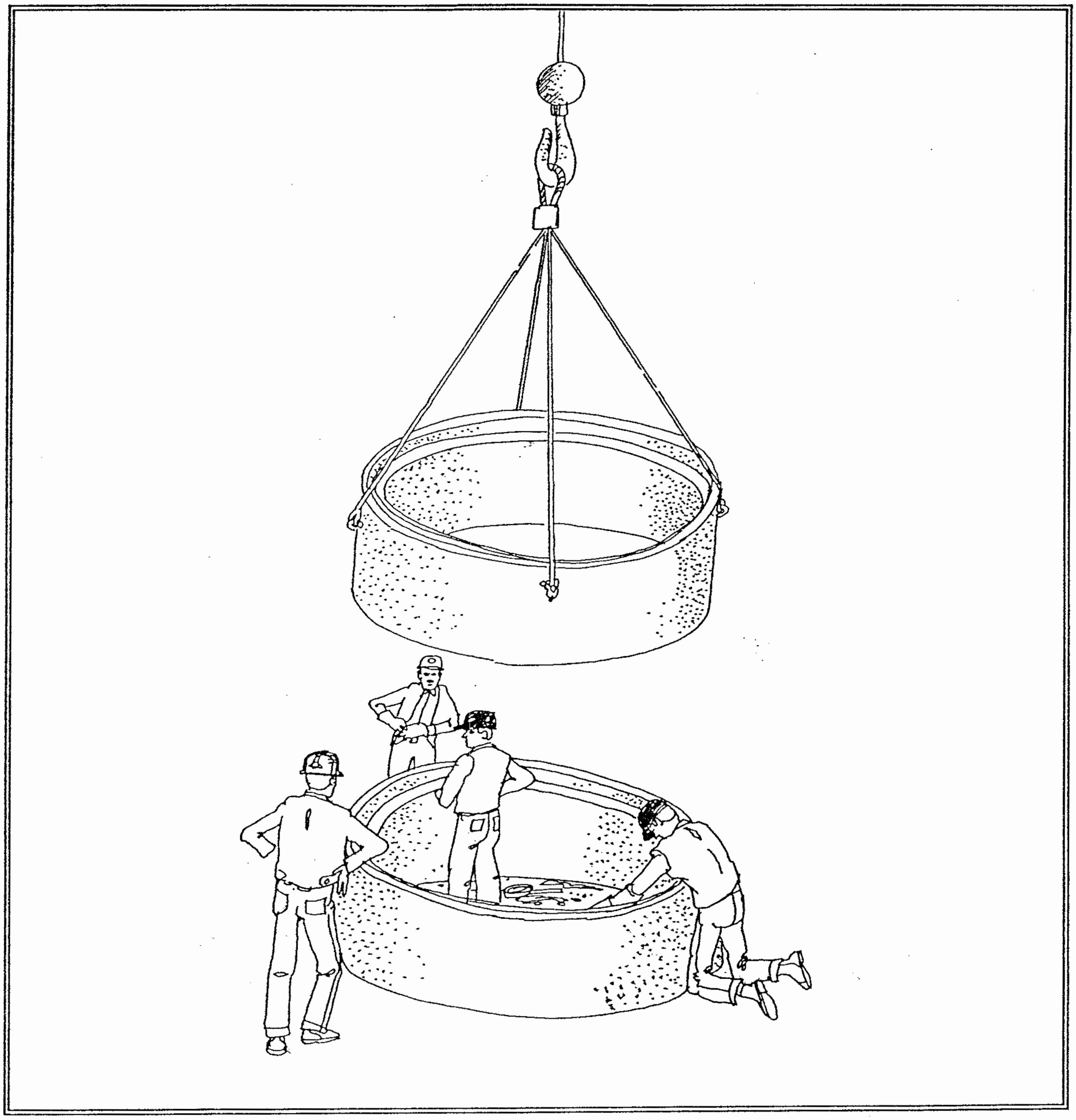
INVESTIGATION OF JULY 1, 1992 FAILURE OF A CRAWLER CRANE IN BOSTON, MASSACHUSETTS

U.S. DEPARTMENT OF LABOR
OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
December 1992



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U.S. Department of Labor
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Office of Construction and Engineering
Charles G. Culver, Director

December 1992

EXECUTIVE SUMMARY

A construction worker (tunnel worker) was fatally injured at about 12:10 p.m. on July 1, 1992, when a 13-ton cylindrical precast concrete section fell on him. The concrete section had been lifted by a crawler crane and was held about four feet above the victim and three other workers when it suddenly released, fell and struck the victim. The accident occurred on Deer Island, Boston, Massachusetts, the site of a sewage rehabilitation construction project, known as the Boston Harbor Project, undertaken by the Massachusetts Water Resources Authority (MWRA). Immediately prior to the sudden fall of the concrete section, four tunnel workers were applying a sealant material to a newly installed manhole section to which the fallen concrete section was to be connected.

Representatives from the Occupational Safety and Health Administration (OSHA) Area Office in Braintree, Massachusetts, arrived at the site on the day of the accident. On July 15, 1992, the Office of Construction and Engineering from the National Office in Washington, D.C., was requested to provide assistance in determining the cause of the accident. A representative from the office arrived at the Braintree, Massachusetts, OSHA Area Office, examined the evidence collected, conducted interviews and held meetings with local OSHA personnel on July 16, 1992. On July 22, 1992, the representative of the office arrived at the accident site, inspected the crane, conducted interviews and examined evidence. Further inspection, examination, and interviews were conducted on August 3, 4, and 6, 1992.

Based on eyewitness accounts, observation and examinations of the evidence, and conducting on-site interviews and investigation, the Occupational Safety and Health Administration concludes that:

(1). The primary friction brakes of the crane failed to hold the suspended load. Post-accident tests conducted by OSHA revealed that these brakes were not functioning properly. This malfunction was corrected when (a) manufacturer's recommended adjustments were made to the brakes and (b) undesirable scale and rust particles accumulated between the brake drums and the brake linings were removed. Disassembly of the friction brake bands and linings indicated the existence of rust patches on the surfaces of both brake drums. In addition, a significant quantity of rust, scale and other foreign particulate matter was collected by OSHA from the interior surfaces of the disassembled brake linings.

(2). The secondary brake system - a mechanism consisting of a pawl engaging the teeth of the lagging flange of the front drum - failed to engage and lock the drum. It was determined that the likely cause of failure of the secondary brake system was excessive and random lateral vacillation of the pawl - causing it to slide off the teeth on which it was designed to engage. It was determined that the major cause of the excessive and random lateral vacillation of the pawl was lack of adequate number of spacer washers intended to provide lateral support for the pawl. The importance of utilizing an adequate number of spacer washers was particularly important since the difference of radii between the pawl and the shaft it was rotating on was significant.

EXHIBIT LIST

EXHIBIT NO.	ITEM	DATE	HIGHLIGHTS
1	Video Tape No.1	July 2, 1992	General observation of the crane
2	Video Tape No.2	July 2, 1992	General observation of the crane
3	Video Tape No.3	July 2, 1992	4:36 p.m. - Load did not hold. It fell through the primary brakes. 4:48 p.m. - Test was conducted on brakes. Brakes did not function properly. Load fell through.
4	Video Tape No.4	July 2, 1992	5:21 p.m. - Test was conducted on primary brakes. Brakes failed.
5	Video Tape No.5	July 7, 1992	General observation of the crane's operation
6	Video Tape No.6	July 8, 1992	7:55 p.m. - "Dog [pawl] engages properly." This statement was made by the post-accident operator.
7	Video Tape No.7	July 10, 1992	General Footage shot at the accident site.
8	Video Tape No.8	July 10, 1992	1:53 p.m. - The [lessor] mechanic disconnecting the hydraulic line underneath the crane. 2:13 p.m. - The mechanic from the [lessor] begins dismantling the shaft and the dog [Pawl].
9	Video Tape No.9	July 10, 1992	General Footage shot at the accident site.
10	Video Tape No.10	July 21, 1992	General Footage shot at the accident site.

11	Video Tape No.11	August 3, 1992	10:30 a.m. - The [lessor] mechanic explaining that operator must "ride the brakes" before use. 10:33 a.m. - The pocket [tooth] shows to have sustain[ed] plastic deformation and significant wear on the side.
12	Video Tape No.12	August 3, 1992	1:22 p.m. - Gap between brake drum and pocket.
13	The Damaged Pawl	July 10, 1992 - Taken out of the crane and given to OSHA.	Significant plastic deformation on the tip of the pawl due to inaccurate contact and wear with the pocket.
14	Fibrous Brushing	July 10, 1992 - Taken out of the crane and given to OSHA.	Significant disintegration of the bushing. Only strands of fiber were recovered.
15	Spacers	July 10, 1992 - Taken out of the crane and given to OSHA.	6 spacers were recovered. All spaces were of gauge 12.

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1. INTRODUCTION

A construction worker (tunnel worker) was fatally injured at about 12:10 p.m. on July 1, 1992, when a 13-ton cylindrical precast concrete section fell on him. The concrete section had been lifted by a 500,000-pound-capacity crawler crane and was held at about four feet above the victim and three other workers when it suddenly released and fell and struck the victim (ref. fig. 1.1). During this operation, the main hoist drum of the crane was used with single part line over the main boom. According to the manufacturer, the lifting capacity of the crane for this configuration was 46,000 pounds. The accident occurred on Deer Island, Boston, Massachusetts, the site of a sewage rehabilitation construction project, undertaken by the Massachusetts Water Resources Authority (MWRA) (ref. fig. 1.2). Immediately prior to the sudden fall of the concrete section, three tunnel workers and an independent truck driver were applying a sealant material to a newly installed manhole section to which the fallen concrete section was to be connected (ref. fig. 1.3).

Representatives from the Occupational Safety and Health Administration (OSHA) Area Office in Braintree, Massachusetts, arrived at the site on the day of the accident. OSHA began its investigation of the accident on the same day and - through visual examination - determined that the accident was not caused by any structural failures of the boom and/or disconnection of any cables or other components between the machine and the load. Further examination, inspection and onsite interviews concentrated on operation of the braking systems utilized in suspending the load above the four tunnel workers. On July 15, 1992, the Office of Construction and Engineering (OCE) from the National Office in Washington, D.C., was requested to provide assistance in determining the cause of the accident. A representative from the office arrived at the Braintree, Massachusetts, OSHA Area Office, examined the evidence, conducted interviews and met with local OSHA personnel on July 16, 1992 (ref. fig. 1.4). On July 22, 1992, the representative of the office accompanied by a team of investigators from the local OSHA Area Office arrived at the accident site, inspected the crane, conducted interviews and examined evidence. Also, the Chief Consultant of the U.S. Navy's Weight Handling Equipment Office (Naval Facilities Engineering Command) participated in the above onsite inspection at the request of OCE. Further inspection, examination, and interviews were conducted on August 3, 4 and 6, 1992 (ref. fig. 1.5).

The OSHA investigation involved eyewitness accounts, interviews of the crane operator, examination and inspection of the crane and its various components, conducting tests on various mechanical systems of the crane, review of the original design drawings of the crane, and interviewing the engineering staff of the crane manufacturer. In addition, as further investigation focused the concentration of the investigative process toward the braking mechanism of the crane, arrangements were made for disassembly of the crane's braking system to further inspect and examine the internal components of the system (ref. fig. 1.6).

Throughout the course of the investigation, the Office of Construction and Engineering worked with personnel of the OSHA Braintree, Massachusetts, Area Office. The Compliance Officers, David P.Grafton, Patrick J. Griffin and James V. Manoli made significant contributions to this investigation.

Dr. Charles G. Culver, Director of the Office of Construction and Engineering, OSHA, U.S. Department of Labor, provided significant technical guidance and supervision to the execution of the investigative project devoted to determining the cause of the accident.

Paul S. Zorich, Chief Consultant, Weight Handling Equipment Office, Naval Facilities Engineering Command, U.S. Navy, provided significant contributions with the onsite investigation and analysis of the failure mode.

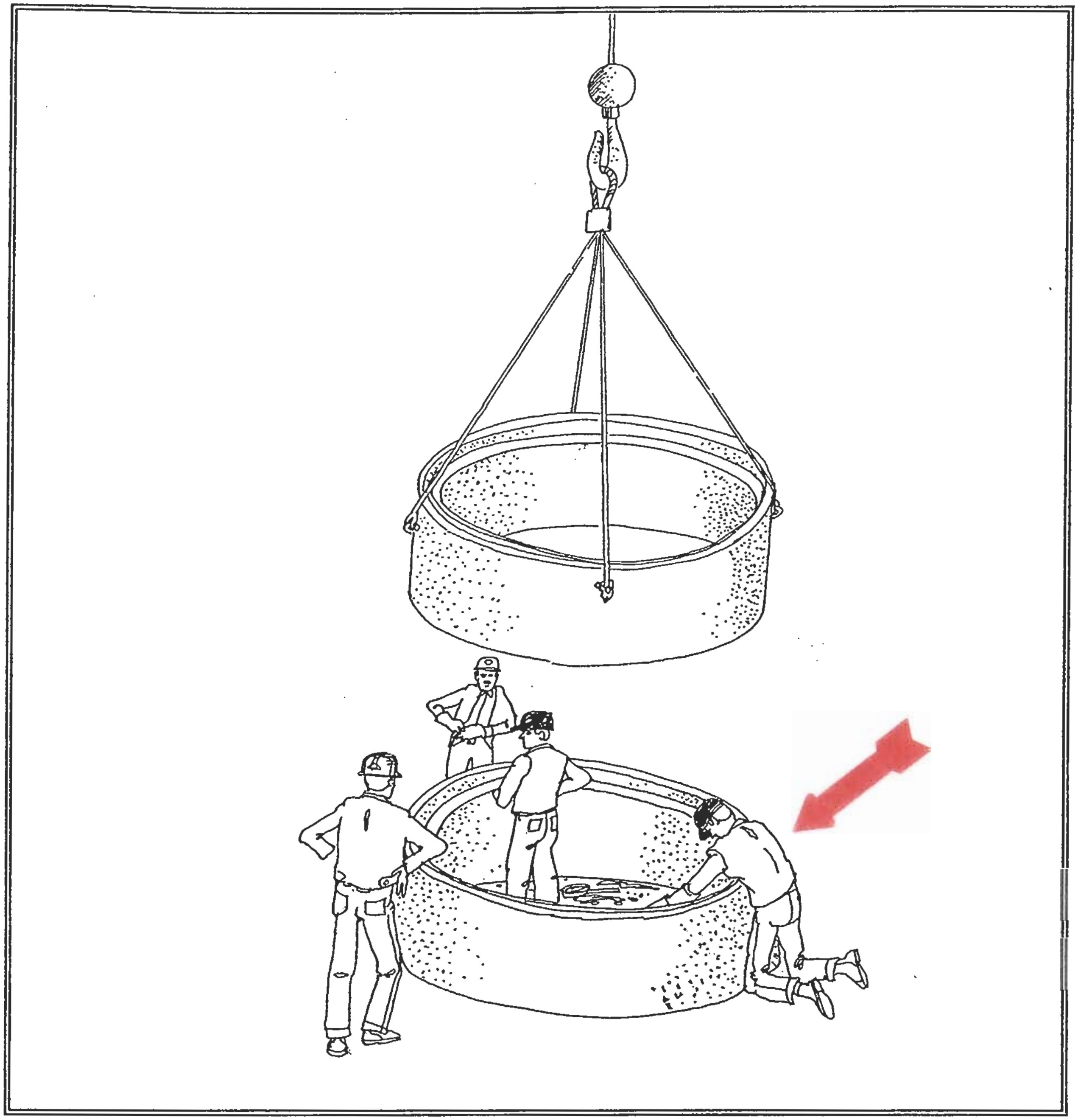


Figure 1.1 The concrete section was lifted and held at about four feet above the victim and three other workers.

