TS-SSC 93-004

Cable Insulation Workshop
February 5, 1992
SSCL

Kapton-Epoxy Insulation and Apical-Cryorad System Tests

R. E. Sims
2/4/92

CONCLUSIONS

Based on small quantities of ten stacks made from DuPont Kapton types H, HA, and LT. The epoxy used on the Kapton was 3M #2290

1. Removing the Glass-Epoxy tape increases stress relaxation as much as 2 to 3 times (unless under layers of polyimide utilize adhesive. See 5 below).

2. This stress relaxation can be minimized by:

   a. Use as few layers of Kapton as possible.
   b. Use high molding pressures (≥ 10 KPSI)
   c. Stay in the mold longer, preferably at the curing temperature
   d. A single ten stack made using DuPont CI and RCI at 225°C (438°F) showed a stress relaxation about 16% greater than Glass-epoxy, i.e., very close to glass epoxy.

3. The Glass-Tape system accommodates approximately twice the material tolerance variation that 3 layers of Kapton can. (.015" for glass tape, .007" for 3 layers of Kapton).

4. Single Kapton insulation systems <u>with no inner layer adhesive</u> have 10% to 25% lower final coil modulus of elasticity.

5. It appears that coils made <u>with inner</u> and <u>outer layer adhesives</u> would have creep levels <u>equal to or better than glass tape</u>.

6. It is difficult to extrapolate coil size from ten stack size with good accuracy. (Curved stacks would be better.)

7. Allied Signal Apical type NP film appears to provide lower creep than DuPont Kapton type K (by apprx. 22% to 50% depending on wraps and layers of adhesive).

8. Apical type NP film also appears to make ten stacks with slightly higher modulus of elasticity properties (by roughly 15%).

9. If "Loaded" films have lower cryogenic shrink and lower bulk modulus than non-loaded films, then DuPont "LT" film should be the "top" layer of insulation.

10. When adhesive is utilized on layers closest to cable, small amounts of adhesive can be found on the cable. (Could these small amounts of adhesive crack, exotherm, and cause a quench?)

11. A Spindel (SSCL) suggested utilizing adhesive on <u>both</u> sides of the top insulation layers, but not on the bottom layers. This should produce a good compromise which cannot leak adhesive onto the cable.

APICAL BRAND INSULATION COMBINATIONS BEING STUDIED AS TEN STACKS

MATERIAL INNER	OUTER	WRAP PATTERN(IN/OUT) 2/1	2/2	3/1	3/2	LAYER ADHESIVE INNER	OUTER	
AV	NP	X		6K 10K X	X		C	BEST ELONG.+TOUGH COVER
AV	NP*	X	X				E	" " " "
NP	NP	6K 10K X	X 10K				C	TOUGHEST INNER+OUTER
NP	NP	10K X				C	C	TEST LAYER TO LAYER GLUE
NP*	NP*	X	X				E	COMPARES CRYORAD AND EPOXY
NP	LT	10K X	X 10K				E	TOUGHEST WITH BEST CRYO
AV	LT	10K X					C	E	LIKE DUPONTS HA+LT
								BUT BOTH LAYERS BONDED
INNER COILS			NEEDED	FOR OUTER COILS				
NP	LT	X	X			C	E	BEST CREEP+CRYO.SHRINK?

AV= APICAL BRAND POLYIMIDE FILM WITH TENSILE MODULUS OF 460 KPSI, 1.0 MILS THICK
NP= APICAL BRAND POLYIMIDE FILM WITH TENSILE MODULUS OF 600 KPSI, 1.0 MILS THICK
C= CRYORAD BRAND ADHESIVE, 0.15 TO 0.25 MILS THICK
E= #2290 EPOXY FROM 3M, 0.15 TO 0.25 MILS THICK

COATED FILMS ARE IDENTIFIED AS FOLLOWS:

MFG.#	FNAL #	BASE FILM	ADHESIVE
100AV	MA-292717	1 MIL. AV	NONE
100NP	MA-292718	1 MIL. NP	NONE
210V	MA-292713	1 MIL. AV	0.2 MIL CRYORAD
210P	MA-292716	1 MIL. NP	0.2 MIL CRYORAD
210VM	MA-292714	1 MIL. AV	0.2 MIL 2290 EPOXY
* 210PM	MA-292715	1.MIL. NP	0.2 MIL.2290 EPOXY

* MATERIAL IS UNAVAILABLE

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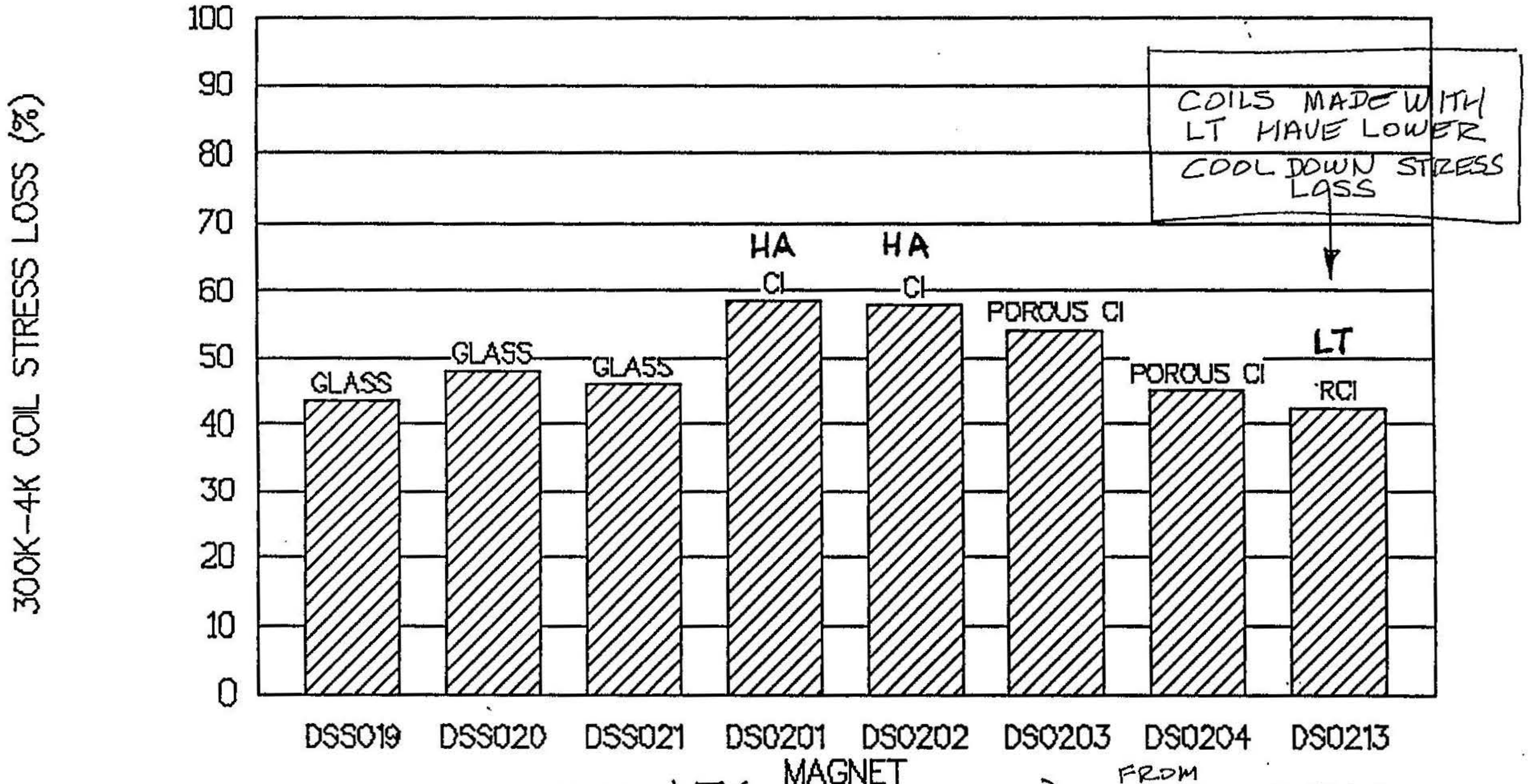
1-16-91

1.8m, 4cm SSC MAGNET DATA

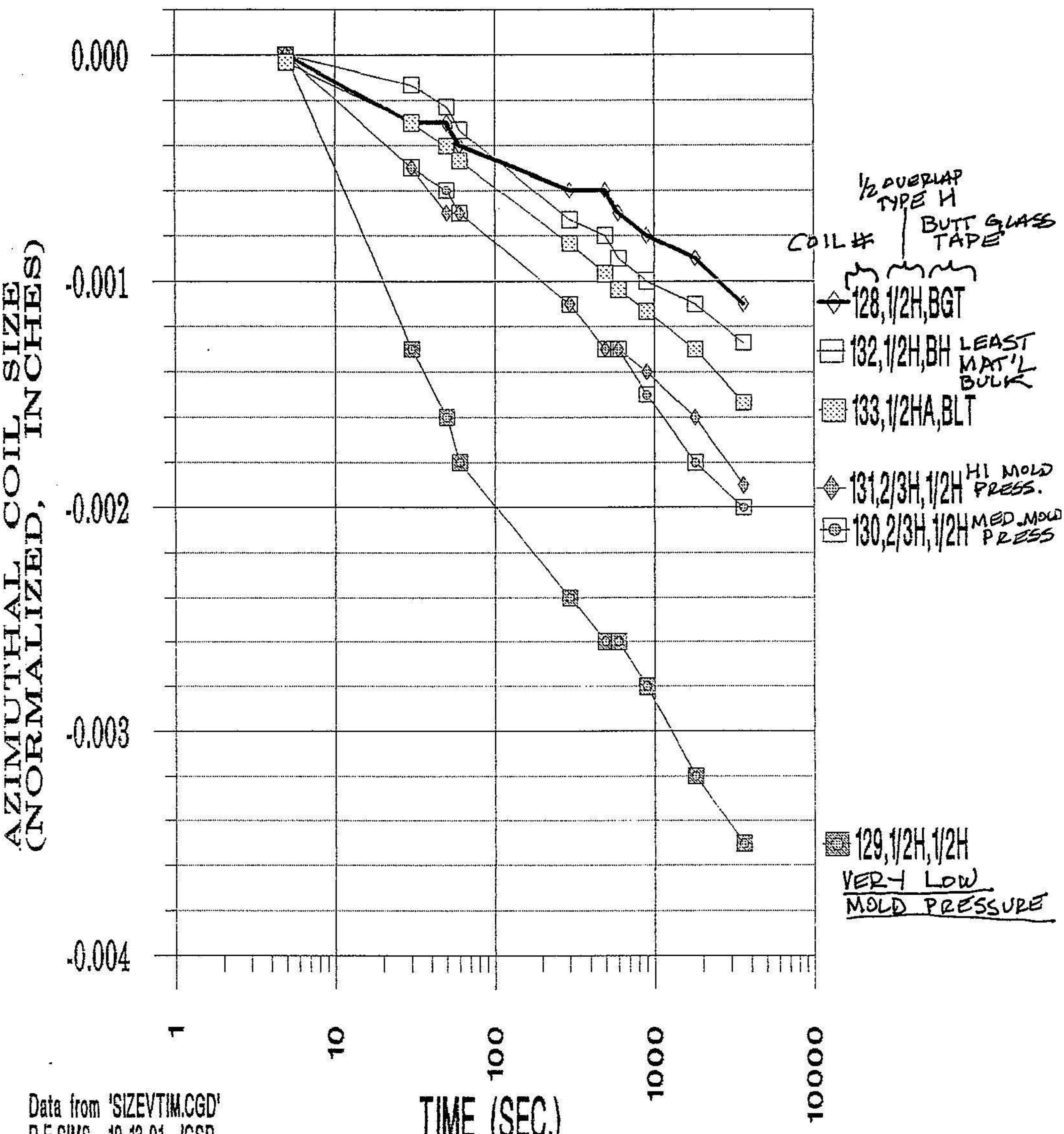
Inner Coil Cooldown Stress Loss



REASON FOR FAVORING LT (LOADED POLYIMIDE) FILM AS THE UPPER LAYER(S) OF INSULATION

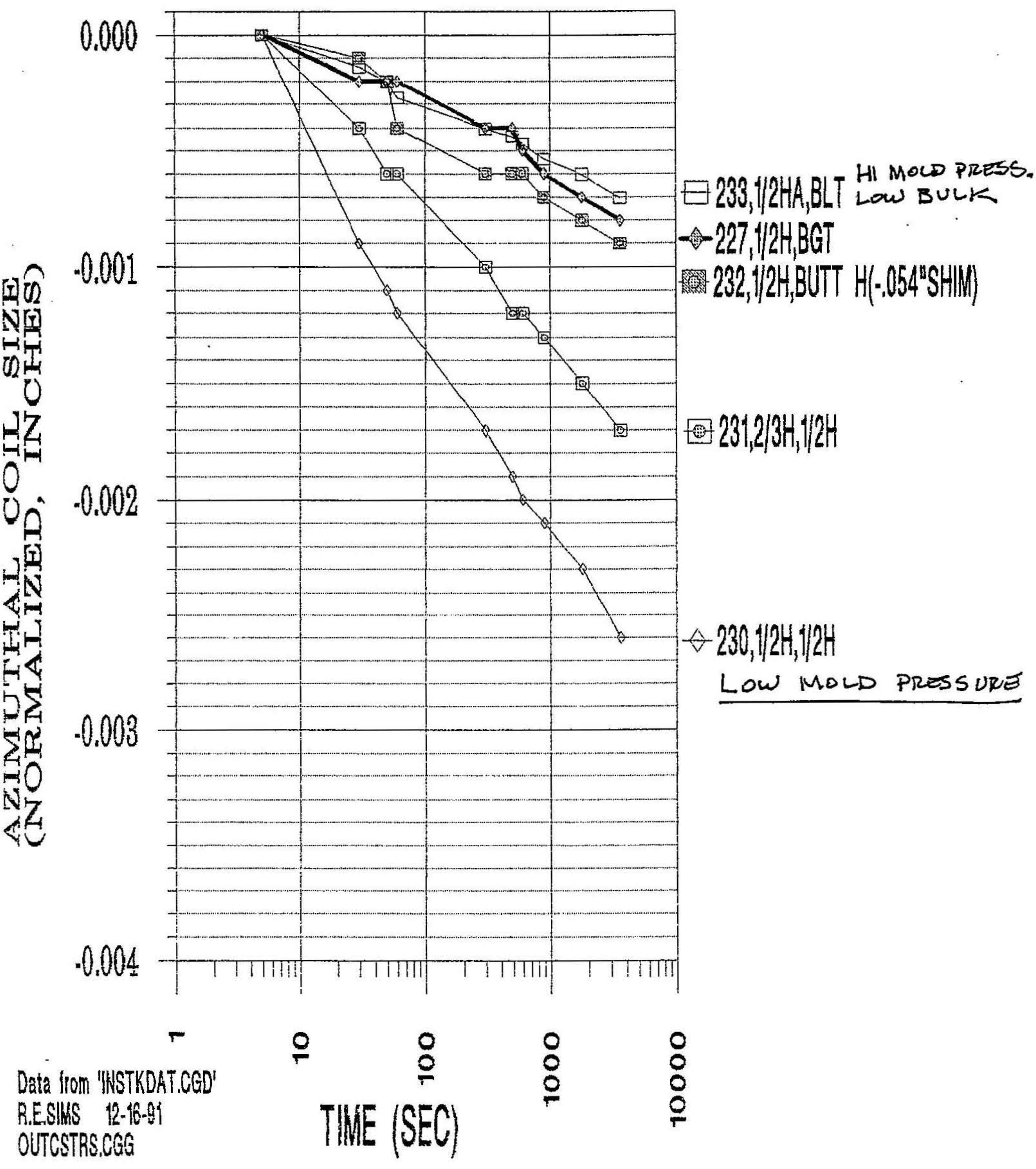
FROM
M. ANERELLA
BNL
8-6-91

SSC 50 mm INNER COIL STRESS RELAXATION AT 12 KPSI WITH VARIOUS INSULATIONS



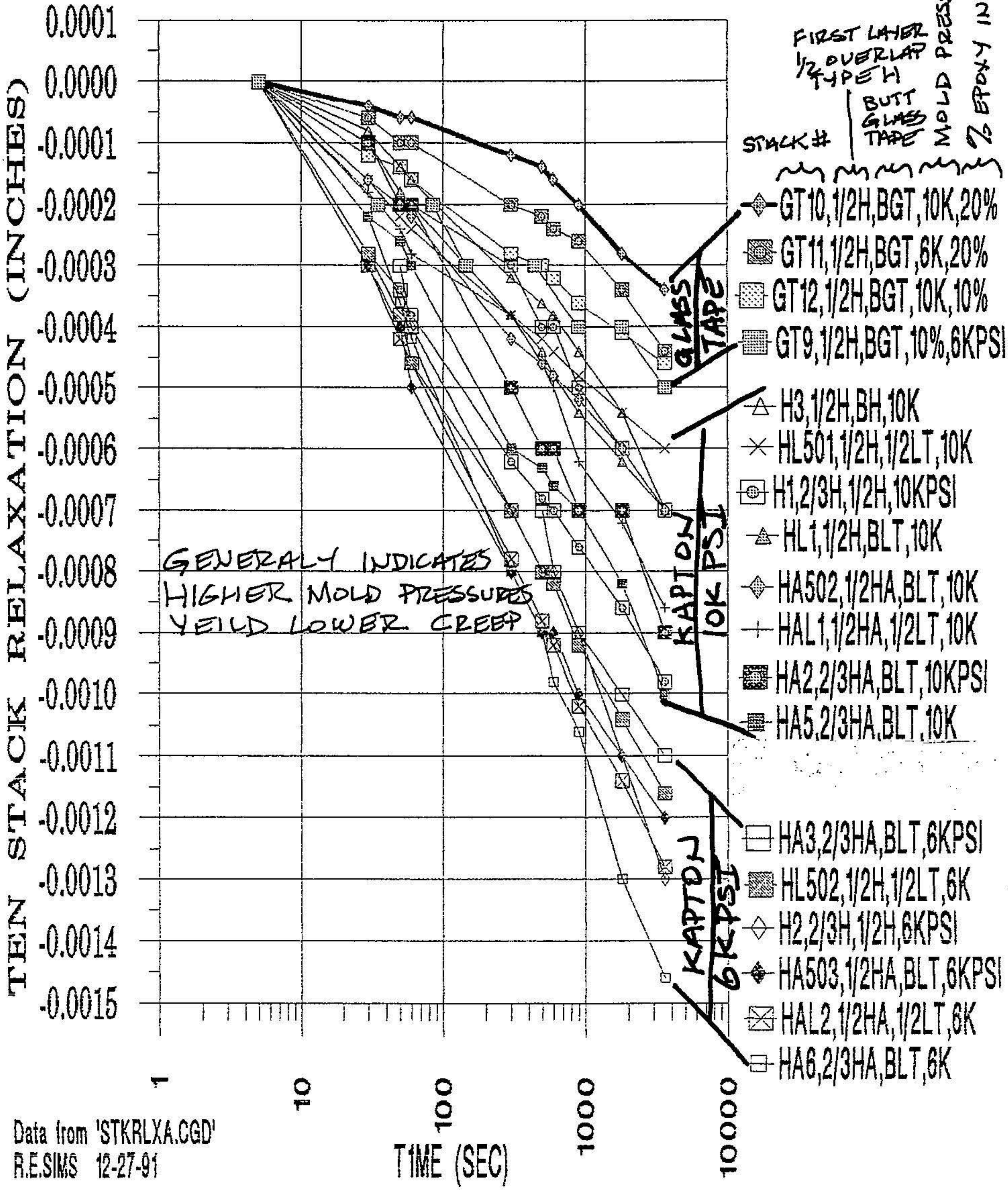
Data from 'SIZEVTIM.CGD'
R.E.SIMS 12-13-91 ICSR

