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## **Component Testing for Modular Pier Replacement at McMurdo Station, Antarctica: Inflatable Pontoons**

Gelbo Flex and Full-Scale Cold Storage/Fold Tests

Jason C. Weale and Margaret A. Knuth

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# **Component Testing for Modular Pier Replacement at McMurdo Station, Antarctica: Inflatable Pontoons**

Gelbo Flex and Full-Scale Cold Storage/Fold Tests

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## Abstract

The National Science Foundation is constantly striving to improve the efficiency and reliability of its support functions for the United States Antarctic Program. The annual ship offload at McMurdo Station is currently dependent on an unreliable ice pier; and a lightweight, rapidly deployable floating causeway system is one potential solution to mitigate challenges associated with the ice pier. This assessment focused on determining the durability and strength of the pontoon fabric when tested at Antarctic temperatures by using a cold-modified Gelbo flex (ASTM F392) test. The neoprene on nylon pontoon fabric performed well during the Gelbo tests. One of the three samples leaked during pressure tests after 510 cycles while the remaining 2 samples survived intact for all 1510 cycles. In addition, the full-scale pontoon was cycled through 10 periods of cold soaking at  $-40^{\circ}\text{C}$  followed by rapid inflation outdoors. Baseline air mass loss calculations before and after the cold cycles indicated that the tests caused no leaks or damage. Based on these results, a field trial of the LMCS at McMurdo Station is recommended provided the remaining components are suitable for the logistical needs and can function in the required environmental conditions.

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## Preface

These tests were conducted for the National Science Foundation (NSF), Division of Polar Programs (PLR), under Engineering for Polar Operations, Logistics, and Research (EPOLAR) EP-ANT-13-25, “Component Testing for Modular Pier Replacement.” The technical monitor was George Blaisdell, Chief Program Manager, NSF-PLR U.S. Antarctic Program.

The work was performed by Jason C. Weale and Margaret A. Knuth (Force Projection and Sustainment Branch, Dr. Edel Cortez, Chief), U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory (ERDC-CRREL). At the time of publication, Dr. Justin Berman was Chief of the Research and Engineering Division. The Deputy Director of ERDC-CRREL was Dr. Lance Hansen, and the Director was Dr. Robert Davis.

The authors thank Glenn Durell of ERDC-CRREL for his technical expertise in adapting and using the MTS equipment to perform the Gelbo tests and his efforts to conduct  $-40^{\circ}\text{C}$  cold storage tests in the middle of winter. They also thank Jimmy Fowler and Joe Padula for making available a Lightweight Modular Causeway System (LMCS) pontoon for testing. They sincerely thank George Blaisdell at NSF-PLR for his enthusiastic support.

COL Jeffrey R. Eckstein was Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

## Acronyms and Abbreviations

CHL	Coastal Hydraulics Laboratory
CRREL	Cold Regions Research and Engineering Laboratory
ERDC	U.S. Army Engineer Research and Development Center
GSL	Geotechnical Structures Laboratory
LMCS	Lightweight Modular Causeway System
MCS	Modular Causeway System
MTS	Material Testing Systems
NSF	National Science Foundation
PLR	Division of Polar Programs
USAP	United States Antarctic Program



## Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
inches	0.0254	meters
ounces (mass)	0.02834952	kilograms
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
square feet	0.09290304	square meters
square yards	0.8361274	square meters
yards	0.9144	meters



# 1 Introduction

The National Science Foundation's United States Antarctic Program (USAP) is constantly striving to introduce to their program materials, methods, and equipment that will increase the efficiency of its logistics and operations activities. During the past several seasons, the ice pier at McMurdo Station has not been viable at all or has only lasted one season, and its construction is labor intensive and sensitive to environmental conditions. The ice pier is vital to Antarctic operations as it is the point where the annual resupply ship is offloaded and retrograde (off Ross Island back to the contiguous U.S.) cargo is loaded each summer.

