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FMP-CS (Facility Modification Package – Coversheet)
(Block 17, 18, 22)*

Section 1: Design Package Identification

1. Mod Title: 324 Building 30-Ton Crane Bridge Wheel Replacement — HPAC0291 101022/BC30

2. USQ Required? USQ # 324-FH-01-349 (initialed 6/4/02) CX # ____ PMG 6/4/02		*3. Assigned Lead Engineer:* J. W. Rich		*4. Design Authority:* J. W. Rich
5. Project No./Work Package No.: 3I-01-00379	*6. Area* *300*	*7. Building* 324	8. System No.: 324-MAT-CRN-706	*Approval Designator:* *Design Authority* Safety Class: GS
9. Related FMPs/Changes: N/A	10. Incorporates ECN/DCNs: N/A		11. Contract Mod. No.: N/A	12. Change Proposal No.: N/A
13. Lead Engineering Discipline: Mechanical	14. Affected Engineering Disciplines: N/A			

15. Change Description (description and reason for requested change):
*An existing design for eccentric bushings (*EDT 627083, EDT 627084 and EDT 627085*) was utilized and updated as necessary to accommodate minor adjustment as required to correct wheel alignment on the North West Idler wheel (the design is revised to install eccentric bushing only one end of one axle).* Original calculations could not be located and do not appear to have been issued into the FH data retrieval system. A new analysis was prepared to reflect the as-built configuration. This FMP will release the analysis to formally document compliance with all applicable design requirements

Section 2: Document Index:

16. Action	*Document*	*Revision*	*FMP Section*	*Revision*	*FMP Page*	*Release To Work?*
N	HNF-11175	0				No

Continuation Sheet Attached? [ ] Yes [X] No

Section 3: Design Authority Concurrence

17. Justification for Accepting or Rejecting Change

Original calculations could not be located and do not appear to have been issued into the FH data retrieval system. A new analysis was prepared to reflect the as-built configuration. This FMP will release the analysis to formally document compliance with all applicable design requirements.

18. Design Authority Approval (Name, Signature, Date):

Name J. W. Rich / Signature [signature] / Date

*Block numbers refer to block numbers on the FMP Flowchart (HNF-PRO-2001, Appendix A) and procedure steps within HNF-PRO-2001. A-6003-082 (10/01)

FMP-CS (Facility Modification Package --Coversheet)
(Block 17, 18, 22)*

Section 4: Approval/Distribution (Name, Signature, Date)

Engineering Approvals	Approval Designator Reviews (Ref. HNF-PRO-233)	Management Reviews
19. Design Engineer (if different from the DA and Lead Engineer)	28. Quality Assurance	37. Project Engineer
20. Lead Engineer	29. Safety	38. Project Engineering Manager (when different from Engineering Management)
21. Engineering Management *G. A. Glover* [signature] 6/4/02	30. Environmental	39. Project Manager
22. Squad Check (when required; if more than one discipline involved, sign below)	31. Fire Protection	40. Operations Manager (OM)
23. Other	32. Radiological Control	41. Ergonomics (when required by OM)
24. Other	33. ALARA Review	42. Field Execution Manager / Startup Manager
25. Other	34. Other	43. Other
26. Other	35. Other	44. Other
27. Other	36. Other	45. Other

46. Modification work complete and field verified as complete for the construction activity (Block 22)*

Design Authority ______________ Date __________

47. Distribution

Name	MSIN
J. W. Rich	L1-06
C. L. Smith	L1-08
P. M. Gent	L1-08
Central Files	B1-07

48. Release:

JUN 04 2002
DATE:
STA: 15
HANFORD RELEASE
ID: 20

49.
[ ] Not Approved/Archive

_______________/__________
Design Authority/Date

*Block numbers refer to block numbers on the FMP Flowchart (HNF-PRO-2001, Appendix A) and procedure steps within HNF-PRO-2001.

FMP-7 (Facility Modification Package – Detailed Design/Verification)

Design Verification Record (Block 15)* [See drawings, calculations, specifications, and other design products]

Design Verification Method (Select method(s) and provide explanation of how to be performed):

[X] ***Peer Review*** [ ] ***Formal Design Review***

[ ] ***Alternate Calculations*** [ ] ***Qualification Testing***

Design Authority	***Date***
J. W. Rich	6/3/02

Design Verification Details

Design verification was performed using the peer review method in accordance with HNF-PRO-1819 and HNF-GD-8336.

Design Verifier	***Date***
	6/4/02

*Block numbers refer to block numbers on the FMP Flowchart (HNF-PRO-2001, Appendix A) and procedure steps within HNF-PRO-2001.

HNF-11175
Revision 0

Evaluation of the 30-Ton CHA Crane Wheel Axle Modification

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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P.O. Box 1000
Richland, Washington

HNF-11175
Revision 0

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HNF-FMP-01-9161-R0D

Evaluation of the 30-Ton CHA Crane Wheel Axle Modification

Document Type: TR   Division: RCP

JW Rich
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Date Published
June 2002

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Janis Aardal   6-4-02
Release Approval   Date

27 pgs.

TABLE OF CONTENTS

1 INTRODUCTION

The 30-Ton CHA Bridge crane located in the 324 Building experienced severe wear between the Bridge Wheels and the rails. The cause of the wear was determined to be the result of poor wheel alignment. A design was prepared and released on EDT 627083, EDT 627084 and EDT 627085 to install eccentric bushings and modified axles to change the wheel alignment and correct the problems based on wheel alignment measurements. In the Fall of 2001, it was determined that by adjusting the Bridge End Truck channels, wheel alignment was vastly improved and wholesale installation of modified axles was not necessary. However, the alignment of the North West Bridge Idler wheel could not be fully corrected without subsequent misalignment of the West Bridge Drive Wheel, thus a modified axle and eccentric bushing was installed in the North West Idler Wheel (with an eccentric bushing on the inboard side only). The final configuration of the axle and eccentric bushing installed in the North West Bridge Idler Wheel is shown on HNF-FMP-01-9161-R0B.

2 DISCUSSION

2.1 Design Requirements

The requirements of the Crane Manufacturers Association of America, Inc. (CMAA) Specification 70, Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes shall be satisfied.

2.2 Modification of the 324 Building CHA 30-Ton Crane Bridge Idler Axle

The modified axle and eccentric bushing was installed in the North West Idler wheel of the 30-Ton CHA crane per work package 3I-01-00378. The new axle was fabricated from

SAE/AISI 4340 Medium Carbon High Alloy Steel. The Eccentric Bushing was fabricated from SAE/AISI 4140 Medium Carbon Alloy Steel. The final configuration of the axle and eccentric bushing is shown on HNF-FMP-01-9161-R0B.

3 SUMMARY

The analysis of the design for modified axles and eccentric bushings were originally prepared to reflect the configuration as originally released on EDT 627083, EDT 627084 and EDT 627085. Changes to the design as reflected in HNF-FMP-01-9161 were enveloped by the original design, however the original calculations could not be located and do not appear to have been issued into the FH data retrieval system. This document was prepared to analyze the as-built configuration and to formally document compliance with all applicable design requirements. As shown in the analysis (Appendix A), the design modifications comply with the Crane Manufacturers Association of America, Inc. (CMAA) Specification 70, Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes and is acceptable.

