Fermilab

TS-SSC 92-065
5/26/92
J. Strait

Cable-Pair Insulation Breakdown Test Results
(Fiberglass-epoxy, Kapton-epoxy and Apical-Cryorad Systems)

We are using a variety of insulation types in the last 5 short (DSA330-334) and last 4 long (DCA320-323) SSC dipoles being built at Fermilab. As part of the program to evaluate these insulation systems a series of breakdown tests have been done with pairs of cables molded with the various insulation types. The tests were done using 40 mm outer cable because fixtures for molding samples and performing the breakdown tests already exist in the Fermilab Materials Development Lab. Up to 10 pairs were molded at one time in a narrow edge to narrow edge configuration in a fixture which has the geometry of a 40 mm outer coil. A piece of 1 mil Kapton with mold release applied was placed between every other turn to define the pairs for the test. Shims were placed at the top of the coil package so that the pressure required to close the fixture to the design (40 mm outer coil) azimuthal size was in the range 7-9 kpsi. The work of preparing and testing the samples was done by Pam Schmidt of the Superconducting Magnet Fabrication group.

Each cable pair was squeezed between a pair of electrically isolated anvils which are shaped to match the keystone angle of the cable. The area of the anvils is 0.3415 square inches (220 mm^2). The load was increased in increments of 1000 lbs (4444 N), corresponding to a stress increment of 2.9 kpsi (20 MPa). After each step a 2 kV hipot was performed. This sequence was repeated until the hipot failed. No attempt was made to determine the location or detailed cause of the insulation failures. Five to ten samples of each of ten different insulation types were tested. Table I lists the types of insulation tested and the magnets in which each type has been used. The results of all tests are given in Table II. The results are plotted in Figures 1 and 2. Figure 1 is a scatter-plot of the breakdown stress versus insulation type. Here multiple samples with the same breakdown stress are plotted as a single point. Figure 2 is a set of histograms of the stresses at which the samples broke down.

The samples insulated with the "traditional" kapton plus fiberglass-epoxy insulation system had breakdown stresses in the range 38-53 kpsi (260-370 MPa) with a mean of 47 kpsi (320 MPa). The other systems had mean breakdown stresses comparable to or larger than this. However one or two samples of 3 different types broke down at stresses lower than the lowest breakdown stress in the fiberglass-epoxy samples. In all three cases these low breakdown results appear to be outside the main distribution of sample results. There is no apparent pattern as to which insulation types show these low breakdown stresses -- two use Apical, one uses Kapton, two have double coated outer wraps, and one has single coated film on both inner and outer wraps -- so it is tempting to believe that the low breakdown stresses resulted from some extrinsic cause, e.g. chips or flaws in the wire, and are not characteristic of the insulation-adhesive system. However, since the location and cause of the breakdown was not investigated, this conjecture cannot be confirmed.

Given the limited statistics of these tests and the variability of the results, it is difficult to draw firm conclusions. If the "anomolously" low breakdowns are ignored, then most of the glassless systems appear to perform better than the fiberglass containing system, and there is some tendency for the Apical-Cryorad systems to perform better than the Kapton-2290 systems. However, all of the distributions overlap one another, and the presence of the low breakdowns clouds these interpretations. As usual, further studies are warrented, but not by us.

Table I
Insulation Types Tested

Inner Wrap Film	Inner Wrap Over-lap	Inner Wrap Adhes.	Outer Wrap Film	Outer Wrap Over-lap	Outer Wrap Adhes.	Magnets	Designation in Table II and the Figures
H	50%	-	Glass	butt	epoxy	[a]	2H - |1FGe
H	50%	-	LT	butt	2290	[b]	2H - |1LT1e
NP	50%	-	NP	butt	2xCR	[c]	2NP- |1NP2c
NP	66%	CR	-	-	-	[d]	3NP1c|
H	50%	-	LT	butt	2x2290	[e]	2H - |1LT2e
H	50%	-	LT	50%	2290	[f]	2H - |2LT1e
NP	50%	-	NP	50%	2xCR	[g]	2NP- |2NP2c
NP	50%	CR	NP	50%	CR	[h]	2NP1c|2NP1c
H	50%	-	LT	50%	2x2290	[i]	2H - |2LT2e
NP	50%	-	NP	50%	CR	none	2NP- |2NP1c

Films

H = DuPont H-film Kapton
LT = DuPont LT-film Kapton
NP = Allied Signal NP-film Apical

Adhesives

2290 = 3M 2290 epoxy on one side
2x2290 = 3M 2290 epoxy on both sides
CR = Allied Signal Cryorad on one side
2xCR = Allied Signal Cryorad on both sides

