RMIS View/Print Document Cover Sheet

This document was retrieved from the Boeing ISEARCH System. It is intended for Information only and may not be the most recent or updated version. Contact a Document Service Center (see Hanford Info for locations) if you need additional retrieval information.

Accession #: D195062916

Document #: SD-SNF-DA-008

Title/Desc:

STRUCTURAL SAFETY EVALUATION OF THE K BASIN
RAILCAR & TRUCK APPLICATIONS

Pages: 115

4. (2)

NOV 27 1995 ENGINEERING DATA TRANSMITTAL

Page 1 of 1
1. EDT 600517

2. To: (Receiving Organization) K Basin Cognizant Engineering		3. From: (Originating Organization) ICF KEH SNF Project Engineering		4. Related EDT No.:	
5. Proj./Prog./Dept./Div.: Spent Nuclear Fuel/K Basins/Rails		6. Cog. Engr.: B. V. Winkel		7. Purchase Order No.: NA	
8. Originator Remarks: Addresses various structural/safety issues associated with the K Basin railcar and truck activities. (Re. USQ #K-95-0092)				9. Equip./Component No.: NA	
				10. System/Bldg./Facility: 59-07/60-07/105 KE/105 KW	
11. Receiver Remarks:				12. Major Assem. Dwg. No.: NA	
				13. Permit/Permit Application No.: NA	
				14. Required Response Date: 7-14-95	

15. DATA TRANSMITTED					(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	WHC-SD-SNF-DA-008		0	Structural Safety Evaluations of the K Basin Railcar and Truck Applications	SQ	1		

16. KEY					
Approval Designator (F)		Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec 12.7)O		1. Approval	4. Review	1. Approved	4. Reviewed no/comment
		2. Release	5. Post-Review	2. Approved w/comment	5. Reviewed w/comment
		3. Information	6. Dist. (Receipt Acknow. Required)	3. Disapproved w/comment	6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)										(G)	(H)
Reason	Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	Reason	Disp.
1	1	Cog. Eng. B. V. Winkel	<i>B. V. Winkel</i>	8-25-95	H5-57	M. J. Langevin	<i>M. J. Langevin</i>	9/6/95	X3-74	1	1
1	1	Cog. Mgr. J. . Dearing	<i>J. Dearing</i>	9/15/95	N1-32	C. T. Miller	<i>C. T. Miller</i>		X3-72	3	1
1	1	QA J. I. Diehl	<i>J. I. Diehl</i>	9/15/95	X3-78						
1	1	Safety J. T. Vistica	<i>J. T. Vistica</i>	11/3/95	X3-80						
		Env.									
1	1	W. A. Frier	<i>W. A. Frier</i>	9/6/95	X3-74						
1	1	C. L. Bennett	<i>C. L. Bennett</i>	10/20/95	X3-79	A. Drager			X3-85		

18. Signature of EDT Originator <i>B. V. Winkel</i> 8-25-95		19. Authorized Representative for Receiving Organization <i>M. J. Langevin</i> 9/6/95		20. Cognizant Manager <i>J. Dearing</i> 11/2/95		21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments	
--	--	--	--	--	--	---	--

RELEASE AUTHORIZATION

Document Number: WHC-SD-SNF-DA-008, REV 0

Document Title: Structural Safety Evaluation of the K Basin Railcar and Truck Application

Release Date: 11/27/95

**This document was reviewed following the
procedures described in WHC-CM-3-4 and is:**

APPROVED FOR PUBLIC RELEASE

WHC Information Release Administration Specialist:

Kara Broz

11/27/95

TRADEMARK DISCLAIMER. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy. Available in paper copy. Printed in the United States of America. To obtain copies of this report, contact:

Westinghouse Hanford Company - Document Control Services
P.O. Box 1970, Mailstop H6-08, Richland, WA 99352
Telephone: (509) 372-2420; Fax: (509) 376-4989

SUPPORTING DOCUMENT		1. Total Pages 112
2. Title Structural Safety Evaluation of the K Basin Railcar and Truck Applications		3. Number WHC-SD-SNF-DA-008
5. Key Words K Basin Truck Fuel Storage Basin Safety Rail Control Bumping Post Rail Stops Railcar		4. Rev No. 0
6. Author Name: B. V. Winkel Signature Organization/Charge Code 5B300/LC053		
7. Abstract There are two rail spurs in the storage/transfer areas of both the K East and K West fuel storage basins. These rail spurs both end at the west edge of the basins. To avoid accidental entry of a railcar into a basin, administrative procedures and rail control hardware have been provided. Based upon a combination of historical documentation and existing administrative controls, a maximum credible impact accident was established. Using this design basis accident, the existing rail control hardware was evaluated for structural adequacy. The K Basin rail spurs are embedded in concrete, which permits truck/trailer entry into the same area. Safety issues for truck applications are also addressed.		
		8. RELEASE STAMP

STRUCTURAL SAFETY EVALUATIONS
OF THE
K BASIN RAILCAR AND TRUCK APPLICATIONS

Issued by

ICF KAISER HANFORD COMPANY

AUGUST 1995

for the

U.S. DEPARTMENT OF ENERGY
RICHLAND OPERATIONS OFFICE
RICHLAND, WASHINGTON

Prepared by:	<u> </u>	<u>8/24/95</u>
	Bob V. Winkel, Fellow Engineer Spent Nuclear Fuel Engineering	Date
Reviewed by:	<u> </u>	<u>8/24/95</u>
	Gary R. Wagenblast, Principal Engineer Civil, Structural, and Environmental Engineering	Date
Approved by:	<u> </u>	<u>9/1/95</u>
	John I. Dearing, Manager Spent Nuclear Fuel Engineering	Date

INDEPENDENT REVIEW CHECKLIST

Document Reviewed WHC-SD-SNF-DA-008, Structural Safety Evaluation of the K Basin
Railcar and Truck Applications

Author B. V. Winkel

<u>Yes</u>	<u>No</u>	<u>N/A</u>	
(X)	()	()	Problem completely defined.
(X)	()	()	Necessary assumptions explicitly stated and supported.
(X)	()	()	Are computer analysis applications documented in the report per EP 2.1? (code, version, hardware, input, output files)
(X)	()	()	Is the software verification documentation either referenced or included in the report?
(X)	()	()	Computer code error reports reviewed for impact if any.
(X)	()	()	Data used in calculations explicitly stated in document.
(X)	()	()	Data checked for consistency with original source information as applicable.
(X)	()	()	Mathematical derivations checked, including dimensional consistency of results.
(X)	()	()	Models appropriate and used within range of validity or use outside range of established validity justified.
(X)	()	()	Hand calculations checked for errors.
(X)	()	()	Computer code run streams correct and consistent with analysis documentation.
(X)	()	()	Computer code output consistent with input and with results reported in analysis documentation.
(X)	()	()	Acceptability limits on analytical results applicable and supported. Limits checked against sources.
(X)	()	()	Safety margins consistent with good engineering practices.
(X)	()	()	Conclusions consistent with analytical results and applicable limits.
(X)	()	()	Results and conclusions address all points required in the problem statement.

Reviewer Shay R. Wagonblast

Date 6-28-95

Note: Any calculations, notes, or summaries generated as part of this review should be signed, dated, and attached to this checklist. Material should be labeled and recorded so that it is intelligible to a technically qualified third party.

SOFTWARE APPLICATION REPORT

SOFTWARE APPLICATION

ANSYS 5.0A
WHC-SD-SQA-CSWD-30014, Rev. 0 (Design verification report)

HARDWARE CONFIGURATION

MODEL: SGI3. Building ETC2

EDT/DOCUMENT NO.

EDT 600517
WHC-SD-SNF-DA-008

DISCUSSION:

Element types used: LINK8, BEAM4

CONTENTS

1.0	INTRODUCTION	1-1
1.1	PURPOSE OF THE EVALUATION	1-1
1.2	RAIL SYSTEM DESCRIPTION	1-1
1.3	RAIL CONTROL COMPONENT DESCRIPTIONS	1-4
1.4	STRUCTURAL ACCEPTANCE CRITERIA	1-5
1.5	TRUCK APPLICATIONS	1-6
2.0	SUMMARY AND CONCLUSIONS	2-1
2.1	RAILCAR APPLICATIONS EVALUATION	2-1
2.2	TRUCK APPLICATIONS EVALUATION	2-2
3.0	RECOMMENDATIONS	3-1
3.1	RAILCAR APPLICATIONS	3-1
3.2	TRUCK APPLICATIONS	3-4
4.0	HISTORICAL INFORMATION SUMMARY	4-1
5.0	DEFINITION OF ENVELOPING IMPACT ACCIDENTS	5-1
5.1	RAILCAR APPLICATIONS ENVELOPING ACCIDENT	5-1
5.2	TRUCK APPLICATIONS ENVELOPING ACCIDENT	5-2
6.0	DERAIL EQUIPMENT DISCUSSION	6-1
7.0	STRUCTURAL ANALYSIS RESULTS	7-1
7.1	RAIL CONTROL STRUCTURAL ANALYSIS PROCEDURE	7-1
7.2	NORTH RAIL SPUR BUMPING POST	7-1
7.3	SOUTH RAIL SPUR EMERGENCY BUMPER	7-1
7.4	SOUTH RAIL SPUR RAILSTOPS	7-2
7.5	TRUCK IMPACT STRUCTURAL EVALUATION	7-4
8.0	REFERENCES	8-1

APPENDICES:

APPENDIX A:	K BASIN RAIL CONTROL STRUCTURAL CALCULATIONS	A-1
APPENDIX B:	ANSYS FINITE ELEMENT MODEL LISTINGS	B-1
APPENDIX C:	COLUMN E-13 FAILURE PROPAGATION	C-1
APPENDIX D:	TRUCK ACCIDENT CALCULATIONS	D-1
APPENDIX E:	MISCELLANEOUS RAIL/TRUCK CORRESPONDENCE	E-1

LIST OF FIGURES

1-1	Sketch of 100K Rail System layout	1-2
1-2	K Basin Rail Control Hardware Layout	1-3
5-1	Summary of Existing Rail Control Defense System	5-1
7-1	Rail Car Wheel/Railstop Spacing at Impact Initiation	7-3

LIST OF TABLES

1-1	List of Rail Control Components and Drawings	1-3
2-1	Summary of Rail Control Component Evaluation Results	2-1
4-1	Rail Control System Historical Documents	4-1
4-2	Historical Definition of Rail Control System Parameters	4-2
7-1	North Rail Spur Bumping Post Structural Analysis Results	7-1
7-2	South Rail Spur Emergency Bumper Structural Analysis Results	7-2

METRIC CONVERSION CHART		
1 inch	=	2.54 centimeters
1 foot	=	30.48 centimeters
1 lb-force	=	4.45 Newtons
1 ft-lb-force	=	1.36 Joules
1 mi/hr	=	1.61 km/hr
1 ft/sec	=	0.30 m/sec
1 lb/in ²	=	6894.8 Pascals
$1\text{ }^{\circ}\text{F} = (9/5)\text{ }^{\circ}\text{C} + 32$		

**STRUCTURAL SAFETY EVALUATIONS
OF THE
K BASIN RAILCAR AND TRUCK APPLICATIONS**

1.0 INTRODUCTION

1.1 PURPOSE OF THE EVALUATION

The north and south rail spurs of both the K East and K West Basins enter into the basin area through door openings on the west wall of the storage/transfer areas. The rails are embedded in concrete, which allows for both truck and railcar entry into the storage/transfer areas adjacent to the basins. As described in Sections 1.2 and 1.3, rail control equipment has been installed on both rail spurs to help prevent an accidental entry of a railcar into the fuel storage basin. This rail control equipment also provides an impediment to accidental truck entries into the basin. The primary safety concern, addressed in this report, is the accidental entry of a railcar or truck into the K East or K West Fuel Storage Basin.

Currently, trucks can also enter into the storage/transfer area through a smaller door on the north end of the west wall. However, truck entry into the basin via the north door is not feasible, due to the presence of a large concrete vault, which encloses the sand filter. Thus, this northern-most truck entry is not addressed in the evaluation described below.

To provide assurance that a railcar or truck will not accidentally enter into the fuel storage basin, both administrative controls and hardware barriers have been established. The primary purpose of this report is to provide documentation on the structural adequacy of the existing control hardware. Secondary purposes include (1) justification and description of the enveloping accidents, (2) rail control historical information, and (3) detailed descriptions of the rail control equipment including vendor supplied information.

1.2 RAIL SYSTEM DESCRIPTION

The layout of the 100K Area rails is sketched in Figure 1-1. Rail vehicles enter the 100K area on the west side of the area. There is a rail switch on the west side which diverts the rail traffic to either the K West or K East facility. The normal position of this switch is open to K East. Prior to reaching the K East facility, there is another switch which is normally open to the dead-end spur. Thus, a runaway railcar entering the 100K area would be diverted to the dead-end spur. In addition to the switch safety control, both the K West and K East rail spurs are equipped with derails as shown.

The two rails entering the Basin storage and transfer areas are shown in Figure 1-2. Note that on the north rail spur a "bumping post" is positioned

Figure 1-1. Sketch of 100K Rail System Layout.

Figure 1-2. K Basin Rail Control Hardware Layout.

to limit rail entry beyond the post location. On the south rail spur, "rail stops" are mounted to the rails which would be impacted by the railcar wheels

if a railcar progressed to that location. Also shown is an "emergency bumper" which is mounted to a beam, which in turn, is mounted to two of the building columns. The bumper is positioned such that it would be impacted by the railcar coupler prior to the rail stop being impacted by the railcar wheels.

1.3 RAIL CONTROL COMPONENT DESCRIPTIONS

A list of the rail control system components is provided in Table 1-1, including the drawing number and title for each component. As indicated in the discussion, below, there are a number of documentation problems associated with the rail control hardware. One rail control component which has no drawing available is the derail hardware. The derail hardware-mounted identification indicates that the manufacturer is Western-Cullen-Hayes, Inc. and the model type is HB. Upon request, the vendor supplied installation and maintenance information on the Model HB derail hardware, but no drawings were provided.

The rails inside the basin structure are embedded into the concrete floor, with only a small groove for the wheels, on the inside of each rail. When the bumping posts were added in 1984, the bumping post installation drawing, H-1-45072, specified that only enough concrete be removed to install a bumping post which does not extend below the bottom of the rails. The

Table 1-1. List of Rail Control Components and Drawings.

Component	Drawing Number	Drawing Title	Rev. No.
Bumping Post	Western-Cullen-Hayes, Inc. Vendor Drawing #10600	Hayes Bumping Post Type WA-R (Modified)	0
	H-1-45072	K-West Ion Exchange Module Installation Drawing	1
Emergency Bumper	Western-Cullen-Hayes, Inc. Vendor Drawing #SP-1	Spring Pad Assembly	0
105-KW Emergency Bumper Beam, New Wheel Stop	H-1-34761	Structural Emergency Cask Car Stop Plan, Sections, and Details	1
105-KE Emergency Bumper Beam, New Wheel Stop	H-1-34447	Structural Emergency Cask Car Stop Plan, Sections, and Details	1
Old Wheel Stop	H-1-5609	Special Wheel Stop Details	1
Railroad Car	Pacific Car and Foundry Vendor Drawing #G-75045 A 326	90-Ton Well Type Flat Car	A

standard Hayes Type WA bumping posts have structural members which are positioned below the bottom of the rails and extend underneath the rails.

The property markers, attached to the installed bumpers, are marked as "Hayes Type WA". However, based upon sketches on the drawing and discussions with the vendor, it appears that the bumping posts are actually Hayes Type WA-R, which are "modified" Type WA bumping posts. It is not possible to visually verify this conclusion, because the lower portion of the bumping posts are embedded in concrete. A drawing of the modified Type WA-R bumping posts was obtained from the vendor as shown in Table 1-1. Since the modified bumping posts are weaker than the standard, Type WA posts, only the modified post design was evaluated in the Appendix A calculations.

The bumping posts, installed on the north rail spurs, are located near the center of the rail span, as shown in Figure 1.2. Currently, there are no plans to use the north rail spurs. However, the bumping posts were evaluated to demonstrate adequacy of the posts for an accidental entry and impact.

The emergency bumpers, installed on the south rails, are mounted to a horizontal beam, which spans between two of the building support columns. The bumpers were designed by the indicated vendor specifically for the K Basin application. The bumper stiffness and capacity properties are listed on the vendor drawing. It is noted that Drawing H-1-34853 specifies that the bumpers are "Shock-Free Heads" by L. B. Foster Company, which is not correct. The "Shock-Free Heads" which are distributed by L. B. Foster are a standard bumper design and are different than the specially-made bumpers used in the K Basins.

The wheel stops, mounted onto the south rail spurs, were also designed specifically for the K Basin application. As indicated in Table 1-1, there are two different wheel stop designs, "old" and "new". The old stops are on the south rail. The old rail stops are smaller, four-bolt designs, and were part of the original K Basin design. The new stops are eight-bolt designs and were mounted to the north rail of the south rail spur. Field inspections of the railstop hardware indicated that there are some differences between the existing hardware and the drawings. These documentation inconsistencies are discussed further in Section 4.0.

The rail control hardware for the K East and K West Basins are identical with the exception of the horizontal beam used for mounting the emergency bumper. The K East beam is deeper (18 in. versus 14 in.) but is lighter (96 lb/ft versus 119 lb/ft). These beams have nearly identical bending/shear stiffness and capacity.

The railcar shown in Table 1-1 is technically not part of the rail control hardware. However, the maximum predicted impact force is significantly affected by the properties of the railcar draft gear (coupler impact buffer). The "90-Ton Type Flatcar" drawing specifies a specific type of draft gear (Miner A-22XB) which, indirectly, is part of the rail control hardware.

The two rail switches (spur switch numbers 1 and 2, Figure 1-1) are non-structural, but important components in the rail control system hardware. The concern for a switch failure was raised during the rail control hardware evaluation. The maintenance schedule and functional adequacy of these switches was investigated as part of the rail control safety evaluation.

1.4 STRUCTURAL ACCEPTANCE CRITERIA

The basic structural design criteria document for Hanford site structures is SDC-4.1 (DOE 1993). The specific guidelines, codes, and standards to be applied to Hanford structures are specified in Section 2.2 of SDC-4.1. For reinforced concrete structures both ACI 318 (ACI 1989) and ACI 349 (ACI 1990) are listed. For steel structures, both the AISC Manual (AISC 1989) and the ANSI/AISC N690 code (ANSI/AISC 1984) are listed.

For the rail control system structural components, the ANSI/AISC N690 (ANSI/AISC 1984) was selected because it addresses off-normal loads. The railcar impact loading was treated as an "abnormal" loading. For the building column anchor bolt capacity, ACI 349 (ACI 1990) was utilized.

The criteria for structural acceptability is also influenced by the functional design criteria for the projects which created the rail control hardware. The functional design criteria for the 105 KW and 105 KE rail control hardware are contained in Gydeson 1975 and Gydeson 1977, respectively. The functional design criteria for both projects state that the rail control hardware "shall be considered to be expendable". This expendable position supports the selection of the higher abnormal loading allowables (typically 1.6 times higher than normal allowables) mentioned in the previous paragraph.

1.5 TRUCK APPLICATIONS

As mentioned in Section 1.1, current truck usage in the storage/transfer areas of the basins is limited to the south entry. Two types of trucks are currently utilized, the Chem Nuclear truck, used for transporting shipping casks, and the IXM transporting truck, which includes trailer numbers HO-64-5712 and HO-64-5728. Both of these truck applications involve a three-axle truck attached to a dual-axle trailer. Additional information on the trucks is provided in Section 5.2 and Appendices D and E.

The existing barriers to prevent accidental entry into the basins were designed to interface with a railcar. Since the trucks are backed into the storage/transfer areas, the interface with the rail control hardware would be the rear of the trailers. Based upon the capacity of the rail control hardware, an allowable truck velocity was established. A summary of the evaluation is provided in Section 2.2. Details are included in Section 7.5 and Appendix D.

2.0 SUMMARY AND CONCLUSIONS

2.1 RAILCAR APPLICATIONS EVALUATION

Although the focus of the railcar application evaluation was structural adequacy of the control hardware, it was necessary to evaluate the railcar control procedures to assure consistency between the structural analysis and the administrative controls. Based upon a review of related historical documents and current administrative requirements, two hypothetical accidents of a runaway train have been identified. The first accident assumes the train approaches K Area at excessive speed and could crash all barriers to enter a fuel storage basin. This is prevented by rail switches which will divert the train away from the basin. The switches are backed up by derailer on the spurs leading to the basins. The second accident assumes that the engineer is unable to stop the train during operations past the derailer. This report primarily evaluates the rail stops and bumper hardware for the second case based on a single definition of a railcar impact accident. As described in Section 5.0, the impact accident design envelope is defined as a 470,000 lb train (230,000 lb railcar, 240,000 lb locomotive) traveling at two mi/hr.

Based upon the Section 5.0 railcar accident definition, the existing K Basin rail control components were evaluated. The calculation details are contained in Appendix A. The analysis procedures and results are summarized in Section 7.0. An overall summary of the rail control system hardware structural adequacy is provided in Table 2-1.