SSC 50 mm OUTER COIL STRESS RELAXATION AT 12 KPSI WITH VARIOUS INSULATIONS



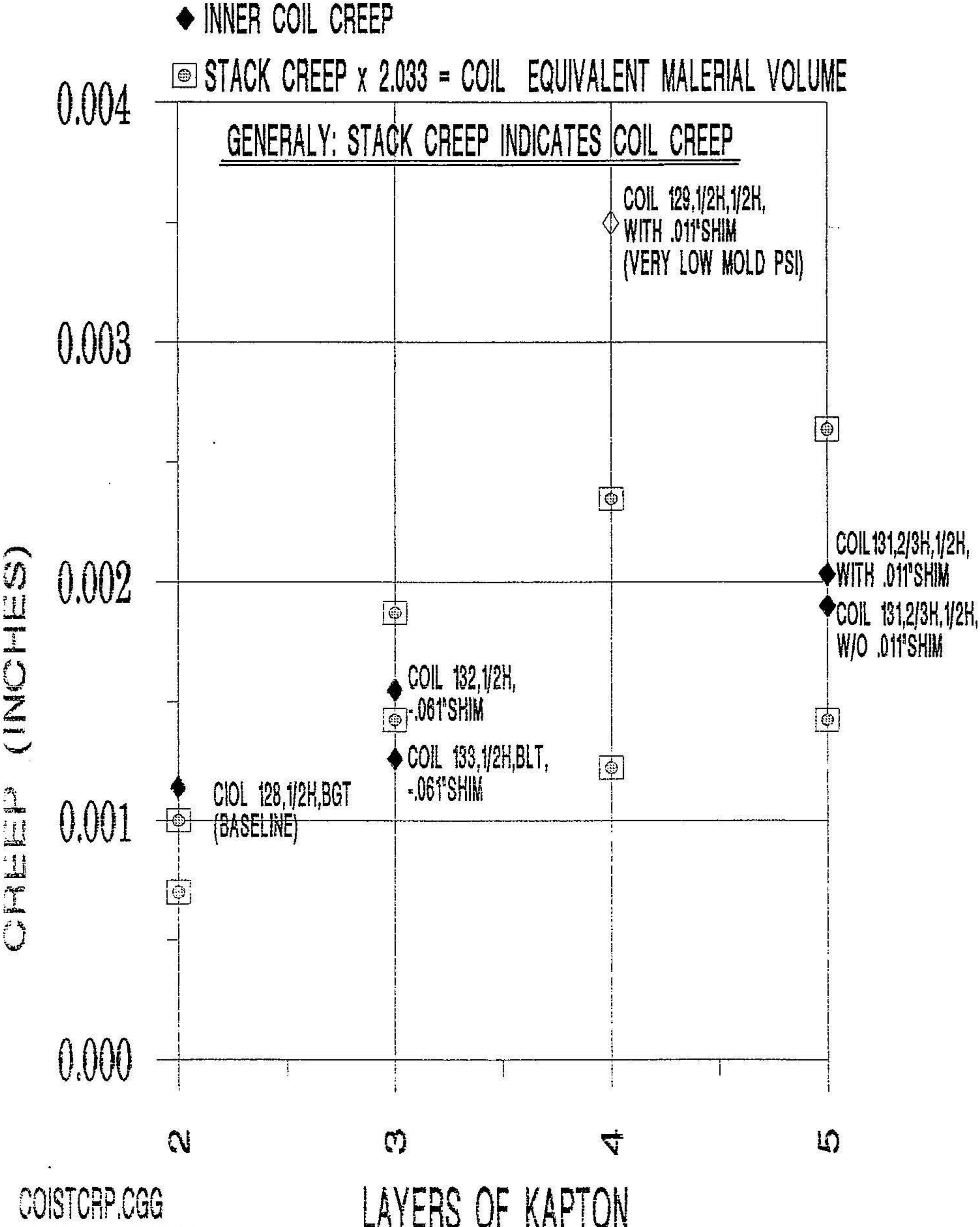
Data from 'INSTKDAT.CGD'
R.E.SIMS 12-16-91
OUTCSTRS.CGG

TEN STACK STRESS RELAXATION WITH 12 KPSI FOR ONE HOUR (SSC 50mm INNER CABLE)



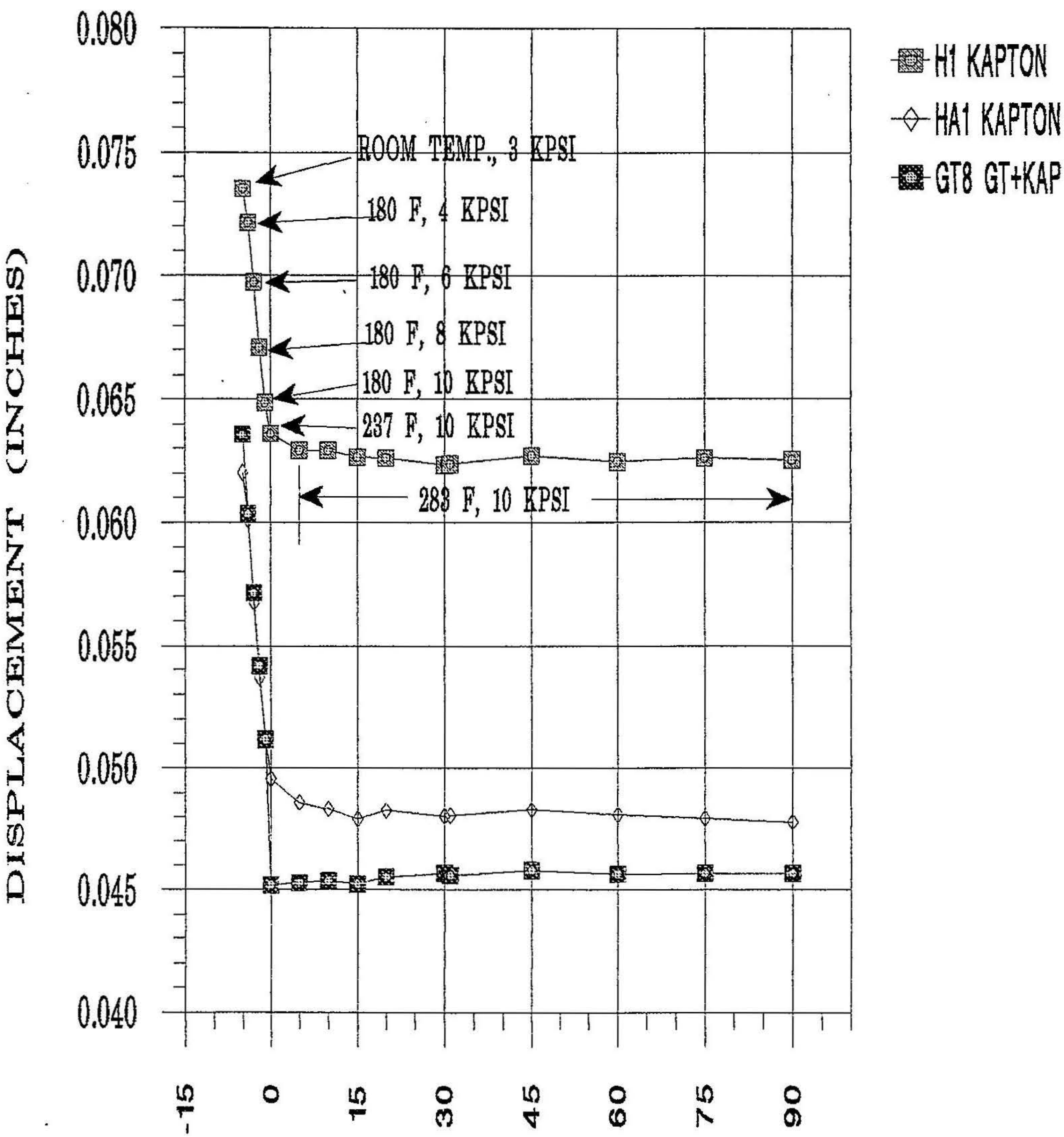
Data from 'STKRLXA.CGD'
R.E.SIMS 12-27-91

COMPARING INNER COIL CREEP TO TEN STACK CREEP
(12 KPSI FOR 60 MINUTES)



COISTCRP.CGG
R.E.SIMS 2-13-92

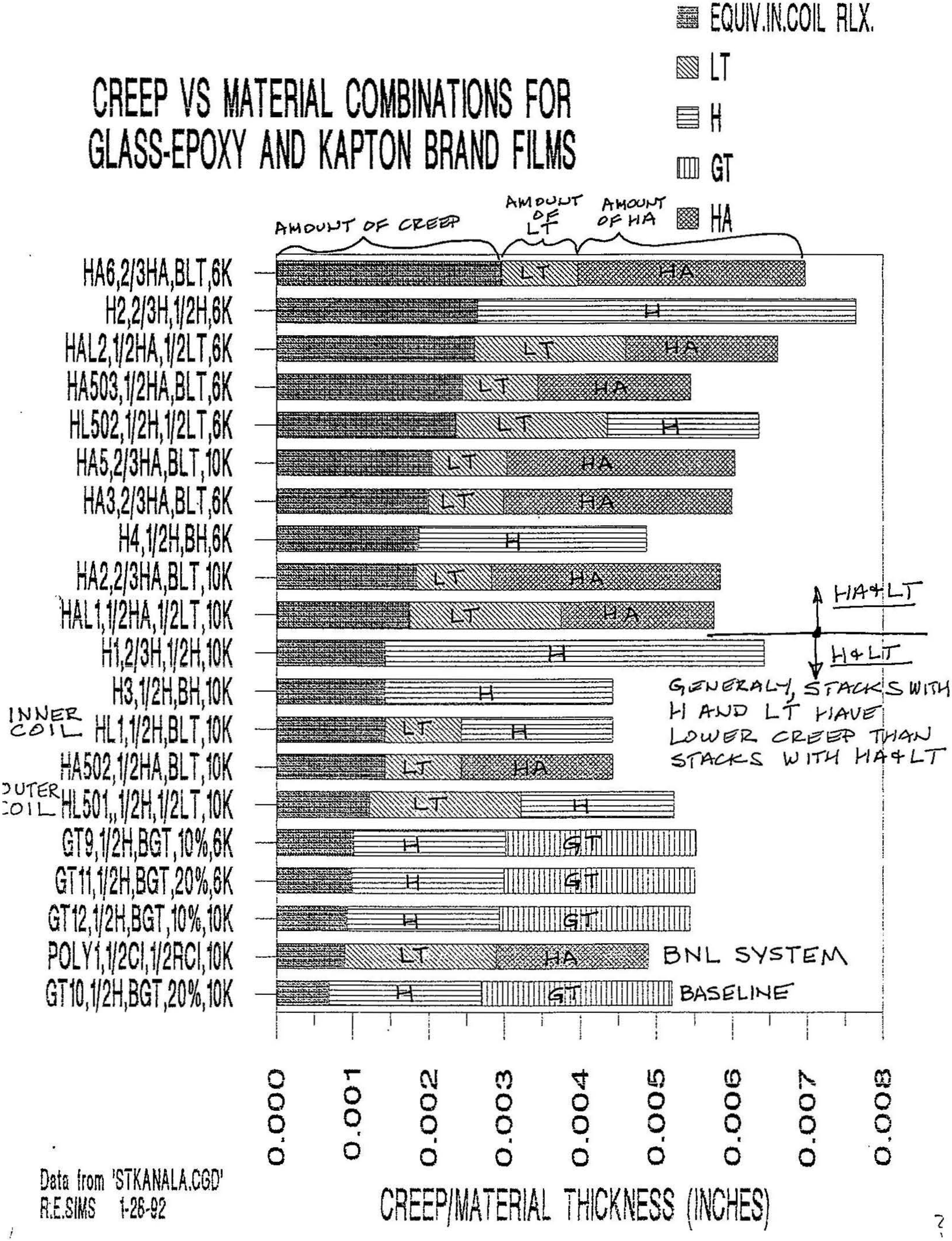
10-STACK INSULATION ONLY



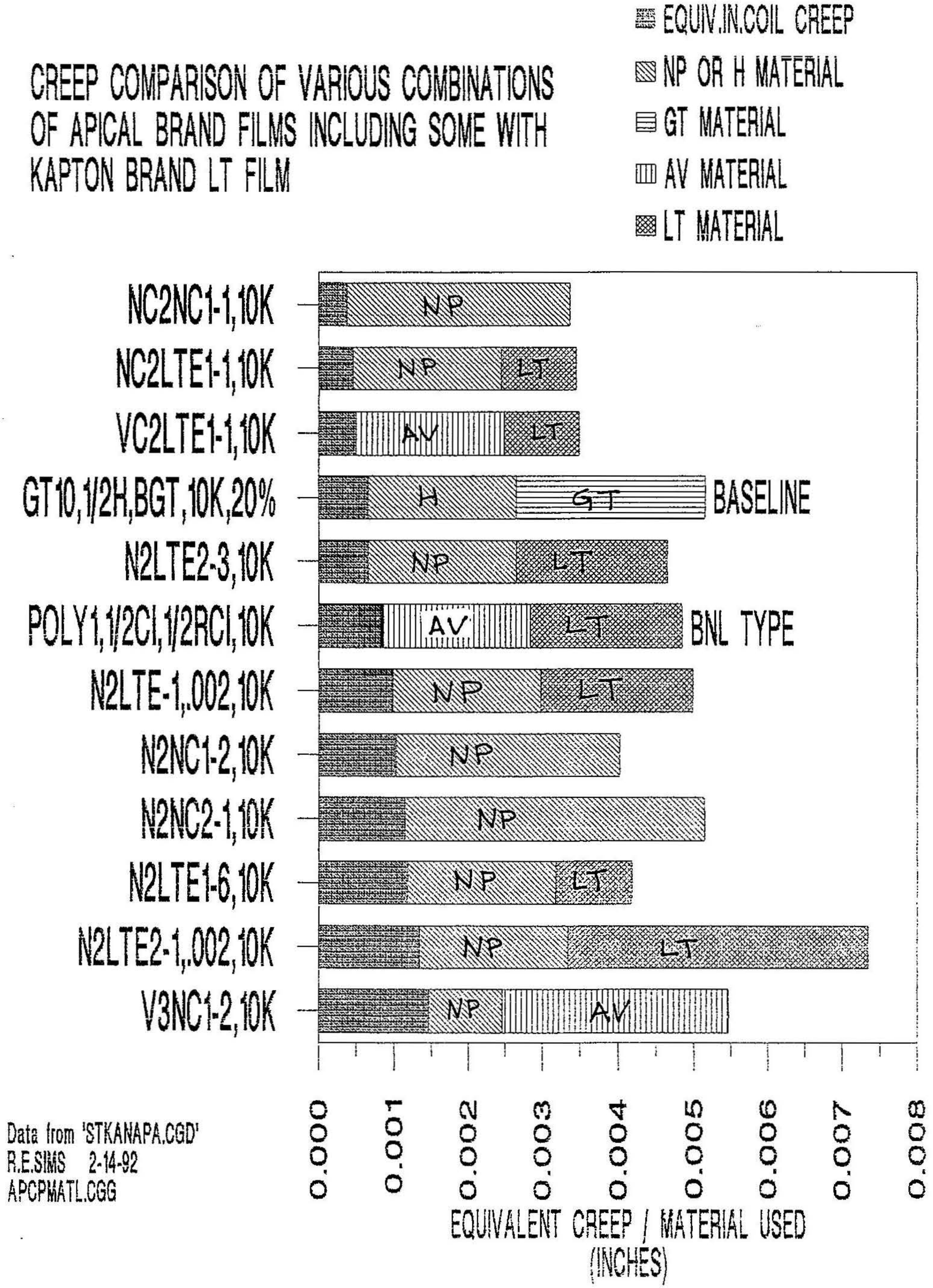
Data from 'GT2.CGD'

