Skid-Steer Rock Saw Modification

Blue Diamond Machinery

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BAE 4022
Senior Design
May 04, 2007
Redesign of Skid-Steer Mounted Rock Saw

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Submission Date: May 04, 2007

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Dr. Paul Weckler  Senior Design Advisor

Dr. Ronald L. Elliott  BAE Department Head
Abstract

A rock saw is a skid-steer attachment used to cut non-reinforced concrete and asphalt as well as other pavement surfaces. One of the many uses for this rock saw is making trenches for laying plumbing or wiring under existing roads and sidewalks. In addition, the rock saw may be used to make a smooth edge along asphalt roadways for the addition of cement curbs. This saw is versatile because it can be powered by a variety of other machines. CONEQTEC Universal produces rock saws capable of various cutting depths. However, their production model is axially driven which limits the depth of cut to less than the blade radius. In order to increase the depth of cut without increasing the blade diameter, the manufacturer designed a prototype in which the blade was rim-driven via a modified ring and pinion gear set. Four senior level students from the Biosystems and Agricultural Engineering Department (BAE) of Oklahoma State University (OSU) have formed a consulting team, Blue Diamond Machinery (BDM), to facilitate the completion of their capstone senior design project under the direction of Dr. Paul Weckler. Blue Diamond Machinery's objective was to modify the CONEQTEC rock saw prototype with the goal of increasing the time between maintenance periods from 50 hours to over 100 hours as well as preventing debris from contacting the motors. To reduce wear, BDM modified the gear set to a circular rack and pinion. Further testing is needed to determine if this gear mesh increased the useful life of the machine. As a result of altering the gear set, the motors were mounted above the blade where they cannot come into contact with debris.

![Figure 1: Left to Right - Production Model, CONEQTEC Prototype, BDM Prototype](CONEQTEC 1)
Acknowledgements

Gary Cochran – CONEQTEC Universal

Dennis Skraba – CONEQTEC Universal

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    Laboratory Manager

Bobby Flores, Robert Harrington, and Robert Harshman – Oklahoma State University - Biosystems and Agricultural Engineering Laboratory

Stillwater Steel – Fabrication

Steve Miller – Interstate Tool – Fabrication

Railroad Yard – Fabrication

Jana Moore - Oklahoma State University - Biosystems and Agricultural Engineering

Dr. John Solie – Oklahoma State University - Biosystems and Agricultural Engineering –

    Professor
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Problem Statement

CONEQTEC Universal designed a prototype of a skid-steer mounted rock saw. While this prototype functioned, the manufacturer required a gear set with a longer design life for the saw to become a production model. When the saw descended to the maximum cutting depth, the motors were forced to run in debris created by the cut. The manufacturer requested that the rock saw be modified to increase the design life of the gear set as well as to prevent debris from contacting the motors.

Statement of Work

In order to increase design life, BDM changed the ring and pinion gear set to a circular rack and pinion gear set. This altered gear set necessitated the relocation of the motors to above the blade thereby preventing debris from coming into contact with the motors.

Patent Research

The patent search revealed a few designs similar to the prototype. While rock saw devices were found, none were driven from the rim of the cutting blade. All the designs found were driven from the central axis of the blade. Most of these designs were intended for cutting concrete or, in the case of one patent held by Mr. Cochran, for cutting slots in pavement. Though some rim driven blades were found, their intended application was in the logging industry to trim either harvested or fallen trees for transport. The scope of application was found to have a more important role in patent approval than the method in which the machine is operated. US Patent No. 3494389 refers to slashing and loading timber. The machine is designed to lift a load of logs off of a stack and place them on a truck for transport after cutting them to a desired length.

US Patent No. 3915209 refers to the process of harvesting trees and brushwood and an improved saw design for the removal of trees or brushwood. Additionally, Patent No. 3915209
refers to a German and U.S. patent that describes a ring and pinion drive which has a U-shaped frame. However, Patent No. 3915209 states that these patent designs are insufficient due to their limited depth of the cut and the gear configuration is not protected. This design has two plates mounted together to house the ring and pinion drive train and form the saw blade. This assembly results in the gear being easily hindered by wood debris and not easily repairable when damage occurs.

US Patent No. 4738291 describes a tree saw run by a ring and pinion configuration which the saw blade can double as a platform to allow the cut tree to be dumped where the operator chooses instead of allowing the tree to fall where it was cut down. This design appears to have some importance due to the saw blade having intentions to be a load bearing surface as well as having an assembled blade design protected from debris, which could easily be maintained. These patents, while unrelated to our products industry, are still potentially important due to their similarities to our drive train concept. This observation could pose a problem in the new design because of patent infringement. It was deduced from these patents that the driving mechanism is not patentable in and of itself; therefore, the scope of the patent holds higher authority than the drive train design making patent infringement less of an issue.

Patent No. US 7,073,495 B1 describes the method and apparatus for removing concrete debris during operation. The device is powered by a small engine, and the blade is contained in a separate housing. Outside the housing is a set of at least two nozzles that use pressurized gas to produce a stream directed toward the lower support during the use of the saw. This stream is used to help clear debris from the saw decreasing wear on the blade and skids. The streams of gas are directed toward the rear of the housing and toward the front of the blade rather than in the plane of the cutting blade. This configuration should not affect the potential design of a debris removal mechanism for the rock saw because the debris weighs too much to push away with a stream.
Design Specifications: CONEQTEC Universal

CONEQTEC Universal of Wichita, Kansas manufactures attachments for skid-steer loaders to substitute for the standard bucket attachment. One of their attachments is a rock saw which is used to cut non-reinforced concrete and asphalt as well as other pavement surfaces. CONEQTEC’s production model of the rock saw is axially driven by a hydraulic motor through a planetary gear set which limits the depth of cut to about 35% of the blade diameter which is slightly less than the radius of the blade.

In order to increase the depth of cut to greater than the radius of the blade, CONEQTEC developed a prototype in which the blade was driven at the rim of the blade via a modified ring and pinion gear set rather than at the axle. The CONEQTEC prototype achieves a maximum cutting depth of 18

<table>
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<td>Removal of Debris</td>
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Figure 2: Production Model Rock Saw (CONEQTEC 1)
inches with a 32 inch total diameter blade, i.e. the depth of cut is about 55% of the blade diameter. Therefore, if both the CONEQTEC prototype and the production model had the same blade size, the prototype would have a 20% deeper depth of cut.

