S

ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN 650919

Proj.
ECN

2. ECN Category (mark one) Supplemental ☐ Direct Revision ☐ Change ECN ☒ Temporary ☐ Standby ☐ Supersedeure ☐ Cancel/Void ☐	3. Originator's Name, Organization, MSIN, and Telephone No. AJ Kostelnik, 08E00, S7-12, 3-0788	4. USQ Required? [X] Yes ☐ No	5. Date 10/7/98																								
	6. Project Title/No./Work Order No. Characterization Project	7. Bldg./Sys./Fac. No. 200 G	8. Approval Designator SQ																								
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) HNF-SD-WM-ETP-213 Rev.0	10. Related ECN No(s). N/A	11. Related PO No. N/A																								
12a. Modification Work ☐ Yes (fill out Blk. 12b) ☒ No (NA Blks. 12b, 12c, 12d)	12b. Work Package No. N/A	12c. Modification Work Complete N/A Design Authority/Cog. Engineer Signature & Date	12d. Restored to Original Condition (Temp. or Standby ECN only) N/A Design Authority/Cog. Engineer Signature & Date																								
13a. Description of Change This ECN releases the complete revision of HNF-SD-WM-ETP-213 Rev.0 . The revision of HNF-SD-WM-ETP-213 is changed from Rev.0 to Rev.1 The title is changed to: "Engineering Task Plan for Upgrades to the Leveling Jacks on Core Sample Trucks #3 and #4"																											
13b. Design Baseline Document? ☐ Yes ☒ No																											
14a. Justification (mark one) Criteria Change ☒ Design Improvement ☐ Environmental ☐ Facility Deactivation ☐ As-Found ☐ Facilitate Const. ☐ Const. Error/Omission ☐ Design Error/Omission ☐																											
14b. Justification Details The ETP is revised to incorporate changes in scope.																											
USQ# Categorical Exclusion TF-96-0690 Rev.2																											
15. Distribution (include name, MSIN, and no. of copies) <table border="0"> <tr> <td>RN Dale</td> <td>S7-12</td> <td>AJ Kostelnik</td> <td>S7-12</td> </tr> <tr> <td>ML McElroy</td> <td>S7-07</td> <td>EE Salinas</td> <td>S7-12</td> </tr> <tr> <td>GP Janicek</td> <td>S7-12</td> <td>JA Ranschau</td> <td>S7-07</td> </tr> <tr> <td>RM Boger</td> <td>S7-12</td> <td>CE Hanson</td> <td>S7-12</td> </tr> <tr> <td>JG Kristofski</td> <td>S7-01</td> <td>DH Shuford</td> <td>S7-03</td> </tr> <tr> <td>HH Ziada</td> <td>R1-56</td> <td></td> <td></td> </tr> </table>				RN Dale	S7-12	AJ Kostelnik	S7-12	ML McElroy	S7-07	EE Salinas	S7-12	GP Janicek	S7-12	JA Ranschau	S7-07	RM Boger	S7-12	CE Hanson	S7-12	JG Kristofski	S7-01	DH Shuford	S7-03	HH Ziada	R1-56		
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JG Kristofski	S7-01	DH Shuford	S7-03																								
HH Ziada	R1-56																										

RELEASE STAMP

DATE:

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HANFORD

RELEASE

ID:

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ENGINEERING CHANGE NOTICE

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1. ECN (use no. from pg. 1)

650919

16. Design Verification Required

☐ Yes
☒ No

17. Cost Impact

ENGINEERING

Additional [N/A] \$
Savings ☐ \$

CONSTRUCTION

Additional [N/A] \$
Savings ☐ \$

18. Schedule Impact (days)

Improvement [N/A]
Delay ☐

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	☐	Seismic/Stress Analysis	☐	Tank Calibration Manual	☐
Functional Design Criteria	☐	Stress/Design Report	☐	Health Physics Procedure	☐
Operating Specification	☐	Interface Control Drawing	☐	Spares Multiple Unit Listing	☐
Criticality Specification	☐	Calibration Procedure	☐	Test Procedures/Specification	☐
Conceptual Design Report	☐	Installation Procedure	☐	Component Index	☐
Equipment Spec.	☐	Maintenance Procedure	☐	ASME Coded Item	☐
Const. Spec.	☐	Engineering Procedure	☐	Human Factor Consideration	☐
Procurement Spec.	☐	Operating Instruction	☐	Computer Software	☐
Vendor Information	☐	Operating Procedure	☐	Electric Circuit Schedule	☐
OM Manual	☐	Operational Safety Requirement	☐	ICRS Procedure	☐
FSAR/SAR	☐	IEFD Drawing	☐	Process Control Manual/Plan	☐
Safety Equipment List	☐	Cell Arrangement Drawing	☐	Process Flow Chart	☐
Radiation Work Permit	☐	Essential Material Specification	☐	Purchase Requisition	☐
Environmental Impact Statement	☐	Fac. Proc. Samp. Schedule	☐	Tickler File	☐
Environmental Report	☐	Inspection Plan	☐		☐
Environmental Permit	☐	Inventory Adjustment Request	☐	None	☒

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision

Document Number/Revision

N/A

Document Number Revision

21. Approvals

Signature	Date	Signature	Date
Design Authority GP Janicek	10/7/98	Design Agent	
Cog. Eng. RN Dale	10/7/98	PE	
Cog. Mgr. JS Schofield	10/7/98	QA	
QA ML McElroy	10-7-98	Safety	
Safety JA Ranschau	10-8-98	Design	
Environ. N/A		Environ.	
Other		Other	
CE Mgr. RM Boger	10/12/98		
CPO Mgr RS Pajelarczyk	12-4-98	DEPARTMENT OF ENERGY	
COGEMA Proj. Mgr CE Hanson	10/7/98	Signature or a Control Number that tracks the Approval Signature	
		ADDITIONAL	

ENGINEERING TASK PLAN FOR UPGRADES TO THE LEVELING JACKS ON CORE SAMPLE TRUCKS #3 AND #4

A.J. Kostelnik
COGEMA Engineering Corporation, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

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Key Words: core sampling, RMCS, outrigger, jack,

Abstract: This Engineering Task Plan defines the requirements and deliverables of the activities associated with the upgrades of the leveling jacks and supporting structure on core sample trucks 3 and 4.

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Release Approval 10/14/98
Date

Approved for Public Release

ENGINEERING TASK PLAN FOR UPGRADES TO THE LEVELING JACKS ON CORE SAMPLE TRUCKS #3 AND #4

A. J. Kostelnik

COGEMA Engineering Corporation

October 7, 1998

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1 INTRODUCTION

Characterizing the waste in underground storage tanks at the Hanford Site is accomplished by obtaining a representative core sample for analysis. Core sampling is one of the numerous techniques that have been developed for use given the environmental and field conditions at the Hanford Site. Core sampling is currently accomplished using either Push Mode Core Sample Truck #1 or; Rotary Mode Core Sample Trucks #2, 3 or 4.

Past analysis (WHC 1994) has indicated that the Core Sample Truck (CST) leveling jacks are structurally inadequate when lateral loads are applied. WHC 1994 identifies many areas where failure could occur. All these failures are based on exceeding the allowable stresses listed in the American Institute of Steel Construction (AISC) code. The mode of failure is for the outrigger attachments to the truck frame to fail resulting in dropping of the CST and possible overturning (Ref. Ziada and Hundal, 1996).

Out of level deployment of the truck can exceed the code allowable stresses in the structure. Calculations have been performed to establish limits for maintaining the truck level when lifting. The calculations and the associated limits are included in appendix A.

The need for future operations of the CSTs is limited. Sampling is expected to be complete in FY-2001. Since there is limited time at risk for continued use of the CSTs with the leveling controls without correcting the structural problems, there are several design changes that could give incremental improvements to the operational safety of the CSTs with limited impact on available operating time. The improvements focus on making the truck easier to control during lifting and leveling. Not all of the tasks identified in this ETP need to be performed. Each task alone can improve the safety.

This engineering task plan is the management plan document for implementing the necessary additional structural analysis. Any additional changes to meet requirements of standing orders shall require a Letter of Instruction from Numatec Hanford Company (NHC).

2 SCOPE

The scope of this Engineering Task Plan (ETP) is to provide the design for the installation of operator enhancements for the safe lifting and leveling of the core sample trucks.

3 DESCRIPTION

3.1 PHYSICAL DESCRIPTION

3.1.1 Functional Design Criteria

The requirements are included in the Design Compliance Matrix (LMHC 1998).

3.1.2 Structural Requirements

The design of any modifications shall consider only the weight of the truck acting vertically in all possible positions. The factor of safety for the design shall be a minimum of 1.5 based upon the appropriate failure theory and tabulated AISC values.

Assumptions:

- 3.1.2.1 Given that the leveling jacks have a safety class of GS there are no procurement requirements such as material certifications etc.
- 3.1.2.2 The existing structural analysis produced for CST #2 shall be considered to bound the design of CSTs #3 and #4.
- 3.1.2.3 The analysis shall consider the CST to be deployed in its worst possible out of level condition. (18 inch extension of 1 rear and the front jack).
- 3.1.2.4 Only the designs of CSTs #3 and #4 will be considered.

