TS-SSC92-018

Cable Insulation Workshop
February 5, 1992
SSCL

Kapton-Epoxy Insulation and Apical-Cryorad System Tests

R. E. Sims
2/4/92

Perceived disadvantages of Glass Tape System:

1. Breaks down at lower pressure (high voltage breakdown, BNL study).

2. Tears during winding - sharp corners on torn glass (usually requiring hand repair).

3. High friction in mold => Less uniform distribution of conductors and more size variation.

4. Larger epoxy volume => Hydraulically stretching Kapton can lead to insulation failure.

5. Limits current density. An all polymide insulation wrap can permit lower insulation volume and allow an additional turn of superconductor.

Perceived disadvantages of eliminating Glass Tape:

1. Change cross-section. (Assumes minimum insulation approach).

2. Increases creep. Higher initial collaring forces would be required.

3. Reduced control of coil size variation from component size variation.

4. Lower modulus (but this may partially compensate for #3).

5. Larger thermal contraction.

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.

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.

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 with no inner layer adhesive have 10% to 25% lower final coil modulus of elasticity.

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

6. It is difficult to extrapolate coil size from ten stack size with good accuracy.

7. Allied Signal Apical type NP film appears to provide lower creep than DuPont Kapton type K.

8. Apical type NP film also appears to make ten stacks with slightly higher modulus of elasticity properties.

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

Follow-on Steps

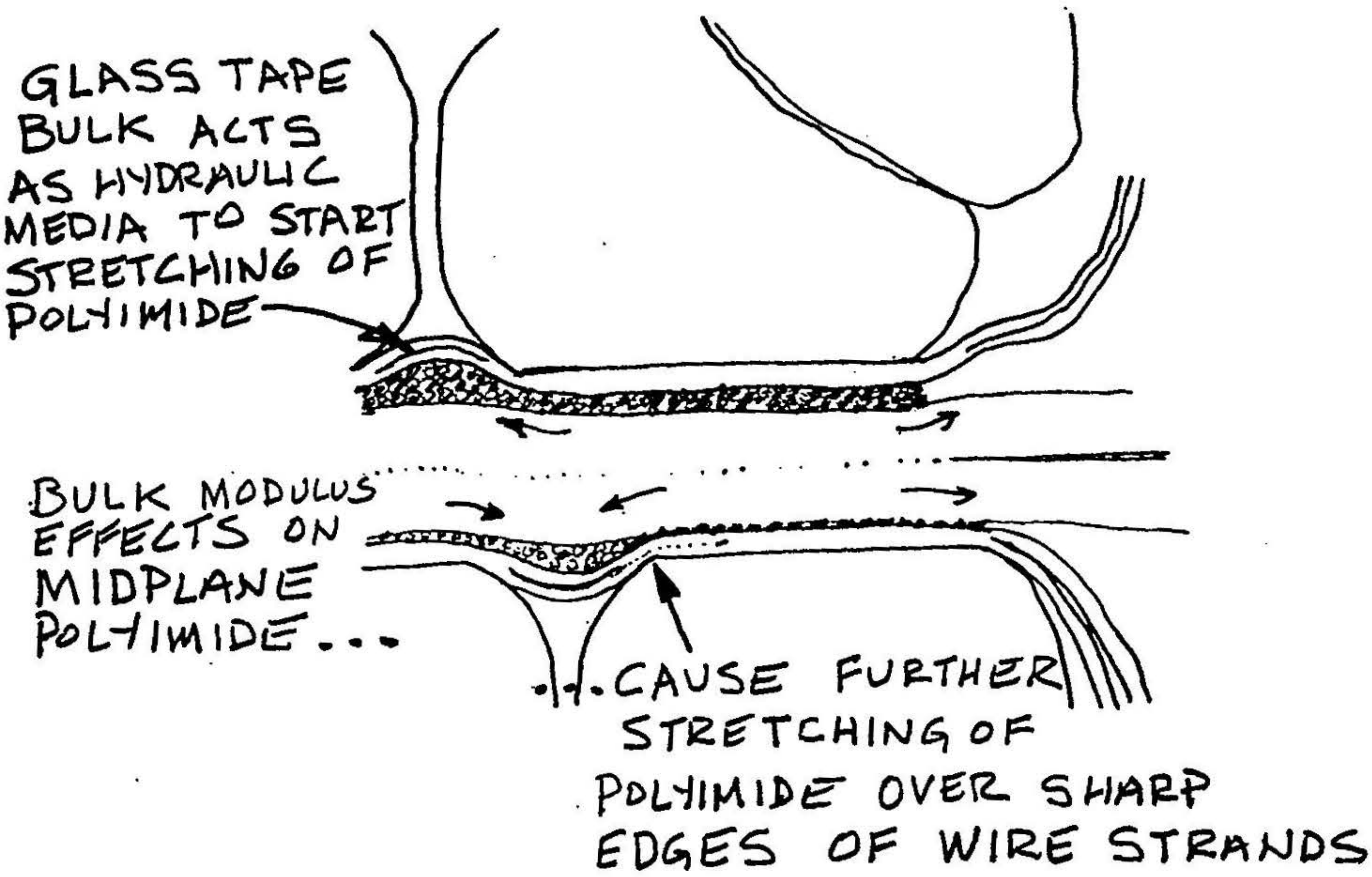
1. Examine "cookies" of the coils to determine the "flow" of the Kapton epoxy system.

2. Take apart Kapton epoxy stacks with first layer adhesives and search for any epoxy leakage on cable.

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 of an assortment of ten stacks while under constant pressure (12 K psi).

POSSIBLE SCENARIO LEADING TO DIELECTRIC BREAKDOWN OF POLYIMIDE MIDPLANE INSULATION



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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.

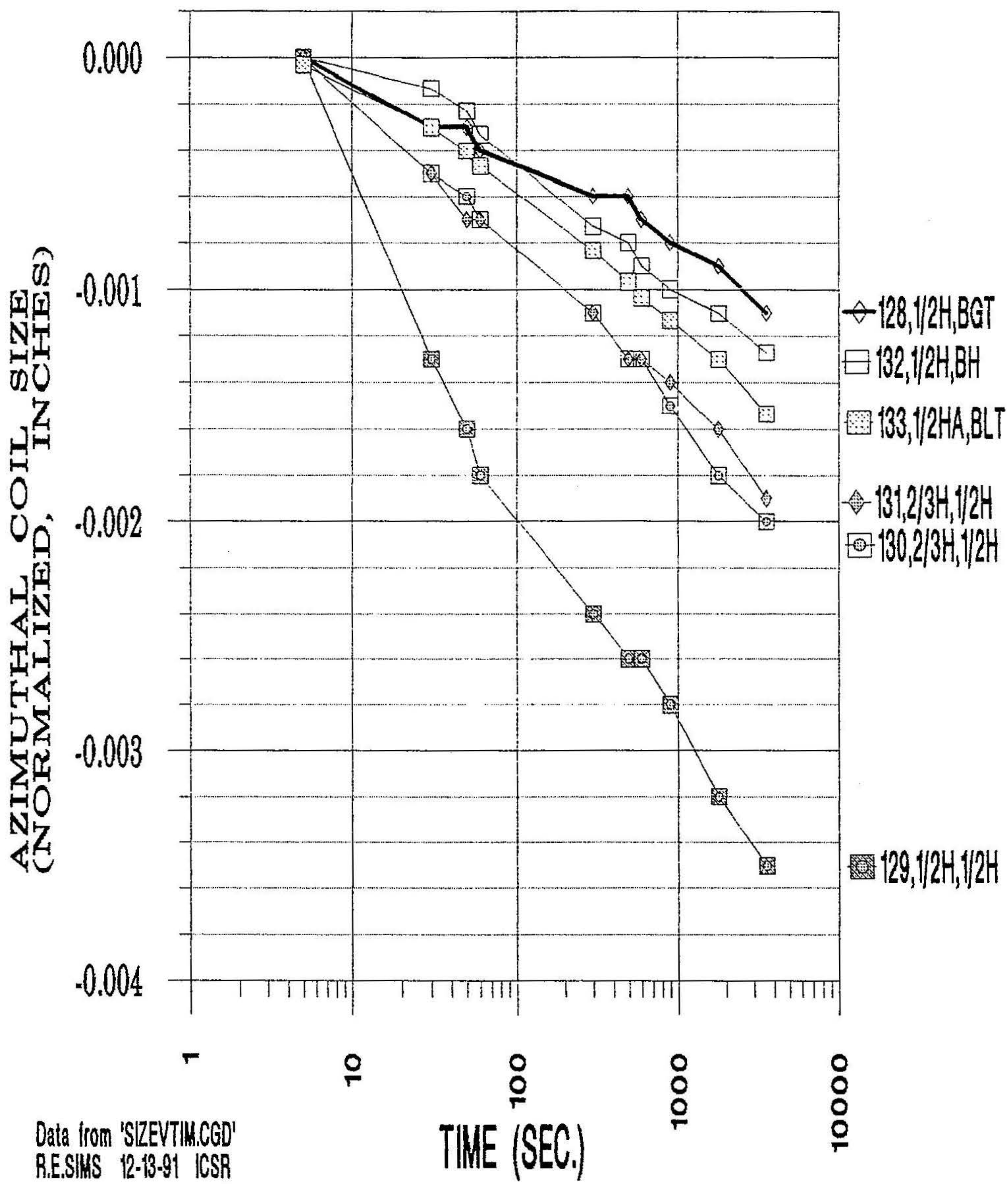
THERMAL PROPERTIES

RICHARD E. SIMS   February 4, 1992

Thermal Properties	Dupont HN Typical Values	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						

