### Engineering Change Notice

**1. ECN Category**
- [ ] Supplemental
- [X] Direct Revision
- [ ] Change ECN
- [ ] Temporary
- [ ] Standby
- [ ] Supersede
- [ ] Cancel/ Void

**2. Source**
- AJ Kostelnik, 08E00, S7-12, 3-0788

**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
- 200 G

**7. Bldg./Sys./Fac. No.**
- SQ

**8. Approval Designator**
- N/A

**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**
- [X] Yes (fill out B1k. 12b)
- [ ] No (NA Biks. 12b, 12c, 12d)

**12b. Work Package No.**
- N/A

**12c. Modification Work Complete**
- N/A

**12d. Restored to Original Condition (Temp. or Standby ECN only)**
- N/A

**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"

**14a. Justification (mark one)**
- [X] Criteria Change
- [ ] Design Improvement
- [ ] Environmental
- [ ] Facility Deactivation
- [ ] As-Found
- [X] Facilitate Const
- [ ] Correct. 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)**

- 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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**Release Stamp**

DATE: OCT 14 1998

A-7900-013-1
## ENGINEERING CHANGE NOTICE

### 16. Design Verification Required
- [ ] Yes
- [X] No

### 17. Cost Impact

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### 18. Schedule Impact (days)
- Improvement: [N/A]
- Delay: [N/A]

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

#### SDD/DD
- Functional Design Criteria
- Operating Specification
- Criticality Specification
- Conceptual Design Report
- Equipment Spec.
- Const. Spec.
- Procurement Spec.
- Vendor Information
- OM Manual
- FSAR/SSR
- Safety Equipment List
- Radiation Work Permit
- Environmental Impact Statement
- Environmental Report
- Environmental Permit

#### Additional
- Seismic/Seismic Analysis
- Stress/Design Report
- Interface Control Drawing
- Calibration Procedure
- Installation Procedure
- Maintenance Procedure
- Engineering Procedure
- Operating Instruction
- Operating Procedure
- Operational Safety Requirement
- iEFD Drawing
- Cell Arrangement Drawing
- Essential Material Specification
- Fac. Proc. Samp. Schedule
- Inspection Plan
- Inventory Adjustment Request

#### Delay
- Tank Calibration Manual
- Health Physics Procedure
- Spares Multiple Unit Listing
- Test Procedures/Specification
- Component Index
- ASME Coded Item
- Human Factor Consideration
- Computer Software
- Electric Circuit Schedule
- ICRS Procedure
- Process Control Manual/Plan
- Process Flow Chart
- Purchase Requisition
- Tiddler File
- 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

#### Document Number/Revision

### 21. Approvals

#### Design Authority
- GP Janicek
- RN Dale
- JS Schofield
- ML McElroy
- JA Ranschau
- N/A
- Other
- RM Boger
- RS Bobielarczyk
- COGEMA Proj. Mgr CE Hanson

#### Design/Construction
- PE
- QA
- Safety
- Design
- Environ.
- Other

#### DEPARTMENT OF ENERGY
- 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

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.
# Engineering Task Plan for Upgrades to the Leveling Jacks on Core Sample Trucks #3 and #4

## Change Control Record

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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/V1, Core Sampling Systems (LMHC 1997).
10 REFERENCES


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 it could 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.
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.

\[ \phi_{AL} := \tan\left(\frac{\Delta L}{282}\right) \] Angle produced by front higher than the rear. \( \phi \) Angle from level.

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

\[ WF_{\Delta L} := 32000 \cdot \frac{110 \cdot \cos(\phi_{AL}) - (46.5) \cdot \sin(\phi_{AL})}{282 \cdot \cos(\phi_{AL}) + \Delta L \cdot \sin(\phi_{AL})} \]

Weight on rear jacks.

\[ WR_{\Delta L} := WF_{\Delta L} - \frac{WR}{\Delta L} \]

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

\[ FFJ_{\Delta L} := WF_{\Delta L} \cdot \cos(\phi_{AL}) \]

\[ FRJ_{\Delta L} := \frac{WF_{\Delta L} \cdot \sin(\phi_{AL})}{2} \]

Force component acting perpendicular to the bolster. (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 bolster.)

