Resolving the Conflict between Building Preservation and the Proper Temperature and Relative Humidity Requirements of Collections

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“Essentially, *relative humidity* expresses the moisture content of air as a percent of what it can hold when the air is saturated.”

[at a given temperature]

The Dehumidification Handbook
Second Edition
Cargocaire

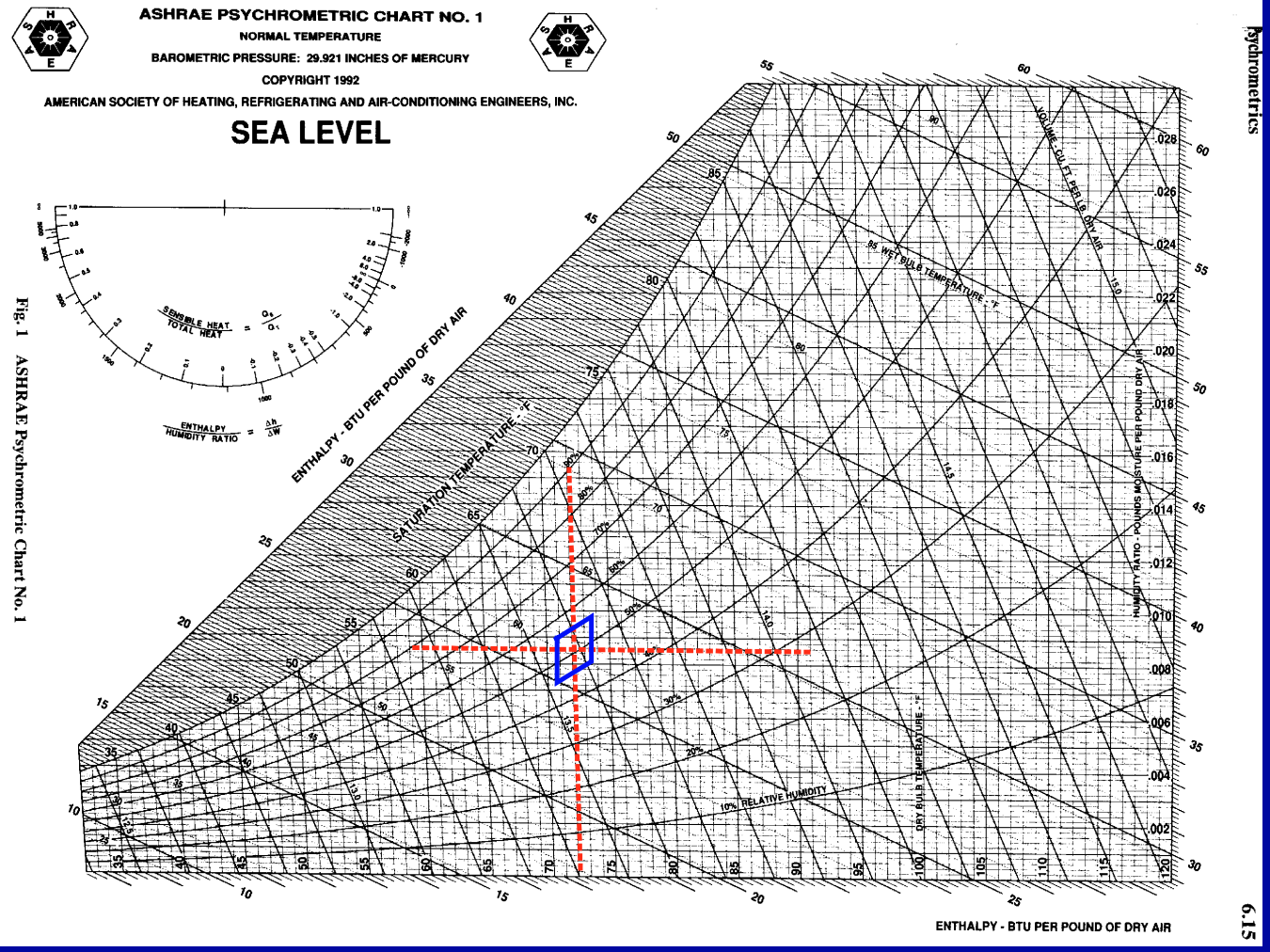


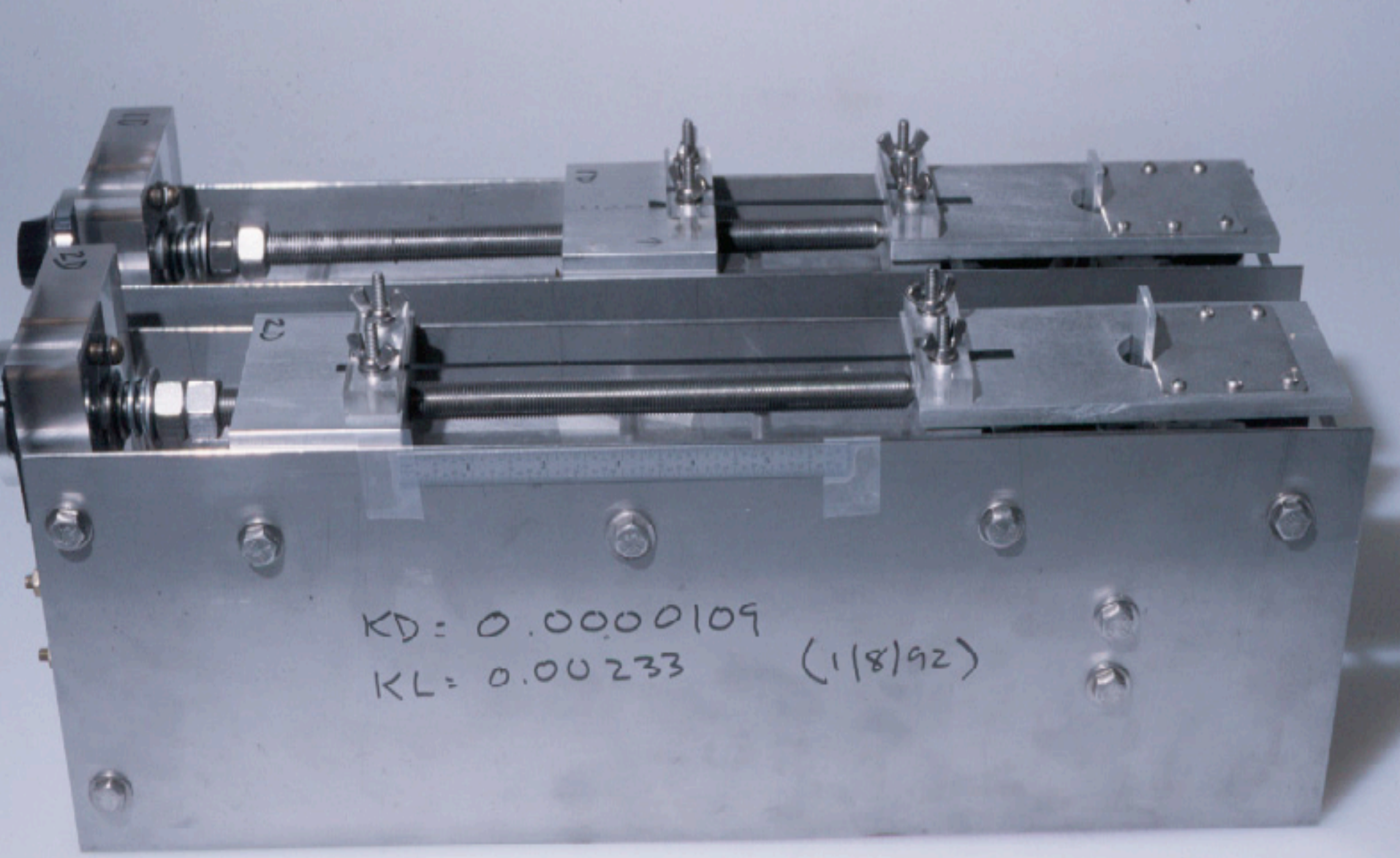
Fig. 1 ASHRAE Psychrometric Chart No. 1

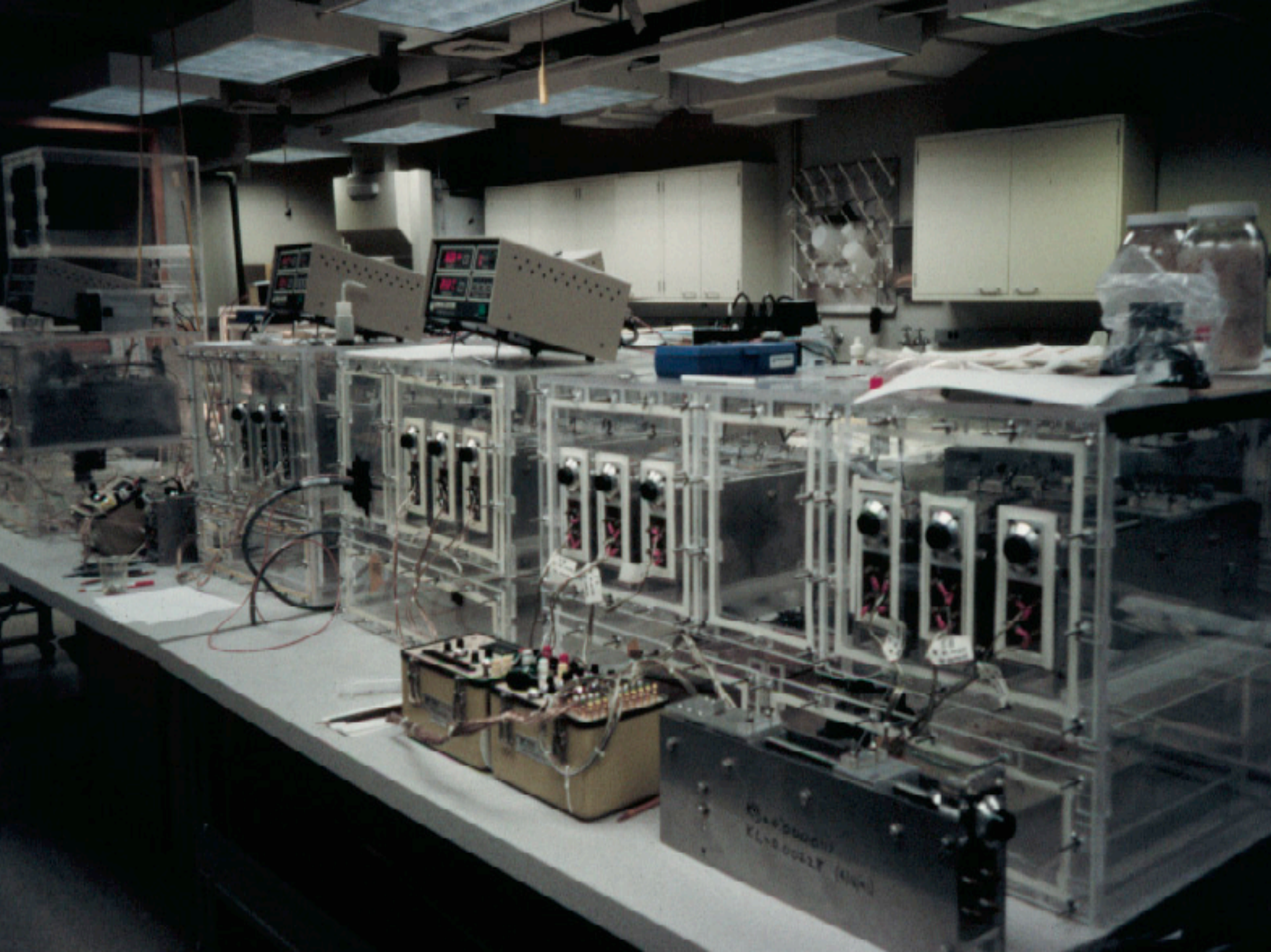
Psychrometrics 6.15

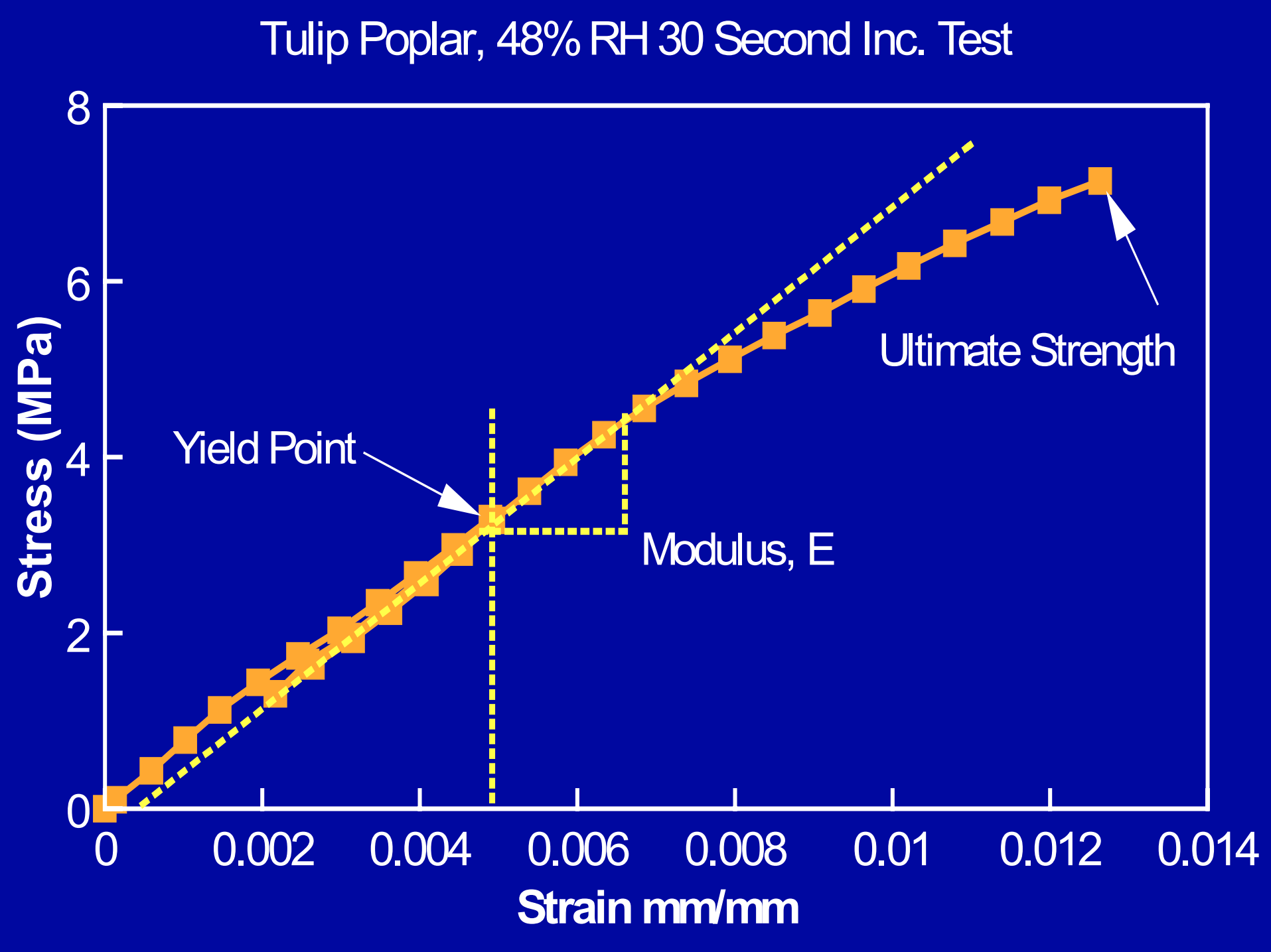
Standard
50% +/- 5% RH