Ring gear teeth were mounted directly to each face near the perimeter of the wheel. The pinion gear was composed of 5 free-turning cylindrical teeth attached to a disk.
According to the manufacturer, the major limiting factor was the lower than expected design life of the ring gear teeth. Due to the fact this gear mesh was not sealed, lubrication was not advantageous
and was, therefore, neglected. The meshing tolerances were somewhat loose, resulting in some impact/abrasive wear on the contact surfaces of the ring and pinion teeth. However, since the ring gear teeth protruded out to the cutting breadth of the picks, the high rate of wear was caused by abrasion on the outer face of the ring gear teeth as they scraped against the slot being cut by the saw. As shown in Figure 6. The ring gear teeth were attached with flat head socket cap screws (1/2 in – 20, 1.5 in long). Wear was expected on the cutting teeth, or picks. The design life of the cutting teeth was acceptable; therefore, BDM was asked to not focus on improving the cutting teeth.

A corner from each ring gear tooth was ground down to allow for better clearance when meshing with the pinion gear. On some teeth, the wear was displayed in a very slight arc.
In the production model, one hydraulic motor was mounted directly to the axle of the blade. In the CONEQTEC prototype, they added an additional motor to distribute the rotational force to each side of the blade (See Figure 1). These hydraulic motors were mounted directly to the pinion gears, and a crescent shaped slot was cut into each side plate to allow the motors to descend with the blade. A brace was installed at the top of each slot for reinforcement.
Special brackets were designed to hold the wheel and the motors in place. The wheel was then able to freely rotate around the axle on two sets of tapered-roller bearings installed in the hub. See the Quantitative Analysis section for motor and hydraulic system details.

![Figure 9: Hub Assembly and Axle of CONEQTEC Rock Saw.]

**Design Specifications: Blue Diamond Machinery**

In order to increase the working life of the saw, BDM altered the gear mesh. The ring gear teeth were replaced with a circular rack composed of gear holes; the pinion gear with cylindrical teeth was replaced with an acme pinion gear. After several iterations in the design process, BDM decided on using three inch tall pieces of ¾ inch diameter round stock and ¼ x ¾ inch bar stock as inserts for each gear hole in the wheel for the pinion gears to press against when driving the blade.
The inserts prevent wear on the wheel itself and are easily replaceable. To improve the ease of maintenance in replacing the round and bar stock, twenty removable retainer plates were bolted to one side of the wheel with 3/4” x 3/8”-16 flat head socket cap screws and twenty were welded to the opposite side. These plates allow the stock inserts to be replaced three sets at a time. The initial wheel and gear hole dimensional calculations did not allow space for the rim-to-wheel weld. Therefore, the outer retainer plates were made shorter in height. Later modifications to the Gear Calculator should have fixed this issue.
The recommended material for the round and bar stock is 440C stainless steel. Any strong material will function; a softer, less corrosion resistant material may be less expensive initially, but these inserts will require replacement more often due to the decreased design life. The pinion gears consisted of a set of two acme gears which were designed to mesh into the cutting wheel. These gears were stacked with \( \frac{1}{4} \) of an inch of clearance between the two gears and the wheel to prevent buildup of debris in the gear holes. Due to the curvature of the circular rack, the top pinion gear has a slightly larger diameter than the bottom pinion gear. The stacking was accomplished by making the gear shafts two different lengths.
These gears were attached to the hydraulic motors with cylindrical shafts. In order to drive the pinion gears in this configuration, the motors were mounted above the wheel.
This modification also eliminated the issue of debris piles adversely affecting the motors. The new prototype's overall blade diameter was increased in size to 32.5 inches, or 38 inches including the rim and cutting teeth. This increase in diameter increased the cutting depth to approximately 23 inches which is about 5% deeper than the CONEQTEC prototype. The outer housing increased in width to 19 inches, in length to 48 inches, and in height to 40 inches in order to accommodate the larger blade. The skid dimensions were increased to fit the new outer housing. In addition, the channel frame assembly was widened to allow room for the gear shafts. The pivot bar was lengthened to accommodate the wider outer housing and channel frame. The hydraulic piston mounting locations and bushing dimensions were modified to accommodate these design changes. No changes were made to the internal workings of the wheel hub and axle.

Quantitative Analysis

The rock saw prototype was designed to function with the most powerful of CONEQTEC Universal’s high flow skid steer hydraulic kits. BDM used the same hydraulic system, motors, and pistons as the CONEQTEC prototype. The CONEQTEC Universal super high flow kit allows the skid steer to produce 89 hp, a flow of 34gpm, and a pressure of 4,500 psi. The prototype uses two
hydraulic motors to drive the saw. The motors are Sauer Danfoss, 400cc displacement, OMT orbital hydraulic motors. This provides 44.6 hp per motor operating at 160 rpm, producing 1,457 ft/lbs of torque from each motor.

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**Hydraulic Motor**

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<tr>
<td>Total Force (lbs)</td>
<td>452.90</td>
<td>322.06</td>
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**Cutting wheel**

| RPM          | 75.08 | 88.33 | 72.87 |
| Torque (ft lbs) | 3122.24 | 2220.26 | 2816.96 |
| Diameter (ft) | 2.67 | 2.67 | 2.67 |
| Force (lbs)   | 8325.98 | 5920.69 | 7511.88 |

**Driving teeth**

| Shear Strength (psi) | 1006.44 | 715.69 | 908.03 |

**Pinion Gear**

| Diameter1 (ft) | 0.32 | 0.32 | 0.32 |
| Diameter2 (ft) | 0.30 | 0.30 | 0.30 |
| Shear Strength (psi) | 301.93 | 214.71 | 272.41 |
| Fatigue Load (psi) | 41247 |

This power is transferred from the hydraulic motors with acme gears meshing into the gear holes on the saw blade. The pinion gear teeth apply 450 lbs of force to the replaceable ¾ inch round stock. The gear ratio is 30 driving holes to 7 gear teeth making it 4.3:1. The motors apply approximately 89 hp as well as 2,914 ft-lbs of torque at the picks at 75 rpm. In a wheel made from A36 mild steel with an ultimate strength of 140 ksi, the 1.57 inch minimum spacing between gear holes and 1.0 inch width base of the pinion gear teeth will withstand the maximum possible forces. The shear force experienced between the gear holes is 1000 psi. The shear force experienced at the base of the
pinion gear teeth is 300 psi. Both of these values are considerably less than the fatigue load strength of 41,000 psi, therefore, preventing failure.