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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.
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 WHC-SD-VV%E-362, 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°.)

\[ FF_{long} := 730 \text{ lbf} \]
\[ FR_{long} := 500 \text{ lbf} \]

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

\[ MF_{long} := FF_{long} \times 31.5 \text{ in} \]
\[ MR_{long} := FR_{long} \times 42.28 \text{ in} \]

\[ MF_{long} = 22905 \text{ lbf-in} \]
\[ MR_{long} = 21140 \text{ lbf-in} \]

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.)

\[ FF_{maxlongH} := \frac{MF_{long}}{(2T + H)} \text{ in} \]
\[ FR_{maxlongH} := \frac{MR_{long}}{(16.28 + H)} \text{ in} \]

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

- \( FF_{JH} \): Force on Front Jack (Horizontal component causing moment at connection)
- \( FR_{JH} \): Force on Rear Jack (Horizontal component causing moment at connection)

### Table

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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.
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).

\[ \phi_{AL} := \tan \left( \angle \frac{AL}{282} \right) \]

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

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

\[ WR_{AL} := \frac{32000 \text{ lbf} \cdot (46.5 \cdot \sin (\phi_{AL}) - 172 \cdot \cos (\phi_{AL}))}{282 \cdot \cos (\phi_{AL}) + AL \cdot \sin (\phi_{AL})} \]

Weight on front jack.

\[ WF_{AL} := 32000 \text{ lbf} - WR_{AL} \]

Force acting on the front and each rear jack cylinder.

\[ FFJ_{AL} := WF_{AL} \cdot \cos (\phi_{AL}) \]
\[ FRJ_{AL} := \frac{WR_{AL}}{2} \cdot \cos (\phi_{AL}) \]

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.)

\[ FFJH_{AL} := WF_{AL} \cdot \sin (\phi_{AL}) \]
\[ FRJH_{AL} := \frac{WR_{AL}}{2} \cdot \sin (\phi_{AL}) \]

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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 12871 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.

WF
WF
FR
AL
LTL

Weight on Front Jack
Weight on Each Rear Jack
Front 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 42.2° moment arm on the Rear Jacks and 31.7° moment arm on the Front Jack. On Trucks 384 the front moment arm is 39° and the rear moment arm is 42.2°.)

\[
\begin{align*}
FF_{\text{long}} &= 730 \text{ lbf} \\
FR_{\text{long}} &= 500 \text{ lbf}
\end{align*}
\]

\[H := 0.18 \text{ Height of jack} \]

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

\[
\begin{align*}
M_{F_{\text{long}}} &= FF_{\text{long}} \cdot 31.5 \text{ in} \\
M_{R_{\text{long}}} &= FR_{\text{long}} \cdot 42.28 \text{ in}
\end{align*}
\]

\[
\begin{align*}
M_{F_{\text{long}}} &= 22995 \text{ lbf-in} \\
M_{R_{\text{long}}} &= 21140 \text{ lbf-in}
\end{align*}
\]

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 384 design. This calculation assumes the bolster sections are fully retracted and the jack feet rest on dunnage (15" under the front and 15" 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.)

\[
\begin{align*}
FF_{\text{maxlongH}} &= \frac{M_{F_{\text{long}}}}{21 + H} \\
FR_{\text{maxlongH}} &= \frac{M_{R_{\text{long}}}}{16.28 + H}
\end{align*}
\]

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

- \( FF_{\text{JH}} \) = Force on Front Jack (Horizontal component causing moment at connection)
- \( FR_{\text{JH}} \) = Force on Rear Jack (Horizontal component causing moment at connection)