4 REFERENCES

1 Blodgett 1963, "*Design of Welded Structures*", James F. Lincoln Arc Welding Foundation, Cleveland, Oh.

2 Shigley & Mischke, 2001, Mechanical Engineering Design, Sixth Edition, McGraw-Hill Book Company

3 AISC, 1989, "*Manual of Steel Construction, Allowable Stress Design*", Ninth Edition, American Institute of Steel Construction, Inc., Chicago, Illinois.

4 (CMAA) Specification 70, 2000, "*Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes*", Crane Manufacturers Association of America, Inc., Charlotte, NC.

5 Roark and Young 1975, "*Formulas for Stress and Strain*", Fifth Edition, McGraw-Hill Book Company

6 Union Machine Works Drawing D64-148, "*30T TROLLEY ASSEMBLY*"

7 Union Machine Works Drawing D64-149, "*30T CRANE GEN'L ARRANG*"

8 Union Machine Works Drawing D64-076, "*BRIDGE ASSEMBLY*"

9 Union Machine Works Drawing B64-055, "*WHEEL PIN, BRIDGE*"

10 Union Machine Works Drawing B64-056, "*BRG SPACER, BRIDGE*"

11 Union Machine Works Drawing C64-060, "*OUTBOARD TRUCK FRAME*"

12 Drawing H-3-309323, "*Prescription Idler Wheel*"

13 Drawing H-3-309312, "*Wheel Shaft for Eccentric*"

14 Drawing H-3-309313, "*Eccentric Bushing*"

jda 6/5

Appendix A

Evaluation of the 30-Ton CHA Crane Wheel Axle Modifications

16 Total Pages

ENGINEERING WORKSHEET

(1) Reference Drawing See Section 3.0 (2) Doc. No. HNF-11175 (3) Page A1 of A15

(4) Building No. 324 Building (5) Rev. 0 (6) Job No. ____

(7) Subject Evaluation of the 30-Ton CHA Crane Wheel Axle Modification

(8) Originator J W Rich [signature] Date 6/3/02

(9) Checker P M GENT [signature] Date 6/4/02

1.0 INTRODUCTION:

The 30-Ton CHA Bridge crane located in the 324 Building experienced severe wear between the Bridge Wheels and the rails. The cause of the wear was determined to be the result of poor wheel alignment. The wheel alignment was originally measured by P&H Morris Material Handling Co. using straight edges and calipers. The measurements indicated severe wheel misalignment associated with several of the bridge wheels. A design was prepared and released on EDT 627083, EDT 627084 and EDT 627085 to install eccentric bushings and modified axles to change the wheel alignment and correct the problems base on these wheel alignment measurements. Wheel alignment measurements were later performed by Fluor Hanford using lasers to improve the resolution of the measurements. Misalignment of the wheels was confirmed, however the degree of misalignment was somewhat different.

In the Fall of 2001, it was determined that by adjusting the Bridge End Truck channels, wheel alignment was vastly improved and wholesale installation of modified axles was not necessary. However, the alignment of the North West Bridge Idler wheel could not be fully corrected without misalignment of the West Drive Wheel, thus a modified axle and eccentric bushing was installed in the North West idler wheel (with an eccentric bushing on the inboard side only). The final configuration of the axle and eccentric bushing installed in the North West Bridge Idler wheel is shown on HNF-FMP-01-9161-R0B.

At the time the wheels were aligned and the modified axle/eccentric bushing was installed, new "Prescription Wheels" designed and manufactured by P&H were also installed to replace the worn wheels.

2.0 PURPOSE:

The analysis included in the report was prepared to:

1. Perform an assessment of the axle/eccentric bushing to demonstrate that the capacity of the new axle was not adversely affected by the design modification.
2. Estimate and document the loads imposed on the modified axle.
3. Demonstrate that the modification complies with the Crane Manufacturers Association of America, Inc. (CMAA) Specification 70 requirements.

Since the replacement "Prescription Wheels" were designed and manufactured by P&H specifically for use on the 30-Ton CHA Crane, further analysis of the wheels as part of this document is not necessary.

ENGINEERING WORKSHEET

(1) Reference Drawing See Section 3.0 (2) Doc. No. HNF-11175 (3) Page A2 of A15

(4) Building No. 324 Building (5) Rev. 0 (6) Job No.____

(7) Subject Evaluation of the 30-Ton CHA Crane Wheel Axle Modification

3.0 REFERENCES:

1. Union Machine Works Drawing D64-148, 30T TROLLEY ASSEMBLY
2. Union Machine Works Drawing D64-149, 30T CRANE GEN'L ARRANG
3. Union Machine Works Drawing D64-076, BRIDGE ASSEMBLY
4. Union Machine Works Drawing B64-055, WHEEL PIN, BRIDGE
5. Union Machine Works Drawing B64-056, BRG SPACER, BRIDGE
6. Union Machine Works Drawing C64-060, OUTBOARD TRUCK FRAME
7. Mechanical Engineering Design, Shigley & Mischke, Sixth Edition
8. Formulas for Stress and Strain, Roark and Young, Fifth Edition
9. American Institute of Steel Construction, Manual of Steel Construction, Ninth Edition
10. Crane Manufacturers Association of America, Inc. (CMAA) Specification 70, Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes
11. Ryerson Stock List & Data Book, 1987-88 Edition.
12. Drawing H-3-309323, Prescription Idler Wheel.
13. Drawing H-3-309312, Wheel Shaft for Eccentric
14. Drawing H-3-309313, Eccentric Bushing
15. HNF-FMP-01-9161-R0B, 324 Building 30-Ton Crane Bridge Wheel Replacement
16. Design of Welded Structures, Blodget, 1963, James F. Lincoln Arc Welding Foundation

4.0 CONCLUSIONS:

1. The modified axle with eccentric bushing was found to have an allowable shear capacity greater than the original axle that it replaces due to improved materials of construction. However, the allowable bending capacity is less than the original axle that it replaces due to the reduced section combined with a stress concentration factor at the shoulder between the larger and smaller diameter of the axle shaft.
2. The design loads were determined and the new axle shaft design was evaluated when subjected to the design loads. The design modifications meet the requirements of the Crane Manufacturers Association of America, Inc. (CMAA) Specification 70 for the applicable load cases.

5.0 EVALUATION:

5.1 Material Properties

Original Axle Material Properties:

The original axle was identified on the drawings (Reference 4) as having been fabricated from C-1018 CRS. Typical properties for this material was obtained and collaborated from Reference 7 and Reference 11. The material properties are considerably different depending on finish. The cold rolled condition exhibits the greatest material properties and was conservatively assumed.