The Army's Modular Causeway System (MCS) was successfully deployed during the 2011–2012 resupply effort in place of the ice pier. Though durable and effective, the MCS and similar commercial systems are heavy and require a large area for storage. Researchers at the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), developed the Lightweight Modular Causeway System (LMCS) concept to be much lighter than the MCS (about 35 lb/ft<sup>2</sup> compared to about 74 lb/ft<sup>2</sup>) and also to use inflatable (vs. hard sided) pontoons so it occupies much less storage and transport volume. In addition, CHL is developing an upgrade for the LMCS that will include fore and aft lateral connections to allow for any final configuration that is needed for the ship offload and onload in McMurdo. Currently, the segments can only be connected end to end, which limits users to a long, narrow causeway system whereas the enhanced connections will allow users to construct a pier-like system of virtually any width and length dimensions required to support ship offload and vehicle operations.

The purpose of our project is to conduct a laboratory performance assessment of the inflatable pontoon fabric to determine whether it is ready for a field test at McMurdo Station or if the ERDC Cold Regions Research and Engineering Laboratory (CRREL) should investigate additional, more durable fabrics.

## 2 Field-Service Conditions, Performance Requirements, and Test Plan

The LMCS system will be used during the late summer season in McMurdo (February); and the pontoons may be filled, lifted, and transported at ambient air temperatures ranging between  $-30^{\circ}\text{C}$  and  $+5^{\circ}\text{C}$  (most of the activity is expected to take place when temperatures are around  $-10^{\circ}\text{C}$  to  $0^{\circ}\text{C}$ ). The pontoons must also survive temperatures approaching  $-55^{\circ}\text{C}$  during the winter if they are stored outside at McMurdo Station. To help avoid catastrophic failure, the pontoons must behave elastically while being inflated, lifted, used as an active causeway during offload and onload activities, folded for storage, and transported to and from storage locations. Though not part of this study, the high latitude, 24-hour summer daylight and potential outdoor storage also have the potential to create significant UV exposure that could impact material performance over time. Accelerated UV exposure tests are standard and can be conducted on these materials at any time in the future.

The LMCS was developed with primary funding from the U.S. Army Corps of Engineers Research, Development, Test, and Evaluation effort. ERDC CHL and Geotechnical Structures Laboratory (GSL) made available to CRREL for testing a full-sized LMCS pontoon at no charge to the project. The pontoon material is a 60 oz/yd<sup>2</sup> neoprene on nylon, Mil-C-14505, type 7 designation. The manufacturer specifications suggested that the material would meet our service conditions and performance requirements. In addition, CRREL also tested a neoprene coated compound with added aramid milled fiber (commonly referred to as a *gum sheet*), Mil-C-14505, by itself and as a compound material vulcanized to the pontoon fabric. The LMCS development team envisions applying the gum sheet to the exterior of the pontoons to provide an added measure of abrasion resistance for the final concept.

In addition to meeting environmental and operating conditions, we expect the full-scale pontoons to achieve a service life of multiple years (perhaps as many as 10 years). Thus we selected a target of 10 cycles of folded cold storage at  $-40^{\circ}\text{C}$  followed by unfolding and inflation at approximately  $0^{\circ}\text{C}$  to represent a multi-year deployment, redeployment, and storage analog.

Future tests of the complete LMCS system are required to determine life-cycle replacement costs for the entire causeway.

### 3 Gelbo Flex Test Descriptions and Results

We performed all tests in a temperature-controlled test chamber on a closed-loop, electro-hydraulic Material Testing Systems (MTS) machine. It has a 25,000 lb actuator with a 6 in. stroke. The insulated test chamber measures 20 in. wide, 36 in. deep, and 40 in. high. Our system additionally has a cascade refrigeration system, which circulates cold air by using a thermocouple in the exiting air stream as feedback to control chamber temperature ( $\pm 0.1^{\circ}\text{C}$ ). The chamber is capable of reaching and maintaining  $-70^{\circ}\text{C}$ .

The Gelbo flex test (ASTM F392\*) is a standard test to evaluate fabric materials under conditions of severe flexing. These tests are not routinely conducted at temperatures relevant to Antarctic needs, and most manufacturers do not know how various combinations of woven fabric and bonded coatings will perform when flexed at  $-40^{\circ}\text{C}$ .