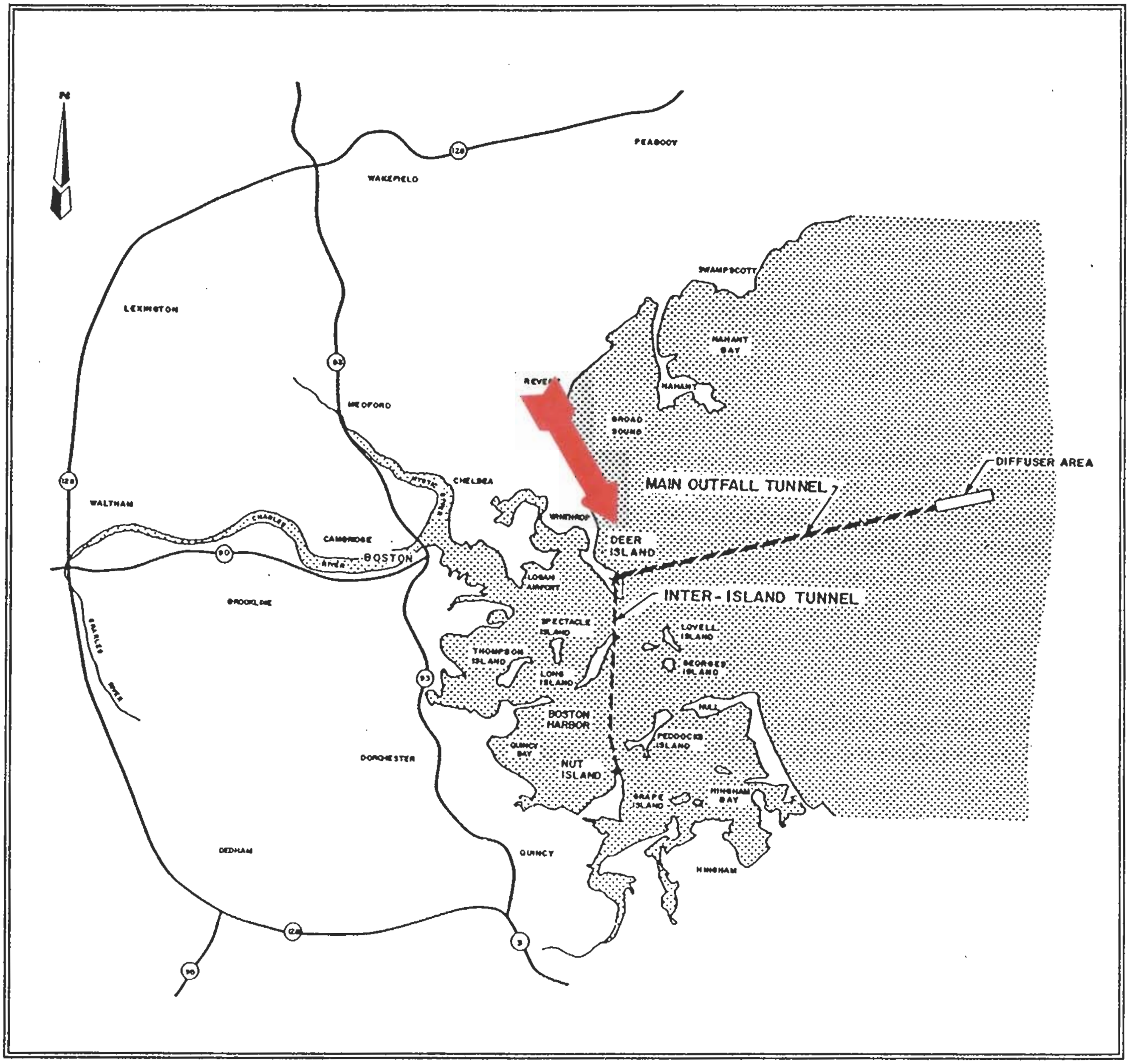


Fig. 1.2 The accident occurred on Deer Island, the construction site of a sewage rehabilitation project - undertaken by the Massachusetts Water Resources Authority (MWRA).

Figure 1.3 The four workers were applying a sealant material at the connection of the concrete sections.

Figure 1.4 Members of the OSHA investigative team examining collected evidence.

Figure 1.5 Under OSHA supervision, the friction brake system of the crane's main hoist drum was disassembled for further investigation.

Figure 1.6 Disassembling of the friction brake system of the crane's main hoist drum.

2. CONDUCT OF THE INVESTIGATION

A representative of the Office of Construction and Engineering (OCE) arrived at the accident site, inspected the crane, conducted interview and examined evidence on July 22, 1992. An earlier pre-site inspection meeting was held in the OSHA Braintree, Massachusetts Area Office on July 16, 1992. During that meeting, collected evidence was examined by the OCE representative and necessary arrangements were made to gain access to the site of the accident at Deer Island, Massachusetts. Furthermore, a meeting between the OSHA representative and an engineering team representing the manufacturer of the crane was held in Boston, Massachusetts on July 22, 1992. Also present at the meeting - at the request of OSHA - was the Chief Consultant of the U.S. Navy's Weight Handling Equipment Office (Naval Facilities Engineering Command).

As the focus of OSHA's investigation began to concentrate on specific mechanical components of the crane's braking system, OSHA requested permission from the owner of the crane for disassembling specific suspect components. On August 3, 1992, several components of the crane's braking system were disassembled under OSHA's supervision. Based on inspection and further examination of the disassembled components, OSHA took possession of several suspect components for the purpose of further evaluation of these components (ref. fig. 2.1). The owner of the crane granted permission for taking the components and rendered full cooperation during the disassembly process.

In addition, the Office of Construction and Engineering requested and obtained the manufacturer's engineering design drawings. Based on the review of the manufacturer's design drawings, further engineering calculations were obtained from the manufacturer pertinent to the suspect components which OSHA had taken possession of. The geometrical properties of suspect components were compared with those as required by the manufacturer's design specifications. All significant deviations noted between the physical properties of the suspect components and those specified by the manufacturer's design data were further investigated (ref. fig. 2.2). Selected samples of the suspect components were submitted to the manufacturer to determine whether the material properties of such components met the minimum requirements of the manufacturer's engineering design specifications. According to the manufacturer, the selected suspect components met the design specifications of the manufacturer.

Furthermore, the crane's primary and secondary braking mechanisms were tested utilizing the same concrete section which was involved in the accident. The proper functioning of the above braking systems was reviewed based on the manufacturer's specifications. The system's malfunctions deviating from the designed mode of operation were noted and further investigated (ref. fig. 2.3).

Figure 2.1 **Disassembled top left (TL) friction brake band of the main hoist drum along with its three brake linings.**

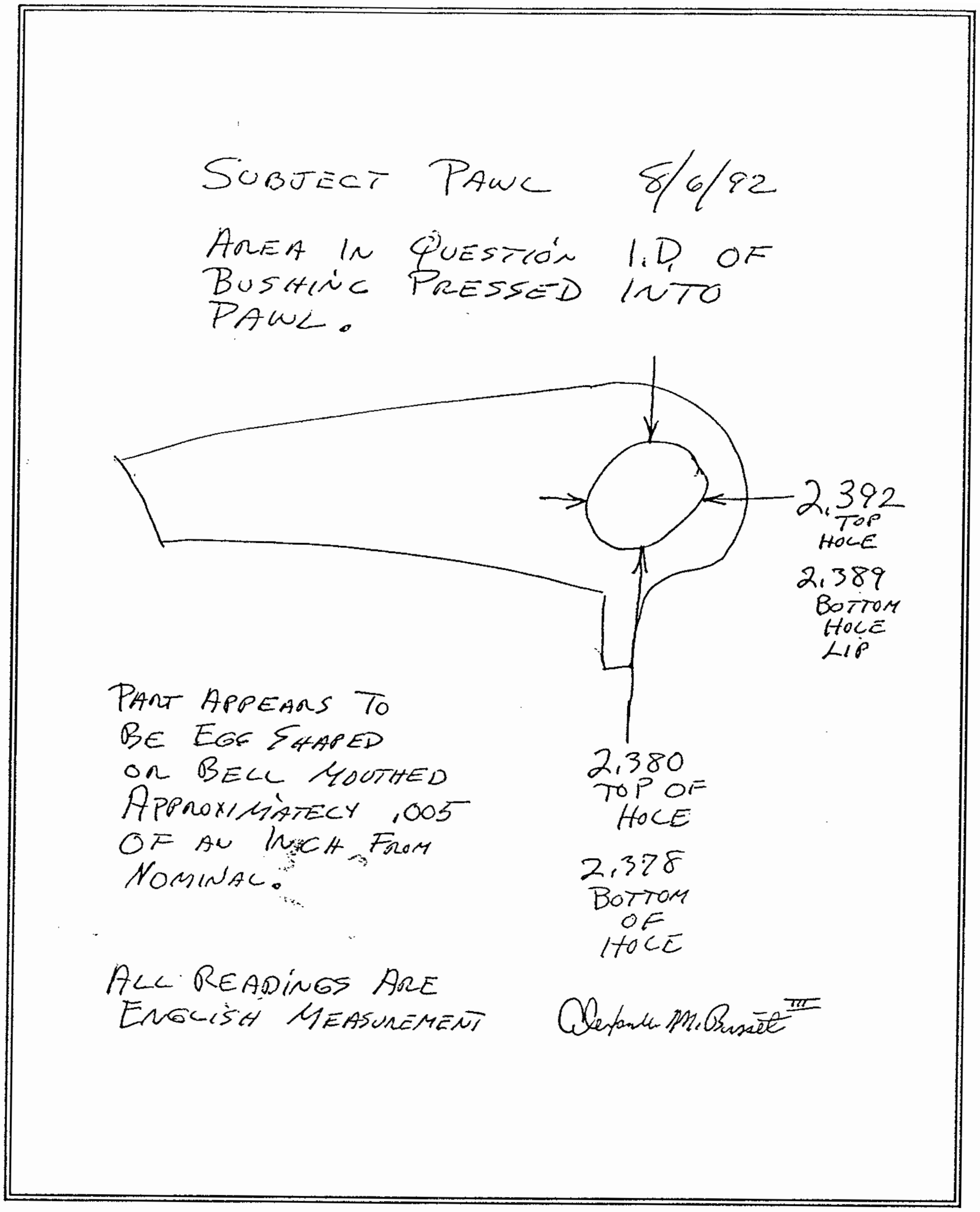


Figure 2.2 OSHA measured the geometric dimensions of the pawl and compared these measurements to those specified by the manufacturer's design specifications.

Figure 2.3 OSHA conducted post-accident functional tests of the crane's primary and secondary brake systems using the same concrete section which was involved in the accident.

3. DESCRIPTION OF THE ACCIDENT

In this chapter, the general observations of the accident are described. Based on examination of the accident site, review of eyewitness statements and inspection of the crane and its components, the following description was generated. The material of this section was used in further investigation and analysis of the accident.

The accident site is located on Deer Island, Boston, Massachusetts. Deer Island is the construction site of a new wastewater treatment facility, which according to design drawings and specifications for the project, includes new primary and secondary wastewater treatment facilities. The project was undertaken by the Massachusetts Water Resources Authority (MWRA) and includes a tunnel and shafts connecting the Deer Island treatment plant and a new headworks facility at Nut Island, Massachusetts, located in Quincy Bay.

The accident occurred as installation of a new 14-foot diameter cylindrical concrete section was in process. The crane involved in the accident was a 500,000-pound capacity crawler crane, model LS-718, leased by one of the construction contractors and brought to the site in October 1991. According to documents obtained by OSHA, the crane was inspected and certified by an OSHA-accredited firm on October 15, 1991. The certificate of inspection stated that the inspection was in accordance with 29 CFR 1926.550.

On the day of the accident, one of the construction contractors requested the lease-holder of the crane for permission to use the crane during the lunch break. The permission was granted by the lease-holder of the crane and the borrowing contractor mobilized its workforce for using the crane in lifting a 14-foot diameter cylindrical concrete section so a sealant material could be placed underneath the section - between the two adjoining concrete sections comprising the top segment of a vertical wastewater shaft. The lifted section weighed 13 tons and it was attached to the load line of the crane by means of four precast steel shear lugs located on the outside diameter of the concrete section. The load was lifted by the operator after the load line was secured to the four connection lugs (ref. fig. 3.1). The load was held at about four feet above the bottom concrete section and three tunnel workers and an independent truck driver proceeded to apply the sealant material to the rim of the bottom concrete section by getting underneath the suspended concrete section. One of the tunnel workers was situated inside of the bottom concrete section while the other three applied the sealant material from positions in the outer perimeter of the concrete section (ref. fig. 3.2).

According to eyewitness statements, the operator had locked the primary brakes by having pressed and locked the latch attached to the foot brake pedal (ref. fig. 3.3). Then, the operator proceeded to activate the (secondary) spring-applied, hydraulically-released brake system. In order to engage the secondary brake system - consisting of a pawl engaging the sloping teeth of the front drum - the operator slightly released the friction brake so the tip of the pawl could position itself on the teeth of the front drum (ref. fig. 3.4). Once having assumed that he had engaged the secondary mechanical brake, the operator proceeded to lock the friction brake by pressing his foot on the pedal. It is at this instant that according to eyewitness statements, the load slid through and struck the victim (ref. fig. 3.5). However, moments prior to the sudden fall of the load, three of the workers had finished application of the sealant material and had stood upright while the victim was still in the kneeling position - engaged in application of the sealant material to the surface of the bottom concrete section (ref. fig. 3.6). The falling section struck the victim and caused him fatal injuries.

Figure 3.1 The 14-foot diameter cylindrical concrete section was lifted by the crane after the load line was attached to the four connection lugs.