"The standard specification of +/- 4 or 5% in RH control is based more on what we can reasonably expect the equipment to do than on any deep knowledge of the effect of small variations on the exhibit".

Thomson, The Museum Environment (1978).


KD = 0.0000109
KL = 0.00233
(1/8/92)

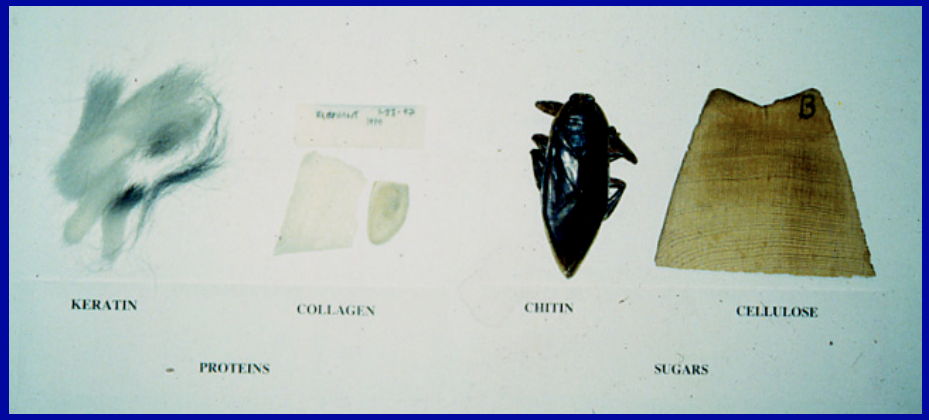



Tulip Poplar, 48% RH 30 Second Inc. Test
Stress (MPa)
8
6
4
2
0
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
Strain mm/mm
Yield Point
Modulus, E
Ultimate Strength

The Mechanical and Dimensional Response of Cultural Materials to Moisture

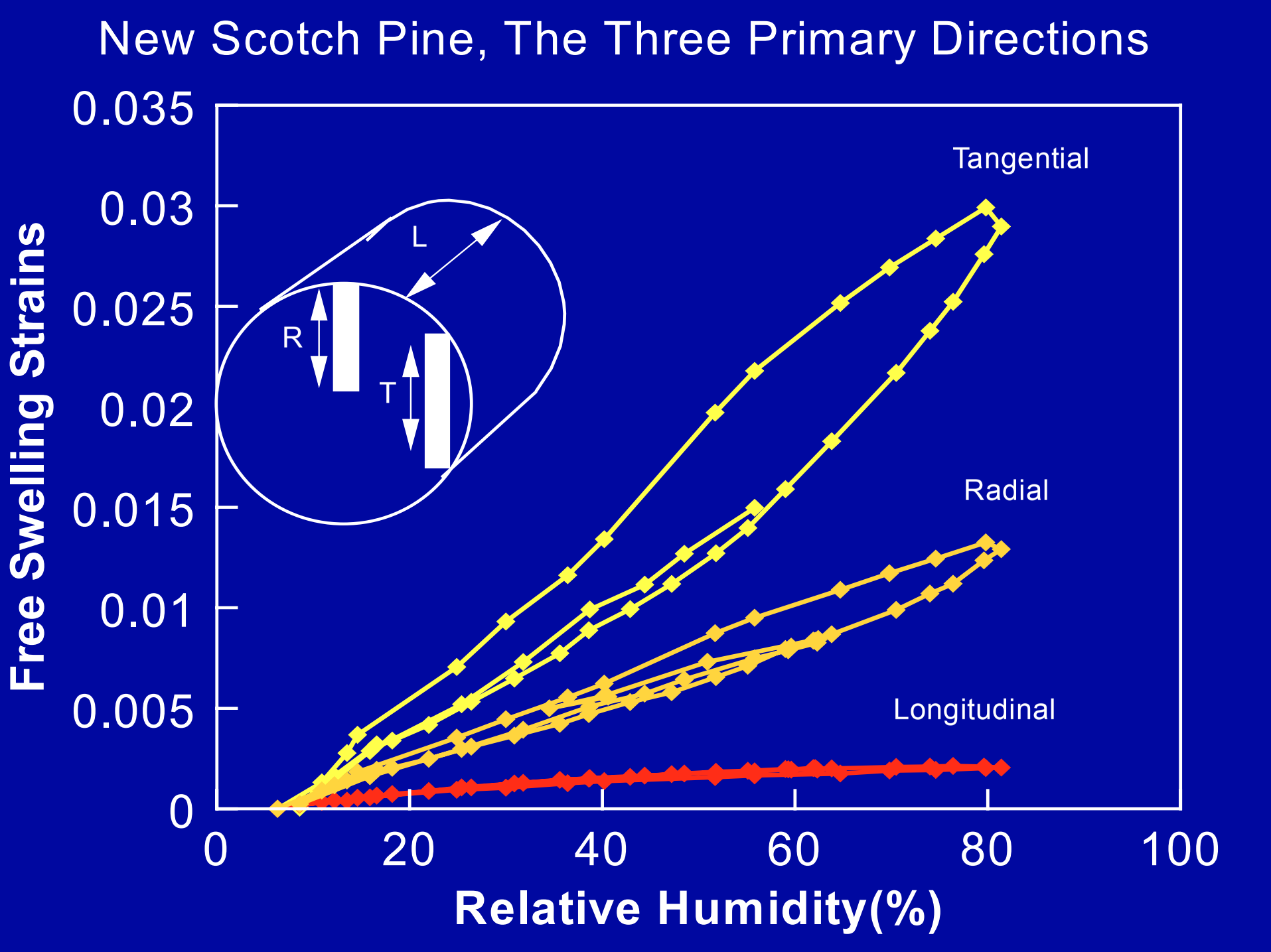
- cellulose wood, paper
- collagen bone, ivory, glue
- artists' paints pigmented films
- minerals
- metals
- ceramics

