Safe, Fast and Cost-Effective Caster Roll Change at SDI Butler

Caster work rolls have historically been difficult to change out in a timely manner, presenting equipment setup and safe roll handling challenges. At Steel Dynamics Inc. (SDI) – Flat Roll Group Butler Division, a near-miss incident occurred that involved changing out a bending unit work roll. During the roll change process, roll bearing blocks must be repositioned to align with the guide rails of the track. During repositioning, the roll became derailed and fell to the floor. During the incident review, the problems with roll handling were obvious. However, other problems were also identified. Setting the roll track was done with a forklift without any good way to secure the track to the forks. The removal and installation of the rolls were accomplished with a cable and winch system, which required the operators to subject themselves to pinch points and fall exposures when installing the cable. In the event of replacing rolls in the withdrawal straightener unit, a forklift was used to pull the rolls out and push the rolls in using the forks against the bearing blocks. This created the potential for equipment damage.

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This paper provides a review of how Steel Dynamics Inc. – Flat Roll Group Butler Division and Hook Industrial Sales Inc. designed a unique system for changing rolls in the caster bending and straightener units. The new designs reduce pinch points and roll handling hazards while also greatly reducing roll change time and equipment damage. Multiple devices were developed to make the process safer and less labor-intensive. A hydraulic motor-activated "crawler" was developed to transport the roll assembly along the track, providing excellent control and speed for removal and installation. Roll tracks were modified to accept the crawler and improve how the tracks are connected and positioned for roll installation. Forklift attachments were engineered to transport track sections and rolls safely and efficiently, thus reducing hazard exposures and operator workload.

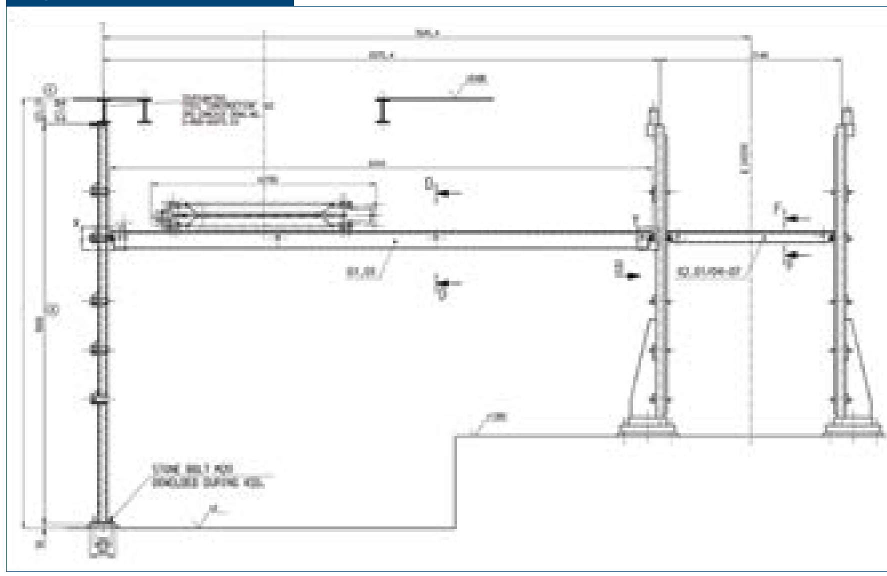
Discussion

Original Equipment Design — The original equipment manufacturer (OEM) design at the bending unit called for a track to be installed by setting the track on pins at the bending unit frame and a support column (Fig. 1).[1] The track was set by using a combination of a hoist trolley system located on the second floor of the caster and a come-along to pull the track close to the bending unit frame to set on its frame pins. This lift system was also used for removing and installing the rolls on the track. Movement of the roll to the unload/load position was originally accomplished by using a come-along and was later improved to a winch and pulley system.