The Gelbo test imposed a combined  $440^{\circ}$  rotation and 5.5 in. compression on the fabric specimens to “condition” them. All specimens were 3.5 in. wide with an approximate gage length of 6 in. The resulting flexing and folding was more severe than we expect will be imposed on pontoons during handling, transport, folding, and use as part of the LMCS system at McMurdo Station. We ran up to 1510 cycles (4 s duration per cycle) on the pontoon fabric specimens and assessed them at 500-cycle intervals for cracks, delamination, or other visual evidence of failure (Figure 1).

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\* ASTM International, *Standard Practice for Conditioning Flexible Barrier Materials for Flex Durability* (West Conshohocken, PA: ASTM International, 2011), ASTM F392/F392M-11.

Figure 1. Photo sequence of LMCS pontoon material undergoing Gelbo flex tests at  $-40^{\circ}\text{C}$ . The apparatus imposed a  $440^{\circ}$  rotation during the first 3.5 in. compression, followed by straight compression for 2.0 in. Each cycle took 2 s to compress the specimen and 2 s to reverse the motion (4 s total cycle time). A mirror allowed visual inspection of the back of the specimen without removing it from the apparatus.



ASTM F392 does not specify how to assess the effects of flexing on the specimens. We chose to use visual inspection followed by an air-permeability test to assess relative flex durability. After conditioning, we visually inspected each specimen for signs of cracking or delamination of the coating from the embedded woven fabric. We marked such regions on the specimen and then conducted a check for air leakage at room temperature. The leakage-test apparatus consisted of two aluminum disks with embedded O-rings, with the upper disk connected to an air reservoir. After pressurizing with air, we sealed off the air reservoir and monitored disk pressure over several minutes to assess the leakage rate (Figure 2). The difference in leakage rates between intact and cracked specimens was readily apparent.

Figure 2. After conditioning material specimens in the Gelbo flex apparatus for a number of cycles, we removed and inspected them for cracks (left) and then clamped over the cracked areas with a leakage-test apparatus to assess failure (right).



We also conducted standard Gelbo tests on the gum-sheet fabric samples and conducted modified Gelbo tests on the vulcanized samples. It was necessary to modify the Gelbo procedure for testing heavier, vulcanized (or very thick) fabrics because the Gelbo test apparatus can be damaged by the rotational forces required to rapidly bend these extremely stiff, frozen specimens. For our test of the vulcanized samples, we reduced the total rotation to  $250^\circ$  and the compression to 2 in. (Figure 3). We ran the first 10 cycles for each of these samples 5 s/cycle to reduce the possibility of damaging the test equipment, and we ran the subsequent 1190 cycles at 1.5 s/cycle.

To evaluate the vulcanized samples further and to simulate potential vibration during use and transport, we installed them in the Gelbo apparatus and slowly brought down the crosshead until it had completed its full  $440^\circ$  rotation and 5.5 in. of total stroke (i.e., half a Gelbo cycle) at room temperature. Then we cold-soaked the specimens at  $-40^\circ\text{C}$  and programmed the MTS machine to cyclically execute  $\pm 0.5$  in cycles at 0.5 s periods (4.5–5.5 in. stroke range at 2 Hz) for 10,000 cycles. Table 1 presents the results for all Gelbo-related tests.



Figure 3. Vulcanized pontoon fabric sample at full compression during Gelbo flex test at  $-40^{\circ}\text{C}$  (left) then at full extension following the test (right). Note folds in the sample following the completion of the tests.

