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PHYSICAL PROPERTIES OF IRRADIATED PLASTICS

by

O. Sisman
C. D. Bopp

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ABSTRACT

A series of graphs and charts are presented depicting quantitatively the changes in physical properties which various plastics undergo when subjected to radiation in the ORNL Reactor. Tests were made of the following properties: tensile properties, shear strength, impact strength, Rockwell hardness, change in weight, specific gravity, water absorption, light transmission and haze, volume resistivity, dielectric strength, and arc resistance.

Certain mineral-filled phenolics and styrene polymers withstood a dose of 10^{19} nvt with little change in properties. Cellulosic, casein, acrylic, and chlorofluoroethylene plastics decrease 50% in tensile strength at 10^{17} nvt. Plastics of intermediate resistance in order of resistance are: polyvinyl carbazole, aniline formaldehyde, polyethylene, nylon, polyester, organic-filled phenolic, melamine, urea, unfilled phenolics, polyvinyl-vinylidene chloride, and polyvinyl chloride acetate.

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INTRODUCTION

Plastic materials are relatively easily damaged by radiation (1), (2), and normally their use is to be avoided in a high intensity radiation field. However, plastics do find extensive application as containers, insulators, gaskets, shields, etc., and, in order to be able to use these materials in a radiation field, it is important to know the extent and type of damage to be expected. It is the primary purpose of this investigation to establish engineering data to guide the designer in selecting a plastic for a specific service. Changes in physical properties with radiation dosage have been determined for all of the commonly used types of commercial plastics.

The data presented are for pile radiation. Though one may roughly estimate the damage to be expected from neutrons, gammas, and other kinds of radiation from the pile data, it is planned to correlate more exactly the effect of gammas and neutrons by additional irradiations, both with pile radiation from which the thermal neutrons have been screened with cadmium, and with a pure gamma or beta-gamma source.

In addition to isolating the damage caused by neutrons and gammas, present plans include study of the following effects:

(1) Intensity of radiation.
(2) Presence of oxygen during irradiation.
(3) Addition of antioxidants to the material.
(4) Time of aging after irradiation.

A supplement to this report will be issued to cover this work.

DISCUSSION

A. Radiation Exposure

The accumulated radiation dose is given in terms of thermal neutron flux times the irradiation time (nvt). Only a very small part of the damage is done by thermal neutrons, however, since the fast neutron flux and the gamma flux are directly proportional to the thermal flux, the thermal nvt is a measure of the total amount of all the radiation which has penetrated the sample.

The neutron flux spectrum and the fast and epithermal flux were determined for the position in the pile where the specimens were irradiated(3). It was found that the fast spectrum was not much different from the fission spectrum. The flux above one Mev was determined to be 4% of the thermal flux. The epithermal flux was determined to be 60% of thermal flux. The gamma energy absorbed by materials in the ORNL reactor was determined by Richardson(4) from calorimetric measurements. Taking the average gamma energy as one Mev, the energy absorbed from gammas corresponds to a gamma flux of about 50% of thermal flux. At 10^{12} thermal flux this is equivalent to about 10^{6} roentgens/hr.

B. Summary of Results

Tests were conducted on thirty-three plastic materials to determine changes in physical properties when subjected to pile radiation. Detailed results of these tests are given in graphs and tables on pages 28 to 188 and the photographs on pages 189 to 196 along with the composition and

history of each material. Data are presented for the following properties:

Stress-strain curves
Tensile strength
Elastic modulus
Percent elongation
Impact strength
Shear strength
Rockwell hardness: R scale and α scale
Change in weight
Specific gravity
Water absorption
Light transmission and haze
Volume resistivity
Dielectric strength
Arc resistance

For the second through the sixth of the properties listed, the percent of the initial value is plotted. The initial values of these properties for non-irradiated specimens are given below the graph for each material.

It must be kept in mind that these values will often vary from batch to batch for plastic materials. For some materials the properties deviate widely for specimens cut from the same sheet of material. For zero irradiation, the figures given are an average of several specimens. For the irradiated materials, it was not practical to test a large number of specimens because of limited space in the pile. In most cases each point on the curve, with the exception of zero irradiation, represents one specimen. For this reason many of the points do not lie exactly on the average curve drawn through the points.

For discussion purposes, the plastics are classified into twelve groups according to order of radiation resistance (Table I). In the following discussion an attempt is made to correlate radiation resistance with chemical structure as a guide to the behavior of materials of similar chemical structure to those tested. The comparison is made in part by comparing each material to polyethylene which has a hydrocarbon-chain structure ($-CH_2-CH_2-$). Other plastics are regarded as having the polyethylene structure but with substitutions to give their structural formulae(5) as listed on pages 28 to 188. The effect of the substituents on radiation resistance is noted by comparison of the changes produced by radiation in other plastics to the changes produced by radiation in polyethylene. The comparison cannot be an exact one, however, since other plastics may have properties initially widely different from those of polyethylene.

It is not intended that Table I be used as a guide for selecting a plastic for a specific service since not enough information is included here. For example, in Table I polystyrene is ranked above polyethylene since the properties of polyethylene change under irradiation while the properties of polystyrene remain unchanged for periods of exposure up to 10^{19} nvt. The initial impact strength of polyethylene, however, is greater than the initial impact strength of polystyrene. It may be seen from Figure 11B that only after a period of irradiation greater than 10^{18} nvt does the impact strength of polyethylene decrease to as low a value as the impact strength of polystyrene.

For applications requiring high impact strength, therefore, polyethylene is superior for periods of exposure less than 10^{18} nvt. For similar selections of plastics for a specific service the graphs of the properties on pages 28 to 188 should be consulted.

TABLE I

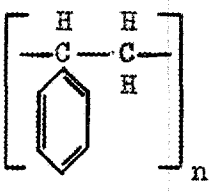
Radiation Resistance of Plastics

	Plastics	Exposure 10^{18} nvt	Change in Properties
1.	Mineral-filled furan and mineral-filled phenolics: Duralon, Haveg 41, asbestos-fiber Bakelite, asbestos-fabric Bakelite, and Karbate	10	Little change except for darkening in color.
2.	Styrene polymers: Amphenol and Styron 411C	10	Little change except for darkening in color.
3.	Modified styrene polymer: Styron 475	10	Impact strength and elongation decrease until the same as unmodified styrene polymers.
4.	Aniline formaldehyde (Cibanite) and polyvinyl carbazole (Polectron)	10	Tensile strength decreases a little.
5.	Polyethylene and Nylon	10	Impact strength decreases but tensile strength increases. These plastics become so brittle that the corners of the specimens chip off.
6.	Mineral-filled polyester: Plaskon Alkyd	10	Tensile strength and impact strength are decreased about 50%.
7.	Unfilled polyesters: Selectron 5038 and CR-39	5	Develop small cracks. Tensile strength and impact strength decrease.
8.	Phenolics with cellulosic fillers: paper-base Bakelite linen-fabric Bakelite, and Micarta	3	Become brittle, swell, and decrease in tensile and impact strength.
9.	Melamine and urea: Melmac, Bettle, Plaskon urea, and Plaskon Melamine	2	Tensile strength and impact strength are decreased about 50%.
10.	Unfilled phenolic: Catalin	1	Tensile strength and impact strength are decreased about 50%.

TABLE I (Cont'd)

	Plastics	Exposure 10^{18} nvt	Change in Properties
11.	Vinylidene chloride (Saran B-115) and vinyl chloride acetate (Vinylite)	0.5	Soften, blacken, evolve HCl, and decrease in tensile strength.
12.	Casein (Ameroid), methyl methacrylate (Lucite), Teflon, Fluorothene, and the cellulosics: Cellulose nitrate (Pyralin), cellulose acetate (Plastacele), cellulose acetate butyrate (Tenite II), cellulose propionate (Forticel), and ethyl cellulose (Ethocel R-2)	0.1	Tensile strength and impact strength are decreased about 50%.

To the plastics of group one of Table I, the mineral filler evidently imparts resistance since unfilled phenolic is much less resistant. In group two the resistance is attributed to the stability of the phenyl group.[6] The structure of group two plastics is like polyethylene except for substituted phenyl groups

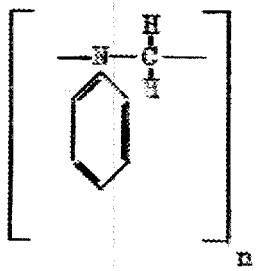


Polystyrene

All of the plastics in the first two groups are hard and have low impact strength except for asbestos-fabric laminate which has moderately high impact strength. The only pronounced change in plastics of the first two groups is darkening in color.

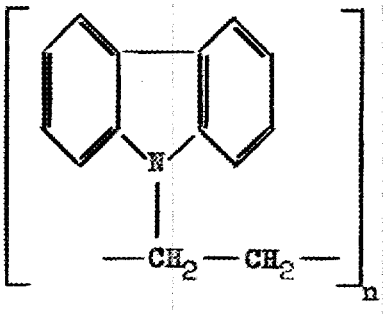
Sytron 475 (Group 3) is a styrene polymer which is modified to give increased impact strength and elongation. The higher values for these properties decrease rapidly until they become about the same as those of unmodified polystyrene. No further change in properties then occurs. Evidently the modifying agent is damaged and not the polystyrene.

There is a small decrease in the tensile strength of analine-formaldehyde plastic (Group 4) which is like polystyrene except that a nitrogen atom replaces the carbon atom to which the phenyl group is attached



Aniline-formaldehyde resin

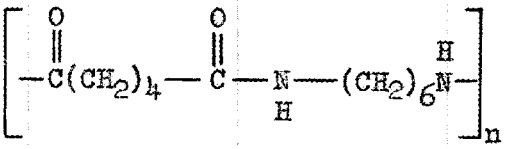
Polyvinyl carbazole has carbazole groups substituted for some of the hydrogen of the hydrocarbon chain



Polyvinyl carbazole

The polyvinyl carbazole is so brittle that the tensile strength of individual specimens deviates widely; however, no change upon irradiation is observed within this deviation.

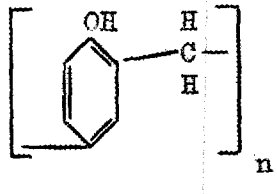
Group five plastics become brittle but show increased tensile strength and elastic modulus. Specimens with the longest irradiation periods used were brittle enough to indicate that they would probably fall apart with much greater periods of exposure. Polyethylene retains a high value of impact strength longer than Nylon. In Nylon amide linkages replace some of the methylene of the hydrocarbon chain



Nylon

Plastics in groups six through ten all are characterized by cross-linkages between chains. Mineral-filled Plaskon Alkyd polyester is more resistant than the unfilled polyester, but is not as resistant as mineral-filled phenolic, probably because the proportion of filler to resin is less. CR-39 polyester, which is very hard to begin with, softens at first and then hardens again, finally becoming filled with small cracks. Selectron polyester, which is very soft to begin with, hardens and also develops cracks.

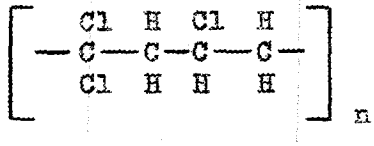
Plastics in groups eight and nine are filled with cellulosic materials. Group eight plastics, which are all laminates, become brittle, blister, swell, and decrease greatly in tensile and impact strength, but do not crumble completely for the maximum period of exposure given. Group nine plastics, which are filled with cellulose pulp, crumble. Unfilled Catalin phenolic also crumbles. Phenolic resins have benzene groups as part of the main chains rather than attached to carbon atoms of the chain as is the case with polystyrene.



Phenol-formaldehyde resin

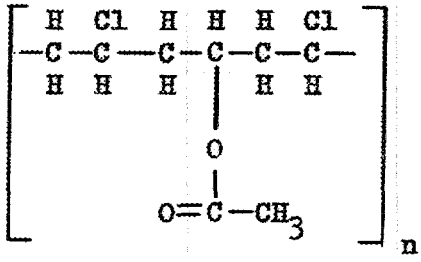
The phenolics that do not have mineral fillers are no more resistant than polyester or urea resins which also have a cross-linked structure.

Group eleven plastics evolve HCl and turn black. Polyvinyl-vinylidene chloride is a partially halogenated hydrocarbon chain.



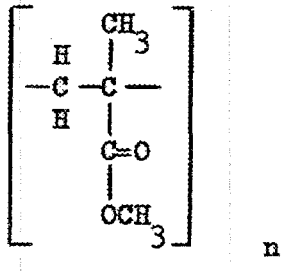
Polyvinyl-vinylidene chloride (Saran)

Polyvinyl chloride acetate is somewhat similar but also has branching acetyl groups.



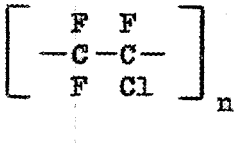
Polyvinyl chloride acetate
(vinylite)

Group twelve plastics show the poorest radiation resistance of all. This group includes all of the cellulose materials and casein, which have complex structures, but also includes the simpler structures of methyl methacrylate and the halogenated polyethylenes. Methyl methacrylate has a hydrocarbon chain structure but with branching methyl and methyl ester groups.

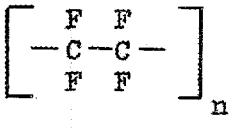


Polymethyl methacrylate

The poor resistance of polymethyl methacrylate as compared to polyethylene would seem to indicate less resistance for structures with branching alkyl chains. All of the hydrogen in the hydrocarbon chain has been replaced by halogens in the structures of Fluorothene and Teflon.



Polymonochlorotrifluoroethylene (Fluorothene)



Polytetrafluoroethylene (Teflon)

C. Changes Produced

Although the chemical changes were not studied, it appears likely that damage in all cases is due to a degradation of the molecular structure. This breakdown is accompanied by changes in mechanical properties which usually occur by one of the following processes:

(1) Elastic modulus, Rockwell hardness, tensile strength, and shear strength increase, but impact strength and elongation decrease (for some brittle plastics this first phase does not occur). Then the plastic becomes so brittle that the tensile strength decreases and shortly the shear strength decreases. At about the same time the plastic cracks when the major load (see page 209) is applied in the Rockwell hardness test. Finally all strength is lost and the plastic crumbles apart. This type of failure occurs with Selectron 5038, plastics in group eight-ten, and all plastics in group twelve except Teflon. Group five plastics start out by this process, but the tensile strength has not yet decreased for the maximum period of exposure given.

(2) Elastic modulus, Rockwell hardness, tensile strength, and shear strength decrease, but impact strength and elongation increase. Group eleven plastics follow this process. Long periods of exposure were not given group eleven plastics since HCl is evolved.

Plaskon Alkyd does not follow either process but all properties drop off gradually. CR-39 polyester starts off by process 2 but eventually a point is reached where the elastic modulus and the hardness increase and the elongation decreases though tensile strength and shear strength continue to decrease. Teflon at first increases in impact strength; decreases in tensile strength, shear strength, and elongation; and remains unchanged in elastic modulus. Later the impact strength decreases and elastic modulus and hardness increase; however, tensile strength and shear strength continue to decrease until the plastic crumbles apart.

For most plastics a sudden increase in the rate of loss in weight coincides with mechanical deterioration since pieces of the specimen are chipped off. Plastics that show a steady loss of weight and decrease in density, probably due to evolution of gaseous decomposition products,are Catalin unfilled phenolic and CR-39 polyester. Vinyl chloride acetate and Saran B-115 evolve liquid decomposition products. Plastics that show a steady increase in weight and specific gravity, probably because of absorption of oxygen or water vapor, are Nylon and polystyrene. A decrease in specific gravity but no change in weight indicates blistering or swelling. Plastics that blister and swell are unfilled phenolic, organic-filled phenolics, melamine, urea, and Plaskon Alkyd polyester. Plastics that shrink, as is indicated by an increase in specific gravity but no change in weight, are Teflon and polyethylene.

As a rule no pronounced change occurs in volume resistivity, dielectric strength, or arc resistance until the mechanical properties deteriorate completely. Plastics in group eleven of Table I are an exception since the volume resistivity, dielectric strength, and arc resistance decrease when the plastics become wet with HCl, a decomposition product. Another exception is Selectron 5038 which increases in electrical resistance as it hardens.

All of the transparent or translucent plastics tested, which have not crumbled after 10^{18} nvt, become very dark as shown by decreased values of light transmission. Color changes are listed on pages 28 to 188.

A few of the sample tubes developed water leaks. It was observed that Nylon, CR-39 polyester, and organic-filled phenolics show greater changes under the combined effect of exposure to water and radiation than under exposure to radiation alone. This is in accord with the high water absorption values obtained for irradiated specimens of these plastics.

D. Theory of the Effect of Ionization on Materials

The theory of the effect of ionization on materials (discussed by A. O. Allen[7]) does not predict the amount of damage as evidenced by change in physical properties. The theory is perhaps most useful, from a physical damage standpoint, in that, with a knowledge of the damage which occurs with one type of radiation, it permits an estimate of the damage to be expected from other types of radiation.

Radiation may be classed as light particle (beta and gamma) or heavy particle (neutrons)[7]. With both types most of the absorption of energy in materials occurs by ionization or electron excitation processes; however, for heavy particle radiation there is an additional process, elastic collisions with atoms. In plastics, damage due to the initial displacement of atoms by elastic collision with heavy particles, is masked by damage due to ionization and excitation processes. However, much of the ionization is caused by fast moving hydrogen ions (protons) ejected by elastic collision with fast neutrons. In metals, the displacement of atoms directly by elastic collision is the only important source of damage since, except for the evolution of heat, metals are unchanged by the ionization process.

Ionic compounds are colored by ionizing radiations. When electrons are ejected from ions that make up the lattice, most of the electrons recombine to form the normal ions of the lattice, but a few of the free electrons are trapped at imperfections in the lattice with the resulting formations of "F centers" and development of color in the material. This coloration has little effect on the general properties.

Organic materials are held together by covalent bonds with bonding energy of the order of four to five electron volts. The energy required to produce ionization is of the order of 15 electron volts. Consequently when an organic

molecule is ionized by radiation and subsequently neutralized, it is given enough energy to break bonds. About four molecules of organic liquids react for each 100 ev of energy input within a factor of less than 10. Radiation effects in organic solids are not as well known. Presumably the number of molecules reacting will be less since there is more constraint on the motion of ruptured molecules and the chance of recombination will be greater(7).

Assuming that the reaction is not too different for plastics than for organic liquids, one may estimate the number of bonds broken for a specified pile exposure. The simple structure of polyethylene, $(CH_2)_n$, is taken as an example. The energy absorbed from fast neutrons and from gamma radiation is reported in(4) for the ORNL reactor at 3,500 kilowatts at 0.764% of maximum flux. The energy absorbed by the CH_2 groups is calculated below.

Material	γ Energy Cal/mole sec	n-Scattering Energy Cal/mole sec	Total Energy Cal/mole sec
C	0.00444	0.00101	0.00545
2 x H	0.00148	0.01345	0.01493
CH_2	0.00592	0.01446	0.02038

Of the total, 71% comes from the scattering of fast neutrons; 29% from gamma radiation. For materials with less hydrogen in proportion to carbon than the CH_2 group, the fast neutron percentage will be reduced.

The total energy absorbed may be expressed as equivalent roentgens, r. One r gives one esu of charge per cubic cm of air at N.T.P. This is equivalent to about 800 esu per gram of matter, and corresponds to an expenditure of about

$$800 \times 32/(4.8 \times 10^{-10}) = 5.3 \times 10^{13} \text{ electron volts/gram}$$

For the CH_2 group, the total energy absorbed in the ORNL Reactor per unit dose, in nvt, is

$$\frac{(0.0204 \text{ cal/gm mole sec})}{(14 \text{ gm/gm mole})(0.764 \times 0.97 \times 10^{12} \text{ neutrons/sq. cm. sec.})}$$

$$\times \frac{1 \text{ r}}{5.3 \times 10^{13} \text{ electron volts/gram} \times 3.82 \times 10^{-20} \text{ cal/ev}}$$

$$= 1.0 \times 10^{-9} \text{ r/(nvt)}$$

$$\text{or } 1.0 \times 10^{9} \text{ r/}(10^{18} \text{ nvt})$$

The approximations are made that equal weight of the CH_2 group and air have the same absorption for gamma radiation and that energy absorbed from fast neutrons and energy absorbed from gamma radiation are equally effective in producing ionization.

If the number of bonds of a long hydrocarbon chain are divided by the number of carbon atoms there results three bonds per CH_2 group. This makes $3 \times 6 \times 10^{23} = 18 \times 10^{23}$ bonds/gm mole. At the rate of 25 electron volts/bond the dose equivalent to energy to break all the bonds is

$$\frac{25 \text{ electron volts/bond} \times 18 \times 10^{23} \text{ bonds/14 grams}}{5.3 \times 10^{13} \text{ electron volts/r gram} \times 1.0 \times 10^{9} \text{ r/}(10^{18} \text{ nvt})}$$

$$= 60 \times 10^{18} \text{ nvt}$$

Plastics in groups one and two of Table I withstood 16% of this exposure without change in properties; the plastics in group twelve crumbled at 0.6% of this exposure.

EXPERIMENTAL

A. Irradiation

Exposures were conducted in Hole 19 of the ORNL Reactor. Hole 19 is a water-cooled hole, and the neutrons entering the specimen cans in this hole are attenuated by 3/16 inches of water and 1/8 inches of aluminum in addition to the graphite surrounding the hole. The water temperature was maintained between 25 and 40°C. Hole 19 is perpendicular to the fuel channels, and midway between two rows of fuel channels.

The radiation exposure was measured in terms of C neutrons (neutrons of energy below the cadmium cut off) by the activation of cobalt foils. Cobalt is ideally suited for this purpose because Co^{60} has a long life and the cross section for its activation is high. (5.3 year half-life, cross section of 33 barns[8]. The foils were prepared as described in[9]. Since cadmium difference measurements reported in[8] give nearly the same value for the cadmium ratio at the center of the pile and at the large penumatic tube terminal, and since the flux values for positions in Hole 19 lie between the values for the above two positions, cadmium difference measurements were not taken. A corrected cross section of 39 barns was determined for the bare foils by calibration at the pneumatic tube terminal where the C neutron flux was taken as the value reported in[8]. The average flux, nv, was calculated from this cross section value, the activity induced in the foils, and the exposure time.

Certain individual foils which were irradiated in various positions throughout the plastic test specimens gave values of flux lower than the average value for several foils exposed at the same time. Probably local variations in the flux resulted from neutron absorption by the plastic specimens. To obtain the values of nvt used in reporting the properties of the irradiated plastics, a correlation was made between the average value of nvt as determined from several foils and the kilowatt hours of exposure.

B. Testing Procedure

Test specimens were conditioned for seven days at 25 ± 1°C and 50 ± 2% humidity. Specimens of some plastics in storage under these conditions changed appreciably in properties after a few months period. When plastics underwent such an aging change, either a correction was made for it or all irradiated specimens were tested within a short time of one another.

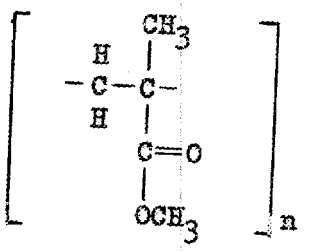
The testing procedures followed are listed in the appendix. They are based on standard ASTM or Federal Specification tests. Changes were made in certain instances to facilitate handling. The overall length of tensile specimens was shortened to increase the number of specimens that would fit into the irradiation space; half of a broken impact specimen was used for the water absorption test in place of a standard water absorption specimen; and the volume resistivity electrodes were made small enough to accomodate the shear strength test specimens.

The plastics were irradiated in an atmosphere of air. A cursory investigation showed no increased damage due to the presence of pure oxygen for a few materials tested. The effect of oxygen will be studied in more detail, however, as will the effect of the conditioning period after irradiation. Some irradiated specimens, that were allowed to age for two months in place of the standard seven days, did show continued change in the same manner as the properties changed during irradiation, but at a much slower rate.

RESULTS

LUCITE

Classification:	Acrylic
Trade name:	Lucite
Company:	E. I. du Pont de Nemours and Company, Inc.
Resin:	Methyl methacrylate polymer
Formula:	



Filler:	None
Description:	Clear - yellows upon irradiation
Thickness of sheets:	0.131 - 0.133 in.
Speed of tensile testing	
Mean rate of straining:	$0.7 - 1.4 \times 10^{-4}$ units/sec.
Mean rate of stressing:	30 - 50 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11060

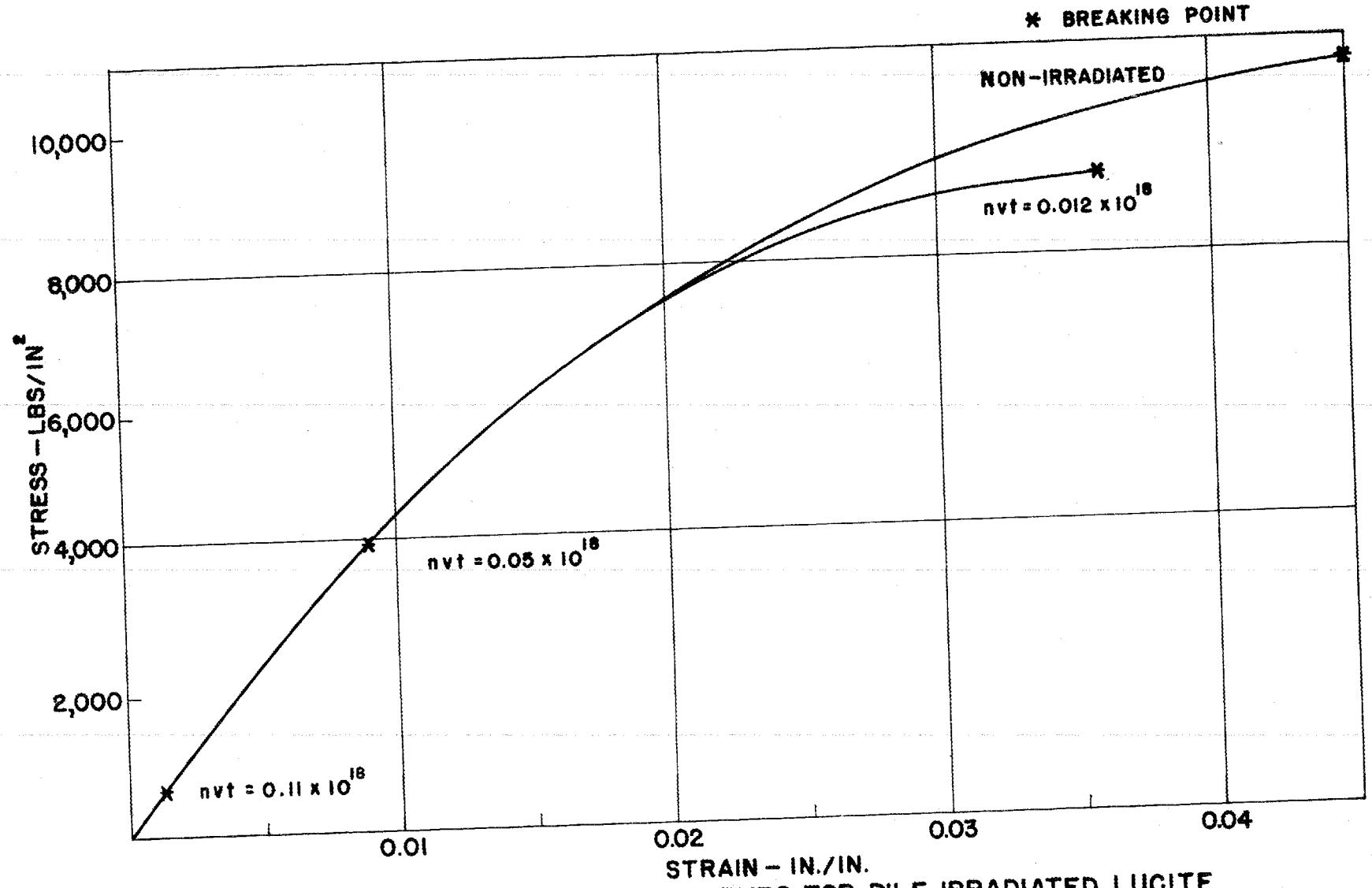
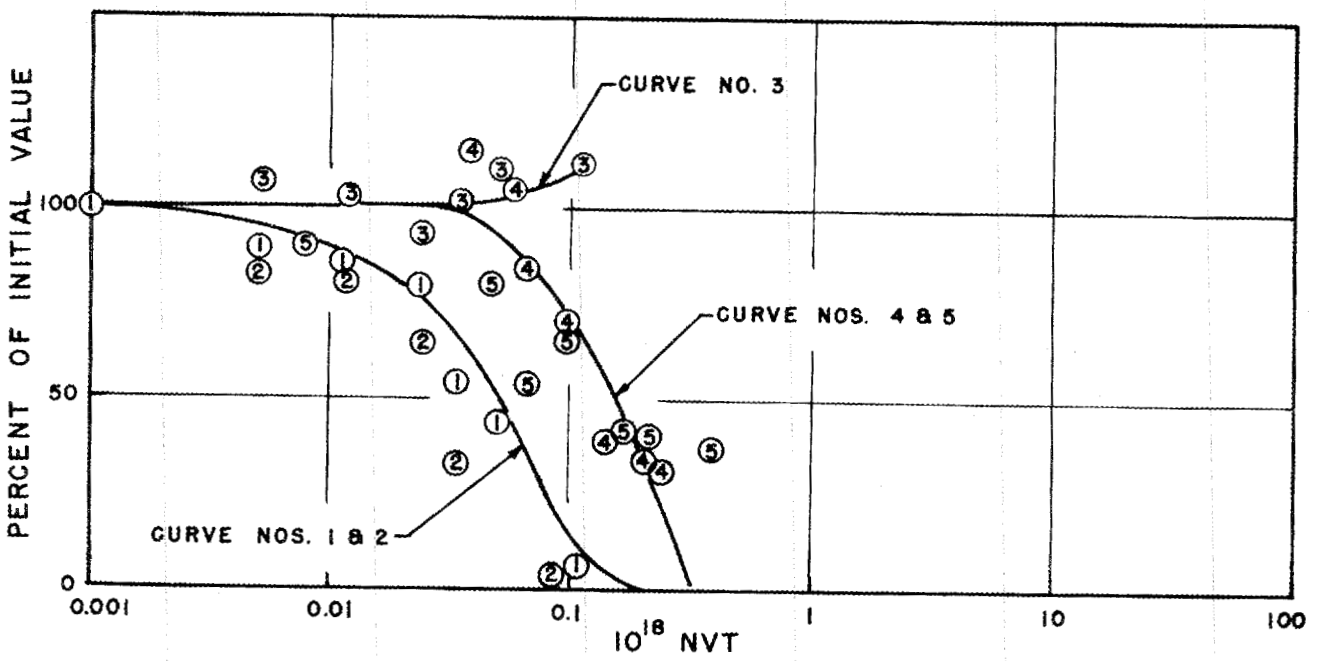


FIGURE 1 A STRESS STRAIN CURVES FOR PILE IRRADIATED LUCITE (METHYL METHACRYLATE)

UNCLASSIFIED
DWG.#11061



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	10,700 LBS./SQ. IN.
2	ELONGATION	4.5 %
3	ELASTIC MODULUS	4.8×10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	6,700 LBS./SQ. IN.
5	IMPACT STRENGTH	0.37 FT. LBS./IN. OF NOTCH

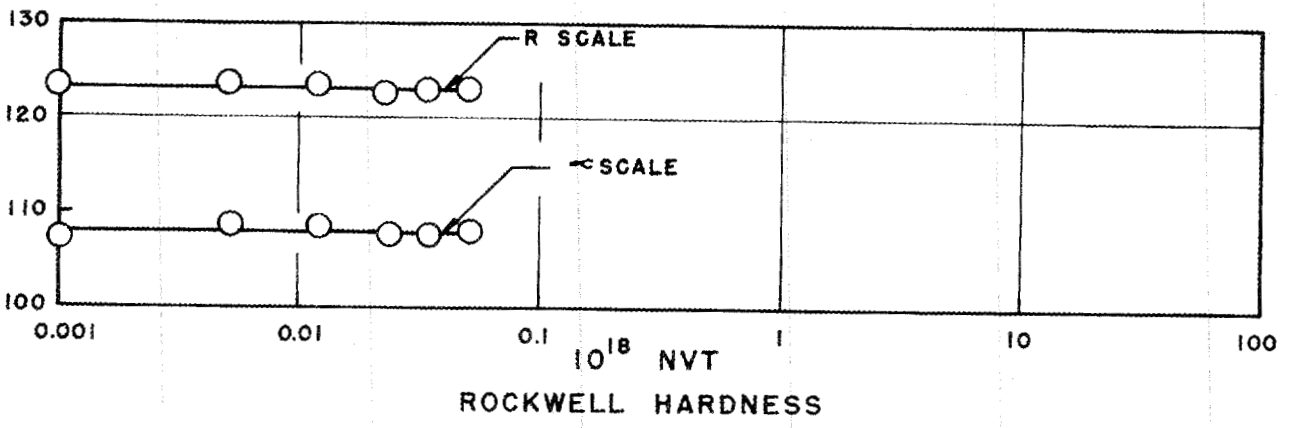
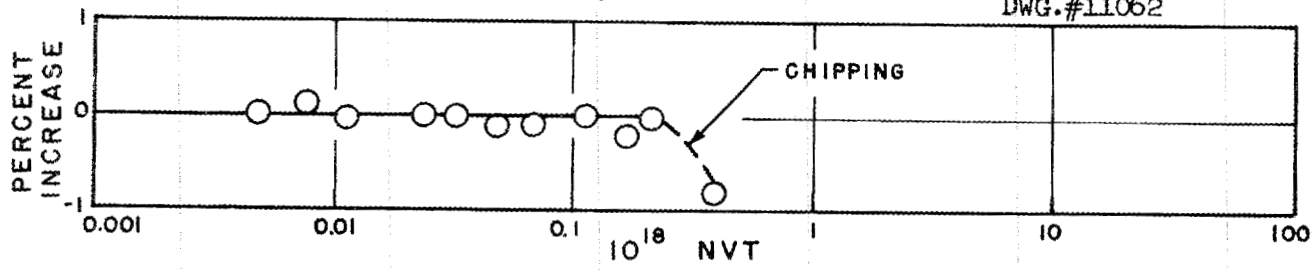
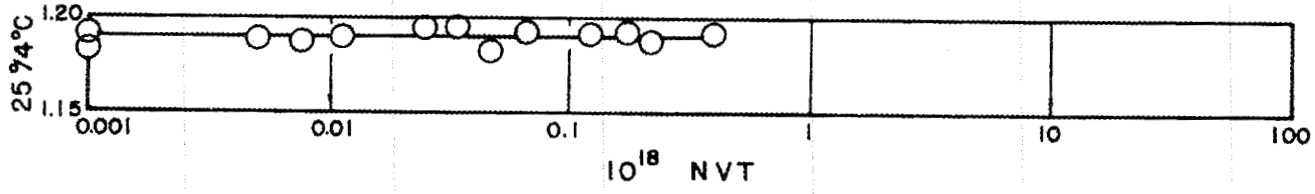


FIGURE 1B METHYL METHACRYLATE

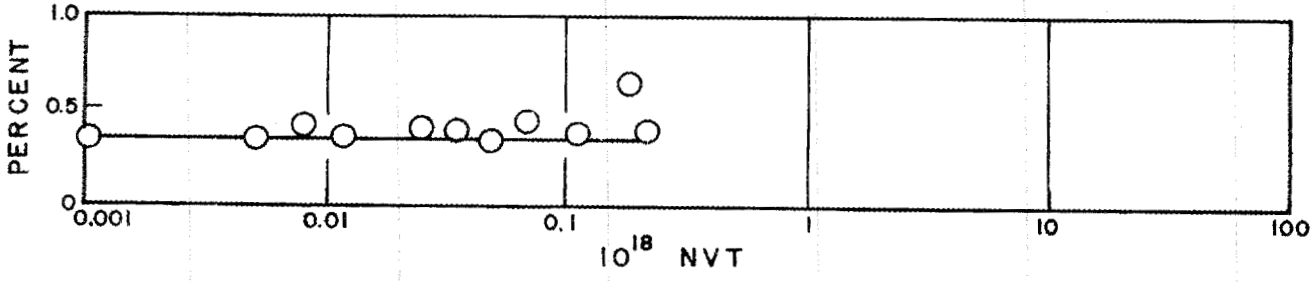
UNCLASSIFIED
DWG.#11062



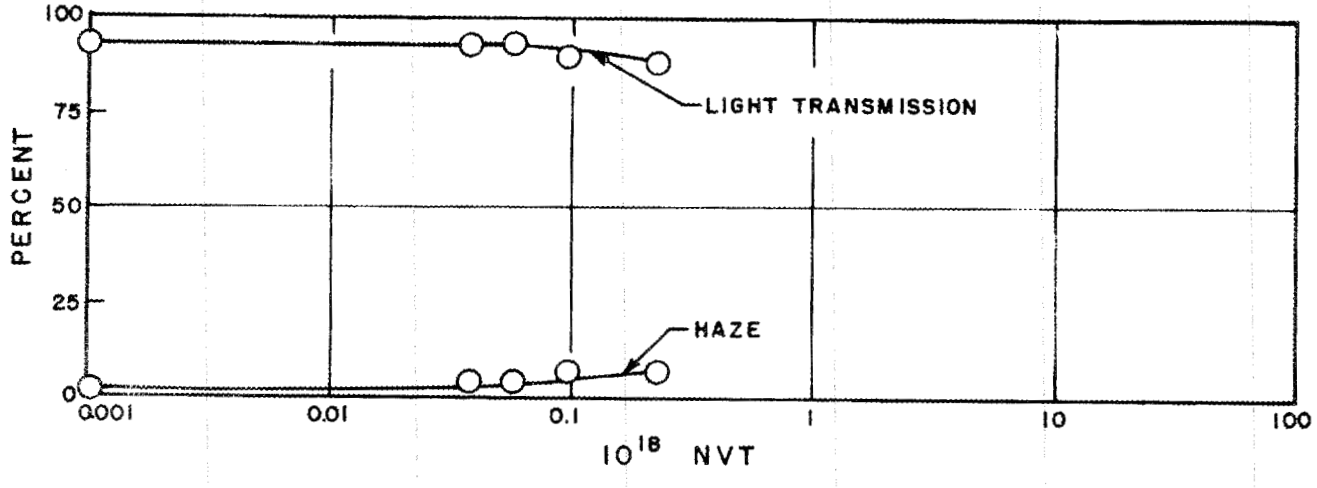
CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION



LIGHT TRANSMISSION AND HAZE

FIGURE 1C METHYL METHACRYLATE

UNCLASSIFIED
DWG.#11063

LUCITE

Volume Resistivity of 60 Mil Specimens

10^{18} nvt	ohm cm
0	$> 10^{14}$
0.3	$> 10^{14}$

Dielectric Strength of 21 Mil Specimens

10^{18} nvt	volts/mil
0	1000
0.23	1000

Arc Resistance of 60 Mil Specimens

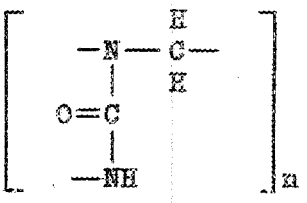
10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	120	Melted
0.15	80	"
0.34	80	"

FIGURE 1 D

BEETLE AND PLASKON UREA

Classification:	Amino resins
Trade names:	Beetle; Plaskon urea
Companies:	American Cyanamid Company; Plaskon Division, Libbey-Owens-Ford Glass Company
Resin:	Urea-formaldehyde

Formula:



Filler:	Cellulose pulp
Description:	Opaque, white - Darkens to tan upon irradiation
Thickness of Beetle:	0.123 - 0.127 in.
Thickness of Plaskon:	0.153 - 0.166 in.
Speed of tensile testing	
Mean Rate of straining:	$0.3 - 0.6 \times 10^{-4}$ units/sec.
Mean Rate of stressing:	40 - 80 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11064

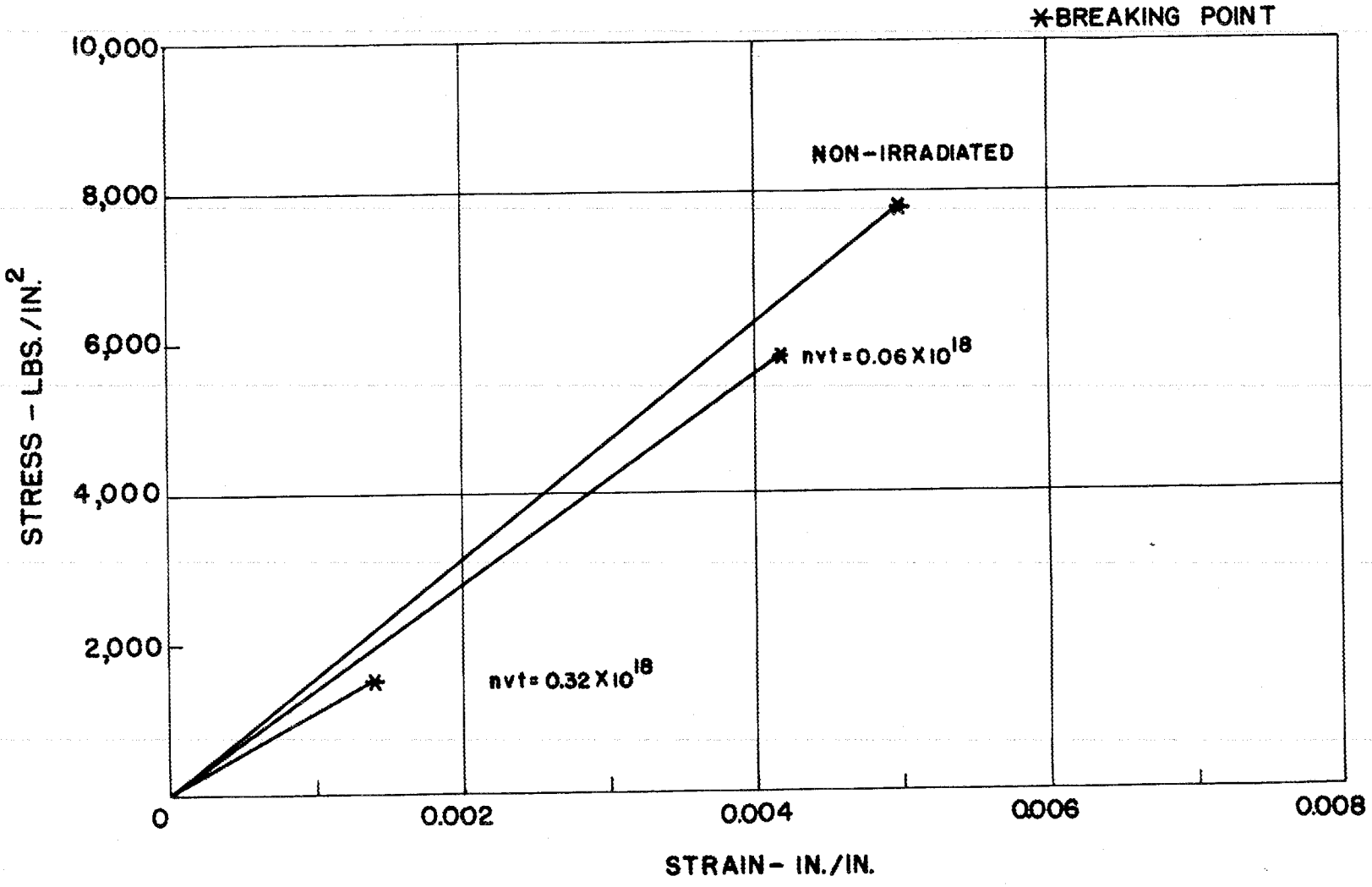
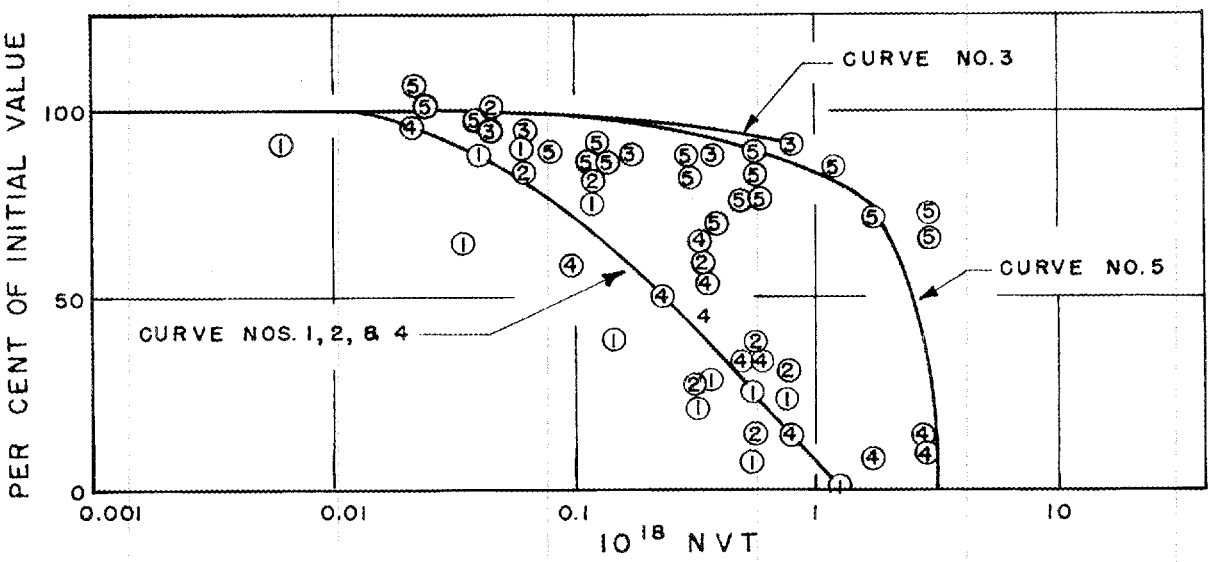


FIGURE 2 A STRESS STRAIN CURVES FOR PILE IRRADIATED UREA FORMALDEHYDE

UNCLASSIFIED
DWG.#11065



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	7,800 LBS./SQ. IN.
2	ELONGATION	0.5 %
3	ELASTIC MODULUS	14 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	10,000 LBS./SQ. IN.
5	IMPACT STRENGTH	0.30 FT. LBS/IN. OF NOTCH

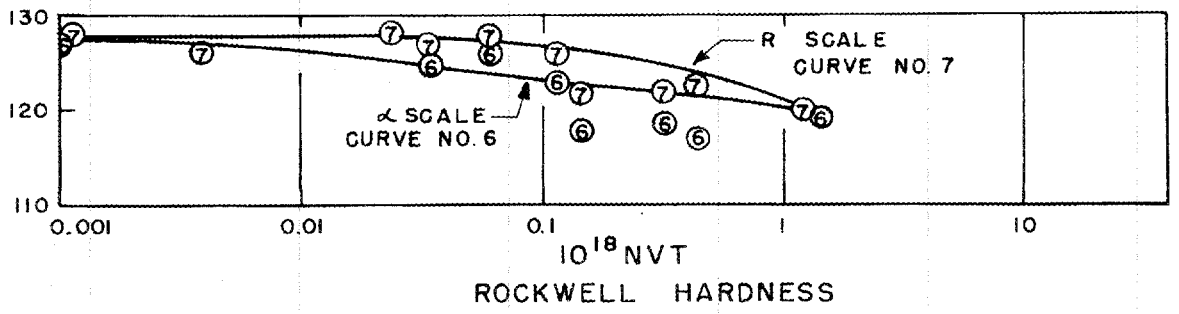
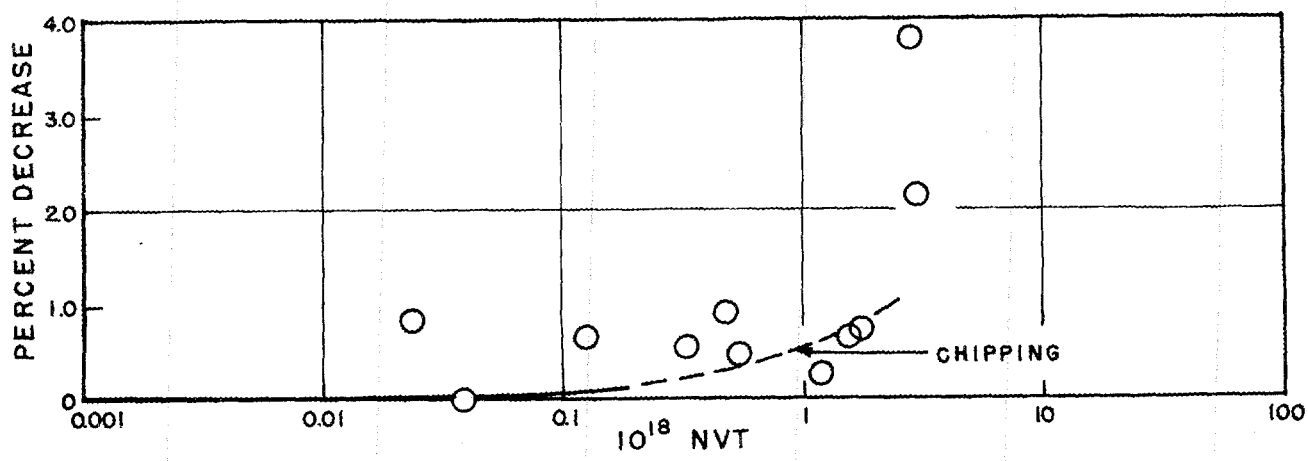
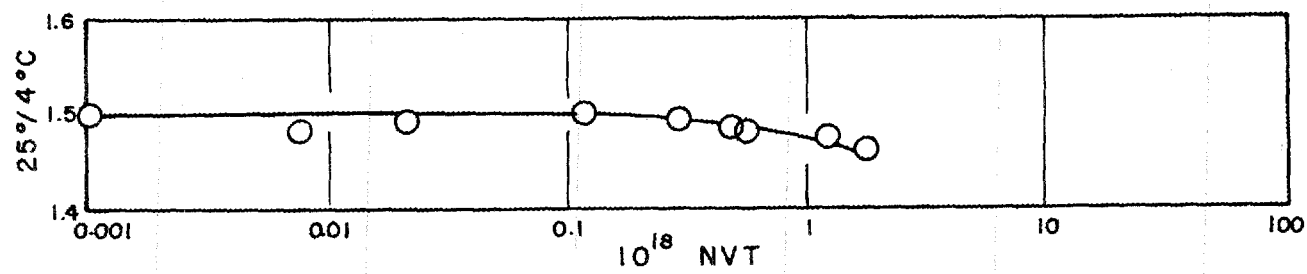


FIGURE 2B UREA FORMALDEHYDE

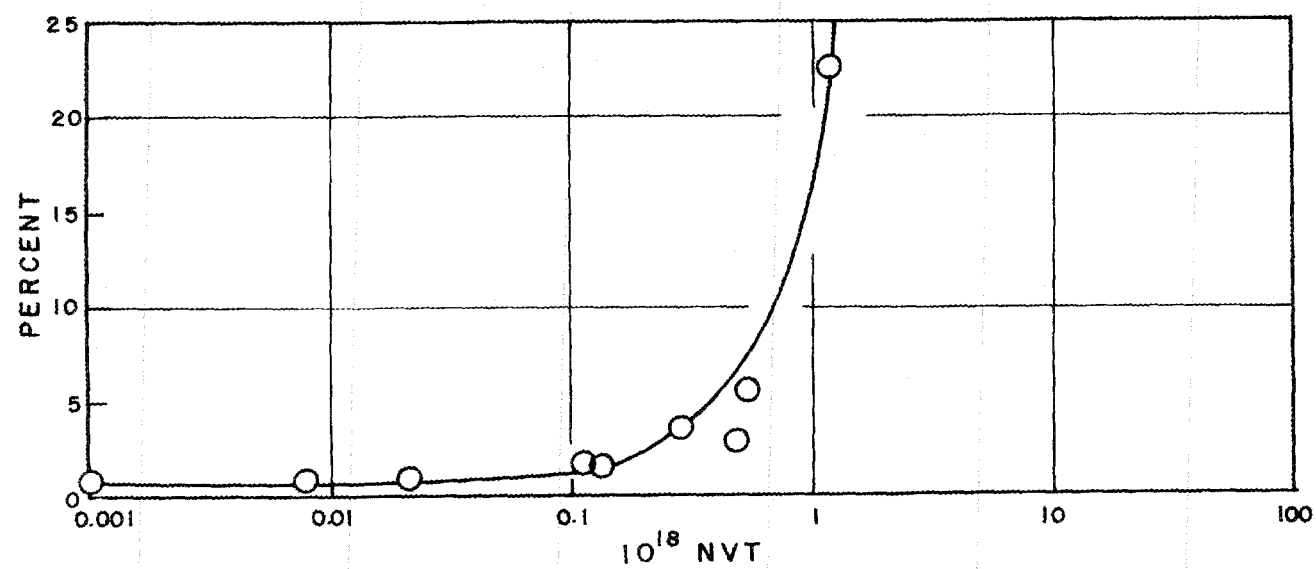
UNCLASSIFIED
DWG.#11066



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 2C UREA FORMALDEHYDE

BEETLE AND PLASKON UREA

Volume Resistivity of 125 Mil Specimens

10^{18} nvt	ohm cm
0	2×10^{13}
3	1×10^{11}

Dielectric Strength of 125 Mil Specimens

10^{18} nvt	volts/mil
0	> 230
1	> 230

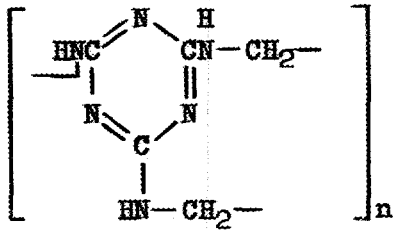
Arc Resistance of 125 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	130	Carbonized
0.23	120	"
0.54	80	"
0.76	60	"
3.0	20	"

FIGURE 2 D

MELMAC AND PLASKON MELAMINE

Classification:	Amino resins
Trade names:	Melmac; Plaskon Melamine
Companies:	Plastics and Resins Division; American Cyanamid Co. Plaskon Division; Libbey-Owens-Ford Glass Co.
Resin:	Melamine-formaldehyde
Formula:	



Filler:	Cellulose pulp
Description:	Opaque, light blue. Darkens to tan upon irradiation
Thickness of Melmac:	0.245 - 0.251 in.
Thickness of Plaskon:	0.137 - 0.179 in.
Speed of tensile testing	
Mean Rate of straining:	$0.1 - 0.6 \times 10^{-4}$ units/sec.
Mean rate of stressing:	30 - 80 lbs/(sq. in) (sec)

UNCLASSIFIED
DWG.#11068

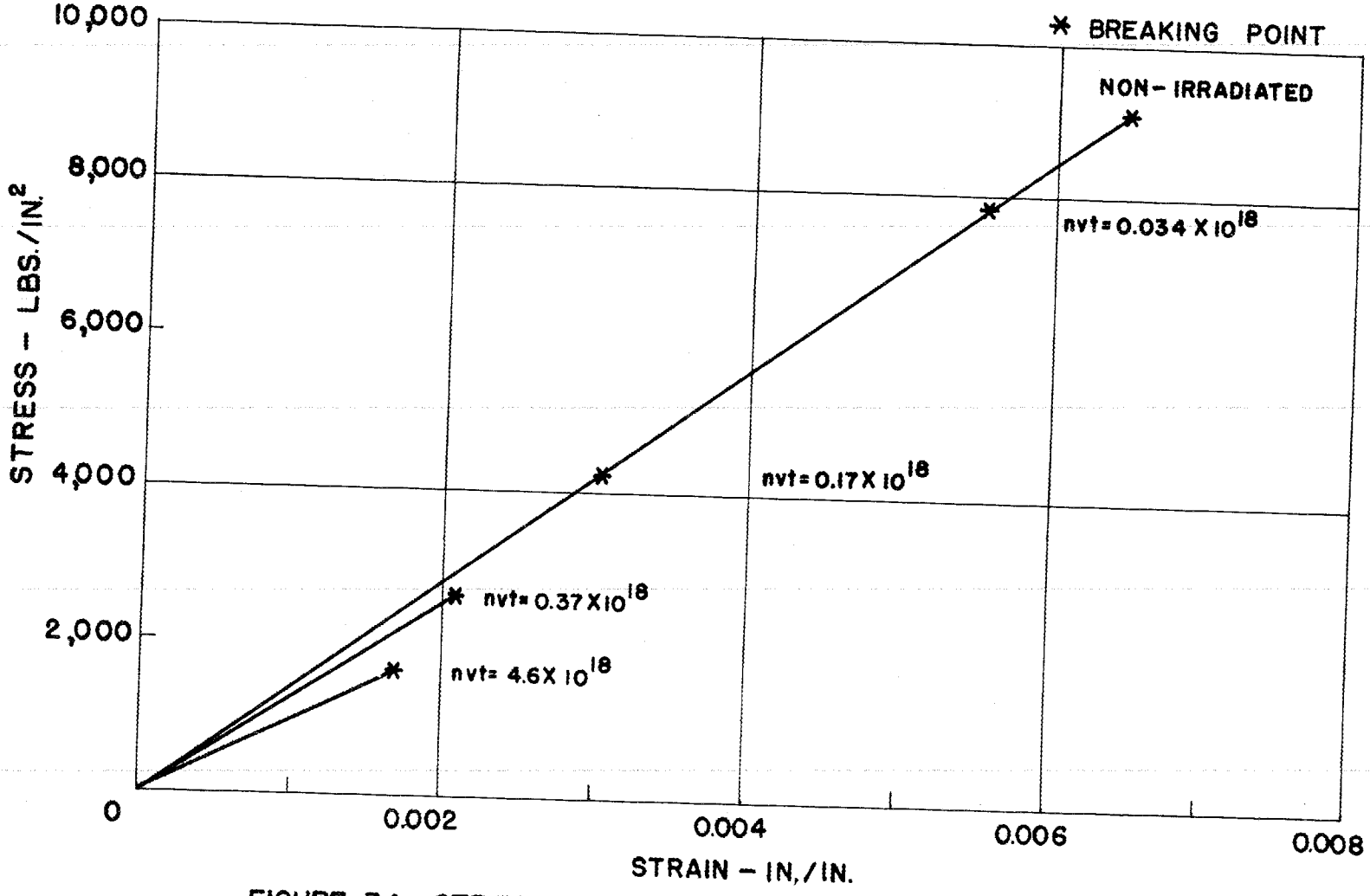
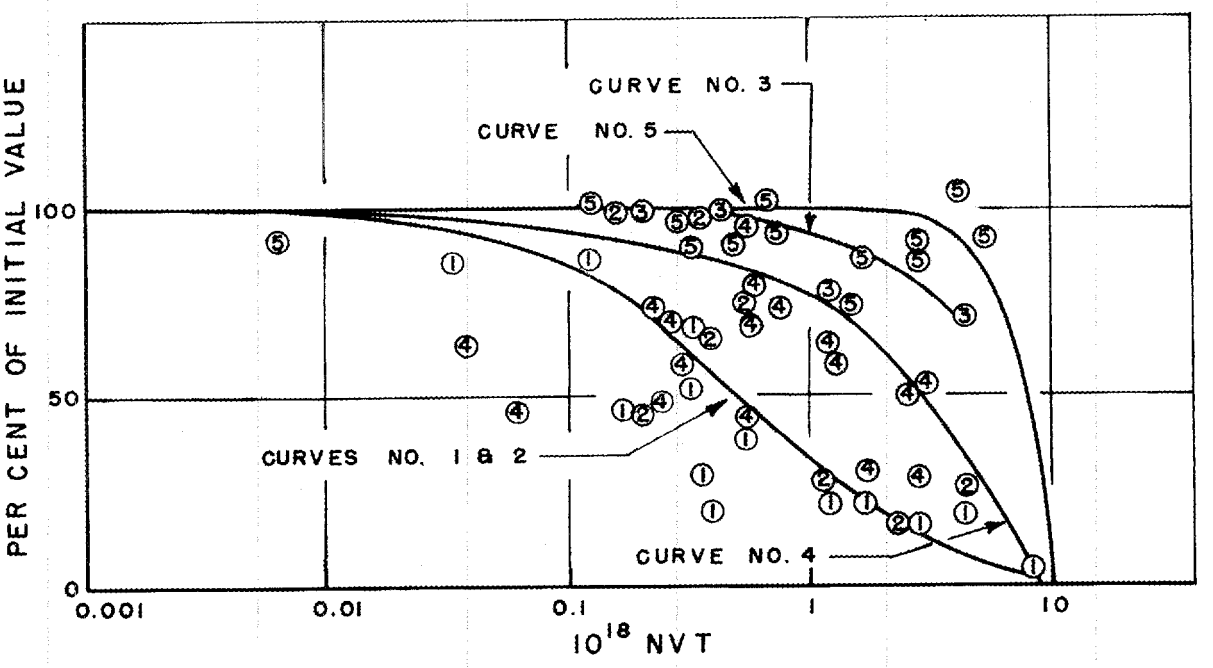