3.2 ENGINEERING TASKS

The deliverables will be in the form of released ECNs and USQ Screenings for the design changes. Required structural analysis for design modifications will be included as appendices to this ETP. The following tasks may be performed.

- 3.2.1 Perform analysis based upon actual possible deployment conditions of the existing design to determine actual capabilities and design structural modifications based upon results of the analysis. Existing analysis for lateral loads is based upon Truck #2 design and does not include design changes made to increase the strength of the structure. Lateral loading analysis has not been performed for the Truck 3 & 4 design. Recommended modifications could include adding gussets or stringers to strengthen the outrigger attachments to the truck frame and permanently limiting the deployment length of the bolsters. The benefit of performing this task is that the existing truck could prove to be adequate and no downtime is required for modifications.
- 3.2.2 Design and install electronic control system to lift and lower the truck within the limits specified. System may be commercially available. Would include installing larger diameter cylinders or higher pressure hydraulic supply for better lifting capability. Requires design and installation of hydraulic valves. The benefit of performing this task is that operator experience is no longer a factor for safe deployment. The current system used requires close attention by the operator to avoid exceeding the limits. The operator could be located a safe distance away from the truck when performing the lifting and levelling operation.

- 3.2.3 Design and install a more user friendly control system for the operator to control the flow of the hydraulic fluid to the cylinders. (Replace the needle valves with sliding spool type valves. The benefit of performing this task is more rapid control of the hydraulic fluid to the cylinders allowing quick adjustments before the truck leans too far.
- 3.2.4 Install separate high pressure (2500 psi) hydraulic system for better control of the hydraulic jacks. Requires installation of PTO on truck transmission with hydraulic pump and reservoir. The current 1100 psi system on the drill rig provides barely adequate lifting capability. The benefit of performing this task is that the existing hydraulic jacks could be used to lift the truck with better control of the load.
- 3.2.5 Install larger hydraulic cylinders on the rear outriggers for better control of the load. Requires structural analysis. The benefit of performing this task is that the existing hydraulic system could be used to lift the truck with better control of the load.
- 3.2.6 Design and install a feedback system for the operator to monitor the level of the truck more easily. (Closed loop liquid level indicators.) The benefit of performing this task is that the operator would have immediate indication of the level of the truck without requiring communication with other operators.
- 3.2.7 Design and install devices to hold the truck axles close to the frame as if the load were on the wheels of the truck. The benefit of performing this task is that when the truck is required to be raised more than 18 inches it must be lifted in steps. During deployment the locks could be used to hold the wheels up, with about 14-15 inches of clearance below, for placing dunnage under the wheels and lifting the truck up higher in steps.

3.3 VERIFICATION

ECNs for the design changes shall receive an informal review per PHMC 1997b. Checking of the analysis will be completed per PHMC 1997b.

4 ORGANIZATION

Responsibilities are assigned to various organizations as identified below:

COGEMA Engineering Corporation will provide the engineering support as requested.

Responsible Manager:	C.E. Hanson
Responsible Engineer:	A.J. Kostelnik

Numatec Hanford Company (NHC) will provide funding and project management.

Responsible Manager:	R.M. Boger
----------------------	------------

Lockheed Martin Hanford Corporation (LMHC) will provide Cognizant Engineer support for review and USQ preparation.

Cognizant Manager: J.S. Schofield
Cognizant Engineer: R.N. Dale

LMHC will also provide support for Design Authority, Quality Assurance and Safety.

Responsible Design Authority: G.P. Janicek
Responsible QA: M.L. McElroy
Responsible Safety: J.A. Ranschau

5 COST and SCHEDULE

Due to the fact that specific startup dates are unknown at this time, only estimates for duration of a given task are supplied.

5.1 ENGINEERING TASKS

5.1.1 Perform analysis

5.1.1.1 Estimated cost = \$20K+ (ECNs, USQs and structural modifications as required by structural analysis.) (8 Weeks duration for analysis).

5.1.2 Design and install electronic control system to lift and lower the truck within the limits specified.

5.1.2.1 Estimated cost: Design = 400 hours - (8 weeks duration),
Hardware = \$30K (each truck)

5.1.3 Design and install a user friendly control system for the operator to control the flow of the hydraulic fluid to the cylinders.

5.1.3.1 Estimated cost: Design = 200 hours - (8 weeks duration)
Hardware = \$15K (each truck)

5.1.4 Install separate high pressure (2500psi) hydraulic system for better control of the hydraulic jacks.

5.1.4.1 Estimated cost: Design = 120 hours - (6 weeks duration),
Hardware = \$5K (each truck)

5.1.5 Install larger hydraulic cylinders on the rear outriggers for better control of the load.

5.1.5.1 Estimated cost: Design = 200 hours - (8 weeks duration),
Hardware = \$5K (each truck)

- 5.1.6 Design and install a feedback system for the operator to monitor the level of the truck more easily. (Closed loop liquid level indicators.)

5.1.6.1 Estimated cost: Design = 50 hours - (3 weeks duration),
Hardware = \$2K (each truck)

- 5.1.7 Design and install devices to hold the truck axles close to the frame as if the load were on the wheels of the truck.

5.1.7.1 Estimated cost: Design = 100 hours - (3 weeks duration),
Hardware = \$5K (each truck)

6 CONFIGURATION MANAGEMENT

All design changes shall be in the form of ECNs against the existing design configuration per procedure HNF-PRO-440 Engineering Document Change Control Requirements (PHMC 1997c).

7 QUALITY ASSURANCE

The Quality Assurance overview for the proposed activities shall be provided by LMHC. It is assumed that the budget for QA support is included in the general Characterization Project budget.

8 SAFETY

The Safety overview for the proposed activities shall be provided by LMHC. It is assumed that the budget for Safety support is included in the general Characterization Project budget.

9 SYSTEM ENGINEERING

This activity is necessary to support the characterization of the waste in the underground waste tanks on the Hanford site. This activity supports the Tank Farms task identified in the work breakdown structure (WBS) as task number 1.1.2.4.08.03/VI, Core Sampling Systems (LMHC 1997).

10 REFERENCES

- LMHC 1997 HNF-SP-1230 *"Waste Characterization FY-98 Multi-Year Work Plan"*, September 26, 1997, Lockheed Martin Hanford Company, Richland, Washington
- LMHC, 1998 *"Baseline Design Compliance Matrix for the Rotary Mode Core Sampling System"*, HNF-SD-WM-CR-062, Rev.1, Lockheed Martin Hanford Corporation, Richland, Washington.
- PHMC, 1997a, *Engineering Design and Evaluation*, HNF-PRO-97 Rev 0, Fluor Daniel Hanford Inc, Richland, Washington.
- PHMC, 1997b, *Design Verification Requirements*, HNF-PRO-445 Rev 0, Fluor Daniel Hanford Inc, Richland, Washington.
- PHMC, 1997c, *Engineering Document Change Control Requirements*, HNF-PRO-440 Rev 1, Fluor Daniel Hanford Inc, Richland, Washington.
- WHC, 1994, *Stress Analysis of Jacks, Frame and Bearing Connections, Drill Rod for Core Sampler Truck #2*, WHC-SD-WM-ER-392, Rev.0, Westinghouse Hanford Company, Richland, Washington.
- Ziada and Hundal, 1996, *Seismic Evaluation of Core Sampler Truck No. 2*, Internal Memo, Westinghouse Hanford Company, Richland, Washington.

Appendix A

Administrative Controls for Core Sample Truck Outrigger Deployment

Discussion

The load capability of the outriggers under loading conditions which are not vertical is limited. The attached calculations, for Trucks 3 and 4, identify limits for safe lifting and leveling operations.

When in the transport mode the jacks of the trucks are fully retracted to maximize ground clearance and the feet of the rear jacks are approximately 8" above the ground and the front jack pad is approximately 15" above the ground. For the purpose of the controls in this letter, fully retracted is treated as 0" extension. The heights referenced in this letter are all calculated from the 0" reference.

The purpose of the calculations was to give the largest safe operating envelope possible. Earlier analysis, WHC-SD-WM-ER-392 by Ziada, determined the Truck #2 supporting structure has the capacity of 1400 pounds laterally when elevated 18" from 0". The 1400 lb limit comes from 500 lbs front to rear on each rear jack and 730 lbs front to rear on the front jack along with 1250 lbs side to side on each rear jack and 730 lbs side to side on the front jack.

A separate analysis, WHC-SD-WM-ER-391 by Ziada, analyzed the Truck #2 structure for rollover possibility. The analysis determined the truck, when deployed out of level by extending a single rear jack 18", would lean at an angle of 13° but would not roll over.