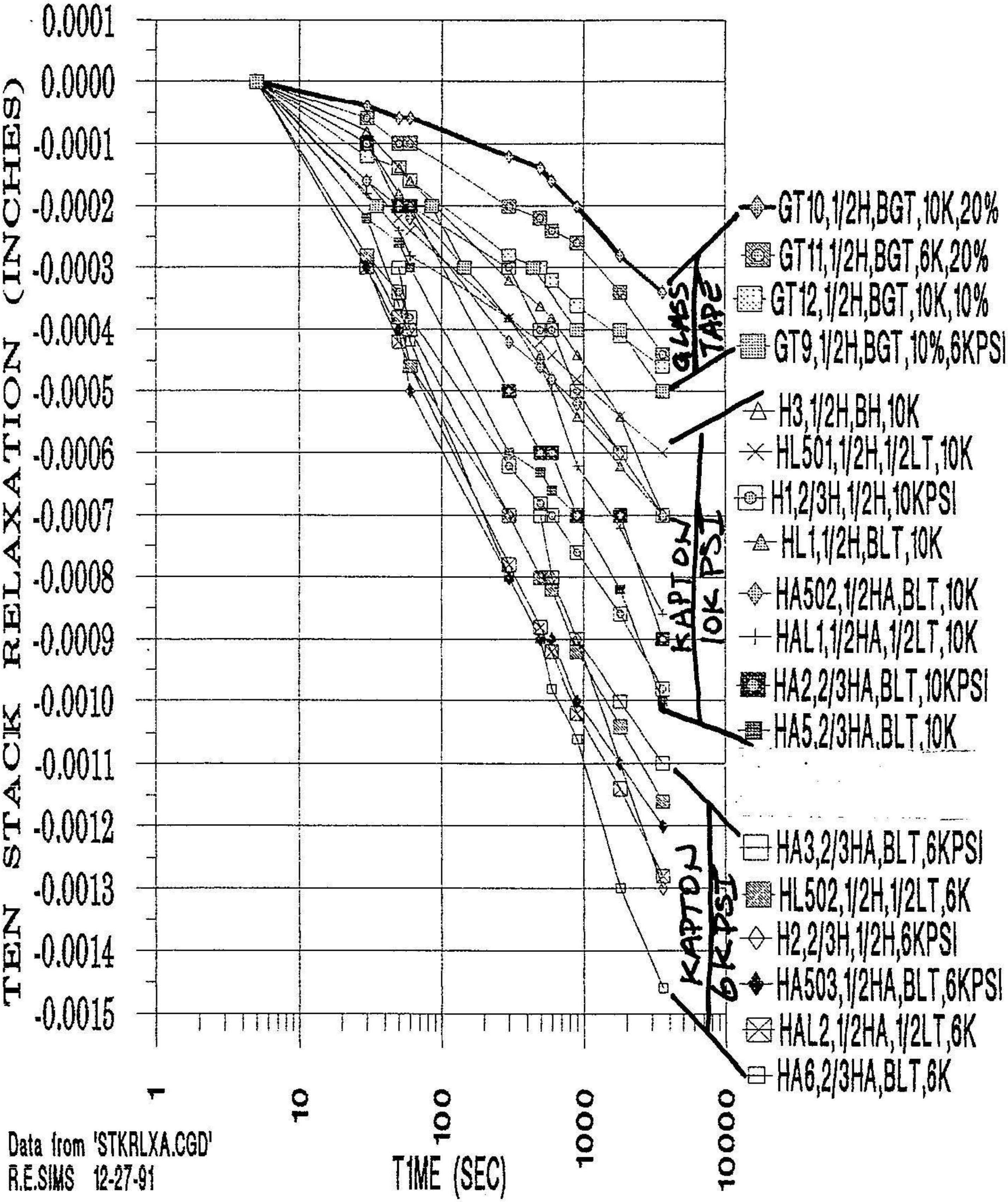
NOTE: All information supplied by the Manufacturers.

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



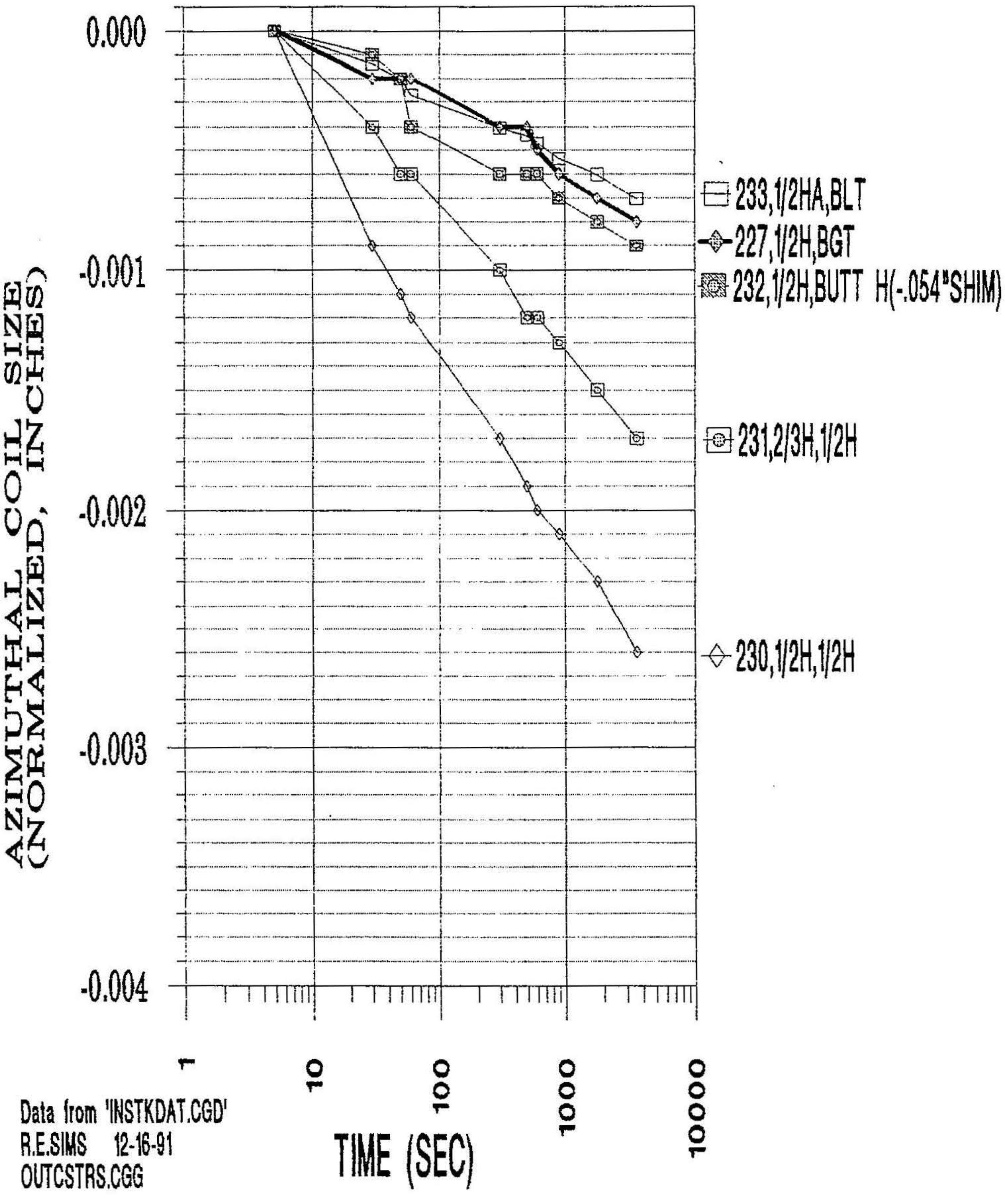
Data from 'SIZEVTIM.CGD'
R.E.SIMS 12-13-91 ICSR