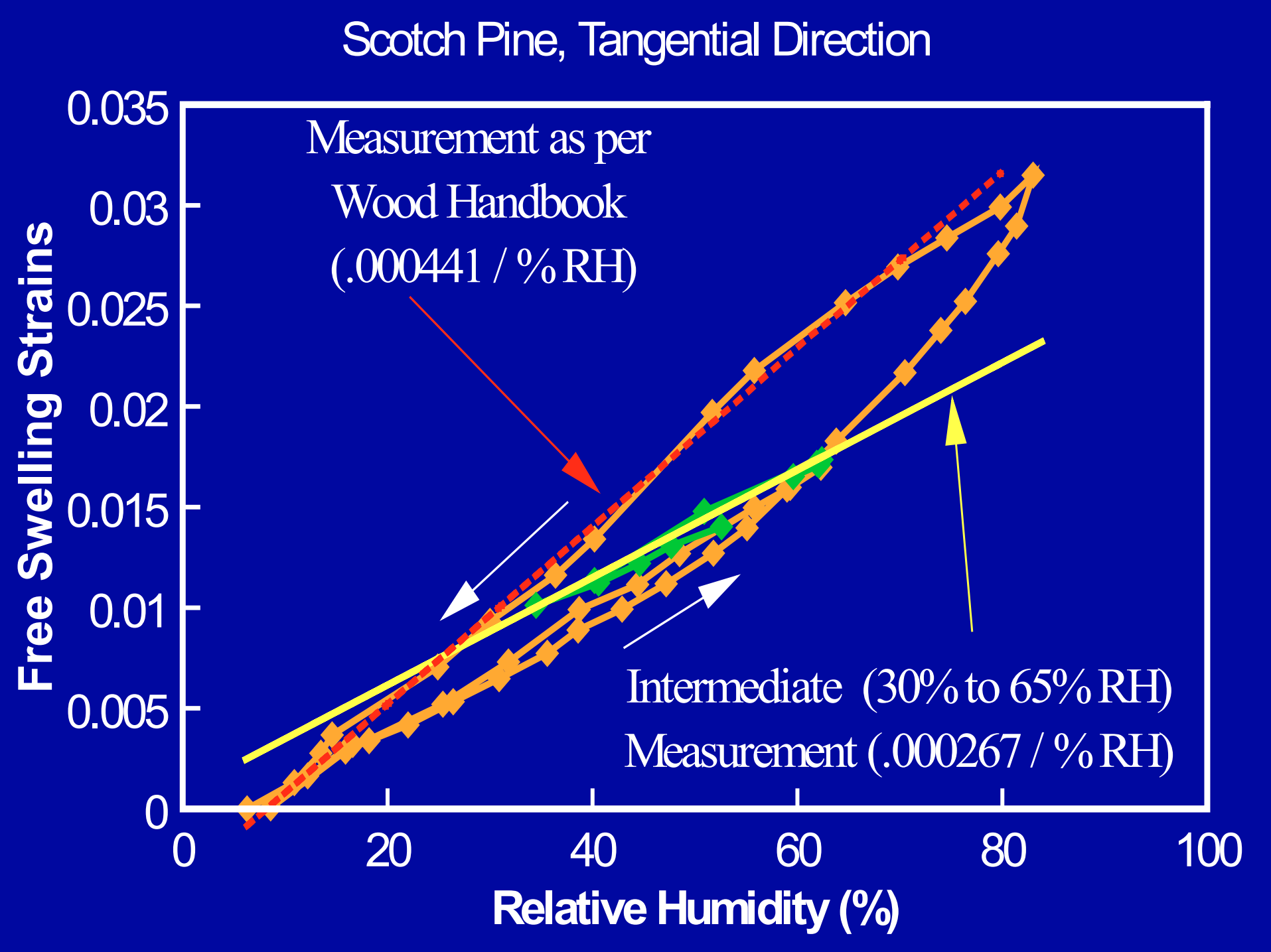
Organic Structural Compounds



Four basic organic structural compounds
Two sugars: chitin and cellulose
Two proteins: keratin and collagen

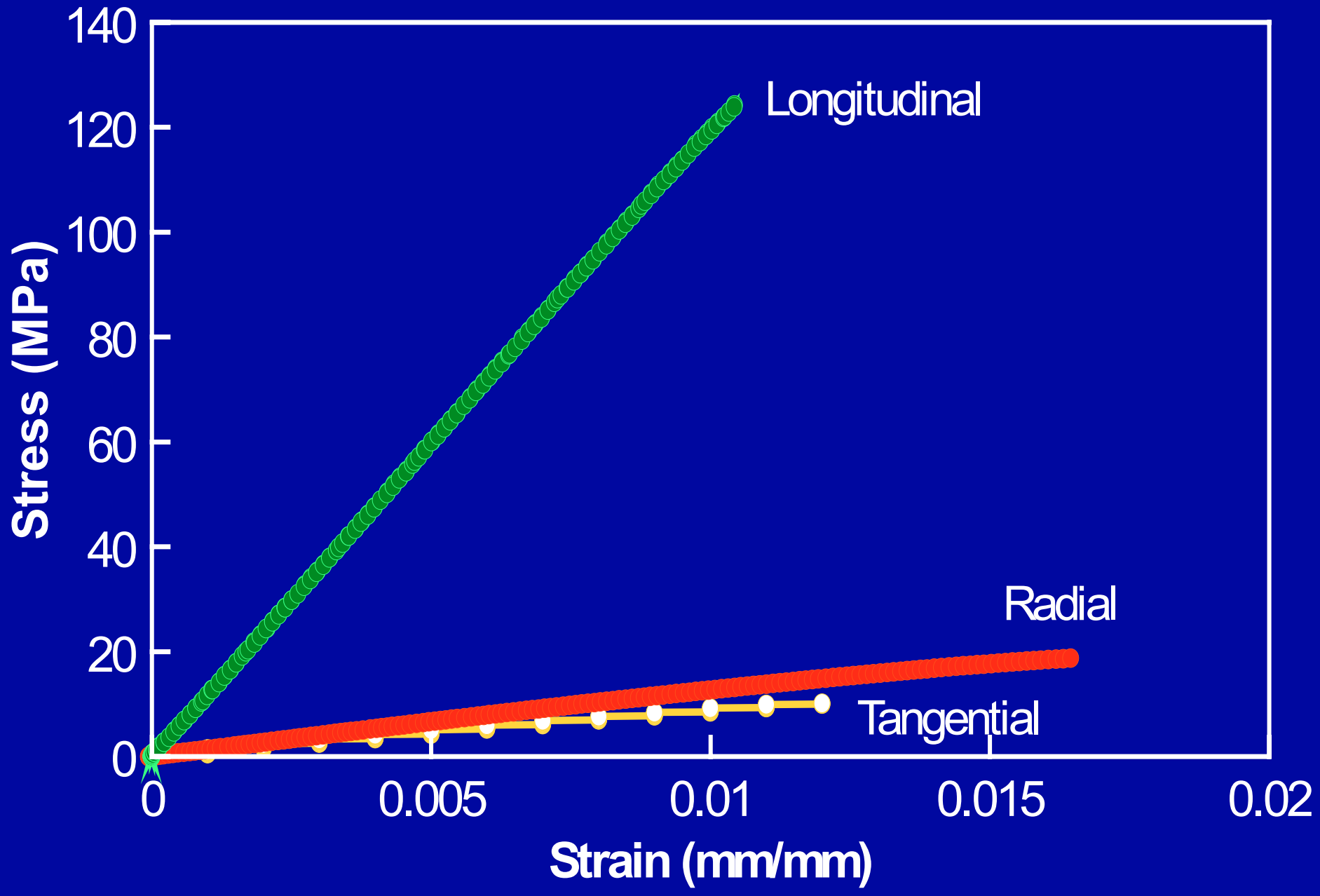
Cellulose


New Scotch Pine, The Three Primary Directions
Free Swelling Strains
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
20
40
60
80
100
Relative Humidity(%)
Tangential
Radial
Longitudinal
L
R
T


Scotch Pine, Tangential Direction
Measurement as per
Wood Handbook
(.000441 / % RH)
Intermediate (30% to 65% RH)
Measurement (.000267 / % RH)
Free Swelling Strains
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
20
40
60
80
100
Relative Humidity (%)

Changes in dimension are
diffusion controlled
and are usually very slow
for wood blocks or books