Table 2-1. Summary of Rail Control Component Evaluation Results.

Component	Critical Category	Critical Value	Allowable	Margin of Safety ¹
North Rail Spur Bumping Post	Capacity of Front Connection to Rail	204,000 lb	238,000 lb	+0.17
South Rail Spur Emergency Bumper	Force Capacity	190,000 lb	220,000 lb	+0.16
South Rail Spur Emergency Bumper Support Hardware	Column Anchor Bolts Tensile Capacity	18,500 lb	16,900 lb	-0.09
South Rail Spur Rail Stops	Shear Capacity of Mounting Bolts	75,000 lb	228,000 lb	+2.04

Margin of Safety = Allowable Value ÷ Predicted Value - 1.0. A positive margin indicates that the structural allowable has been met. A negative safety margin indicates that the allowable has not been met, but does not necessarily mean that a structural failure is predicted.

Comments are in order relative to the capacities listed in the "Critical Value" column in Table 2-1. The current K Basin SAR (Meichle 1994) presents rail control component capacities in terms of energy absorption rather than impact force capacities as listed in Table 2-1. Based upon the current

evaluation, energy absorption capacities are not very meaningful for the rail control equipment because the majority of the impact energy is absorbed by the railcar draft/buffer gear rather than the rail control hardware. This is especially true for the relatively rigid bumping posts and rail stops. Even for the relatively soft bumper, energy absorption capability can be deceiving because the supporting column anchor bolt capacity is exceeded before the bumper capacity is achieved.

Note that all safety margins in Table 2-1 are positive with the exception of the anchor bolt capacity of the building support column (Column E-13) which is connected to the bumper support beam. As indicated by the table footnote, a negative safety margin means that code allowables are exceeded and does not necessarily indicate failure. The column in question does support the basin superstructure roof. The horizontal movement of the column base is limited to the railcar movement which in turn is limited by the rail stops mounted to the tracks. As discussed in Section 7.3, an upper bound column displacement of two inches was predicted. For this maximum displacement, the column centerline would be about 16 in. from the edge of the basin. Thus, the column vertical support may be weakened, but not lost. Based upon this upper bound displacement prediction, plus redundancy in the roof support, there is high confidence that roof collapse would not occur.

The position that the roof should not collapse is further supported by the conservatism in the definition of the two mi/hr maximum impact velocity. The current operating procedures (WHC 1995) specify a velocity range switch setting of 0.1 to 1 mi/hr, while in the basin. As shown in Appendix A, a positive safety margin for the column base is obtained if the impact velocity is reduced to 1.75 mi/hr.

In addition to roof support, Column E-13 supports the crane rail. Thus, a column anchor bolt failure raises concern for rail movement and a potential dropping of the crane, if the crane was positioned near the column. As indicated in Section 7.3, a crane rail movement of less than 0.1 in. was predicted for the impact loading, eliminating the concern for crane drop.

The conclusion of the structural evaluation is that the existing rail control hardware is structurally adequate. This conclusion is conditional on the assumption that the railcar accident event, defined in Section 5.0 is not exceeded.

As discussed in Section 1.3, the predicted impact force is very sensitive to the properties of the railcar draft gear (coupler impact buffer). The structural evaluation performed in the Appendix A calculations are based upon a specific draft gear (Miner A-22XB), which is identified on one of the original well car drawings. The analysis is also limited to a 470,000 lb train (230,000 lb railcar plus a 240,000 lb locomotive). Care must be taken to assure that the basin rail operations are consistent with these analysis limitations.

The structural adequacy of all rail control components is addressed in Appendix A, except for the derail equipment. The issue of derail hardware adequacy is functional, not structural. The current K Basin SAR (Meichle 1994) states that the derails are functional for railcar velocities up to five mi/hr. As discussed in Section 6.0, no evidence was found to support this specific velocity rating. However, the Section 6.0 discussion also indicates

that there is high confidence that the derail hardware is adequate for the velocities achievable in the short distances involved.

The issue of functional adequacy of the rail switches was also investigated. As indicated in the telephone conversation memorandum provided in Appendix E, the switches are inspected on a monthly basis. It was concluded that a functional failure of a basin rail spur switch is highly unlikely. In the judgement of the Hanford rail maintenance manager, the only feasible way that a switch malfunction could occur would be through a deliberate act of sabotage. The probability of sabotage coinciding with a runaway railcar or train is extremely low. Therefore, a switch failure was not considered to be a viable issue.

2.2 TRUCK APPLICATIONS EVALUATION

Only three-axle trucks, dual-axle trailer combinations, entering the south rail spur door, were considered for this evaluation. Based upon known weights, plus normal load limits for this type of truck/trailer combination, a gross weight envelope of 100,000 lb was assumed. Currently, there are two types of trailers used for K Basin applications, the Chem Nuclear trailer and the IXM trailers. The interfacing of the rear of these trailers with the existing rail control hardware was evaluated. It was concluded that it was not feasible for these trailers to pass through to the basin without impacting the rail control bumper. Based upon the capacity of the bumper, it was concluded that a three mi/hr maximum truck velocity would provide a reasonable limit for the K Basin truck applications. Additional details are provided in Section 7.5 and Appendix D.

Since the current truck applications involve neither automatic speed nor emergency stop controls, a truck accident is more likely than a railcar accident. On the other hand, due to the less massive size of trucks, the relative likelihood of an accidental truck entry into the basin is less than for a train. However, if the frequency of truck usage increases in the future, additional truck controls may be prudent.

3.0 RECOMMENDATIONS

3.1 RAILCAR APPLICATIONS

As indicated by the conclusions in Section 2.0, no modifications to the existing rail control hardware are recommended. However, to assure that the analysis envelope is not exceeded, K Basin rail usage must be limited to a 470,000 lb train travelling at a maximum speed of two mi/hr. Any future usage would either need to fall within this envelope or additional evaluations would be necessary.

Although some weight information was found in railcar SARPs (Nguyen 1993) and Hanford Rail Operations files, no single document was found which demonstrates that the railcars and locomotives planned for K Basin usage fall within the assumed weight envelope (230,000 lb well car, 240,000 lb locomotive, 470,000 lb combined). The combined weight envelope of 470,000 lb should be verified for each type of planned shipment. To assist in this weight envelope verification, a table of locomotive weights and some empty railcar weight information is provided in Appendix E. Note that the Appendix E locomotive weights shown are slightly higher than the 240,000 lb values used in the rail control hardware evaluations. These higher weight values were not used because they became available after the calculations were performed.

Concerning the inconsistencies between the field installations and drawings discussed in Section 1.3, at the time of this report writing this problem had been resolved by developing the as-built drawing H-1-80791.

3.2 TRUCK APPLICATIONS

As discussed in Section 5.0, a reasonable envelope for K Basin truck applications is a weight limit of 100,000 lbs and a maximum velocity of three mi/hr. These limits should be specified in appropriate documents such as the K Basin SAR (Meichle 1994) and the IXM Shipping procedure (WHC 1995a). Procedures should also be documented for other applications, such as the Chem Nuclear, shipping cask application.

4.0 HISTORICAL INFORMATION SUMMARY

Structural/safety evaluations of the K Basin rail control system components have occurred in the past. The available documentation from past evaluations was reviewed for potential applicability to the current evaluation. The purpose of this section of the report is to summarize the results of the review.

The rail control system evaluation available documents are listed chronologically and briefly commented on in Table 4-1. A review of these

Table 4-1. Rail Control and Truck Historical Documents.

Document Title	Reference	Comments
Rail Stop Design for 105KE	Norris 1975	Contains calculations addressing both old and new railcar wheel stops.
Preliminary Engineering Study Report Contingent Irradiated Fuel Storage Facility, 105 KE/KW	DeMaria 1979	Briefly describes rail control components and accident definitions and acceptance criteria
Computer Model of Train Falling in Basin	Hultgren 1983	Brief evaluation of the consequences of a railcar entering a basin travelling at 4 mi/hr
Safety Analysis Irradiated N Reactor Fuel	Meichle 1994	Section 5.6 of the SAR addresses the rail control system safety evaluation
Control Railroad Cars Entering 105-KE or 105-KW (Procedure # 59/60-07-13)	WHC 1995	Specifies procedures for controlling railcar entry into the storage/transfer areas of the basins
Ship Ion Exchange Module from 100-K to Burial (Procedure #59/60-07-95)	WHC 1995	Specifies procedure for shipping IXM's from K Basins to 200-West area for burial

documents indicated that the available rail control system documentation is very brief and inconsistent. A summary listing of rail control system parameters addressed in the historical documentation is provided in Table 4-2. Note, for example, the inconsistencies in the definition of the railcar accident. In Section 5.0 of this report a single design basis accident was selected which is consistent with the current rail control administrative controls.

As indicated in Section 1-3 and in Table 4-2, there are inconsistencies between the existing hardware and some of the information on the current drawings and reports. For example, the "new railstops" installed in the field are different than the drawings and the definition given in (Norris 1975).

Table 4-2. Historical Definition of Railcar Control System Parameters.

Parameter	Description	References	Year	Comments
Design Basis Train Accident	2-Car, 700k, Train, $V_{max} = 1.5$ mph	Vitro Job #C33373, UNI 108		Currently, the K Basin SAR prevents entry of a 2-Car Train.
	1-Car, 470k, Train, $V_{max} = 2$ mph	Vitro Job #C33373, UNI 108, UNI 1285, K Basin SAR	1975 1977 1979 1994	Note that this single car, 2 mph train is common to several historical documents. The origin of the 470 k weight is not given.
	1-Car, 470k, Train, $V_{max} = 4$ mph	UNC Memo, Author: G. Hultgren	1983	It is unclear what motivated this evaluation of this more severe accident condition.
Bumper Design per Drawing	"Shock-Free Heads" by L. B. Foster	Dwg. H-1-34853, Rev. 2	1983	There is no evidence that these standard bumpers were ever used in the K Basin rail controls.
Bumper Design per Field Inspection	"Special" Bumper by Western-Cullen-Hayes	Section 54-10 of W-C-H Catalogue	1995 Fax	According to the information supplied by the vendor, these special bumpers were designed for the K Basin application.
Bumper Capacity	59,000 ft-lb energy absorption	Section 5.6.4 of K Basin SAR	1994	No historical documentation provides the origin of this bumper capacity, but is consistent with current calculations, assuming that the supporting hardware is adequate.
Bumping Post Capacity	250,000 ft-lb energy absorption	Section 5.6.4 of K Basin SAR	1994	The origin of this figure was not found. Based upon current calculations, this figure is too high.
Derail Capacity	5 mi/h	Section 5.6.2.1 of K Basin SAR	1994	Origin not found. Per discussions with the manufacturer, derail capacities are not meaningful and they will not provide ratings.

Therefore, for the calculations provided in Appendix A, special care was taken to assure consistency between the structural calculations and the existing hardware.

Since much of the hardware associated with rail control is vendor supplied, the available vendor files at the Hanford site were searched for pertinent information. When no information was found in the Hanford vendor files, the vendors were contacted directly and information on the rail control hardware was requested. This information has been compiled and added to the Hanford vendor information files.

5.0 DEFINITION OF ENVELOPING IMPACT ACCIDENTS

5.1 RAILCAR APPLICATIONS ENVELOPING ACCIDENT

As discussed in Section 4.0, historically, there were some inconsistencies in the definition of the K Basin railcar accident. The purpose of this section is to provide a single definition of a railcar impact accident consistent with the current administrative controls and control hardware. The K Basin rail operating procedures are described in Procedure No. 59/60-07-13, Rev. 8 (WHC 1995). This operating procedure was reviewed relative to the development of a consistent, reasonably conservative definition of a credible impact accident.

The multilevel defense system against accidental entry of a train into one of the basins is illustrated in Figure 5-1. The first three levels are

Figure 5-1. Summary of Existing Rail Control Defense System.

administrative, which is described in detail in the operating procedure (WHC 1995). The operating procedure contains a multi-step list to control cars entering the K Basins. Each step must be sequentially initiated by personnel under the direction of the shift manager.

In order for a train to enter either basin, it is required that both a double-locked switch and a double-locked derail be unlocked by both the train

crew and the K Basin shift manager. Once the switch is unlocked and opened, the K Basin manager boards the train and rides to the derail. A five mi/hr speed control is imposed by the procedure between the switch and the derail. Before opening the derail, the procedure requires that the automatic speed control be set to the 0.1 to 1 mi/hr range. The procedure also contains a highlighted warning message, which limits the train to a locomotive and a single well car, as required by the Operational Safety Requirements (Meichle 1995).

Following the operating procedure limit of a single car and the historical one-car train maximum weight, discussed in Section 4.0, a maximum train size of 470,000 lb was selected. It was also assumed that the 470,000 lb weight was distributed between the locomotive and car as 240,000 lb and 230,000 lb, respectively, which is the historical split. Since the operating procedure requires that a one mi/hr range switch be imposed before entering the basin storage area, the historical impact speed of two mi/hr appears to be conservative, and allows for some inaccuracy in the range switch control. In conclusion, the maximum credible accident selected for the current evaluation is a 470,000 lb train, travelling at two mi/hr.

5.2 TRUCK APPLICATIONS ENVELOPING ACCIDENT

An enveloping accident for truck applications entering the south door of the K Basin storage/transfer area has not previously been defined. In Dobbin and Hecht 1995, a specific application is addressed, namely the Chem Nuclear truck with a specified gross weight of 57,000 lb. A velocity limit of five mi/hr was recommended for this specific truck application. The Dobbin and Hecht 1995 memo conservatively neglected the fact that the trailer wheels would impact the floor rail stops prior to impacting the bumper. WHC 1995a addresses the use of trucks in shipping IXM modules from the basins. However, no weight or velocity limits are specified. Both the Chem Nuclear and the IXM trucks are three-axle trucks with dual-axle trailers.

Since the current truck applications are limited to three-axle trucks, dual-axle trailers, it is reasonable to limit the enveloping accident definition to this type of truck. Per telephone conversations with the Washington commercial vehicle control officials, the state of Washington limit on this type of truck is currently 80,000 lb, without a special permit. Although, the current K Basin trucks will not travel on public highways, it is likely that the K Basin trucks will stay within this 80,000 lb limit. However, to provide some margin over the 80,000 lb limit, an enveloping weight of 100,000 lb was assumed in the Appendix D calculations.

Using the 100,000 lb weight limit, the Appendix D calculations indicated that a velocity limit of three mi/hr would not exceed the capacity of the existing control hardware. Therefore, the truck impact accident envelope consists of a 100,000 lb truck travelling at three mi/hr. If a planned future truck application exceeds this envelope, a case-specific evaluation should be performed.

6.0 DERAIL EQUIPMENT DISCUSSION

As shown in Figure 1-2, there is derail hardware located outside the K Basin facilities on all four K West and K East rail spurs. Other than a brief mention in the current SAR (Meichle 1994), no documentation on this derail equipment has been found in the historical references. As discussed in Section 1.3, through identification numbers on the derail hardware, plus conversations with the manufacturer, it was determined that the derail equipment is identified as "Hayes Sliding Derails, Model HB". Documentation on this derail model hardware was requested from the manufacturer (Western-Cullen-Hayes, Inc., Richmond, IN). The requested documentation contains installation, inspection, and maintenance information, but provides no capacity information.

Subsequent conversations with the manufacturer indicated that it is not customary to provide maximum velocity ratings for the derails, because there are too many variables affecting the effectiveness of the derail hardware. For example, a light unloaded car is much less likely to be derailed than a heavier car, because it can bounce over the derail. This concern for derail capacity was discussed with the Hanford rail maintenance manager. See telephone conference memorandum in Appendix E. It was pointed out that the limited distance between the switch and the derail hardware would limit the train to very low velocities at the derail locations. Based upon prior derail experiences at Hanford, it is highly unlikely that a railcar and locomotive could pass through a derail with all wheels remaining on the track.

It was concluded from the derail hardware evaluation that, although no quantitative basis for the 5 mi/hr rating value was found, the issue is academic because of the short distances between the switches and derails. The derails definitely contribute to the overall rail accident prevention within the basins. They provide the final defense against accidental entry into the storage/transfer area of the basins. They also provide the boundary beyond which strict train speed and emergency stop controls are in effect.

7.0 STRUCTURAL ANALYSIS RESULTS

The structural calculations of the rail control components are provided in Appendix A. A description of the analysis procedures used in evaluating the structural adequacy of the rail control components is described in Section 7.1. A summary of the results for each rail control structural component is provided in Sections 7.2 through 7.4.

7.1 STRUCTURAL ANALYSIS PROCEDURE

The more challenging portion of the analysis was to obtain a reasonably conservative estimate of the maximum impact force for the components evaluated. The basic approach, as described in Appendix A, was to assume an elastic impact and obtain the impact force by equating the kinetic energy ($mv^2/2$) of the train mass, m , with the impact spring potential energy ($kx^2/2$). As anticipated, the maximum impact force was found to be sensitive to the effective impact spring constant, k . The effective impact spring constant was a composite of the elasticity of the target and the impacting rail car.

The rail car elasticity was conservatively estimated from a railcar model found in the literature. The dominant component in the railcar elasticity is the "draft gear" or "buffer" which is in line with the railcar coupler. Based upon drawings of the K Basin well cars, the draft gears are a friction type gear, manufactured by Miner Industries. The force/deflection properties of the specific draft gear used in the well cars was obtained from the vendor and included in the Appendix A models.

In general, the impact target properties were obtained via an ANSYS (Swanson 1993) finite element model. The ANSYS models were also used to obtain the stress response of the impacted component for the predicted impact force. One exception to this was the contribution of the emergency bumper on the south rail spur. As described in Section 1.3, the emergency bumpers are specially made components. Through vendor contact, the force/deflection properties of the bumper were obtained and incorporated into the impact spring model.

Having obtained the maximum impact force, the individual member stresses were obtained for the rail control components and compared to the allowable values, which were obtained from (ANSI/AISC 1984) and (ACI 1990).

7.2 NORTH RAIL SPUR BUMPING POST

A bumping post has been installed on the north rail spur of each basin as shown in Figure 1-2. As discussed in Section 1.3, the bumping posts are apparently a modified version of a standard Hayes Type WA post. The bumping post was evaluated for the standard two mi/hr impact accident defined in Section 5.0. An impact force of 380,000 lb was predicted. The safety margins associated with this impact loading are summarized in Table 7-1. Note that positive safety margins were predicted for all components. The smallest safety margin (+0.17) occurred for the uplift force on the front (tension side) of the bumping post. In order to obtain a positive safety margin for

this connection, it was necessary to take credit for the shear strength of the concrete embedment.

Table 7-1. North Rail Spur Bumping Post Structural Analysis Results.

Component	Category	Max. Value	Allowable	Margin of Safety
Compression Beams	Compressive Stress (Buckling)	13,340 psi	31,520 psi	+1.36
Tension Straps	Tensile Stress	12,940 psi	34,560 psi	+1.67
Front Rail Connection	Allowable Uplift Force	203,700 lb	238,300 lb	+0.17

7.3 SOUTH RAIL SPUR EMERGENCY BUMPER

The south rail emergency bumper includes the special Hayes bumper, the support beam, and the support columns. The bumper is impacted by the railcar coupler. For the two mi/hr impact, an impact force of 190,000 lb was predicted. A summary of the associated component structural evaluation results is provided in Table 7-2.

Note that positive safety margins are indicated in all categories except for the column anchor bolts which were calculated to have a slightly negative margin. This negative margin occurs in the column closest to the bumper (Column Line E).

Table 7-2. South Rail Spur Emergency Bumper Structural Analysis Results.

Component	Category	Max. Value	Allowable	Margin of Safety
Bumper	Force Capacity	190,000 lb.	220,000 lb	+0.16
Bumper Beam & Columns	Bending Stress	32,300 psi	34,600 psi	+0.11
Bumper Beam & Columns	Shear Stress	15,000 psi	20,000 psi	+0.34
Bumper Beam Mounting Bolts	Tensile Force	123,000 lb	221,000 lb	+0.80
Column Anchor (Col. Line E)	Anchor Bolt Shear Force	18,500 lb	16,900 lb	-0.09

The negative safety margin, indicated for the column base shear, raises the possibility that an impact could move the base of the column towards the basin. The column is 18 in. deep and the center of the column is 18.5 in.

from the edge of the basin, as shown in Appendix A. If the column base is knocked into the basin, there is a possibility that a roof collapse could occur. However, the distance the railcar, and column, can move is limited by the rail stops. As shown in Section 7.4, the strength of the rail stops is sufficient to stop the car movement.

The distance the car, and column base, can be moved is addressed in Appendix A. The dimensions associated with railcar wheel travel after the coupler comes in contact with the bumper is shown in Figure 7-1. Accounting

Figure 7-1. Rail Car Wheel/Railstop Spacing at Impact Initiation.

for bumper compression, a column base movement of about two inches was predicted prior to wheel/rail stop impact. Thus, the edge of the column would remain over seven inches from the edge of the basin, which eliminates the concern for roof collapse.

