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DETERMINATION OF THE AIRWORTHINESS OF ZPG-3W COTTON D-621 AND THE ZPG-2 DACRON GDC-5 AIRSHIP ENVELOPES

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FINAL REPORT

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two nonrigid airship envelopes were removed from storage at NAS, Lakehurst, New Jersey., where they were placed in 1961. The envelopes were inspected to determine their suitability for further flight service. These were a ZPG-3W 1,496,000 cu. ft. cotton envelope (D621) and a ZPG-2 975,000 cu. ft. Dacron envelope (GDC-5). The inspection consisted of internal and external visual examination and removal and tests of specimens. The ZPG-3W envelope was found to be extensively damaged due to conditions under which

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it was stored. It was judged irrepairable and was scrapped. The ZPG-2 envelope was in good condition generally. An area of the upper surface exhibited low interply adhesion and reinforcement of that portion was recommended prior to applying loads of any magnitude. The envelope was considered to be suitable for further flight service when reinforcement of the upper surface was accomplished.

SUMMARY

During March 1976, two nonrigid airship envelopes, formerly used with airship models ZPG-3W and ZPG-2, were removed from storage and inspected to determine their suitability for further flight service. The two envelopes had been in storage at the NAS (Naval Air Station), Lakehurst, New Jersey since 1961 and were subject to an adverse environment of occasional rain soaking, and uncontrolled temperature and humidity.

The ZPG-3W airship cotton envelope D-621, design volume of 1,496,000 cubic feet, was examined first and found to be extensively deteriorated. The deterioration was of such a nature and extent that the envelope was judged irrepairable and was scrapped.

On examination, the ZPG-2 airship Dacron envelope (GDC-5), design volume of 975,000 cubic feet was found to be in good condition generally. An area of the upper surface exhibited low interply adhesion. It was recommended that the area of low interply adhesion be reinforced or replaced prior to use. The envelope was considered to be suitable for further flight service following repair of the upper surface and providing that the loading conditions and stresses involved in use do not exceed design values.

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INTRODUCTION

A ZPG-3W and a ZPG-2 airship envelope were placed in storage at the NAS, Lakehurst since 1961 and 1962 when the Navy discontinued the use of airships as operational aircraft. The ZPG-3W envelope was a cotton fabric type 1,496,000 cubic feet in volume, with manufacturer's Serial Number D-621. The ZPG-2 was a 975,000 cubic feet Dacron (polyester) type, Serial Number GDC-5.

These envelopes were stored in the envelope storage fingers of the Fabric Shop, Building No. 123 which was specifically designed for such purposes and was originally equipped to maintain controlled environmental conditions. During the 14 years of storage, however, efforts to furnish a controlled atmosphere stopped; the air conditioning equipment had been removed. In addition, the building itself was in need of repair. Hence, both envelopes were subjected to temperature and humidity variations produced by climatic changes and to accumulations of rainwater from leaks in the roof.

Because of recent interest in the Navy in new uses for LTA vehicles such as reconnaissance, transporation, and heavy lift operations, a possible need was seen for employing the stored envelopes in experimental programs. Preliminary examinations of the envelopes were made while they were in storage. These included removal of a few specimens of fabric for physical tests. On the basis of these tests, reference (a), and the visual appearance of the fabric, it was concluded that a full and detailed inspection was warranted to determine airworthiness and the NAVAIRDEVCEN (Naval Air Development Center) was charged by the NAVAIRSYSCOM (Naval Air Systems Command) (AIR 03P3) to conduct the inspection.

The detailed inspection was performed primarily by personnel from NAVAIRDEVCEN and National Aeronautics and Space Administration Headquarters, assisted by personnel from the United States Air Force Range Measurement Laboratory.

On removal from storage and during the "unrolling" the ZPG-3W cotton hull was found to contain large quantities of water within the folds especially concentrated on the top center area. The forward and aft ends had been folded into and laid on the center top.

The aft end of the envelope had the characteristic musty smell of mildew and the fabric was uniformly stained with the naturally produced pigments of mildew. Mildew had fed on the cotton fabric of the aft end completely rotting and weakening the fabric.

Other fabric areas, in contact with water, were similarly stained but to a lesser degree. Sample fabric discs were removed from both stained and unstained areas. Physical tests confirmed the degradation of the strength in the stained areas.

The decision was made to scrap the ZPG-3W envelope and to validate the airworthiness of the ZPG-2 Dacron envelope, (GDC-5).

On removal from storage, and after the unfolding, the center top of the ZPG-2 hull (GDC-5) was found to be wet. The inspection consisted of internal and external examination and removal and test of specimens. The GDC-5 envelope was in good condition generally. An area of the upper surface exhibited low interply adhesion.

HISTORY AND BACKGROUND

1. ZPG-3W Cotton Envelope D-621

The ZPG-3W cotton envelope was constructed in 1959 - 1960 by the Goodyear Aerospace Corporation (formerly Goodyear Aircraft Corporation) of a two ply cotton neoprene material; a bias outer ply and a straight inner ply. The basic dimensions were 85 feet by 403 feet, reference (b). The panels and gore seams of the envelope were bonded, double stitched and taped. There were four ballonets within the envelopes; one forward, one aft and two amidship. The ballonets were constructed of a two ply neoprene coated nylon fabric. All fabrics were designed for operation in temperatures from 25°F. to 140°F.

The D-621 envelope was built as a spare as part of the contract for the ZPG-3W airships. Upon delivery to the Navy, it was placed in storage at Lakehurst. The envelope log could not be located and therefore a detailed service history is not available.

2. ZPG-2 Dacron Envelope GDC-5

The GDC-5 was constructed by the General Development Corporation (no longer in business) in 1960 of a two ply neoprene coated Dacron polyester fabric bonded together with neoprene and neoprene hypalon (aluminum) coating on the surface; a bias outer ply and a straight inner ply. The four ballonets were constructed of a two ply lightweight nylon.

The envelope was configured for use with either a ZPG-2 or ZPG-2W type airship installation. The ZPG-2/2W was a smaller airship envelope than the ZPG-3W; 75 feet by 339 feet.

A compilation of data on the GDC-5 was obtained from H. Walker, reference (c). The information was garnered from O&R (Overhaul and Repair) inventories, status tests and the airship flight logs.