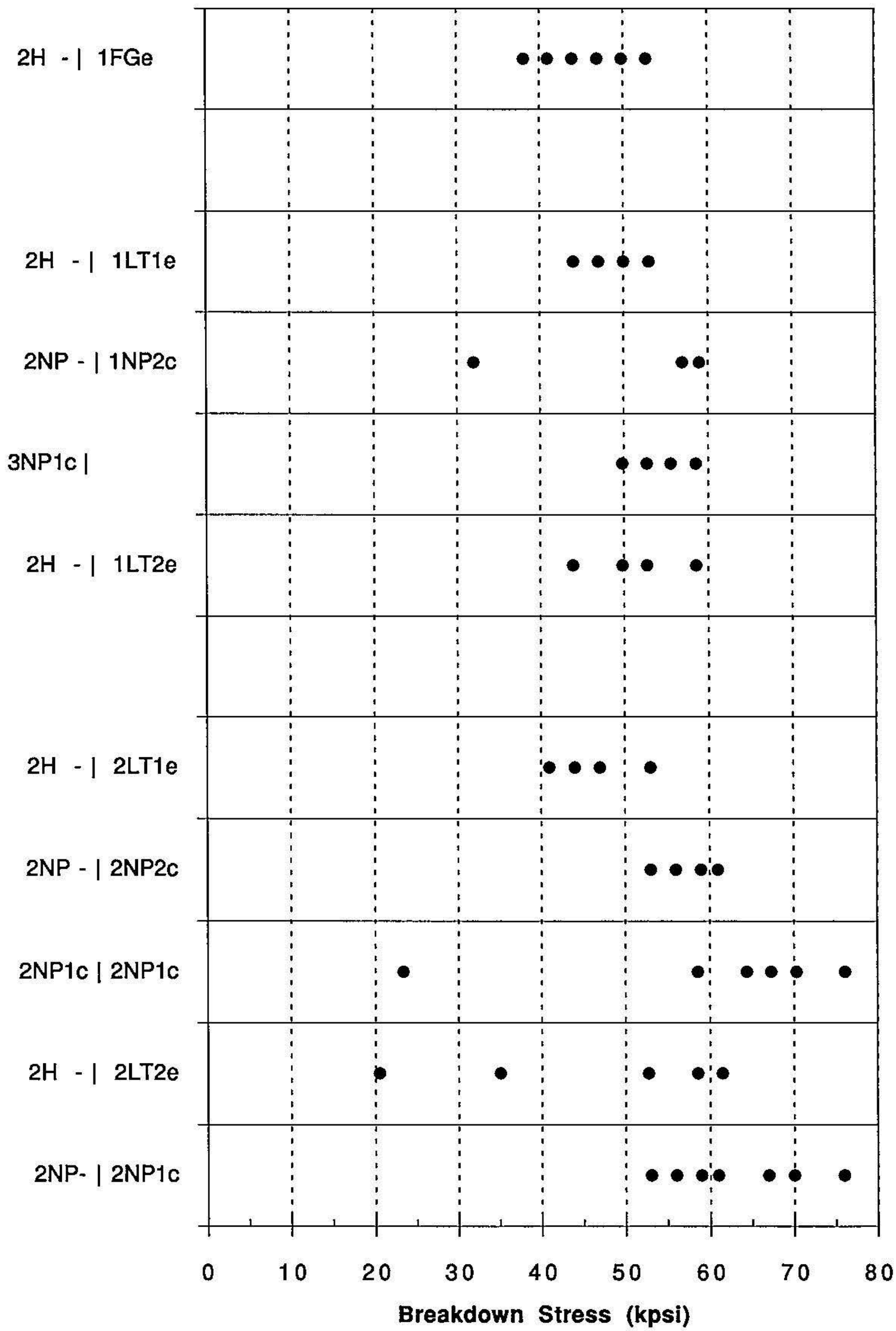
Magnets

[a] Tevatron, HERA, ASST, UNK
[b] DSA330,332, DCA320,321 inner coils
[c] DSA334 DCA332,323 inner coils
[d] DSA331 inner coils
[e] DSA333 inner coils
[f] DSA330,332, DCA320,321 outer coils
[g] DSA334 DCA332,323 outer coils
[h] DSA331 outer coils
[i] DSA333 outer coils