FIGURE 3A STRESS STRAIN CURVES FOR PILE IRRADIATED MELAMINE FORMALDEHYDE

UNCLASSIFIED
DWG.#11069



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	9,100 LBS./SQ. IN.
2	ELONGATION	0.65 %
3	ELASTIC MODULUS	14 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	11,000 LBS./SQ. IN.
5	IMPACT STRENGTH	0.29 FT. LBS./IN. OF NOTCH

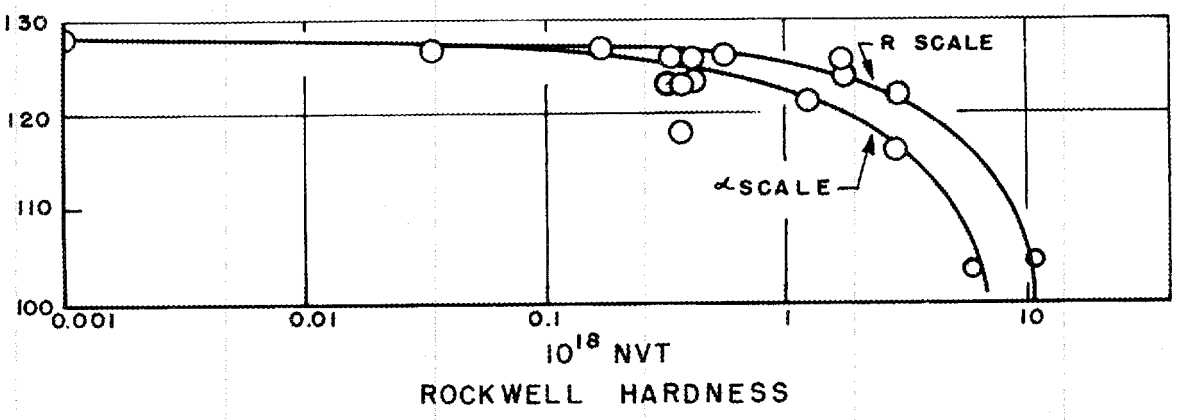
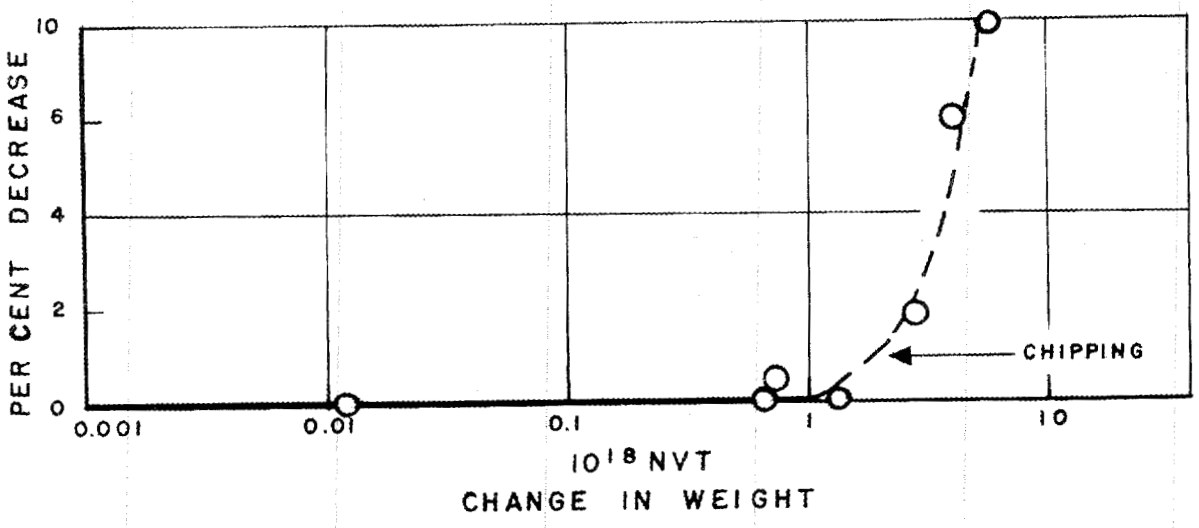
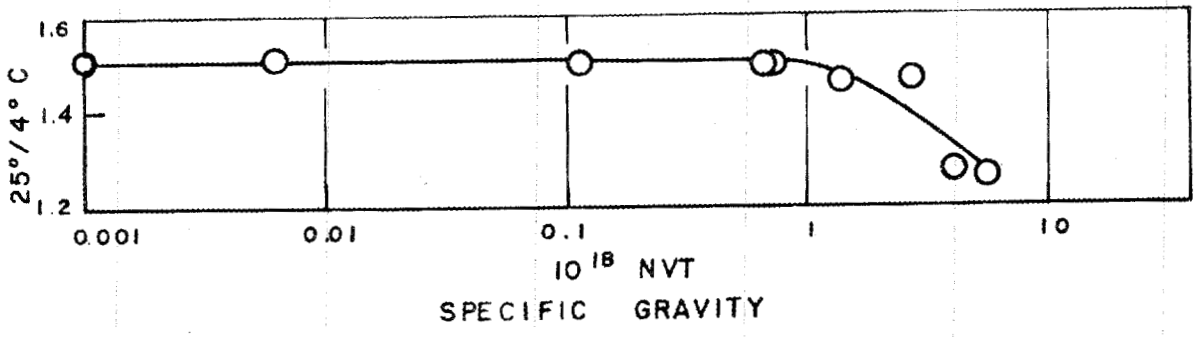


FIGURE 3B MELAMINE FORMALDEHYDE

UNCLASSIFIED
DWG.#11070





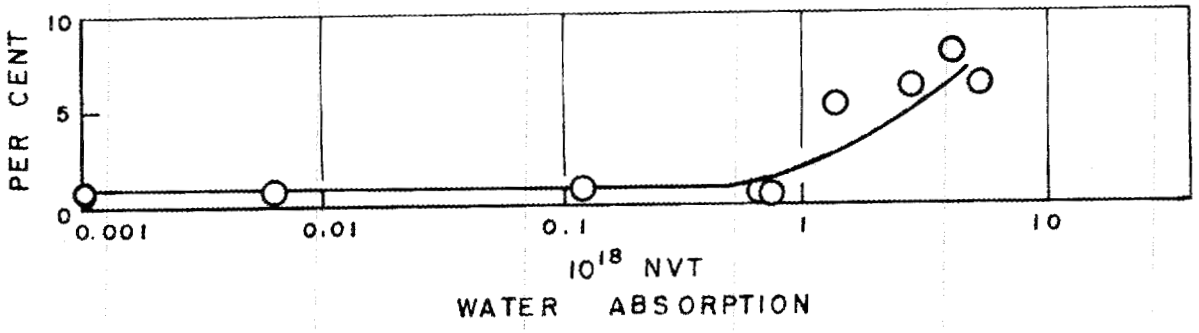


FIGURE 3C MELAMINE FORMALDEHYDE

UNCLASSIFIED
DWG.#11071

MELMAC AND PLASKON MELAMINE

Volume Resistivity of 150-200 Mil Specimens

10^{18} nvt	ohm cm
0	10^{11}
3	10^{11}

Dielectric Strength of 150-200 Mil Specimens

10^{18} nvt	volts/mil
0	> 200
2	> 200

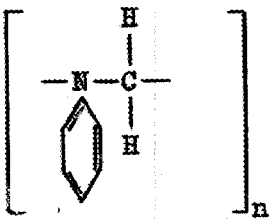
Arc Resistance of 150-200 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	190	Carbonized
0.23	130	"
0.53	120	"
0.66	80	"
3.0	70	"

FIGURE 3 D

CIBANITE

Classification:	Amino resin
Trade name:	Cibanite
Company:	Ciba Company, Inc.
Resin:	Aniline-formaldehyde
Formula:	



Filler:	None
Description:	Opaque, dark brown. No color change upon irradiation
Thickness of Cibanite:	0.181 - 0.228 in.
Speed of tensile testing	
Mean rate of straining:	0.5 - 1.0 x 10^{-4} units/sec.
Mean rate of stressing:	30 - 60 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11072

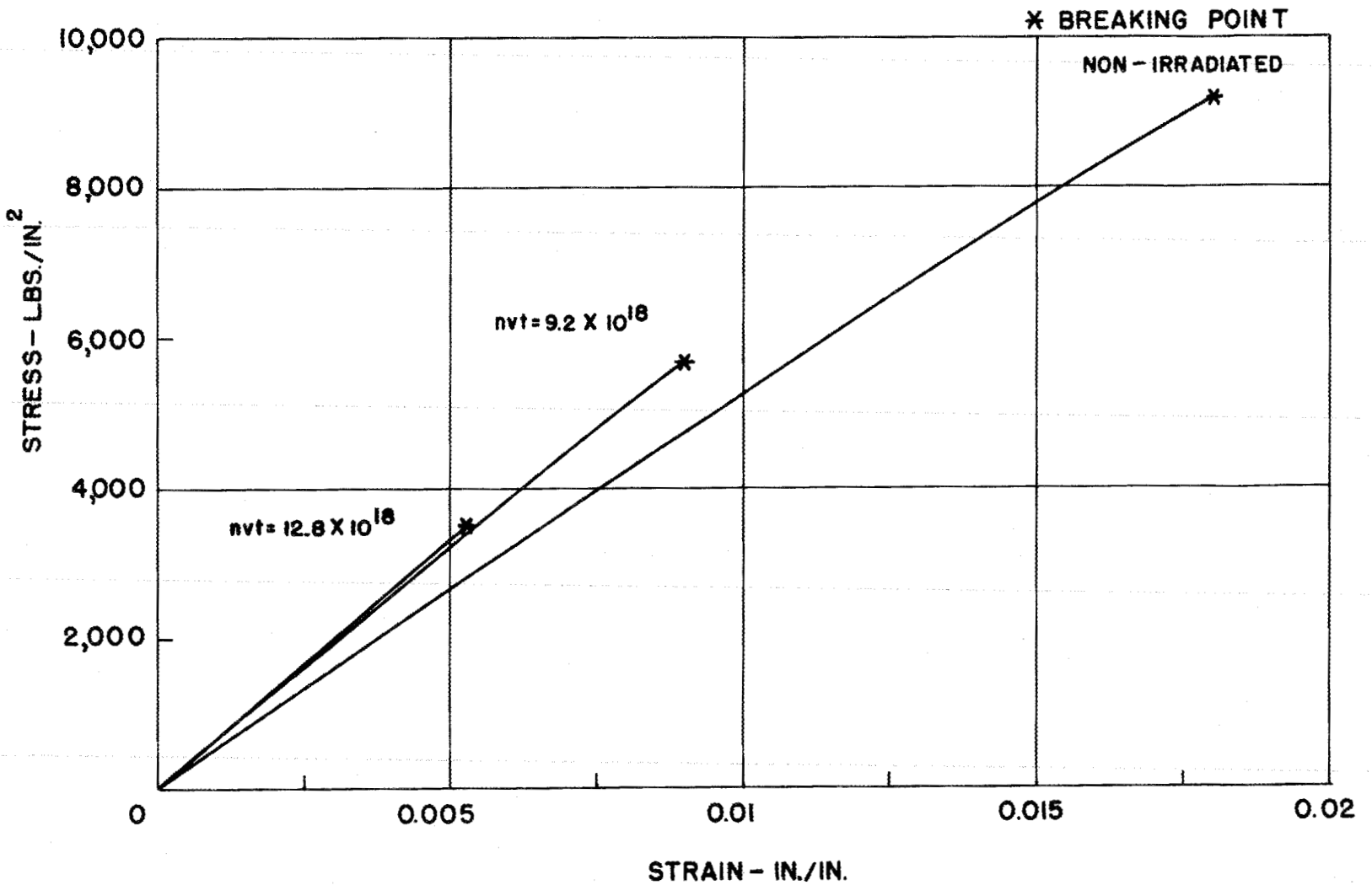
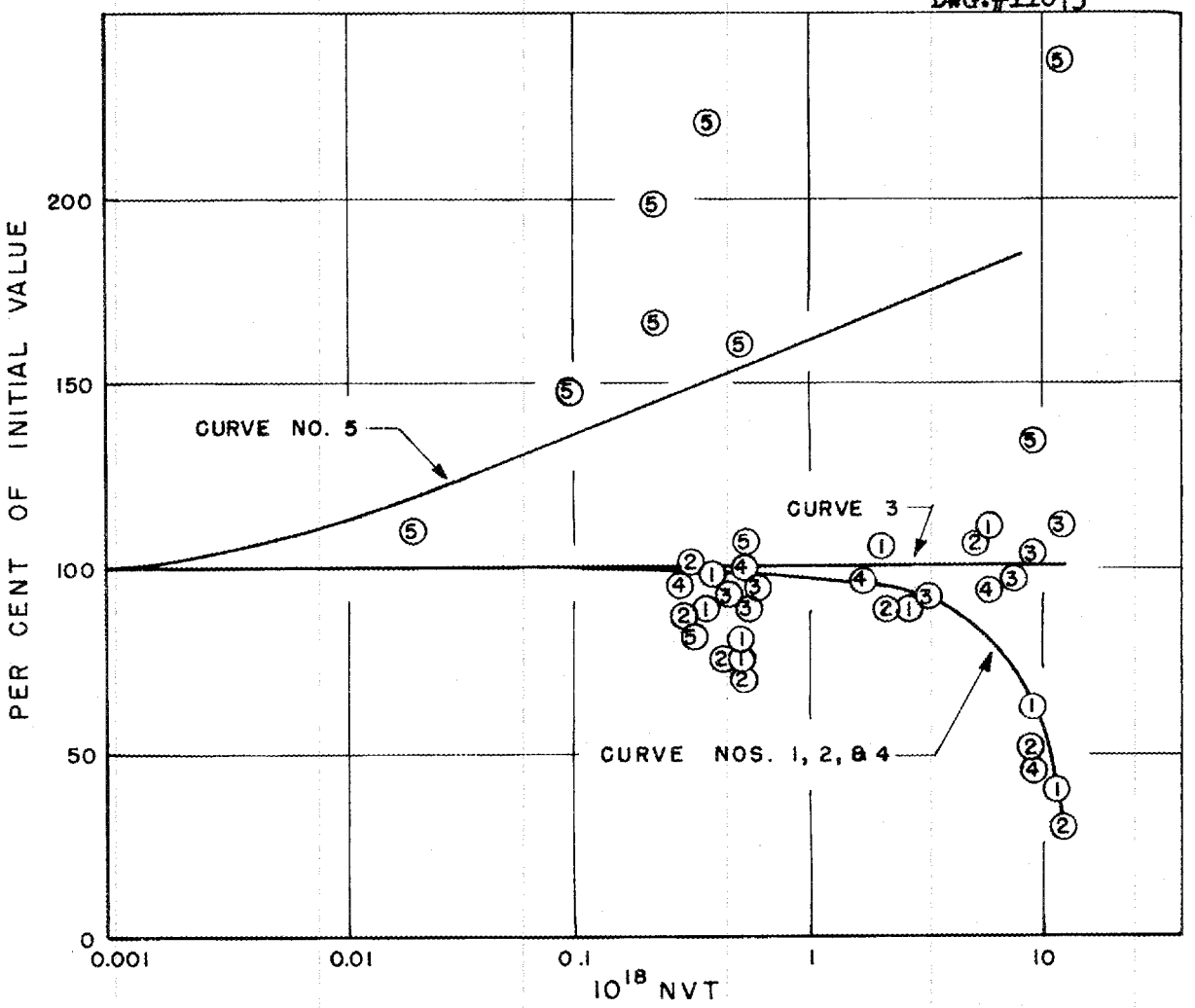


FIGURE 4A STRESS STRAIN CURVES FOR PILE IRRADIATED ANILINE FORMALDEHYDE

UNCLASSIFIED
DWG.#11073



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	9,200 LBS. / SQ. IN.
2	ELONGATION	1.8 %
3	ELASTIC MODULUS	6.0 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	9,700 LBS./SQ. IN.
5	IMPACT STRENGTH	0.20 FT. LBS. / IN. NOTCH

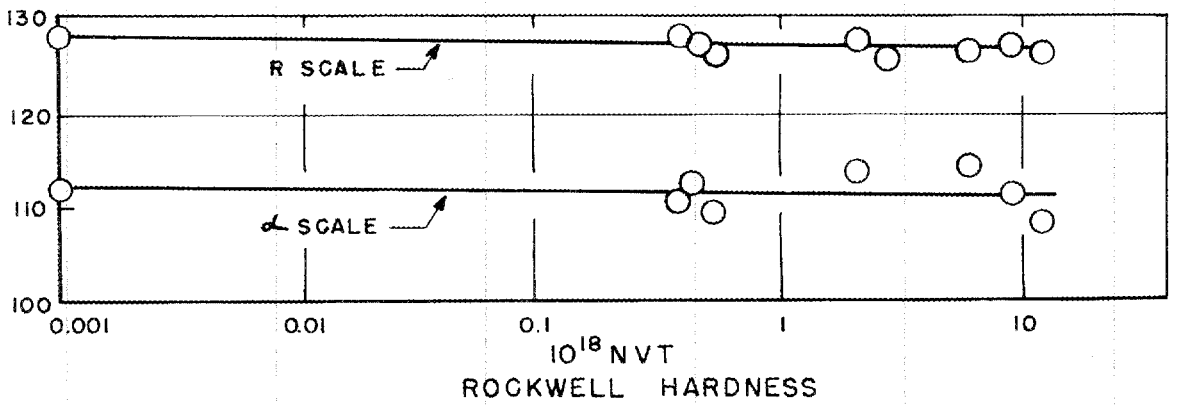
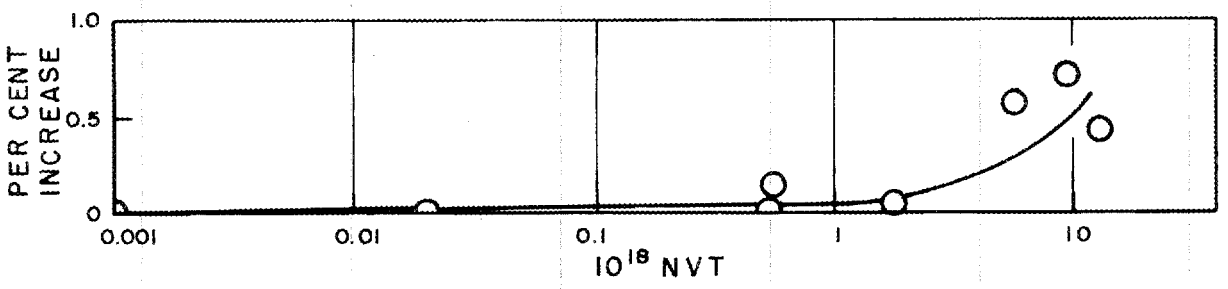
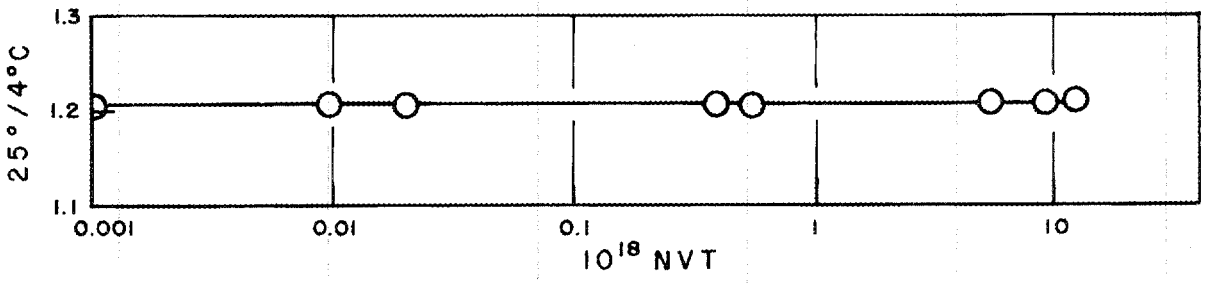


FIGURE 4B ANILINE FORMALDEHYDE

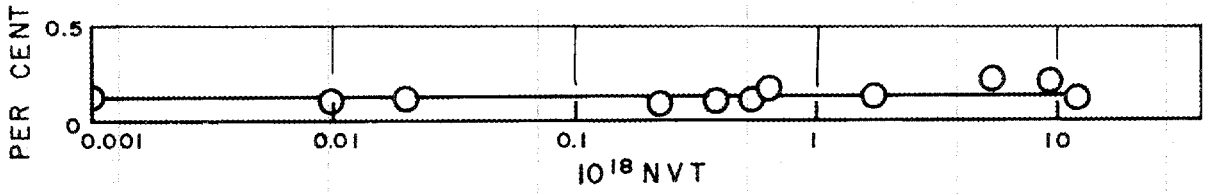
UNCLASSIFIED
DWG.#11074



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 4C ANILINE FORMALDEHYDE

UNCLASSIFIED
DWG.#11075

CIBANITE

Volume Resistivity of 140 Mil Specimens

10^{18} nvt	ohm cm
0	$>10^{14}$
6	$>10^{14}$

Dielectric Strength of 140 Mil Specimens

10^{18} nvt	volts/mil
0	> 200
6	> 200

Arc Resistance of 140 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	20	Carbonized
9	20	"

FIGURE 4 D

AMEROID CASEIN

Classification:	Casein plastic
Trade name:	Ameroid
Company:	American Plastics Corporation
Formula:	Complex

(protein structure)

Filler:	None
Description:	Opaque - yellows upon irradiation
Thickness of sheets:	0.22 - 0.247 in.
Speed of tensile testing	
Mean rate of straining:	$0.6 - 1.3 \times 10^{-4}$ units/sec.
Mean rate of stressing:	40 - 80 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG. #11076

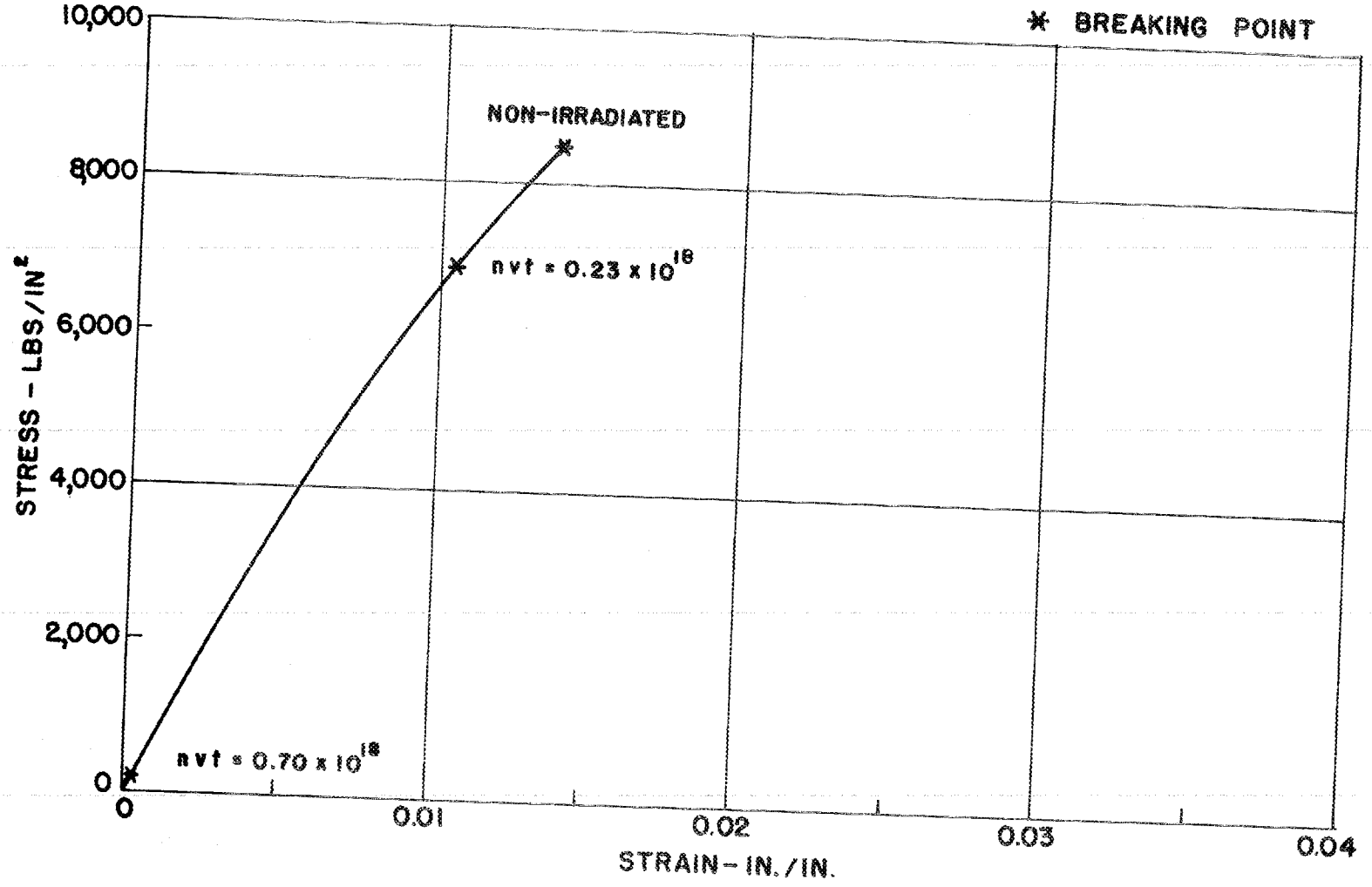
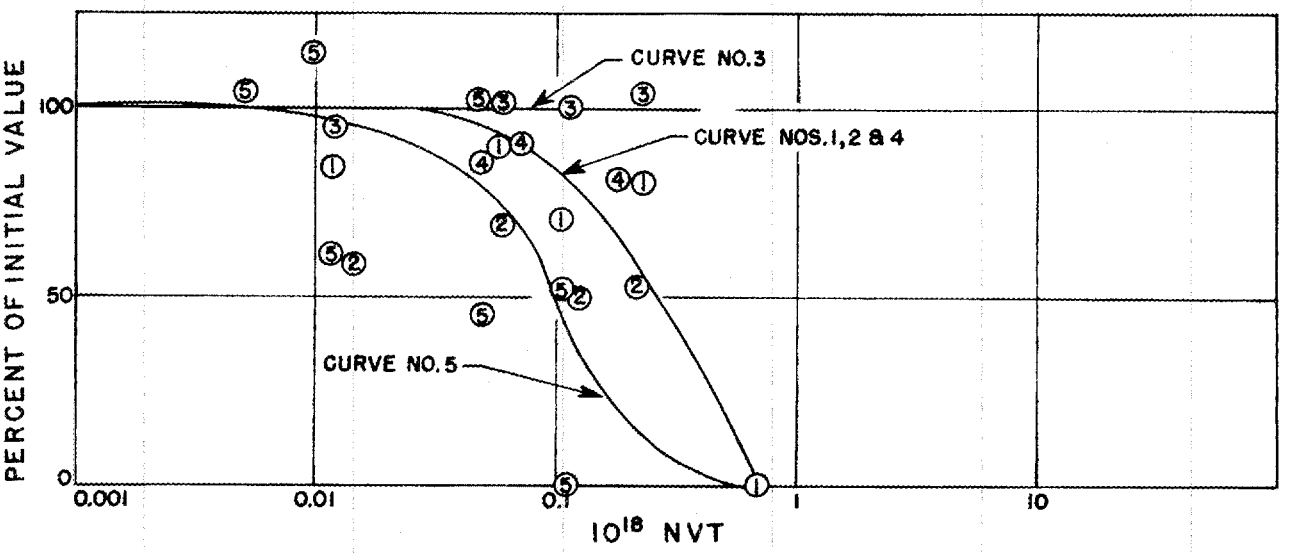


FIGURE 5A STRESS STRAIN CURVES FOR PILE IRRADIATED CASEIN

UNCLASSIFIED
DWG.#11077



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	8,500 LBS./SQ. IN.
2	ELONGATION	2.0 %
3	ELASTIC MODULUS	5.7 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	9800 LBS./SQ. IN.
5	IMPACT STRENGTH	0.50 FT. LB./IN. OF NOTCH

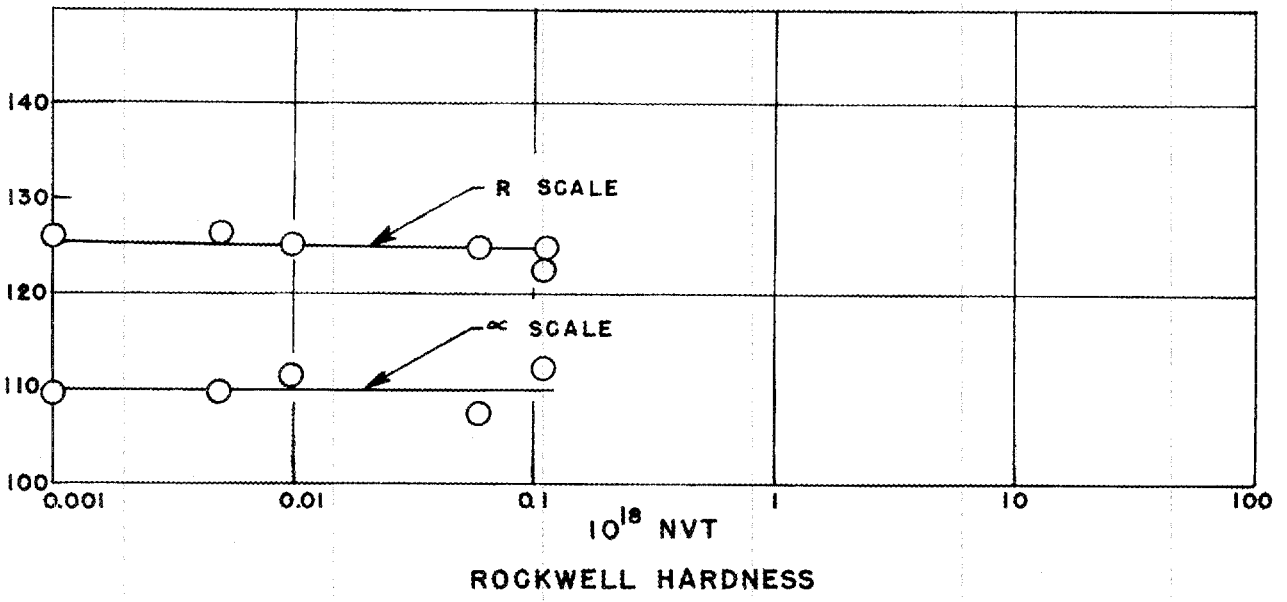
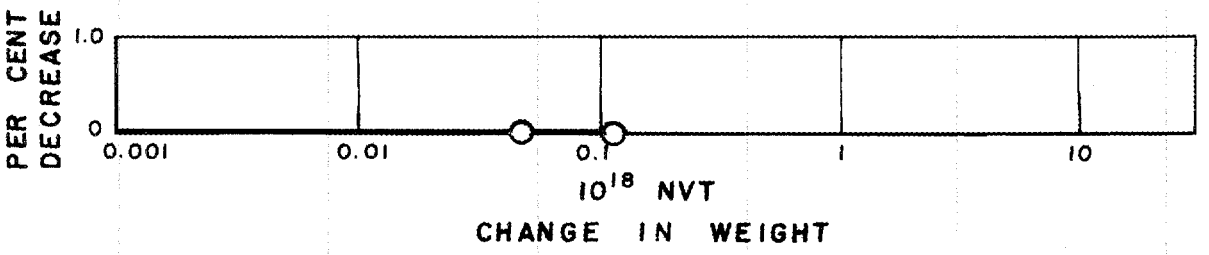
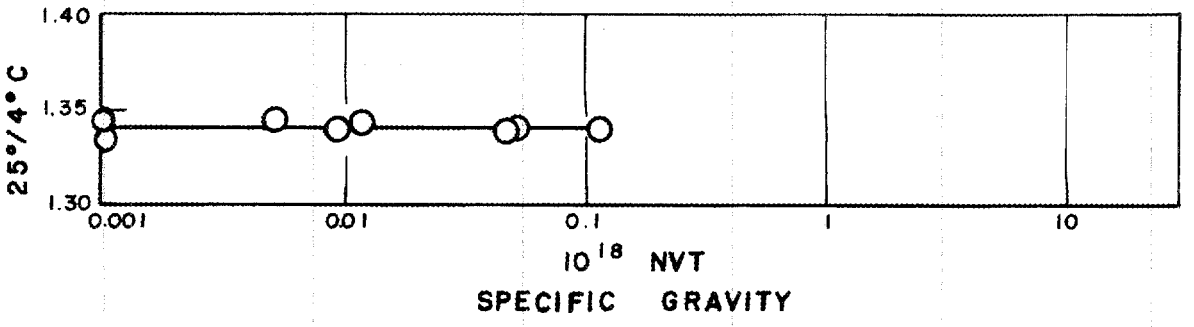


FIGURE 5B CASEIN

UNCLASSIFIED
DWG.#11078





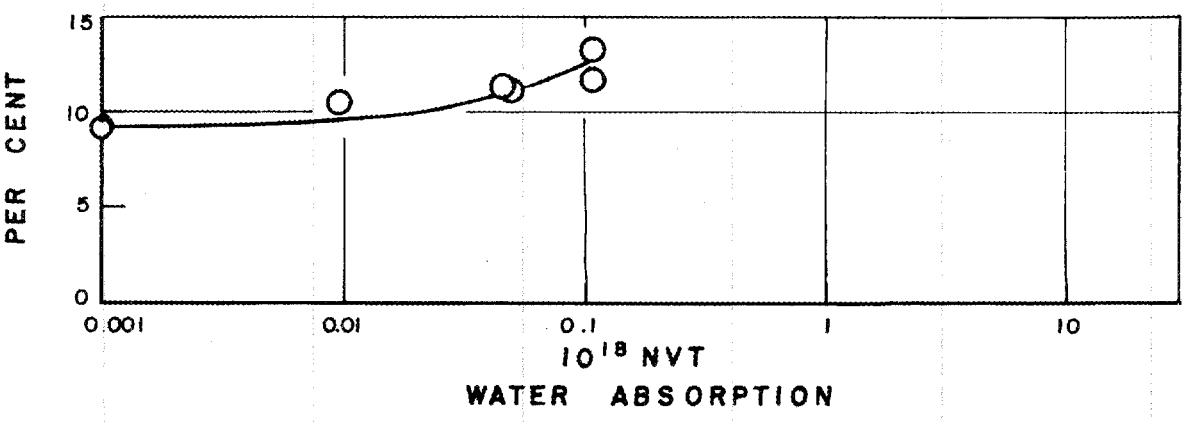


FIGURE 5C CASEIN

AMEROID

Volume Resistivity of 120 Mil Specimens

10^{18} nvt	ohm cm
0	1×10^{11}
0.23	1×10^{11}

Dielectric Strength of 120 Mil Specimens

10^{18} nvt	volts/mil
0	600
0.53	600

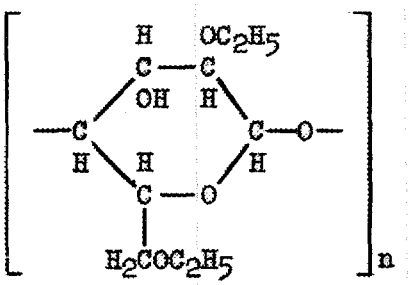
Arc Resistance of 120 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	70	Carbonized
0.23	60	"

FIGURE 5 D

ETHOCEL R-2

Classification:	Cellulosic
Trade name:	Ethocel R-2
Company:	Dow Chemical Company
Resin:	Ethyl cellulose
Formula:	



Filler:	None
Description:	Opaque, yellow-white - darkens upon irradiation
Thickness of sheets:	0.820 - 0.832 in.
Speed of tensile testing	
Mean rate of straining:	0.9 - 1.7 x 10^{-4} units/sec.
Mean rate of stressing:	20 - 40 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11080

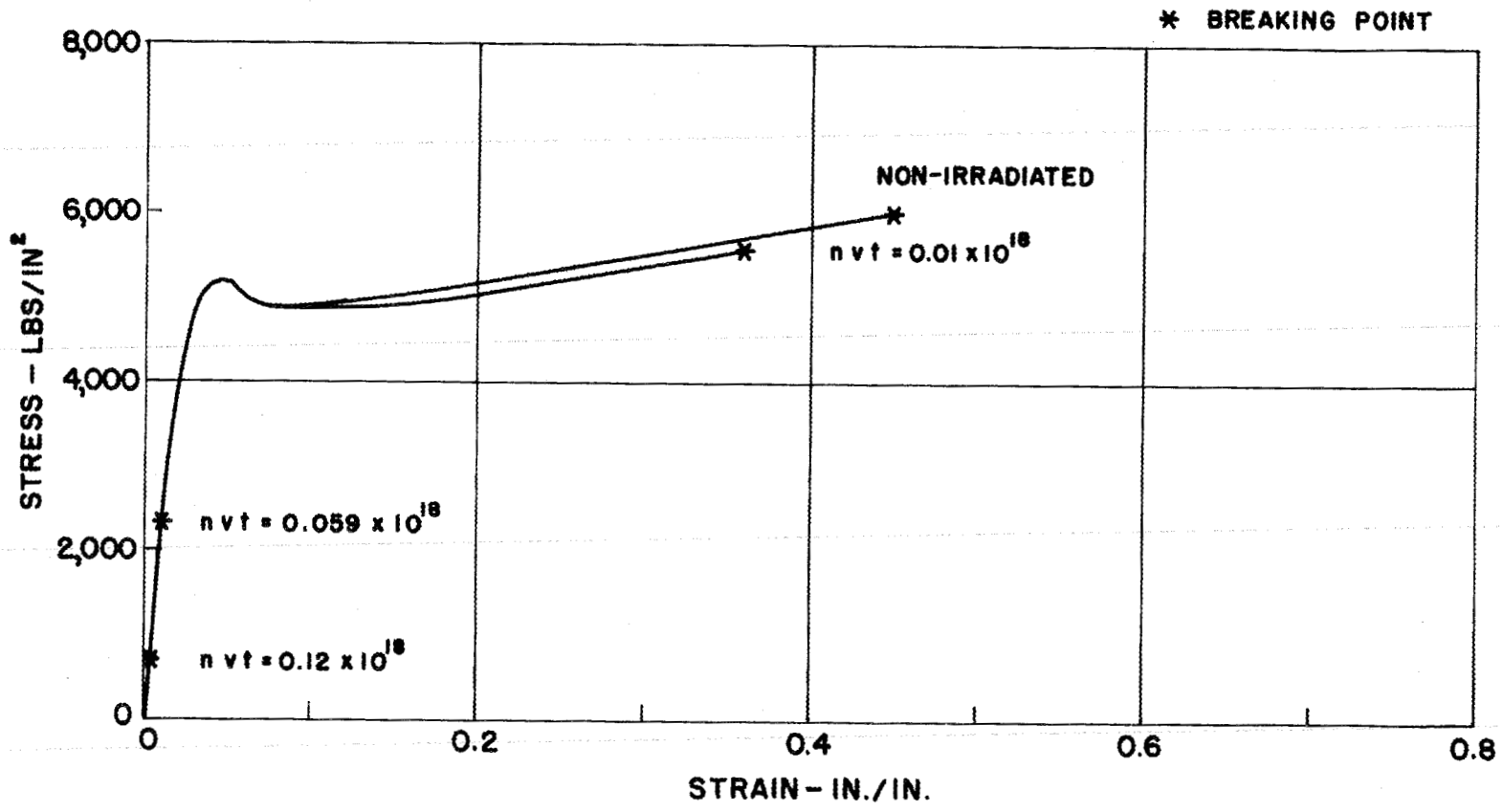
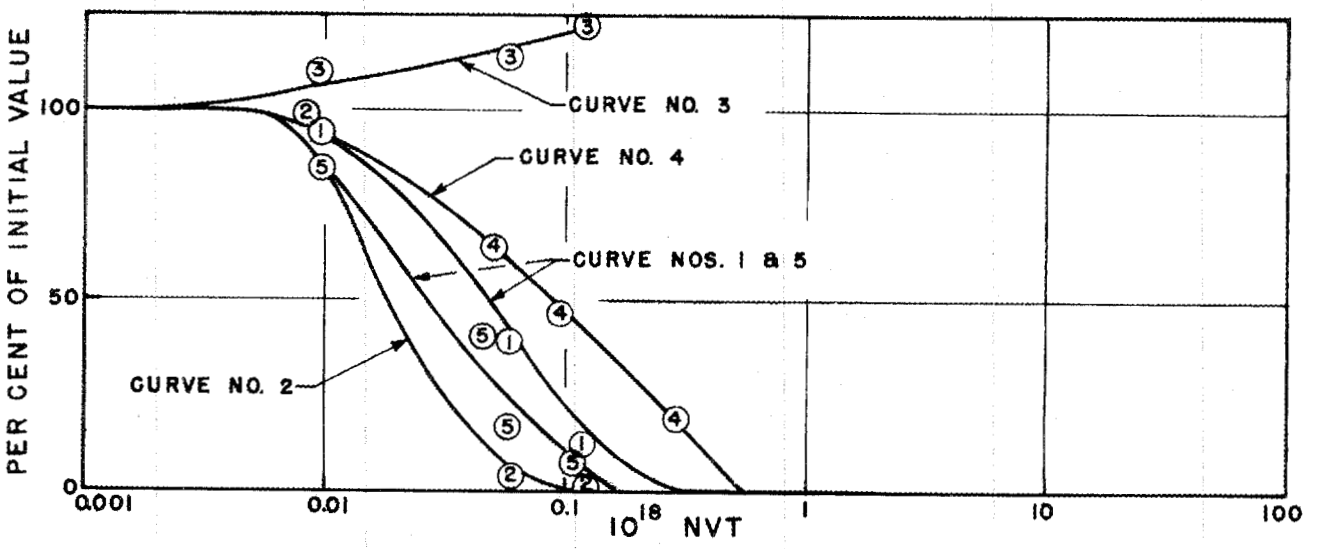


FIGURE 6A STRESS STRAIN CURVES FOR PILE IRRADIATED ETHYL CELLULOSE

UNCLASSIFIED
DWG.#11081



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	6000 LBS./SQ. IN.
2	ELONGATION	40 %
3	ELASTIC MODULUS	2.1 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	6700 LBS./SQ. IN.
5	IMPACT STRENGTH	2.0 FT. LBS./IN. OF NOTCH

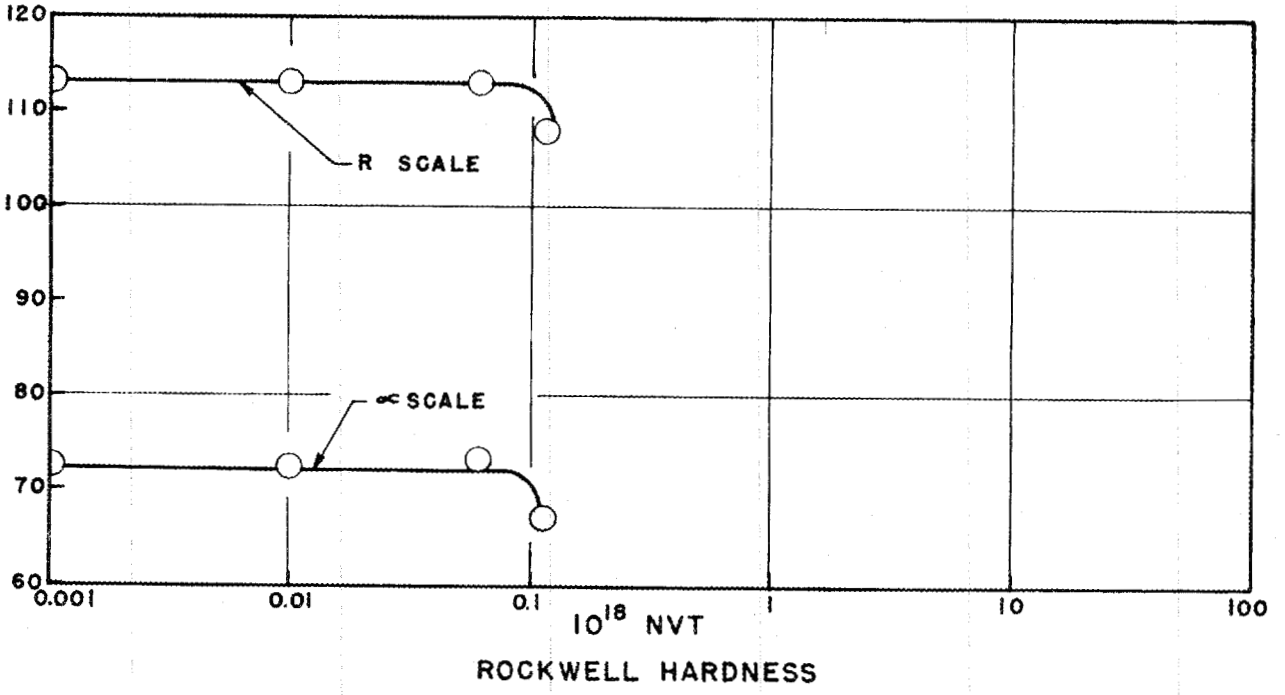
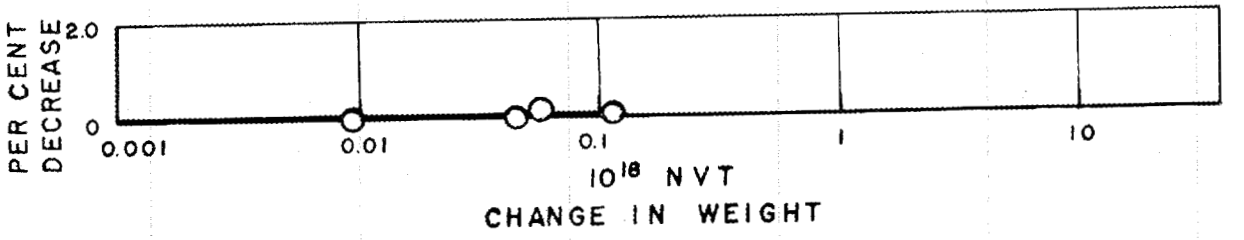
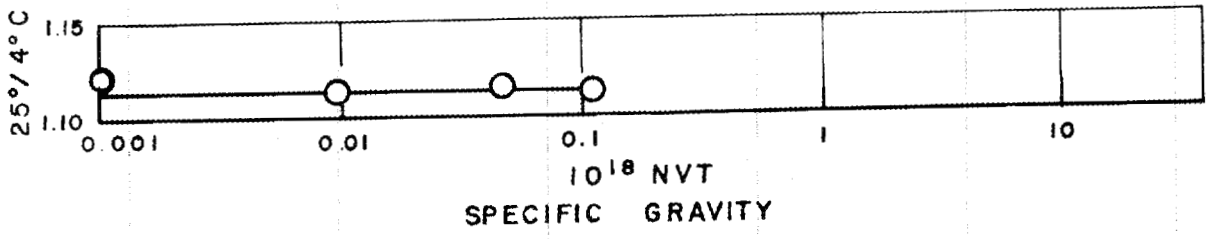


FIGURE 6B ETHYL CELLULOSE

UNCLASSIFIED
DWG.#11082





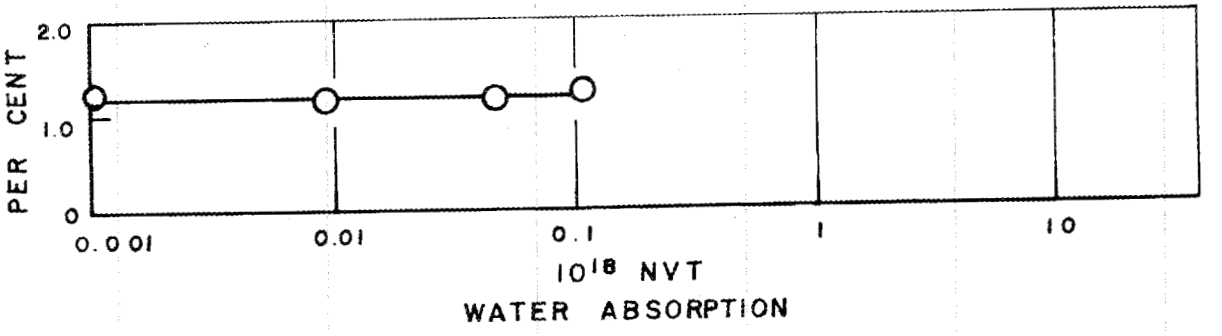


FIGURE 6C ETHYL CELLULOSE

ETHOCEL R-2

Volume Resistivity of 150 Mil Specimens

10^{18} nvt	ohm cm
0	10^{14}
0.29	10^{14}

Dielectric Strength of 21 Mil Specimens

10^{18} nvt	volts/mil
0	1250
0.23	1250

Arc Resistance of 150 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	120	Melted
0.05	100	"
0.29	70	"

FIGURE 6 D

FORTICEL

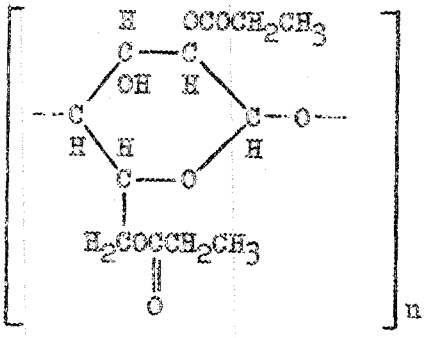
Classification: Cellulosic

Trade name: Forticel

Company: Celanese Corporation of America

Resin: Cellulose propionate

Formula:



Filler: none

Description: Translucent, amber.
Becomes opaque, but lighter in color upon irradiation.

Thickness of sheets: 0.618 - 0.625 in.

Speed of tensile testing

Mean rate of straining: 0.6 - 0.9 x 10^{-4} units/sec.

Mean rate of stressing; 11 - 16 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11084

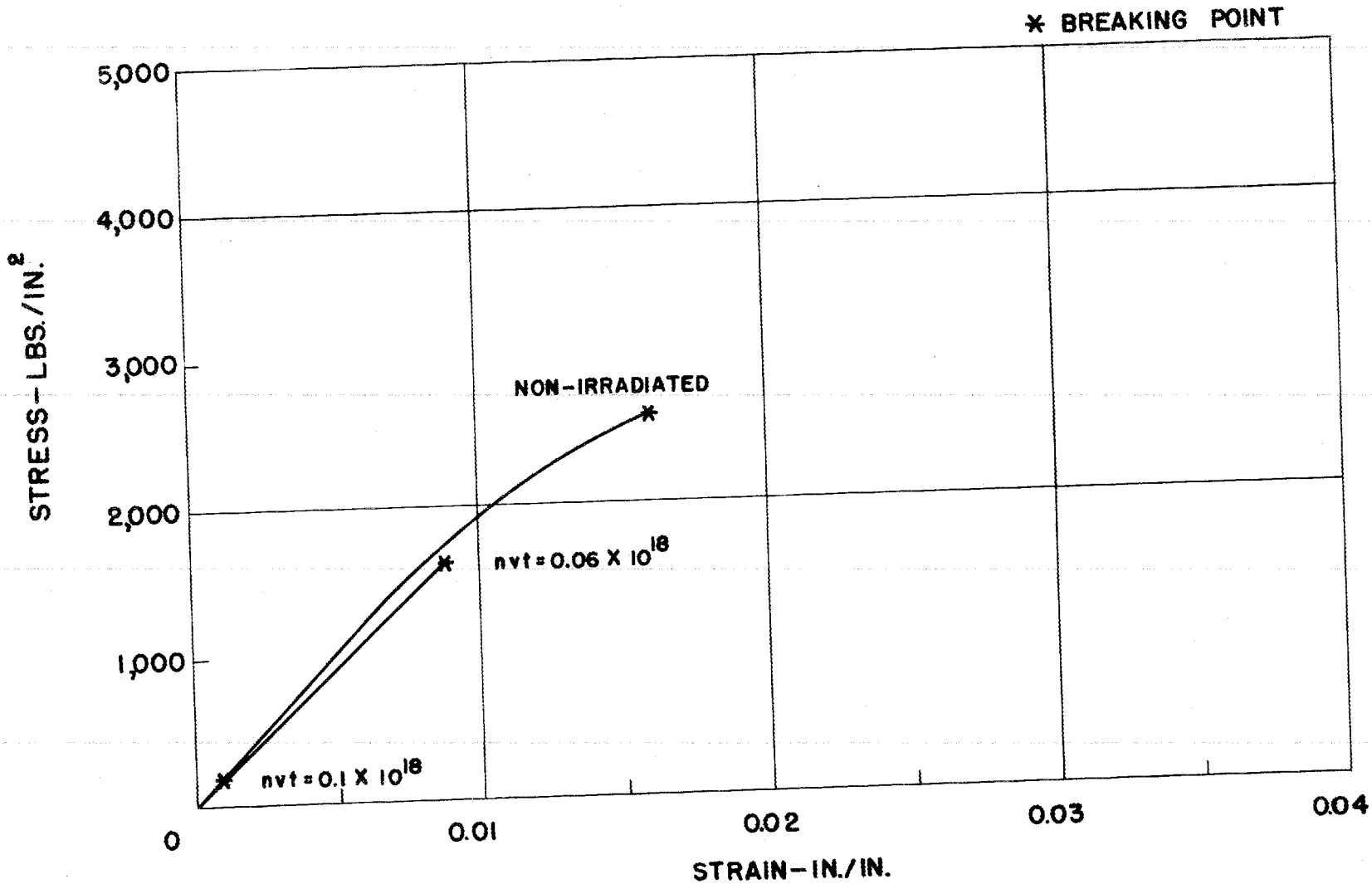
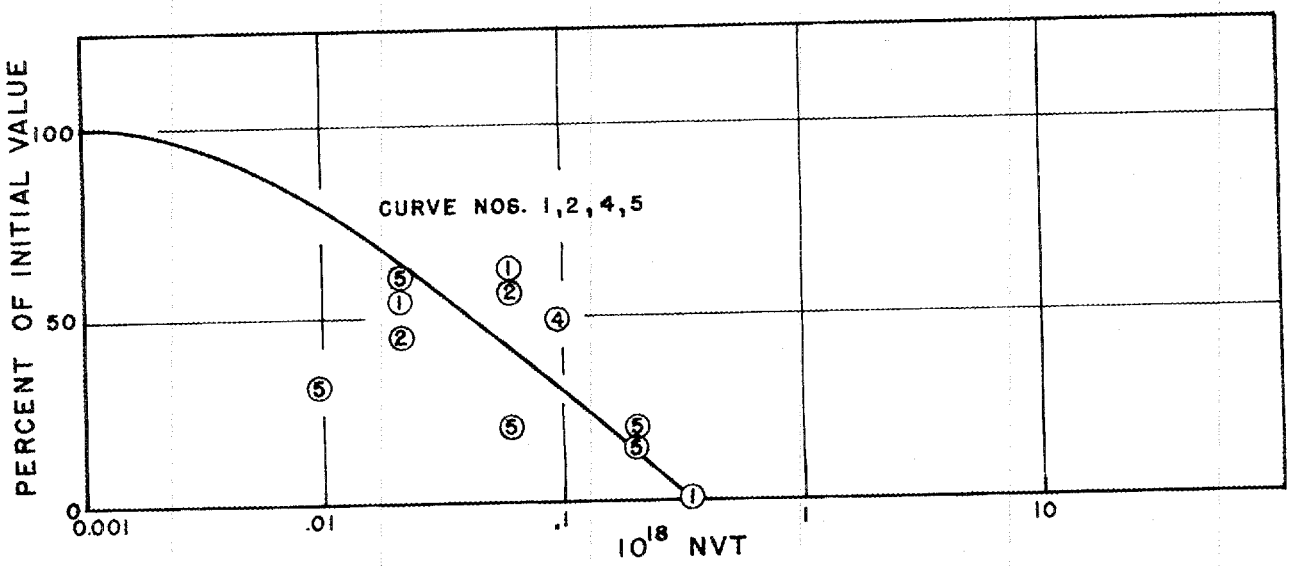
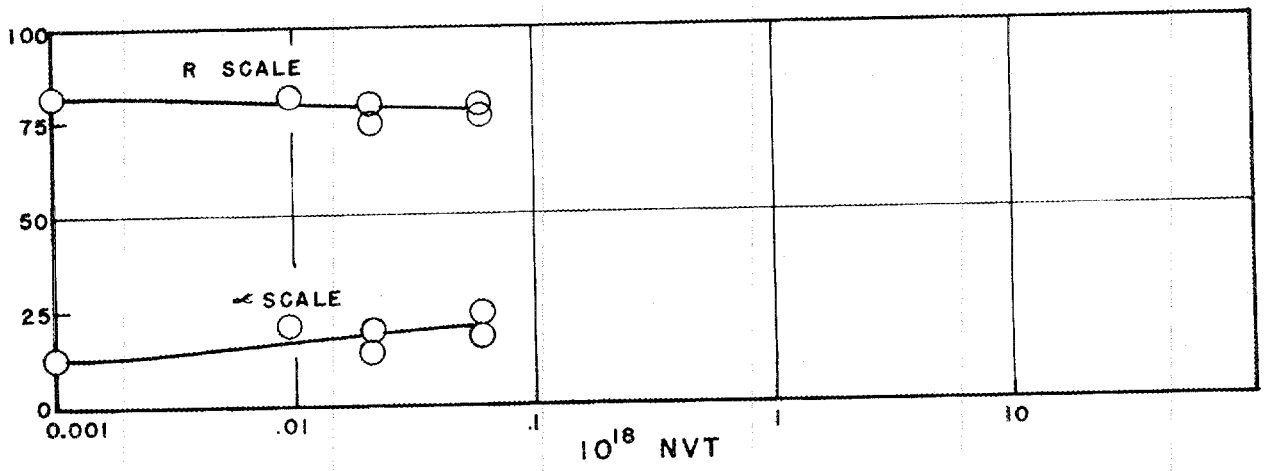


FIGURE 7A STRESS STRAIN CURVES FOR PILE IRRADIATED CELLULOSE PROPIONATE

UNCLASSIFIED
DWG.#11085



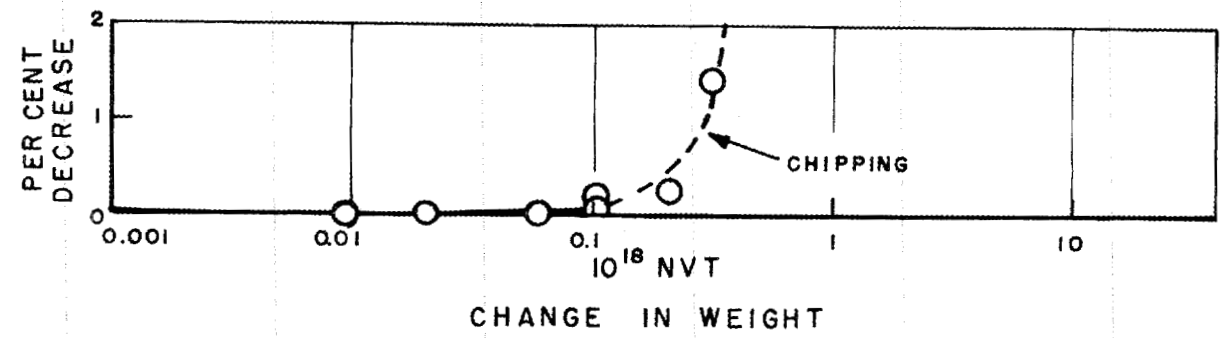
CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	2600 LBS. / SQ. IN.
2	ELONGATION	1.6 %
4	SHEAR STRENGTH	2900 LBS. / SQ. IN.
5	IMPACT STRENGTH	1.1 FT. LBS. / IN. NOTCH