The GDC-5 was completed 10 November 1960. The airship was delivered and placed in storage in December 1968.

The envelope was first erected on airship ZPG-2, No. 141560 in 1960. Envelope GDC-5 was modified to the ZPG-2 configuration prior to its inflation.

Between March and June 1961, the ZPG-2, No. 141460 (with envelope GDC-5) logged 56 flights or a total of 694.1 flight hours.

On 30 June 1961, all fleet airship flight activity was halted and ZPG-2, No. 141560 was decommissioned and envelope GDC-5 was stored. Two research and development airships remained in flight status. One of these, the ZPG-2, No. 141561, remained in service for 14 more months. On 2 August 1961, No. 141561 was ordered transferred from Naval Air Development Unit, South Weymouth to Lakehurst for assignment to Airship Test and Development Squadron. Envelope GDC-5 was installed on ZPG-2, No. 141561. After GDC-5 was installed, the ZPG-2, No. 141561 airship made 61 flights through August 1962 logging 618.2 flight hours. Many of the components including the envelope of ZPG-2, No. 141561 were stored at NAS, Lakehurst following its decommissioning.

Summing up the entire service, the GDC-5 envelope has logged 1,312.3 total flight hours on the two airships with 117 flights.

EQUIPMENT AND MATERIALS

When the airship components were placed in storage at NAS, Lakehurst in 1961, the Navy technology of the O&R of airships came to a complete halt. Consequently, it was not surprising that many problems and difficulties were encountered in amassing the needed equipment, materials and personnel to undertake the task of inspecting an airship.

Little in the way of equipment for airship envelope maintenance and inspection was known to be available at NAS, Lakehurst. Through the cooperation of station personnel, a few experienced airship O&R technicians were located, some of whom still retained the tools used in the O&R of airships.

Both cotton and Dacron repair materials were supplied by the Goodyear Aerospace Corporation. Fortunately, useable material of the proper weight and strength still existed in sufficient quantities.

A detailed list and description of the equipment and tools used during the inspection are presented in the Appendix.

EXAMINATION TECHNIQUES AND FINDINGS

Two methods of examination were used to determine the condition and airworthiness of the envelope: (1) Visual inspection and (2) Laboratory testing of samples removed from the envelope.

The necessary manpower (70 - 80 persons) necessary to move, unroll and position the envelope were employed through a contractor, reference (e). The work was divided into three phases as follows:

Phase I - Unroll envelope and position for preliminary inspection.

Phase II - Reposition envelope for further inspection to other side of envelope.

Phase III - Fold the envelope for return to storage.

1. Visual Inspection

The visual inspection was conducted to determine the condition of the envelope fabric, security of bonded seams and to determine any injury to the fabric. Visual inspection included the examination of the surface of the envelope fabric, and the seams, inside and outside the envelopes. The permanently attached ballonets and airlines were also examined, inside and outside.

a. ZPG-3W Cotton Envelope D-621

The D-621 had been stored in a configuration wherein the fore and aft ends had been folded in and laid on the surface of the top center area. After unrolling, it was observed that pools of water were present on the surface of the top center area; the fore and aft ends were wet.

The aluminum-hypalon surface had changed to a bronze color and some cracking of the coating had occurred.

Stained and discolored areas were observed; these occurred in the areas where water had laid or where the fabric had been in contact with the water.

The aft end of the envelope had the characteristic musty odor of mildew and contained the largest area of stained and discolored fabric. On close examination, it was found that the cotton in the aft end had been completely digested, undoubtedly by mildew micro organisms. Nothing remained of the original two ply cotton except the neoprene which was very elastic. The slightest finger pressure created a hole in this area.

b. ZPG-2 Dacron Envelope GDC-5

The GDC-5 had been stored in a configuration similar to the D-621; the forward and aft ends folded into and in contact with the top center area. Again on unfolding, evidence of the presence of moisture was found; the top center area was wet.

The visual inspection was conducted by a group of eight divided into four teams of two each.

A complete inspection report is presented in Tables I, II, III and IV.

In general, the surface of the fabric had a good silver color and appeared to be that of a new fabric. Areas in the top center and the aft and forward ends were, however, discolored and contained a yellowish-green surface deposit. In these same areas, blisters under the tapes were observed and some had trapped water inside, Figure 1. The presence of trapped water was verified in that water spurted out of blisters when pierced with a knife point. During the time the envelope was on the deck, many of the blisters dried. Dried blisters are also seen in Figure 1.

Damage from handling during transport occurred in pattern 38P.

The envelope was partially inflated with air to facilitate the inspection of the inside. The ballonets were entered from the helium chamber by slitting open the access panels.

Inspections of the ballonets were conducted by two person teams; one person was inside and the second person was on the outside carrying a bright light. The outside person passed the light over the ballonet, pattern by pattern, holding the light approximately 8 - 10 inches from the fabric. The person on the opposite side checked for the transmission of the light. Pin holes in the fabric appeared as bright points of light. The ballonet fabric appeared to be in excellent condition. Three holes were found: (1) In the forward ballonet and (2) and (3) in the center port ballonet.

The access slits from the helium chamber were left open for future use.

Load sleeves, access sleeves, inspection sleeves, ECM antenna sleeves, etc., were not inspected.

2. Laboratory Testing

Laboratory testing of sample discs, removed from the envelope, were conducted to determine the strength and permeability characteristics of the fabric at the time of inspection.

Physical tests were conducted in accordance with references (f) and (g); one inch wide specimens were used to enable the maximum number of tests for a given sample disc.

a. ZPG-3W Cotton Envelope D-621

During the removal of the first sample disc frome one of the stained areas, panel 41/gore E, it was noted that the fabric cut with ease. The removed sample disc tore easily with very slight hand pull. Four other test discs were removed, two each from stained and unstained areas. The test results are presented in Table V.

The cotton fabric in the aft end was completely deteriorated. While this cotton condition was fairly local, the physical tests indicated degradation. Specimens from the stained and discolored patterns showed degradation of strength and increased permeability. The stained and discolored areas were undoubtedly evidence of the effect of mildew. Those patterns not subject to mildew, unstained, showed good retention of physical properties, Table VI.

b. ZPG-2 Dacron Envelope GDC-5

Initially, four test discs, spaced over intervals of the top of the Dacron envelope, were removed and tested. The test disc included one from the discolored area (44H).