TIME

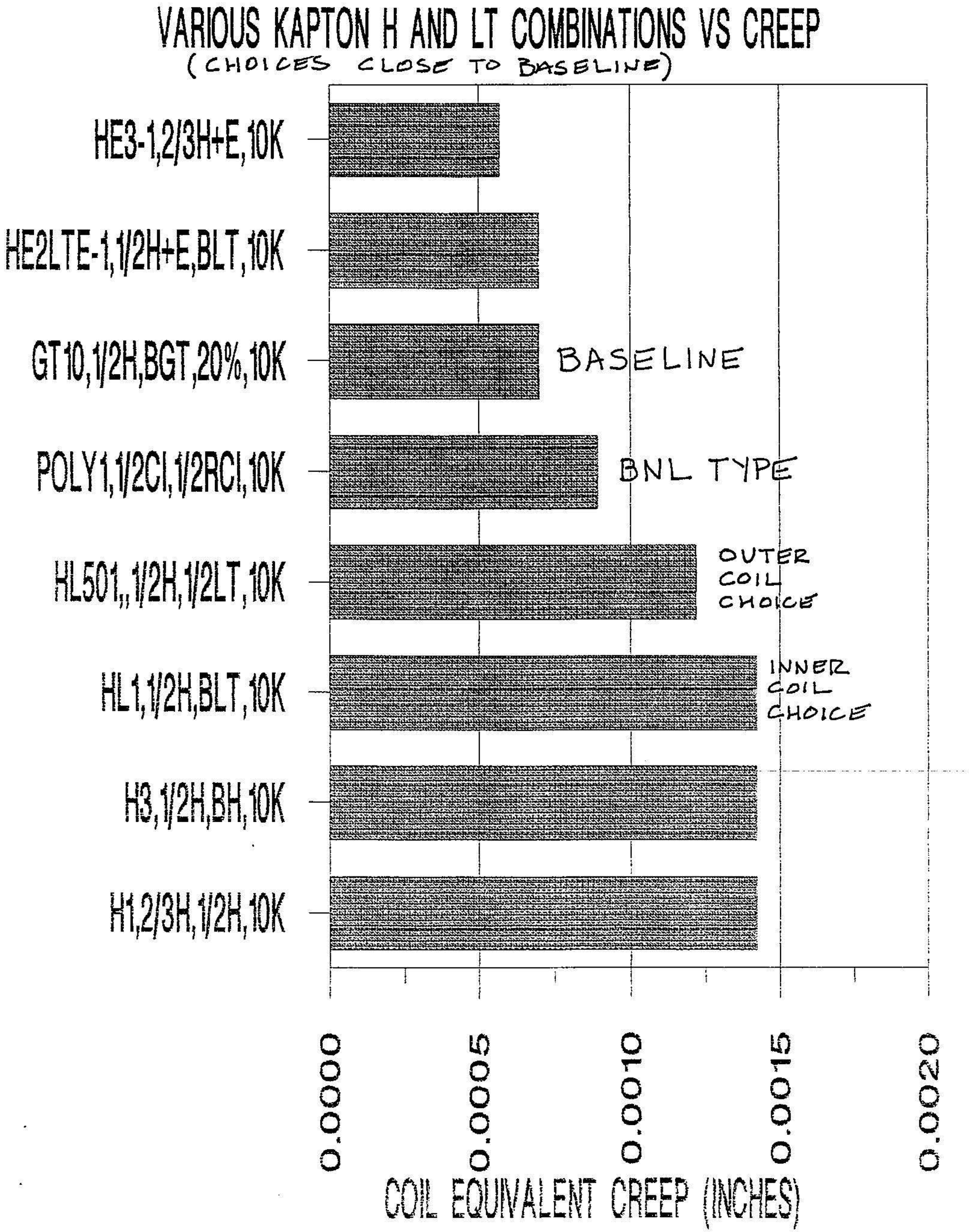
CREEP VS MATERIAL COMBINATIONS FOR GLASS-EPOXY AND KAPTON BRAND FILMS



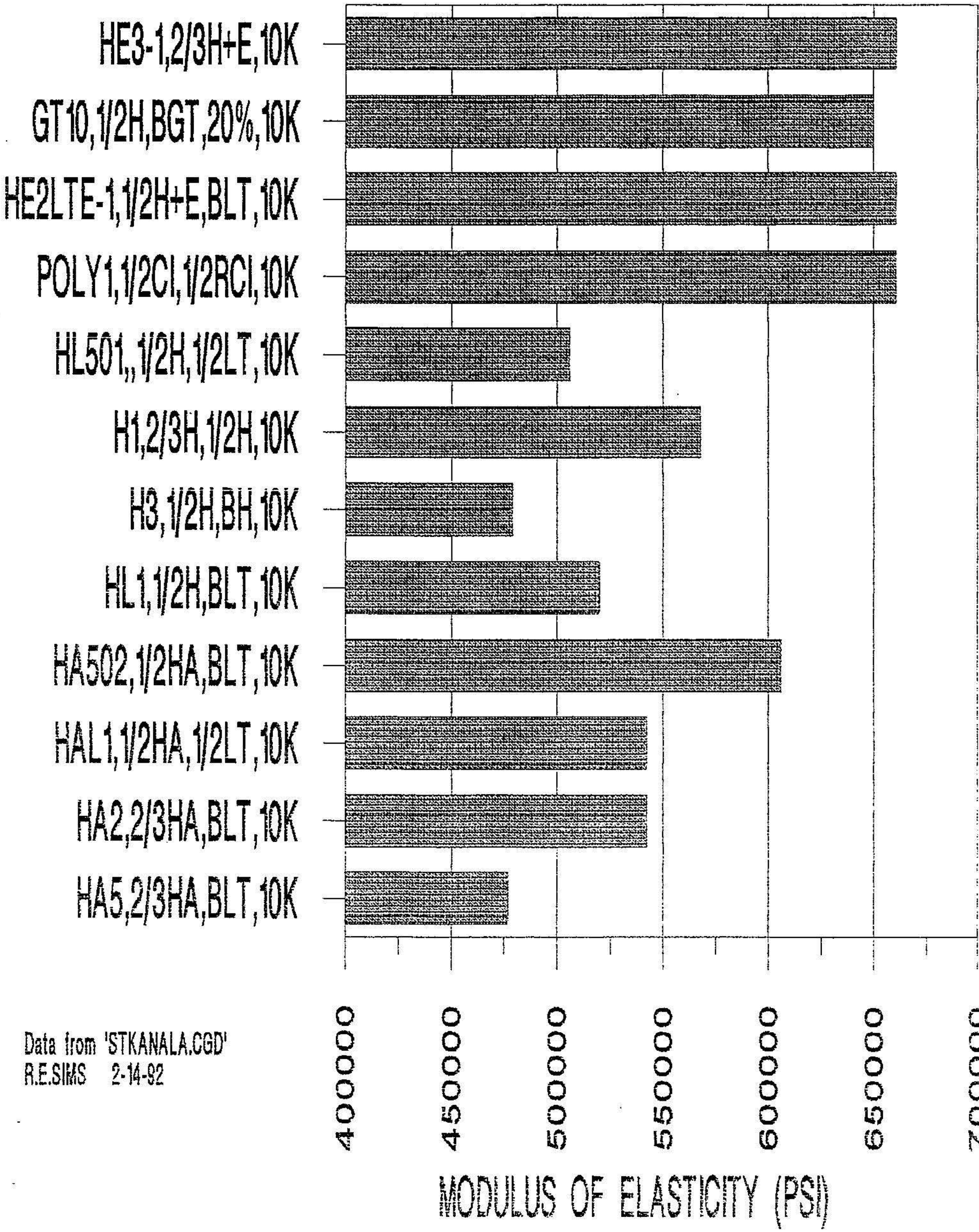
Data from 'STKANALA.CGD'
R.E.SIMS 1-26-92



CREEP COMPARISON OF VARIOUS COMBINATIONS OF APICAL BRAND FILMS INCLUDING SOME WITH KAPTON BRAND LT FILM
EQUIV.IN.COIL CREEP
NP OR H MATERIAL
GT MATERIAL
AV MATERIAL
LT MATERIAL
NC2NC1-1,10K
NC2LTE1-1,10K
VC2LTE1-1,10K
GT10,1/2H,BGT,10K,20%
N2LTE2-3,10K
POLY1,1/2CI,1/2RCI,10K
N2LTE-1,.002,10K
N2NC1-2,10K
N2NC2-1,10K
N2LTE1-6,10K
N2LTE2-1,.002,10K
V3NC1-2,10K
NP
LT
AV
H
GT
BASELINE
BNL TYPE
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
EQUIVALENT CREEP / MATERIAL USED (INCHES)
Data from 'STKANAPA.CGD'
R.E.SIMS 2-14-92
APCPMATL.CGG

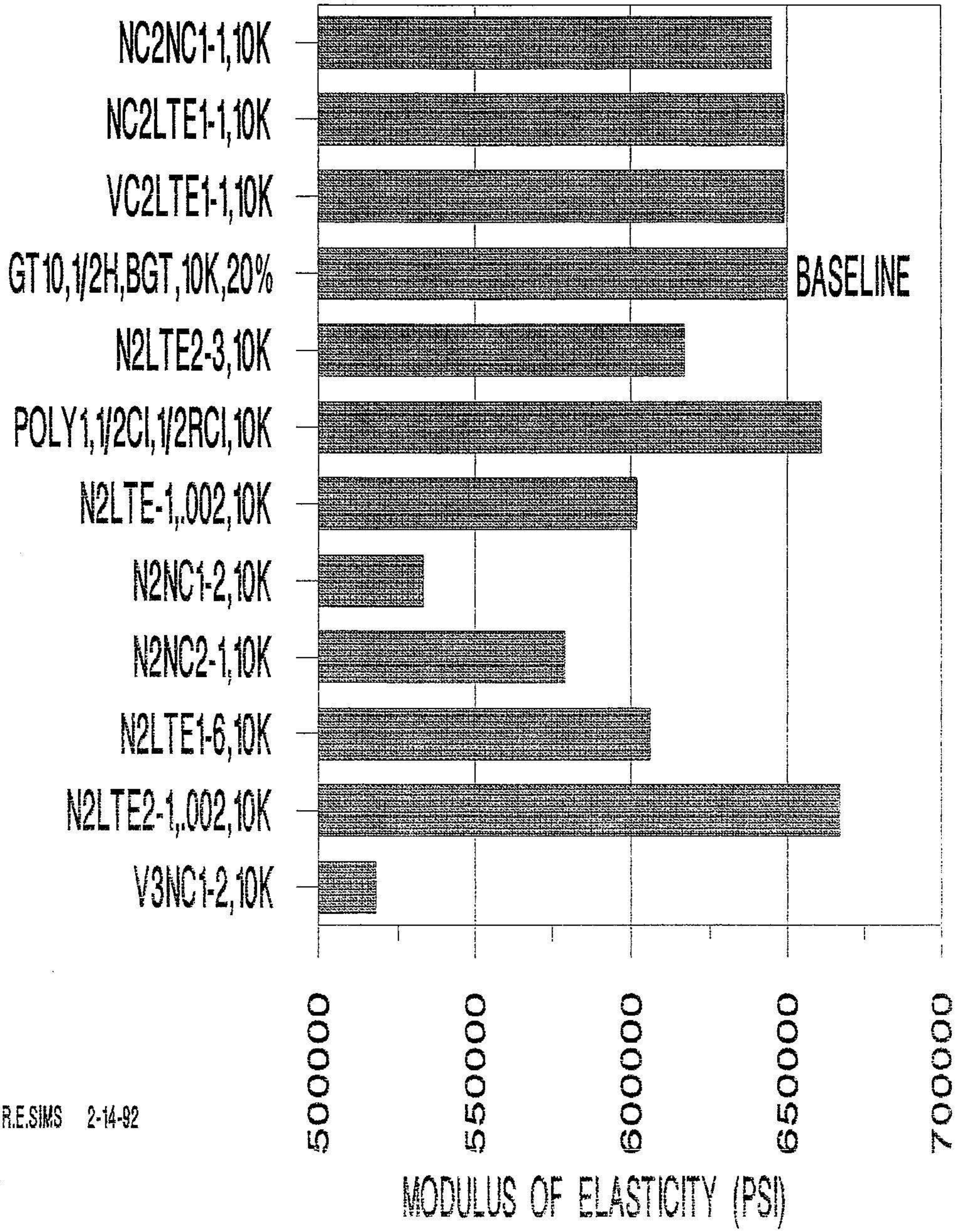

VARIOUS KAPTON H AND LT COMBINATIONS VS CREEP
(CHOICES CLOSE TO BASELINE)
HE3-1,2/3H+E,10K
HE2LTE-1,1/2H+E,BLT,10K
GT10,1/2H,BGT,20%,10K
BASELINE
POLY1,1/2CI,1/2RCI,10K
BNL TYPE
HL501,,1/2H,1/2LT,10K
OUTER COIL CHOICE
HL1,1/2H,BLT,10K
INNER COIL CHOICE
H3,1/2H,BH,10K
H1,2/3H,1/2H,10K
0.0000
0.0005
0.0010
0.0015
0.0020
COIL EQUIVALENT CREEP (INCHES)

COMPARING MODULII OF ELASTICITY OF STACKS MADE WITH VARIOUS KAPTON BRAND FILMS



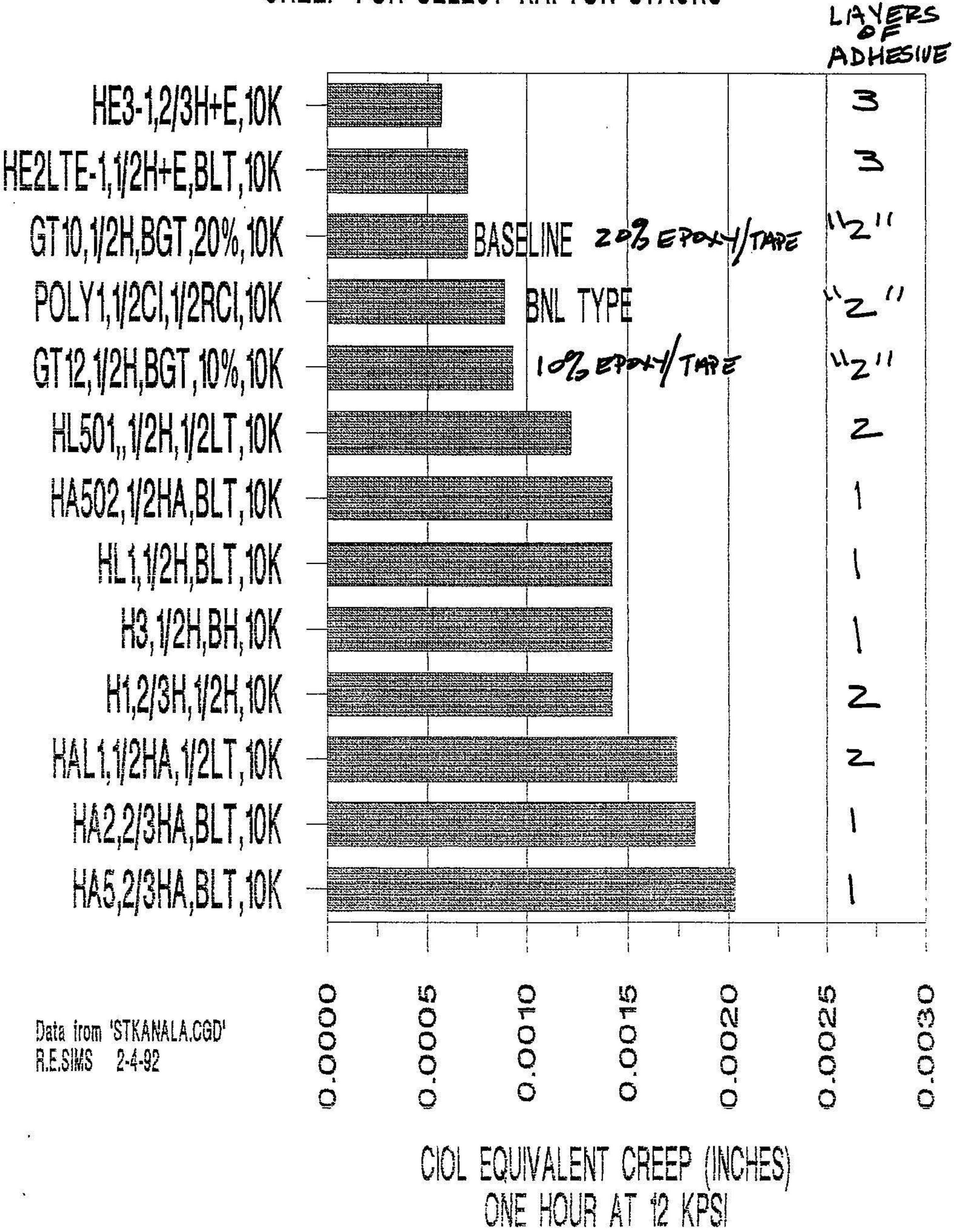
Data from 'STKANALA.CGD'
R.E.SIMS 2-14-92