The original design at the withdrawal straightening unit[2] included frames that were set on embedded bases in the concrete floor and a long track section. The long section was later converted to a two-piece track with a 45° bolted connection. Tracks and rolls were set with a hoist trolley system, which is shown in Fig. 2. One problem associated with the initial efforts of changing rolls was the atmosphere around the caster. High temperature, water and dust limited the longevity of the equipment and structures. The roll removal steel superstructures have dirt and rust accumulations on them, creating difficulties for movement of the hoist trolleys. The beams' required cleaning and lifting equipment needed to be installed and removed for every roll change. The withdrawal straightener unit (WSU) roller removal equipment shown in Fig. 2 was time-consuming to install and store when finished.

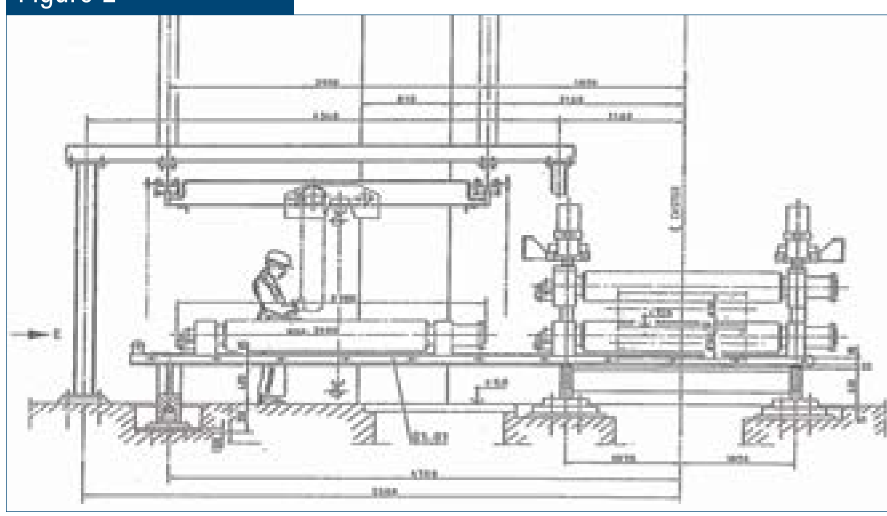
Early efforts to improve the process resulted in abandoning the hoists altogether and replacing them with the use of forklifts to handle the rolls and tracks. Another change was utilizing a winch and pulley system for the bending unit rolls. This provided a faster method of removing and installing the rolls but also created many hazards, such as having to set up and mount pulleys and manually feed the cable through the machine to install a roll.

Figure 1



View of original equipment manufacturer (OEM) bending unit roll removal equipment.

Figure 2



View of OEM withdrawal straightener unit (WSU) roll removal equipment.

Project Goals — The main goals of this project were to eliminate hazard exposures and to simplify the process of a roll change. Other desired benefits from this work included reducing the time it takes to set up and change rolls and eliminating the potential for equipment damage. In order to reduce the hazard exposure of workers, ways to minimize or eliminate how they interacted with moving and setting rolls in the track were investigated. Caster operators were integral in the development of concepts which would achieve these goals.

One idea was to use a platform with a scissor lift, which would roll up to the machine with a track that had side-to-side movement. Benefits of this concept included the ability to load the roll on the track at a low elevation and elimination of the use of a jib crane or forklift to set the track. This idea presented some challenges as well, such as having to disconnect the track from the frame, lowering the scissor lift to unload and load rolls, and purchasing a bending and withdrawal straightener system for each caster. Multiple machine builders were contacted to submit pricing for these ideas. It was decided to develop a system that wouldn't require equipment to be permanently located by the caster machine. The new design modified the existing tracks with a method of setting and connecting them to the machine, featured a safer way to load and unload rolls, and included a driven device to install rolls.

The two key items developed to accomplish these requirements are a hydraulic crawler and a roll spreader bar. The hydraulic crawler provides a more hands-off method by allowing operators to simply hook to the roll bearing torque support with a pin connection. Controls for the crawler are remote from the unit so the operator can stand away from the roll and manipulate it out of harm's way. The use of the crawler eliminates any need to use a cable and winch system for roll replacement in the bending unit and the use of a forklift at the withdrawal straightener unit. As part of the hydraulic crawler design concept, modifications were made to the roll tracks. The track for the bending unit was modified by adding slots with holes to accept the pegged wheels on the crawler. Also, a flange was added to the machine end so that it could be bolted to the frame. The tracks for the withdrawal straightener were modified to accept the crawler, which simplified installing it in the machine, and to be bolted to another section of track. A spreader bar was developed to eliminate the use of lifting straps around the roll, which were prone to slip if not centered properly. Using the spreader bar, rolls were now rigged with cables at the journals between the roll and the bearings. Bearing blocks were also clamped in position so they would not rotate when setting the roll assembly in the track. Lastly, track installation attachments were designed to load the track assembly into the withdrawal straightener. These simplified the process of installing the track section at the correct angle for the multiple roll positions.