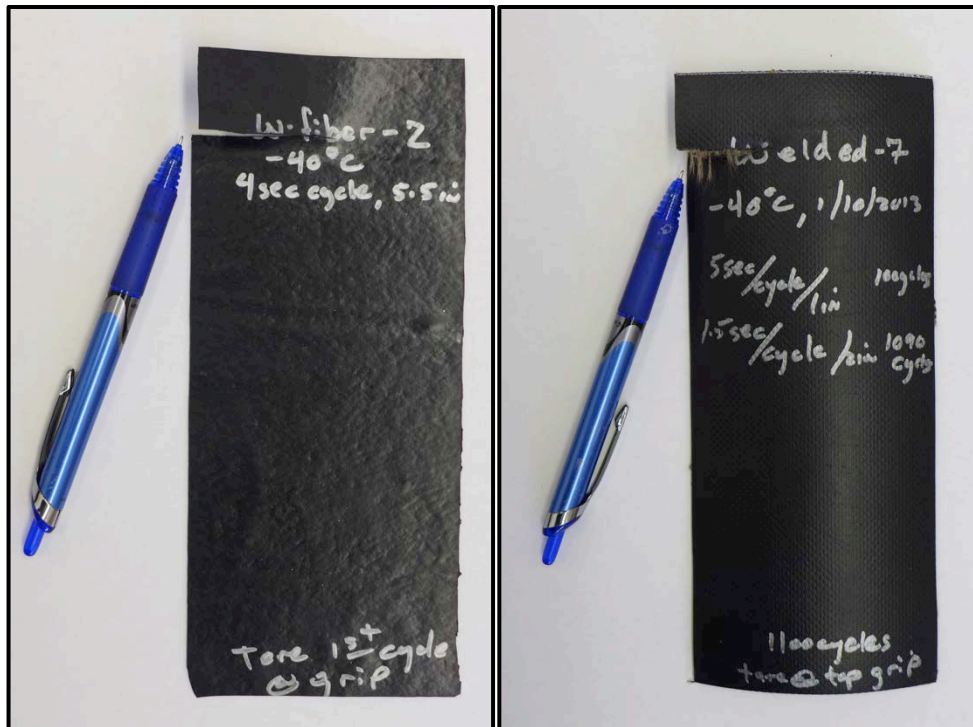


Table 1. Gelbo flex test results for the LMCS pontoon fabric, gum (abrasion) sheet, and composite fabric (the gum sheet vulcanized to the pontoon fabric).

Sample Number	Sample	Temp. ( $^{\circ}\text{C}$ )	Compression Rate (in./s)	Twist Angle (degrees)	Total Cycles	Damage
Pontoon-1	LMCS fabric	$-40$	2.75	440	1510	None
Pontoon-2	LMCS fabric	$-40$	2.75	440	1510	None
Pontoon-3	LMCS fabric	$-40$	2.75	440	1510	Leaked at 510 cycles
Fiber-1	Gum sheet	$-40$	2.75	440	1	Tear at grip
Fiber-2	Gum sheet	$-40$	2.75	440	1	Tear at grip
Welded-5	Vulcanized	$-40$	0.80	250	10	None
			2.70	250	1100	None
Welded-6	Vulcanized	$-40$	0.80	250	10	Tear on sides
			2.70	250	1100	No leak
Welded-7	Vulcanized	$-40$	0.80	250	10	Tear at grip
			2.70	250	1100	No leak
Welded-2	Vulcanized	$-40$	4	0	10,000	No leaks
Welded-3	Vulcanized	$-40$	4	0	10,000	No leaks
Welded-4	Vulcanized	$-40$	4	0	10,000	No leaks

The LMCS pontoon fabric (samples Pontoon-1 to 3) fared well in the extreme Gelbo tests with only the third sample developing a crack, which leaked after 510 cycles. The gum sheets (Fiber-1 and Fiber-2) tore immediately at the grip locations (Figure 4). Two of the vulcanized fabric (gum sheet bonded to pontoon fabric) tore at the sides, likely due to edge-effects from the test apparatus (Figure 4), during the complete Gelbo cycle tests; but none of the specimens developed leaks in the central part of the sample and none of the bonded fabrics developed tears or leaks during the rapid cycling, minimal compressive tests.

Figure 4. Tears in the gum-sheet (abrasion) material (left) and the vulcanized (welded) compound (right) resulting from a failure at grip location during Gelbo flex tests at  $-40^{\circ}\text{C}$ . Note that these failures were likely due to stress concentrations caused by extreme edge-effect conditions of the test procedure and not from folds imposed by the Gelbo test.



Our assessment is that the pontoon fabric performed very well considering the extreme nature of the Gelbo tests compared with the expected field conditions under which the LMCS will be deployed and stored. The edge-tears in the vulcanized fabrics were likely due to stress concentrations imposed by the test method that are not indicative of field conditions. The result obtained from the gum-sheet material should not be considered a “failure” but rather an observation that it should be relied upon only for abrasion resistance.