COMPARING MODULI OF ELASTICITY FOR APICAL BRAND FILMS INCLUDING SOME WITH KAPTON BRAND LT FILM

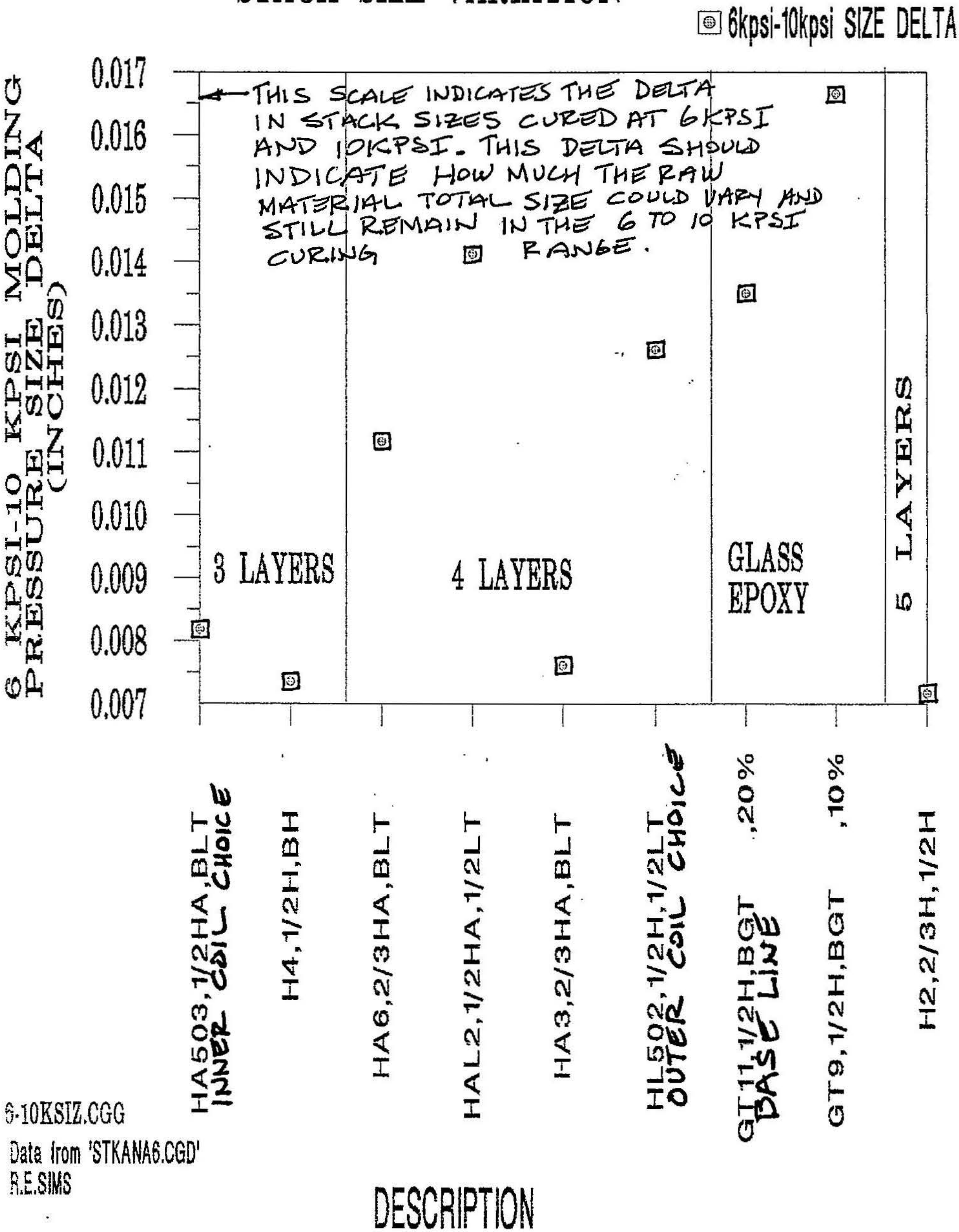


R.E.SIMS 2-14-92

CREEP FOR SELECT KAPTON STACKS



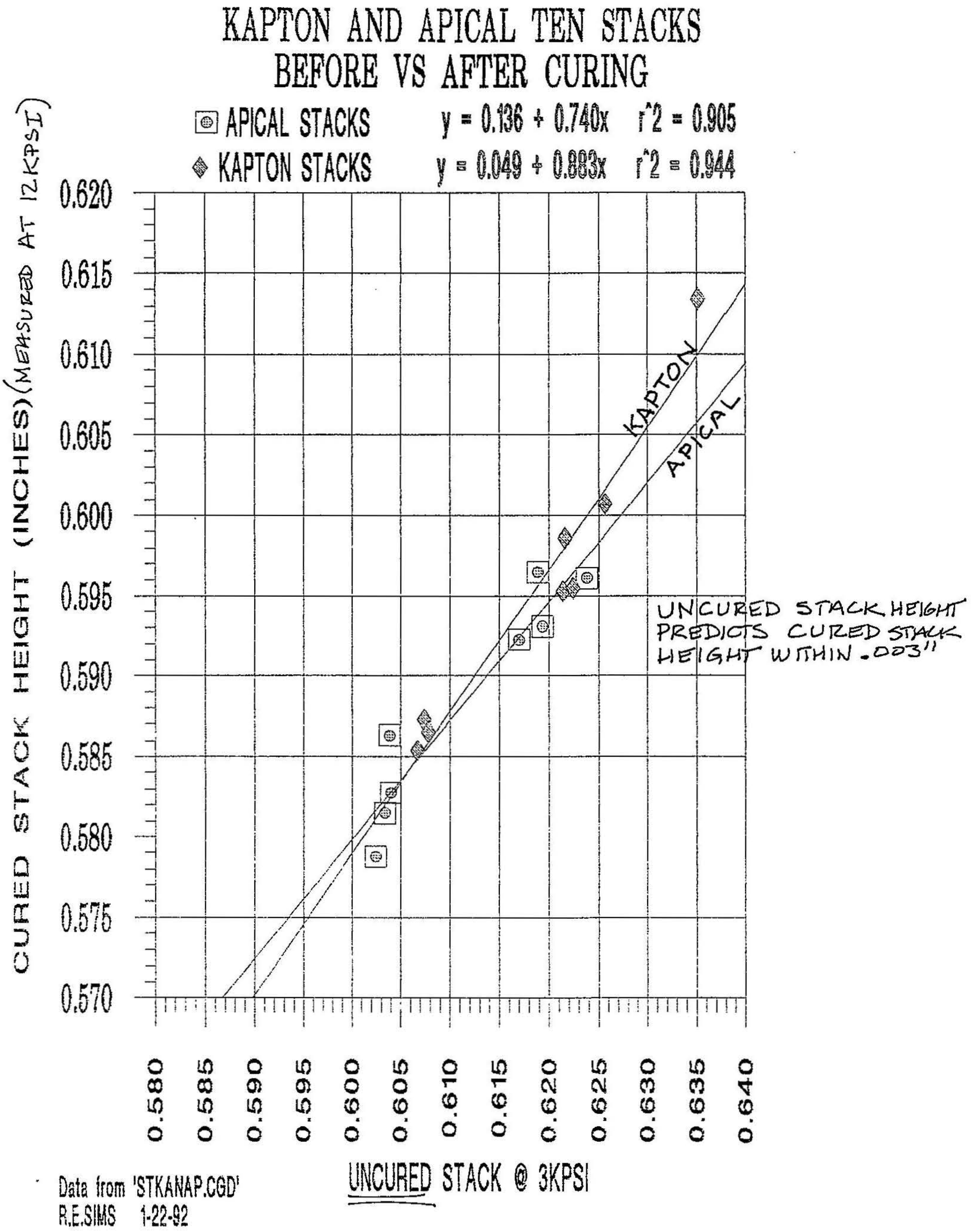
6 KPSI-10 KPSI MOLDING PRESSURE
STACK SIZE VARIATION



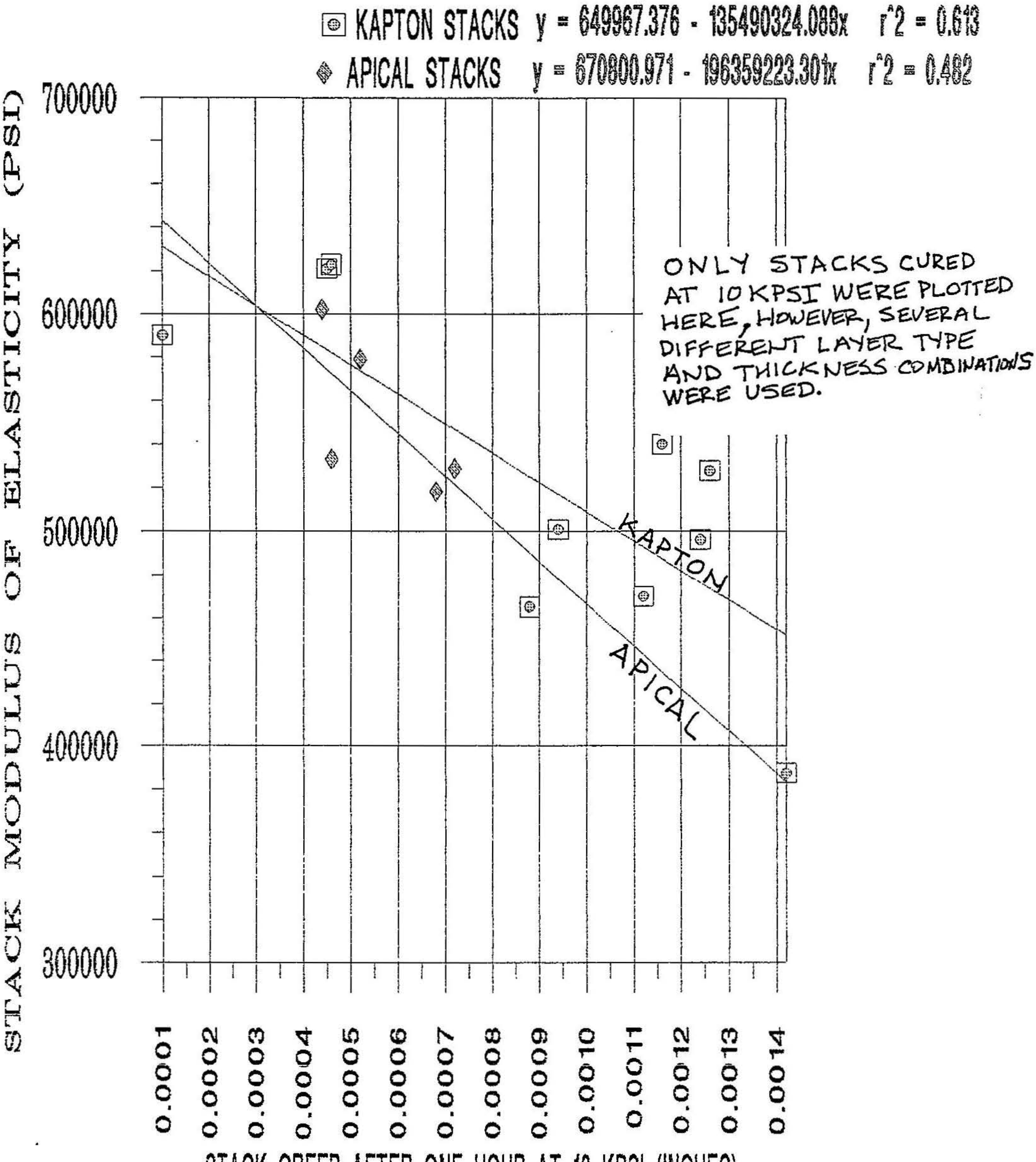
6-10KSIZ.CGG

Data from 'STKANA6.CGD'

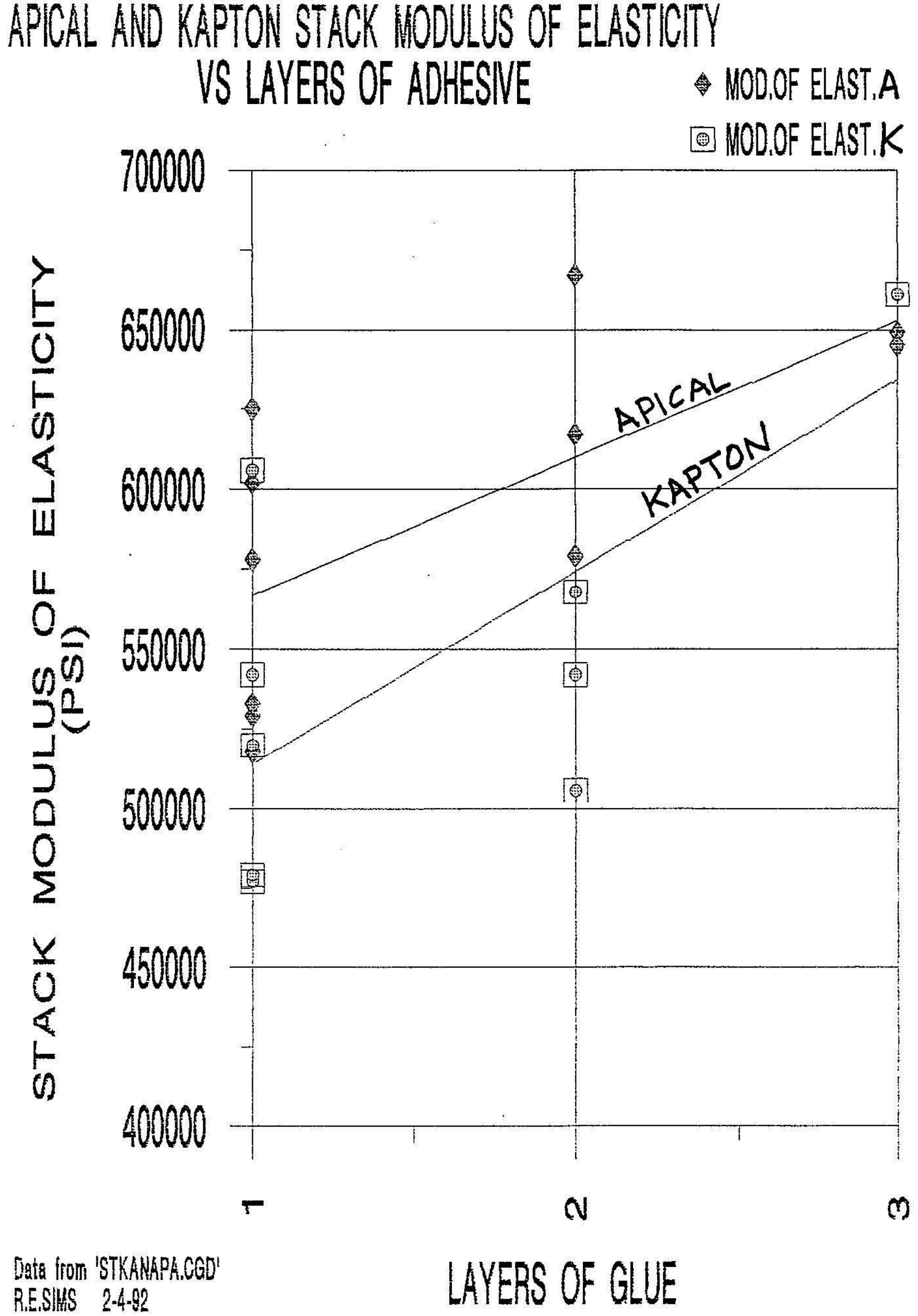
R.E.SIMS

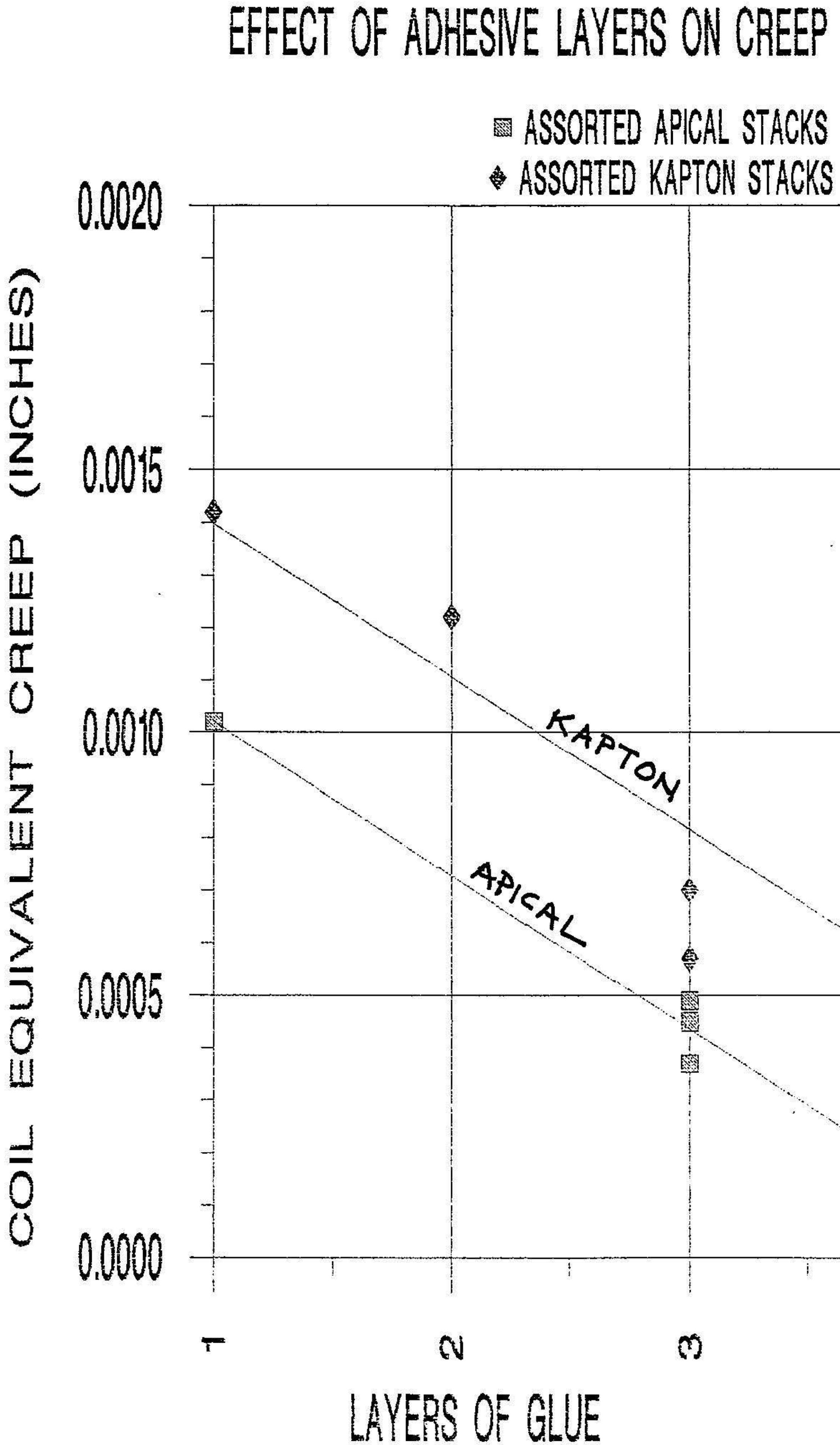

KAPTON AND APICAL TEN STACKS
BEFORE VS AFTER CURING
APICAL STACKS y = 0.136 + 0.740x r^2 = 0.905
KAPTON STACKS y = 0.049 + 0.883x r^2 = 0.944
CURED STACK HEIGHT (INCHES) (MEASURED AT 12KPSI)
0.620
0.615
0.610
0.605
0.600
0.595
0.590
0.585
0.580
0.575
0.570
KAPTON
APICAL
UNCURED STACK HEIGHT PREDICTS CURED STACK HEIGHT WITHIN .003"
0.580
0.585
0.590
0.595
0.600
0.605
0.610
0.615
0.620
0.625
0.630
0.635
0.640
UNCURED STACK @ 3KPSI
Data from 'STKANAP.CGD'
R.E.SIMS 1-22-92

