2. To: (Receiving Organization)
   North General Purpose Facility Maintenance
3. From: (Originating Organization)
   Structural Assessments
4. Related EDT No.:
   N/A
5. Proj./Prog./Dept./Div.:
   Roof Inspections
6. Cog. Engr.:
   R. M. McCoy
7. Purchase Order No.:
   N/A
8. Originator Remarks:
   This reports the Load Test of the 277W Building High Bay Roof Deck and Support Structure
9. Equip./Component No.:
   N/A
10. System/Bldg./Facility:
    N/A
11. Receiver Remarks:
12. Major Assm. Dwg. No.:
    N/A
13. Permit/Permit Application No.:
    N/A
14. Required Response Date:
    10/11/94

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<th>Sheet No.</th>
<th>Rev. No.</th>
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<th>Reason for Transmittal</th>
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Key:
- 1. Approval
- 2. Release
- 3. Information
- 4. Review
- 5. Post-Review
- 6. Dist. (Receipt Acknow. Required)
- 1. Approved
- 2. Approved w/comment
- 3. Disapproved w/comment
- 4. Reviewed no/comment
- 5. Reviewed w/comment
- 6. Receipt acknowledged

15. DATA TRANSMITTED
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<th>Reason for Transmittal</th>
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<td>SQ</td>
<td>1</td>
<td>1</td>
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16. Impact Level (F) Reason for Transmittal (G) Disposition (H & I)
- 1. Approval
- 2. Release
- 3. Information
- 4. Review
- 5. Post-Review
- 6. Dist. (Receipt Acknow. Required)
- 1. Approved
- 2. Approved w/comment
- 3. Disapproved w/comment
- 4. Reviewed no/comment
- 5. Reviewed w/comment
- 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION

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<th>Reason</th>
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<th>(I) Date</th>
<th>(M) MSIN</th>
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<th>(I) Date</th>
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<th>Reason</th>
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<td>10/6/94</td>
<td>S6-21</td>
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<td>10/6/94</td>
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<th>Disapproved w/comments</th>
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19. Signed for Receiving Organization

20. Engineer's Manager

21. Project Engineer's Manager

NOTE: THIS DOCUMENT IS UNLIMITED
**RELEASE AUTHORIZATION**

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<tr>
<th>Document Number:</th>
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</thead>
<tbody>
<tr>
<td>Document Title:</td>
<td>Load Test of the 277W Building High Bay Roof Deck and Support Structure</td>
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<tr>
<td>Release Date:</td>
<td>11/30/94</td>
</tr>
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**APPROVED FOR PUBLIC RELEASE**

WHC Information Release Administration Specialist:

[Signature]

11/30/94

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Load Test of the 277W Building High Bay Roof Deck and Support Structure

roof inspection, load testing

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TEST REPORT
WHC-SD-GN-TRP-20026

Revision 0

LOAD TEST OF THE 277W BUILDING HIGH BAY ROOF DECK AND SUPPORT STRUCTURE
For Personnel Access Using a Remotely Operated Robot

Prepared By: R. M. McCoy, Senior Engineer Structural Assessments
Date: 9-27-94

Reviewed By: R. A. Giller, Senior Engineer Structural Assessments
Date: 9-29-94

Approved By: T. J. Conrads, Manager Structural Assessments
Date: 10-3-94

WESTINGHOUSE HANFORD COMPANY
Hanford Operations and Engineering Contractor
for the Department of Energy

Distribution of this document is unlimited.
CONTENTS

1.0 INTRODUCTION

2.0 EXECUTIVE SUMMARY

3.0 LOAD TEST
   3.1 LOAD-TEST RISKS
   3.2 TEST PROCEDURE
   3.3 PRE-TEST APPROVALS, RELEASE TO PROCEED
   3.4 TEST ENGINEER’S QUALIFICATION
   3.5 PRE-TEST CHECKLIST