$F_{y\_1018} := 54000 \cdot \frac{lb}{in^2}$ Yield Strength of SAE/AISI 1018 Cold Drawn Carbon Steel

$F_{u\_1018} := 64000 \cdot \frac{lb}{in^2}$ Ultimate Strength of SAE/AISI 1018 Cold Drawn Carbon Steel

New Axle Material Properties:

The new axle was fabricated from SAE/AISI 4340 Medium Carbon High Alloy Steel (UNS G43400) as specified on drawing H-3-309312. The selected material was intended to have a minimum yield strength of 162 ksi and a minimum ultimate strength of 182 ksi (as specified on the drawing, Reference 13). Upon receipt of the material, the Certified Material Test Report identified actual material properties that were less than specified and an NCR was processed to document the discrepancy. The CMTR (included in Appendix B) identified the following properties:

$F_{y\_4340} := 133835 \cdot \frac{lb}{in^2}$ Yield Strength of SAE/AISI 4340 Medium Carbon High Alloy Steel (UNS G43400)

$F_{u\_4340} := 149350 \cdot \frac{lb}{in^2}$ Ultimate Strength of SAE/AISI 4340 Medium Carbon High Alloy Steel (UNS G43400)

New Eccentric Bushing Material Properties:

The new eccentric bushing was fabricated from SAE/AISI 4140 Medium Carbon Alloy Steel Cold Drawn (UNS G41400) as specified on drawing H-3-309313. The selected material was specified with a minimum yield strength of 90 ksi and a minimum ultimate strength of 102 ksi (as specified on the drawing, Reference 14):

$F_{y\_4140} := 90000 \cdot \frac{lb}{in^2}$ Yield Strength of SAE/AISI 4140 Medium Carbon High Alloy Steel (UNS G41400)

$F_{u\_4140} := 102000 \cdot \frac{lb}{in^2}$ Ultimate Strength of SAE/AISI 4140 Medium Carbon High Alloy Steel (UNS G41400)

5.2 Allowable Stresses

Allowable Bearing, Shear and Tensile Stresses:

Stress Level 1 (Load Case 1):

New Axle and Eccentric:

$\sigma_{a\_axle\_1} := 0.6 \cdot F_{y\_4340}$ or $\sigma_{a\_axle\_1} = 80301 \frac{lb}{in^2}$ Allowable Axial and Bending of New Axle

$\tau_{v\_axle\_1} := 0.35 \cdot F_{y\_4340}$ or $\tau_{v\_axle\_1} = 46842.25 \frac{lb}{in^2}$ Allowable Shear of New Axle

$\sigma_{b\_ecc\_1} := 0.75 \cdot F_{y\_4140}$ or $\sigma_{b\_ecc\_1} = 67500 \frac{lb}{in^2}$ Allowable Bearing of Eccentric

Original Axle:

$\sigma_{a\_old} := 0.6 \cdot F_{y\_1018}$ or $\sigma_{a\_old} = 32400 \frac{lb}{in^2}$ Allowable Axial and Bending of Original Axle

$\tau_{v\_old} := 0.35 \cdot F_{y\_1018}$ or $\tau_{v\_old} = 18900 \frac{lb}{in^2}$ Allowable Shear of Original Axle

Stress Level 2 (Load Case 2) - *New Axle and Eccentric*:

$\sigma_{a\_axle\_2} := 0.66 \cdot F_{y\_4340}$ or $\sigma_{a\_axle\_2} = 88331.1 \frac{lb}{in^2}$ Allowable Axial and Bending of New Axle

$\tau_{v\_axle\_2} := 0.375 \cdot F_{y\_4340}$ or $\tau_{v\_axle\_2} = 50188.125 \frac{lb}{in^2}$ Allowable Shear of New Axle

$\sigma_{b\_ecc\_2} := 0.80 \cdot F_{y\_4140}$ or $\sigma_{b\_ecc\_2} = 72000 \frac{lb}{in^2}$ Allowable Bearing of Eccentric

Stress Level 3 (Load Case 3) - *New Axle and Eccentric*:

$\sigma_{a\_axle\_3} := 0.75 \cdot F_{y\_4340}$ or $\sigma_{a\_axle\_3} = 1.004 \times 10^5 \frac{lb}{in^2}$ Allowable Axial and Bending of New Axle

$\tau_{v\_axle\_3} := 0.43 \cdot F_{y\_4340}$ or $\tau_{v\_axle\_3} = 57549.05 \frac{lb}{in^2}$ Allowable Shear of New Axle

$\sigma_{b\_ecc\_3} := 0.90 \cdot F_{y\_4140}$ or $\sigma_{b\_ecc\_3} = 81000 \frac{lb}{in^2}$ Allowable Bearing of Eccentric

5.3 Comparison of Allowable Bending, Shear and Bearing

The capacity of the axle is a dependent upon the materials of construction, geometry and the loads imposed. Assuming the imposed loads are the same for both the new and old axle design, capacity of the new configuration can be compared to that of the original configuration.

Original Axle:

$d_{big} := 3.5419 \cdot in$ Minimum Diameter of Original Axle (Reference 4)

$S_{old} := \frac{\left[\pi \cdot (d_{big})^3\right]}{32}$ or $S_{old} = 4.362\, in^3$ Minimum Section Modulus

$A_{old} := \frac{\left(\pi \cdot d_{big}^{\ 2}\right)}{4}$ or $A_{old} = 9.853\, in^2$ Minimum Area

$M_{max} := S_{old} \cdot \sigma_{a\_old}$

or $M_{max} = 1.413 \times 10^5\, in \cdot lb$ Maximum Allowable Bending Moment

$V_{max} := A_{old} \cdot \tau_{v\_old}$

or $V_{max} = 1.862 \times 10^5\, lb$ Maximum Allowable Shear

ENGINEERING WORKSHEET

(1) Reference Drawing See Section 3.0 (2) Doc. No. HNF-11175 (3) Page A5 of A15

(4) Building No. 324 Building (5) Rev. 0 (6) Job No.____

(7) Subject Evaluation of the 30-Ton CHA Crane Wheel Axle Modification

New Axle:

$d_{small} := 3.041 \cdot in$ Minimum Diameter of New Axle (Reference 15)

$S_{axle\_small} := \frac{(\pi \cdot d_{small}{}^3)}{32}$ or $S_{axle\_small} = 2.761\, in^3$ Minimum Axle Section Modulus

$S_{axle\_large} := S_{old}$ or $S_{axle\_large} = 4.362\, in^3$ Maximum Axle Section Modulus

$A_{axle\_small} := \frac{(\pi \cdot d_{small}{}^2)}{4}$ or $A_{axle\_small} = 7.263\, in^2$ Minimum Axle Section Area

$A_{axle\_large} := A_{old}$ or $A_{axle\_large} = 9.853\, in^2$ Maximum Axle Section Area

Since the new configuration introduces a stress concentration at the interface between the larger and smaller diameters, a stress concentration factor should be included. The stress concentration factor based on Reference 7, Figure E-15-9, "Round Shaft with Shoulder Fillet in Bending".

Ratio of Large to Small Shaft Diameter: $D_{ratio} := \frac{d_{big}}{d_{small}}$ $D_{ratio} = 1.165$

Shoulder Radius: $radius := 0.1875 \cdot in$

Ratio of Shoulder Radius to Small Shaft Diameter: $r_{ratio} := \frac{radius}{d_{small}}$ $r_{ratio} = 0.062$

Stress Concentration Factor:

$$K_t := 0.632 + 0.377 \cdot (D_{ratio})^{-4.4} + (r_{ratio})^{-0.5} \cdot \sqrt{\frac{-0.14 - 0.363 \cdot (D_{ratio})^2 + 0.503 \cdot (D_{ratio})^4}{1 - 2.39 \cdot (D_{ratio})^2 + 3.368 \cdot (D_{ratio})^4}}$$

$K_t = 1.921$

$$M_{max} := \frac{(S_{axle\_small} \cdot \sigma_{a\_axle\_1})}{K_t}$$

or $M_{max} = 1.154 \times 10^5\, in \cdot lb$ Maximum Allowable Bending Moment at Small Section

$V_{axle\_max} := A_{axle\_small} \cdot \tau_{v\_axle\_1}$

or $V_{axle\_max} = 3.402 \times 10^5\, lb$ Maximum Allowable Shear at Small Section

Since the maximum allowable bending moment of the new axle design is less than that of the original axle, a more complete evaluation of the new axle is necessary based upon the actual loads imposed.