The attached analysis looks at the loads that are applied to the structure of the truck to check on the structural capability of the outriggers and jacks. The analysis is based upon the lateral load limits in ER-392. The calculations apply the lateral load limits that were found for Truck #2 and apply them to Trucks #3 and #4 because the designs are almost identical. Trucks #3 and #4 weigh 32000 lbs, 2000 lbs more than Truck #2. The truck frame at the front of Trucks #3 and #4 is also approximately 20 inches higher off the ground than on Truck #2. No checking was done on the limits in ER-392 to see if the added 2000 lbs significantly affects the lateral load capability.

The conditions to be avoided are as follows:

1. Extending the jacks over 15" significantly reduces their capacity to the point where leaning beyond 3° front to rear will overload the front jack and it could twist off shearing the mounting bolts on the jack attachment to the truck frame.
2. Extending the jacks over 5" significantly reduces their capacity to the point where leaning beyond 3° from side to side will overload the front jack and could cause it to twist off, shearing the mounting bolts on the jack attachment to the truck frame.
3. Extending the telescoping bolsters farther than would be necessary if deployed on level ground will significantly reduce the capability of the truck jacks to withstand lateral loads. (Over extension creates a longer moment arm for the lateral loads to act through.)

4. Truck out of level conditions also produce movement of the jack feet relative to each other. As the truck leans the distance between the jack feet changes. The change becomes significant when the truck is lifted higher. As the distance changes 1 of 3 things must happen. The jack feet must slide on the dunnage, the dunnage must lean, and/or the structure must bend.

Controls

The following "Controls" should be implemented to prevent operating under the conditions described above and exceeding the structural capabilities of the outrigger structures. The controls are prescribed to prevent the loading of the outriggers beyond the AISC code allowables. Because the failure mode of the weak connections is in shear, there is little plastic deformation that will occur before the material separates and the jacks fail. Failure could come rapidly without warning.

Control-1 The truck should be leveled within 5° prior to deploying the truck jacks.

Basis: Leveling the truck prior to deploying the jacks will effectively shorten the bolster length and will prevent laterally loading the jacks with the lean of the truck. The truck could be leveled to within 5° initially by driving on to dunnage. Then the truck should be levelled side to side using the rear jacks and front to rear leveling should be completed before proceeding to lift the truck.

Control-2 The bolsters should be limited to no more than an 18" extension. (Locking the collar, which is driven by the hydraulic cylinder, to the bolster will prevent telescoping the internal sections.) See sketch above.

Basis: The hydraulic cylinders have an 18" stroke. The 18" stroke is the basis for the analysis and the controls. Extension of the bolsters more than 18" reduces the lateral load bearing capability beyond the limits of these controls.

Control-3 The truck should be lifted level within 3° (The angle of 3° is approximately 4" difference in stroke length of the hydraulic cylinders from side to side and 15" difference front to rear). If 3° is exceeded the ascent of the truck should be halted and the high side of the truck lowered back to level prior to continuing to raise.

Basis: The point in which the RMCS is laterally loaded beyond the AISC Code allowables is 3° when Control-2 is satisfied.

Precautions

The following "Precautions" are to limit the damage that would be incurred if the truck failed structurally. Operating within the administrative controls above will not stress the truck beyond the allowable stresses and should prevent it from failing.

Precaution-1 The locking collars on the bolsters should be continuously adjusted up the bolster at every opportunity to prevent the free descent of the truck should a hydraulic cylinder fail or become overloaded.

Basis: Failure of a hydraulic ram would cause the truck to free fall to the locking collar. The collar would prevent the truck from building enough momentum as it fell to do more significant damage. An unrestrained fall could produce enough momentum to slide the truck off of the dunnage or cause the outrigger structure to fail. Overloading caused by out of level condition beyond 6° can cause the truck to begin descending on the overloaded ram and rapidly increase the lateral load.

Precaution-2 Dunnage should be stacked under the wheels or frame in 4" increments as the truck is raised.

Basis: This control will help to catch the truck should the bolsters fail due to lateral loads. This control provides additional protection from overloading or free descent of a jack that causes an outrigger failure.

Precaution-3 Inadvertent contact between the outriggers and the ground during transport should be prevented (such as dragging the jack pads when crossing ditches). If the outriggers contact the ground during transport they should be inspected for cracked welds, bent components, and joint misalignment prior to deployment. All components from the outrigger foot to the joint with the truck frame should be checked.

Basis: Prevents deployment with damaged structural members.

Precaution-4 The dunnage should have a large enough surface (at least 2 times the jack foot dimensions) and the jack foot centered on the dunnage to prevent the truck from sliding off the dunnage.

Basis: Lifting the truck out of level or rocking it as it goes up can cause the jack feet to "walk" on the dunnage. This could significantly shift the weight distribution on the dunnage causing it to tip or worst case the foot could fall off the side.

Truck #2

Truck #2 was also analyzed for limits related to the lateral loading conditions. It weighs approximately 2000 pounds less than Trucks 3 and 4 and the front jack is mounted lower. The two features combined make the Truck #2 structure relatively stronger than Trucks 3 and 4. The controls applied to Trucks 3 and 4 are more restrictive (ie. the controls of Trucks 3 and 4 envelope the controls of Truck 2) than would be applied to Truck 2. Two sets of controls are not given because it would increase the likelihood that the wrong controls would be applied in the field.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH ZladaDate: 9/11/98
Date: 9-11-98

Front to Rear Loading with the Front Higher than the Rear

Calculations to show how the rear jack loads increase when the front of the truck is raised higher than the rear and shifts the center of gravity backwards. Assume Trucks 3 & 4 weigh 32000 pounds. Reference diagram titled "FRONT HIGHER THAN REAR" (Page 14).

 $\Delta L := 0.18$ Difference in jack length. $\phi_{\Delta L} := \arctan\left(\frac{\Delta L}{282}\right)$ Angle produced by front higher than the rear. Angle from level.

Weight on front jack (Derived from moments about rear jack pad)

$$WF_{\Delta L} := 32000 \cdot \text{lbf} \cdot \frac{110 \cdot \cos(\phi_{\Delta L}) - (46.5) \cdot \sin(\phi_{\Delta L})}{282 \cdot \cos(\phi_{\Delta L}) + \Delta L \cdot \sin(\phi_{\Delta L})}$$

Weight on rear jacks.

$$WR_{\Delta L} := 32000 \cdot \text{lbf} - WF_{\Delta L}$$

$$FFJ_{\Delta L} := WF_{\Delta L} \cdot \cos(\phi_{\Delta L})$$

$$FRJ_{\Delta L} := \frac{WR_{\Delta L}}{2} \cdot \cos(\phi_{\Delta L})$$

Axial force acting on the front and each rear jack cylinder.

Force component acting perpendicular to the bolsters. (The force component actually produces a bending moment in the bolster. For comparison it is projected to act at the jack pad. The "force" is produced by the weight of the truck on the leaning bolsters.)

$$FFJH_{\Delta L} := WF_{\Delta L} \cdot \sin(\phi_{\Delta L})$$

$$FRJH_{\Delta L} := \frac{WR_{\Delta L}}{2} \cdot \sin(\phi_{\Delta L})$$

ΔL	$\phi_{\Delta L} \frac{180}{\pi}$	$WF_{\Delta L}$ lbf	$WR_{\Delta L}$ lbf	$FFJ_{\Delta L}$ lbf	$FRJ_{\Delta L}$ lbf	$FFJH_{\Delta L}$ lbf	$FRJH_{\Delta L}$ lbf
0	0	12482	19518	12482	9759	0	0
1	0.2	12463	19537	12463	9768	44	35
2	0.4	12444	19556	12444	9778	88	69
3	0.6	12425	19575	12424	9787	132	104
4	0.8	12405	19595	12404	9797	176	139
5	1	12385	19615	12383	9806	220	174
6	1.2	12364	19636	12362	9816	263	209
7	1.4	12344	19656	12340	9825	308	244
8	1.6	12323	19677	12318	9835	349	279
9	1.8	12301	19699	12295	9844	392	314
10	2	12280	19720	12272	9854	435	349
11	2.2	12258	19742	12248	9864	478	385
12	2.4	12236	19764	12225	9873	520	420
13	2.6	12213	19787	12200	9883	562	456
14	2.8	12190	19810	12175	9893	604	491
15	3	12167	19833	12150	9902	646	527
16	3.2	12144	19856	12124	9912	688	562
17	3.4	12120	19880	12098	9922	729	598
18	3.7	12096	19904	12072	9932	771	634

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada*AJ Kostelnik*
*Heather H. Zlada*Date: 9/11/98
Date: 9-11-98

Front to Rear Loading with the Front Higher than the Rear

The graph below shows how the weight of the truck shifts to the rear jacks when the front of the truck is raised higher than the rear and shifts the center of gravity. Approximately 19518 pounds is acting on the rear jacks when the truck is level. When the front of the truck is higher than the rear, the weight on the rear reaches 19904 pounds.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Ziada

AJ Kostelnik
HH Ziada

Date: 7-11-98
Date: 9-11-98

Front to Rear Loading with the Front Higher than the Rear. Comparison with Limits from Previous Analysis.