4.0 RESULTS AND RECOMMENDATIONS
   4.1 LOAD-TEST DATA
   4.2 QUALIFICATION RESULTS
   4.3 RECOMMENDATIONS

5.0 REFERENCES

Appendix A
   STRESS/DEFLECTION CALCULATIONS

Appendix B
   BUILDING PLAN

Appendix C
   JOB HAZARDS ANALYSIS

Appendix D
   FALL-PROTECTION PROGRAM

Appendix E
   PRE-JOB BRIEFING MINUTES
1.0 INTRODUCTION

The 277W Building high bay roof area was load tested according to the approved load-test procedure, WHC-SD-GN-TP-30015, Revision 1. The 277W Building is located in the 200 West Area of the Hanford Site and has the following characteristics:

- Roof deck - wood decking supported by 4 x 14 timber purlins
- Roof membrane - tar and gravel
- Roof slope - flat (<10 deg)
- Roof elevation - maximum height of about 63 ft.

The 277W Building was visited in March 1994 for a visual inspection. During this inspection, cracked areas were visible in the decking, but it was not possible to determine whether these cracks extended completely through the decking, which is 2-in. thick. The building was revisited in March 1994 for the purpose of writing this test report. Because the roof requires personnel access, a test was determined to be the best way to qualify the roof.

2.0 SUMMARY

The 277W Building high bay roof was load tested according to the approved load-test procedure, WHC-SD-GN-TP-30015, Revision 1; the specific directions of this test report were followed. The test was performed on September 24, 1994, from 7:00 a.m. to 11:00 a.m.

All pre-test approvals and pre-test checklist items were signed off as shown in Sections 3.3, 3.4, and 3.5 below. On the day of the test, the pre-test briefing was held. The pre-test briefing consisted of filling out the pre-test checklist, discussing proper lifting techniques, reviewing the fall-protection plan, reviewing the job hazards analysis, and reviewing the robot travel path.

The load-test results consist of visual observations and the test engineer's conclusions. Visual observations found no adverse conditions such as large deflections or permanent deformations. No deflection measurements were recorded because the tar and gravel on roofs get displaced by the robot tracks; the result is large variations in deflection measurements.

The conclusions are that the roof has been qualified for 500-lb total roof load and that the "No Roof Access" signs can be changed to "Roof Access Restricted" signs as section 4.3.
3.0 LOAD TEST

3.1 LOAD-TEST RISKS

Roof load tests involve risks. These risks must be addressed and mitigated by the load-test team and the results accepted or rejected by Safety and the building manager before the test begins. The risks associated with the roof load test fall into two categories: personnel injury and building or equipment damage.

Personnel risks are minimized by evacuating and barricading the work areas, testing the procedure steps, and verifying that the risks are acceptable. Test personnel are also protected by procedures that incorporate job hazards analyses and fall-protection evaluations.

The risks to buildings, building equipment, and the robot are much higher than those for personnel and were evaluated on the basis of the following cost-benefit evaluation based on the 25 buildings to be tested initially.

- Roof access is needed for routine maintenance of roof-mounted equipment, roof membrane repair, and re-roofing work.
- The estimated cost of load testing a roof is $8,000 per building including the cost of the robot, equipment, and test plan development.
- The estimated cost to move roof-mounted equipment to the ground level is more than $10,000 per building.
- The estimated cost to remove and replace rigid drywall ceilings so that the roof can be inspected rather than tested is more than $50,000 per building.
- If a robot falls through the roof, the financial losses are the cost of the robot @ $50,000 and the repair of building equipment @ $10,000. [Note: Damage to the building is not included because the roof would have to be repaired anyway.]

Possible damage to building, equipment, and robot is a cost-only risk that is mitigated as follows.

- Visual inspections shall be performed to look for deterioration and test feasibility.
- Expensive equipment is removed from the test areas and the areas beneath.
- The roof is evaluated structurally to verify that, as designed, it is adequate to support the robot.
- Testing of roofs that perform poorly, such as pre-cast concrete or gypsum materials, or structurally suspect roofs will be avoided. Testing of these roofs shall be contingent on further cost-benefit analyses.
Test failures are expected to be localized, e.g., one wheel of the robot punches through the roof membrane. During the test, deflections are monitored so that if a local failure occurs the test can be stopped before the whole robot falls through the roof.