\[
\begin{array}{cccccccc}
\text{FRONT} & & \text{REAR} \\
\hline
\text{AL} & \frac{AL}{\pi} & 180 & \text{H} & \text{Ibf} & \text{H} & \text{Ibf} \\
0 & 0 & 0 & 0 & 1095 & 0 & 1299 \\
1 & 0.2 & 1 & 1 & 1045 & 1 & 1223 \\
2 & 0.4 & 2 & 2 & 1000 & 2 & 1156 \\
3 & 0.6 & 3 & 3 & 955 & 3 & 1095 \\
4 & 0.8 & 4 & 4 & 920 & 4 & 1042 \\
5 & 1 & 5 & 5 & 884 & 5 & 983 \\
6 & 1.2 & 6 & 6 & 852 & 6 & 949 \\
7 & 1.4 & 7 & 7 & 821 & 7 & 908 \\
8 & 1.6 & 8 & 8 & 793 & 8 & 871 \\
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14 & 2.8 & 14 & 14 & 657 & 14 & 698 \\
15 & 3 & 15 & 15 & 639 & 15 & 676 \\
16 & 3.2 & 16 & 16 & 621 & 16 & 655 \\
17 & 3.4 & 17 & 17 & 605 & 17 & 635 \\
18 & 3.7 & 18 & 18 & 590 & 18 & 617
\end{array}
\]
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.*
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.)

\[ \theta_{\Delta L} = \tan\left(\frac{\Delta L}{\theta_0}\right) \]

- Angle produced with rotation around a line between a rear jack and the front jack.

\[ WR := 19700 \text{ lbf} \]

- Average weight supported by the jacks on the rear of the truck from calculations on page 6.

\[ \Delta L \]

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

\[ WTR := \frac{40 \cdot \cos(\theta_{\Delta L}) - 46.5 \cdot \sin(\theta_{\Delta L})}{80 \cdot \cos(\theta_{\Delta L}) + \Delta L \cdot \sin(\theta_{\Delta L})} \]

\[ \text{Weight on front jack.} \]

\[ WTR_{\Delta L} := 19700 \times \cos(\theta_{\Delta L}) \]

\[ WSR_{\Delta L} := \text{WR} - WTR_{\Delta L} \]

- Weight on short rear jack.

\[ \text{Force acting on jack cylinders.} \]

\[ F_{\text{FTFJ}} := WTR_{\Delta L} \cdot \cos(\theta_{\Delta L}) \]

\[ F_{\text{FRJ}} := WTR_{\Delta L} \cdot \sin(\theta_{\Delta L}) \]

\[ F_{\text{FSRJ}} := WSR_{\Delta L} \cdot \cos(\theta_{\Delta L}) \]

\[ F_{\text{FSRJH}} := WSR_{\Delta L} \cdot \sin(\theta_{\Delta L}) \]

- 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.)

\[ \begin{array}{cccccccc}
\theta_{\Delta L} & 0 & 1 & 2 & 3 & 4 & 5 & 6 \\
W_{\Delta L} & 9850 & 9850 & 12300 & 9850 & 9850 & 12300 & 9850 \\
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W_{\Delta L} & 9850 & 9705 & 12300 & 9850 & 9705 & 12300 & 9850 \\
\end{array} \]

\[ \begin{array}{cccccccc}
\text{WTF}_{\Delta L} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} \\
\text{FSRJ}_{\Delta L} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} \\
\text{FSRJH}_{\Delta L} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} & 19700 \text{ lbf} \\
\end{array} \]
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.
Side 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 WHC-SD.WM-ER-392, 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°.)

$$\text{FR}_{\text{Lat}} := 1250\text{ lbf}$$  $$\text{FF}_{\text{Flat}} := 730\text{ lbf}$$

$$\theta_{AL} := \tan^{-1}\left(\frac{AL}{H}\right)$$  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,

$$\text{M}_{\text{Flat}} := \text{FF}_{\text{Flat}} \cdot 31.5\text{ in}$$  $$\text{M}_{\text{Rlat}} := \text{FR}_{\text{Lat}} \cdot 34.125\text{ in}$$

$$\text{M}_{\text{Flat}} = 22995\text{ lbf-in}$$  $$\text{M}_{\text{Rlat}} = 42656\text{ lbf-in}$$

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 6° 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.)

$$\text{FF}_{\text{maxlat}}_{H} := \frac{\text{M}_{\text{Flat}}}{(21 + H)\text{ in}}$$  $$\text{FR}_{\text{maxlat}}_{H} := \frac{\text{M}_{\text{Rlat}}}{(8.125 + H)\text{ in}}$$