KAPTON AND APICAL STACK MODULUS VS CREEP

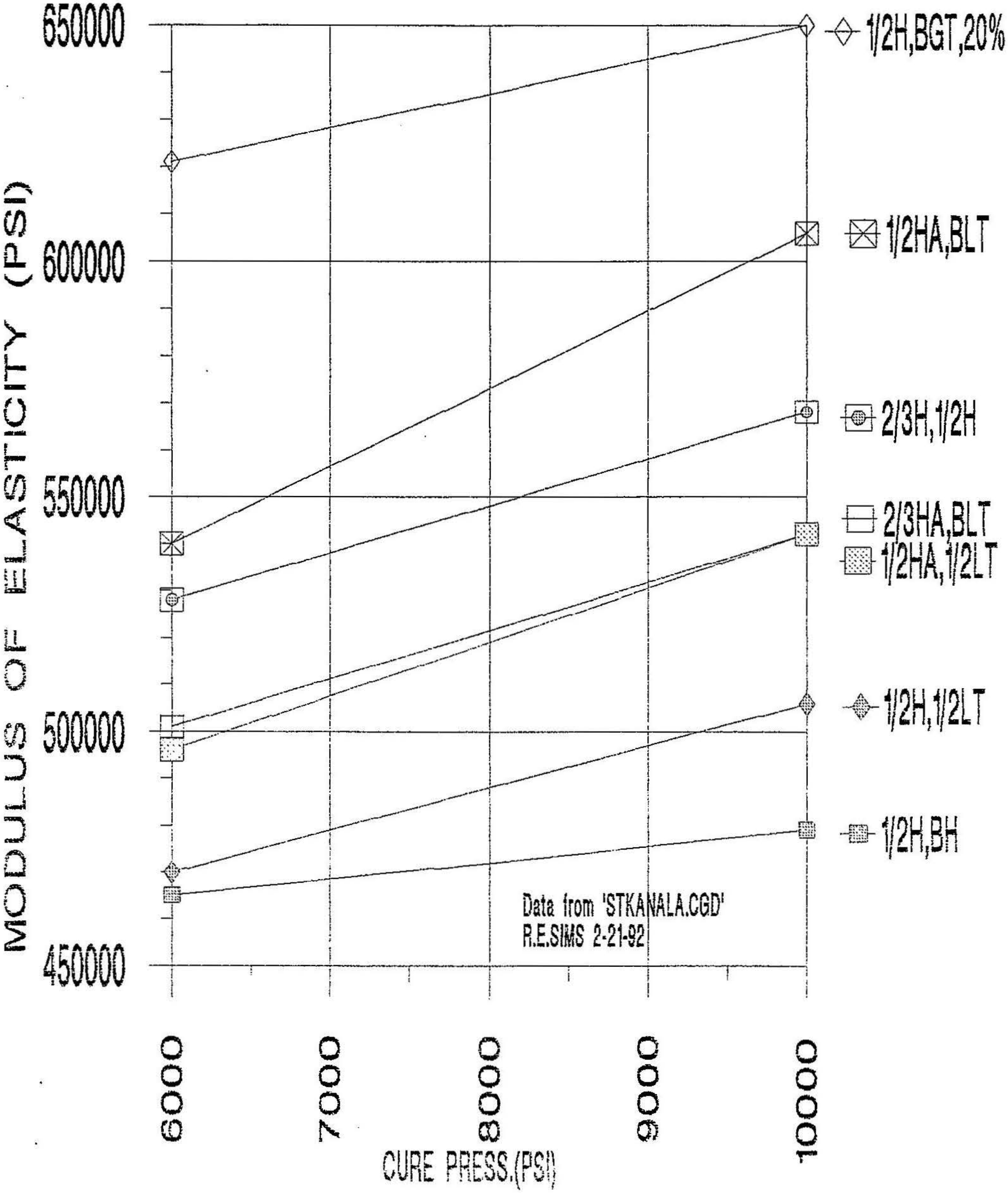


Data from 'STKANA6.CGD'
R.E.SIMS 1-22-92

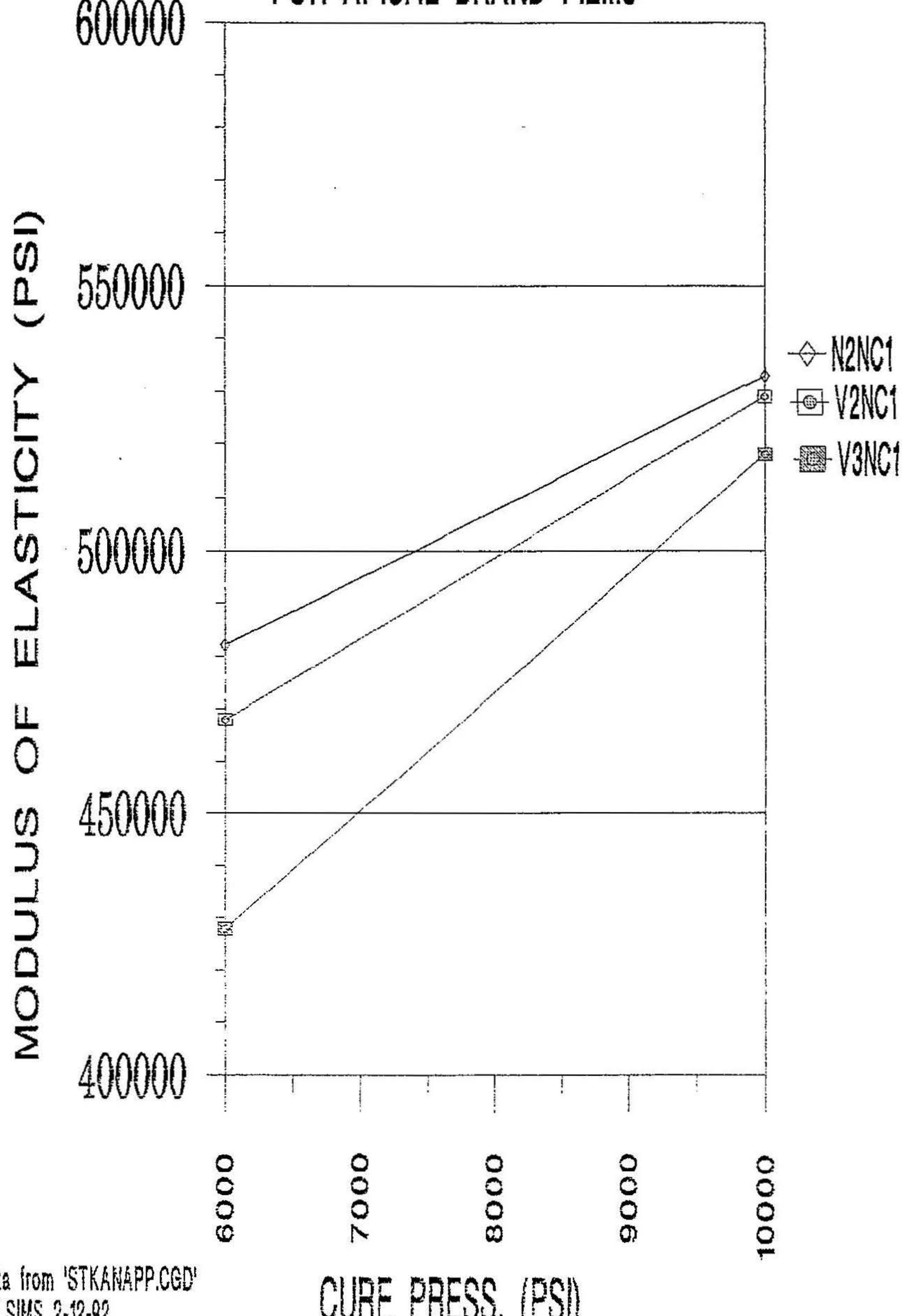

APICAL AND KAPTON STACK MODULUS OF ELASTICITY
VS LAYERS OF ADHESIVE
MOD.OF ELAST.A
MOD.OF ELAST.K
STACK MODULUS OF ELASTICITY (PSI)
700000
650000
600000
550000
500000
450000
400000
APICAL
KAPTON
1
2
3
LAYERS OF GLUE
Data from 'STKANAPA.CGD'
R.E.SIMS 2-4-92


EFFECT OF ADHESIVE LAYERS ON CREEP
ASSORTED APICAL STACKS
ASSORTED KAPTON STACKS
COIL EQUIVALENT CREEP (INCHES)
0.0020
0.0015
0.0010
0.0005
0.0000
KAPTON
APICAL
1
2
3
4
LAYERS OF GLUE

MODULUS OF ELASTICITY VS CURING PRESSURE FOR KAPTON BRAND FILMS



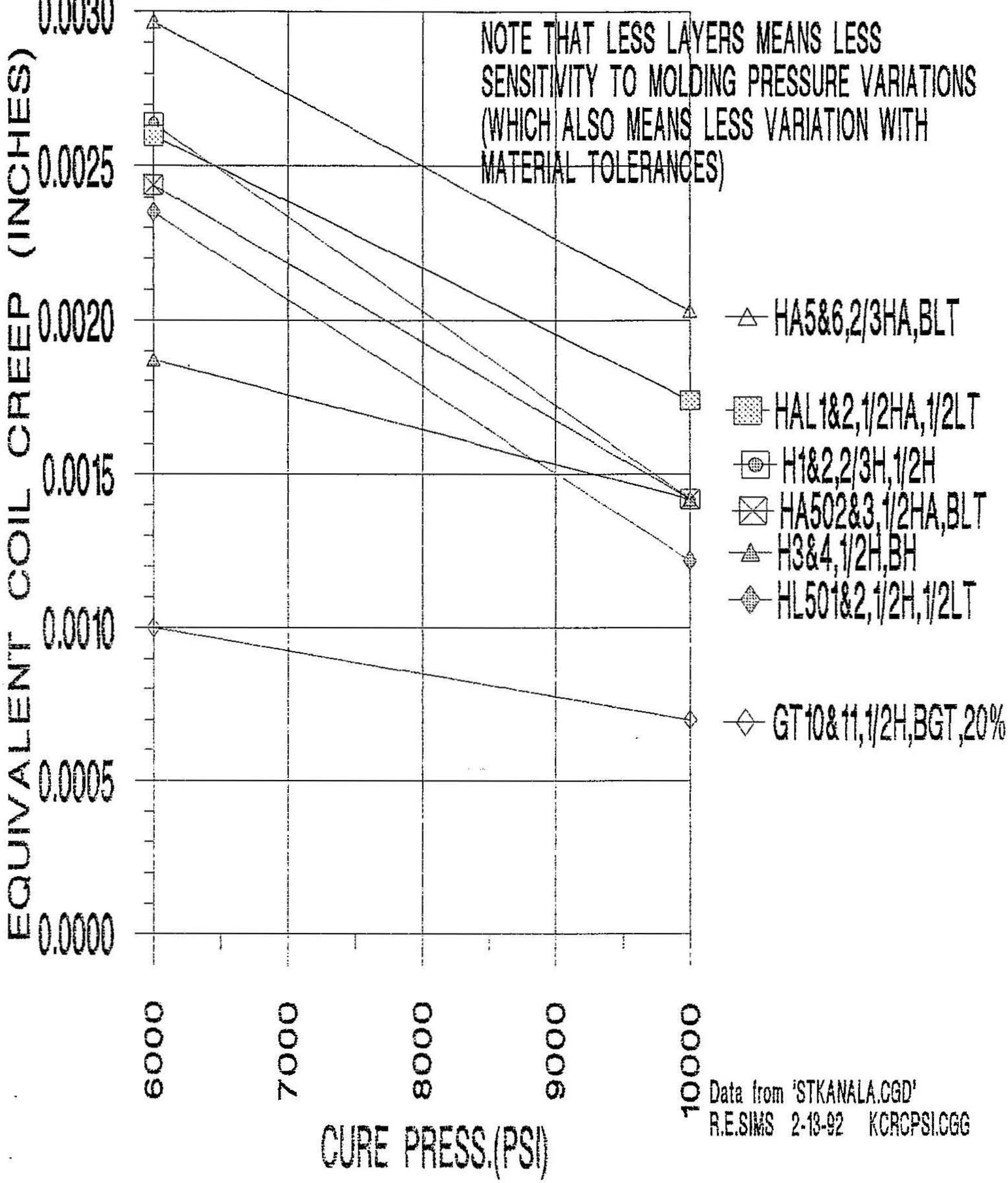
MODULUS OF ELASTICITY VS CURING PRESSURE
FOR APICAL BRAND FILMS



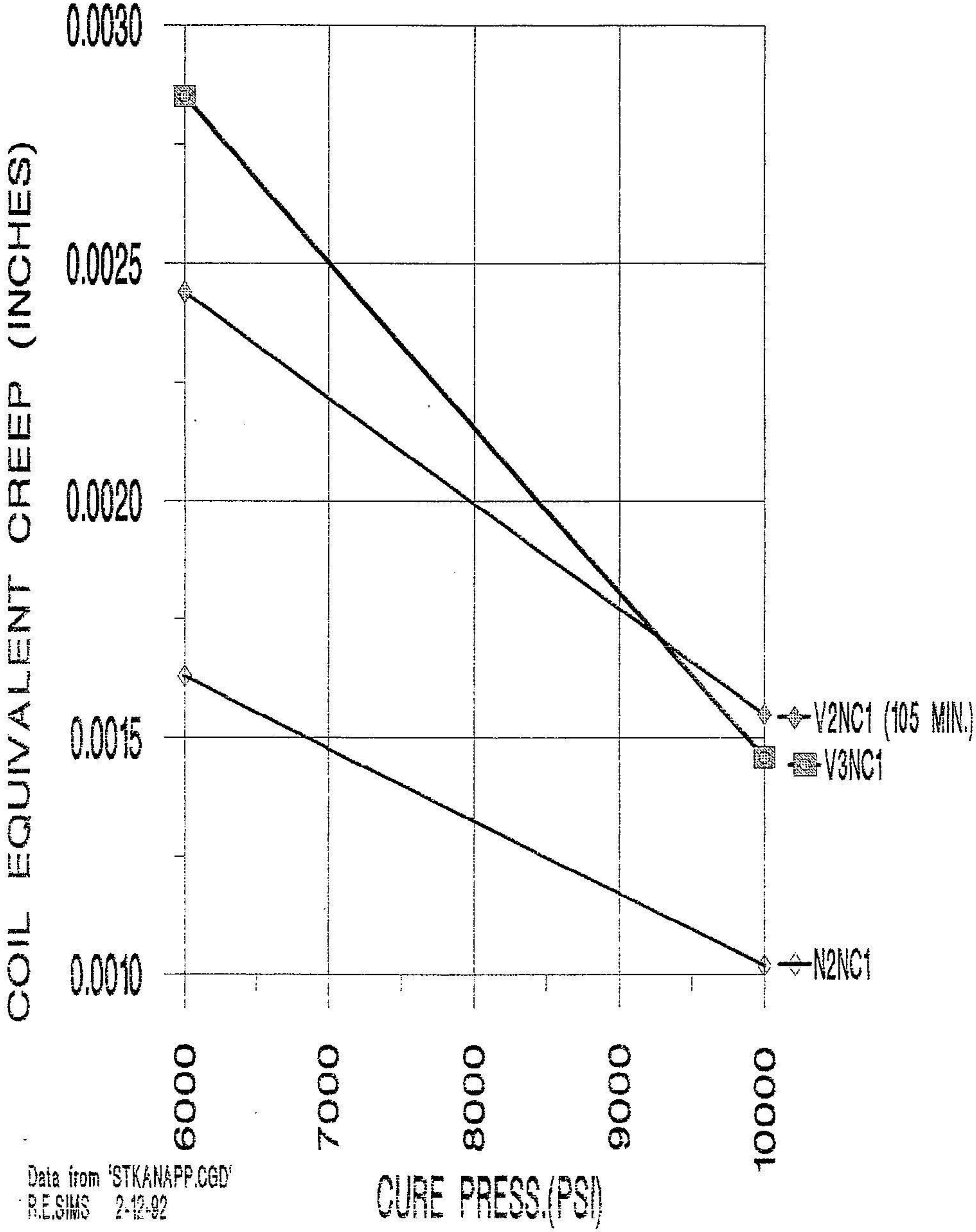
Data from 'STKANAPP.CGD'
R.E.SIMS 2-12-92

KAPTON CREEP VS CURE PRESSURE

TEN STACKS WERE CURED AT BOTH 6 KPSI AND
10 KPSI AT 275 F FOR 90 MINUTES

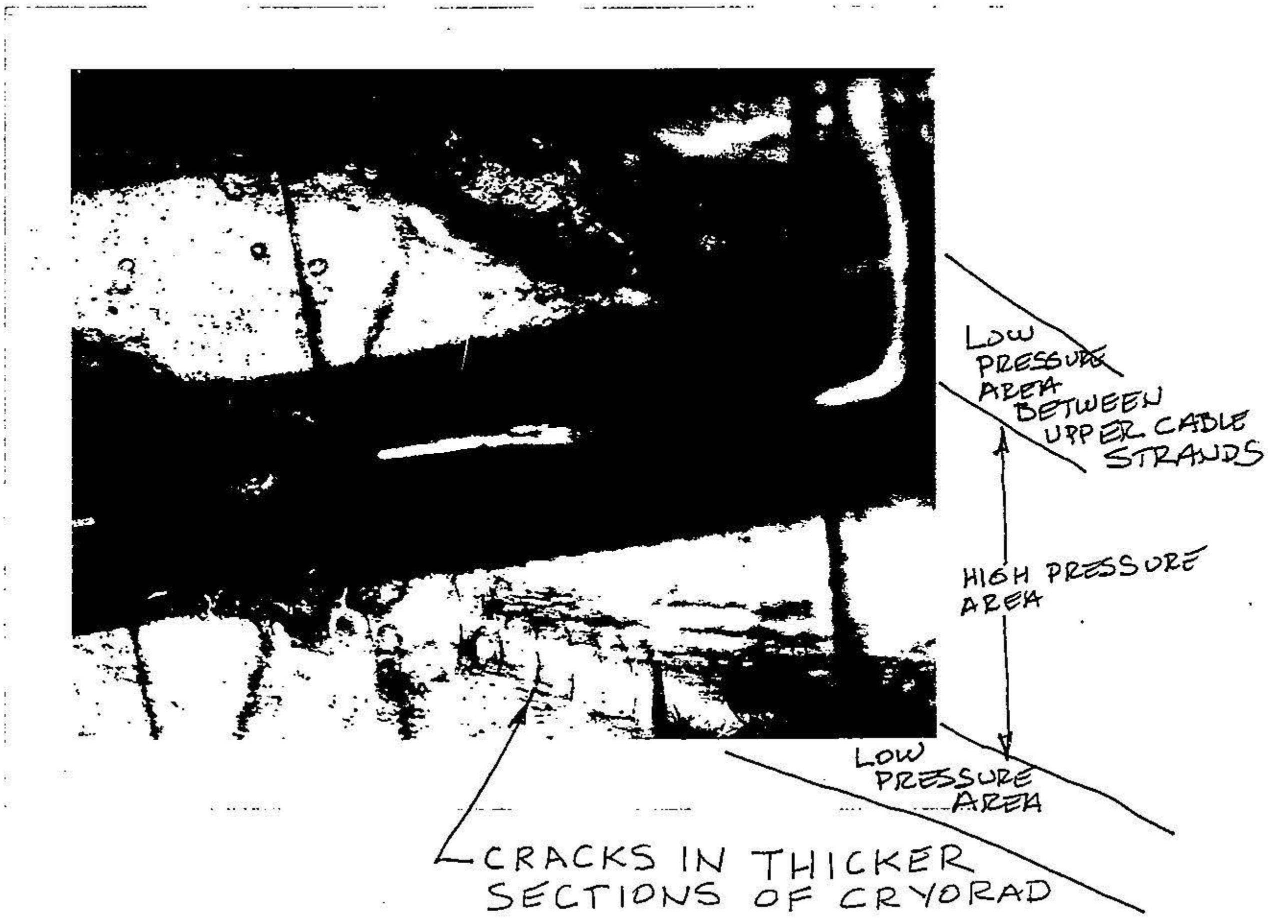


CREEP VS CURING PRESSURE FOR APICAL BRAND FILMS



Data from 'STKANAPP.CGD'
R.E.SIMS 2-12-92

STACK N2CLTE1 (1/2 OVERLAPPED NP WITH CRYORAD, BUTT WRAP LT WITH 2290 EPOXY ON TOP SIDE) WAS PARTIALY CUT APPART TO EXAMINE HOW THE CRYORAD ADHESIVE FLOWED AND IF IT LEAKED ONTO THE CABLE. (NEXT 3 PAGES)



VIEW OF BOTTOM LAYER OF 50% OVERLAP WRAPPED .001" THICK APICAL TYPE NP WHICH HAS APROX. .00025" CRYORAD TOP COAT BEFORE IT WAS CURED. HERE THE STACK WAS CURED AT ~275°F AND THE TOP LAYER OF KAPTON TYPE LT (BUTT WRAPPED) WAS PEALED OFF.