Thought was given to tethering the robot to anchor points or overhead cranes. However, it would cost an estimated $10,000 per building (for a total of $250,000) to secure the $50,000 robot. Additionally, the sudden snap of the securing cable system or crane boom movement would be more dangerous to the robot operators than letting the robot free fall.

The roof deck on 277W is constructed of 2 by 8 tongue-and-grooved decking. The tongue-and-grooved construction allows for the sharing of load. If a section of decking is deteriorated, failure will be localized and the tracks on the robot will prevent it from completely falling through the deck.

3.2 TEST PROCEDURE

The test engineer was designated as R. M. McCoy.

The 277W Building high bay roof area was visited for inspection in March 1994; an inspection of the roof was performed, but the roof must be qualified for personnel access.

Deflection calculations (Appendix A) indicate a maximum deflection at the point of greatest deflection of 0.18 in. for 1,062 lb.

The building plan provided in Appendix B indicates the test area, the observation area, the route that the robot will take to get to and from the roof, and the route the robot will take to test the roof.

The test engineer has prepared this test report and obtained the pre-test approvals indicated in Section 3.3.

The job hazards analysis appears in Appendix C.

A fall-protection program appears in Appendix D.

Pre-job briefing minutes appear in Appendix E.

The 277W Building high bay is a shop and houses personnel on a full-time basis. The interior of the building shall be barricaded off with "CAUTION" tape and posted with "DANGER" signs. The load test will be performed during off-hours.

The area around the exterior of the building where the load test is being performed shall be barricaded off at ground level with "CAUTION" tape, and all doors leading into the test area shall be posted with "DANGER" signs.

Observation ladders and platforms are required for this load test.

The qualified robot operator for this test shall be R. M. McCoy.
The robot is to be placed on the roof by ICF Kaiser hoisting and rigging personnel.

The robot shall move across the roof following the path specified on the building plan in Appendix B. The first pass shall be made with an unloaded robot (600 lb). The second pass shall be made with the fully loaded robot (1,062 lb). Note: The fully loaded robot weighs 1,062 lb; that weight divided by the robot footprint yields a uniform load under the robot of 90 lb/ft².

The test engineer shall observe the movement of the robot and look for abnormally large or permanent deflections. The test engineer shall base the pass/fail determination on these observed deflections. [Note: This pass/fail determination deviates from the approved test procedure.] Failed roof deck and support members shall be considered unsafe to walk on or under, and appropriate safety measures shall be taken by the building manager.

The robot shall be removed from the roof after this test by ICF Kaiser hoisting and rigging personnel.

The test engineer or building manager shall remove the load-test postings following the test.

The building manager shall post the building as unsafe, as required, on the basis of the results of the load testing or at the recommendation of Industrial Safety.

The test engineer shall complete this test report.
3.3 PRE-TEST APPROVALS, RELEASE TO PROCEED

Your signature on this form signifies your agreement with this roof deck load-test plan, and with the pre-test checklist items. The load test may proceed anytime within three months of signing this form.

R. M. McCoy/ R. M. McCoy Date: 8-24-94
Test Engineer (Printed/Signature)

T. J. Conrads/ T. J. Conrads Date: 8/3/94
Engineering, Analysis and Technology Management (Printed/Signature)

C. M. Hartman/ C. M. Hartman Date: 8/12/94
Industrial Safety (Printed/Signature)

A. K. Sharma/ A. K. Sharma Date: 7/9/94
Quality Assurance (Printed/Signature)

W. A. Retterer/ W. A. Retterer Date: 8-31-94
Building Manager (Printed/Signature)

3.4 TEST ENGINEER'S QUALIFICATION

• Degree or equivalent work experience in structural, civil, or mechanical engineering fields.

• Two years of combined field and analysis experience in the design, evaluation and construction of building structures.

• Experience in the construction materials of the building being tested, e.g., steel concrete, or wood.

• Approval of the engineering manager shall testify to the ability and credentials of the test engineer.