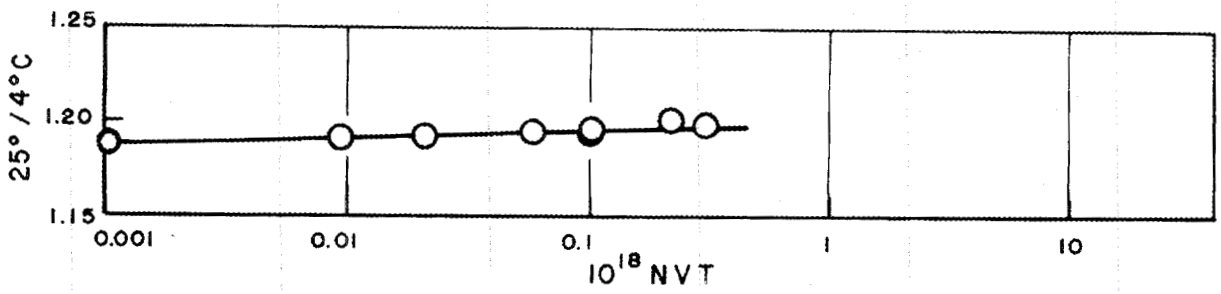
ROCKWELL HARDNESS

FIGURE 7B CELLULOSE PROPIONATE

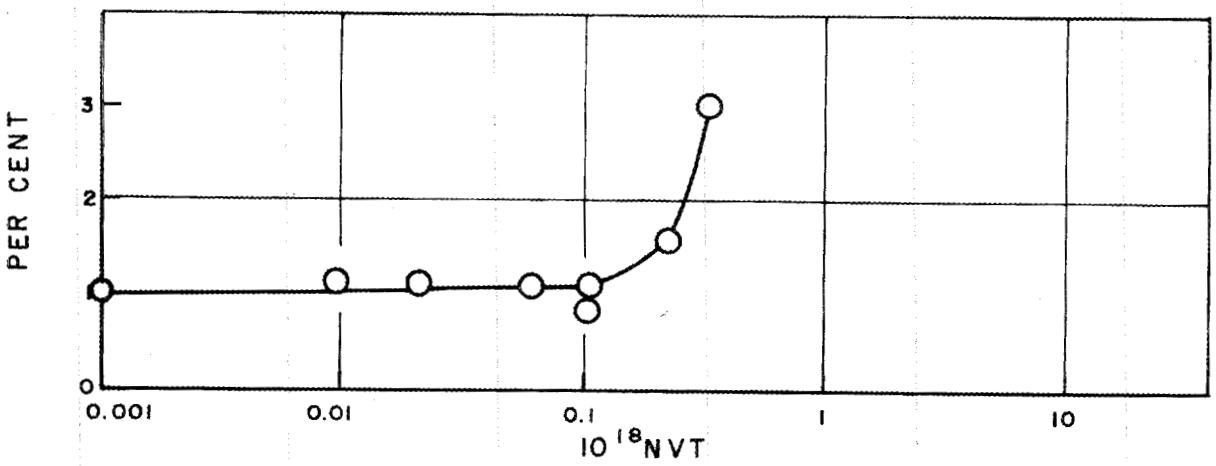
UNCLASSIFIED
DWG.#11086



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 7C CELLULOSE PROPRIONATE

UNCLASSIFIED
DWG.#11087

FORTICEL

Volume Resistivity of 180 Mil Specimens

10^{18} nvt	ohm cm
0	$> 10^{14}$
0.2	$> 10^{14}$

Dielectric Strength of 20 Mil Specimens

10^{18} nvt	volts/mil
0	1000
0.23	1000

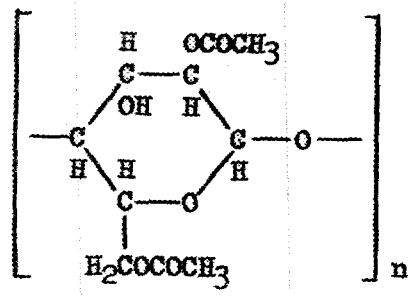
Arc Resistance of 180 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	125	Melted
0.096	120	"
0.34	110	"

FIGURE 7 D

PLASTACELE

Classification:	Cellulosic
Trade name:	Plastacele
Company:	E. I. du Pont de Nemours & Company, Inc.
Resin:	Cellulose acetate
Formula:	



Filler:	None
Description:	Clear - yellows upon irradiation
Thickness of sheets:	0.125 - 0.126 in.
Speed of tensile testing	
Mean rate of straining:	0.9 - 1.9 x 10^{-4} units/sec.
Mean rate of stressing:	20 - 50 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11088

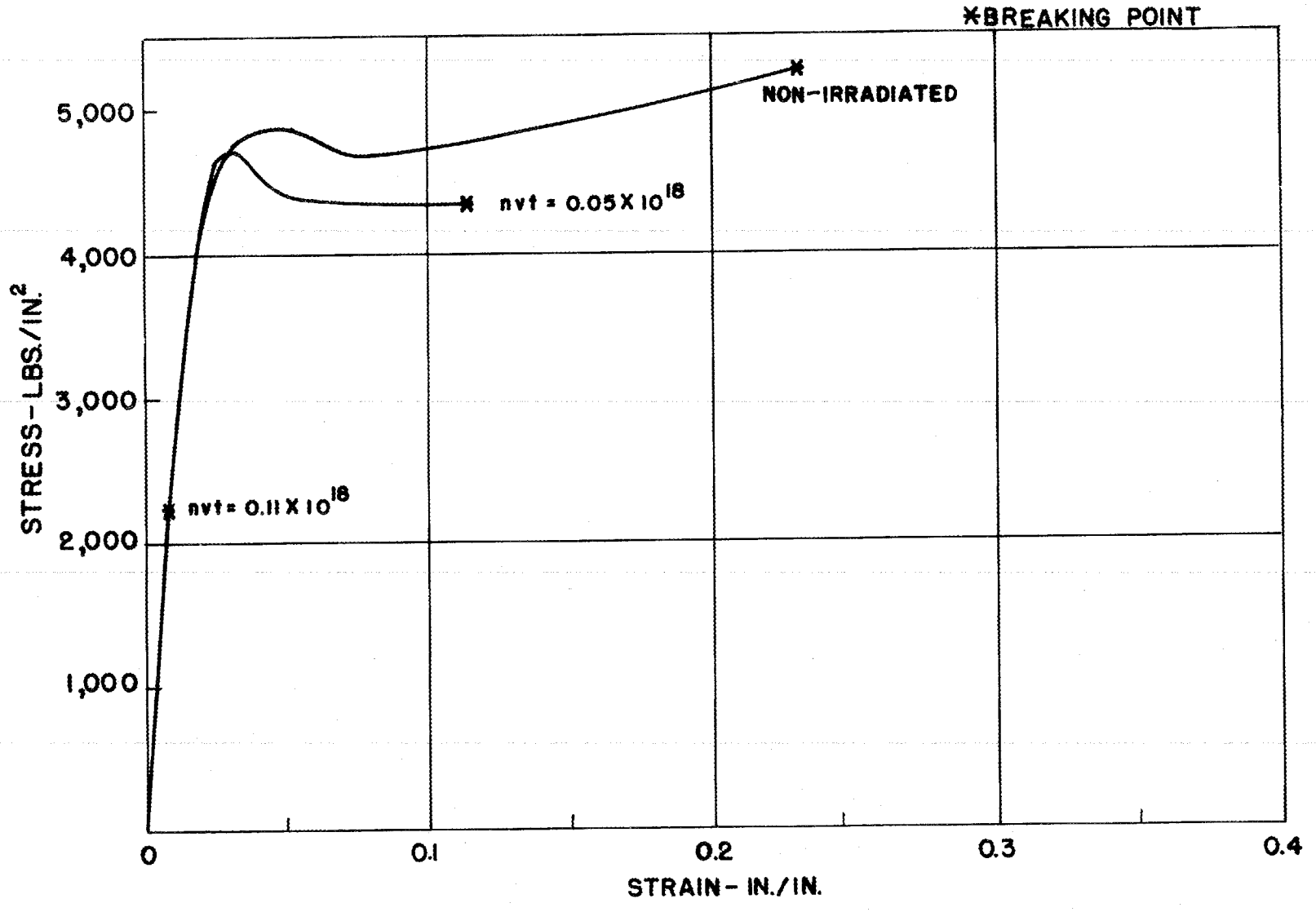
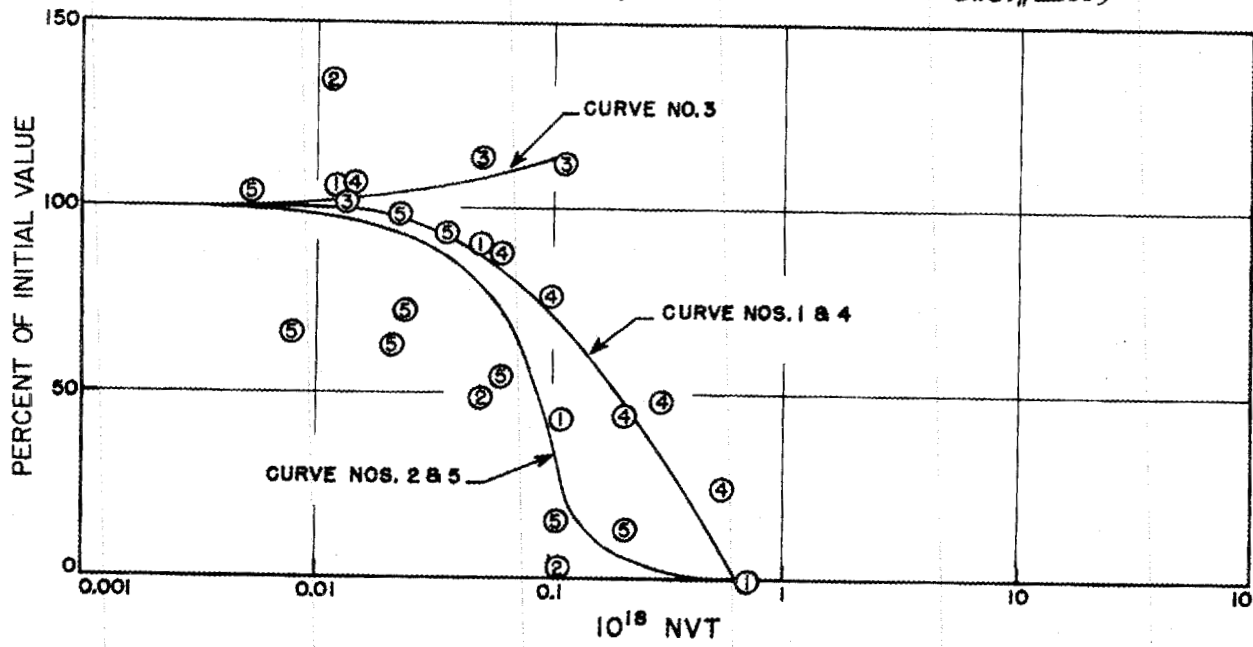
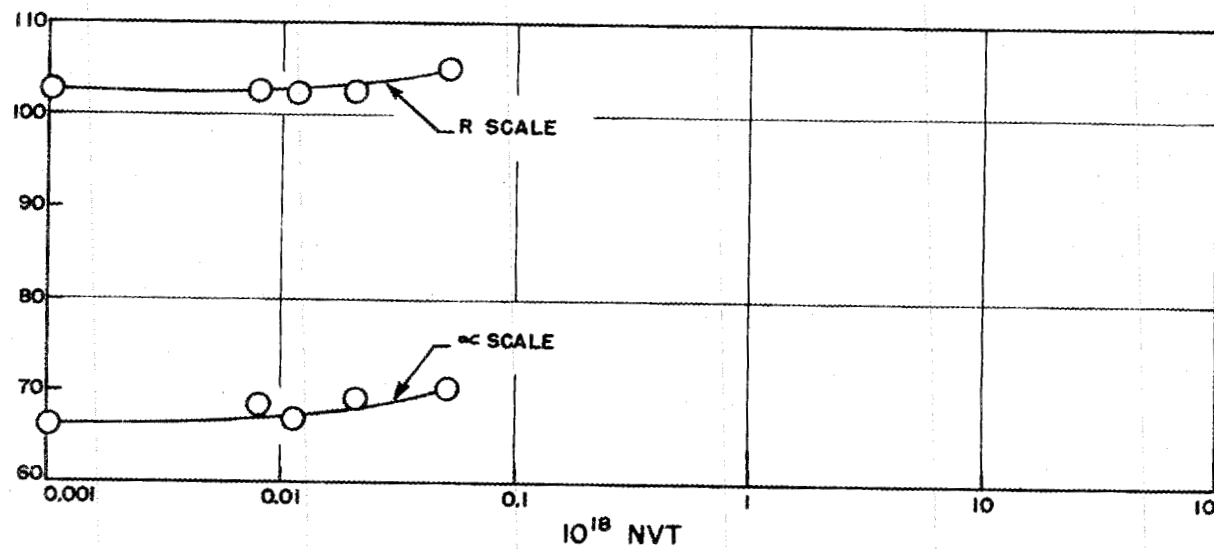


FIGURE 8A STRESS STRAIN CURVES FOR PILE IRRADIATED CELLULOSE ACETATE

UNCLASSIFIED
DWG.#11089



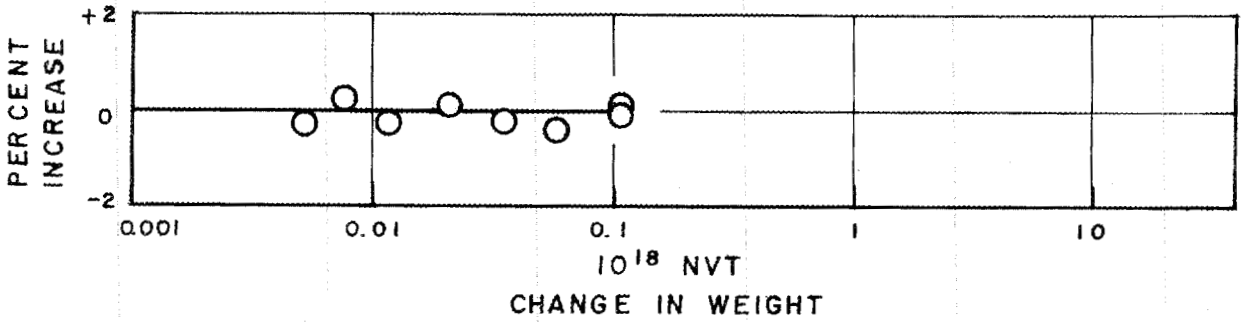
CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	5,300 LBS./SQ. IN.
2	ELONGATION	20 %
3	ELASTIC MODULUS	2.6 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	6,400 LBS./SQ. IN.
5	IMPACT STRENGTH	1.37 FT. LBS./IN. OF NOTCH



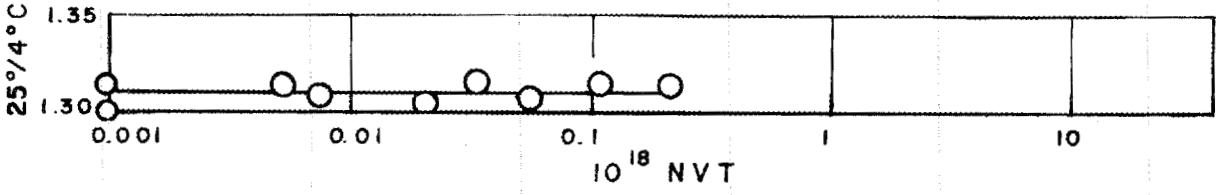
ROCKWELL HARDNESS

FIGURE 8B CELLULOSE ACETATE

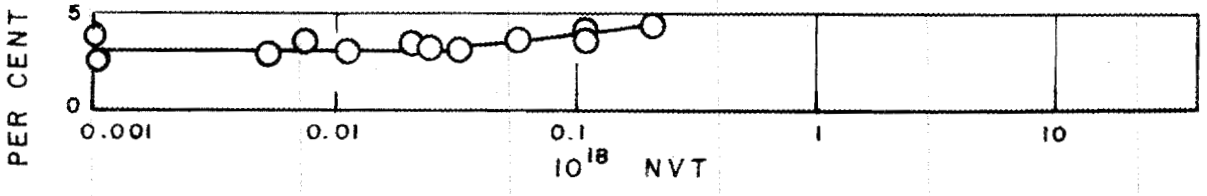
UNCLASSIFIED
DWG.#11090



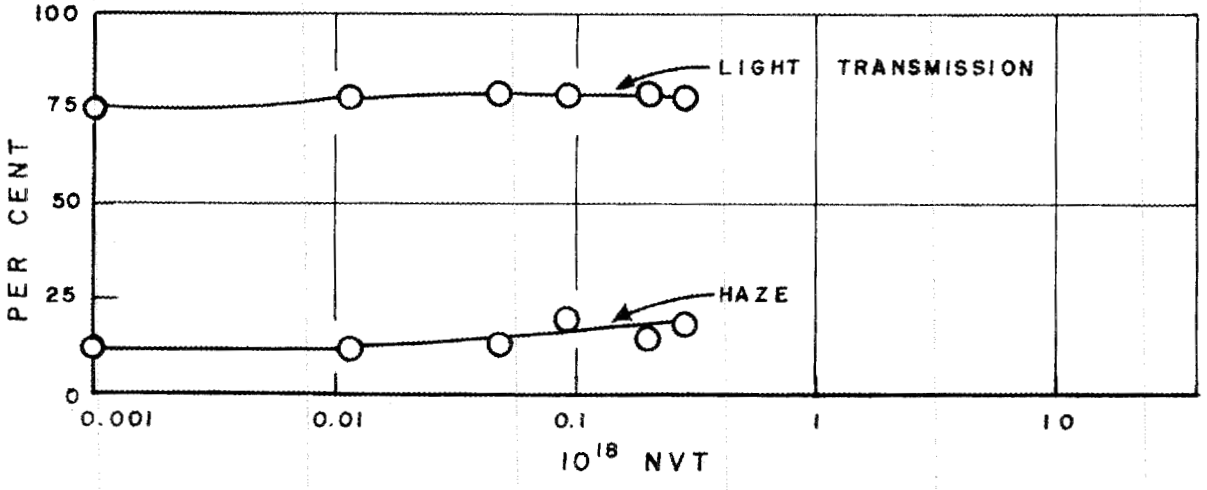
CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION



LIGHT TRANSMISSION AND HAZE

FIGURE 8C CELLULOSE ACETATE

CELLULOSE ACETATE

Volume Resistivity of 125 Mil Specimens

10^{18} nvt	ohm cm
0	5×10^{12}
0.1	2×10^{12}
0.2	2×10^{11}
0.5	2×10^{11}

Dielectric Strength of 25 Mil Specimens

10^{18} nvt	volts/mil
0	750
0.53	750

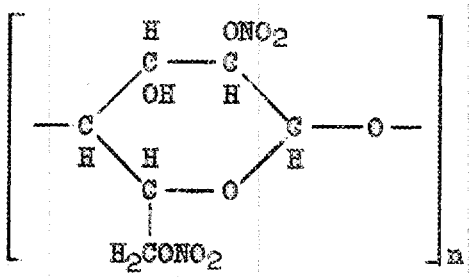
Arc Resistance of 125 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	190	Melted
0.54	190	"

FIGURE 8 D

PYRALIN

Classification:	Cellulosic
Trade name:	Pyralin
Company:	E. I. du Pont de Nemours & Company, Inc.
Resin:	Cellulose nitrate
Formula:	



Filler	None
Description:	Clear - yellows upon irradiation
Thickness of sheets	0.122 - 0.124 in.
Speed of tensile testing	
Mean rate of straining:	0.3 - 1.4 x 10^{-4} units/sec.
Mean rate of stressing:	10 - 40 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11092

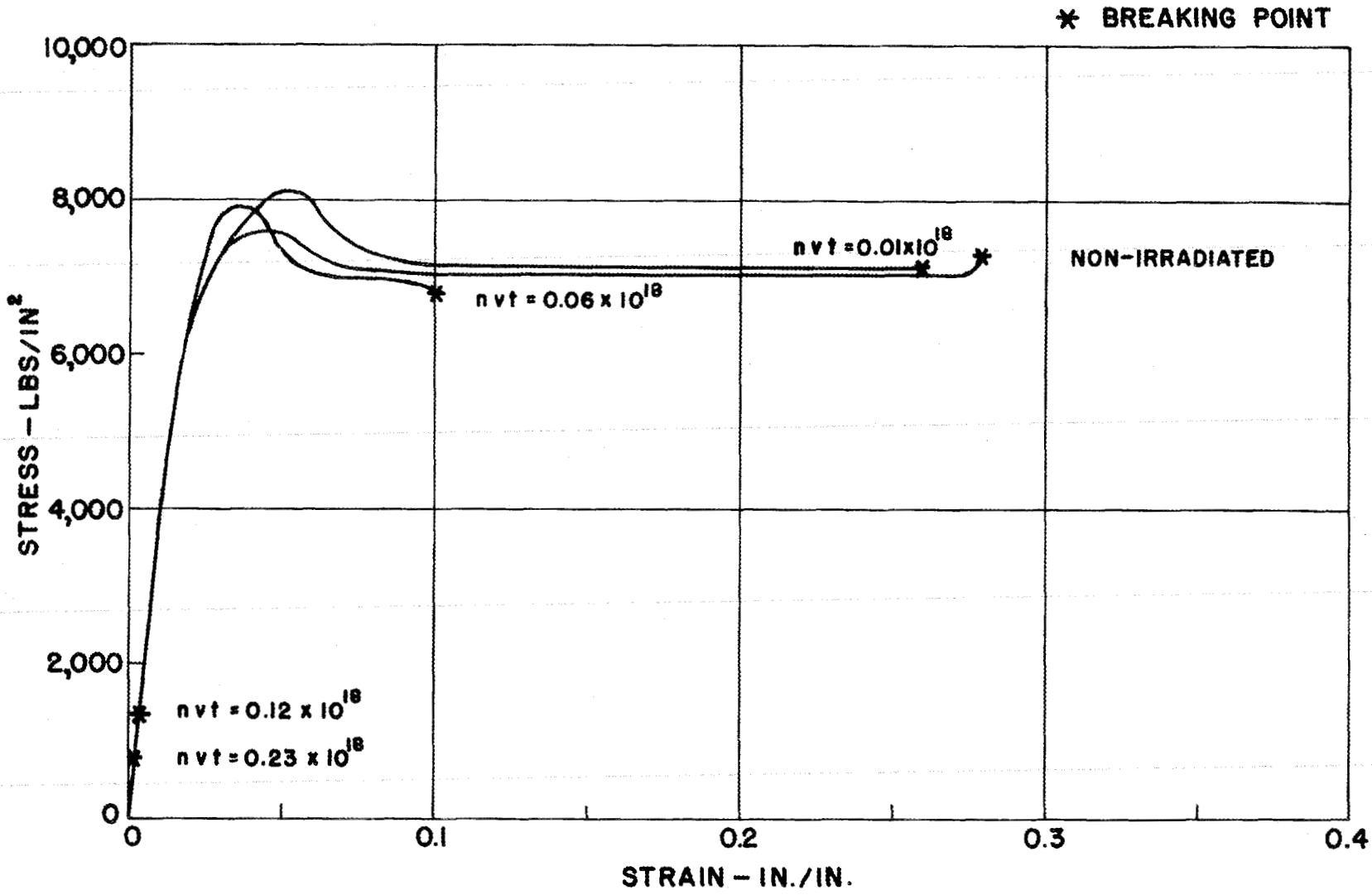
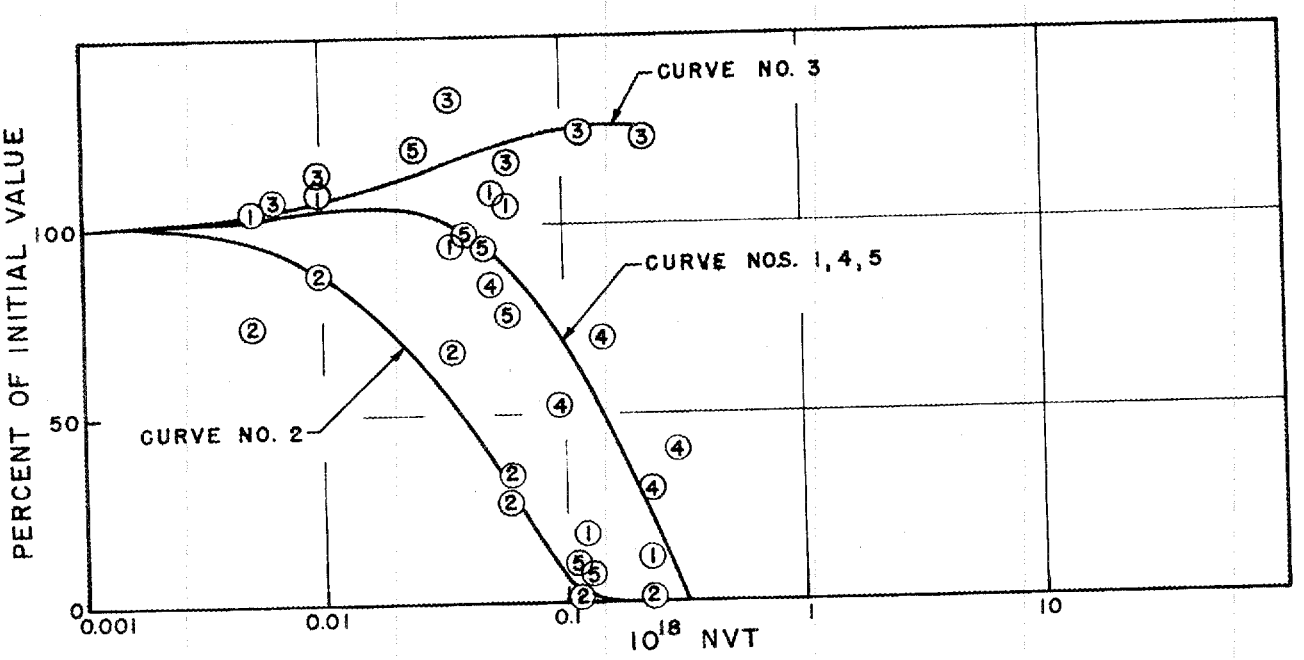


FIGURE 9A STRESS STRAIN CURVES FOR PILE IRRADIATED CELLULOSE NITRATE

UNCLASSIFIED
DWG.#11093



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	7600 LBS. / SQ. IN.
2	ELONGATION	30 %
3	ELASTIC MODULUS	3.6×10^5 LBS. / SQ. IN.
4	SHEAR STRENGTH	8800 LBS. / SQ. IN.
5	IMPACT STRENGTH	2.75 FT. LBS. / IN. OF NOTCH

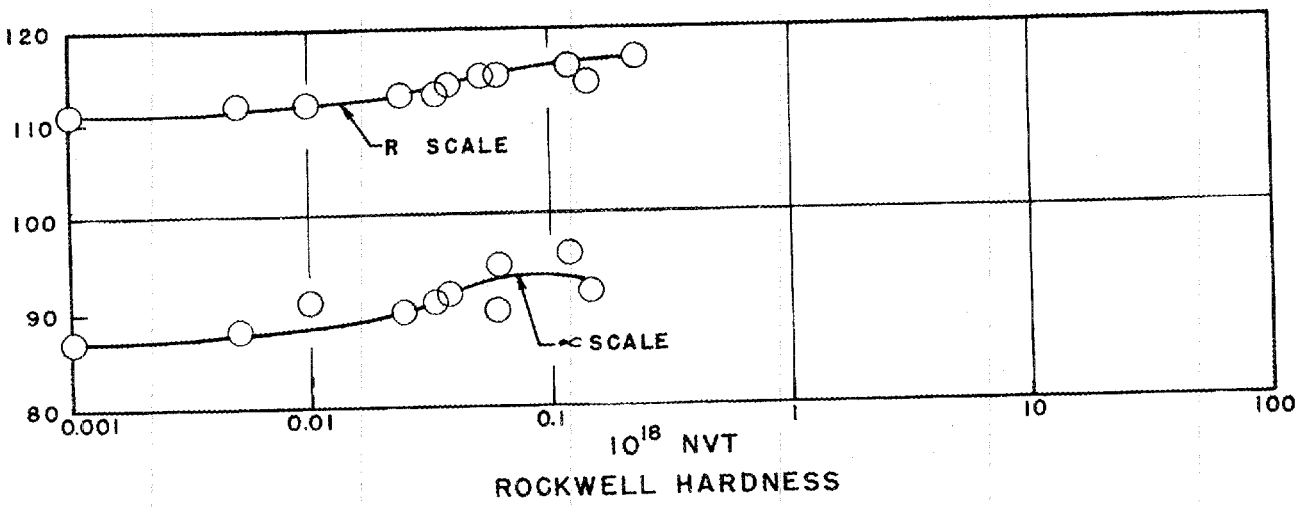


FIGURE 9B CELLULOSE NITRATE

UNCLASSIFIED
DWG.#11094

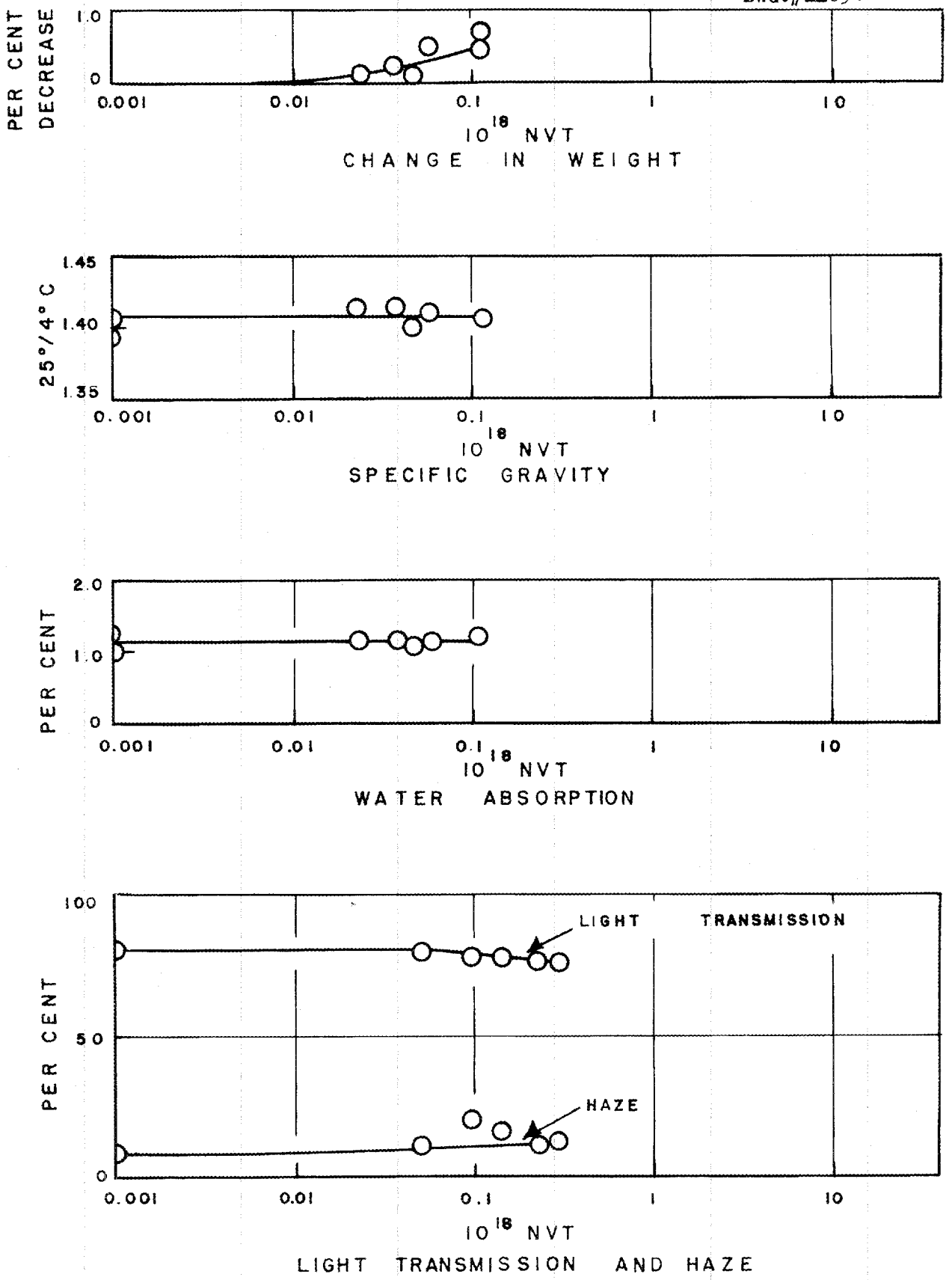


FIGURE 9C CELLULOSE NITRATE

UNCLASSIFIED
DWG.#11095

CELLULOSE NITRATE

Volume Resistivity of 122 Mil Specimens

10^{18} nvt	ohm cm
0	2×10^{11}
0.23	1×10^{11}

Dielectric Strength of 25 Mil Specimens

10^{18} nvt	volts/mil
0	900
0.53	700

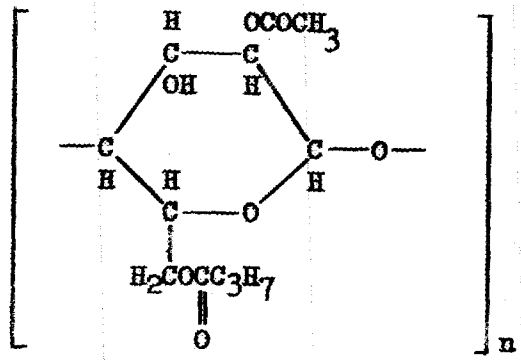
Arc Resistance of 122 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	22	Flamed
0.29	13	"

FIGURE 9 D

TENITE II

Classification:	Cellulosic
Trade name:	Tenite II
Company:	Tennessee Eastman Corporation
Resin:	Cellulose acetate butyrate
Formula:	



Filler:	None
Description:	Opaque, red. No change upon irradiation
Thickness of sheets:	0.180 - 0.186 in.
Speed of tensile testing	
Mean rate of straining:	0.9 - 1.4 x 10^{-4} units/sec.
Mean rate of stressing:	10 - 20 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG. #11096

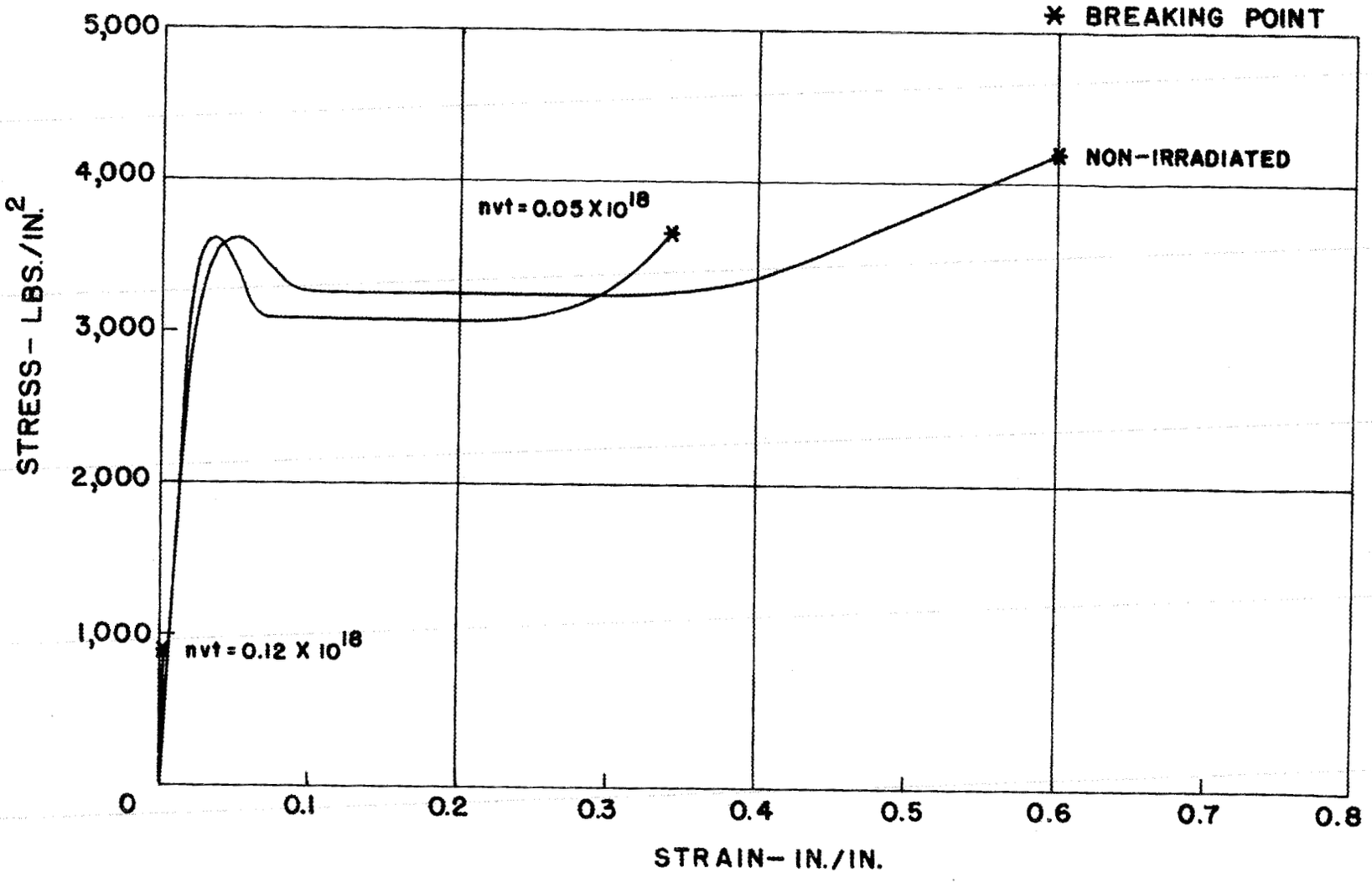
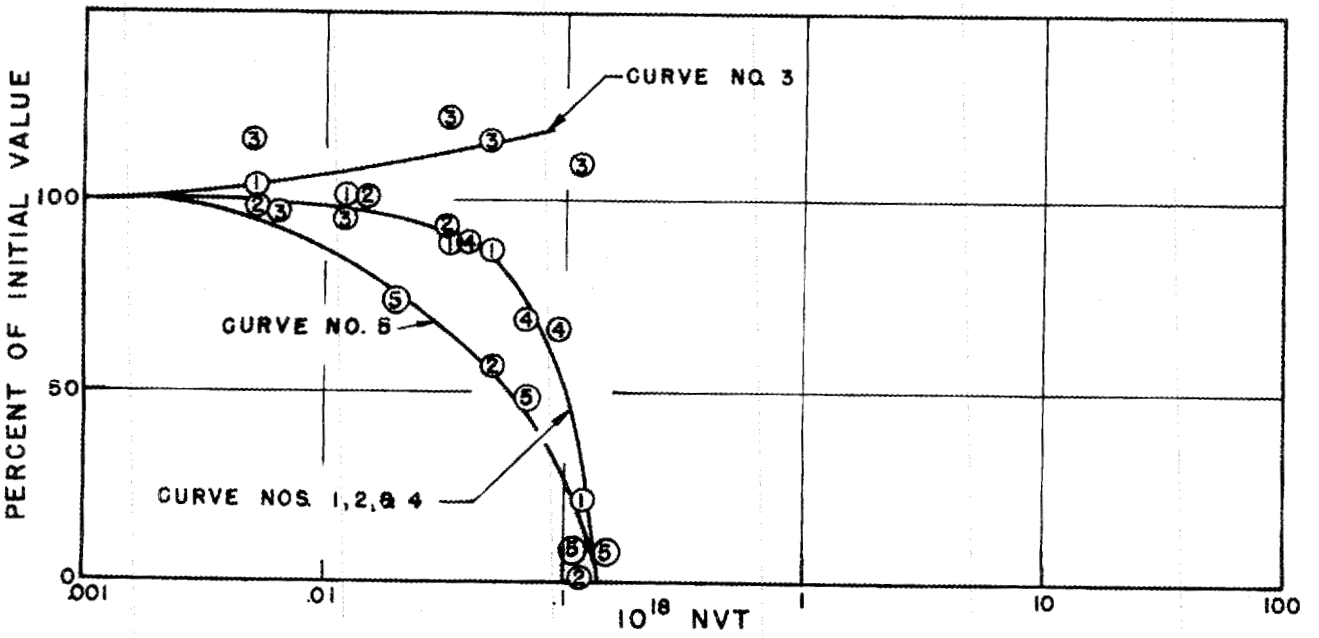


FIGURE 10A STRESS STRAIN CURVES FOR PILE IRRADIATED

CELLULOSE ACETATE BUTYRATE

UNCLASSIFIED
DWG.#11097



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	4200 LBS./SQ. IN.
2	ELONGATION	60 %
3	ELASTIC MODULUS	1.6×10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	4000 LBS./SQ. IN.
5	IMPACT STRENGTH	3.3 FT. LBS./IN. OF NOTCH

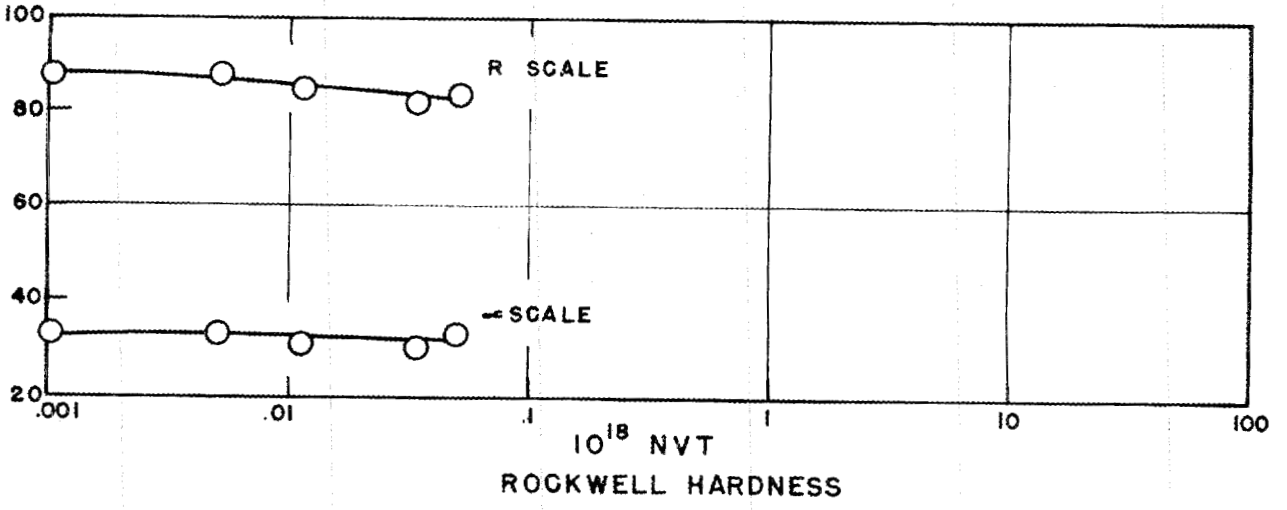
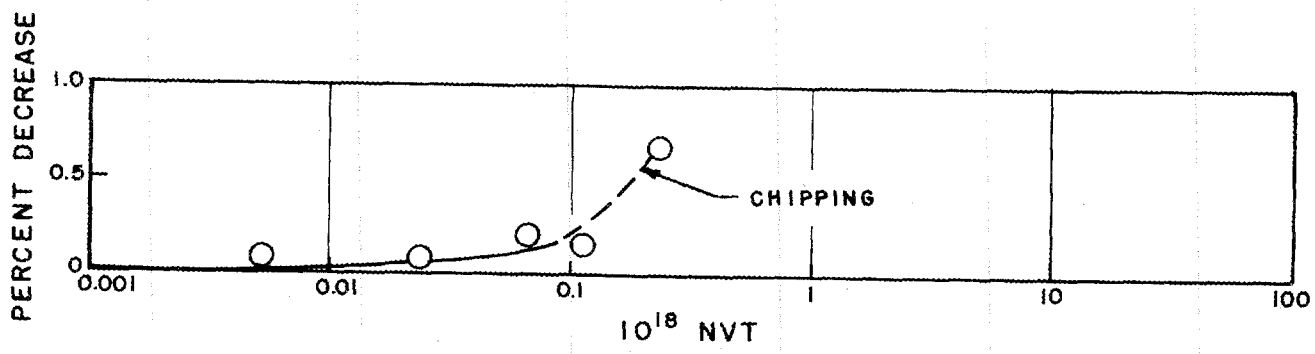
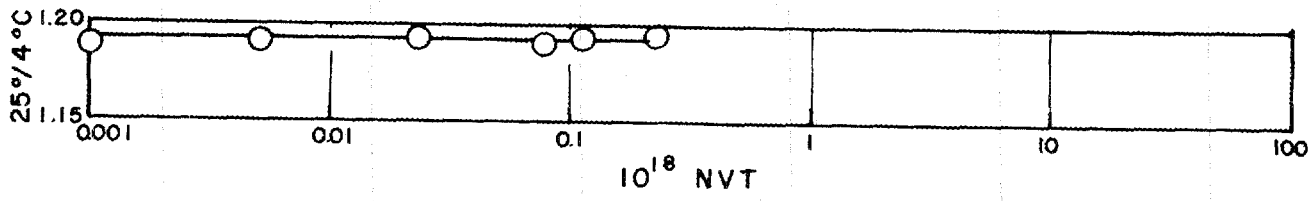


FIGURE 10B CELLULOSE ACETATE BUTYRATE

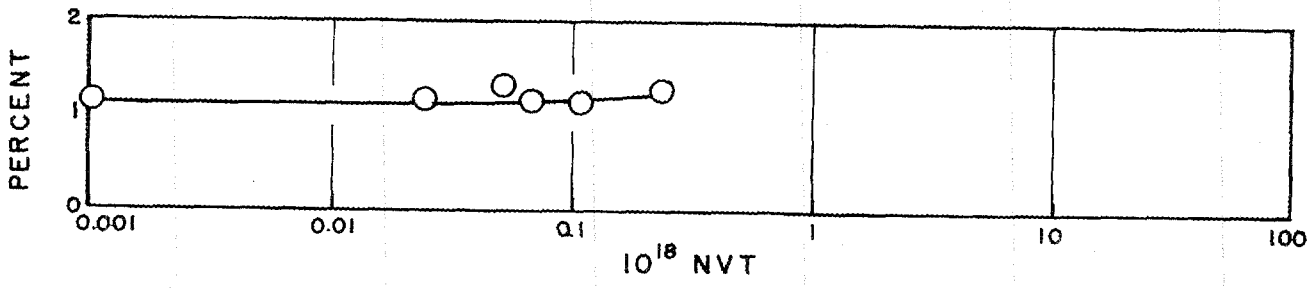
UNCLASSIFIED
DWG-#11098



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 10C CELLULOSE ACETATE BUTYRATE

UNCLASSIFIED
DWG.#11099

CELLULOSE ACETATE BUTYRATE

Volume Resistivity of 195 Mil Specimens

10^{18} nvt	ohm cm
0	$> 10^{14}$
0.07	5×10^{13}
0.26	2×10^{12}

Dielectric Strength of 20 Mil Specimens

10^{18} nvt	volts/mil
0	1000
0.53	700

Arc Resistance of 195 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	140	Melted
0.07	115	"
0.26	85	"

FIGURE 10 D

POLYTHENE

Classification:	Ethylene polymer
Trade name:	Polythene
Company:	E. I. du Pont de Nemours & Company, Inc.
Resin:	Polyethylene
Formula:	

$$\left[-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}- \right]_n$$

Filler:	None
Description:	Translucent, blue-white; darkens upon irradiation.
Thickness of sheets:	0.190 - 0.194 in.
Speed of tensile testing	
Mean rate of straining:	$1.0 - 2.0 \times 10^{-4}$ units/sec.
Mean rate of stressing:	5 - 20 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11100

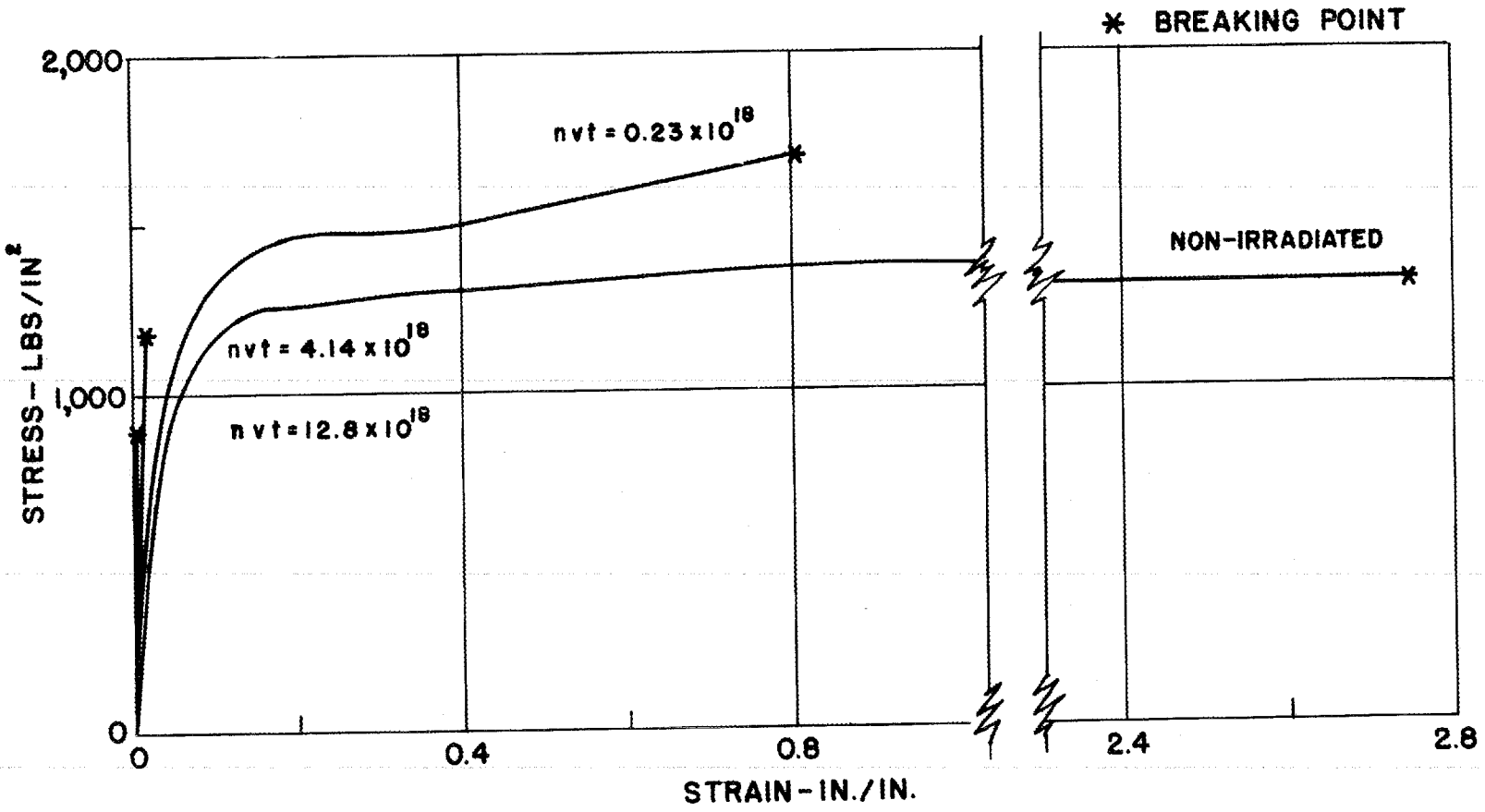
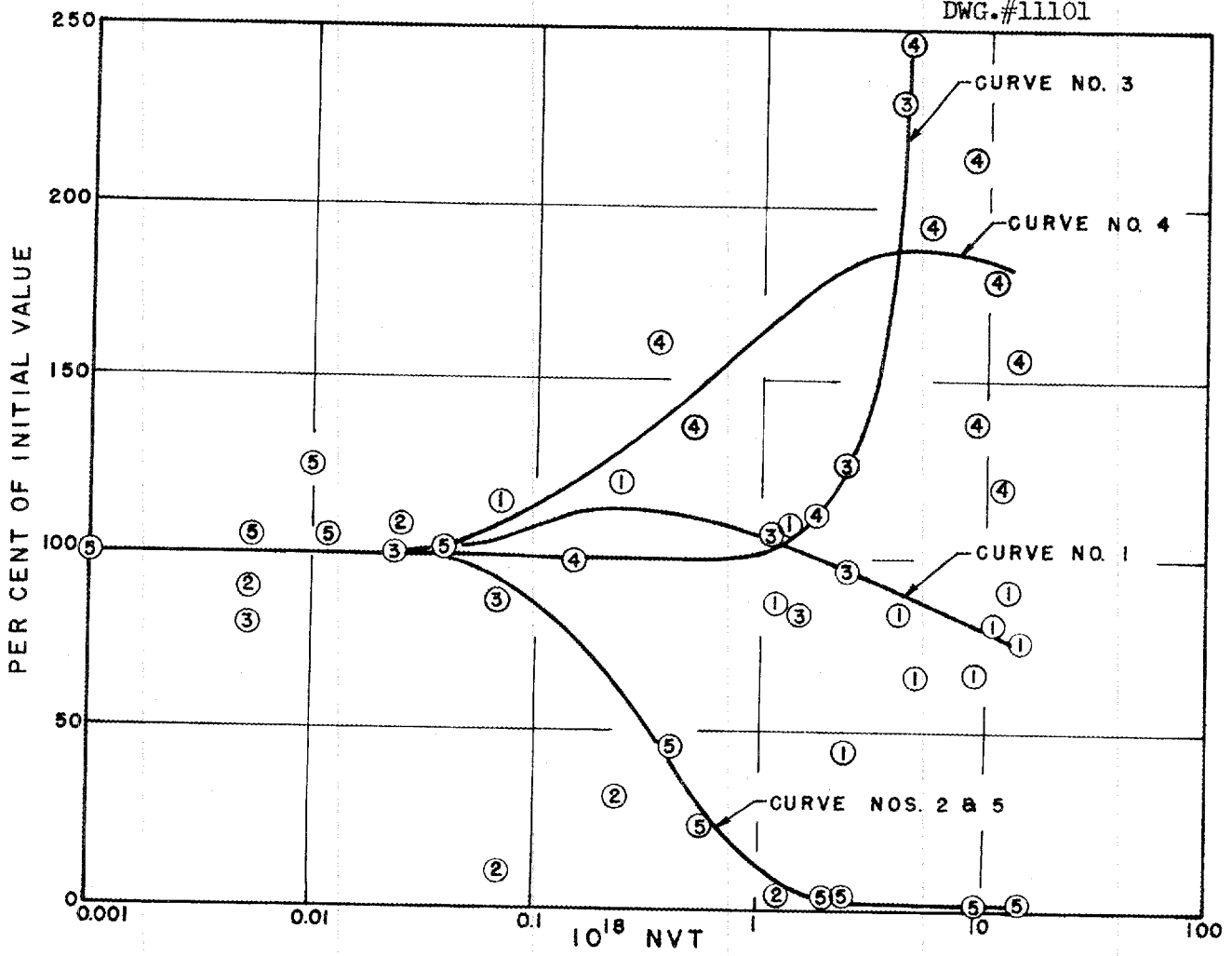
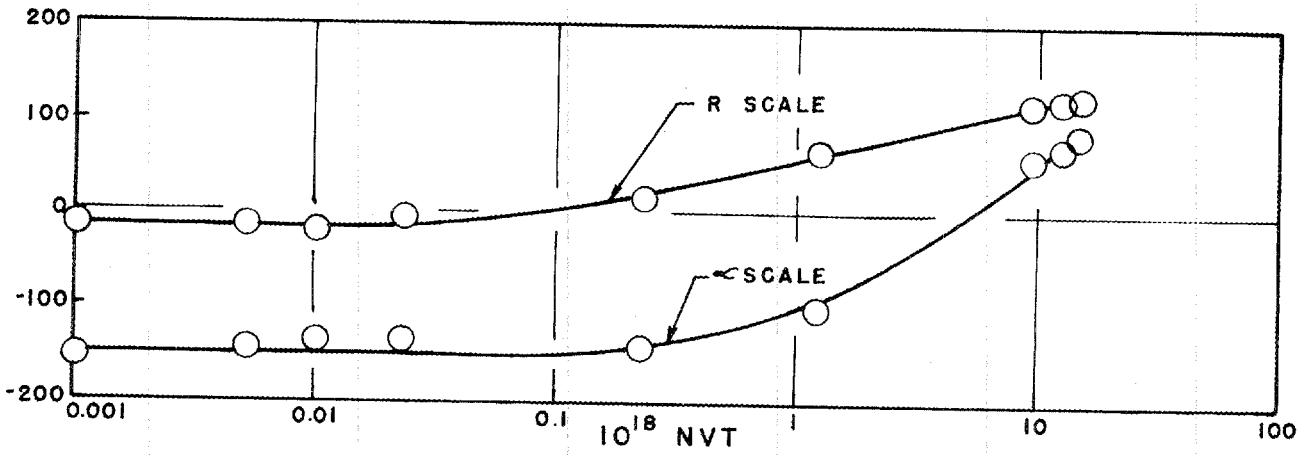


FIGURE 11A STRESS STRAIN CURVES FOR PILE IRRADIATED POLYETHYLENE

UNCLASSIFIED
DWG.#11101



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	1400 LBS. / SQ. IN.
2	ELONGATION	250 %
3	ELASTIC MODULUS	0.30 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	1400 LBS. / SQ. IN.
5	IMPACT STRENGTH	11.2 FT. LBS. / IN. OF NOTCH



ROCKWELL HARDNESS

FIGURE 11B POLYETHYLENE

UNCLASSIFIED
DWG.#11102

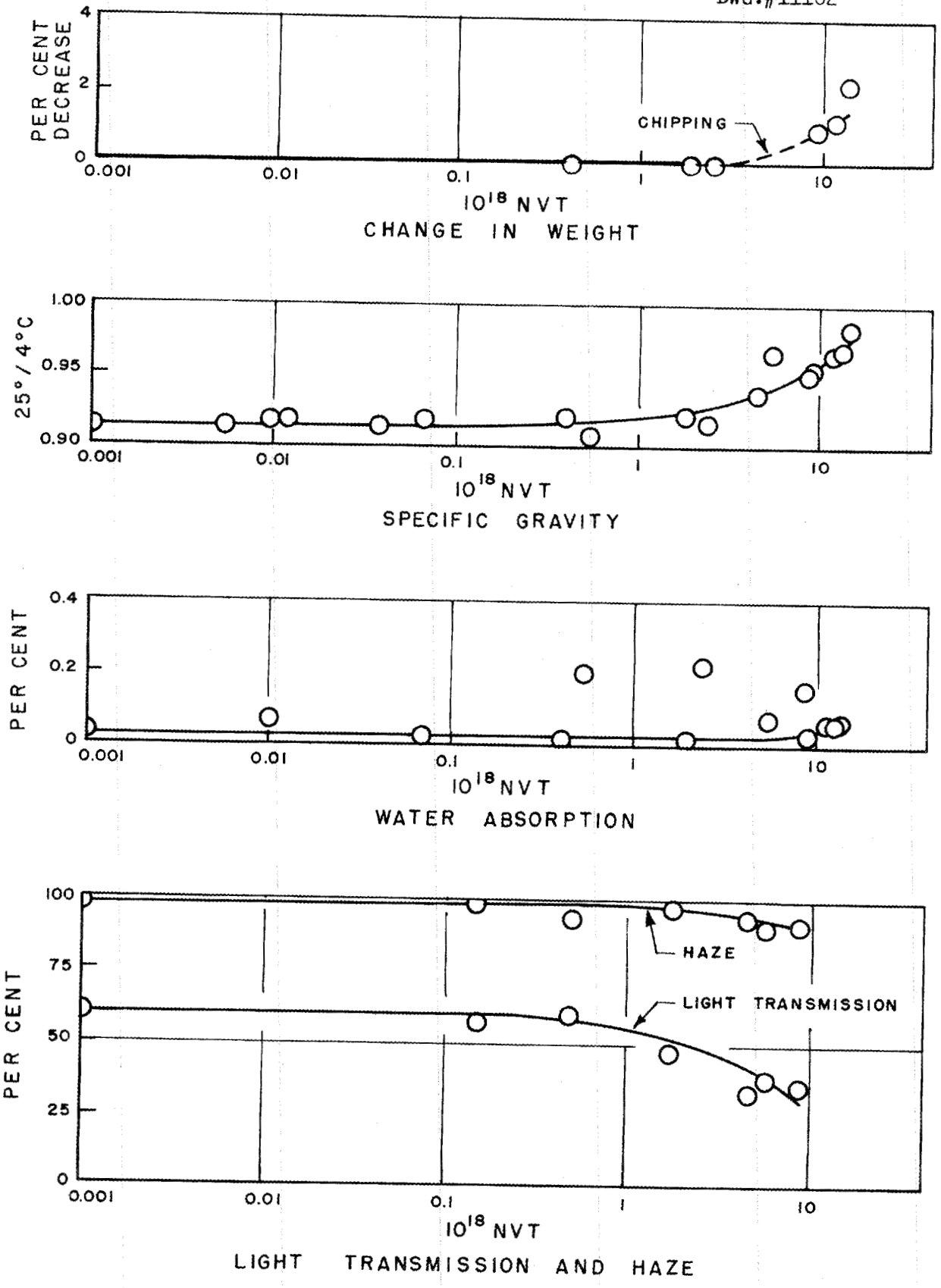


FIGURE IIC POLYETHYLENE

UNCLASSIFIED
DWG.#11103

POLYTHENE

Volume Resistivity of 65 Mil Specimens

10^{18} nvt	ohm cm
0	$> 10^{14}$
9	$> 10^{14}$

Dielectric Strength of 50 Mil Specimens

10^{18} nvt	volts/mil
0	> 600
15	500

Arc Resistance of 65 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	130	Melted
15	130	"

FIGURE 11 D

FLUOROTHENE

Classification:	Chlorofluoroethylene polymer
Trade name:	Fluorothene
Company:	K-25 (Fluorothene is similar to Kel-F made by the M. W. Kellog Co.)
Resin:	Monochlorotrifluoroethylene polymer

Formula:

$$\left[\begin{array}{cc} F & F \\ -C- & -C- \\ F & Cl \end{array} \right]_n$$

Filler:	None
Description:	Nearly transparent, but slightly hazy. Developes a orange-red tint upon irradiation
Thickness of sheets:	0.122 - 0.128 in.
Speed of tensile testing	
Mean rate of straining:	$0.9 - 1.9 \times 10^{-4}$ units/sec.
Mean rate of stressing:	15 - 40 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11104