2 Gears – 7 teeth
3/4” thick steel
1/4” spacing between gears
Top Gear
- Dedendum circle diameter (D): 6.16”
- Addendum circle diameter (A): 8.08”
Bottom Gear
- Dedendum circle diameter (D): 5.76”
- Addendum circle diameter (A): 7.62”

Figure 16: Pinion Gear Specifications

Figure 17: Final BDM Prototype – Full Assembly
Recommendations

*Design and Manufacturing Alternatives*

In order to reduce cost, BDM recommends the use of different motors. The current motors can be replaced with motors that have the wheel mount flange housing. The wheel mount flange motors are the same as the current motors with an alternative mounting location.

![Figure 18: OMT Wheel Mount Flange Motor (Sauer Danfoss 1)](image)

Instituting this type of motor with make the pinion gears easier to replace and will make the gear retainer parts obsolete. BDM also recommends that an x-y-z adjustable motor mounting system be developed. The combination of using the alternative motors and the adjustable motor mounts may eliminate the costly production of the gear shafts as well as ease the assembly process. BDM would also like to recommend some alternative manufacturing methods. The ear cylinder and plate2 should be one part. The pivot boss inner should be increased to 13 ¼ inches to allow for welding. This part should also have a piece removed from its middle to allow for lubrication.
The next recommendation is to either thread the motor mount instead of plate2, or move the motor mount to the other side of plate2 and then lengthen the mount wheel shaft bracket top, leaving the bolt holes referenced to the inside edge. (Motor mount is a misnomer. It now describes the part the gears protrude through.) If the gear shafts are replaced by conforming to the previous recommendations, the parts in the following picture do not need to be changed. More suitable part names or part numbers should be instituted to avoid confusion during production.
**Testing**

BDM recommends a complete endurance test for the rock saw. This test may include analyzing different materials for the gear hole inserts as well as the pinion gear material. Since the there are 10 retainer plates which retain 3 sets of 2 gear hole inserts, BDM recommends testing up to 10 different materials for a broad wear comparison. The materials BDM recommends for testing range from low carbon steel to highly corrosion and abrasion resistant stainless steels. BDM also recommends testing some exotic materials such as titanium or a Kevlar/ceramic material. These alternatives may be expensive initially; however, a cost benefit analysis may show the exotic inserts to be less expensive if their design life is extended to over a few hundred hours. This test will determine the optimum operational life before replacement of the ring gear teeth. A similar test can be done for the pinion gear. However, a hardened, corrosion resistant stainless steel should be sufficient. The mounting locations of the hydraulic cylinders on the outer housing may need adjustment in order to achieve the maximum depth of cut.

**Safety**

The last set of recommendations by BDM refers to the addition of safety devices to increase the overall safety of the rock saw. The first would be the addition of a detachable flap to the front opening of the outer housing.
This flap may prevent other equipment or appendages from coming into contact with the blade. A hole could but cut in the outer housing to reduce weight and increase serviceability. A hinged or detachable flap could be added in place of the hole to ensure safety.

**Budget**

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Works Cited

CONEQTEC Universal. 2007 <http://www.coneqtecuniversal.com/>


Patents

Markley, Charles E. 2006. Method and Apparatus for Cleaning Concrete During Cutting. US Patent No. 7073497 B1


Appendix 1

Parts List
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Appendix 2

Gantt Charts
### Appendix 3

#### Gear Calculator

<table>
<thead>
<tr>
<th>Gear Mesh Calculator</th>
<th>Equations</th>
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<tr>
<td>Wheel Diameter to bottom of hole ((d_B))</td>
<td>(2.25) in</td>
</tr>
<tr>
<td>Wheel Radius to bottom of hole ((r_B))</td>
<td>(11.125) in</td>
</tr>
<tr>
<td>Wheel Circumference at bottom of hole ((C_B))</td>
<td>(65.900) in</td>
</tr>
<tr>
<td>Wheel Hole Spacing ((d_d))</td>
<td>(2.31301756) in</td>
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<tr>
<td>Angle Between Holes (\theta )</td>
<td>(12.000) deg.</td>
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<tr>
<td>Arc Length Between Holes (s_B)</td>
<td>(2.330) in</td>
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<tr>
<td>Arc Length Between Gear Teeth (s_G)</td>
<td>(2.313) in</td>
</tr>
<tr>
<td>Wheel Disk Radius</td>
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<tr>
<td>Wheel Disk Diameter</td>
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<tr>
<td>Wheel Radius With Rim and Picks</td>
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<tr>
<td>Height of Gear Holes</td>
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<td>Number of Gear Holes ((s_B))</td>
<td>(30,000) holes</td>
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<tr>
<td>Wheel Diameter With Rim and Picks</td>
<td>(36) in</td>
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**Note:** Feel free to change the orange cells to manipulate the table values.

