

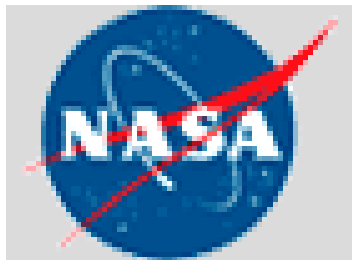
NBS Encasements: History and Examinations Prior to Disassembly



**National Archives and
Records Administration**



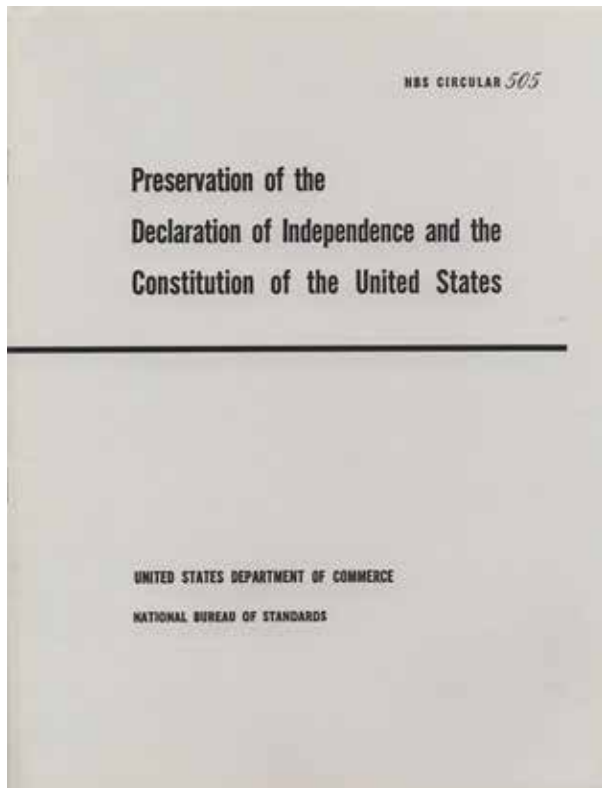
**National Bureau of Standards /
National Institute of Standards and
Technology**



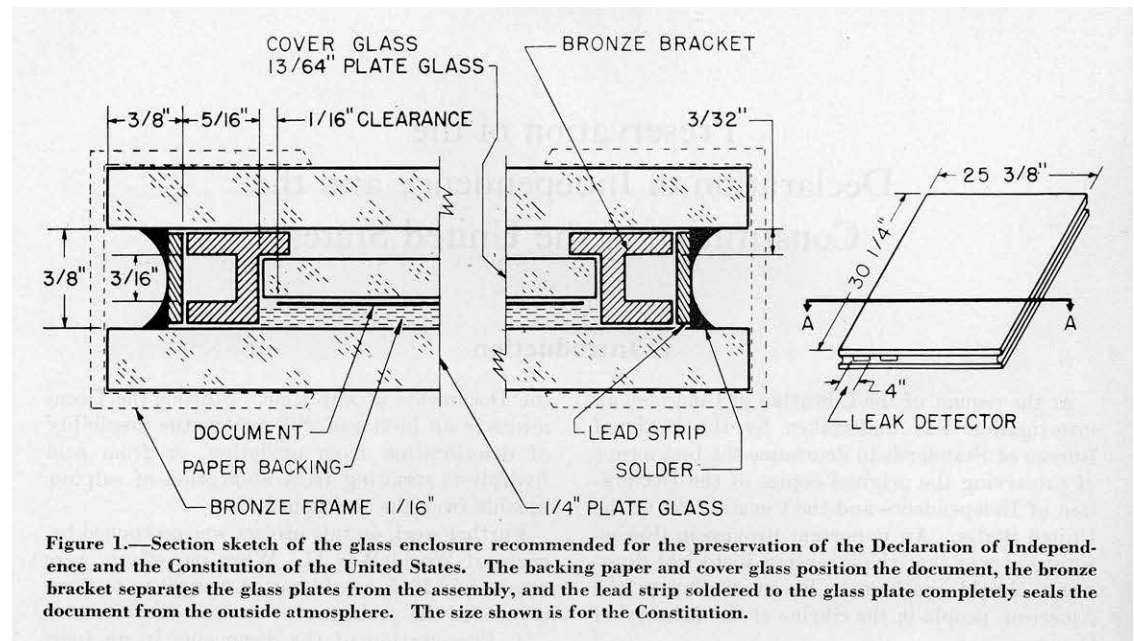
**National Aeronautics and
Space Administration**



NBS Circular 505 (1951)



