1 of 2

2
5

DEC 01 1993 ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT NO 141466

2. To: (Receiving Organization) Life Extension Program		3. From: (Originating Organization) Wiss, Janney, Elstner Associates, Inc.,		4. Related EDT No.: 141464					
5. Proj./Prog./Dept./Div.: Roof Repairs/Programs/Fuel Storage Basins		6. Cog. Engr.: S. E. Moustafa		7. Purchase Order No.: MMB-SCV-267622					
8. Originator Remarks: Asbestos Cement Panel Test Report, 105KW, WHC-SP-0868, REV 1				9. Equip./Component No.: N/A					
				10. System/Bldg./Facility: 60/105KW					
11. Receiver Remarks:				12. Major Assm. Dwg. No.: N/A					
				13. Permit/Permit Application No.: N/A					
				14. Required Response Date:					
15. DATA TRANSMITTED									
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Impact Level	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition	
1.	WHC-SD-NR-TRP-016	N/A	0	Asbestos Cement Panels Test Report, 100K Area, Hanford Washington	3SQ	1	1	1	
16. KEY									
Impact Level (F)		Reason for Transmittal (G)			Disposition (H) & (I)				
1, 2, 3, or 4 (see MRP 5.43)		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 (See Impact Level for required signatures)									
(G)	(H)	(J) Name (K) Signature (L) Date (M) MSIN				(G) (H)			
Reason	Disp.					Reason Disp.			
1	1	Cog. Eng. S. E. Moustafa 9/13/93 X0-36							
1	1	Cog. Mgr. W. A. Frier 9/13/93 X0-36							
1	1	QA J. I. Diehl 10-12-93 X1-80							
1	1	Safety L. C. Haslam 10-13-93 X0-51							
		Env.							
1	1	M. R. Lindquist 9/29/93 X5-57							
18. Signature of EDT Originator S. E. Moustafa 9/13/93		19. Authorized Representative Date for Receiving Organization W. A. Frier 11/4/93		20. Cognizant/Project Engineer's Manager Date W. A. Frier 10/13/93		21. DOE APPROVAL (if required) Ltr. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments			

Date Received: 12/1/93 KMB		INFORMATION RELEASE REQUEST		Reference: WHC-CM-3-4	
Complete for all Types of Release					
Purpose ☐ Speech or Presentation ☐ Full Paper (Check only one suffix) ☐ Summary ☐ Abstract ☐ Visual Aid ☐ Speakers Bureau ☐ Poster Session ☐ Videotape			☒ Reference ☐ Technical Report ☐ Thesis or Dissertation ☐ Manual ☐ Brochure/Flier ☐ Software/Database ☐ Controlled Document ☐ Other		
			ID Number (include revision, volume, etc.) WHC-SD-NR-TRP-016/REV 0		
			List attachments.		
			Date Release Required		
Title Asbestos Cement Panels Test Report, 100K Area, Hanford, Washington				Unclassified Category UC-904	
				Impact Level 3 SQ	
New or novel (patentable) subject matter? ☒ No ☐ Yes If "Yes", has disclosure been submitted by WHC or other company? ☐ No ☐ Yes Disclosure No(s).			Information received from others in confidence, such as proprietary data, trade secrets, and/or inventions? ☒ No ☐ Yes (Identify)		
Copyrights? ☒ No ☐ Yes If "Yes", has written permission been granted? ☒ No ☐ Yes (Attach Permission)			Trademarks? ☒ No ☐ Yes (Identify)		
Complete for Speech or Presentation					
Title of Conference or Meeting			Group or Society Sponsoring		
Date(s) of Conference or Meeting		City/State	Will proceedings be published?		☐ Yes ☐ No
			Will material be handed out?		☐ Yes ☐ No
Title of Journal					
CHECKLIST FOR SIGNATORIES					
Review Required per WHC-CM-3-4		Yes	No	Reviewer - Signature Indicates Approval	
				Name (printed)	Signature Date
Classification/Unclassified Controlled Nuclear Information	☒	☐		R. J. Pyzel	<i>[Signature]</i> 11/1/93
Patent - General Counsel	☒	☒			
Legal - General Counsel	☒	☐		S. W. Berglin	<i>[Signature]</i> 11/18/93
Applied Technology/Export Controlled Information or International Program	☐	☒			
WHC Program/Project	☒	☐		V. L. Hoefer	<i>[Signature]</i> 11/01/93
Communications	☐	☒			
RL Program/Project	☒	☐		O. M. Holgado	<i>[Signature]</i> 11/23/93
Publication Services	☒	☐		C. A. Collins	<i>[Signature]</i> 12/1/93
Other Program/Project	☐	☒			
Information conforms to all applicable requirements. The above information is certified to be correct.					
		Yes	No	INFORMATION RELEASE ADMINISTRATION APPROVAL STAMP	
References Available to Intended Audience	☒	☐		Stamp is required before release. Release is contingent upon resolution of mandatory comments.
Transmit to DOE-HQ/Office of Scientific and Technical Information	☐	☒			
Author/Requestor (Printed/Signature)		Date			
W. A. Frier	<i>[Signature]</i>	10/13/93			
Intended Audience					
☐ Internal ☐ Sponsor ☒ External					
Responsible Manager (Printed/Signature)			Date		
W. A. Frier			10/13/93		
			Date Cancelled		Date Disapproved

SUPPORTING DOCUMENT		1. Total Pages 08
2. Title Asbestos Cement Panels Test Report, 100K Area, Hanford, Washington		3. Number WHC-SD-NR-TRP-016
		4. Rev No. 0
5. Key Words 105KW, Asbestos Cement Roof Panels, Roof Proof Load, Roof Consultant <i>KMB 12/1/93</i>		6. Author W. A. Frier <i>W. A. Frier</i> 11810/KK3JE
7. Abstract The objective of the complete test program is to determine the structural capacity of the existing corrugated asbestos-cement roof panels installed in the 105KE and 105KW facilities. The data from this test indicated that the roof is capable of resisting the design loads and could be considered potentially safe.		
8. PURPOSE AND USE OF DOCUMENT - This document was prepared for use within the U.S. Department of Energy and its contractors. It is to be used only to perform, direct, or integrate work under U.S. Department of Energy contracts. This document is not approved for public release until reviewed. PATENT STATUS - This document copy, since it is transmitted in advance of patent clearance, is made available in confidence solely for use in performance of work under contracts with the U.S. Department of Energy. This document is not to be published nor its contents otherwise disseminated or used for purposes other than specified above before patent approval for such release or use has been secured, upon request, from the Patent Counsel, U.S. Department of Energy Field Office, Richland, WA. DISCLAIMER - This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.		10. RELEASE STAMP <div style="border: 1px solid black; padding: 5px; text-align: center;"> OFFICIAL FOR RELEASE IN WHC DATE DEC 01 1993 <i>Sta. 4</i> </div>
9. Impact Level 3SQ		

Wiss, Janney, Elstner Associates, Inc.

WHC-SD-NR-TRP-016
REV: 0

ASBESTOS-CEMENT PANELS

TEST REPORT, 100K AREA, ILANFORD, WASHINGTON

WIIC PURCHASE ORDER No. MMB-SCV-267622

WJE No. 930496

Saad E. Moustafa, Ph.D., P.E.
Project Manager

Scott M. Rodchaver
Project Engineer

CERTIFICATION:

WJE certifies that testing was performed in accordance with the applicable ASTM Standards.

Jerry G. Stockbridge
President

Wiss, Janney, Elstner Associates, Inc.
5700 Sixth Avenue South, Suite 220
Seattle, Washington 98108
(206) 768-3460

MASTER

JAN 07 1994

OCT 1

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

87B

TABLE OF CONTENTS

LIST OF TABLES	iii
LIST OF FIGURES	iv
1.0 INTRODUCTION	1
1.1 Background	1
1.2 Dead and Live Loads	1
1.3 Roof Test Program	2
1.3.1 190KE Building	2
1.3.2 105KW A/C Coupons	2
1.3.3 Proof Load Test	3
2.0 DESCRIPTION OF TEST METHOD AND TEST EQUIPMENT	3
2.1 Asbestos Containment	3
2.2 190KE Wall Panels	4
2.2.1 Full Panel Tests	4
2.2.2 Coupon Tests	4
2.2.3 Other Tests	4
2.3 105KW Coupon Testing	4
2.4 105KW Roof Proof Load Test	5
2.4.1 Test Item	5
2.4.2 Test Preparations	5
2.4.3 Loading System	6
2.4.4 Deflection Measurement	6
2.4.5 Test Sequence	6
3.0 TEST RESULTS AND ANALYSIS	7
3.1 190KE Wall Panels	7
3.1.1 Full Panel Tests	7
3.1.2 Coupon Tests	8
3.1.3 Other Tests	8
3.2 105KW Coupons	8
3.2.1 Coupon Tests	8
3.2.2 Other Tests	9
3.2.3 Effect of Moisture on Perlite Concrete	9
3.3 Roof Proof Load Test	9
3.3.1 Design Loads	9
3.3.2 Required Test Load	9
3.3.3 Probabilities of Passing the Test Load	9
3.4 105KW Roof Proof Load Test	10

4.0 CONCLUSIONS AND RECOMMENDATIONS 11

 4.1 190KE Wall Panels 11

 4.1.1 Full Panel Test 11

 4.1.2 Coupon Tests 11

 4.2 105KW Roof Panels 12

 4.2.1 Coupon Tests 12

 4.2.2 Roof Proof Load Test 12

5.0 DISPOSITION OF TEST ITEM(S) 13

6.0 REFERENCES 13

LIST OF TABLES

<u>TABLE</u>	<u>PAGE</u>
1 - Full Panel 190KE Test Specimens	14
2 - 190KE Full Panel Test Results	15
3 - 190KE Coupon Test Specimens	16
4 - Results of Other Tests - 190KE Wall Panels	17
5 - 105KW Coupon Test Specimens	18
6 - Results of Other Tests - 105KW Roof Coupons	19
7 - Probabilities of A/C Roof Panels Successfully Resisting the Test Load	20
8 - LVDTs Calibration Factor	21
9 - Roof Proof Load Test Results	22

LIST OF FIGURES

<u>FIGURE</u>		<u>PAGE</u>
1	Overall view of 105KW	23
2	Signs of cracking in the A/C roof panels	24
3	Coupon removed from 105KW basin roof	25
4	Full panel test setup	26
5	Flexural test of full size panels	27
6	Strain indicators used to monitor load cell during the flexure tests	27
7	ASTM C221-88 Specimen extracted from asbestos-cement roof panels	28
8	ASTM C221-88 Test setup	29
9	End view of ASTM C221-88 Test setup	30
10	ASTM C221-88 flexural coupon test	31
11	Plan view of test area	32
12	Section through test area	33
13	Roof proof load test area	34
14	Reflected framing plan at test area	35
15	Backup shoring system - overall view	36
16	Backup shoring system (closeup)	36
17	Flow meter and manifold system	37
18	Water bags layout	38
19	Water bags in place over roof area	39
20	Close-up of LVDT	40
21	Observation and recording station	40
22	Failed wall panel specimen	41
23	Roof proof load test - Load vs. Deflection	42
24	Roof proof load test - Time History for uniform load of 35 psf	43

LIST OF APPENDICES

- A Calibration Sheets**
- B Calculations**
- C Roof Proof Load Test Data Sheets**
- D Carter Lift Bag Catalog**

1.0 INTRODUCTION

Westinghouse Hanford Company (WHC) has engaged Wiss, Janney, Elstner Associates, Inc. (WJE) to perform laboratory and field tests on asbestos-cement roof panels of the 105KW building and also to make recommendations for panel replacement, maintenance or upgrade that will maintain the structural integrity of the roof panels for an additional 20 years of service. This report contains the results of laboratory and in-situ testing performed by WJE. Funding for the test was provided by WHC contract number MMB-SCV-267622. A Roof Proof Load Test Plan was prepared by WJE and approved by WHC, Ref. 1. WJE performed the proof load test from July 26 to July 29, 1993. Laboratory tests were conducted before and after the proof load test.

1.1 Background

The 105KE/105KW reactor facilities were constructed in the mid 1950s (Fig. 1). The 105KE/105KW fuel-basin roof panels are in a radiation controlled area where there is smearable contamination. Background radiation levels of 5-15 mR/hr exist in 105KE. Background radiation levels of 2 mR/hr exist in 105KW.

Sections of the 105KE/105KW basin roof were recently inspected by WHC. These sections cover the office areas (east side of the building), the fuel storage basin, and the transfer area. The roof panels in all of the inspected areas were constructed from corrugated asbestos-cement (A/C) panels. The panels were covered with perlite insulating concrete (level with overlap of approximately 2 1/2 in. thick), 1 inch of rigid insulation, and layers of asphalt and gravel. Steel beams, joists, and columns support these roof panels.

The corrugated A/C roof panels are made from a brittle material that have common signs of aging including cracking, chipping, spalling, or a combination of the above (Fig. 2). The original construction specification required a breaking strength of not less than 40 lbs/ft² nor more than 60 lbs/ft² for panels with a 6-foot span, Ref. 2. Assuming that the panels, which predominantly have greater than 6-foot spans, will have a breaking strength of less than the minimum for that of a 6-foot span (e.g., 29 lbs/ft² for a 7-foot span), the structural integrity of all of the roof panels is considered questionable because the current site dead (~ 20 lbs/ft²) plus live (20 lbs/ft²) load exceeds this value (<40 lbs/ft²). All panels that contain significant visual deficiencies were considered "unacceptable" until further analysis or testing indicates otherwise.

1.2 Dead and Live Loads

A structural analysis of the 105KW roof panels and building structural steel was performed in 1987, before the addition of a new roof over the 105KW basin. For this analysis, it was assumed that the corrugated A/C panels were made of a material called Transite, as was manufactured by Johns-Manville. The material properties of this transite material were used in the analysis. A dead load of 18.2 lbs/ft² (weight of roof materials) and a live load of 20 lbs/ft² (per UBC), Ref. 4, were used in the analysis. Using these loads with a 1.5 factor of safety, the calculations indicated that the allowable stress of the dry transite material was exceeded. Similarly, these loads challenged the ultimate panel capacity when the transite was considered wet. The addition of the new roof over the 105KW basin eliminated the 20 lbs/ft²

live load requirement on the corrugated A/C panels once the infiltration of water between the reactor and the new roof was stopped.