## 4 Full-Scale Pontoon Cold Storage and Inflation Tests

CHL and GSL made a full-scale pontoon available to CRREL for testing. The objective of these tests was to determine whether the folding, cold storage, unfolding, and inflation sequence would have the potential to cause cracking or leaks in the fabric or fabric joint welds. Upon receiving the pontoon, we inflated it and determined that there were 5 leaks caused from prior use as the pontoon was taken from a prototype LMCS that had undergone extensive field testing (Figure 5). Once we identified 4 of the 5 locations using a soap-bubble product and, based on leak rates (rate of bubble production), the relative sizes of the damage, we determined that only the fifth site (identified visually and audibly) was large enough to require patching (Figure 6).

Figure 5. The LMCS pontoon as delivered to CRREL and partially inflated prior to leak identification and patching.



Figure 6. Bubbles forming above a small leak in a thumbnail-sized arc (left), and 2 large gouges at the center of a section prepared for patching (right). The gouges on the right are each approximately the size of a quarter, and the entire prepared area is approximately 8 × 6 in.



The test plan called for the 25 ft long × 5 ft diameter pontoon to be tri-folded longitudinally and then tri-folded transversely and stored in a cold room for 24 hr at  $-40^{\circ}\text{C}$  (Figure 7) prior to unfolding and immediate inflation outdoors. We conducted ten folding–cold storage–unfolding–inflation test cycles during the New Hampshire winter (between 25 January and 13 March 2013) to best represent the summer daytime temperatures at McMurdo Station. Our previous material-testing experiences helped determine the recommended timeframes for cold soaking the pontoon and subsequently inflating the pontoon and letting it rest outdoors to equilibrate and to provide sufficient pressure data to determine whether leaks were present. We selected a minimum cold soaking period of 24 hr and a minimum inflation period of at least 2 diurnal cycles.

Figure 7. LMCS pontoon tri-folded in 2 directions (left) and ready for cold cycling at  $-40^{\circ}\text{C}$  in CRREL's basement cold room (right).



We calculated and compared the rate of air mass loss over time rather than reporting only the internal air pressure because the pressure reflected temperature swings (particularly the diurnal swings while the pontoon was outside) while potentially masking the volume of air leakage. To calculate air mass loss, we designed and constructed a data monitoring system that measured and recorded the internal pontoon temperature, the external (ambient) air temperature, and the pontoon gauge pressure and fitted the instruments to the pontoon's pressure relief valve (Figure 8). In this test, it was reasonable to assume the ideal gas law applied to a fixed volume of air because the pontoon fabric was not designed to expand or shrink and the relative diurnal temperature swings were expected to be only  $\pm 20^{\circ}\text{C}$ .

Figure 8. Pressure transducer and thermocouple instruments fitted to the pontoon's pressure relief valve (left) and data monitoring system that measured and recorded the internal pontoon temperature, the external (ambient) air temperature, and the pontoon (gauge) pressure (right).



We conducted a baseline air mass loss test just outside of the cold room in the basement of CRREL prior to initiating the cold cycling test sequence. We later compared the baseline air mass loss rate with an identical post-test baseline loss rate to determine whether or not the cold cycles and folding and unfolding caused additional damage to the pontoon. We also measured and recorded air temperatures and pressures during the exterior inflations between cold cycles and calculated air mass loss rates during each of those tests (Figure 9).

Figure 9. Inflating the LMCS pontoon outdoors during post cold-cycle test 3. Note that instruments are not yet installed in the pressure relief valve at the far end of the pontoon as per Figure 8 above.



Based on the manufacturer's specifications, we established the target pontoon inflation pressure to be 1.8–2.0 psi (the maximum design pressure for the pontoons is 3.0 psi). After allowing the large patched area to cure, we inflated the pontoon to approximately 1.9 psi and determined the background air mass loss rate for the pontoon at the ambient basement air temperature (about 13°C). We applied a linear regression analysis to the air mass loss calculations to determine the air mass loss rate. The average air mass loss rate for 25–30 January 2013 was  $-0.020$  lb/hr. Table 2 contains the air mass loss rate and notes from each test and Appendix A illustrates comparisons of the two baseline and post cold-cycle inflation tests.

Following the baseline test, we tri-folded the pontoon in both directions (as discussed above) and placed it in the cold room at  $-40^{\circ}\text{C}$  for 24 hours; and we then removed it from the cold room and placed it outside. There, we immediately unfolded the pontoon, installed the instruments in the pressure relief valve, and inflated the pontoon to approximately 2.0 psi, leaving it outside for approximately 70 hr. We repeated this process nine additional times and conducted a post cold-cycle baseline test inside the basement.