The issue of roof collapse was further addressed in appendix C, which addresses potential overstressing of members adjacent to Column E-13. A model of the entire super structure was utilized and loaded with the predicted impact force. By taking credit for friction, due to dead weight loading in the column, a column base movement of less than an inch was calculated (p. C-17). The Appendix C analysis also indicated a very small displacement of about 0.02 inches in Column E-13 at the crane level, eliminating the concern for a crane fall following impact.

If exceeding anchor bolt shear allowables is judged to be unacceptable, the energy at impact could be reduced by restricting the train velocity within the basin. As shown in Appendix A, the maximum impact velocity which would keep the bolt shear stress to within allowables is 1-1/3 mi/hr. This impact velocity exceeds the maximum velocity range switch setting of 1 mi/hr

specified in the operating procedure (WHC 1995), indicating that column base failure is unlikely.

7.4 SOUTH RAIL SPUR RAIL STOPS

There are two rail stops on the south rail spur in each basin. Mounted to the south track of the south spur is an older four-bolt design and the north track has a newer eight-bolt rail stop mounted to the track. Since the emergency bumper, discussed in Section 7.3 would be impacted before the railcar wheels would impact the rail stops, the railstops would only be needed if the bumper and its supporting hardware fails to stop the train. Assuming a support column failure when the column base shear allowables are exceeded, there is a possibility that a rail stop impact of 0.6 mi/hr could occur. The 0.6 mi/hr velocity is the residual velocity remaining following a two mi/hr bumper impact, estimated in Appendix A.

Using the residual impact velocity of 0.6 mi/hr, a maximum impact force of 75,000 lb was predicted. The combined capacity of the rail stops per AISC/N690 (ANSI/AISC 1984) was calculated to be 228,000 lb, yielding a positive safety margin of +2.1.

7.5 TRUCK IMPACT STRUCTURAL EVALUATION

As indicated in Sections 3.2 and 5.2, a truck weight limit of 100,000 lb is recommended for the K Basin truck applications. This weight limit was assumed in the calculations contained in Appendix D. The Appendix D calculations also assumed that the primary defense against a truck entering the basin is the emergency railcar bumper.

The trailer/bumper interface requires some explanation. As indicated in Appendix D, the trailer beds will pass under the bumper, unless the beds are raised a few inches. However, prior to reaching the bumpers, the trailer tires will impact the rail stops, which in most instances should stop the truck. However, since the trailer tire radius exceeds the height of the rail stops, it is possible for the tires to climb over the rail stops. If that occurs, the back of the trailer would be raised and after another foot of horizontal travel, the trailer would reach the bumper.

Since the north/south position of the trucks is not constrained by the rails, the precise north/south position of the trailer during an impact accident is not known. However, due to a mezzanine column on the south and the drip pan stand columns on the north, the available path is relatively narrow. The eight-foot-wide trailer can only move eighteen inches north and fifteen inches south without interfering with a column.

The various feasible interfaces between the rear of the trailers and the existing rail control hardware are addressed in Appendix D. As demonstrated in the Appendix D calculations, in order for the trailer tires to miss the rail stops, the trailer must move about two feet to the north or south. An offset greater than two feet, coupled with a significant impact accident, is judged to be extremely unlikely. Even if it does occur, the rear of the trailer bed would be raised by an existing concrete curb.

In the Appendix D study, it was concluded that it was not feasible for the rear of the trailer to pass through to the basin without impacting the bumper. Conservatively ignoring the energy absorbed in getting to the bumper, the bumper energy absorbing capability was utilized to establish the truck velocity limit. A velocity limit of three mi/hr was derived as a reasonable limit on truck velocities in the storage/transfer area of the basins.

8.0 REFERENCES

- ACI, 1989, *Building Code Requirements for Reinforced Concrete*, ACI 318-89, American Concrete Institute, Detroit, Michigan.
- ACI, 1990, *Code Requirements for Nuclear Safety Related Concrete Structures*, ACI 349-90, American Concrete Institute, Detroit, Michigan.
- AISC, 1989, *Manual of Steel Construction, Allowable Stress Design*, Ninth Edition, American institute of Steel Construction, Chicago, Illinois.
- ANSI/AISC 1984, *American National Standard, Nuclear Facilities, Steel Safety Related Structures for Design Fabrication and Erection*, N690-1984, American Institute of Steel Construction, Chicago, Illinois.
- DeMaria, L. D., 1979, *Preliminary Engineering Study Report Contingent Irradiated Fuel Storage Facility*, UNI-1285, Rev. 0, United Nuclear Inc., Richland, Washington.
- Dobbin, K. D. and Hecht, S. L., 1995, "Resolution of Fuel Characterization Prestart Punchlist Item D Relating to the Height of the Cask Trailer with Respect to the Restraining Barrier," Memo No. 95kDD.001 to Plant Readiness Team, Westinghouse Hanford Company, Richland, Washington.
- DOE, 1993, Hanford Plant Standards, DOE Order 6430.1C, SDC-4.1, Rev. 12, *Standard Arch-Civil Design Criteria - Design Loads for Facilities*, U.S. Department of Energy, Richland Field Office, Richland, Washington.
- General Electric Co., 1952b, "Construction Specification, Project CA-512-R, 100-K Reactor Facilities; Reinforcing Steel for Concrete," Rev. 0, HW-4739, November 11, 1952.
- Gydesen, C. H., 1975, *Functional Design Criteria Supplemental N Reactor Irradiated Fuel Storage 105 KW*, UNI-410, Rev. 0, UNC Nuclear Industries, Richland, Washington.
- Gydesen, C. H., 1977, *Functional Design Criteria Supplemental N Reactor Irradiated Fuel Storage 105 KE*, UNI-108, Rev. 0, UNC Nuclear Industries, Richland, Washington.
- Hultgren, G. O., "Computer Model of Train Falling in Basin," Memo to T. L. Deobald, UNC Nuclear Industries, Richland, Washington.
- Mathsoft, 1993, *Mathcad 4.0 User's Guide*, Mathsoft Inc., Cambridge, Massachusetts.
- Meichle, R. H., 1994, *Safety Analysis Irradiated N Reactor Fuel*, WHC-SD-WM-SAR-062, Rev. 1, Westinghouse Hanford Company, Richland, Washington.
- Meichle, R. H., 1995, *Operations Safety Requirements, 100-KE and 100-KW Fuel Storage Basins*, WHC-SD-WM-OSR-006, Rev. 0b, Westinghouse Hanford Company, Richland, Washington.

- Nguyen, M., 1993, *Safety Analysis Report for Packaging (Onsite) Irradiated Fuel Cask Cars*, SD-RE-SAP-014, Rev. 1b, Westinghouse Hanford Company, Richland, Washington.
- Norris, E. V., 1975, "Rail Stop Design for 105KE, Job No. C33373," memo to C. H. Gydesen, Vitro Engineering, Richland, Washington.
- Swanson, 1993, *ANSYS User's Manual for Revision 5.0*, Swanson Analysis Systems, Inc., Houston, Pennsylvania.
- WHC, 1995, "Control Railroad Cars Entering 105-KE or 105-KW," Procedure No. 59/60-07-13, Rev. 8 (Draft), Westinghouse Hanford Company, Richland, Washington.
- WHC, 1995a, "Ship Ion Exchange Module from 100-K to Burial," Procedure No. 59/60-07-95, Rev 0 (New), Westinghouse Hanford Company, Richland, Washington.

APPENDIX A

K BASIN RAIL CONTROL HARDWARE STRUCTURAL CALCULATIONS

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 1 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winker Date 6-8-95
 (9) Checker Harvey Hunt Date 6-9-95

INTRODUCTION

The following calculations were performed on the K Basin rail control hardware using the Mathcad computer software. Some structural calculations were also performed using the ANSYS finite element program, with the results appropriately interspersed among the Mathcad calculations. The K Basin rail control system and hardware are described in the report text. Specific hardware, addressed below, includes the bumping post on the north rail spur, the south rail spur bumper and associated beam/column hardware, and the rail stops mounted to the south spur rails.

The calculation begins with a basic list of input parameters, which are common to the various analyses performed. For example, the design basis rail car impact involves a single car plus locomotive, with a total weight of 470,000 lb traveling at a velocity of 2 mph.

Input Parameters:

$$v_o = 2 \cdot \frac{\text{mi}}{\text{hr}} \quad v_o = 2.933 \cdot \frac{\text{ft}}{\text{sec}}$$

Max. impact velocity

$$W = 470000 \cdot \text{lbf}$$

Design basis train weight

$$g = 32.2 \cdot \frac{\text{ft}}{\text{sec}^2}$$

Accel. of gravity

$$KE = \frac{W \cdot v_o^2}{2 \cdot g}$$

$$KE = 6.28 \cdot 10^4 \cdot \text{ft} \cdot \text{lbf}$$

Kinetic energy of design basis impact

$$f_c = 3000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

K Basin concrete design strength

$$\phi_s = 0.85$$

Concrete shear strength reduction factor

$$E = 29 \cdot 10^6 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Carbon steel modulus of elasticity

$$\sigma_{yA36} = 36000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

A36 carbon steel min. yield stress

$$\sigma_{yA7} = 33000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

A7 carbon steel min. yield stress

$$f_s = 70000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Anchor bolt min. ultimate strength per K Basin Construction Spec. HW-4731

DESIGN CALCULATION

WHC-SD-SNF-008, Rev. 0

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 2 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker Shirley L. Lott Date 6-9-95

Elastic Impact:

The impact force is a function of the impact stiffness:

Once the mass (train) comes in contact with the spring (bumping post), the problem can be obtained by evaluating the response of a single-degree-of-freedom spring/mass system, knowing the peak velocity, v_o . If only the peak displacement/force in the spring is desired, an even simpler solution can be found by equating the maximum kinetic energy ($mv_o^2/2$) with the maximum potential energy in the spring ($lx^2/2$). Solving for the maximum force as a function of the spring constant, k :

$$F_{\max}(k) = \sqrt{2 \cdot k \cdot KE}$$

A curve showing the relationship between impact stiffness and maximum force is shown on the next page. A few representative values are shown below.

$$F_{\max}\left(10000 \cdot \frac{\text{lbf}}{\text{in}}\right) = 1.228 \cdot 10^5 \cdot \text{lbf}$$

$$F_{\max}\left(100000 \cdot \frac{\text{lbf}}{\text{in}}\right) = 3.882 \cdot 10^5 \cdot \text{lbf}$$

$$F_{\max}\left(1000000 \cdot \frac{\text{lbf}}{\text{in}}\right) = 1.228 \cdot 10^6 \cdot \text{lbf}$$

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 3 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-2-95
 (9) Checker Michael Ballant Date 6-9-95

$$k = 10000 \frac{\text{lbf}}{\text{in}}, 20000 \frac{\text{lbf}}{\text{in}}, 1 \cdot 10^6 \frac{\text{lbf}}{\text{in}}$$

The effective impact stiffness is a function of both the stiffness of the target (bumping post) and the impacting mass (rail car). An estimate of the stiffness of the bumping post was obtained by modeling the bumping post assembly using the ANSYS finite element code. The bumping post description was obtained from the manufacturer, Western-Cullen-Hayes (drawing # WA-100). The ANSYS model is shown on the next page. The model was composed of truss elements. A single force, in the direction of impact was applied as shown. Note from the second figure, that a displacement of 0.0123 in. was obtained for a force of 100,000 lbf. The corresponding stiffness is:

$$k_b = \frac{100000 \cdot \text{lbf}}{0.0123 \cdot \text{in}} \quad k_b = 8.13 \cdot 10^6 \frac{\text{lbf}}{\text{in}}$$

DESIGN CALCULATION

WHC-SD-SNF-DA-008, Rev. 0

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 4 of 27
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 5 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-1-95
 (9) Checker [Signature] Date 6-9-95

Because of the complexity of the geometry and having no drawing details, it is difficult to estimate the stiffness of the railcar. An approximate stiffness can be obtained from a railcar model found in the literature (Ref.: Sutton, A. and Lewis, J. H., "Elastic/Plastic Interaction of Rakes of Rail Vehicles," *Structural Impact and Crashworthiness*, V. 2 Conference Papers, Elsevier Applied Science Publishers, London and New York.) The railcar model is shown below. This railcar model is conservative in the sense that the K Basin well cars are "drop center" cars which are more flexible than a standard flat car.

FIG. 1. INDIVIDUAL VEHICLE MODEL

Assuming the entire train mass is concentrated between the car and locomotive (weights are approximately equal), the composite stiffness of the railcar can be used as the impact stiffness value. Initially, the properties of the "buffers" (draft gear) in line with couplers was not known. Thus, the max. stiffness of a single coupler was used for k_1 as shown. The composite stiffness $k_c = 1/(1/k_1 + 1/k_2 + \dots)$. For a single railcar,

$$k_2 = 3.67 \cdot 10^6 \frac{\text{lb}}{\text{in}} \quad k_3 = k_2 \quad k_4 = k_2 \quad k_5 = k_2$$

$$k_1 = 1.68 \cdot 10^6 \frac{\text{lb}}{\text{in}}$$

$$k_c = \frac{1}{\left(\frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \frac{1}{k_4} + \frac{1}{k_5} \right)}$$

$$k_c = 5.934 \cdot 10^5 \frac{\text{lb}}{\text{in}}$$

Railcar composite stiffness. Note that the truck (bogie) to frame flexibility is conservatively ignored.

DESIGN CALCULATION

WHC-SD-SNF-DA-008, Rev. 0

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 6 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker SPJ/eng - 6-1-95 Date 6-9-95

The railcar/bumping-post composite stiffness is therefore

$$k_t = \frac{1}{\left(\frac{1}{k_c} + \frac{1}{k_b}\right)}$$

$$k_t = 5.53 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

Substituting in this stiffness into the Fmax equation:

$$F_{\max}(k_t) = 9.13 \cdot 10^5 \cdot \text{lbf} \quad \text{Peak impact force prediction.}$$

This peak impact force prediction was made initially before verifying that the rail car is equipped with draft gear, which will soften the impact force. An example of a nonlinear draft gear force/deflection response is shown on the figure on the previous page ("Single Coupler"). A drawing of one of the 2-axle, drop-center rail cars used for transporting fuel in the K Basin was located in the Hanford rail maintenance shop files (Pacific Car and Foundry, Dwg. # A 326). This drawing called out a "Miner Friction Draft Gear Class A-22XB). The draft gear manufacturer, Miner Enterprises, was contacted and the force/deflection properties of the Miner A-22XB draft gear was obtained. A copy is shown on the next page. According to the Hanford railroad maintenance shop, similar draft gear is found on the locomotives. However, the energy absorbed by the locomotive draft gear was conservatively ignored. Note that the Miner draft gear response is close to linear. As shown on the force/deflection plot, the draft gear stiffness can be approximated by a spring stiffness, k_d . The linear approximation is conservative in that it results in less energy absorption, i.e. less area under the force/deflection curve than the actual draft gear data.

$$k_d = \frac{295000 \cdot \text{lbf}}{2.5 \cdot \text{in}}$$

$$k_d = 1.18 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

7 of 29

DYNAMIC CLOSURES

BUFF AND DRAFT

MINER A-22-XL DRAFT GEAR

MINER A-22-XB DRAFT GEAR

NOV. 28, 1967

A-8

DRG. NO. 24392

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 8 of 27
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

Factoring in the draftgear flexibility results in a revised total impact stiffness of

$$k_t = \frac{1}{\left(\frac{1}{k_t} + \frac{1}{k_d} \right)}$$

$$k_t = 9.725 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}}$$

Using the impact force/stiffness relationship derived above, the revised maximum impact force can be obtained:

$$F_{\max}(k_t) = 3.828 \cdot 10^5 \cdot \text{lbf}$$

Thus, by accounting for the additional energy absorbed by the draft gear, the peak impact force is reduced by over a factor of 2. This conclusion emphasizes the importance of assuring that the rail cars, used on the north rail spur, be equipped with draft gear. Note that the maximum impact force prediction exceeds the draftgear maximum force of 295,000 lb given on the Miner data sheet. This raises the possibility that the draft gear could "bottom out" and become much stiffer at loads above 295,000 lb, since no data is shown beyond 295,000 lb. However, $F_{\max}$ is only 23% higher than the data and this potential nonconservatism should be outweighed by the conservatism of ignoring the flexibility of the locomotive and locomotive draftgear.

The above impact force prediction conservatively ignores the draft gear on the other end of the railcar and the draft gear on the locomotive. The type of draft gear on the locomotive is not known, and was conservatively ignored. The draft gear on the opposite end of the railcar can be accounted for by considering a two-mass model (230,000 lb railcar and a 240,000 lb locomotive), with a single draft gear spring between (k_d). The impact response can be obtained by a half-cycle response of a two-mass, two-spring model. The model fundamental frequency can be obtained using the "static deflection method" (Ref.: Jacobsen & Ayre, *Engineering Vibrations*, Sect. 2-5):

$$W_1 = 240000 \cdot \text{lbf}$$

$$W_2 = 230000 \cdot \text{lbf}$$

$$k_d = 1.18 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 9 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

$$\Delta_2 = \frac{W_1 + W_2}{k_t} \quad \Delta_2 = 4.833 \cdot \text{in}$$

$$\Delta_1 = \frac{W_1}{k_d} + \Delta_2 \quad \Delta_1 = 6.867 \cdot \text{in}$$

$$\omega = \sqrt{\frac{W_1 \cdot \Delta_1 + W_2 \cdot \Delta_2}{W_1 \cdot \Delta_1^2 + W_2 \cdot \Delta_2^2} \cdot g}$$

$$\omega = 7.993 \cdot \frac{1}{\text{sec}}$$

The half-cycle velocity response can be expressed as $v = v_o \cos \omega t$ and the corresponding acceleration is expressed as $a = -v_o \omega \sin \omega t$. Thus, the peak acceleration of the two masses is

$$a_{\max} = v_o \cdot \omega$$

$$a_{\max} = 281.366 \cdot \frac{\text{in}}{\text{sec}^2}$$

The peak impact force is in equilibrium with the inertial forces:

$$F_{\max} = \frac{W_1 + W_2}{g} \cdot a_{\max}$$

$$F_{\max} = 3.422 \cdot 10^5 \cdot \text{lbf}$$

Recall, from above,

$$F_{\max}(k_t) = 3.828 \cdot 10^5 \cdot \text{lbf}$$

Thus, accounting for the additional draft gear reduces the impact force by about 10%.

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 10 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

BUMPING POST STRUCTURAL ADEQUACY

The bumping post member forces, stresses, and constraint reactions can be obtained by ratioing up the ANSYS results, generated for a force of 100,000 lbs.

Member Force/Stress Results:

***** POST1 ELEMENT TABLE LISTING *****		
STAT	CURRENT	CURRENT
ELEM	FORCE	STRESS
1	-45853.	-3899.1
2	-43170.	-3670.9
3	34025.	3780.6
4	31356.	3464.0

Reaction Force Results:

***** POST1 TOTAL REACTION SOLUTION LISTING *****						
LOAD STEP= 1 SUBSTEP= 1						
TIME= 1.0000 LOAD CASE= 0						
THE FOLLOWING X, Y, Z SOLUTIONS ARE IN GLOBAL COORDINATES						
NODE	FX	FY	FZ	MX	MY	MZ
1	34049.	25217.	17530.	0.00000E+00	0.00000E+00	0.00000E+00
2	31112.	23042.	-19099.	0.00000E+00	0.00000E+00	0.00000E+00
3						0.00000E+00
4						0.00000E+00
5						0.00000E+00
6	18485.	-25605.	-12666.	0.00000E+00	0.00000E+00	0.00000E+00
7	16354.	-22653.	14234.	0.00000E+00	0.00000E+00	0.00000E+00
TOTAL VALUES						
VALUE	0.10000E+06	-0.10914E-10	-0.54570E-11	0.00000E+00	0.00000E+00	0.00000E+00

Note: Symmetry of the results does not occur because the bumping post center line is slightly offset from the centeline of the tracks.

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 11 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

Note that a max. stress of 3899.1 psi occurs in Member #1, for a bumping post force of 100,000 lb. Using the estimated impact force of 342,200 lb ($F_{max(kt)}$), the stress becomes

$$\sigma_1 = \frac{F_{max} \cdot 3899.1 \text{ lbf}}{100000 \text{ lbf} \cdot \text{in}^2}$$

$$\sigma_1 = 1.334 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}^2}$$

For an "Abnormal" load condition, ANSI/AISC N-690 specifies a stress limit coefficient of 1.6. For the basic stress allowable of $0.6F_y$, the stress allowable becomes $1.6 \times 0.6F_y = 34.6$ ksi (assuming A36 steel), which is well above the predicted member stress. Since Member #1 is in compression, the compression allowable specified in Q1.5.1.3 of N690 applies:

Beam Properties:

Beam type: 8WF40 (Ref.: Western Cullen Hayes Dwg. # WA-100)

$$A_b = 11.76 \cdot \text{in}^2$$

$$r_{min} = 2.04 \cdot \text{in}$$

$$I_{min} = 49.0 \cdot \text{in}^4$$

$$I_{max} = 146.3 \cdot \text{in}^4$$

$$r_{max} = 3.53 \cdot \text{in}$$

$$r = r_{min}$$

$$l = 68.01 \cdot \text{in}$$

Using Eq. Q1.5-1,

$$C_c = \sqrt{\frac{2 \cdot \pi^2 \cdot E}{\sigma_y A36}}$$

$$K = 1.0$$

Assume pinned ends

DESIGN CALCULATION

WHC-SD-SNF-DA-008, Rev. 0

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 12 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

$$F_a = \frac{1 - \left(\frac{K \cdot l}{r}\right)^2}{2 \cdot C_c^2} \cdot \sigma_{yA36} \quad F_a = 1.97 \cdot 10^4 \cdot \frac{\text{lb}}{\text{in}^2}$$

$$\left(\frac{5}{3}\right) + \frac{3 \cdot K \cdot l}{8 \cdot C_c} - \frac{\left(\frac{K \cdot l}{r}\right)^3}{8 \cdot C_c^3}$$

Using the stress limit coefficient of 1.6, the safety margin for member1 becomes

$$MS = \frac{1.6 \cdot F_a}{\sigma_1} - 1 \quad MS = 1.362$$

indicating a positive margin against the N690 code allowable.