Table II

Cable pair data

Insulation Type	Breakdown Stress (kpsi)										min	max	mean	sigma
2 H - | 1 FG e	47	50	47	47	38	44	50	41	50	53	38	53	47	4.5
2 H - | 1 LT 1e	50	50	53	44	47						44	53	49	3.4
2 NP - | 1 NP 2c	32	57	57	59	57						32	59	52	11.4
3 NP 1c |	50	56	50	59	53	56	50	50	50	50	50	59	52	3.3
2 H - | 1 LT 2e	50	44	59	50	44	53	50	44	50	50	44	59	49	4.6
2 H - | 2 LT 1e	41	44	47	44	44	41	53	47	44		41	53	45	3.7
2 NP - | 2 NP 2c	56	56	59	53	56	61	53	56	56		53	61	56	2.5
2 NP 1c | 2 NP 1c	67	59	64	70	76	59	67	59	64	24	24	76	61	14.3
2 H - | 2 LT 2e	53	62	62	59	59	59	59	59	21	35	21	62	52	13.6
2 NP - | 2 NP 1c	53	53	56	76	61	59	70	59	67	56	53	76	61	7.7



2H - | 1FGe
2H - | 1LT1e
2NP - | 1NP2c
3NP1c |
2H - | 1LT2e
2H - | 2LT1e
2NP - | 2NP2c
2NP1c | 2NP1c
2H - | 2LT2e
2NP- | 2NP1c
0
10
20
30
40
50
60
70
80
Breakdown Stress (kpsi)