**Table 2. Results of the LMCS pontoon inflation tests during cold cycling to  $-40^{\circ}\text{C}$  for 24 hr and inflation outdoors for 2 diurnal cycles.**

Mass Loss Test	Date	Test Duration (hr)	Air Mass Loss Rate (lb/hr)	Test Notes
Pre-Cold-Cycle Baseline	25–30 Jan. 2013	87	0.020	Equals 5% air mass loss from time of inflation.
Post-Cold Cycle #1	1–4 Feb. 2013	70	0.020	Lengthy test due to weekend.
Post-Cold Cycle #2	5–7 Feb. 2013	40	0.047	Strong diurnal temperature swings.
Post-Cold Cycle #3	11–13 Feb. 2013	38	0.041	Very warm ( $+5^{\circ}\text{C}$ ) daytime temperature at 25 hr mark.
Post-Cold Cycle #4	14–16 Feb. 2013	46	0.025	Warm daytime ( $+10^{\circ}\text{C}$ ) and nighttime ( $-5^{\circ}\text{C}$ ) temperatures.
Post-Cold Cycle #5	17–19 Feb. 2013	n/a	n/a	High winds caused sensors to disengage from pontoon valve. Test not valid.
Post-Cold Cycle #6	20–22 Feb. 2013	22	0.046	Pressure sensor O-ring leaked for first 23 hr. Gage was repositioned, pontoon re-inflated, and test data valid from 23 to 45 hr.
Post-Cold Cycle #7	25–27 Feb. 2013	42	0.060	
Post-Cold Cycle #8	1–4 Mar. 2013	n/a	n/a	Pressure transducer O-ring leaked over weekend test. Data not valid.
Post-Cold Cycle #9	5–7 Mar. 2013	46	0.033	
Post-Cold Cycle #10	8–11 Mar. 2013	70	0.041	Lengthy test due to weekend.
Post-Cold-Cycle Baseline	11–13 Mar. 2013	43	0.014	Equals 2% air mass loss from time of inflation.

## **5 Discussion of Pontoon Cold-Cycle Test Results**

Upon the pontoon fabric's successful survival of the Gelbo flex tests (ASTM F392) we set out to determine the impact of extreme cold cycling of a full-scale LMCS pontoon. As noted above, we patched a significant leak on the previously used pontoon and conducted a baseline air mass loss test to determine the background leak rate of the pontoon prior to cycling it to  $-40^{\circ}\text{C}$  in a cold room. The initial background leak rate was 0.020 lb/hr (air mass loss), or approximately 5% of the original air mass over a period of 87 hr.

Following 10 cycles of folding, cold storage, unfolding, inflating, pressure measurements, deflation, and refolding, the final background leak rate was 0.014 lb/hr (air mass loss), or approximately 2% of the original air mass over a period of 43 hours. Using a linear regression model and assuming constant loss over time, we calculated the final background leak rate at 87 hr to be 4.3% of the original air mass. Considering the different ambient air temperatures and initial inflation pressures, these results are nearly identical and lead us to conclude that the cold cycles and folding and storage procedures did not add leaks or exacerbate the small leaks detected prior to the test.

We did find that the white painted-on pontoon coating cracked in fold locations (see Figure 10) during the tests. Note that we attempted to fold the pontoon along the same axes during each cycle to simulate annual cold storage conditions at McMurdo Station. Despite the cracks in the coating, we did not notice any cracks forming in the base pontoon fabric or any increase in size of the existing holes identified prior to the tests.



Figure 10. Cracks in the white painted-on coating formed at the “double-fold” points. We identified these cracks while unfolding the pontoon prior to inflation after Cold Cycle #3. Note that cracks in the coating did not affect pontoon performance.



A final observation in the analysis of the air mass loss data determined that the pontoon had higher mass loss rates in 7 of the 8 valid tests than it did during the two baseline tests. We suspect that temperature changes caused by diurnal cycling and direct exposure to the sun contributed to air loss in two ways: (1) by causing increased internal pressures and (2) by affecting the elasticity of the pontoon fabric. These changes would make it easier for air to escape at the small leak locations while it was outdoors than when it was at a relatively consistent basement temperature during the baseline tests.