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



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

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



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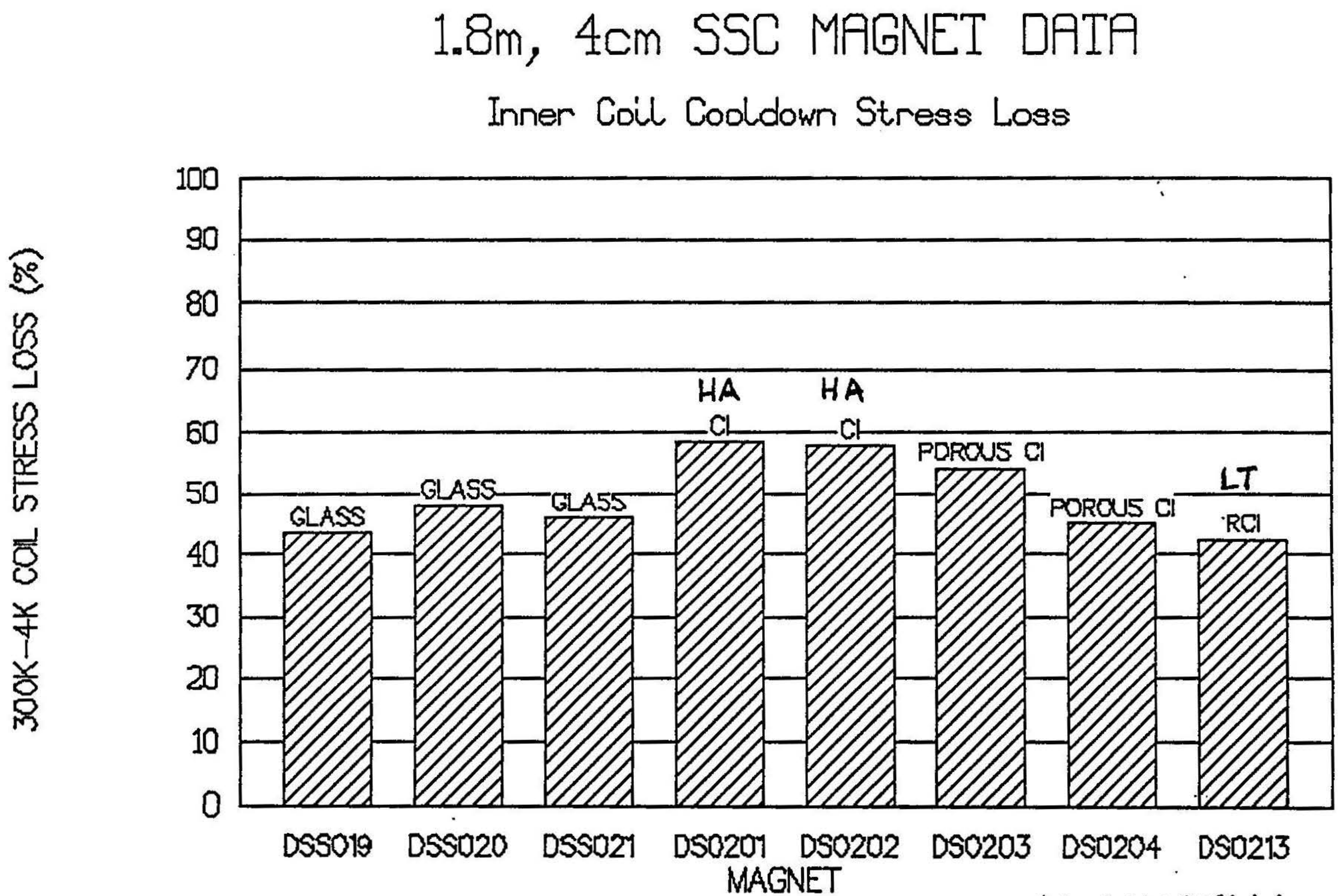
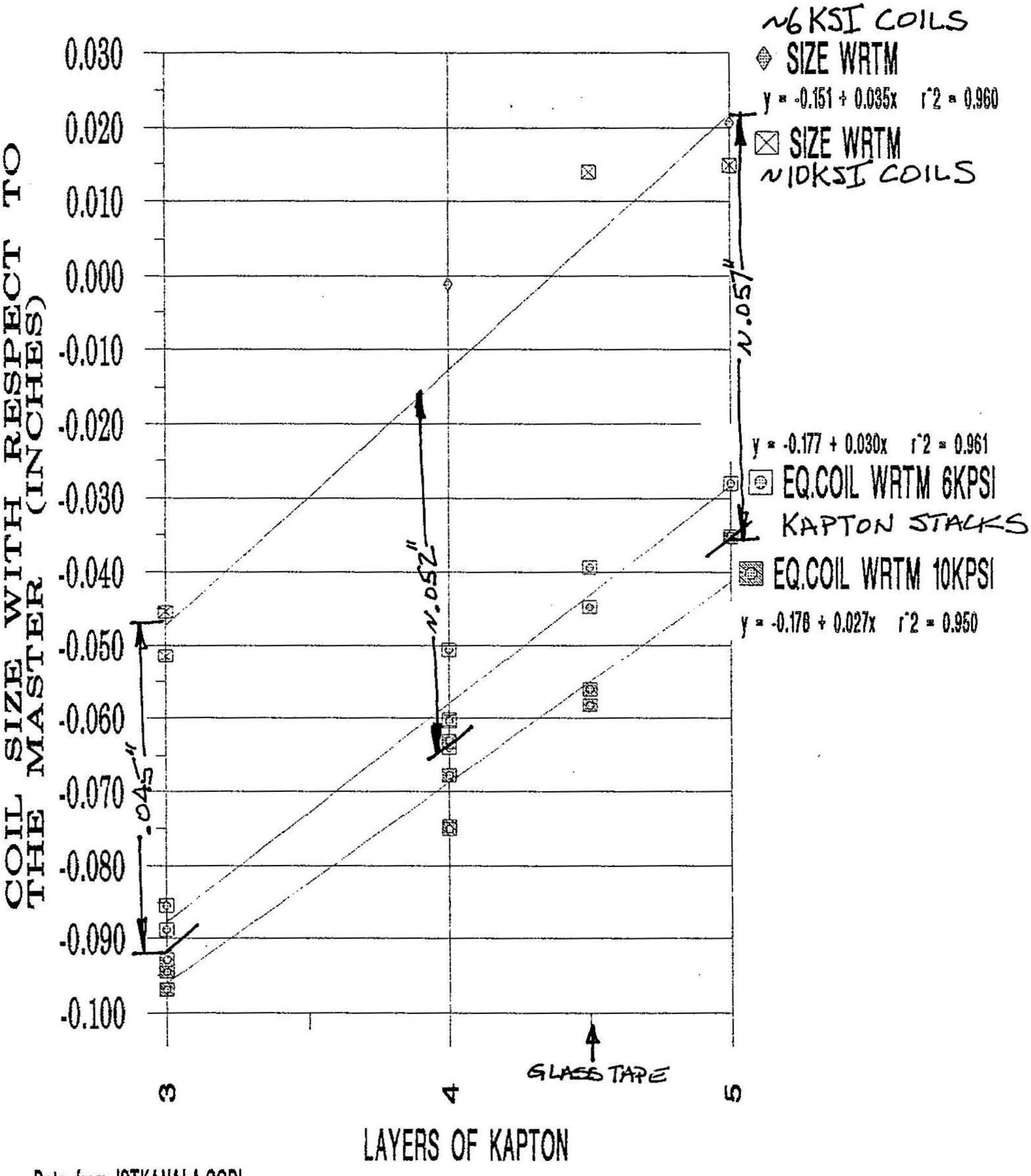
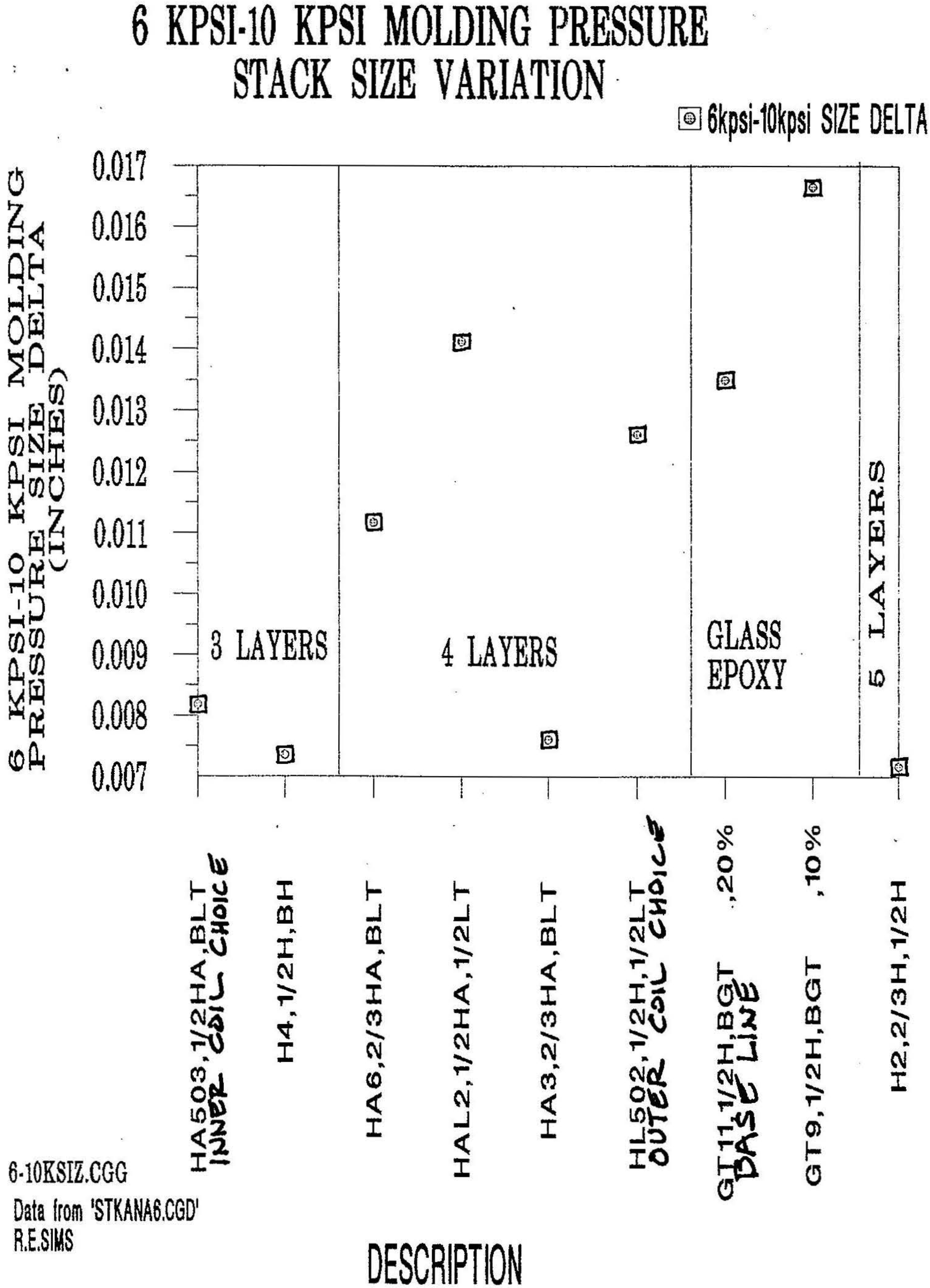
R.E.SIMS 12-16-91
OUTCSTRS.CGG