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<th>Gear Ratio</th>
<th>Gear Radius to Base of Teeth ((r_G))</th>
<th>Gear Diameter to Base of Teeth ((D_G))</th>
<th>Gear Circumference to Base of Teeth ((C_G))</th>
<th>Number of Gear Teeth ((n_G))</th>
<th>Angle Between Gear Teeth ((\theta_G))</th>
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Appendix 4

Fire Protection Safety Report
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<th>Hazard</th>
<th>Effects</th>
<th>Causal Factors</th>
<th>IMRI</th>
<th>Recommended Action</th>
<th>FMRI</th>
<th>Comments</th>
<th>Status</th>
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<tr>
<td>Dry Cutting System</td>
<td>A-3</td>
<td>Airborne Dust and Rock Particles</td>
<td>Respiratory Problems Silicosis</td>
<td>Absence of Respiratory Protection</td>
<td>1A</td>
<td>Equip Employees with Respiratory Protection</td>
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<td>See Appendix A</td>
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<td>Drive System</td>
<td>A-4</td>
<td>System Failure</td>
<td>System Malfunction, Breakdown</td>
<td>Fatigue</td>
<td>2C</td>
<td>Periodic Maintenance</td>
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<tr>
<td>Saw Blade</td>
<td>A-5</td>
<td>Exposed Saw Blade Teeth (Foreign Object Put Near Running Blade)</td>
<td>Bodily Harm in Abrasion, Amputation, Laceration</td>
<td>Absence of Safety Guards</td>
<td>1C</td>
<td>Keep a Safe Distance from Blade Install Safety Guards</td>
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<td>A-6</td>
<td>Dull Saw Blade Teeth</td>
<td>Decreased Effectiveness, Productivity</td>
<td>Unmaintained Equipment</td>
<td>3B</td>
<td>Increased Maintenance</td>
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<td>Dull Saw Blade Teeth</td>
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<td>Dull Saw Blade Teeth</td>
<td>Increased Noise &gt; 90dBA</td>
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<td>Cutting Into Ground</td>
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<td>Unexpected Buried Utilities</td>
<td>Break in Gas Line, Electric Line, Sewer Line, Water Line</td>
<td>Unsurveyed Area</td>
<td>2C</td>
<td>Survey Site Prior to Cut</td>
<td>Can Create Explosion And/Or Electrocution</td>
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<td>Saw Blade</td>
<td>A-10</td>
<td>Jammed Blade</td>
<td>Damage to Gear Teeth, Hydraulic System, Housing</td>
<td>Forced to Cut Too Much Unexpected Material</td>
<td>2E</td>
<td>Install Proper Guarding</td>
<td>See Appendix D</td>
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<td>A-11</td>
<td>Jammed Blade</td>
<td>Failure of Blade, System</td>
<td>Material Impeding On Rotary Motion</td>
<td>2E</td>
<td>Install Proper Guarding</td>
<td>See Appendix D</td>
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<td>Jammed Blade</td>
<td>System Shutoff</td>
<td>Loss Of Hydraulic Pressure</td>
<td>2E</td>
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</table>
| Control Saw (pitch) | B-1        | Broken Hydraulic Line                 | Inability to control saw pitch                | Absence of hydraulic line guards
Damage to hydraulic line (puncture, rip, tear, etc.)
Poor up keep of hydraulic hose | 3D     | Pre-operations checks
Hydraulic pressure alarms
Periodic maintenance |      | Notified design team                  |                                                      |
|                   | B-2        | Broken Hydraulic Line                 | Burn to person                                | Improper PPE
Improper position of operator
Poor up keep of hydraulic hose | 1D     | Labels/Warnings
Mandatory training
Proper PPE |      | PPE: Eye, Ear, Body Protection        |                                                      |
|                   | B-3        | Broken Hydraulic Line                 | Injury to eye of person                       | Improper PPE
Improper position of operator
Poor up keep of hydraulic hose | 2C     | Labels/Warnings
Mandatory training
Proper PPE |      | PPE: Eye, Ear, Body Protection        |                                                      |
|                   | B-4        | Broken Hydraulic Line                 | Injection of fluid                            | Improper PPE
Improper position of operator
Poor up keep of hydraulic hose | 2D     | Labels/Warnings
Mandatory training
Proper PPE |      | See Appendix B
PPE: Eye, Ear, Body Protection |                                                      |
|                   | B-5        | Broken Hydraulic Line                 | Ingestion of fluid                            | Improper PPE
Poor up keep of hydraulic hose | 2D     | Sanitation stations
Proper PPE |      | PPE: Eye, Ear, Body Protection        |                                                      |
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<th>B-6</th>
<th>Broken Hydraulic Line</th>
<th>Inhalation of fluid &amp; fumes</th>
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<td>B-7</td>
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<td>Damage to environment</td>
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<td>B-8</td>
<td>Broken Hydraulic Line</td>
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<td>Hydraulic Fluid Spill</td>
<td>Damage to environment and wildlife</td>
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<td>B-11</td>
<td>Loose Line</td>
<td>Injury to eye of person</td>
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### Precautions

- **Proper PPE**: Eye, Ear, Body Protection
- **Ventilate/Outdoor Work Environment**: Periodic maintenance
- **Proprietary position of operator**: Add hydraulic fluid in controlled setting to accommodate spill
- **Poor, up keep of hydraulic hose**: Warnings/Training
- **Improper PPE**: Labels/Warnings Mandatory Training
- **Improper position of operator**: Labels/Warnings Mandatory Training
- **Poor, up keep of hydraulic hose**: Labels/Warnings Mandatory Training
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<th>Mitigation</th>
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<td>Injection of fluid</td>
<td>Improper PPE&lt;br&gt;Improper position of operator&lt;br&gt;Poor up keep of hydraulic hose</td>
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<td>Labels/Warnings&lt;br&gt;Mandatory training&lt;br&gt;Proper PPE</td>
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<td>Improper PPE&lt;br&gt;Poor up keep of hydraulic hose</td>
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<td>Sanitation stations&lt;br&gt;Proper PPE</td>
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<td>System shutdown</td>
<td>Absence of hydraulic line guards&lt;br&gt;Damage to hydraulic line (puncture, rip, tear, etc.)&lt;br&gt;Poor up keep of hydraulic hose</td>
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<td>B-18</td>
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APPENDIX A

Silicosis
NIOSH Publication No. 2004-108:

_Silicosis: Learn the Facts!

This document presents information in an easy to read format describing silica exposures, the effects of silicosis, and methods to protect against silicosis.

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NIOSH Safety and Health Topic Page - Silica

This document is also available in PDF format.

The print version contains both the English and Spanish texts.