Examination of the test results, Table VII, indicated that test specimens from the 44H sample disc exhibited extremely low interply adhesion. An effort was made to determine the extent of the poor ply adhesion keeping in mind the need to limit sampling to as few as possible without limiting any critical area. A simple peel test was devised that consisted of the following procedure: (1) a thin-bladed knife was carefully inserted between the two plies of fabric; (2) two parallel cuts, separated by one inch were made on the outer fabric; and (3) a horizontal cut connected the parallel ones thereby forming a tongue. The "tongue" was pulled back. The following patterns were tested with this peel test: (1) 39I; (2) 42I (discolored), (3) 43I (discolored); (4) 43H (slightly discolored); (5) 48I; (6) 52D; (7) 60I and (8) 67H. Of these peel tests, those close to the 44H pattern that exhibited low interply adhesion, behaved in a similar manner. The "tongue" of the 42I, 43I and 43H discolored I patterns peeled back with very little effort and one surface of the ply interface was clean. Test discs were removed from these patterns. The "tongue" of the remaining peel tests required great effort to pull back. These patterns were judged to have good interply adhesion. Sample test discs 43H and 52D were tested by the United States Air Force Range Measurement Laboratory and the results are presented in reference (h). There was good agreement between their test data and the test results of NAVAIRDEVCEN, Table VIII. Low interply adhesion was shown by the test specimens from the sample discs in proximity to pattern 44H.

Test specimens were heated for 16 hours at 100°F to determine if temperature would improve the interply adhesion. Two specimens showed a slight improvement in the ply adhesion and two, a decrease in the ply adhesion, Table VII. Because of the inconclusiveness of these results; no further temperature tests were conducted.

A sample disc was removed from each of the four ballonents. The test results are presented in Table IX.

The results of the fabric tests at the time of manufacture were entered in the envelope manufacturer's log, reference (i). Each roll of fabric had been assigned an individual identification number. The envelope manufacturer's log lists the envelope number, every pattern in the envelope and the number of the roll from which each was cut.

The currently generated physical test data is compared to the original test values, Tables X and XI. The original test values were obtained by consulting the manufacturer's log to find the number of the roll from which the pattern in question was cut. The original test data was then located in the laboratory test records. Examination of the test results shows excellent retention of strength and permeability.

Physical tests were conducted on the Dacron-neoprene repair fabric, Table XII.

3. Electron Microscopy Examination

An electron microscopy examination was made by the Range Measurement Laboratory. The photomicrographs, Figure 2, show that the neoprene pulled off the polyester monofilaments of the better ply adhesion test specimens with difficulty, leaving pull marks (irregular mottled spots). These pulled marks are raised deformations caused by tension. No such pull marks appear on the monofilaments of test specimens with low ply adhesion.

4. Instrumental Analysis and Solubility Tests

Efforts were made to identify the yellowish material deposited on the surface of the fabric with discolored patterns. Infra-red analysis indicate that the material was of inorganic structure; no organic structure was identified. Emission spectroscopy for metallic constituents indicated that the material was predominately of a silicate nature; an inorganic. Microscopic examination further confirmed the inorganic nature of this material.

Solubility tests indicated that the material was insoluble in the solvents used, behaving in a manner similar to vermiculite, a hydrated silicate material.

It is hypothesized that this material is the residue of the talcum powder used to destroy the tack of the excess cement. The dusting powder is a hydrated magnesium silicate, an inorganic material.

R E P A I R S

Repairs consisted primarily of installing patches over cut-outs from which test specimens had been removed.

The repair materials included: (1) polyester (Dacron) two ply fabric (Code N 313-A-130); (2) polyamide (Nylon) two ply fabric (Code N 288-A-220); and (3) Adhesive system (1451 cement and accelerators 983 and 1467C).

The Dacron fabric was of similar weight, strength and permeability to the NH 311E76-15A fabric originally used for the envelope, Table XII. The compatibility of bonding the Dacron fabric to the envelope fabric with the 1451 adhesive system was tested and reported to be satisfactory, reference (j).

The Nylon fabric from current stock was of similar strength and permeability to the N 202B34 fabric originally used. No physical tests were made of this repair fabric due to the limited amount of material.

All repairs to the airship fabrics involved the preparation of the repair materials and the cleaning and preparation of fabric surfaces. These procedures are thoroughly discussed in references (d), Section V, (k) and (1). The specific preparation procedures used for the different surfaces encountered were done in accordance with Table XIII. Trichlorethane 1.1.1 (stabilized) solvent was used. Scotch-Brite was used to buff the surface of the fabric.

In making repairs on the Dacron fabric, it was necessary to use a second accelerator, the 1467-C, to ensure a proper bond. The proper preparations are shown, Table XIV, for the three different mixtures: (1) extra light, (2) light; and (3) heavy.

Nine coats of adhesive were applied to the mating surfaces as follows:

(1) First and second coats - extra light mixture.

(2) Third and fourth coats - light mixture.

(3) Fifth to ninth coats - heavy mixture.

Repair procedures are presented in Section V of reference (d). Patches were placed on the inside and outside of areas requiring repair. Table XIII and XVI include a complete tabulation of the repairs made to the fabric envelope and ballonets.

D I S C U S S I O N

ZPG-3W - It was obvious that the deterioration of the ZPG-3W envelope was caused by bacteriological attack on the natural fiber (cotton) of the fabric. Such evidence as was actually evaluated by specimen removal, and other visual checks was sufficient to indicate to the inspection team that major portions of the envelope were in similar condition and extensive sampling would have been necessary to locate the usable portions. Repairs would have been required to such extent so as to exceed the available supply of materials with no guarantee of 100% airworthiness. It was on this basis that the envelope was scrapped.

ZPG-2 - The discolored patterns of the ZPG-2 were in contact with water. Test specimens from these patterns showed low ply adhesion, and a "clean" peel at the interface.

Neoprene compounds can be affected by moisture. Data, reference (n), available on life jackets and other multiple plies of bonded fabrics, suggest that under conditions of moderate temperature and moisture, neoprene compounds exhibit a phenomena of a loss of adhesion at the interface.