R. M. McCoy/ R. M. McCoy Date: 8-24-94
Test Engineer (Printed/Signature)

T. J. Conrads/ T. J. Conrads Date: 8/31/94
Manager (Printed/Signature)
### 3.5 PRE-TEST CHECKLIST

<table>
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<tr>
<th>STEP</th>
<th>SIGNATURE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BEFORE THE LOAD TEST IS SCHEDULED:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verify that an attempt was made to inspect the roof visually, to find deficiencies and to determine the feasibility of making a load test.</td>
<td>R.M. Reddy</td>
<td>8-25-94</td>
</tr>
<tr>
<td>Verify that the roof needs to be load tested.</td>
<td>R.M. Reddy</td>
<td>8-25-94</td>
</tr>
<tr>
<td>Prepare building roof plan.</td>
<td>R.M. Reddy</td>
<td>8-25-94</td>
</tr>
<tr>
<td>Prepare stress and deflection calculations based on the as-built member strengths.</td>
<td>R.M. Reddy</td>
<td>8-25-94</td>
</tr>
<tr>
<td>Prepare job hazards analysis.</td>
<td>R.M. Reddy</td>
<td>8-25-94</td>
</tr>
<tr>
<td>Prepare fall-protection plan.</td>
<td>R.M. Reddy</td>
<td>8-25-94</td>
</tr>
<tr>
<td>Obtain pre-test approvals.</td>
<td>R.M. Reddy</td>
<td>8-25-94</td>
</tr>
<tr>
<td>Schedule test date.</td>
<td>R.M. Reddy</td>
<td>9-6-94</td>
</tr>
<tr>
<td>Notify Industrial Safety of test date.</td>
<td>R.M. Reddy</td>
<td>9-6-94</td>
</tr>
<tr>
<td>Notify QA of test date.</td>
<td>R.M. Reddy</td>
<td>9-6-94</td>
</tr>
<tr>
<td><strong>DAY BEFORE TEST:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check robot batteries for full charge.</td>
<td>R.M. Reddy</td>
<td>9-24-94</td>
</tr>
<tr>
<td>Hold pre-job briefing. (May be conducted on the day of the test.)</td>
<td>R.M. Reddy</td>
<td>9-24-94</td>
</tr>
<tr>
<td><strong>ON THE TEST DAY:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verify that personnel and valuable/critical equipment have been removed from the building below the load-test area.</td>
<td>R.M. Reddy</td>
<td>9-24-94</td>
</tr>
<tr>
<td>Barricade off and post danger signs in the load-test area.</td>
<td>R.M. Reddy</td>
<td>9-24-94</td>
</tr>
<tr>
<td>De-energize or shut down equipment or switchgears that are installed under or on the roof test area</td>
<td>R.M. Reddy</td>
<td>9-24-94</td>
</tr>
<tr>
<td>Place observation ladders or platforms.</td>
<td>N/A</td>
<td>—</td>
</tr>
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</table>
4.0 RESULTS AND RECOMMENDATIONS

4.1 LOAD-TEST DATA

The load-test data consist of the following visual observations by the test crew.

- Turning of the robot resulted in the gravel on the roof being moved.
- The tar roof membrane under the gravel layer was not damaged.
- No large deflection or permanent deformation of the deck was noted.

4.2 QUALIFICATION RESULTS

The loads for this test were 600 lb for the unloaded robot and 1,062 lb for the fully loaded robot. With these loads no large deflections or permanent deformations were noted. Visual observations reported no soft or weak spots in the roof deck.

On the basis of these observations, the roof deck is qualified for limited personnel access. Personnel and equipment should be limited to half of the tested load or about 500 lb on any one area of the roof. Roof area is defined by the purlin spacing and the width of 4-ft: roughly one person on any 4- by 4-ft area.

4.3 RECOMMENDATIONS

The roof of the high bay is qualified for 500 lb of personnel and equipment in each roof area. The "No Roof Access" signs can be changed to the following:

"Roof Access Restricted. See Building Manager for Access."

NOTE: Purlin along column line C' between columns 10 and 11 is broken. Personnel shall not have access to the area around this purlin until repairs are completed.