The original construction specifications for the A/C panels did not specify a "wet" or "dry" allowable strength but defined the minimum breaking strength (ultimate capacity) of a 6-foot span as 40 lbs/ft². However, many panels span more than 6 feet, some as large as 7 feet. The breaking strength for a 7-foot span is reduced to 29 lbs/ft². The minimum weights of the roofing material given were not less than 7.4 lbs/ft². WHC's conclusions of roof inspections and evaluations are that the roof will not carry the current dead and live load requirements; therefore, it is considered suspect and should be upgraded, Ref. 7.

1.3 Roof Test Program

A roof test program, Ref. 3, recommended a testing plan for the corrugated A/C panels. This report includes the results and recommendations of the following tests:

1.3.1 190KE Building

1.3.1.1 Full Panel Tests

In order to experimentally determine the structural capacity of a typical roof panel, six (6) corrugated A/C panels (42 in. by 78 in. or 69 in. each) from the 190KE building walls were tested at the WJE laboratory in Northbrook, Illinois, according to ASTM E72-80, Ref. 11. These panels are similar to the roof panels of the 105KE and 105KW facilities

1.3.1.2 Coupon Tests

Coupons, cut from failed portions of the tested 190KE wall panels, were tested at the WJE Laboratory according to ASTM C221-88, Ref. 12. These tests provided additional data for determining the structural capacity of the roof panels.

1.3.1.3 Other Tests

Portions of the tested 190KE wall panels were also tested for the fiber and moisture contents, water absorption, and density.

1.3.2 105KW A/C Coupons

1.3.2.1 Coupon Tests

Eight (8) asbestos-cement coupons randomly selected from the basin area of the 105KW (Fig. 3) were tested by WJE at their Northbrook laboratory, according to ASTM C221-88, Ref. 12. Perlite concrete, which was bonded to the top surface of the coupons retrieved from the 105KW basin roof, was not removed before testing. It was feared that any attempt to remove the perlite may result in damage to the A/C specimen. The thickness of the

perlite concrete varied noticeably from one specimen to another. It was felt that testing of the coupons with the perlite concrete in place is desirable from the point of view of reflecting any composite action that may exist for this type of construction.

1.3.2.2 Other Tests

Tested coupons from the 105KW building were also analyzed for their fiber and moisture contents, water absorption, and density.

1.3.3 Proof Load Test

A roof area, including several A/C panels, was tested under uniform load. The load test was conducted according to ASTM E196-80, Ref. 10, and ASTM E72-80, Ref. 11. The only load testing procedure of existing structures specified in the Uniform Building Code (UBC) (Ref. 4) is that of the American Concrete Institute (ACI 318) (Ref. 5). The ACI 318 procedure is intended for reinforced and prestressed concrete structures. Criteria for the roof proof load test were based on the results of the initial materials testing program, 1.3.1 and 1.3.2 above.

Because the lab tests were performed before the proof load test, the results of the 190KE panel and coupon tests, as well as tests on two of the eight coupons obtained from the 105KW roof, were used to estimate the in-situ load capacity of the roof panels. The results also provided a guide during the performance of the roof proof load test. The results of the roof proof load test and the eight coupons from the 105KW roof provided a basis for the integrity of the asbestos/cement roof panels for an additional 20 years of service. The A/C corrugated roof panels were found to meet the criteria for the service design load. Therefore, except for the few deficient panels, no recommendations for panel replacement, maintenance or upgrade are made. Furthermore, the roof is found capable of supporting design service load and could be considered potentially safe.

A second phase test to address the roof resistance to personnel and roof removal/roofing system installation equipment, Ref. 8, is recommended. This type of test will assist in the selection of reroofing methods and equipment.

2.0 DESCRIPTION OF TEST METHOD AND TEST EQUIPMENT

2.1 Asbestos Containment

Two enclosures with special air filters were constructed in the WJE Laboratory in Northbrook, Illinois, for this project. One compartment housed sawing equipment used for cutting the coupons and the other housed the test equipment for both the ASTM E72-80, Ref. 11, and the ASTM C221-88, Ref. 12, tests. WJE personnel involved with these activities wore protective clothing and masks.

Air quality was monitored before, during, and after any activities related to the A/C panels. Micro-Fiber Laboratories, Inc. (MFLI) of Northbrook, Illinois, was subcontracted by WJE to act as an independent industrial hygienist for the air quality monitoring.

2.2 190KE Wall Panels

2.2.1 Full Panel Tests

The six wall panels from the 190KE building walls were tested in flexure according to ASTM E72-80, Ref. 11 (Figs. 4 and 5). Four of the six panels were tested in the as-received moisture condition and the other two were tested in the wet condition. Wet condition was obtained by soaking the panels in water for 24 hours prior to testing. It is understood that the flexural strength of wet panels is lower than the strength of the panels when dry. Three of the six panels from the 190KE walls measured about 42 inches wide by 78 inches long. The other three measured about 42 inches wide by 69 inches long.

A test span "S" of 72 inches was used for the 78 inch long panels, and a span "S" of 60 inches was used for the 69 inch long panels. Table 1 lists the designations, dimensions and spans of the 190KE panel test specimens.

Load was applied using a 2-ton hydraulic jack and a load cell. The load cell deformation under load was monitored by 2 strain indicators. One indicator monitored the strain in the cell continuously, while the other recorded the highest readings reached before failure of the test specimen (Fig. 6).

One micro-strain deformation in the load-cell corresponded to 0.331 lb of load applied to the panel. A calibration chart with traceable national standards, is provided in Appendix A. Deflection was monitored using 2 dial indicators, each having an accuracy of 0.001 in. The accuracy of both the load cell and the dial indicators meets the ± 1 percent requirement of ASTM E72-80, Ref. 11.

2.2.2 Coupon Tests

After the full panel tests were complete, two (2) test specimens (coupons) for flexural strength testing according to ASTM C221-88, Ref. 12, were cut from each of the failed full panels (Fig. 7). The load setup for these tests is shown in Figs. 8 through 10. The load was applied using the same 2-ton hydraulic jack and load cells used in the full panel tests.

2.2.3 Other Tests

Fiber content tests were performed by MFLI. The samples were analyzed using the U.S. Environmental Protection Agency (EPA) interim test method EPA-600/M4-82-020, employing polarized light microscopy with EPA recommended central stop dispersion staining.

2.3 105KW Coupon Testing

Eight coupons from the A/C roof panels in the basin area of 105KW were tested in flexure according to ASTM C221-88, Ref. 12. The load was applied using the same 2-ton hydraulic jack and load cells used during the 190KE panel and coupon tests.

2.4 105KW Roof Proof Load Test

A roof proof load test plan was developed and approved prior to the proof load test, Ref. 1. The proof load test involves the application of a uniform load maximum of 35 psf, see section 3.3.2. The load was applied in small increments of 5 psf each. Roof deflection was measured at the center of each A/C roof panel following each applied load increment. After each load increment, the effect of end restraint and equivalent simple span was calculated using the recorded deflections (see procedure in Appendix B). Based on the lab test results (1.3.1 and 1.3.2 above), Appendix B, and the equivalent simple span, the probability of the roof to successfully support the next load increment was determined, Ref. 9. If the probability of success was higher than 95 percent, the next load increment of 5 psf was applied. A maximum total load of 35 psf was achieved. Had any of the probabilities fallen short of the 95 percent limit, the proof load test would have been terminated.

2.4.1 Test Item

A portion of the 105KW roof approximately 16 ft by 21 ft was tested (Figs. 11 through 13). Nine A/C panels were monitored during the test.

2.4.2 Test Preparations

2.4.2.1 Back-up Shoring System

A back-up shoring system was installed to minimize the effect of accidental or unanticipated premature failure of one or more A/C roof panels during the test. The back-up shoring was composed of 2 by 8 and 2 by 4 timber members clamped to the steel framing members which support the A/C panels (Figs. 14 through 16).

2.4.2.2 Asbestos Containment

Because there is a chance that one or more corrugated A/C roof panels may fracture during the proof load test, special measures were taken to contain the asbestos material from being released into the atmosphere. A clear plastic membrane (visqueen) was taped to the underside of the A/C roof panels before the start of the test to contain the asbestos in case of fracture.

2.4.2.3 Roof Access

Scaffolding was used inside the building to provide access to the underside of the roof for installation of the back-up shoring system, visqueen, and instrumentation. A scissors lift, with a 6 ft by 12 ft working platform, was

used to provide access to the roof for placement of the loading system. Aluminum swing staging was placed around the perimeter of the test area to distribute the personnel loads while on top of the roof.

2.4.2.4 Authorization to Proceed

Industrial Safety reviewed the 105KW roof proof-load test plan and authorized the activity for testing to proceed as prescribed in the Test Plan, Ref. 1.

2.4.3 Loading System

Load was applied using 40-ounce per square yard urethane coated nylon water bags, see Appendix D. Six (6) bags, measuring 85 in. by 99 in. each, were used to cover the test area. The volume of water in each bag was measured using a Fill-Rite flow meter (model 807AN-1-X250) which had an accuracy of ± 1 percent. This accuracy meets the 2 percent requirement of ASTM E-196, Ref. 10. Calibration data can be found in Appendix A. The manufacturer's calibration of the meter was checked manually by correlating the weight of the water to the meter reading using a bucket and certified scale (see calibrations sheet in Appendix A). Hoses were attached to the nylon water bags at one end and connected to a manifold system at the other end (Fig. 17). This system was used to supply water or drain water from different bags in a given sequence during the test. See Figs. 18 and 19 for arrangement of bags over the test area.

2.4.4 Deflection Measurement

Deflection was measured using Linear Variable Differential Transformers (LVDT) which had a deflection range of ± 1 in. and ± 0.5 in. The LVDTs were mounted on the back-up shoring system (Figs. 12 and 20), which was used to restrain the A/C panels from deflecting more than 1 inch in case of fracture. The back-up shoring is in turn supported by the steel framing system that supports the A/C panels. Therefore, the deflection readings recorded represent the net deflection of the A/C panels. The LVDTs had an accuracy of ± 0.001 in., which meets the ± 0.01 in. requirements of ASTM E-72, Ref. 11. Calibration documents can be found in Appendix A.

An observation and recording station was set up inside the 105KW building in the mezzanine area below the proof load test area (Fig. 21). Deflection monitoring/readings and general visual monitoring were maintained during the entire time test loads were applied to the roof. Communication with personnel in charge of load application was maintained at all times.

A set of initial (or zero) deflection readings were taken prior to the placement of the water bags. Another set of deflection readings was recorded after the water bags had been placed in their proper position. This second set of deflection readings corresponded to the dead load of the bags which was ignored.

2.4.5 Test Sequence

After the test preparations were completed and all of the systems were operating properly, the test was performed in the following order:

1. Initial deflections were checked again and recorded.
2. The first load increment was applied by allowing 33.5 gallons of water to flow into each water bag. This corresponds to a load of 280 lbs. and a uniform load of 5 lb/ft² over the 56 ft² bag surface area. The loading system was visually monitored from the roof during each load increment.
3. The deflection of all nine panels was monitored continuously during the application of the load increment.
4. After each load increment was applied and panel deflections stabilized, deflection readings were recorded. Then equivalent simple span and the probability of the roof panels' ability to carry the full service design load were determined, see Appendix B.
5. Before the application of the next load increment the underside of the roof panels was visually inspected for possible cracks or signs of distress.
6. Steps 2, 3, 4, and 5 were repeated until the test load of 35 lb/ft² was reached.
7. Once the test load of 35 psf was achieved and had a probability of success greater than 95 percent (actual probability was 99 percent), the load was maintained for 24 hrs.
8. During the 24 hrs. of holding the maximum load on the roof, deflections were recorded at 15 minute intervals for the first hour, at 30 minute intervals for the following 2 hours, and at one-hour intervals for the remaining 21 hrs.
9. Instantaneous deflection-recovery was recorded and monitored for all nine panels. When all of the panels recovered at least 75 percent of the final deflection, the test was complete. This recovery indicated satisfactory performance according to ACI 318, Chapter 20, Ref. 5.

3.0 TEST RESULTS AND ANALYSIS

3.1 190KE Wall Panels

3.1.1 Full Panel Tests

Table 2 lists maximum deflection recorded during the test and corresponding load and modulus of elasticity (see Appendix B), as well as ultimate load recorded at

failure and corresponding bending moments in ft lb/ft. Table 2 also lists equivalent ultimate uniform load for several spans. Appendix B contains sample calculations of values shown in Table 2. Equivalent loads for other spans may be obtained by using the square of the ratio of the spans as shown in Appendix B. To make the comparison meaningful, equivalent ultimate uniform load for a 6 ft - 0 in. span will be used in this discussion. According to Table 2, an average ultimate uniform load of 58.3 psf (52.5 psf minimum and 63.0 psf maximum) was obtained for the four specimens tested in the as-received moisture condition. This load agrees well with the construction specifications for the A/C panels (Ref. 2). See Fig. 22 for failed specimens.

Test Panel No. 190KE-300 had bolt holes in the mid span of the panel. Although the panel did not fracture through a hole, it was obvious from the start of the test that it had much lower stiffness than the other five panels. As seen in Table 2, the modulus of elasticity for Panel 190KE-300 was about 28 to 44 percent lower than the other five panels. Therefore, it is recommended that the test results of this panel, as well as the test specimens retrieved from the 190KE-300 panel (190KE-301 and 190KE-302), be discarded.

3.1.2 Coupon Tests

Table 3 lists the designations, dimensions, ultimate load and bending moment obtained in the tests, as well as equivalent ultimate uniform load for several spans for the 12 coupons. Again, according to Table 3, an average ultimate uniform load of 72.9 psf (66.7 psf minimum and 78.9 psf maximum) was obtained for all specimens excluding 190KE-301 and 190KE-302.

