrails shall be appropriately spaced to provide continuous support to a moving person and within convenient reach" – in addition to the spacing issue, these handrails taper away from each other with increasing height, so the "continuous support" recommendation is similarly not met.

Another issue is that the dimensions of handhold **B** fell short of what is recommended in J185. Figure 10 shows a relative scalar comparison of the subject handhold and the J185 minimum grasping diameter of 0.63 inches.

Figure 10
Comparison of Handholds

Feasible Alternate Designs

There are many options for providing a superior access system on the basic existing design of the subject digger derrick. Several of these design options are presented below and illustrated with simple graphical representations. The design of the digger derrick structure is straightforward metal fabrication and welding – as are the suggested alternate designs. The manufacturer provided no discovery documentation indicating any specialized design methodology or functional task analysis that necessitated the subject access system be designed the way it was. As such, it seemed unlikely that digger derrick design experience was necessary in order to opine on this machine's issues – this counters the defendant's legal challenge #4 above.

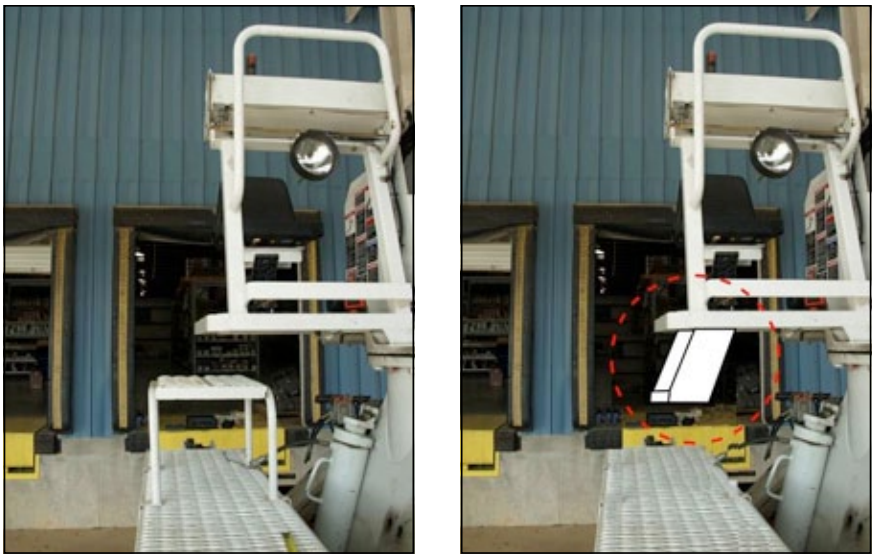
Figures 11 & 12 show a feasible alternate design that could have been implemented in place of handrail **A**, at a comparable cost. The pommel-style hand grip would have complied with SAE J185 by being easier to grip at all points during turret ingress/egress. Additionally, it would have allowed for less separation between left and right hand grips during boarding by moving it closer to handgrip **C**.

Figures 11 and 12
Alternate design for Handrail **A**

Figures 13 & 14 show a feasible alternate design for handrail **C** that is comprised of tubing welded to the seat base. It is formed to extend forward along the side of the seat and towards handrail **A**. The result is a handhold that is visible from all access positions prior to turret boarding and that is much closer to handrail **A**. This design would allow the manufacturer to stay within with the maximum distance between parallel handrails of 600mm (23.6 inches) as recommended by SAE J185, at a comparable cost to the existing design.

Figures 13 and 14
Comparison view showing alternate design for Handrail **C**

Figures 15 & 16 show a feasible alternate design for platform step **D**, at a comparable cost. This design involves mounting a stirrup step to the underside of the rotating platform. This step has J185-compliant sides that resists lateral slippage off the step. Additionally, it would have allowed the leading edge of the step to be set back from the edge of the fixed walkway, reducing obstruction of one's feet when climbing and descending. Vertical spacing of the walkway-step and step-platform distances could be set evenly in accordance with known best practices[10].



Figures 15 and 16
Comparison view showing alternate design for Step **D**

Feasible Competitor Designs

The subject vehicle manufacturer's competitors also used feasible alternative designs that were presented and discussed in the report and deposition for this case. However, these are not presented in this paper, as finding appropriate and non-copyrighted images for reference has proven difficult.

Conclusions from a Product Defect perspective

Generally speaking, there are five points that need to be addressed in a product defect claim. They are as follows:

1. The product was actually defective.
2. The defect existed at the time the product left the control of the defendant.
3. The defendant knew or should have known of the defect.
4. Feasible design alternatives existed that, if implemented, would have reduced or eliminated the risk posed.
5. The defect caused harm to plaintiff's person or property.

Testing the design of the subject digger derrick against these five points results in the following conclusions.

1. *The product was actually defective.* It was established that the access system design did not provide reasonably safe 3-point contact for the operator.
2. *The defect existed at the time the product left the control of the defendant.* The functional state of the digger derrick truck's access system at the time of the incident was just as it had been at time of original manufacture except for the repositioning of the platform step, which did not improve the deficient handhold design.

3. *The defendant knew or should have known of the defect.* The manufacturer should have discerned the lack of access system guidelines in A10.31, should have researched the applicability of SAE J185, and should have implemented the well-known recommendations of J185 as it is the "standard of care" for common off-road construction machines.

4. *Feasible design alternatives existed that, if implemented, would have reduced or eliminated the risk posed.* As discussed above, there were alternative designs that could have been implemented with nominally equivalent cost, resulting in a reduced risk of falling while boarding/dismounting the turret control platform.

5. *The defect caused harm to plaintiff's person or property.* Had the manufacturer complied with SAE J185 design recommendations, the risk of fall would have been reduced. However, as an un-witnessed fall, whether the access system design was causally related to the incident would be a question for the jury.

Case Disposition

Following deposition, this case settled before trial.

Recent OSHA Rulings

Effective November 8, 2010, and some time after the settlement of this case, a series of OSHA Rules were changed[11] related to crane and derricks used in construction; in the new rules SAE J185 is codified for certain machines. Included in the Rulemaking documents are extensive discussions of the complexities surrounding the regulation of digger derricks, which can be used as either a crane or an auger – occupational tasks which are regulated differently within OSHA. Based on the new crane and derrick rules, digger derricks such as the subject machine are now specifically excluded from these new rules and instead are regulated only by "generic" rules for occupations involved in telecommunications and power transmission utilities. These generic rules do not reference SAE J185. It is possible that the ANSI-ASSE A10.31 committee would have a different interpretation of the applicability of J185 to digger derricks based on these new rules.

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