Neoprene and hypalon plus heat degradation or oxidation will yield sulphur, carbon dioxide and hydrogen chloride. The hydrogen chloride in combination with moisture produces hydrochloric acid which attacks the adhesion at the interface. Instead of a cohesive failure where some of the adhesive sticks to each side of the interface, the break at the interface is clean. The adhesive adheres to one side and the other side is "clean".

The Range Measurement Laboratory, reference (h), hypothesized that the poor adhesion was caused by hydrolytic deterioration of the surface of the polyester yarns monofilaments. The electron photomicrographs do not verify that the weak adhesion of the neoprene interply is the result of such hydrolytic decomposition. The photomicrographs, however, do show that the neoprene pulled off the areas of good ply adhesion with difficulty leaving "pull marks" evidenced by the irregular mottled spots. Tension between the plies probably caused these deformations. In contrast, the specimens with poor ply adhesion did not show any "pull marks" but the surface of the polyester monofilaments were smooth.

It was agreed that small but finite tension is provided by neoprene "interlocking" through the interstices of the weave.

There is also data available that when accelerators are used in excess, they will also combine with moisture to cause the breakdown of the adhesion value at the interface. A clean pull will occur between the adhesive and the fabric interface.

The current test data suggests that the low interply adhesion seems to be confined to the top two patterns of the hull (gore H and I) and extends from panel 40 to panel 63. There is also some evidence of poor ply adhesion in the aft and forward ends.

RESULTS

Visual inspection indicated that in general the bonded areas in the ZPG-2 Dacron envelope GDC-5 were intact and the fabric showed little damage.

Laboratory tests of specimens from the sample discs removed from the envelope indicated that, at the time of test, the permeability and strength characteristics were good showing little change from the original test values. The interply adhesion, however, showed deterioration. This deterioration of ply adhesion was especially marked in the discolored areas.

Electron photomicrographs showed that the neoprene in the "better" ply adhesion areas pulled off with difficulty, leaving pull marks. In comparison the areas of poor ply adhesion did not show any pull marks.

Efforts to identify a yellowish surface deposit indicated that the material was of inorganic nature, a siliceous material, probably the talcum powder used to destroy the excess tack of the adhesive system.

CONCLUSIONS

In general, the inside and outside of the envelope fabric and the ballonets (forward, aft, center port and starboard) of the GDC-5 appeared to be in excellent condition.

Physical test results showed little deterioration in the strength and permeability characteristics. Deterioration, however, was evident in the interply adhesion and was particularly marked in the center top gores. The poor ply adhesion was confined to a very limited area and will require future repair. The ZPG-2 GDC-5 Dacron envelope appears to be airworthy.

Personnel from NASA, Range Measurement Laboratory and NAVAIRDEVCEN agreed that the center areas exhibiting low ply adhesion would have to be reinforced or replaced. The exact method of repair would be determined prior to actual commitment to use. The envelope was considered to be in an acceptable condition for further flight use following such repair, provided that the loading conditions and stresses involved in such use did not exceed design values.

RECOMMENDATIONS

It was recommended by the inspection team that the areas of the ZPG-2 Dacron envelope GDC-5 exhibiting low ply adhesion be reinforced or replaced. The exact method of repair should be determined prior to actual commitment to use. The loading conditions and stresses should not exceed design values.

It was further recommended that the airship hull be subjected to a full pressure test to ensure the integrity of the seams.

It was strongly recommended that the envelope be stored in an area that will be safe from rain soaking and with controls on the temperature and humidity.

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(j) Telephone conversation between Mr. G. Faurote Goodyear Aerospace Corp. and Miss E. Th. Vadala of Naval Air Development Center of 12 Mar 1976

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TABLE I

RESULTS OF VISUAL INSPECTION OF GDC-5, GORES A TO P, PANELS 1 THROUGH 31

Gore		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Panel	1														W	W	W
	2														W	W	W
	3														W	W	W
	4														W	W	W
	5														W	W	W
	6														BW	W	W
	7									L					BW	W	W
	8									L					BW	BW	W
	9														BW	BW	W
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B - Blister
C - Chafing
D - Defective Tape

H - Hole
H*- Hole, Ripped and Torn
L - Loose Tape
T - Trapped Water

W - Water Stain
( )- Loose Cover Patch

TABLE II

RESULTS OF VISUAL INSPECTION OF GDC-5, GORES A TO P, PANELS 32 THROUGH 62

Gore		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Panel	32																
	33																
	34																
	35																
	36																
	37																
	38																H*
	39																H*
	40								BWT	BWT							
	41								BWT	BWT	L	L					
	42								BWT	BWT							
	43							(W)	BWT	BWT							
	44							W	BWT	BWT							
	45								BWT	BWT							
	46								BWT	BWT	L						
	47								BWT	BWT							
	48								BWT	BW							
	49								BWT	BWT							
	50				Test Disc Hole				BWT	B(W)T							
	51								BWT	BWT							
	52								BWT	BW							
	53																
	54																
	55		H						(W)	W				Test Disc Hole			
	56		H						W	W							
	57																
	58																
	59																
	60						C										
	61																
	62																

TABLE III

RESULTS OF VISUAL INSPECTION OF GDC-5, GORES A TO P, PANELS 63 THROUGH 93

Gore		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Panel	63																
	64																
	65																
	66																
	67																
	68																
	69																
	70																
	71																
	72																
	73																
	74																
	75																
	76																
	77																
	78																
	78																
	80																
	81																
	82																
	83																
	84																
	85												L				
	86																
	87																
	88																
	89																
	90																
	91																
	92																
	93																

TABLE IV

RESULTS OF VISUAL INSPECTION OF GDC-5, GORES A TO P, PANELS 94 THROUGH 123

Gore		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Panel	94																
	95																
	96																
	97								*								
	98								*								
	99								*								
	100						C		*								
	101								*								
	102																
	103																
	104																
	105																
	106																
	107																
	108																
	109																
	110																
	111																
	112																
	113																
	114																
	115																
	116																
	117										W	W					
	118										W	W	W	W			
	119										W	W	W	W	W		
	120												W	W	W		
	121											W	W				
	122																
	123																

* Defective Cement (crystalized)