3.1.3 Other Tests

Table 4 lists fiber and moisture contents, density, and water absorption values obtained for samples taken from the six 190KE wall panels. The values obtained are reasonable and do not warrant further discussion.

3.2 105KW Coupons

3.2.1 Coupon Tests

Two of the eight coupons were tested before the proof load test and their results were used in the planning of the proof load test. The other six coupons were tested later. Table 5 lists the designations, dimensions, ultimate load and bending moment obtained in the test as well as equivalent ultimate uniform load of several spans for the eight coupons. As can be seen from Table 5, the magnitude of the ultimate load ranged from 1,084 lbf minimum to 2,370 lbf maximum. The high values corresponded to specimens with a thicker layer of perlite concrete in the top, and the smallest value represented a specimen with virtually no perlite concrete. Therefore, it is concluded that the presence of perlite concrete increases the flexural resistance of A/C panels through composite action.

All coupons were tested in the dry conditions per ASTM C221-88, Ref. 12. However, tests performed on full panel specimens showed that the strength of the perlite concrete decreases with an increase in moisture content.

3.2.2 Other Tests

Table 6 lists fiber and moisture contents, density, and water absorption values obtained for samples taken from the eight coupons. Again, the values obtained are reasonable and does not warrant further discussion.

3.2.3 Effect of Moisture on Perlite Concrete

All samples with perlite concrete topping were tested in the dry condition. In order to study the effect of moisture on the integrity of perlite concrete, a qualitative assessment of the loss of strength of the perlite concrete when wet was conducted by comparing ease of chipping both dry and wet samples. It was observed that chipping into wet perlite concrete was somewhat easier than chipping into dry.

3.3 Roof Proof Load Test

3.3.1 Design Loads

According to Design Loads, Ref. 6, the A/C panels should be capable of supporting a maximum downward service load of 42.3 psf. A factor of safety of 1.5 is recommended with this design load. The design memorandum assumed a dead load for the roof system of 19.2 psf. Therefore, the roof should safely support an external service load of $(42.3 - 19.2) = 23.1$ psf, and should have adequate strength to support an external load of $(1.5 \text{ by } 42.3 - 19.2) = 44.3$ psf before failure.

3.3.2 Required Test Load

The test program, Ref. 3, calls for a proof load test of a selected area of the 105KW Building roof (area between building column M-N and 11.2 - 12). Criteria for the proof test were based on the results of the initial materials testing program (Sections 3.1 and 3.2 above). ACI 318, Chapter 20 (Ref. 5), specifies a total test load, including dead loads already acting, equivalent to $0.85 (1.4D + 1.7L)$. Since the load value in parenthesis, $(1.4D + 1.7L)$, is the ACI code design ultimate strength, one could then use a similar approach and call for a proof load test for the A/C panels including dead loads already acting equivalent to 85 percent of the design ultimate load of $(1.5 \text{ by } 42.3) = 63.5$ psf. In other words, an external test load of $(0.85 \text{ by } 63.5 - 19.2) = 35$ psf. Comparison of this amount, 35 psf, with strength values obtained from the material testing follows:

The 35 psf external roof load is equivalent to a $(35 + 15.2) = 49.9$ psf load on the panel without the roofing system, which is composed of perlite concrete, insulation, built up roof, and gravel. The roofing system weight is estimated at 15.2 psf, (i.e., excluding the 4 psf unit weight of the corrugated A/C panels), Ref. 1.

3.3.3 Probabilities of Passing the Test Load

Flexure test results of five of the six full panel tests, namely panel numbers 190KE-100, 200, 400, 500 and 600, and twelve coupons numbered 190KE-101, 102, 201, 202, 401, 402, 501, 502, 601, 105KW-AB0338 and BC-0531, were used in planning the proof load test. The equivalent average ultimate uniform load for the 6 ft - 0 in. span of the above mentioned specimens is 69.6 psf with a standard deviation of 8.11 psf. The corresponding average ultimate bending moment is 313.2 ft lb/ft and the standard deviation is 36.5 ft lb/ft. Based on these results, there is a probability of 99.25 percent that the strength of the A/C roof panels will exceed the 35 psf external roof proof load for a 6 ft - 0 in. span. Table 7 lists probabilities of the A/C roof panels successfully resisting the external load of 35 psf for several spans.

As shown in Table 7, the probability of the A/C panels in the selected roof area of the 105KW Building to support the required proof load test is between 79 and 99 percent depending on the clear span and the effect of constraints offered by the overlapping of the panels and the roofing system (perlite concrete). The degree of restraint was verified experimentally during the proof load test. This was accomplished by comparing the deflection values obtained under small increments of load at the start of the test with those measured in the lab. Appendix B shows the derivation of the calculations.

3.4 105KW Roof Proof Load Test

The roof proof load test was carried out on July 28, and 29, 1993, in accordance with the Test Plan, Ref. 1, and as described in section 2.4 above. Completed data sheets are included in Appendix C.

After the backup shoring and LVDTs were in place, a set of deflection readings was taken (at 9:00 a.m. on July 28, 1993). After the water bags were placed on top of the roof and the hoses connected, another set of deflection readings was taken. After that, the lead hoses to each bag were filled with water and deflection readings were taken again (at 1:30 p.m. on July 28, 1993), and reading on the flow meter was recorded. This represented the start of the load test, and the first increment of load was applied, see Appendix C. The load was applied in six (6) increments. The maximum load was reached at 5:15 p.m. on July 28, 1993, and was held for 24 hours. The flow meter reading was recorded again, and the total amount of water in the bags was verified, see Appendix C.

Removal of the test load (emptying of the water bags) was started at 5:15 p.m. and concluded at 7:30 p.m. on July 29, 1993, see Appendix C. In addition to manually recording the readings during the load test, the readings were also entered into a spread sheet using a lap top computer, see Fig. 21. The data were instantly analyzed and the probability of the panels to successfully carry the next load increment was computed, see Appendix C.

Deflection was calculated by subtracting the current voltage reading from the initial voltage reading and then multiplying the difference by the LVDT calibration factor, see Table 8 for LVDT I.D. number, location, and calibration factor. Given the applied load and corresponding deflection, the effective span of the panel due to both composite action and

edge restraints was calculated (sample calculations are shown in Appendix B). Knowing the effective span, the predicted ultimate moment was calculated after each load increment. The average ultimate moment and standard deviation, calculated from the laboratory tests (see section 3.3.3 above), was used to calculate the multiple of standard deviations. Given the multiple of standard deviations, the probability of success was calculated, see Appendix C.

These calculations were made before each additional load increment to assure that the probability of success was greater than 95 percent. The load was incremented by 5 psf, except the third increment was 10 psf. Because the deflections were much lower than expected, an assumption was made that the panels would have the capacity to carry 20 psf. Therefore, the larger load increment was applied to save time.

The deflections after the first load increment ranged from 0.008 in. to 0.02 in., which corresponded to a maximum effective span of 4.94 ft and a computed ultimate moment of 152 ft lb/ft. The load-deflection relationship remained approximately linear throughout the test, as shown in Fig. 23. The maximum deflection for the 35 psf load was 0.145 in., which corresponded to an effective span of 5.0 ft and an ultimate moment of 156 ft lb/ft. The panels closest to the roof edge, numbers 3, 2, and 1 (Fig. 23) deflected the most throughout the test, which was expected because of the lack of restraint at the free edge. Generally, the deflection of the remaining panels in descending order, was 9, 8, 7, 4, 6 and 5. Throughout the test, the probability of success did not fall below 99.9 percent.

During the 24-hour period where the maximum test load was held, creep was recorded in all of the panels (Fig. 24). Creep deflection ranged from 1 to 26 percent compared to the instantaneous deflection measured at the final load increment. The central panel (No. 5) exhibited a negative creep (a decrease in deflection), signifying a redistribution of the load to the outer panels. Panel 5 also had the smallest deflection of the 9 panels, which was expected because it had the most edge restraint. All of the panels recovered at least 82 percent of their instantaneous deflection when the load was removed.

Seven out of the nine panels recovered more than 75 percent of the total deflection developed after 24 hours at the removal of the load, and the other two panels (Numbers 6 and 7) recovered their deflection two hours later. Since all panels recovered at least 75 percent of the maximum total deflection within 24 hours of load removal, the roof proof load test is considered successful. Therefore, the roof is capable of supporting design service loads and is considered safe.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 190KE Wall Panels

4.1.1 Full Panel Test

Flexural strength of the full panels ranged between 52.5 psf minimum to 63.0 psf maximum, for a six foot span. This load range agrees well with the construction specifications for the A/C panels (Ref. 2).

4.1.2 Coupon Tests

Flexural strength for coupons cut from the 190KE wall panels exhibited about 25 percent increase over the corresponding values for the full size panels. This is somewhat expected since one would expect fewer flaws in a small specimen than in a larger one. Flexural strength values obtained from the coupons corresponded to 66.7 psf minimum and 78.9 psf maximum for a 6 ft span.

4.1.3 Other Tests

The asbestos fiber content is about 30 percent, moisture content is between 1.3 and 2.6 percent, and water absorption is between 2.8 and 7.9 percent. Density is about 130 psf. These values are reasonable.

4.2 105KW Roof Panels

4.2.1 Coupon Tests

Flexural strength of coupons taken from failed panel area of the 105KW basin ranged from 70.9 psf minimum to 157.2 psf maximum for a 6 ft span. This drastic increase over the 190KE wall panels is attributed to the presence of bonded layer of perlite concrete on top of the tested specimen. The magnitude of the ultimate load increased as a function of the thickness of the perlite concrete layer. It is, therefore, concluded that the apparent increase in the flexural strength of the A/C panels is due to the composite action offered by the perlite concrete.

4.2.2 Roof Proof Load Test

The roof area chosen for the proof load test successfully passed the load test. The effect of the perlite concrete was clearly demonstrated through the short effective spans obtained during the test (5 ft maximum). In other words, the composite action offered by the perlite concrete resulted in reduced midspan deflections, as well as, providing some continuity between adjacent spans. Table 9 shows maximum instantaneous deflection obtained in each panel under 35 psf load, computed effective span, and bending moment corresponding to this load. Comparing the maximum bending moment value in Table 9 (156.9 ft lb/ft) with the minimum ultimate bending moment value obtained in the coupon tests shown in Table 5 (319 ft lb/ft), it can be stated that the 105KW roof panels could support a minimum of 87 psf of external uniform load, see Appendix B. Therefore, the 105KW roof is capable of supporting the design loads and can be considered potentially safe.

4.2.3 Effect of Moisture on Perlite Concrete

A qualitative assessment of the loss of strength of the perlite concrete when wet was conducted by comparing ease of chipping both dry and wet samples. It was observed that chipping into wet perlite concrete was somewhat easier than chipping into dry.

5.0 DISPOSITION OF TEST ITEM(S)

Since the panels met the service design load, an additional load test on the roof is proposed, which will test the resistance of the roof panels to personnel and roof removal/roofing system installation equipment loads. This additional test will require the same test preparations for back-up shoring and asbestos containment as the proof load test. Therefore, the asbestos containment and shoring systems were left in place. All equipment and instruments were surveyed by a Health Physicist Technician and released.

6.0 REFERENCES

1. WHC, 1993a, "105KW Roof Proof Load Test," WHC-SD-NR-TP-019, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
2. GE, 1952, Construction Specification "Cement Asbestos Sheets," HW-4748, General Electric Company, Richland, Washington.
3. WHC, 1992, "Test Program for Structural Assessment of Roof Panels in Buildings 105KE and 313 for Hanford Nuclear Site," WHC-SD-NR-ER-098, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
4. Uniform Building Code, International Conference of Building Officials, Whittier, CA, 1991.
5. American Concrete Institute, Building Code Requirements for Reinforced Concrete and Commentary 318-89, Detroit, MI, 1989.
6. Giller, R.A., 1992, "105KE New Roof Design Loads," 92:RAG:029, Westinghouse Hanford Company, Richland, Washington.
7. Giller, R.A., 1993, "Roof Capacity and Access", 93:RAG:045, Westinghouse Hanford Company, Richland, Washington.
8. WHC, 1993b, "Building 1717K Roof Structural Evaluation and Qualification," WHC-SD-NR-DA-028, REV 0, Westinghouse Hanford Company, Richland, Washington.
9. Miller, I. and Freund, J.E., "Probability and Statistics for Engineers, 3rd Edition", 1985, Prentice Hall, Inc., Englewood Cliffs, NJ.
10. ASTM, 1988, "Standard Practice for Gravity Load Testing of Floors and Flat Roofs, ASTM E196-80." ASTM Standards in Building Codes Volume II, Philadelphia, PA.
11. ASTM, 1988, "Standard Methods of Conducting Strength Tests of Panels for Building Construction, ASTM E72-80," ASTM Standards in Building Codes Volume II, Philadelphia, PA.
12. ASTM, 1988, "Standard Specifications for Corrugated Asbestos-Cement Sheets, ASTM C221-88", ASTM Standards in Building Codes Volume II, Philadelphia, PA.