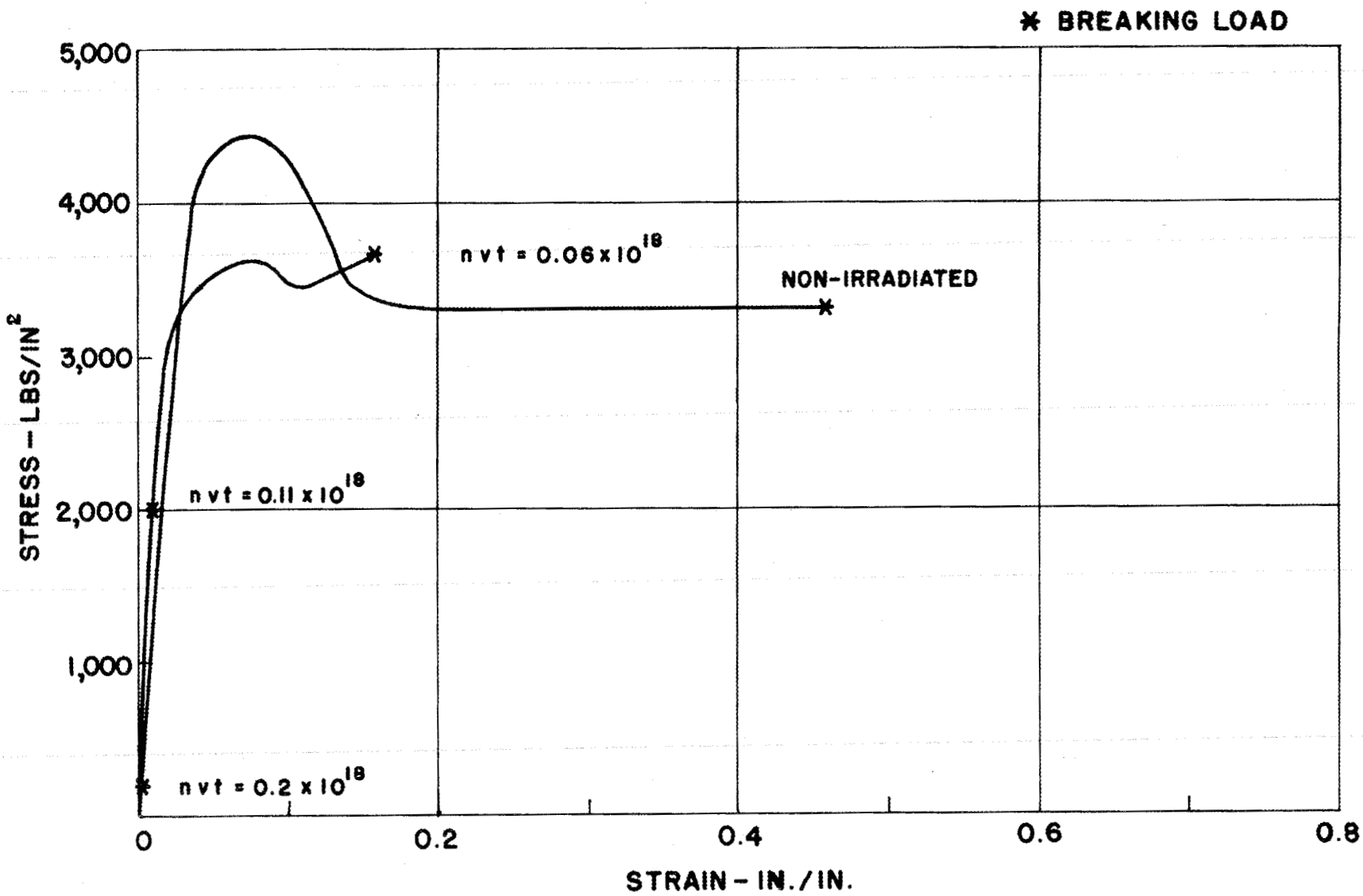
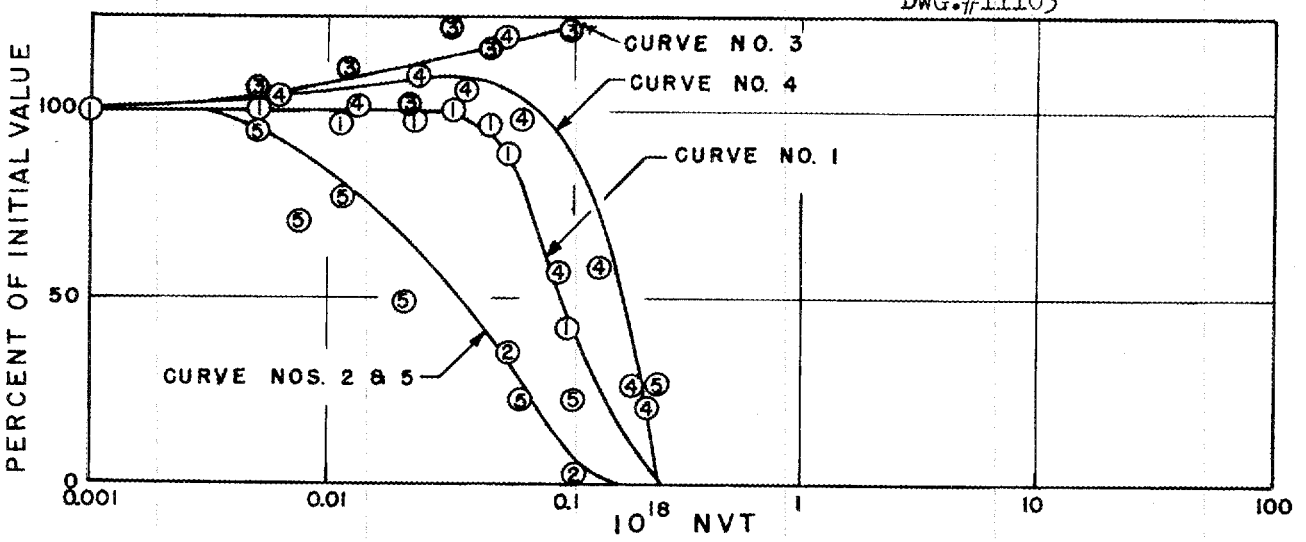
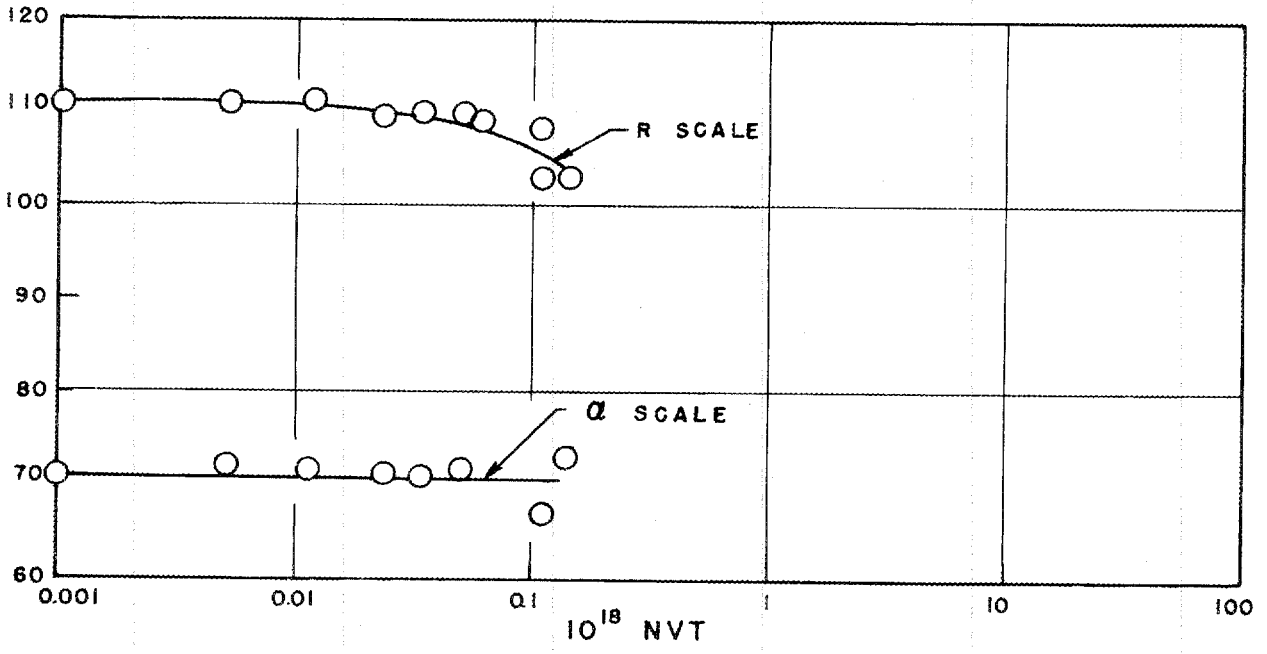


FIGURE 12A STRESS STRAIN CURVES FOR PILE IRRADIATED FLUOROTHENE

UNCLASSIFIED
DWG.#11105



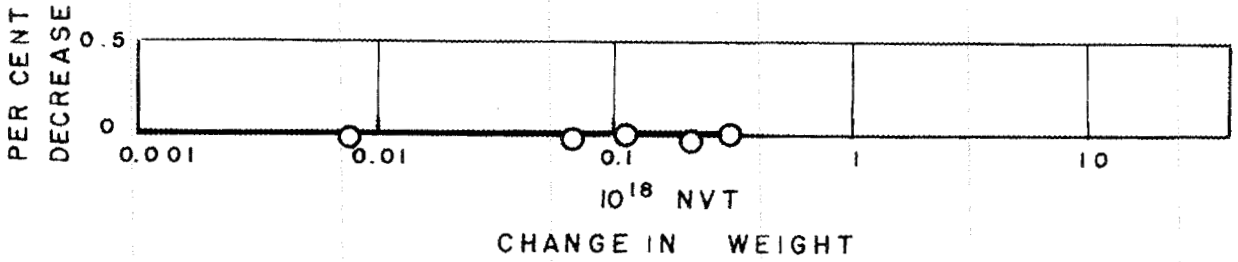
CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	4900 LBS./SQ. IN.
2	ELONGATION	50 %
3	ELASTIC MODULUS	1.8×10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	5300 LBS./SQ. IN.
5	IMPACT STRENGTH	1.9 FT LBS./IN. OF NOTCH



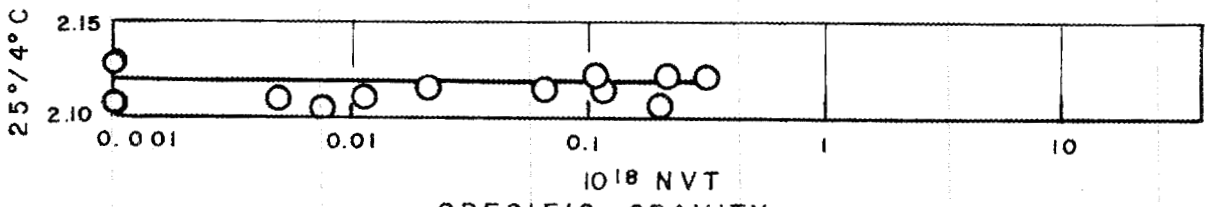
ROCKWELL HARDNESS

FIGURE 12B FLUOROTHENE

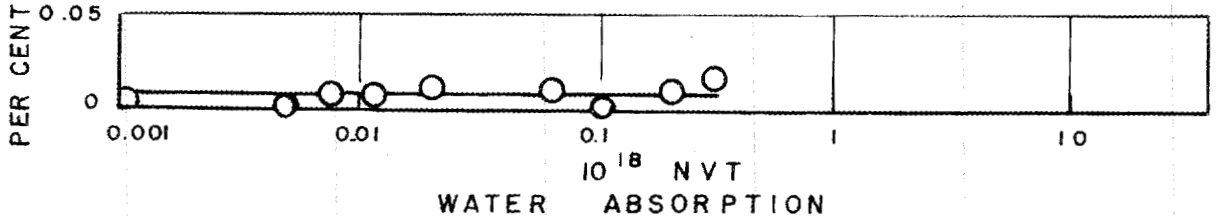
UNCLASSIFIED
DWG.#11106



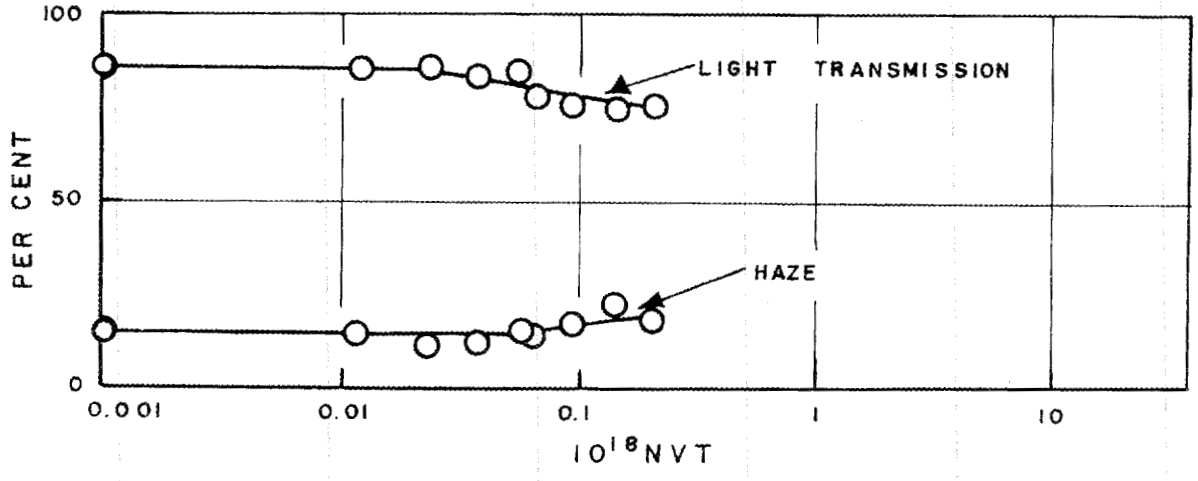
CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION



LIGHT TRANSMISSION AND HAZE

FIGURE 12C FLUOROTHENE

FLUOROTHENE

Volume Resistivity of 125 Mil Specimens

10^{18} nvt	ohm cm
0	$>10^{14}$
0.3	$>10^{14}$

Dielectric Strength of 30 Mil Specimens

10^{18} nvt	volts/mil
0	900
0.5	900

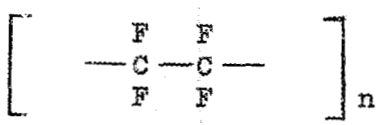
Arc Resistance of 125 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	200	Melted
0.3	200	"

FIGURE 12 D

TEFLON

Classification:	Fluoroethylene polymer
Trade name:	Teflon
Company:	E. I. du Pont de Nemours & Co., Inc.
Resin:	Polytetrafluoroethylene
Formula:	



Filler:	None
Description:	Opaque, white. No color change upon irradiation.
Thickness of sheets:	0.134 - 0.143 in.
Speed of tensile testing	
Mean rate of straining:	0.4 - 1.5 x 10^{-4} units/sec.
Mean rate of stressing:	5 - 12 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11108

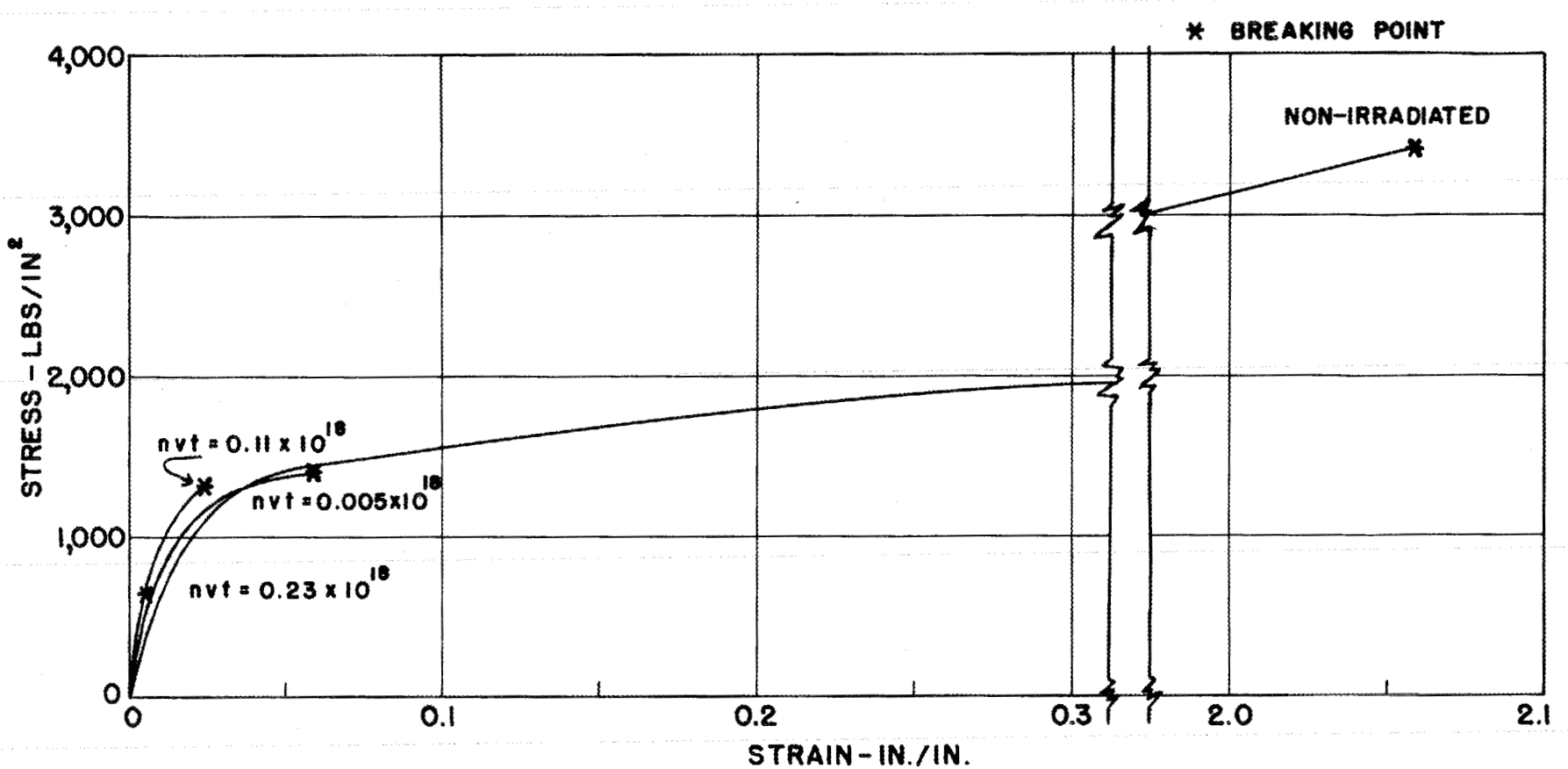
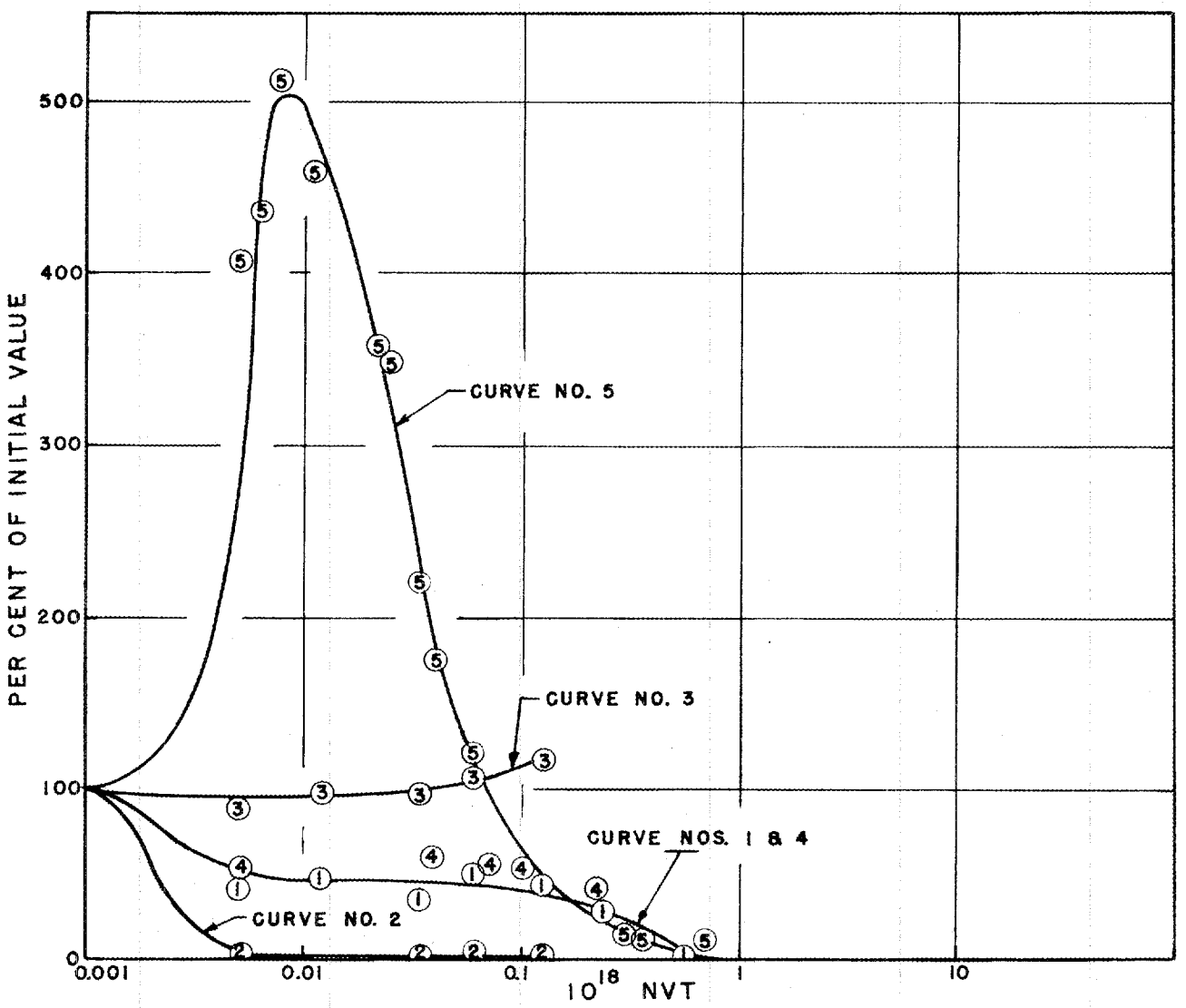


FIGURE 13A STRESS STRAIN CURVES FOR PILE IRRADIATED TEFLON
(POLYTETRAFLUOROETHYLENE)

UNCLASSIFIED
DWG.#11109



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	3400 LBS./SQ. IN.
2	ELONGATION	250 %
3	ELASTIC MODULUS	1.0×10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	2830 LBS./SQ. IN.
5	IMPACT STRENGTH	3.3 FT. LBS./IN. OF NOTCH

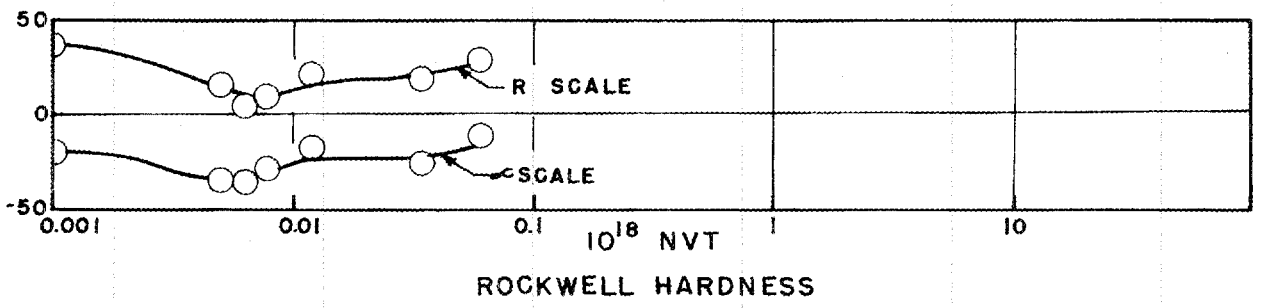
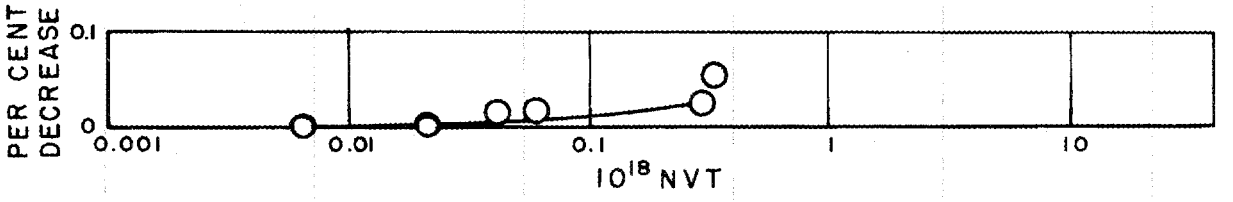
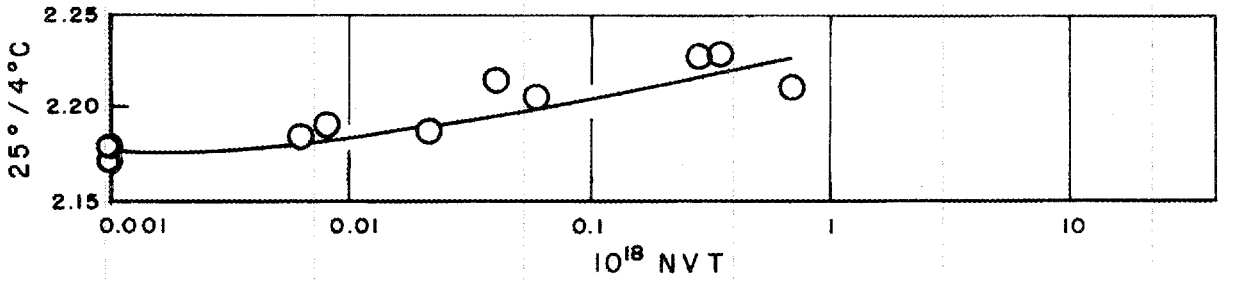


FIGURE 13B POLYTETRAFLUOROETHYLENE

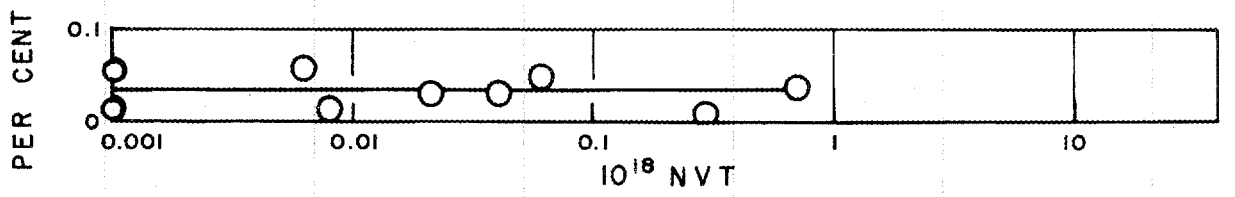
UNCLASSIFIED
DWG.#11110



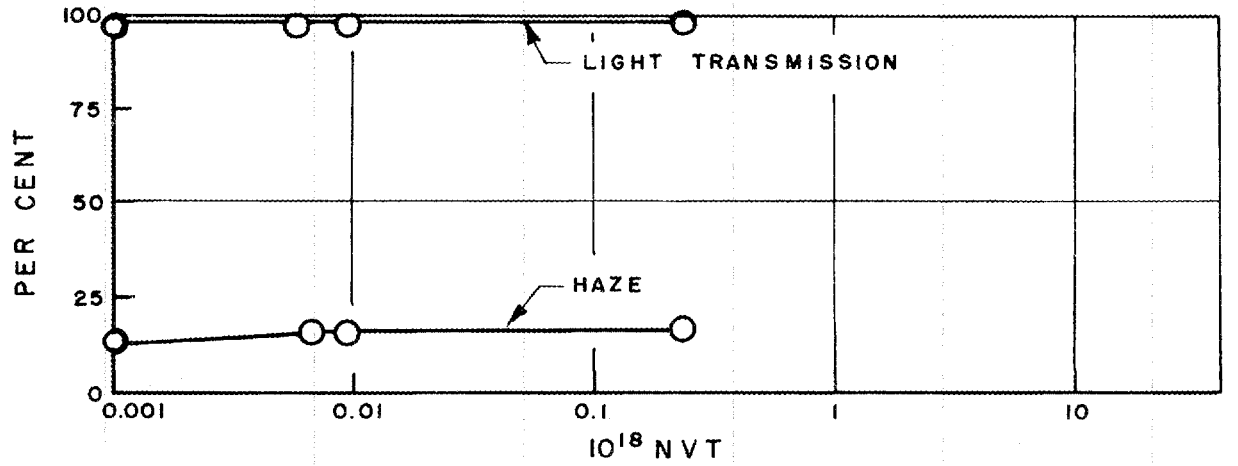
CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION



LIGHT TRANSMISSION AND HAZE

FIGURE 13C POLYTETRAFLUOROETHYLENE

TEFLON

Volume Resistivity of 135 Mil Specimens

10^{18} nvt	ohm cm
0	$>10^{14}$
0.23	10^{14}

Dielectric Strength of 23 Mil Specimens

10^{18} nvt	volts/mil
0	1100
0.53	800

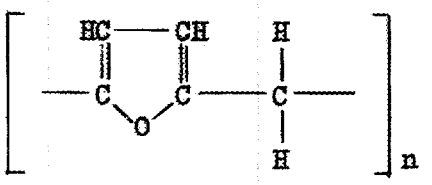
Arc Resistance of 135 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	>300	(electrode holder burned)
0.23	250	Melted

FIGURE 13 D

DURALON

Classification:	Furan resin
Trade name:	Duralon
Company:	U. S. Stoneware Company
Resin:	Furan
Formula:	



Filler:	Asbestos and carbon black
Description:	Opaque, black - no color change upon irradiation.
Thickness of sheets:	0.368 - 0.373 in.
Speed of tensile testing	
Mean rate of straining:	0.4 - 0.5 x 10^{-4} units/sec.
Mean rate of stressing:	20 - 30 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11112

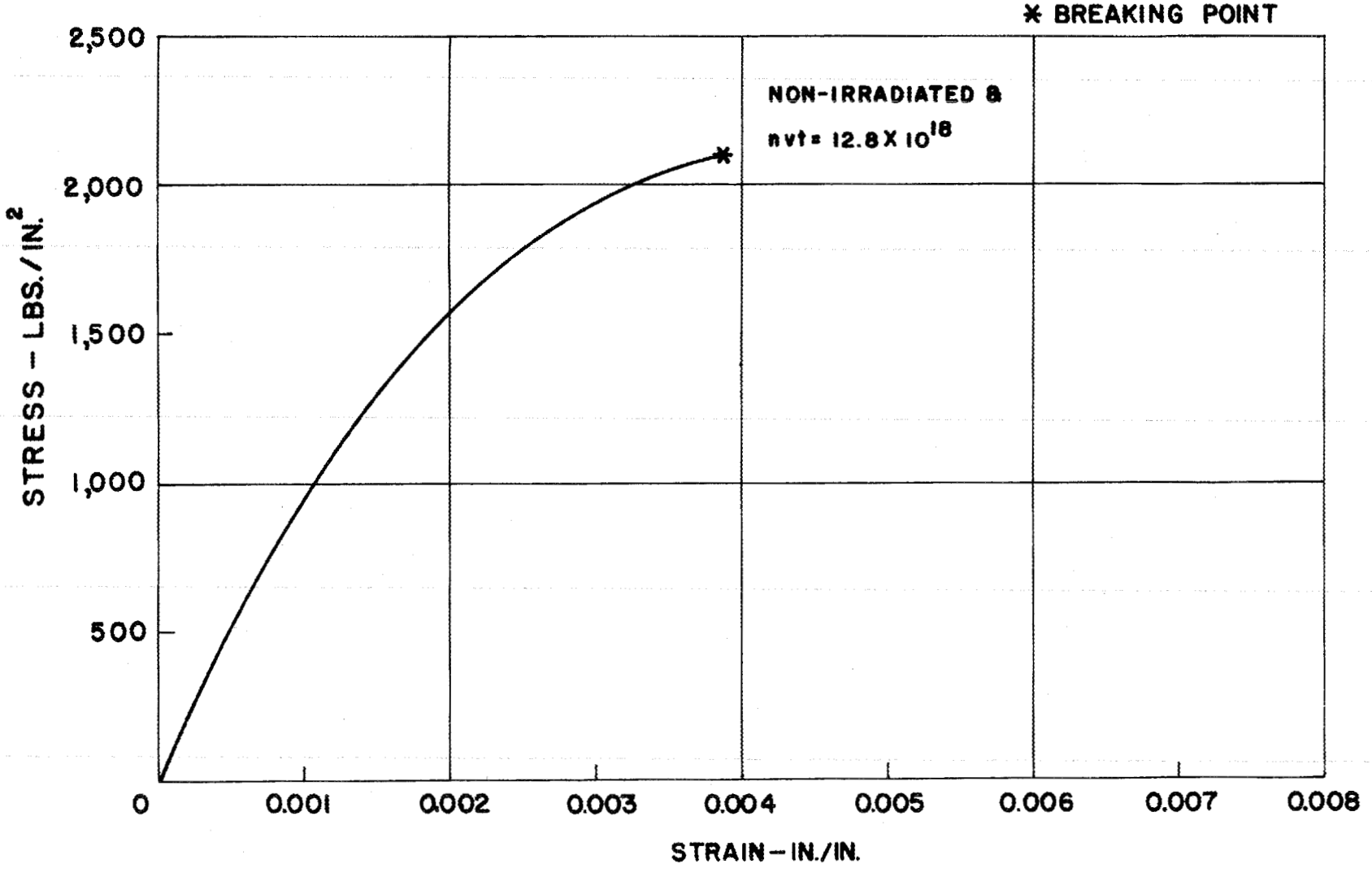
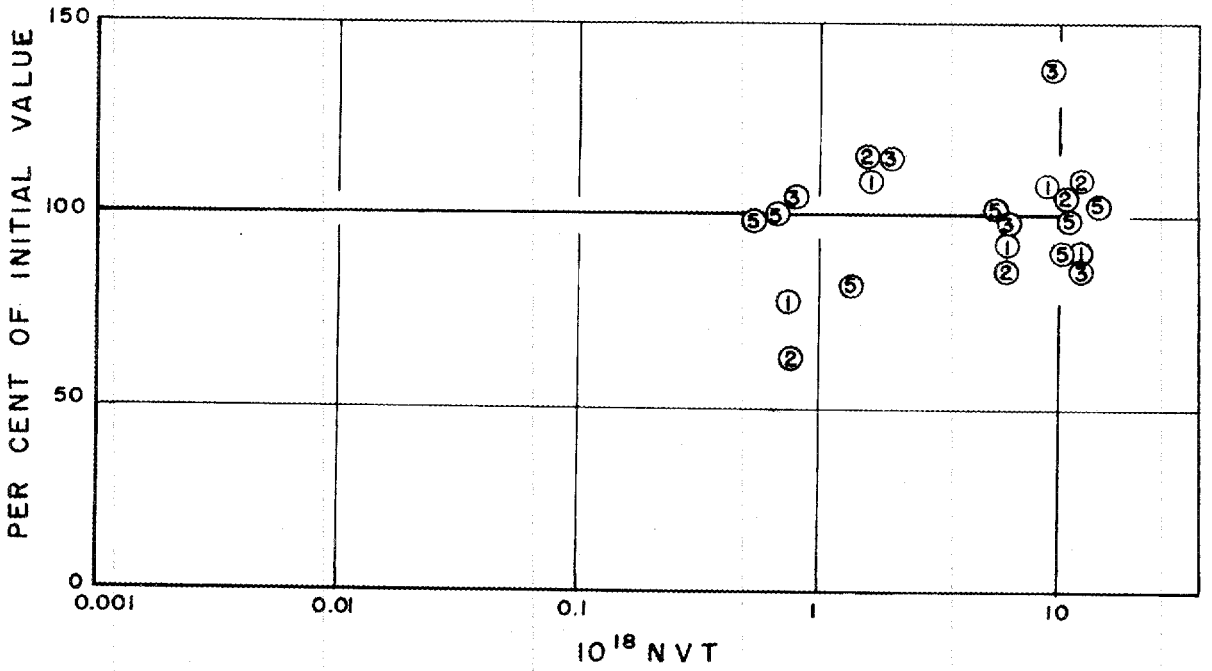


FIGURE 14A STRESS STRAIN CURVES FOR PILE IRRADIATED FURAN RESIN

(ASBESTOS AND CARBON BLACK FILLER)

UNCLASSIFIED
DWG.#11113



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	2,200 LBS./SQ. IN.
2	ELONGATION	0.39 %
3	ELASTIC MODULUS	8 X 10^5 LBS./SQ. IN.
5	IMPACT STRENGTH	0.31 FT. LBS./IN. OF NOTCH

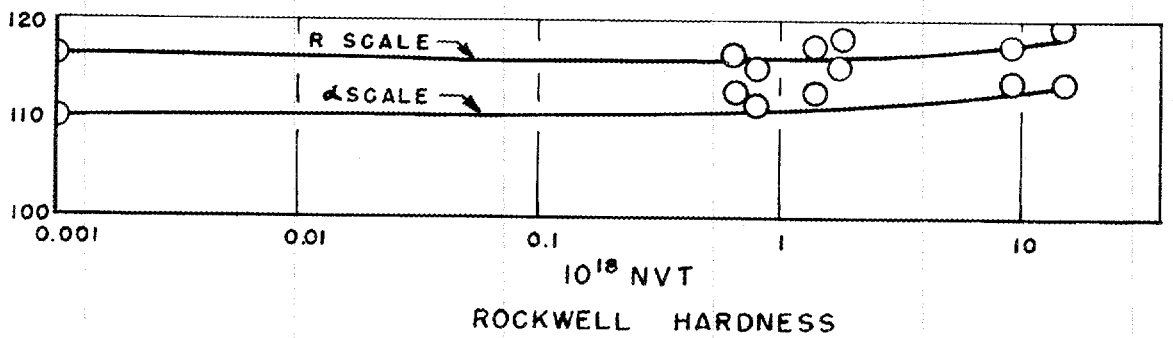
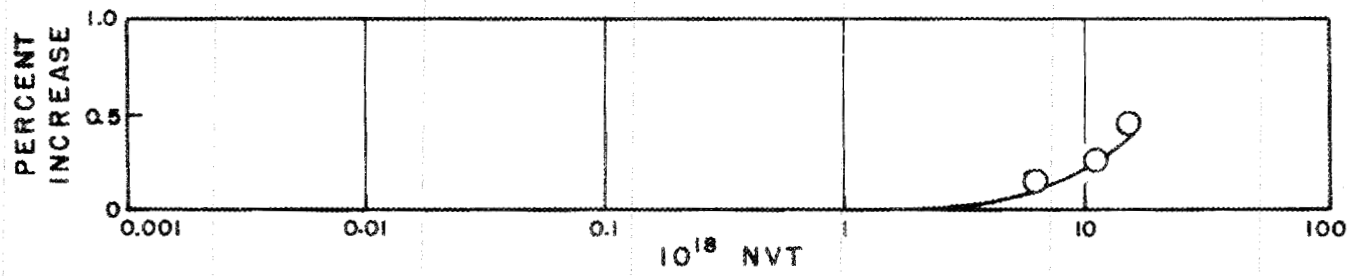
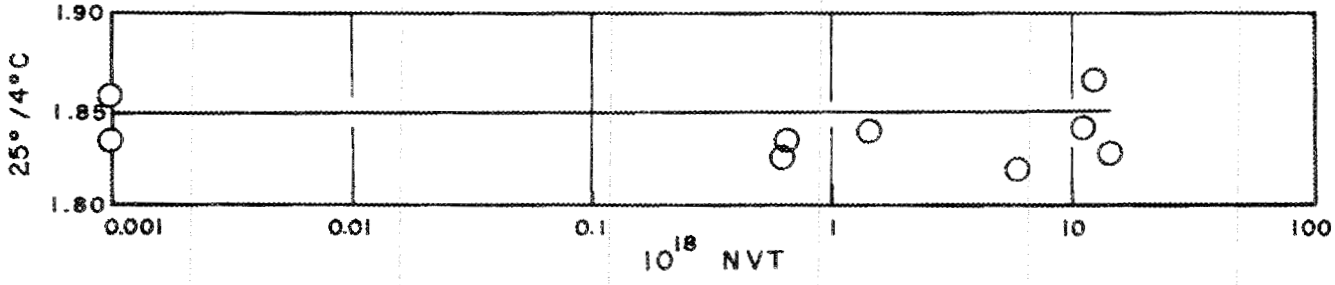


FIGURE 14B FURAN RESIN (ASBESTOS & CARBON BLACK FILLER)

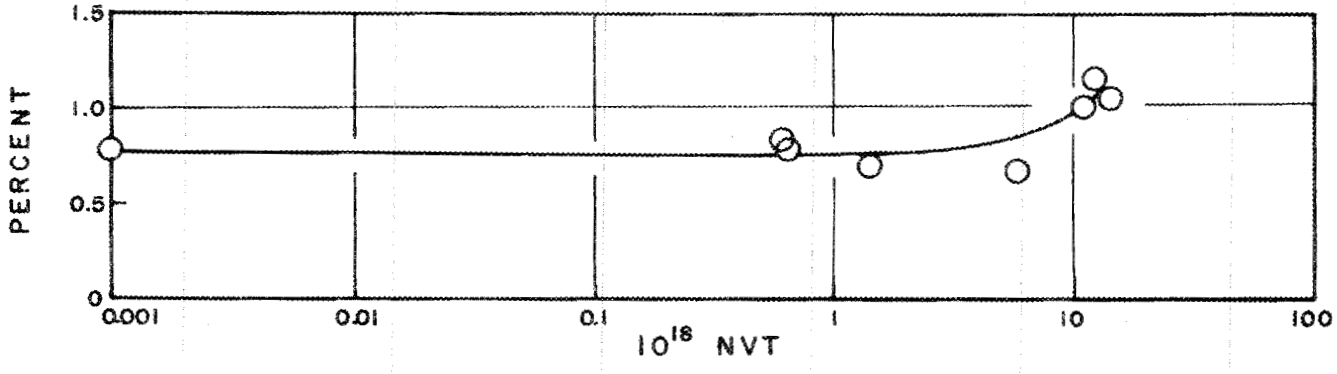
UNCLASSIFIED
DWG.#11114



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 14C FURAN RESIN (Asbestos & Carbon Black Filler)

UNCLASSIFIED
DWG.#11115

DURALON

Volume Resistivity of 175 Mil Specimens

10^{18} nvt	ohm cm
0	10^9
15	10^9

Dielectric Strength of 175 Mil Specimens

10^{18} nvt	volts/mil
0	55
11	55

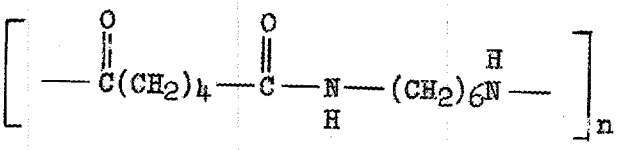
Arc Resistance of 175 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	4	Carbonized
15	4	"

FIGURE 14 D

NYLON FM-3003

Classification:	Nylon resin
Trade name:	Nylon FM-3003
Company:	E. I. du Pont de Nemours & Co., Inc.
Resin:	Polyamide
Formula:	



Filler:	None
Description:	Translucent, blue-white. Darkens upon irradiation.
Thickness of sheets:	0.223 - 0.270 in.
Speed of tensile testing	
Mean rate of straining:	0.8 - 1.3 x 10^{-4} units/sec.
Mean rate of stressing:	20 - 40 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11116

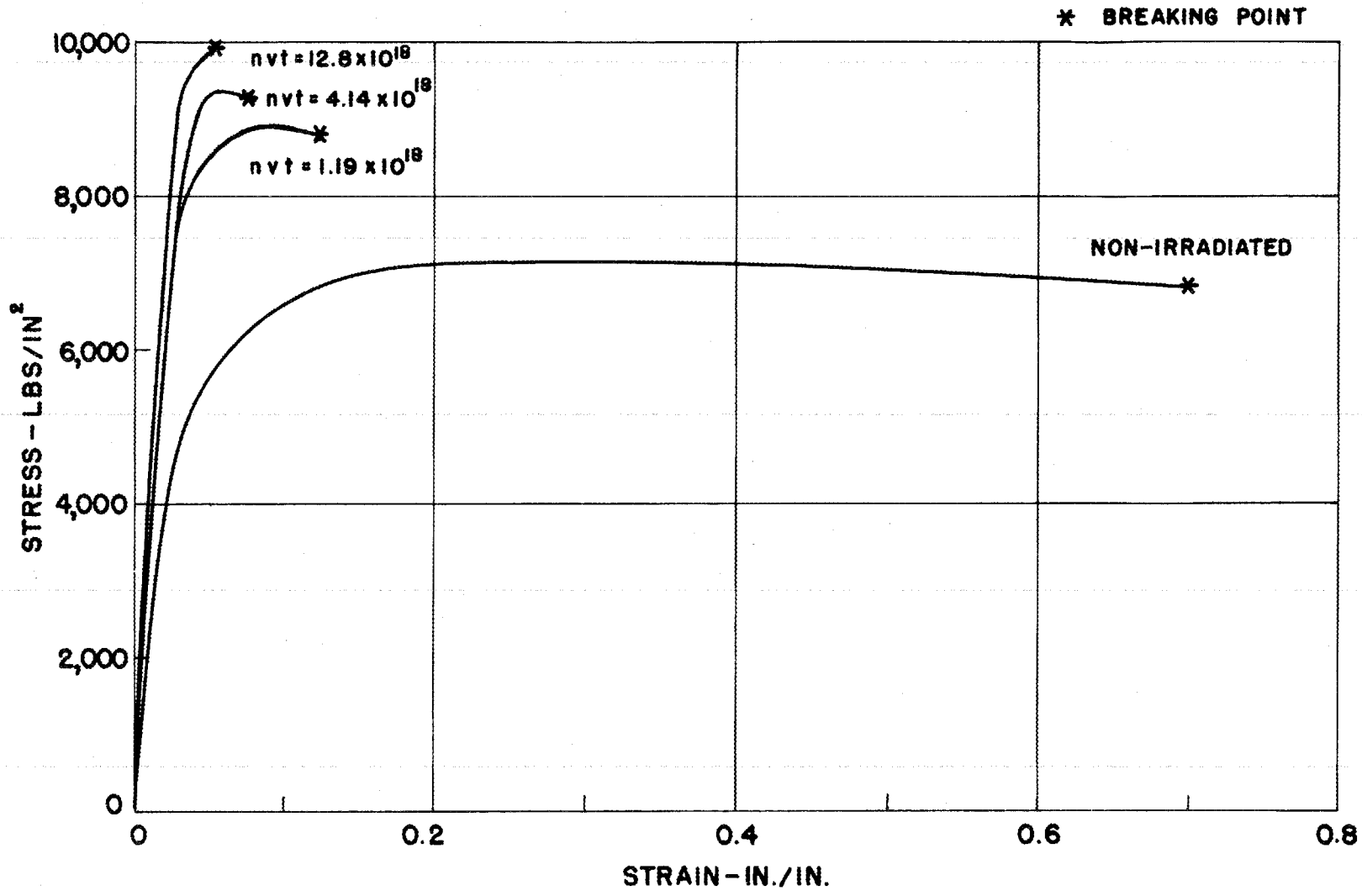
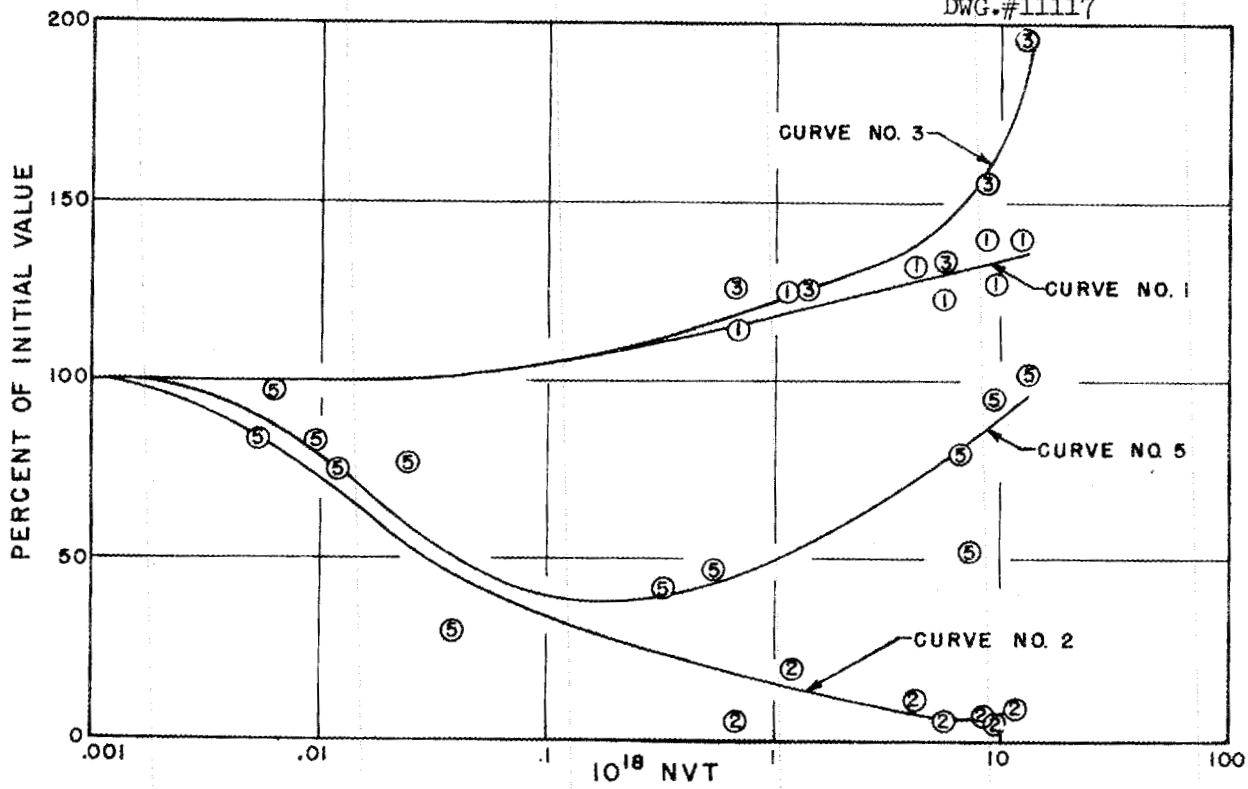
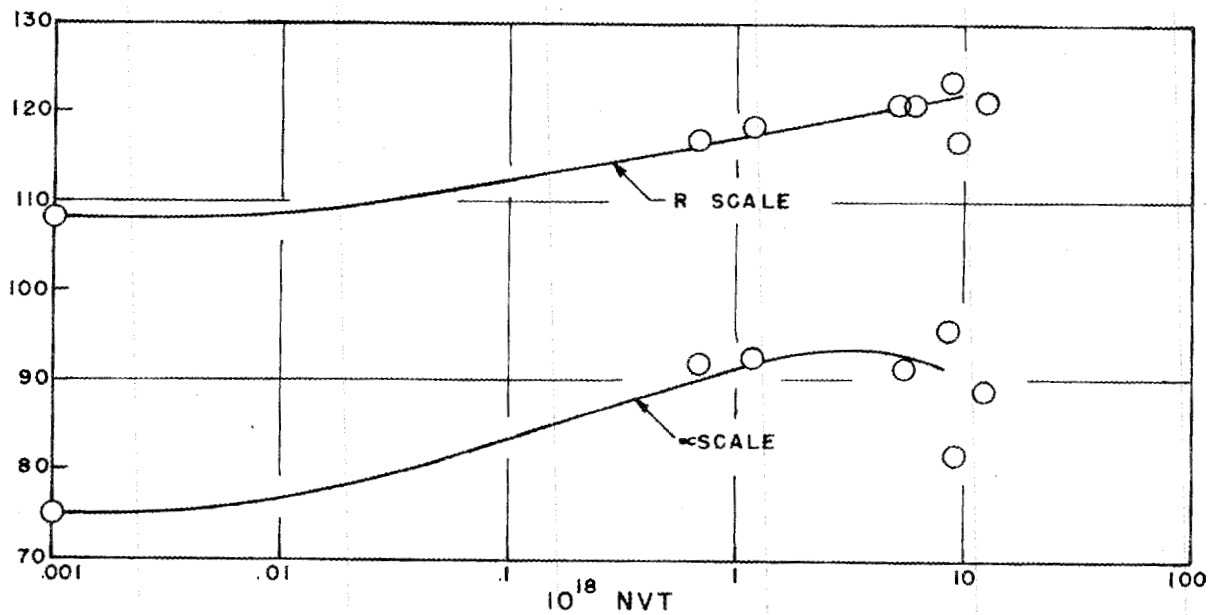


FIGURE 15A STRESS STRAIN CURVES FOR PILE IRRADIATED NYLON FM-3003

UNCLASSIFIED
DWG.#11117



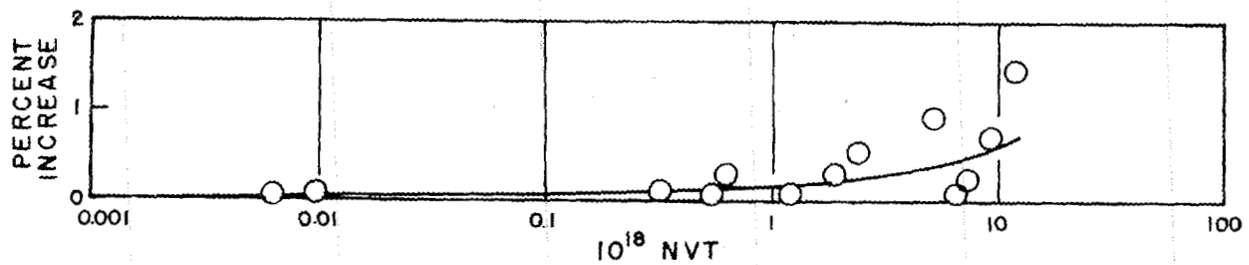
CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	7,100 LBS./SQ. IN.
2	ELONGATION	70 %
3	ELASTIC MODULUS	2.3×10^5 LBS./SQ. IN.
5	IMPACT STRENGTH	0.48 FT. LBS./IN. OF NOTCH



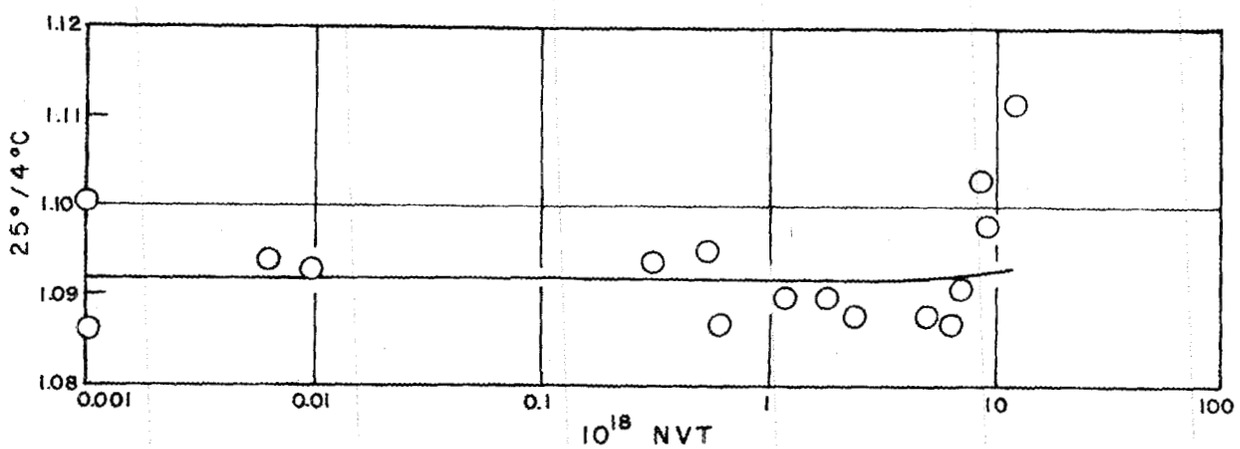
ROCKWELL HARDNESS

FIGURE 15B NYLON FM 3003

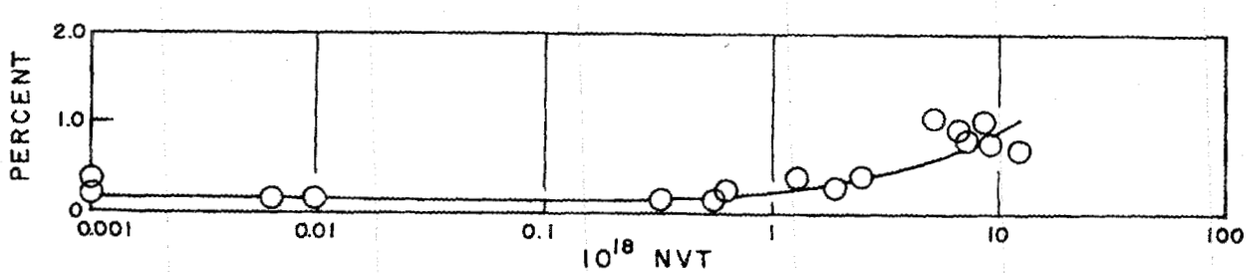
UNCLASSIFIED
DWG.#11118



CHANGE IN WEIGHT



SPECIFIC GRAVITY

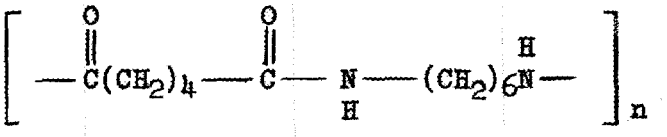


WATER ABSORPTION

FIGURE 15C NYLON FM-3003

NYLON FM-10001

Classification:	Nylon resin
Trade name:	Nylons FM-10001 and FM-1
Company:	E. I. du Pont de Nemours & Co., Inc.
Resin:	Polyamide
Formula:	



Filler:	None
Description:	Translucent, blue-white. Darkens upon irradiation.
Thickness of sheets:	0.103 - 0.113 in.
Speed of tensile testing	
Mean rate of straining:	0.4 - 1.4 x 10^{-4} units/sec.
Mean rate of stressing:	20 - 40 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11119