From the previously determined longitudinal load capability for the outriggers, determine the equivalent horizontal force capacity in the direction of front to rear at the deployment height.

Per VHC-SD-WM-ER-392, Ziada, the maximum horizontal load, front to rear, the front and rear truck jacks can withstand when extended to support the truck 18" from rest on level ground is 730 pounds on the Front and 500 pounds on the Rear. (On Truck #2, the elevation creates a 42.28" moment arm on the Rear Jacks and 31.5" moment arm on the Front Jack. On Trucks 3&4, the front moment arm is 39" and the rear moment arm is 42.28".)

$$FFlong := 730 \cdot lbf$$

$$FRlong := 500 \cdot lbf$$

$$H := 0..18 \quad \text{Height of jack}$$

Calculate the maximum moment in the bolsters to remain within limits per Truck #2 analysis by Ziada.

$$MFlong := FFlong \cdot 31.5 \cdot in$$

$$MRlong := FRlong \cdot 42.28 \cdot in$$

$$MFlong = 22995 \cdot lbf \cdot in$$

$$MRlong = 21140 \cdot lbf \cdot in$$

Calculate the force component perpendicular to the bolster that would equal the maximum horizontal load capacity previously determined with adjustment for bolster length and truck 3&4 design. This calculation assumes the bolster sections are fully retracted and the jack feet rest on dunnage (15" under the front and 8" under the rear). (The analysis of the front jack on Truck #2 did not drop the bolsters to the ground prior to lifting as was done for the rear jacks.)

$$FFmaxlong_H := \frac{MFlong}{(21 + H) \cdot in}$$

$$FRmaxlong_H := \frac{MRlong}{(16.28 + H) \cdot in}$$

When the front of the truck is elevated the forces of concern are:

FFJH=Force on Front Jack (Horizontal component causing moment at connection)

FRJH=Force on Rear Jack (Horizontal component causing moment at connection)

FRONT

REAR

ΔL		$\frac{180}{\pi}$	FFmaxlong _H		FFJH	
ΔL	$\frac{\Delta L}{\pi}$		H	lbf	ΔL	lbf
0	0		0	1095	0	0
1	0.2		1	1045	1	44
2	0.4		2	1000	2	88
3	0.6		3	958	3	132
4	0.8		4	920	4	176
5	1		5	884	5	220
6	1.2		6	852	6	263
7	1.4		7	821	7	306
8	1.6		8	793	8	349
9	1.8		9	767	9	392
10	2		10	742	10	435
11	2.2		11	719	11	478
12	2.4		12	697	12	520
13	2.6		13	676	13	562
14	2.8		14	657	14	604
15	3		15	639	15	646
16	3.2		16	621	16	688
17	3.4		17	605	17	729
18	3.7		18	590	18	771

FRmaxlong _H		FRJ _H Δ	
H	lbf	ΔL	lbf
0	1299	0	0
1	1223	1	35
2	1156	2	69
3	1096	3	104
4	1042	4	139
5	993	5	174
6	949	6	209
7	908	7	244
8	871	8	279
9	836	9	314
10	804	10	349
11	775	11	385
12	748	12	420
13	722	13	456
14	698	14	491
15	676	15	527
16	655	16	562
17	635	17	598
18	617	18	634

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada*AJ Kostelnik*
*Harold H. Zlada*Date: 8/11/78
Date: 8-11-78**Front to Rear Loading with the Front Higher than the Rear.
Comparison with Limits from Previous Analysis.**

The line with x's on it below shows how the weight of the truck produces a lateral load in the front truck jack when the front is raised higher than the rear.

The line with boxes on it below shows how the weight of the truck produces a lateral load in the rear truck jacks when the front is raised higher than the rear.

The solid line shows how the longitudinal load capacity of the front jack of the truck decreases as the truck is raised.

The dotted line shows how the longitudinal load capacity of rear jacks of the truck decreases as the truck is raised.

The structural capacity of the truck is not exceeded unless the truck jacks are extended more than 15 inches. If the jacks must be extended beyond 15 inches the truck must be maintained within 3 degrees of level front to rear or the front jack will become overloaded.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada*AJ Kostelnik*
*HH Zlada*Date: 7/1/98
Date: 9-11-98

Front to Rear Loading with the Rear Higher than the Front

Calculations to show how the front jack load increases when the rear of the truck is raised higher than the front and shifts the center of gravity forward. Assume the truck weighs 32000 pounds (Trucks 3 & 4). Reference diagram titled "REAR HIGHER THAN FRONT" (Page 14).

$$\phi_{\Delta L} := \tan^{-1}\left(\frac{\Delta L}{282}\right)$$

Angle produced by rear higher than the front. Angle from level.

Weight on both rear jacks. (Derived from moments about front jack pad.)

$$WR_{\Delta L} := 32000 \cdot \text{lb} \cdot \frac{172 \cdot \cos(\phi_{\Delta L}) - (46.5) \cdot \sin(\phi_{\Delta L})}{282 \cdot \cos(\phi_{\Delta L}) + \Delta L \cdot \sin(\phi_{\Delta L})}$$

Weight on front jack.

$$WF_{\Delta L} := 32000 \cdot \text{lb} - WR_{\Delta L}$$

Force acting on the front and each rear jack cylinder.

$$FFJ_{\Delta L} := WF_{\Delta L} \cdot \cos(\phi_{\Delta L}) \quad FRJ_{\Delta L} := \frac{WR_{\Delta L}}{2} \cdot \cos(\phi_{\Delta L})$$

Force component acting perpendicular to the bolsters. (The force component actually produces a bending moment in the bolster. For comparison it is projected to act at the jack pad. The "force" is produced by the weight of the truck on the leaning bolsters.)

$$FFJH_{\Delta L} := WF_{\Delta L} \cdot \sin(\phi_{\Delta L}) \quad FRJH_{\Delta L} := \frac{WR_{\Delta L}}{2} \cdot \sin(\phi_{\Delta L})$$

ΔL	$\phi_{\Delta L} \frac{180}{\pi}$	$WF_{\Delta L}$ lb	$WR_{\Delta L}$ lb	$FFJ_{\Delta L}$ lb	$FRJ_{\Delta L}$ lb	$FFJH_{\Delta L}$ lb	$FRJH_{\Delta L}$ lb
0	0	12482	19518	12482	9759	0	0
1	0.2	12501	19499	12501	9749	44	35
2	0.4	12521	19479	12520	9739	89	69
3	0.6	12541	19459	12540	9729	133	104
4	0.8	12561	19439	12560	9719	178	138
5	1	12582	19418	12580	9708	223	172
6	1.2	12603	19397	12600	9698	268	206
7	1.4	12625	19375	12621	9684	313	240
8	1.6	12648	19352	12642	9672	359	274
9	1.8	12670	19330	12664	9660	404	308
10	2	12694	19306	12686	9647	450	342
11	2.2	12717	19283	12708	9634	496	376
12	2.4	12742	19258	12730	9620	542	409
13	2.6	12766	19234	12753	9607	588	443
14	2.8	12792	19208	12776	9592	634	476
15	3	12817	19183	12799	9578	681	509
16	3.2	12843	19157	12823	9563	728	543
17	3.4	12870	19130	12847	9548	774	576
18	3.7	12897	19103	12871	9532	822	608

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada

AJ Kostelnik
HH Zlada

Date: 9/1/98
Date: 9-11-98

Front to Rear Loading with the Rear Higher than the Front

The graph below shows how the weight of the truck shifts to the front jack when the rear of the truck is raised higher than the front and shifts the center of gravity forward. Approximately 12482 pounds is acting on the front jack when the truck is level. When the rear of the truck is higher than the front, the weight on the front reaches 12871 pounds.

12482
9/1/98

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH ZiadaDate: 9/1/88
Date: 9-11-88Front to Rear Loading with the Rear Higher than the Front.
Comparison with Limits from Previous Analysis.

From the previously determined longitudinal load capability for the outriggers, determine the equivalent horizontal force capacity in the direction of front to rear at the deployment height.

Per WHC-SD-WM-ER-392, Ziada, the maximum horizontal load, front to rear, the front and rear truck jacks can withstand when extended to support the truck 18" from rest on level ground is 730 pounds on the Front and 500 pounds on the Rear. (On Truck #2, the elevation creates a 42.28" moment arm on the Rear Jacks and 31.5" moment arm on the Front Jack. On Trucks 3&4 the front moment arm is 39" and the rear moment arm is 42.28".)

FFlong := 730-lbf

FRlong := 500-lbf

H := 0.18 Height of jack

Calculate the maximum moment in the bolsters to remain within limits per Truck #2 analysis by Ziada.

MFlong := FFlong*31.5-in

MRlong := FRlong*42.28-in

MFlong = 22995-lbf-in

MRlong = 21140-lbf-in

Calculate the force component perpendicular to the bolster that would equal the maximum horizontal load capacity previously determined with adjustment for bolster length and truck 3&4 design. This calculation assumes the bolster sections are fully retracted and the jack feet rest on dunnage (15" under the front and 8" under the rear). (The analysis of the front jack on Truck #2 did not drop the bolsters to the ground prior to lifting as was done for the rear jacks.)