Table 1 - Full Panel 190KE Test Specimens

Specimen I.D.	Dimensions (inches)	Test Span "S" (inches)	Moisture Condition
190KE-100	42 x 77.75	72	As Received
190KE-200	42 x 77.75	72	As Received
190KE-300	42 x 77.75	72	Wet
190KE-400	42 x 68.75	60	Wet
190KE-500	42 x 68.75	60	As Received
190KE-600	42 x 68.75	60	As Received

Table 2 - 190KE Full Panel Test Results

Panel I.D.		190KE-100	190KE-200	190KE-300	190KE-400	190KE-500	190KE-600
Max. deflection recorded (in.)		0.661	0.613	0.616	0.536	0.480	0.445
Load corresponding to max. deflection (lbs)		1,090	1,090	710	1,490	1,390	1,590
Modulus of Elasticity (ksi)		3,540	3,810	2,470	3,440	3,590	4,420
Ultimate Load (lbs)		1,103	1,185	785	1,552	1,540	1,589
Ultimate bending moment (ft lb/ft)		236.5	253.9	168.1	277.1	274.9	283.8
Load in (psf) for	6'0" span	52.5	56.4	37.4	61.6	61.1	63.0
	6'6" span	44.7	48.1	31.9	52.5	52.1	53.7
	6'9" span	41.5	44.6	29.6	48.7	48.3	49.8
	7'0" span	38.6	41.4	27.5	45.3	44.9	46.3

Table 3 - 190KE Coupon Test Specimens

Specimen I.D.	Size (inches)	Ultimate Load (lbs)	Ultimate Moment (ft lb/ft)	Equivalent Ultimate Uniform Load (psf)			
				6'0" span	6'6" span	6'9" span	7'0" span
190KE-101	17.13 x 36	1,142	333	74.1	63.1	58.5	54.4
190KE-102	16.88 x 36	1,194	354	78.6	67.0	62.1	57.7
190KE-201	17 x 36	1,090	321	71.3	60.8	56.3	52.4
190KE-202	17 x 36	1,153	339	75.4	64.2	59.6	55.4
190KE-301	17.25 x 36 - 1" hole	762	223	49.4	42.1	39.0	36.3
190KE-302	16.75 x 36	1,008	301	66.9	57.0	52.9	49.2
190KE-401	13 x 36	923	355	78.9	67.2	62.3	38.0
190KE-402	17.25 x 36	1,036	300	66.7	56.8	52.7	49.0
190KE-501	17.25 x 36	1,130	327	72.8	62.0	57.5	53.5
190KE-502	16.75 x 36	1,027	307	68.1	58.0	53.8	50.0
190KE-601	16.75 x 36	1,023	305	67.9	57.9	53.6	49.9
190KE-602	17 x 36	1,150	338	75.2	64.1	59.4	55.2

Table 4 - Results of Other Tests - 190KE Wall Panels

Sample I.D.	Fiber Content Percent Average of Four Tests	Moisture Content Percent Average of Two Tests	Density lb/cft	Water Absorption Percent - Average of Six Tests
190KE-100	32.5	2.6	133.4	2.8
190KE-200	30.0	2.0	130.1	7.9
190KE-300	30.0	---	134.5	6.3
190KE-400	30	---	135.4	7.3
190KE-500	30	1.3	127.6	4.5
190KE-600	30	1.6	133.7	7.3

Table 5 - 105KW Coupon Test Specimens

Specimen I.D.	Size (inches)	Ultimate Load (lbs.)	Ultimate Moment (ft lb/ft)	Equivalent Ultimate Uniform Load (psf)			
				6'0" span	6'6" span	6'9" span	7'0" span
105KW-AB 0338	16.13 x 36	1,171	363	80.7	68.8	63.8	59.3
105KW-BC 0531	17 x 36	1,084	319	70.9	60.4	56.0	52.1
105KW-BC 2529	16.75 x 36	2,370	707	157.2	134.0	124.2	115.5
105KW-BC 2331	16.75 x 36	1,494	446	99.1	84.4	78.3	72.8
105KW-CD 0719	17 x 36	1,730	509	113.0	96.3	89.3	83.0
105KW-CD 2019	17.25 x 36	1,512	438	97.4	83.0	77.0	71.6
105KW-DE 2010	16.75 x 36	1,859	555	123.3	105.1	97.4	90.6
105KW-DE 1210	17 x 36	1,849	544	120.9	103.0	95.5	88.8

Table 6 - Results of Other Tests - 105KW Roof Coupons

Sample I.D.	Fiber Content Percent Average of Four Tests	Density lb/cft	Water Absorption Percent Average of Two Tests
105KW-AB 0338	30	137.5	11.1
105KW-BC 0531	27.5	106.7	19.0
105KW-BC 2529	23.8	134.2	13.1
105KW-BC 2331	22.5	137.6	13.8
105KW-CD 0719	20	132.6	12.5
105KW-CD 2019	22.5	138.7	12.0
105KW-DE 2010	23.8	152.3	9.5
105KW-DE 1210	25	147.1	10.2

**Table 7 - Probabilities of A/C Roof Panels
Successfully Resisting the Test Load**

Span Length	Probability of Success - Percent
5'0"	99.99
5'6"	99.97
6'0"	99.25
6'6"	91.31
6'9"	78.80
7'0"	58.30

Table 8 - LVDTs Calibration Factor

Location (Panel No.)	LVDT I.D. No.	Calibration Factor Inches per Volt
1	18	0.099335
2	23	0.122827
3	14	0.096045
4	21	0.123678
5	20	0.126514
6	12	0.096045
7	15	0.098102
8	22	0.126126
9	17	0.094844

Table 9 - Roof Proof Load Test Results

Panel No.	Maximum Deflection (in.)	Effective Span L (ft)	Maximum Moment (ft lb) for Effective Span L
1	0.141	4.9	151.9
2	0.145	5.0	154.4
3	0.148	5.0	155.9
4	0.094	4.5	124.0
5	0.083	4.3	117.0
6	0.093	4.4	123.5
7	0.096	4.5	125.7
8	0.104	4.6	130.7
9	0.131	4.8	146.6

Fig. 1. Schematic diagram of the ship.

Fig. 2 - Signs of cracking in the A/C roof panels

Fig. 3 - Coupon removed from 105KW basin roof

FIG. 4 - FULL PANEL TEST SETUP

Fig. 5 - Flexural test of full size panel

Fig. 6 - Strain indicators used to monitor load cell during the flexure tests

FIG. 1 - ASTM C221-88 SPECIMEN EXTRACTED
FROM ASBESTOS-CEMENT ROOF PANELS

FIG. 8 - ASTM C221-88 TEST SET-UP

FIG. 9 - END VIEW OF ASTM C221-88 TEST SET-UP

THE HISTORY OF THE

FIG. II - PLAN VIEW OF TEST AREA

FIG. 12 - SECTION THROUGH TEST AREA

Fig. 13 - Roof Proof Load Test area

FIG. 14 - REFLECTED FRAMING PLAN AT TEST AREA

Fig. 15 Backup shoring system - overall view

Fig. 16 Backup shoring system (close up)

Fig. 17 Flow meter and manifold system

FIG. 18 - WATER BAGS LAYOUT

Fig 19 - Water bags in place over roof test area

Fig. 20 - Close up of LVDT

Fig. 21 - Observation and recording station

Fig. 22 - Failed wall panel specimen

Fig. 23 - Roof Proof Load Test - load vs deflection

Fig. 24 - Roof Proof Load Test - Time history for uniform load of 35 psf

Appendix A
Calibration Sheets

WHC-SD-NR-TRP-016
REV: 0
A-2

Load Cell Calibration

DATA 2/K LOAD CELL CALIBRATION # 262474

DATA RECORDED BY JE/CLG DATE 2/10/92
REVIEWED BY _____ DATE _____

SATEC Systems, Inc.

Grove City, Pa. 16127

SA011

Report and Certificate of Verification

This is to certify That the following described machine has been verified in accordance with the latest issue of ASTM-E4 and found to be within a tolerance of $\pm$ / %.

Location WISS JANNEY ELETHER ASSOC.
330 Pflingsten Rd.
Northbrook IL 60062

Machine SATEC
(Model) MKTH 120 HVL
(Ser. No.) 1240
Low Range Cell 1200/lbs #64319

Machine Range: 1200 lbs.

MACHINE READING	RING READING	MACHINE ERROR		C.D. CODE
		UNIT	%	
120	120.4	.40	.33	2
240	240.79	.79	.33	2
480	478.18	-1.82	.38	1
720	715.78	-1.22	.03	1
960	959.81	-1.19	.02	1
1200	1201.8	1.8	.15	1

Machine Range: 240 lbs.

MACHINE READING	RING READING	MACHINE ERROR		C.D. CODE
		UNIT	%	
24	24	0	0	3+4
48.1	48	.1	.21	3+4
96	96.48	.48	.50	2
144	144.81	.81	.56	2
192	193.64	1.64	.85	2
240	241.27	1.27	.53	2

Machine Range:

MACHINE READING	RING READING	MACHINE ERROR		C.D. CODE
		UNIT	%	

Machine Range: 60 lbs.

MACHINE READING	RING READING	MACHINE ERROR		C.D. CODE
		UNIT	%	
6.0	6	0	0	3+4
12.0	12	0	0	3+4
24.05	24	.05	.21	3+4
36.10	36	.10	.28	3+4
48.15	48	.15	.31	3+4
60.20	60	.20	.33	3+4

Machine Range: 12 lbs.

MACHINE READING	RING READING	MACHINE ERROR		C.D. CODE
		UNIT	%	
1.5	1.5	0	0	3+4
2.455	2.5	.005	.20	3+4
4.55	5	.01	.20	3+4
6.585	7	.015	.23	3+4
9.585	10	.015	.20	3+4
11.975	12	.025	.21	3+4

check # 33.85 lbs.

LOAD VALUES CORRECTED FOR TEMP. OF 70 °F.

Verification By:

Standard Weights

☒ Elastic Calibration Device

Primary Load Indicating Device:

MKTH Digital Indicator

C.D. CODE	SERIAL NO.	MANUFACTURER	VERIFICATION HIGH VALUE	LOADING RANGE CLASS A VALUE	CALIB. DATE	CALIBRATION AGENCY LAB NO.
1	891026C	STRAIN SENSE	20000	356	7/8/92	01/105214
2	3936	MORSE LOUSE	500	53.2	5/19/92	01/105159
3	CW	Asorted	1-10 lbs.	A	5/2/84	21/242697
4	CW	Asorted	1-5 lbs.	C	12/8/58	73/230655

Method of verification and pertinent data in accordance with A.S.T.M. Specification E4 and SATEC Systems, Inc. "Procedure for Calibration Tension and Compression Testing Machines". The testing device(s) used for this verification have been calibrated per A.S.T.M. Specification E74 and are traceable to the National Institute of Standards Technology.

Date of Verification 12/31/92

Witness

By [Signature] Service Engineer

LVDT Calibration Sheets

WJE 203

WTS 12

LVDT Calibration - Simple Regression

LVDT sn. 820125-10

DMV SN 482864

DATE INT.

WHC-SD-NR-TRP-016

REV: 0

A-7

Defl. (in)	Output Volts			
	RUN 1	RUN 2	RUN 3	Avg.
0	-5.199	-5.201	-5.201	-5.200
0.1	-4.129	-4.132	-4.129	-4.130
0.2	-3.075	-3.08	-3.081	-3.079
0.3	-2.033	-2.037	-2.037	-2.036
0.4	-0.987	-0.995	-0.997	-0.993
0.5	0.038	0.038	0.037	0.038
0.6	1.08	1.08	1.076	1.079
0.7	2.118	2.115	2.117	2.117
0.8	3.162	3.159	3.16	3.160
0.9	4.201	4.196	4.2	4.199
1	5.225	5.223	5.222	5.223

Regression Output:

Constant	0.496699
Std Err of Y Est	0.001278
R Squared	0.999986
No. of Observations	11
Degrees of Freedom	9

X Coefficient(s)	0.096045
Std Err of Coef.	0.000117
Inchs per volt	10.41174

Volt meter serial No.: 482964

[illegible]

DATA RECORDED BY David A. Nixon : DATE July 15, 1993

REVIEWED BY _____ DATE _____

WSE / 3

WHC-SD-NR-TRP-016
REV: 0
A-9

LVDT Calibration - Simple Regression

LVDT sn. 82025-52 DMV SN 482964

DATE INT.

Defl. (in)	Output Volts			
	RUN 1	RUN 2	RUN 3	Avg.
0	-5.356	-5.363	-5.363	-5.361
0.1	-4.287	-4.296	-4.296	-4.293
0.2	-3.222	-3.229	-3.228	-3.226
0.3	-2.171	-2.172	-2.172	-2.172
0.4	-1.107	-1.115	-1.114	-1.112
0.5	-0.066	-0.07	-0.071	-0.069
0.6	0.984	0.977	0.976	0.979
0.7	2.029	2.019	2.022	2.023
0.8	3.083	3.074	3.072	3.076
0.9	4.124	4.121	4.116	4.120
1	5.152	5.152	5.152	5.152

Regression Output:

Constant 0.507626
Std Err of Y Est 0.001415
R Squared 0.999983
No. of Observations 11
Degrees of Freedom 9

X Coefficient(s) 0.095149
Std Err of Coef. 0.000128
Inchs per volt 10.50977

WISS, JANNEY, ELSTNER ASSOCIATES, INC.

PROJECT NO. 930496 CLIENT W H C SHEET 3 OF 10

DATA LVDT calibrations 1944-1945 Serial No.: 820226-19

WJE ID No.: 14
Volf Meter Serial No.: 402964

Ru1 IV0 1	Ru2 IV0 2	Ru3 IV0 3
-----------	-----------	-----------

Gay	Block	(1)	-4.792	0	-4.754	0	-4.793
D.M.M	Reading	10	-3.823	10	-3.827	10	-3.829
10	2	10	-2.858	20	-2.858	20	-2.859
30	-1.898	30	-1.898	30	-1.898	30	-1.900
40	-930	40	-930	40	-930	40	-930
50	046	50	044	50	044	50	043
60	1.021	60	1.019	60	1.017	60	1.017
70	1.987	70	1.987	70	1.987	70	1.985
80	2.956	80	2.958	80	2.958	80	2.956
90	3.912	90	3.914	90	3.914	90	3.913
1.0	4.837	1.0	4.838	1.0	4.838	1.0	4.838

DATA RECORDED BY David A. Wilson DATE 7/15/93

REVIEWED BY _____ DATE _____

WJE 203

WJE 14

WHC-SD-NR-TRP-016
REV: 0
A-11

LVDT Calibration - Simple Regression

LVDT sn 820226-19 DMV SN 4FL964

DATE INT.