Tensile Tests of Birch in the 3 Directions

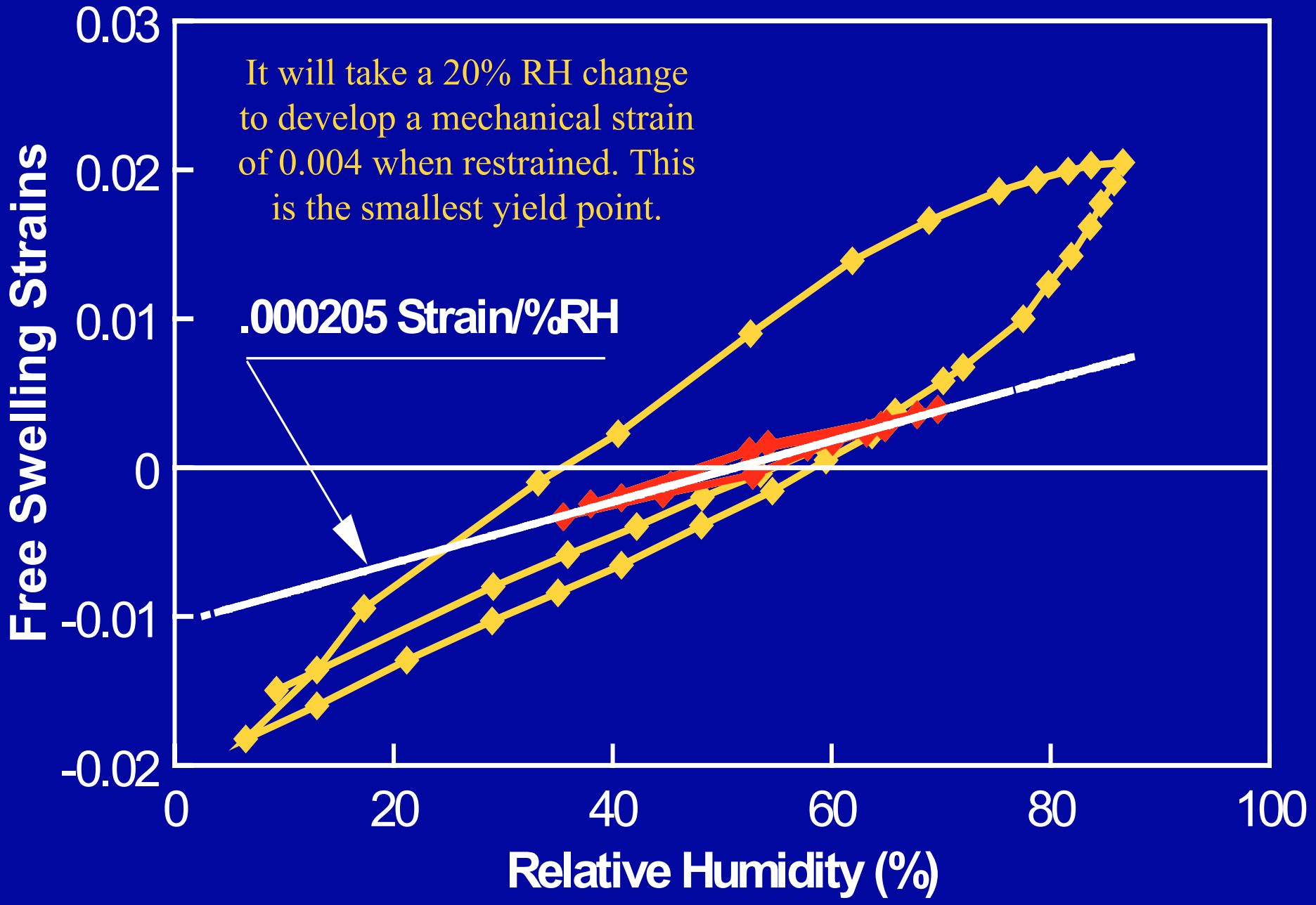


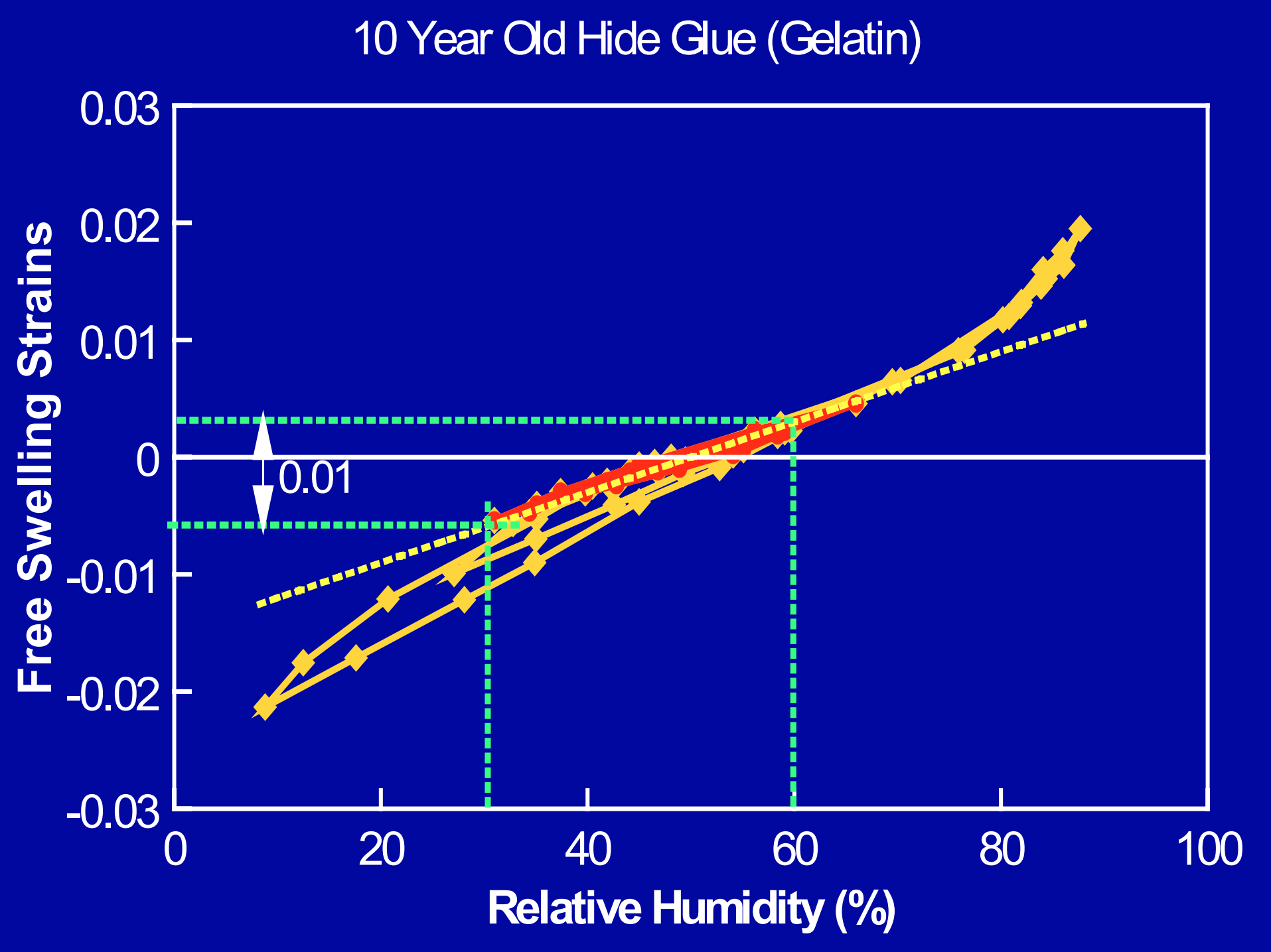
Collagenous Materials

glues, gelatins, skins, parchments, leathers

Gelatins have been used extensively for centuries as glues. The gelatin is from rendered animal skins and bones. A particularly strong glue is from sturgeon swim bladders. Gelatins are found in furniture, sizes for canvas paintings, image emulsions for photographic prints and films. It is one of the strongest of the cultural materials.

Walrus Tusk, Tang./ Radial Direction

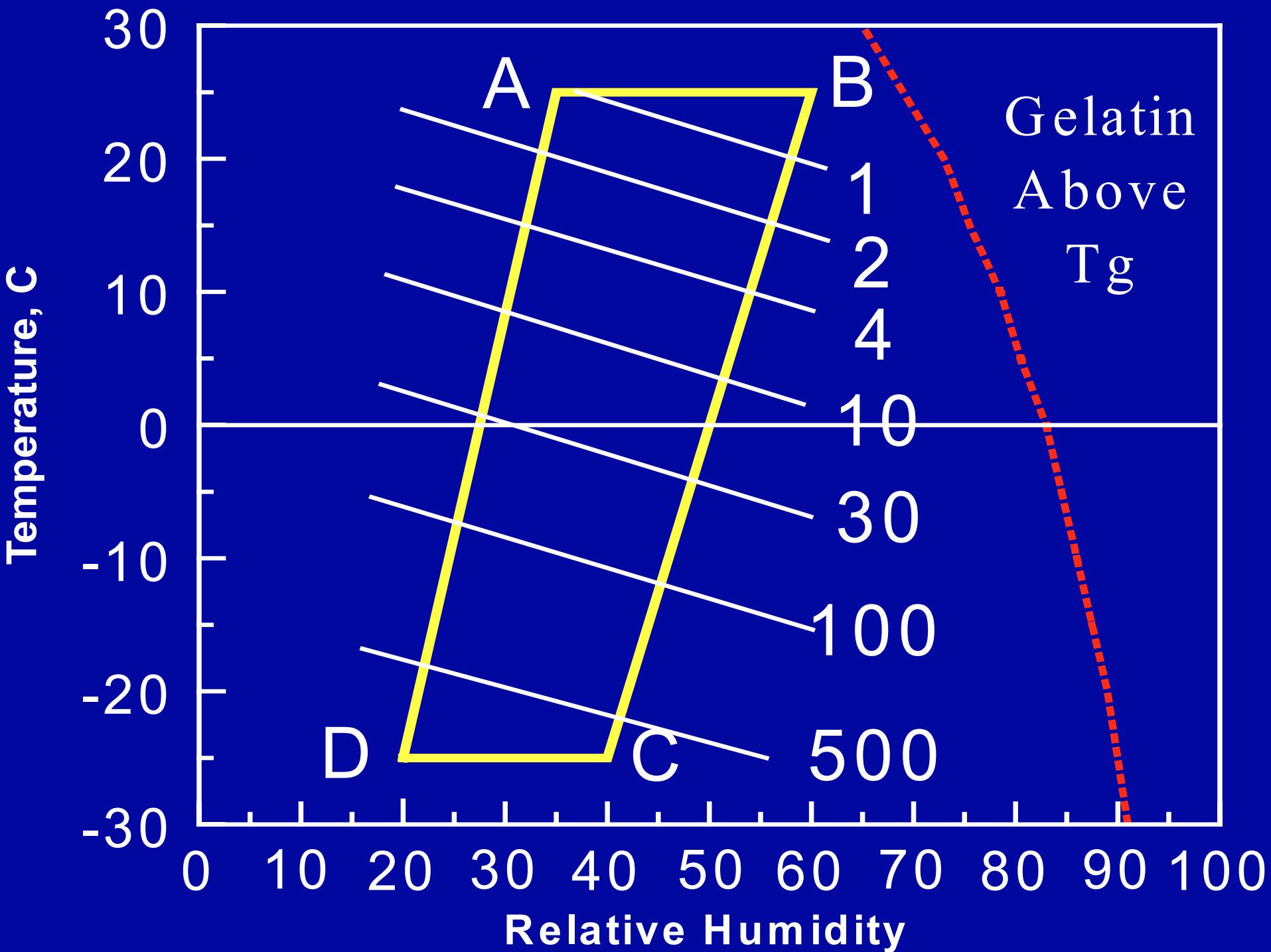



10 Year Old Hide Glue (Gelatin)
Free Swelling Strains
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0.01
0
20
40
60
80
100
Relative Humidity (%)

The gelatins even when restrained can easily be cycled from 50% RH +/- 15% RH without damage.

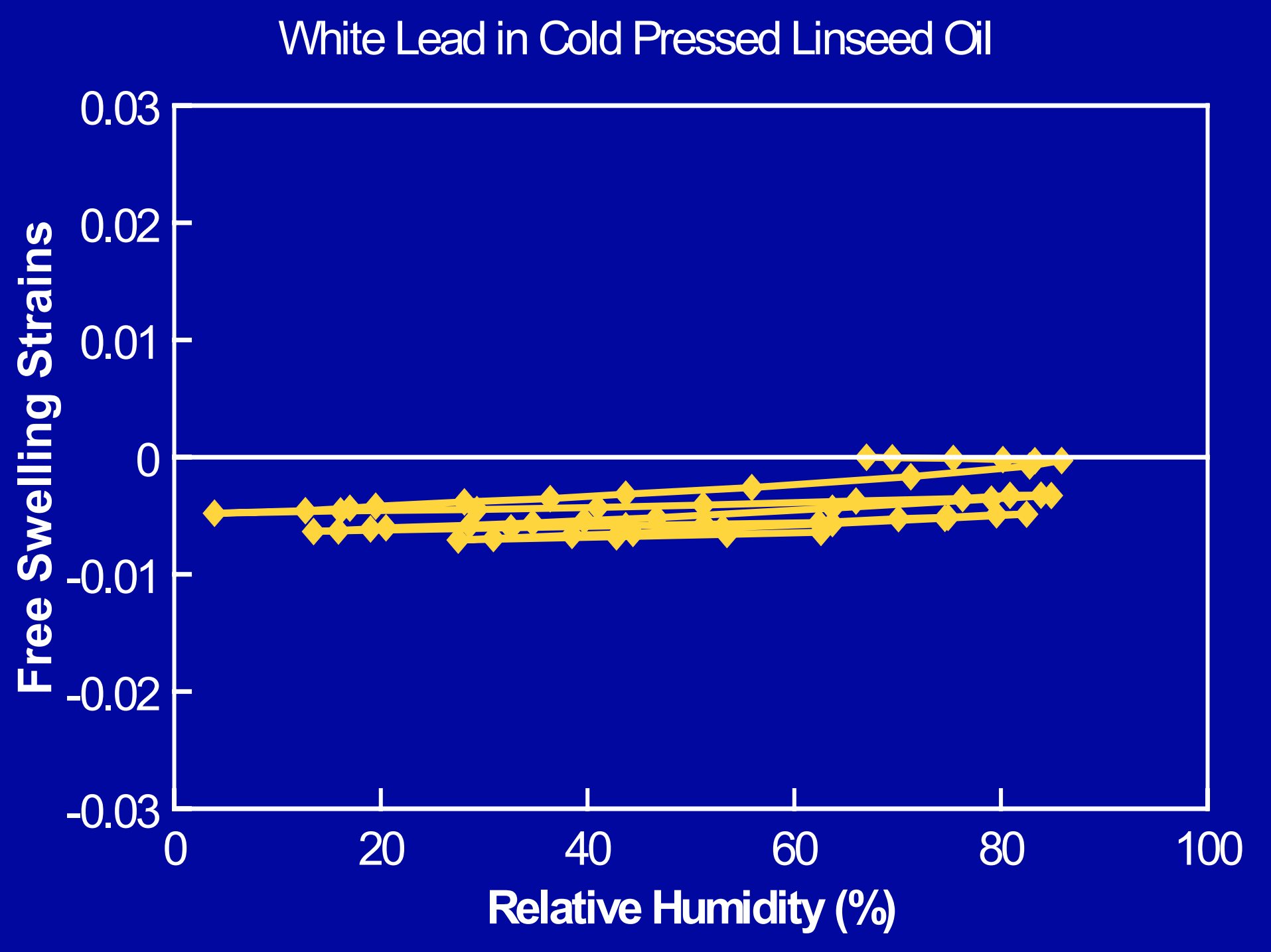
20th Century Photographic Materials

The allowable environment for 20th century photographic materials. This includes the image emulsion layers, the paper and plastic substrates, and the dyes and silvers.