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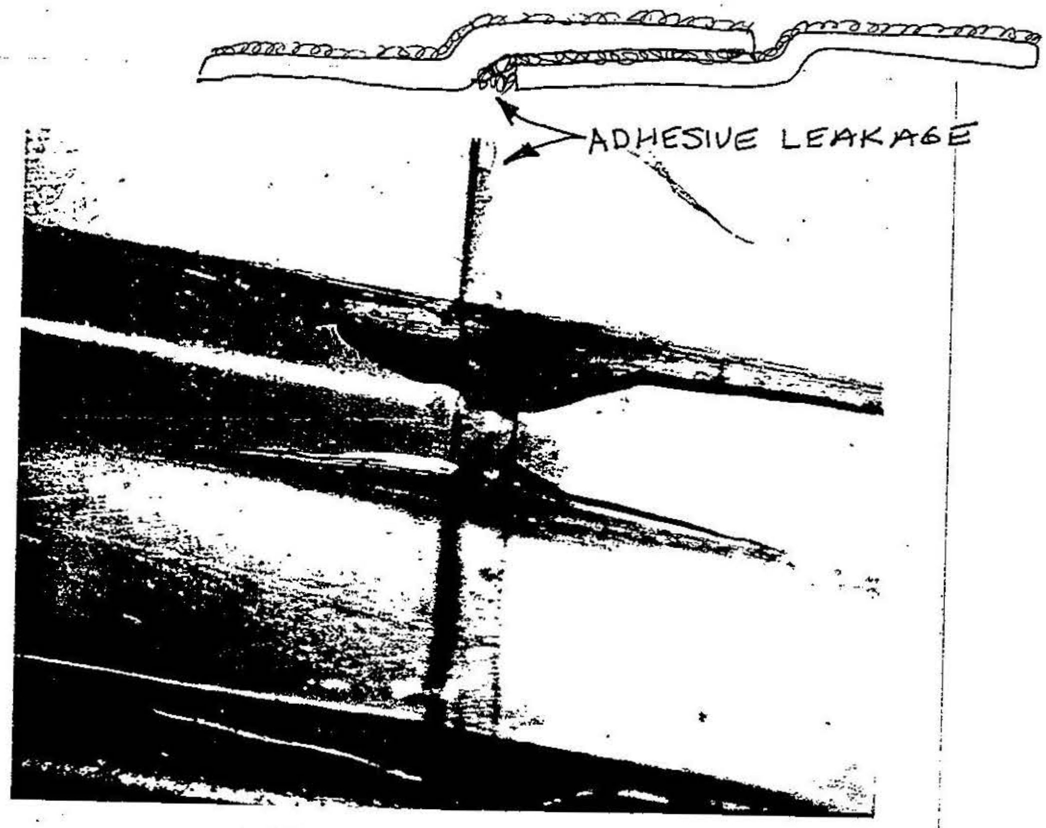
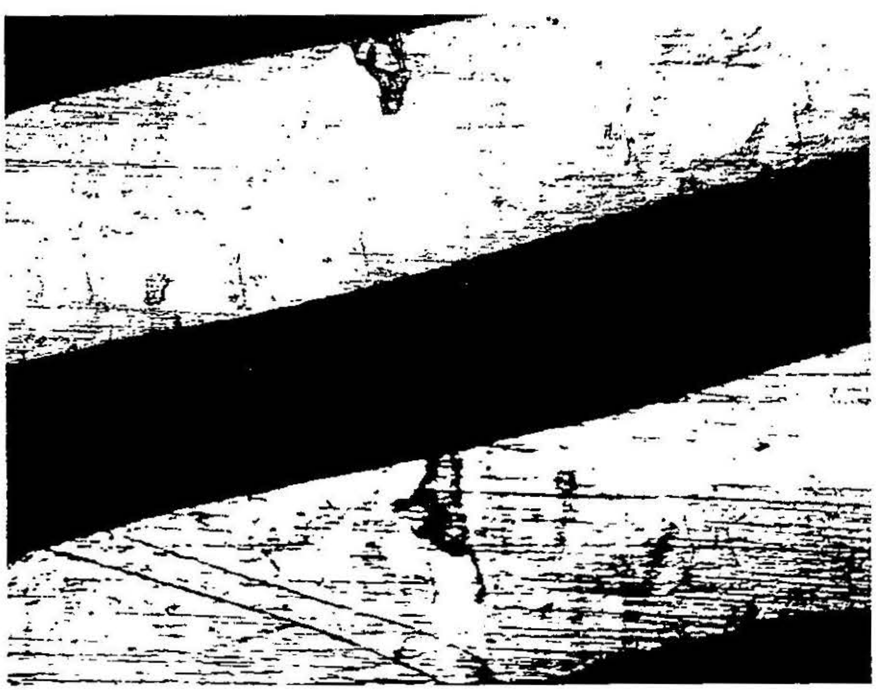
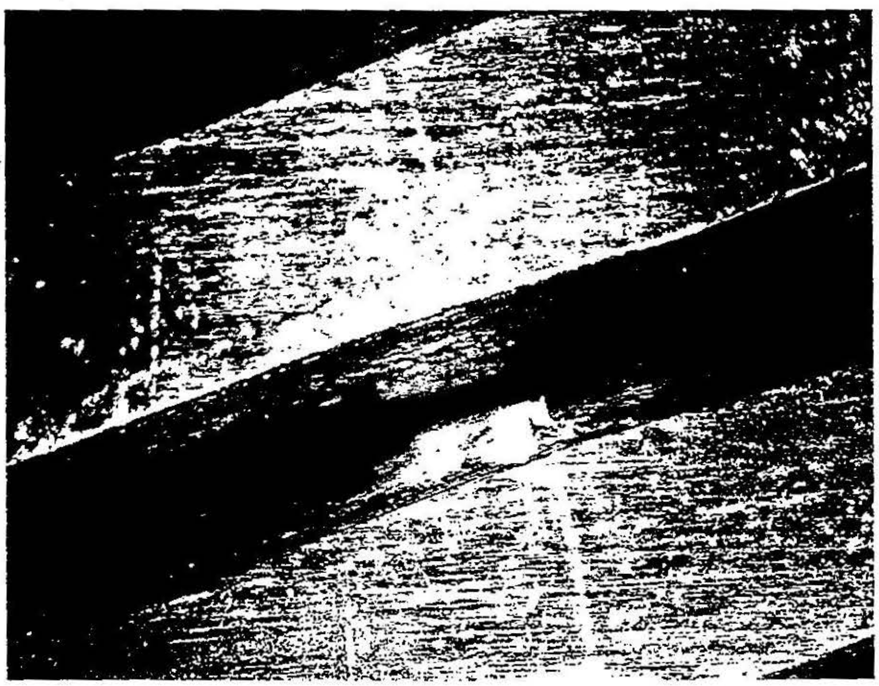


SEAM OF 50% OVERLAPPED APICAL TYPE NP WITH CRYORAD ADHESIVE ON TOP SIDE OF FILM. SOME CRYORAD ADHESIVE HAS FLOWED TO THE LOW PRESSURE AREAS.



SMALL PATCHES OF CRYORAD HAVE "LEAKED" ON TO THE SURFACE OF THE STRANDS.

L.E.J. SMIT 7-4-77

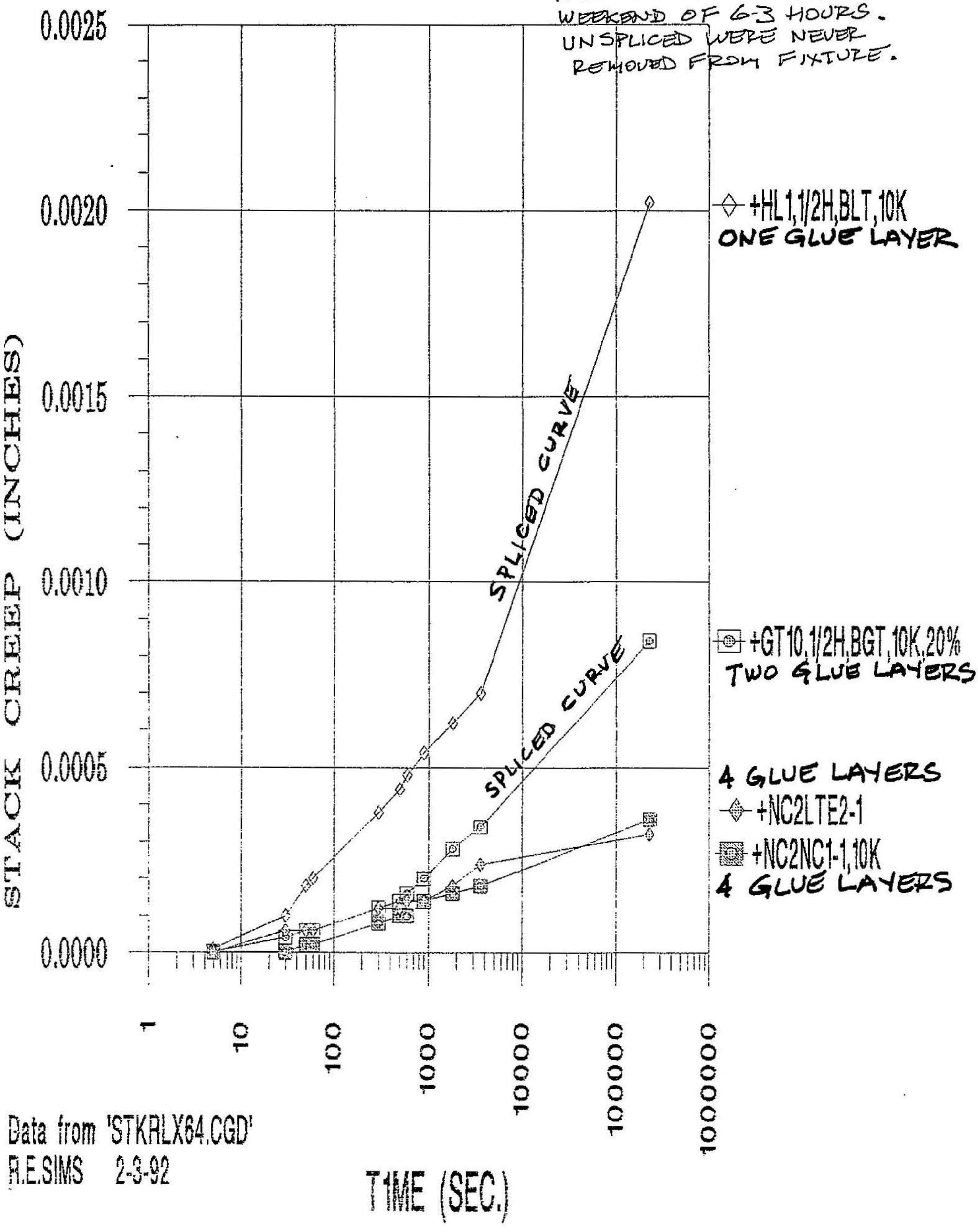


CRYORAD DROPLET BETWEEN STRANDS

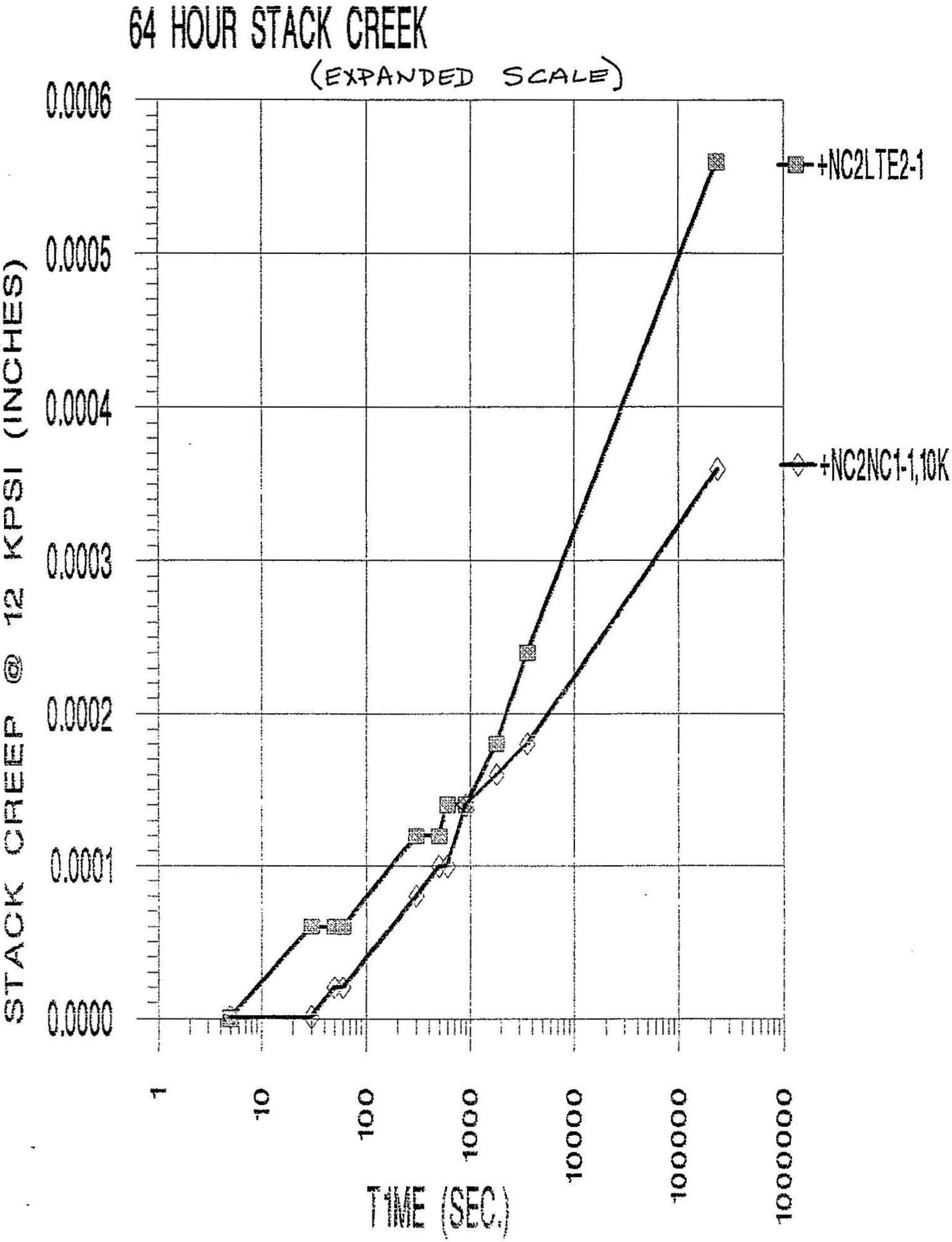
R.E. SIMS 2-4-92

64 HOUR STACK CREEP

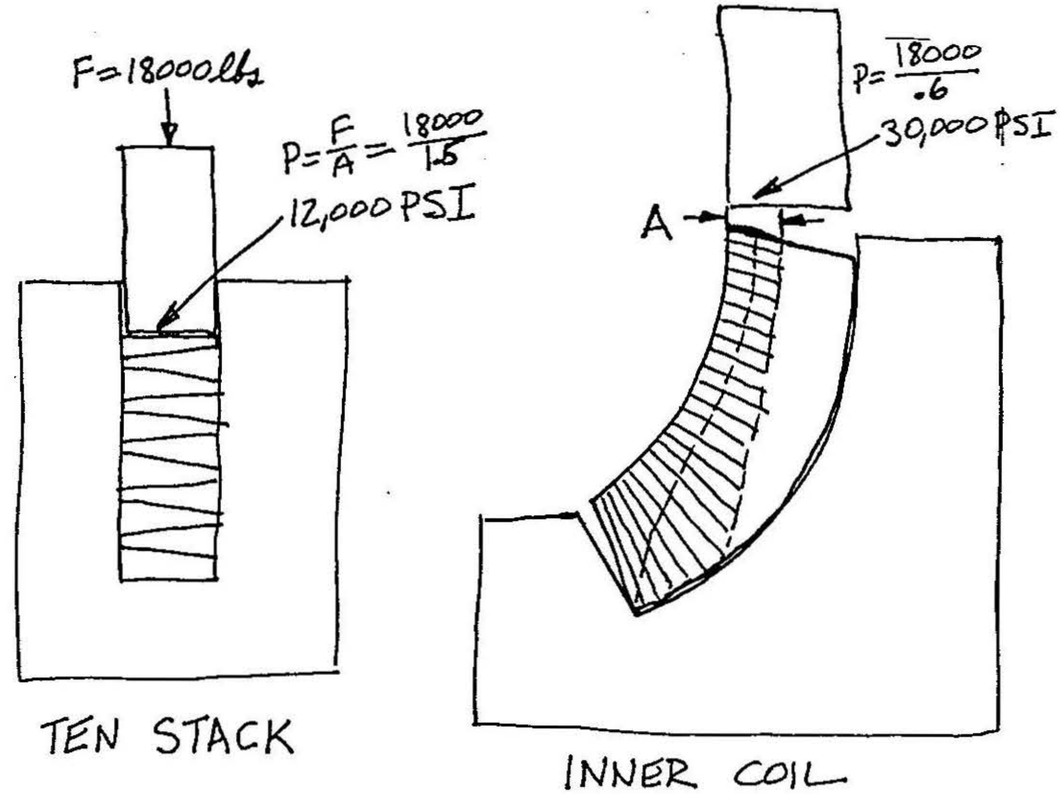
SPLICED CURVES WERE STACKS WHICH WENT ONE HOUR OF CREEP, UNLOADED THEN RELOADED FOR A WEEKEND OF 63 HOURS. UNSPLICED WERE NEVER REMOVED FROM FIXTURE.