M. ANERELLA
BNL
8-6-91

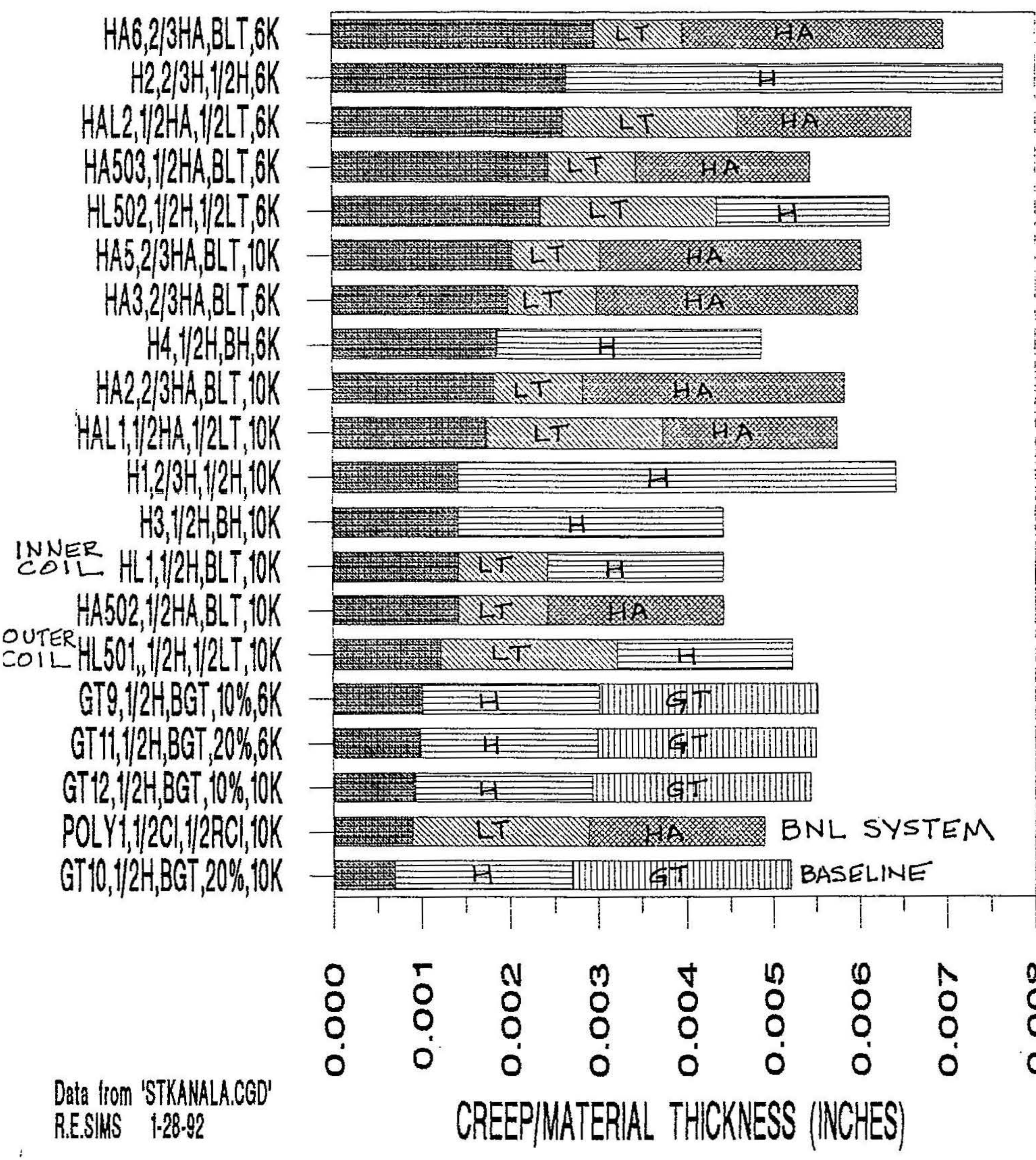


Data from 'STKANALA.CGD'



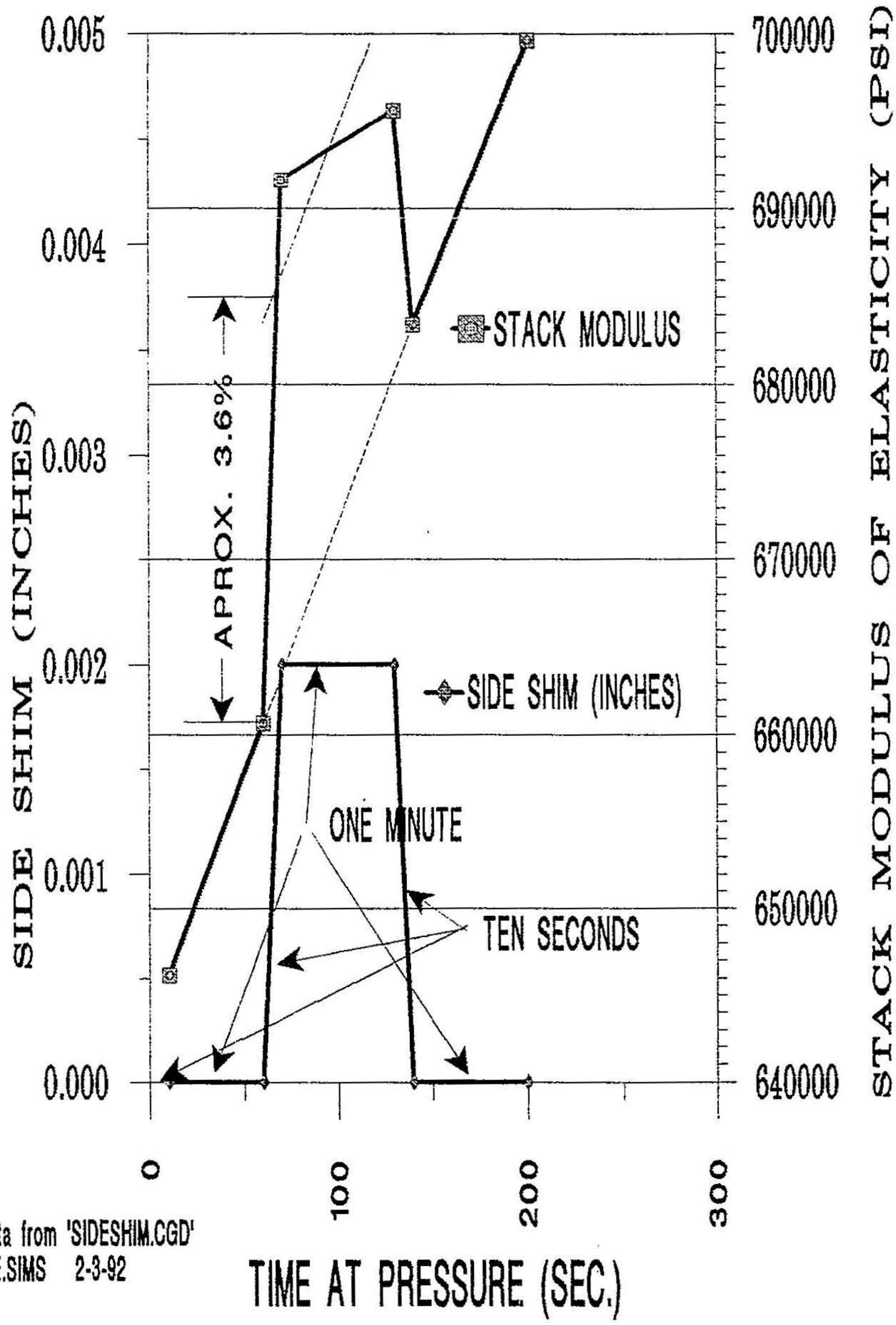
6-10KSIZ.CGG
Data from 'STKANA6.CGD'
R.E.SIMS