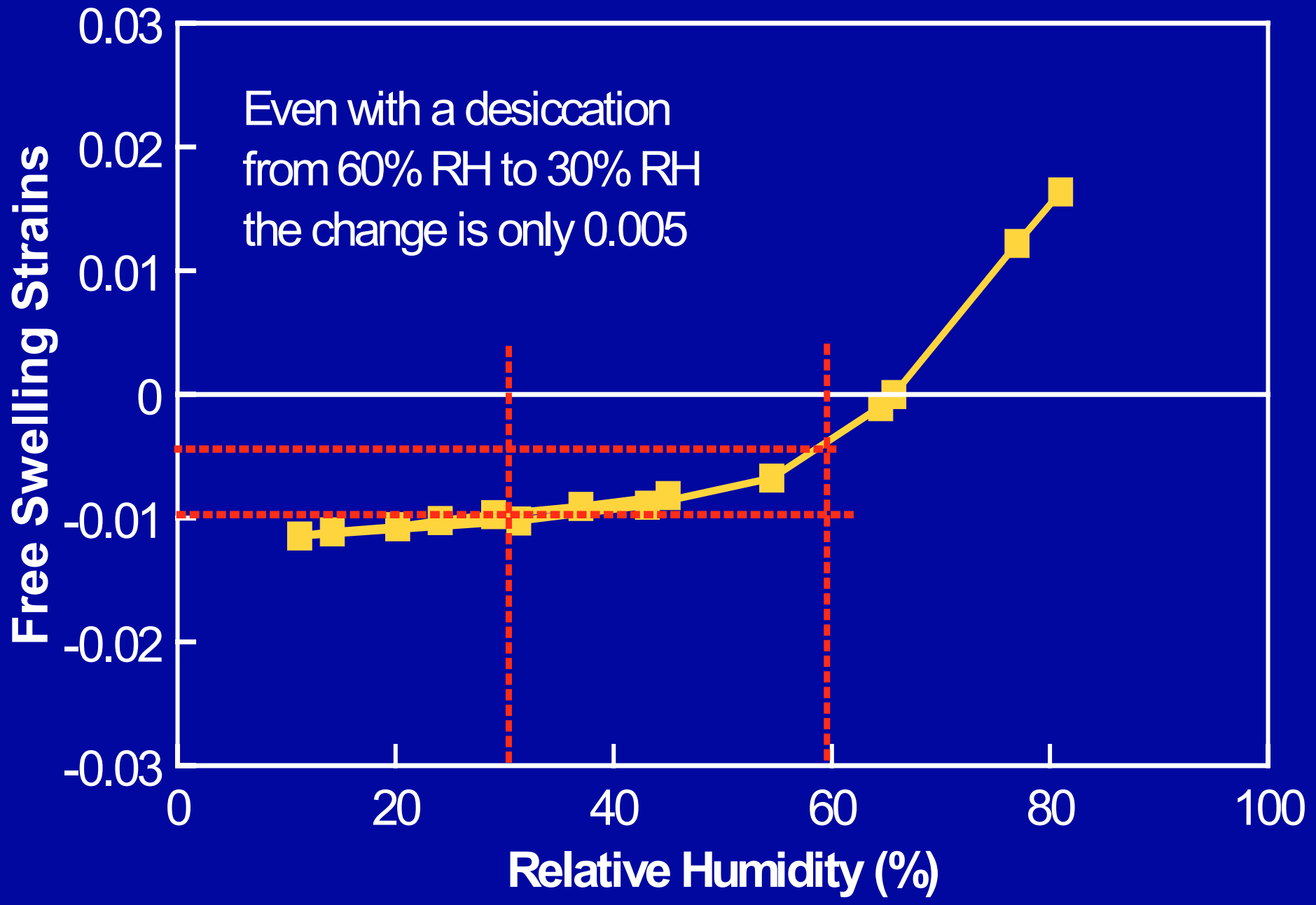

Gelatin
Above
Tg
A
B
C
D
1
2
4
10
30
100
500
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100
Temperature, C
Relative Humidity

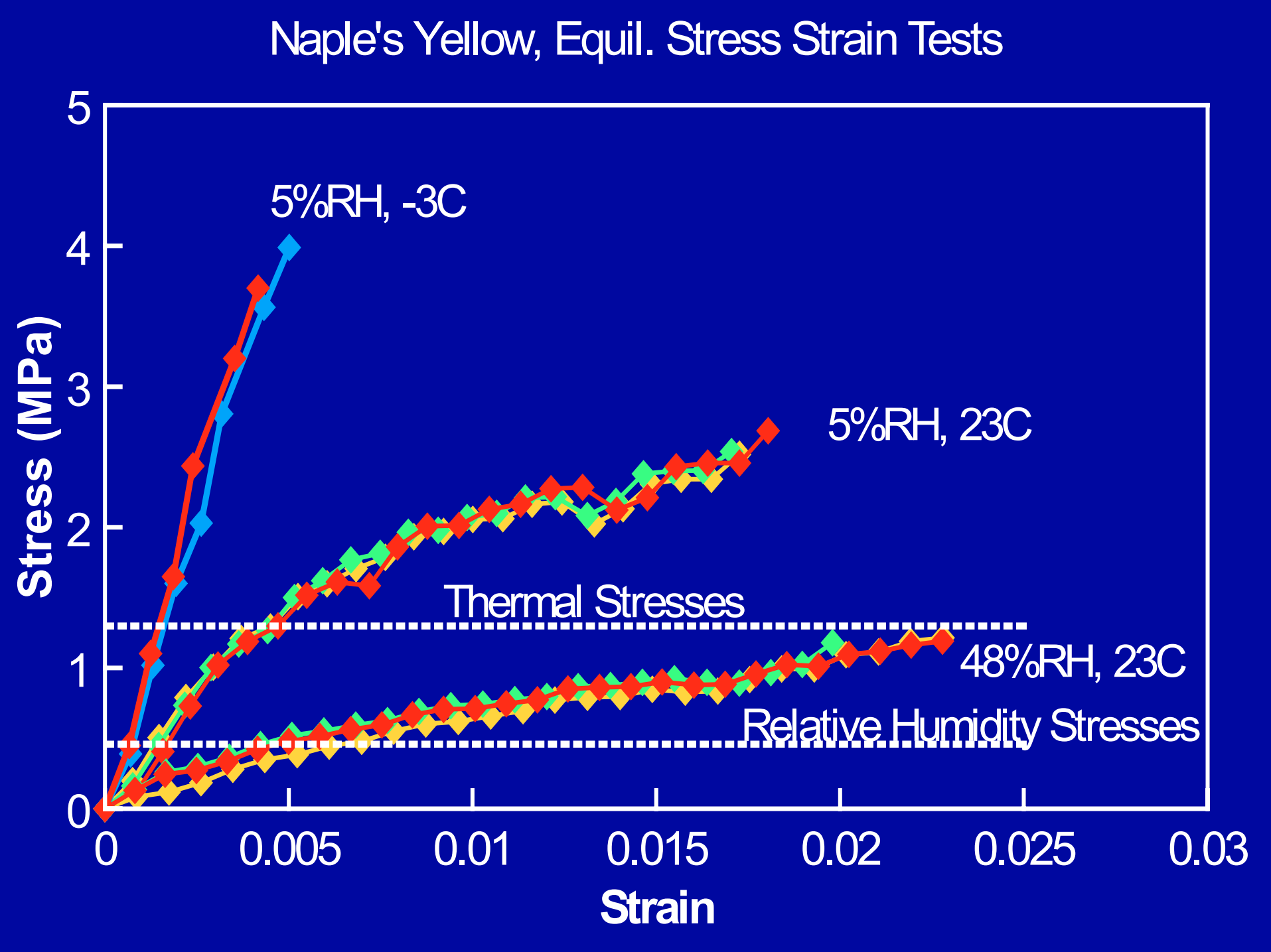
Artists' Paints

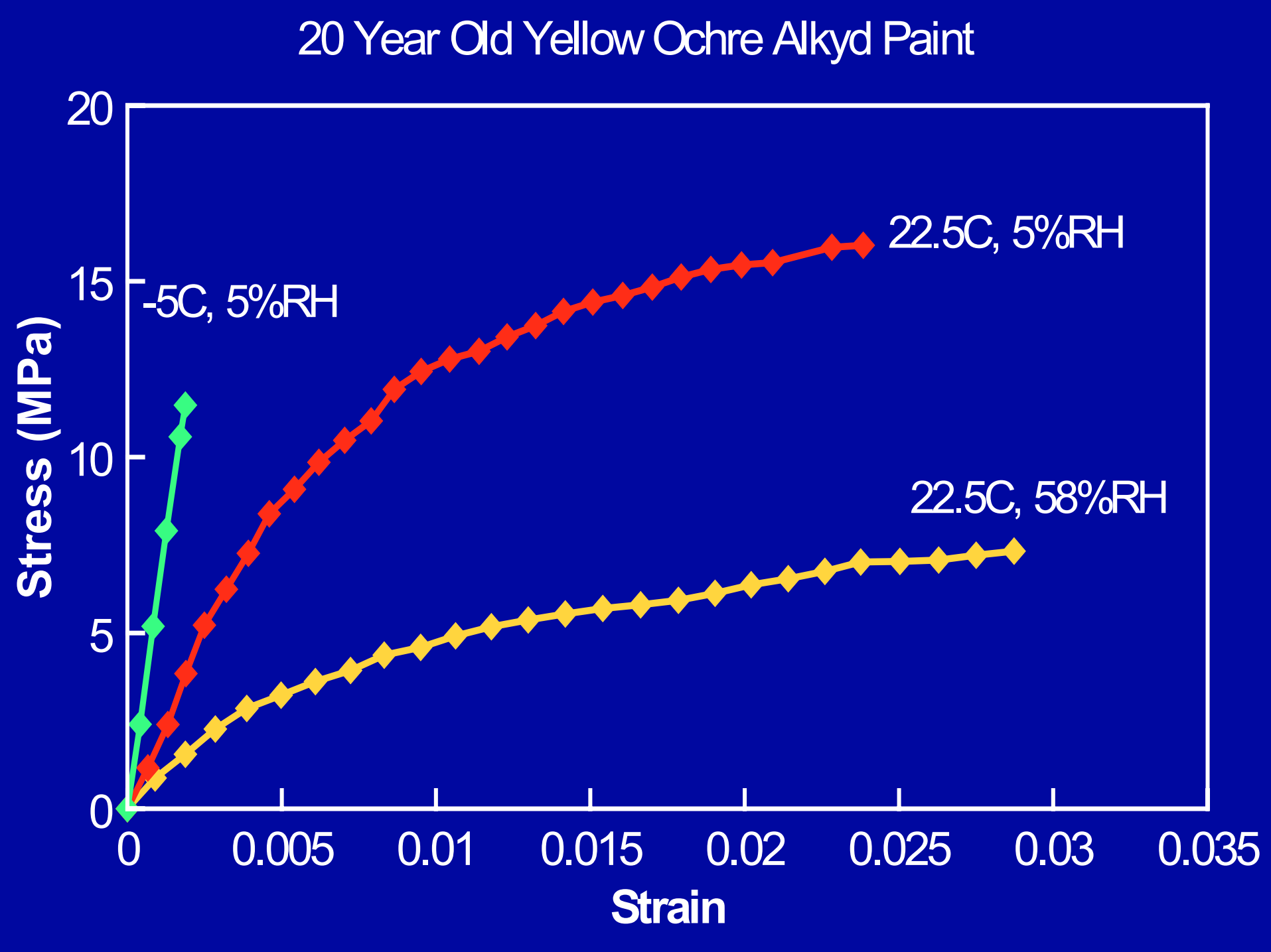
This category can include oil paints, acrylic emulsion paints, alkyd paints, egg tempera, and others. Low temperature is a far greater problem than low relative humidity