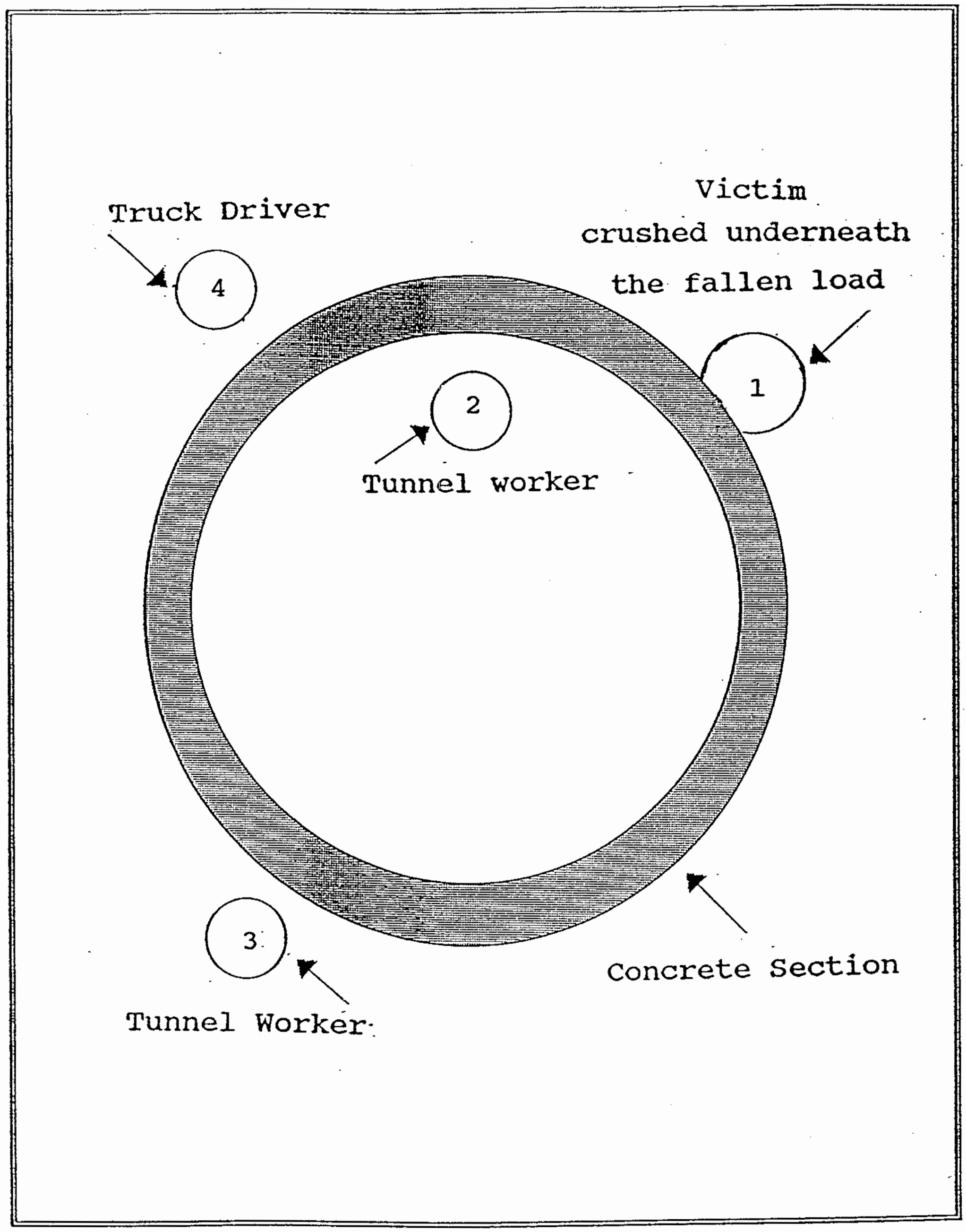
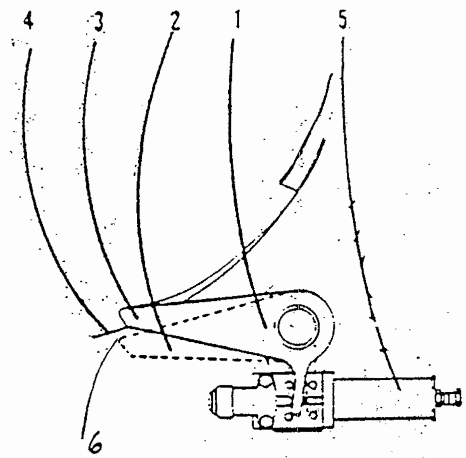


Figure 3.2 The topview of the accident scene immediately prior to the release and fall of the concrete section.

Figure 3.3 The friction brake foot pedal. The brake locking latch is shown in top left corner of the pedal.



Drum Pawls:
(1) Drum Pawl
(2) Released Position
(3) Engaged Position
(4) Lagging Flange
(5) Pawl Actuator
(6) 1/2" Clearance

Figure 3.4 The main hoist drum shaft has a pawl assembly which rides on teeth cut in the lagging flange. When the pawl is engaged, the rope can't wind off the drum.

Figure 3.5 The load slid through the brakes and struck the victim. The victim's tape of sealant material and the bottom concrete section are shown above.

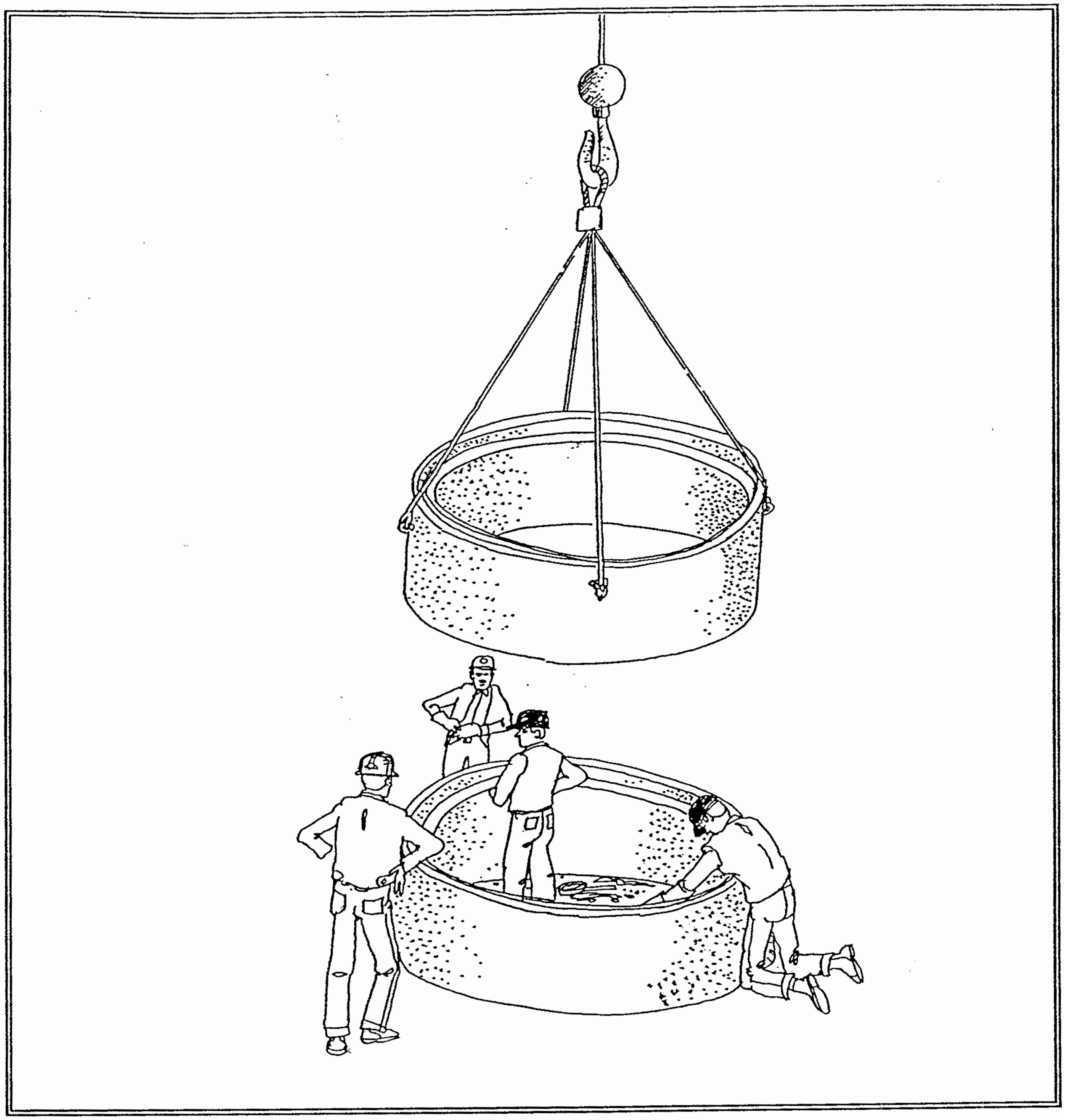


Figure 3.6 Three of the workers were in the process of applying the sealant material and stood upright. The victim was still in the kneeling position.

4. SUMMARY OF EVIDENCE EXAMINATION

The following excerpts are adopted from the daily journal on the subject crane.

JOURNAL OF THE CRANE	
DATE	HIGHLIGHT OF COMMENTS
11/19/91	● Boom hoist motor leaking (bad). ● Converter filters still leaking.
11/26/91	● Boom hoist motor still leaks. ● Converter filters still leak.
12/3/91	● Asked mechanic to look at the machine (no response).
12/9/91	● Asked mechanic to look at crane and change hyd. [hydraulic] filters and fuel filters (no response).
12/11/91	● Received wrong wiper for crane ask mechanic to return (no response).
1/6/92	● Bad smell coming from engine starter solenoid smoking.
1/8/92	● Crane started but would not swing, master mechanic says swing solenoid S/B was replaced.
1/16/92	● Crane would not travel or swing.
1/17/92	● Crane would not swing, travel [,] all controls on the left side frozen.
1/24/92	● Hyd. [hydraulic] filters still leaking. ● Track pad cracked.
1/28/92	● Spoke with the [lessor] equipment supt. [superintendent] ● Hyd. [hydraulic] filters still leak.
1/30/92	● Main load drum hyd. [hydraulic] cylinder leaking bad, called the [lessor].
1/31/92	● Hyd. [hydraulic] cylinder still not fixed. ● Problems with boom hoist motor having severe vibration problem.

5/15/92	●	Gantry pins still snapping.
5/18/92	●	Gantry pins still cracking.
5/21/92	● ●	Replace bushings in gantry. Boom running fine now.
6/11/92	●	Asked Goodwrench to look at leak under machine (no show).
6/16/92	●	Asked Goodwrench to check hyd. [hydraulic] leak (no response).
6/18/92	●	Told Goodwrench hyd. [hydraulic] filters must be changed.
6/19/92	●	Showed assistant superintendent leak under machine [,] he said let it run out.
6/29/92	● ● ●	Crane leaking hyd. [hydraulic] oil bad. Hyd. [hydraulic] filters still leaking. Still no maintenance.
7/1/92	●	Brakes fail on mainload.

5. ANALYSIS

The objective of this section is to describe the procedure utilized by the OSHA Office of Construction of Engineering in analyzing the basic mode of failure and then trace the specific characteristics of the failure in relation to the manufacturer's design intents of the pertinent crane mechanisms which could have interfered with the intended operation of the crane.

At the initial stages of this investigation, examination and inspection of the material evidence ruled out the possibility of structural failure in the boom and/or cables and components which were in the line of connection between the suspended load and the main hoist drum which was used to hoist the load.

Further inspection and examination indicated that the focus of the analysis needed to be concentrated on the internal mechanism of the crane. Thus, a thorough inspection of the mechanical and hydraulic systems of the machine's braking mechanism was conducted.

On July 2, 1992, the primary friction braking system of the crane was tested under OSHA supervision. The test was conducted by hoisting the same concrete section that was involved in the accident. Several attempts were made to hold the load by application of the primary friction brake system. Out of a total of five attempts, the primary friction brake system failed to function on three occasions - resulting in sudden release of the load and its fall to the ground, as it had occurred during the accident. On two occasions, the primary brake system functioned and held the load at the desired suspended elevation (ref. exhibit no.s 3 & 4).

Subsequently, OSHA proceeded to adjust the friction brakes in accordance with the instructions given in the Operator's Manual (ref. Appendix B). However, the brakes continued to function erratically and not hold the load at all times even after the above adjustments had been made. Under OSHA supervision, actions were undertaken to free the surfaces of the brake drum and the linings from any undesirable particulate matter by tapping the outside of the brake bands with a hammer. Subsequent to undertaking the above action, under OSHA supervision, several tests were conducted on the friction brake system involving the same load that was used in earlier tests. The friction brake system functioned properly during all these subsequent tests. Based on this observation, OSHA proceeded to have the friction brake system disassembled so the condition of the brake drums and linings could be further investigated (ref. fig. 5.1). The surface of the brake drums were observed to contain patches of rust (ref. fig. 5.2) and significant quantity of rust, scale and other particulate matter which were collected from the interior surfaces of the disassembled brake linings (ref. fig. 5.3).

Based on observation of the disassembled shaft and the pawl, it was determined that the lateral vacillation of the pawl would be arbitrary - one factor being the machine's vibration. In other words, the pawl could have, at occasions, engaged the tooth head-on and without significant lateral vacillation to either extremes. During such occasions, the pawl would be able to engage the tooth and stop the rotation of the drum at once.

According to engineering documentation obtained by OSHA from the manufacturer, during the 1970's the manufacturer received information from the field which indicated that the bushing between the pawl and the shaft was not adequately withstanding the conditions in the field. According to the same documents, the manufacturer revised its design drawings and specifications for the bushing by switching from a material called "nylatron" to the material which was used in the subject crane - called "fiberglide". The engineering document which generated the above revision was dated November 17, 1977. This document stated the reason for the revision as, "to provide stronger bushings...nylatron does not withstand forces as published." However, according to the manufacturer, since the fiberglide bushing was thinner than the nylatron, on October 6, 1977, a "steel mechanical tubing" was added as another bushing inside the diameter of the pawl. However, a July 25, 1980, revision of the pawl's engineering drawing indicates that the steel tubing bushing was to become nickel-plated. A nickel-plating of 0.0007 inches to 0.001 inches was applied to the steel bushing per the above revision. The manufacturer cited "rusting of the non-plated" bushing as the reason for the above revision. According to the manufacturer, their field data indicated that "... the fiberglide was porous and retained water.... which rusted the steel bushing and caused swelling of the bushing. The swelling caused the pawl to bind and not function properly."

Therefore, when the crane involved in the accident was manufactured in May 1981, it contained both the new fibrous bushing and the nickel-plated bushing. However, OSHA inspection and examination of the fibrous bushing indicated that its disintegrated remains were soaked with a fluid substance. In addition, the inside of the nickel-plated bushing bears identifiable evidence of rust.

OSHA determined that the clearance between the inside diameter of the steel bushing of the pawl (2.383" inches-as per OSHA measurements) and the outside diameter of the shaft (2.249 inches - as per OSHA measurements) was about 0.134 inches.(ref. Appendix A).

In order to determine the effect of the significant difference of radii between the pawl and the shaft the pawl was rotating on and the effect of the 3 washers found on each side of the pawl, OSHA conducted the following calculations:

1. Computations were performed to determine the maximum possible vacillation of the pawl for a hypothetical condition in which no washers were placed on each side of the pawl. (ref. Appendix A).

2. A second set of computations was preformed to determine the maximum possible vacillation with the 3 washers on each side of the pawl providing lateral restraint (ref. Appendix A).