5.4 Loads Applied to Crane Bridge Idler Wheel

The weight of the 30-Ton CHA Bridge Crane is identified on several of the original Union Machine Works drawings. The weight of the entire crane is shown on Reference 2 as 30,000 pounds. The weight of the bridge is identified as 18,560 pounds on Reference 3 while the weight of the trolley is listed as approximately 10,000 pounds on Reference 1. Since the sum of the weights listed for the trolley and bridge is less than the total weight of the crane, it is conservative to assume the additional weight is part of the trolley (wire rope, lower block etc.). Therefore the weight of the trolley was assumed to be 11,440 pounds. The load cases to be considered are from Reference 10, Section 3.3.2, "Loadings".

$DL := 18560 \cdot lb$ Dead load associated with the crane bridge

$TL := 11440 \cdot lb$ Dead load associated with the crane trolley

$LL := 60000 \cdot lb$ Rated crane lift load

There are a number of Load Factors that must be considered as per Reference 10, Section 3.3.2, "Loadings"

5.4.1 Vertical Forces:

Dead Load Factor:

$DLF := 1.05 + \frac{65}{2000}$ or $DLF = 1.083$

$DLF_{min} := 1.1$

$DLF_{max} := 1.2$

Vertical Dead Load Factor to be applied only to the dead loads of the crane , trolley and associated equipment. The minimum Dead Load Factor applies for the maximum travel speed of 65 feet per minute (max bridge travel speed).

Hoist Load Factor:

$HLF := 0.005 \cdot (20)$ or $HLF = 0.1$

$DLF_{min} := 0.15$

$DLF_{max} := 0.5$

Vertical Hoist Load Factor to be applied only to the rated working loads of the crane based on maximum hoist speed of 20 feet per minute. The minimum Hoist Load Factor applies.

5.4.2 Lateral Forces:

Lateral forces include Inertia Forces from Drives (IFD) and are dependent upon the acceleration or deceleration of the crane bridge and trolley drives as 7.8 times the acceleration or deceleration with a minimum of 2.5% of the vertical load. The available vendor information does not identify the acceleration and deceleration rates. Field measurement or additional analysis would be necessary to determine these parameters. However, since the controls on the 30-Ton crane allow operation of only one motion at a time, and since the hoisting loads combined with dead loads will likely subject the axle and eccentric bushing to the most significant loading, the minimum IFD forces of 2.5% of the vertical load will be conservatively considered to act in conjunction with Load Case 2, principal and additional loading.

$IFD := 0.025$ Lateral Inertia Forces

5.4.3 Additional Loads and Extraordinary Loads

The forces identified by Reference 10 as "Additional Loads" or "Extraordinary Loads" include wind load (WLO), Skewing Forces (SK), Stored Wind Load (WLS) and "Collision Forces". Since the crane is operated in the CHA, the loads associated with wind need not be considered. Forces associated with a collision of the bridge against the building structure could have a significant affect on the bridge structure and trolley, but would not impose high loads on the idler wheel axle and are not considered here. However, collision forces between the trolley and the bridge end stops would impose a lateral load against the bridge wheels and must be considered. The skewing SK forces will also be considered. Even though the collision forces could occur only when the trolley is in motion and the skewing forces could occur only when the bridge is in motion (which is precluded by the control system design), it is conservative to consider then acting together to ensure their effects are bounded.

Skewing Forces:

Skewing forces are determined per Reference 10, Section 3.3.2.1.2.2 based on the crane bridge span and wheel base.

$BL := 400 \cdot in$ Bridge Span (Reference 3)

$WL := 114.625 \cdot in$ Wheel Base of the end trucks (Reference 6)

$Ratio := \frac{BL}{WL}$ or $Ratio = 3.49$

$S_{sk} := 0.05$ Skew Force Coefficient (Reference 10, Section 3.3.2.1.2.2)

Collision Forces:

Only the potential collision associated with the trolley hitting the travel stops at the ends of each bridge beam needs to be considered. Since the 30-Ton Crane is not equipped with energy absorbing bumpers, the collision forces must be absorbed by the crane bridge and building structures. Only the weight of the trolley needs to be considered per Reference 10, since the suspended load is free to oscillate. For the purpose of this analysis, It is conservative to assume that:

1. The building is a rigid structure and absorbs no energy associated from the impact load. If the crane is situated in the vicinity of the hot cells, the building is indeed rigid.
2. While it is likely that both end trucks will absorb some of the energy, it is conservatively assumed that only one pair of wheels is in contact with the rails and only one end truck absorbs all of the energy associated with the impact.
3. The mass of the bridge (and its ability to receive some of the collision energy) is neglected.
4. The Maximum trolley speed is 30 feet per minute per Reference 20. Per Reference 10, the collision velocity is assumed to be 40% of the maximum velocity.

ENGINEERING WORKSHEET

$W := \frac{TL}{2}$ Assume the load applied at each Bridge Beam to End Truck Connection is 1/2 of the total.

$Vel := 0.4 \cdot \left(40 \cdot \frac{ft}{min}\right)$ $Vel = 16 \frac{ft}{min}$ Collision Velocity

$L_{truck} := 114.625 \cdot in$ Length of Bridge End Truck (Wheel Base)

$W_{bridge} := 72 \cdot in$ Distance Between Bridge Beams

$a := \frac{1}{2} \cdot (L_{truck} - W_{bridge})$ Dimension "a" between Centerline of Bridge Rail and Bridge Wheel

$E := 29 \cdot 10^6 \cdot \frac{lb}{in^2}$ Modulus of Elasticity, (Reference 9, Page 6-30)

$I_{yy} := 8.13 \cdot in^4$ Area Moment of Inertia for End Tuck C-Channels (Reference 9)

The end trucks are composed of two C 15 x 33.5 channels in parallel. It is assumed that each channels will deflect the same and hence they will share the loads. The deflection for a simply supported beam (supported at a distance equal to the centerline of the bridge wheels) with two equal loads located an equal distance from each support is:

$y = \frac{(F \cdot a)}{6 \cdot E \cdot I} \cdot \left(3 \cdot L \cdot a - 3 \cdot a^2 - a^2\right)$ Reference 16, Page 8.1-6, Case 3Ac

The stiffness of each of the two channels is represented by a spring constant. k:

k = F/y

The stiffness of both channels is:

$k := \frac{2 \cdot (6 \cdot E \cdot I_{yy})}{\left(3 \cdot L_{truck} \cdot a^2 - 4 \cdot a^3\right)}$ $k = 24084.104 \frac{lb}{in}$

The maximum deflection of the channels as a result of the collision is:

$y_{max} := \frac{Vel}{\sqrt{\frac{k \cdot g}{W}}}$ $y_{max} = 0.079\, in$ Reference 7, Equation 4-84

The maximum collision force applied at each connection between the bridge beam and the end truck (and hence the maximum lateral load applied to each of the two bridge wheels assumed to carry the load) is:

$CF := k \cdot y_{max}$ $CF = 1911.48\, lb$

5.4.4 Load Combinations

Load Case 1 - Principal Loads (Stress Level 1):

$$DL\cdot(DLF_B) + TL\cdot(DLF_T) + LL\cdot(1 + HLF) + IFD$$

Load Case 2 - Principal and Additional Loads (Stress Level 2):

$$DL\cdot(DLF_B) + TL\cdot(DLF_T) + LL\cdot(1 + HLF) + IFD + WLO + SK$$

$DLF_B := DLF_{min}$

$DLF_T := DLF_{min}$

Since the crane travel speeds are slow, the minimum Dead Load Factor applies to both the bridge and trolley.