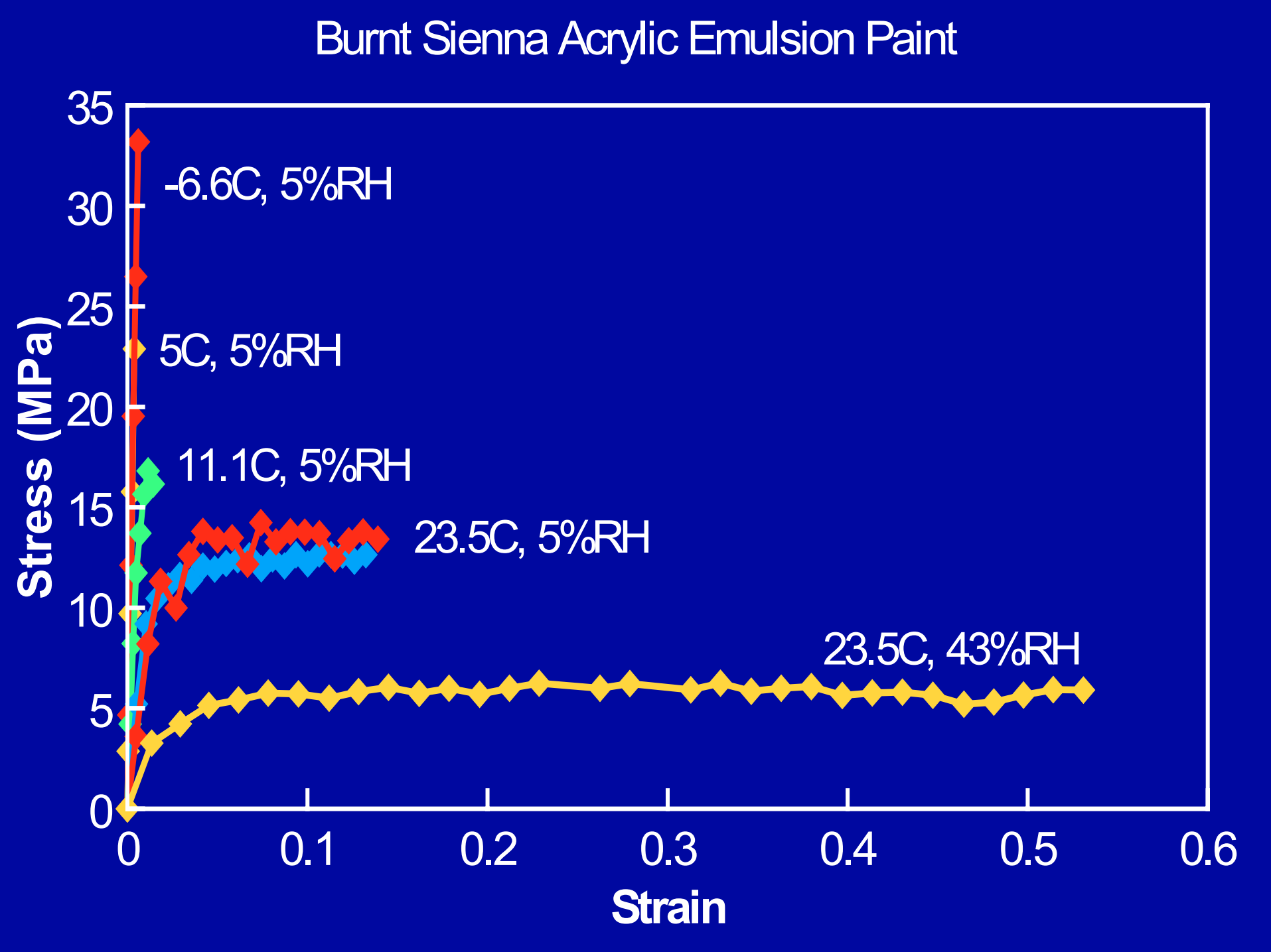

White Lead in Cold Pressed Linseed Oil
Free Swelling Strains
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0
20
40
60
80
100
Relative Humidity (%)

20 Year Old Yellow Ochre in Linseed Oil




Naple's Yellow, Equil. Stress Strain Tests
5%RH, -3C
5%RH, 23C
48%RH, 23C
Thermal Stresses
Relative Humidity Stresses
Stress (MPa)
Strain
0
1
2
3
4
5
0
0.005
0.01
0.015
0.02
0.025
0.03


20 Year Old Yellow Ochre Alkyd Paint
Stress (MPa)
Strain
-5C, 5%RH
22.5C, 5%RH
22.5C, 58%RH
0
5
10
15
20
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035


Burnt Sienna Acrylic Emulsion Paint
-6.6C, 5%RH
5C, 5%RH
11.1C, 5%RH
23.5C, 5%RH
23.5C, 43%RH
Stress (MPa)
Strain
0
5
10
15
20
25
30
35
0
0.1
0.2
0.3
0.4
0.5
0.6

Glass Transition Temperature

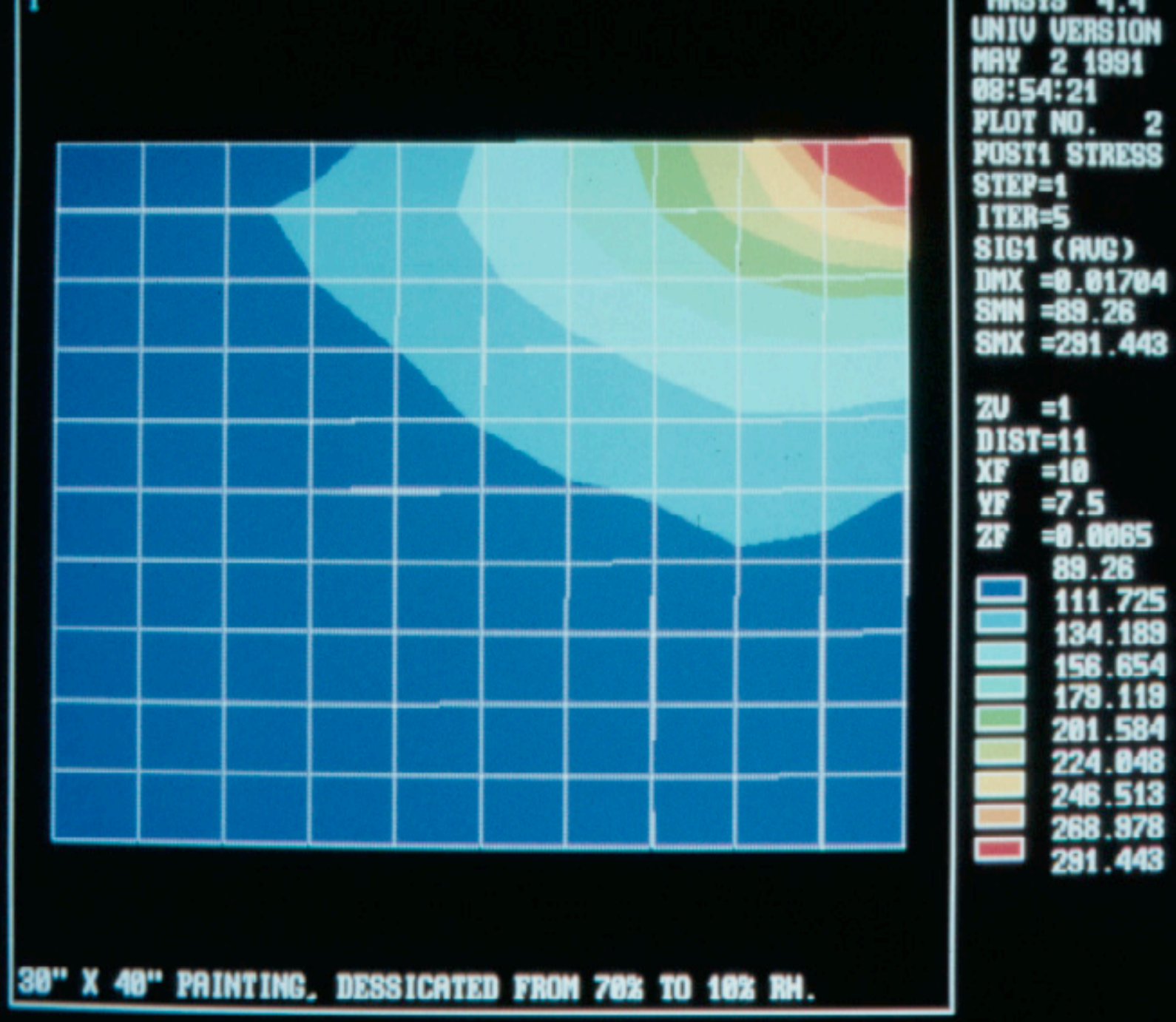
- Acrylic paints +5 C
- Oil paints -10 C
- Alkyd paints -15 C

Paints can sustain fairly large swings in relative humidity.

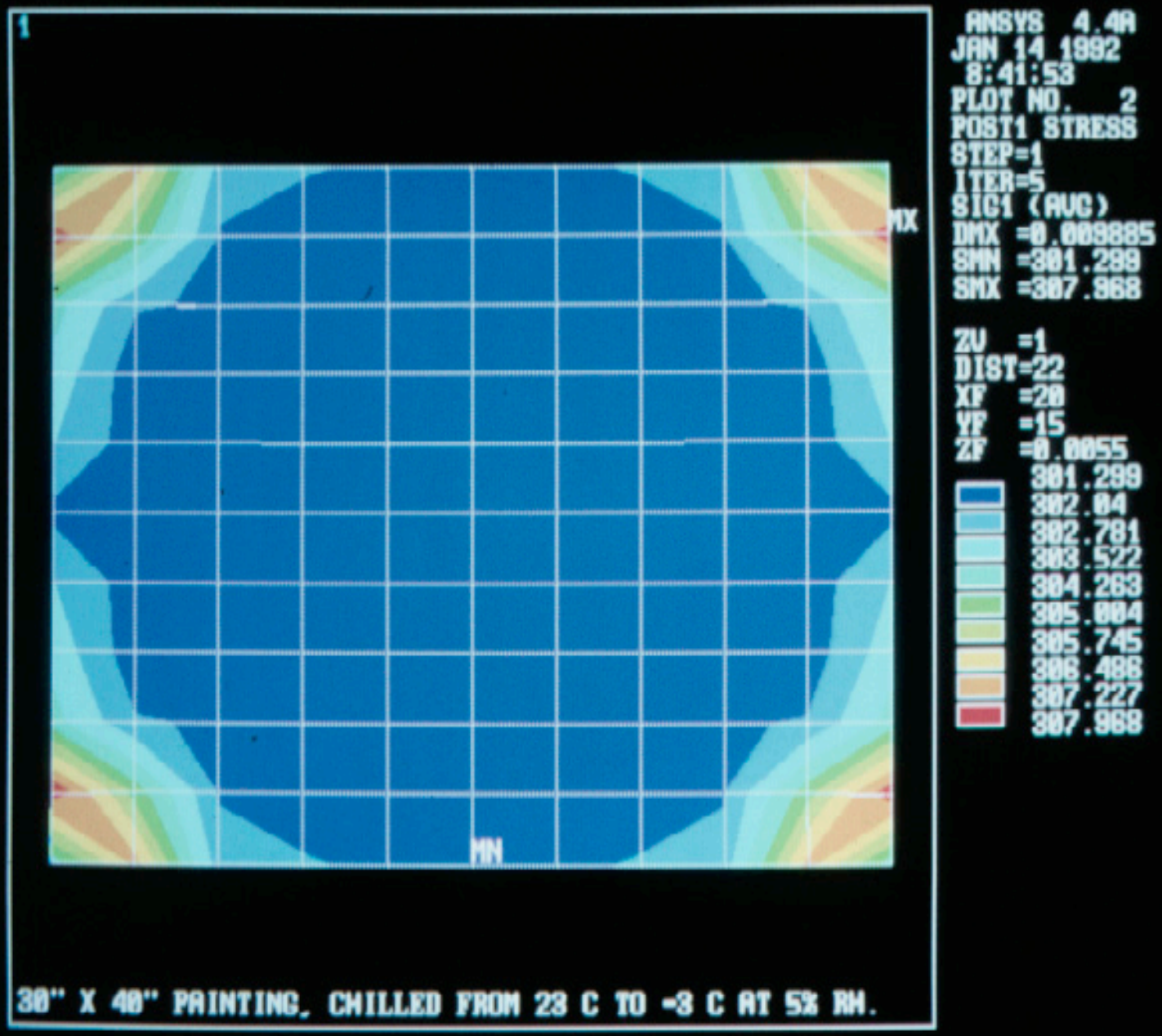
Tests indicates that 40% RH +/- 15 can be tolerated easily. Low temperatures are a bigger threat to the stability of the paint films.