For the 277W Building low bay roof area, refer to supporting document WHC-SD-GN-TRP-20009.

The roof deck should be load tested at 2-year intervals. This interval is recommended as the maximum inspection interval on the basis of the present condition of the roof. It assumes that the roof is maintained to prevent deterioration from both interior and exterior sources (e.g., roof or steam leaks). The recommended interval should be shortened, should the possibility of deterioration occur (e.g., roof leaks). If the roof is to have regular foot traffic, the load-test interval should be reduced to half of the suggested interval.
5.0 REFERENCES


APPENDIX A

STRESS/DEFLECTION CALCULATIONS
2x T&G Decking Supported @ 4'-8"

\[ l = 4.67' = 56'' \]
\[ d = 1.5'' > \text{Ref. Timber Construction Manual} \]
\[ b = 5.5'' \]

Assume 4 Simple Span & Concentrated Loads

Load is distributed uniformly to 4 contact points (\( P = 26.5.5'' \)) acts over 1'

\[ S = 12(1.5)^{3/2} \approx 4.5 \text{ in}^3/\text{ft}^2 \]

\[ \omega_0 = \text{Built-Up Roof} = 6 \text{ psf} \]
\[ 2x SHEATHING = 3 \text{ psf} \]
\[ 14 \text{ psf} \approx 0.97 15''^2 \]
\[ P = 26.5.5'' \]

\[ M_{max} = \frac{pl}{4} + \frac{wL^2}{8} = \frac{26.5.5(56)}{4} + \frac{0.97(56)^2}{8} \approx 4173 \text{ in} \cdot \text{lb} \]
\[ J = \frac{4173}{4.5} \approx 927 \text{ psi} < 1200 \text{ psi} \]

Deflection

\[ I = 12(1.5)^{3/2} = 3.375''^4 \]
\[ E = 1.6 \times 10^6 \text{ (Southern Pine HW Spec. 1822)} \]

\[ A_{LL} = \frac{PL^3}{48EI} = \frac{26.5.5(56)^3}{48(1.6E6)3.375} \approx 0.18'' \]
APPENDIX B

BUILDING PLAN
Prepared By: R. M. McCoy
Date: 08/24/94
Area: 200W
Scope/Description: Roof load test of the 277W Building using a remotely operated robot

Emergency Contact Person(s):
Primary:
Secondary:
Emergency Radio/Phone Number: MOBIL 811

Specific Work Location(s): 277W Building Roof

---

**KNOWN OR POTENTIAL HAZARDS**

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<th>Reference</th>
<th>Yes</th>
<th>No</th>
<th>Reference</th>
</tr>
</thead>
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<tr>
<td>1. Radiation Area Work</td>
<td>X</td>
<td>✓</td>
<td>●</td>
<td>10. Respiratory Hazards</td>
<td>X</td>
</tr>
<tr>
<td>3. Confined Space Entry</td>
<td>X</td>
<td>✓</td>
<td>●</td>
<td>12. Lock and Tag</td>
<td>X</td>
</tr>
<tr>
<td>6. Fall Hazards (&gt; = 10')</td>
<td>X</td>
<td></td>
<td></td>
<td>15. Asbestos Removal</td>
<td>X</td>
</tr>
<tr>
<td>7. Excavation/Trenching</td>
<td>X</td>
<td></td>
<td></td>
<td>16. Other (see JHA Sht. 2):</td>
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**Other Hazards**