The most highly stressed tensile member is element 3, which has an allowable stress of 1.6(0.6fy), which results in the following positive safety margin:

$$\sigma_3 = \frac{F_{\max}}{100000 \cdot \text{lb}} \cdot 3780.6 \cdot \frac{\text{lb}}{\text{in}^2} \quad \sigma_3 = 1.294 \cdot 10^4 \cdot \frac{\text{lb}}{\text{in}^2}$$

$$MS = \frac{1.6 \cdot 0.6 \cdot \sigma_{yA36}}{\sigma_3} - 1 \quad MS = 1.671$$

The bumping post drawing obtained from the manufacturer does not provide all of the details such as weld configurations and weld sizes, which is considered by the manufacturer to be proprietary information. In discussing the capacity of the bumping post with the manufacturer rep., N. Barr, he stated that the Type WA bumping post load-to-yield is 891,000 lb and the load to failure is 1,490,000 lb. Unfortunately, the manufacturer does not provide documented evidence of these values. If the Member #1 predicted stress is ratioed with respect to yield stress, an estimate of the load to yield can be obtained:

$$F_y = \frac{\sigma_{yA36}}{\sigma_1} \cdot F_{\max}$$

$$F_y = 9.233 \cdot 10^5 \cdot \text{lb}$$

Since F_y is very close to the manufacturer's stated value of load-to-yield, this implies that Member #1 is the critical member of the bumping post (i.e. first to yield), and that failure would not be expected at a member connection (e.g. at a weld) for a Hayes Type WA bumping post.

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 13 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker W. W. Winkler Date 6-9-95

The bumping posts installed in the basins are actually *modified* type WA bumping posts. See Dwg. Nos. H-1-45071 and 45072. The standard bumping post are welded to two horizontal members which fit under the rails, between railroad ties. The basin rails are on concrete floors and are attached to the floors with embedded bolts (no railroad ties). Therefore, the standard WA model would not fit into the basin rails. In the modified design the horizontal members are shorter and fit between the tracks. In both designs, the posts are bolted to the rails with 10 bolts.

Standard Hayes Type WA:

Modified Type WA:

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 14 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-91
 (9) Checker [Signature] Date 6-9-91

The original design is stronger in the sense that it is captured under the rails. However, the lower portion of the modified bumpers are embedded in concrete up to the top of the rails, as shown below. This concrete embedment adds considerable lift resistance on the impact side of the bumping post, as indicated below.

1 THIS AREA REQUIRING REMOVAL OF EXISTING CONCRETE FOR PLACEMENT OF BUMPING POST ASSY. AFTER PLACEMENT OF ASSY. CONCRETE WILL BE REPLACED PER THE FOLLOWING REQUIREMENTS.

For the modified post design, the concern is that there is sufficient lift resistance on the two front bars (impact side). The lift resistance is a composite of the capacity of the member/rail bolted connection and the concrete embedment capacity.

From Dwg. No. H-1-45071 and Hayes Dwg. No. WA-100, the tensile members are attached to the rails with two 1" Dia. H-T bolts. Per telecon with the manufacturer (Westerns-Cullens-Hayes, Mr. Norman Barr) the bolts are Grade 8. Grade 8 bolts with a tensile strength of 150 ksi, correspond to A 490 tensile strength. Per AISC N-690, the normal condition shear stress allowable is 40 ksi (bearing type connection, no threads in shear plane). For an abnormal load category, the stress limit coefficient is limited to 1.4 (footnote g, Table Q1.5.7.1). Thus, the maximum allowable for an A 490 bolt is $1.4(40) = 56$ ksi. Thus, the total uplift resistance of the four front bolts is

$$Cap_b = 56000 \cdot \frac{lbf}{in^2} \cdot 4 \cdot \pi \cdot \frac{(1 \cdot in)^2}{4}$$

$$Cap_b = 1.759 \cdot 10^5 \cdot lbf$$

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 15 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

The connection also derives considerable strength from the concrete embedment. The front legs of the bumping post are welded to an angle iron, which bridges between the legs. Following installation, the space between the tracks was filled with concrete (Ref. Dwg. # H-1-45071 and H-1-45072). The concrete shear allowable is

$$v_c = 2 \cdot \sqrt{f_c} \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2} \quad v_c = 109.545 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

The uplift resistance of the concrete can be conservatively approximated by the following assumptions: (1) Assume the entire resistance is due to shear stresses in the concrete, i.e. no credit taken for bonding to the old concrete or inertial resistance. (2) No credit is taken for the shear resistance of the steel connector hardware, which is captured underneath the track flange. (3) Assume, in the direction of the tracks, an effective slab width equal to the slab thickness (ACI 349, Para. 11.11). This results in a two-way, rectangular shear section of dimension, d , in the track direction and a dimension equal to the track gage (4 ft, 8 in.) transverse to the tracks. The geometry of the concrete fill is shown below (Ref. Dwg H-1-21073). Note that the track height is 5.625 in. and the shear depth next to the tracks is closer to 3 in.

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 16 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

From the above dimensions, the concrete shear area is estimated as

$$A_s = 2 \cdot (56.5 \cdot \text{in} \cdot 5.625 \cdot \text{in} + 5.625 \cdot \text{in} \cdot 3 \cdot \text{in})$$

$$A_s = 669.375 \cdot \text{in}^2$$

The resulting concrete shear resistance is

$$\phi = 0.85$$

$$V_c = A_s \cdot v_c \cdot \phi$$

$$V_c = 6.233 \cdot 10^4 \cdot \text{lbf}$$

The total uplift resistance is

$$F_u = V_c + C_{apb}$$

$$F_u = 2.383 \cdot 10^5 \cdot \text{lbf}$$

From the ANSYS results, above, the resultant out-of-plane reaction (diagonal uplift force), for a 100,000 lb impact force is

$$F_x = 18485 \cdot \text{lbf} + 16354 \cdot \text{lbf}$$

$$F_y = 25605 \cdot \text{lbf} + 22653 \cdot \text{lbf}$$

$$F_t = \sqrt{F_x^2 + F_y^2} \quad F_t = 5.952 \cdot 10^4 \cdot \text{lbf}$$

$$F_{ul} = \frac{F_{\max}}{100000 \cdot \text{lbf}} \cdot F_t \quad F_{ul} = 2.037 \cdot 10^5 \cdot \text{lbf}$$

Since the uplift resistance, F_u , is greater than the predicted impact uplift force, F_{ul} , a positive safety margin is predicted:

$$MS = \frac{F_u}{F_{ul}} - 1 \quad MS = 0.17$$

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 17 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker W. J. Agnew Date 6-9-95

SOUTH RAIL SPUR BUMPER EVALUATION

The south rail spur in both the KE and KW basins has a Hayes bumper mounted to a beam on Column Line 13 traversing between Column Lines E and F (Ref.: Dwg. # H-1-34853). The bumper was manufactured by Western-Cullens-Hayes. The bumper properties are shown on the next page. Note that the bumper spring rate is 36,700 lb/in and has a total travel of 6.22 in., resulting in a capacity of 220,000 lb. This effective spring rate will be reduced somewhat by the flexibility of the railroad car, the beam column, and the railroad car draft gear. An ANSYS model of the beam/column assembly was constructed, as shown below.

The horizontal bumper beams in 105-KW and 105-KE are different (WF14x119 versus WF18x96). Only the shallower beam (105-KW) was modelled and evaluated. The base of each column was fixed against both translation and rotation (four-bolt anchor plate). The top of the columns was assumed to be pinned at the elevation of the first row of beam connections as a simplification of the field configuration. Loads of 50,000 lb were applied at the edge bolt locations of the bumper (nodes 4 & 6) as shown. A corresponding max. displacement of 0.181 in. was calculated as shown, resulting in an approximate spring rate of

$$k_b = \frac{100000 \text{ lbf}}{0.181 \text{ in}}$$

$$k_b = 5.525 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 18 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker MWeymiller Date 6-9-95

BUMPER SPRING PROPERTIES:

Ref.-- Western-Cullen-Hayes Dwg. No. SP-1

SPRING SPECIFICATIONS	
O.D.	$11\frac{7}{16} \pm \frac{1}{4}$ "
Free Ht.	$25\frac{1}{2}$ " Max. } 6" TRAVEL
Solid Ht.	$19.28 \pm \frac{7}{32}$ " }
Bar Dia.	$2\frac{1}{2}$ " $ENERGY = \frac{220,000 (9/2)}{2} = 55,000 \text{ FT-LB}$
Spring Rate ea	$12,222 \text{ lb/in.} \pm 10\% \text{ ea.}$ $36,666 \text{ lb/in. Total}$
Solid Cap. ea.	$76,000 \text{ lb. ea.}$ $220,000 \text{ lb. Total}$
Mat'l.	AISI 4160 ST'L
No. Req'd.	3 per unit
Ends	Ground
Mag. Part. Insp.	100%
Mfg. per	ASTM A-125-73

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 19 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker Shirley Hall Date 6-9-95

From above, the railcar and draftgear flexibilities were estimated as

$$k_c = 5.934 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}} \quad k_d = 1.18 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

As noted on the previous page, the bumper stiffness is

$$k_{\text{bmp}} = 36700 \cdot \frac{\text{lbf}}{\text{in}}$$

The railcar/draftgear/beam/bumper composite flexibility estimate is therefore

$$k_t = \frac{1}{\left(\frac{1}{k_c} + \frac{1}{k_d} + \frac{1}{k_b} + \frac{1}{k_{\text{bmp}}} \right)}$$

$$k_t = 2.55 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}}$$

From above, the maximum impact force, F_{max} , was derived as a function of the impact stiffness, k ($F_{\text{max}} = \text{SQRT}(2k\text{KE})$), where KE is the impact energy. For the 2 mph bumper impact, the peak force estimate is

$$F_{\text{max}}(k_t) = 1.96 \cdot 10^5 \cdot \text{lbf}$$

This impact force estimate can be reduced somewhat by considering the draftgear at the other end of the rail car. Following the same procedure as for the bumping post evaluation above:

$$W_1 = 240000 \cdot \text{lbf}$$

$$W_2 = 230000 \cdot \text{lbf}$$

$$k_d = 1.18 \cdot 10^5 \cdot \frac{\text{lbf}}{\text{in}}$$

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 20 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

$$\Delta_2 = \frac{W_1 + W_2}{k_t} \quad \Delta_2 = 18.432 \cdot \text{in}$$

$$\Delta_1 = \frac{W_1}{k_d} + \Delta_2 \quad \Delta_1 = 20.466 \cdot \text{in}$$

$$\omega = \sqrt{\frac{W_1 \cdot \Delta_1 + W_2 \cdot \Delta_2}{W_1 \cdot \Delta_1^2 + W_2 \cdot \Delta_2^2}} \cdot g$$

$$\omega = 4.449 \cdot \frac{1}{\text{sec}}$$

The half-cycle velocity response can be expressed as $v = v_0 \cos \omega t$ and the corresponding acceleration is expressed as $a = -v_0 \omega \sin \omega t$. Thus, the peak acceleration of the two masses is

$$a_{\max} = v_0 \cdot \omega \quad a_{\max} = 156.595 \cdot \frac{\text{in}}{\text{sec}^2}$$

$$F_{\max} = \frac{W_1 + W_2}{g} \cdot a_{\max} \quad F_{\max} = 1.905 \cdot 10^5 \cdot \text{lb}_f$$

Note that the predicted maximum force is less than the bumper capacity of 220,000 lb. Therefore, the bumper should not "bottom out" and the spring flexibility calculation approach is valid.

ANSYS Model Element
and Node Numbers:

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 11 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker MR Wagnell Date 6-9-95

The beam model element stresses and reaction forces for the 100,000 lb loading are shown below from the ANSYS analysis.

Beam Bending Stresses:

ELEM	SBENDYI	SBENDYJ	SBENDZI	SBENDZJ
1	4857.6	-2165.4	0.00000E+00	-2165.4
2	-2165.2	0.29762E-12	0.00000E+00	-0.29762E-12
3	2698.5	-1202.7	0.00000E+00	-1202.7
4	-1202.9	0.00000E+00	0.00000E+00	0.00000E+00
5	0.00000E+00	0.00000E+00	16.727	-12880.
6	0.00000E+00	0.00000E+00	-16443.	-14.858
7	0.00000E+00	0.00000E+00	-12880.	-16443.

Beam Shear Results (lbf):

ELEM	SHRYI	SHRYJ	SHRZI	SHRZJ
1	-57351.	-57351.	0.00000E+00	0.00000E+00
2	6936.4	6936.4	0.00000E+00	0.00000E+00
3	-31858.	-31858.	0.00000E+00	0.00000E+00
4	3853.8	3853.8	0.00000E+00	0.00000E+00
5	0.00000E+00	0.00000E+00	-64288.	-64288.
6	0.00000E+00	0.00000E+00	35712.	35712.
7	0.00000E+00	0.00000E+00	-14288.	-14288.

***** POST1 TOTAL REACTION SOLUTION LISTING *****

LOAD STEP= 1 SUBSTEP= 1
 TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

NODE	FX	FY	FZ	MX	MY	MZ
1	-57351.	0.00000E+00	0.00000E+00	0.00000E+00	-3085.1	0.19001E+07
3	-6936.4	0.00000E+00	0.00000E+00			
5	-31858.	0.00000E+00	0.00000E+00	0.00000E+00	2740.3	0.10556E+07
7	-3853.8	0.00000E+00	0.00000E+00			

TOTAL VALUES

VALUE	-0.10000E+06	0.00000E+00	0.00000E+00	0.00000E+00	-344.74	0.29557E+07
-------	--------------	-------------	-------------	-------------	---------	-------------

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 12 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkler Date 6-8-95
 (9) Checker _____ Date 6-9-95

The predicted stresses/forces are obtained by ratioing with respect to ANSYS analysis force (100,000 lb) and the predicted impact force:

$$R = \frac{F_{\max}}{100000 \text{ lbf}}$$

$$R = 1.905$$

Note that the maximum bending stresses occur in the horizontal beam (elements 6 and 7). The peak bending stress is

$$s_{\text{bend}} = 16443 \frac{\text{lbf}}{\text{in}^2} R$$

$$s_{\text{bend}} = 3.132 \cdot 10^4 \frac{\text{lbf}}{\text{in}^2}$$

For an abnormal load condition AISC/N690 specifies a stress limit coefficient of 1.6. For a normal condition bending allowable of $0.6F_y$, the abnormal bending stress allowable for A36 steel is

$$s_{\text{bend allow}} = 1.6 \cdot 0.6 \cdot 36000 \frac{\text{lbf}}{\text{in}^2}$$

resulting in the following positive safety margin:

$$MS = \frac{s_{\text{bend allow}}}{s_{\text{bend}}} - 1 \quad MS = 0.103$$

The beam/column connections involves four 1-1/8 in. , A325 bolts, as shown below (Ref.: Dwg. # H-1-34447 & H-1-34761).

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 23 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker Shirley H. Hitt Date 6-9-95

The predicted max. end shear in the bumper beam occurs at node 2 (reacted as tension in bolts)

$$V_{\max} = R \cdot 64288 \cdot \text{lbf}$$

$$V_{\max} = 1.225 \cdot 10^5 \cdot \text{lbf}$$

The allowable tension stress in an A325 bolt is 44 ksi. Using a tensile stress limit coefficient of 1.6 for an abnormal load condition, per AISC/N690, the capacity of four bolts is

$$S_{\text{allow}} = 1.6 \cdot 44000 \cdot \frac{\text{lbf}}{\text{in}^2} \cdot 4 \cdot \pi \cdot \frac{1}{4} \cdot \text{in}^2$$

$$S_{\text{allow}} = 2.212 \cdot 10^5 \cdot \text{lbf}$$

Thus, the bolt stress predictions result in a positive safety margin:

$$MS = \frac{S_{\text{allow}}}{V_{\max}} - 1$$

$$MS = 0.806$$

The maximum member shear stress occurs in element 5 ($V = 64,288 \text{ lb}$). The effective shear area of element 5 (depth times web thickness) is

$$A_s = 14.5 \cdot \text{in} \cdot .570 \cdot \text{in}$$

$$A_s = 8.265 \cdot \text{in}^2$$

Using a stress limit coefficient of 1.4 (Table Q1.5.7.1 of AISC/N690) and a normal stress limit of $0.4F_y$, the allowable shear stress is

$$F_v = 1.4 \cdot 0.4 \cdot \sigma_{yA36}$$

$$F_v = 2.016 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}^2}$$

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 24 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

Which results in the following positive safety margin for beam/column shear stresses:

$$MS = \frac{F_v}{\left(\frac{R \cdot 65338 \cdot \text{lb} \cdot \text{f}}{A_s} \right)} - 1$$

$$MS = 0.339$$

The base of the columns are connected to reinforced concrete columns which are built into the basin walls as shown below (Ref.: Dwgs. H-1-21054 & H-1-21077). Note that the 1-1/2 in. anchor bolts are positioned next to the column rebar and are embedded 3.5 ft. At the bottom of the embedment, each pair is welded to a 12-in. long bar. In this configuration, the anchor bolts can be considered as rebar dowels and the shear capacity of the anchor plate/concrete joint can be evaluated as a shear-friction joint. Section B.6.2.2.2 of ACI 349 specifies that for a grouted anchor plate, the friction coefficient shall be 0.55 and a ϕ factor of 0.85 shall be used to evaluate the shear friction strength. The K Basin steel construction spec. (HW-4731) does not designate a bolt material type but specifies a minimum bolt tensile strength of 70,000 psi. By comparing this ultimate strength requirement with other carbon steels, a conservative estimate of 33,000 psi yield strength was assumed for the shear friction calculation.

$$A_{vf} = \frac{4 \cdot \pi \cdot (1.5 \text{ in})^2}{4}$$

$$\phi = 0.85$$

$$f_y = 33000 \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

$$\mu = 0.55$$

$$F_c = 26300 \cdot \text{lb} \cdot \text{f}$$

Col. E-13 Dead
Weight Load
(Ref.:
WHC-SD-NO31--
SA-002, App.
B-121)

From ACI 349, Para. 11.7.4.1,

$$\phi V_n = (A_{vf} f_y + F_c) \cdot \mu \cdot \phi$$

$$\phi V_n = 1.213 \cdot 10^5 \cdot \text{lb} \cdot \text{f}$$

Note that the shear strength estimate includes the column dead weight, as permitted by ACI 349, Para. 11.7.7.

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 25 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker SRW/ajc Date 6-9-95

From the ANSYS model reaction results, given above, the predicted column reactions at Nodes 1 and 5 are obtained, resulting in positive safety margins for the column base shears:

$$R_1 = R \cdot 57351 \cdot \text{lbf} \quad R_1 = 1.092 \cdot 10^5 \cdot \text{lbf}$$

$$MS = \frac{\phi V_n}{R_1} - 1 \quad MS = 0.111 \quad \text{Column Line E}$$

$$R_5 = R \cdot 31858 \cdot \text{lbf} \quad R_5 = 6.068 \cdot 10^4 \cdot \text{lbf}$$

$$MS = \frac{\phi V_n}{R_5} - 1 \quad MS = 1 \quad \text{Column Line F}$$

The anchor bolts in the column base are also subjected to tension due to the column bending moment. The max. moment of 1,900,000 in-lb occurs at the base of Col. E-13 (Node 1 reaction, above). Conservatively ignoring the column dead weight, the bolt tension from the bending moment can be estimated as:

$$A_b = \frac{\pi (1.5 \cdot \text{in})^2}{4}$$

$$f_t = \frac{1.9 \cdot 10^6 \cdot \text{in} \cdot \text{lbf}}{29 \cdot \text{in} \cdot 2 \cdot A_b}$$

$$f_t = 1.854 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}^2}$$

From ANSI/AISC N690, Para. Q1.6.3, the tension allow. for A307 bolts with shear is

$$f_v = \frac{R_5}{4 \cdot A_b} \quad f_v = 8.585 \cdot 10^3 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$F_t = 26000 \cdot \frac{\text{lbf}}{\text{in}^2} - 1.8 \cdot f_v \quad F_t = 1.055 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Using the N690 abnormal stress coef. of 1.6, results in a negative safety margin for bolt tension:

$$MS = \frac{1.6 \cdot F_t}{f_t} - 1 \quad MS = -0.09$$

This marginal result for the column anchor bolts raises the possibility of an anchor bolt failure. An anchor bolt failure does not necessarily mean roof collapse because vertical column support is maintained. If the column base moves the railcar wheels will eventually impact the rail stops. The column base potential movement is addressed below. Calculations were also performed to address the possibility of a propagating failure for the structural members adjacent to Column E-13.