## 6 Conclusions and Recommendations

The National Science Foundation (through the USAP) is constantly striving to improve efficiency and reliability of its support operations in Antarctica. The annual ship offload has historically been dependent on the formation and maintenance of an ice pier during annual ship resupply efforts. The ice pier can be unreliable; and during the 2011–2012 season, it was not serviceable, and the resupply required use of the Army's MCS. Success of that system, coupled with improvements to develop a lightweight version of the system, led the USAP to have CRREL test the inflatable LMCS pontoons to determine whether they can function in the demanding Antarctic environment.

We conducted Gelbo flex tests on the pontoon fabric and its gum sheet (abrasion layer) at the minimum service temperature of  $-40^{\circ}\text{C}$ . The 60 oz/yd<sup>2</sup> neoprene on nylon, Mil-C-14505, type 7 designation pontoon fabric performed well during the Gelbo tests. One of the three samples leaked during pressure tests after 510 cycles while the remaining 2 samples survived intact for all 1510 cycles. These results indicated the prototype pontoon was ready for full-scale cold-cycle tests. Though the gum-sheet abrasion layer tore immediately, which indicated it has no value as an air vessel, this did not eliminate its value as an abrasion layer.

We also conducted modified Gelbo flex tests on vulcanized samples of the composite neoprene-on-nylon pontoon fabric bonded to the neoprene-coated compound with added aramid milled fiber gum sheet. Two of these three samples tore at their edges (likely due to stress concentrations caused by the extremely stiff compound material in the testing apparatus), but none of them leaked in the center region of repetitive folds after 10,000 cycles. Because the pontoon fabric (without the gum-sheet abrasion layer) did not experience sudden, brittle, or catastrophic failures, we proceeded with full-scale cold-cycling tests of a prototype pontoon provided by ERDC CHL and GSL. The pontoon sample was not vulcanized but was painted with a white surface coating.

The full-scale pontoon contained some leaks (one of which was repaired prior to testing) but performed well during 10 cycles of cold soaking at  $-40^{\circ}\text{C}$  followed by unfolding and rapid inflation outdoors. Baseline air

mass loss calculations before and after the cold cycles indicated that the leak tests caused no new leaks or damage. The baseline leak rates before and after testing were 0.020 lb/hr and 0.014 lb/hr, respectively. Outdoor leak rates during the tests varied between 0.020 lb/hr and 0.060 lb/hr, which appeared to indicate that diurnal fluctuations, direct exposure to the sun, and colder outdoor temperatures likely influenced the rate of air loss from the existing leaks. We did not locate on the pontoon material any new or increased damage caused by the cold-cycling tests.

Based on our reported results from Gelbo flex tests of the fabric and the full scale cold-cycling tests of the prototype pontoon, we recommend a field trial of the LMCS at McMurdo Station, provided the remaining components are suitable for the logistical needs and can function in the required environmental conditions.

# REPORT DOCUMENTATION PAGE

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<b>13. SUPPLEMENTARY NOTES</b> Engineering for Polar Operations, Logistics, and Research (EPOLAR)						
<b>14. ABSTRACT</b> The National Science Foundation is constantly striving to improve the efficiency and reliability of its support functions for the United States Antarctic Program. The annual ship offload at McMurdo Station is currently dependent on an unreliable ice pier; and a lightweight, rapidly deployable floating causeway system is one potential solution to mitigate challenges associated with the ice pier. This assessment focused on determining the durability and strength of the pontoon fabric when tested at Antarctic temperatures by using a cold-modified Gelbo flex (ASTM F392) test. The neoprene on nylon pontoon fabric performed well during the Gelbo tests. One of the three samples leaked during pressure tests after 510 cycles while the remaining 2 samples survived intact for all 1510 cycles. In addition, the full-scale pontoon was cycled through 10 periods of cold soaking at -40°C followed by rapid inflation outdoors. Baseline air mass loss calculations before and after the cold cycles indicated that the tests caused no leaks or damage. Based on these results, a field trial of the LMCS at McMurdo Station is recommended provided the remaining components are suitable for the logistical needs and can function in the required environmental conditions.						
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