Load Case 3 - Extraordinary Loads (Stress Level 3):

$$DL + TL + LL + CF$$

5.4.5 Load Case 1 - Horizontal and Vertical Forces

As shown in Figure 1, the main hook approach distance is 5 feet from the center of the bridge rails. As shown in figure 2 (and Reference 1), the main hook is centered on the trolley between the two bridge beams.

Vertical Loads on Idler Wheel:

$$P_{v1} := \frac{DL}{4}\cdot(DLF_B) + \frac{(BL - 5\cdot ft)}{BL}\cdot\left[\frac{TL}{2}\cdot(DLF_T) + \frac{LL}{2}\cdot(1 + HLF)\right]$$

or $P_{v1} = 29475.3\ lb$

Lateral Loads on Idler Wheel:

$P_{h1} := P_{v1}\cdot IFD$ or $P_{h1} = 736.882\ lb$

5.4.6 Load Case 2- Horizontal and Vertical Forces

Since wind loads are not applicable, the Load Case 2 is nearly identical to Load Case 1 with the addition of lateral Skewing Forces (vertical loads are the same as Load Case 1).

Lateral Loads on Idler Wheel:

$P_{h2} := P_{v1}\cdot IFD + P_{v1}\cdot S_{sk}$ or $P_{h2} = 2210.647\ lb$

5.4.7 Load Case 3- Horizontal and Vertical Forces

Vertical Loads on Idler Wheel:

$$P_{v3} := \frac{DL}{4} + \frac{(BL - 5\cdot ft)}{BL}\cdot\left(\frac{TL}{2} + \frac{LL}{2}\right)$$

or $P_{v3} = 35002\ lb$

Lateral Loads on Idler Wheel:

$P_{h3} := CF$ or $P_{h3} = 1911.48\ lb$

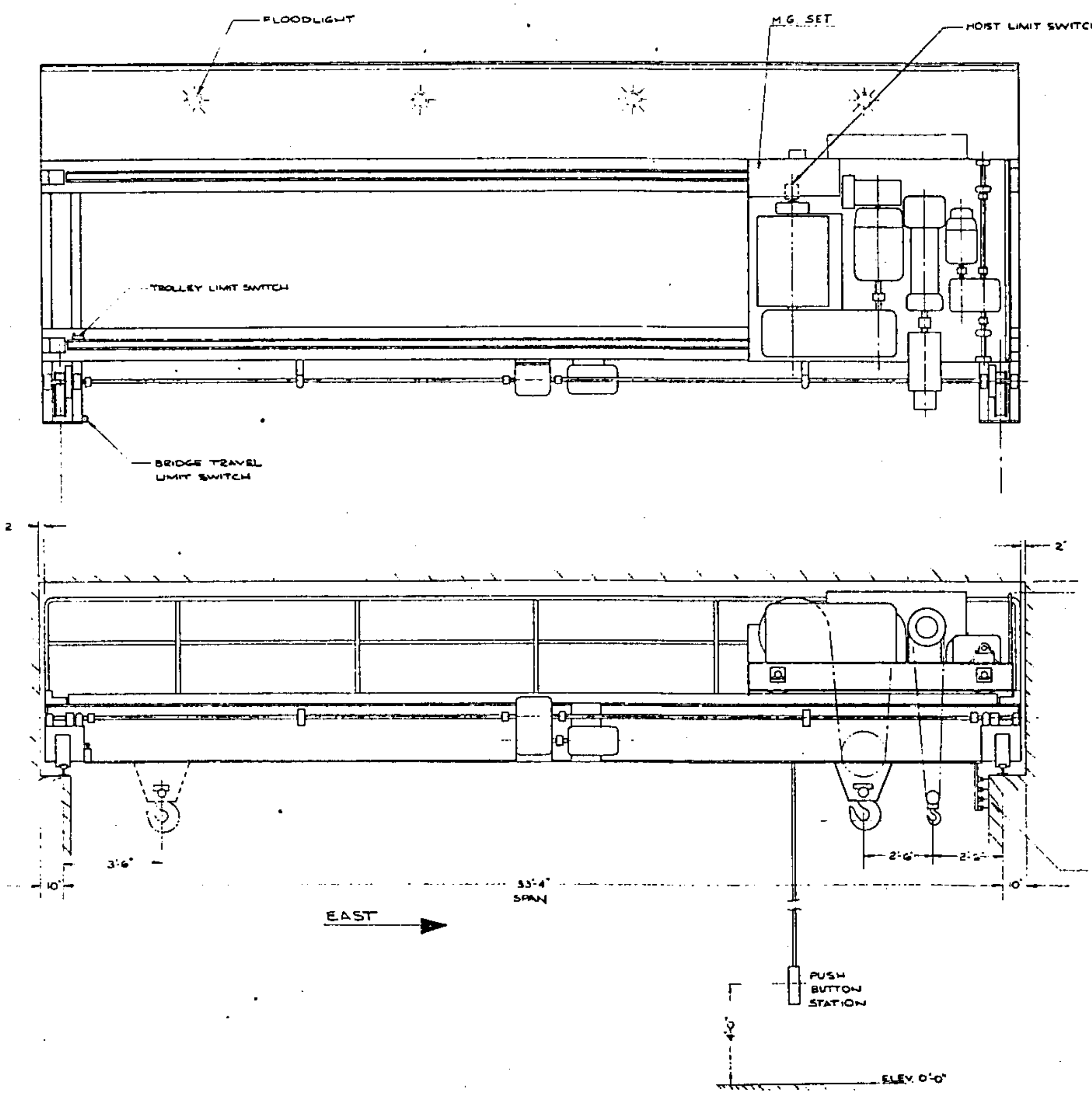
ENGINEERING WORKSHEET

(1) Reference Drawing See Section 3.0 (2) Doc. No. HNF-11175 (3) Page A10 of A15

(4) Building No. 324 Building (5) Rev. 0 (6) Job No.____

(7) Subject Evaluation of the 30-Ton CHA Crane Wheel Axle Modification

Figure 1: 30-Ton Crane General Arrangement:



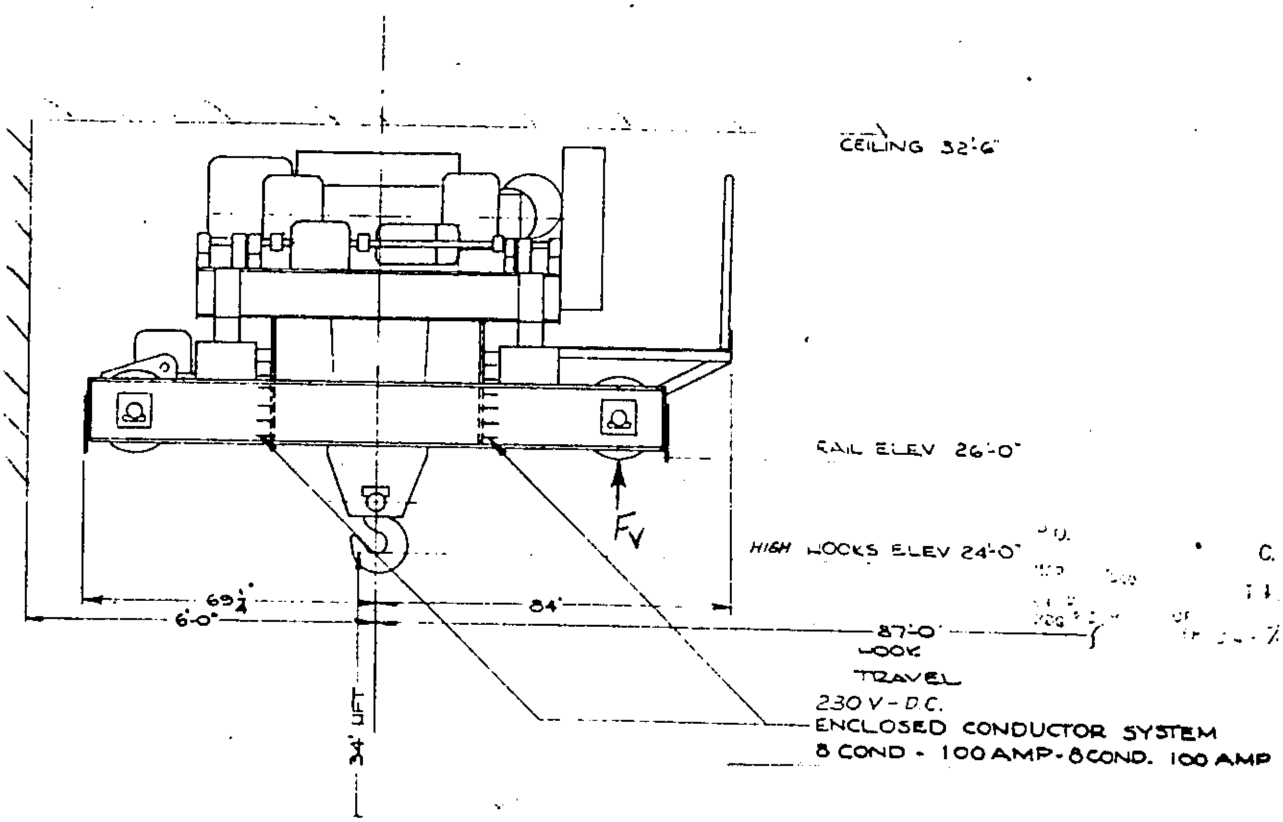
ENGINEERING WORKSHEET

(1) Reference Drawing See Section 3.0 (2) Doc. No. HNF-11175 (3) Page A11 of A15

(4) Building No. 324 Building (5) Rev. 0 (6) Job No.____

(7) Subject Evaluation of the 30-Ton CHA Crane Wheel Axle Modification

Figure 2: 30-Ton Crane End View:



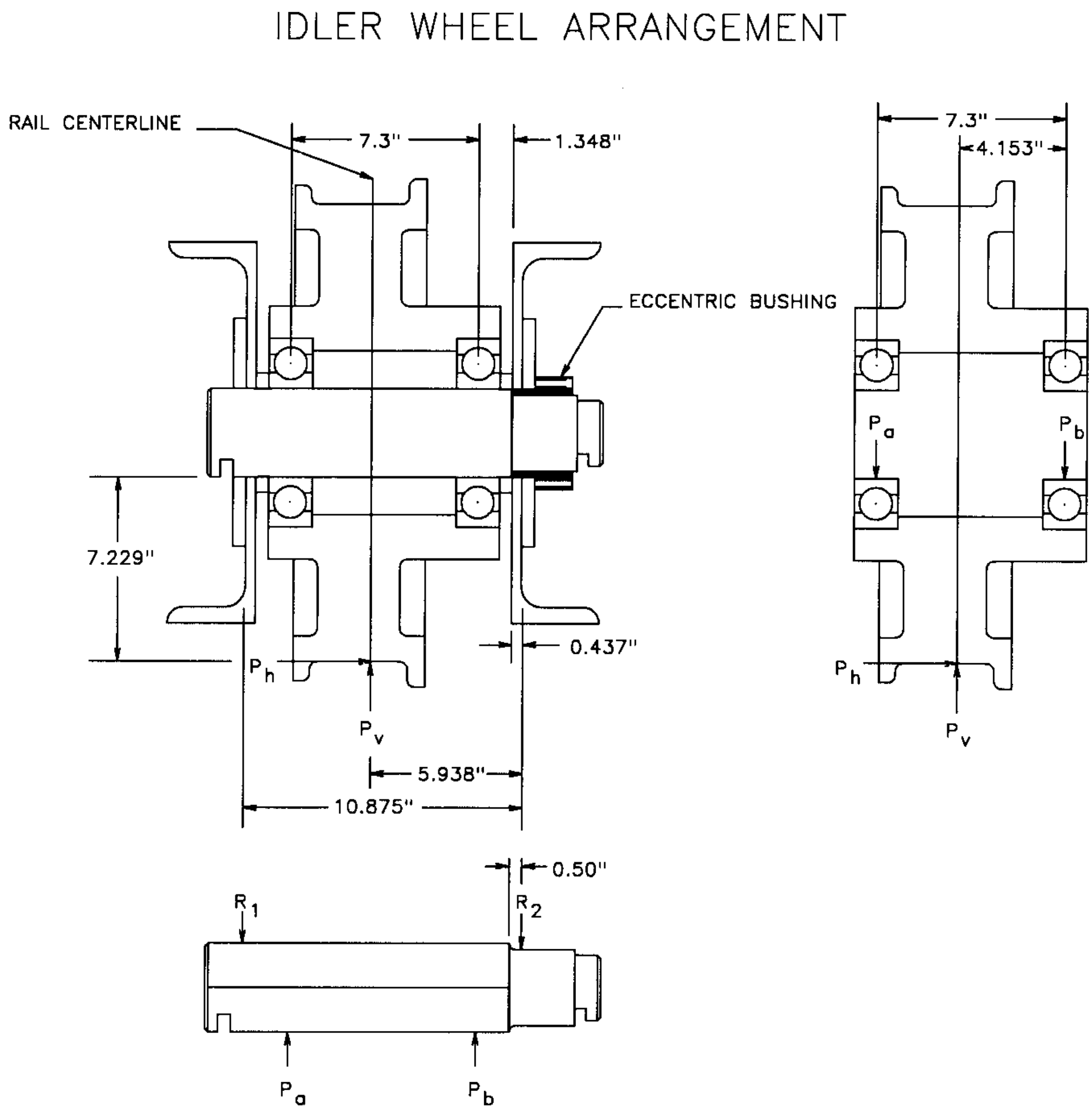
ENGINEERING WORKSHEET

(1) Reference Drawing See Section 3.0 (2) Doc. No. HNF-11175 (3) Page A12 of A15

(4) Building No. 324 Building (5) Rev. 0 (6) Job No.