TABLE V

TEST RESULTS OF SPECIMENS FROM SAMPLE DISCS FROM THE ZPG-3W, COTTON ENVELOPE, D-621

Panel/Gore		40I Slight Stain	40H Unstained	41I Strongly Stained	84I Unstained
Tensile Strength (lbs./in.)					
Straight Warp	1	182	247	54	225
	2	180	237	60	213
	3	185	223	77	218
	Avg.	182	236	64	219
Filling	1	155	294	30	191
	2	183	198	52	190
	3	167	225	44	186
	Avg.	168	239	42	189
Bias Warp	1	145	190	No	199
	2	152	194	Test	217
	Avg.	148	192		208
Fill	1	238	215	No	205
	2	164	188	Test	206
	Avg.	201	201		205
Weight (oz./yd.^{2})		29.6	28.0	25.3	26.0
Helium Permeability L/sq. m/24hrs.					
	1	56	3.6	Over	2.4
	2	108	1.7	400	2.0
	3	210	11.0		2.3
	Avg.	125	5.4	Over 400	2.2
Ply Adhesion					
	1	13.2	15.8	No	14.8
	2	9.8	15.0	Test	11.2
	Avg.	11.5	15.4		13.0

TABLE VI

COMPARISON OF TEST RESULTS OF SPECIMENS FROM THE ZPG-3W, COTTON ENVELOPE, D-621 TESTED BY NADC (1976) AND GAC (1959)

			40I		40H		41I		84I	
Panel/Gore			Slightly Stained		Unstained		Badly Stained		Unstained	
Original Fabric Identification			N 113 A520		N 113 A530		N 113 A520		N 113 A510	
Fabric Roll No.			8472		8470		8465		8483	
Tested by:			NADC	GAC	NADC	GAC	NADC	GAC	NADC	GAC
Tensile Strength(lbs./in.)										
Straight	Warp	1	182	Not available	247	Not available	54	200	225	210
		2	180		237		60	220	213	212
		3	185		223		77	228	218	212
		Avg.	182		236		64	223	217	211
	Filling	1	155	Not available	294	Not available	30	235	191	218
		2	183		198		53	238	190	210
		3	167		225		44	230	186	208
		Avg.	168		239		42	234	189	212
Bias	Warp	1	145	Not available	190	Not available	No test	210	199	212
		2	152		194			215	217	215
		Avg.	148		192			213	208	214
	Fill	1	238	Not available	215	Not available	No test	234	205	247
		2	164		188			241	206	251
		Avg.	201		201			238	205	249

TABLE VI (Cont'd)

COMPARISON OF TEST RESULTS OF SPECIMENS FROM THE ZPG-3W, COTTON ENVELOPE, D-621 TESTED BY NADC (1976) AND GAC (1959)

Panel/Gore		40I Slightly Stained		40H Unstained		41I Badly Stained		84I Unstained	
		NADC	GAC	NADC	GAC	NADC	GAC	NADC	GAC
Weight (oz/yd.^{2})		29.6	Not available	28.0	Not available	25.3	25.25	26.0	24.10
Helium Permeability L/sq. m/24 hrs.									
	1	56	Not available	3.6	Not available	Over 400	3.4	2.4	3.8
	2	108		1.7			2.8	2.0	3.1
	3	210		11.0			12.4	2.3	3.1
	Avg.	125		5.4		Over 400	3.1	2.2	3.3
Ply Adhesion									
	1	13.2	Not available	15.8	Not available	No test	13.3	14.8	14.5
	2	9.8		15.0			14.3	11.2	14.8
	Avg.	11.5		15.4			13.3	13.0	14.7

TABLE VII

PHYSICAL TESTS RESULTS OF FABRIC DISCS FROM PATTERNS 24H, 44I, 67H AND 87I OF THE ZPG-2 DACRON ENVELOPE GDC-5

Panel/Gore			24H	44H*	67H	87I
Tensile Strength (lbs./in.)						
Straight	Warp		315	300	265	305
			316	286	275	299
			310	289	289	297
		Avg.	314	292	276	300
	Fill		274	260	253	294
			273	256	250	295
			266	262		290
		Avg.	271	259	252	293
Bias	Warp		210	210	196	217
			179	212	206	206
					200	
		Avg.	194	211	201	212
	Fill		190	149**	177	195
			210	162**	164	189
					185	
		Avg.	200	156	175	192
Helium Permeability L/sq. m/24hrs.			0.8	1.1	0.9	0.6
Ply Adhesion (lbs./in.)			7.1	2.0***	6.8	10.4

* Discolored with yellowish white deposit.

** Ply separation observed.

*** Approximated value.

TABLE VIII

PHYSICAL TEST RESULTS OF SAMPLE DISC 39I, 42I, 43H, 43I, 50D, 52D, AND 68I
FROM THE ZPG-2 DACRON ENVELOPE GDC-5

Panel/Gore		39I	42I (Discolored)		43I (Discolored)	43H (Discolored)	50D	52D	68I
Tested by		NADC	NADC		NADC	Range Measurement Lab.	Range Measurement Lab.	NADC	NADC
Tensile Strength (lbs./in.)									
Straight Warp		293	296		293	303	282	290	298
		285	298		296	297	272	290	302
		288			287	306	283	294	306
						312	284		
	Avg.	289	297		292	305	280	291	302
Fill		262	258		252	267	267	263	283
		266	258		250	263	272	241	283
		265			240	269			285
	Avg.	264	258		247	266	270	252	281
Bias Warp			197					214	
			203					213	
	Avg.		200					214	
Fill			160					201	
			160					172	
			160					187	
			Warp	Fill					
Ply Adhesion		4.8	2.8	1.5	2.2	1.85	-	9.2	5.4
(lbs./in.)		5.5	2.8	1.4	2.1	2.0		9.3	6.5
			2.4			1.9			
						1.95			
						1.9			
	Avg.	5.1	2.6	1.5	2.2	1.9	—	9.3	6.0
After 16 hrs. at 100°F		5.0	3.4		-	-	-	7.3	6.2
Helium Permeability		1.0	1.2		1.2	-	0.889	0.6	0.9
L/sq. m/24 hrs.		1.3	1.1		1.0		0.9004	0.6	0.9
		1.1	0.8		0.8				0.8
		1.1	1.0		1.0	—	0.9	0.6	0.9
Weight (oz/yd.^{2})		15.73	31		16.90	16.32	16.14	-	15.73

TABLE IX

PHYSICAL TEST RESULTS OF TEST DISC SAMPLE FROM EACH OF THE BALLONETS

Ballonet Identification		Forward	Aft	Center Port	Center Starboard
Panel/Gore		39I	72A	55B	57B
Tensile Strength (lbs./in.)					
Straight Warp		128	126	194	177
		125	125	186	177
		121	125	180	177
	Avg.	125	125	186	177
Fill		121	120	178	163
		117	123	178	164
		111	121	172	164
	Avg.	116	121	176	164
Ply Adhesion (lbs./in.)		3.8	3.2	4.2	7.0
Helium Permeability L/sq. m/24 hrs.		No[1] test	0.4	1.0	0.3
			0.4	0.9	0.3
			0.4	1.0	0.1
			0.4	1.0	0.2
Weight (oz./yd.^{2})		6.09	6.44	8.00	8.76

[1] Torn sample, could not be tested for permeability.