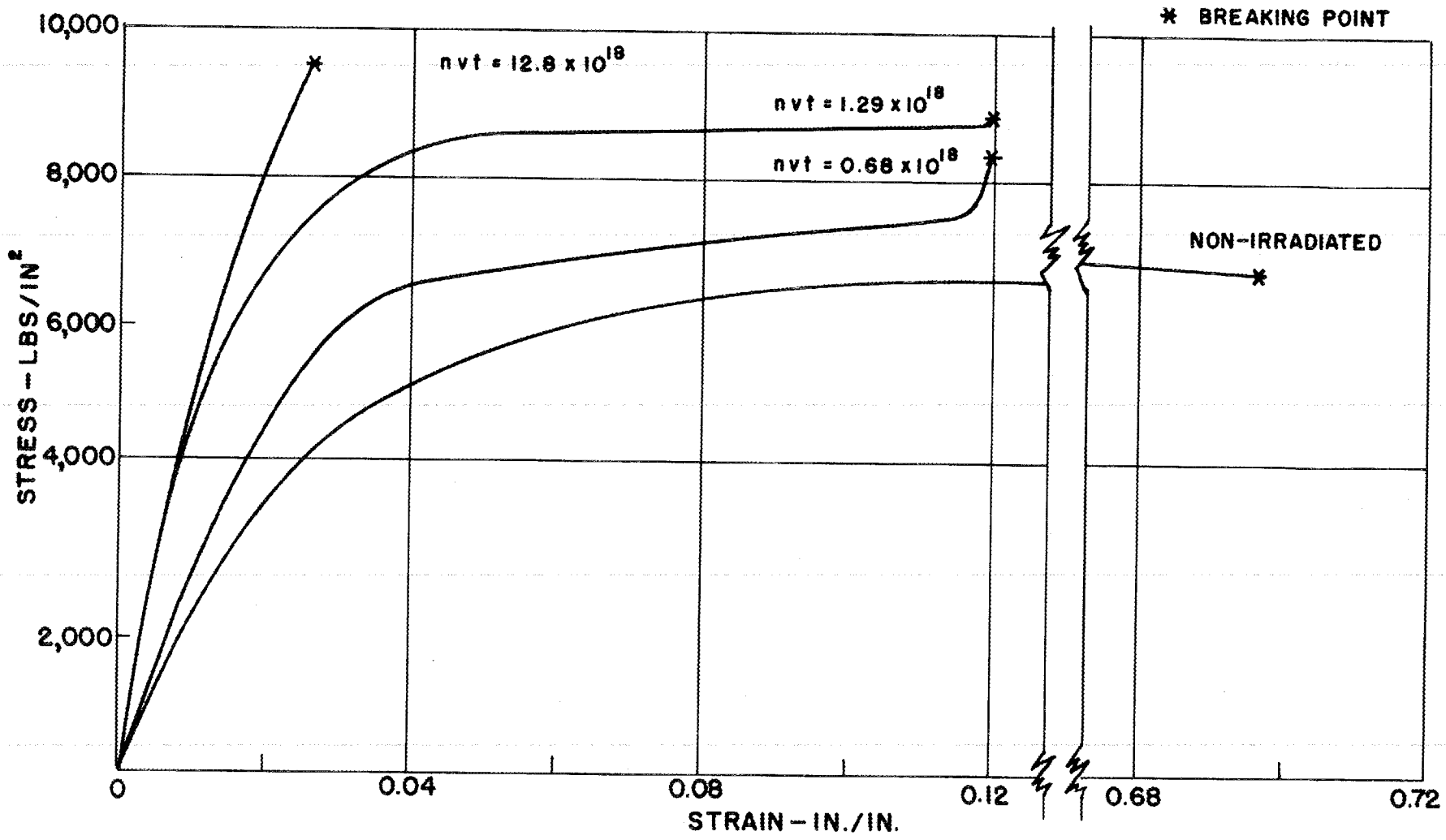
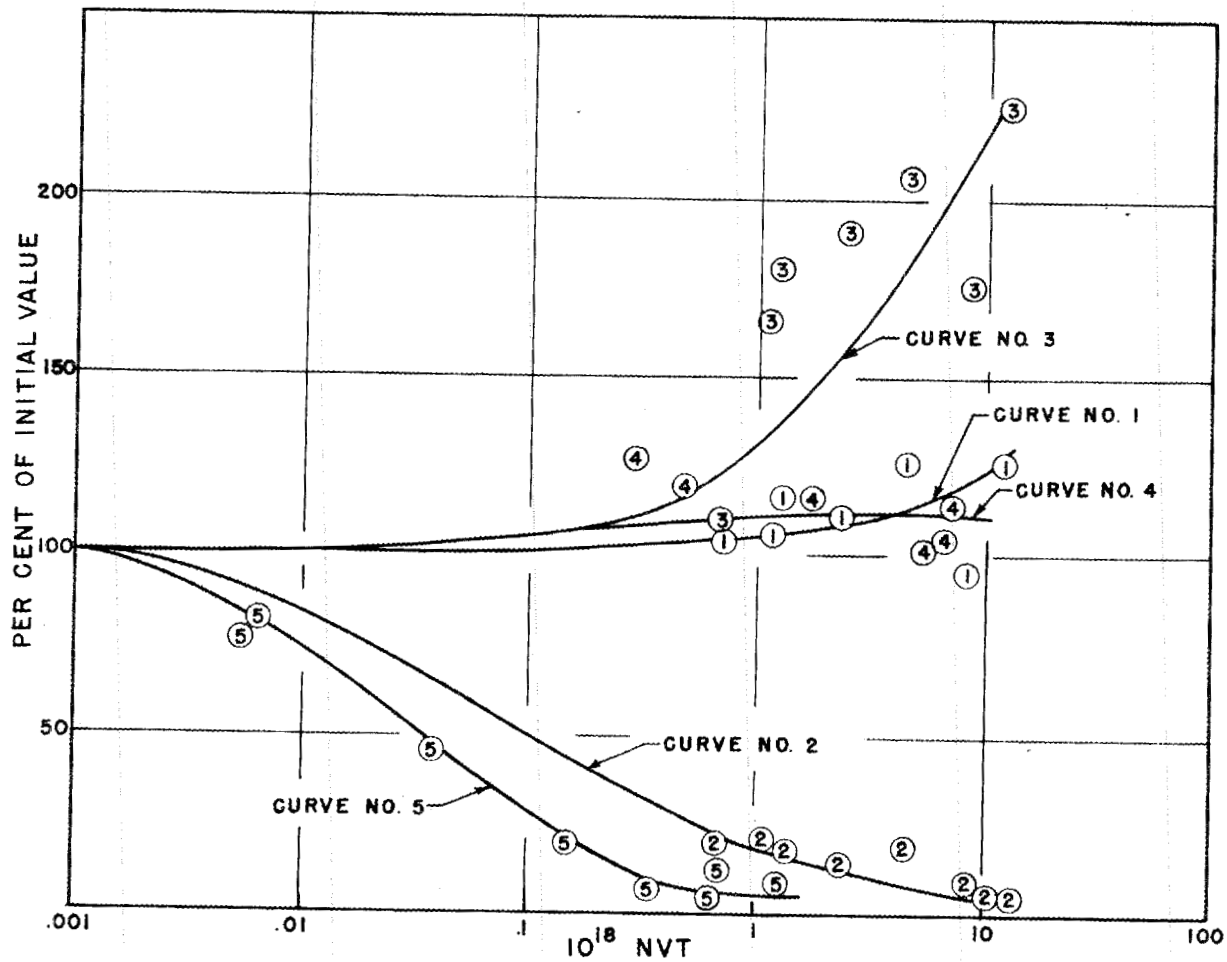


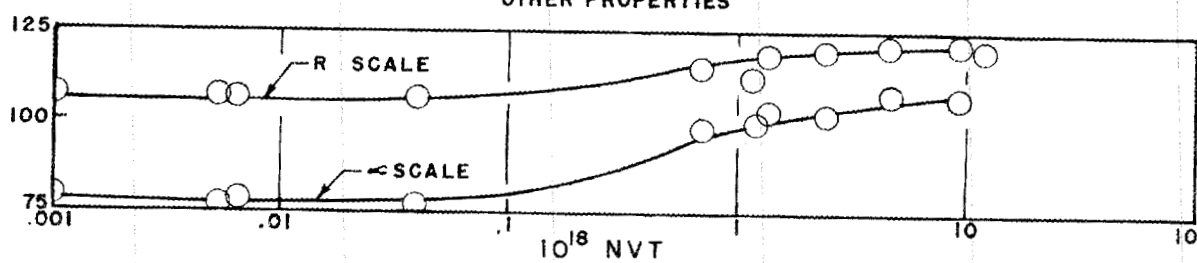
FIGURE 16A STRESS STRAIN CURVES FOR PILE IRRADIATED NYLON-FM 10,001

UNCLASSIFIED
DWG.#11120



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	7600 LBS./SQ. IN.
2	ELONGATION	62 %
3	ELASTIC MODULUS	2.0×10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	7300 LBS./SQ. IN.*
5	IMPACT STRENGTH	2.8 FT. LBS./IN. OF NOTCH

*NYLON FM-1 SPECIMENS USED FOR SHEAR STRENGTH; NYLON FM-10001, FOR THE OTHER PROPERTIES



ROCKWELL HARDNESS

FIGURE 16B NYLON FM-10001

UNCLASSIFIED
DWG.#11121

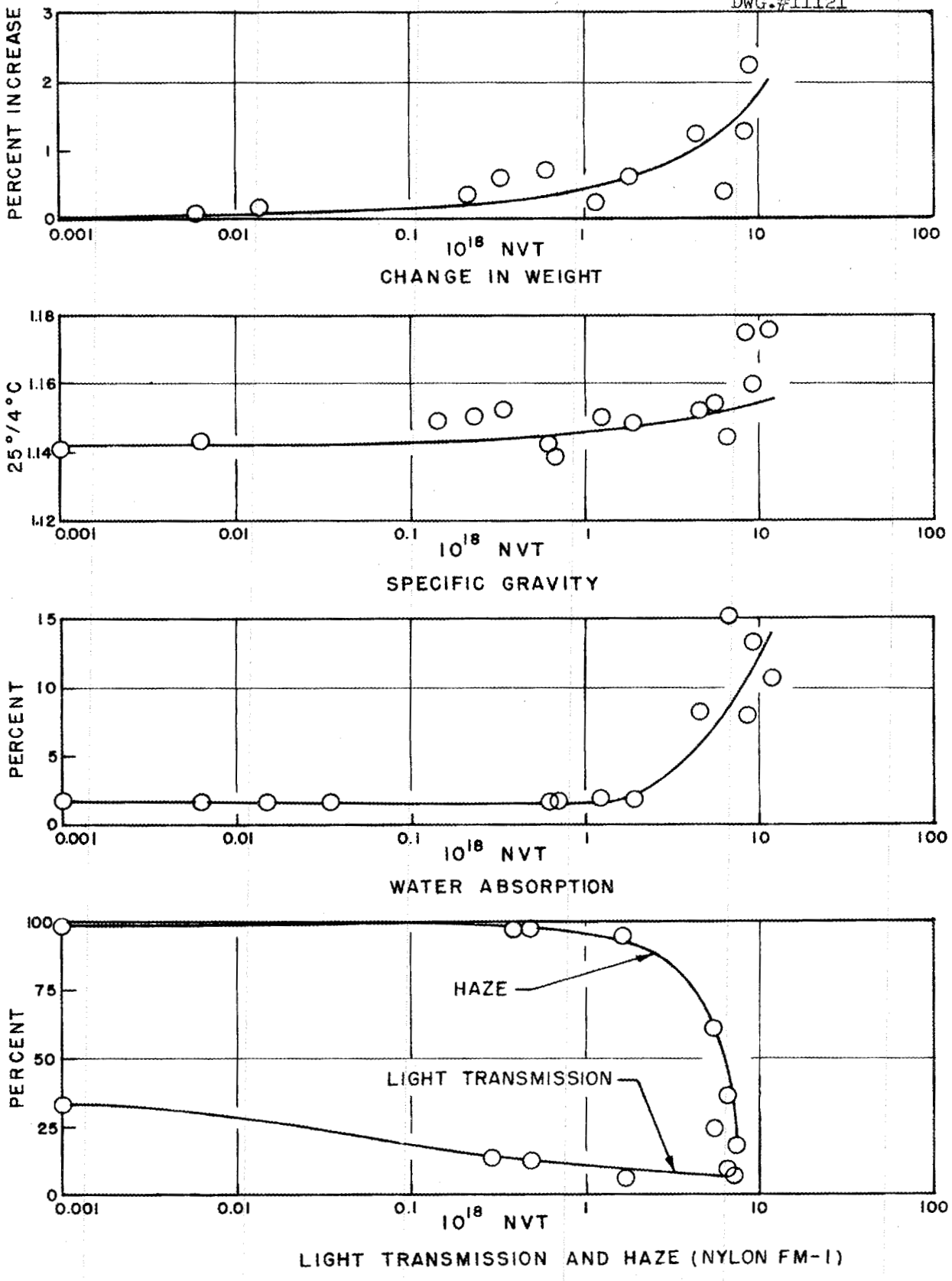


FIGURE 16C NYLON FM-10001

UNCLASSIFIED
DWG.#11122

NYLON FM-1

Volume Resistivity of 140 Mil Specimens

10^{18} nvt	ohm cm
0	1×10^{13}
7	4×10^{13}

Dielectric Strength of 26-32 Mil Specimens

10^{18} nvt	volts/mil
0	860
5	860

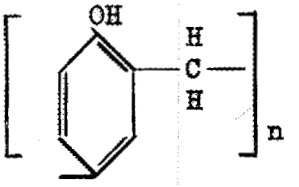
Arc Resistance of 140 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	120	Carbonized
0.29	100	"
1.7	80	"
7	70	"

FIGURE 16 D

ASBESTOS-FABRIC BAKELITE

Classification:	Phenolic, mineral-filled
Trade name:	Bakelite
Company:	Bakelite Division, Union Carbide and Carbon Corporation
Resin:	Phenol-formaldehyde
Formula:	



Filler:	Asbestos fabric (laminate)
Description:	Opaque, brown with fabric texture. Darkens upon irradiation.
Thickness of sheets:	0.124 - 0.128 in.
Speed of tensile testing	
Mean rate of straining:	0.5 - 1.0 x 10^{-4} units/sec.
Mean rate of stressing:	50 - 100 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11123

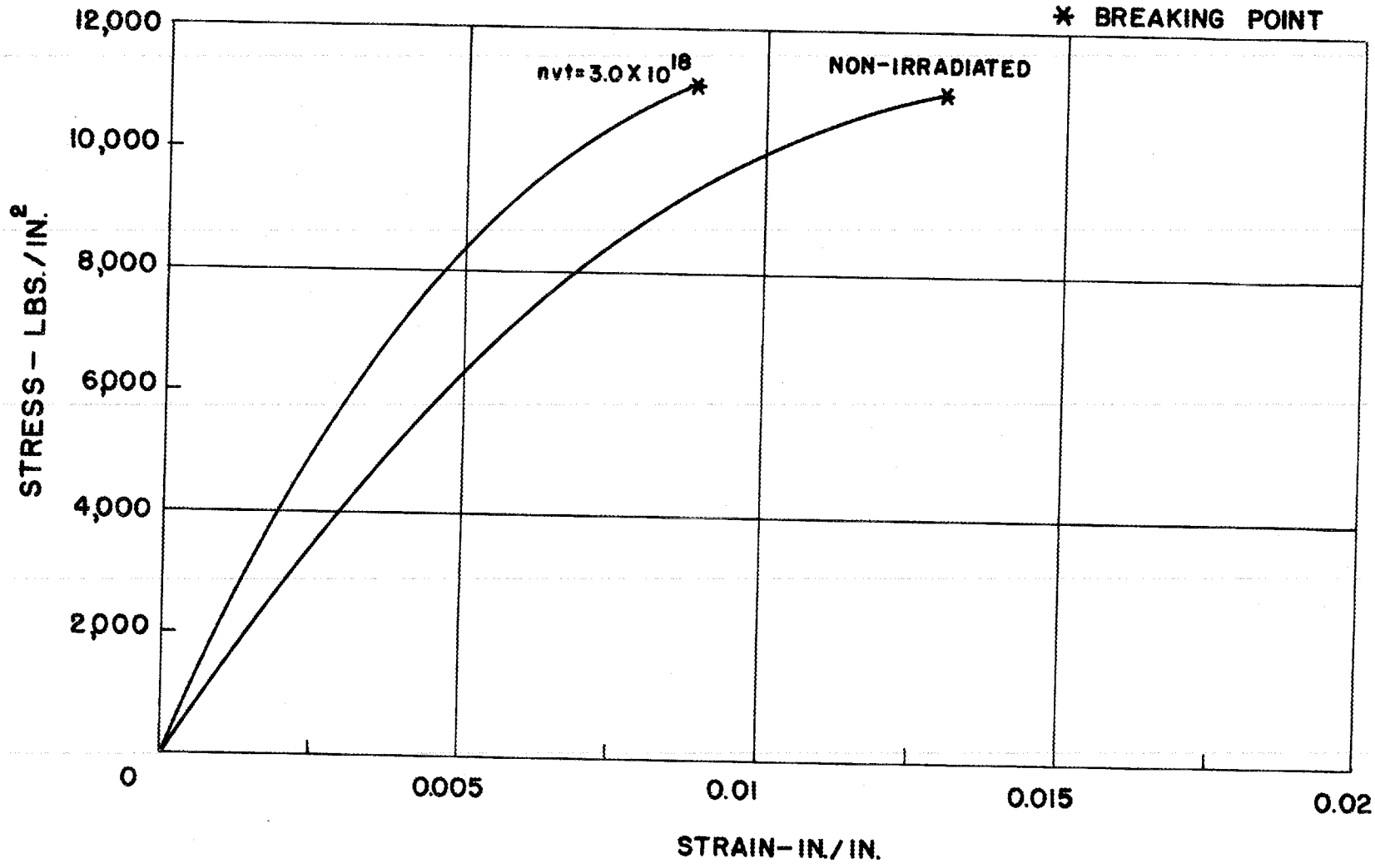
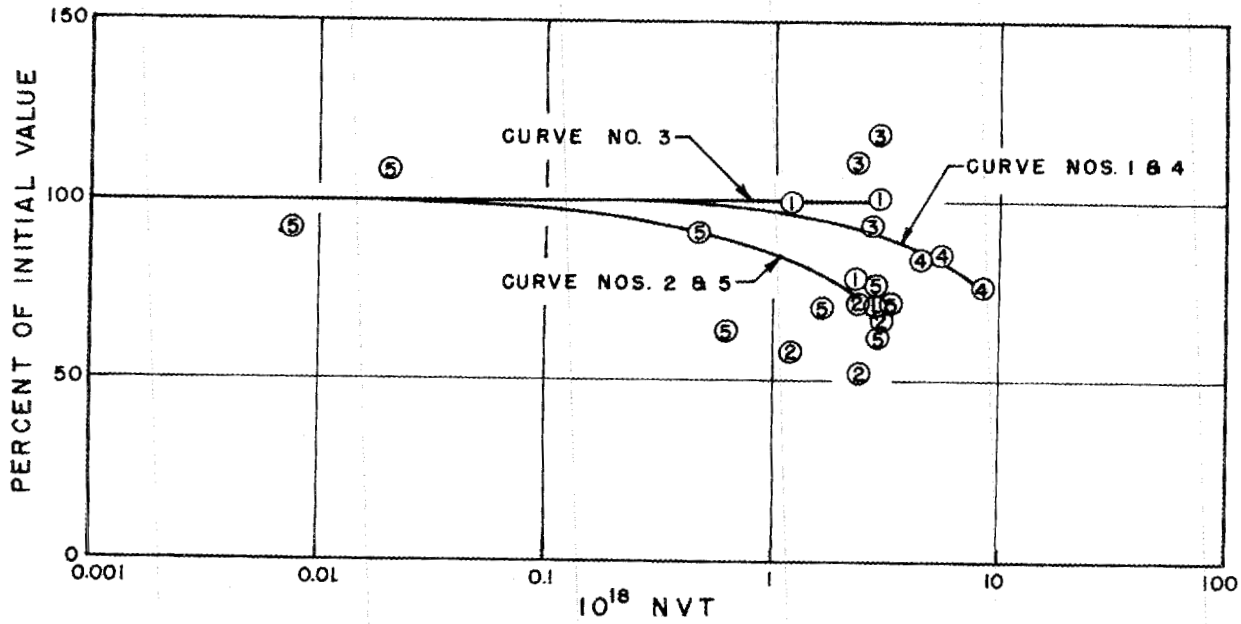
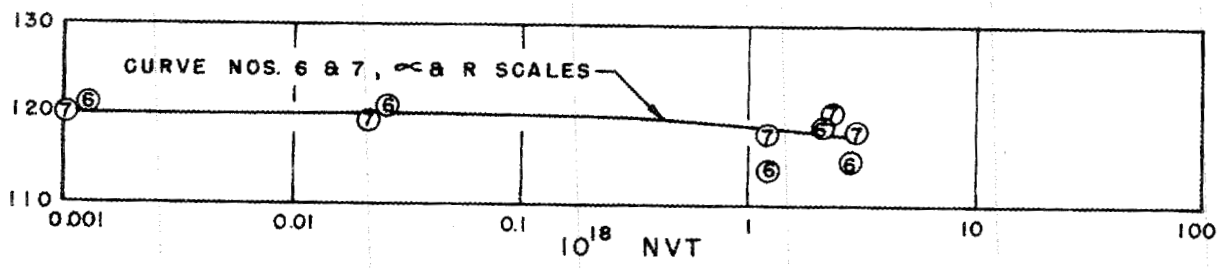


FIGURE 17A STRESS STRAIN CURVES FOR PILE IRRADIATED ASBESTOS FABRIC PHENOLIC

UNCLASSIFIED
DWG.#11124



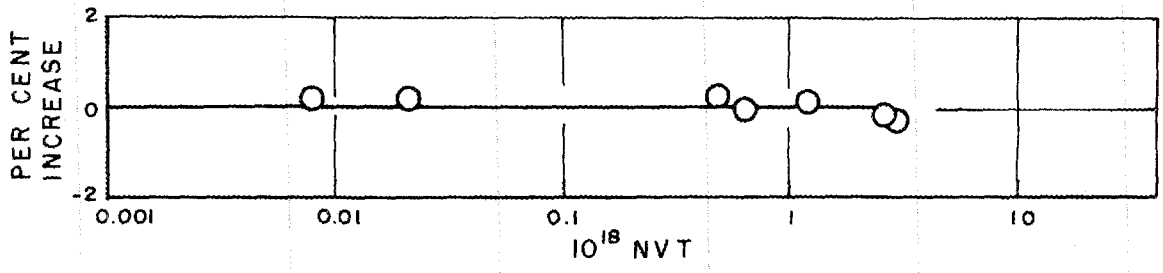
CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	11,000 LBS./SQ. IN.
2	ELONGATION	1.3 %
3	ELASTIC MODULUS	18 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	15,000 LBS./SQ. IN.
5	IMPACT STRENGTH	5.2 FT. LBS./IN. OF NOTCH



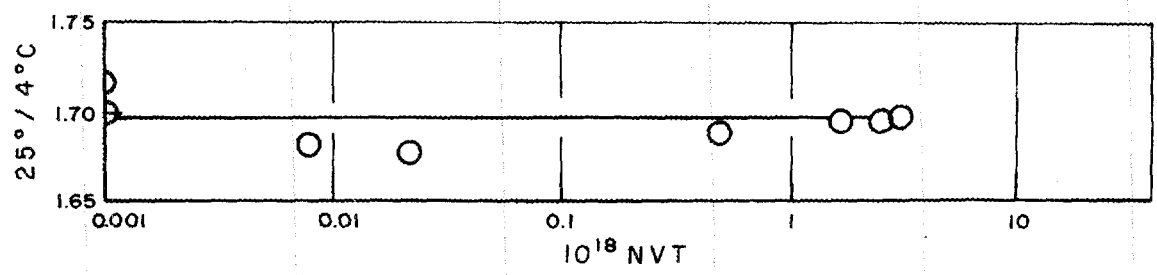
ROCKWELL HARDNESS

FIGURE 17B ASBESTOS FABRIC PHENOLIC

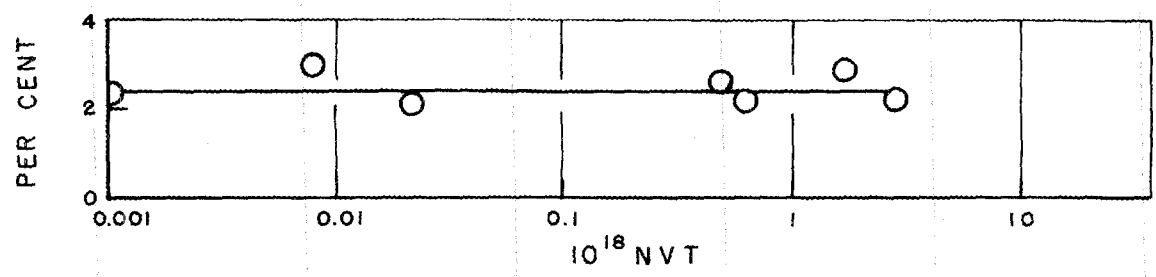
UNCLASSIFIED
DWG.#11125



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 17C ASBESTOS FABRIC PHENOLIC

UNCLASSIFIED
DWG.#11126

BAKELITE, ASBESTOS FABRIC FILLER

Volume Resistivity of 138 Mil Specimens

10^{18} nvt	ohm cm
0	2×10^{9}
6	1×10^{10}

Dielectric Strength of 138 Mil Specimens

10^{18} nvt	volts/mil
0	80
9	100

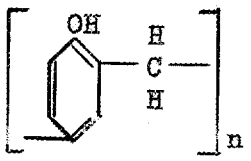
Arc Resistance of 138 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	4	Carbonized
9	4	"

FIGURE 17 D

ASBESTOS-FIBER BAKELITE

Classification:	Phenolic, mineral filler
Trade name:	Bakelite
Company:	Bakelite Division, Union Carbide and Carbon Corporation
Resin:	Phenol-formaldehyde
Formula:	



Filler:	Asbestos fiber
Description:	Opaque, brown, - darkens upon irradiation
Thickness of sheets:	0.129 - 0.131 in.
Speed of tensile testing	
Mean rate of straining:	$0.4 - 0.7 \times 10^{-4}$ units/sec.
Mean rate of stressing:	75 - 100 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11127

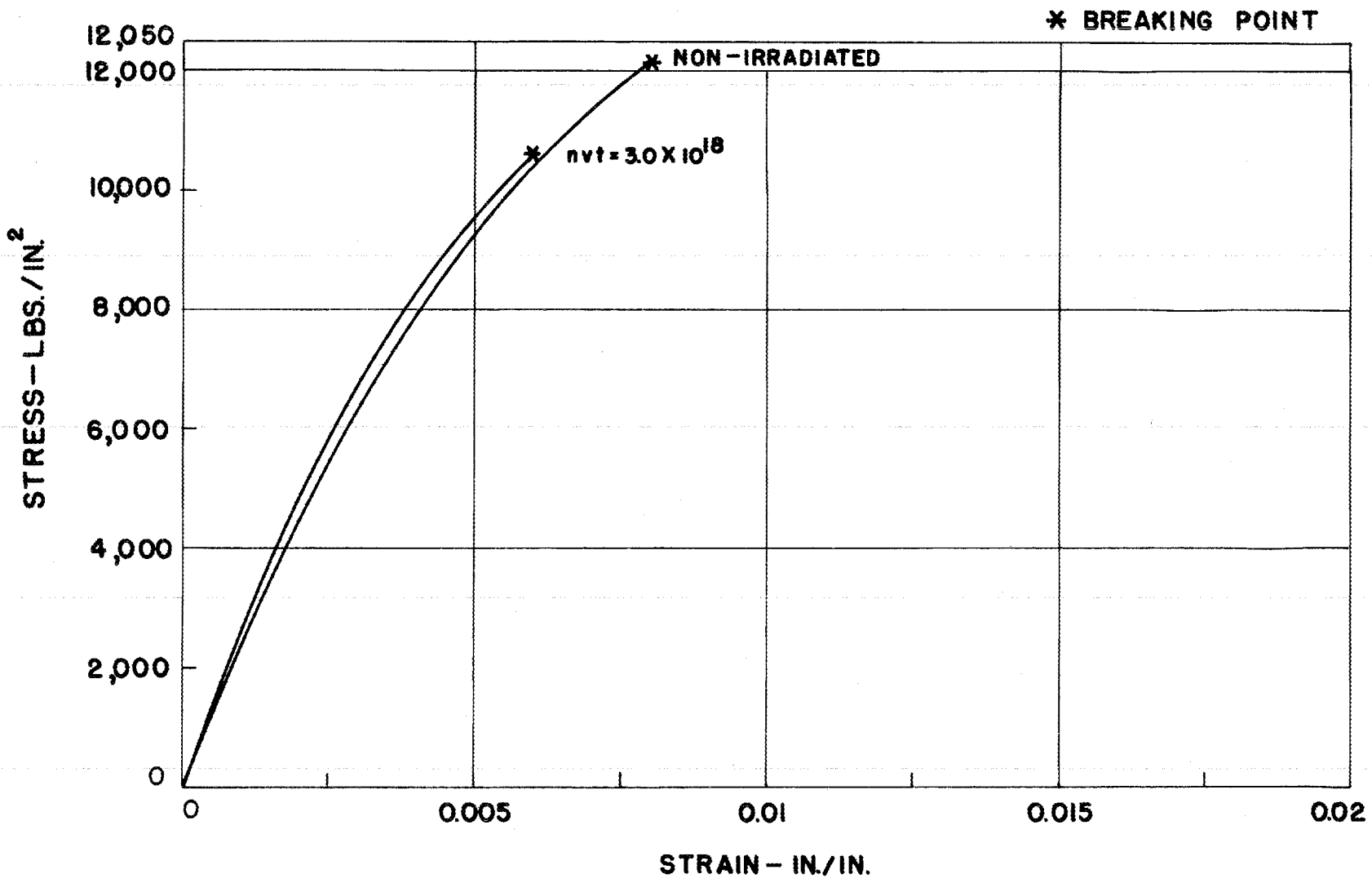
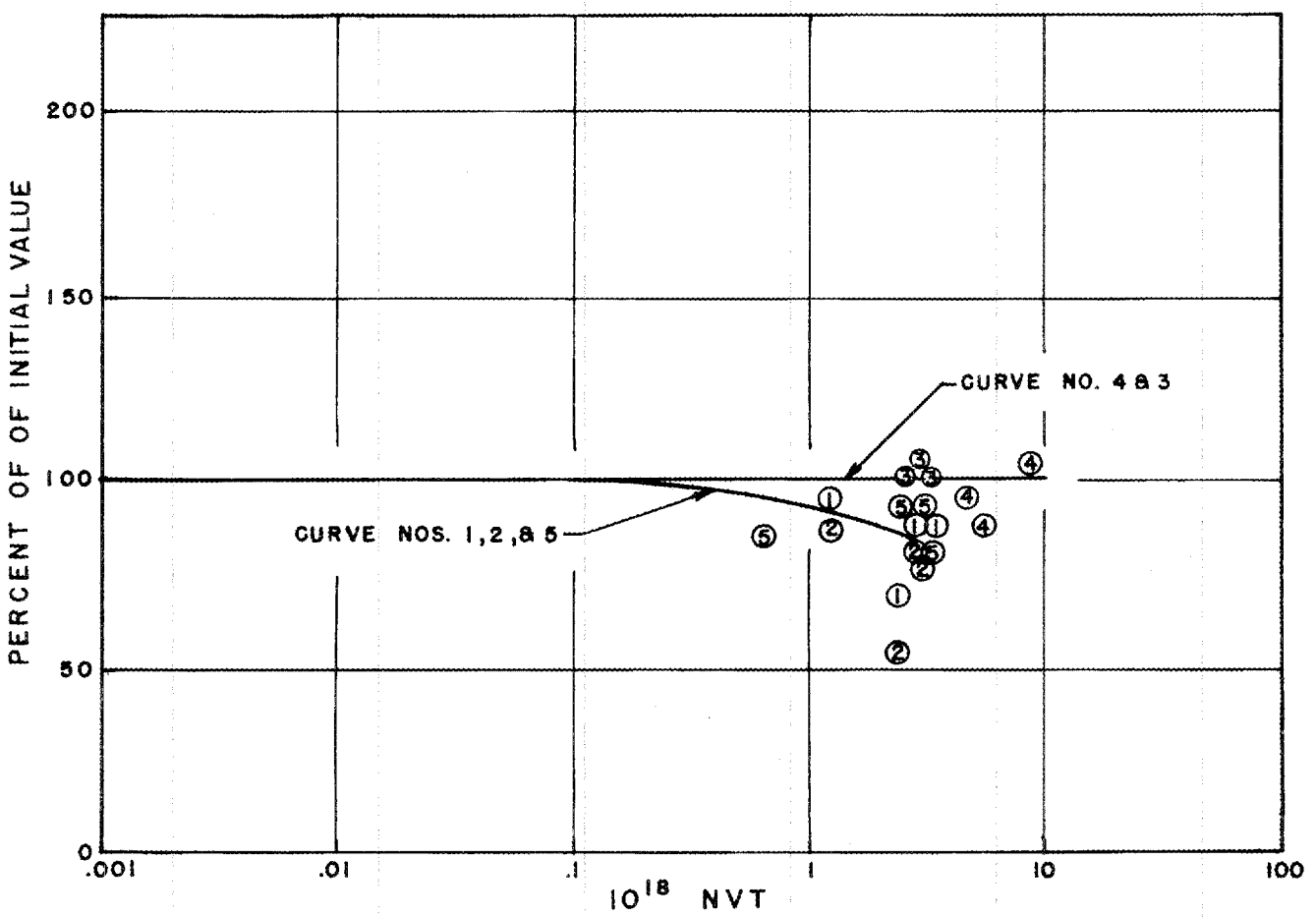
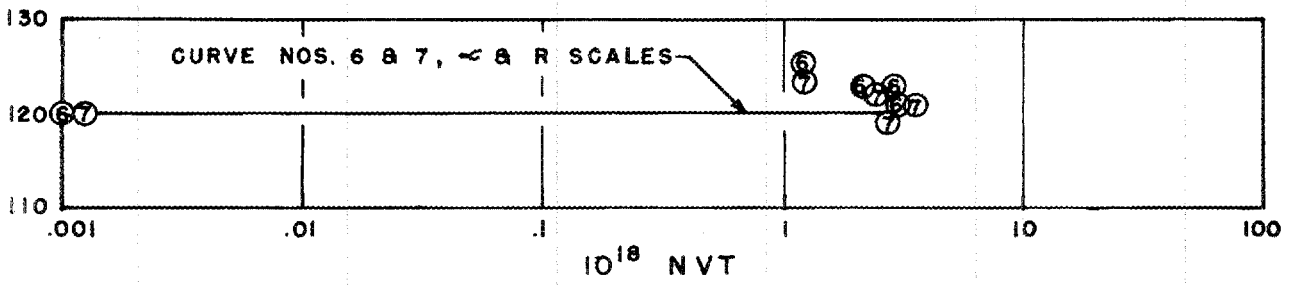


FIGURE 18A STRESS STRAIN CURVES FOR PILE IRRADIATED FIBER ASBESTOS PHENOLIC

UNCLASSIFIED
DWG.#11128



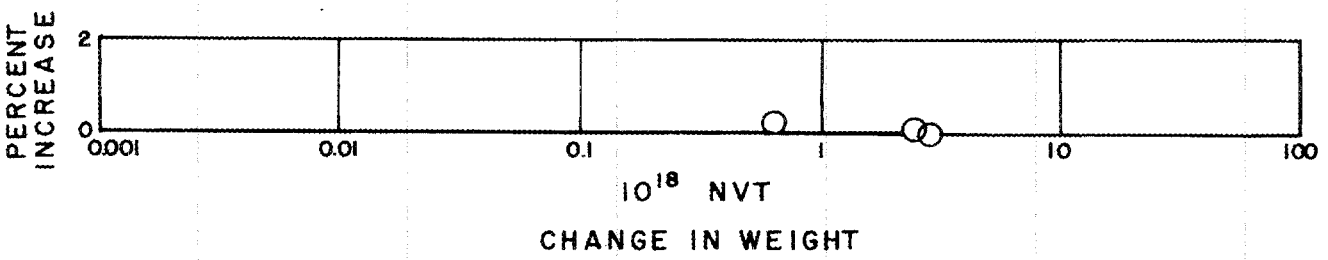
CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	12,200 LBS./SQ.IN.
2	ELONGATION	0.81 %
3	ELASTIC MODULUS	25 X 10^5 LBS./SQ.IN.
4	SHEAR STRENGTH	11,000 LBS./SQ.IN.
5	IMPACT STRENGTH	1.02 FT. LBS./IN. OF NOTCH



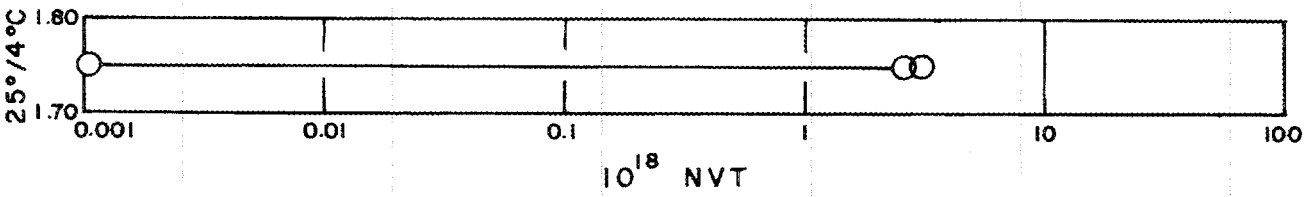
ROCKWELL HARDNESS

FIGURE 18B FIBER ASBESTOS PHENOLIC

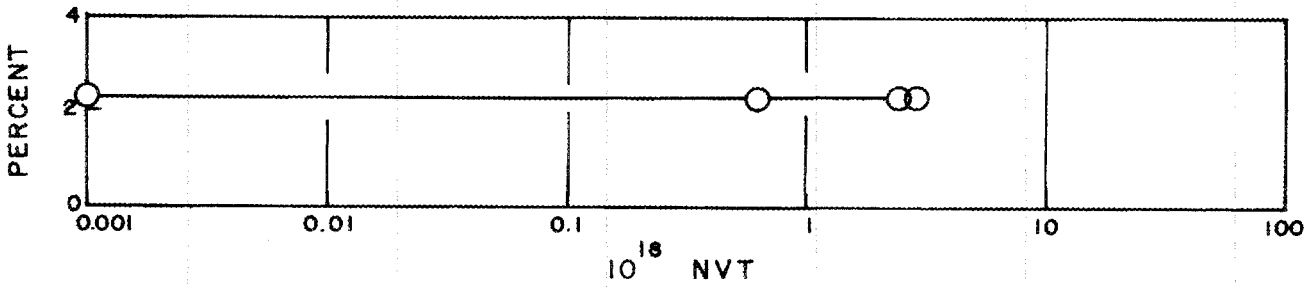
UNCLASSIFIED
DWG.#11129



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 18C FIBER ASBESTOS PHENOLIC

UNCLASSIFIED
DWG.#11130

BAKELITE, ASBESTOS FIBER FILLER

Volume Resistivity of 130 Mil Specimens

10^{18} nvt	ohm cm
0	2×10^{10}
9	3×10^{10}

Dielectric Strength of 130 Mil Specimens

10^{18} nvt	volts/mil
0	160
9	200

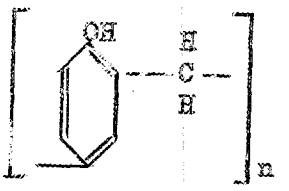
Arc Resistance of 130 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	4	Carbonized
9	4	"

FIGURE 18 D

HAVEG 41

Classification:	Phenolic, mineral filler
Trade name:	Haveg 41
Company:	Haveg Corporation
Resin:	Phenol-formaldehyde
Formula:	



Filler:	Asbestos
Description:	Opaque, brown - Darkens upon irradiation
Thickness of sheets:	0.44 - 0.55 in.
Speed of tensile testing	
Mean rate of straining:	0.2 - 0.4 x 10^{-4} units/sec.
Mean rate of stressing:	18 - 22 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11131

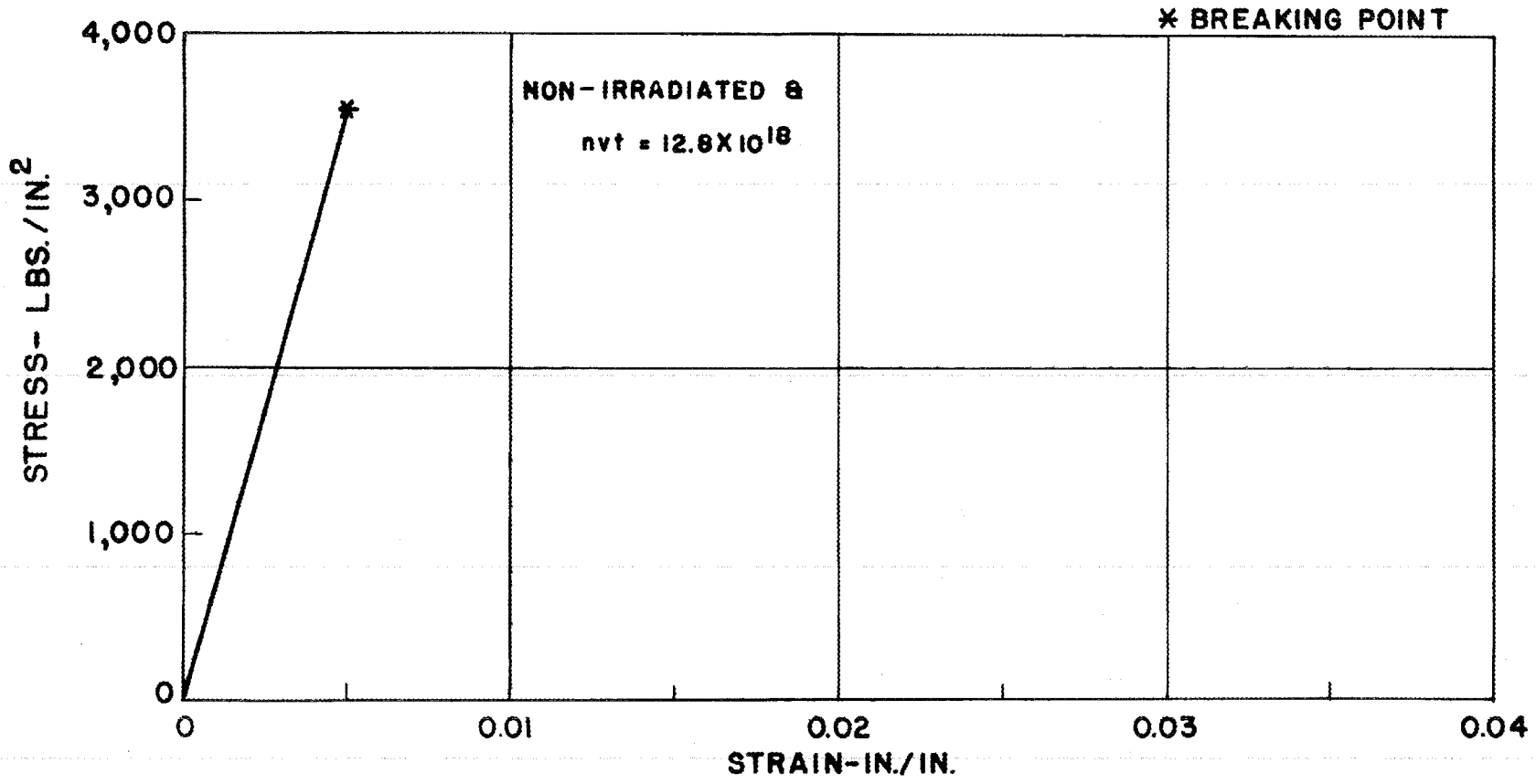
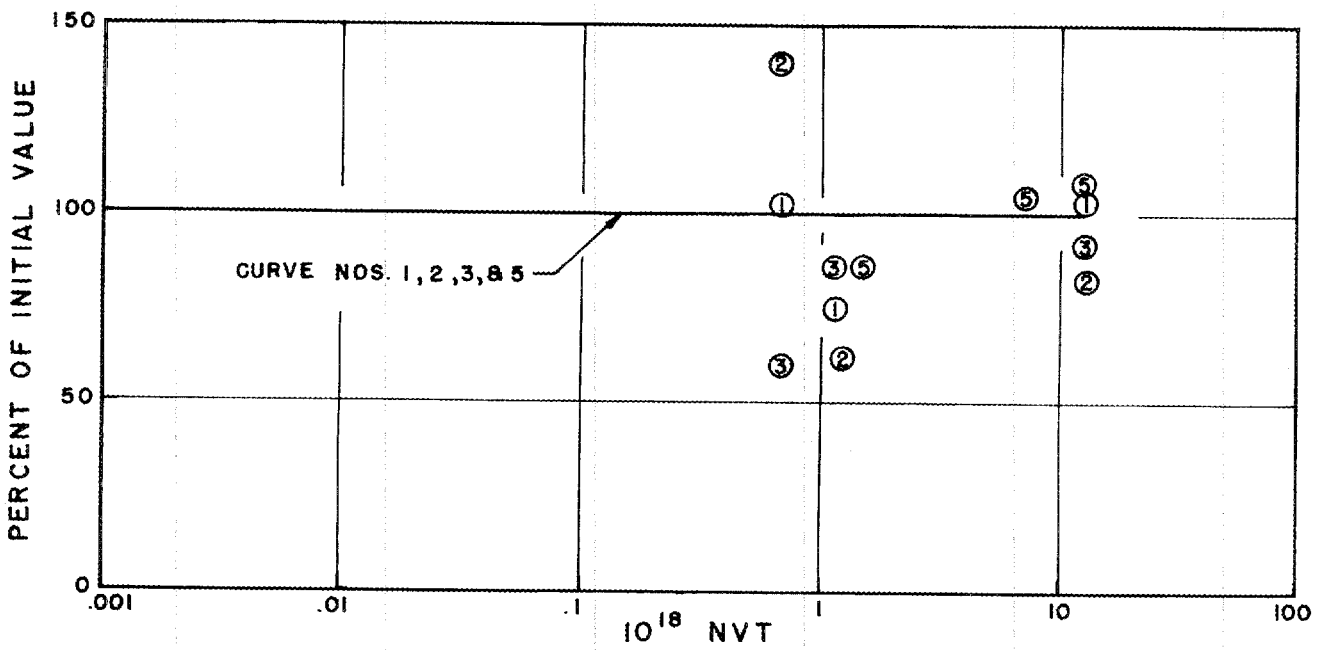


FIGURE 19A STRESS STRAIN CURVES FOR PILE IRRADIATED

PHENOLIC BONDED ASBESTOS (HAVEG 41)

UNCLASSIFIED
DWG.#11132



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	3500 LBS./SQ. IN.
2	ELONGATION	0.5 %
3	ELASTIC MODULUS	10×10^5 LBS. /SQ. IN.
5	IMPACT STRENGTH	0.31 FT. LBS./IN. OF NOTCH

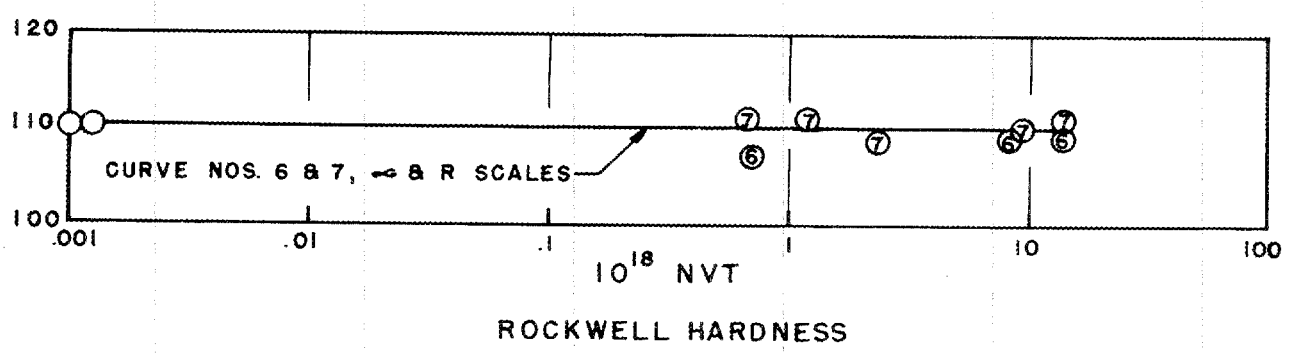
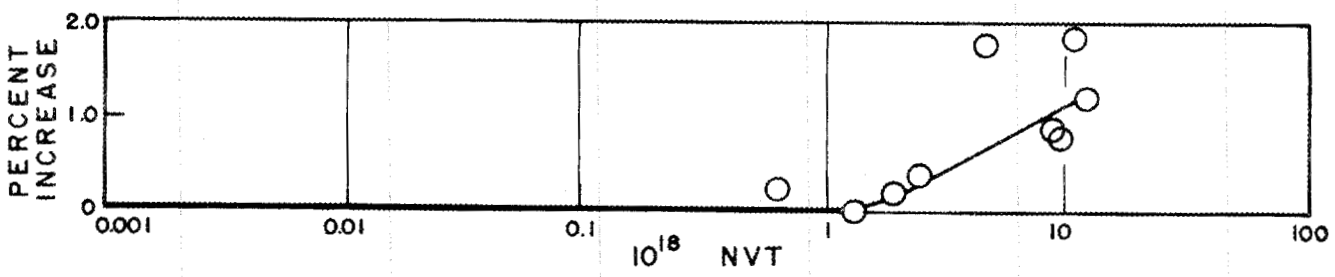
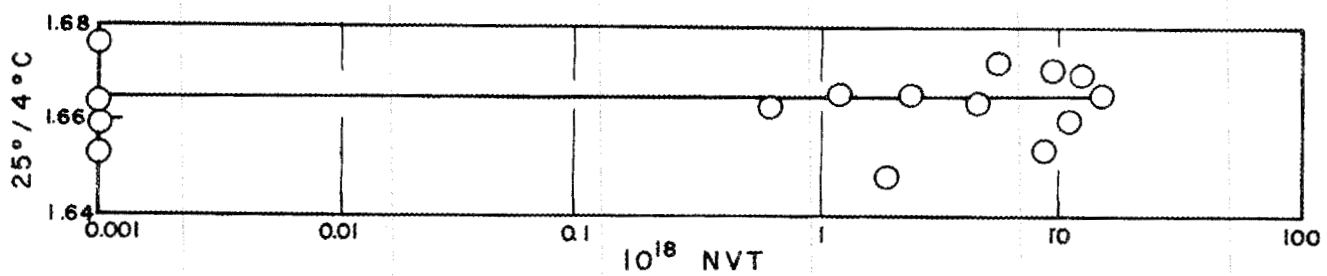


FIGURE 19B PHENOLIC BONDED ASBESTOS (Haveg.41)

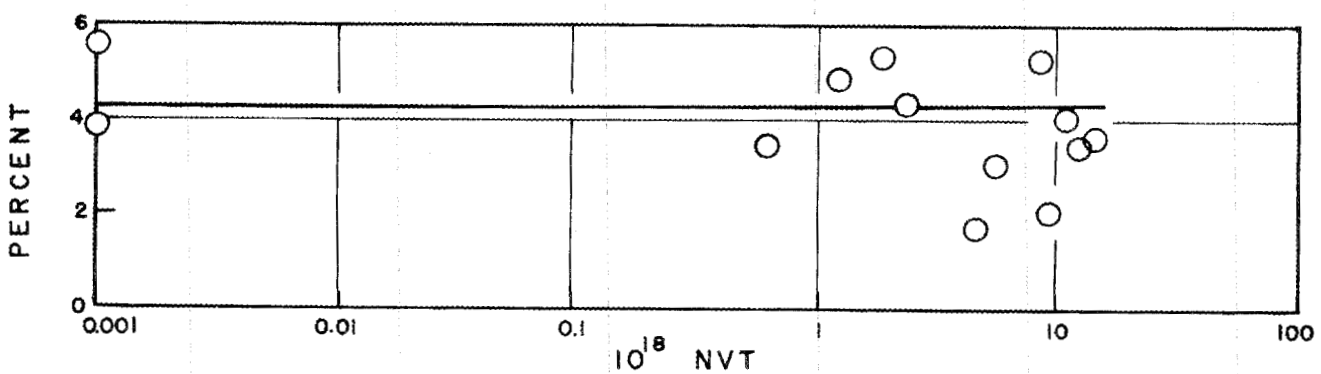
UNCLASSIFIED
DWG.#11133



CHANGE IN WEIGHT



SPECIFIC GRAVITY

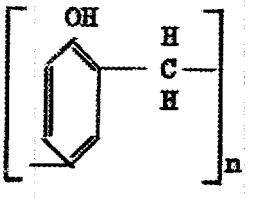


WATER ABSORPTION

FIGURE 19C PHENOLIC BONDED ASBESTOS (Haveg 41)

KARBATE

Classification:	Phenolic, mineral filler
Trade name:	Karbate
Company:	National Carbon Company, Inc.
Resin:	Phenol-formaldehyde
Formula:	



Filler:	Graphite
Description:	Opaque, black. No color change upon irradiation.
Thickness of sheets:	0.124 - 0.125 in.
Speed of tensile testing	
Mean rate of straining:	0.1 - 0.3 x 10^{-4} units/sec.
Mean rate of stressing:	20 - 30 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11134

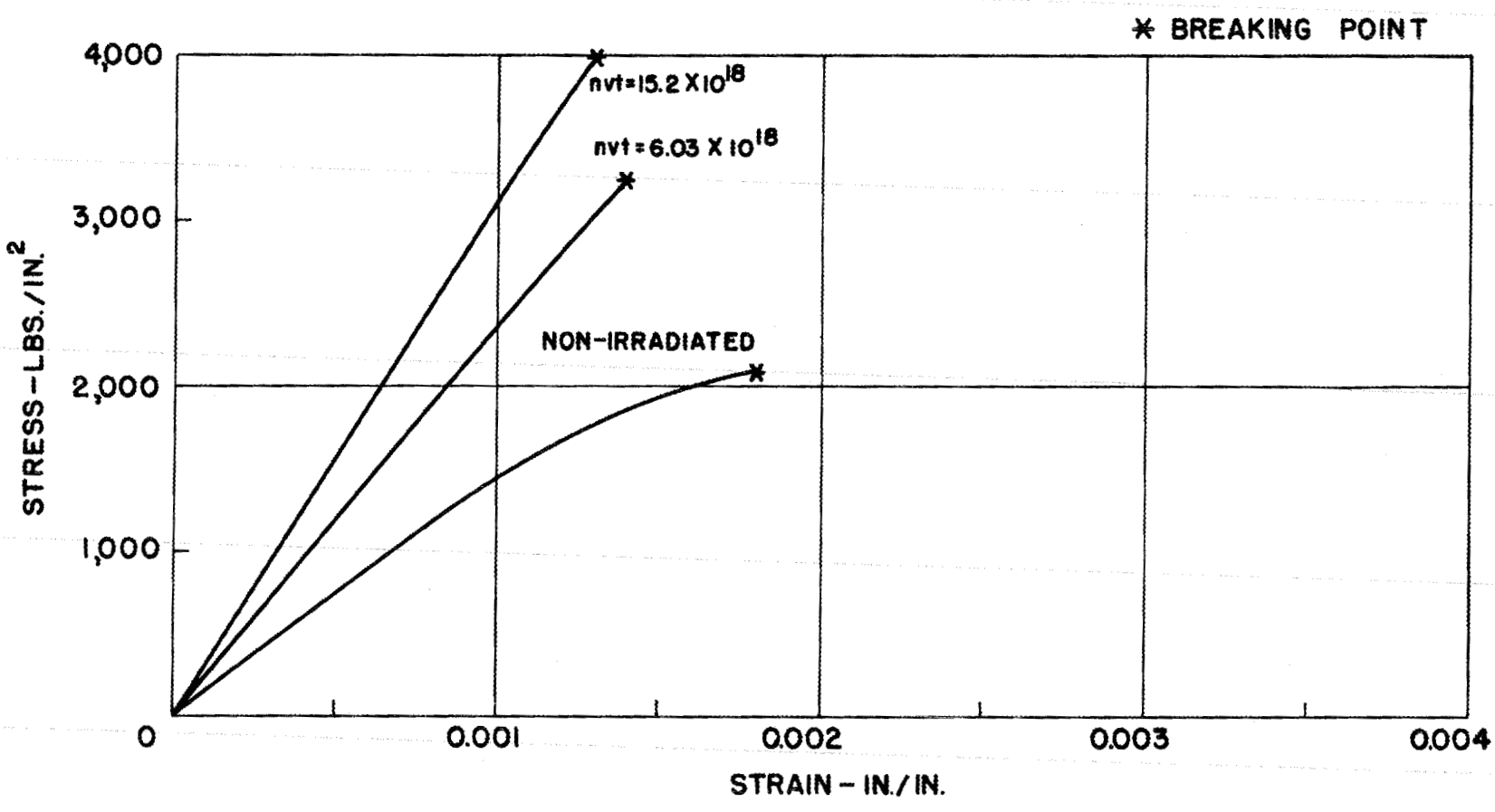
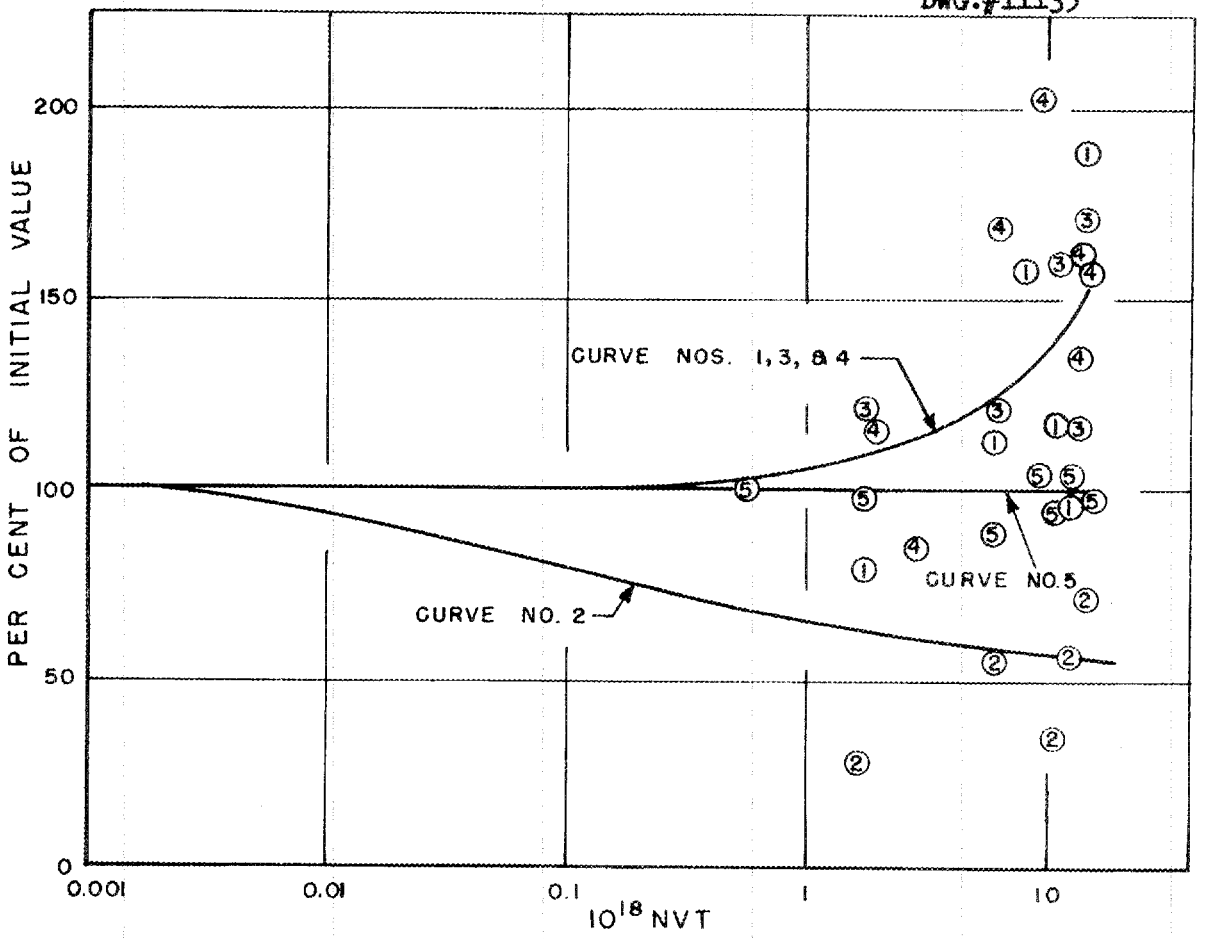


FIGURE 20A STRESS STRAIN CURVES FOR PILE IRRADIATED PHENOLIC BONDED GRAPHITE

UNCLASSIFIED
DWG.#11135



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	2,100 LBS. / SQ. IN.
2	ELONGATION	0.18 %
3	ELASTIC MODULUS	18 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	2,200 LBS./SQ. IN.
5	IMPACT STRENGTH	0.27 FT. LBS./IN. NOTCH

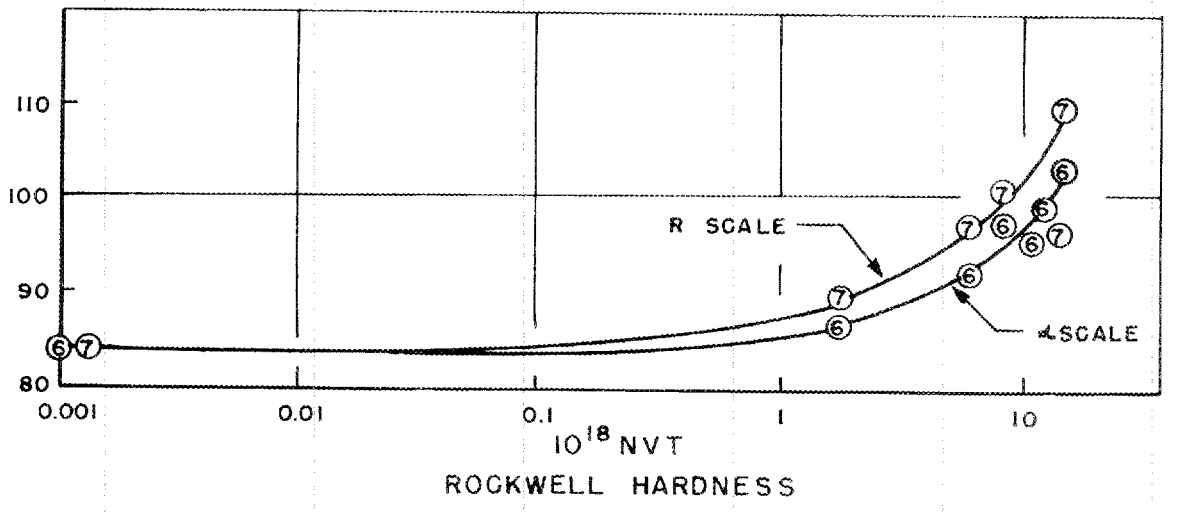
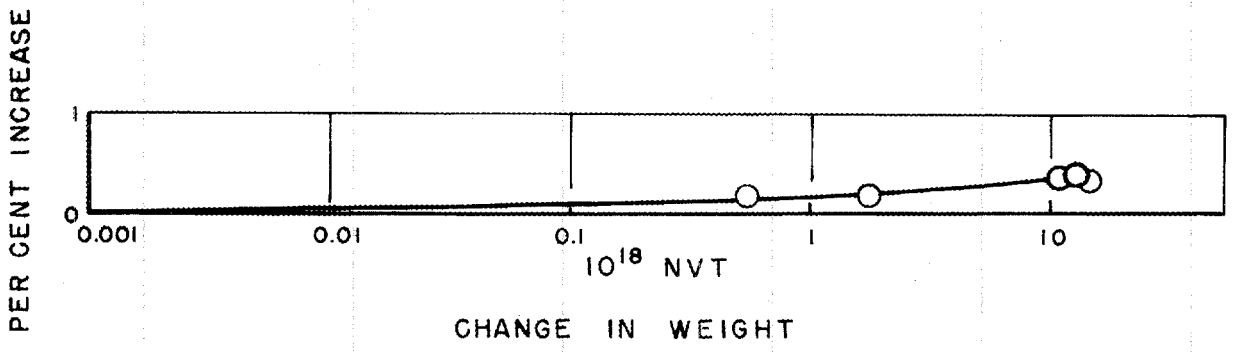
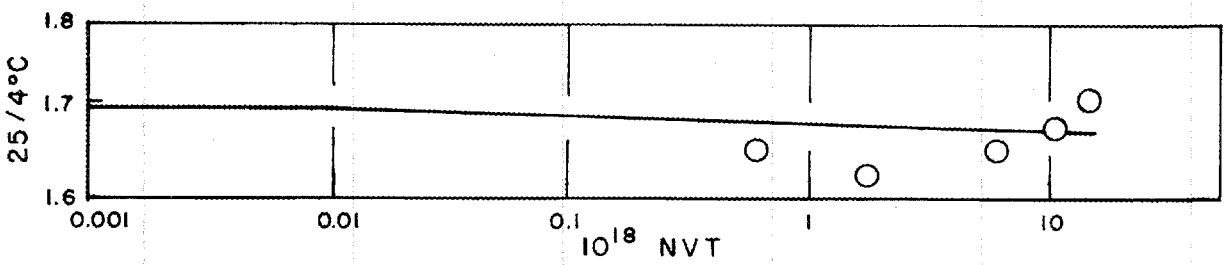


FIGURE 20B PHENOLIC BONDED GRAPHITE

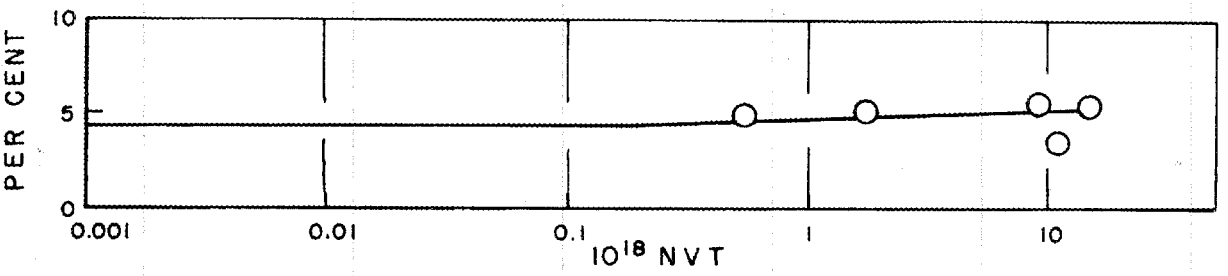
UNCLASSIFIED
DWG.#11136



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 20C PHENOLIC BONDED GRAPHITE

UNCLASSIFIED
DWG.#11137

KARBATE

Since this material is not a good insulator, no measurements of resistivity or arc resistance were made.