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 26 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-26-95
 (9) Checker Harry R. [Signature] Date 6-26-95

The distances associated with a railcar impact are shown below. These distances were extracted from Dwg. Nos. H-1-34853, H-1-3610, H-1-34447, H-1-34761, Pacific Car & Foundry Dwg. A 326, plus field measurements.

Note that the distance from the edge of the wheel to the end of the coupler has an approximate range from 29 to 32 inches. The 32-in. distance came from the Pacific Car and Foundry drawing for Car HO-10B-3631, which is one of the well cars used for the basins. The well cars are kept roped off, due to contamination. Measurements were made on similar cars, which ranged down to 29 in. Thus, the 29 to 32-in. range appears to be reasonable. Therefore, the distance between the railcar wheels and railstops, at impact initiation, is approximately

Lower Bound:

$$d_{lb} = 6 \text{ in}$$

Upper Bound:

$$d_{ub} = 9 \text{ in}$$

Thus, the wheels are predicted to travel a distance ranging from about 6 to 9 in. before impacting the rail stops, after bumper impact initiation. After impact initiation, the bumper springs and railroad car draft gear will begin to compress. This compression distance will bring the wheels closer to the railstop, as shown below.

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 27 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-26-95
 (9) Checker [Signature] Date 6-26-95

The impact force associated with column base capacity is approximately

$$F_{is} = F_{max} \left(\frac{1.6 \cdot F_t}{f_t} \right) \quad F_{is} = 1.734 \cdot 10^5 \cdot \text{lbf}$$

$$\delta = \frac{F_{is}}{k_t} \quad \delta = 6.8 \cdot \text{in} \quad \text{Impact deformation when shear capacity reached}$$

Since δ is greater than d_b , it is possible for the railstop to be impacted by the wheels before reaching the column capacity. The max. wheel travel before reaching the railstop is $9 - 6.8 = 2.2$ in. Thus, the upper bound column base movement prediction is about two inches.

Another item of interest is the impact velocity which would keep the impact force below the column base capacity:

$$KE_s = \frac{F_{is} \cdot \delta}{2}$$

$$v = \sqrt{\frac{2 \cdot KE_s \cdot g}{W}} \quad v = 1.769 \cdot \frac{\text{mi}}{\text{hr}}$$

Thus, if the impact velocity is reduced to 1.75 mi/hr, the capacity would not be exceeded. Although the column base loading exceeds the allowable capacity for a 2 mi/hr impact, a significant amount of energy is absorbed before the railstops are impacted. The energy remaining to be absorbed by the railstops is

$$\delta KE = KE - \frac{W \cdot v^2}{2 \cdot g} \quad \delta KE = 1.366 \cdot 10^4 \cdot \text{ft} \cdot \text{lbf}$$

$$v = \sqrt{\frac{2 \cdot \delta KE \cdot g}{W}} \quad v = 0.933 \cdot \frac{\text{mi}}{\text{hr}}$$

The railstops are very rigid, but the wheel-to-bed hardware connection is relatively flexible. On page 4, the railcar model shown, has an estimated wheel truck flexibility of 44,000 lb/in. Using this value for the impact stiffness, the peak wheel stop impact force can be estimated:

$$k = 44000 \cdot \frac{\text{lbf}}{\text{in}}$$

$$F_{max}(k) = \sqrt{2 \cdot k \cdot \delta KE} \quad F_{max}(k) = 1.201 \cdot 10^5 \cdot \text{lbf}$$

This impact force prediction is compared with the railstop capacity below.

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 27 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

The impact force associated with column base capacity is approximately

$$F_{is} = F_{\max} \left(\frac{1.6 \cdot F_t}{f_t} \right) \quad F_{is} = 1.734 \cdot 10^5 \cdot \text{lbf}$$

$$\delta = \frac{F_{is}}{k_t} \quad \delta = 6.8 \cdot \text{in} \quad \text{Impact deformation when shear capacity reached}$$

Thus, a more reasonable wheel travel distance estimate is

$$d_{lb} = d_{lb} - \delta \quad d_{lb} = 3.77 \cdot \text{in}$$

$$d_{ub} = d_{ub} - \delta \quad d_{ub} = 6.77 \cdot \text{in}$$

Another item of interest is the impact velocity which would keep the impact force below the column base capacity:

$$KE_s = \frac{F_{is} \cdot \delta}{2}$$

$$v = \sqrt{\frac{2 \cdot KE_s \cdot g}{W}} \quad v = 1.769 \cdot \frac{\text{mi}}{\text{hr}}$$

Thus, if the impact velocity is reduced to 1.75 mi/hr, the capacity would not be exceeded. Although the column base loading exceeds the allowable capacity for a 2 mi/hr impact, a significant amount of energy is absorbed before the railstops are impacted. The energy remaining to be absorbed by the railstops is

$$\delta KE = KE - \frac{W \cdot v^2}{2 \cdot g} \quad \delta KE = 1.366 \cdot 10^4 \cdot \text{ft} \cdot \text{lbf}$$

$$v = \sqrt{\frac{2 \cdot \delta KE \cdot g}{W}} \quad v = 0.933 \cdot \frac{\text{mi}}{\text{hr}}$$

The railstops are very rigid, but the wheel-to-bed hardware connection is relatively flexible. On page 4, the railcar model shown, has an estimated wheel truck flexibility of 44,000 lb/in. Using this value for the impact stiffness, the peak wheel stop impact force can be estimated:

$$k = 44000 \cdot \frac{\text{lbf}}{\text{in}}$$

$$F_{\max}(k) = \sqrt{2 \cdot k \cdot \delta KE}$$

$$F_{\max}(k) = 1.201 \cdot 10^5 \cdot \text{lbf}$$

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 28 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

RAIL STOP CAPACITY

There are two railstops on the south spur of the tracks. The south track railstop is an older design, connected to the rail with four A307 bolts (Dwg. No. H-1-5610). The newer, north track railstop is connected to the rail with eight A490 bolts (Dwg. Nos. H-1-34447 & H-1-34761). Capacity calculations for these railstops follows below.

8-Bolt Configuration:

A490 Bolt Capacity (double shear, AISC/N690 stress lim. coef. = 1.4)

$$A_b = \frac{\pi (1 \text{ in})^2}{4}$$

$$V_{A490} = 28000 \cdot \frac{\text{lb} \cdot \text{f}}{\text{in}^2} \cdot A_b \cdot 1.4 \cdot 2$$

A490 Shear Allow. = 28 ksi per
Table Q.1.5.2 of AISC/N690
(Bearing connection, slippage OK)

$$V_{A490} = 6.158 \cdot 10^4 \cdot \text{lb} \cdot \text{f}$$

$$P_e(P) = \frac{19.375 \cdot P}{2 \cdot \left(21 + 15 \cdot \frac{15}{21} + 9 \cdot \frac{9}{21} + 3 \cdot \frac{3}{21} \right)}$$

$$P_s(P) = \frac{P}{8}$$

$$P = 100000$$

$$P = \text{root} \left(\sqrt{P_e(P)^2 + P_s(P)^2} - 61580, P \right)$$

$$P = 2.075 \cdot 10^5$$

DESIGN CALCULATION

(1) Drawing H-1-45071 & H-1-45072 (2) Doc. No. _____ (3) Page 29 of 29
 (4) Building 105-KE, 105-KW (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN RAIL CONTROL (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker KW Date 6-9-95

A307 Bolt Capacity (double shear, 1.4 stress limit coef., 10 ksi allow.):

$$V_{A307} = 10000 \cdot \frac{\text{lbf}}{\text{in}^2} \cdot A_b \cdot 1.4 \cdot 2$$

$$V_{A307} = 2.199 \cdot 10^4 \cdot \text{lbf}$$

$$P_e(P) = \frac{19.375 \cdot P}{2 \cdot \left(9 + 3 \cdot \frac{3}{21} \right)}$$

$$P_s(P) = \frac{P}{4}$$

$$P = 10000$$

$$P = \text{root} \left(\sqrt{P_e(P)^2 + P_s(P)^2} - 21990, P \right)$$

$$P = 2.08 \cdot 10^4$$

Combined capacities: $P_{\text{cap}} = 207500 \cdot \text{lbf} + 20800 \cdot \text{lbf}$ $P_{\text{cap}} = 2.283 \cdot 10^5 \cdot \text{lbf}$

The combined capacity exceeds the predicted impact force, yielding a positive safety margin of

$$MS = \frac{P_{\text{cap}}}{F_{\text{max}}(k)} - 1$$

$$MS = 0.901$$

APPENDIX B

ANSYS FINITE ELEMENT MODEL LISTINGS

SOUTH RAIL BUMPER BEAM/COLUMN MODEL

/COM,ANSYS REVISION 5.0

A

10:30:22

04/25/1995

/NOPR

/TITLE,

ANTYPE, 0

NUMOFF,NODE, 7

NUMOFF,ELEM, 6

NUMOFF,MAT, 1

NUMOFF,REAL, 2

NUMOFF,TYPE, 1

ET, 1, 4

DOF,UX,UY,UZ,ROTX,ROTY,ROTZ,

REAL, 2

R,R5.0, 1,LOC, 1, 24.1000000, 1752.40000, 89.6000000

R,R5.0, 1,LOC, 4, 20.8600000, 8.9600000,

R,R5.0, 2,LOC, 1, 28.2200000, 206.800000, 1674.70000

R,R5.0, 2,LOC, 4, 18.1600000, 11.7500000,

N,R5.0,LOC, 1, 0.000000000E+00,

N,R5.0,LOC, 2, 0.000000000E+00, 47.9000000,

N,R5.0,LOC, 3, 0.000000000E+00, 170.000000,

N,R5.0,LOC, 4, 0.000000000E+00, 47.9000000, 37.0000000

N,R5.0,LOC, 5, 0.000000000E+00, 0.000000000E+00, 168.000000

N,R5.0,LOC, 6, 0.000000000E+00, 47.9000000, 168.000000

N,R5.0,LOC, 7, 0.000000000E+00, 170.000000, 168.000000

N,R5.0,LOC, 8, 0.000000000E+00, 47.9000000, 83.0000000

EN,R5.0,ATTR, 2, 1, 1, 1, 1, 0

EN,R5.0,NODE, 1, 2,

EN,R5.0,ATTR, 2, 1, 1, 1, 2, 0

EN,R5.0,NODE, 2, 3,

EN,R5.0,ATTR, 2, 1, 1, 1, 3, 0

EN,R5.0,NODE, 5, 6,

EN,R5.0,ATTR, 2, 1, 1, 1, 4, 0

EN,R5.0,NODE, 6, 7,

EN,R5.0,ATTR, 2, 1, 1, 2, 5, 0

EN,R5.0,NODE, 2, 4,

EN,R5.0,ATTR, 2, 1, 1, 2, 6, 0

EN,R5.0,NODE, 6, 8,

EN,R5.0,ATTR, 2, 1, 1, 2, 7, 0

EN,R5.0,NODE, 4, 8,

MPTEMP,R5.0, 1, 1, 0.000000000E+00,

MPDATA,R5.0, 1,EX, 1, 1, 29000000.0,

MPTEMP,R5.0, 1, 1, 0.000000000E+00,

MPDATA,R5.0, 1,NUXY, 1, 1, 0.300000000,

AUTOTS,OFF

NSUBST, 1

KBC, 0

KUSE, 0

TIME, 0.000000000E+00

TREF, 0.000000000E+00

ALPHAD, 0.000000000E+00

BETAD, 0.000000000E+00

DMPRAT, 0.000000000E+00

```

TIMINT,OFF ,STRU
CRPLIM, 0.100000000
NCNV, 1, 0.000000000E+00, 0, 0.000000000E+00, 0.000000000E+00
LNSRCH,OFF
NEQIT, 0
PRED,OFF ,OFF
ERESX,DEFA
ACEL, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
OMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0
DOMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGLOC, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGOMEG, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
DCGOME, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
IRLF, 0
D, 1,UX , 0.000000000E+00, 0.000000000E+00
D, 1,UY , 0.000000000E+00, 0.000000000E+00
D, 1,UZ , 0.000000000E+00, 0.000000000E+00
D, 1,ROTX, 0.000000000E+00, 0.000000000E+00
D, 1,ROTY, 0.000000000E+00, 0.000000000E+00
D, 1,ROTZ, 0.000000000E+00, 0.000000000E+00
D, 3,UX , 0.000000000E+00, 0.000000000E+00
D, 3,UY , 0.000000000E+00, 0.000000000E+00
D, 3,UZ , 0.000000000E+00, 0.000000000E+00
D, 5,UX , 0.000000000E+00, 0.000000000E+00
D, 5,UY , 0.000000000E+00, 0.000000000E+00
D, 5,UZ , 0.000000000E+00, 0.000000000E+00
D, 5,ROTX, 0.000000000E+00, 0.000000000E+00
D, 5,ROTY, 0.000000000E+00, 0.000000000E+00
D, 5,ROTZ, 0.000000000E+00, 0.000000000E+00
D, 7,UX , 0.000000000E+00, 0.000000000E+00
D, 7,UY , 0.000000000E+00, 0.000000000E+00
D, 7,UZ , 0.000000000E+00, 0.000000000E+00
F, 4,FX , 100000.000 , 0.000000000E+00
/GOPR

```

ANSYS MODEL LISTINGS USING THE CDWRITE OPTION

NORTH RAIL BUMPING POST MODEL

```

/COM,ANSYS REVISION  5.0          A          10:37:40    04/25/1995
/NOPR
/TITLE, K BASIN BUMPING POST ANALYSIS
ANTYPE, 0
NUMOFF,NODE,      7
NUMOFF,ELEM,      6
NUMOFF,MAT ,      1
NUMOFF,REAL ,      3
NUMOFF,COUP,      2
NUMOFF,TYPE,      2
ET,  1,  8
ET,  2,  4
DOF,UX ,UY ,UZ ,ROTX,ROTY,ROTZ,
TYPE,      2
REAL,      3
R,R5.0,      1,LOC,      1,  9.00000000 ,
R,R5.0,      2,LOC,      1, 11.76000000 ,
R,R5.0,      3,LOC,      1, 100.000000 , 1000.00000 , 1000.00000
R,R5.0,      3,LOC,      4, 10.0000000 , 10.0000000 ,
N,R5.0,LOC,      1, 0.00000000E+00,
N,R5.0,LOC,      2, 0.00000000E+00, 0.00000000E+00, 57.0000000
N,R5.0,LOC,      3, 50.5000000 , 37.4000000 , 18.5000000
N,R5.0,LOC,      4, 50.5000000 , 37.4000000 , 26.0000000
N,R5.0,LOC,      5, 50.5000000 , 37.4000000 , 33.5000000
N,R5.0,LOC,      6, 77.5000000 ,
N,R5.0,LOC,      7, 77.5000000 , 0.00000000E+00, 57.0000000
EN,R5.0,ATTR,      2,      1,      1,      2,      1,      0
EN,R5.0,NODE,      1,      4,
EN,R5.0,ATTR,      2,      1,      1,      2,      2,      0
EN,R5.0,NODE,      2,      4,
EN,R5.0,ATTR,      2,      1,      1,      1,      3,      0
EN,R5.0,NODE,      6,      3,
EN,R5.0,ATTR,      2,      1,      1,      1,      4,      0
EN,R5.0,NODE,      7,      5,
EN,R5.0,ATTR,      2,      1,      2,      3,      5,      0
EN,R5.0,NODE,      3,      4,
EN,R5.0,ATTR,      2,      1,      2,      3,      6,      0
EN,R5.0,NODE,      4,      5,
MPTEMP,R5.0, 1, 1, 0.00000000E+00,
MPDATA,R5.0, 1,EX ,      1, 1, 29000000.0 ,
CP,R5.0,  2,  1,UX ,      3,      5,
CP,R5.0,  2,  2,UY ,      3,      5,
AUTOTS,OFF
NSUBST,      1
KBC,      0
KUSE,      0
TIME, 0.00000000E+00
TREF, 0.00000000E+00
ALPHAD, 0.00000000E+00
BETAD, 0.00000000E+00

```



```

DMPRAT, 0.000000000E+00
TIMINT, OFF ,STRU
CRPLIM, 0.100000000
NCNV, 1, 0.000000000E+00, 0, 0.000000000E+00, 0.000000000E+00
LNSRCH, OFF
NEQIT, 0
PRED, OFF , OFF
ERESX, DEFA
ACEL, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
OMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00, 0
DOMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGLOC, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGOMEG, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
DCGOME, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
IRLF, 0
D, 1, UX , 0.000000000E+00, 0.000000000E+00
D, 1, UY , 0.000000000E+00, 0.000000000E+00
D, 1, UZ , 0.000000000E+00, 0.000000000E+00
D, 1, ROTX, 0.000000000E+00, 0.000000000E+00
D, 1, ROTY, 0.000000000E+00, 0.000000000E+00
D, 1, ROTZ, 0.000000000E+00, 0.000000000E+00
D, 2, UX , 0.000000000E+00, 0.000000000E+00
D, 2, UY , 0.000000000E+00, 0.000000000E+00
D, 2, UZ , 0.000000000E+00, 0.000000000E+00
D, 2, ROTX, 0.000000000E+00, 0.000000000E+00
D, 2, ROTY, 0.000000000E+00, 0.000000000E+00
D, 2, ROTZ, 0.000000000E+00, 0.000000000E+00
D, 3, ROTZ, 0.000000000E+00, 0.000000000E+00
D, 4, ROTZ, 0.000000000E+00, 0.000000000E+00
D, 5, ROTZ, 0.000000000E+00, 0.000000000E+00
D, 6, UX , 0.000000000E+00, 0.000000000E+00
D, 6, UY , 0.000000000E+00, 0.000000000E+00
D, 6, UZ , 0.000000000E+00, 0.000000000E+00
D, 6, ROTX, 0.000000000E+00, 0.000000000E+00
D, 6, ROTY, 0.000000000E+00, 0.000000000E+00
D, 6, ROTZ, 0.000000000E+00, 0.000000000E+00
D, 7, UX , 0.000000000E+00, 0.000000000E+00
D, 7, UY , 0.000000000E+00, 0.000000000E+00
D, 7, UZ , 0.000000000E+00, 0.000000000E+00
D, 7, ROTX, 0.000000000E+00, 0.000000000E+00
D, 7, ROTY, 0.000000000E+00, 0.000000000E+00
D, 7, ROTZ, 0.000000000E+00, 0.000000000E+00
F, 4, FX , -100000.000 , 0.000000000E+00

```

SOUTH RAIL BUMPER BEAM/COLUMN MODEL

```

/COM,ANSYS REVISION  5.0          A          10:30:22    04/25/1995
/NOPR
/TITLE,
ANTYPE, 0
NUMOFF,NODE,      7
NUMOFF,ELEM,      6
NUMOFF,MAT ,      1
NUMOFF,REAL,      2
NUMOFF,TYPE,      1
ET, 1, 4
DOF,UX ,UY ,UZ ,ROTX,ROTY,ROTZ,
REAL, 2
R,R5.0, 1,LOC, 1, 24.1000000 , 1752.40000 , 89.6000000
R,R5.0, 1,LOC, 4, 20.8600000 , 8.96000000 ,
R,R5.0, 2,LOC, 1, 28.2200000 , 206.800000 , 1674.70000
R,R5.0, 2,LOC, 4, 18.1600000 , 11.7500000 ,
N,R5.0,LOC, 1, 0.000000000E+00,
N,R5.0,LOC, 2, 0.000000000E+00, 47.9000000 ,
N,R5.0,LOC, 3, 0.000000000E+00, 170.000000 ,
N,R5.0,LOC, 4, 0.000000000E+00, 47.9000000 , 60.0000000
N,R5.0,LOC, 5, 0.000000000E+00, 0.000000000E+00, 168.000000
N,R5.0,LOC, 6, 0.000000000E+00, 47.9000000 , 168.000000
N,R5.0,LOC, 7, 0.000000000E+00, 170.000000 , 168.000000
EN,R5.0,ATTR, 2, 1, 1, 1, 1, 0
EN,R5.0,NODE, 1, 2,
EN,R5.0,ATTR, 2, 1, 1, 1, 2, 0
EN,R5.0,NODE, 2, 3,
EN,R5.0,ATTR, 2, 1, 1, 1, 3, 0
EN,R5.0,NODE, 5, 6,
EN,R5.0,ATTR, 2, 1, 1, 1, 4, 0
EN,R5.0,NODE, 6, 7,
EN,R5.0,ATTR, 2, 1, 1, 2, 5, 0
EN,R5.0,NODE, 2, 4,
EN,R5.0,ATTR, 2, 1, 1, 2, 6, 0
EN,R5.0,NODE, 4, 6,
MPTMP,R5.0, 1, 1, 0.000000000E+00,
MPDATA,R5.0, 1,EX , 1, 1, 29000000.0 ,
MPTMP,R5.0, 1, 1, 0.000000000E+00,
MPDATA,R5.0, 1,NUXY, 1, 1, 0.300000000 ,
AUTOTS,OFF
NSUBST, 1
KBC, 0
KUSE, 0
TIME, 0.000000000E+00
TREF, 0.000000000E+00
ALPHAD, 0.000000000E+00
BETAD, 0.000000000E+00
DMPRAT, 0.000000000E+00
TIMINT,OFF ,STRU
CRPLIM, 0.100000000
NCNV, 1, 0.000000000E+00, 0, 0.000000000E+00, 0.000000000E+00

```

```

LNSRCH,OFF
NEQIT,      0
PRED,OFF , ,OFF
ERESX,DEFA
ACEL, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
OMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00,      0
DOMEGA, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGLOC, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
CGOMEG, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
DCGOME, 0.000000000E+00, 0.000000000E+00, 0.000000000E+00
IRLF,      0
D,      1,UX  , 0.000000000E+00, 0.000000000E+00
D,      1,UY  , 0.000000000E+00, 0.000000000E+00
D,      1,UZ  , 0.000000000E+00, 0.000000000E+00
D,      1,ROTX, 0.000000000E+00, 0.000000000E+00
D,      1,ROTY, 0.000000000E+00, 0.000000000E+00
D,      1,ROTZ, 0.000000000E+00, 0.000000000E+00
D,      3,UX  , 0.000000000E+00, 0.000000000E+00
D,      3,UY  , 0.000000000E+00, 0.000000000E+00
D,      3,UZ  , 0.000000000E+00, 0.000000000E+00
D,      5,UX  , 0.000000000E+00, 0.000000000E+00
D,      5,UY  , 0.000000000E+00, 0.000000000E+00
D,      5,UZ  , 0.000000000E+00, 0.000000000E+00
D,      5,ROTX, 0.000000000E+00, 0.000000000E+00
D,      5,ROTY, 0.000000000E+00, 0.000000000E+00
D,      5,ROTZ, 0.000000000E+00, 0.000000000E+00
D,      7,UX  , 0.000000000E+00, 0.000000000E+00
D,      7,UY  , 0.000000000E+00, 0.000000000E+00
D,      7,UZ  , 0.000000000E+00, 0.000000000E+00
F,      4,FX  , 100000.000      , 0.000000000E+00
/GOPR

```

APPENDIX C

COLUMN E-13 FAILURE PROPOGATION EVALUATION

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 1 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker B. V. Winkel Date 6-9-95

INTRODUCTION

Capacity calculations of the south rail bumper indicate that the anchor bolt allowables on Column E-13 are exceeded for a 2 mi/hr impact of the design basis railcar (470,000 lb, one-car train). Using an existing model of the K Basin superstructure, the potential for propagating the failure beyond the column anchor bolts was evaluated. Calculation details follow below.