Defl. (in)	Output Volts			
	RUN 1	RUN 2	RUN 3	Avg.
0	-4.792	-4.794	-4.793	-4.793
0.1	-3.823	-3.827	-3.829	-3.826
0.2	-2.858	-2.858	-2.859	-2.858
0.3	-1.898	-1.898	-1.9	-1.899
0.4	-0.93	-0.93	-0.93	-0.930
0.5	0.046	0.044	0.043	0.044
0.6	1.021	1.019	1.017	1.019
0.7	1.987	1.987	1.985	1.986
0.8	2.956	2.958	2.956	2.957
0.9	3.912	3.914	3.913	3.913
1	4.837	4.838	4.838	4.838

Regression Output:

Constant 0.496699
Std Err of Y Est 0.001278
R Squared 0.999986
No. of Observations 11
Degrees of Freedom 9

X Coefficient(s) 0.096045
Std Err of Coef. 0.000117
Inchs per volt 10.41174

456 15.

WHC-SD-NR-TRP-016

REV: 0

A-13

LVDT Calibration - Simple Regression

LVDT sn. 820226-13

DMV SN 482964

DATE INT.

Defl. (in)	Output Volts			
	RUN 1	RUN 2	RUN 3	Avg.
0	-5.141	-5.143	-5.145	-5.143
0.1	-4.106	-4.108	-4.11	-4.108
0.2	-3.082	-3.083	-3.083	-3.083
0.3	-2.063	-2.063	-2.067	-2.064
0.4	-1.047	-1.051	-1.049	-1.049
0.5	-0.041	-0.042	-0.043	-0.042
0.6	0.98	0.976	0.976	0.977
0.7	1.996	1.992	1.992	1.993
0.8	3.024	3.019	3.019	3.021
0.9	4.051	4.048	4.047	4.049
1	5.069	5.066	5.065	5.067

Regression Output:

Constant	0.503409
Std Err of Y Est	0.000830
R Squared	0.999994
No. of Observations	11
Degrees of Freedom	9

X Coefficient(s)	0.098102
Std Err of Coef.	0.000077
Inchs per volt	10.19339

PROJECT NO. 930496 CLIENT W H C SHEET 5 OF 10
DATA LVDI Calibrations Manufacturers Serial No.: 820125-20

Unit Meter Serial No.: 482964

DATA RECORDED BY David A. NIA017 DATE July 15, 1993
REVIEWED BY _____ DATE _____

WAE 17

WHC-SD-NR-TRP-016

REV: 0

A-15

LVDT Calibration - Simple Regression

LVDT sn. 820125-10

DMV SN 1182964

DATE INT.

Defl. (in)	Output Volts			
	RUN 1	RUN 2	RUN 3	Avg.
0	-5.361	-5.361	-5.36	-5.361
0.1	-4.282	-4.282	-4.284	-4.283
0.2	-3.213	-3.212	-3.215	-3.213
0.3	-2.156	-2.154	-2.158	-2.156
0.4	-1.104	-1.104	-1.106	-1.105
0.5	-0.062	-0.065	-0.067	-0.065
0.6	0.983	0.982	0.979	0.981
0.7	2.034	2.033	2.032	2.033
0.8	3.094	3.093	3.093	3.093
0.9	4.154	4.156	4.152	4.154
1	5.206	5.212	5.208	5.209

Regression Output:

Constant	0.506136
Std Err of Y Est	0.001234
R Squared	0.999987
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	0.094844
Std Err of Coef.	0.000111
Inchs per volt	10.54352

WJE 18

WHC-SD-NR-TRP-016
REV: 0
A-17

LVDT Calibration - Simple Regression

LVDT sn. 820125-28 DMV SN 1182864

DATE	INT.				
Defl. (in)	RUN 1	Output Volts RUN 2	RUN 3	Avg.	
0	-5.117	-5.117	-5.117	-5.117	
0.1	-4.087	-4.087	-4.084	-4.086	
0.2	-3.065	-3.065	-3.067	-3.066	
0.3	-2.055	-2.056	-2.057	-2.056	
0.4	-1.046	-1.046	-1.048	-1.047	
0.5	-0.045	-0.045	-0.046	-0.045	
0.6	0.96	0.958	0.956	0.958	
0.7	1.96	1.958	1.956	1.958	
0.8	2.956	2.959	2.956	2.957	
0.9	3.965	3.965	3.961	3.964	
1	4.97	4.97	4.97	4.970	

Regression Output:

Constant	0.505508
Std Err of Y Est	0.001338
R Squared	0.999985
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	0.099335
Std Err of Coef.	0.000126
Inchs per volt	10.06690

Run 1403

WJE 203

was 20

WHC-SD-NR-TRP-016
REV: 0
A-19

LVDT Calibration - Simple Regression
LVDT sn. WJ520 DMV SN 482964
DATE INT.

Defl. (in)	Output Volts			
	RUN 1	RUN 2	RUN 3	Avg.
0	-7.92	-7.913	-7.916	-7.916
0.2	-6.321	-6.317	-6.319	-6.319
0.4	-4.765	-4.762	-4.762	-4.763
0.6	-3.167	-3.164	-3.166	-3.166
0.8	-1.586	-1.584	-1.585	-1.585
1	-0.004	-0.003	-0.004	-0.004
1.2	1.581	1.581	1.581	1.581
1.4	3.168	3.167	3.168	3.168
1.6	4.756	4.755	4.758	4.756
1.8	6.302	6.302	6.301	6.302
2	7.887	7.887	7.888	7.887

Regression Output:

Constant	1.000674
Std Err of Y Est	0.001521
R Squared	0.999995
No. of Observations	11
Degrees of Freedom	9
X Coefficient(s)	0.126514
Std Err of Coef.	0.000091
Inchs per volt	7.904204

WJE 21

WHC-SD-NR-TRP-016

REV: 0

A-21

LVDT Calibration - Simple Regression

LVDT sn. WJE 21 DMV SN 482944

DATE INT.

Defl. (in)	Output Volts			
	RUN 1	RUN 2	RUN 3	Avg.
0	-8.08	-8.081	-8.081	-8.081
0.2	-6.494	-6.494	-6.495	-6.494
0.4	-4.874	-4.874	-4.876	-4.875
0.6	-3.247	-3.249	-3.249	-3.248
0.8	-1.635	-1.635	-1.634	-1.635
1	0.024	0.023	0.022	0.023
1.2	1.594	1.593	1.592	1.593
1.4	3.219	3.213	3.219	3.217
1.6	4.856	4.853	4.853	4.854
1.8	6.478	6.474	6.474	6.475
2	8.051	8.05	8.05	8.050

Regression Output:

Constant 1.001349
 Std Err of Y Est 0.002309
 R Squared 0.999989
 No. of Observations 11
 Degrees of Freedom 9

X Coefficient(s) 0.123678
 Std Err of Coef. 0.000136
 Inches per volt 8.085451

JE 22

WHC-SD-NR-TRP-016
REV: 0
A-23

LVDT Calibration - Simple Regression

LVDT sn. W56 22 DMV SN 482964
DATE INT.

Defl. (in)	Output Volts			Avg.
	RUN 1	RUN 2	RUN 3	
0	-7.949	-7.945	-7.944	-7.946
0.2	-6.402	-6.397	-6.396	-6.398
0.4	-4.8	-4.799	-4.793	-4.797
0.6	-3.208	-3.21	-3.199	-3.206
0.8	-1.618	-1.621	-1.613	-1.617
1	-0.027	-0.027	-0.025	-0.026
1.2	1.565	1.568	1.567	1.567
1.4	3.148	3.15	3.149	3.149
1.6	4.73	4.73	4.73	4.730
1.8	6.304	6.303	6.307	6.305
2	7.883	7.881	7.882	7.882

Regression Output:

Constant	1.004112
Std Err of Y Est	0.001571
R Squared	0.999994
No. of Observations	11
Degrees of Freedom	9

X Coefficient(s)	0.126126
Std Err of Coef.	0.000094
Inchs per volt	7.928555

DATA LVDT calibrations Manufacturers Serial No.:

volt meter serial no.: 482964

WJE 203

WTE 23

WHC-SD-NR-TRP-016
REV: 0
A-25

LVDT Calibration - Simple Regression

LVDT sn. ~~820-5-10-441~~ DMV SN 48L96Y
DATE INT. WTE 23

Defl. (in)	Output Volts			
	RUN 1	RUN 2	RUN 3	Avg.
0	-8.181	-8.185	-8.186	-8.184
0.2	-6.583	-6.588	-6.586	-6.586
0.4	-4.955	-4.957	-4.957	-4.956
0.6	-3.314	-3.315	-3.31	-3.313
0.8	-1.675	-1.676	-1.673	-1.675
1	-0.041	-0.042	-0.043	-0.042
1.2	1.601	1.603	1.6	1.601
1.4	3.233	3.234	3.234	3.234
1.6	4.852	4.855	4.857	4.855
1.8	6.462	6.462	6.463	6.462
2	8.039	8.038	8.04	8.039

Regression Output:

Constant 1.006305
Std Err of Y Est 0.003044
R Squared 0.999981
No. of Observations 11
Degrees of Freedom 9

X Coefficient(s) 0.122827
Std Err of Coef. 0.000178
Inchs per volt 8.141487

WHC-SD-NR-TRP-016
REV: 0
A-26

Flow Meter Calibration

Calibration Report

P.O.#: N/A

—NIST Test #: _____ SPECIFICATION _____ ACCURACY _____

P.O. BOX 81205 / 5700 6TH AVE. S., #101 • SEATTLE, WA 98108-1205 • (206) 762-2515 • 1-800-779-2515 • FAX: (206) 762-5880

Appendix B

Calculations

WHC-SD-NR-TRP-016

Wiss, Janney, Elstner Associates, Inc. 5700 Sixth Avenue South, Suite 220, Seattle, WA 98108	MADE BY SEM	SHEET NUMBER B1/28
TEST DATA REDUCTIONS WHC No. MMB-SCV-267622	CHECKED BY SMR	PROJ. NUMBER 930496
	DATE 7/1/93

ASTM C221-88

ASTM E72-80

SAMPLE CALCULATION OF VALUES IN TABLE 2:

ISSUE PANEL NO. 190KE-100:

$$S = 72", \text{ PANEL WIDTH} = 42" = 3.5 \text{ ft.}$$

$$\text{BREAKING (FAILURE) LOAD } P_n = 1,103 \text{ lbs. (FROM TEST)}$$

$$\text{OR } P_n = \frac{1,103}{3.5} = 315 \text{ \# / ft. width}$$

$$\therefore M_n = \frac{P_n S}{8} = \frac{(315)(72)}{8} = \underline{\underline{2,837 \text{ in. lb. / ft.}}}$$

WHC-SD-NR-TRP-016

Wiss, Janney, Elstner Associates, Inc. 5700 Sixth Avenue South, Suite 220, Seattle, WA 98108	MADE BY SEM	SHEET NUMBER B2/B8
TEST DATA REDUCTIONS WHC No. MMB-SCV-267622	CHECKED BY SMR	PROJ. NUMBER
	DATE 7/1/93	

EQUIVALENT UNIFORM LOAD:

ASSUME A SIMPLE SPAN "L" UNDER UNIFORM LOAD "W",

THE MAX. BENDING MOMENT $M = \frac{WL^2}{8}$

FOR A GIVEN SPAN L (ft.) AND BENDING MOMENT
 M (in. lb./ft.), THEN THE CORRESPONDING UNIFORM
 LOAD W (psf) CAN BE WRITTEN AS:

$$W \text{ (psf)} = \frac{8 M \text{ (in. lb./ft.)}}{(12 \text{ in.}) (L \text{ ft.})^2} = \text{(psf)}$$

FOR A 6'-0" SPAN, EQUIVALENT ULTIMATE UNIFORM
 LOAD $W_n = \frac{8 M_n}{12(36)}$

FOR TEST PANEL No. 190KE-100, $M_n = 2,837 \text{ in. lb./ft.}$

$$W_n = \frac{8(2,837)}{12(36)} = \underline{\underline{52.5 \text{ psf.}}}$$

EQUIVALENT ULTIMATE LOAD FOR OTHER SPANS,

$$W_{n2} = W_{n1} \left(\frac{L_1}{L_2} \right)^2$$

FOR 7'-0" SPAN SAY;

$$W_{n(7'-0')} = 52.5 \left(\frac{6}{7} \right)^2 = \underline{\underline{38.6 \text{ psf}}}$$

Wiss, Janney, Elstner Associates, Inc. 5700 Sixth Avenue South, Suite 220, Seattle, WA 98108	MADE BY SEM	SHEET NUMBER 83/88
TEST DATA REDUCTIONS WHC No. MMB-SCV-267622	CHECKED BY SMR	PROJ. NUMBER
	DATE 7/1/93	930496

SAMPLE CALCULATIONS OF VALUES IN TABLE 3:

ASSUME PANEL NO. 190KE-501:

BREAKING FAILURE LOAD $P_n = 1,130$ lbs (FROM TEST)

$$\text{OR } P_n = \frac{1,130 \times 12}{17.25} = 786 \text{ lbs/ft.}$$

$$\therefore M_n = 5P_n = 5 \times 786 = \underline{\underline{3,929 \text{ in. lb./ft.}}}$$

$$W_n (6'-0" \text{ SPAN}) = \frac{8(3,929)}{12(36)} = \underline{\underline{72.8 \text{ psf}}}$$

$$W_n (7'-0" \text{ SPAN}) = 72.8 \left(\frac{6}{7}\right)^2 = \underline{\underline{53.5 \text{ psf}}}$$