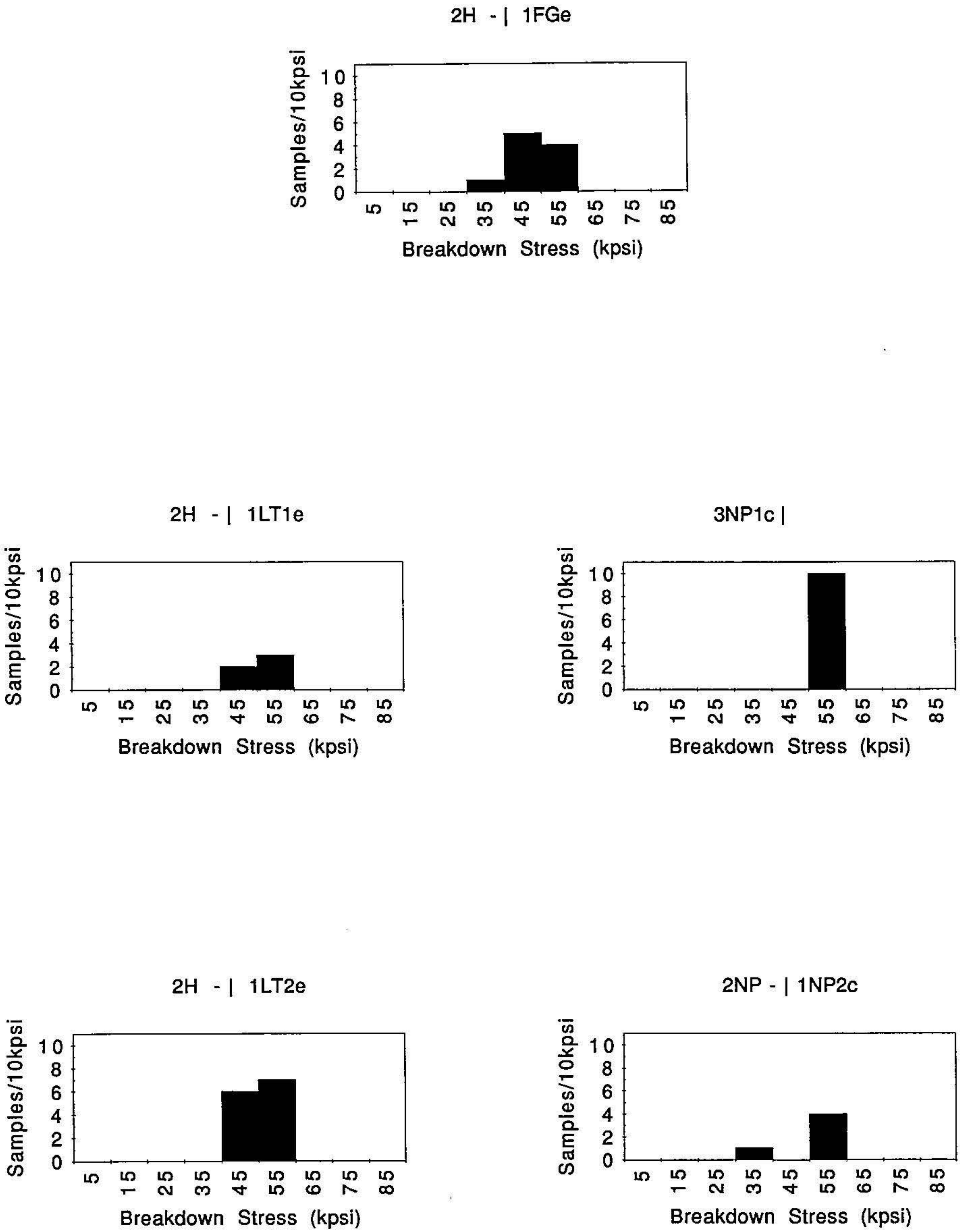
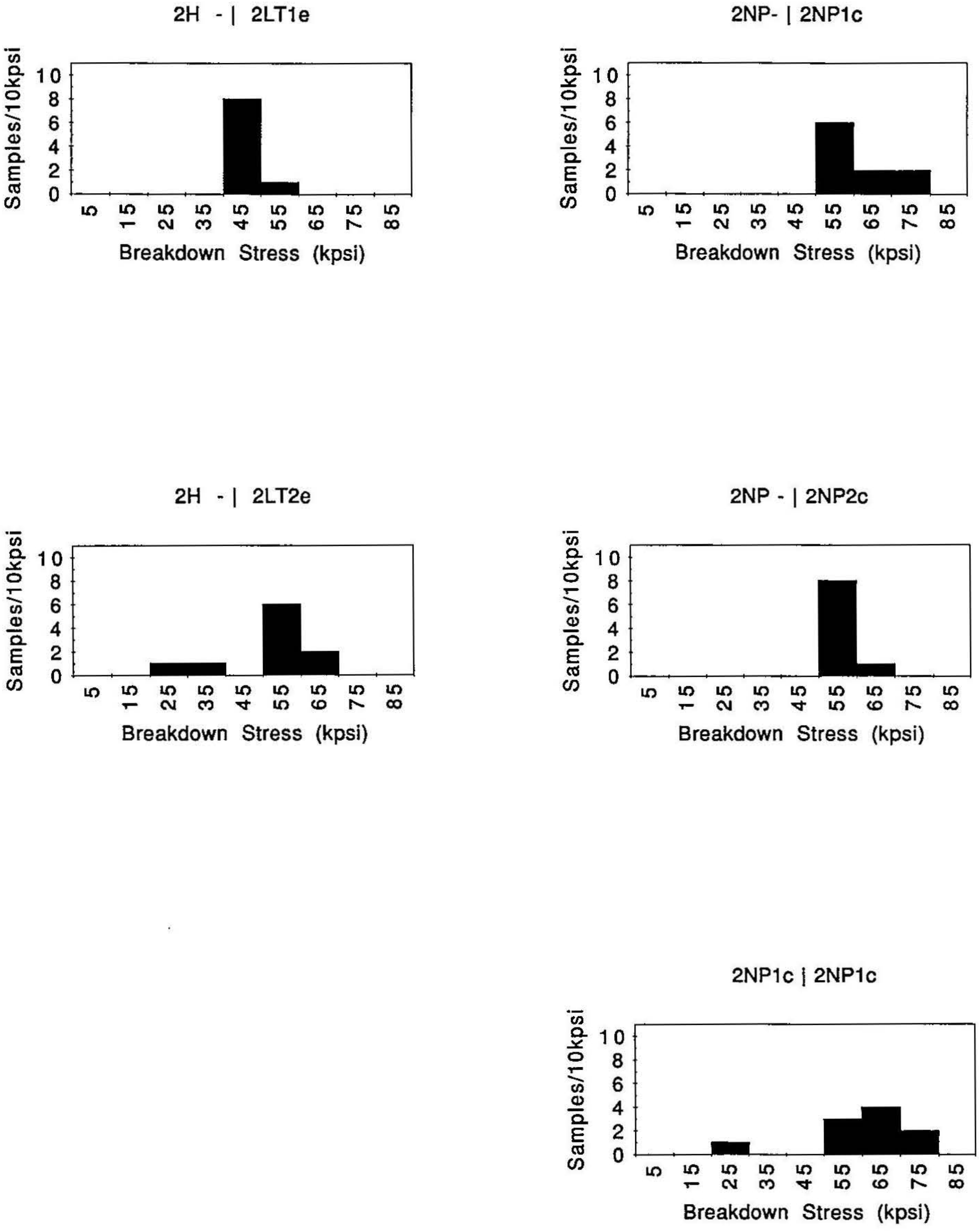

2H - | 1FGe
Samples/10kpsi
Breakdown Stress (kpsi)
2H - | 1LT1e
3NP1c |
2H - | 1LT2e
2NP - | 1NP2c
0
2
4
6
8
10
5
15
25
35
45
55
65
75
85

Figure 2a



2H - | 2LT1e
2NP- | 2NP1c
2H - | 2LT2e
2NP - | 2NP2c
2NP1c | 2NP1c
Samples/10kpsi
0 2 4 6 8 10
5 15 25 35 45 55 65 75 85
Breakdown Stress (kpsi)

Figure 2b

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