STRUCTURAL MODEL DESCRIPTION

An ANSYS model of the basin superstructure and storage/transfer structure was recently utilized for a wind loading evaluation (Kanjilal 1995). The south rail emergency bumper beam between columns E-13 and F-13 was added to the model. The model was subjected to dead weight loading plus an impact load of 184,000 lbs. (Note: A later iteration of the impact loading predicted an impact load of 190,000 lb. To account for this increased impact loading, a 3% increase was applied to the ANSYS results.) The model was also modified to eliminate the anchor bolt constraint at the base of column E-13, i.e. an anchor bolt failure was assumed. Vertical support was maintained, and an appropriate friction load was applied, simulating the friction resistance of the sliding column. A sketch of the column and adjacent model elements is shown below.

DESIGN CALCULATION

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 2 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker AKW/mll/lost Date 6-9-95

Column E-13 has a relatively large dead weight load (44,600 lb), resulting in a resisting friction loading of 24,500 lb. A friction coefficient of 0.55 was assumed (Ref.: ACI 349, B.6.2.2.2(c)). The column E-13 and adjacent member response to the impact plus dead weight loading is summarized below (See attached ANSYS output. 3% increase to be applied per previous page):

Element No.	Ax. For. (lbf)	Shr. For. (lbf)	Mom. X (in-lbf)	Mom. Y (ft-lbf)
706	166,000	8200	287,200	33,910
712	183,000	8400	428,900	21,400
1067	13,000	---	---	---
1097	9420	---	---	---
1813	40,300	93,800	4,546,000	1700
1814	39,400	94,500	5,283,000	15,700
1815	31,600	89,800	4,854,000	5700

Elements 706/712 (Basin Roof Truss, Bottom Chord)

Note: Although Element 712 has the higher stresses, both elements were checked because Element 706 has a longer unsupported length.

The bottom chord of the basin roof truss is comprised of two 9x4x1/2 angles which are welded directly to Col. E-13 (Ref.: WHC-SD-NR-SA-024, App. B1, p. 88). Checking ANSI/AISC N690 for bending stress requirements:

1. Flanges are continuously connected (OK).
2. N/A
3. N/A
4. From above Ref., section properties are:

$$I_{xx} = 106.4 \cdot \text{in}^4$$

$$I_{yy} = 175 \cdot \text{in}^4$$

$$S_{xx} = 18.7 \cdot \text{in}^3$$

$$S_{yy} = 25.8 \cdot \text{in}^3$$

$$A = 12.5 \cdot \text{in}^2$$

$$r_{xx} = 2.92 \cdot \text{in}$$

$$r_{yy} = 1.05 \cdot \text{in}$$

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 3 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker R. W. Agall Date 6-9-95

$$F_{ax} = 1.03 \cdot 183000 \cdot \text{lb}f$$

$$f_a = \frac{F_{ax}}{A} \quad f_a = 1.508 \cdot 10^4 \cdot \frac{\text{lb}f}{\text{in}^2}$$

$$F_y = 33000 \cdot \frac{\text{lb}f}{\text{in}^2} \quad \text{A7 Steel}$$

$$\frac{f_a}{F_y} = 0.457$$

Eq. Q1.5-3b applies:

$$\frac{257}{\sqrt{F_y \cdot \frac{\text{in}^2}{(\text{lb}f \cdot 1000)}}} = 44.738$$

$$d = 9 \cdot \text{in} \quad t = 0.5 \cdot \text{in}$$

$$\frac{d}{t} = 18 < 44.738, \text{ Cond. 4. satisfied}$$

5.

$$b_f = 4 \cdot \text{in}$$

$$\frac{76 \cdot b_f}{\sqrt{F_y \cdot \frac{\text{in}^2}{\text{lb}f \cdot 1000}}} = 52.92 \cdot \text{in}$$

$$A_f = 4 \cdot \text{in} \cdot 0.5 \cdot \text{in}$$

$$\frac{20000}{\left(\frac{d}{A_f}\right) \cdot F_y \cdot \frac{\text{in}^2}{\text{lb}f \cdot 1000}} = 134.68 \cdot \text{in}$$

For Elements 706 and 712, the longest unsupported length is 35" (Ele. 706), thus Cond. 5. is satisfied for both elements.

6. N/A

7. N/A

Therefore, the bottom chord qualifies per Section Q1.5.1.4.1 and the allow. stress is $0.66F_y$.

DESIGN CALCULATION

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 4 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

Checking N690 Section Q1.6.1 for axial compression and bending. Note that the bending about the vertical axis is relatively small and will be ignored (justified by size of safety margin).

$$E = 29 \cdot 10^6 \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

$$l_b = 35 \cdot \text{in} \quad (\text{Ele. 706 controls})$$

$$r_{bx} = r_{xx}$$

$$K = 1 \quad \text{Conservative K value for continuous member}$$

$$F_{ex} = \frac{12 \cdot \pi^2 \cdot E}{\left(K \cdot \frac{l_b}{r_{bx}} \right)^2} \cdot 23 \quad F_{ex} = 1.039 \cdot 10^6 \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

$$C_m = 0.85$$

$$F_{bx} = 0.66 \cdot F_y$$

$$f_{bx} = \frac{1.03 \cdot 287200 \cdot \text{in} \cdot \text{lb} \cdot \text{f}}{S_{xx}} \quad f_{bx} = 1.582 \cdot 10^4 \frac{\text{lb} \cdot \text{f}}{\text{in}^2}$$

In order to address axial compression plus bending, it is necessary to obtain the compression allowable, Section Q1.5.1.3:

$$C_c = \sqrt{\frac{2 \cdot \pi^2 \cdot E}{F_y}} \quad C_c = 131.706$$

$$l = l_b$$

$$\frac{K \cdot l}{r_{xx}} = 11.986 \quad Kl/r < C_c, \text{ use Eq. Q1.5-1}$$

$$F_a = \frac{\left[1 - \frac{\left(\frac{K \cdot l}{r_{xx}} \right)^2}{2 \cdot C_c^2} \right] \cdot F_y}{\left(\frac{5}{3} \right) + \frac{3 \cdot K \cdot \frac{l}{r_{xx}}}{8 \cdot C_c} - \frac{\left(K \cdot \frac{l}{r_{xx}} \right)^3}{8 \cdot C_c^3}}$$

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 5 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel CRW Date 6-8-95
 (9) Checker K. W. Winkel Date 6-9-95

$$F_a = 1.932 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\frac{f_a}{F_a} = 0.78 \quad f_a/F_a > 0.15, \text{ Q1.6-2 does not apply}$$

Checking Eqs. Q1.6-1a and Q1.6-1b:

$$\frac{f_a}{F_a} + \frac{C_m \cdot f_{bx}}{\left(1 - \frac{f_a}{F_{ex}}\right) F_{bx}} = 1.407 \quad \text{Eq. Q1.6-1a}$$

$$\frac{f_a}{0.6 F_y} + \frac{f_{bx}}{F_{bx}} = 1.488 \quad \text{Eq. Q1.6-1b}$$

Applying the abnormal stress limit coefficient of 1.6, the combined compression and bending stress limit is satisfied for the impact loading to the bottom chord of the basin roof truss.

Elements 1067/1097 (Bottom Chord Bracing)

Bracing size: 3-1/2x2-1/2x1/4 (Ref.: Dwg. H-1-34853)

$$r_{xx} = 1.12 \cdot \text{in}$$

$$r_{yy} = 0.735 \cdot \text{in}$$

$$r_{zz} = 0.544 \cdot \text{in}$$

$$A = 1.44 \cdot \text{in}^2$$

Checking the slenderness ratio, Kl/r :

$$l = \sqrt{6.96^2 + \left(\frac{16.96}{2}\right)^2} \cdot 12 \cdot \text{in} \quad l = 131.646 \cdot \text{in}$$

$$\frac{K \cdot l}{r_{zz}} = 241.996$$

$Kl/r > 200$, Per Q1.8.4 brace cannot be used as a compression member.

Thus, the bracing compression loads must be carried by the bottom chord. This increase in bottom chord loading is addressed on the next page.

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 6 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel BN Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

From Elements 1067 & 1097, the increase in bottom chord loading is obtained by ratioing:

$$\delta F_{ax} = \frac{101.76 \cdot \text{in}}{131.646 \cdot \text{in}} \cdot (13000 \cdot \text{lbf} + 9420 \cdot \text{lbf}) \cdot 1.03$$

$$\delta F_{ax} = 1.785 \cdot 10^4 \cdot \text{lbf}$$

$$A = 12.5 \cdot \text{in}^2$$

$$f_a = \frac{F_{ax} + \delta F_{ax}}{A}$$

$$f_a = 1.651 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Checking Eqs. Q1.6-1a and Q1.6-1b:

$$\frac{f_a}{F_a} + \frac{C_m \cdot f_{bx}}{\left(1 - \frac{f_a}{F_{ex}}\right) F_{bx}} = 1.482 \quad \text{Eq. Q1.6-1a}$$

$$\frac{f_a}{0.6 \cdot F_y} + \frac{f_{bx}}{F_{bx}} = 1.56 \quad \text{Eq. Q1.6-1b}$$

Thus, the N690 stress limit of 1.6 is not exceeded for the increase in load.

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 7 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel BW Date 6-8-95
 (9) Checker SKW/gm/llt Date 6-1-95

Elements 1813-1815 (Column E-13)

From the element moments and forces given above, the critical column element is Ele. 1814.

$$F_{ax} = 1.03 \cdot 39400 \cdot \text{lbf}$$

$$F_{sh} = 1.03 \cdot 94500 \cdot \text{lbf}$$

$$M_x = 1.03 \cdot 5283000 \cdot \text{lbf} \cdot \text{in}$$

$$M_y = 1.03 \cdot 15700 \cdot \text{lbf} \cdot \text{in}$$

Note that M_y is small relative to M_x and will be ignored.

Col. E-13 section properties (21 WF 82):

$$A = 24.1 \cdot \text{in}^2$$

$$I_{xx} = 1752.4 \cdot \text{in}^4$$

$$d = 20.86 \cdot \text{in}$$

$$A_w = 0.499 \cdot \text{in} \cdot 20.86 \cdot \text{in} \quad A_w = 10.409 \cdot \text{in}^2$$

$$r_{xx} = 8.53 \cdot \text{in}$$

Checking Shear:

$$F_v = 0.40 \cdot F_y$$

$$1.4 \cdot F_v = 1.848 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}^2}$$

N690 abnormal cond. shear allow.

$$f_v = \frac{F_{sh}}{A_w}$$

$$f_v = 9.351 \cdot 10^3 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$f_v < 1.4F_v$, OK

DESIGN CALCULATION

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 8 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker Shirley West Date 6-9-95

Combined bending and axial compression (N690, Section Q1.6.1):

$$f_a = \frac{F_{ax}}{A} \quad f_a = 1.684 \cdot 10^3 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$K = 1.0$$

$$l = 120 \text{ in} \quad \text{Ref.: Dwg. H-1-34853}$$

$$F_a = \frac{\left[1 - \frac{\left(\frac{K \cdot l}{r_{xx}} \right)^2}{2 \cdot C_c^2} \right] \cdot F_y}{\left(\frac{5}{3} \right) + \frac{3 \cdot K \cdot \frac{l}{r_{xx}}}{8 \cdot C_c} - \frac{\left(K \cdot \frac{l}{r_{xx}} \right)^3}{8 \cdot C_c^3}}$$

$$F_a = 1.923 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\frac{f_a}{F_a} = 0.088$$

Since $f_a/F_a < 0.15$, Eq. Q1.6-2 applies:

$$f_{bx} = \frac{M_x \cdot \frac{d}{2}}{I_{xx}}$$

$$f_{bx} = 3.239 \cdot 10^4 \cdot \frac{\text{lbf}}{\text{in}^2}$$

Checking section conditions in Q1.5.1.4.1,

$$\frac{65}{\sqrt{F_y \cdot \frac{\text{in}^2}{1000 \cdot \text{lbf}}}} = 11.315$$

$$d = \frac{8.962 \cdot \text{in}}{2}$$

DESIGN CALCULATION

WHC-SD-SNF-DA-008, Rev. 0

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 9 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker [Signature] Date 6-9-95

$$t = 0.795 \text{ in}$$

$$\frac{d}{t} = 5.636 < 11.315, \text{ Cond. 2. OK}$$

$$\frac{f_a}{F_y} = 0.051 \quad \text{Eq. Q1.5-3a applies}$$

$$d = 20.86 \text{ in}$$

$$t = 0.499 \text{ in}$$

$$\frac{d}{t} = 41.804$$

$$\frac{640}{\sqrt{F_y \frac{\text{in}^2}{1000 \cdot \text{lbf}}}} \left(1 - 3.74 \frac{f_a}{F_y} \right) = 90.148 > d/t, \text{ Cond. 4 satisfied}$$

Condition 5., Section Q1.5.1.3.1:

$$A_f = \frac{d \cdot \text{in}}{2.93}$$

$$\frac{20000}{\left(\frac{d}{A_f} \right) \frac{F_y \text{ in}^2}{1000 \cdot \text{lbf}}} = 206.847 \cdot \text{in}$$

$$b_f = 8.962 \text{ in}$$

$$\frac{76 \cdot b_f}{\sqrt{F_y \frac{\text{in}^2}{1000 \cdot \text{lbf}}}} = 118.566 \cdot \text{in}$$

Maximum unbraced length = 6 ft (72 in).
 Cond. 5 met. Bending Allow. = 0.66F_y

$$F_{bx} = 0.66 \cdot F_y$$

DESIGN CALCULATION

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 10 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel Date 6-8-05
 (9) Checker [Signature] Date 6-9-05

Substituting into Eq. Q1.6-2:

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} = 1.575 < 1.6 \text{ (N690 abnorm. cond) OK}$$

Column F-13 Anchor Bolts

The anchor bolts for Column F-13 were checked for the case of Column E-13 anchor bolt failure, as provided below.

From the attached ANSYS output, the Column F-13 reactions are (global coord.):

$$F_x = 517.4 \cdot \text{lbf} \cdot 1.03$$

$$F_y = 15498 \cdot \text{lbf} \cdot 1.03$$

$$F_z = 49804 \cdot \text{lbf} \cdot 1.03$$

$$M_x = 1442400 \cdot \text{in} \cdot \text{lbf} \cdot 1.03$$

$$M_y = 10054 \cdot \text{in} \cdot \text{lbf} \cdot 1.03$$

$$M_z = 11427 \cdot \text{in} \cdot \text{lbf} \cdot 1.03$$

Following the same procedure used to evaluate the Column E-13 anchor bolts:

$$\phi = 0.85$$

$$f_y = 33000 \cdot \frac{\text{lbf}}{\text{in}^2}$$

$$\mu = 0.55$$

$$A_{vf} = \frac{4 \cdot \pi \cdot (1.5 \cdot \text{in})^2}{4}$$

$$F_c = 15498 \cdot \text{lbf}$$

Column dead load from above

$$\phi V_n = (A_{vf} f_y + F_c) \cdot \mu \cdot \phi$$

$$\phi V_n = 1.163 \cdot 10^5 \cdot \text{lbf}$$

Anchor bolt capacity (all 4 bolts)

DESIGN CALCULATION

WHC-SD-SNF-DA-008, Rev. 0

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 11 of 17
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
 (8) Originator B. V. Winkel Date 6-8-95
 (9) Checker AKWagell Date 6-9-95

Checking shear:

$$F_v = \sqrt{(F_x)^2 + (F_z)^2}$$

Direct shear force, from above

$$MS = \frac{\phi V_n}{F_v} - 1$$

$$MS = 1.267$$

Col. F-13 Anchor Bolts
OK for shear alone

Checking Bolt Tension (same procedure as used for the Col. E-13 anchor bolts):

$$A_b = \frac{\pi (1.5 \text{ in})^2}{4}$$

$$f_t = \frac{M_x}{29 \text{ in} \cdot 2 \cdot A_b}$$

$$f_t = 1.45 \cdot 10^4 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{in}^2}$$

$$f_v = \frac{F_v}{4 \cdot A_b}$$

$$F_t = 26000 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{in}^2} - 1.8 \cdot f_v$$

$$F_t = 1.294 \cdot 10^4 \cdot \frac{\text{lb} \cdot \text{ft}}{\text{in}^2}$$

$$MS = \frac{1.6 \cdot F_t}{f_t} - 1$$

$$MS = 0.428$$

Col. F-13 anchor bolts OK

DESIGN CALCULATION

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 12 of 17
(4) Building 105-KE (5) Rev. _____ (6) Job No. _____
(7) Subject COLUMN E-13 FAILURE PROPAGATION EVALUATION
(8) Originator B. V. Winkel CBW Date 6-8-95
(9) Checker B. V. Winkel Date 6-9-95

ANSYS OUTPUT

The following pages provide the ANSYS output for the members evaluated above. Member forces and moments are provided for elements 706,712, 1813-1815, 1067, and 1097. Also provided is the page of post-processing output containing the reactions for Column F-13 (Node 5395).

SELECT FOR ITEM=ELEM COMPONENT=
IN RANGE 706 TO 712 STEP 6

2 ELEMENTS (OF 2126 DEFINED) SELECTED BY ESEL COMMAND.

PRINT F ELEMENT SOLUTION PER ELEMENT

***** POST1 ELEMENT NODE TOTAL FORCE LISTING *****

LOAD STEP= 1 SUBSTEP= 1

TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM=	706	FX	FY	FZ
4870	906.62	7256.4	0.16595E+06	
4872	-906.62	-7380.4	-0.16595E+06	
ELEM=	712	FX	FY	FZ
4872	-674.92	7627.5	0.18320E+06	
4873	674.92	-7693.1	-0.18320E+06	

PRINT M ELEMENT SOLUTION PER ELEMENT

***** POST1 ELEMENT NODE TOTAL FORCE LISTING *****

LOAD STEP= 1 SUBSTEP= 1

TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM=	706	MX	MY	MZ
4870	-31042.	2181.8	-3.0870	
4872	0.28719E+06	-33914.	3.0870	
ELEM=	712	MX	MY	MZ
4872	-0.28719E+06	33914.	-3.0870	
4873	0.42890E+06	-21428.	3.0870	

2126 ELEMENTS (OF 2126 DEFINED) SELECTED BY EALL COMMAND.

SELECT FOR ITEM=ELEM COMPONENT=
IN RANGE 1813 TO 1815 STEP 1

3 ELEMENTS (OF 2126 DEFINED) SELECTED BY ESEL COMMAND.

PRINT F ELEMENT SOLUTION PER ELEMENT

***** POST1 ELEMENT NODE TOTAL FORCE LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM= 1813 FX FY FZ

8050	142.47	-40318.	-93694.
9381	-142.47	39481.	93694.