WHC-SD-NR-TRP-016

<p>Wiss, Janney, Elstner Associates, Inc. 5700 Sixth Avenue South, Suite 220, Seattle, WA 98108</p>	<p>MADE BY SEM</p>	<p>SHEET NUMBER B4/B8</p>
<p>COMPUTATION OF MODULUS OF ELASTICITY WHC NO. MMB-SCV-267622</p>	<p>CHECKED BY SMR</p>	<p>PROJ. NUMBER 930496</p>
	<p>DATE 7/1/93</p>	

$$\delta_{max} = \frac{Pa}{24EI} (3l^2 - 4a^2)$$

1) $l = 72"$, $a = 18"$, $I = 0.714 \text{ in}^4/\text{ft}$ (FORM JOHNS-MANVILLE)

$$\delta_{max} = \frac{M}{24EI} (3(72)^2 - 4(18)^2) = 832 \frac{M}{E}$$

2) $l = 60"$, $a = 15"$, $I = 0.714 \text{ in}^4/\text{ft}$

$$\delta_{max} = \frac{M}{24EI} (3(60)^2 - 4(15)^2) = 577.7 \frac{M}{E}$$

3) $l = 30"$, $a = 10"$, $I = 0.714 \text{ in}^4/\text{ft}$

$$\delta_{max} = \frac{M}{24EI} (3(30)^2 - 4(10)^2) = 134.2 \frac{M}{E}$$

Wiss, Janney, Elstner Associates, Inc. 5700 Sixth Avenue South, Suite 220, Seattle, WA 98108 COMPUTATION OF MODULUS OF ELASTICITY WHC NO. MMB-SCV-267622	MADE BY	SHEET NUMBER
	SEM	B5/B8
	CHECKED BY	PROJ. NUMBER
	SMR	930496
	DATE	
	7/1/93	

ESTIMATE OF E (Modulus of Elasticity)

Specimen #	$\Delta^{(1)}$ in.	$M^{(2)}$ in.-lb./ft	E psi
190KE-100	0.661	2,809	$E = 832 \frac{M}{\delta} = 3.54 \times 10^6$
190KE-200	0.613	2,809	$\sim = 3.81 \times 10^6$
190KE-300(WET)	0.616	1,830	$\sim = 2.47 \times 10^6$
190KE-400(WET)	0.536	3,192	$E = 577.7 \frac{M}{\delta} = 3.44 \times 10^6$
190KE-500	0.480	2,979	$\sim = 3.59 \times 10^6$
190KE-600	0.445	3,405	$\sim = 4.42 \times 10^6$

(1) MAX. DEFLECTION RECORDED DURING THE TEST

(2) BENDING MOMENT CORRESPONDING TO " Δ ".

AVERAGE "E" OF 190KE-100, 200, 500 & 600

$$= 3.84 \times 10^6 \text{ psi} \quad \& \quad \sigma = 0.404 \times 10^6$$

$$E \pm \sigma = 4.24 / 3.44 \times 10^6 \text{ psi}$$

$$E \pm 2\sigma = 4.65 / 3.03 \times 10^6 \text{ psi}$$

Wiss, Janney, Elstner Associates, Inc. 5700 Sixth Avenue South, Suite 220, Seattle, WA 98108 TEST DATA REDUCTIONS WHC No. MMB-SCV-267622	MADE BY	SHEET NUMBER
	SEM	B6/B8
	CHECKED BY	PROJ. NUMBER
	SMP	930496
	DATE	
	7/2/93

LAB TEST
ASTM E72-88

$$\delta_T = \frac{11 P_T l_T^3}{768 E_T I_T}$$

EQUIV. SIMPLE
SPAN UNDER
UNIFORM LOAD

$$\delta_s = \frac{5 w_s l_s^4}{384 E_T I_T}$$

ACTUAL SPAN
IN THE STRUCTURE

$$\delta_A = K \left(\frac{w_A l_A^4}{E_T I_T} \right)$$

$$w_s = \frac{P_T l_T}{8} \left(\frac{8}{l_s^2} \right) = \text{EQUIVALENT SIMPLE SPAN UNIFORM LOAD, BASED ON LAB TEST BENDING MOMENT}$$

$$\therefore \delta_s = \left[\frac{P_T l_T}{l_s^2} \right] \left[\frac{5 l_s^4}{384 E_T I_T} \right] = \frac{5 P_T l_T l_s^2}{384 E_T I_T}$$

$$\therefore (\delta_s / \delta_T) = \frac{5 P_T l_T l_s^2}{11 P_T l_T^3} \times \frac{768 E_T I_T}{384 E_T I_T} = \frac{10}{11} \left(\frac{l_s}{l_T} \right)^2$$

ASSUMING $\delta_A = \delta_s$ FIND l_s EQUIVALENT TO PROOF LOAD TEST.

FOR SAME w , i.e. $w_A = w_s$

$$l_s^4 = \left(\frac{384 E_T I_T}{5} \right) \left(\frac{\delta}{w} \right) \quad \text{OR} \quad l_s = \left[\frac{384 E_T I_T}{5} \times \frac{\delta}{w} \right]^{1/4}$$

NOTE: VALUES OF E_T ARE LISTED ON SHEET B5/B7.

WHC-SD-NR-TRP-016

Wiss, Janney, Elstner Associates, Inc. 5700 Sixth Avenue South, Suite 220, Seattle, WA 98108 TEST PLAN - PROOFLoad TEST - 105KW WHC No. MMB-SCV-267622	MADE BY	SHEET NUMBER
	SEM	B7/B8
	CHECKED BY	PROJ. NUMBER
	SMP	930496
	DATE	
	7/7/93

ASSUMING E & I , AND GIVEN W & δ FROM THE TEST
 ONE COULD COMPUTE EQUIVALENT SIMPLE SPAN AS FOLLOWS;

FOR A SIMPLE SPAN $\delta = \frac{5WL^4}{384EI}$

OR $L = \left[\left(\frac{384EI}{5} \right) \left(\frac{\delta}{W} \right) \right]^{1/4}$

- 1) $E = \text{AVERAGE VALUE FROM TESTS} = 3.84 \times 10^6 \text{ psi}$, (SHT. B5/B7) , $(*)$
 $I = 0.714 \text{ in}^4/\text{ft.}$, $\delta = \text{inches}$, $W = \text{psf.}$

$$L = \left[\frac{384(3.84 \times 10^6)(0.714)}{(5)(12)^3} \left(\frac{\delta}{W} \right) \right]^{1/4} = 18.684 \left(\frac{\delta}{W} \right)^{1/4} \text{ ft.}$$

- 2) $E = E_{\text{AVE.}} \pm 2\sigma = 4.65 / 3.03 \times 10^6 \text{ psi}$, $(*)$

$$L = 19.599 \left(\frac{\delta}{W} \right)^{1/4} \text{ ft. max.}, 17.609 \left(\frac{\delta}{W} \right)^{1/4} \text{ ft. min.}$$

FROM THE SPAN "L" AND THE LOAD W , A PROBABILITY
 OF SUCCESS COULD BE OBTAINED.

WHC-SD-NR-TRP-016

WJE Wiss, Janney, Elstner Associates, Inc. 5700 Sixth Avenue South, Suite 220, Seattle, WA 98108	MADE BY	SHEET NUMBER
	SEM	B8/B8
	CHECKED BY	PROJ. NUMBER
TEST REPORT- ROOF PROOF LOAD TEST-105KW	SMR	
WHC NO. MMB-SCV-267622	DATE 9/16/93	930496

BASED ON THE RESULTS OF THE ROOF PROOF LOAD TEST,
TABLE 9, AN EFFECTIVE SPAN OF 5.0' MAX. WAS OBTAINED.
UNDER A TEST LOAD OF 35 psf;

$$\text{TOTAL LOAD ON ASBESTOS PANEL} = 35 + 15.2 = 50.2 \text{ psf}$$

(MAX. DURING PROOF TEST)

Externally applied load

Roofing System
(perlite Conc. + Insul. + Gravel)

- MAXIMUM BENDING MOMENT DURING PROOF TEST;

$$= (50.2) \frac{(5)^2}{8} = 156.9 \text{ ft. lb. / ft.}$$

- From Table 5, THE MINIMUM ULTIMATE BENDING MOMENT OBTAINED FOR A COUPON WITH PERLITE = 319 ft. lb. / ft.

- CORRESPONDING ULTIMATE UNIFORM LOAD;

$$W = \frac{319 \times 8}{(5)^2} = 102.1 \text{ psf}$$

∴ PREDICTED ROOF ULTIMATE EXTERNAL LOAD ;

$$= 102 - 15.2 = 86.9 \text{ psf}$$

Appendix C

Roof Proof Load Test Data Sheets

7/28/93Start of Roof load Test;

Fill up hoses @ 13:30
each hose took 1.7 gal. to fill.

* Flow meter Reading before filling the
bags = 438.1

* Flow Meter Reading after filling all 6-Bags
to max. load = 1,845.7

* Total Water in Bags = $1,845.7 - 438.1 = 1,407.6$
gallons

gallons per bag = $\frac{1,407.6}{6} = 234.6$ gallons/bag

wt. per bag = $234.6 \times 8.346 = 1,958$ #

psf = $\frac{1,958}{56} = 35$ psf $\leftarrow$ o.k.

APPLIED LOAD

1

By: <u>Saad Moustafa</u>	Date: <u>7/28/93</u>
LOAD INCREMENT <u># 1</u>	<u>5 psf</u>
INCREMENT AMOUNT <u>33.5G.</u>	TOTAL LOAD <u>280 # 5 psf.</u>

Bag ID	Time	Flow (gal.)	Weight (lb)	Uniform Load (psf)
1	13:43	33.5 - 67.0	280	5
2	13:40	0 → 33.5	280	5
3	13:45	67 - 100.5	280	5
4	13:55	167.5 - 201.0	280	5
5	13:49	100.5 - 134	280	5
6	13:52	134 - 167.5	280	5

PANEL DEFLECTIONS

By: _____	Date: _____	Time: _____
LOAD INCREMENT _____	TOTAL LOAD _____	

Panel	LVDT ID	Uniform Load (psf)	Deflection (in.)	Effective Span (ft)	Probability of Success (%)
1					
2					
3					
4					
5					
6					
7					
8					
9					

APPLIED LOAD

#2

By: <u>Saad Moustafa</u>	Date: <u>7/28/13</u>
LOAD INCREMENT <u>#2</u> <u>5 psf</u>	
INCREMENT AMOUNT <u>5 psf</u>	TOTAL LOAD <u>10 psf</u>

Bag ID	Time	Flow (gal.)	Weight (lb)	Uniform Load (psf) <u>79.0</u>
1	14:09	0 → 33.5	280	5 → 10
2	14:11	33.5 → 67.0	280	
3	14:14	67 - 100.5	280	
4	14:17	100.5 - 134.0	280	
5	14:21	134 - 167.5	280	
6	14:24	167.5 - 201.0	280	

PANEL DEFLECTIONS

By: _____	Date: _____	Time: _____
LOAD INCREMENT _____	TOTAL LOAD _____	

Panel	LVDT ID	Uniform Load (psf)	Deflection (in.)	Effective Span (ft)	Probability of Success (%)
1					
2					
3					
4					
5					
6					
7					
8					
9					

APPLIED LOAD

By: <u>Saad Mousa</u>	Date: <u>7/28/93</u>
LOAD INCREMENT <u># 3</u>	
INCREMENT AMOUNT <u>10</u>	TOTAL LOAD <u>20 psf</u>

Bag ID	Time	Flow (gal.)	Weight (lb)	Uniform Load (psf)
1	3:06	1 → 68	560	10 → 20
2	3:12	68 - 35	560	
3	3:19	35 - 02 10.8	560	
4	3:26	02 - 69 8.8 77.8	560	
5	3:32	69 - 36 77.8 44.8	560	
6	3:38	36 - 03 44.8 11.8	560	

PANEL DEFLECTIONS

By: _____	Date: _____	Time: _____
LOAD INCREMENT _____	TOTAL LOAD _____	

Panel	LVDT ID	Uniform Load (psf)	Deflection (in.)	Effective Span (ft)	Probability of Success (%)
1					
2					
3					
4					
5					
6					
7					
8					
9					

APPLIED LOAD

By: <u>Sueel Mouda</u>	Date: <u>7/28/93</u>
LOAD INCREMENT <u># 4</u>	
INCREMENT AMOUNT <u>5 psf</u>	TOTAL LOAD <u>25 psf</u>

Bag ID	Time	Flow (gal.)	Weight (lb)	Uniform Load (psf)
1	3:55 ^{pm}	33.5	280	20 → 25
2	4:00 ^{pm}	67	280	
3	4:02	91.7 100.5	280	
4	4:05	134	280	
5	4:07	167.5	280	
6	4:09	201.0	280	

PANEL DEFLECTIONS

By: _____	Date: _____	Time: _____
LOAD INCREMENT _____	TOTAL LOAD _____	

Panel	LVDT ID	Uniform Load (psf)	Deflection (in.)	Effective Span (ft)	Probability of Success (%)
1					
2					
3					
4					
5					
6					
7					
8					
9					

APPLIED LOAD

By: <u>Saad Moustafa</u>	Date: <u>7/28/93</u>
LOAD INCREMENT <u>#5</u>	
INCREMENT AMOUNT <u>5 psf</u>	TOTAL LOAD <u>30 psf</u>

Bng ID	Time	Flow (gal.)	Weight (lb)	Uniform Load (psf)
1	16:21	0 → 33.5 34.2	280	25 → 30
2	16:24	33.5 → 67 34.2 67.7	280	
3	16:26	67 → 100.5 67.7 101.2	280	
4	16:30	0 → 33.5	280	
5	16:33	33.5 → 67	280	
6	16:41	67 → 100.5	280	

PANEL DEFLECTIONS

By: _____	Date: _____	Time: _____
LOAD INCREMENT _____	TOTAL LOAD _____	

Panel	LVDT ID	Uniform Load (psf)	Deflection (in.)	Effective Span (ft)	Probability of Success (%)
1					
2					
3					
4					
5					
6					
7					
8					
9

2 of 2

APPLIED LOAD

By: <u>Saad Moustafa</u>	Date: <u>7/28/93</u>
LOAD INCREMENT <u>#6</u>	
INCREMENT AMOUNT <u>5 psf</u>	TOTAL LOAD <u>35 psf</u>