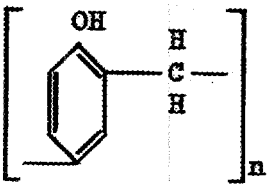
Dielectric Strength of 124 Mil Specimens

10^{18} nvt	volts/mil
0	70
15	70

FIGURE 20 D

PAPER-BASE BAKELITE

Classification:	Phenolic, organic filler
Trade name:	Bakelite
Company:	Bakelite Division, Union Carbide and Carbon Corporation
Resin:	Phenol-formaldehyde
Formula:	



Filler:	Paper base (laminate)
Description:	Opaque, black. No color change upon irradiation.

Thickness of tensile and impact specimens: 0.183 - 0.191 in.

Thickness of shear specimens: 0.126 - 0.131 in.

Speed of tensile testing

Mean rate of straining:	0.4 - 1.0 x 10^{-4} units/sec.
Mean rate of stressing:	40 - 70 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11138

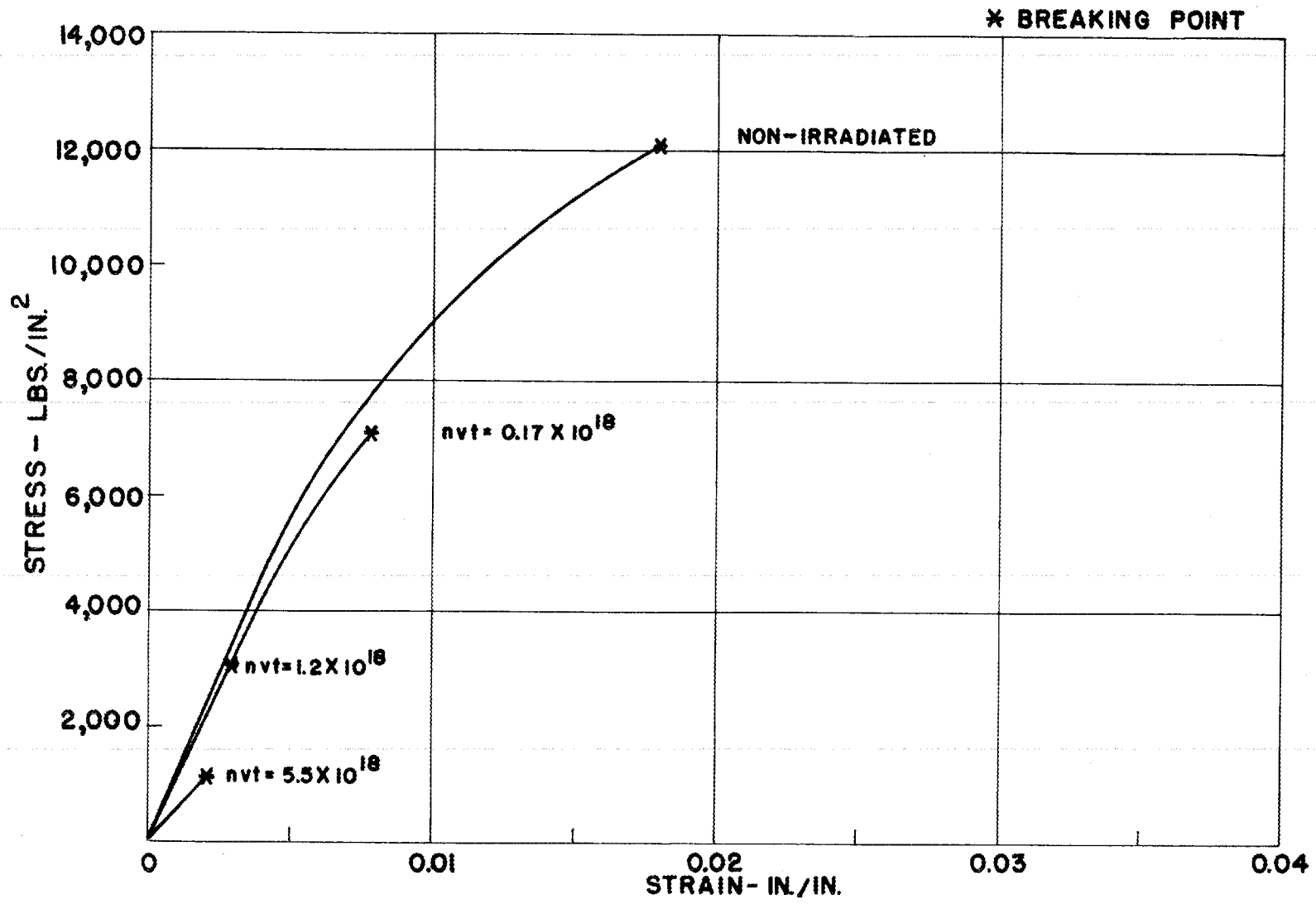
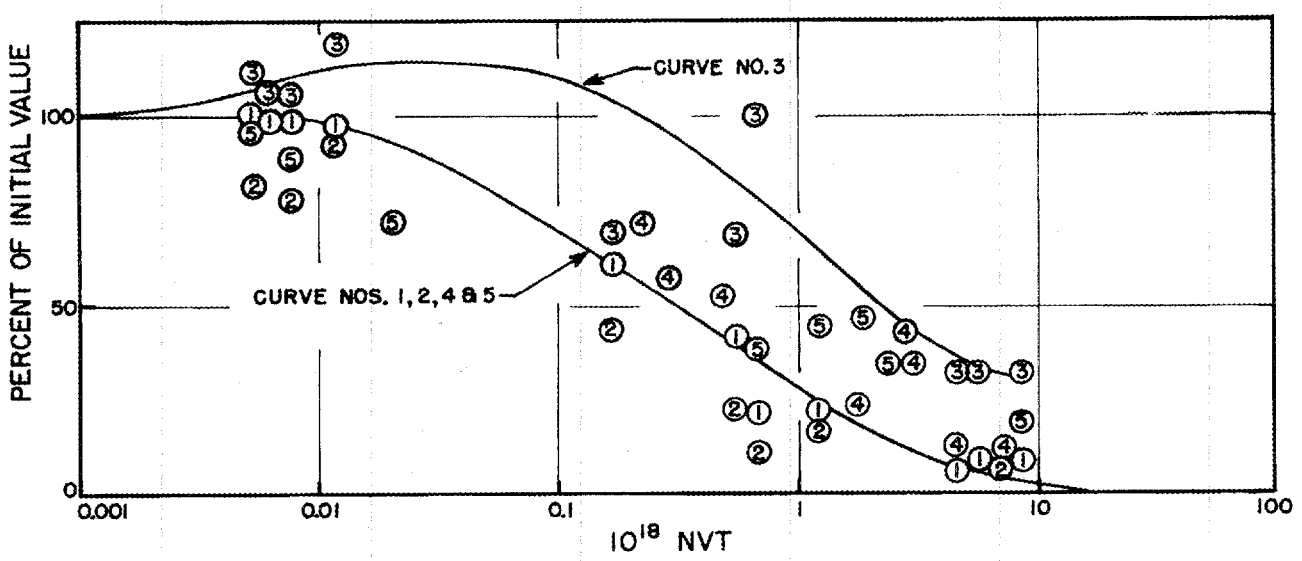


FIGURE 21A STRESS STRAIN CURVES FOR PILE IRRADIATED PAPER BASE PHENOLIC

UNCLASSIFIED
DWG.#11139



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	12,100 LBS. / SQ. IN.
2	ELONGATION	1.8 %
3	ELASTIC MODULUS	16 X 10^5 LBS. / SQ. IN.
4	SHEAR STRENGTH	14,400 LBS./SQ. IN.
5	IMPACT STRENGTH	0.58 FT. LBS. / IN. OF NOTCH

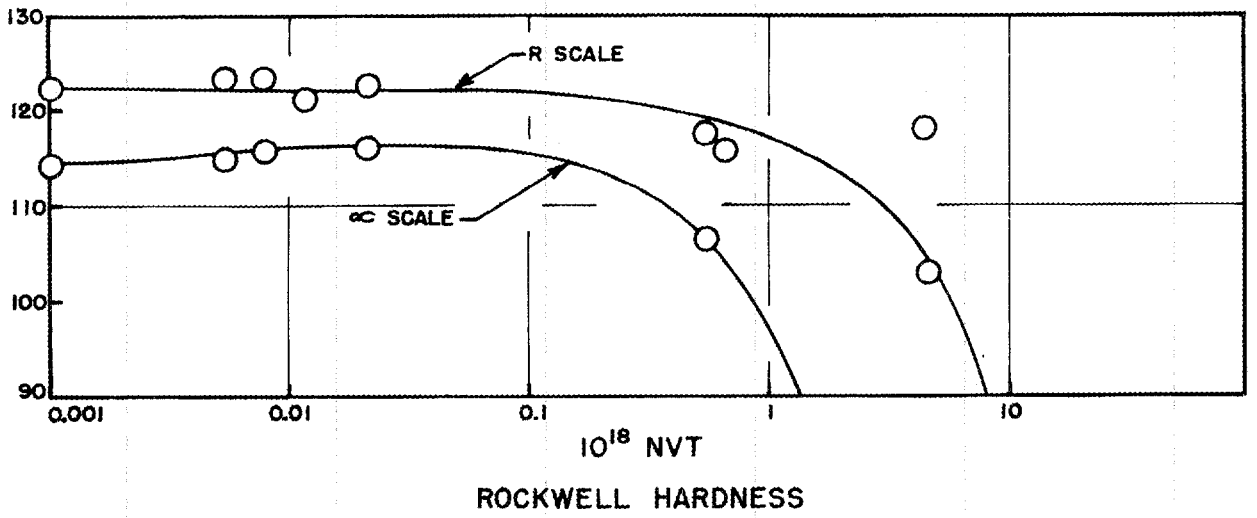
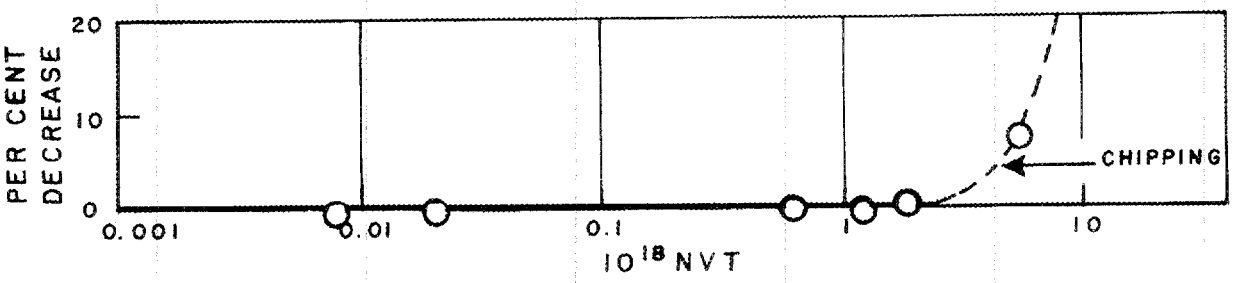
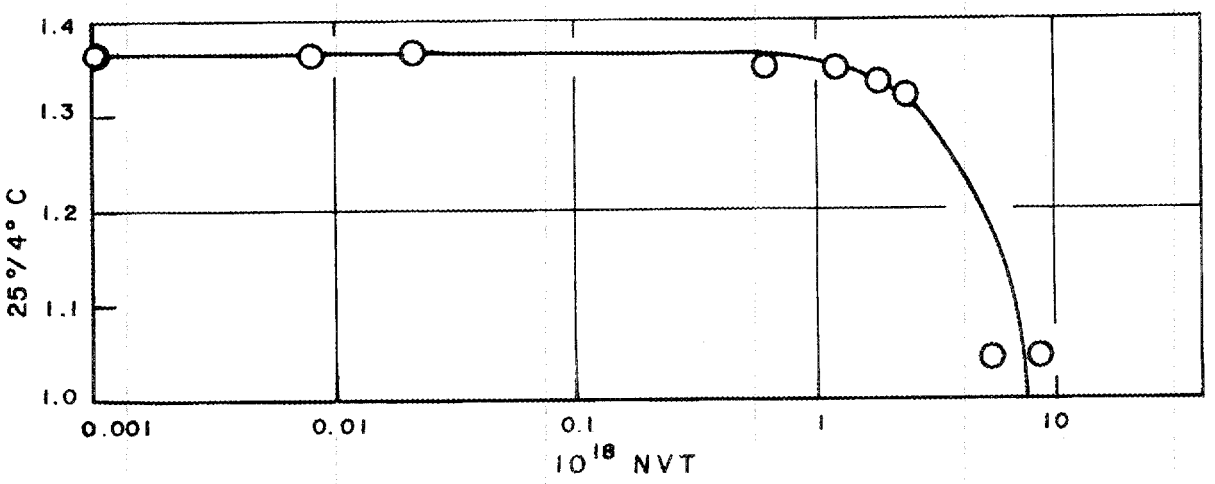


FIGURE 21B PAPER BASE PHENOLIC

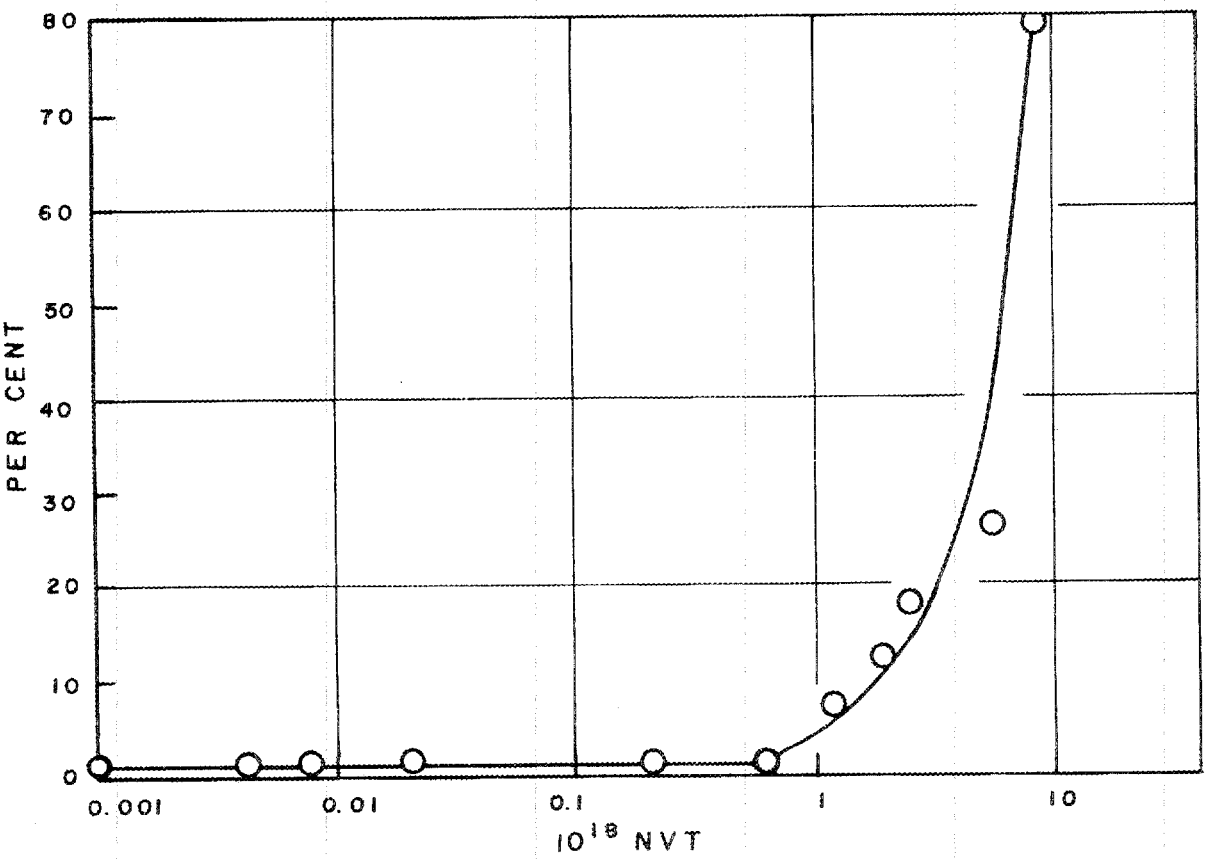
UNCLASSIFIED
DWG.#11140



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 21C PAPER BASE PHENOLIC

UNCLASSIFIED
DWG.#11141

BAKELITE, PAPER BASE

Volume Resistivity of 125 Mil Specimens

10^{18} nvt	ohm cm
0	3×10^{11}
3	2×10^{12}
9	2×10^{11}

Dielectric Strength of 125 Mil Specimens

10^{18} nvt	volts/mil
0	>250
5	240

Arc Resistance of 125 Mil Specimens

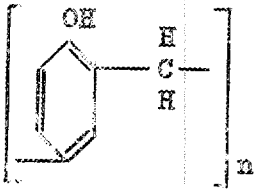
10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	2	Carbonized
9	2	"

FIGURE 21 D

LINEN-FABRIC BAKELITE

Classification:	Phenolic, organic filler
Trade name:	Bakelite
Company:	Bakelite Division, Union Carbide and Carbon Corporation
Resin:	Phenol-formaldehyde

Formula:



Filler:	Linen fabric (laminate)
Description:	Opaque, brown with fabric-texture. Darkens upon irradiation.
Thickness of sheets:	0.253 - 0.259 in.
Speed of tensile testing	
Mean rate of straining:	$0.5 - 1.4 \times 10^{-4}$ units/sec.
Mean rate of stressing:	40 - 70 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11142

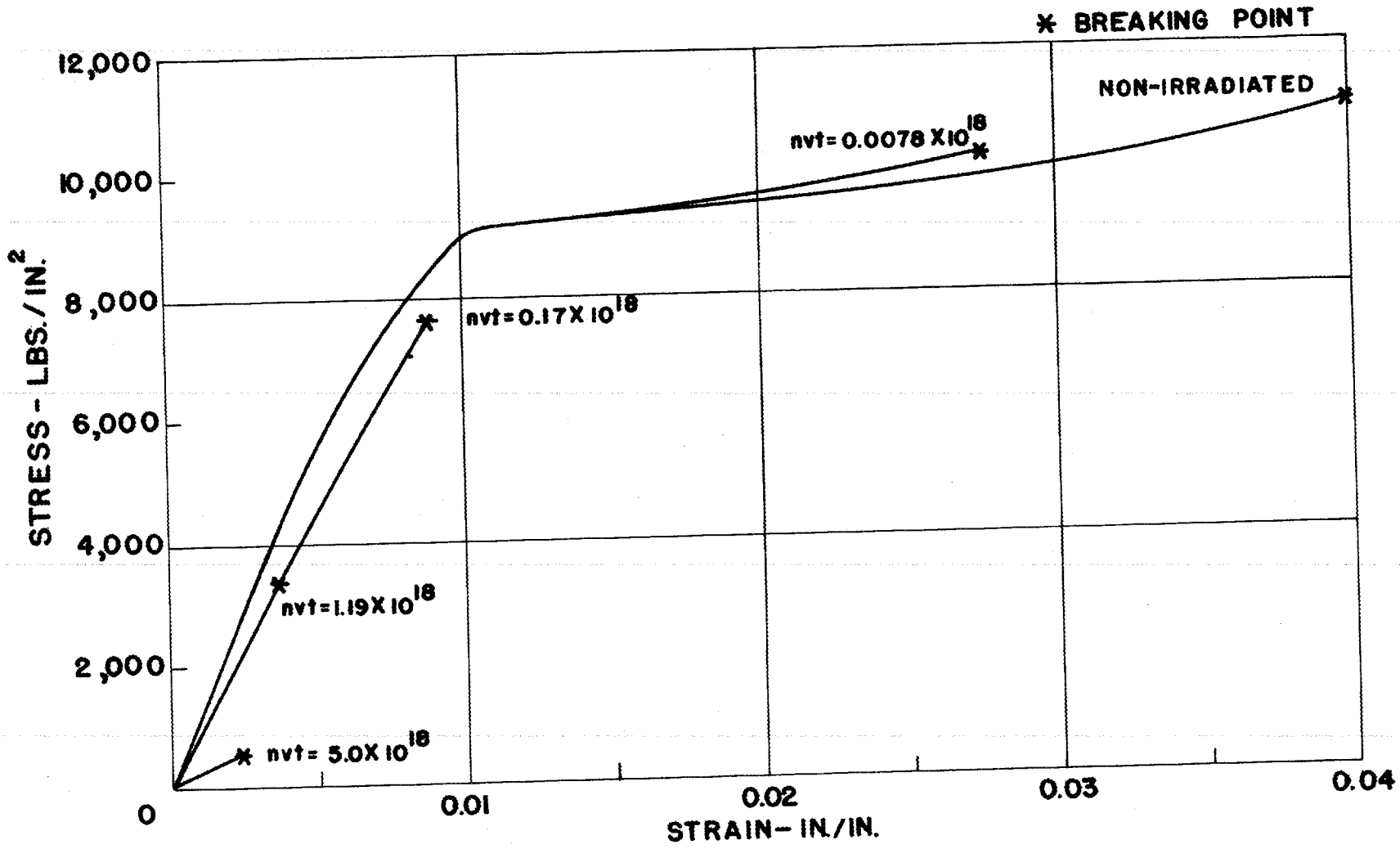
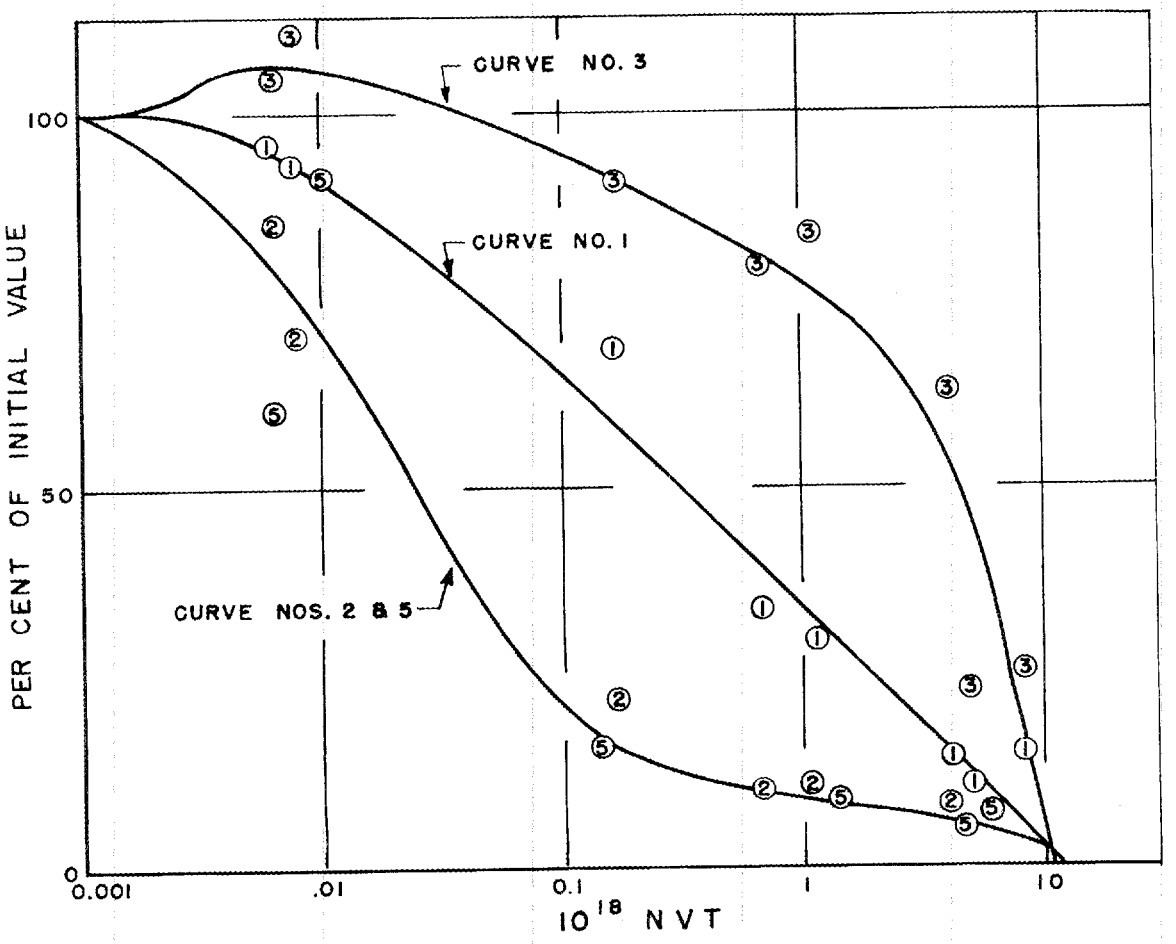


FIGURE 22A STRESS STRAIN CURVES FOR PILE IRRADIATED PHENOLIC, LINEN FABRIC LAMINATE

UNCLASSIFIED
DWG.#11143



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	11,000 LBS./SQ. IN.
2	ELONGATION	4.0 %
3	ELASTIC MODULUS	11 X 10^5 LBS./SQ. IN.
5	IMPACT STRENGTH	2.75 FT. LBS./IN. OF NOTCH

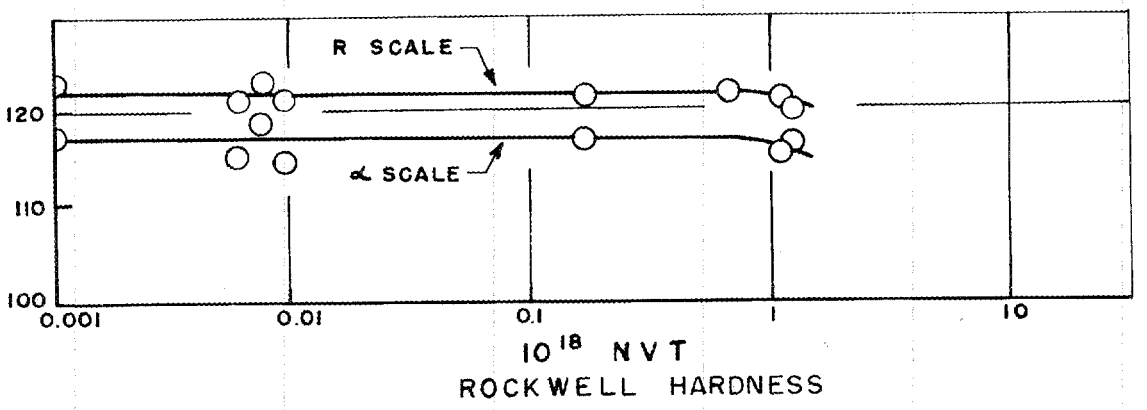
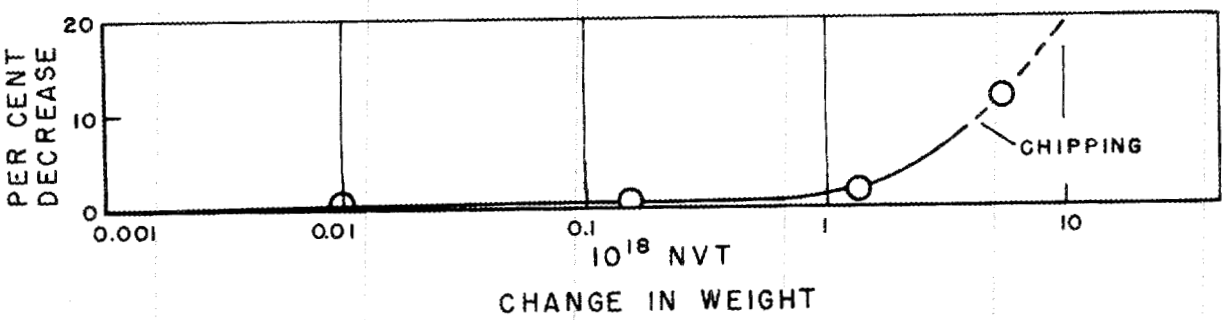
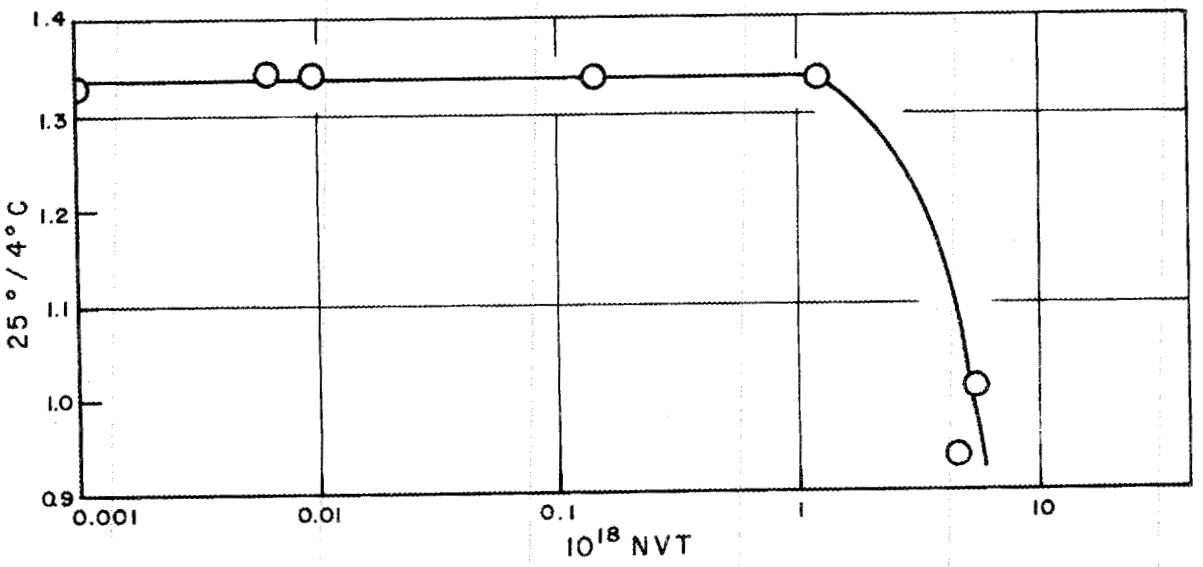


FIGURE 22B PHENOLIC LINEN FABRIC LAMINATE

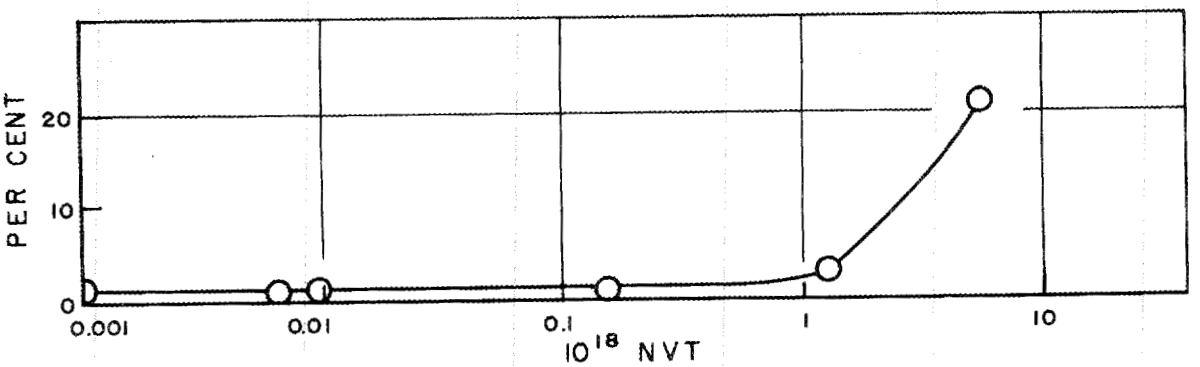
UNCLASSIFIED
DWG.#11144



CHANGE IN WEIGHT



SPECIFIC GRAVITY

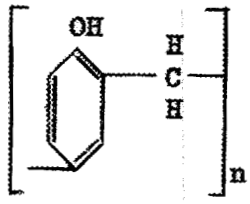


WATER ABSORPTION

FIGURE 22C PHENOLIC LINEN FABRIC LAMINATE

MICARTA

Classification:	Phenolic, organic filler
Trade name:	Micarta
Company:	Micarta Division, Westinghouse Electric Corporation
Resin:	Phenol-formaldehyde
Formula:	



Filler:	Paper (laminate)
Description:	Opaque, brown. Darkens upon irradiation
Thickness of sheets:	0.254 - 0.257 in.
Speed of tensile testing	
Mean rate of straining:	0.4 - 1.0 x 10^{-4} units/sec.
Mean rate of stressing:	40 - 70 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11145

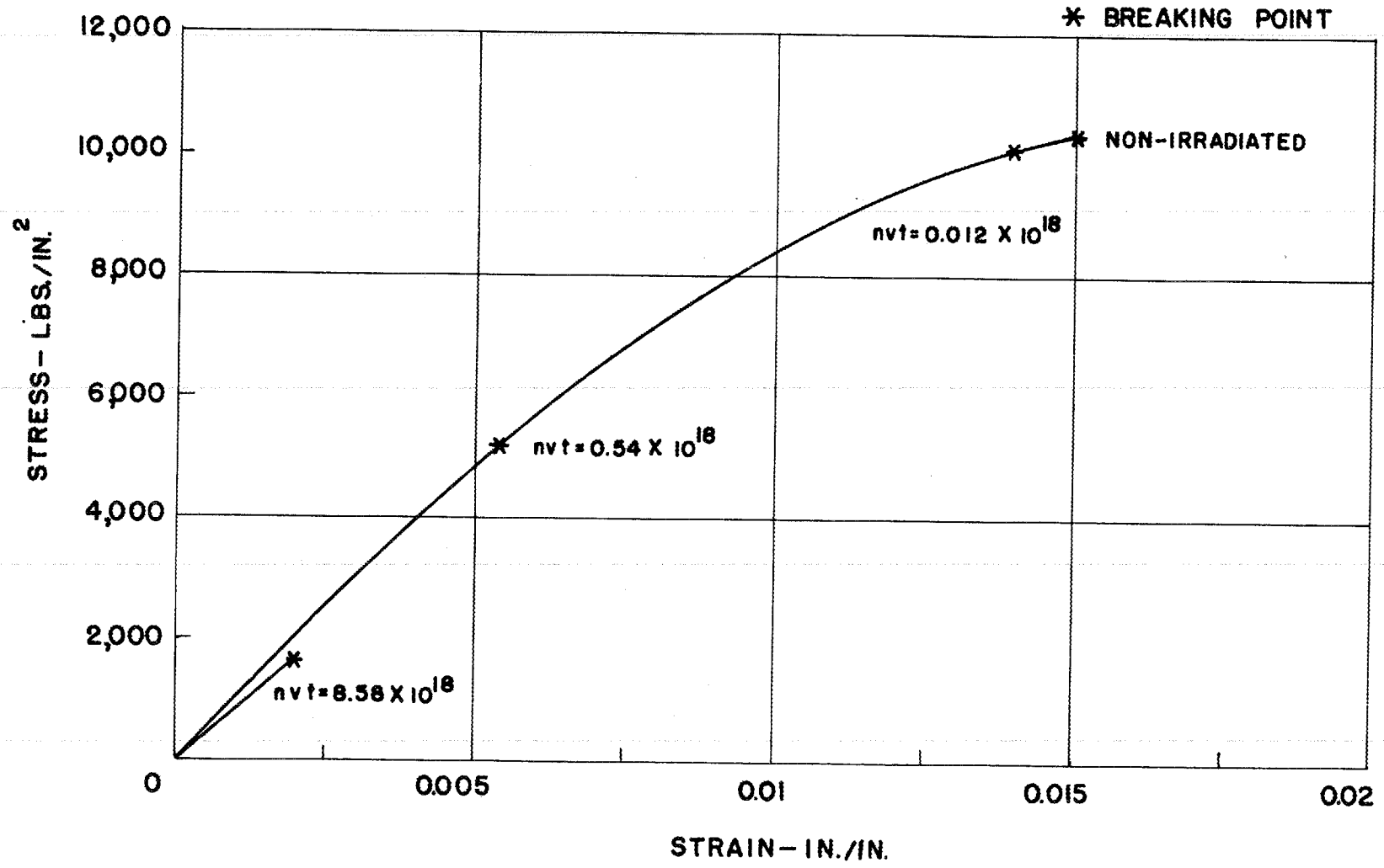
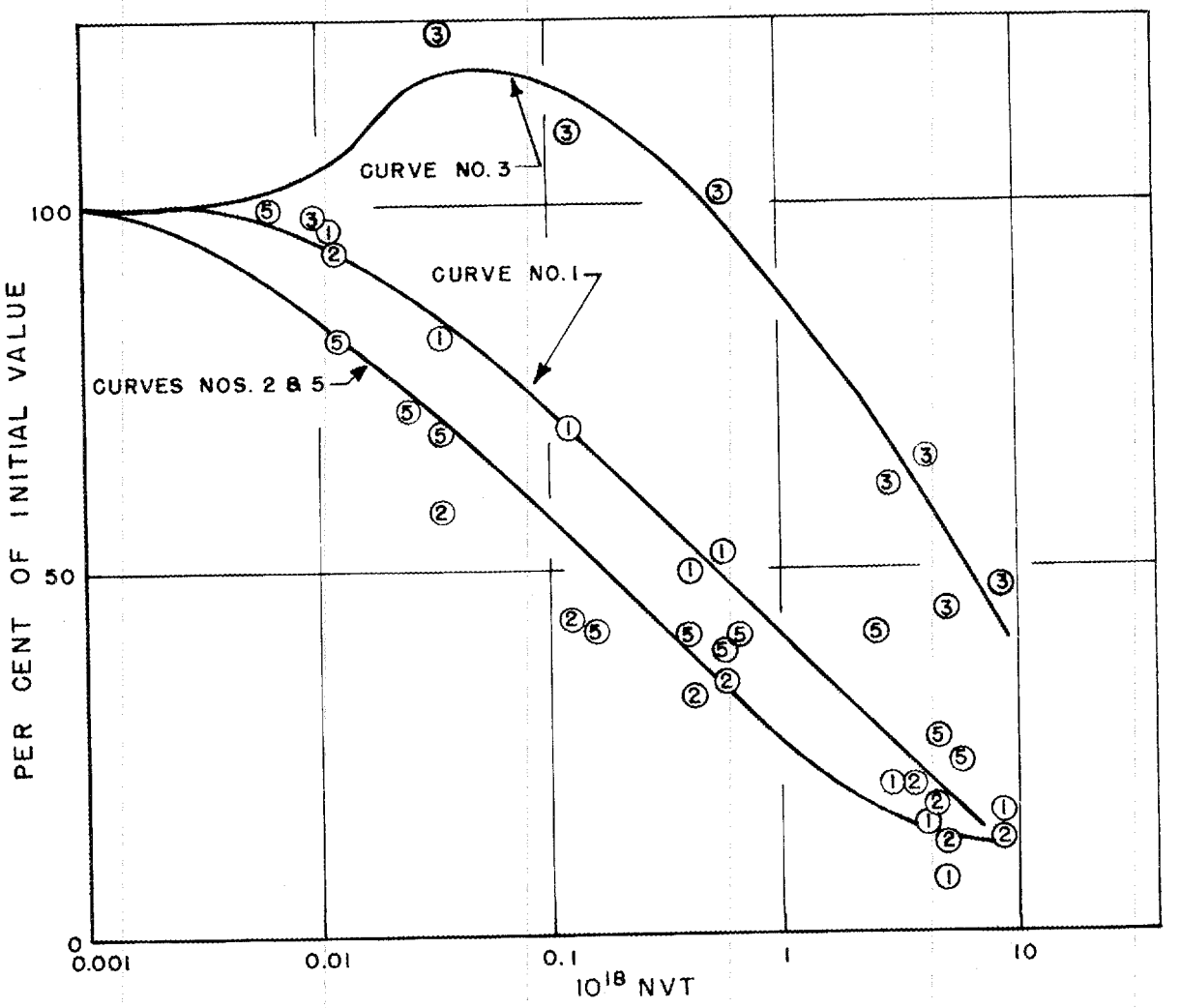


FIGURE 23A STRESS STRAIN CURVES FOR PILE IRRADIATED PHENOLIC LAMINATE (MICARTA)

UNCLASSIFIED
DWG.#11146



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	10,300 LBS./SQ. IN.
2	ELONGATION	1.5 %
3	ELASTIC MODULUS	10.4×10^5 LBS./SQ. IN.
5	IMPACT STRENGTH	0.66 FT. LBS./ IN NOTCH

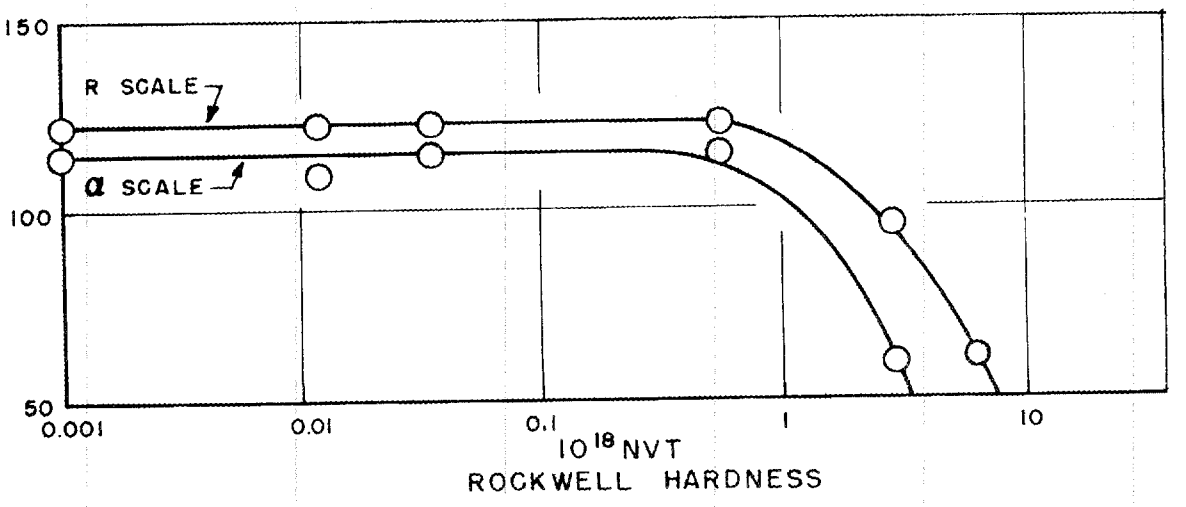
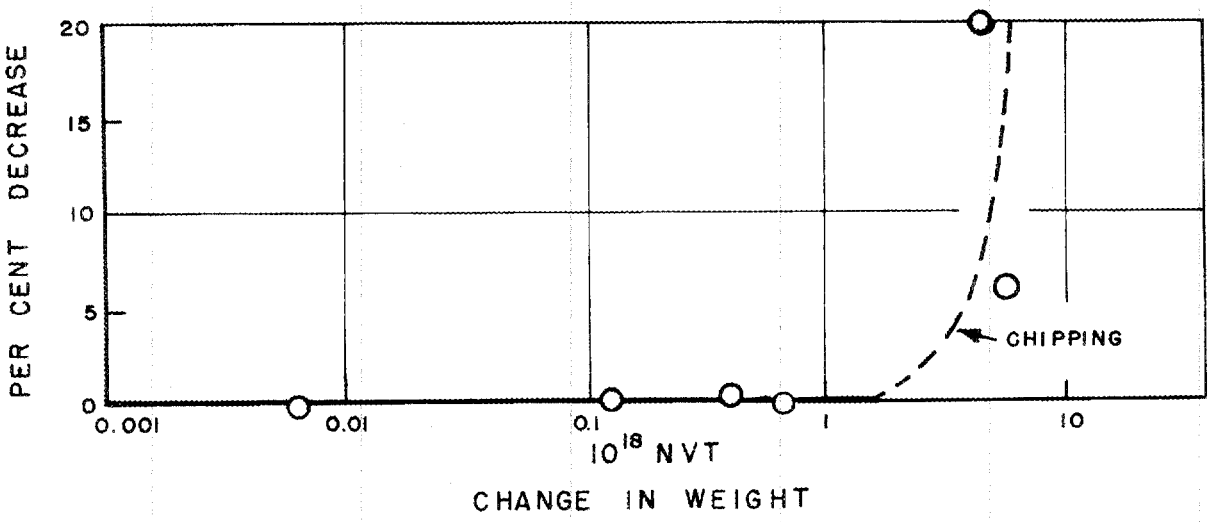
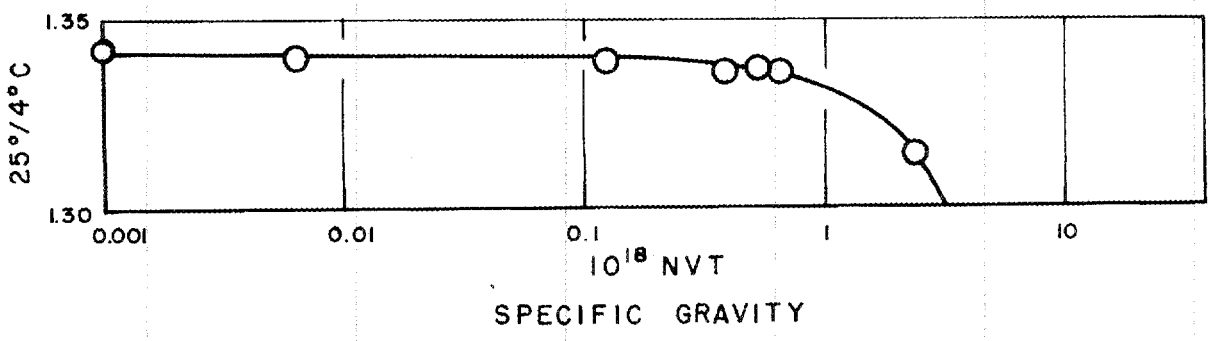


FIGURE 23B MICARTA (PHENOLIC LAMINATE)

UNCLASSIFIED
DWG.#11147





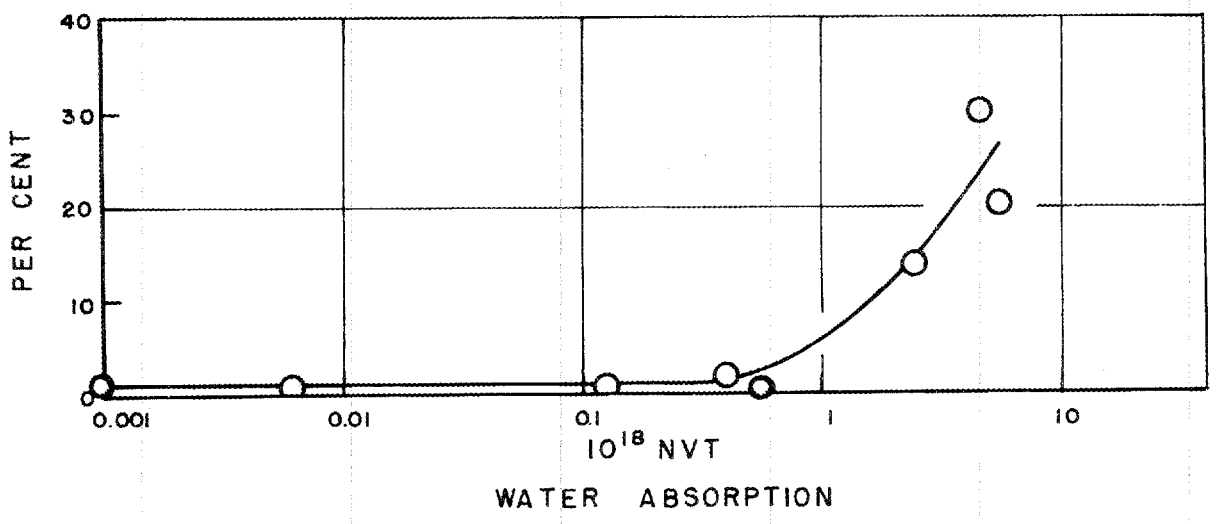
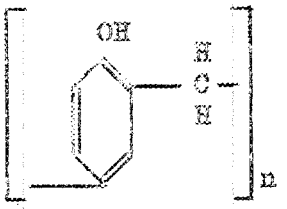


FIGURE 23C PHENOLIC LAMINATE (MICARTA)

CATALIN UNFILLED PHENOLIC

Classification:	Phenolic, no filler
Trade name:	Catalin
Company:	Catalin Corporation of America
Resin:	Phenol-formaldehyde
Formula:	



Filler:	None
Description:	Opaque, yellow-white. Darkens upon irradiation.
Thickness of sheets:	0.178 - 0.181 in.
Speed of tensile testing	
Mean rate of straining:	0.9 - 1.5 x 10^{-4} units/sec.
Mean rate of stressing:	20 - 60 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11148

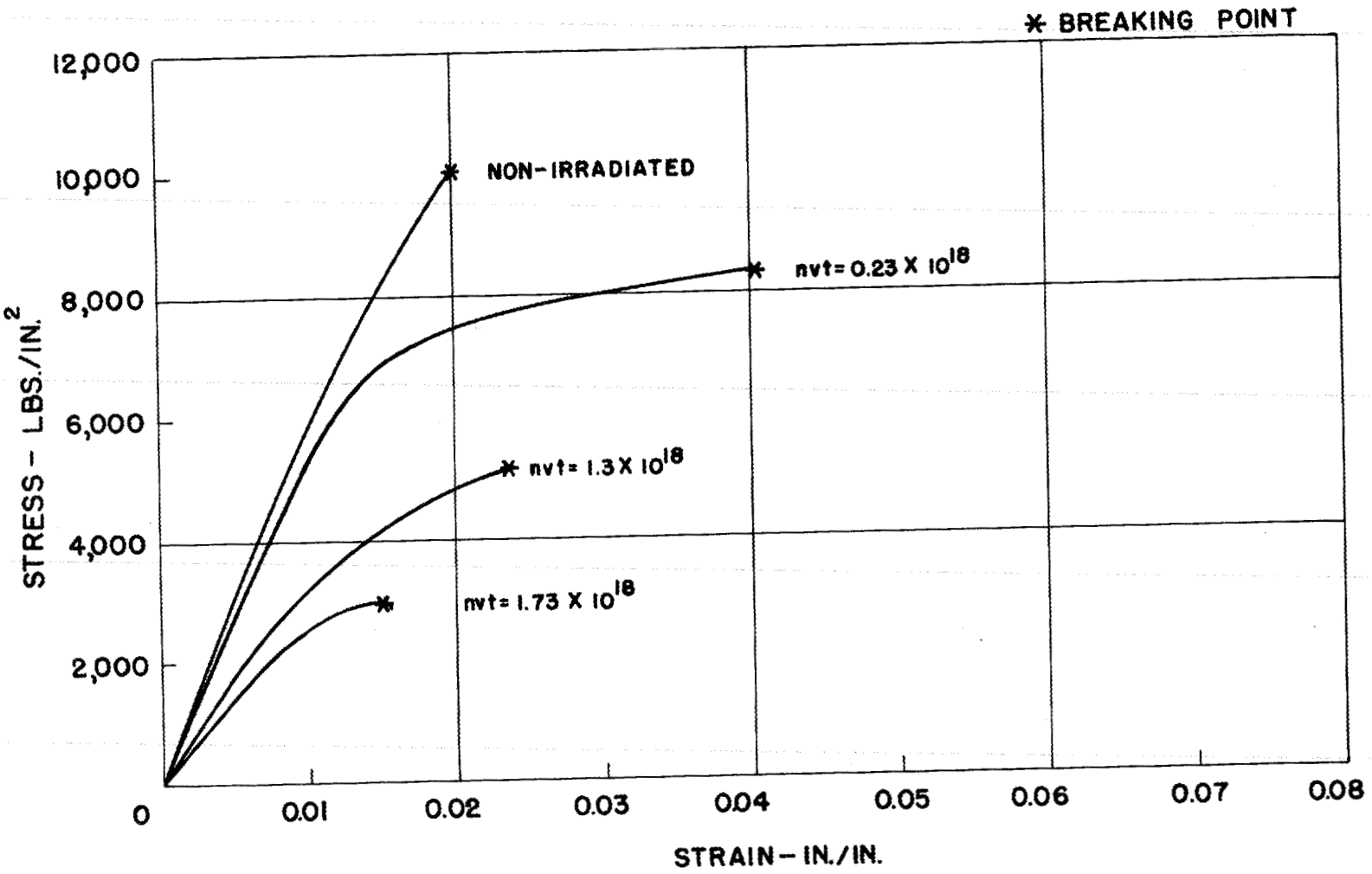
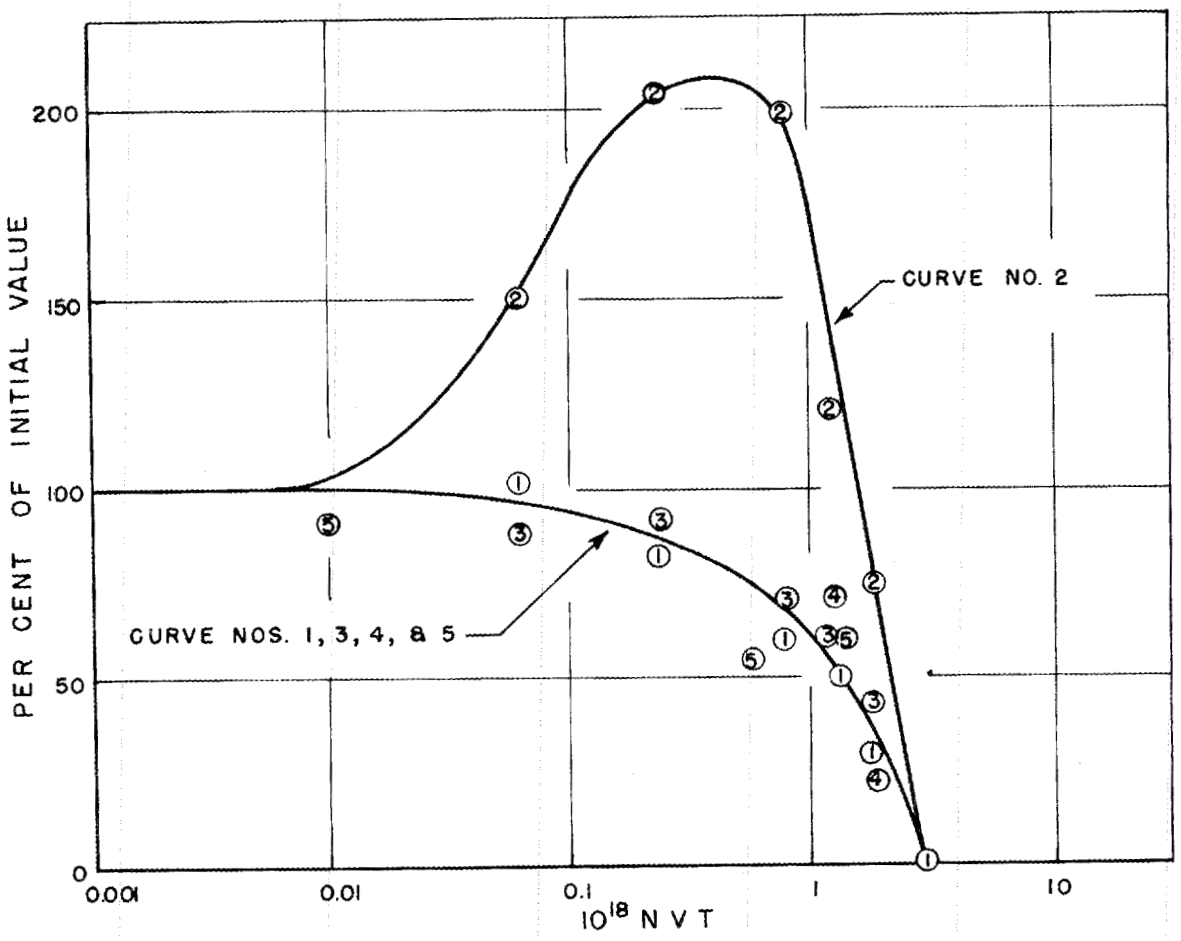


FIGURE 24A STRESS STRAIN CURVES FOR PILE IRRADIATED UNFILLED PHENOLIC

UNCLASSIFIED
DWG.#11149



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	10,000 LBS. / SQ. IN.
2	ELONGATION	2 %
3	ELASTIC MODULUS	6 X10^5 LBS. / SQ. IN.
4	SHEAR STRENGTH	8,600 LBS. / SQ. IN.
5	IMPACT STRENGTH	0.53 FT. LBS/IN. NOTCH