20 pages, 1748kb

20 pages, 1748kb
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DHHS (NIOSH) Publication No. 2004-108
August 2004

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**Safety Information**

For more information on silicosis and how it can affect you and your family, visit our Web site at:

http://www.cdc.gov/niosh/topics/silica

For more information or for answers to questions about any safety and health regulatory matters, contact the Occupational Safety and Health Administration (OSHA)

U.S. Department of Labor
Occupational Safety & Health Administration
200 Constitution Avenue
Washington, D.C. 20210

1-800-321-OSHA (6742)
(Spanish speaking staff available)

**Silicosis: Learn the Facts!**

Do you work in construction or do abrasive blasting?

If so, here are some important facts you need to know:

- Since 1968, more than 14,000 workers in the U.S. have died from a disease called silicosis.

- In the U.S. each year more than 200 workers die with this disease while hundreds more become disabled.
Many workers with silicosis are only in their thirties; some are as young as 22 years old. Many of them are unable to take care of themselves and their families.

What is silicosis and how can you avoid or prevent it?

This booklet will give you information about silicosis, what causes it, the symptoms, and the ways you can avoid developing the disease.

**WARNING!**

Silicosis IS NOT CURABLE, but it IS PREVENTABLE. Learn the facts and know how to protect yourself. Silicosis affects both your health AND the welfare of your family.

**Description of Silicosis**

Silicosis is a disabling and often fatal lung disease caused by breathing dust that has very small pieces of crystalline silica in it. Crystalline silica is found in concrete, masonry, sandstone, rock, paint, and other abrasives. The cutting, breaking, crushing, drilling, grinding, or abrasive blasting of these materials may produce fine silica dust. It can also be in soil, mortar, plaster, and shingles. The very small pieces of silica dust get in the air that you breathe and become trapped in your lungs. Even the very small pieces of dust that you cannot see will harm you. As the dust builds up in your lungs, the lungs are damaged and it becomes harder to breathe.

Are YOU breathing silica dust?
If YOU do one of the following jobs, you ARE at risk for breathing silica dust:

- Removal of paint and rust with powertools;
- Abrasive blasting of bridges, pipes, tanks, and other painted surfaces especially while using silica sand;
- Grinding mortar;
- Abrasive blasting of concrete (many bridges and buildings are made of concrete);
- Crushing, loading, hauling, chipping, hammering, drilling, and dumping of rock or concrete;
- Chipping, hammering, drilling, sawing, and grinding concrete or masonry;
- Demolition of concrete and masonry structures;
- Dry sweeping or pressurized air-blowing of concrete or dust; or
- Jackhammering on various materials.

**ATTENTION!**

When you wear dusty clothing at home or in your car, you may be carrying silica dust that your family will breathe.

**Who is at Risk?**

Workers in the following occupations are at risk for developing silicosis:

- Highway and bridge construction and repair
- Building construction, demolition, and repair
- Abrasive blasting
- Masonry work
- Concrete finishing
• Drywall finishing
• Rock drilling
• Mining
• Sand and gravel screening
• Rock crushing (for road base)

ATTENTION!

If you work near dust clouds like the ones in these photos, you might be exposed to silica. You may be exposed even when dust is not visible.

Types of Silicosis

There are three types of silicosis:

1. *Chronic silicosis*: Usually occurs after 10 or more years of exposure to crystalline silica at low levels. This is the most common type of silicosis.

2. *Accelerated silicosis*: Results from exposure to higher levels of crystalline silica and occurs 5 to 10 years after exposure.
3. *Acute silicosis:* Can occur after only weeks or months of exposure to very high levels of crystalline silica. Death occurs within months. The lungs drown in their own fluids.

![Healthy Lung](image1) ![Diseased Lung](image2)

**Symptoms**

Symptoms may not appear in the early stages of chronic silicosis. In fact, chronic silicosis may go undetected for 15 to 20 years after exposure. As silicosis progresses, symptoms may include:

- Shortness of breath
- Severe cough
- Weakness

Because the body's ability to fight infections may be weakened by silica in the lungs, other illnesses (such as tuberculosis) may result and can cause:

- Fever
- Weight loss
- Night sweats
- Chest pains
- Respiratory failure

These symptoms can become worse over time, leading to death.

**WARNING!**

*Victims of silicosis are also at risk for getting lung infections such as tuberculosis (TB). TB is a disease that can be spread by coughing,*
Silicosis has affected many workers and their families

The following is based on a true story of a construction worker from Central Texas who died at age 35, leaving behind his wife and four children, ages 10, 14, 16, and 17.

"When I first started working, I was very young and full of energy. I was anxious about starting my first real job in the United States and being able to support my wife and children like I wanted. Sandblasters made quite a bit of money. I noticed that there was a lot of dust, but I never thought that it would hurt me. I wore a bandana everyday to cover my mouth and nose. Everyone said that this was good and that I would be fine. Well, I guess that wasn't so true after all. Now I'm 35 years old, and I have silicosis. No one ever told me about silicosis. My wife noticed that I was doing a lot of coughing and wheezing at night and she was very concerned. Now I get tired very easily, and I have a hard time enjoying the things I used to do like playing games with my children and taking them places. I am often depressed and it bothers me a lot that I'm not able to take care of my family. My doctor said that I have advanced silicosis and probably will die in a few years. Silicosis really changes your life and affects your family. I never pictured myself dying this young and not seeing my children grow up. I wish that I would have known this before it was too late."

Silicosis cases in Texas

In November 1988, 10 cases of silicosis were reported in west Texas. All of the workers were sandblasters employed at a company that sandblasted oil-well drilling pipes. Each had been exposed to silica dust and had high levels of silica in their lungs. Their job included the use of sandblasting machinery that was in poor condition and leaked silica dust into the air. All of the workers were Hispanic males with an average age of 31 years. One of the workers died from silicosis at the age of 34 [CDC 1990].

Did you know?

- Over 1 million U.S. workers are at risk of developing silicosis.
- Hundreds die of silicosis each year.
- The construction industry has one of the highest numbers of deaths due to silicosis.

Individual cases

A tile-installer was diagnosed with advanced silicosis, emphysema, and asthma at age 49. Although he didn't directly perform risky tasks, he worked near sandblasting and was exposed to silica dust (tile installers can also be directly exposed to silica dust when cutting tile). He did not wear a respirator [NIOSH
A 39-year-old sandblaster was diagnosed with progressive silicosis and tuberculosis in 1993. He had reported shortness of breath, wheezing, and lack of energy. He had worked for 22 years sandblasting welds during water tank construction. He wore a charcoal filter respirator while sandblasting, but it was the wrong type and did not protect him. Two brothers and three nephews who worked with him all tested positive for tuberculosis as well [NIOSH 1996].