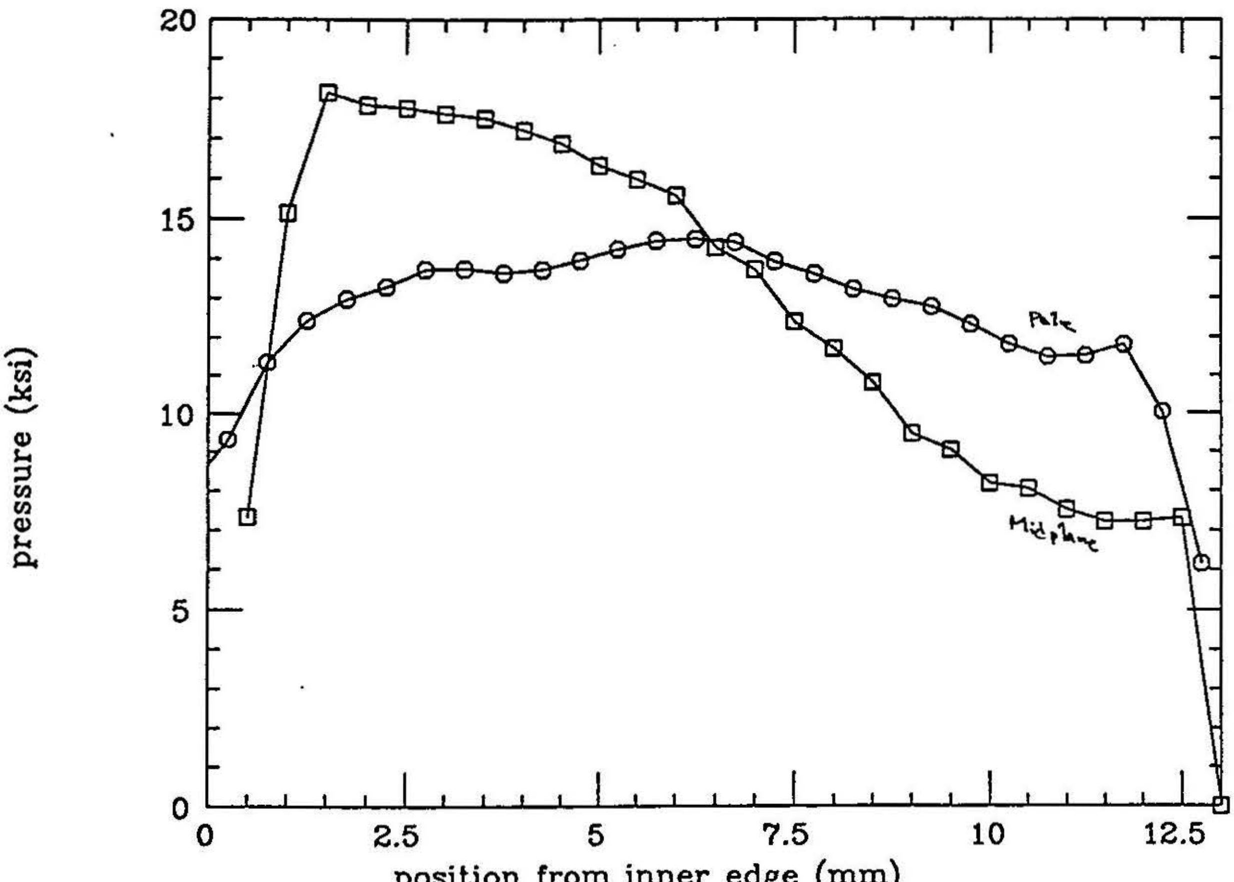
Data from 'STKRLX64.CGD'
R.E.SIMS 2-3-92



64 HOUR STACK CREEK
(EXPANDED SCALE)
STACK CREEP @ 12 KPSI (INCHES)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
1
10
100
1000
10000
100000
1000000
TIME (SEC.)
+NC2LTE2-1
+NC2NC1-1,10K

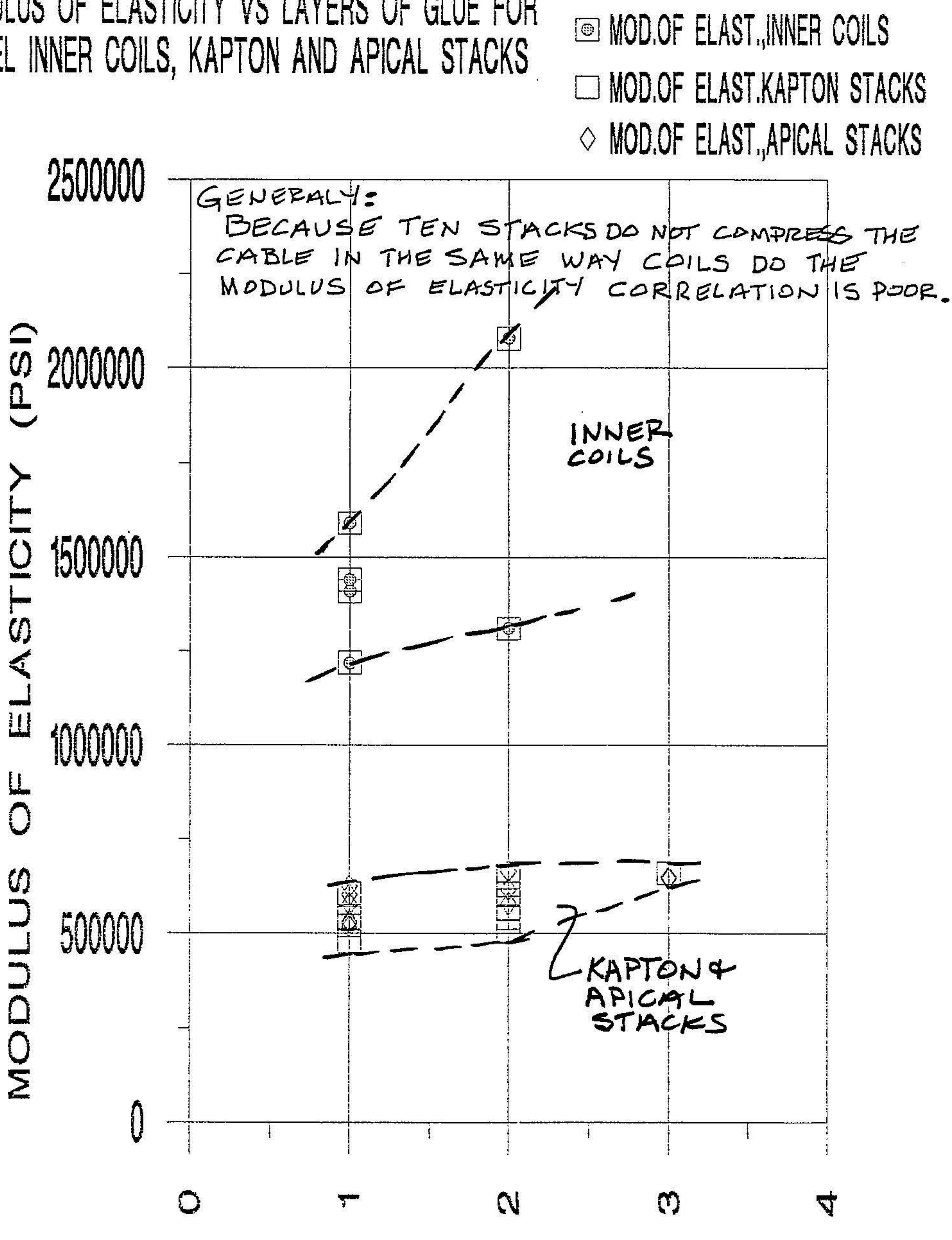


DSA327 inner coil (Q2)



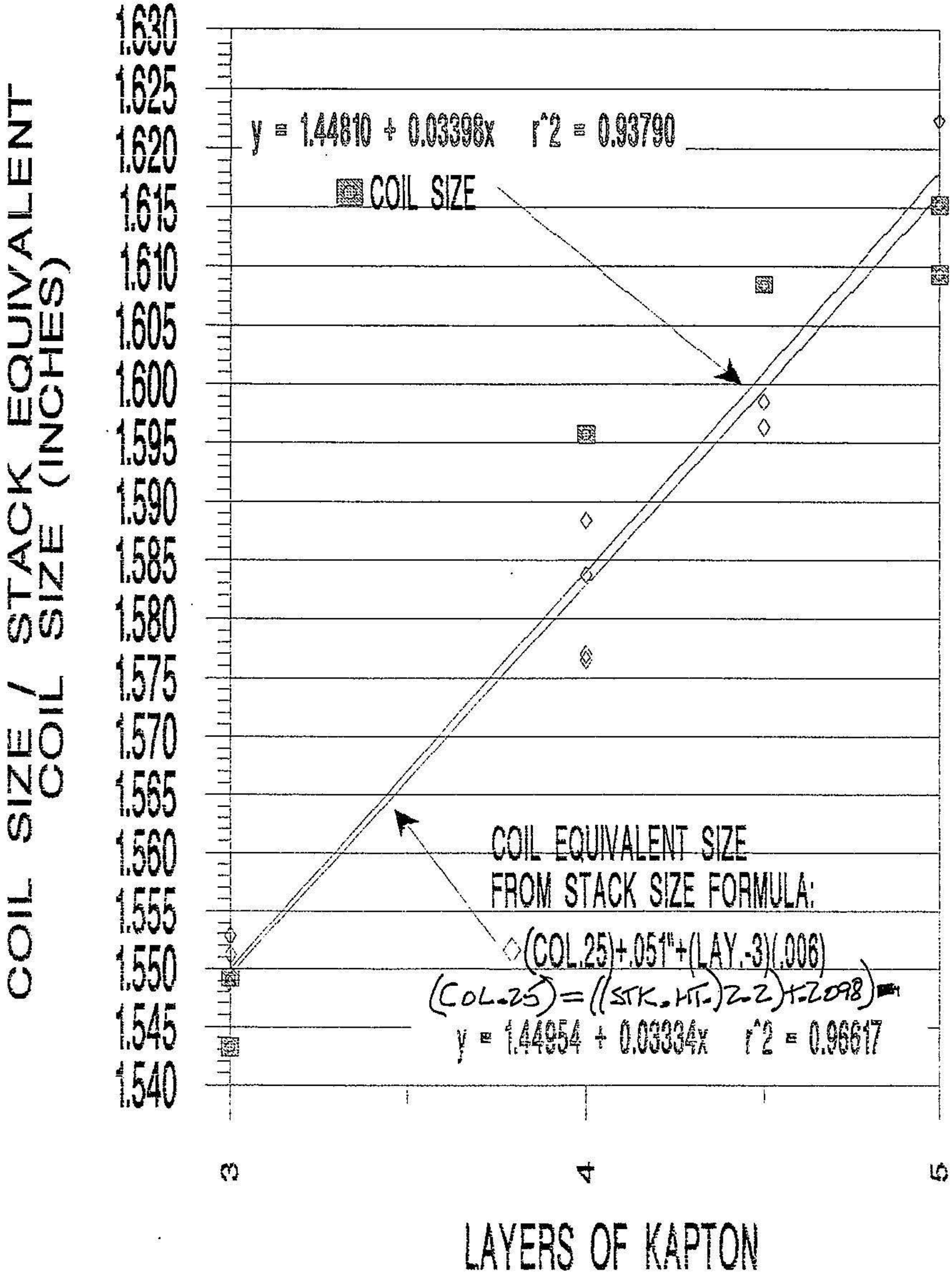
FROM
M. WAKE

MODULUS OF ELASTICITY VS LAYERS OF GLUE FOR MODEL INNER COILS, KAPTON AND APICAL STACKS



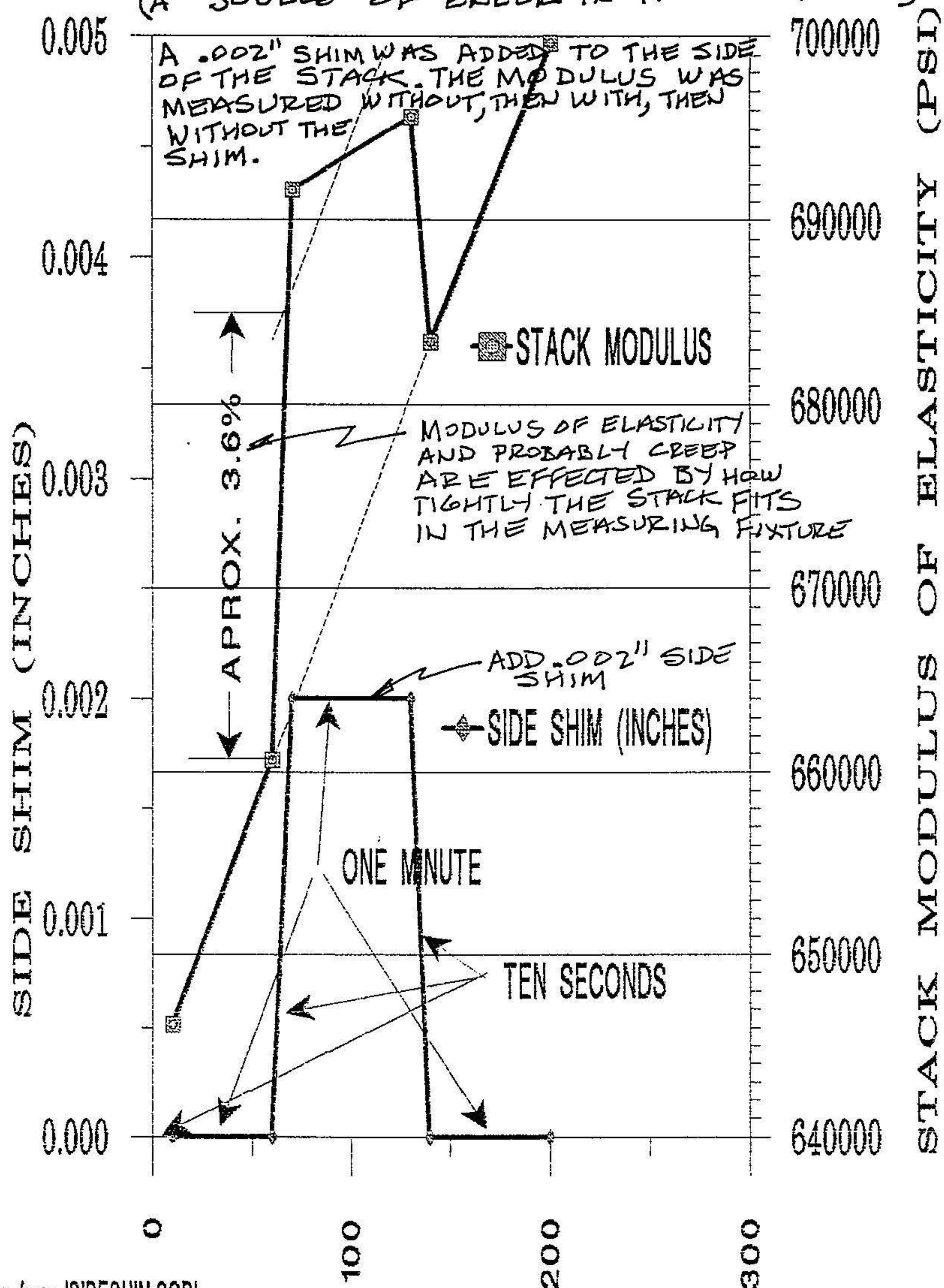
Data from 'STKANC10.CGD'
R.E.SIMS 2-3-92

PREDICTING COIL SIZE FROM STACK SIZE



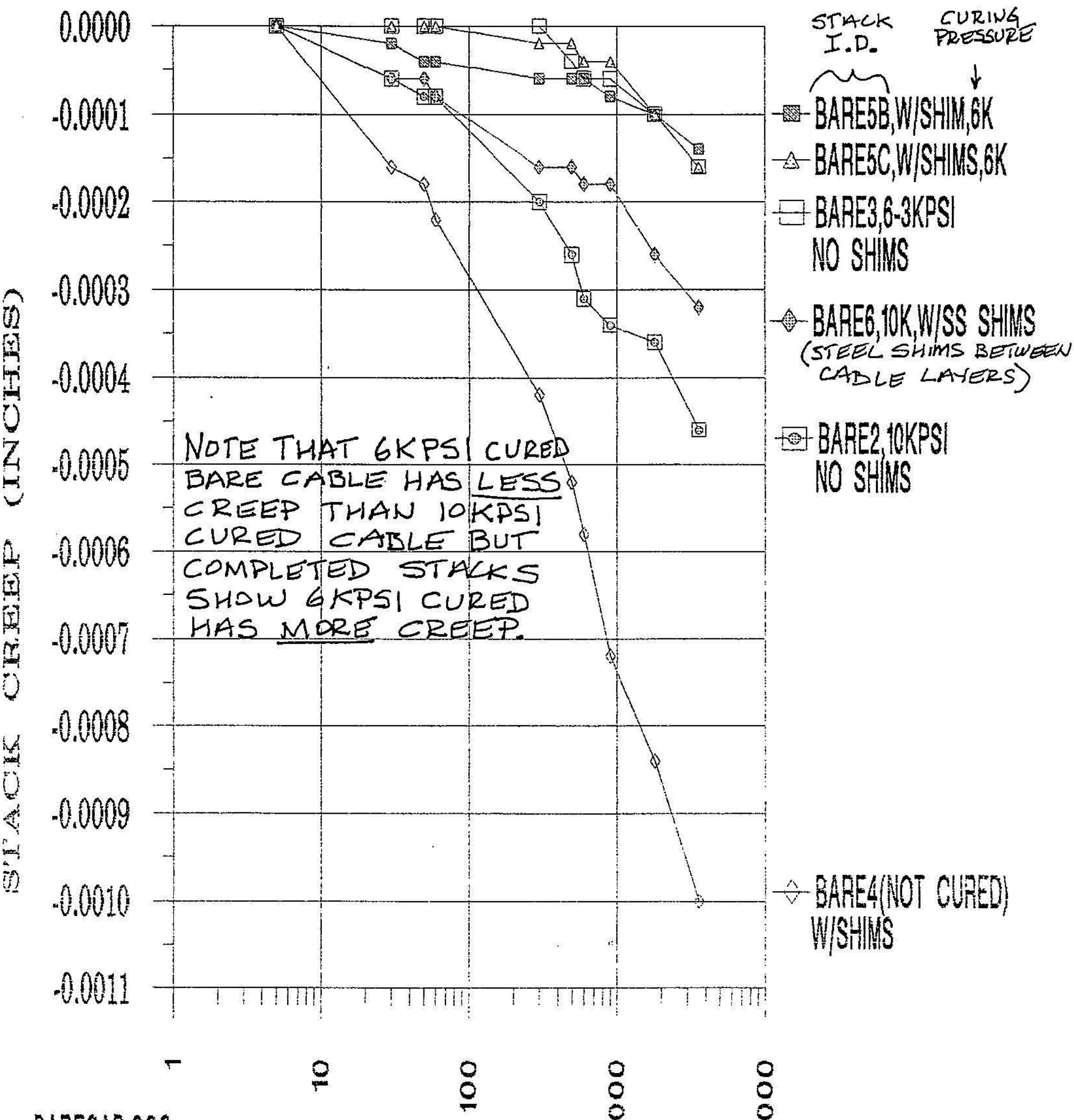
CHANGE IN MODULUS OF ELASTICITY WITH THE ADDITION OF A .002" SIDE SHIM STACK NC2LTE1-1