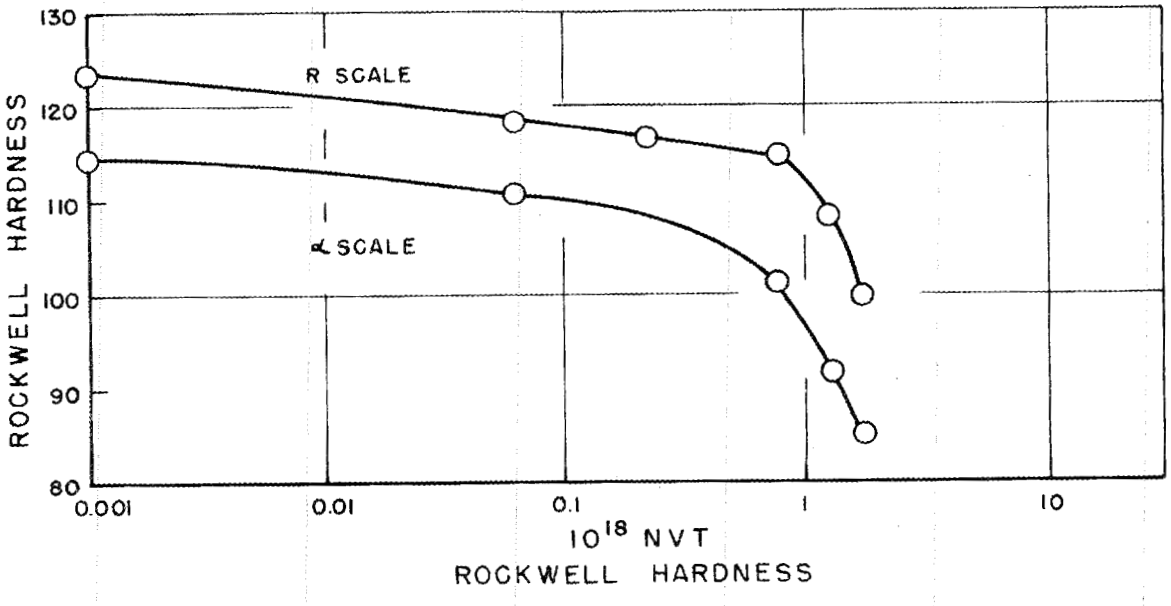


FIGURE 24B UNFILLED PHENOLIC

UNCLASSIFIED
DWG.#11150

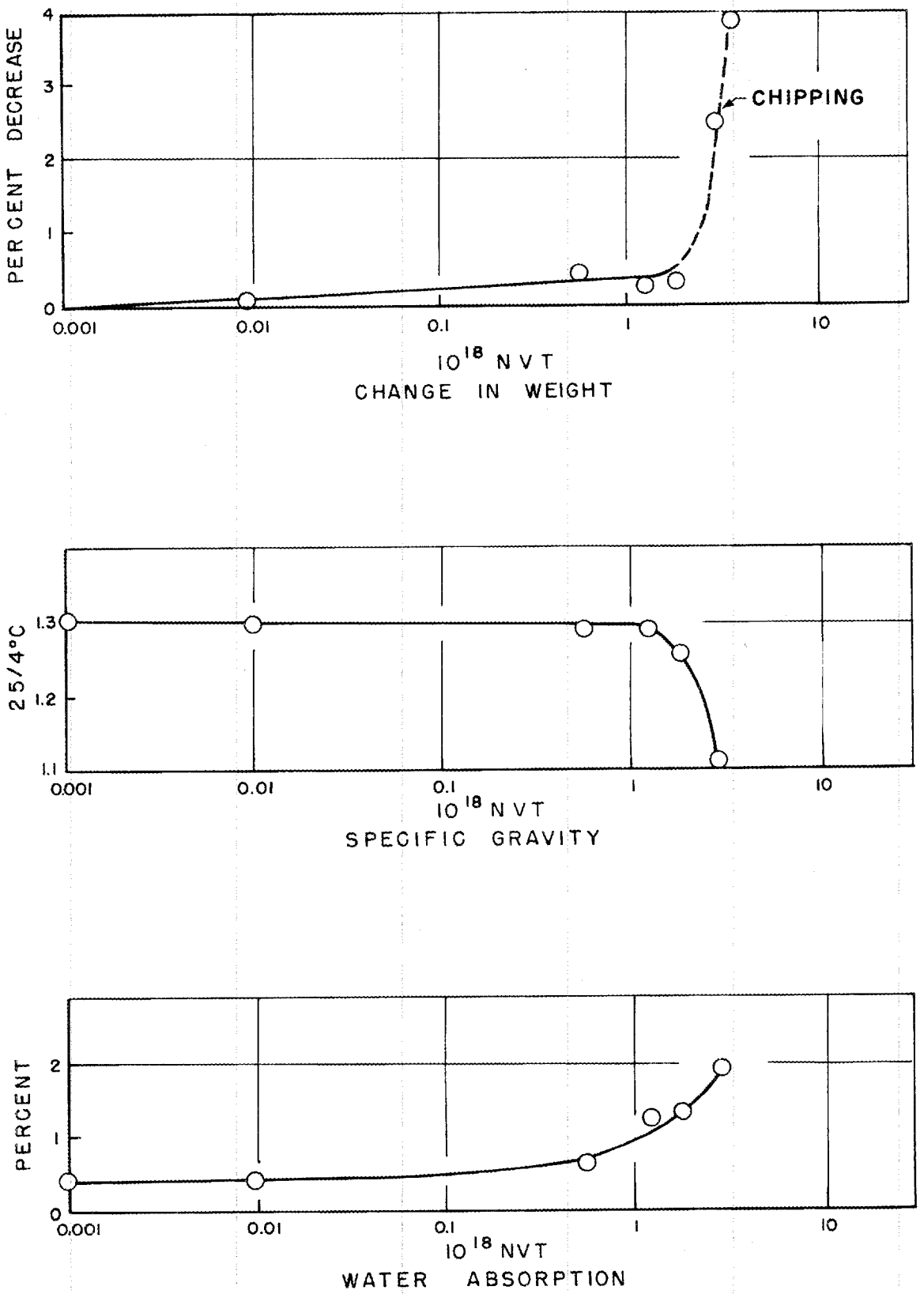


FIGURE 24C UNFILLED PHENOLIC

Volume Resistivity of 180 Mil Specimens

10^{18} nvt	ohm cm
0	10^{12}
2	10^{12}

Dielectric Strength of 180 Mil Specimens

10^{18} nvt	volts/mil
0	> 170
2	> 170

Arc Resistance of 180 Mil Specimens

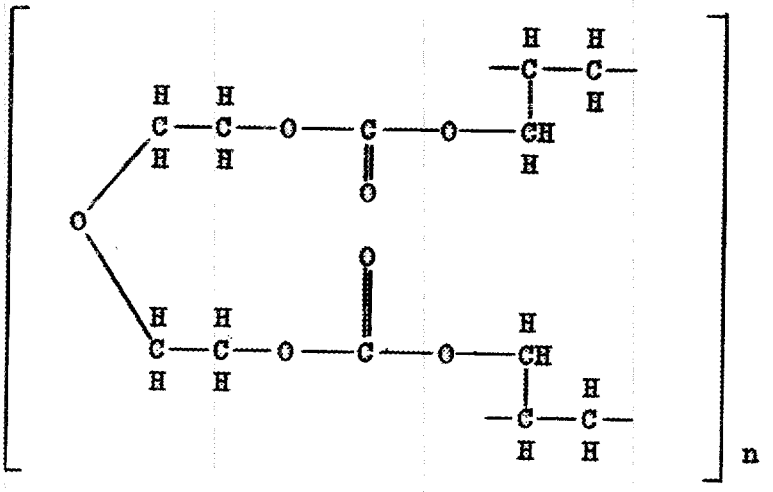
10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	5	Carbonized
0.54	< 2	"

FIGURE 24 D

CR-39

Classification:	Polyester resin
Trade name:	CR-39
Company:	Columbia Chemical Division, Pittsburgh Plate Glass Company
Resin:	Allyl diglycol carbonate

Formula:



Filler:	None
Description:	Clear - Darkens upon irradiation
Thickness of sheets:	0.116 - 0.121 in.
Speed of tensile testing	
Mean rate of straining:	0.8 - 1.6 x 10^{-4} units/sec.
Mean rate of stressing:	10 - 30 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11152

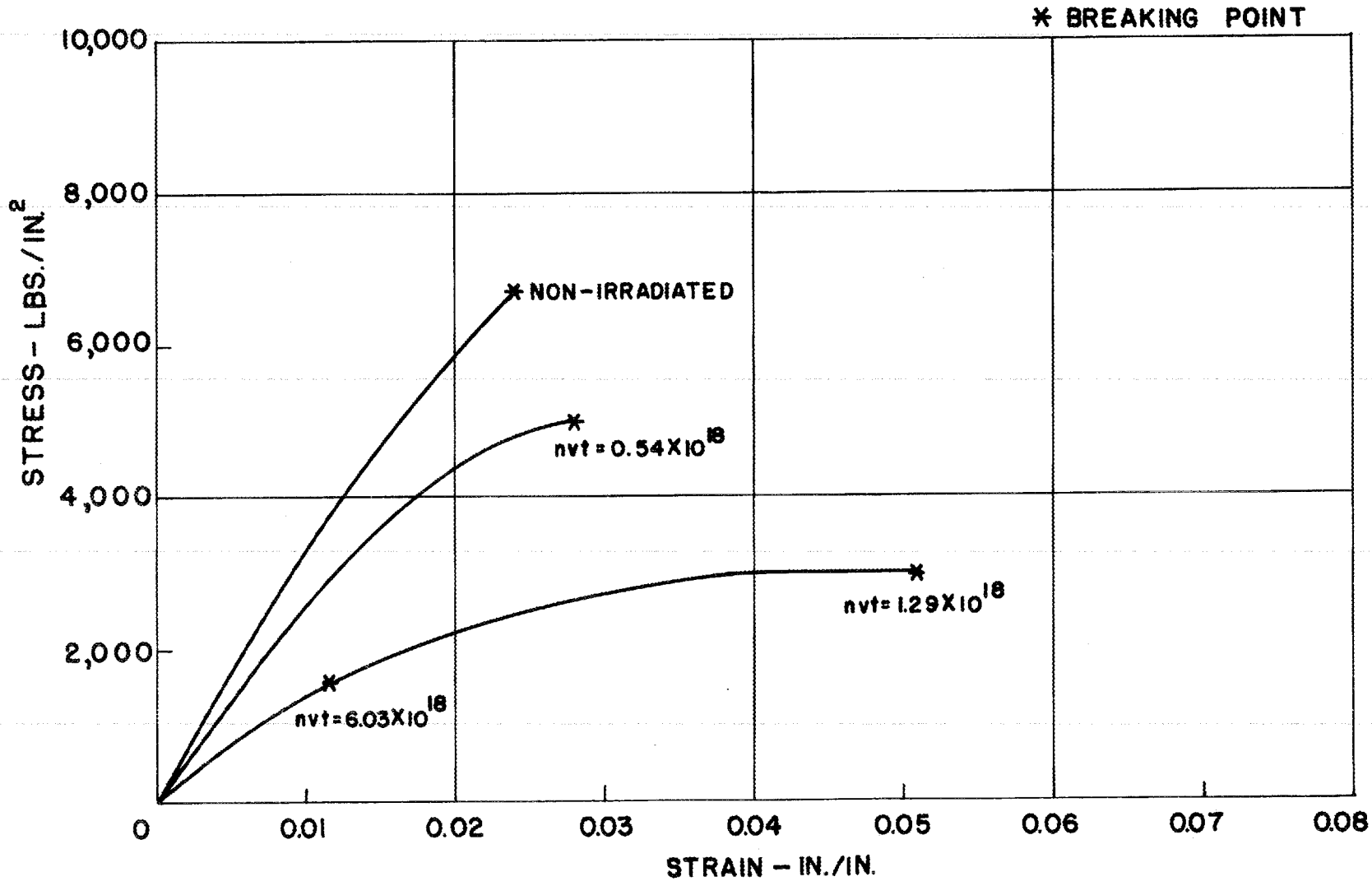
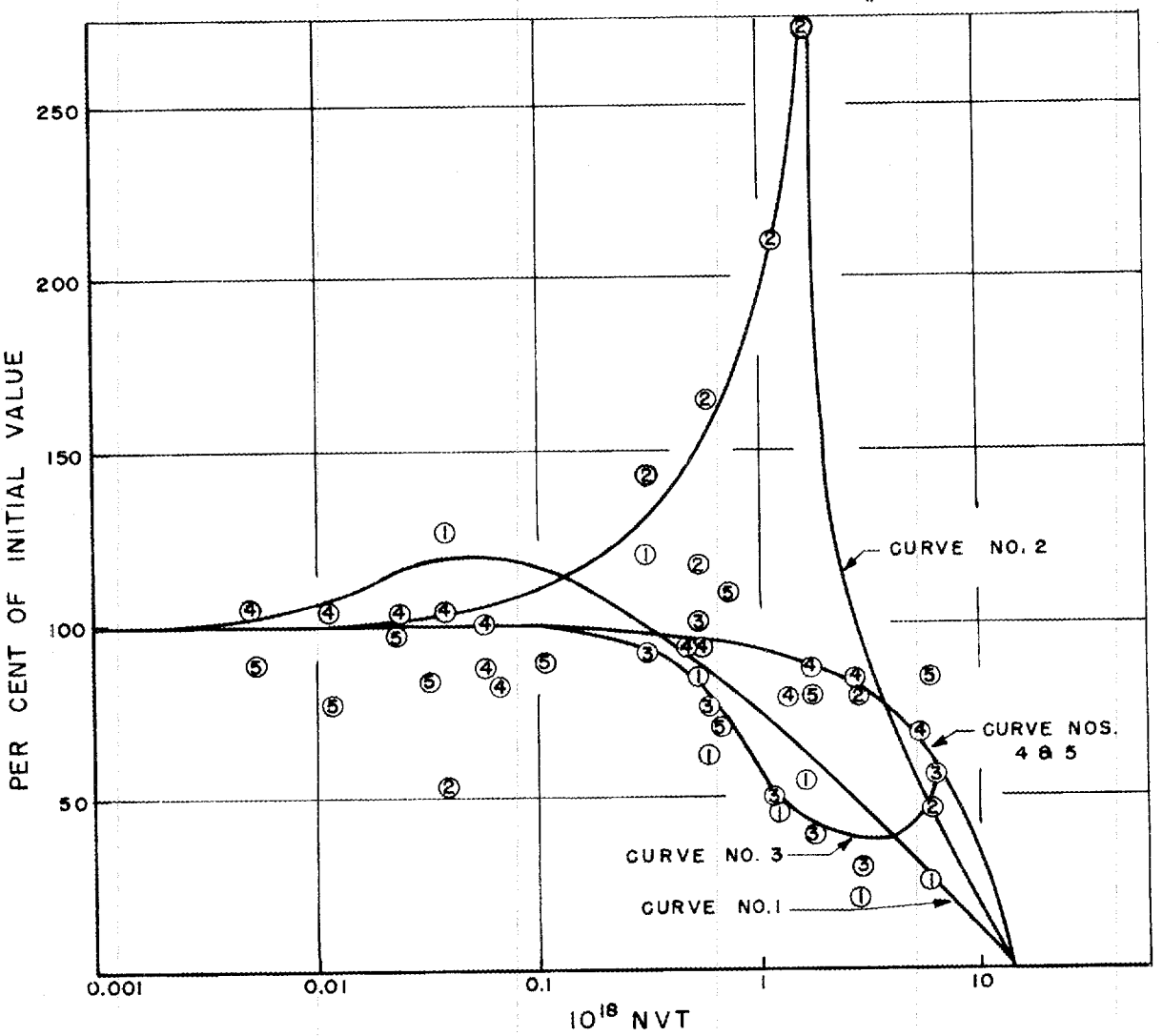


FIGURE 25A STRESS STRAIN CURVES FOR PILE IRRADIATED ALLYL DIGLYCOL CARBONATE

UNCLASSIFIED
DWG.#11153



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	6,700 LBS. / SQ. IN.
2	ELONGATION	2.4 %
3	ELASTIC MODULUS	2.8 X 10^5 LBS. / SQ. IN.
4	SHEAR STRENGTH	5,000 LBS. / SQ. IN.
5	IMPACT STRENGTH	0.35 FT. LBS. / IN. NOTCH

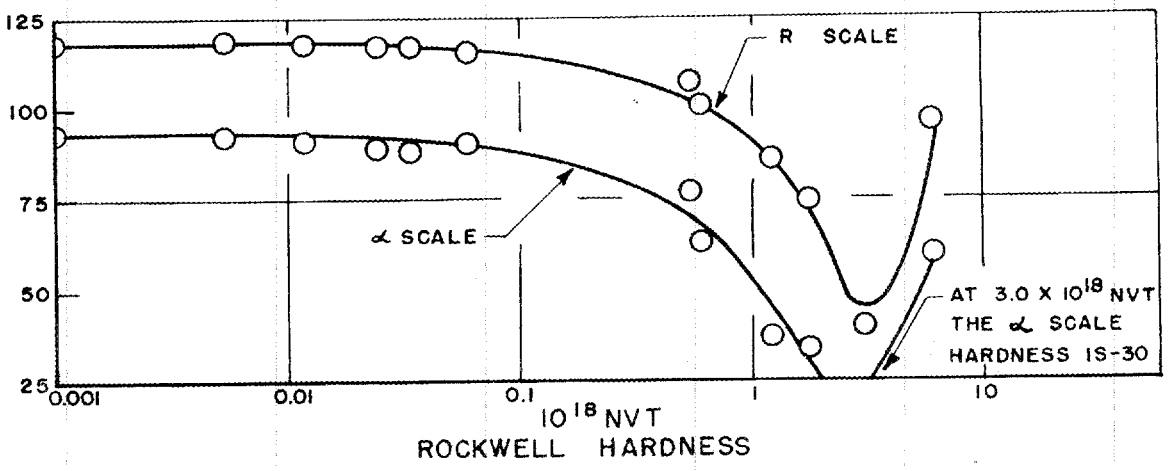


FIGURE 25B ALLYL DIGLYCOL CARBONATE

UNCLASSIFIED
DWG.#11154

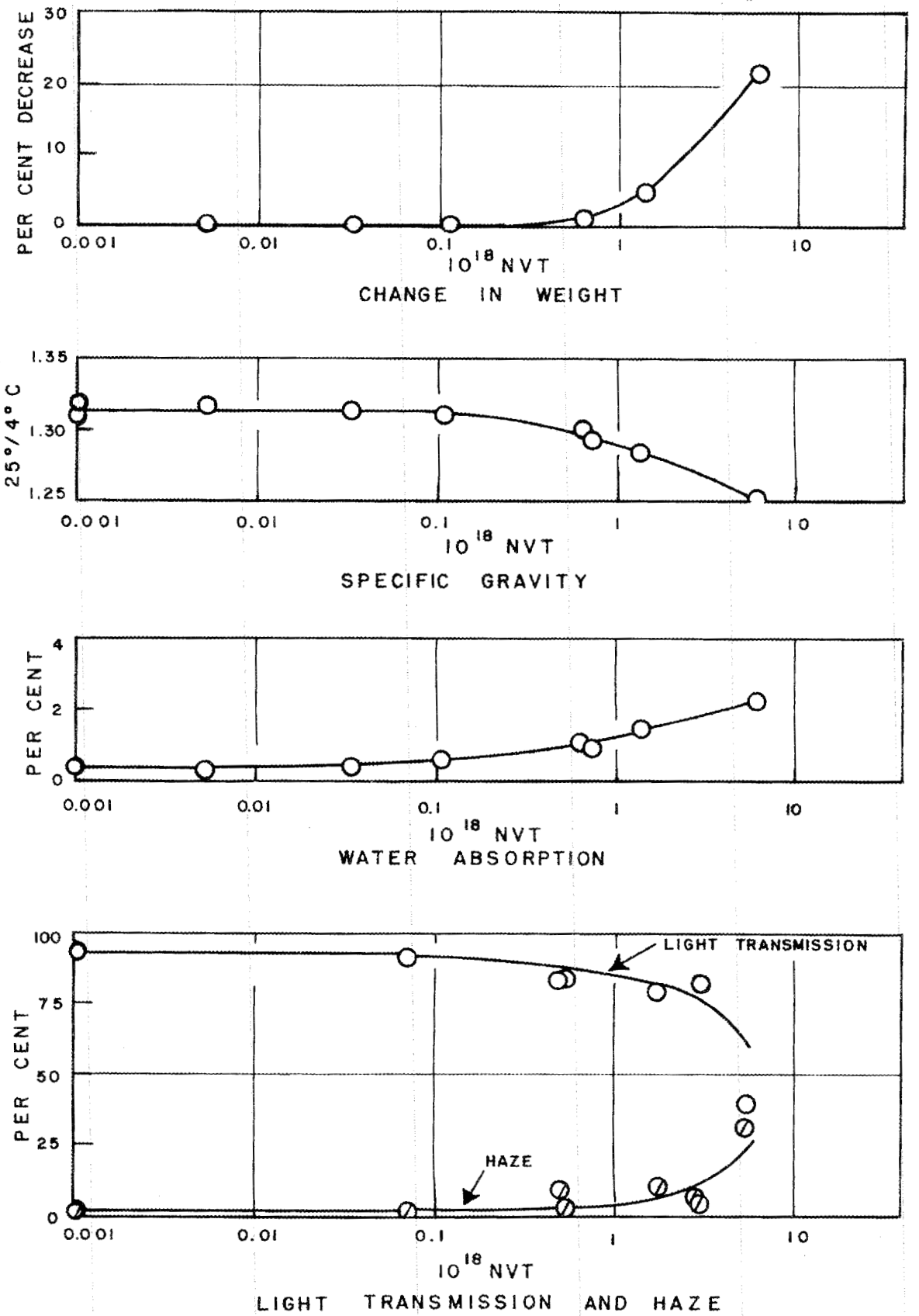


FIGURE 25C ALLYL DIGLYCOL CARBONATE

UNCLASSIFIED
DWG.#11155

CR-39

Volume Resistivity of 125 Mil Specimens

10^{18} nvt	ohm cm
0	$> 10^{14}$
1.5	6×10^{13}
3.0	2×10^{12}

Dielectric Strength of 30 Mil Specimens

10^{18} nvt	volts/mil
0	850
3	600

Arc Resistance of 125 Mil Specimens

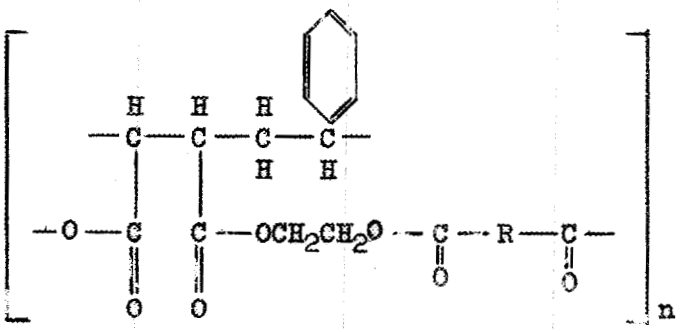
10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	120	Melted
5	120	"

FIGURE 25 D

PLASKON ALKYD

Classification:	Polyester resin
Trade name:	Plaskon Alkyd
Company:	Plaskon Division, Libbey-Owens-Ford Glass Company
Resin:	Polyester

Formula:



Filler:	Mineral filler
Description:	Opaque, light brown. No color change upon irradiation.
Thickness of sheets:	0.109 - 0.156
Speed of tensile testing	
Mean rate of straining:	0.1 - 0.2 x 10^{-4} units/sec.
Mean rate of stressing:	40 - 80 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11156

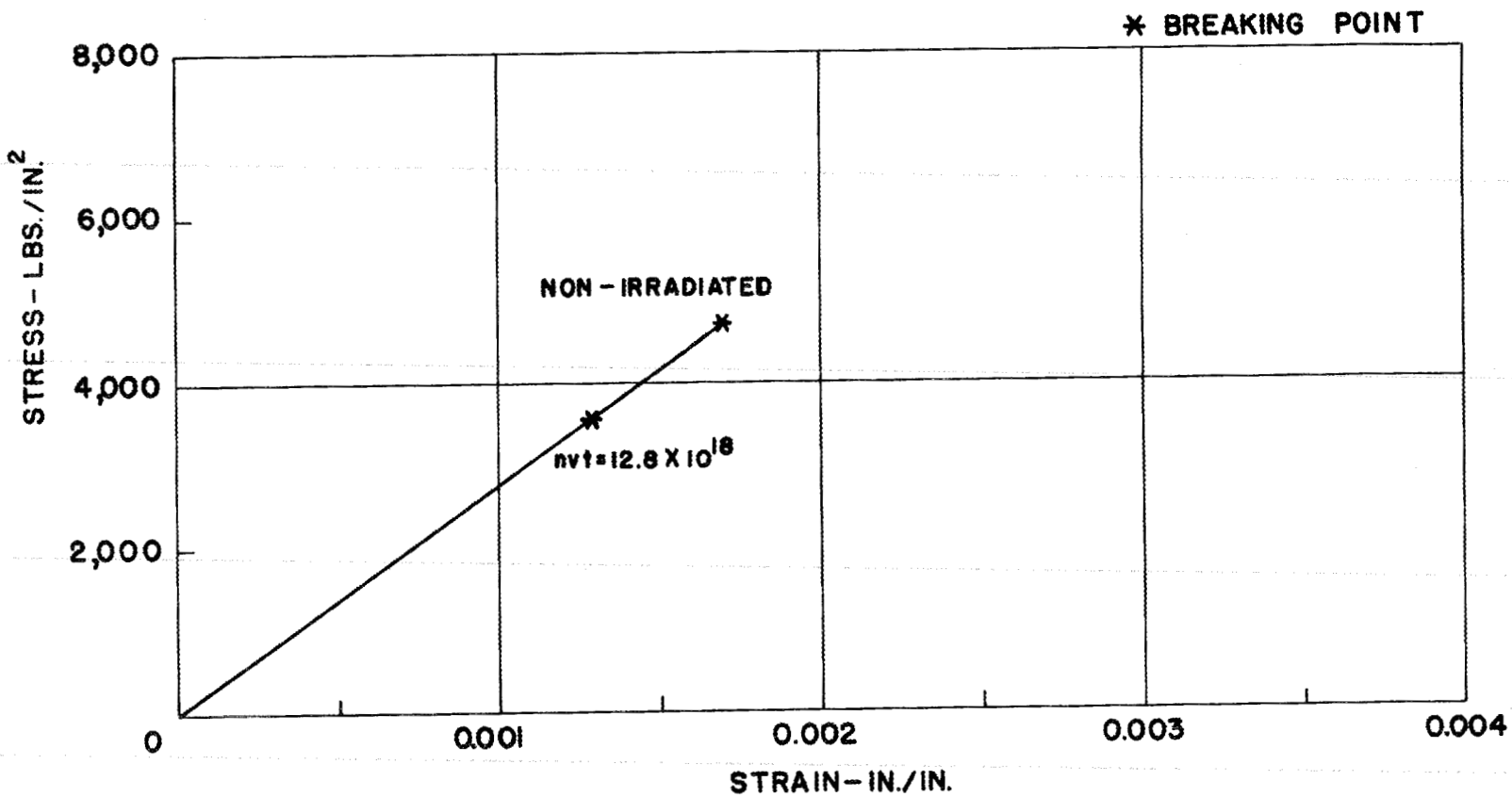
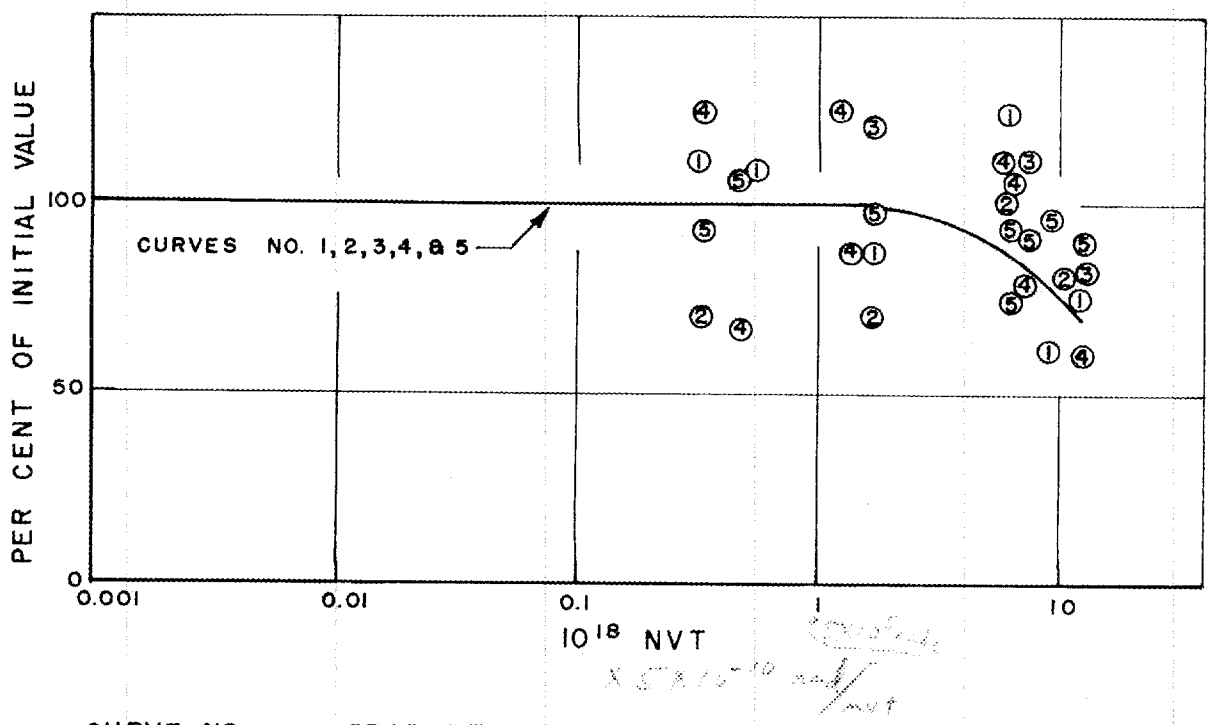


FIGURE 26A STRESS STRAIN CURVES FOR PILE IRRADIATED PLASKON ALKYD

UNCLASSIFIED
DWG.#11157



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	4,700 LBS./SQ. IN.
2	ELONGATION	0.17 %
3	ELASTIC MODULUS	32 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	7,000 LBS./SQ. IN
5	IMPACT STRENGTH	0.39 FT. LBS./IN. OF NOTCH

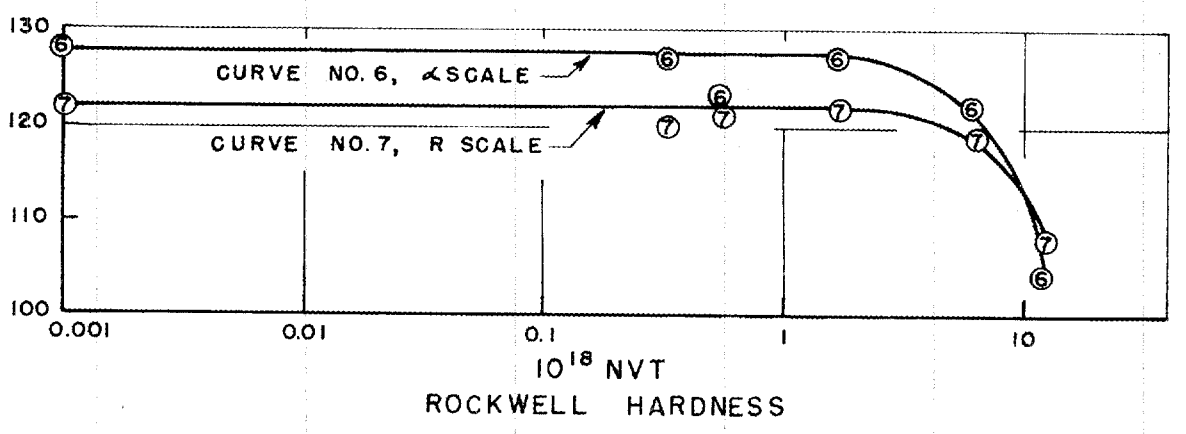
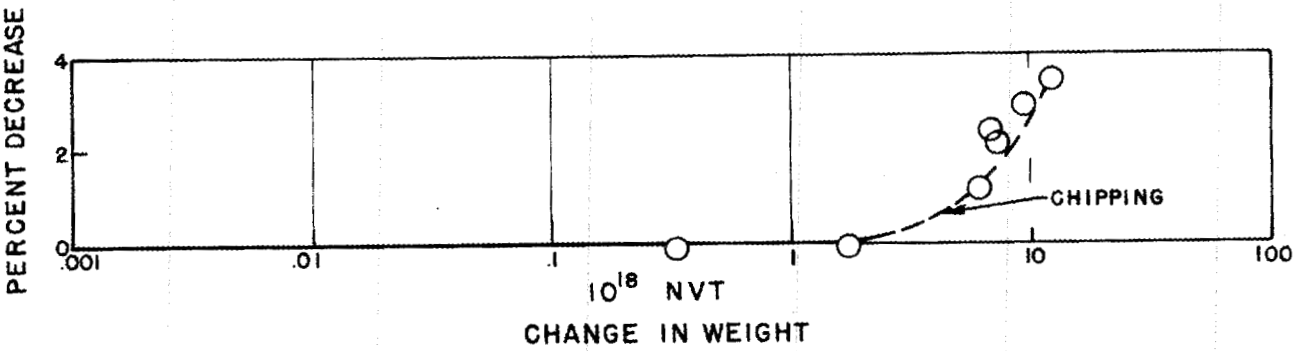
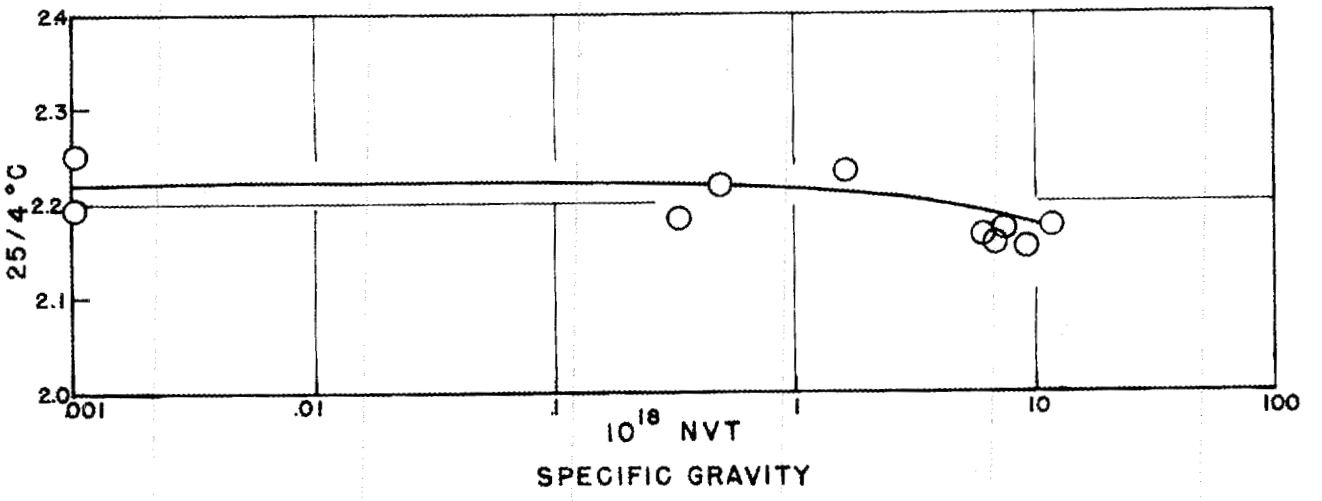


FIGURE 26B PLASKON ALKYD

UNCLASSIFIED
DWG.#11158





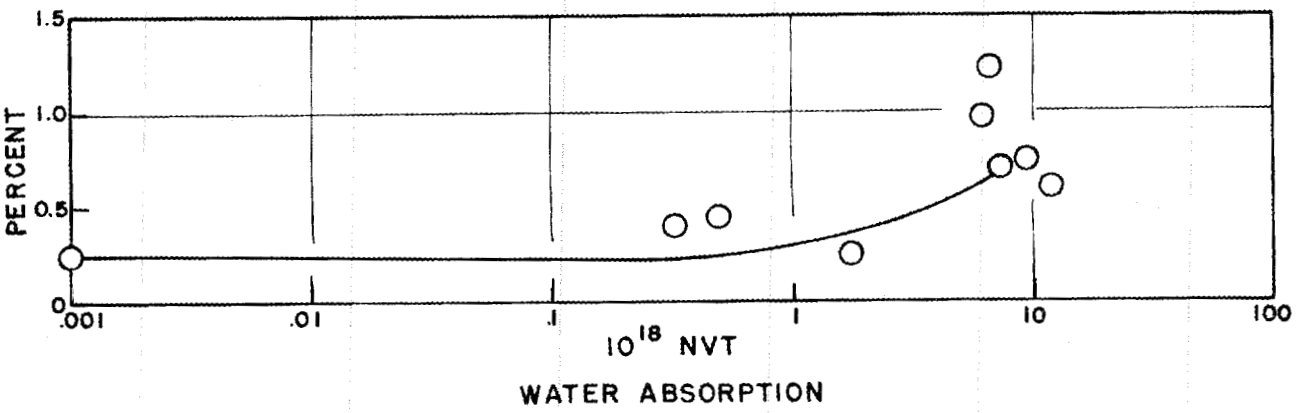


FIGURE 26C PLASKON ALKYD

PLASKON ALKYD

Volume Resistivity of 120 Mil Specimens

10^{18} nvt	ohm cm
0	$> 10^{14}$
7	$> 10^{14}$
13	3×10^{13}

Dielectric Strength of 120 Mil Specimens

10^{18} nvt	volts/mil
0	>250
7	>250
13	245

Arc Resistance of 120 Mil Specimens

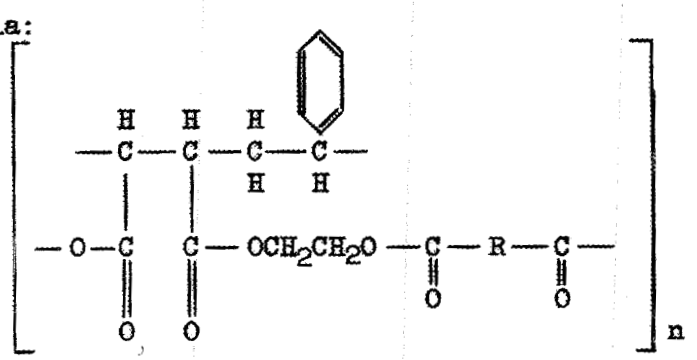
10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	180	Carbonized
13	180	"

FIGURE 26 D

SELECTRON 5038

Classification:	Polyester resin
Trade name:	Selectron 5038
Company:	Columbia Chemical Division, Pittsburgh Plate Glass Company
Resin:	Polyester

Formula:



Filler:	None
Description:	Clear - darkens upon irradiation
Thickness of sheets:	0.238 - 0.271 in.
Speed of tensile testing	
Mean rate of straining:	1.2 - 1.4 x 10^{-4} units/sec.
Mean rate of stressing:	3 - 40 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11160

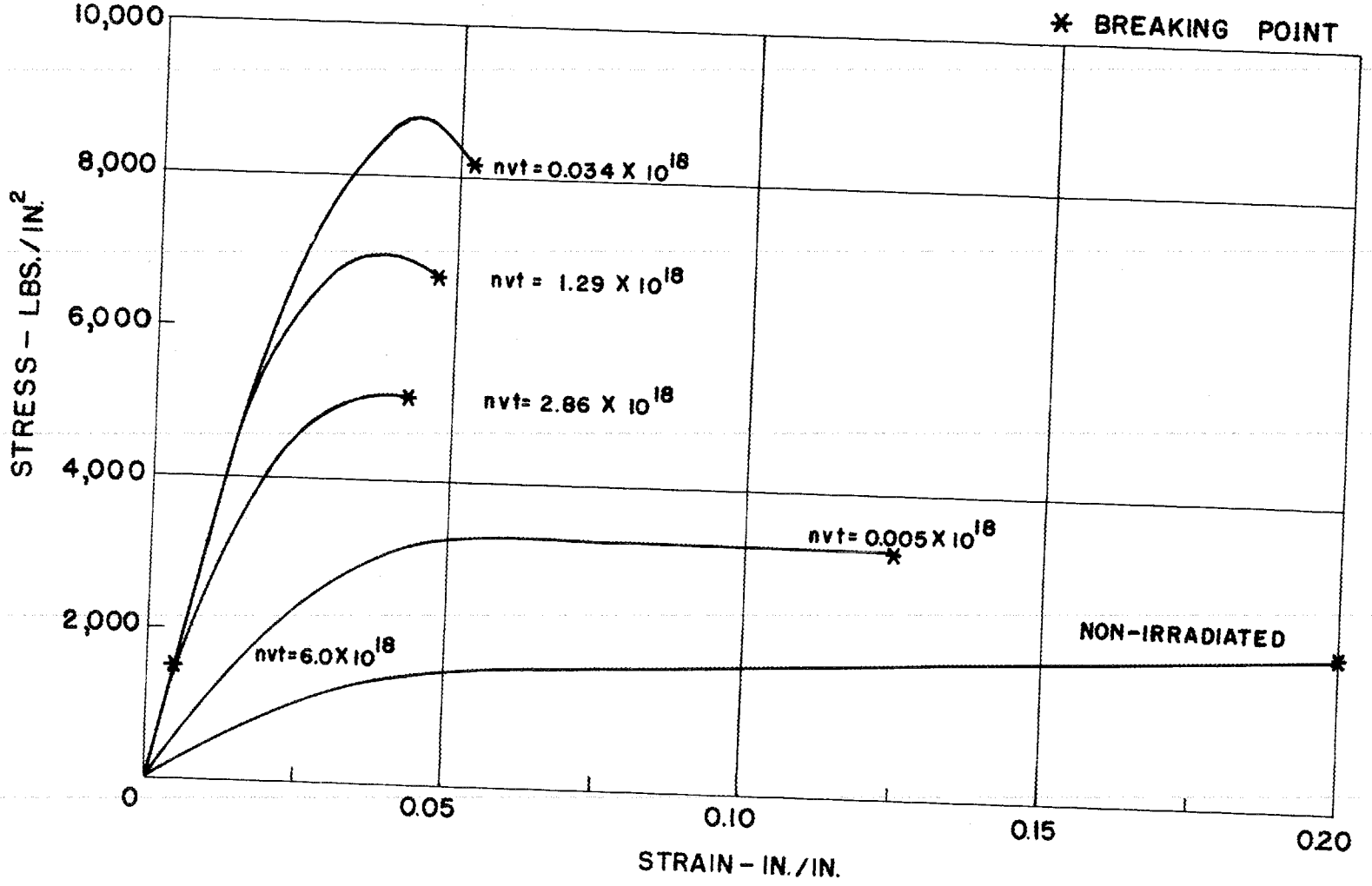
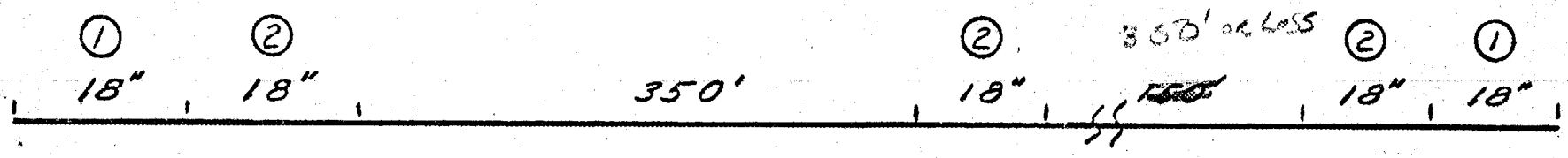


FIGURE 27A STRESS STRAIN CURVES FOR PILE IRRADIATED POLYESTER (SELECTRON 5038)



PLAN FOR BML SAMPLE OF LONG LENGTHS

FIGURE 3

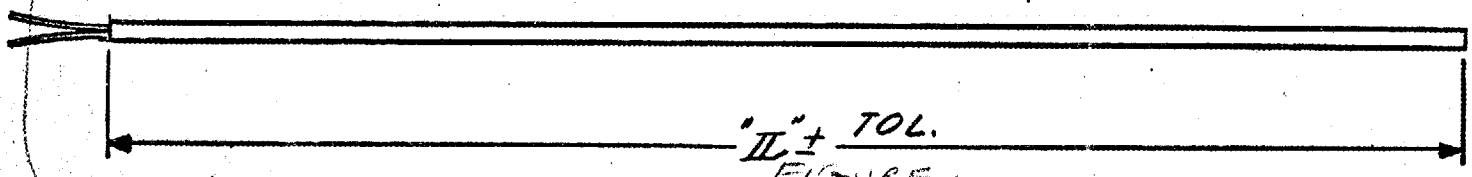


FIGURE 6

1 ARCHIVE SAMPLE

2 BULK MATERIAL SAMPLE FOR TESTING

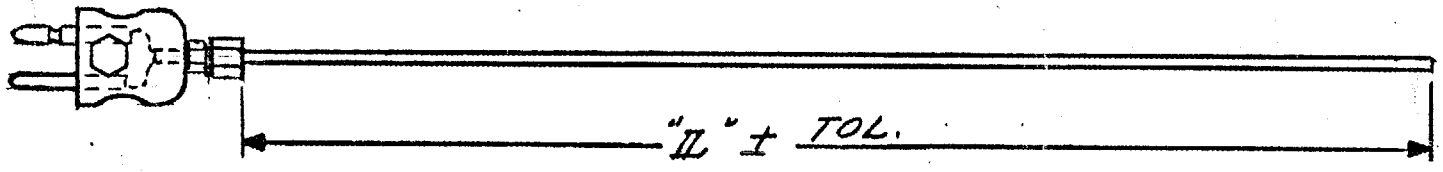


FIG. 4 LENGTH OF T/C ASS'Y. WITH CONNECTOR

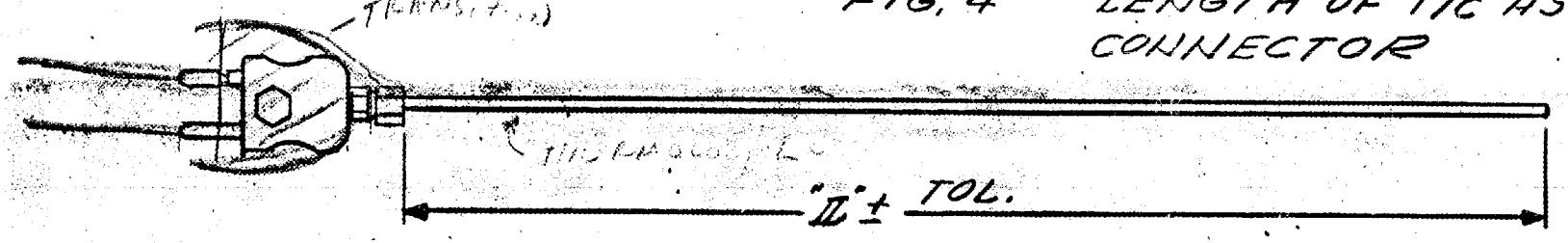
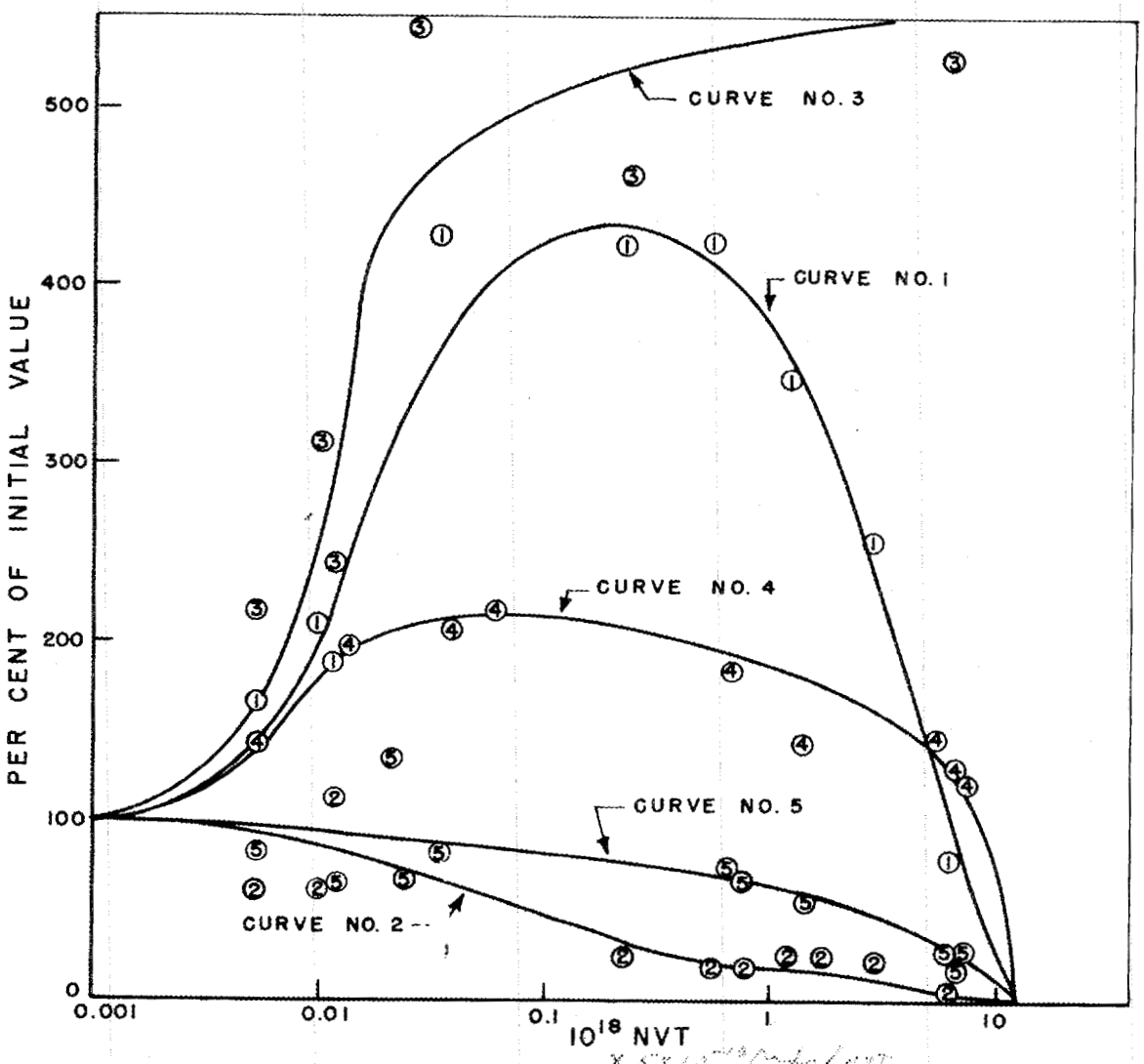


FIG. 5 LENGTH OF T/C ASS'Y., WITH TRANSITION

UNCLASSIFIED
DWG.#11161



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	2,000 LBS./SQ. IN.
2	ELONGATION	20 %
3	ELASTIC MODULUS	0.58 X 10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	3,100 LBS./SQ. IN.
5	IMPACT STRENGTH	0.73 FT. LBS./IN. OF NOTCH

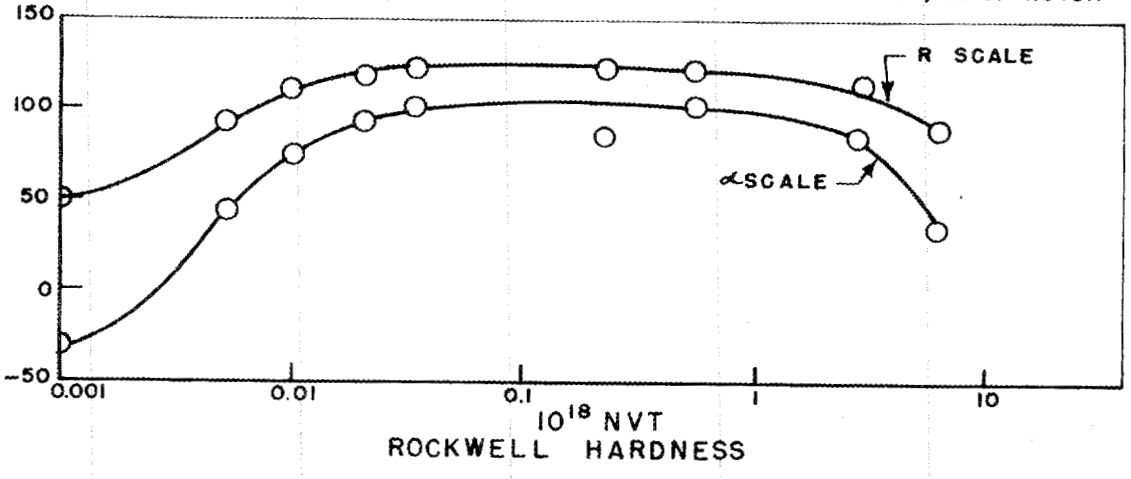


FIGURE 27B POLYESTER (SELECTRON 5038)

UNCLASSIFIED
DWG.#11162

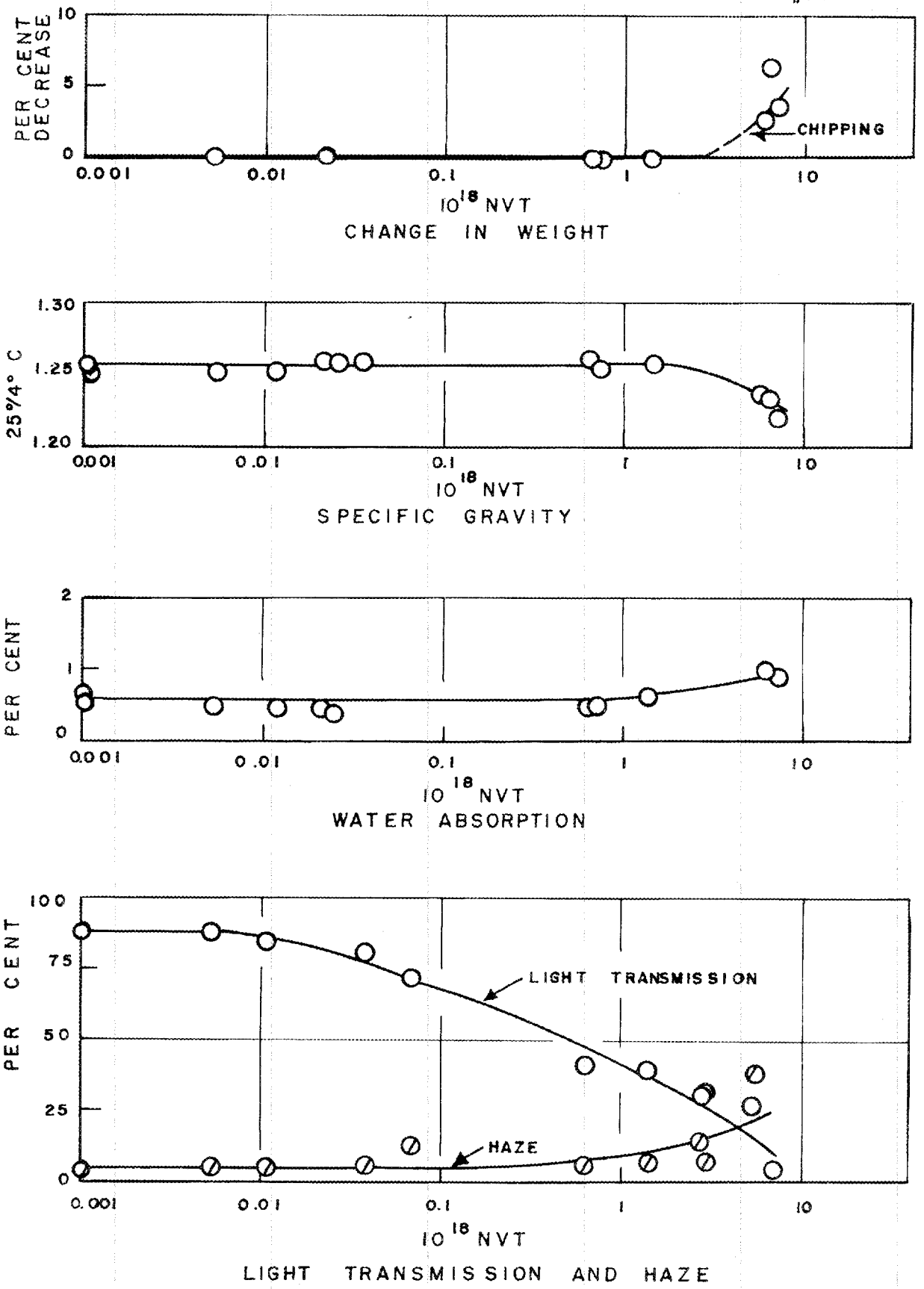


FIGURE 27C POLYESTER (SELETRON 5038)

UNCLASSIFIED
DWG.#11163

SELECTRON 5038

Volume Resistivity of 250 Mil Specimens

10^{18} nvt	ohm cm
0	1×10^{11}
3	6×10^{12}
7	$> 10^{14}$

Dielectric Strength of 21 Mil Specimens

10^{18} nvt	volts/mil
0	800
3.0	800

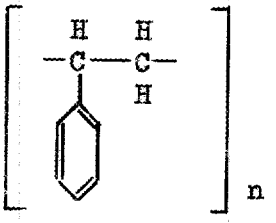
Arc Resistance of 250 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	63	Melted
7	69	"

FIGURE 27 D

AMPHENOL POLYSTYRENE

Classification:	Styrene polymer
Trade name:	Amphenol
Company:	American Phenolic Company
Resin:	Polystyrene
Formula:	



Filler:	None
Description:	Clear - Darkens upon irradiation
Thickness of tensile and impact specimens:	0.123 - 0.132 in.
Thickness of shear specimens:	0.07 in. - 0.09 in.
Speed of tensile testing	
Mean rate of straining:	0.5 - 1.2 x 10^{-4} units/sec.
Mean rate of stressing:	20 - 50 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11164

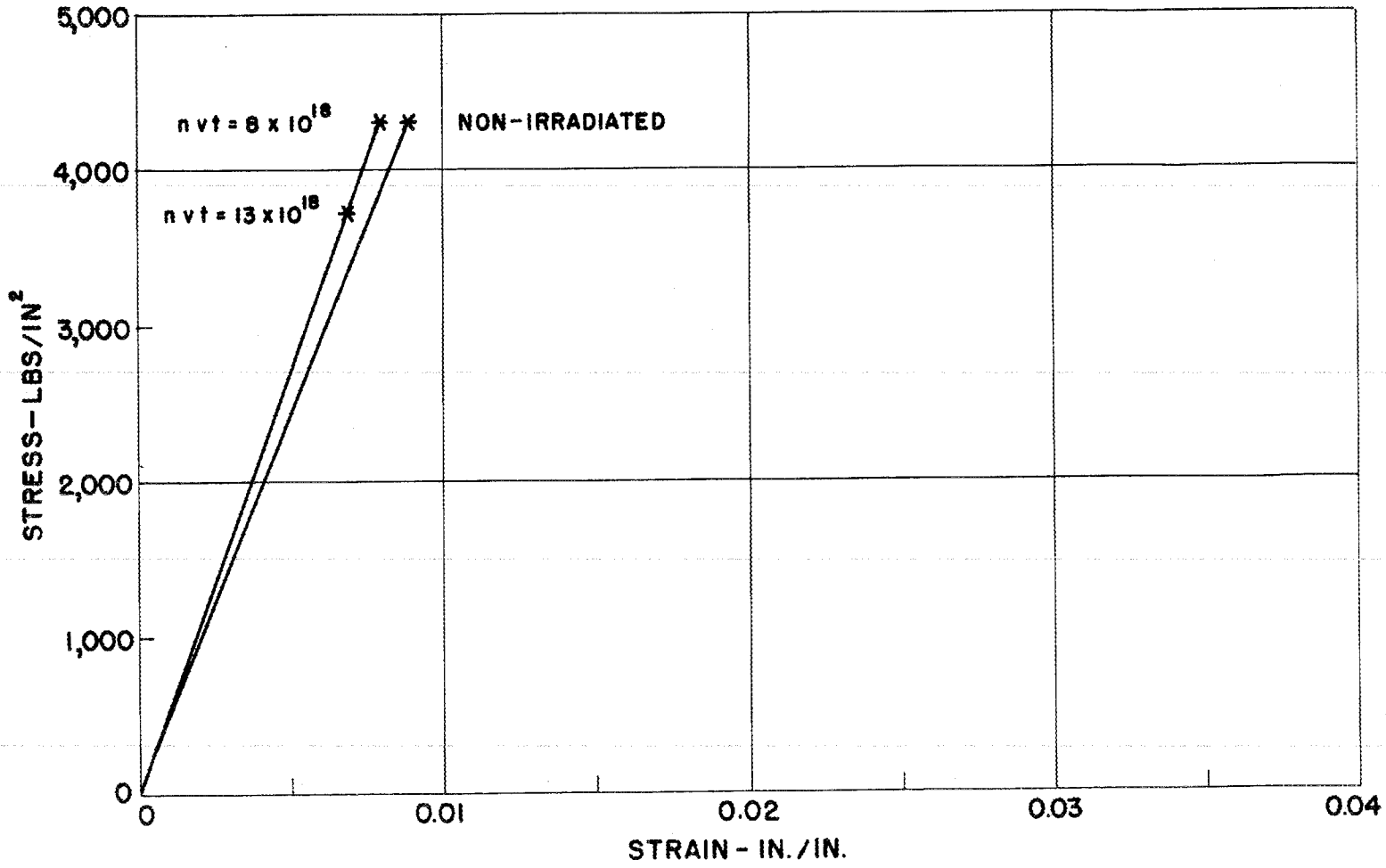
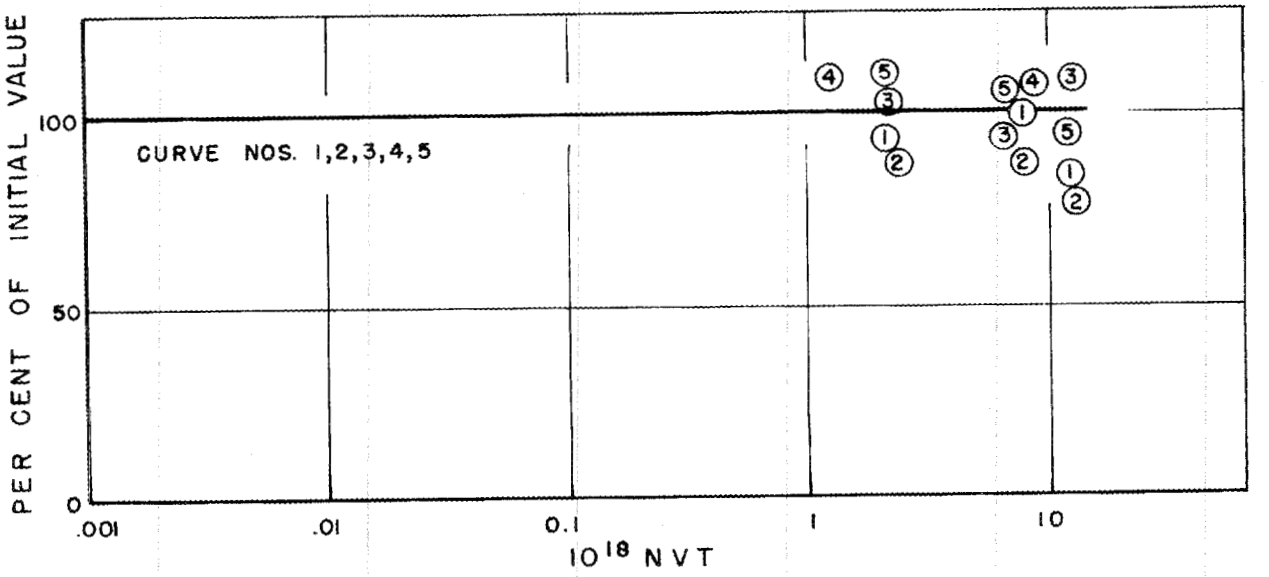