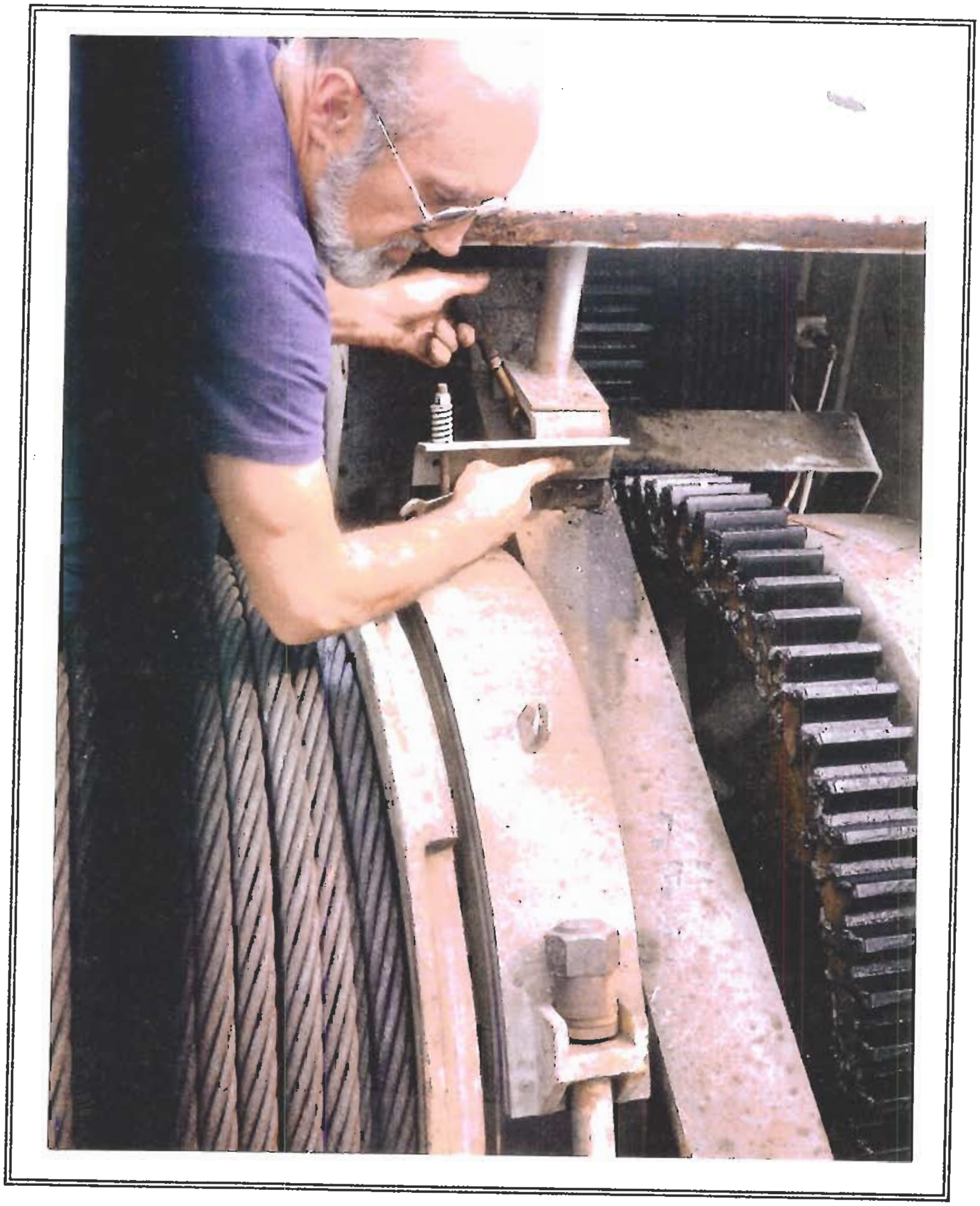


Figure 5.1 The brake bands of the main hoist drum were disassembled so the condition of the brake drums and linings could be further investigated.

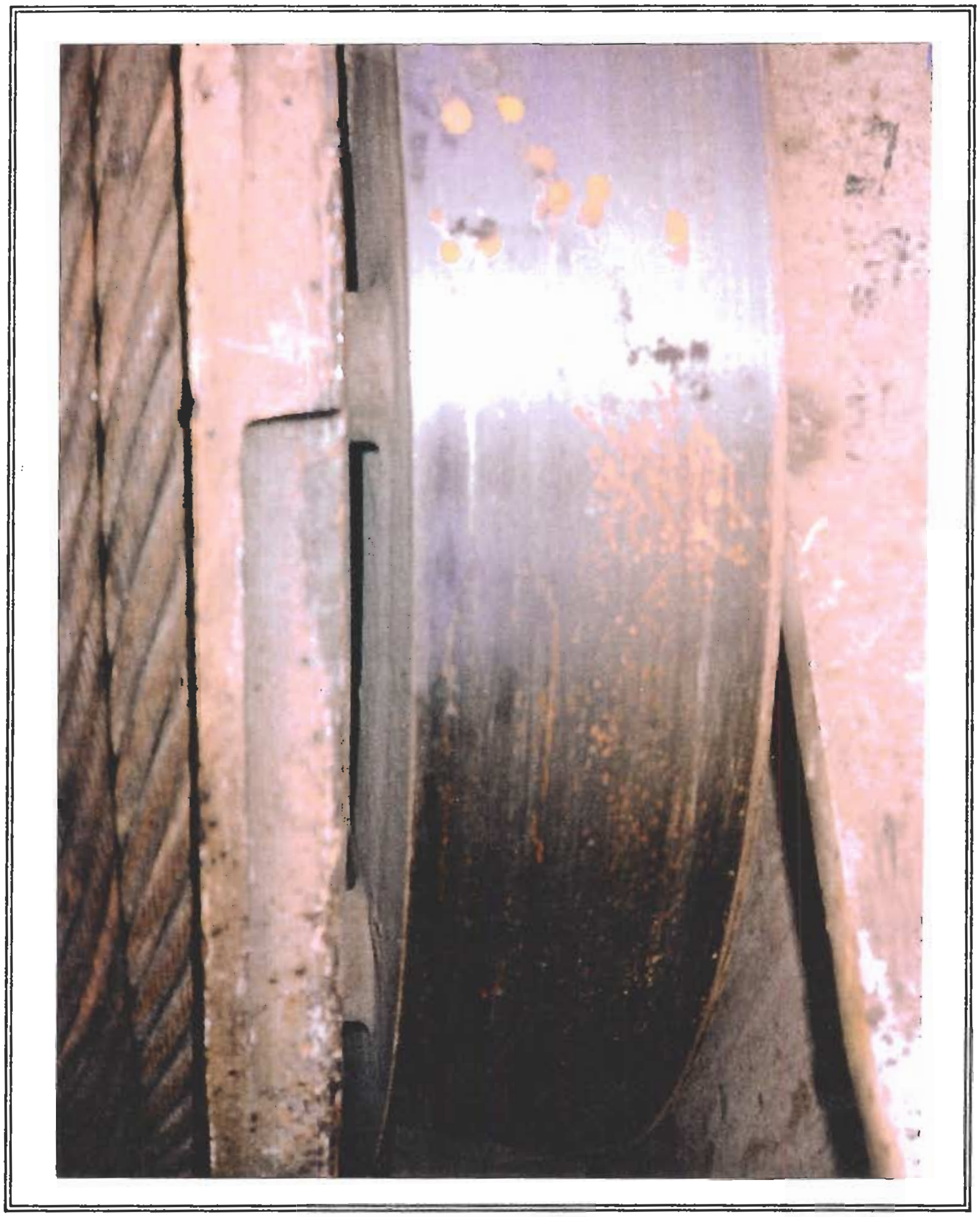


Figure 5.2 The surface of the brake drums contained patches of rust and scale.

Figure 5.3 OSHA collected significant quantity of rust, scale and other particulate matter from the interior surfaces of the disassembled brake linings.

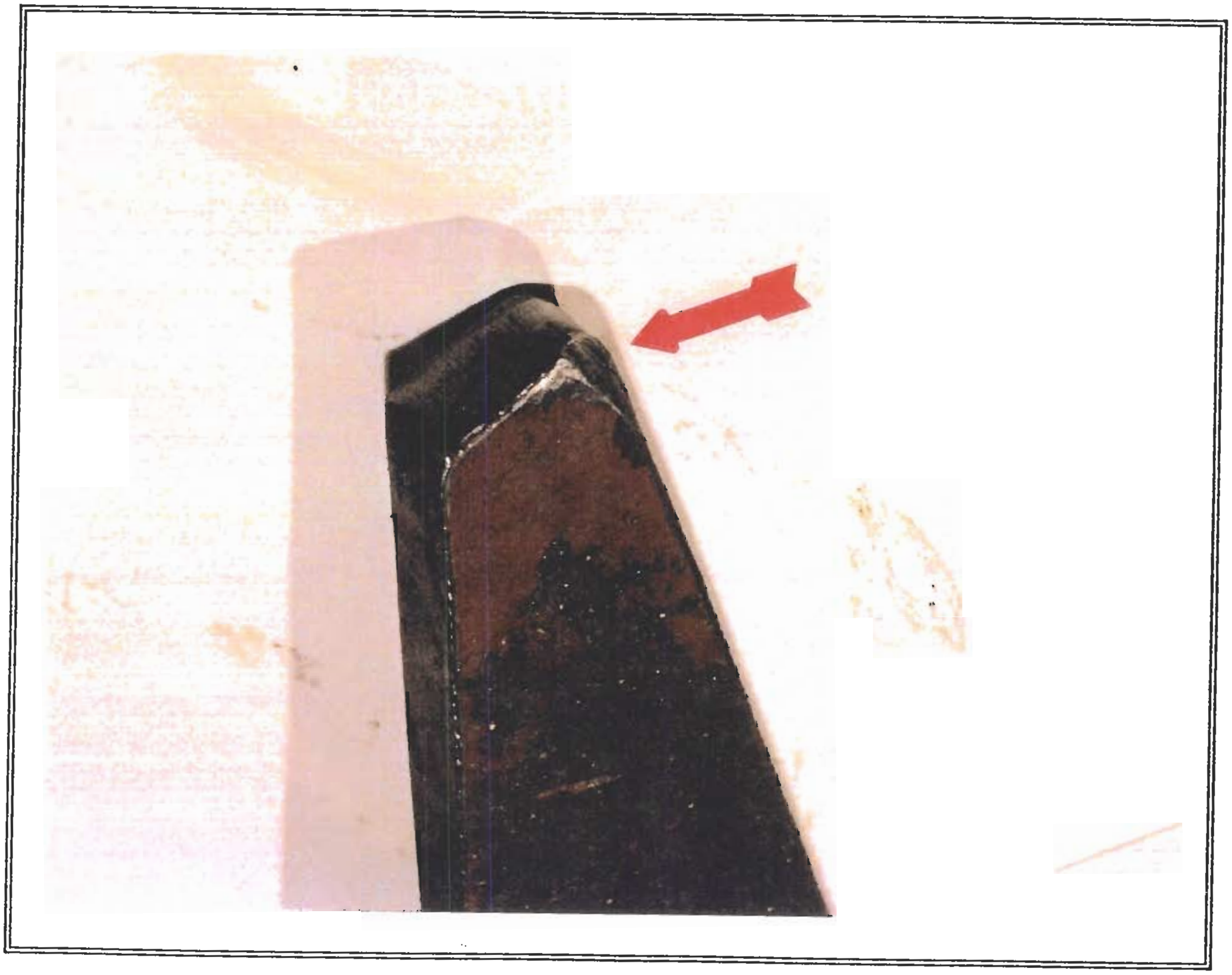


Figure 5.4 Evidence of plastic deformation and wear on the right edge tip of the pawl matches deformation on the edge of teeth - indicative of the two edges wearing against each other.

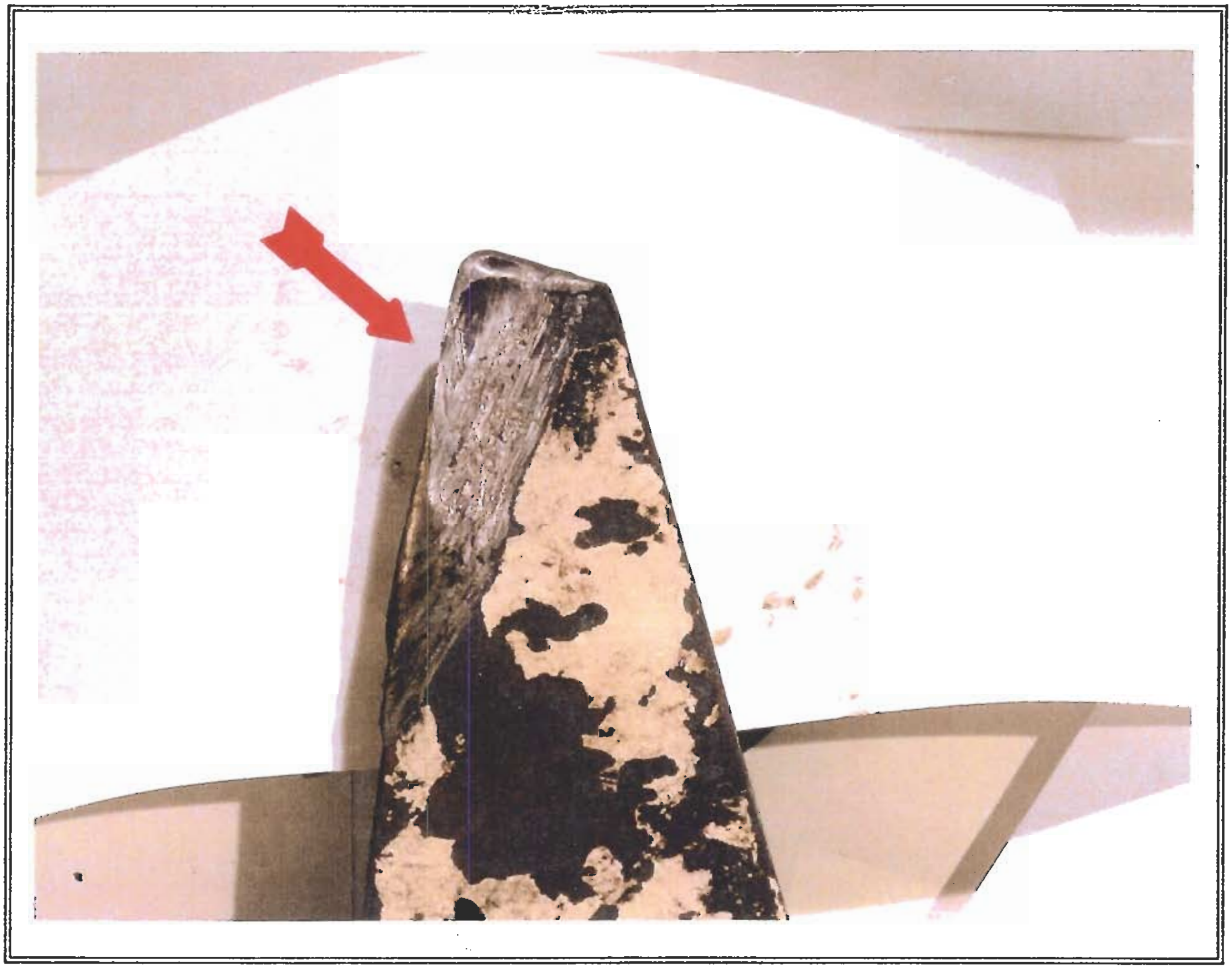


Figure 5.5 Evidence of plastic deformation and significant wear on the left edge of the pawl's tip matches deformation and wear of the brake drum's sheet metal panel.