FFmaxlong_H := $\frac{MFlong}{(21 + H) \cdot \pi}$

FRmaxlong_H := $\frac{MRlong}{(16.28 + H) \cdot \pi}$

When the rear of the truck is elevated the forces of concern are:

FFJH=Force on Front Jack (Horizontal component causing moment at connection)

FRJH=Force on Rear Jack (Horizontal component causing moment at connection)

FRONT

REAR

ΔL	$\frac{\Delta L}{\pi}$
0	0
1	0.2
2	0.4
3	0.6
4	0.8
5	1
6	1.2
7	1.4
8	1.6
9	1.8
10	2
11	2.2
12	2.4
13	2.6
14	2.8
15	3
16	3.2
17	3.4
18	3.7

FFmaxlong _H		FFJH	
H	lbf	ΔL	lbf
0	1095	0	0
1	1045	1	44
2	1000	2	89
3	958	3	133
4	920	4	178
5	884	5	223
6	852	6	268
7	821	7	313
8	793	8	359
9	767	9	404
10	742	10	450
11	719	11	496
12	697	12	542
13	676	13	588
14	657	14	634
15	639	15	681
16	621	16	728
17	605	17	774
18	590	18	822

FRmaxlong _H		FRJH	
H	lbf	ΔL	lbf
0	1299	0	0
1	1223	1	35
2	1156	2	69
3	1096	3	104
4	1042	4	138
5	993	5	172
6	949	6	206
7	908	7	240
8	871	8	274
9	836	9	308
10	804	10	342
11	775	11	376
12	748	12	409
13	722	13	443
14	698	14	476
15	676	15	509
16	655	16	543
17	635	17	576
18	617	18	608

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH ZladaJohn J. Kostelnik
Harold H. ZladaDate: 9/14/88
Date: 9-11-88**Front to Rear Loading with the Rear Higher than the Front.
Comparison with Limits from Previous Analysis.**

The line with x's on it below shows how the weight of the truck produces a lateral load in the front truck jack when the rear is raised higher than the front.

The line with boxes on it below shows how the weight of the truck produces a lateral load in the rear truck jacks when the rear is raised higher than the front.

The solid line shows how the longitudinal load capacity of the front jack of the truck decreases as the truck is raised.

The dotted line shows how the longitudinal load capacity of rear jacks of the truck decreases as the truck is raised.

The structural capacity of the truck is not exceeded unless the truck jacks are extended more than 15 inches. If the jacks must be extended beyond 15 inches the truck must be maintained within 3 degrees of level front to rear or the front jack will become overloaded.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada

Paul Kostelnik
Harold H. Zlada

Date: 9/14/88
Date: 9-11-88

Free Body Diagrams for Front to Rear

REAR HIGHER THAN FRONT

FRONT HIGHER THAN REAR

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada*AJ Kostelnik*
*Harold H. Zlada*Date: 9/11/98
Date: 9-11-98

Side to Side Loading with One Side Higher than the Other

Calculations to show how the rear jack loads change when the truck leans to the side and shifts the center of gravity. Analyzed with all jacks fully compressed with one rear jack and the front jack, both extended one inch at a time. Reference diagram titled "ONE SIDE HIGHER THAN OTHER" (Page 19.)

$$\theta_{\Delta L} := \text{atan}\left(\frac{\Delta L}{80}\right) \quad \text{Angle produced with rotation around a line between a rear jack and the front jack.}$$

$$WR := 19700 \cdot \text{lb} \cdot \text{f} \quad \text{Average weight supported by the jacks on the rear of the truck from calculations on page 6.}$$

 ΔL

Weight on extended (tall) rear jack.
(Derived from moments about short rear jack pad.)

$$WTR_{\Delta L} := (WR) \cdot \frac{40 \cdot \cos(\theta_{\Delta L}) - 46.5 \cdot \sin(\theta_{\Delta L})}{80 \cdot \cos(\theta_{\Delta L}) + \Delta L \cdot \sin(\theta_{\Delta L})}$$

Weight on front jack.

Weight on short rear jack.

$$WTF_{\Delta L} := 32000 \cdot \text{lb} \cdot \text{f} - WR$$

$$WSR_{\Delta L} := WR - WTR_{\Delta L}$$

Force acting on jack cylinders.

$$FTFJ_{\Delta L} := WTF_{\Delta L} \cdot \cos(\theta_{\Delta L})$$

$$FTRJ_{\Delta L} := WTR_{\Delta L} \cdot \cos(\theta_{\Delta L})$$

$$FSRJ_{\Delta L} := WSR_{\Delta L} \cdot \cos(\theta_{\Delta L})$$

Force component acting perpendicular to the bolsters. (The force component actually produces a bending moment in the bolster. For comparison it is projected to act at the jack pad. The "force" is produced by the weight of the truck on the leaning bolsters.)

$$FTFJH_{\Delta L} := WTF_{\Delta L} \cdot \sin(\theta_{\Delta L})$$

$$FTRJH_{\Delta L} := WTR_{\Delta L} \cdot \sin(\theta_{\Delta L})$$

$$FSRJH_{\Delta L} := WSR_{\Delta L} \cdot \sin(\theta_{\Delta L})$$

ΔL	$\theta_{\Delta L} \frac{180}{\pi}$	$WSR_{\Delta L}$ lb	$WTR_{\Delta L}$ lb	$WTF_{\Delta L}$ lb	$FSRJ_{\Delta L}$ lb	$FTRJ_{\Delta L}$ lb	$FTFJ_{\Delta L}$ lb	$FSRJH_{\Delta L}$ lb	$FTRJH_{\Delta L}$ lb	$FTFJH_{\Delta L}$ lb
0	0	9850	9850	12300	9850	9850	12300	0	0	0
1	0.7	9995	9705	12300	9994	9705	12299	125	121	154
2	1.4	10142	9558	12300	10139	9555	12298	253	239	307
3	2.1	10293	9407	12300	10285	9401	12291	386	353	461
4	2.9	10446	9254	12300	10433	9243	12285	522	482	614
5	3.6	10601	9099	12300	10581	9081	12278	661	568	767
6	4.3	10759	8941	12300	10729	8916	12268	805	669	920
7	5	10919	8781	12300	10878	8747	12253	952	765	1072
8	5.7	11081	8619	12300	11026	8576	12239	1103	858	1224
9	6.4	11245	8455	12300	11175	8402	12223	1257	945	1375
10	7.1	11411	8289	12300	11323	8225	12205	1415	1028	1526
11	7.8	11578	8122	12300	11470	8046	12185	1577	1106	1675
12	8.5	11747	7953	12300	11617	7865	12164	1742	1180	1825
13	9.2	11916	7784	12300	11762	7683	12141	1911	1248	1973
14	9.9	12087	7613	12300	11906	7499	12116	2084	1312	2120
15	10.6	12259	7441	12300	12049	7314	12089	2259	1371	2267
16	11.3	12431	7269	12300	12189	7128	12061	2438	1426	2412
17	12	12604	7096	12300	12328	6941	12031	2620	1475	2557
18	12.7	12777	6923	12300	12465	6754	12000	2805	1520	2700

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada

AJ Kostelnik
HH Zlada

Date: 9/1/98
Date: 9-11-98

Side to Side Loading with One Side Higher than the Other

The graph below shows how the rear jack loads change when the truck leans to the side and shifts the center of gravity. The front jack is assumed to carry a constant 12300 pound load when the truck leans side to side.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH ZiadaDate: 9/14/98
Date: 9-11-98Side to Side Loading with One Side Higher than the Other.
Comparison with Limits from Previous Analysis

From the previously determined lateral load capability for the outriggers, determine the equivalent horizontal force capacity in the direction of side to side at the deployment height.

Per VHC-SD-WM-ER-392, Ziada, the maximum horizontal load, side to side, the front and rear truck jacks can withstand when extended to support the truck 18" from rest on level ground is 730 pounds on the Front and 1250 pounds on the Rear. (On Truck #2, the elevation creates a 34.125" moment arm on the Rear Jacks and 31.5" moment arm on the Front Jack. On Trucks 3&4 the front moment arm is 39" and the rear moment arm is 34.125")

FRlat := 1250-lbf

FFlat := 730-lbf

$$\theta_{\Delta L} := \text{atan}\left(\frac{\Delta L}{80}\right) \quad \text{Angle produced from side to side}$$

H := 0.. 18 Height of jack

Calculate the maximum moment in the bolsters to remain within limits per Ziada.