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

- $\text{F}_{\text{TRJH}}$: Force on Tall Rear Jack (Horizontal component causing moment at connection)
- $\text{F}_{\text{RJH}}$: Force on Short Rear Jack (Horizontal component causing moment at connection)
- $\text{F}_{\text{TFJH}}$: Force on Tall Front Jack (Horizontal component causing moment at connection)
- $\text{F}_{\text{FFJH}}$: Force on Short Front Jack (Horizontal component causing moment at connection)
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.
Free Body Diagram for Side to Side

\[ \text{center of gravity} \]

\[ 80(\cos\theta) + dL(\sin\theta) - 40(\cos\theta) - 46.5(\sin\theta) \]

\[ \text{location of weak connection} \]

\[ \text{one side higher than the other} \]
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.

\[ P := 1150 \text{ psi} \]
\[ d := 3.5 \text{ in} \]
\[ A := \pi \frac{d^2}{4} \]

\[ \text{REAR} := PA \]
\[ \text{REAR} = 11064 \text{ inlbf} \]

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.

\[ \text{FRONT} := 2PA \]
\[ \text{FRONT} = 22129 \text{ inlbf} \]

The front jacks should never become overloaded.
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.

\[ \Delta L := 0.9 \quad H := 0.9 \]

\[ \theta_{\Delta L} := \cot\left(\frac{9^\circ - \Delta L}{80^\circ}\right) \]

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.

\[ WR := 19700\text{-lbf} \]

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.)

\[ W_{TR} := \left(\frac{40\cos(\theta_{\Delta L}) - 46.5\sin(\theta_{\Delta L})}{60\cos(\theta_{\Delta L}) + (\Delta L)\sin(\theta_{\Delta L})}\right)WR \]

\[ W_{FL} := 32000\text{-lbf} - WR \]

Weight on front jack.

\[ W_{SR} := \frac{WR - W_{TR}}{\Delta L} \]

Weight on short rear jack.

Force acting on jack cylinders.

\[ \text{FRONTCYL}_{\Delta L} := W_{FL}\cos(\theta_{\Delta L}) \quad \text{TREARCYL}_{\Delta L} := W_{TR}\cos(\theta_{\Delta L}) \quad \text{SREARCYL}_{\Delta L} := W_{SR}\cos(\theta_{\Delta L}) \]

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.)

\[ \text{FRONTHOR}_{\Delta L} := W_{FL}\sin(\theta_{\Delta L}) \quad \text{TREARHOR}_{\Delta L} := W_{TR}\sin(\theta_{\Delta L}) \quad \text{SREARHOR}_{\Delta L} := W_{SR}\sin(\theta_{\Delta L}) \]

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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.
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 WHC-SD-WM.ER-392, the maximum horizontal load, side to side, the front and rear truck jacks can withstand when extended to support the truck 18° from rest the 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°.)

\[ \theta_{\Delta L} := \text{atan} \left( \frac{9 - \Delta L}{80} \right) \]

Angle produced from side to side

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

\[ M_{\text{Flat}} := F_{\text{Flat}} \times 31.5 \text{ in} \]
\[ M_{\text{Rlat}} := F_{\text{Rlat}} \times 34.125 \text{ in} \]
\[ M_{\text{Flat}} = 22995 \text{ lbf-in} \]
\[ M_{\text{Rlat}} = 42656 \text{ lbf-in} \]

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.)

\[ F_{\text{maxlatH}} := \frac{M_{\text{Flat}}}{(21 + H) \text{ in}} \]
\[ F_{\text{maxlatH}} := \frac{M_{\text{Rlat}}}{(3.125 + H) \text{ in}} \]

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

- \( T_{\text{RearHor}} \): Horizontal force projected to act at the foot of the higher rear jack
- \( S_{\text{RearHor}} \): Horizontal force projected to act at the foot of the lower rear jack
- \( F_{\text{FrontHor}} \): Horizontal force projected to act at the foot of the front jack

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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.