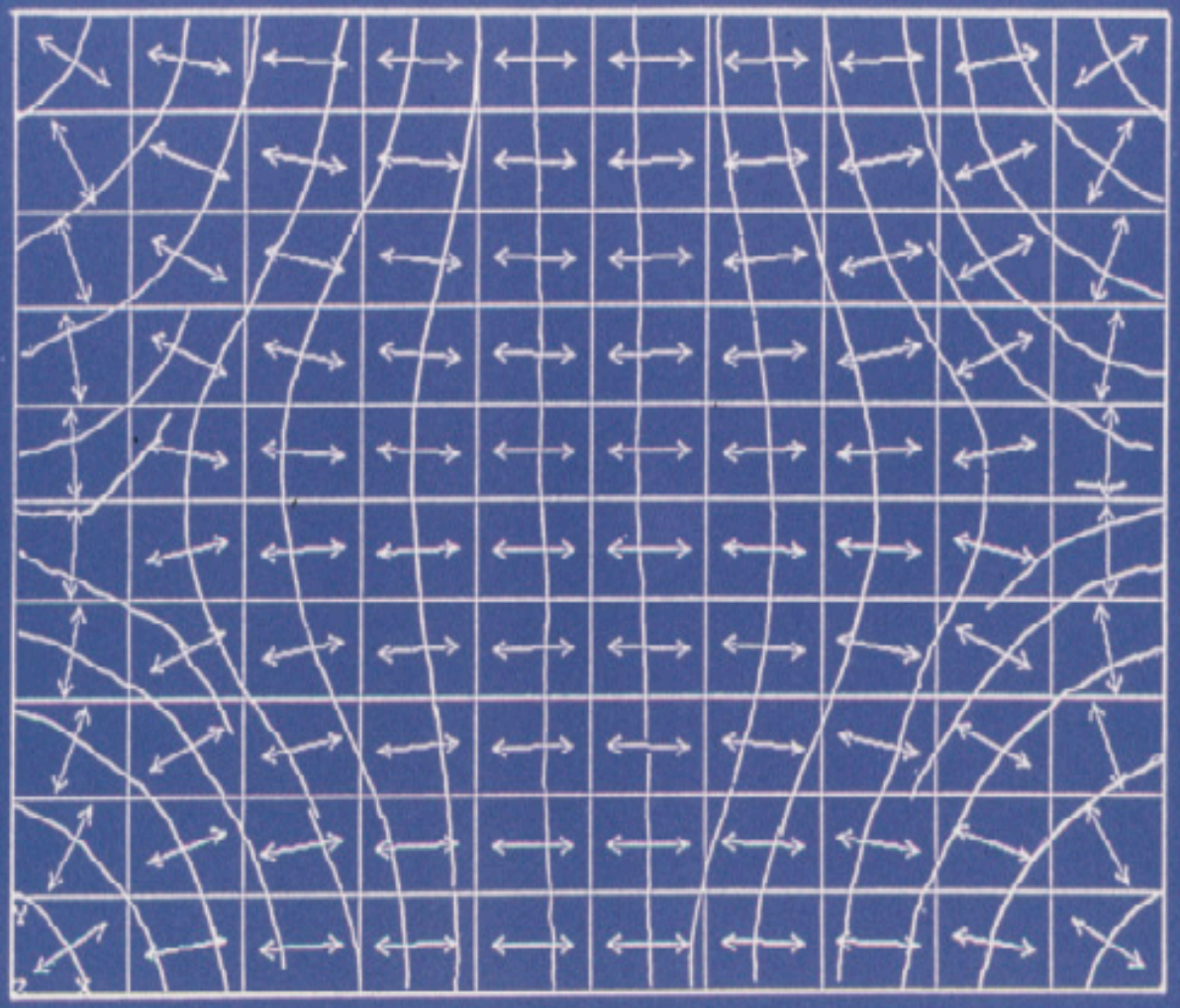
Computer Modeling of Canvas Supported Paintings

Models include all layers of the painting, linen fabric, glue size, oil ground and the oil design layers.


ANSYS 4.4
UNIV VERSION
MAY 2 1991
08:54:21
PLOT NO. 2
POST1 STRESS
STEP=1
ITER=5
SIG1 (AVG)
DMX =0.01704
SMN =89.26
SMX =291.443
ZV =1
DIST=11
XF =10
YF =7.5
ZF =0.0065
89.26
111.725
134.189
156.654
179.119
201.584
224.048
246.513
268.978
291.443
30" X 40" PAINTING, DESSICATED FROM 70% TO 10% RH.

9 CYCLES
90% TO 35% RH


1
MX
MN
ANSYS 4.4A
JAN 14 1992
8:41:53
PLOT NO. 2
POST1 STRESS
STEP=1
ITER=5
SIC1 (AVG)
DMX =0.009885
SMN =301.299
SMX =307.968
ZV =1
DIST=22
XF =20
YF =15
ZF =0.0055
301.299
302.04
302.781
303.522
304.263
305.004
305.745
306.486
307.227
307.968
30" X 40" PAINTING, CHILLED FROM 23 C TO -3 C AT 5% RH.



SIMULATED COOLING FROM 23 C TO -3 C AT 5% RH:
COMPUTER GENERATED STRESS DIRECTIONS
WITH SUPERIMPOSED CRACK PATTERN

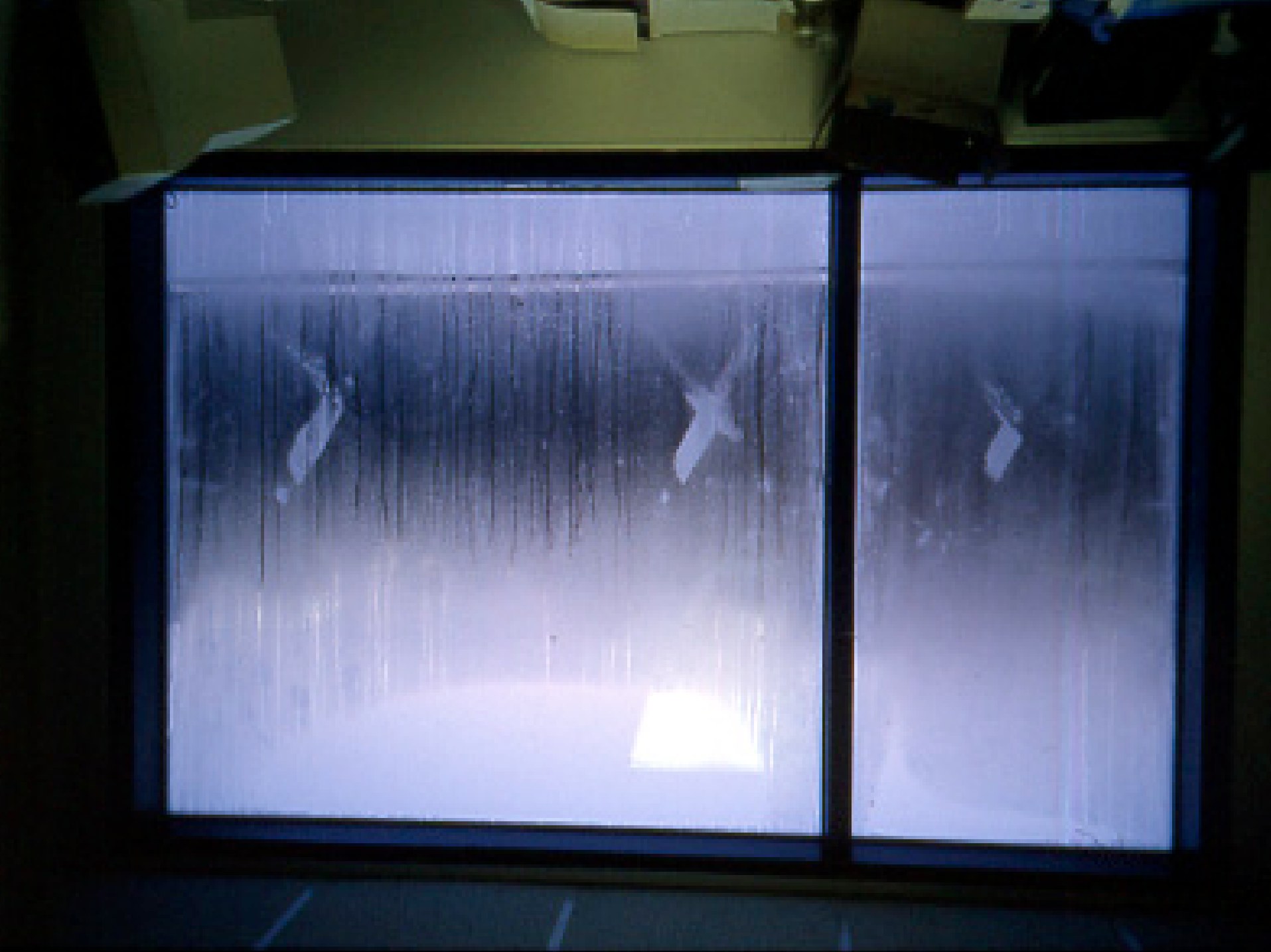
WEFT

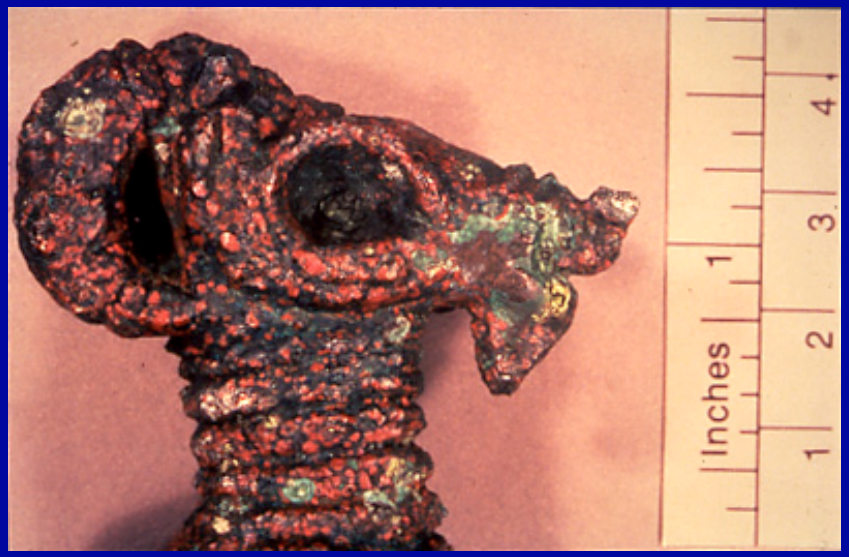
Environmental Settings to Reduce Building Maintenance

Mold Growth

Effects of high relative humidity can be localized; by lack of air circulation and/or by condensation

Inappropriate relative humidity can cause salts to migrate to the surface of ceramics or to accelerate reactions at the surface of objects.





Metal corrosion from salt deposits reacting with ambient moisture

So….. What Is the Right Value?