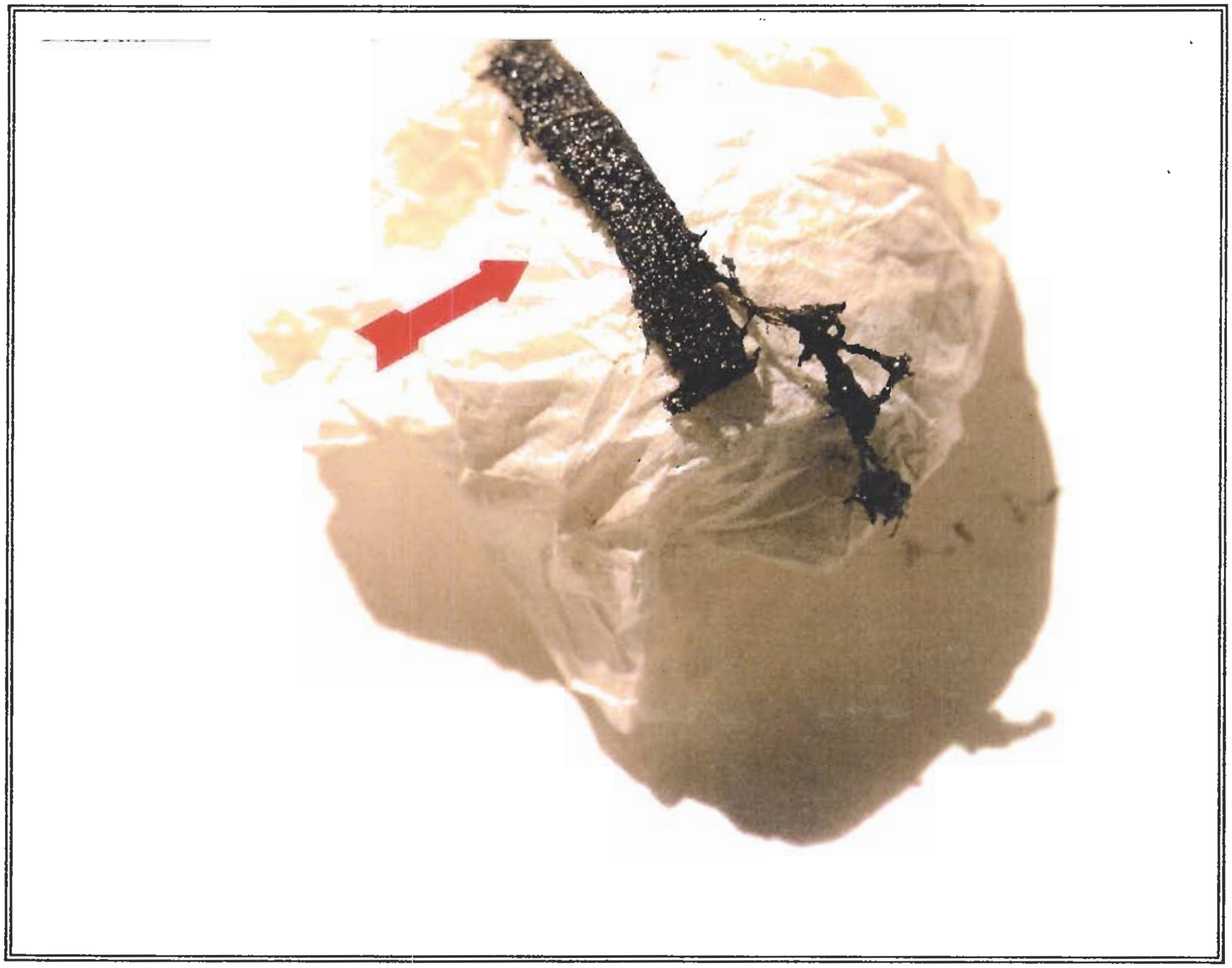


Figure 5.6. The fibrous bushing between the pawl and the shaft was found to be significantly disintegrated.

6. RESULTS OF ANALYSIS

Based on the investigative analysis undertaken by OSHA in regard to the failure of both the primary and secondary braking systems of the subject crane, the following results are obtained:

(1). The failure of the primary braking system was due to (a) lack of adequate periodic adjustments of the brakes and (b) development and accumulation of rust and other undesirable particulate matter between the friction surfaces of the brake drum and linings. According to eyewitness statements taken by OSHA under oath, the specific drum used on the day of the accident had not been utilized for about a month. OSHA discovered a significant number of rust patches on the metallic surface of the brake drums when it disassembled the machine's friction brake system and examined the condition of both the brake drums and the brake linings. In addition, significant quantities of rust and other undesirable particulate matter were collected from the space between the surfaces of the brake drums and linings. Furthermore, material evidence obtained by OSHA - a daily journal kept by the oiler of the crane - (ref. chapter 5) demonstrates the existence of a pattern of conduct which can be reasonably evaluated as not attentive to the crane's periodic maintenance requirements. In fact according to the manufacturer's Operator's Manual, the adjustment of brakes must be part of a regular weekly maintenance program (ref. Appendix B). No records were submitted to OSHA which indicated compliance with such a maintenance requirement by the users of the crane.

(2). The secondary braking system failed to function properly during the accident. The main hoist drum shaft has a pawl assembly which rides on teeth cut in the lagging flange. As per the manufacturer's design specifications, when the pawl is engaged, the rope can't wind off the drum because the pawl holds the drum against rotation. The pawl is spring-applied and hydraulically-released. The pawl is operated by control knobs on the operator's front instrument panel. OSHA determined that the lateral vacillation of the pawl was excessive to the extent that it caused the pawl to miss the required engagement surface with the teeth cut in the lagging flange. During disassembly of the pawl mechanism, six 12-gauge (0.1046 in.) spacer washers were found to be providing the only lateral restraint (three spacer washers on each side) of the pawl against vacillation. According to measurements by OSHA, the spacer washers (3 on each side of the pawl) were the only lateral restraint for the pawl. Two sets of 1.875" calculations were performed. The first set was based on the distance between bosses (frame components) as determined from the manufacturer's design drawings. The second set of calculations was based on the distance between bosses (frame components) of 1.975" as measured by OSHA after the accident. Based on the results of calculations performed, it was determined that if there had been no washers, the amount of vacillation at the tip of the pawl would be approximately 1.431" and it would not contact the flange. However, in the first set of calculations, it was determined that because of the presence of 3 washers on each side of the pawl the vacillation at the tip of the pawl was reduced to approximately 7/8".

The results of the first set of calculations considering the existence of 3 washers on each side of the pawl indicated that the tip of the pawl would vacillate as much as 0.851". Also the force imposed on the pawl, resulting in contact with the flange, would result in an additional lateral deflection of the pawl. The total amount of the pawl's displacement was determined to be approximately 1.00". (ref. Appendix A). The summation of the above 3 factors resulted in the pawl not engaging the lagging flange (ref. Appendix A).

The results of the second set of calculations indicated that the pawl, with 3 washers on each side, missed the tooth of the engaging flange by .188" due to vacillation of the pawl (ref. Appendix A). It was observed that the edge of the tip of the pawl - on the engaging tooth side - had in fact been plastically deformed by approximately 1/8" reducing the width to 0.875" from 1.0".

7. CONCLUSIONS

The following conclusions by the Office of Construction and Engineering, Occupational Safety and Health Administration are based on the inspection and examination of the subject crane and its components, conducting interviews and investigations, and performing engineering analysis and measurements:

(1). The primary friction brakes of the crane failed to hold the suspended load. Post-accident tests conducted by OSHA revealed that these brakes were not functioning properly. This malfunction was corrected when (a) manufacturer's suggested adjustments were made to the brakes and (b) a team of mechanics - under OSHA supervision - succeeded in releasing and removing undesirable scale and rust particles accumulated between the brake drums and the brake linings. Disassembly of the friction brake bands and linings indicated the existence of rust patches on the surfaces of both brake drums. In addition, a significant quantity of rust, scale and other particulate matter was collected by OSHA from the interior surfaces of the disassembled brake linings.

(2). The secondary brake system - a mechanism consisting of a pawl engaging the teeth of the lagging flange of the front drum - failed to engage and lock the drum. It was determined that the likely cause of failure of the secondary brake system was excessive and random lateral vacillation of the pawl - causing it to slide off the teeth on which it was designed to engage. It was determined that the major cause of the excessive and random lateral vacillation of the pawl was lack of adequate number of spacer washers intended to provide lateral support for the pawl. The importance of utilizing an adequate number of spacer washers was particularly important since the difference of radii between the pawl and the shaft if was rotating on was significant.

APPENDIX A - CALCULATIONS

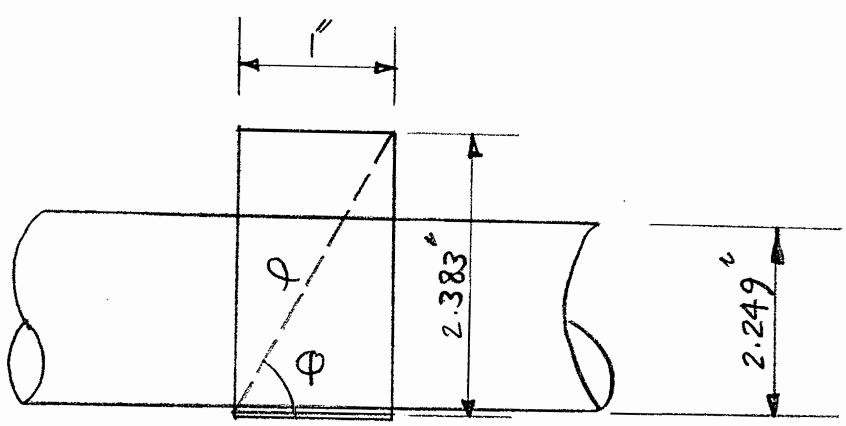
CALCULATIONS OF PAWL'S TIP DEVIATION OFF ENGAGING TOOTH

CASE ONE : NO INTERFERENCE FROM WASHERS

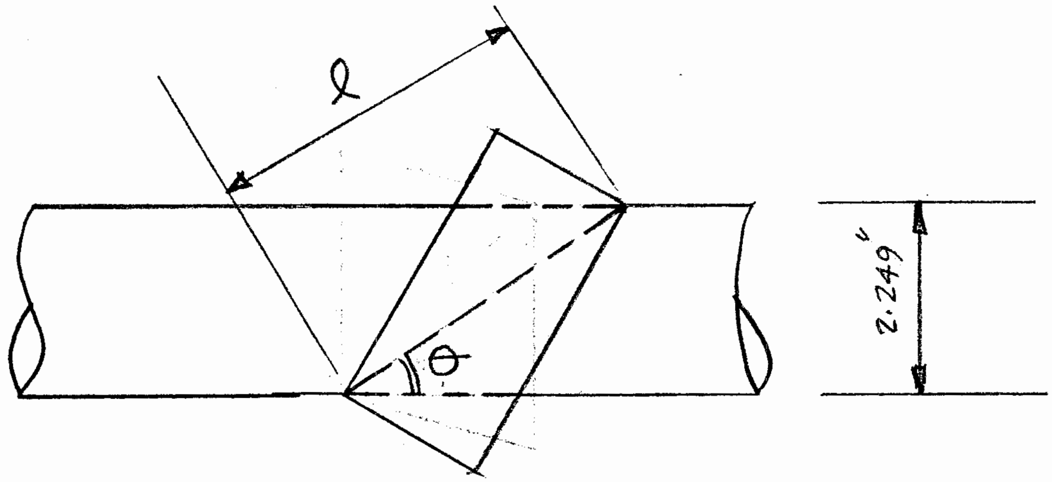
AVERAGE INSIDE DIAMETER OF STEEL BUSHING FITTED IN THE EYE OF THE PAWL – AS MEASURED BY OSHA = 2.383" (REF. FIG. A-1).

DIAMETER OF THE SHAFT – AS MEASURED BY OSHA = 2.249" (REF. FIG. A-2).

DIFFERENCE OF RADII OF PAWL AND SHAFT = 0.134"



SHAFT & STEEL BUSHING
(BEFORE TIPPING)



SHAFT & STEEL BUSHING

(AFTER TIPPING)

N.T.S.

BEFORE TIPPING $\Rightarrow \tan^{-1}\phi = \frac{2.383''}{1} = 67.24°$

$l = \sqrt{(2.383)^2 + 1^2} = 2.584''$

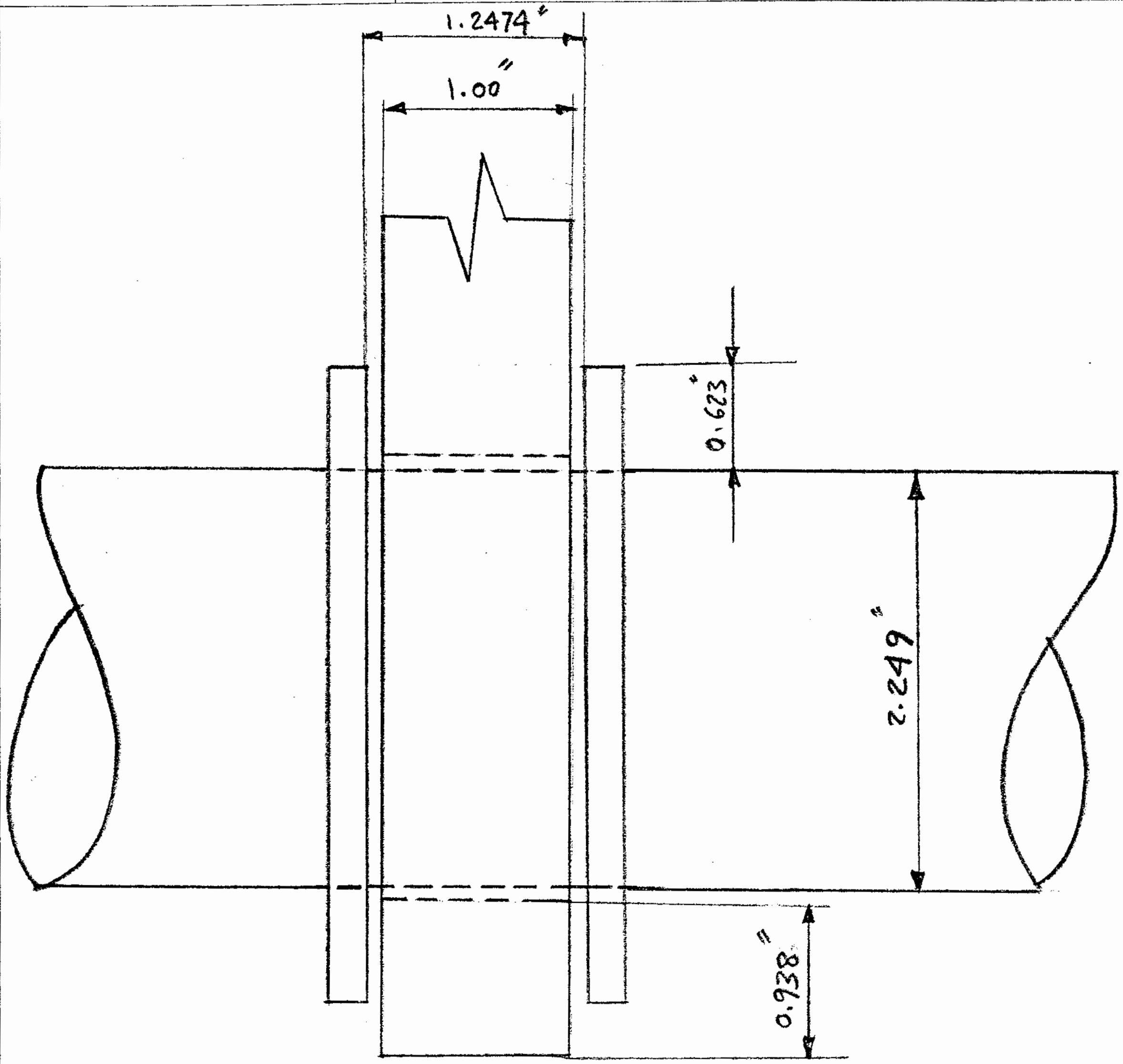
$\sin^{-1}\theta = \frac{2.249''}{l} = \frac{2.249''}{2.584''} = 60.50°$

$\lambda = \phi - \theta = 67.24° - 60.50° = 6.74°$

MOMENT ARM OF PAWL $= 11.00'' + \frac{2.383''}{2} = 12.19''$

$\Delta = [\sin\lambda][12.19] = 1.431''$

Δ = MAXIMUM LATERAL DEVIATION OF THE PAWL'S TIP BASED ON EFFECT OF RADII DIFFERENCES.