MFlat := FFlat*31.5-in

MRlat := FRlat*34.125-in

MFlat = 22995-lbf-in

MRlat = 42656-lbf-in

Calculate the force component perpendicular to the bolster that would equal the maximum horizontal load capacity previously determined with adjustment for bolster length and truck 3&4 design. This calculation assumes the bolster sections are fully retracted and the jack feet rest on dunnage (15" under the front and 8" under the rear). (The analysis of the front jack on Truck #2 did not drop the bolsters to the ground prior to lifting as was done for the rear jacks.)

$$FF_{\text{maxlat}} := \frac{M_{\text{Flat}}}{(21 + H) \cdot \text{in}}$$

$$FR_{\text{maxlat}} := \frac{M_{\text{Rlat}}}{(8.125 + H) \cdot \text{in}}$$

When the side of the truck is elevated the forces of concern are:

FTRJH=Force on Tall Rear Jack (Horizontal component causing moment at connection)

FSRJH=Force on Short Rear Jack (Horizontal component causing moment at connection)

FTFJH=Force on Tall Front Jack (Horizontal component causing moment at connection)

FRONT						REAR						
ΔL	$\theta_{\Delta L}$	$\frac{180}{\pi}$	FFmaxlat _H		FTFJH _{ΔL}		FRmaxlat _H		FTRJH _{ΔL}		FSRJH _{ΔL}	
			H	lbf	ΔL	lbf	H	lbf	ΔL	lbf	ΔL	lbf
0	0		0	1095	0	0	0	5250	0	0	0	0
1	0.7		1	1045	1	154	1	4875	1	121	1	125
2	1.4		2	1000	2	307	2	4213	2	239	2	253
3	2.1		3	958	3	461	3	3834	3	353	3	386
4	2.9		4	920	4	614	4	3518	4	462	4	522
5	3.6		5	884	5	767	5	3250	5	568	5	681
6	4.3		6	852	6	920	6	3020	6	669	6	805
7	5		7	821	7	1072	7	2820	7	765	7	952
8	5.7		8	793	8	1224	8	2645	8	858	8	1103
9	6.4		9	767	9	1375	9	2491	9	945	9	1257
10	7.1		10	742	10	1526	10	2353	10	1028	10	1415
11	7.8		11	719	11	1675	11	2230	11	1106	11	1577
12	8.5		12	697	12	1825	12	2120	12	1180	12	1742
13	9.2		13	676	13	1973	13	2019	13	1248	13	1911
14	9.9		14	657	14	2120	14	1928	14	1312	14	2084
15	10.6		15	639	15	2267	15	1845	15	1371	15	2259
16	11.3		16	621	16	2412	16	1768	16	1426	16	2438
17	12		17	605	17	2557	17	1698	17	1475	17	2620
18	12.7		18	590	18	2700	18	1633	18	1520	18	2805

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada

Date: 9/11/98
Date: 9-11-98

Side to Side Loading with One Side Higher than the Other. Comparison with Limits from Previous Analysis

The line with x's on it below shows how the weight of the truck produces a lateral load in the shorter rear truck jack when one side is raised higher than the other.

The line with boxes on it below shows how the weight of the truck produces a lateral load in the taller rear truck jack when one side is raised higher than the other.

The line with diamonds on it below shows how the weight of the truck produces a lateral load in the front truck jack when one side is raised higher than the other.

The solid line shows how the lateral load capacity of the front jack of the truck decreases as the truck is raised. The dotted line shows how the lateral load capacity of the rear jacks of the truck decreases as the truck is raised.

The structural capacity of the truck is not exceeded unless the truck jacks are extended more than 5 inches. If the jacks must be extended beyond 5 inches the truck must be maintained within 3 degrees of level from side to side or the front jack will become overloaded.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada

AJ Kostelnik
HH Zlada

Date: 9/14/96
Date: 9-11-98

Free Body Diagram for Side to Side

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada

AJ Kostelnik
HH Zlada

Date: 9/11/98
Date: 9-11-98

Check On Jack Capacity

Calculations for the load lifting capability of the front and rear hydraulic rams for comparison to loads from leaning the truck and shifting the center of gravity. Assume the hydraulic pressure available is 1150 psi. The Outside diameter of the cylinders is 4" so assume the bore/piston diameter is 3.5". The front jack has 2 hydraulic cylinders.

$$P := 1150 \text{ psi}$$

$$d := 3.5 \text{ in}$$

$$A := \pi \frac{d^2}{4}$$

$$\text{REAR} := P \cdot A$$

The maximum weight that each rear jack can lift is 11000 pounds. The lifting capacity is exceeded when the truck leans more than 5.7 degrees to the side. The angle of 5.7 degrees corresponds to a difference in stroke length of 8" between the two rear rams.

$$\text{REAR} = 11064 \text{ lbf}$$

$$\text{FRONT} := 2 \cdot P \cdot A$$

$$\text{FRONT} = 22129 \text{ lbf}$$

The front jacks should never become overloaded.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH ZladaDate: 9/11/98
Date: 9-11-98

STARTING TO LIFT WHILE OUT OF LEVEL SIDE TO SIDE

Calculations to show how the jack loads change when the truck leans to the side and shifts the center of gravity. Analyzed with the truck starting from a 5.7 degree lean with all jacks fully retracted and proceeding to level with the short rear jack extended one inch at a time.

$$\Delta L := 0.9 \quad H := 0.9$$

$$\theta_{\Delta L} := \arctan\left(\frac{9 - \Delta L}{80}\right)$$

Angle produced with rotation around a line between a rear jack and the front jack. Deployment starts with one side 9" lower than the other. Reference diagram on page A19.

$$WR := 19700 \text{ lbf} \quad \text{Average weight supported by the jacks on the rear of the truck from calculations on page A6.}$$

Weight on extended (tall) rear jack. (Derived from moments about short rear jack pad.)

$$WTR_{\Delta L} := (WR) \cdot \frac{40 \cdot \cos(\theta_{\Delta L}) - 46.5 \cdot \sin(\theta_{\Delta L})}{80 \cdot \cos(\theta_{\Delta L}) + (\Delta L) \cdot \sin(\theta_{\Delta L})}$$

Weight on front jack.

Weight on short rear jack.

$$WTF_{\Delta L} := 32000 \text{ lbf} - WR$$

$$WSR_{\Delta L} := WR - WTR_{\Delta L}$$

Force acting on jack cylinders.

$$FRONTCYL_{\Delta L} := WTF_{\Delta L} \cdot \cos(\theta_{\Delta L})$$

$$TREARCYL_{\Delta L} := WTR_{\Delta L} \cdot \cos(\theta_{\Delta L})$$

$$SREARCYL_{\Delta L} := WSR_{\Delta L} \cdot \cos(\theta_{\Delta L})$$

Calculate the force component acting perpendicular to the bolsters. (The force component actually produces a bending moment in the bolster. For comparison it is projected to act at the jack pad. The "force" is produced by the weight of the truck on the leaning bolsters.)

$$FRONTHOR_{\Delta L} := WTF_{\Delta L} \cdot \sin(\theta_{\Delta L})$$

$$TREARHOR_{\Delta L} := WTR_{\Delta L} \cdot \sin(\theta_{\Delta L})$$

$$SREARHOR_{\Delta L} := WSR_{\Delta L} \cdot \sin(\theta_{\Delta L})$$

ΔL	$\theta_{\Delta L} \cdot \frac{180}{\pi}$	$WSR_{\Delta L}$ lbf	$WTR_{\Delta L}$ lbf	$WTF_{\Delta L}$ lbf	$SREARCYL_{\Delta L}$ lbf	$TREARCYL_{\Delta L}$ lbf	$FRONTCYL_{\Delta L}$ lbf	$SREARHOR_{\Delta L}$ lbf	$TREARHOR_{\Delta L}$ lbf	$FRONTHOR_{\Delta L}$ lbf
0	6.4	11138	8562	12300	11068	8508	12223	1245	957	1375
1	5.7	11006	8694	12300	10951	8651	12239	1095	865	1224
2	5	10871	8829	12300	10830	8795	12253	948	770	1072
3	4.3	10734	8966	12300	10704	8941	12266	803	671	920
4	3.6	10594	9106	12300	10573	9088	12276	661	568	767
5	2.9	10451	9249	12300	10438	9237	12285	522	462	614
6	2.1	10306	9394	12300	10299	9388	12291	386	352	461
7	1.4	10157	9543	12300	10154	9540	12296	254	238	307
8	0.7	10005	9695	12300	10004	9694	12299	125	121	154
9	0	9850	9850	12300	9850	9850	12300	0	0	0

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada*AJ Kostelnik*
*HH Zlada*Date: 9/11/98
Date: 9-11-98

STARTING TO LIFT WHILE OUT OF LEVEL SIDE TO SIDE

The graph below shows how the rear jack loads change when the truck leans to the side and shifts the center of gravity. The front jack is assumed to carry a constant 12300 pound load when the truck leans side to side.

CALCULATIONS

Prepared by: AJ Kostelnik

Prepared by: HH Ziada

Date: 9/11/98

Date: 9-11-98

STARTING TO LIFT WHILE OUT OF LEVEL SIDE TO SIDE

Comparison with Limits from Previous Analysis

From the previously determined lateral load capability for the outriggers, determine the equivalent horizontal force capacity in the direction of side to side at the deployment height.