Recommendations

An appropriate museum exhibition environment would be:

Winter; 40% RH +/- 5% RH

Summer; 55% RH +/- 5% RH

Temperature; basic visitor comfort

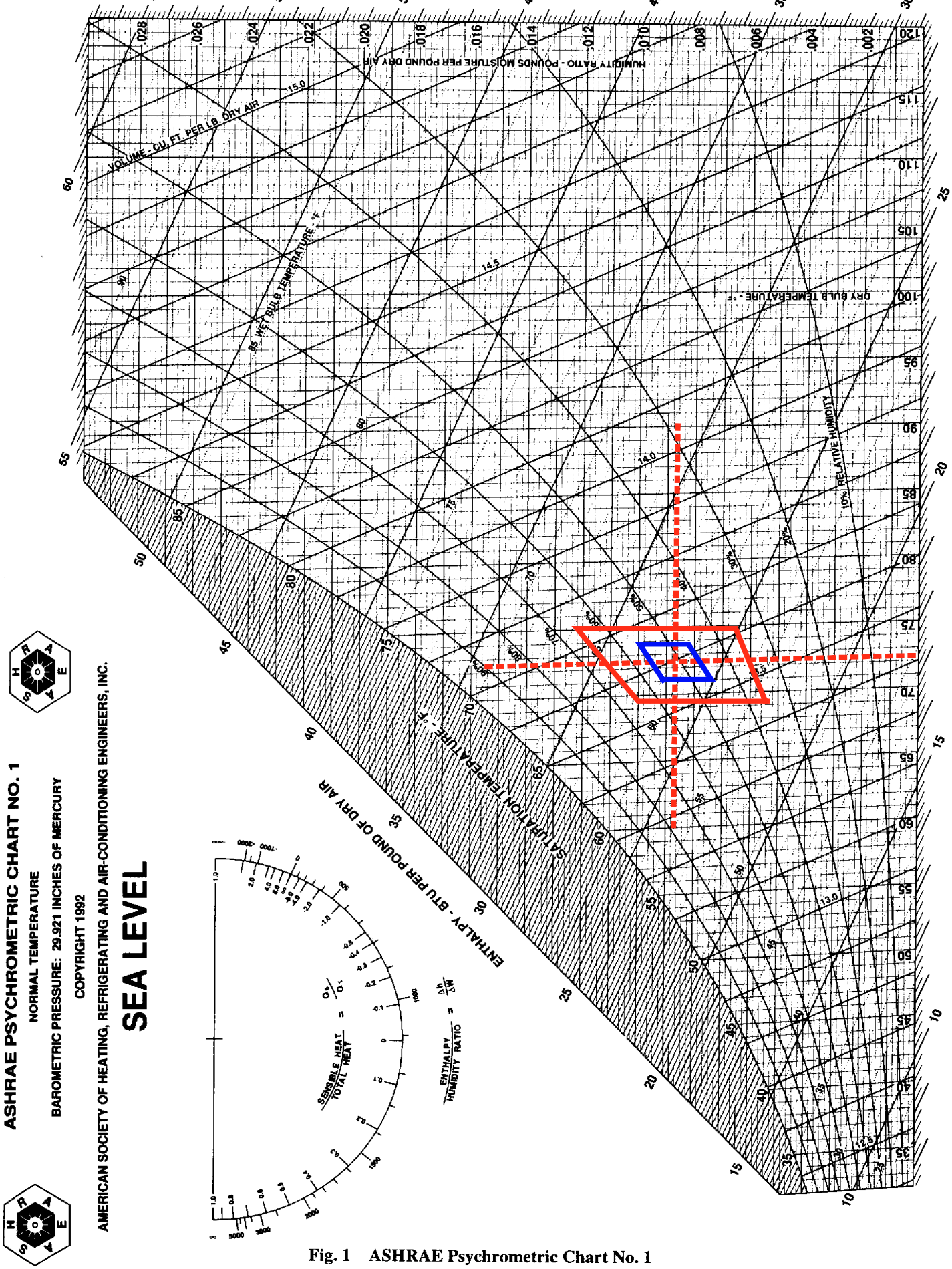
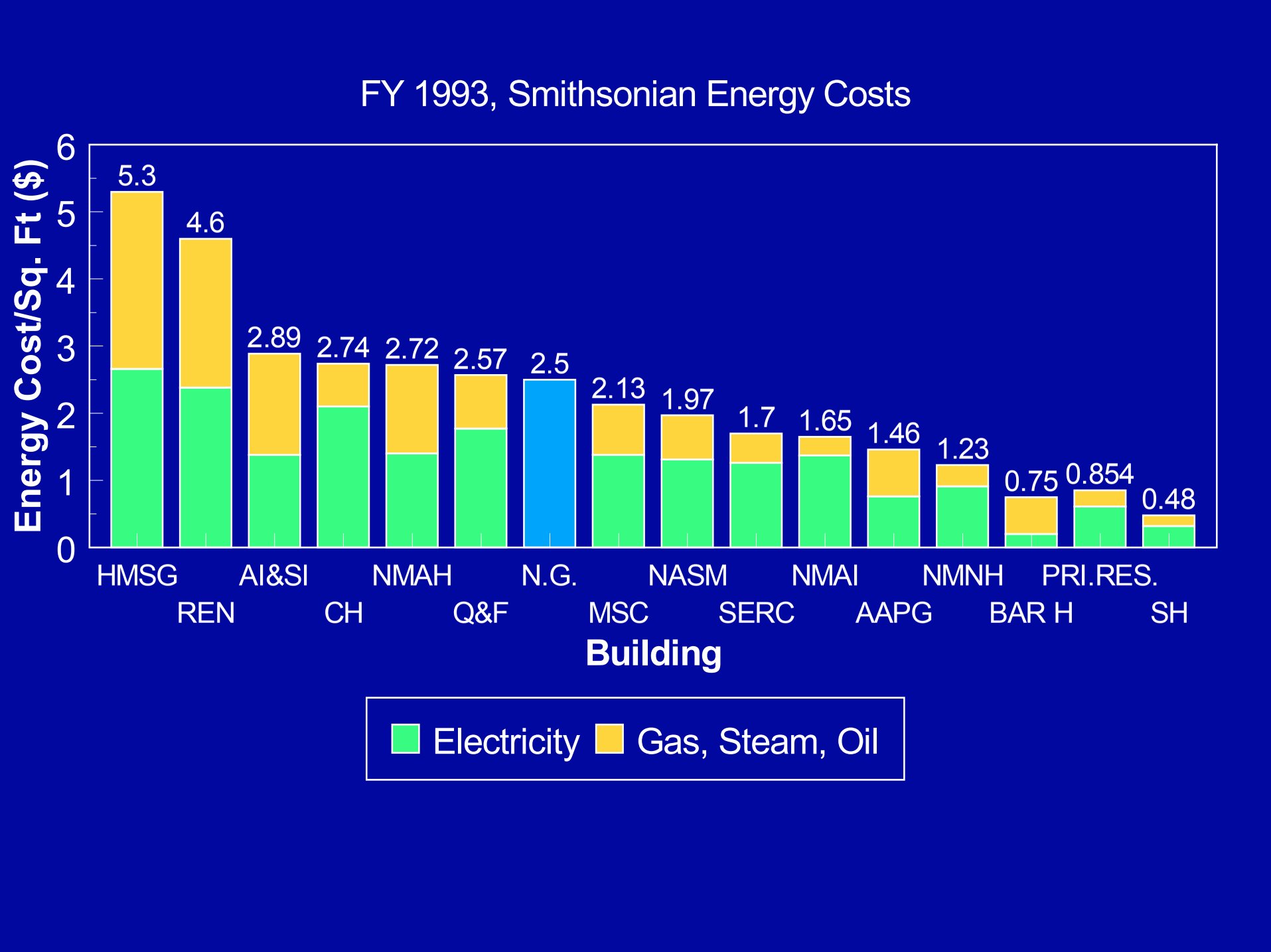
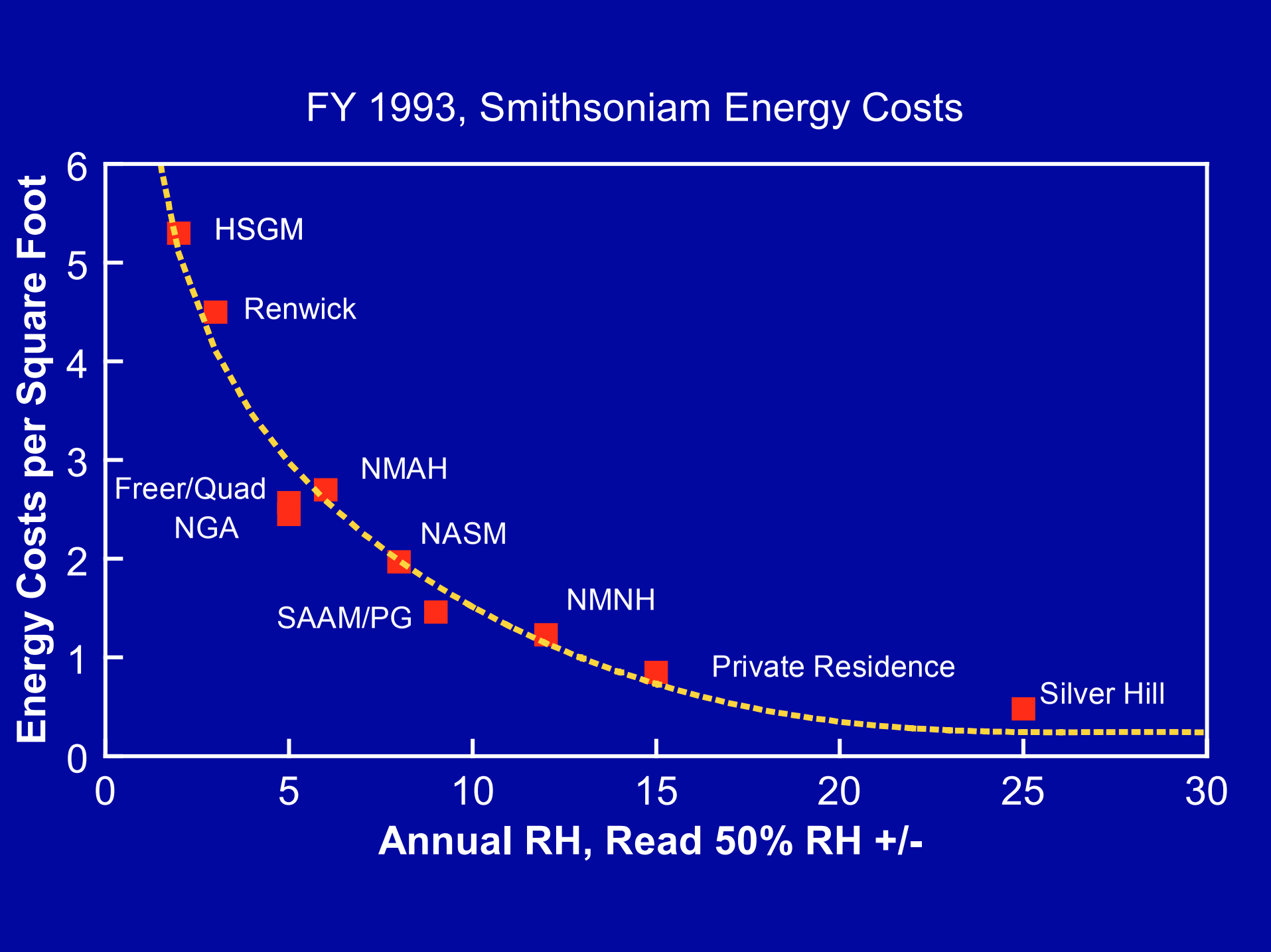


Fig. 1 ASHRAE Psychrometric Chart No. 1


FY 1993, Smithsonian Energy Costs
Energy Cost/Sq. Ft ($)
0
1
2
3
4
5
6
5.3
4.6
2.89
2.74
2.72
2.57
2.5
2.13
1.97
1.7
1.65
1.46
1.23
0.75
0.854
0.48
HMSG
REN
AI&SI
CH
NMAH
Q&F
N.G.
MSC
NASM
SERC
NMAI
AAPG
NMNH
BAR H
PRI.RES.
SH
Building
Electricity
Gas, Steam, Oil


FY 1993, Smithsoniam Energy Costs
Energy Costs per Square Foot
0
1
2
3
4
5
6
HSGM
Renwick
NMAH
Freer/Quad
NGA
NASM
SAAM/PG
NMNH
Private Residence
Silver Hill
0
5
10
15
20
25
30
Annual RH, Read 50% RH +/-

New Smithsonian Environmental Guidelines

"For general collections and public spaces ….
70 +/- 4 degrees F and
Relative Humidity at **45 +/-8%.**"

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