CASE TWO: EFFECTS OF WASHERS CONSIDERED

NUMBER OF WASHERS RECOVERED SUBSEQUENT TO THE ACCIDENT = 6 (THREE ON EACH SIDE OF THE PAWL).

THICKNESS OF EACH WASHER = 0.1046" (REF. FIG. A-5).

TOTAL THICKNESS OF SIX WASHERS = 0.6276"

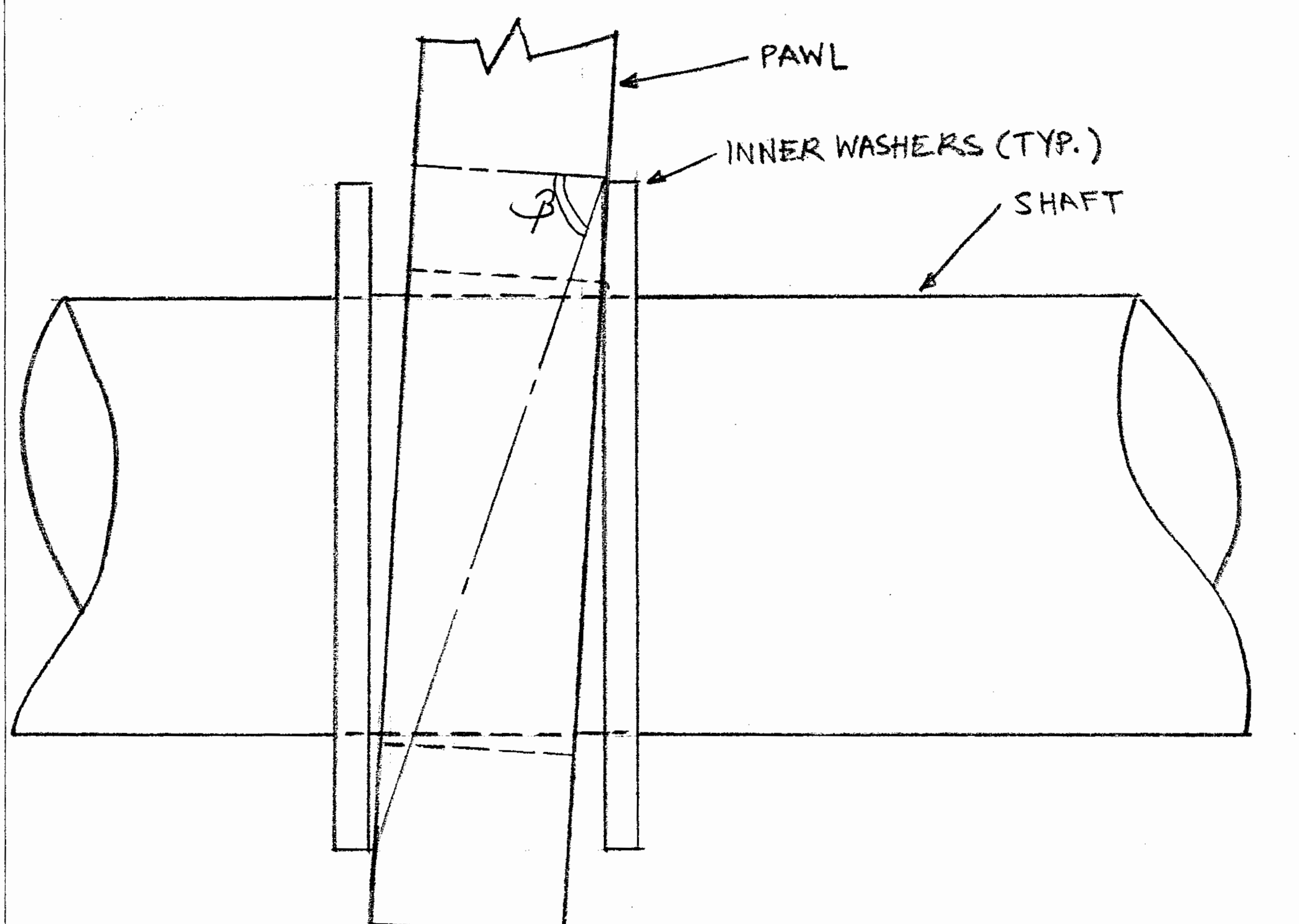
THICKNESS OF THE PAWL = 1.0"

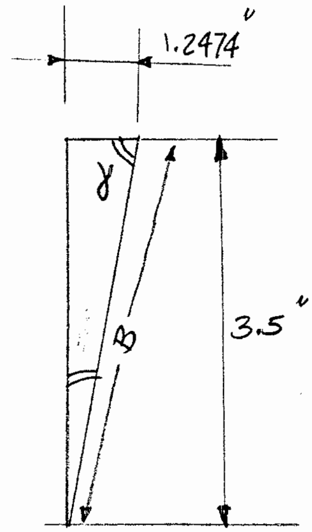
a. DISTANCE BETWEEN BOSSES (FRAME COMPONENTS) – AS PER MANUFACTURER'S DESIGN DRAWINGS $= 1.875''$ (REF. FIG. A-4).

FREE DISTANCE BETWEEN WASHERS AND THE PAWL

$= (1.875'' - 1.00'' - 0.6276'') = 0.2474''$

ACCORDING TO THE MANUFACTURER, DEVIATIONS OF MORE THAN $1.00''$ – AT THE TIP OF THE PAWL – CAUSE THE PAWL TO MISS ENGAGING THE TOOTH OF THE LAGGING (REF. FIG. A-3) $\Rightarrow \Delta_{MIN} = 1.00''$





$$B = \sqrt{(1.2474)^2 + (3.5)^2} = 3.7156''$$

$$\tan\gamma = \frac{3.5}{1.2474} \Rightarrow \gamma = 70.38^\circ$$

$$\cos\beta = \frac{1''}{3.7156''} \Rightarrow \beta = 74.387^\circ$$

$$\beta - \gamma = 4.0^\circ = \theta_2$$

$$X = 1/\cos\theta_2 = 1.0024$$

$$\tan\phi_2 = \frac{1.2474 - 1.0024}{3.5} \Rightarrow \phi_2 = 4.0041^\circ$$

TOTAL VACILLATION AT TIP $= (\sin\phi_2)(12.19'')$

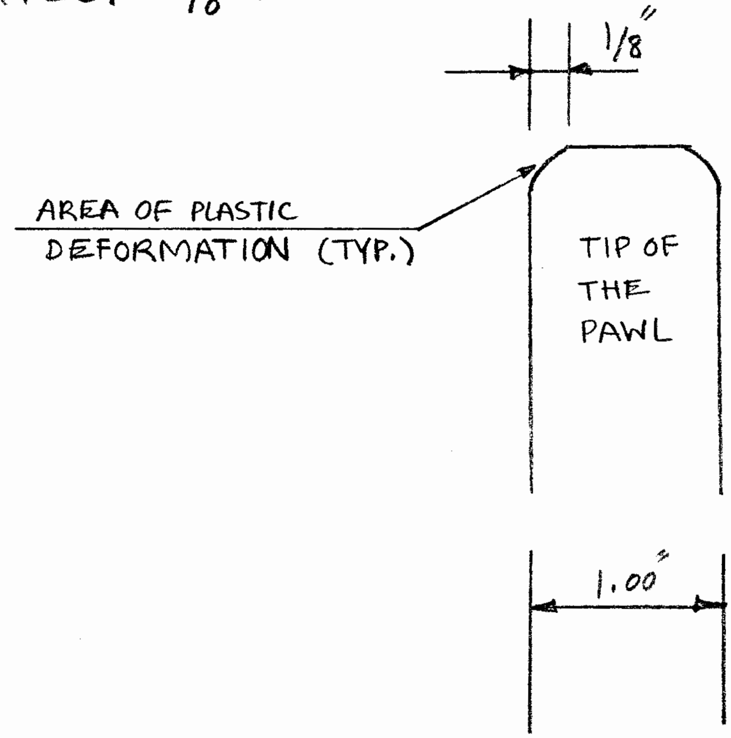
$= 0.851''$

THUS, COMPARISON OF RESULTS OF CASES 1 & 2 INDICATES THAT THE PAWL'S TIP DEVIATION IS CONTROLLED BY CASE 2.

$\Rightarrow \Delta_{MIN} = 1.00''$ (REF. P. 41)

$1.00'' - 0.851'' = 0.149''$

(1). HOWEVER, TIP OF THE PAWL SHOWS SIGNS OF SIGNIFICANT PLASTIC DEFORMATION (REF. FIGS. 6.4 & 6.5). THE PLASTIC DEFORMATION ON THE TOOTH SIDE IS MEASURED TO BE APPROXIMATELY 1/8".



(2). CONSIDERING DEFLECTION OF TIP OF PAWL DUE TO CANTILEVERED BEAM ACTION :

DEFLECTION OF THE TIP DUE TO CANTILEVERED BEAM ACTION $= D_{TIP}$

$$D_{TIP} = \frac{WL^3}{3EI}$$

$I = \frac{bh^3}{12}$, AVERAGE b ALONG LENGTH

$\Rightarrow b = 2.75$

$$I = \frac{(2.75)(1.00)^3}{12} = 0.23 \text{ IN}^3$$

ASSUMING 100% SHEEVE EFFICENCY,

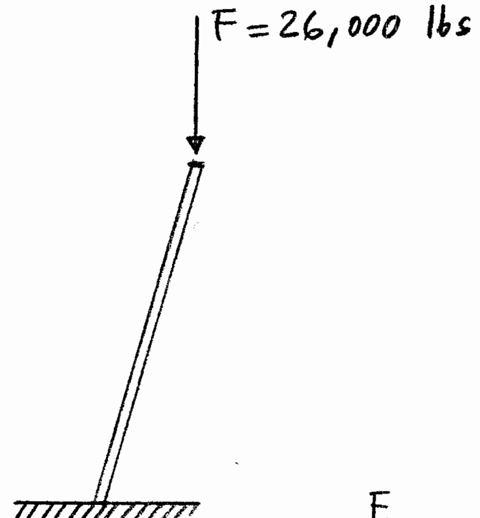
$F = 26{,}000$ lbs.

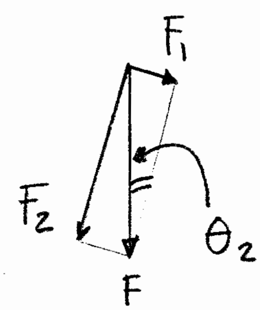
$F_1 = (\sin\theta_2)(26{,}000 \text{ lbs.})$

$F_1 \cong 1815$ lbs.

$$D_{TIP} = \frac{WL^3}{3EI}$$

$$D_{TIP} = \frac{(1815)(12.19)^3}{3(30{,}000)(0.23)} = 0.159''$$





$\Rightarrow 0.851 + 1/8'' = 0.976''$

$1.00'' - 0.976'' = 0.024''$ REQ'D D_{TIP}

REQUIRED $D_{TIP} \ll$ ACTUAL D_{TIP}

$0.024'' \ll 0.159''$

$\Rightarrow$ PAWL MISSES TOOTH.

6. DISTANCE BETWEEN BOSSES (FRAME COMPONENTS) - AS MEASURED BY OSHA = 1.975"

FREE DISTANCE BETWEEN WASHERS AND THE PAWL = (1.975" - 1.00" - 0.6276") = 0.3474"

$$B = \sqrt{(1.3474)^2 + (3.5)^2} = 3.750$$

$$\tan \gamma = \frac{3.5}{1.3474} = 2.598 \Rightarrow \gamma = 68.945^\circ$$

$$\cos \beta = \frac{1''}{3.750} \Rightarrow \beta = 74.534^\circ$$

$$\beta - \gamma = 74.534^\circ - 68.945^\circ = 5.589^\circ = \theta_2$$

$$X = 1/\cos\theta_2 = 1.0048$$

$$\tan \theta_2 = \frac{1.3474 - 1.0048}{3.5} \Rightarrow \theta_2 = 5.591^\circ$$

$$\text{TOTAL VACILLATION AT TIP} = (\sin\theta_2)(12.19'') = 1.188''$$

$\Delta_{MIN} = 1.00''$ (REF. P. 41)

$\Rightarrow \Delta_{ACTUAL} > \Delta_{MIN} \Rightarrow$ PAWL MISSES TOOTH

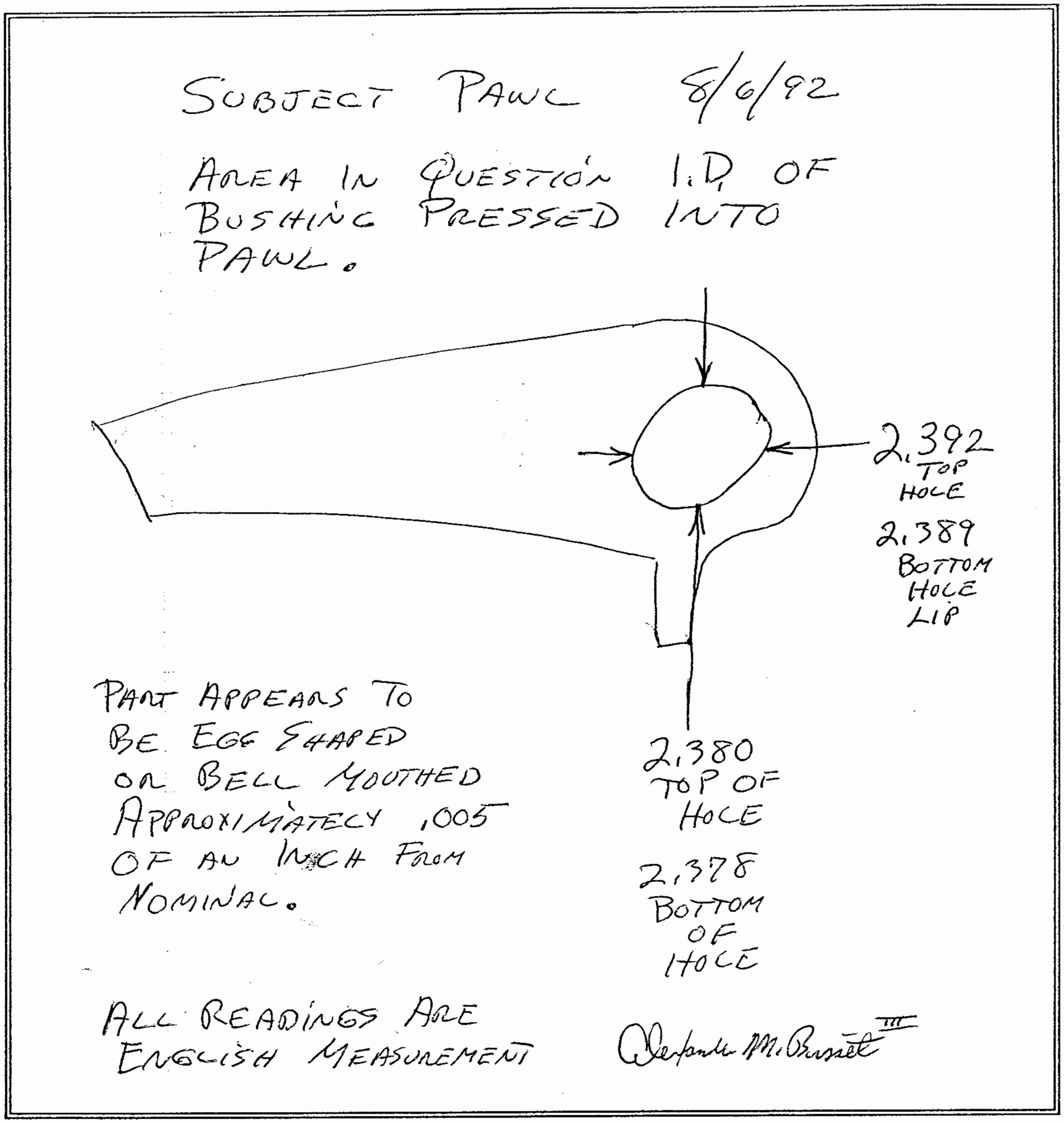
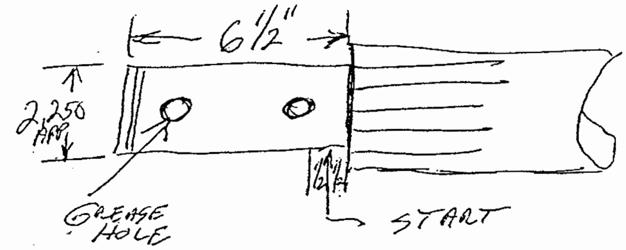


Figure A-1. The inside diameter of the steel bushing of the pawl involved in the accident was measured by OSHA.