Encasement design



Thermal Conductivity Leak Detector

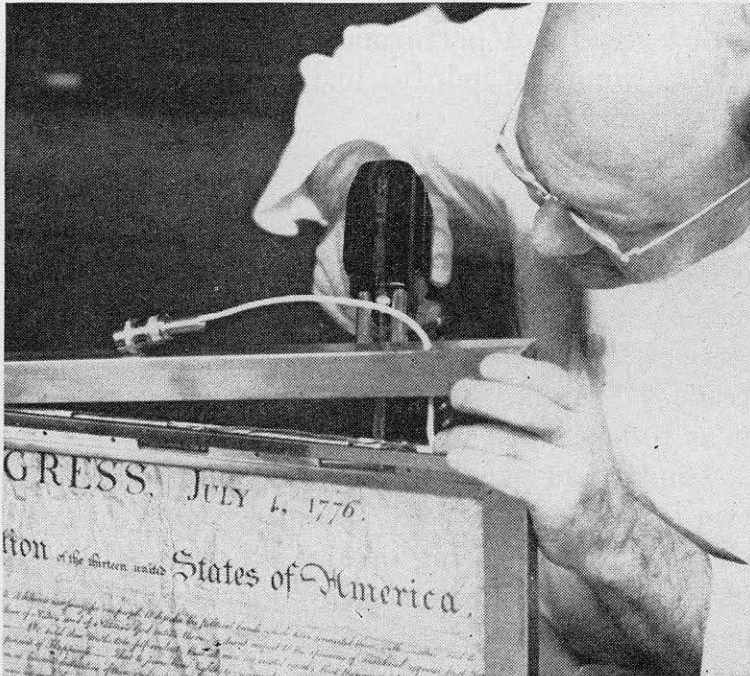


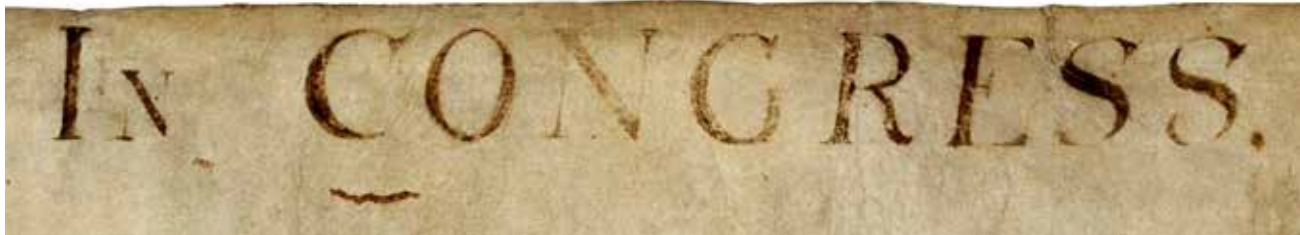
Figure 17.—After the holes have been sealed, the outer bronze frame is fitted to the enclosure. The wires from the reference cells and the two cells inside the enclosure are connected to a line that passes through the bronze frame and terminates in a socket. At any time, the ammeter of the leak detector can be plugged into this socket to determine whether air has leaked into the enclosure. Here Mr. E. C. Creitz is soldering the lead from a reference cell to the external lead.



Charters Monitoring System (1987)



CMS Images: Declaration of Independence



Ink Surface



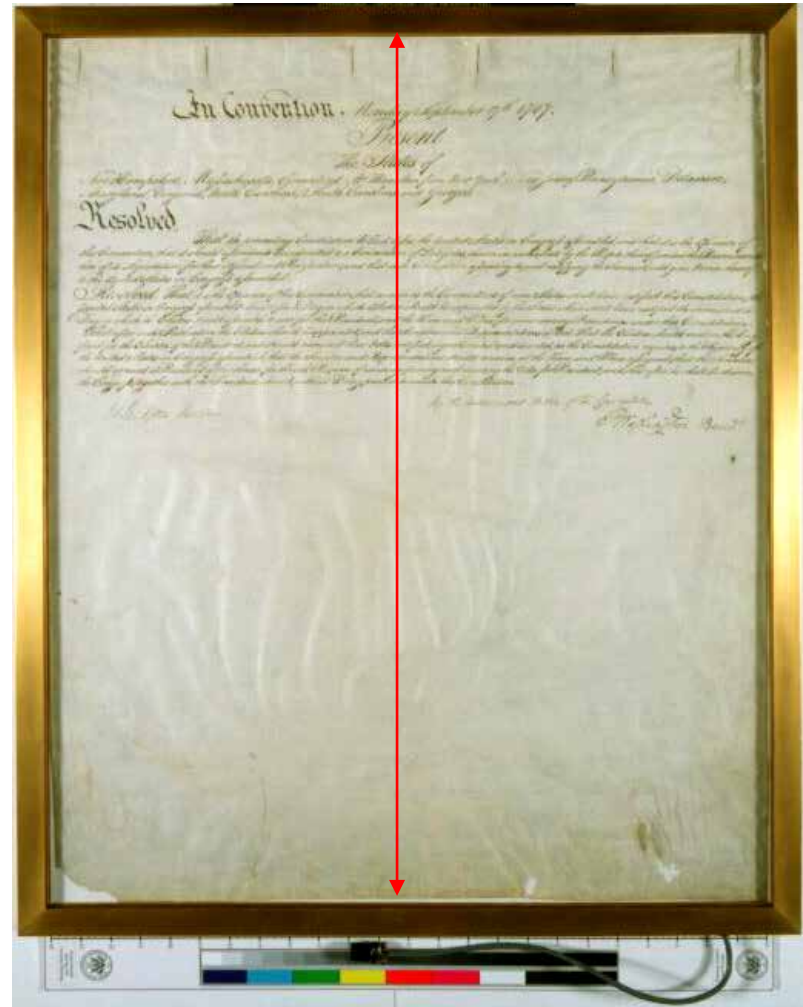
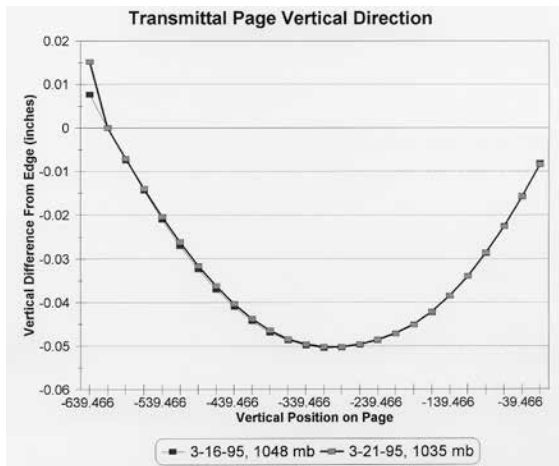
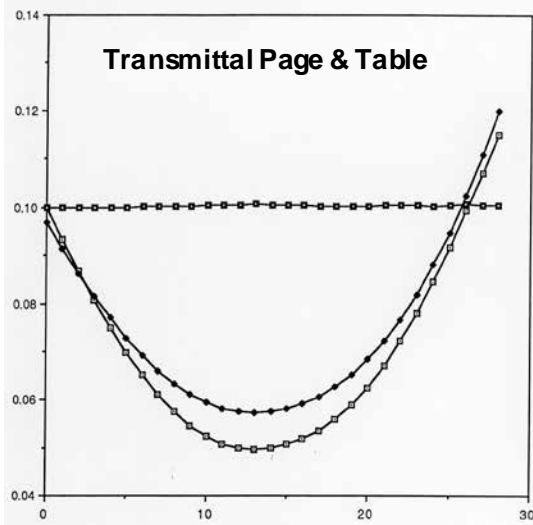
Ratio Image