Per VWHC-SD-WM-ER-392, Ziada, the maximum horizontal load, side to side, the front and rear truck jacks can withstand when extended to support the truck 18" from rest on level ground is 730 pounds on the Front and 1250 pounds on the Rear. (On Truck #2, the elevation creates a 34.125" moment arm on the Rear Jacks and 31.5" moment arm on the Front Jack. On Trucks 3&4, the front moment arm is 39" and the rear moment arm is 34.125")

$$FFlat := 1250 \cdot \text{lbft}$$

$$FFlat := 730 \cdot \text{lbft}$$

$$\theta_{\Delta L} := \arctan\left(\frac{9 - \Delta L}{80}\right)$$

Angle produced from side to side

Calculate the maximum moment in the bolsters to remain within limits per Ziada.

$$MFlat := FFlat \cdot 31.5 \cdot \text{in}$$

$$MRlat := FFlat \cdot 34.125 \cdot \text{in}$$

$$MFlat = 22995 \cdot \text{lbft} \cdot \text{in}$$

$$MRlat = 42656 \cdot \text{lbft} \cdot \text{in}$$

Calculate the force component perpendicular to the bolster that would equal the maximum horizontal load capacity previously determined with adjustment for bolster length and truck 3&4 design. This calculation assumes the bolster sections are fully retracted and the jack feet rest on dunnage (15" under the front and 8" under the rear). (The analysis of the front jack on Truck #2 did not drop the bolsters to the ground prior to lifting as was done for the rear jacks.)

$$FFmaxlat_H := \frac{MFlat}{(21 + H) \cdot \text{in}}$$

$$FRmaxlat_H := \frac{MRlat}{(8.125 + H) \cdot \text{in}}$$

When the truck is not level at the start the forces of concern are:

TREARHOR=Horizontal force projected to act at the foot of the higher rear jack

SREARHOR=Horizontal force projected to act at the foot of the lower rear jack

FRONTHOR=Horizontal force projected to act at the foot of the front jack

FRONT

REAR

$\theta_{\Delta L}$ 180 π	H	FFmaxlat _H lbft	FRONTHOR ΔL lbft
6.4	0	1095	1375
5.7	1	1045	1224
5	2	1000	1072
4.3	3	958	920
3.6	4	920	767
2.9	5	884	614
2.1	6	852	461
1.4	7	821	307
0.7	8	793	154
0	9	767	0

H	FRmaxlat _H lbft	TREARHOR ΔL lbft	SREARHOR ΔL lbft
0	5250	957	1245
1	4675	865	1095
2	4213	770	948
3	3834	671	803
4	3518	568	661
5	3250	462	522
6	3020	352	386
7	2820	238	254
8	2645	121	125
9	2491	0	0

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH ZladaAli A. Kostelnik
Heather H. ZladaDate: 9/11/98
Date: 9-11-98**STARTING TO LIFT WHILE OUT OF LEVEL SIDE TO SIDE**
Comparison with Limits from Previous Analysis

The structural capacity of the truck is not exceeded when it leans approximately 6 degrees side to side unless the front jack is extended 3 inches or more. If the front jack must be extended beyond 3 inches before contacting the dunnage to level the truck, the truck must be within 5 degrees of level from side to side or the front jack will become overloaded. The rear jacks can withstand more lean than the front jack so 5 degrees should be the limit for initial deployment of the jacks to bring the truck to level prior to lifting.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH ZladaDate: 9/11/98
Date: 7-9-11-98

Deployment with the Rear Higher than the Front

Calculations to show how the front jack load increases when the rear of the truck is 24" higher than the front and shifts the center of gravity forward. Assume the truck weighs 32000 pounds (Trucks 3 & 4). Reference diagram titled "REAR HIGHER THAN FRONT" (Page 14).

$$\Delta L := 0..18 \quad H := 0..18$$

$$\phi_{\Delta L} := \tan\left(\frac{24 - \Delta L}{282}\right)$$

Angle from level produced by the rear higher than the front. Deployment starts with the rear 24" higher than the front. Reference diagram on page A14.

Weight on both rear jacks. (Derived from moments about front jack pad.)

$$WR_{\Delta L} := 32000 \cdot \text{lb} \cdot \frac{172 \cdot \cos(\phi_{\Delta L}) - (46.5) \cdot \sin(\phi_{\Delta L})}{282 \cdot \cos(\phi_{\Delta L}) + \Delta L \cdot \sin(\phi_{\Delta L})}$$

Weight on front jack.

$$WF_{\Delta L} := 32000 \cdot \text{lb} - WR_{\Delta L}$$

Force acting on the front and each rear jack cylinder.

$$FFJ_{\Delta L} := WF_{\Delta L} \cdot \cos(\phi_{\Delta L})$$

$$FRJ_{\Delta L} := \frac{WR_{\Delta L}}{2} \cdot \cos(\phi_{\Delta L})$$

Force component acting perpendicular to the bolsters. (The force component actually produces a bending moment in the bolster. For comparison it is projected to act at the jack pad. The "force" is produced by the weight of the truck on the leaning bolsters.)

$$FFJH_{\Delta L} := WF_{\Delta L} \cdot \sin(\phi_{\Delta L})$$

$$FRJH_{\Delta L} := \frac{WR_{\Delta L}}{2} \cdot \sin(\phi_{\Delta L})$$

ΔL	$\phi_{\Delta L} \frac{180}{\pi}$	$WF_{\Delta L}$ lb	$WR_{\Delta L}$ lb	$FFJ_{\Delta L}$ lb	$FRJ_{\Delta L}$ lb	$FFJH_{\Delta L}$ lb
0	4.9	12931	19069	12885	9500	1097
1	4.7	12918	19082	12875	9509	1050
2	4.5	12904	19096	12865	9519	1004
3	4.3	12890	19110	12855	9528	957
4	4.1	12876	19124	12843	9538	911
5	3.9	12861	19139	12832	9548	865
6	3.7	12845	19155	12819	9558	818
7	3.4	12829	19171	12806	9568	772
8	3.2	12813	19187	12792	9578	725
9	3	12796	19204	12777	9589	680
10	2.8	12778	19222	12762	9599	634
11	2.6	12760	19240	12747	9610	588
12	2.4	12742	19258	12730	9620	542
13	2.2	12723	19277	12713	9631	496
14	2	12703	19297	12695	9642	450
15	1.8	12683	19317	12677	9653	405
16	1.6	12663	19337	12658	9665	359
17	1.4	12642	19358	12638	9676	314
18	1.2	12621	19379	12618	9687	268

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada

[Signature]
[Signature]

Date: 9/1/88
Date: 9-11-88

Deployment with the Rear Higher than the Front.

The graph below shows how the weight of the truck shifts to the front jack when the rear of the truck is raised higher than the front and shifts the center of gravity forward. Approximately 12482 pounds is acting on the front jack when the truck is level. When the rear of the truck is higher than the front, the weight on the front reaches 12931 pounds.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada*AJ Kostelnik*
*HH Zlada*Date: 9/1/96
Date: 9-11-98**Deployment with the Rear Higher than the Front.
Comparison with Limits from Previous Analysis**

From the previously determined longitudinal load capability for the outriggers, determine the equivalent horizontal force capacity in the direction of front to rear at the deployment height.

Per WHC-SD-WM-ER-392, Ziada, the maximum horizontal load, front to rear, the front and rear truck jacks can withstand when extended to support the truck 18" from rest on level ground is 730 pounds on the Front and 500 pounds on the Rear. (On Truck #2, the elevation creates a 42.28" moment arm on the Rear Jacks and 31.5" moment arm on the Front Jack. On Trucks 3&4, the front moment arm is 39" and the rear moment arm is 42.28".)

FFlong := 730·lbf

FRlong := 500·lbf

H := 0.. 18 Height of jack

Calculate the maximum moment in the bolsters to remain within limits per Truck #2 analysis by Ziada.