SUBJECT SHAFT 8/6/92
AREA IN QUESTION 6½ LONG
BY APPROXIMATELY 2.250 DIAMETER.
TWO READINGS TAKEN 180° OPPOSITE
APPROXIMATELY ½ SPACINGS
STARTING AT SPLINE END
FIRST READING IN LINE WITH
7/16" GREASE HOLE.



ALL READINGS ARE ENGLISH MEASUREMENT.

			180°
½"	(1)	2.2493	2.2493
1"	(2)	2.2492	2.2492
1½"	(3)	2.2490	2.2490
2"	(4)	2.2490	2.2490
2½	(5)	2.2490	2.2490
3"	(6)	2.2490	2.2490
3½"	(7)	2.2494	2.2494
4"	(8)	2.2492	2.2494
4½"	(9)	2.2490	2.2493
5"	(10)	2.2492	2.2493
5½"	(11)	2.2492	2.2492

STRAIGHTNESS OF SUBJECT AREA APPEARS VISUALLY TO BE STRAIGHT WITHIN APPROXIMATELY .002 OR BETTER.

Alexander M. Bassett III

Figure A-2. The diameter of the shaft involved in the accident was measured by OSHA.

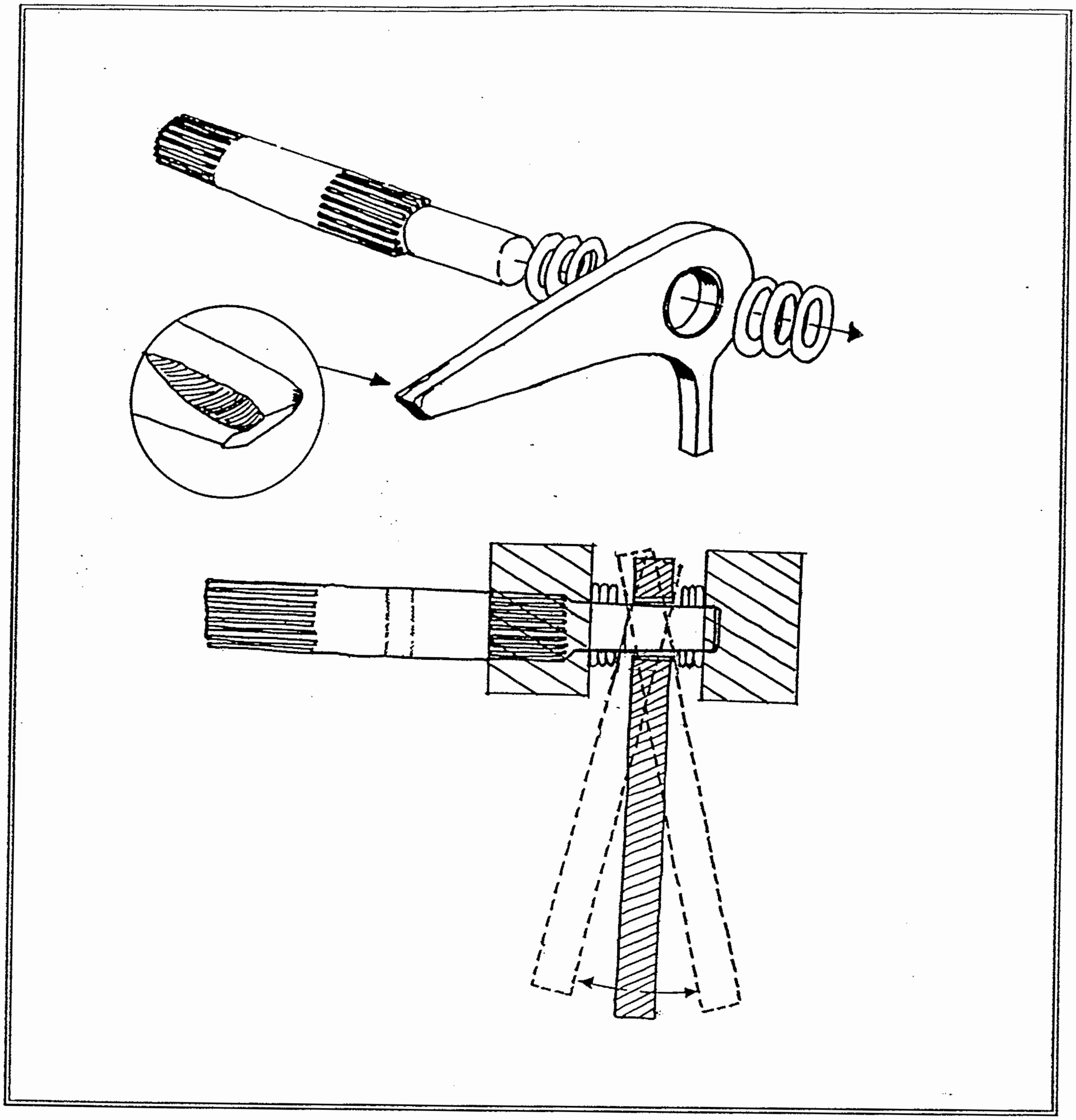


Figure A-3. The pawl vacillated laterally due to lack of adequate lateral restraint. The existence of adequate lateral restraint (spacer washers) was particularly important since the difference between the radii of the shaft and the steel bushing was significant.

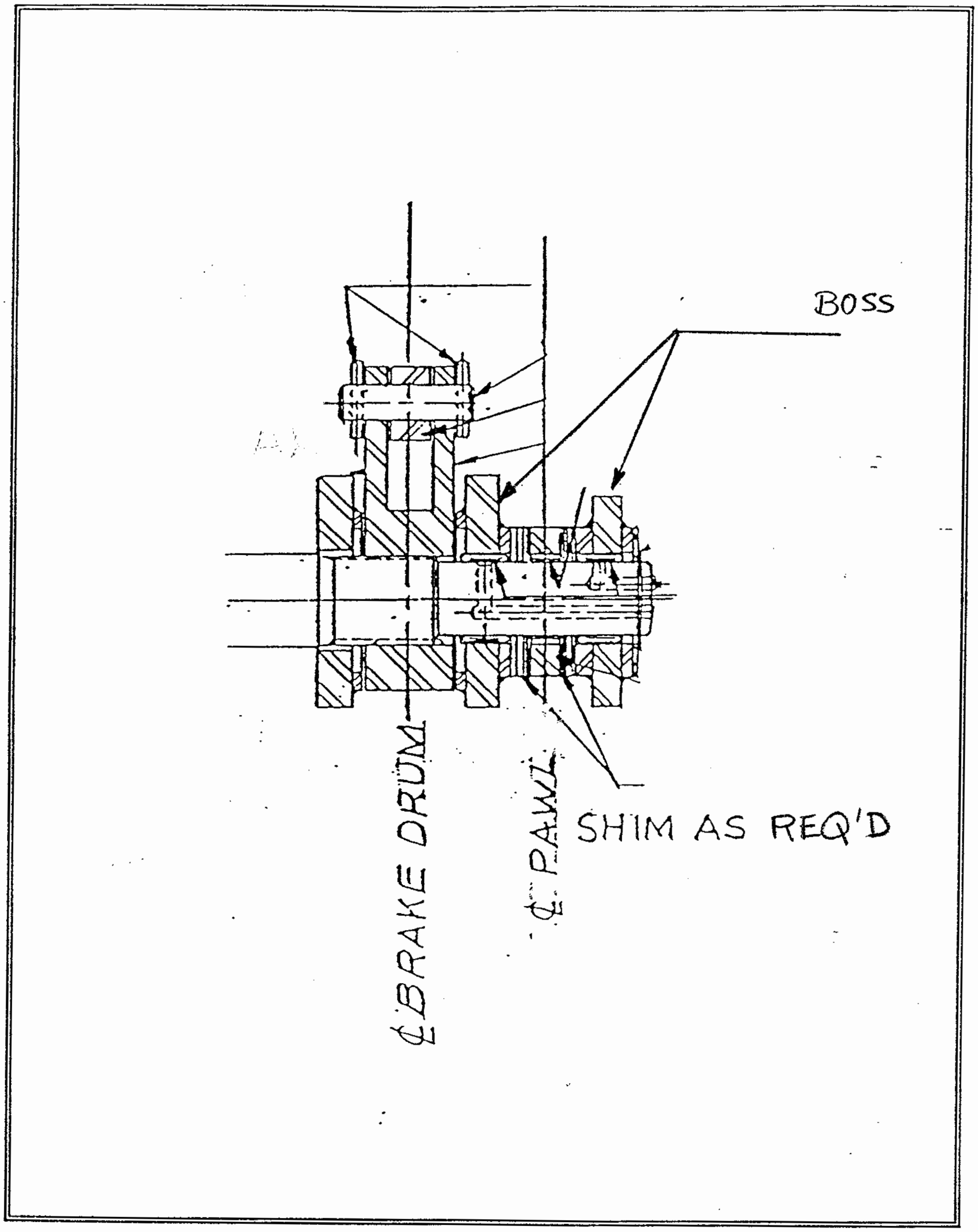


Figure A-4. Three washers installed at each side of the pawl provided the lateral restraint between the pawl and the frame components (bosses).

Figure A-5. **The space between the pawl and the frame (bosses) were to be shimmed as required by gauge-twelve spacer washers.**

APPENDIX B - PERTINENT SECTIONS OF THE CRANE'S OPERATOR'S MANUAL

Section 1 - Continued
Operating Instructions

fairleader position) are a change in boom length, a change in boom angle, varying the distance from the machine at which the bucket inhaul is started, etc.

Cab Elevation Control: The operators cab may be elevated four feet from its normal position for better operator visibility. The cab is mounted on a track, and is elevated by two hydraulic cylinders. The cab is lowered to its normal position by gravity due to its own weight. The cab can be stopped at any position between normal operating position, and the four foot elevated position. To elevate the cab, move the control to the "up" position. To lower the cab, move the control to the "down" position. To stop the cab in any desired position, return control to neutral.

CAUTION

Always Fully Lower The Cab Before Attempting To Leave It. A Serious Fall Could Occur If The Operator Left The Cab When It Was Elevated. Make Sure All Personnel Are Clear When Lowering The Cab.

Cab Positioning Control: When the upper is removed from the lower for transporting, the cab must be moved to the right to reduce overall width of the machine below twelve feet. This is accomplished by hydraulic cylinders. Moving the switch to the "in" position will move the cab to the right. Moving the switch to the "out" position will move the cab to the left.

CAUTION

Cab Must Be In Full Left (Out) Position When Boom Is On Machine Or Cab Will Contact Boom. Never Actuate Switch When Boom Is On Machine Or Damage To Cab And Boom May Result. Make Sure All Personnel Are Clear When Repositioning Cab

Drum Rotation: To actuate the drum rotation indicators push the switches to "engage". To turn off the rotation indicators, push the switches to "disengage". For more information on drum rotation indicators, see Page 1-14

Dome Light: To turn on the dome light, move the switch to "on". To turn off the dome light, move the switch to "off".

Boom Hoist Limiting By-Pass Switch: In some cases it is necessary to boom up slightly to release the boom hoist pawl after the boom hoist limiting device has functioned. (See crane boom section for more information). In this case, by pass the limiting device by pulling down on the switch, and moving it to "off".

CAUTION

Boom Up With Extreme Caution When Overriding The B.H. Limiting Device. The Limiting Device Is No Longer Effective. The Boom Backstops, Or Boom Lower Section May Be Damaged By Booming Up Past Minimum Radius. This Damage May Cause Boom Failure.

Reset the B.H. limiting system by pulling down on the switch, and moving to the "on" position.

Drum Shaft Pawl Controls: Each drum shaft has a pawl assembly which rides on teeth cut in the lagging flange. When the pawl is engaged, rope can't wind off of the drum because the pawl holds the drum against rotation. To wind off rope (lower a load or the boom) the pawl must be disengaged.

To engage pawls, turn the appropriate control clockwise (right) to the engaged position. To disengage a pawl, turn the appropriate control counterclockwise (left) to the disengaged position.

Note: Pawls are spring applied and hydraulically released. If S-o-M pressure is lost, the pawls will apply. The boom or a load may be raised with a pawl engaged, but the pawl must be disengaged to lower the boom or a load.

CAUTION

Keep Boom Hoist Pawl Engaged At All Times Except When Lowering Boom. Keep Drum Pawls Engaged When Holding A Load. These Devices Are Reserve Safety Features And Serve To Back Up The Brakes.

S-o-M Pressure Gauge: This gauge indicates the pressure available in the S-o-M control system. Under normal machine use the gauge will fluctuate between a low of 900 P.S.I. and a high of 1,050 P.S.I. If the system malfunctions and is working over relief pressure, the gauge would indicate 1,250 P.S.I. If the gauge fluctuates rapidly, when no clutch is engaged, or reflects a reading other than described above, the S-o-M system is malfunctioning. Repair before further use.

Converter Pressure: This gauge indicates the amount of charging pressure in the torque converters. It should read 30-60 P.S.I. when the engine is running and master clutch is engaged. There is a warning buzzer connected to the hoist converter which sounds until charging pressure is built up. Never operate machine if buzzer is sounding or pressure gauge is not reading correctly. Loss of control of load can result, causing an accident.

Swing Converter Temperature: This gauge indicates the operating temperature in the swing torque converter. The oil temperature should never exceed 250° F when the machine is operating. If the temperature is too high, shut the machine down and determine the cause. Refer to manufacturer's manuals shipped with the machine for further information. Operation at temperatures exceeding 250° F. can result in damage, explosion, and/or fire.

Hoist Converter Temperature: This gauge indicates the operating temperature in the hoist torque converter. The oil temperature should never exceed 250° F. when the machine is operating. If the

Section 1 - Continued
Operating Instructions

train, and the descent of the load is controlled by engine speed. A sprag in the torque converter prevents machinery from turning faster than the engine. Lowering heavy loads may cause the engine to run faster as the load is now trying to drive the engine. The speed of descent can be controlled by the drum brake. To stop a load, the brake must be applied and clutch disengaged.

(c) A load can be lowered by gravity, and controlling the rate of descent with the drum brakes. Control lever is left in neutral position. To stop the load, the brake must be applied. This method is allowable for light loads, high cycle or any occasional work.