(A SOURCE OF ERROR IN THESE STUDIES)



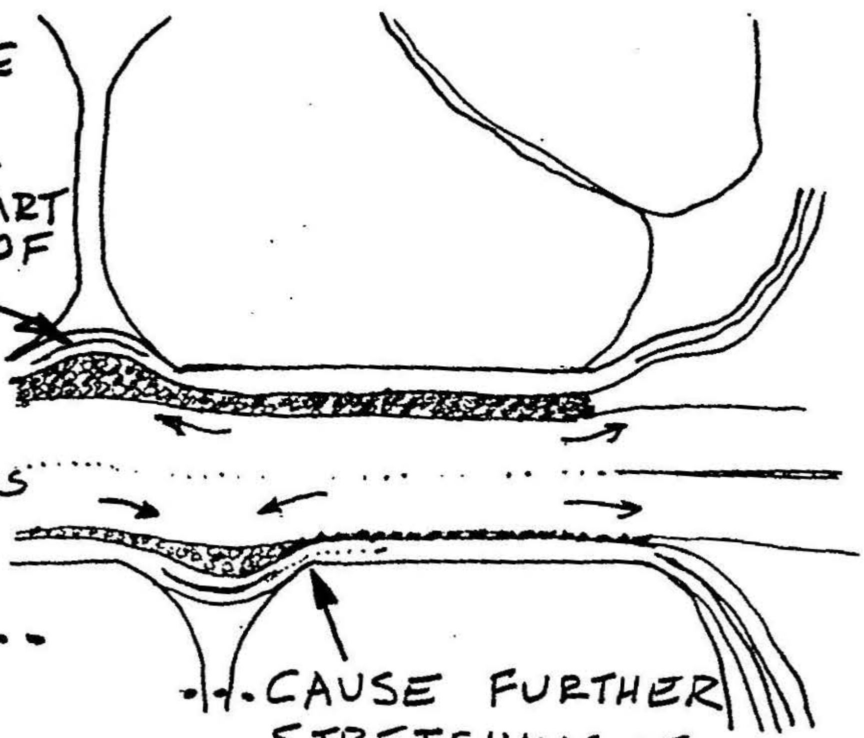
Data from 'SIDESHIM.CGD'
R.E.SIMS 2-3-92

50 mm INNER CABLE WITH NO INSULATION WRAP AFTER CREEPING FOR ONE HOUR AT 12 KPSI

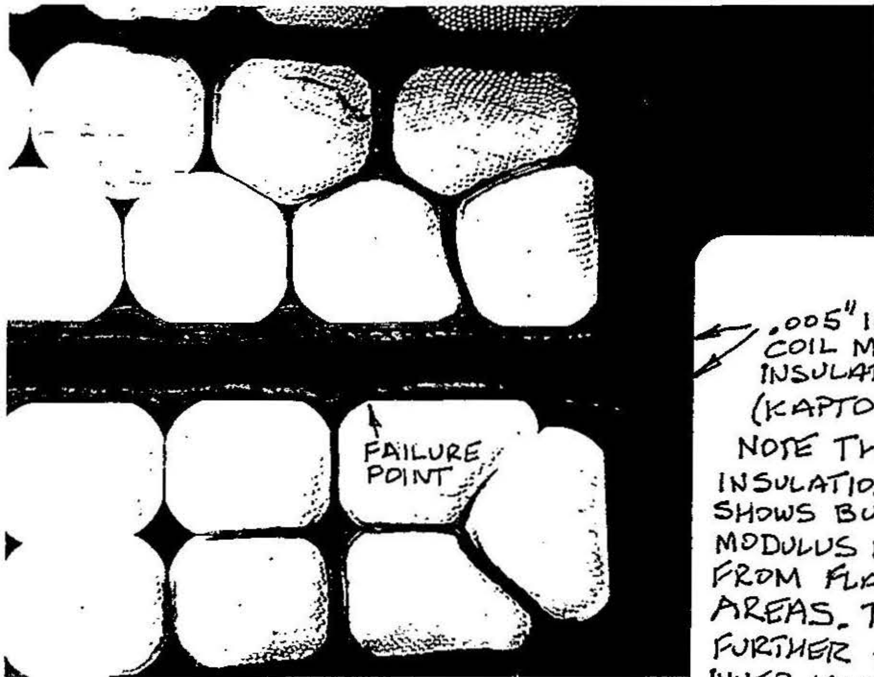


BARECAB.CGG
R.E.SIMS 1-30-92

POSSIBLE SCENARIO LEADING TO DIELECTRIC BREAKDOWN OF POLYIMIDE MIDPLANE INSULATION

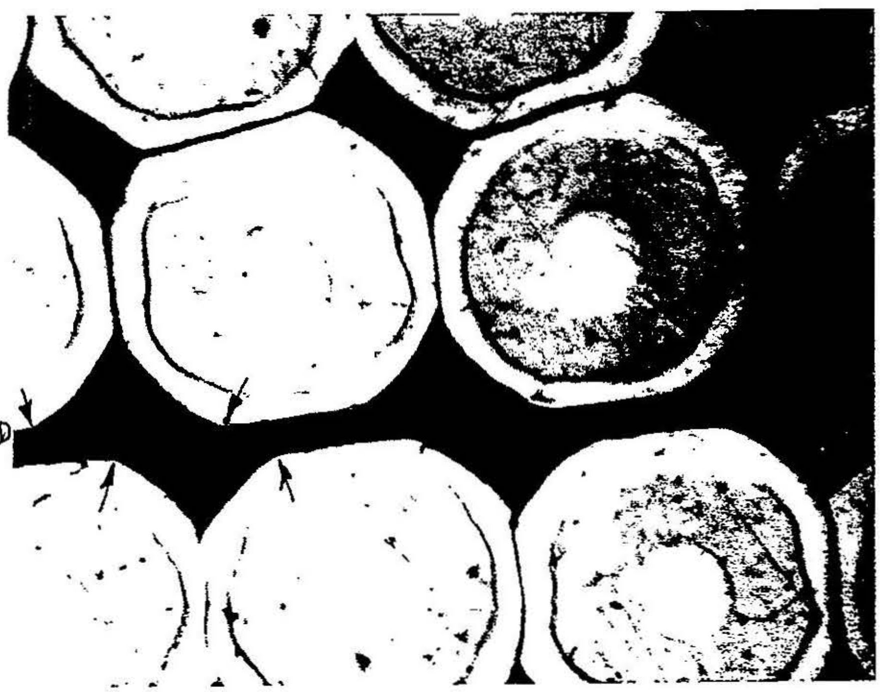


.E.SIMS 2-4-92



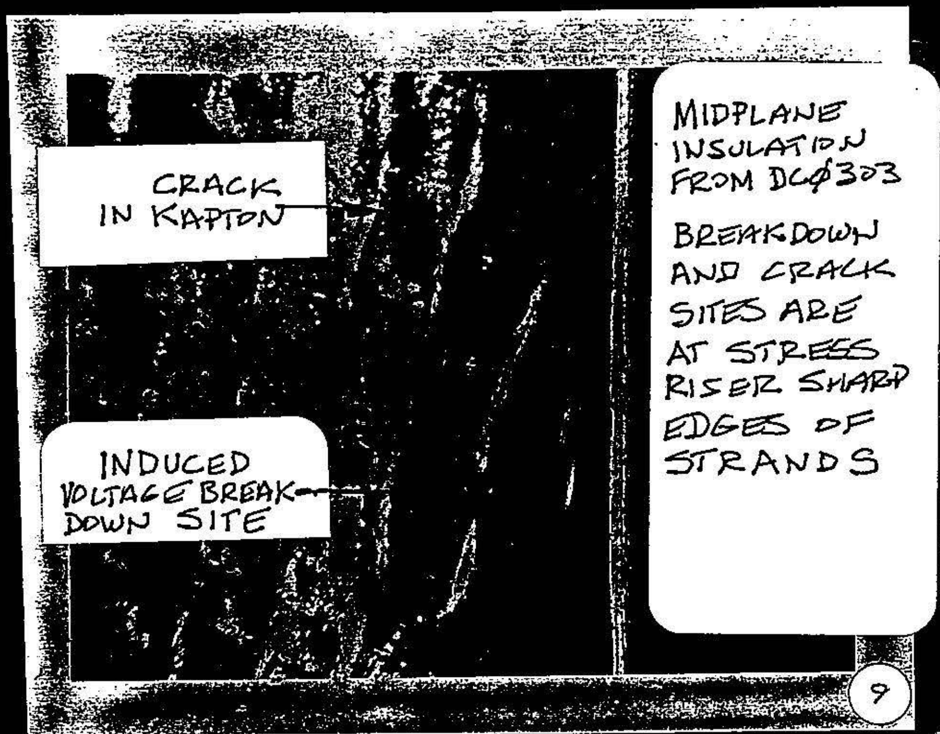
DSA 320
X32

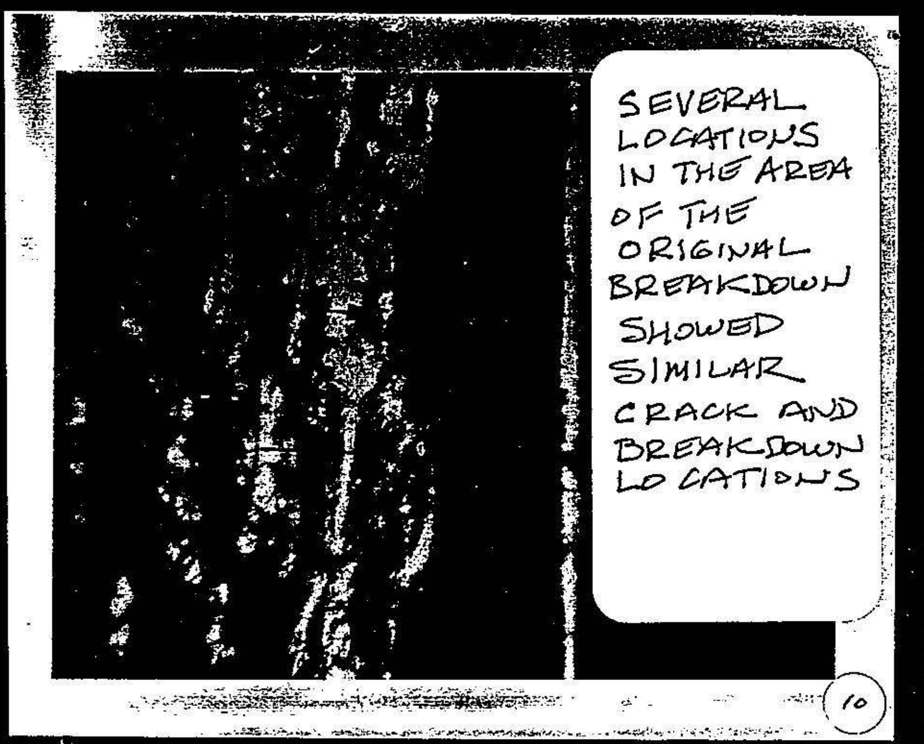
.005" INNER COIL MIDPLANE INSULATION (KAPTON H)
NOTE THAT INSULATION SHOWS BULK MODULUS EFFECTS FROM FLAT STRAND AREAS. THIS FURTHER STRESSES INNER KAPTON AGAINST SHARP EDGE OF STRANDS



225°
#72
KAP ONLY
X64

WITHOUT GLASS TAPE KAPTON IS NOT STREACHED OVER SHARP EDGES


CRACK IN KAPTON
INDUCED VOLTAGE BREAK-DOWN SITE
MIDPLANE INSULATION FROM DCØ303
BREAKDOWN AND CRACK SITES ARE AT STRESS RISER SHARP EDGES OF STRANDS
9


SEVERAL LOCATIONS IN THE AREA OF THE ORIGINAL BREAKDOWN SHOWED SIMILAR CRACK AND BREAKDOWN LOCATIONS
10

COMPARISON OF POLYIMIDE FILM DATA

All data on 1 mil thick film unless noted

RICHARD E. SIMS February 4, 1992

Physical Properties	Dupont HN		Dupont	Dupont	Dupont	Allied (-Apical)		Dupont	
	Typical Values	Test Conditions	H	HA	LT	AV	NP	120 CT-1	135 RCI
Physical Properties at (Temp.)	23° C (73°F)	200°C (392°F)	23°C	23°C	23°C	23°C	23°C	23°C, 1.2 Mil	23°C, 1.35 Mil
Ultimate Tensile (MD) Strength, MPa (psi) (36.000)	231 (33,500)	139 (20,000)	(32 K psi)	(31 K psi)	(24 K psi)	(35 K psi)	(44 K psi)	(30 K psi)	(20 K psi)
Yield Point (MD) at 3%, MPa (psi)	69 (10,000)	41 (6,000)				(10,000)			
Stress to Produce (MD) 5% Elongation, MPa (psi)	90 (13,000)	61 (9,000)				(13,000)			
Ultimate Elongation (MD),%	72	83	70	83	80	95	90	85	65
Tensile Modulus, GPa (MD) (psi)	2.5 (370,000)	2 (290,000)	(400,000)	(310,000)	(500,000)	2.92 (460,000)	4.26 (600,000)	(350,000)	(475,000)
Impact Strength, Kg-cm (ft-lb)	8(.58)								
Folding Endurance (MIT), cycles	285000			>1,000,000		>1,000,000	>150,000		
Tear Strength (MD)-Propagating (Elmendorf),g	7		16	35		8	7		
Tear Strength (MD) - Initial (Graves),g	729					520	600		
Density, g/cm3	1.42					1.42	1.45		
Coefficient of Friction - Kinetic (Film-to-Film)	0.48					0.40			
Coefficient of Friction - Static (Film to Film)	0.63					0.5			
Refractive Index (Becke Line)	1.66								
Poisson's Ratio	0.34								
Low Temperature Flex Life	Pass								
Dielectric Constant		3.4				3.4	3.3	3.5	3.8
Dielectric Strength V/Mil		7,700		6500	3500	7800	8000	6000	4500

NOTE: All information supplied by the manufacturers.

THERMAL PROPERTIES

RICHARD E. SIMS   February 4, 1992

Thermal Properties	Dupont HN Typical Values	Dupont HN Test Conditions	Dupont H	Dupont HA	Dupont LT	Allied (-Apical) AV	Allied (-Apical) NP
Melting Point	none	none					
Thermal Coefficient of Expansion	20 ppm/°C (11ppm/°F)	-14 to 38°C (7 to 100°F)				2.1 X 10-8 In/In/°C	.8 X 10-50°C
Coefficient of Thermal Conductivity , W/m*K	.12	296°K					
(Cal) (cm)(sec)(°C)	(2.87 X 10-4)	23°C					
Specific Heat	1.09(.261)	°J/ g °K(cal/g/°C)					
Shrinkage, %	.17 1.25	30 min @ 150°C 120 min @ 400°C					
Limiting Oxygen Index, %	37						

NOTE: All information supplied by the Manufacturers.

Follow-on Steps

(R.E. Sims, Revised 2-20-92)

1. Examine "cookies" of the coils to determine the "flow" of the Kapton epoxy system. (DSI340 & DSI341)

2. Take apart Kapton epoxy stacks with first layer adhesives and search for any epoxy leakage on cable. (Cryorad done, do Kapton +2290)

3. Make some Kapton and Apical ten stacks with increased cure temperatures (+20°F) and increased time (+30 min) to gauge reductions in creep, etc.

4. Make cryogenic shrinkage measurement of an assortment of ten stacks while under constant pressure (12 K psi).

5. Obtain Apical NP film coated on both sides with Cryorad adhesive and Kapton LT film coated on both sides with 2290 adhesive. Evaluate the creep and modulus of elasticity of the following ten stacks:

   a. 1/2 NP, butt NP coated 2 sides
      1) Cured at 275°F, 90 min, 10 KPSI
      2) Cured at 295°F, 90 min, 10 KPSI
      3) Cured at 275°F, 120 min, 10 KPSI
      4) Cured at 275°F, 90 min, 6 KPSI

   b. 1/2 NP, 1/2 NP coated 2 sides.
      1) through 4) same as above. (COULD BE #1 ONLY BECAUSE PROCESS VARIATIONS SHOULD FALL INTO ABOVE FAMILY "a.")

   c. 1/2 H, butt LT coated 2 sides.
      1) through 4) same as above. (COULD BE #1 ONLY)

   d. 1/2 H, 1/2 LT coated 2 sides.
      1) through 4) same as above. (COULD BE #1 ONLY)

   e. 1/2 NP, BUTT LT COATED 2 SIDES (OPTIONAL, CURE AS a.1 ABOVE)

6. Measure cryogenic shrinkage of the "1" and "4" ten stacks in #5 above.