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



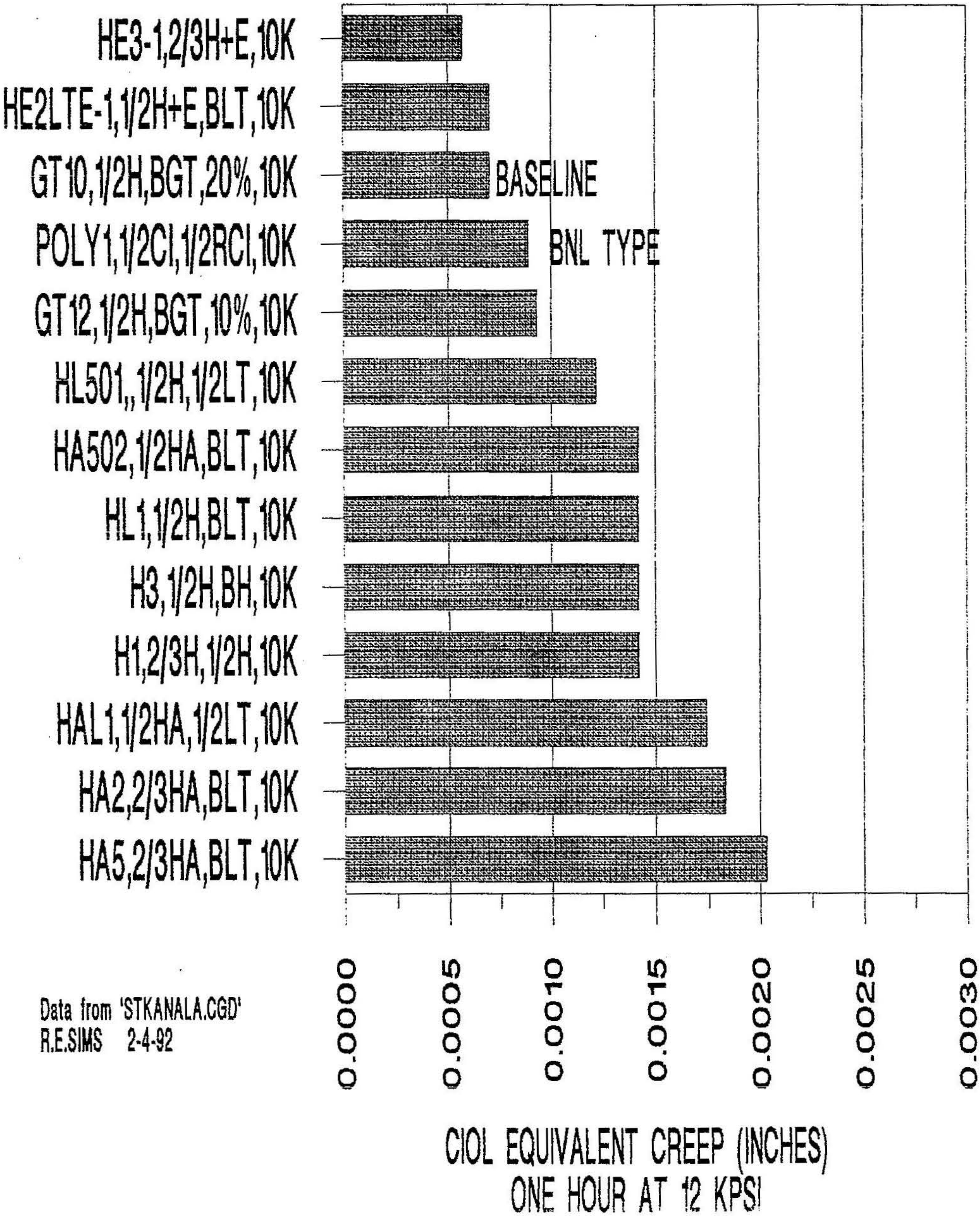
Data from 'STKANALA.CGD'
R.E.SIMS 1-28-92

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



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

CREEP FOR SELECT KAPTON STACKS



Data from 'STKANALA.CGD'
R.E.SIMS 2-4-92

APICAL BRAND INSULATION COMBINATIONS BEING STUDIED AS TEN STACKS

MATERIAL INNER	MATERIAL OUTER	WRAP PATTERN(IN/OUT) 2/1	2/2	3/1	3/2	LAYER ADHESIVE INNER	LAYER ADHESIVE 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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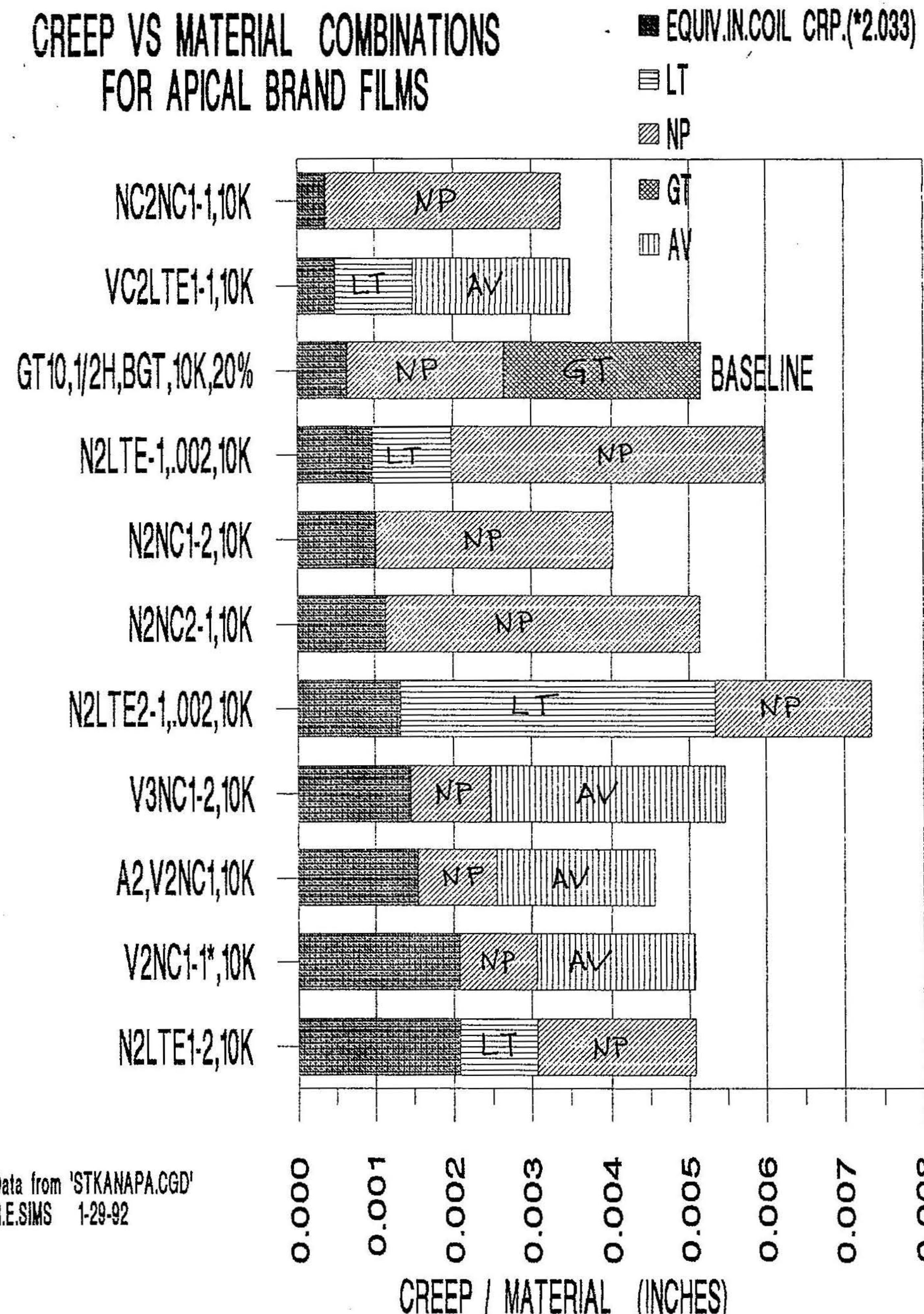
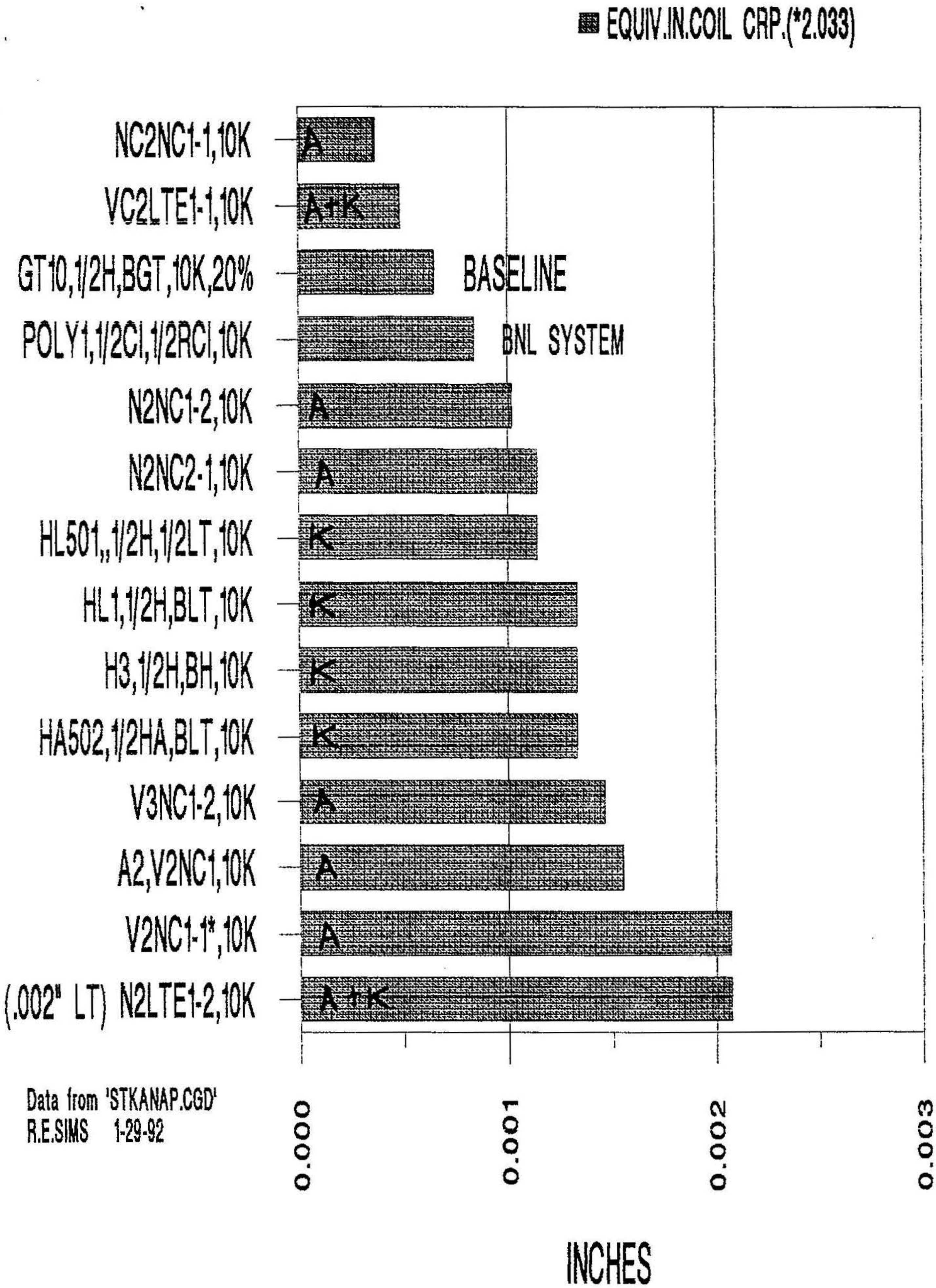
1-16-91