Glass Surface



Profilometry (1989)



Fiber-Optic Raking Light (1995)



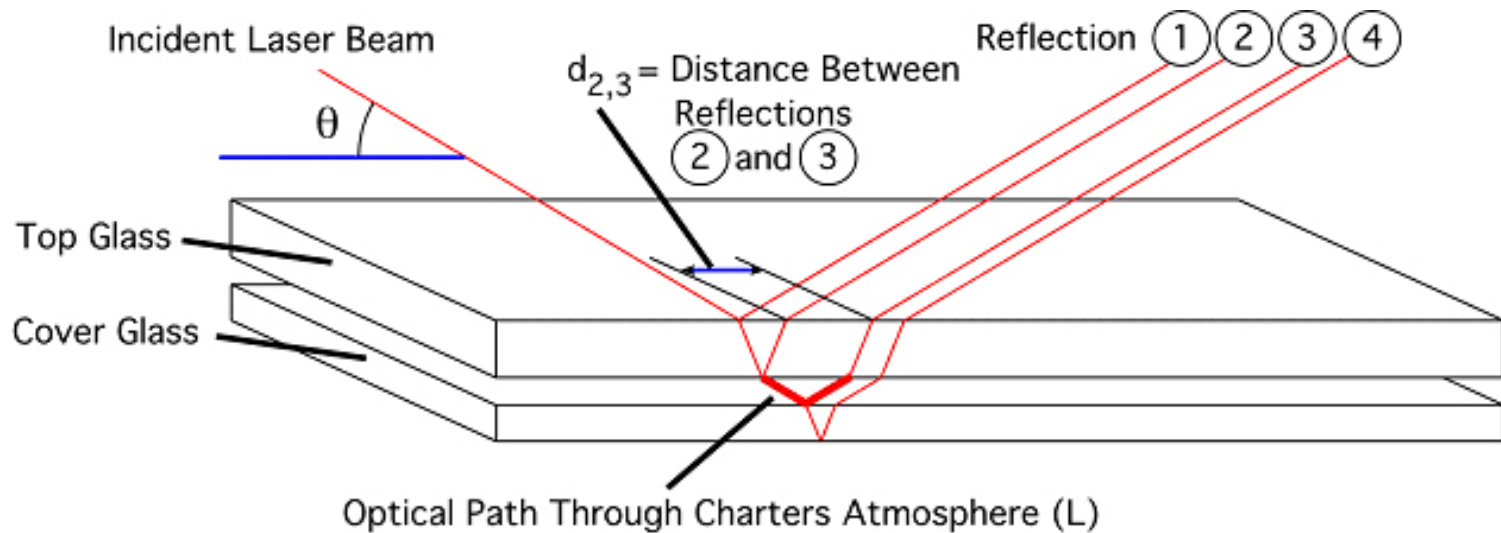
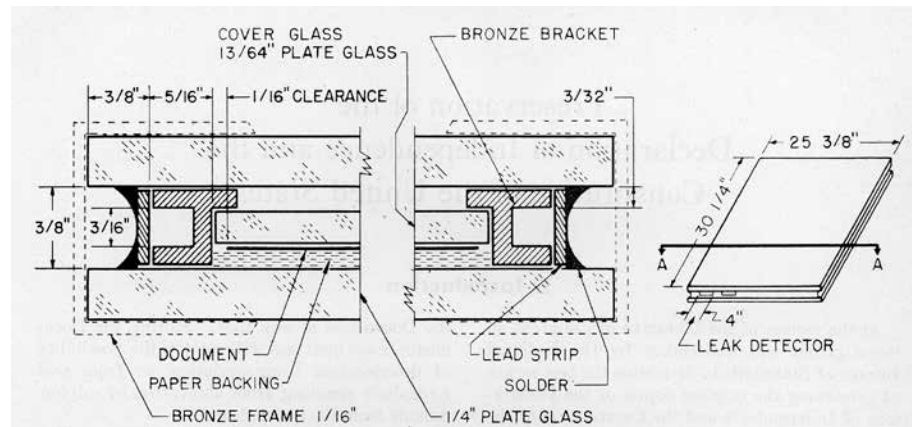
Enable overall scrutiny of encasement to determine extent/distribution of observed haziness

Characterize glass deterioration (microspots/drops/dendrites/fissures)

Facilitate spot-condensation test to estimate internal humidity conditions

Confirm absence of actively-growing “biologics”

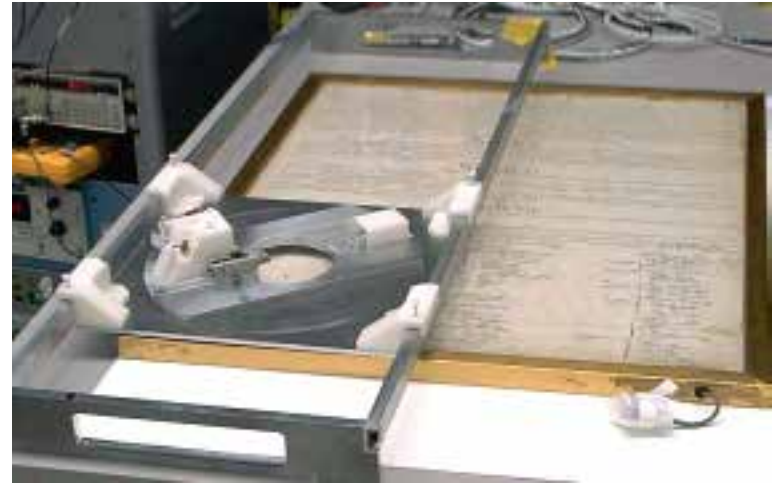
Diode Laser Analysis (1999-2001)