TABLE X

ZPG-2 DACRON ENVELOPE GDC-5 1976 TEST DATA (NADC AND RML) COMPARED TO THE ORIGINAL 1960 (GDC) TEST VALUES

Panel/Gore	8L		24H		39I		42I		43H		43I		43 Car Canopy	
Original Fabric Identification	NH 311 E76-15A		NH 311 Re 76-15A		NH 311 LE76-15A		NH 311 E76-15A		NH 311 F76-15A		NH 311 F76-15A		NH 311 E61-15	
Fabric Roll No.	251		271		260		230		252		252		149	
Data Generated by:	Test NADC	Original GDC	Test NADC	Original GDC	Test NADC	Original GDC	Test NADC	Original GDC	Test RML	Original GDC	Test NADC	Original GDC	Test NADC	Original GDC
Tensile Strength (lbs./in.) Straight Warp	292	287	315	282	293	250	296	280	303	295	293	295	257	222
	284	280	316	287	285	250	298	265	297	282	296	282	235	240
	281	280	310	300	288	250		265	312	280	287	280	236	244
		275		300		250		275		275		275		232
		260		300		275		275		285		285		235
		250		304		275		272		262		262		238
						280								
Avg.	286	272	314	296	288	261	297	273	304	280	292	280	236	235
Fill	267	262	273	300	262	270	258	260	267	265	252	265	272	221
	250	257	266	300	266	262	258	255	263	275	250	275	273	229
	259	255	274	300	265	262		255	269	267	240	267	276	233
		250		290		262		255		265		265		236
		250		287		260		255		250		250		240
		250		295		257		256		237		237		251
Avg.	259	254	271	295	264	262	258	256	266	258	247	258	272	231
Ply Adhesion (lbs./in.)														
Straight Warp	3.6	12.5	6.2	7.5	4.8	11.0	2.8	20.5	1.85	14.2	2.2	14.2	9.8	11.0
	3.8	13.0	6.2	7.5	5.5	11.6	2.8	20.4	2.0	14.6	2.1	14.6	10.1	14.0
		14.7		7.5		11.4	2.4	19.5	1.9	15.3		15.3		15.0
		9.0		9.5		10.0		10.0	1.95	13.4		13.4		15.0
		9.0		8.3		10.5		9.8	1.9	13.6		13.6		15.0
		8.7		7.5		11.0		16.5		15.3		15.3		16.0
Avg.	3.7	11.2	6.2	8.0	5.1	11.3	2.6	16.1	1.92	14.4	2.2	14.4	10.0	14.4
Helium Permeability														
L/sq. m/24 hrs.	0.9	0.7	0.7	.3	1.0	.1	1.2	0.4	-	.1	1.2	.1	1.0	2.0
	0.8	0.3	1.0	2.0	1.3	.4	1.1	0.9	-		1.0		1.2	1.8
	0.9		0.7		1.1		.8				0.8		0.8	
Avg.	0.9	0.5	0.8	1.2	1.1	0.3	1.0	0.7	—	0.1	1.0	0.1	1.0	1.9
Weight (ozs./yd.^{2})	16.68	16.11		15.82	15.73	15.90		16.03	16.32	16.11	16.9	16.11	15.2	15.79

TABLE X

ZPG-2 DACRON ENVELOPE GDC-5 1976 TEST DATA (NADC AND RML) COMPARED TO THE ORIGINAL 1960 (GDC) TEST VALUES (CONTINUED)

Panel/Gore	44H		46 Car Canopy		50D		52D		67H		68I		87I	
Original Fabric Identification	NH 311 E76-15A		NH 311 E61-15		N 311 E76-15A		N 311 E76-15A		N 311 E76-15A		NH 311 Re 76-15A		NH 311 LE76-15A	
Fabric Roll No.	230		149		218		218		220		262		265	
Data Generated by:	Test NADC	Original GDC	Test NADC	Original GDC	Test RML	Original GDC	Test NADC	Original GDC	Test NADC	Original GDC	Test NADC	Original GDC	Test NADC	Original GDC
Tensile Strength (lbs./in)														
Straight Warp	300	280	243	222	282	272	290	272	265	275	298	300	305	275
	286	265	240	240	272	275	290	273	275	275	302	300	299	287
	289	265	247	244	263	277	294	277	289	287	306	300	297	283
		275		232	284	280		280		287		305		282
		275		235		285		285		280		290		265
		272		238		278		278		275		262		257
Avg.	292	273	243	235	280	287	291	287	276	279	302	293	300	275
Fill	260		228	221	267	240	263	240	253	245	283	275	294	275
	256		217	229	272	242	241	242	250	275	275	290	295	275
	262		226	233		247		247		262	285	290	290	275
				236		247		247		270		282		280
				240		252		252		270		280		285
				251		246		246		270		267		285
Avg.	259	256	224	231	270	242	252	242	252	265	281	280	293	279
Ply Adhesion (lbs./in.)														
Straight Warp	1.2	20.5	9.8	11.0	No test	18.2	8.4	18.2	7.0	22.5	5.4	10.8	10.4	13.4
	2.0	20.4	10.0	14.0		19.5	7.3	19.5	6.8	24.0	6.5	11.2	11.0	15.6
		19.5		15.0		20.0		20.0		25.6		14.3	11.2	15.7
		10.0		15.0		12.6		12.8		18.2		6.0		16.4
		9.8		15.0		15.0		15.0		21.0		8.0		17.2
		16.5		16.0		15.1		15.1		21.5		7.4		17.3
Avg.	1.6	16.1	9.9	14.4	—	16.8	7.8	16.8	6.9	22.1	6.0	10.0	10.9	15.9
Helium Permeability														
L/sq. m/24 hrs.	0.9	0.4	0.8	2.0	0.889	1.2	0.6	1.2	No test	1.8	0.9	.3	.7	.8
	1.2	0.9	0.4	1.8	0.904	1.4	0.6	1.4		1.1	0.9	.2	.6	.5
	1.1		0.7								0.8		.4	
Avg.	1.1	0.7	0.6	1.9	0.89	1.3	0.6	1.3	—	1.5	0.9	0.3	0.9	0.7
Weight (ozs./yd.^{2})	No test	16.03	15.9	15.79	16.14	14.98	No test	14.98	No test	15.40	15.73	15.79	No test	15.98