MFlong := FFlong·31.5·in

MRlong := FRlong·42.28·in

MFlong = 22995 ·lbf·in

MRlong = 21140 ·lbf·in

Calculate the force component perpendicular to the bolster that would equal the maximum horizontal load capacity previously determined with adjustment for bolster length and truck 3&4 design. This calculation assumes the bolster sections are fully retracted and the jack feet rest on dunnage (15" under the front and 8" under the rear). (The analysis of the front jack on Truck #2 did not drop the bolsters to the ground prior to lifting as was done for the rear jacks.)

$$FFmaxlong_H := \frac{MFlong}{(21 + H) \cdot in}$$

$$FRmaxlong_H := \frac{MRlong}{(16.28 + H) \cdot in}$$

When the rear of the truck is elevated the forces of concern are:

FFJH=Force on Front Jack (Horizontal component causing moment at connection)

FRJH=Force on Rear Jack (Horizontal component causing moment at connection)

FRONT

ΔL	$\frac{\Delta L}{\pi}$	H	$\frac{FFmaxlong_H}{lbf}$	ΔL	$\frac{FFJH}{lbf}$
0	4.9	0	1095	0	1097
1	4.7	1	1045	1	1050
2	4.5	2	1000	2	1004
3	4.3	3	958	3	957
4	4.1	4	920	4	911
5	3.9	5	884	5	865
6	3.7	6	852	6	818
7	3.4	7	821	7	772
8	3.2	8	793	8	726
9	3	9	767	9	680
10	2.8	10	742	10	634
11	2.6	11	719	11	588
12	2.4	12	697	12	542
13	2.2	13	676	13	496
14	2	14	657	14	450
15	1.8	15	639	15	405
16	1.6	16	621	16	359
17	1.4	17	605	17	314
18	1.2	18	590	18	268

REAR

H	$\frac{FRmaxlong_H}{lbf}$	ΔL	$\frac{FRJH}{lbf}$
0	1299	0	809
1	1223	1	776
2	1156	2	743
3	1096	3	710
4	1042	4	676
5	993	5	643
6	949	6	610
7	908	7	577
8	871	8	543
9	836	9	510
10	804	10	477
11	775	11	443
12	748	12	409
13	722	13	376
14	698	14	342
15	676	15	308
16	655	16	274
17	635	17	240
18	617	18	206

Disregard rear jack forces. The rear jacks would not be extended yet because the truck is not level.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada

AJ Kostelnik
HH Zlada

Date: 9/11/98
Date: 9-11-98

**Deployment with the Rear Higher than the Front.
Comparison with Limits from Previous Analysis.**

The structural capacity of the truck is not exceeded unless the truck jacks are deployed with the truck at an angle of more than 5 degrees.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH ZladaDate: 9/11/88
Date: 9-11-88

Deployment with the Front Higher than the Rear.

Calculations to show how the rear jack loads increase when the front of the truck is raised higher than the rear and shifts the center of gravity backwards. Assume Trucks 3 & 4 weigh 32000 pounds. Reference diagram titled "FRONT HIGHER THAN REAR" (Page 14).

 $\Delta L := 0..18$ Difference in jack length.

$$\phi_{\Delta L} := \arctan\left(\frac{30 - \Delta L}{282}\right)$$

Angle from level produced by the front higher than the rear. Deployment starts with the front 30" higher than the rear. Reference diagram on page A14.

Weight on front jack (Derived from moments about rear jack pad)

$$WF_{\Delta L} := 32000 \cdot \text{lb} \cdot \frac{110 \cdot \cos(\phi_{\Delta L}) - (46.5) \cdot \sin(\phi_{\Delta L})}{282 \cdot \cos(\phi_{\Delta L}) + \Delta L \cdot \sin(\phi_{\Delta L})}$$

Weight on rear jacks.

$$WR_{\Delta L} := 32000 \cdot \text{lb} - WF_{\Delta L}$$

$$FFJ_{\Delta L} := WF_{\Delta L} \cdot \cos(\phi_{\Delta L})$$

$$FRJ_{\Delta L} := \frac{WR_{\Delta L}}{2} \cdot \cos(\phi_{\Delta L})$$

Axial force acting on the front and each rear jack cylinder.

Force component acting perpendicular to the bolsters. (The force component actually produces a bending moment in the bolster. For comparison it is projected to act at the jack pad. The "force" is produced by the weight of the truck on the leaning bolsters.)

$$FFJH_{\Delta L} := WF_{\Delta L} \cdot \sin(\phi_{\Delta L})$$

$$FRJH_{\Delta L} := \frac{WR_{\Delta L}}{2} \cdot \sin(\phi_{\Delta L})$$

ΔL	$\phi_{\Delta L} \frac{180}{\pi}$	$WF_{\Delta L}$ lb	$WR_{\Delta L}$ lb	$FFJ_{\Delta L}$ lb	$FRJ_{\Delta L}$ lb	$FFJH_{\Delta L}$ lb	$FRJH_{\Delta L}$ lb
0	6.1	11921	20079	11854	9983	1261	1062
1	5.9	11935	20065	11873	9980	1227	1026
2	5.7	11950	20050	11891	9976	1181	991
3	5.5	11965	20035	11910	9972	1140	955
4	5.3	11980	20020	11930	9968	1100	919
5	5.1	11996	20004	11949	9963	1059	883
6	4.9	12011	19989	11969	9958	1019	848
7	4.7	12028	19972	11988	9953	978	812
8	4.5	12044	19956	12007	9948	937	776
9	4.3	12061	19939	12027	9942	896	740
10	4.1	12078	19922	12047	9936	854	705
11	3.9	12095	19905	12068	9930	813	669
12	3.7	12113	19887	12088	9924	772	633
13	3.4	12130	19870	12108	9917	730	598
14	3.2	12149	19851	12129	9910	688	562
15	3	12167	19833	12150	9902	646	527
16	2.8	12186	19814	12171	9895	604	491
17	2.6	12205	19795	12192	9887	562	456
18	2.4	12225	19775	12213	9879	520	420

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada

[Signature]
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Date: 9/11/98
Date: 9-11-98

Deployment with the Front Higher than the Rear.

The graph below shows how the weight of the truck shifts to the rear jacks when the front of the truck is raised higher than the rear and shifts the center of gravity. Approximately 19518 pounds is acting on the rear jacks when the truck is level. When the front of the truck is higher than the rear, the weight on the rear reaches 20079 pounds.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH ZiadaDate: 7/1/98
Date: 9-11-98**Deployment with the Front Higher than the Rear.
Comparison with Limits from Previous Analysis.**

From the previously determined longitudinal load capability for the outriggers, determine the equivalent horizontal force capacity in the direction of front to rear at the deployment height.

Per WHC-SD-WM-ER-392, Ziada, the maximum horizontal load, front to rear, the front and rear truck jacks can withstand when extended to support the truck 18" from rest on level ground is 730 pounds on the Front and 500 pounds on the Rear. (On Truck #2, the elevation creates a 42.28° moment arm on the Rear Jacks and 31.5° moment arm on the Front Jack. On Trucks 3&4, the front moment arm is 39° and the rear moment arm is 42.28°.)

FFlong := 730-lbf

FRlong := 500-lbf

H := 0..18 Height of jack

Calculate the maximum moment in the bolsters to remain within limits per Ziada.

MFlong := FFlong*31.5-in

MRlong := FRlong*42.28-in

MFlong = 22995-lbf-in

MRlong = 21140-lbf-in

Calculate the force component perpendicular to the bolster that would equal the maximum horizontal load capacity previously determined with adjustment for bolster length and truck 3&4 design. This calculation assumes the bolster sections are fully retracted and the jack feet rest on dunnage (15" under the front and 8" under the rear). (The analysis of the front jack on Truck #2 did not drop the bolsters to the ground prior to lifting as was done for the rear jacks.)

$$FFmaxlong_H := \frac{MFlong}{(21 + H) \cdot \pi}$$

$$FRmaxlong_H := \frac{MRlong}{(16.28 + H) \cdot \pi}$$

When the front of the truck is elevated the forces of concern are:

FFJH=Force on Front Jack (Horizontal component causing moment at connection)

FRJH=Force on Rear Jack (Horizontal component causing moment at connection)

FRONT

REAR

ΔL	$\phi \Delta L \frac{180}{\pi}$	H	FFmaxlong _H lbf	ΔL	FFJH lbf
0	6.1	0	1095	0	1261
1	5.9	1	1045	1	1221
2	5.7	2	1000	2	1181
3	5.5	3	958	3	1140
4	5.3	4	920	4	1100
5	5.1	5	884	5	1059
6	4.9	6	852	6	1019
7	4.7	7	821	7	978
8	4.5	8	793	8	937
9	4.3	9	767	9	896
10	4.1	10	742	10	854
11	3.9	11	719	11	813
12	3.7	12	697	12	772
13	3.4	13	676	13	730
14	3.2	14	657	14	688
15	3	15	639	15	646
16	2.8	16	621	16	604
17	2.6	17	605	17	562
18	2.4	18	590	18	520

H	FRmaxlong _H lbf	ΔL	FRJH lbf
0	1299	0	1062
1	1223	1	1026
2	1156	2	991
3	1096	3	955
4	1042	4	919
5	993	5	883
6	949	6	848
7	908	7	812
8	871	8	776
9	836	9	740
10	804	10	705
11	775	11	669
12	748	12	633
13	722	13	598
14	698	14	562
15	676	15	527
16	655	16	491
17	635	17	456
18	617	18	420

Disregard front jack forces.
The front jack would not be
extended yet because the truck
is not level.

CALCULATIONS

Prepared by: AJ Kostelnik
Prepared by: HH Zlada*AJ Kostelnik*
*Heese H. Zlada*Date: 9/11/98
Date: 9-11-98**Deployment with the Front Higher than the Rear.
Comparison with Limits from Previous Analysis.**

The structural capacity of the truck is not exceeded unless the truck jacks are deployed with the rear of the truck more than 30 inches below the front. Level the truck within 6 degrees of level front to rear or the rear jacks will become overloaded.
The angle of inclination is bounded by the 5 degree limit established for the condition of the rear higher than the front.