Diode Laser Analysis: Constitution Page 4 Encasement



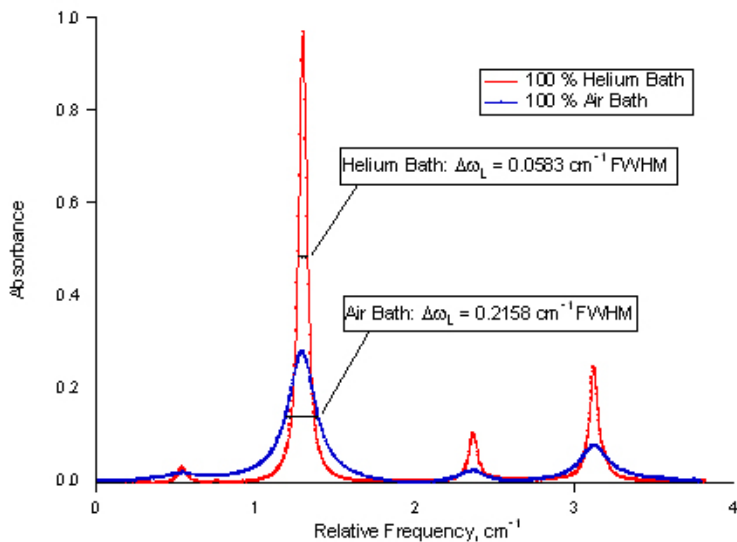
**Measure Water Vapor
Absorption**



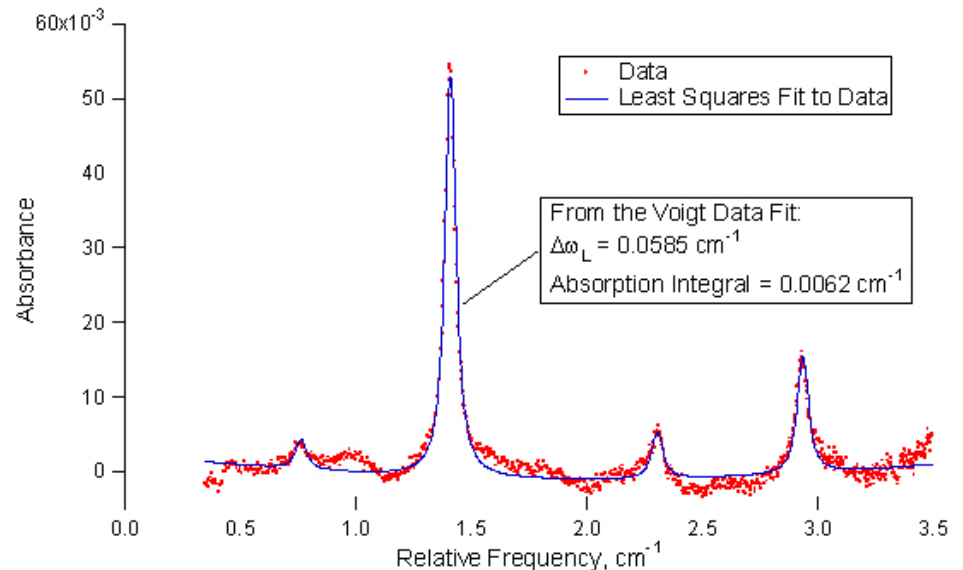
**Measure Absorption
Path Length**

Diode Laser Analysis

Water Vapor Absorption at 7181.17 cm⁻¹



**Calibration spectra:
Water Vapor in pure
Helium; in pure Air**



**Absorption spectrum:
Constitution Page 4
encasement atmosphere**

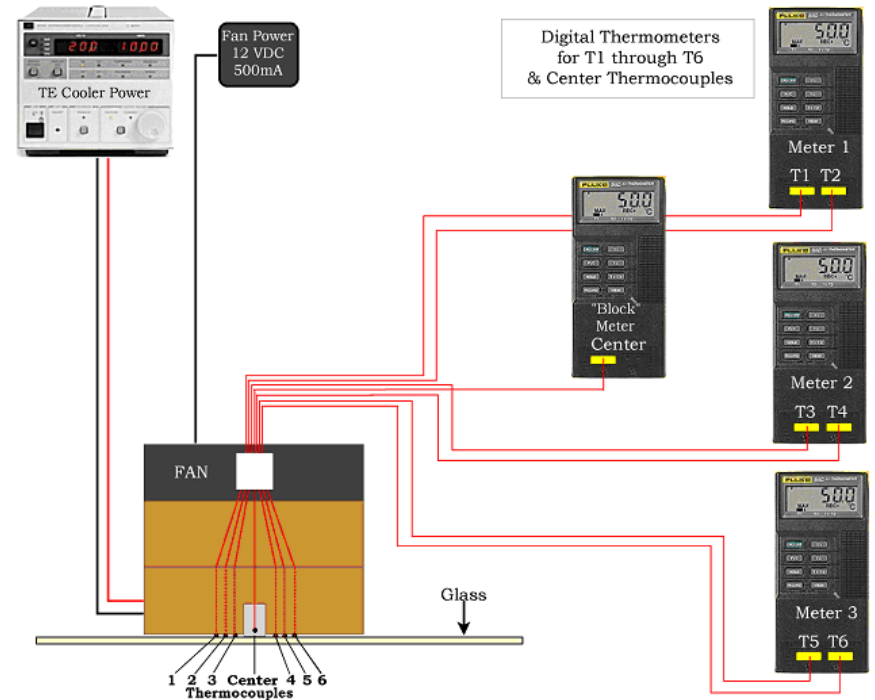
Diode Laser Analysis

Encasement	Dew Point ($\pm 1^{\circ}$ C)	RH @ 20 °C (%)	Helium Content (%)
Declaration of Independence	8.7	48	97 \pm 2
Constitution Transmittal Page	---	---	76 \pm 4
Constitution Page 1	9.1	50	100 \pm 2
Constitution Page 2	---	---	100 \pm 4
Constitution Page 3	---	---	84 \pm 4