TABLE XI
NAVAIRDEVCEN 1976 TEST DATA COMPARED TO THE ORIGINAL 1960 (GDC) TEST VALUES

Panel/Gore	39P		72A		55B		57B	
Ballonet Location	Forward		Aft		Center - Port		Center - Starboard	
Fabric Identification	N 202 B 34		N 202 B 34		N 202 B 43		N 202 B 43	
Fabric Roll No.	787-1A		902-1		953-4A		953-2B	
Tested by:	NADC	GDC	NADC	GDC	NADC	GDC	NADC	GDC
Tensile Strength (lbs./in.)								
Strength Warp	128	104	126	110	194	182	177	186
	125	102	125	114	186	183	177	182
	121	103	123	115	180		177	189
				120				
				121				
Avg.	125	—	125	116	186	182	177	186
Fill	121	115	120	102	178	149	163	143
	117	122	123	103	178	159	164	151
	111	101	121	113	172	167	164	157
Avg.	116	113	121	106	176	158	164	150
Ply Adhesion (lbs./in.)								
	3.8	5.3	3.2	6.3	4.2	5.0	7.0	8.9
		5.5		7.8		6.9		10.0
		5.8		4.6		5.0		10.4
		5.1		6.2		5.0		8.0
		5.4		6.8		5.5		8.6
		5.2						9.0
	3.8	5.4	3.2	6.3	4.2	5.5	7.0	9.1
Helium Permeability L/sq. m/24 hrs.			0.4	2.4	1.0	5.6	0.3	0.7
			0.4	2.2	0.9	5.5	0.3	0.4
			0.4		1.0		0.1	
			0.4	2.3	1.0	5.5	0.2	0.6
Weight (oz./yd.^{2})	6.09	5.50	6.44	6.19	8.00	7.41	8.76	7.90

TABLE XII

PHYSICAL TEST RESULTS OF DACRON - NEOPRENE REPAIR FABRIC, CODE N 313A130

Dacron - Neoprene Fabric Code No.	N 313-A-130
Tensile Strength (lbs./in.)	
Straight Warp	279 277 291 279
Fill	253 250 240 248
Bias Warp	257 276 265 264
Fill	232 245 230 236
Adhesion Between Plies (lbs./in.)	9.4 7.3 8.4
Helium Permeability L/sq. m/24 hrs.	0.4 0.4 0.4 0.4
Weight (oz./yd^2)	15.66

TABLE XIII

SUMMARY OF SURFACE PREPARATION FOR CEMENTING

NOTE NAVWEPS 01-195-503 Section V

Any surface completely prepared for repairs must be dry, clean, reasonably smooth; free from oil or paraffin, reasonably free from paints and pebbled-cement, uniform in color, and free from streaks.

SURFACE	REMOVE	EXTENT	PROCESS	FINISHED APPEARANCE	PAR. REF
a. Plain NOTE Remove sheen on Dacron fabrics before cementing.	Curing dust	All	Scrub surface* and wash surface with cloth dampened with tolnaphtha solution, Solvesso, trichloroethane 1.1.1 (stabilized), or toluene.	Dark coat is free from dirt streaks and has a velvety appearance and feel.	5-24 5-25
b. Paraffined	Paraffin	All	Buff surface* with fiber bristle brush and wash surface with cloth dampened with trichloroethane 1.1.1 (stabilized).	Dark coat is free from dirt streaks and pinpoints of light. Surface has a velvety appearance and feel.	5-26 5-27
c. Aluminized	Neoprene aluminum paint	Reasonably free of paint coat	Buff surface* and wash surface with cloth dampened with tolnaphtha solution, Solvesso, trichloroethane 1.1.1 (stabilized), or toluene.	Dark grey finish is free from dirt streaks and has even color. Surface has a velvety feel.	5-28 5-29 5-30
d. Exposed (cement-pebbled)	Old cement	Reasonably free of cement	Rub surface with fabric eraser*; wash with cloth dampened with tolnaphtha solution, Solvesso, trichloroethane 1.1.1 (stabilized), or toluene.	Some cement may be firmly attached to surface. Surface is fairly smooth and of an even color.	5-31 5-32
e. Painted with anti-static coating	Anti-static coating and paraffin (refer to "b")	All	Buff surface* and wash surface with cloth dampened with trichloroethane 1.1.1.	Dark coat is free from dirt streaks and has a velvety appearance and feel.	5-32A
f. Coated with anti-radiation paint	Anti-radiation coating and paraffin (refer to "b")	All	Buff surface* and wash surface with cloth dampened with tolnaphtha or trichloroethane 1.1.1 (stabilized).	Dark coat is free from dirt streaks and has a velvety appearance and feel.	5-32D
g. Hypalon-aluminum weather-resistant paint	Hypalon paint down to neoprene coating	All	Rub surface with fabric eraser*; wash with cloth dampened with tolnaphtha solution, Solvesso, or trichloroethane 1.1.1 (stabilized).	Dark grey finish is free from dirt streaks and has even color.	5-30A 5-30B

TABLE XIV

PREPARATIONS FOR MIXTURES OF 1451-C ADHESIVE SYSTEM

Ingredient	Heavy Mixture	Light Mixture	Extra-Light Mixture
Neoprene Cement (1451-C)	1.00 gallon	1.00 gallon	1.00 gallon
Accelerator (983-C)	100 cc	100 cc	100 cc
Accelerator (1467-C)	None	None	200 cc
Trichloroethane 1.1.1 (stabilized)	None	0.33 gallon (43 fluid oz.)	0.50 gallon (64 fluid oz.)