Equipment Review — The hydraulic crawler shown in Fig. 3 is a hydraulic motor operating a pair of peg wheels through a series of gears that engage drilled holes on the track. The peg wheel design was chosen because it seemed to be the most effective way to make use of the existing track. The crawler is locked to the track by milled slots in the track and tangs on the crawler. The end of the track has perpendicular slots that allow the crawler to disengage the track and be lifted vertically off of the track. The crawler weighs approximately 80 lbs. A chain fixed diagonally allows the unit to be single-point lifted with an overhead crane or properly equipped forklift.

Coupling bars attach the crawler to the rolls and are capable of pushing and pulling the rolls into the desired position. The crawler is capable of exerting 6,500 lbs. of force and traveling at 18 ft/minute. A dedicated power unit with onboard directional control valves controls the crawler remotely. The power unit is a 7.5 hp, 1,725 RPM, 240–480 V, three-phase motor driving a 7.54 GPM pump. The power unit successfully operates the crawler near the designed input.

Hydraulic motor design point is 7.9 GPM[3] flow at 1,030 psi[3] with a published torque of 3,115 in-lb at a speed of 72 RPM. The motor operates through a gear train where a 14-tooth pinion meshes with a 42-tooth spur gear on an intermediate shaft. An 18-tooth pinion on the intermediate shaft meshes with a 42-tooth on the peg wheel shaft. Another 42-tooth gear on a separate peg wheel shaft meshes with the first to give synchronized motion in the opposite direction.

The motor pinion and mating intermediate gear are 8 diametral pitch, the final drive gears are 6 diametral pitch, all gears are 20° pressure angle and are readily available from several sources. The peg wheels engage holes in the track and change rotary motion into linear motion. The holes in the track are positioned on both sides directly opposite. They are 16 mm (0.63 inch) in diameter and are placed 33.5 mm (1.319 inches) apart. The peg wheels and holes essentially function as a rack and pinion.

The motor to final drive ratio is 7:1 and is shown in Eq. 1:

$$(42/14) * (42/18) = 7{:}1 \quad \text{(Eq. 1)}$$

The torque at the final drive at the design point is 21,805 in-lb and is shown in Eq. 2.

$$3{,}115 \text{ in-lb} * 7 = 21{,}805 \text{ in-lb} \quad \text{(Eq. 2)}$$

The final drive speed is 10.3 RPM and is shown in Eq. 3.

$$72 \text{ RPM}/7 = 10.3 \text{ RPM} \quad \text{(Eq. 3)}$$

The pitch diameter of the peg wheel is approximately 6.72 in. Therefore at 10.3 RPM the crawler would move at a rate of 18.1 ft/minute. This is shown in Eq. 4:

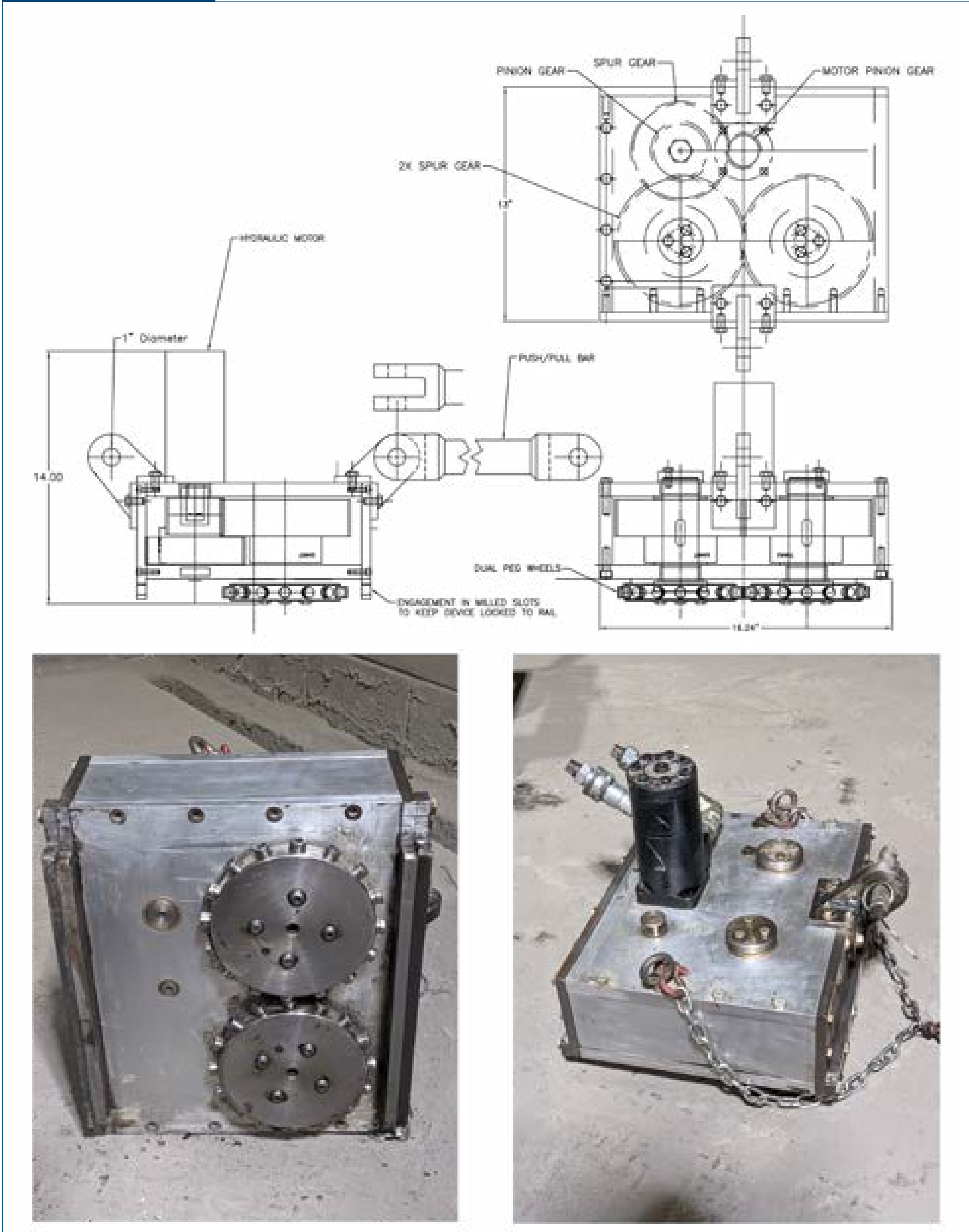
$$(\text{PI} * 6.72 \text{ in}) * 10.3 \text{ RPM} = 217.4 \text{ in/minute or } 18.1 \text{ feet/minute} \quad \text{(Eq. 4)}$$

The force developed by the crawler is 6,490 lbs. and is shown in Eq. 5:

$$21{,}805 \text{ in-lb}/(6.72 \text{ in}/2) = 6{,}490 \text{ lbs.} \quad \text{(Eq. 5)}$$

A 360-mm-diameter roller assembly weighs 4,226 lbs. The worst-case published coefficient of friction for steel on steel found was 0.844. This means that the force required to move the roller assembly along the track under worst-case conditions is 3,550 lbf. This is shown in Eq. 6:

Figure 3



Drawing of hydraulic crawler (top) and photos of hydraulic crawler (bottom).

$$0.84 * 4{,}226 \text{ lbs.} = 3{,}550 \text{ lbf} \quad \text{(Eq. 6)}$$

The designed crawler has almost twice the force needed to move the roller assembly under worst-case conditions. Precise fit between the crawler and track and safety shields limits the possibility of pinch points. The crawler mounted in the withdrawal straightener track is shown in Fig. 4.