(7) Subject Evaluation of the 30-Ton CHA Crane Wheel Axle Modification

Figure 3: 30-Ton Crane Bridge Idler Wheel Arrangement:



5.5 Evaluation of New Axle

5.5.1 Wheel and Axle Loads

Wheel and Axle Loads - Load Case 1:

By Sum of the Moments about point "a" on the Idler Wheel (See Figure 3):

$$P_{b\_case1} := \frac{\left[(P_{v1})\cdot(7.3\cdot in - 4.153\cdot in) + (P_{h1})\cdot(7.229\cdot in)\right]}{7.3\cdot in} \quad \text{or} \quad P_{b\_case1} = 13436.396\,lb$$

By Sum of the Forces on the Idler Wheel in the Y direction:

$$P_{a\_case1} := P_{v1} - P_{b\_case1} \quad \text{or} \quad P_{a\_case1} = 16038.904\,lb$$

By Sum of the Moments about point "1" on the Axle (See Figure 3):

$$R_{1\_case1} := \frac{(P_{b\_case1})\cdot(1.348\cdot in + 0.437\cdot in) + (P_{a\_case1})\cdot(1.348\cdot in + 0.437\cdot in + 7.3\cdot in)}{10.875\cdot in}$$

or $R_{1\_case1} = 15604.359\,lb$

By Sum of the Forces on the Axle in the Y direction:

$$R_{2\_case1} := P_{a\_case1} + P_{b\_case1} - R_{1\_case1} \quad \text{or} \quad R_{2\_case1} = 13870.941\,lb$$

Wheel and Axle Loads - Load Case 2:

By Sum of the Moments about point "a" on the Idler Wheel (See Figure 3):

$$P_{b\_case2} := \frac{\left[(P_{v1})\cdot(7.3\cdot in - 4.153\cdot in) + (P_{h2})\cdot(7.229\cdot in)\right]}{7.3\cdot in} \quad \text{or} \quad P_{b\_case2} = 14895.827\,lb$$

By Sum of the Forces on the Idler Wheel in the Y direction:

$$P_{a\_case2} := P_{v1} - P_{b\_case2} \quad \text{or} \quad P_{a\_case2} = 14579.473\,lb$$

By Sum of the Moments about point "1" on the Axle (See Figure 3):

$$R_{1\_case2} := \frac{(P_{b\_case2})\cdot(1.348\cdot in + 0.437\cdot in) + (P_{a\_case2})\cdot(1.348\cdot in + 0.437\cdot in + 7.3\cdot in)}{10.875\cdot in}$$

or $R_{1\_case2} = 14624.695\,lb$

By Sum of the Forces on the Axle in the Y direction:

$$R_{2\_case2} := P_{a\_case2} + P_{b\_case2} - R_{1\_case2} \quad \text{or} \quad R_{2\_case2} = 14850.605\,lb$$

Wheel and Axle Loads - Load Case 3:

By Sum of the Moments about point "a" on the Idler Wheel (See Figure 3):

$$P_{b\_case3} := \frac{\left[(P_{v3})\cdot(7.3\cdot in - 4.153\cdot in) + (P_{h3})\cdot(7.229\cdot in)\right]}{7.3\cdot in} \quad \text{or} \quad P_{b\_case3} = 16982.107\,lb$$

By Sum of the Forces on the Idler Wheel in the Y direction:

$$P_{a\_case3} := P_{v3} - P_{b\_case3} \quad \text{or} \quad P_{a\_case3} = 18019.893\,lb$$

By Sum of the Moments about point "1" on the Axle (See Figure 3):

$$R_{1\_case3} := \frac{(P_{b\_case3})\cdot(1.348\cdot in + 0.437\cdot in) + (P_{a\_case3})\cdot(1.348\cdot in + 0.437\cdot in + 7.3\cdot in)}{10.875\cdot in}$$

or $R_{1\_case3} = 17841.268\,lb$

By Sum of the Forces on the Axle in the Y direction:

$$R_{2\_case3} := P_{a\_case3} + P_{b\_case3} - R_{1\_case3} \quad \text{or} \quad R_{2\_case3} = 17160.732\,lb$$

5.5.2 Evaluation of New Axle

Axle Shear and Bending at Smallest Section:

The maximum moment on the smallest diameter portion of the axle will occur near the radius shoulder adjacent to the applied load R_2. The maximum shear will also occur at the minimum area.

Load Case 1:

$$M_{case1\_small} := R_{2\_case1}\cdot(0.50\cdot in)$$

$$\sigma_{b\_case1\_small} := \frac{K_t\cdot M_{case1\_small}}{S_{axle\_small}} \quad \text{or} \quad \sigma_{b\_case1\_small} = 4826.092\frac{lb}{in^2} \quad \text{OK}$$

$$\tau_{max} := \frac{R_{2\_case1}}{A_{axle\_small}} \quad \text{or} \quad \tau_{max} = 1909.779\frac{lb}{in^2} \quad \text{OK}$$

ENGINEERING WORKSHEET

Load Case 2:

$M_{case2\_small} := R_{2\_case2} \cdot (0.50 \cdot in)$

$\sigma_{b\_case2\_small} := \dfrac{K_t \cdot M_{case2\_small}}{S_{axle\_small}}$ or $\sigma_{b\_case2\_small} = 5166.944 \dfrac{lb}{in^2}$ OK

$\tau_{max} := \dfrac{R_{2\_case2}}{A_{axle\_small}}$ or $\tau_{max} = 2044.661 \dfrac{lb}{in^2}$ OK

Load Case 3:

$M_{case3\_small} := R_{2\_case3} \cdot (0.50 \cdot in)$

$\sigma_{b\_case3\_small} := \dfrac{K_t \cdot M_{case3\_small}}{S_{axle\_small}}$ or $\sigma_{b\_case3\_small} = 5970.703 \dfrac{lb}{in^2}$ OK

$\tau_{max} := \dfrac{R_{2\_case3}}{A_{axle\_small}}$ or $\tau_{max} = 2362.725 \dfrac{lb}{in^2}$ OK

5.5.3 Evaluation of New Eccentric Bushing

The eccentric bushing is limited by bearing load from the axle. The bearing loads against the end truck channel and doubler plate were not changed by the modifications. The bearing stresses between the axle and the eccentric bushing were calculated to be:

$w_{bearing} := 0.375 \cdot in + 0.500 \cdot in$ Assume bearing area is the thickness of the C-Channel plus the 1/2" doubler plate.