![Graph](image_url)

**Graph Title:** Horizontal Loads vs Delta Length

- Short Rear Jack
- Tall Rear Jack
- Front Jack
- Front Jack Capacity (H)
- Each Rear Jack Capacity (H) — OFF SCALE

**Axes:**
- ΔL, AL, ΔL, H, H
- Horizontal Loads (Ibf)

**Legend:**
- SREARHOR: Short Rear Jack
- TREARHOR: Tall Rear Jack
- FPRONTHOR: Front Jack
- FFFmaxlatH: Front Jack Capacity (H)
- FFFmaxlatH: Each Rear Jack Capacity (H)
### 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).

\[
\Delta L := 0.18 \quad H := 0.18
\]

\[
\phi_{AL} := \text{atan}\left(\frac{24 - \Delta L}{282}\right)
\]

**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.)**

\[
WR_{AL} := 32000-lbf - \frac{172 \cos(\phi_{AL}) - (46.5) \sin(\phi_{AL})}{282 \cos(\phi_{AL}) + \Delta L \sin(\phi_{AL})}
\]

**Weight on front jack.**

\[
WF_{AL} := 32000-lbf - WR_{AL}
\]

**Force acting on the front and each rear jack cylinder.**

\[
FFJ_{AL} := WF_{AL} \cdot \cos(\phi_{AL}) \quad FRJ_{AL} := \frac{WF_{AL}}{2} \cdot \cos(\phi_{AL})
\]

**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 bolts.)**

\[
FFJH_{AL} := WF_{AL} \cdot \sin(\phi_{AL}) \quad FRJH_{AL} := \frac{WF_{AL}}{2} \cdot \sin(\phi_{AL})
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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.

![Graph showing weight distribution on front and rear jacks](image-url)
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-VM-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°.)

\[ FF_{long} = 730 \text{lbf} \]
\[ FR_{long} = 500 \text{lbf} \]

\[ H = 0 \ldots 18 \text{ Height of jack} \]

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

\[ M_{Flong} := FF_{long} \times 31.5 \text{ in} \]
\[ MR_{long} := FR_{long} \times 42.28 \text{ in} \]

\[ M_{Flong} = 22995 \text{lbf-in} \]
\[ MR_{long} = 21140 \text{lbf-in} \]

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.)

\[ FF_{maxlong} := \frac{M_{Flong}}{21 + H} \text{ in} \]
\[ FR_{maxlong} := \frac{MR_{long}}{18.28 + H} \text{ in} \]

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

\[ FF_{JH} = \text{Force on Front Jack (Horizontal component causing moment at connection)} \]
\[ FR_{JH} = \text{Force on Rear Jack (Horizontal component causing moment at connection)} \]

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

![Graph showing Front Jack Horizontal Load and Capacity](image-url)
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.

\[ \phi_{AL} := \tan \left( \frac{30 - \Delta L}{282} \right) \]  
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)

\[ W_F := \frac{32000 \cdot \text{lbf} - 282 \cdot \cos(\phi_{AL}) + \Delta L \cdot \sin(\phi_{AL})}{282} \]

Weight on rear jacks.

\[ W_R := 32000 \cdot \text{lbf} - W_F \]

\[ FFJ_{AL} := W_F \cdot \cos(\phi_{AL}) \]

\[ FRJ_{AL} := W_R \cdot 2 \cdot \cos(\phi_{AL}) \]  
Axial force acting on the front and each rear jack cylinder.

Force component acting perpendicular to the bolster. (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 bolster.)

\[ FFJH_{AL} := W_F \cdot \sin(\phi_{AL}) \]

\[ FRJH_{AL} := W_R \cdot 2 \cdot \sin(\phi_{AL}) \]

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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 19516 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.

![Weight on Front and Rear Graph]

- Weight on Front Jack
- Weight on Each Rear Jack
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".)

\[ FF_{long} := 730 \text{ lbf} \quad FR_{long} := 500 \text{ lbf} \]

\[ H := 0.18 \text{ Height of jack} \]

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

\[ MF_{long} := FF_{long} \cdot 31.5 \text{ in} \quad MR_{long} := FR_{long} \cdot 42.28 \text{ in} \]

\[ MF_{long} = 22995 \text{ lbf-in} \quad MR_{long} = 21140 \text{ lbf-in} \]

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.)

\[ FF_{maxlong} := MF_{long} \quad FR_{maxlong} := MR_{long} \]

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

- \( FF_{JH} = \text{Force on Front Jack (Horizontal component causing moment at connection)} \)
- \( FR_{JH} = \text{Force on Rear Jack (Horizontal component causing moment at connection)} \)

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

![Graph showing Rear Jack Loads and Capacity](image-url)