CREEP VS MATERIAL COMBINATIONS FOR APICAL BRAND FILMS

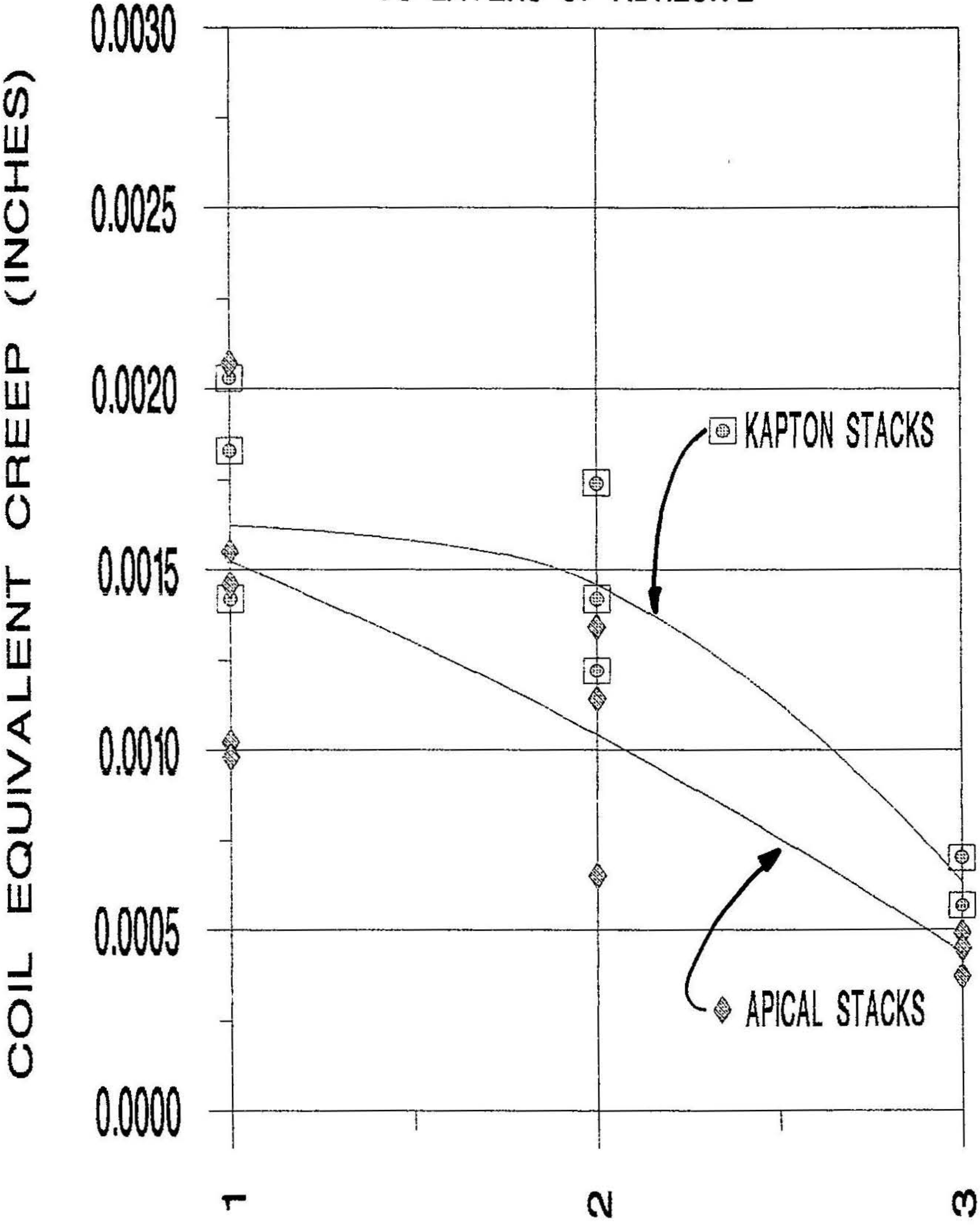


Data from 'STKANAPA.CGD'
R.E.SIMS 1-29-92

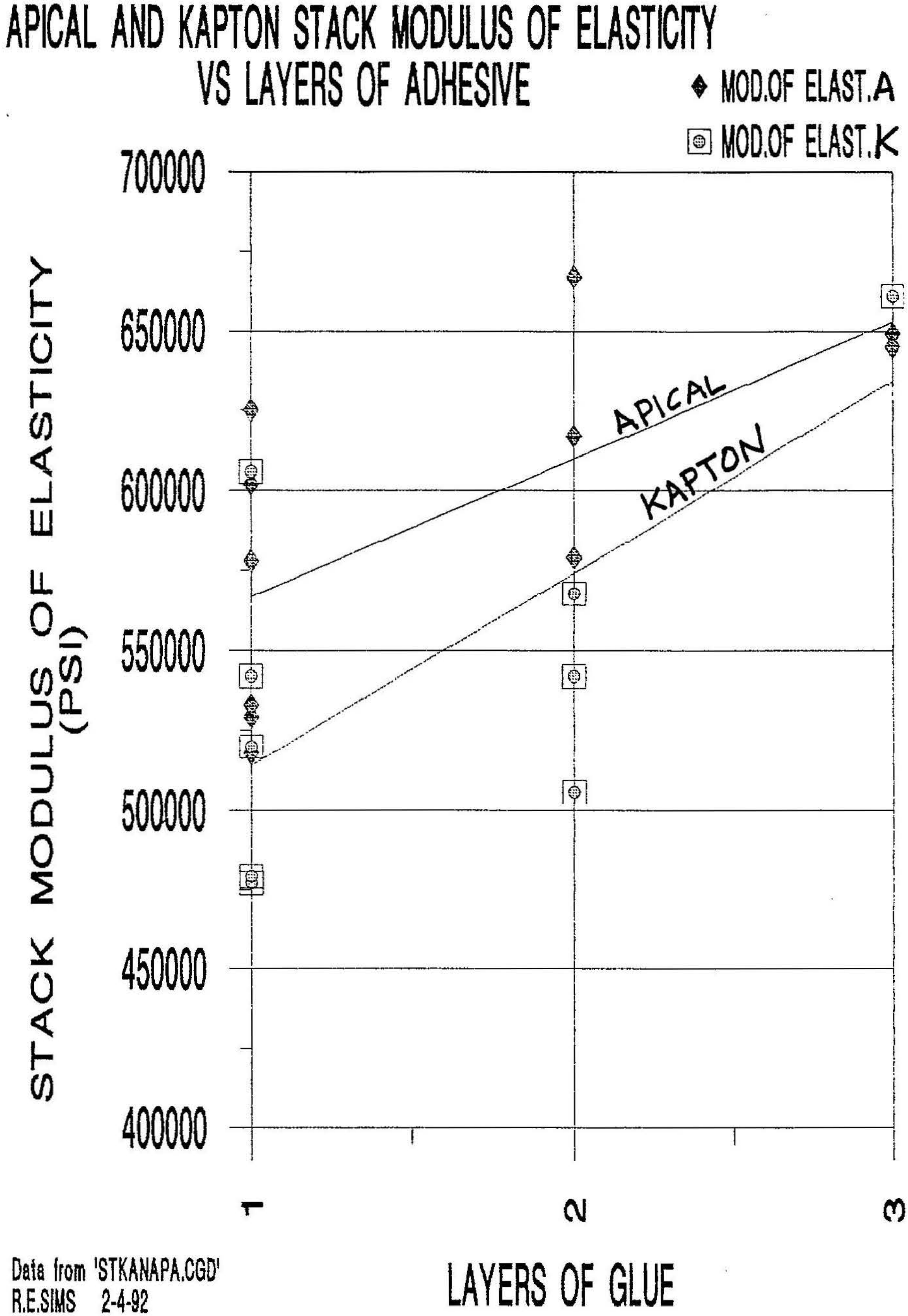


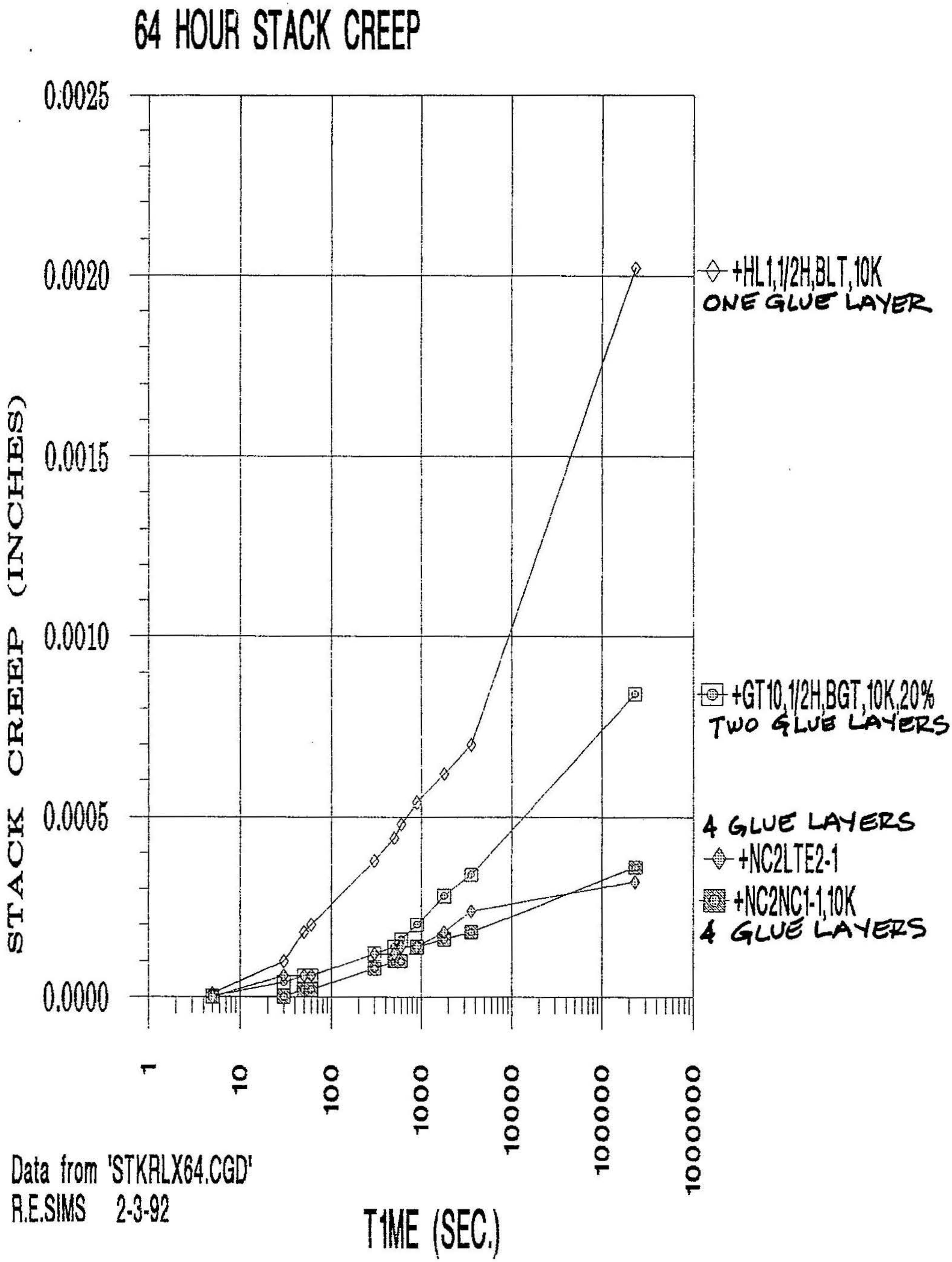
Data from 'STKANAP.CGD'
R.E.SIMS 1-29-92