Bag ID	Time	Flow (gal.)	Weight (lb)	Uniform Load (psf)
1	16:50	0.5 → 34.0	280	30 → 35
2	16:54	34 → 66.8	280	
3	16:56	66.8 → 100.3	280	
4	17:00	0 → 33.5	280	
5	17:03	33.5 → 67.0	280	
6	17:06	67 → 100.5	280	

PANEL DEFLECTIONS

By: _____	Date: _____	Time: _____
LOAD INCREMENT _____	TOTAL LOAD _____	

Panel	LVDT ID	Uniform Load (psf)	Deflection (in.)	Effective Span (ft)	Probability of Success (%)
1					
2					
3					
4					
5					
6					
7					
8					
9					

~~7:30~~ 9:00

7/28/93

Time etc.	1	2	3	4	5	6	7	8	9
N.L.A.									
9:00 Seed	9.544	7.022	4.842	1.934	-7.888	-4.850	3.075	7.139	5.363
12:40 NL	4.537	6.993	4.853	1.932	-7.877	-4.833	3.034	7.093	5.340
13:36 NL	4.547	6.991	4.859	1.941	-7.890	-4.827	3.035	7.088	5.343
14:01 Load ①	4.357	6.828	4.673	1.867	-7.814	-4.742	2.915	6.980	5.188
14:31	4.141	6.660	4.457	1.766	-7.718	-4.614	2.760	6.856	4.985
15:50	3.731	6.304	3.987	1.490	-7.490	-4.305	2.463	6.615	4.587
16:12	3.537	6.142	3.762	1.407	-7.410	-4.168	2.327	6.501	4.375
16:42	3.330	5.973	3.535	1.296	-7.311	-4.020	2.190	6.385	4.170
17:13	3.120	5.810	3.311	1.174	-7.217	-3.865	2.052	6.267	3.958
17:33	3.102	5.798	3.295	1.161	-7.210	-3.844	2.044	6.261	3.942
19:30	4.192	6.788	4.570	1.738	-7.833	-4.405	2.658	6.970	5.102
					-20.20	-4.411	2.674		

By: Scott / Sand / Rob

Date: 7/28 - 7/29/93

TOTAL LOAD 35 psf

Panel		1	2	3	4	5	6	7	8	9
Time (hr)	Actual Time	<div style="display: flex; justify-content: space-between;"> Voltage Deflection (in.) </div>								
.25	17:38	3.102	5.798	3.295	1.161	-7.210	-3.844	2.044	6.261	3.942
.50	17:41	3.098	5.797	3.292	1.161	-7.210	-3.837	2.041	6.262	3.942
.75	18:00	3.096	5.797	3.292	1.158	-7.211	-3.830	2.038	6.262	3.938
1.0	18:15	3.091	5.796	3.289	1.156	-7.214	-3.822	2.036	6.262	3.940
1.5	18:45	3.086	5.795	3.287	1.153	-7.215	-3.811	2.032	6.266	3.934
2.0	19:15	3.078	5.796	3.284	1.151	-7.221	-3.804	2.036	6.276	3.945
2.5	19:45	3.069	5.793	3.279	1.145	-7.220	-3.793	2.033	6.280	3.942
3.0	20:15	3.062	5.792	3.272	1.141	-7.223	-3.783	2.032	6.285	3.946
4.0	21:15	3.050	5.788	3.262	1.133	-7.226	-3.769	2.029	6.291	3.946
5.0	22:15	3.038	5.786	3.255	1.122	-7.232	-3.755	2.017	6.292	3.930
6.0	23:15	3.023	5.781	3.238	1.116	-7.236	-3.739	2.010	6.296	3.935
7.0	00:15	3.011	5.776	3.231	1.115	-7.239	-3.731	2.002	6.298	3.935
8.0	1:15	3.006	5.775	3.229	1.115	-7.241	-3.723	1.994	6.300	3.934
9.0	2:15	3.000	5.776	3.226	1.105	-7.245	-3.709	1.990	6.308	3.938
10.0	3:15	2.993	5.776	3.220	1.105	-7.247	-3.703	1.984	6.310	3.932
11.0	4:15	2.985	5.778	3.217	1.098	-7.252	-3.693	1.976	6.311	3.932
12.0	5:15	2.975	5.778	3.212	1.090	-7.258	-3.679	1.968	6.316	3.933
13.0	6:15	2.975	5.788	3.214	1.090	-7.270	-3.674	1.963	6.324	3.938
14.0	7:15	2.968	5.782	3.210	1.089	-7.271	-3.668	1.953	6.320	3.934
15.0	8:15	2.961	5.780	3.209	1.089	-7.272	-3.667	1.942	6.315	3.926
16.0	9:15	2.947	5.776	3.203	1.083	-7.271	-3.662	1.932	6.311	3.918
17.0	10:15	2.942	5.770	3.199	1.081	-7.269	-3.658	1.923	6.308	3.918
18.0	11:15	2.932	5.759	3.189	1.077	-7.266	-3.651	1.902	6.285	3.901
19.0	12:15	2.923	5.745	3.183	1.074	-7.259	-3.642	1.891	6.277	3.882
20.0	13:15	2.924	5.748	3.179	1.078	-7.263	-3.637	1.881	6.267	3.876
21.0	14:15	2.932	5.751	3.181	1.080	-7.266	-3.632	1.876	6.265	3.877
22.0	15:15	2.937	5.747	3.174	1.081	-7.262	-3.622	1.868	6.260	3.872
23.0	16:15	2.942	5.746	3.177	1.084	-7.261	-3.613	1.865	6.259	3.876
24.0	17:15	2.949	5.753	3.182	1.085	-7.262	-3.608	1.862	6.260	3.884

(16:57)

Load Increment 1
Increment Amount 5
Total Load 5

Bag ID	Time	Flow (gal)	Weight (lb)	Uniform Load (psf)
1	13:43	33.5	279.6	4.95
2	13:40	33.5	275.7	4.88
3	13:45	33.5	275.7	4.97
4	13:55	33.5	275.7	4.97
5	13:49	33.5	275.7	4.88
6	13:52	33.5	275.7	4.88

Time 14:01

LVDT ID	Position	Uniform Load (psf)	Calibration Factor	Voltage	Difference Vinitial - V	Deflection
18	1	5	0.099335	4.357	0.18	0.017880
23	2	5	0.122827	6.828	0.165	0.020266
14	3	5	0.096045	4.673	0.18	0.017288
21	4	5	0.123678	1.867	0.065	0.008039
20	5	5	0.126514	-7.814	0.063	0.007970
12	6	5	0.096045	-4.742	0.091	0.008740
15	7	5	0.098102	2.915	0.119	0.011674
22	8	5	0.126126	6.98	0.113	0.014252
17	9	5	0.094844	5.188	0.152	0.014416

Position	Effective Span L (ft.)	W ult given Moment for probability of Success of 95%	W ult - DL of 15.2 psf	Moment given eff. span and applied uniform load and DL	k (mult. of stdevs.) M - M ave./ stdev.	Probability of Success
1	4.79	88.18	72.98	143.28	-4.66	99.99
2	4.95	82.83	67.63	152.54	-4.40	99.99
3	4.75	89.68	74.48	140.89	-4.72	99.99
4	3.92	131.51	116.31	96.07	-5.95	99.99
5	3.92	132.08	116.88	95.66	-5.96	99.99
6	4.01	126.13	110.93	100.17	-5.84	99.99
7	4.31	109.13	93.93	115.77	-5.41	99.99
8	4.53	98.77	83.57	127.92	-5.08	99.99
9	4.54	98.21	83.01	128.65	-5.06	99.99

Load Increment 2
 Increment Amount 5
 Total Load 10

Bag ID	Time	Flow (gal)	Weight (lb)	Uniform Load (psf)
1	14:09	33.5	275.7	4.88
2	14:11	33.5	275.7	4.88
3	14:14	33.5	275.7	4.97
4	14:17	33.5	275.7	4.97
5	14:21	33.5	275.7	4.88
6	14:24	33.5	275.7	4.88

Time 14:31

LVDT ID	Positon	Uniform Load (psf)	Calibration Factor	Voltage	Difference Vi-Vn	Deflection
18	1	10	0.099335	4.141	0.396	0.039337
23	2	10	0.122827	6.66	0.333	0.040901
14	3	10	0.096045	4.457	0.396	0.038034
21	4	10	0.123678	1.766	0.166	0.020531
20	5	10	0.126514	-7.718	0.159	0.020116
12	6	10	0.096045	-4.614	0.219	0.021034
15	7	10	0.098102	2.76	0.274	0.026880
22	8	10	0.126126	6.856	0.237	0.029892
17	9	10	0.094844	4.985	0.355	0.033670

Position	Effective Span L (ft.)	W ult given Moment for probability of Success of 95%	W ult - DL of 15.2 psf	Moment given eff. span and applied uniform load and DL	k (mult. of s) M - M ave./ stdev.	Probability of Success
1	4.91	84.08	68.88	150.27	-4.46	99.99
2	4.96	82.45	67.25	153.23	-4.38	99.99
3	4.87	85.51	70.31	147.76	-4.53	99.99
4	4.17	116.38	101.18	108.56	-5.61	99.99
5	4.15	117.58	102.38	107.46	-5.64	99.99
6	4.20	114.98	99.78	109.88	-5.57	99.99
7	4.46	101.71	86.51	124.22	-5.18	99.99
8	4.58	96.45	81.25	131.00	-4.99	99.99
9	4.72	90.88	75.68	139.03	-4.77	99.99

Load Increment 3
Increment Amount 10
Total Load 20

Bag ID	Time	Flow (gal)	Weight (lb)	Uniform Load (psf)
1	15:06	67	551.4	9.75
2	15:12	67	551.4	9.75
3	15:19	67	551.4	9.93
4	15:26	67	551.4	9.93
5	15:32	67	551.4	9.75
6	15:38	67	551.4	9.75

Time 15:50

LVDT ID	Postion	Uniform Load (psf)	Calibration Factor	Voltage	Difference Vi-Vn	Deflection
18	1	20	0.099335	3.731	0.806	0.080064
23	2	20	0.122827	6.304	0.689	0.084628
14	3	20	0.096045	3.987	0.866	0.083175
21	4	20	0.123678	1.49	0.442	0.054666
20	5	20	0.126514	-7.49	0.387	0.048961
12	6	20	0.096045	-4.305	0.528	0.050712
15	7	20	0.098102	2.463	0.571	0.056016
22	8	20	0.126126	6.615	0.478	0.060288
17	9	20	0.094844	4.577	0.763	0.072366

Position	Effective Span L (ft.)	W ult given Moment for probability of Success of 95%	W ult - DL of 15.2 psf	Moment given eff. span and applied uniform load and DL	k (mult. of s) M - M ave./ stdev.	Probability of Success
1	4.93	83.35	68.15	151.59	-4.43	99.99
2	5.00	81.07	65.87	155.85	-4.31	99.99
3	4.98	81.77	66.57	154.51	-4.35	99.99
4	4.48	100.87	85.67	125.26	-5.15	99.99
5	4.36	106.58	91.38	118.55	-5.33	99.99
6	4.40	104.72	89.52	120.65	-5.28	99.99
7	4.51	99.64	84.44	126.80	-5.11	99.99
8	4.59	96.05	80.85	131.55	-4.98	99.99
9	4.81	87.67	72.47	144.12	-4.63	99.99

Load Increment 4
 Increment Amount 5
 Total Load 25

Bag ID	Time	Flow (gal)	Weight (lb)	Uniform Load (psf)
1	15:55	33.5	275.7	4.88
2	16:00	33.5	275.7	4.88
3	16:02	33.5	275.7	4.97
4	16:05	33.5	275.7	4.97
5	16:07	33.5	275.7	4.88
6	16:09	33.5	275.7	4.88

Time 16:12

LVDT ID	Position	Uniform Load (psf)	Calibration Factor	Voltage	Difference Vi-Vn	Deflection
18	1	25	0.099335	3.537	1	0.099335
23	2	25	0.122827	6.142	0.851	0.104526
14	3	25	0.096045	3.762	1.091	0.104785
21	4	25	0.123678	1.407	0.525	0.064931
20	5	25	0.126514	-7.41	0.467	0.059082
12	6	25	0.096045	-4.168	0.665	0.063870
15	7	25	0.098102	2.327	0.707	0.069358
22	8	25	0.126126	6.501	0.592	0.074667
17	9	25	0.094844	4.375	0.965	0.091524

Position	Effective Span L (ft.)	W ult given Moment for probability of Success of 95%	W ult - DL of 15.2 psf	Moment given eff. span and applied uniform load and DL	k (mult. of s) M - M ave./ stdev.	Probability of Success
1	4.92	83.66	68.46	151.03	-4.44	99.99
2	4.98	81.55	66.35	154.92	-4.34	99.99
3	4.99	81.45	66.25	155.12	-4.33	99.99
4	4.42	103.47	88.27	122.11	-5.24	99.99
5	4.32	108.47	93.27	116.48	-5.39	99.99
6	4.41	104.33	89.13	121.10	-5.26	99.99
7	4.50	100.12	84.92	126.20	-5.12	99.99
8	4.58	96.49	81.29	130.94	-4.99	99.99
9	4.82	87.15	71.95	144.97	-4.61	99.99

Load Increment 5
 Increment Amount 5
 Total Load 30

Bag ID	Time	Flow (gal)	Weight (lb)	Uniform Load (psf)
1	16:21	34.2	281.5	4.98
2	16:24	33.5	275.7	4.88
3	16:26	33.5	275.7	4.97
4	16:30	33.5	275.7	4.97
5	16:33	33.5	275.7	4.88
6	16:41	33.5	275.7	4.88

Time 16:42

LVDT ID	Position	Uniform Load (psf)	Calibration Factor	Voltage	Difference Vi-Vn	Deflection
18	1	30	0.099335	3.33	1.207	0.119897
23	2	30	0.122827	5.973	1.02	0.125284
14	3	30	0.096045	3.535	1.318	0.126587
21	4	30	0.123678	1.296	0.636	0.078659
20	5	30	0.126514	-7.311	0.566	0.071607
12	6	30	0.096045	-4.02	0.813	0.078085
15	7	30	0.098102	2.19	0.844	0.082798
22	8	30	0.126126	6.385	0.708	0.089297
17	9	30	0.094844	4.17	1.17	0.110967