A 36-year-old man in Texas died in 1995 from advanced silicosis after working as a sandblaster for 11 years. He had been exposed to silica dust for only three years while sandblasting oil field pipes and tanks [CDC 1998].

A 30-year-old sandblaster in Texas died 10 years after his first exposure to silica dust. He had been exposed to silica dust for only four years [CDC 1998].

**What Can I Do to Protect Myself and My Family?**

Silicosis is a disabling and often fatal disease that prevents hundreds of workers from being able to care for their families. It could also prevent you from providing for your family. If your work causes you to breathe silica dust, there are things you can do to prevent silicosis from happening to you.

- Be aware of the health effects of breathing air that has silica dust in it.
- Avoid working in dust whenever possible.
- Know what causes silica dust at your workplace.
- Remember if there is no visible dust, you could be at risk. If there is visible dust, you are almost definitely at risk.
- Reduce the amount of silica dust by doing the following:
  - Use water sprays and ventilation when working in confined structures. For example:
    - Use a water hose to wet dust before it becomes airborne.
    - Use saws that add water to the blade.
    - Use drills that add water through the stem or have dust collection systems.
    - Use blast cleaning machines or cabinets to control dust.
• When water sprays and ventilation alone are not enough to reduce silica dust levels, your employer MUST provide you with a properly fitted and selected respirator (e.g. particulate filter or airline supplied air respirator) designated for protection against crystalline silica.

• Changes should not be made to the respirator.

• Workers who use tight-fitting respirators cannot have beards or mustaches because they do not let the respirator properly seal to the face.

• Take health (or lung screening) programs offered by your employer.

• Sandblasting or abrasive blasting requires the highest level of protection, which is a type CE abrasive blasting respirator (see photo 7).

• Practice good personal hygiene at the workplace:

• Do not eat, drink, or use tobacco products in dusty areas.
  
  o Wash hands and face before eating, drinking, or smoking outside dusty areas.

  o Park cars where they will not be contaminated with silica.

  o Change into disposable or washable work clothes at the worksite.

  o Shower (if possible) and change into clean clothes before leaving the worksite to prevent contamination of other work areas, cars, and homes.

• It is your employers' legal responsibility to provide a safe workplace. If you think you are not protected call OSHA.
Your employer must make sure that you have the proper protective equipment for reducing silica dust levels; but, it's up to you to use them!

Taking time to protect yourself on the job is worth it.

AFTER ALL, NOTHING IS MORE IMPORTANT THAN YOUR HEALTH AND THE HEALTH OF YOUR FAMILY!

REMEMBER!

If you are a construction worker, you may be exposed to silica dust. To protect you and your family, remember to follow these recommendations each and every time you may be exposed.

Silicosis IS NOT CURABLE, but it IS PREVENTABLE—to live a long and healthy life, learn the facts and know how to protect yourself and your family.

What Type of Respirator Should I Use?

Choosing the right respirator that fits you snugly is important for protecting your health. Your employer will help you choose the type of respirator you need. ALWAYS USE NIOSH-APPROVED RESPIRATORS. The type of respirator you need depends on:

- The amount of silica dust to which you are exposed, and
- The kind of work you need to do.
- If you must do abrasive blasting, use only a type CE pressure demand abrasive blasting respirator (see photo 7).

Respirators used for protection from crystalline silica should not cause undue discomfort. If you have problems with your respirators, report immediately to your supervisor.
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| **Model MM2K**<br>Photo courtesy of MSA. | **Full-face mask air-purifying respirator with replaceable N-95 (or higher) filters.**<br>Photo courtesy of MSA. | **Type CE abrasive-blasting respirator (SAR), operated in a pressure demand or other positive pressure.**

Covering your face with a cloth such as a bandana or T-shirt **WILL NOT** protect you.

These are filtering facepiece respirators.
- Disposable
- N-95 Type or higher
- Provide minimal protection

Half-face mask air-purifying respirator with replaceable N-95 (or higher) filters.

**No Protection** .................................................. **Least Protection**
Powered air purifying respirator (PAPR) equipped with:
• Full facepiece
• High efficiency particulate filters

NOTE: Uses battery-powered motor to filter the air.

Supplied-air respirator (SAR) equipped with:
• Full facepiece
• Pressure-demand or other positive pressure mode.

NOTE: A tight-fitting mask is worn under the blasting hood.
This is the only respirator that can be used for abrasive blasting.

More Protection .................................................... Most Protection

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The following sources were used in preparing this brochure:

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APPENDIX B

Dangers of Hydraulics
OSHA FATAL FACTS

Hydraulic Pressure

Fatal Facts - Hydraulic Pressure and the Dangers

- Description of the Accident:
  - A machine operator was fatally injured while he was attempting to bleed trapped air from a hydraulic cylinder located on an automated forming machine. The injuries occurred when he opened a bleed-to-atmosphere type air-bleed valve located on a hydraulic cylinder, causing high pressure hydraulic oil to be injected into his hand.
The Dangers of Hydraulic Pressure

- Injection Injuries
- Dangerous properties of fluid (toxic)
- Contact with hot fluid
- Other material movement (explosion, whipping hose, etc.)

High Pressure Injection Injuries

High Pressure Injection Injury - "The Lethal Strike!"
What is an High Pressure Injection Injury?

- Fluid at pressure that punctures and penetrates the skin and body tissue.
- Injected substance passes rapidly thru the subcutaneous tissue and enters the tendons and deep spaces of hand/body.

High Pressure Injection Injury

- A pinhole leak in a hydraulic hose that’s under pressure can release toxic fluid at a speed of 600+ feet per second.
- Close to the muzzle velocity of a gun.
- Sufficient to penetrate protective equipment depending upon velocity.
- Penetration recorded in distances of up to four inches between fluid source and skin.
Where Do You Find?

- Some type of fluid (water, paint, oil-based solvents, etc.) or air
- Measured in force exerted upon a surface per unit area
  - Usually pounds per square inch (PSI)

Where Do You Find?