Constitution Page 4	11.5	58	98 \pm 2
Bill of Rights	9.0	49	99 \pm 2

Thermo-Electric Micro-Cooling (2001)



Determining dew point
temperature of
Constitution Page 1
encasement atmosphere

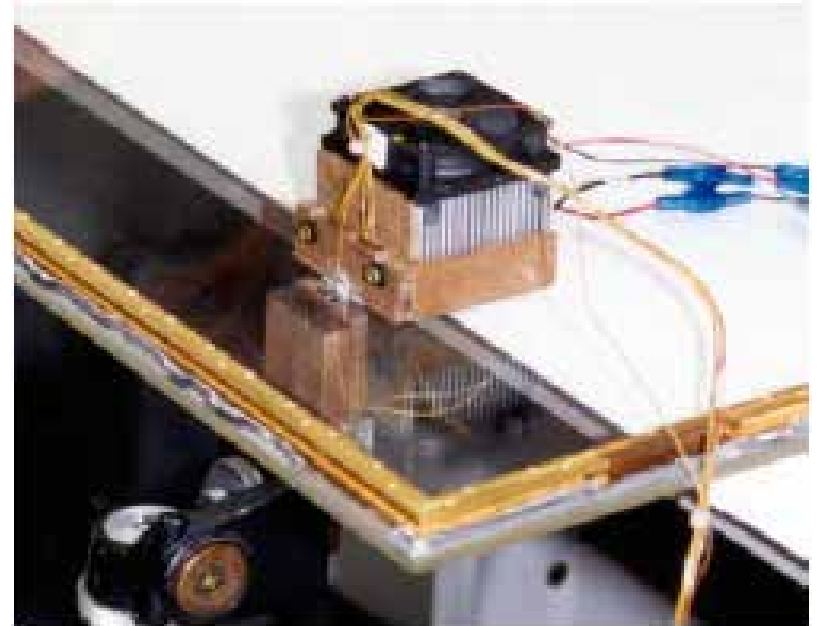


Thermo-electric cooler
device

Thermo-Electric Micro-Cooling



Observing dew formation



Measuring dismantled encasement glass

Thermo-Electric Micro-Cooling

Encasement	Dew Point (°C)	% Relative Humidity at 20 °C
Declaration of Independence	9.6	57.8
Constitution Page 1	9.2	56.1
Constitution Page 4	10.2	60.2
Bill of Rights (#1)	9.2	56.1

Gas Extraction & Analysis (1999-2002)

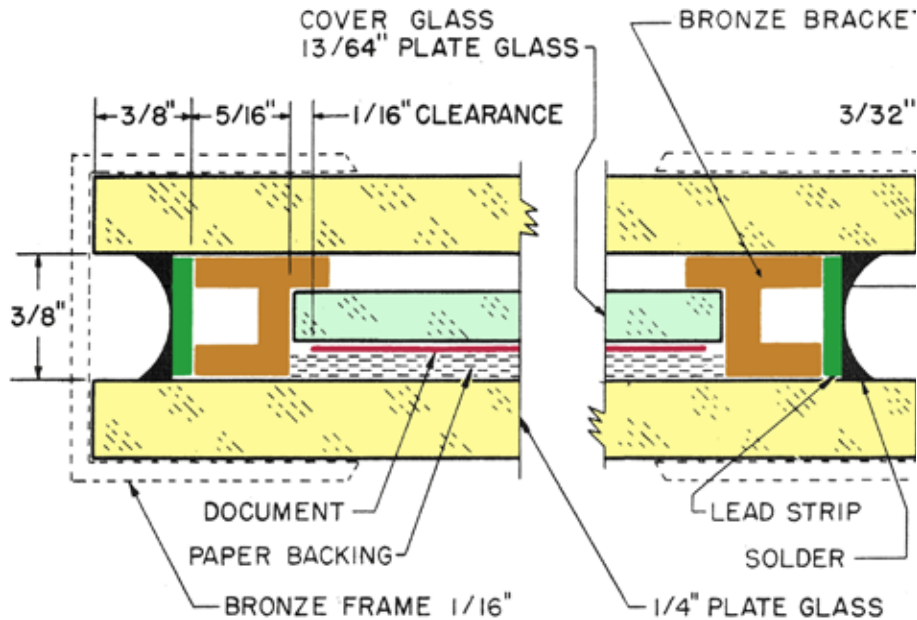
Obtain samples for:

Mass spectrometry (30 to 100 cc)

Gas Chromatography (300 to 1000 cc)