Figure 4

Hydraulic crawler and track section.

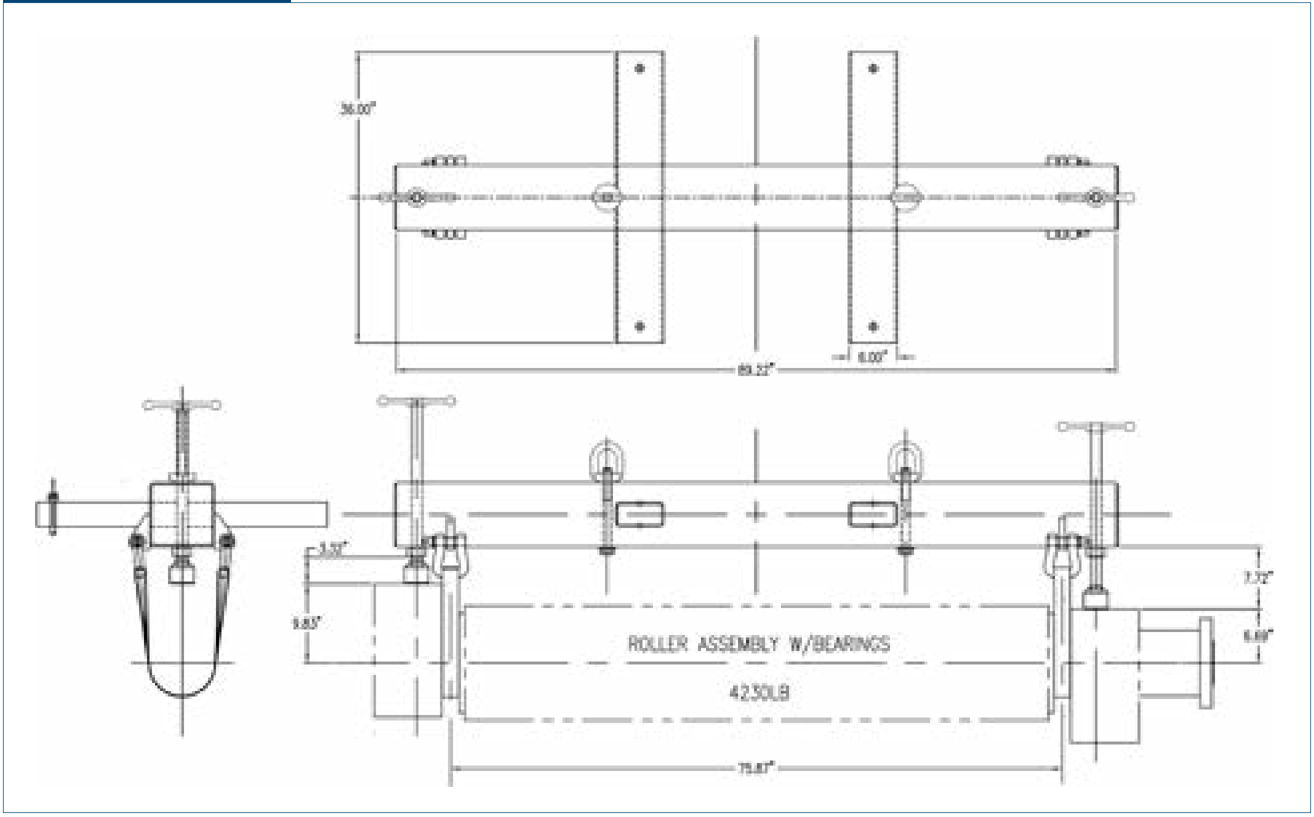
The forklift spreader bar shown in Fig. 5 is used to lift and move the roller and bearing assemblies. It is designed to maintain bearing alignment when the assembly is lifted and/or moved. The device is designed for use with a standard 5,000-lb. forklift.