- hydraulic lines
- airless paint sprayers, fluid 100 PSI or above
- high-pressure fuel injection
- high-pressure air lines
- high-pressure grease guns,
- high pressure grease and paint guns most common cause
  - 60% paint
  - 25% grease/oil
High Pressure

- 100 PSI to puncture skin
- 3000-10000 PSI
  - <2000 PSI - 40% amputation
  - >2000 PSI - 50% amputation
  - <7000 PSI - non prognostic
  - >7000 PSI - 100% amputation
- Amputation rates vary between 16-48%

Severity/Prognostic Factors

- Material injected
  - grease - fibrosis
  - paint - necrosis
  - gangrene
- Paint/paint thinners - pain and swelling in few hours
- greases/oils/hydraulic fluid - pain in a day or two
Toxicology

- Absorption into system
- Organic solvent
- Water based

Injury Info

- Injection typically occurs when operator is trying to wipe clear a blocked nozzle or when operator is attempting to steady the gun with a free hand during the testing or operation of equipment
  - Pad of thumb or index finger (most common)
  - Palm and long finger (second most frequent)
  - Non dominant hand
  - Usually pin hole size
  - Men between 21-59
Burn Injuries

- Complex injuries
- Burns effect kidney, liver and cardiovascular function.

Degree of Burn

- First Degree
  - Outer layer of skin
- Second Degree
  - First and second layer of skin
- Third Degree
  - All layers of skin
  - Most serious
Injection Burns

- Hot liquid injected into body
  - Bypassed skin as protective device
  - Debreeing of burn must be surgical
- Toxicity of chemical

2\textsuperscript{nd} & 3\textsuperscript{rd} Degree Tar Burn
How to Avoid Injection Injuries

- To check a hose for leaks while pressurized, run a piece of cardboard or paper along the hose, wear gloves, long sleeves, and safety glasses
- Don’t “crack” high pressure connectors or lines to “check” for pressure and/or flow

How to Avoid Injection Injuries

- Shut down all equipment when looking for leaks
- Relieve pressures (Hose, etc.)
- Check to ensure pressure relieved
- Lockout/tagout - deactivation to zero energy

APPENDIX C

Death By Moving Machinery Parts
SUBJECT: A Concrete Saw Operator was Killed when He was Pinned between the Boom and the rear of a Backhoe

SUMMARY

A 56-year old concrete saw operator died on December 31, 2003, from asphyxiation and compression injuries received when he was pinned between the boom and the rear end of a backhoe. The decedent was working alone at a roadway construction site. He was working in the late evening and early morning hours to finish saw cutting newly poured concrete. The decedent was using a rubber-tired front-end loader and backhoe for lighting and to transport the concrete saws to the maintenance building. The backhoe, which did not have a boom swing lock pin installed, was left running to maintain a charged battery. After completing the work, the victim laid a handheld portable concrete saw on the floor of the backhoe through the opening in the rear. The saw was placed on the right boom swing pedal, causing the boom to swing to the side, pinning the victim between the boom arm and the rear of the backhoe. The decedent was found later that morning by the superintendent and pronounced dead at a local hospital.

Oklahoma Fatality Assessment and Control Evaluation (OKFACE) investigators concluded that to prevent similar occurrences, employers should:

- Ensure that machine guarding is in place, and that any additional safeguards needed to eliminate hazards are utilized prior to equipment operation.
- Ensure that all employees receive documented training on existing and potential hazards on or around mobile and stationary equipment.
- Ensure that special work procedures are in place for all employees working alone, including training on any unique hazards that exist.
- Review modifications or additions to equipment with the manufacturer and obtain authorization from the manufacturer prior to alteration.

INTRODUCTION

A 56-year old concrete saw operator employed by a construction contracting company died on December 31, 2003, from asphyxiation and compression injuries received when he was pinned between the boom arm and the rear end of a backhoe (Figure 1). OKFACE investigators reviewed the death certificate and reports from the Occupational Safety and Health Administration (OSHA), the Medical Examiner, the investigating police officer, and emergency medical services (EMS). An incident site visit and an interview with a company official at the home office were conducted on March 17, 2004.
Figure 1. Backhoe model involved in incident

The contracting company that employed the decedent had been in business for 18 years and, at the time of the incident, employed 65 people. The decedent had worked for the company for five years and had five years of experience as a concrete saw operator. However, he had not been trained on the backhoe’s operator’s manual or on safe operating procedures, since it was not a part of his normal work duties. When the incident occurred, the victim had worked all day and into the early morning hours in order to complete saw cuts in concrete poured that afternoon.

The company had a management safety and health committee and a written comprehensive safety and health program in place. Also, there were machine-specific safe operating instructions for all equipment used. Training for specific tasks was completed through on-the-job training and equipment manufacturer and company videos. Employees were required to attend weekly safety meetings. Machinery operators were required to be tested for proficiency before they were allowed to operate company equipment.

**INVESTIGATION**

At the time of the incident, the ground was dry and the temperature was approximately 34 degrees Fahrenheit. The decedent was working into the early morning hours on a level surface of concrete that had been poured the previous afternoon. The decedent was assigned the task of sawing the concrete road surface and was allowed to use a rubber-tired front-end loader and backhoe for lighting and transport of two concrete saws. The backhoe, which was left running to maintain a charged battery, was missing the operator’s manual, the boom lock pin, and the swing lock pin. With the engine running, the hydraulic system remained active to the boom and could not be disabled. Installation of the boom swing lock pin and boom lock pin were necessary to prevent movement of the boom. The decedent, who was last seen alive around 2:30 a.m. by a co-worker leaving the site, continued working alone.
Sometime between 2:30 a.m. and 6:30 a.m., the decedent finished sawing the concrete and began to load the backhoe with his tools. From the rear of the backhoe, he proceeded to lay the handheld portable concrete saw on the floor of the cab. The saw was placed on top of the right boom swing foot pedal. With the engine running and the boom swing lock pin not installed, the boom was activated and free to move. The boom swung to the right and crushed the victim between it and the rear of the backhoe. With no witnesses to the incident, the decedent was pinned for an undetermined amount of time. The superintendent, who arrived to work around 6:30 a.m., found the victim.