Obtain *in situ* humidity measurements as samples are withdrawn

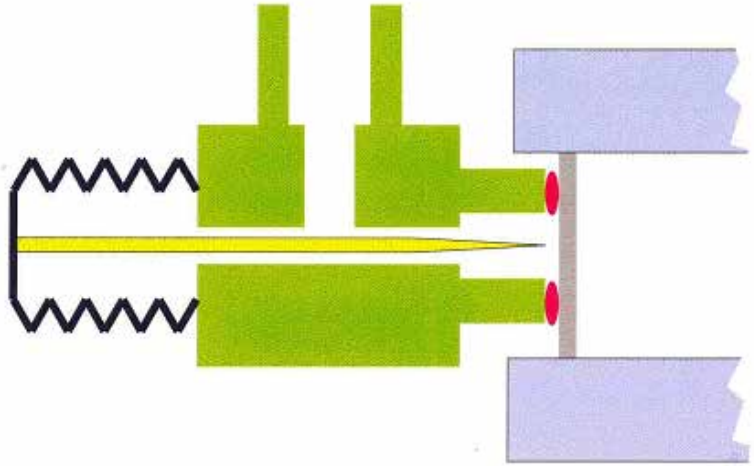
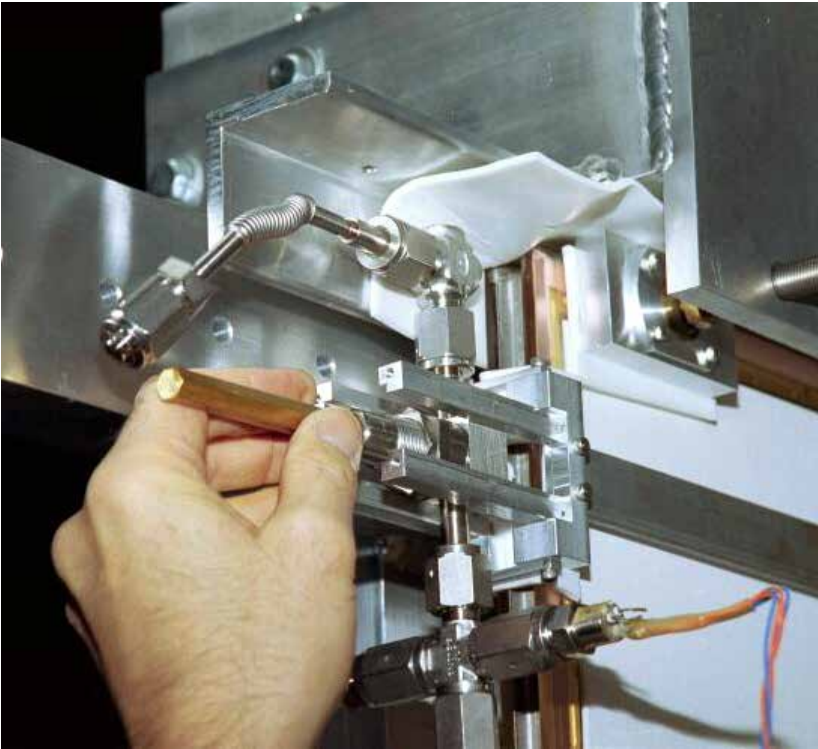
Gas Extraction



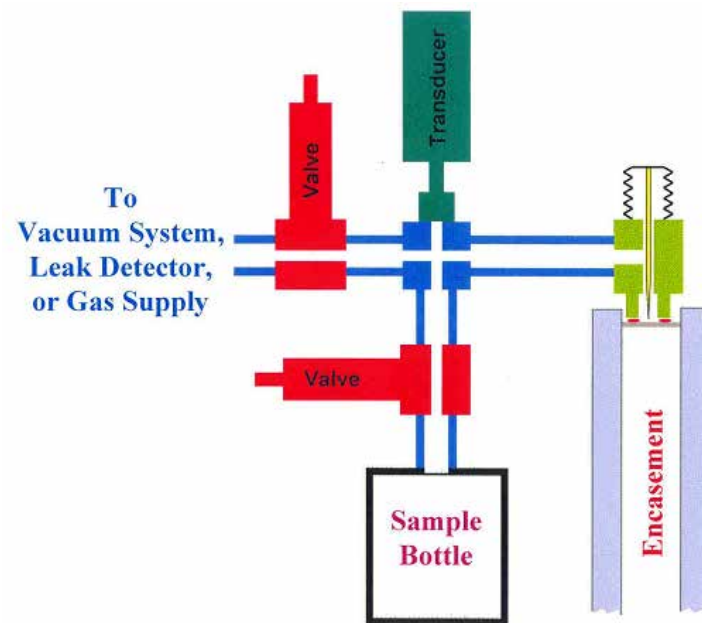
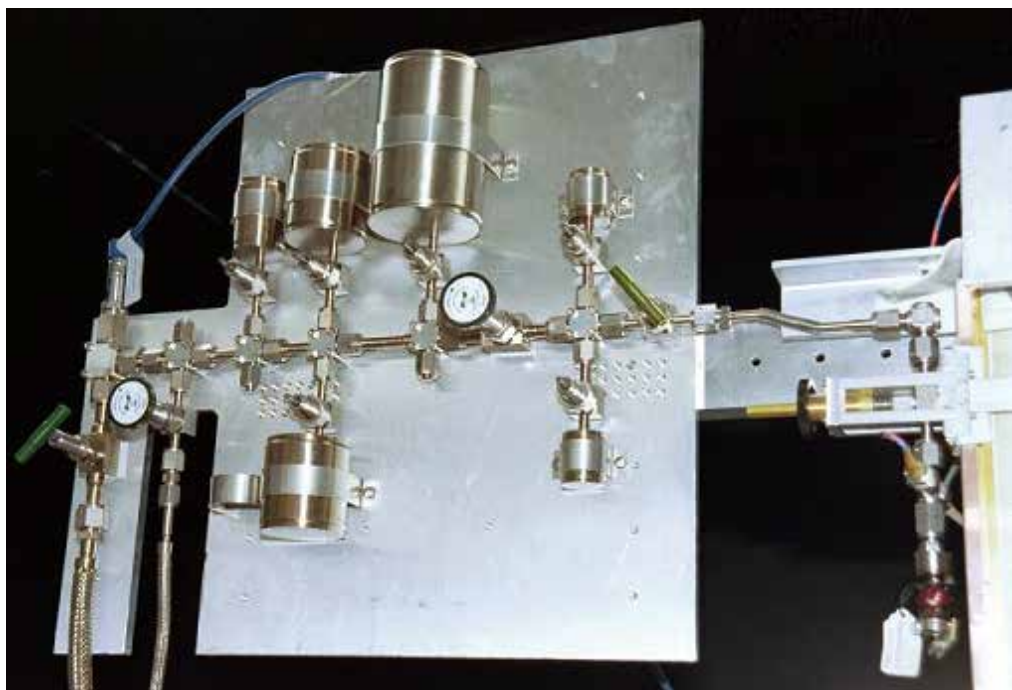
NBS Encasement Structure