TABLE XV

PERMANENT REPAIRS MADE ON THE ZPG-2 DACRON ENVELOPE, GDC-5

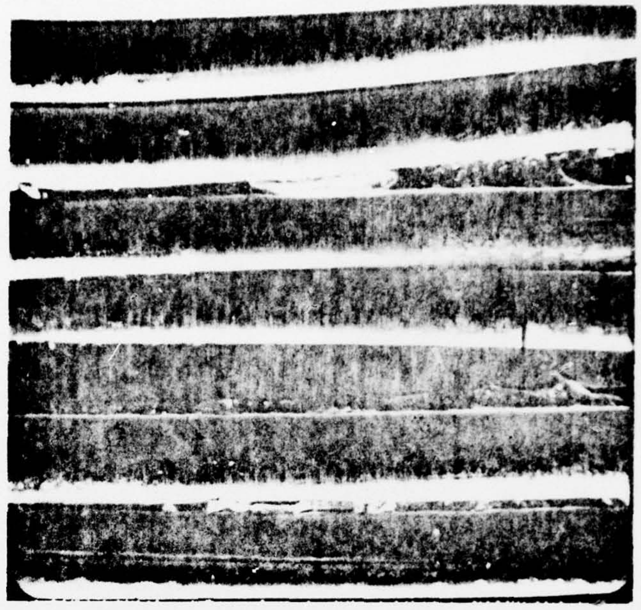
Test Disc	Test Disc Car Cover	Peel Test (Tongue Test)	
Panel/Gore			Batten patch 18 H and I
8L			Hole in antenna plate 44/H
24H			
39I			Handling damage - oblong patch 37/H
42H, 42I			Piasecki test sample, 35/F
43H, 43I	43		Holes: 55B
44H		44H, 44H	56M
	46		56B (5)
		48I	81P
50D, 50D			Large oblong hole in air tunnel
50M			
52D			
53D		60I	
67H		67H	
68I			
87I			
117J			

TABLE XVI

PERMANENT REPAIRS MADE ON THE BALLONETS OF THE ZPG-2 DACRON ENVELOPE, GDC-5

Test Disc From Ballonet	Panel/Gore
Forward	39P; Hole part of 20% mark
Center - Starboard	57B; Hole near Panel 56, 12' above shoe
	Hole near Panel 57 - high
Center - Port	55B
Aft	72A

Figure 1. Water Blisters Present under a Taped Seam in the ZPG-2W Dacron Envelope, GDC-5



Specimen from Sample Disc with Good Ply Adhesion

Specimen from Samples Disc with Low Ply Adhesion

Figure 2. Photomicrographs of Specimens from the ZPG-2 Dacron Envelope GDC-5, (552X)

APPENDIX A

APPENDIX A

The equipment and material items included the following:

1. Items Purchased, on Hand or in Stock

Blower - used to inflate the envelope for overhaul work and to supply a constant flow of fresh air; capable of delivering 500 cubic feet of air per minute and operated on 115 volts A.C.

Brush, paint flat hair bristle brush used to apply adhesive (cement) system.

Brush, wire - copper bristle brush used to buff fabric surface to prepare for application of adhesive (cement) system.

Crayon, marking - wax crayon used to mark test discs on the envelopes during inspection for repairs. Crayons used were soluble in 1.1.1 tricholoethylene.

Foot Covers - foot coverings made of coated heavy muslin and worn while working on either the inflated or deflated envelopes. The foot covers were placed over shoes while on the ground cloth to prevent the dirt on the shoes coming in contact with the envelope. The foot covers were removed before leaving the ground cloth.

Lamp Guards - used to prevent any breakage of bulbs from falling in the vicinity of fabric repair activity.

Lamp, heat standard infra-red bulb mounted in explosive-proof housing used to hasten drying and curing of adhesive system.

Roller - rubber faced roller used to roll patches when installing on the envelope.

Roller - steel faced roller used to roll patches when installing on the envelope; available in widths of 1, and 1-1/2 inches.

Solvent, stabilized 1.1.1 trichoroethylene - used as washing solution for cleaning ballonet fabric and envelope fabric, inside and outside prior to repair.

Stitcher - a 1/4 inch wide steel roller. It is used to securely position patch prior to rolling.

Talcum Powder - hydrated magnesium silicate used to destroy the tack of excess cement.

Tape, masking - 3 inch wide cloth tape, 60 yards to a roll.

Tube socks were utilized as foot covers in place of rigger moccasins by the personnel who assisted in unrolling, moving and positioning the envelope. The tube socks were placed over shoes or socks while on ground cloth to prevent scuff damage to the envelope. The tube socks were removed before leaving the ground cloth.

2. Items Fabricated

Air Tubes - open end cylindrical tubes (2) measuring 18-1/2 inches by 75 feet were made of lightweight nylon.

Tunnel Frames, access - 42 inch wide by 60 feet long steel frames.

Cloth, Ground - assembled of 8 ozs. 72 inches wide E duck and masking tape to provide a protective ground cloth for the airship envelopes. The cloth was greater in size than the deflated envelope.

Templates - for test discs and repair patches.

(1) Test disc - plywood template consisting of two concentric circles, 12 inch and 15 inches in diameter.

(2) Repair patch - bristol board template approximately 15 inch in diameter alternately notched and scalloped on the outer edge.

3. Repair Fabrics and Neoprene Adhesive (Cement) Systems (identified with Goodyear Aerospace Corp., codes).

1. Repair Fabric

a. Cotton-neoprene fabric for repair of the ZPG-3W cotton envelope D-621.

(1) Code N 113-A-120 fabric.

(2) Code N 113A-520 fabric.

b. Dacron-neoprene fabric for repair of the ZPG-2 Dacron polyester envelope GDC-5.

(1) Code N 313-A-130 fabric

c. Nylon fabric for ballonet repair.

(1) Code N-228-A-220 fabric.

2. Neoprene Adhesive Systems

a. Two part neoprene-adhesive system for the ZPG-3W cotton envelope:

1451 Cement with 983 accelerator.

b. Three part cement system for the ZPG-2 Dacron polyester envelope GDC-5:

1451 Cement with 983 accelerator and 1467-C accelerator.

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