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<th>Control Measures</th>
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<td>2. Noise</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>3. Poor Lighting</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>4. Animals/Insects</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>5. Process Chemicals/Steam</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>6. Dust</td>
<td>X</td>
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</tr>
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<td>7. Flammable/Combustible Materials</td>
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<td>8. Ladders</td>
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<td>9. Wet/Slippery Floors</td>
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<td>10. Uneven Terrain</td>
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</tr>
<tr>
<td>11. Open Excavations/Trenches</td>
<td>X</td>
<td>No roof access in untested areas</td>
</tr>
<tr>
<td>12. Adjacent Water Hazard</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>13. Vehicle Traffic</td>
<td>X</td>
<td>Baracade off work area and post</td>
</tr>
<tr>
<td>14. Heavy Equipment</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>15. Rigging Operation</td>
<td>X</td>
<td>Will be preformed by WHC hoisting &amp; rigging personnel</td>
</tr>
<tr>
<td>16. Manual Lifting</td>
<td>X</td>
<td>Manual lifting of weights, see page 2 for control measures</td>
</tr>
<tr>
<td>17. Power Tools</td>
<td>X</td>
<td>Robot will be operated by trained and qualified operators</td>
</tr>
<tr>
<td>18. Pinch Points</td>
<td>X</td>
<td>See page 2 for control measures</td>
</tr>
<tr>
<td>19. Falling Objects</td>
<td>X</td>
<td>Baracade off work area and post area as no access.</td>
</tr>
<tr>
<td>20. Sharp Objects</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>21. Overhead Obstructions</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>22. Site Control (Signs/Barricades)</td>
<td>X</td>
<td>&quot;CAUTION&quot; tape &amp; &quot;DANGER&quot; sign will be used to baracade area</td>
</tr>
<tr>
<td>23. Remote Work Area</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>24. Other (see JHA Sht. 2):</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

**MINIMUM DRESS REQUIREMENTS:** See page 2

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**APPROVALS**

Does further evaluation of the job steps, associated hazards, or safety measures need to be performed?  [ ] Yes  [ ] No

If Yes, continue job hazard analysis on the following pages.

Supervisor, Person In Charge: R. M. McCoy
Industriary Safety/Hygiene (Signature) C. M. Hartman
(Signature)
HANFORD JOB HAZARD ANALYSIS CHECKLIST

Roof Work

Load testing the roof deck and supporting structure will be performed from the roof top.

Fall Hazard

The fall hazard associated with this task is a property-damage risk and a personnel hazard. See fall-protection program.

Manual Lifting

Lifting of the robot weights has the potential for back injury.

Correct lifting methods shall be used, and the robot operators who will be doing the lifting have been trained in these methods during group safety meetings.

Weights shall be lifted onto the robot only on areas of the roof that have already been qualified by visual inspection.

Pinch Points

The operation of the robot produces pinch points. During the operation of the robot, all personnel shall maintain a minimum distance of 10 ft except for the operators of the robot. The operators shall maintain a distance of 2 ft from the pinch point areas during the robot operations.

Minimum Dress

The following is the minimum dress requirements:
- dress for outside work
- safety shoes
- safety classes and
- hard hat (only required when there are overhead hazards).
APPENDIX D

FALL-PROTECTION PROGRAM
FALL-PROTECTION PROGRAM

PART A: ROBOT ROOF ACCESS

The fall hazard associated with the robot is loss of property only.

To restrict access to the area under the roof that is being load tested, the following precautions will be used where applicable.

- Lock doors into the test area and post with "DANGER" signs.
- Barricade off the area with "CAUTION" tape and post with "DANGER" signs.

PART B: PERSONNEL ROOF ACCESS

Personnel and the robot shall be separated by a minimum of one column line, except when the robot is located directly over the ridge beam. The ridge beam is the only place on the roof where the robot, the weights, and test personnel are permitted to be in the same roof area at the same time.

Personnel are to maintain a minimum distance of 6 ft from the edge of the roof. If personnel are required to be within 6 ft of the edge, then an approved fall-arrest system will be used.
APPENDIX E

PRE-JOB BRIEFING MINUTES
Pre-Job Briefing Minutes

Date: 9-24-94

Building: 277W BUILDING HIGH BAY

Attendance: R. M. McCoy, C. J. Furubotten

The pre-job briefing meeting was attended by Engineering, Analysis and Technology (EAT). The meeting covered the procedure to load test the 277W Building high bay.

The following topics were reviewed:

- Risk associated with the load test
- The building plan
- The job hazards analysis
- The fall-protection program
- Safety barricading requirements.

Any additional personnel who come onto the test site must read the 277W Building high bay test report (WHC-SD-GN-TRP-20026) and review the above topics.