Site of Original Fill Port (sealed)

Gas Extraction Penetrator Assembly



Gas Extraction Sample Collection



Gas Extraction

Initial Encasement Conditions

Encasement	Glass deflection (in)	Internal pressure differential (kPa)
Declaration of Independence	+ 0.003 recto	- 0.16
Constitution Transmittal Page	- 0.050 recto	- 1.90
Constitution Page 1	- 0.011 recto	- 0.29
Constitution Page 2	- 0.018 recto	- 0.30
Constitution Page 3	- 0.024 recto	- 0.60
Constitution Page 4	+0.006 verso	- 0.33
Bill of Rights	+0.012 recto	- 0.09

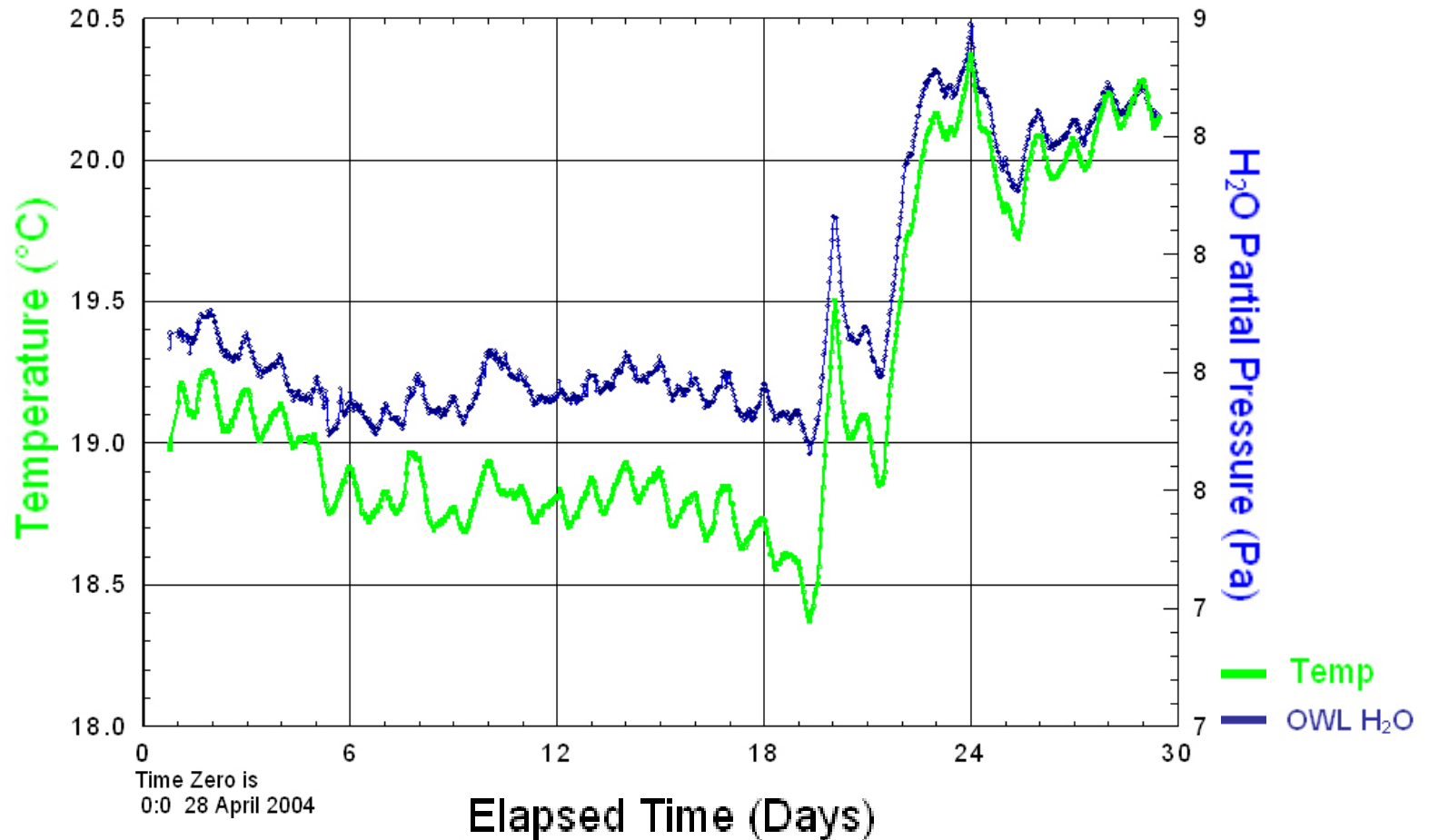
Gas Extraction / Analysis Results

Encasement	% "Air" in Helium	"Air" Composition (%)		
		N ₂	O ₂	CO ₂
Declaration of Independence	0.1	0.90	0.006	0.60
Constitution Transmittal Page	26	20.5	3.5	1.10
Constitution Page 1	0.2	0.16	0.007	0.24
Constitution Page 2	0.1	0.11	0.023	0.22
Constitution Page 3	22	16.8	2.7	0.76
Constitution Page 4	0.03	0.01	0.007	0.19
Bill of Rights	0.25	0.20	0.010	0.52
Normal Air		78.2	20.8	0.036