APICAL AND KAPTON STACK CREEP VS LAYERS OF ADHESIVE

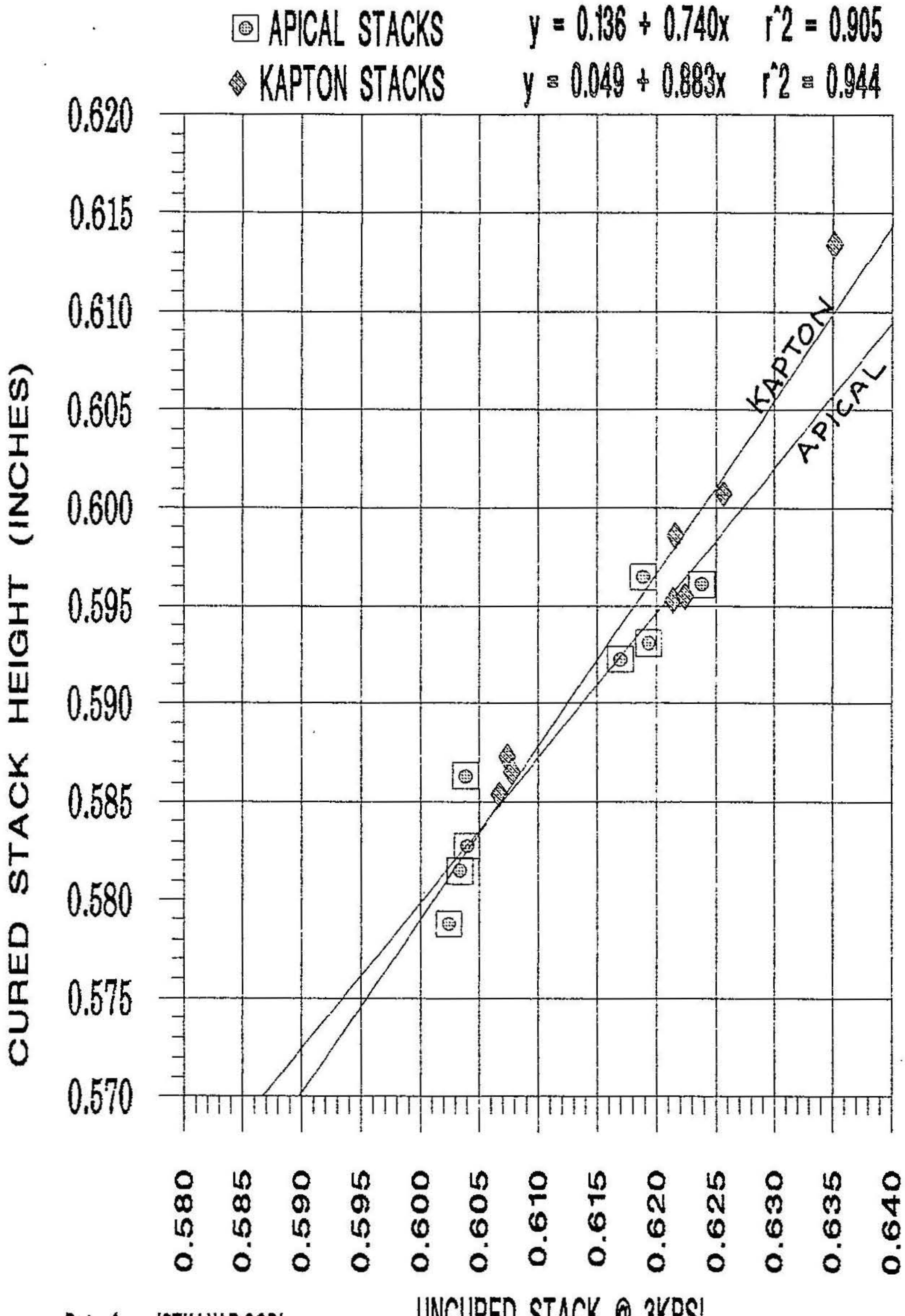


Data from 'STKANALA.CGD'
R.E.SIMS 2-4-92


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

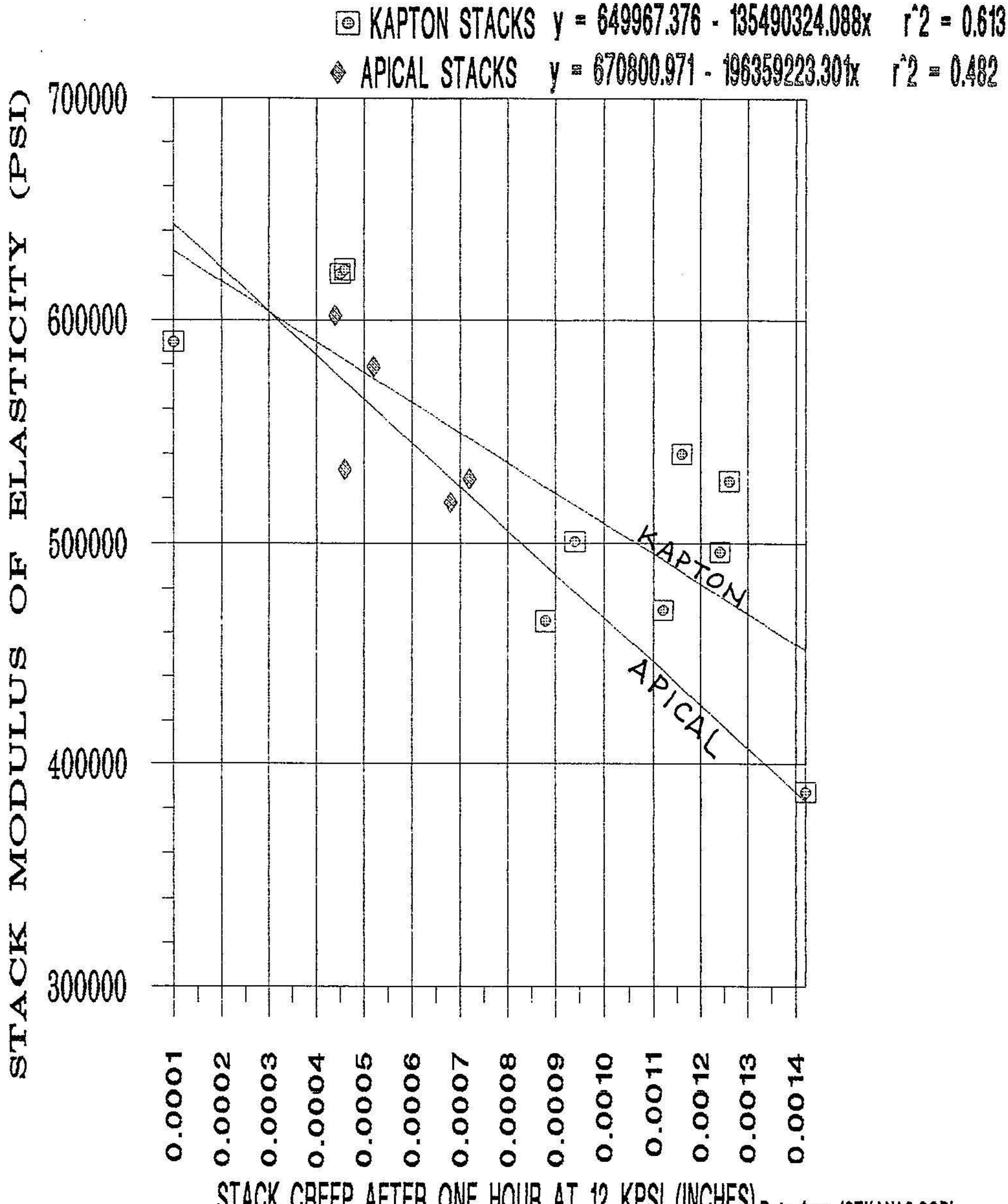

64 HOUR STACK CREEP
STACK CREEP (INCHES)
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
1
10
100
1000
10000
100000
1000000
TIME (SEC.)
+HL1,1/2H,BLT,10K
ONE GLUE LAYER
+GT10,1/2H,BGT,10K,20%
TWO GLUE LAYERS