ELEM= 1814 FX FY FZ

9381	899.85	-39414.	-93606.
4873	-899.85	39306.	93606.

ELEM= 1815 FX FY FZ

4873	224.93	-31613.	89594.
9382	-224.93	31231.	-89594.

PRINT M ELEMENT SOLUTION PER ELEMENT

***** POST1 ELEMENT NODE TOTAL FORCE LISTING *****

LOAD STEP= 1 SUBSTEP= 1
TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM= 1813 MX MY MZ

8050	-0.11792E+07	-6394.1	-9034.7
9381	-0.45456E+07	1709.4	2324.7

ELEM= 1814 MX MY MZ
 9381 0.45455E+07 -11035. -1708.4
 4873 -0.52832E+07 15715. -7350.4

ELEM= 1815 MX MY MZ
 4873 0.48543E+07 5712.2 7347.3
 9382 -0.23573E+07 -1232.5 -12045.

2126 ELEMENTS (OF 2126 DEFINED) SELECTED BY EALL COMMAND.

SELECT FOR ITEM=ELEM COMPONENT=
 IN RANGE 1067 TO 1097 STEP 30

2 ELEMENTS (OF 2126 DEFINED) SELECTED BY ESEL COMMAND.

PRINT F ELEMENT SOLUTION PER ELEMENT

***** POST1 ELEMENT NODE TOTAL FORCE LISTING *****

LOAD STEP= 1 SUBSTEP= 1
 TIME= 1.0000 LOAD CASE= 0

THE FOLLOWING X,Y,Z FORCES ARE IN GLOBAL COORDINATES

ELEM=	1067	FX	FY	FZ	$\sqrt{F_x^2 + F_y^2}$
4872	8240.8	-13.472	-9982.2		12,944
4881	-8240.8	-13.472	9982.2		

ELEM=	1097	FX	FY	FZ	
4872	-5999.1	-13.472	-7266.8		9423
4681	5999.1	-13.472	7266.8		

PRINT M ELEMENT SOLUTION PER ELEMENT

*** WARNING *** CP= 211.180 TIME= 14:17:46
 No data is available for the selected model or FORCE location specifications.

EXIT THE ANSYS POST1 DATABASE PROCESSOR

***** ROUTINE COMPLETED ***** CP = 211.230

SELECTED DISPLACEMENTS

THE FOLLOWING DEGREE OF FREEDOM RESULTS ARE IN GLOBAL COORDINATES

NODE	UX	UY	UZ	ROTX	ROTY	ROTZ
9384	0.11681E-01	-0.10231E-01	0.75007E-02	-0.86374E-03	-0.62292E-03	
0.40834E-05						
9385	0.76317E-02	-0.46171E-02	0.75007E-02	-0.86366E-03	-0.62292E-03	
0.41379E-05						
9386	0.33782E-02	-0.60840E-02	-0.62168E-01	-0.48020E-03	-0.23016E-03	-0.32929E-03
9387	0.23976E-02	-0.63108E-02	-0.81177E-01	-0.41549E-03	-0.84924E-04	-0.13712E-04
9388	0.19730E-02	-0.42334E-02	-0.81177E-01	-0.41548E-03	-0.84915E-04	-0.13845E-04
9398	0.22274E-02	-0.36830E-02	-0.62168E-01	-0.48019E-03	-0.23017E-03	-0.32962E-03
<i>U2 - COL. E-13 BASE</i>						
MAXIMUM VALUES						
NODE	4963	4838	5379	8050	5379	9398
VALUE	0.66607E-01	-0.12861	0.91747	-0.62865E-02		
0.42207E-02	-0.32962E-03					
4974	0.46668E-03	-0.57448E-02	0.76729E-01	0.80585E-03	-0.41475E-03	
0.37245E-04						
4975	0.91435E-03	-0.61155E-02	0.95150E-01	0.41172E-03	-0.13345E-03	
0.50503E-04						
4976	-0.56284E-03	0.34140E-02	0.96077E-01	-0.11046E-03	0.13959E-03	
0.29163E-03						
4988	0.18752E-02	0.44920E-02	0.95833E-01	0.52461E-05	0.85104E-04	
0.22802E-03						
5365	0.00000E+00	0.00000E+00	0.00000E+00	0.40760E-03		
0.00000E+00	-0.23552E-04					
5367	0.00000E+00	0.00000E+00	0.00000E+00	0.16427E-02	0.00000E+00	
0.15318E-03						
5371	0.00000E+00	0.00000E+00	0.00000E+00	0.11093E-02		
0.00000E+00	-0.32457E-04					
5375	0.00000E+00	0.00000E+00	0.00000E+00	0.11765E-02	0.00000E+00	
0.44846E-04						
5379	0.33329E-03	0.00000E+00	0.91747	-0.57535E-02	0.42207E-02	
0.32893E-04						
8050	-0.12423E-02	-0.27289E-02	0.63337	-0.62865E-02	0.42207E-02	
0.32893E-04						
9381	0.11774E-02	-0.60849E-02	0.27525			
-0.43329E-02	-0.28069E-02	-0.88182E-04				
9382	0.28923E-02	-0.77207E-02	0.17386	-0.16742E-02	-0.16045E-02	
0.13778E-04						
9383	0.11400E-01	-0.10091E-01				
0.20586E-01	-0.88119E-03	-0.51682E-03	-0.39834E-04			

U2 CRANE LEVEL, COL. E-13

***** POST1 NODAL DEGREE OF FREEDOM LISTING *****

REACTIONS IN GLOBAL COORDINATES:

NODE	FX	FY	FZ	MX	MY	MZ
5381	0.11899	9899.1	-652.51		4612.5	
5382	0.00000E+00	366.13	-8761.8		0.00000E+00	
5383	-61.177	853.01	-827.54		11866.	
5385	-181.71	11623.	-772.44		10117.	
5386	0.00000E+00	378.67	-9989.9		0.00000E+00	
5387	-210.77	1417.3	-642.69		600.39	
5389	-88.358	11187.	-727.72		3636.6	
5390	0.00000E+00	-181.10	-9488.7		0.00000E+00	
5391	0.74194	1223.0	-553.53		4744.7	
5393	-81.747	9437.1	-522.25		-50402.	
5394	-0.37961E-11	-1832.1	-5828.4		0.00000E+00	
5395	517.43	15498.	-49804.	-0.14424E+07	10054.	-11427.
5706	1003.0	417.38	-54.249	4.1454	5126.4	17662.
5711	2398.1	382.05	-217.19	4.6510	8609.7	12712.
5712	144.94	545.22	-355.52	5.6011	14273.	20720.
5716	2944.6	651.40	-284.47	0.75314	12584.	30523.
5721	-1112.8	745.52	-176.22	-0.90406E-01	7597.4	29654.
5725	-3487.5	687.56	-295.53	1.2641	12708.	32959.
5731	-448.98	843.78	-160.01	0.63710	7196.7	32976.
5738	1561.4	671.61	-278.99	-4.3358	12368.	31823.
5741	-921.47	428.79	-167.20	-4.4286	7373.4	15732.
5749	5351.2	473.31	-244.93	-6.7588	15772.	22925.
5761	-3626.9	320.09	-98.188	-6.2813	7292.5	10001.
5768	-837.72	405.84	-25.706	-2.4980	2515.3	15661.
9105	-1162.7	3905.4	-944.05			
9106	829.04	3673.1	442.38			
9107	-828.57	1532.7	1.8210			
9115	-1613.1	10850.	-2950.8			
9116	1037.8	10847.	636.85			
9117	170.70	3195.0	0.00000E+00			
9125	-5173.2	9187.2	-8373.2			
9126	1839.3	9634.1	654.09			
9127	388.23	2799.0	0.00000E+00			
9135	-12045.	9129.8	-17178.			
9136	1449.8	9556.1	-781.84			
9137	-306.46	3222.4	0.00000E+00			
9143	14585.	28581.	-379.68	-37030.	1548.6	50.528

APPENDIX D

TRUCK ACCIDENT CALCULATIONS

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 1 of 5
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN TRUCK ACCIDENT SAFETY EVALUATION
 (8) Originator B. V. Winkel B.V. Date 6-26-95
 (9) Checker AKW/gjllust Date 6-26-95

INTRODUCTION

The purpose of the calculations below is to evaluate the safety concerns relative to the use of trucks entering in the south door of the storage/transfer area of the K Basins. Currently, there are two types of trucks being utilized, the IXM transport truck/trailer (HO-64-5712 & HO-64-5728) and the Chem Nuclear truck, which was recently used for fuel characterization shipments. The Chem Nuclear truck weight is 55,000 lb. The IXM truck weight is not known. Based upon a telephone conversation with the WA commercial vehicle control office in Patterson, the limit on 3-axle truck, 2-axle trailer vehicles on public highways is 80,000 lb, without a special permit. To cover the IXM application and future operations with truck/trailer combinations, a maximum truck weight of 100,000 lb was assumed.

The normal operation mode is for a truck to back in the south door, approximately centered on the door opening and tracks. As shown below, the most likely first impact would be between the tires and the rail stops on the floor. If the truck is moving fast enough, the back wheels could ride up onto the rail stops until the trail impacts the emergency bumper. Mathcad calculations associated with this impact scenario are provided below.

INPUT PARAMETERS

$W = 100000 \text{ lbf}$	Upper bound truck weight (see above)
$R1 = 18.5 \text{ in}$	IXM trailer tire radius (measured)
$R2 = 20.5 \text{ in}$	Chem Nuclear trailer tire radius (measured)
$w = 9 \text{ in}$	Tire width (IXM trailer tire measurement)
$p_o = 100 \frac{\text{lbf}}{\text{in}^2}$	Normal tire pressure (read from IXM trailer tire)

TIRE IMPACT CALCULATIONS

To simplify the calculations, assume the tire impacts a flat surface (e.g. the vertical face of the rail stop). Assume tire response is two-dimensional.

$$R = R1$$

Start with the smaller tire.
 (Results were found to be insensitive to tire size.)

$$A(\alpha) = \frac{R^2}{2} (2\alpha - \sin(2\alpha))$$

Ref.: Myers, JA,
 "Handbook of Equas.
 for Mass & Area...", AD
 274 936, Nat. Bureau of
 Standards, April 1962.

$$\delta(\alpha) = R - R \cos(\alpha)$$

DESIGN CALCULATION

WHC-SD-SNF-DA-008, Rev. 0

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 2 of 5
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN TRUCK ACCIDENT SAFETY EVALUATION
 (8) Originator B. V. Winkel Date 6-26-95
 (9) Checker [Signature] Date 6-26-95

$$V_o = 2 \cdot \pi (R - 6 \cdot \text{in}) \cdot 12 \cdot \text{in} \cdot w$$

Approx. initial tire volume

$$\delta V(\alpha) = w \cdot A(\alpha)$$

Assume vol. change due to flattened area only

$$V(\alpha) = V_o - \delta V(\alpha)$$

$$p(\alpha) = \frac{V_o}{V(\alpha)} p_o$$

Gas law, no temperature change ($p_1 \cdot V_1 = p_2 \cdot V_2$)

$$d(\alpha) = 2 \cdot R \cdot \sin(\alpha)$$

$$F(\alpha) = p(\alpha) \cdot w \cdot d(\alpha)$$

Assumes tire material has no bending or shear strength (membrane strength only)

Plotting above equations to verify reasonableness of results:

$\alpha = 0.1, 0.2 \dots 1.0$

Note that α is in radians

Results appear to be reasonable.

DESIGN CALCULATION

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 3 of 5
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN TRUCK ACCIDENT SAFETY EVALUATION
 (8) Originator B. V. Winkel Date 6-26-95
 (9) Checker [Signature] Date 6-26-95

Obtaining the approximate tire stiffness:

$$k(\alpha) = \frac{F(\alpha)}{\delta(\alpha)}$$

$$\alpha = 0.1, 0.2, \dots, 0.8$$

The above stiffness estimate is conservative in the sense that the impact will not be against a simple flat surface. The rail stops are about 4 inches wide (less than half the tire width) and project 16 inches above the floor (less than the tire radius). The emergency bumper has a specified spring rate of 36,700 lb/in, which is close to the max. stiffness estimate for a single tire. If both rail stops are impacted at the same time, the stiffness would double. For a deflection of one inch, the double stiffness would be about 20,000 lb/in, which is less than the bumper stiffness. Therefore, for establishing the maximum truck velocity, a spring constant of 36,700 lb/in is used below. Note that while the above estimate tire stiffness is very approximate, it is somewhat academic, since the tires and railstops are considered to be "sacrificial", i.e. the bumper is assumed to be the primary truck stop. As shown below, the trailer must travel 13 in. beyond the tire/rail stop impact before impacting the bumper. Any energy involved in bursting the tires and damaging the tire rims and rail stops is conservatively ignored in establishing the allowable truck velocity. A key assumption in this impact accident description is that if the rail stops don't stop the truck, the rail stops will raise the back of the trailer at least 2 in., resulting in the trailer/bumper impact.

TRUCK MAX. VELOCITY TO AVOID COLUMN ANCHORAGE FAILURE

The impact force associated with Column E-13 base capacity:

$$F_{is} = 1.734 \cdot 10^5 \text{ lbf} \quad (\text{Ref.: p. 27 of Rail Control Calcs.})$$

$$k_i = 36700 \frac{\text{lbf}}{\text{in}} \quad \text{Bumper spring stiffness}$$

$$\delta_i = \frac{F_{is}}{k_i} \quad \delta_i = 4.725 \text{ in} \quad \text{Spring deformation when column capacity reached}$$

DESIGN CALCULATION

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 4 of 5
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN TRUCK ACCIDENT SAFETY EVALUATION
 (8) Originator B. V. Winkel Date 6-26-95
 (9) Checker Mike Wagonblast Date 6-26-95

$$KE = \frac{F_{is} \cdot \delta_i}{2}$$

$$KE = 3.414 \cdot 10^4 \cdot \text{ft} \cdot \text{lbf}$$

Energy absorption capability
prior to exceeding col.
capacity

$$v = \sqrt{\frac{2 \cdot KE \cdot g}{W}}$$

$$v = 3.196 \cdot \frac{\text{mi}}{\text{hr}}$$

Thus, a 100,000 lb truck impacting the railcar bumper could exceed the allowable capacity of the column anchor, if the velocity exceeds 3.2 mi/hr. Although this velocity limit ignores the energy associated with the tire/railstop impact, it is recommended that a velocity limit of 3.0 mi/hr be specified for truck operations.

EVALUATION OF TRAILER INTERFACES WITH THE RAIL CONTROL HARDWARE

The above evaluation addresses only tire/railstop and trailer bed/bumper impacts. Since the north/south location of the truck/trailer is not constrained by the rails, as is a railcar, other locations were evaluated below.

Truck/Railstop Interface:

Note: Bottom of bumper is 43" above the floor (trailer bed will pass under the bumper, unless it raises up).

Option 1: Truck centered on tracks. Inner tires will impact railstops. Tire(s) may burst. If enough velocity, back of trailer would raise up and impact bumper.

DESIGN CALCULATION

(1) Drawing H-1-34853 (2) Doc. No. _____ (3) Page 5 of 5
 (4) Building 105-KE (5) Rev. _____ (6) Job No. _____
 (7) Subject K BASIN TRUCK ACCIDENT SAFETY EVALUATION
 (8) Originator B. V. Winkel Date 6-26-95
 (9) Checker AKWagantlast Date 6-26-95

Option 2: Trailer is off track centerline by 1 to 2 feet to the south. The northern most tire would impact a rail stop. The tire may burst. If enough velocity, the north side of the rear of the trailer would raise up and impact the bumper.

Option 3: Trailer is off track centerline by more than 2 feet to the south. This option is very unlikely because there is a small column which would have to be displaced on the south side of the trailer. If this option did occur, the tires on the south should be raised by the curb and the axle should clear the rail stop and the back of the trailer should impact the bumper.

Options 2 and 3 are also possible for truck movement to the north of the track centerline. However, the possibility of Option 3 on the north side is very remote because of the drip pan platform which prevents movement to the north beyond Column Line E.

Conclusion: Using bumper stiffness to establish truck velocity is reasonable. Also, there does not appear to be a feasible path for the trailer to bypass the bumper and enter the basin.

APPENDIX E

MISCELLANEOUS RAIL/TRUCK CORRESPONDENCE

CONTENTS:

- Tabular List of Hanford Railcar Data
- Telecon Memorandum: "100K Rail Control Hardware"
- UNC Nuclear Industries Memorandum: "Fuel Car Movement in 105 KE/KW Basin Areas"
- WHC Internal Memo: "Resolution of Fuel Characterization Prestart Punchlist Item D Relating to the Height of the Cask Trailer with Respect to the Restraining Barrier"
- WHC Internal Memo: "Fuel Characterization Prestart Punchlist Item D: Determine the Measured Height of the Cask Trailer with Respect to the Restraining Barrier that Keeps the Trailer from Accidently Running into Pit"

Hanford Railcar and Locomotive Weight Information Table, Source: M. J. Brown, ICF Kaiser Company

CAR NUMBER	CAR DESCRIPTION	VENDOR	EMPTY WEIGHT	SOURCE OF INFORMATION
HO-10B-03636	Three Well Car (mounted on 2 4-wheel railroad car trucks)	Pacific Car & Foundry	63,600 lbs, with 2 steel tanks and steel covers; 3rd tank installed 4/8/54	Receiving and Inspection Report for Equipment and Tools, HEW (5/1/44, 6/17/54); Government Owned file card
HO-10B-03637	Three Well Car (mounted on 2 4-wheel railroad car trucks)	Pacific Car & Foundry	61,400 lbs, with 2 steel tanks and steel covers; 3rd tank installed 5/18/54	Receiving and Inspection Report for Equipment and Tools, HEW (5/11/44, 6/17/54); Government Owned file card
HO-10B-03638	Three Well Car (mounted on 2 4-wheel railroad car trucks)	Pacific Car & Foundry	63,980 lbs, with 2 steel tanks and steel covers; 3rd tank installed 5/4/54	Receiving and Inspection Report for Equipment and Tools, HEW (5/16/44, 6/17/54); Government Owned file card
HO-10B-03639	Three Well Car (mounted on 2 4-wheel railroad car trucks)	Pacific Car & Foundry	61,220 lbs, with 2 steel tanks and steel covers; 3rd tank installed 2/5/54	Receiving and Inspection Report for Equipment and Tools, HEW (5/16/44, 6/17/54); Government Owned file card
HO-10B-3640	Three Well Car (mounted on 2 4-wheel railroad car trucks)	Pacific Car & Foundry	63,600 lbs, with 2 steel tanks and steel covers; 3rd tank installed 6/4/54	Receiving and Inspection Report for Equipment and Tools, HEW (5/23/44, 6/17/54); Government Owned file card
HO-10B-3641	Three Well Car (mounted on 2 4-wheel railroad car trucks)	Pacific Car & Foundry	63,100 lbs, with 2 tanks and steel covers; 3rd tank installed (no date)	Receiving and Inspection Report for Equipment and Tools, HEW (5/23/44); Government Owned file card
HO-10B-3642	Three Well Car (mounted on 2 4-wheel railroad car trucks)	Pacific Car & Foundry	100,480 lb, with 2 tanks and 2 steel covers; 3rd tank installed (no date)	Receiving and Inspection Report for Equipment and Tools, HEW (2/6/45); Government Owned file card

CAR NUMBER	CAR DESCRIPTION	VENDOR	EMPTY WEIGHT	SOURCE OF INFORMATION
HO-10B-3643	Three Well Car (mounted on 2 4-wheel railroad car trucks)	Pacific Car & Foundry	100,480 lbs, with 2 tanks and 2 steel covers; 3rd tank installed (6/17/54)	Receiving and Inspection Report for Equipment and Tools, HEW (2/6/45, 6/17/54); Government Owned file card
HO-10B-3644	Three Well Car (mounted on 2 4-wheel railroad car trucks)	Pacific Car & Foundry	36,100 lbs; 3rd tank installed 3/4/54	Receiving and Inspection Report for Equipment and Tools, HEW (11/24/43, 6/17/54); Government Owned file card
HO-10B-3645	Three Well Car (mounted on 2 4-wheel railroad car trucks)	Pacific Car & Foundry	3rd tank installed 4/19/54	Receiving and Inspection Report for Equipment and Tools, HEW (1/19/45, 6/17/54); Government Owned file card
HO-10B-5598	Three Well Car (mounted on 3 axle railroad car trucks)	Pacific Car & Foundry	lt wt 91,000 lbs	Receiving and Inspection Report for Equipment and Tools, HEW (10/1/54, 10/10/55); Government Owned file card
HO-10B-5599	Three Well Car (mounted on 3 axle railroad car trucks)	Pacific Car & Foundry	lt wt 91,000 lbs	Receiving and Inspection Report for Equipment and Tools, HEW (6/20/55); Government Owned file card
HO-10B-19936	Cask Car	Milwaukee Railroad	Total weight (cask, tank & car) 153,600 lbs; lt wt of car 47,800 lbs; cask plus tank 105,800 lbs; lt wt 46,600 lbs	Receiving and Inspection Report for Equipment and Tools (12/29/64); Equipment Control Data card; Inter-Contractor Transfer Order
HO-10B-19937	Cask Car	Milwaukee Railroad	Total weight (cask, tank & car) 153,600 lbs; lt wt of car 47,800 lbs; cask plus tank 105,800 lbs; lt wt 45,400 lbs	Receiving and Inspection Report for Equipment and Tools (11/23/64); Equipment Control Data card

CAR NUMBER	CAR DESCRIPTION	VENDOR	EMPTY WEIGHT	SOURCE OF INFORMATION
HO-10B-19944	Cask Car	Milwaukee Railroad	Total weight (cask, tank & car) 153,600 lbs; lt wt of car 47,800 lbs; cask plus tank 105,800 lbs; lt wt 45,400 lbs	Receiving and Inspection Report for Equipment and Tools (11/23/64); Equipment Control Data card
HO-10B-19945	Cask Car	Milwaukee Railroad	Total weight (cask, tank & car) 153,600 lbs; lt wt of car 47,800 lbs; cask plus tank 105,800 lbs; lt wt 45,400 lbs	Receiving and Inspection Report for Equipment and Tools (11/23/64); Equipment Control Data card
39-3727	Locomotive	Electro-Motive Division, General Motor Corporation	No. 1 end 124,502 lbs; No. 2 end 124,316 lbs; total wt. 248,818 lbs	Electro-Motive Division General Motors Corporation, Locomotive Serial Record; Equipment Control Data card
39-3728	Locomotive	Electro-Motive Division, General Motor Corporation	No. 1 end 125,016 lbs; No. 2 end 123,918 lbs; total wt. 248,934 lbs	Electro-Motive Division General Motors Corporation, Locomotive Serial Record; Receiving and Inspection Report for Equipment and Tools

Company

ICF Kaiser Hanford Co.