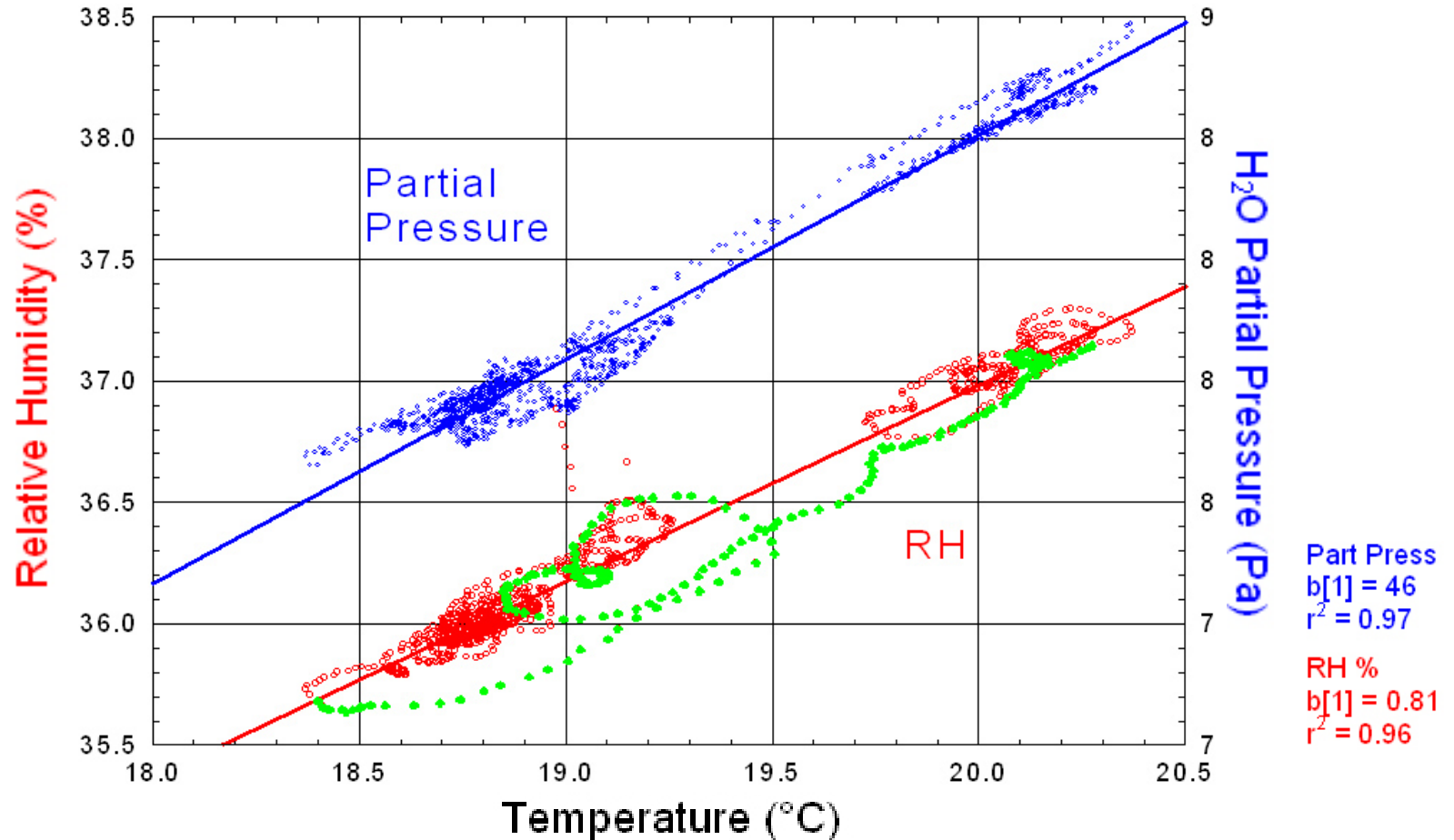
Humidity Measurements

Encasement	% Relative Humidity at 20 °C			
	In-Situ during Gas Extraction	Diode Laser Analysis	Thermo-Electric Micro-Cooling	GC
Declaration of Independence	45	48	57.8	
Constitution Transmittal Page	52			
Constitution Page 1	48	50	56.1	57.8
Constitution Page 2	55			72.1
Constitution Page 3	59			72.2
Constitution Page 4	52	58	60.2	59.0
Bill of Rights	47	49	56.1	
5 °C dewpoint specified by NBS Circular 505	37% Relative Humidity @ 20 °C			

Transmittal Page New Encasement Monitoring 28 April to 27 May 2004



Transmittal Page New Encasement Monitoring 28 April to 27 May 2004



Observations and Inferences

All encasements demonstrate initial negative pressure differentials consistent with slow outward diffusion of helium over 50 years

All encasements still contain a preponderance of helium; five contain 0.25% or less of “air” as indicated by nitrogen content

Constitution Transmittal Page and Page 3 exhibit greater initial negative pressure differentials, and contain 26% and 22% of air as indicated by nitrogen content: observations consistent with molecular diffusion leaks (greater egress of helium than influx of air)

Observations and Inferences

Deterioration of cellulose backing paper proceeds even in the absence of oxygen

Organic acids formed on deterioration react with 3% calcium carbonate in backing paper to form carbon dioxide

In the presence of a slow molecular influx of oxygen (Transmittal Page and Page 3), deterioration as reflected in carbon dioxide production increases

Deterioration reactions also produce water vapor