(d) A load can be lowered, or held in position by use of the torque converter. Lowering a load through the converter will work on heavy loads (high line pulls) only. This is accomplished by leaving the control lever in the hoist position (hoist clutch engaged) and regulating the engine speed to either hold the load, or reducing engine speed and allowing the load to creep down. When this method is being used, the engine is turning normally, and the hoist gear train is turning backwards.

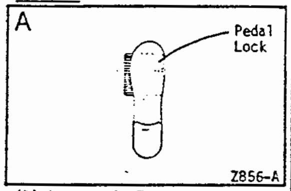
The load can be stopped by either increasing the engine speed, or applying the brake. To hold the load suspended, other than momentarily, the brake should be applied, and the clutch disengaged. This method of lowering is recommended only for precise spotting of heavy loads.

CAUTION

The Brake Pedal Locks Are Intended To Allow The Operator To Rest His Legs When Suspending A Load For A Short Period Of Time, But The Operator Must Remain In The Seat With His Feet On The Pedals. Engage The Drum Pawl When Holding A Load. Failure To Follow These Instructions May Result In An Accident. Never Leave Machine With A Load In The Air. It May Fall.

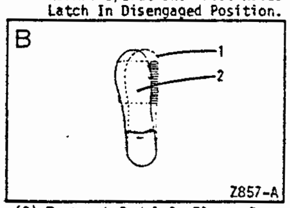
Brake Pedal Locks Are Operated As Follows:

A



(1) Operator's Foot Is In This Position On Latch During Normal Operation. Foot Holds Latch In Disengaged Position.

B



(2) To Latch Pedal In Place, Depress Pedal Fully With Foot In Position (1). Pivot Foot To Position (2) While Holding Brake Pedal Down, To Allow Latch To Engage.

(3) To Disengage, Position Foot As Shown In A. Depress Latch And Pedal At The Same Time To Disengage Latch.

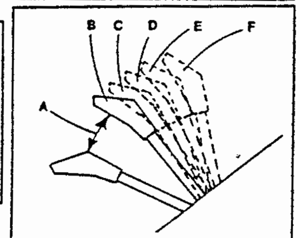
To better explain the operation of a torque converter in a crane, we can make a direct comparison to a modern automobile equipped with an automatic transmission. As an example, an automobile can be headed up hill on a steep grade. Gear selector placed in forward gear, and by regulating the engine speed, the car can be made to move forward, stand still, or roll backwards. The same thing is happening with a load on a crane outlined in method (d) above.

It is not practical to give engine speeds required to handle various loads because of parts of line, drum size, etc. Until the operator has gained familiarity with the machine, the loads to be lifted, the sound of engine, and so forth it is necessary to understand and take the following step:

(a) To prevent the load from coming down it is necessary to have the engine running fast enough to lift the load. With engine at an idle, release brake gradually while accelerating engine. As load start up, increase engine speed as necessary. 1

CAUTION

Regardless Of The Method Used To Control The Load Always Keep Foot On Hoist Brake Pedal Ready To Take Over Control Of The Load As Necessary.



Sketch

Fig. 12
Control Positions (Example)
(A) Forward Quadrant (Lowering)
(B) Neutral Position
(C) Load Lowers
(D) Load Stationary
(E) Load Raises
(F) Load Raises Faster

Front And Rear Drum Control Lever And Brake (With Modulating Clutch Operating)

Note: Hoist converter switch on front dash panel is in "off" position.

The front and rear drum control levers actuate a variable pressure control valve which engages the front or rear drum raising or lowering clutch, and an actuator which controls engagement of the modulating clutch inside the hoist converter. This clutch can operate in any mode from locked up (fully engaged) to 100% slip (fully disengaged) depending upon

Section 1 - Continued
Operating Instructions

(3) An operator must not eat, read, or otherwise divert his attention while operating a machine. Remember, operating is a full time job.

(4) Don't allow crane loads, buckets, grapples, etc., to pass over people, or endanger their safety. Remove all loose objects from load. All non-operating personnel should leave the immediate area when machine is operating.

(5) Don't let anyone ride the hook block, bucket, grapple, etc. These machines are intended to lift objects, not people. They are not elevators.

(6) Be sure your work area is clear. Make sure you have proper clearance for machine, boom, and load. Don't swing, hoist or lower load, raise or lower boom, without first making sure no one is in the way. Make sure everyone is clear of the swinging upper.

If your vision is obscured, locate a signal man so you can see him, and he can see all areas you can't. Follow his signals. Be sure you and the signal man understand each others signals. Use the horn to signal or warn.

(7) Inspect machine daily. Don't operate a damaged or poorly maintained machine. Pay particular attention to the clutches, brakes, attachment, and wire ropes. If a component is worn or damaged, replace it before operating. Remember, parts are cheaper than people.

Be sure clutch and brake surfaces are clean and dry. A small amount of clutch or brake slippage may dry out wet linings. Avoid excessive heating; it shortens lining life. If oil or grease gets on linings clean them immediately with a non-flammable, low toxicity solvent. If linings are saturated, replace them.

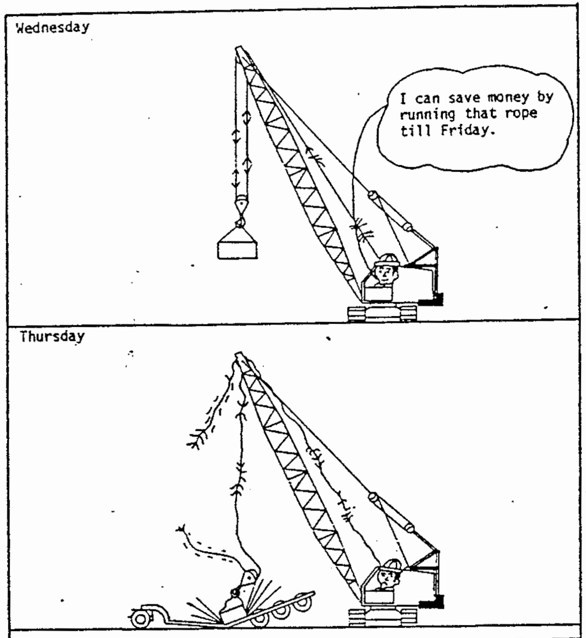


Fig. 20
Don't Work With Worn Or Damaged Rope

OSHA (Occupational Safety And Health Act) regulations state, "A thorough inspection of all ropes shall be made once a month and a full, written, dated and signed report of rope condition kept on file where readily available". Replace any worn or damaged rope. Pay particular attention to boom hoist ropes and pendants. Check end connections (pins, sockets, wedges, etc.) for wear or damage.

(8) Don't let the load or bucket hit the boom. Don't let the boom rest on or hit against a building or any other object. A damaged or dented boom may result which will weaken the boom. If the damage is severe the boom may collapse. If a lattice

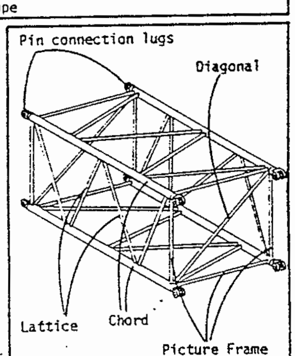


Fig. 21
Boom Section Nomenclature

Weekly or 50 Hours - Continued	
Operation	**Remarks**
Master Clutch	(1) Remove hand hole cover and inspect clutch for wear or damage. Pay particular attention to the throwout collar and the grease hose and fittings leading to it. If the hose breaks or works loose, the throwout collar will not receive adequate lubrication. This may cause damage to the clutch assembly.
Side Housing Bearings (All Horizontal Shafts)	(1) Pump in 8 to 10 shots of grease at each lubrication. As many as three bearings may be lubricated through one fitting. (2) Wipe up any excess grease to keep it off the clutch linings.
Clutch Heel Blocks Control Lever Linkage Swing Lock and Brake Linkage S-o-M Valve Spools	(1) Lubricate all pivot points with oil. (2) Lubricate valve spools with clean S-o-M oil. If rust or corrosion is evident, disassemble and clean before operating.
Clutches Brakes	(1) Check all clutches and brakes for proper adjustment. Adjust as explained later in this manual if necessary. (2) Greasey, aged, or worn linings should be replaced because continued operation may be unsafe. (3) Check linings for foreign particles which may score the drums. If any particals are evident, replace linings before continued operation.
General, Upper, Lower, and Attachment	(1) Lubricate all remaining 40 hour points as shown on the lubrication chart.
Turntable Bearing	(1) This bearing must be kept full of grease for proper lubrication and long life. Pump grease into each fitting until clear grease appears around the bearing shield. Rotate the upper and again pump grease into each fitting.
Wedge Packs (Side Frame and Bearing Units)	(1) Check to make sure wedge packs are tight.

Monthly or 250 Hours	
Operation	**Remarks**
First perform all operation listed under "Weekly or 50 Hours".	
Engine	(1) Consult engine manufacturers manual supplied with the machine.
S-o-M Filter	(1) Change the filters every 250 operating hours as explained later in this section.
Hydraulic System Filters	(1) Change filters after first 250 hours of operation on a new machine or after substantial repairs have been made to system.
Master Clutch	(1) Check adjustment. Adjust if necessary.
Boom Hoist Brake	(1) Visually check band connecting lugs, actuating linkage, relating pins, and mounting hardward for any signs of wear or damage. Replace or repair if required. (2) Visually check band for any indications of bending, interference, or unusual lining wear which would indicate excessive wear of the boom hoist brake parts. Repair or replace if required.

Section 2 - Continued

Preventive Maintenance & Lubrication

Machine Storage Suggestions

Listed below are a number of important points which should be followed when putting a machine into storage. Machine stored outside must be thoroughly protected or serious deterioration will result.

(1) Lower boom to ground, and slack off on boom suspension, or remove boom entirely. Tie down all ropes and pendants to prevent whipping in the wind, etc.

(2) Machines should be stored under cover to reduce the possibility of rust and deterioration.

If stored outside, certain procedures must be followed to protect the machine as much as possible from the elements.

(1) Clean the unit thoroughly, removing all dirt and other foreign material.

(2) Lubricate the entire machine as outlined in this section.

(3) The hydraulic system must be drained and refilled as explained in Section 2 of this manual. Operate B.H. and travel functions for 15 minutes after the oil change to circulate the new oil throughout the system before storage.

(4) Touch up any spots where paint has been knocked off to reduce rust and deterioration.

(5) Cover all unpainted machine surfaces, except friction surfaces such as clutch and brake drums, with a coating of heavy grease to reduce rusting. Cover all clutch and brake surfaces with a cover of waterproof paper or plastic to protect these surfaces from rust.

(6) Set crawler tracks on planks.

(7) Cover intake and exhaust openings on engine to reduce moisture entry.

(8) If anti-freeze is not to be used, completely drain the cooling system. Leave all drains open.

(9) Remove batteries and store them where they will not freeze. Charge them periodically during storage.

(10) Cover open spaces around drums and gantry with waterproof paper or plastic to keep rain and snow off machinery. Cover entire upper with a tarp if available.

(11) Leave all control levers in neutral position. Leave foot brake pedals in released position.

(12) Refer to engine, clutch, and torque convertor manuals for information on storing these units.

(13) Lock all doors on machine and cover all window glass with metal or wood covers to guard against vandalism and unauthorized entry.

Note: Store machine so it doesn't provide a plaything for children. Such a unit can be an attractive nuisance for children to play on. If they fall off or become entangled, serious injury may result.

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are actually two systems working together in each drum brake: (1) Normal foot operated drum brakes which are hydraulically applied and spring released, (2) a spring applied brake which, if adjusted properly, will apply the brakes if S-o-M control pressure is lost.

When the engine is running and S-o-M pressure is built up, oil under pressure is directed to a port on the actuator. This oil pressure compresses the large external brake spring, disengaging the spring brake, allowing the foot brakes to operate in their normal manner. If S-o-M pressure is lost for any reason, oil pressure is exhausted from the actuators allowing the spring to fully apply the brakes. The brakes cannot be released until S-o-M pressure is available again.

For normal brake operation, depressing the pedal actuates a valve (4 in Fig. 4-8) on the brake controls through a push-pull cable, bell crank, and linkage arrangement. This valve directs S-o-M oil under pressure to a port on the brake actuator (2 in Fig. 4-23) to apply the brake. The further the operator depresses the pedal, the more pressure is directed to the actuator and the harder the brake is applied. As the pedal is released, pressure is released from the actuator port (2 in Fig. 4-19) allowing the internal brake spring (7 in Fig. 4-19) to release the brake.

A third port on the actuator (3 in Fig. 4-14) is a drain port to allow any oil seepage from the actuator to flow back to the sump tank.

Drum Brake Adjustment

Adjustment of the drum brakes should be checked upon delivery of a new machine, and every 200 hours after that. Inspect components for wear or damage at the same interval and if any is apparent, correct before further use.

Operating a machine with damaged or improperly adjusted drum brakes can lead to load dropping, machine damage, or injury.

Brake Pedal Adjustment: (Fig. 4-17)

(a) Lower any loads, and/or hook block to the ground before performing adjustments on the drum brakes.
(b) Adjust the capscrews (9) until there is 1/32 to 1/16" clearance at (C) with pedal fully depressed.
(c) Adjust nuts (6) until dimension (A) is 4 5/8" (early cab) or 3 1/2" (late cab) with pedal latched.
(d) Adjust capscrew (10) until (B) is 1 3/8" (early cab) or 3/4" (late cab) with pedal released. Tighten jam nut.

Brake Control Adjustment: (Fig. 4-17) The brake controls should never need adjusting unless a component has been replaced. In this case, adjust as follows:

(a) First make sure pedals are properly adjusted as explained previously in this section.
(b) With pedal latched down, adjust linkage rod (2) until valve (4) bottoms out in fully engaged position. Back off rod 1 full turn. Tighten jam nuts.

Drum Brake Band Adjustments: (Fig 4-15, 4-16) Adjustments to compensate for lining wear are to be made at the band bolts in the split between the two bands.

(a) Lower any loads, and/or hook block to the ground before performing adjustments on the drum brakes.
(b) Adjust the band bolt between the two halves of the band until the dimension at "A" is 3/8". This must be measured with the brake in the applied position.
(c) As the brake lining wears, dimension "A" will decrease. Never let dimension (A) become less than 1/8" because loss of braking force will occur. Adjust or replace brake linings as necessary.
(d) Dimension (B) should be 14-5/8", with the brake applied and a 3/8" measurement at "A". This measurement can be changed by turning the locknut on the spring rod (8 in Fig. 4-19).

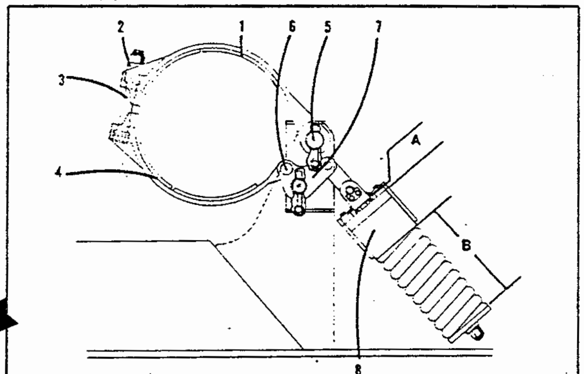

Fig. 4-16 W21-C
Third Drum Brake

(A) 3/8" Measurement
(1) Long Band Section
(2) Spacer
(3) Band Bolt
(4) Short Band Section
(B) 14-5/8" Measurement
(5) Dead End Pin
(6) Live End Pin
(7) Bell Crank
(8) Actuator