TELEPHONE CONFERENCE MEMORANDUM

[] INCOMING [X] OUTGOING DATE: 7-21-95 TIME: 2 pm
WITH: Larry Fahnholz OF: ICF Kaiser PHONE: 376-9861
WITH: OF: PHONE:
Copies to: R. H. Meichle X3-79
M. J. Langevin X3-74

Subject: 100K Rail Control Hardware

SNF Project Engineering

376-5736

Department

Bob V. Winkel

Telephone No.

Summary of Conference

I contacted Larry Fahnholz to discuss maintenance and other safety issues associated with the 100K rail control hardware. Larry is in charge of railroad operations planning for the Hanford Site. A summary of our conversation follows below.

Switch Hardware Safety Concerns

Since the primary defense against accidental entry of a railcar or train into the 105K Basins is the double-locked 105 KE and 105 KW rail spur switches, the adequacy of these switches was discussed. Larry stated that essentially the only way that a switch malfunction could occur would be through switch sabotage by a knowledgeable saboteur. The probability of such an event coinciding with a runaway train are very small. If it did occur, all of the wheels of the runaway rail vehicle would also have to pass through the derailer without derailing in order for a train to enter the 105 K building. Larry mentioned that there was a remote possibility that a defective railroad tie could also cause a switch malfunction. However, this is also very unlikely, because the switches and supporting ties are inspected monthly in accordance with CFR 49, Part 213. Thus, there does not appear to be a significant safety issue associated with the 105 K rail switches.

Derailers

The adequacy of the derailers was also discussed relative to the statement made by the manufacturer that they could not provide a velocity capacity rating for a specific derailer. Larry stated that the derailers have always functioned properly in the few occasions when they were accidentally encountered during Hanford rail operations in the past. When quizzed about the lack of speed control prior to reaching the 105K derailers, he pointed out that the distance between the switches and the derailers would not allow a high velocity to be achieved at the derailer locations. In his judgement, the derailers would be adequate for the velocity achievable by the train, for the short distances involved.

A UNC RESOURCES Company

P.O. Box 490
Richland, Washington 99352

Telephone 509/376-7411

Memorandum

To: T. A. Galioto

Date: May 16, 1983

From:

J. R. Kelly

J R Kelly

Subject:

FUEL CAR MOVEMENT IN 105 KE/KW BASIN AREAS

The current method of moving a fuel car into the subject areas utilizes an Alco diesel electric locomotive. The throttle is padlocked so that the speed is 2 miles per hour maximum.

To not exceed the capacity of the rail stops, it is desirable to accurately control and monitor the train speed at 1.5 mph or less and/or reduce the weight of the prime mover (the locomotive).

Three different types of prime movers were investigated that would be suitable for this operation.

1. Diesel Electric Locomotive

A new locomotive, #3728, manufactured by the Electromotive Division of General Motors Corp., has been in service for the past several months. This 1500 HP, Model #EMD-MP15AC diesel electric locomotive is equipped with a cab mounted Vapor Corp. "Pace Setter" speed controller including a digital speedometer. This solid state device monitors the axle speed and accordingly controls the generator's field which controls the current to the direct current traction motors to maintain the present speed. With the controller operating, the specified velocity is accurately maintained on the digital speedometer. This is true even if the engine throttle is opened and diesel engine speed is increased accordingly. The controller will operate in either forward or reverse and on level or upgrade tracks. This locomotive was not ordered with automatic braking controls to maintain a set downgrade speed.

T. A. Galioto
Page 2
May 16, 1983

1. Diesel Electric Locomotive (Cont'd)

The black box on the controller has several speed ranges that may be selected. For 105K basin fuel car movement, the 0.1 to 1 mph range would be used. The percentage dial, zero to 100, would maintain a speed up to one mile per hour maximum. The "range" selection switches are the single critical command. A lockable plexiglas cover would be placed over the range selection part of the panel to assure the locomotive would not exceed one mile per hour.

The selection of the "automatic" switch (not the manual switches) allows the controller to start and control the engine speed.

Braking is by air brakes that are more responsive than those on the Alco engines. More accurate car spotting is, therefore, possible. An emergency "dynamite" valve in the cab will set all brakes and stop the diesel when it is thrown.

Using the speed controller, this locomotive has been demonstrated and is used in the 200 Area. The Rockwell Operations people believe it is safe and more reliable than the Alco locomotives with the locked throttle. They use the speed controller without any lockable range cover such as mentioned for K-Area basin usage.

An identical second locomotive has been ordered by Rockwell and should be at Hanford in January 1984. The new locomotives weigh 120 tons - the same as the Alco.

Information in-the-cab demonstration rides are available at the Rockwell shops on a couple of days notice.

T. A. Galioto
Page 3
May 16, 1983

2. Shuttle Wagon

For in-plant rail car movements, small diesel powered car movers are commonly used. One such device is the model SWX-20 Shuttle Wagon manufactured by the T&J industries Inc. in Kansas City, Missouri. It is powered by a 140 HP GM 4-53 diesel engine coupled to an automatic transmission with three equal speeds forward and reverse. The power is transmitted to rubber tired 4-wheel drive for either rail or road usage. When used on rails, eight steel guide wheel direct the mover. Standard rail couplers are front and rear mounted. The service brakes are air over hydraulic disc brakes. There is a separate 11 cubic foot air storage vessel and hose connector for the rail car(s) brakes, with a cab mounted control valve.

There is a two man enclosed operating cab with the required controls and instruments. Though normally not equipped with a speedometer, the vendor states that it could easily be added to the instrument panel.

Forward or reverse speeds on the transmission are:

1st	5 mph (max.)
2nd	9 mph (max.)
3rd	23 mph (max.)

To control the vehicle speed, a lockable clamp may be put on the transmission shift lever to hold it in the first speed. The diesel fuel throttle valve has an adjustable linkage that can be fixed in position (such as welded) to limit the engines' fuel supply and therefore the shuttlewagon and fuel rail car speed.

T. A. Galioto
Page 4
May 16, 1983

2. Shuttle Wagon (Cont'd)

On level rail, such as is found on the approaches to 105 KE/KW basins, this shuttle wagon will move 1000 plus tons (1/6 the weight of the 120 ton diesel electric locomotive), the impact load at 2 mph on the rail stops is reduced proportionally.

For 100K Area operation, the fuel car would be decoupled from the locomotive at 50 to 100 feet outside of the basin. The shuttle wagon would then couple to and push the fuel car into the basin area at a controlled velocity.

This T&J shuttlewagon is priced at about \$90,000, FOB Kansas City, MO. Delivery is approximately 30 days.

3. Car Pullers

These are electro mechanical devices consisting of an electric motor driving a high reduction worm gear speed reducer with a capstan on the output shaft. Typically, a 5HP unit can move 1 to 3 loaded cars at a maximum speed of 42 ft./minute. Tension on the free end of the rope controls the car speed and to stop the car, the operator simply releases his tension on the rope.

Several of these 5HP car pullers are in the 100K Area and are not presently being used. A demonstration of their operation on an empty fuel car could be made, providing one unit is operational.

To remove and relocate two pullers, one at 105KE and the second at 105KW, new foundation and electrical service would be required at each location. A rough order of magnitude is \$40K for each or \$80K total.

T. A. Galioto
Page 5
May 16, 1983

3. Car Pullers (Cont'd)

Operation into the 105 KE/KW basins would require spotting the fuel car just outside of the basin door. The locomotive would be decoupled and the car puller rope hooked to the fuel car. Pulling the fuel car into the basin would be at a slow rate of 42 ft./minute with a quick and positive capability of car stoppage by the UNC operator relaxing his tension on the capitan rope. In an emergency, switching off the electric motor would also stop car movement. Controllable, minor personnel safety hazards would be rope failure and rope radioactive contamination from the basin floors.

The installed rail car stops are more than adequate since they must just stop a single fuel car (120 tons) moving at 42 ft./minute or less with no locomotive weight.

4. Upgrade of Existing Bumpers

Upgrading the existing railroad bumpers capacity was also considered. This option was discussed with Kaiser Engineers Hanford, and it was agreed it would require replacement of the existing bumpers and rails. A rough order of magnitude to do this for both facilities is \$900K.

Conclusions and Recommendations

It is our recommendation that option 1, the Diesel Electric Locomotive, be pursued by Fuel Processing. This option can be accomplished at the least cost to UNC and requires no change to existing UNC procedures. Fuel Processing has indicated the earliest possible need date for hanging fuel storage in the east ends of 105-KE/KW is October 1984. This allows sufficient time for the second new engine to be put into service to insure 100% utilization of speed controlled motive power.

T. A. Galito
Page 6
May 16, 1983

Should option 1 be unacceptable to Nuclear Safety and/or Fuel Processing, it is suggested they pursue funding for options 2 or 3, in that order. Option 2 should be pursued through Rockwell Transportation and option 3 pursued as a Design Change.

Completion of option 4 by the required date, October 1984, would be extremely difficult. The earliest available funding source would be as an FY 1984 GPP, which would result in a late FY 1984 construction completion date at best. Acceleration of this completion date would be very difficult.

RPB:ddl

cc: RP Brown
JRK-File/LB

**Westinghouse
Hanford Company**
**Internal
Memo**

From: Program and Administration
 Phone: 373-1608 X3-72
 Date: March 10, 1995
 Subject: RESOLUTION OF FUEL CHARACTERIZATION PRESTART PUNCHLIST ITEM D
 RELATING TO THE HEIGHT OF THE CASK TRAILER WITH RESPECT TO THE
 RESTRAINING BARRIER

95KDD.001

To: Plant Readiness Team X3-71

cc: L. D. Alwardt X3-77
 C. L. Bennett X3-77
 D. W. Bergmann R3-86
 K. D. Dobbin X3-72
 J. C. Hamrick X3-80
 S. L. Hecht L5-01
 C. D. Kirk X3-72
 M. J. Langevin X3-74
 C. T. Miller X3-72
 R. P. Omberg R3-85
 J. P. Schmidt X3-78
 S. A. Slinn X3-74
 C. A. Thompson X3-72
 J. T. Vistica X3-80

- References: (1) Internal Memo, L. D. Alwardt and C. L. Bennett to Plant Readiness Team, "Fuel Characterization Prestart Punchlist Item D 'Determine the Measured Height of the Cask Trailer with Respect to the Restraining Barrier that Keeps the Trailer from Accidently Running into the Pit'," dated March 8, 1995.
- (2) Internal Memo, Readiness Assessment Team to T. B. Veneziano, "Prestart Punchlist (Corrected from the March 3 Submittal)," dated March 6, 1995.

Present rail car barrier mechanisms in 105 KW will be used to assure that the Chem-Nuclear Shipping Cask (CNSC) trailer cannot back too far into the building and drop into the west bay of the fuel storage basin. Reference 2 requested measurements to determine the height of the trailer bumper relative to the height of the rail car bumper in the building. Reference 1 provided the requested measurements, but excluded the wheel well structure as part of the main trailer bumper structure. Because of this exclusion, Reference 1 concluded that the height difference was unacceptable.

Figure 1 shows the measurements including the wheel well structure. The CNSC trailer will strike the rail car bumper five inches down from the top of the wheel well, which is a part of the bed of the trailer. These measurements were obtained separately from those in Reference 1 but are within an inch. Differences are probably caused by ground variations where

Plant Readiness Team
Page 2
March 9, 1995

95KDD.001

the trailer is parked. The measurements are for the trailer without the cask, but no perceptable upward movement of the trailer was observed at the time the cask was removed. In any case, there could be five inches of downward motion of the trailer before the attached analysis is invalid, which was obviously not observed.

The attached calculations show that the wheel well assembly will remain essentially intact and that the rail car bumper will absorb most of the kinetic energy without failure with the trailer absorbing the rest. Deformation to the CNSC trailer wheel well will be minor with no major damage except for possibly some local deformation. Therefore, the trailer will not proceed farther than the rail car bumper shown on Figure 1.

K. D. Dobbin, Senior Principal Engineer
Program and Administration

S. L. Hecht Principal Engineer
Nuclear Fuel Evaluations

Attachments

clg

Dobbin

3-9-95

Rail Car
Bumper

PROBLEM TRACTOR TRAILER WITH WKK RUNS INTO
BUMPER, 5700 SYSTEM AT K-W? DO IT STOP AT

KINETIC ENERGY (KE)

$$\begin{array}{rcl} W = & 28,250 \text{ lb} & \text{TRACTOR + TRAILER} \\ & + 26,800 & \text{CASH} \\ \hline & 55,050 \text{ lb} & \text{TOTAL} \end{array}$$

$$M = \frac{W}{g} = 55,050 / 32.2 = 1710 \text{ lb-sec}^2/\text{ft}$$

$$KE = \frac{1}{2} MV^2 =$$

$$V = (5 \text{ mile/HK}) \left(\frac{5280 \text{ ft}}{\text{mi}} \right) \left(\frac{1 \text{ hr}}{3600 \text{ sec}} \right) = 7.33 \text{ ft/sec}$$

$$KE = (.5)(1710)(7.33)^2 = \underline{\underline{45,980 \text{ FT-LBS}}}$$

NOTE: Ref H-34751 - TW GSK (ALL) 1.5 WFF $\Rightarrow$ KE 52,000 FT-LB
DESIGN LOAD
RAIL BUMPER

RATED AT 59,000 FT-LBS @ 220,000 LB MAX LOAD

BUMPER SHOULD BE ABLE TO ABSORB ALL

ENERGY WITHIN FORCE LIMITATION

4 SPRING (ASSUME LINEAR)

$$W = \int F \cdot dx; F = KX, \text{ then}$$

$$KE \rightarrow PE = \frac{1}{2} KX^2, \quad - \text{PRO K GIVEN ESTIMATE}$$

FROM DEQN, 2 UNKNOWN. $F = KX$

$$59,000 = \frac{1}{2} K X^2 \quad (1)$$

$$220,000 = K X \quad (2)$$

$$(2) \Rightarrow K = (220,000 / X) \quad |$$

$$\Rightarrow (1) \Rightarrow 59,000 = \frac{1}{2} (220,000 / X) X^2$$

$$X^2 = (59,000) = 110,000 X$$

$$X = \underline{\underline{.536 \text{ FT}}}$$

$$\text{then } K = 220,000 / .536 = 410,169 \text{ lb/ft}$$

$$F_{\text{MAX}} \quad \text{D} \quad 45,980 \text{ FT-16}$$

$$K_E = \frac{1}{2} K X^2$$

$$45,980 = (.5)(410,169) X^2$$

$$X = \sqrt{1,224} = .4735$$

$$F = K X = \underline{\underline{194,200 \text{ lb}}}$$

This is less than the 220,000 lb design load
of the SUPPORT STRUCTURE, Ref. H-1-34353

WHAT WILL THIS FORCE DO TO THE TRAILED

Look at Main CHASSIS, and TOP PLATE

LOAD TRANSMITTAL TO 2 I Beam.

$$A_{\text{EST}} = 19 \times \left(\frac{3}{8}\right) + (2)(6)\left(\frac{1}{2}\right) = 13.125$$

$$= 2 \text{ beam} = 26.25$$

1/4 inch thick top plate =

$$(48" \text{ wide}) \left(\frac{1}{4}\right) = 12 \text{ in}^2$$

TOTAL = 38 in² - neglect skirt & other
mini

$$\sigma_A = P/A = 194,200 / 38 = 5,100 \text{ psi}$$

$S_y = 36,000 \text{ psi}$ - assume A-36

is no major damage to trailer

Possibly some local dents, etc.

Check shear of box - 1 box

$$A_s = \left(\frac{1}{4}\right) \left[(80)(2) + 2(24) \right] = 52$$

$$\tau_{\text{AVG}} = 194,200 / 52 = 3,730 \text{ psi}$$

$$\tau_{ys} \leq \frac{1}{2} S_y = \underline{\underline{15 \text{ Ksi}}}$$

Box will not shear.

checked: RPO mberg 3/10/95

**Westinghouse
Hanford Company****Internal
Memo**

From: Technical Safety 95LDA008
Phone: 373-1591 X3-77
Date: March 8, 1995
Subject: FUEL CHARACTERIZATION PRESTART PUNCHLIST ITEM D "DETERMINE THE MEASURED HEIGHT OF THE CASK TRAILER WITH RESPECT TO THE RESTRAINING BARRIER THAT KEEPS THE TRAILER FROM ACCIDENTLY RUNNING INTO PIT"

To: Plant Readiness Team X3-71

cc: C. D. Kirk X3-72
M. J. Langevin X3-74
C. T. Miller III X3-72
R. P. Omberg R3-85
J. P. Schmidt X3-78
S. A. Slinn X3-74
C. A. Thompson X3-72
LDA:CLB File/LB

Reference: Internal Memo, Readiness Assessment Team to T. B. Veneziano, "Prestart Punchlist (Corrected from the March 3 Submittal)", dated March 6, 1995

Physical measurements of the Chem Nuclear-supplied truck trailer to be used for fuel characterization shipments were taken on March 6, 1995. Measurements of the railcar bumper in the 105 KW basin were taken on March 7, 1995 which confirmed dimensional information contained on drawings H-1-34853, sheet 1 and H-1-34761.

As shown on the attached drawing, the top of the trailer bumper (without the cask on the trailer bed) is approximately 38 inches above the ground and spans the 91 inch width of the trailer. On each side at the rear of the trailer are 27 inch wide, eight inch high wheel wells. The bottom of the railcar bumper is 42 inches above the basin area floor elevation. The railcar bumper is 42 inches wide and is clamped to a beam that spans the 14 foot distance on column line 13 between building columns E and F.

In the current configuration if the truck trailer was allowed to back into the railcar bumper, the trailer contact with the lower edge of the railcar bumper would be approximately four inches below the top of the wheel well structures (approximately four inches above the main trailer bumper structure). This is unacceptable with respect to the fuel characterization safety evaluation (WHC-SD-SNF-TA-002, Rev. 0) described controls for prevention of a cask and trailer drop into the west bay of the fuel storage basin.

Plant Readiness Team
Page 2
March 8, 1995

95LDA008

Following are five options for dealing with the current trailer and railcar bumper height configurations:

- 1) Install a barrier (such as a concrete traffic barrier) west of the railcar bumper that the trailer would impact prior to reaching the railcar bumper. Use of a barrier would require documented qualification as equivalent to the railcar bumper.
- 2) Install a ramp west of the railcar bumper to raise the rear of the trailer at least six inches so that the trailer bumper would contact the railcar bumper.
- 3) Lower the railcar bumper so that its height is compatible with the trailer bumper.
- 4) Utilize a trailer with a higher bumper that is compatible with the height of the railcar bumper.
- 5) Fuel characterization personnel perform a structural analysis to qualify (if practical) the trailer wheel well structural steel for impact with the railcar bumper.

E. D. Alwardt
Principal Engineer

C. L. Bennett, Manager
Technical Safety

1da

Attachment

Elevation View of Rear of Trailer

Elevation View of Railcar Bumper