It consists of an 8-inch square beam that spans the length of the roller. There are lifting straps fixed to each end along with clamps that press against the bearing housings on each end to keep them aligned. Angled feet can be fitted to the clamps so that the bearing blocks can be positioned at specific angles to aid in some installations. The total weight of the spreader bar is approximately 295 lbs.

Perpendicular to the beam are two 3-inch x 6-inch rectangular tubes to accommodate forklift forks. Later, eyebolts were added so that the spreader bar could be used with a mobile crane. The forklift spreader bar with a roll assembly is shown in Fig. 6.

The track installation attachment is for loading the first section of track into the straightener roll stand. It is a welded steel structure with rectangular tubing that fit the forks of a 5,000-lb. forklift. A chain and hook are used to secure it to the forklift mast. Built on top of the rectangular tubing is a flange that mates with the first section of straightener roll track. The flange is attached to an axle. A round steel tube is attached to the rectangular tube structure. The

Figure 5



Drawing of forklift spreader bar.

flange and axle are secured to the round tube with a pin. With the pin removed, the flange can be rotated and removed from the main structure. The holes through the tube and axle are drilled so that the track can be tilted to match the angles of the rollers in the straightener roll stand.

This assembly removes a number of people from hazardous positions while eliminating collateral damage to the sled being installed. The track installation attachment is shown in Fig. 7.

The bending unit track shown in Fig. 8 is used to remove and install bending rolls. A new track was designed that could be used with the existing crawler similar to the withdrawal straightening roll track. This required the section of track that the crawler operated on to be narrower than the original track in order to support bearing blocks that were oriented differently.

To accommodate this, on the crawler portion of the track, a ramp and side rails were added to clear the features required for the crawler and assure the bearing blocks could not slide sideways. Lifting eyes were also later added.

The withdrawal straightener track sections are used to remove and install the rolls in the withdrawal straightener. The previous withdrawal straightener unit track sections were joined with a keyed bevel joint with a bolted connection to secure the sections together. The front half, which fits into the withdrawal straightener unit, is 6.31 inches deep x 14.5 inches wide x 10 feet 11 inches long and weighs approximately 966 lbs. There were two sets of legs added to the rear section used outside the roll stand. The outer section is similar dimensionally, approximately 11 feet 6 inches long, and weighs approximately 1,000 lbs. The legs were fitted at different angles and were capable of being raised and lowered by means of tube-in-tube pockets with locking pins. This allowed the track to match the angle and height of the different rollers in the straightening unit stand.

The front section of the track was modified with a keyed flange that would fit to the track installation attachment and provide a simple bolted connection to the rear section. A swivel mechanism was added to the rear track section so it would tilt the track to angles of 0, 6 and 18°, which match the angles of the straightener roll stand. The telescoping legs were modified to adjust to six different heights to accommodate both upper and lower roll removal and installation. The track stand arrangement drawing is shown in Fig. 9.

Both the telescoping legs and swivel mechanism lock in place with a pin. The final changes were made, which consisted of mill work and a series of drilled holes to accept the crawler device. The complete assembly is shown in Fig. 10.

Figure 6

Roll spreader bar and forklift setting a roll.

Figure 7

Track installation attachment.