4 GLUE LAYERS
+NC2LTE2-1
+NC2NC1-1,10K
4 GLUE LAYERS
Data from 'STKRLX64.CGD'
R.E.SIMS 2-3-92

KAPTON AND APICAL TEN STACKS
BEFORE VS AFTER CURING

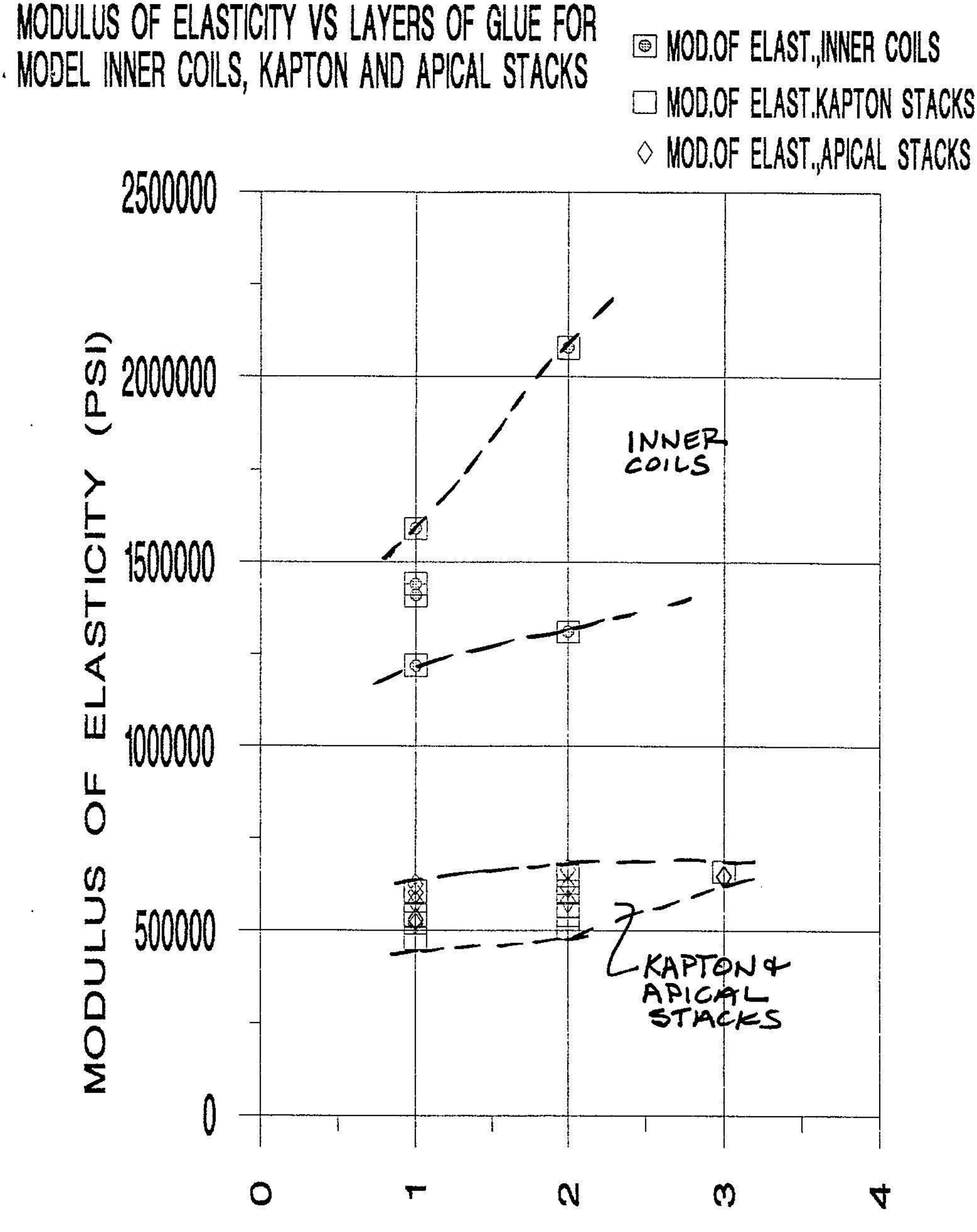


Data from 'STKANAP.CGD'
R.E.SIMS 1-22-92

KAPTON AND APICAL STACK MODULUS VS CREEP

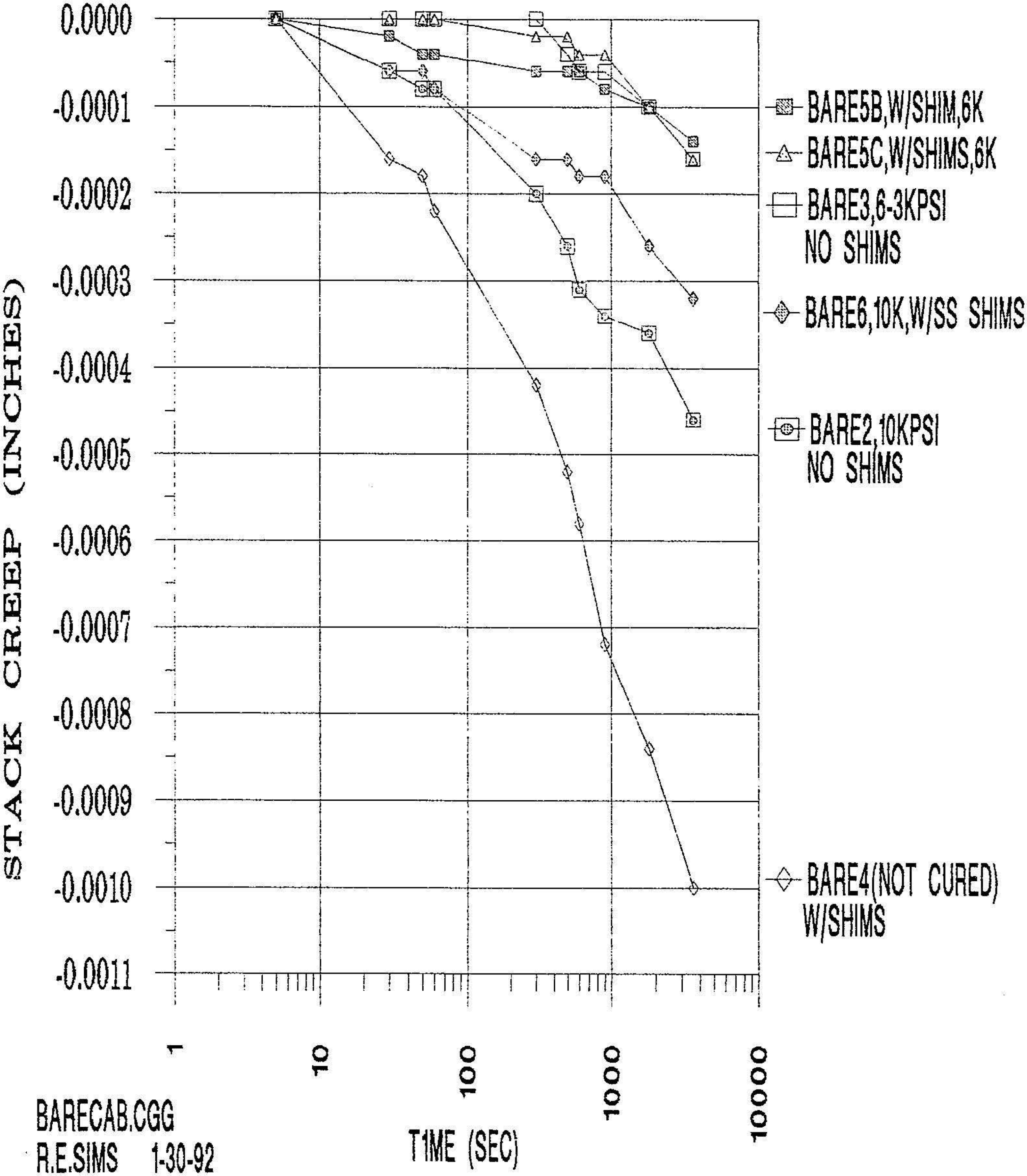


Data from 'STKANA6.CGD'
R.E.SIMS 1-22-92



Data from 'STKANC10.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