$A_{projected} := (w_{bearing}) \cdot (d_{small})$ or $A_{projected} = 2.661\, in^2$ (Axle Bearing Area in Channel)

Load Case 1:

$\sigma_{bearing} := \dfrac{R_{2\_case1}}{A_{projected}}$ or $\sigma_{bearing} = 5212.925 \dfrac{lb}{in^2}$ OK

Load Case 2:

$\sigma_{bearing} := \dfrac{R_{2\_case2}}{A_{projected}}$ or $\sigma_{bearing} = 5581.098 \dfrac{lb}{in^2}$ OK

Load Case 3:

$\sigma_{bearing} := \dfrac{R_{2\_case3}}{A_{projected}}$ or $\sigma_{bearing} = 6449.282 \dfrac{lb}{in^2}$ OK

Appendix B

Certified Material Test Report
New Modified Idler Wheel Axle

5 Total Pages

1/0867

PURCHASE ORDER

GARCIA
324/300

Mail Invoice To:
Fluor Hanford, Inc.
ATTN: ACCOUNTS PAYABLE G1-80
PO Box 1000
Richland WA 99352

Purchase Order : 00012934
Revision :
Release :
Printed : 11/08/01
Page : 1

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Please Direct Inquiries to:
THERESA A. HANSON
Title: CONTRACT ADMIN
Phone: (509) 373-2098 Ext:
Fax : (509) 372-3668

Vendor:
BARRY FAX# 547-6318
MONARCH MACHINE & TOOL CO INC
410 S OREGON
PASCO WA 99301

DRAFT ONLY ** STATUS OPEN ** CONFIRMING ORDER ONLY
**** DUPLICATE COPY ****

Payment Terms	%	Days	Net 30 Days	ERS: N	Ref Contract:

Primary Ship To: FLUOR HANFORD
Hanford Reservation
2355 Stevens Drive
RICHLAND WA 99352

Attention :

Transit Type	Carrier Name	FOB	FOB Point
	MISC TRUCK	PREPAID	RICHLAND, WA

Instructions & Notes

EMERGENCY ORDER!!! PLEASE NOTIFY THE BUYER WHEN READY FOR PICK-UP!!! PLEASE MARK THE PURCHASE ORDER NUMBER ON THE OUTSIDE OF THE PACKAGE, ON THE PACKING SLIP AND ON THE INVOICE.

BEST AVAILABLE COPY

5/ 1 BNDL short ON A Pallet OK

HNF-11175, REV. 0
PAGE B2

110867

PURCHASE ORDER

Mail Invoice To:
Fluor Hanford, Inc.
ATTN: ACCOUNTS PAYABLE G1-80
PO Box 1000
Richland WA 99352

Purchase Order : 00012934
Revision :
Release :
Printed : 11/08/01
Page : 2

Line	Qty	UP	Item Description	Unit Price	Extension
0001	5	EA	Catalog ID: 0000604458 3	$98.000000	$490.00

NON-TAXABLE

Qty: 5 Delivery Date: 11/08/01

BAR, ROUND, ALLOY STEEL STOCK SAE / AISI 4340 (UNS G43400) MEDIUM CARBON, HOT ROLLED, HEAT TREATED 1550 DEG. F , QUENCHED, TEMPERED 1000 DEG. , STRAIGHTENED, STRESS RELIEVED (QTSR), 302 BRINELL HARDNESS MINIMUM. 182 KSI ULTIMATE STRENGTH, NOMINAL. 162 KSI YIELD STRENGTH, NOMINAL. 15 % ELONGATION , NOMINAL. 40 % REDUCTION OF AREA, NOMINAL. DIAMETER: 3-5/8 " (3.625") , CUT LENGTH: 17.25 " LONG MINIMUM. NOTE: 3-3/4 " DIA. MAY BE SUBSTITUTED IF THE 3-5/8 DIA. IS NOT AVAILABLE. DOCUMENTATION TO INCLUDE: CERTIFIED MATERIAL TEST REPORT WITH CHEMISTRY, HEAT AND LOT NUMBER, MECHANICAL PROPERTIES.

Mfr/Vendor: UNKNOWN
Model : N/A
Part : N/A

NCR-01-FHAOS-0328
JY 11/12/01
USE AS IS JY 11/20/01

FH 103 NOV 20 2001

5 EA

CQ-1-2934-1A
HT # A8616

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Line Terms and Conditions - Text at End

Fac	Standard	Name	Type	Description	Last Revised
	B040	R000	P	CERTIFIED MATERIAL TRACEABILITY ID	10/19/01
	B049	R000	P	CERTIFIED MATERIAL TEST REPORT	02/22/00

5/ 1 BNDL OK BKA

QUALITY ASSURANCE INSPECTION PLAN

Sheet 1 of 1

RCP-324-PO12934

1. Item Description 1. BAR, ROUND, ALLOY STEEL STOCK	3. Quality Level 3 4. Safety Class GS	7. Purchase Order or Contract Order No. 12934 8. Release No. (for blanket orders) N/A
2. Prepared/Approved by (Print and Sign Name)*: Howard Rew/QA Engineer [signature] Date 11/8/01 Jim Rich/Design Authority [signature] Date 11/8/01 Date *Signature not required if submitted as PassPort attachment	5. Supplier Name MONARCH MACHINE & TOOL CO INC 509-547-7753 6. Drawing/Spec. No./Revision N/A	9. Inspection/Receiver No. 110867 10. Item No. 1 11. Quantity 5 12. Inspected By (Print name, signature, and apply stamp) John Heicke [signature] FH 103 NOV 12 2001

Char. No.	14. Inspection Characteristics	15. Acc	16. Hld Tag	17. Rej	18. In-Process	19. Cond. Acc	20. Remarks
***	Please send a copy of the completed QAIP to Howard Rew, L1-06.						JCS 31-01-234 CHA 30 TON CRANE CAT ID 604458
1	Verify no handling or shipping damage.	FH 103 NOV 12 2001					
2	Verify item(s) meet PO Item Description(s).	FH 103 NOV 12 2001 ✓ JN 11/12/01					
3	Verify compliance with the following selected QA Clauses: [ ] None [ ] B34: Identification of Items [ ] B37: Traceability of Items [X] B40: Certified Material Marking [X] B49: Certified Material Test Reports [ ] B52: Inspection and Test Reports [ ] B70: OEM Procurements [ ] B73: Control of Graded Fasteners [ ] B76: Suspect/Counterfeit Items [ ] B79: Certificate of Conformance	FH 103 NOV 20 2001 ✓					NCR-01-FHAOS-0328 USE AS IS JN 11/20/01 CQ-1-2934-1A HT# A8616

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- 59941 DUNKERQUE - CEDE

GROUPE USINOR

TEST REPORT

HNF-11175, REV.0, PAGE B4

CERTIFICATE Nr 7/71980	CUSTOMER	CUSTOMER Nr 015125
WORKS Nr 211/1358 /08-01	PACIFIC MACHINERY & TOOL STEEL	HEAT Nr A8616
DESCRIPTION SIZES WEIGHTS	13 BARS 3"667 x17'05"/23'09" = 4,675 MT	
GRADE	AISI4340VIT	

CHEMICAL COMPOSITION %

C	Mn	Si	S	P	Ni	Cr	Mo	Cu				
.407	.740	.181	.020	.020	1.737	.816	.235	.236				

MECHANICAL PROPERTIES

* TC PR	HEAT TREATMENT	* L T	Y S PSI .2%	U T S PSI	E % IN 2"	R.A. %			HARDNESS BHN
PR	Heat treated and stress relieved	L	133835	149350	20.7	58.0			311/ 321

* CHECKED ON => TC=TEST COUPON PR=PRODUCT AS DELIVERED L=LONGITUD. T=TRANSVER.

OTHER RESULTS

Grain size :6/7 M. Quaid
Electric furnace vacuum degassed
Heat treatment : Water quenched : 1607°F 2.00 HRS
Tempered : 1112°F 4.00 HRS
Stress relieved: 1058 F 4.00 HRS

Conforms to ASTM A 434 class BD
Spec 4340 HRQT

CQ-1-2934-1A

1-22-98
Attn: Doug
509 547 6318

Acier exempt de radioactivité anormale - Steel free from abnormal radioactivity - Stahl Frei von anormaler Radioaktivität

TOTAL P.01

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FH 103

NOV 1 2 2001