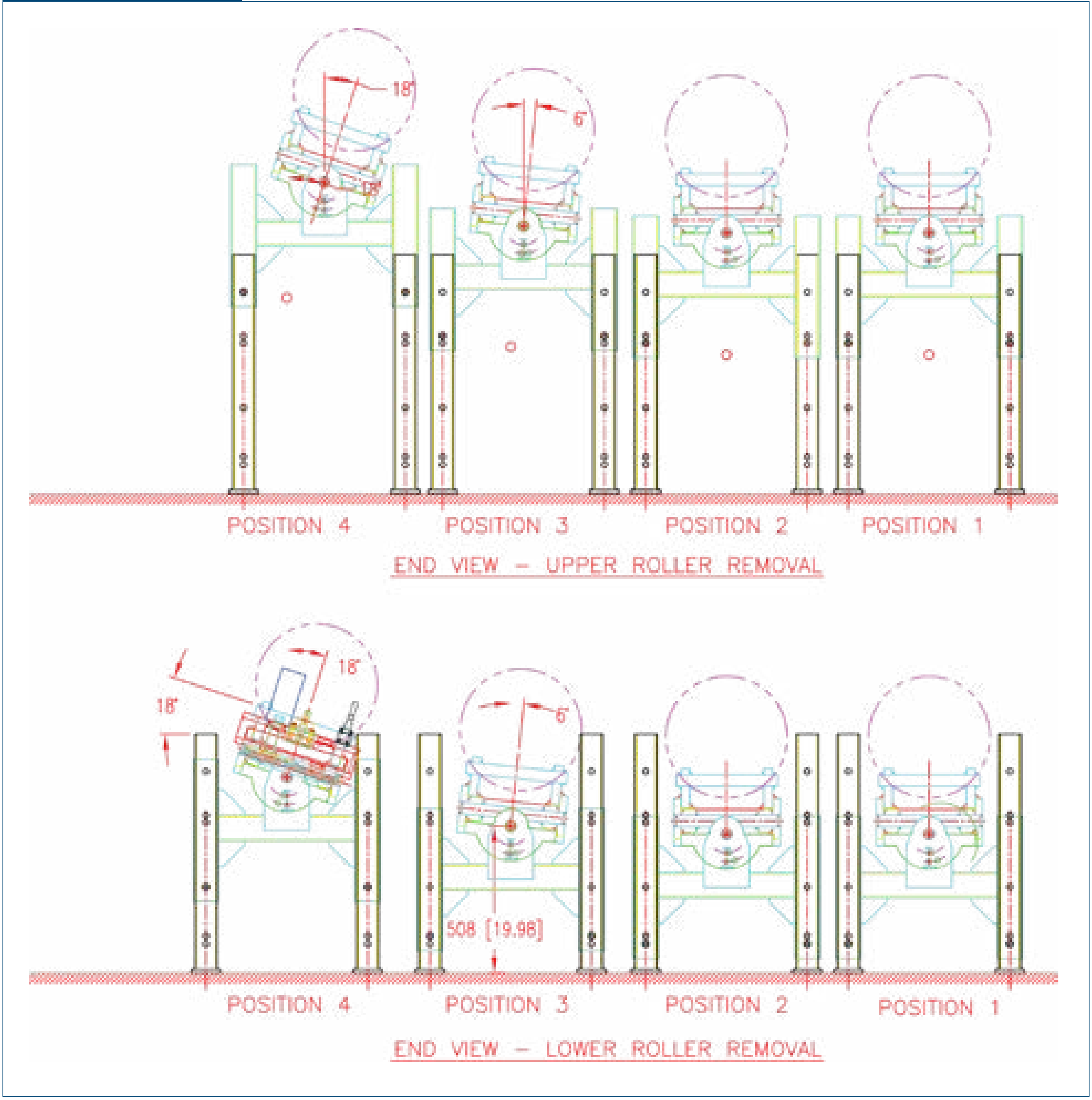
Figure 8

Bending unit track with crawler installed moving a new roll into the machine.

Conclusions

This project successfully designed and implemented modifications to the existing OEM equipment resulting in safer and quicker roll changes. The entire project was a collaboration of Steel Dynamics Inc. – Flat Roll Group Butler Division employee ideas and suggestions with the technical and manufacturing expertise of Hook Industrial Sales Inc. Hazard exposures were greatly reduced by improving the rigging and setting of the tracks, developing a roll spreader bar, and the design and use of the hydraulic crawler. Minimizing the potential for equipment damage was another benefit and was achieved by improving how rolls were removed and installed. Roll change-out times were reduced by approximately 60–70% on the bending unit and 40% on the WSU. All roll change equipment is easily stored out of the way on racks and in storage rooms. The new system is being used for both the bending unit and withdrawal straightener

Figure 9



Track stand arrangement showing different withdrawal straightener roll positions.

unit rolls on both casters. The total cost of all new and modified equipment for this project was less than 15% of other systems currently available. In summary, the new system is safer, cost-effective and highly favored by SDI personnel.

Acknowledgments

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Figure 10

Complete withdrawal straightener track assembled with crawler and roll spreader bar.

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