The decedent was found in a standing position pinned between the boom arm and the back of the vehicle. The superintendent contacted the police, and three officers responded immediately. CPR was initiated and administered until EMS personnel arrived. The victim was transported to a local hospital where he was pronounced dead 35 minutes after being found.

During the investigation, it was determined that the backhoe’s factory equipped foot pedal controls had been modified to accommodate an additional set of hand lever controls. When this process was performed, the foot controls were still present and operable; however, the original foot controls became easier to press down than before the installation. With nothing to keep an employee from placing equipment into the operator compartment through the openings on either side of the boom, it remained very easy to actuate the foot pedals with the weight of the equipment or materials.

**CAUSE OF DEATH**

The Medical Examiner listed the cause of death as asphyxiation due to a compression injury.

**RECOMMENDATIONS**

**Recommendation #1:** Employers should ensure that machine guarding is in place, and that any additional safeguards needed to eliminate hazards are utilized prior to equipment operation.

**Discussion:** The equipment in use at the time of the incident was not equipped with the required lock pins, which would have kept the boom arm from swinging. The model-specific operator’s manual specifies to install boom and swing lock pins when use of the backhoe boom is complete. Furthermore, removal, installation, and storage procedures for the pins are outlined in the manual.

**Recommendation #2:** Employers should ensure that all employees receive documented training on existing and potential hazards on or around mobile and stationary equipment.

**Discussion:** Utilization of manufacturer’s specification manuals and operator’s manuals can help to identify hazards that exist around equipment. Also a competent person, defined by OSHA as knowledgeable and experienced in the use of the equipment and the hazards that can be produced, could evaluate the equipment, site, or processes to determine the need for additional
hazard controls. Employees should be properly trained on all equipment they operate, and all training should be documented and kept on file with the company.

**Recommendation #3:** Employers should ensure that special work procedures are in place for all employees working alone, including training on any unique hazards that exist.

**Discussion:** It is the company’s responsibility to provide procedures and training on any specific hazards to which the employee might be exposed. This training might include special procedures for use of equipment when working alone, or when working at a time or place when very few other individuals will be present or in the general vicinity.

**Recommendation #4:** Employers should review modifications or additions to equipment with the manufacturer and obtain authorization from the manufacturer prior to alteration.

**Discussion:** It is important to consult with manufacturers prior to making equipment modifications in order to anticipate potential hazards and possible additional safeguards. Some hazards, such as the foot pedals becoming easier to depress with hand lever installation, are known and can be controlled prior to use. All upgrades or alterations should be authorized by the manufacturer and should meet all mandatory safety guidelines established for the upgrading or alteration.

**REFERENCES**

- 29 CFR 1926.602 Earthmoving Equipment, Occupational Safety and Health Administration
- Association of Equipment Manufacturer’s Safety Manual, Backhoe/Loader, 1989.1
- Equipment specific operator’s manual
- Operating Techniques for the Tractor, Loader, & Backhoe, Ober Publishing, Northridge, California
- 29 CFR 1910.211-.219 Machine(ry) Guarding, Occupational Safety and Health Administration

The Oklahoma Fatality Assessment and Control Evaluation (OKFACE) is an occupational fatality surveillance project to determine the epidemiology of all fatal work-related injuries and identify and recommend prevention strategies. FACE is a research program of the National Institute for Occupational Safety and Health (NIOSH), Division of Safety Research.

These fatality investigations serve to prevent fatal work-related injuries in the future by studying the work environment, the worker, the task the worker was performing, the tools the worker was using, the energy exchange resulting in injury, and the role of management in controlling how these factors interact.

For more information on fatal work-related injuries, please contact:
Oklahoma State Department of Health
Injury Prevention Service
1000 NE 10th Street
Oklahoma City, OK 73117-1299
nancyk@health.state.ok.us

1-800-522-0204 or 405-271-3430
www.health.state.ok.us/program/injury

Courtesy of <http://www.health.state.ok.us/program/injury/okface/Backhoe.htm>
APPENDIX D

Jammed Saw Blade
NO. 30 USE OF CONCRETE CUTTING SAWS June 2001

OBJECTIVE:
The object of this alert is to highlight one of the dangers associated with the use of concrete cutting equipment.

BACKGROUND:
In January 2001 an employee died as a result of injuries he received when the concrete saw he was using became uncontrollable, striking him in the throat area.
This accident follows a similar accident that occurred in Western Australia in September 2000 that also resulted in a fatality.
In both of these accidents the cause was attributed to the jamming of the blade followed by instantaneous reactive forces that caused the saw to become uncontrollable.
The jamming of the blade occurred while cutting of a length of concrete that was only supported at one end. When the beam/pipe was nearly cut through, the downward force distorted the beam pinching the blade.

STATUTORY REQUIREMENTS:
Under section 19 of the Occupational Health, Safety and Welfare Act 1986 an employer is required to provide and maintain a safe working environment and safe systems of work.
Division 1.3 of the Occupational Health, Safety and Welfare Regulations 1995 require employers to take appropriate steps to identify all reasonable foreseeable hazards arising from work which may affect the health or safety of employees or other persons.

PREVENTATIVE MEASURES:
1. Care should be taken when selecting the saw and cutting wheel.
2. Hold the concrete saw firmly in two hands.
3. Maintain good balance and footing at all times. Never cut while standing on a ladder.
4. Do not cut any material with a blade that is not suitable.
5. Do not overreach.
6. Do not cut above shoulder height.
7. Be especially alert for reactive forces exerted by the saw.
8. Be alert to shifting of the work piece or anything that could cause the cut to close and pinch the wheel.
9. Release the pressure on the concrete saw as you reach the end of the cut. Too much pressure may cause the operator to lose control of the saw when the blade completes the cut.
10. Use extreme caution when re-entering a cut and do not turn the wheel at an angle or push the wheel into the cut as this may result in a pinching of the wheel.

FURTHER INFORMATION:
For further information in relation to the contents of this Alert, please contact:
Department for Administrative and Information Services

Workplace Services
GPO Box 465, ADELAIDE SA 5001
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Website: http://www.eric.sa.gov.au