Position	Effective Span L (ft.)	W ult given Moment for probability of Success of 95%	W ult - DL of 15.2 psf	Moment given eff. span and applied uniform load and DL	k (mult. of s) M - M ave./ stdev.	Probability of Success
1	4.93	83.41	68.21	151.47	-4.43	99.99
2	4.98	81.60	66.40	154.83	-4.34	99.99
3	5.00	81.18	65.98	155.64	-4.32	99.99
4	4.43	102.98	87.78	122.69	-5.22	99.99
5	4.33	107.94	92.74	117.06	-5.37	99.99
6	4.43	103.36	88.16	122.24	-5.23	99.99
7	4.49	100.38	85.18	125.87	-5.13	99.99
8	4.58	96.66	81.46	130.72	-5.00	99.99
9	4.83	86.71	71.51	145.72	-4.59	99.99

Load Increment 6
Increment Amount 5
Total Load 35

Bag ID	Time	Flow (gal)	Weight (lb)	Uniform Load (psf)
	1	16:50	33.5	275.7
	2	16:54	33.5	275.7
	3	16:56	33.5	275.7
	4	17:00	33.5	275.7
	5	17:03	33.5	275.7
	6	17:06	33.5	275.7

Time 17:13

LVDT ID	Position	Uniform Load (psf)	Calibration Factor	Voltage	Difference Vi-Vn	Deflection
18	1	35	0.099335	3.12	1.417	0.140758
23	2	35	0.122827	5.81	1.183	0.145304
14	3	35	0.096045	3.311	1.542	0.148101
21	4	35	0.123678	1.174	0.758	0.093748
20	5	35	0.126514	-7.217	0.66	0.083499
12	6	35	0.096045	-3.865	0.968	0.092972
15	7	35	0.098102	2.052	0.982	0.096336
22	8	35	0.126126	6.267	0.826	0.104180
17	9	35	0.094844	3.958	1.382	0.131074

Position	Effective Span L (ft.)	W ult given Moment for probability of Success of 95%	W ult - DL of 15.2 psf	Moment given eff. span and applied uniform load and DL	k (mult. of s) M - M ave./ stdev.	Probability of Success
1	4.94	83.15	67.95	151.94	-4.42	99.515
2	4.97	81.84	66.64	154.38	-4.35	99.515
3	5.00	81.07	65.87	155.86	-4.31	99.515
4	4.46	101.89	86.69	124.00	-5.18	99.515
5	4.33	107.96	92.76	117.03	-5.37	99.515
6	4.45	102.32	87.12	123.49	-5.20	99.515
7	4.49	100.51	85.31	125.70	-5.14	99.515
8	4.58	96.66	81.46	130.72	-5.00	99.515
9	4.85	86.17	70.97	146.62	-4.56	99.515

PRFLOAD XLS

24 Hour Readings

Position

calibration Factor

Time

Time	Actual Time	1 0 099335		2 0 122827		3 0 096045		4 0 123678		5 0 126514		6 0 096045		7 0 098102		8 0 126126		9 0 094844	
		Voltage	Deflection	Voltage	Deflection	Voltage	Deflection	Voltage	Deflection	Voltage	Deflection	Voltage	Deflection	Voltage	Deflection	Voltage	Deflection	Voltage	Deflection
0		3 120	0 140758	5 81	0 145304	3 311	0 148101	1 174	0 093748	-7 217	0 083499	-3 865	0 092972	2 052	0 096336	6 267	0 104180	3 958	0 131074
0.25	17.33	3 102	0 142546	5 798	0 146778	3 295	0 149638	1 161	0 095356	-7 21	0 084385	-3 844	0 094989	2 044	0 097121	6 261	0 104937	3 942	0 132592
0.5	17.48	3 098	0 142943	5 797	0 146901	3 292	0 149926	1 161	0 095356	-7 21	0 084385	-3 837	0 095661	2 041	0 097415	6 262	0 104811	3 942	0 132592
0.75	18.00	3 096	0 143142	5 797	0 146901	3 292	0 149926	1 158	0 095727	-7 211	0 084258	-3 83	0 096333	2 036	0 097906	6 262	0 104811	3 938	0 132971
1	18.15	3 091	0 143638	5 796	0 147024	3 289	0 150214	1 156	0 095974	-7 214	0 083879	-3 822	0 097101	2 033	0 098200	6 262	0 104811	3 94	0 132782
1.5	18.45	3 086	0 144135	5 795	0 147147	3 287	0 150406	1 153	0 096345	-7 215	0 083752	-3 811	0 098158	2 032	0 098298	6 266	0 104306	3 934	0 133351
2	19.15	3 078	0 144930	5 796	0 147024	3 284	0 150695	1 151	0 096593	-7 221	0 082993	-3 804	0 098830	2 036	0 097906	6 276	0 103045	3 945	0 132307
2.5	19.45	3 069	0 145824	5 793	0 147392	3 279	0 151175	1 145	0 097335	-7 22	0 083120	-3 793	0 099887	2 033	0 098200	6 28	0 102540	3 942	0 132592
3	20.15	3 062	0 146519	5 792	0 147515	3 272	0 151847	1 141	0 097829	-7 223	0 082740	-3 783	0 100847	2 032	0 098298	6 285	0 101910	3 946	0 132213
4	21.15	3 05	0 147711	5 788	0 148007	3 262	0 152808	1 133	0 098819	-7 226	0 082361	-3 769	0 102192	2 029	0 098593	6 291	0 101153	3 946	0 132213
5	22.15	3 038	0 148903	5 786	0 148252	3 255	0 153480	1 122	0 100179	-7 232	0 081602	-3 755	0 103537	2 017	0 099770	6 292	0 101027	3 93	0 133730
6	23.15	3 023	0 150393	5 781	0 148866	3 238	0 155113	1 116	0 100921	-7 236	0 081095	-3 739	0 105073	2 01	0 100456	6 296	0 100522	3 935	0 133256
7	0.15	3 011	0 151585	5 776	0 149480	3 231	0 155785	1 115	0 101045	-7 239	0 080716	-3 731	0 105842	2 002	0 101241	6 298	0 100270	3 935	0 133256
8	1.15	3 006	0 152082	5 775	0 149603	3 229	0 155977	1 115	0 101045	-7 241	0 080463	-3 723	0 106610	1 994	0 102026	6 3	0 100018	3 934	0 133351
9	2.15	3	0 152678	5 776	0 149480	3 226	0 156265	1 105	0 102282	-7 245	0 079957	-3 709	0 107955	1 99	0 102418	6 308	0 099009	3 938	0 132971
10	3.15	2 993	0 153373	5 776	0 149480	3 22	0 156841	1 105	0 102282	-7 247	0 079704	-3 703	0 108531	1 984	0 103007	6 31	0 098757	3 932	0 133540
11	4.15	2 985	0 154168	5 778	0 149235	3 217	0 157130	1 098	0 103147	-7 252	0 079071	-3 693	0 109491	1 976	0 103792	6 311	0 098631	3 932	0 133540
12	5.15	2 975	0 155161	5 778	0 149235	3 212	0 157610	1 09	0 104137	-7 258	0 078312	-3 679	0 110836	1 968	0 104577	6 316	0 098000	3 933	0 133446
13	6.15	2 975	0 155161	5 778	0 149235	3 214	0 157418	1 09	0 104137	-7 27	0 076794	-3 674	0 111316	1 963	0 105067	6 324	0 096991	3 938	0 132971
14	7.15	2 968	0 155857	5 782	0 148743	3 21	0 157802	1 089	0 104261	-7 271	0 076667	-3 668	0 111892	1 953	0 106048	6 32	0 097495	3 934	0 133351
15	8.15	2 961	0 156552	5 78	0 148989	3 209	0 157898	1 089	0 104261	-7 272	0 076541	-3 667	0 111988	1 942	0 107127	6 315	0 098126	3 926	0 134109
16	9.15	2 947	0 157943	5 776	0 149480	3 203	0 158474	1 083	0 105003	-7 269	0 076921	-3 658	0 112853	1 923	0 108991	6 301	0 099892	3 912	0 135437
17	10.15	2 942	0 158439	5 77	0 150217	3 199	0 158858	1 081	0 105250	-7 269	0 076921	-3 651	0 113525	1 902	0 111051	6 285	0 101910	3 901	0 136481
18	11.15	2 932	0 159433	5 759	0 151569	3 189	0 159819	1 077	0 105745	-7 266	0 077300	-3 642	0 114390	1 891	0 112131	6 277	0 102919	3 882	0 138283
19	12.15	2 923	0 160327	5 745	0 153288	3 183	0 160395	1 074	0 106116	-7 259	0 078186	-3 642	0 114390	1 891	0 112131	6 277	0 102919	3 882	0 138283
20	13.15	2 924	0 160227	5 748	0 152920	3 179	0 160779	1 078	0 105621	-7 263	0 077680	-3 637	0 114870	1 881	0 113112	6 267	0 104180	3 876	0 138852
21	14.15	2 932	0 159433	5 751	0 152551	3 181	0 160587	1 08	0 105374	-7 266	0 077300	-3 632	0 115350	1 876	0 113602	6 265	0 104432	3 877	0 138757
22	15.15	2 937	0 158936	5 747	0 153042	3 174	0 161260	1 081	0 105250	-7 262	0 077806	-3 622	0 116310	1 868	0 114387	6 26	0 105063	3 872	0 139231
23	16.15	2 942	0 158439	5 746	0 153165	3 177	0 160971	1 084	0 104879	-7 261	0 077933	-3 613	0 117175	1 865	0 114681	6 259	0 105189	3 876	0 138852
24	17.15	2 949	0 157744	5 753	0 152305	3 182	0 160491	1 085	0 104755	-7 262	0 077806	-3 608	0 117655	1 862	0 114976	6 26	0 105063	3 884	0 138093
26.5		4 192	0 034271	6 788	0 025180	4 57	0 027181	1 738	0 023994	-7 833	0 005567	-4 411	0 040531	2 674	0 035317	6 97	0 015513	5 102	0 022573

WMC-SD-NR-TRP-016
REV: 0
C-17

WHC-SD-NR-TRP-016
REV: 0
D-1

Appendix D
Carter Lift Bag Catalog

STANDARD OPEN BOTTOM LIFT BAGS

These bags are very versatile light-to-medium duty lift bags. They are excellent for sport divers, and are suitable for most types of underwater lifting and light salvage. All but the 50 lb. bag have diver-actuated dump valves, and all are open at the bottom to vent expanding air as they ascend. They are economical, light weight, and roll into a neat, compact roll for easy handling underwater.

TOTALLY ENCLOSED PILLOW BAGS

Pillow bags are totally enclosed, with over-pressure valves to vent expanding air as they ascend. The advantage of pillow bags over the open-bottom bags is that they can attain their maximum lift in much less water. For this reason, they are excellent for raising sunken boats, and for towing jobs. Like the Boulder Bags and the Ocean Salvage Tubes, all pillow bags come with brass quick-disconnect fittings.

BOULDER BAGS

Boulder bags are designed to get the maximum amount of lift in the minimum amount of water. For example, the 2000 lb Boulder Bag gets its total lift in less than three feet of water. This bag has one stainless steel attachment ring, located at its center. Boulder Bags were originally developed for lifting boulders out of the way of gold dredgers in the shallow rivers of California's mother-lode country, but they are equally well suited for deep ocean salvage jobs. Because their low profile offers a minimum amount of drag, they are also excellent for long, open-water towing jobs.

OCEAN SALVAGE TUBES

Ocean Salvage Tubes are highly versatile in the number of ways in which they can be deployed. They are excellent for pipe-laying and other underwater construction projects, but where Ocean Salvage Tubes really come into their own is when they are used in raising sunken boats. They can be used vertically, to bring the boat out of deep water. When the boat is suspended near the surface, they can be slung under the boat with one end on each side to get the boat high enough out of the water to pump out. In shallow water, two bags can be slung together, one on each side of the boat, like pontoons. The ends of the tubes can also be tied together so the bag will only draw half as much water. Ocean Salvage Tubes are constructed out of 40 ounce urethane-coated ballistic nylon fabric, which is extremely strong and very resistant to abrasion.

Model Number	Lift (lbs)	Shipping Weight	Height/Width
OPEN BOTTOM LIFT BAGS			
CB-50	50	1 lb	25" X 18"
CB-100	100	2 lb	28" X 25"
CB-200	200	3 lb	30" X 32"
CB-300	300	5 lb	46" X 32"
CB-500	500	9 lb	56" X 36"
CB-1000	1000	12 lb	50" X 52"
CB-2000	2000	19 lb	86" X 52"
CB-5000 *	5000	42 lb	94" X 86"
CB-12000 *	12000	80 lb	136" X 96"

TOTALLY ENCLOSED PILLOW BAGS

CB-EP-250	250	5 lb	26" X 32"
CB-EP-500	500	9 lb	36" X 56"
CB-EP-1000	1000	13 lb	52" X 50"
CB-EP-2000	2000	22 lb	52" X 86"
CB-EP-4000 *	4000	37 lb	75" X 96"
CB-EP-6000 *	6000	46 lb	87" X 96"

OCEAN SALVAGE TUBES (Totally Enclosed)

CB-ST-2000 *	2000	30 lb	180" X 29"
CB-ST-3000 *	3000	40 lb	264" X 29"

BOULDER BAG (Totally Enclosed)

CB-BB-2000 *	2000	27 lb	58" X 42"
--------------	------	-------	-----------

*Super heavy-duty 40 ounce urethane-coated nylon.

CARTER LIFT BAG, INC.

29500 Green River Gorge Road
ENUMCLAW, WASHINGTON 98022
(206) 886-2302 (206) 825-5412
FAX (206) 886-2454

DATE

FILMED

2 / 11 / 94

END