FIGURE 28A STRESS STRAIN CURVES FOR PILE IRRADIATED POLYSTYRENE (AMPHENOL)

UNCLASSIFIED
DWG.#11165



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	1,800 LBS. / SQ. IN.
2	ELONGATION	0.32 %
3	ELASTIC MODULUS	5.8×10^5 LBS./ SQ. IN.
4	SHEAR STRENGTH	3,500 LBS. / SQ. IN.
5	IMPACT STRENGTH	0.19 FT. LBS. / IN. NOTCH

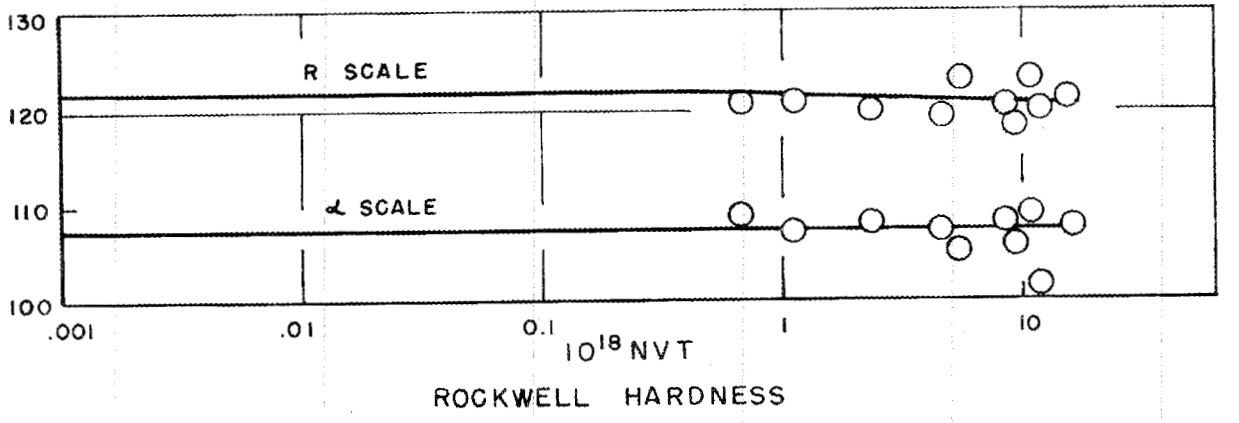
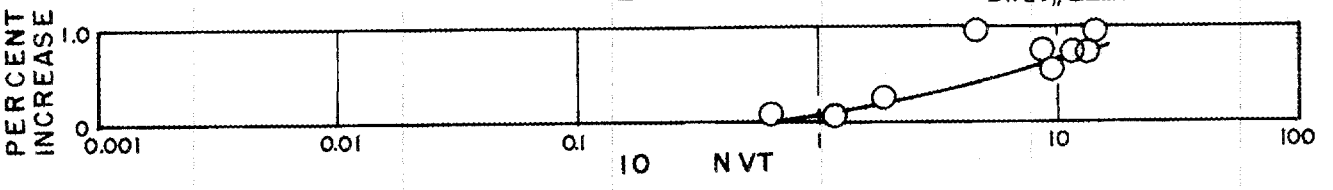
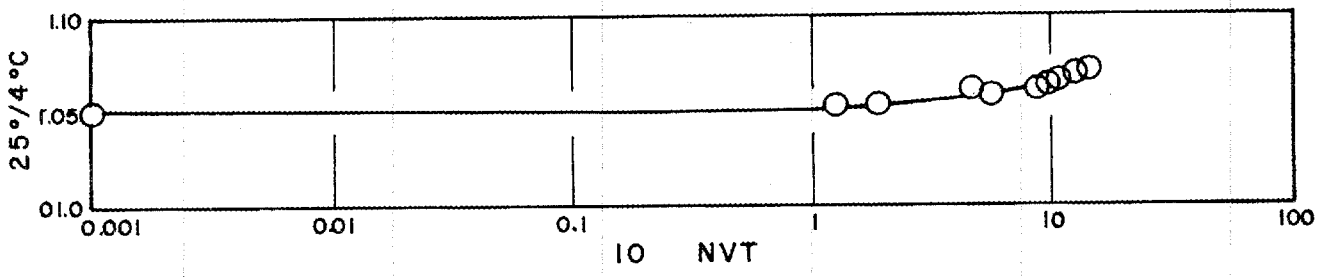


FIGURE 28B POLYSTYRENE (AMPHENOL)

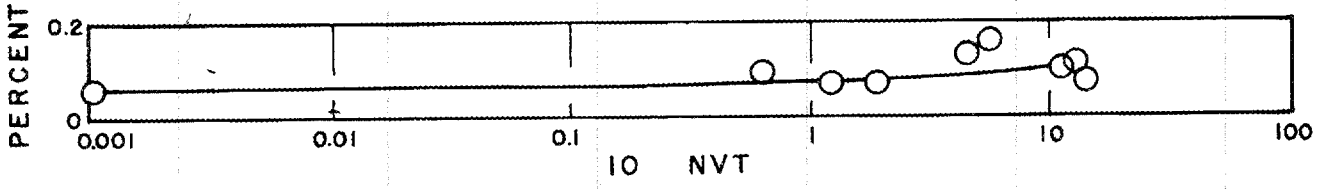
UNCLASSIFIED
DWG.#11166



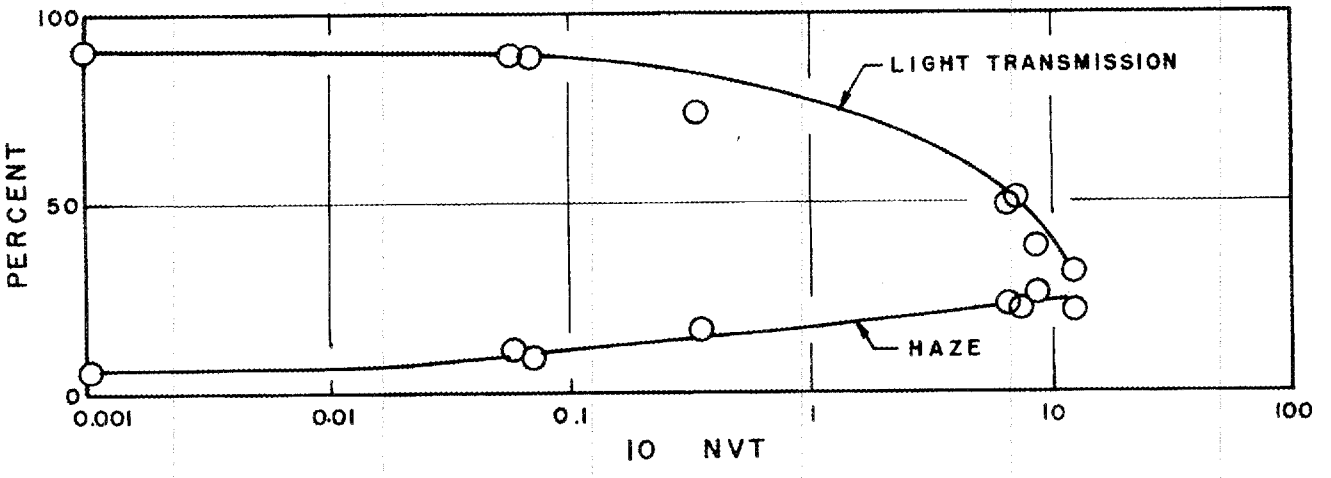
CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION



LIGHT TRANSMISSION AND HAZE

FIGURE 28C POLYSTYRENE (Amphenol)

UNCLASSIFIED
DWG.#11167

AMPHENOL

Volume Resistivity of 90 Mil Specimens

10^{18} nvt	ohm cm
0	$> 10^{14}$
9	$> 10^{14}$

Dielectric Strength of 19 Mil Specimens

10^{18} nvt	volts/mil
0	1600
9	1300

Arc Resistance of 90 Mil Specimens

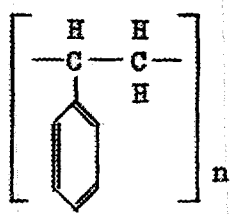
10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	$\sim$ 3-10	Melted
13	26	Carbonized

FIGURE 28 D

STYRON 411C

Classification:	Styrene polymer
Trade name:	Styron 411-C
Company:	Dow Chemical Company
Resin:	Polystyrene

Formula:



Filler:	White pigment
Description:	White, opaque- darkens upon irradiation
Thickness of sheets:	0.10 - 0.13 in.
Speed of tensile testing	
Mean rate of straining:	0.5 - 1.2 x 10^{-4} units/sec.
Mean rate of stressing:	20 - 50 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11168

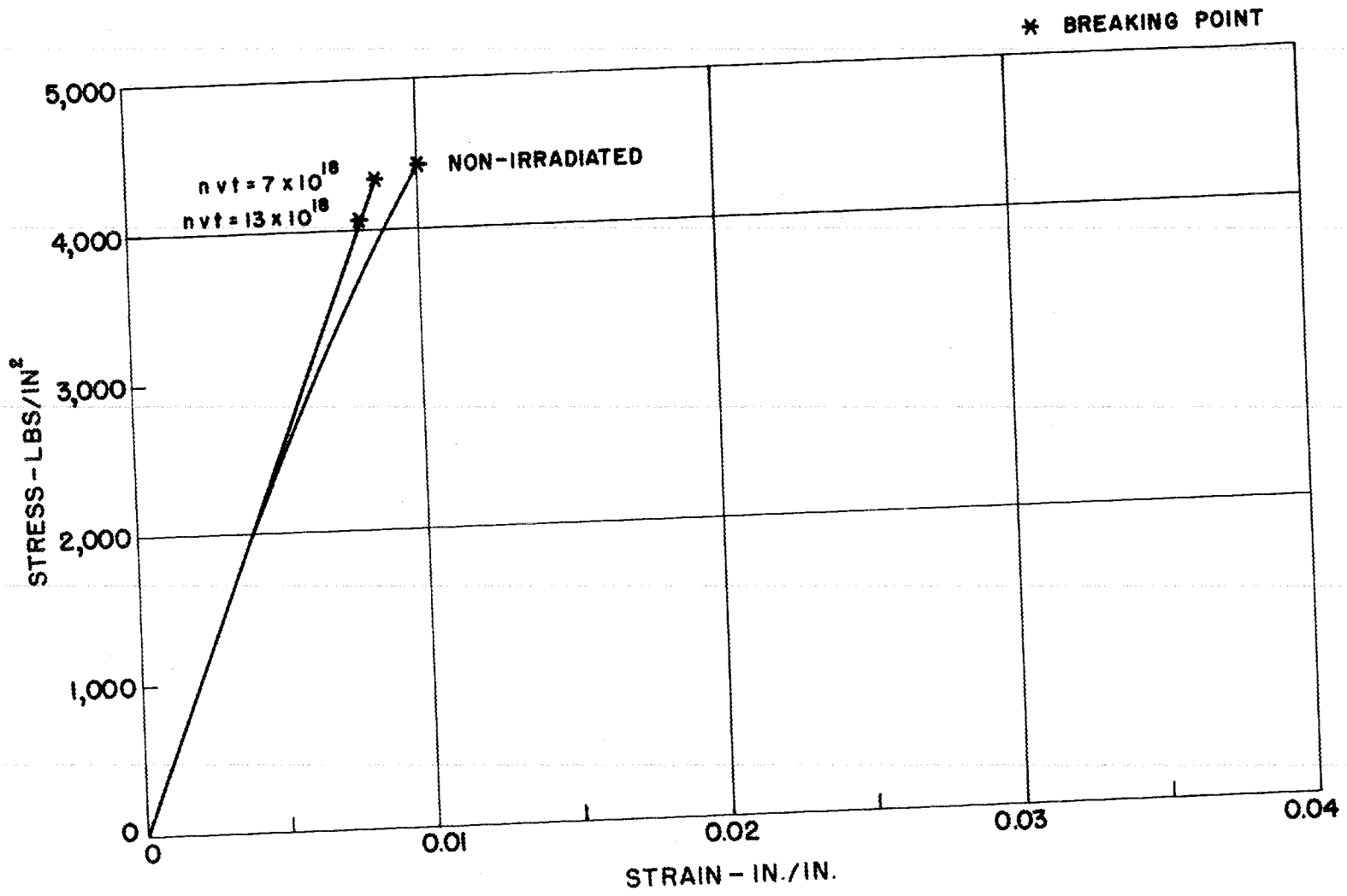
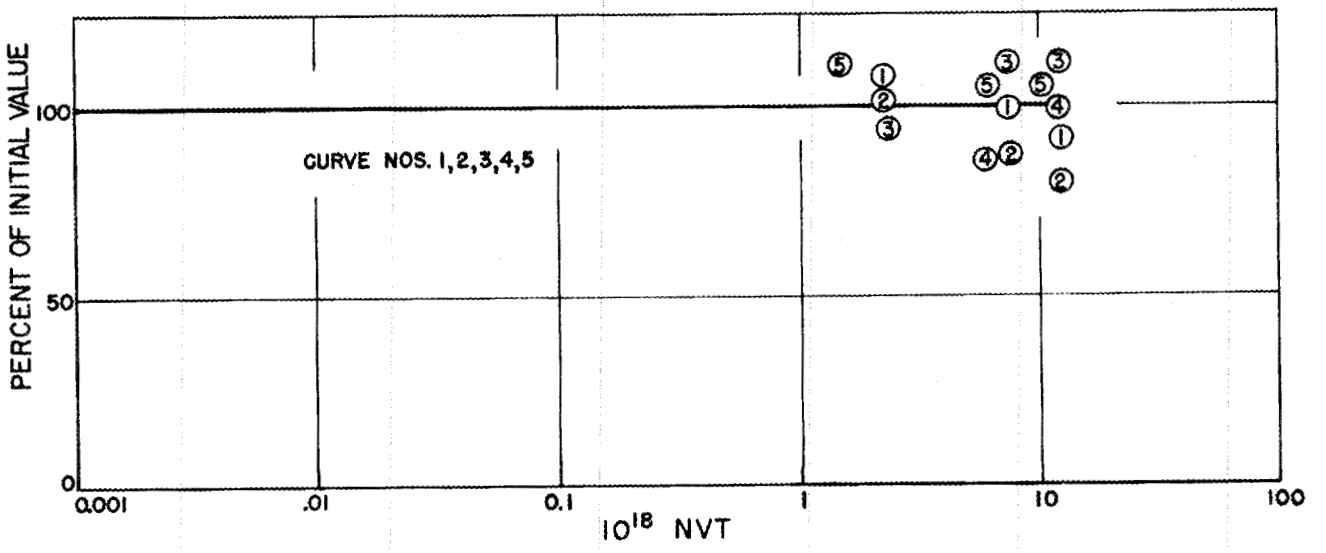


FIGURE 29A STRESS STRAIN CURVES FOR PILE IRRADIATED POLYSTYRENE (STYRON-411C)

UNCLASSIFIED
DWG.#11169



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	4,400 LBS./SQ. IN.
2	ELONGATION	1.0 %
3	ELASTIC MODULUS	4.8×10^5
4	SHEAR STRENGTH	5,500 LBS./SQ. IN.
5	IMPACT STRENGTH	0.20 FT. LB./IN. NOTCH

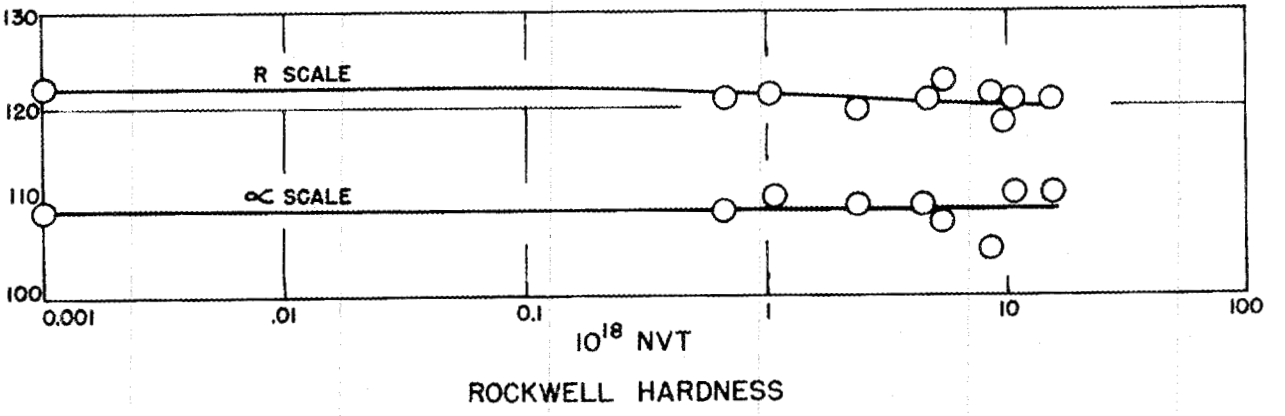
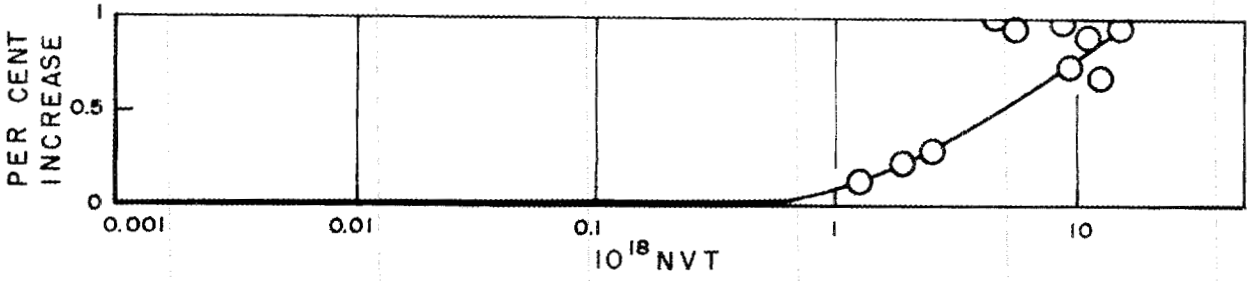
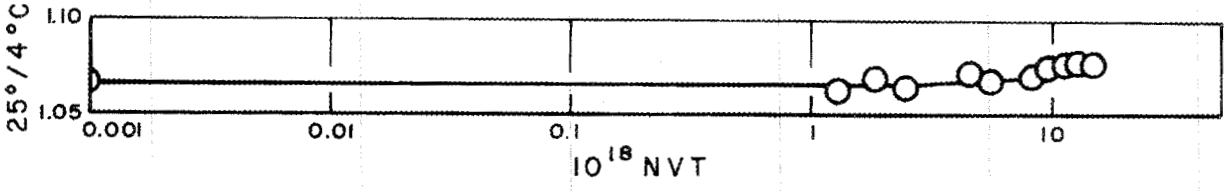


FIGURE 29B POLYSTYRENE (STYRON 411C)

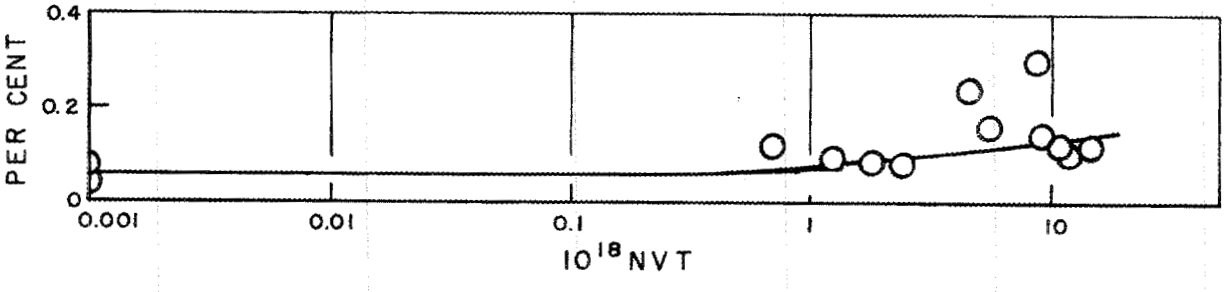
UNCLASSIFIED
DWG.#11170



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 29C POLYSTYRENE (STYRON 411C)

UNCLASSIFIED
DWG.#11171

STYRON 411C

Volume Resistivity of 125 Mil Specimens

10^{18} nvt	ohm cm
0	$> 10^{14}$
13	$> 10^{14}$

Dielectric Strength of 25 Mil Specimens

10^{18} nvt	volts/mil
0	1000
7	1000

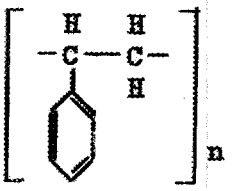
Arc Resistance of 125 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	50	Carbonized
13	50	"

FIGURE 29 D

STYRON 475

Classification:	Styrene polymer
Trade name:	Styron 475
Company:	Dow Chemical Company
Resin:	Polystyrene
Formula:	



Filler:	Black pigment
Description:	Black, opaque- No color change upon irradiation.
Thickness of sheets:	0.10 - 0.11
Speed of tensile testing	
Mean rate of straining:	0.9 - 2.0 x 10^{-4} units/sec.
Mean rate of stressing:	20 - 50 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11172

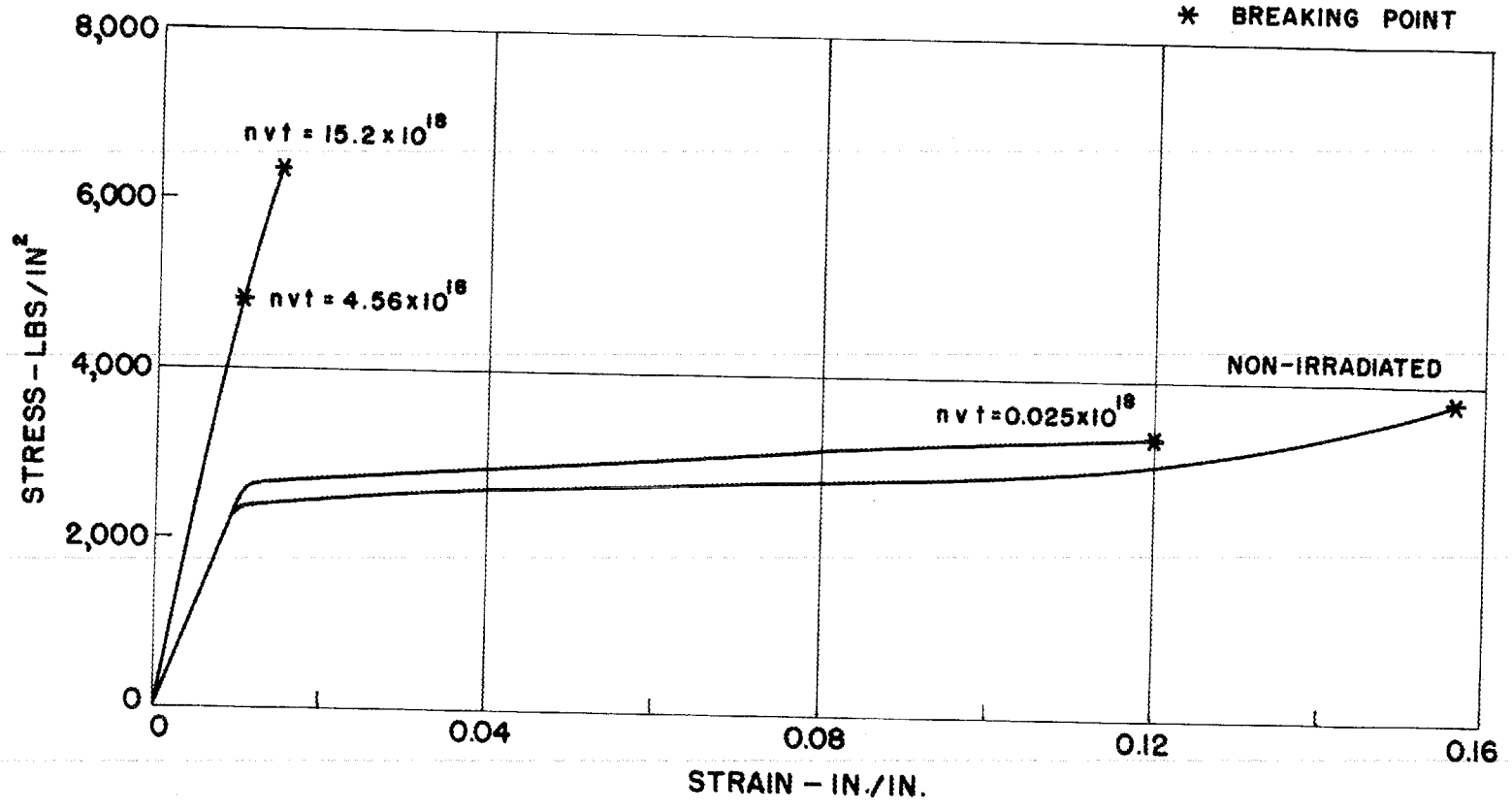
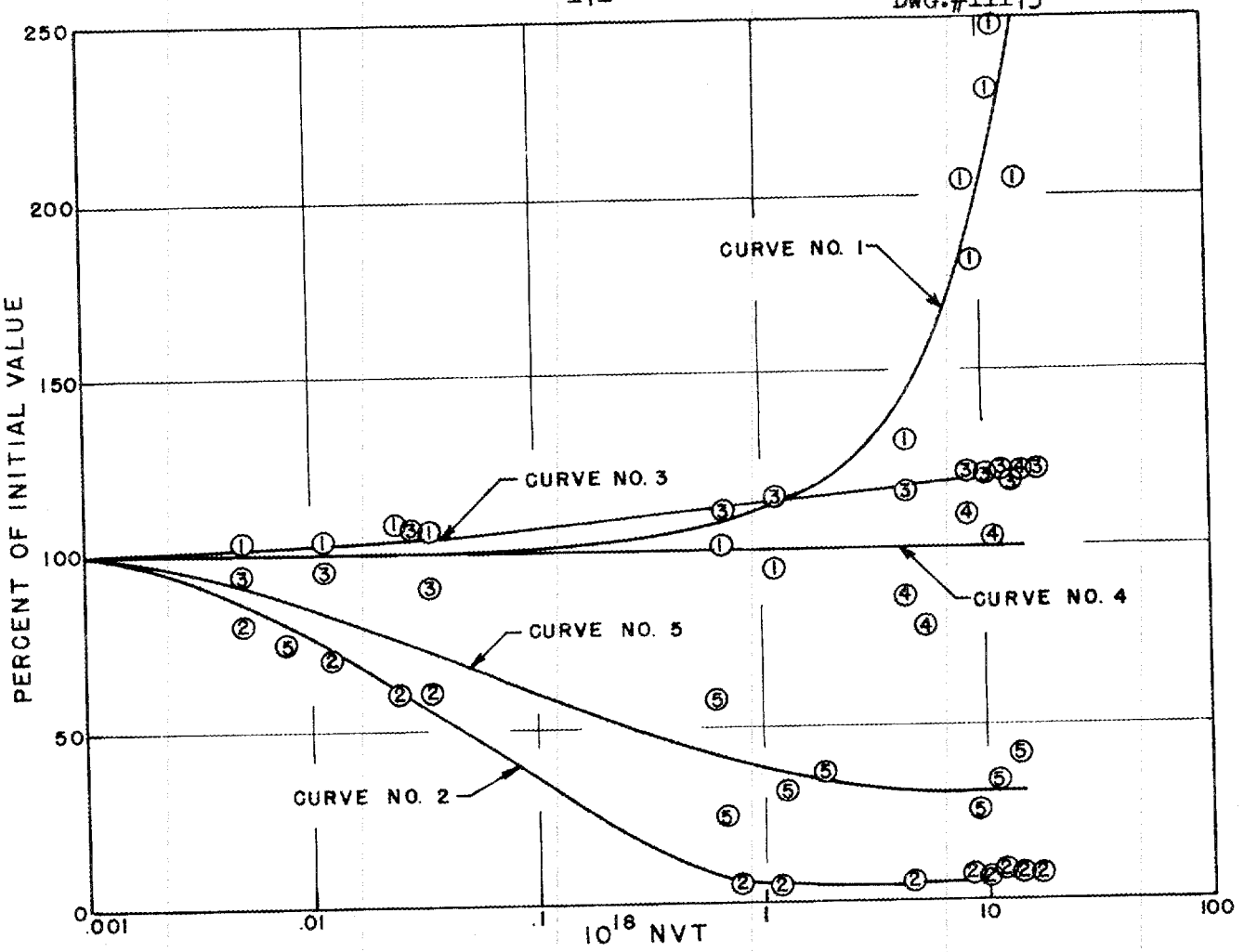
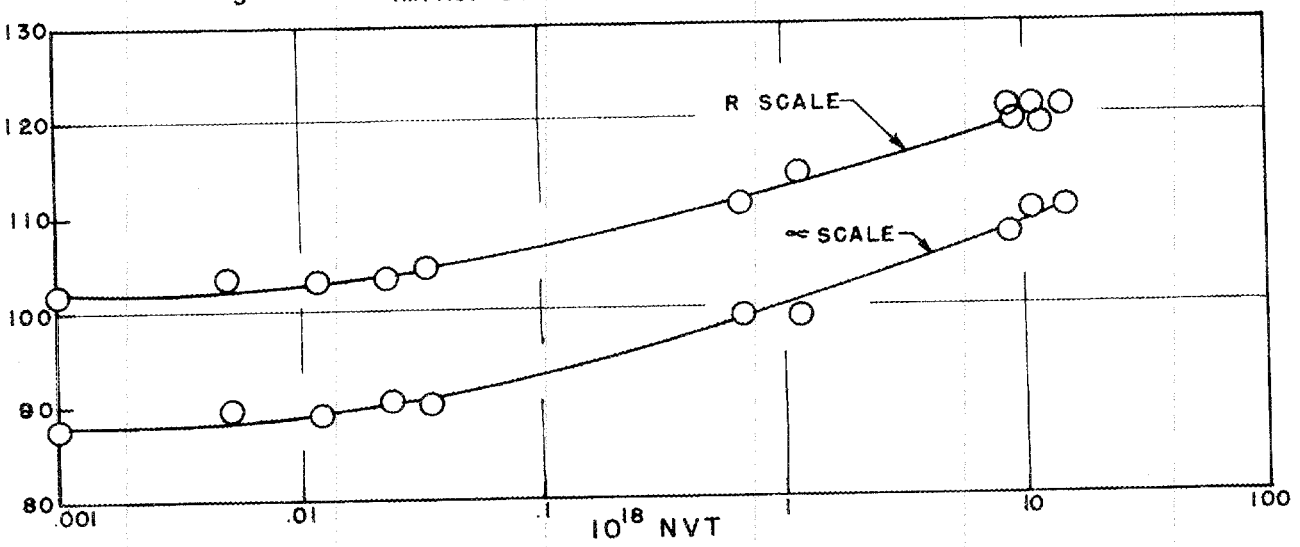


FIGURE 30A STRESS STRAIN CURVES FOR PILE IRRADIATED POLYSTYRENE (STYRON-475)

UNCLASSIFIED
DWG.#11173



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	3100 LBS. / SQ. IN.
2	ELONGATION	20 %
3	ELASTIC MODULUS	2.6 X 10^5 LBS. / SQ. IN
4	SHEAR STRENGTH	5600 LBS. / SQ. IN.
5	IMPACT STRENGTH	0.67 FT. LBS. / IN. OF NOTCH



ROCKWELL HARDNESS

FIGURE 30B POLYSTYRENE (STYRON 475)

UNCLASSIFIED
DWG.#11174

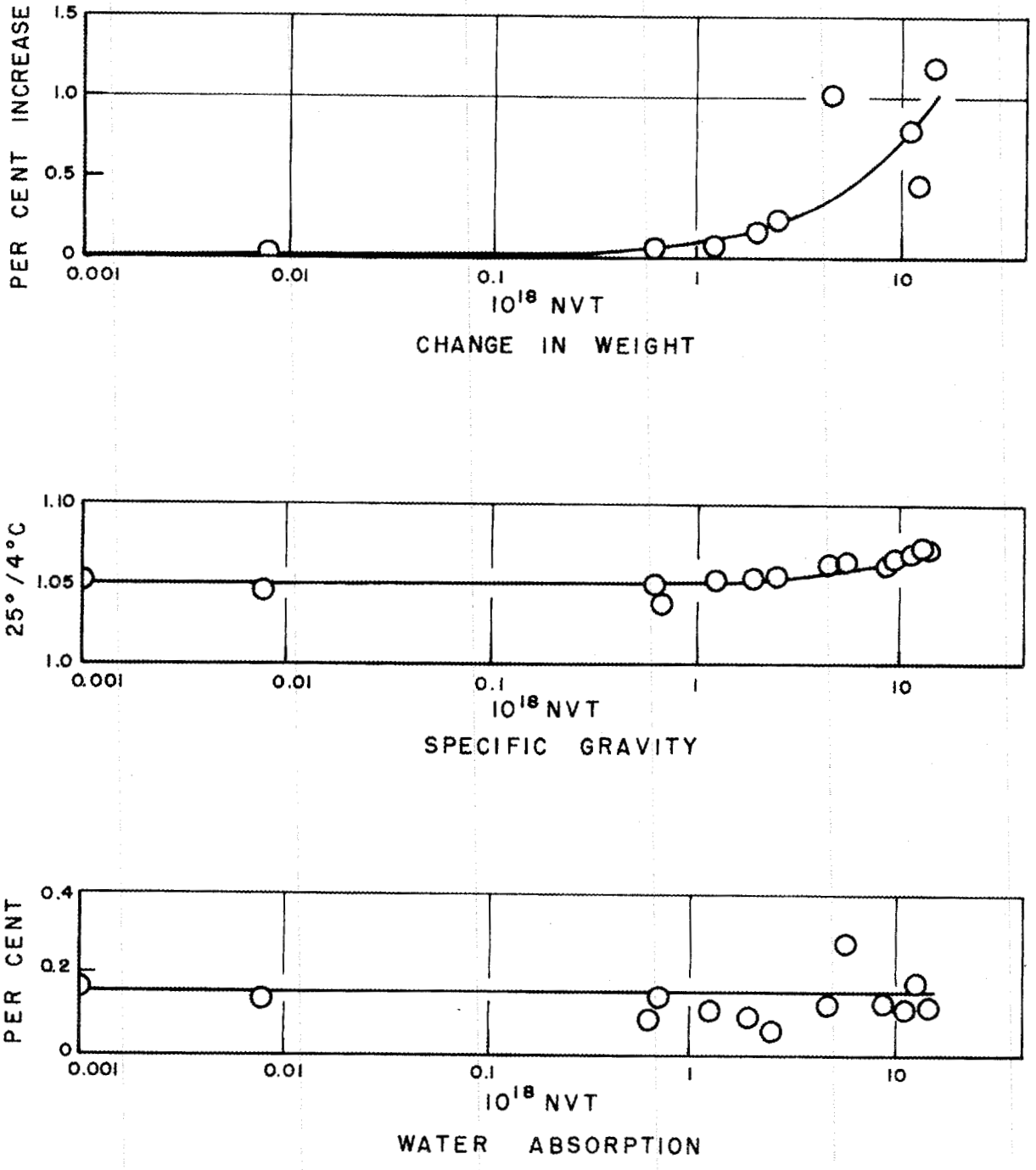


FIGURE 30C POLYSTYRENE (STYRON 475)

UNCLASSIFIED
DWG.#11175

STYRON 475

Volume Resistivity of 100 Mil Specimens

10^{18} nvt	ohm cm
0	$> 10^{14}$
9	$> 10^{14}$

Dielectric Strength of 25 Mil Specimens

10^{18} nvt	volts/mil
0	1100
9	1000

Arc Resistance of 100 Mil Specimens

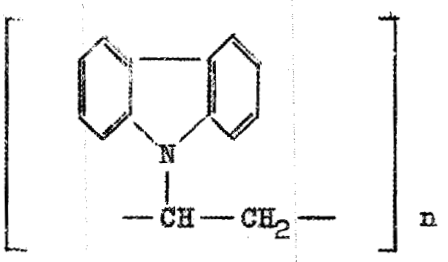
10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	60	Carbonized
11	60	"

FIGURE 30 D

POLECTRON

Classification:	Vinyl polymer
Trade name:	Polectron
Company:	General Aniline and Film Corporation, Easton, Pa.
Resin:	Polyvinyl carbazole

Formula:



Filler:	None
Description:	Opaque, light tan Darkens upon irradiation.
Thickness of sheets:	0.141 - 0.157 in.
Speed of tensile testing	
Mean rate of straining:	$0.4 - 0.7 \times 10^{-4}$ units/sec.
Mean rate of stressing:	20 - 50 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11176

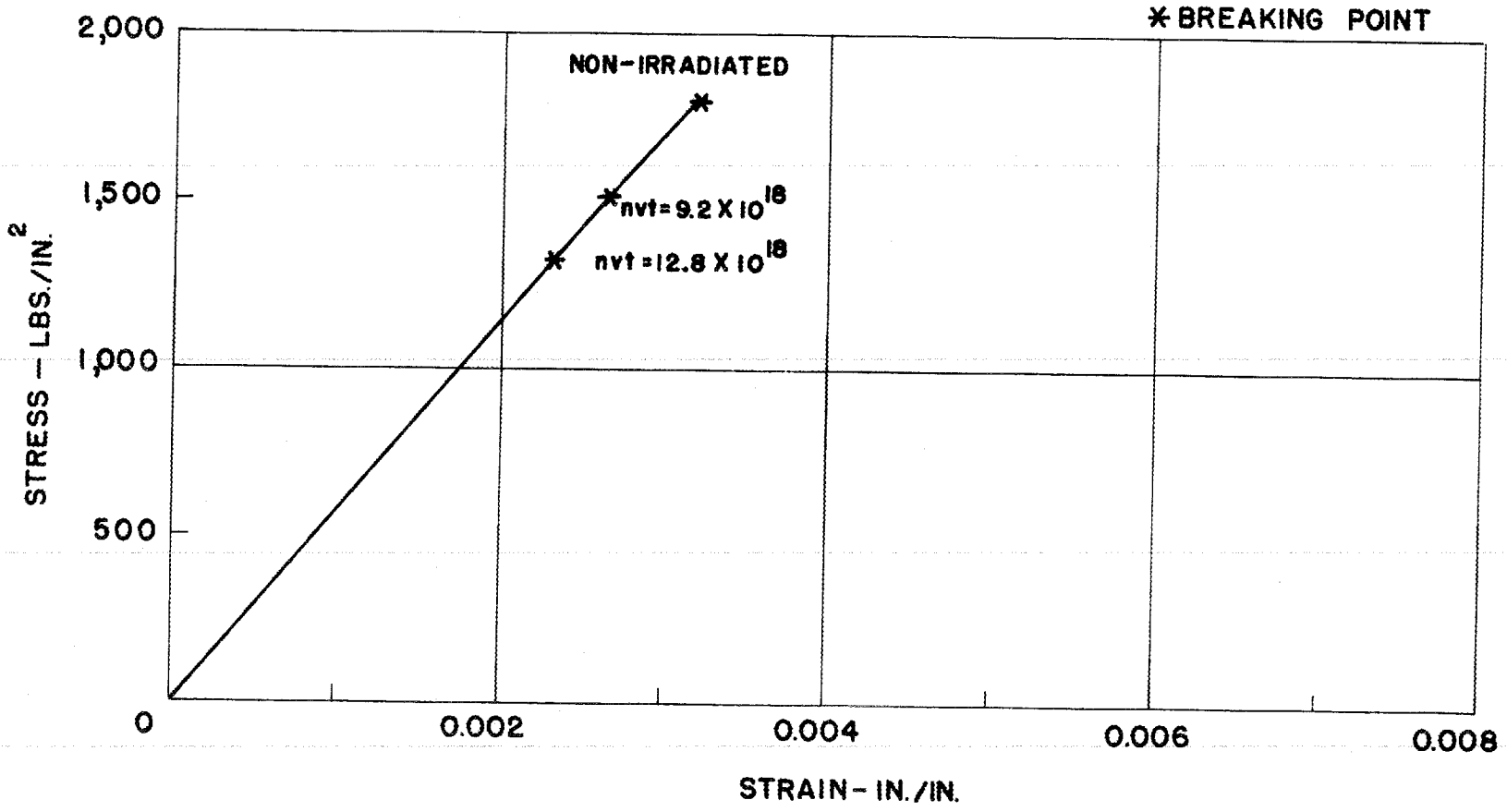
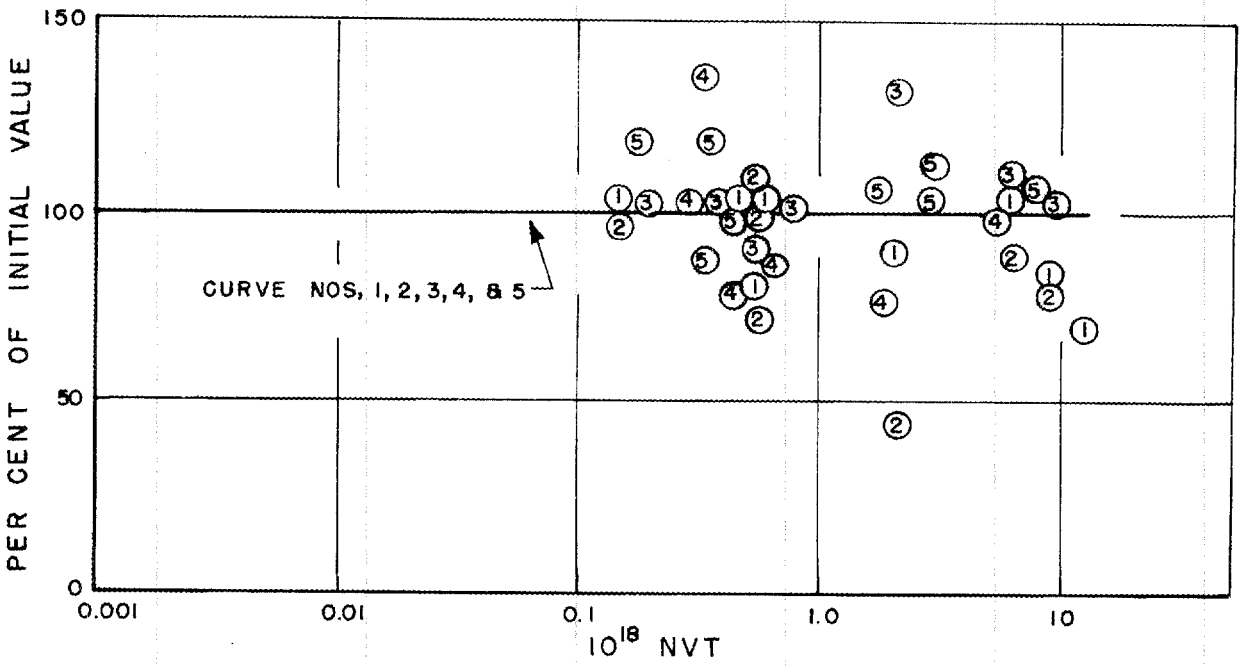


FIGURE 31A STRESS STRAIN CURVES FOR PILE IRRADIATED POLYVINYL CARBAZOLE



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	1,800 LBS. / SQ. IN.
2	ELONGATION	0.32 %
3	ELASTIC MODULUS	5.8×10^5 LBS./SQ. IN.
4	SHEAR STRENGTH	3,500 LBS./SQ. IN.
5	IMPACT STRENGTH	0.19 FT. LBS. / IN. NOTCH

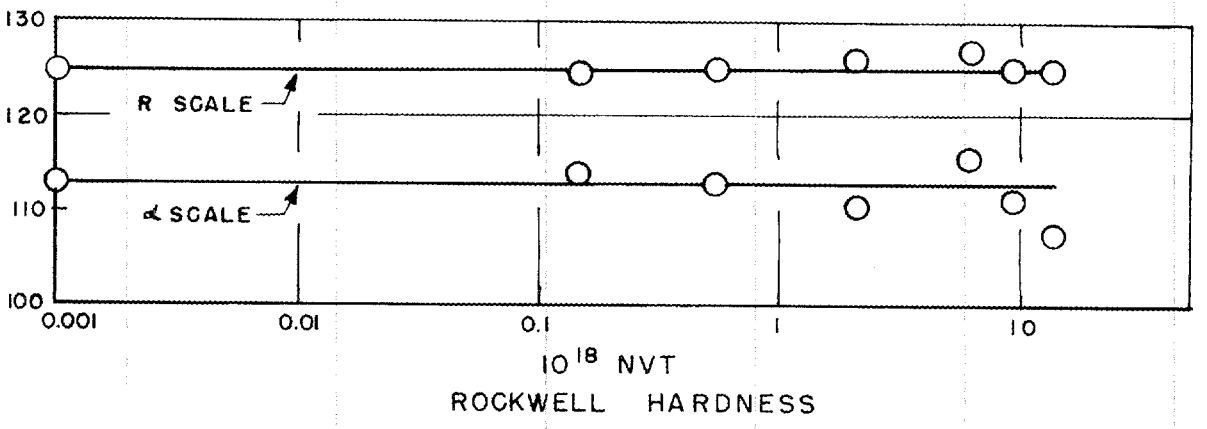
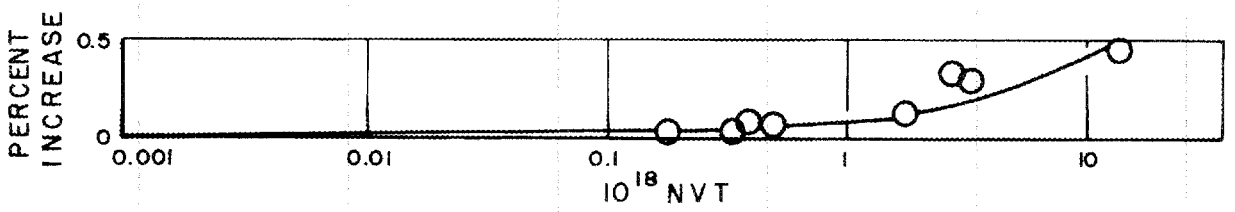
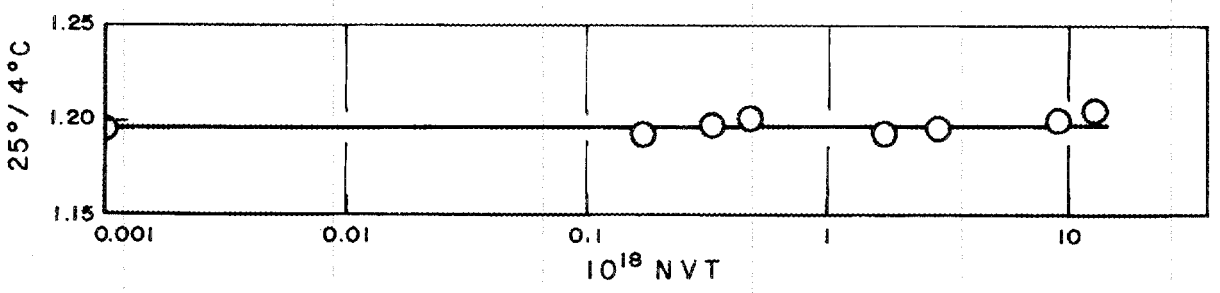


FIGURE 31B POLYVINYLCARBAZOLE

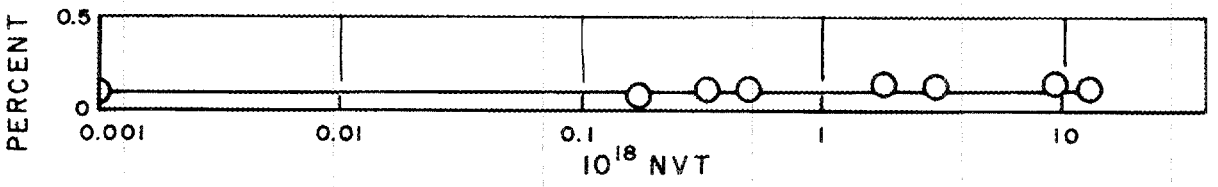
UNCLASSIFIED
DWG.#11178



CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION

FIGURE 31C POLYVINYL CARBAZOLE

UNCLASSIFIED
DWG.#11179

POLECTRON

Volume Resistivity of 150 Mil Specimens

10^{18} nvt	ohm cm
0	$>10^{14}$
5	$>10^{14}$

Dielectric Strength of 150 Mil Specimens

10^{18} nvt	volts/mil
0	$>$ 200
5	$>$200

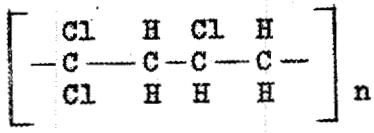
Arc Resistance of 150 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	20	Carbonized
5	20	"

FIGURE 31 D

SARAN B-115

Classification:	Vinyl polymer
Trade name:	Saran B-115
Company:	Dow Chemical Company
Resin:	Vinyl-Vinylidene chloride polymer
Formula:	



Filler:	None
Description:	Tranlucent, yellow-tan. Turns black after a short period of irradiation.
Thickness of sheets:	0.130 - 0.133 in.
Speed of tensile testing	
Mean rate of straining:	1.8 - 2.4 x 10^{-4} units/sec.
Mean rate of stressing:	10 - 20 lbs./(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11180

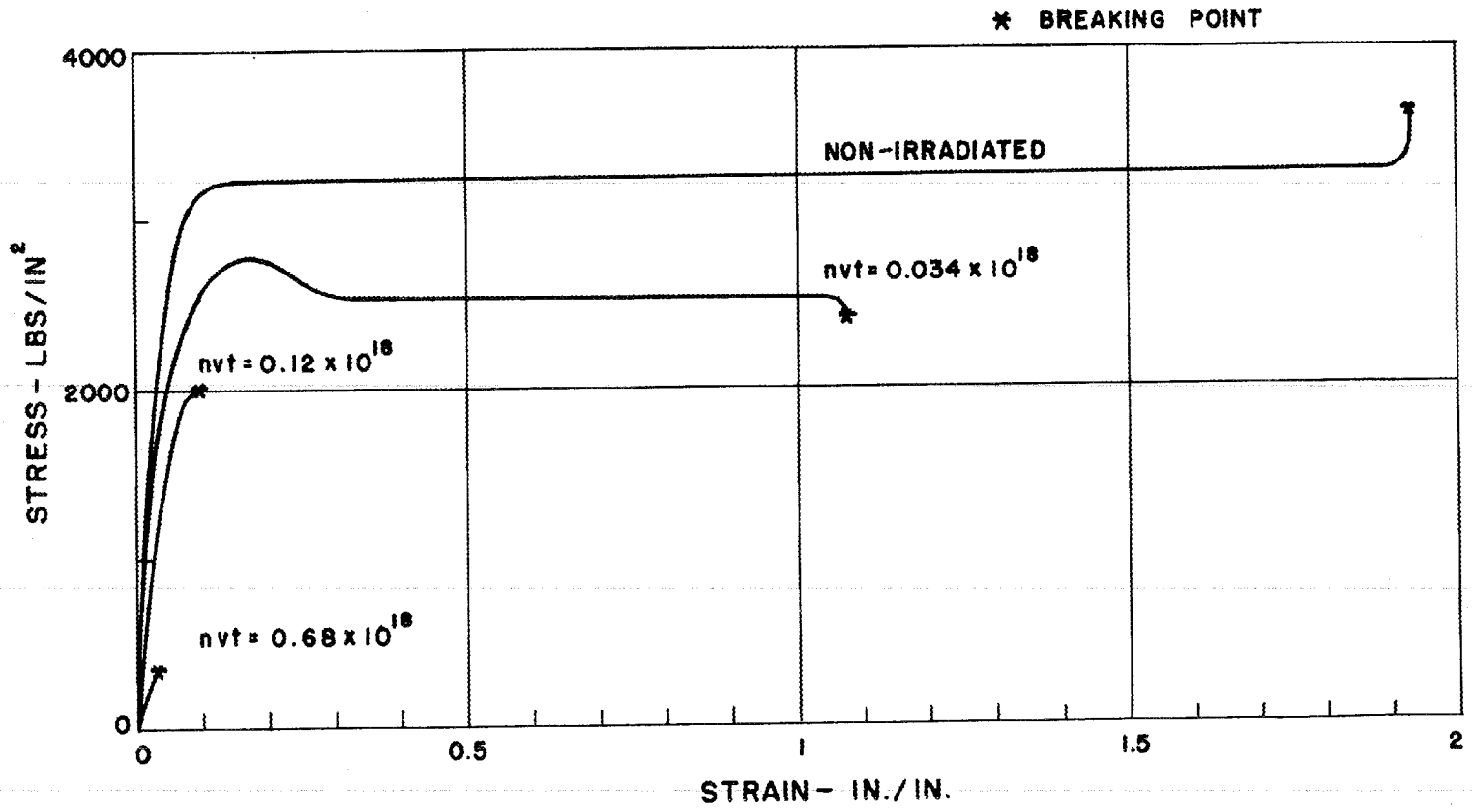
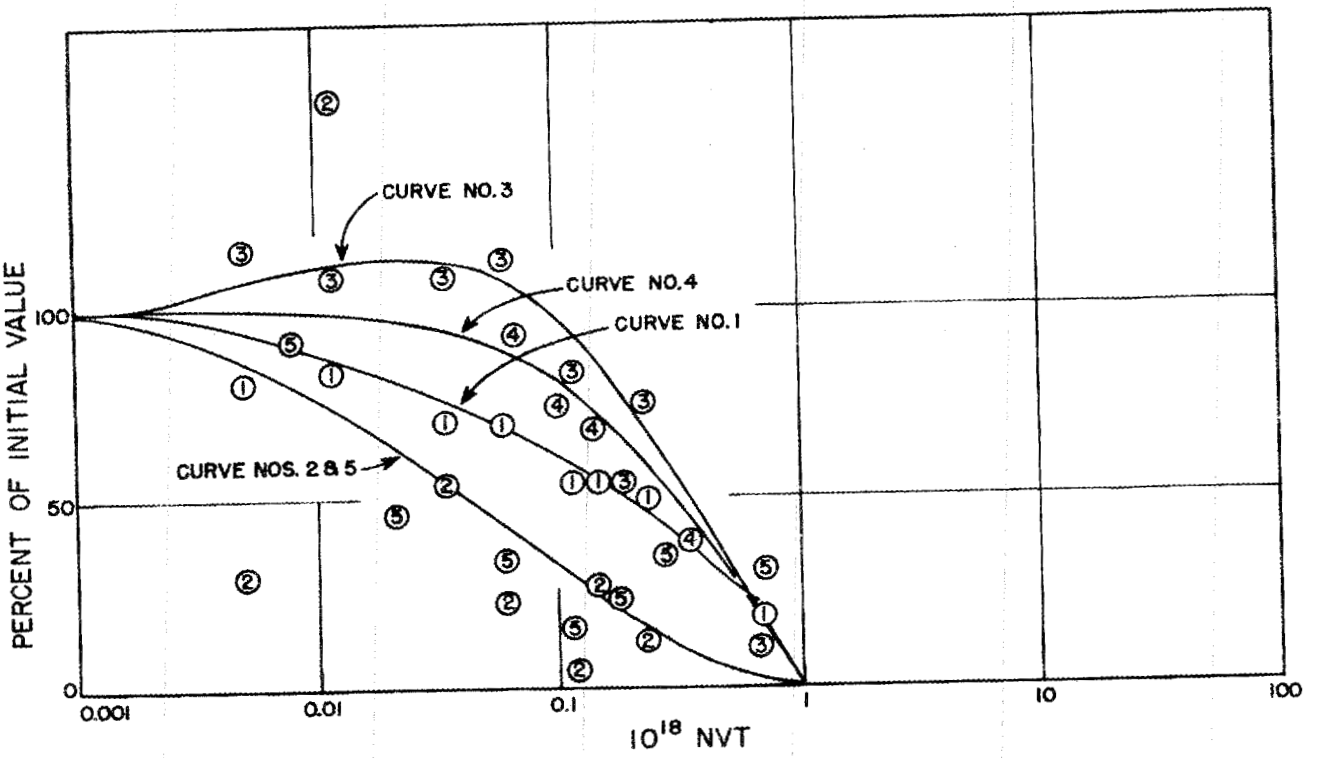


FIGURE 32A STRESS STRAIN CURVES FOR PILE IRRADIATED SARAN

UNCLASSIFIED
DWG.#11181



CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	3700 LBS. / SQ. IN.
2	ELONGATION	200%
3	ELASTIC MODULUS	0.65 X 10^5 LBS. / SQ. IN.
4	SHEAR STRENGTH	2,900 LBS. / SQ. IN.
5	IMPACT STRENGTH	1.6 FT. LBS. / IN. OF NOTCH

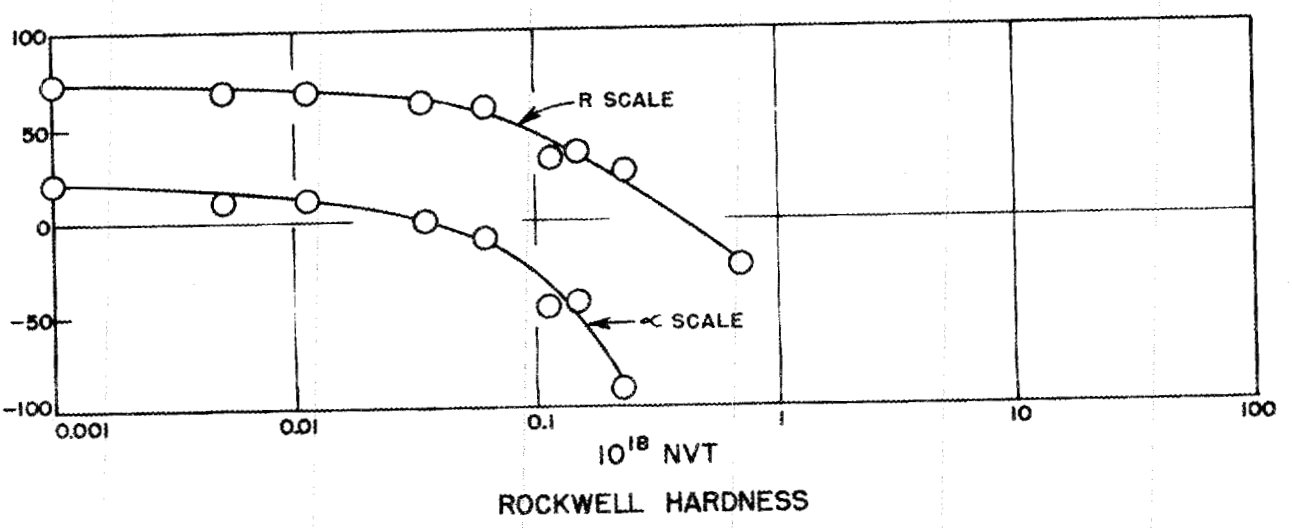


FIGURE 32B SARAN

UNCLASSIFIED
DWG.#11182

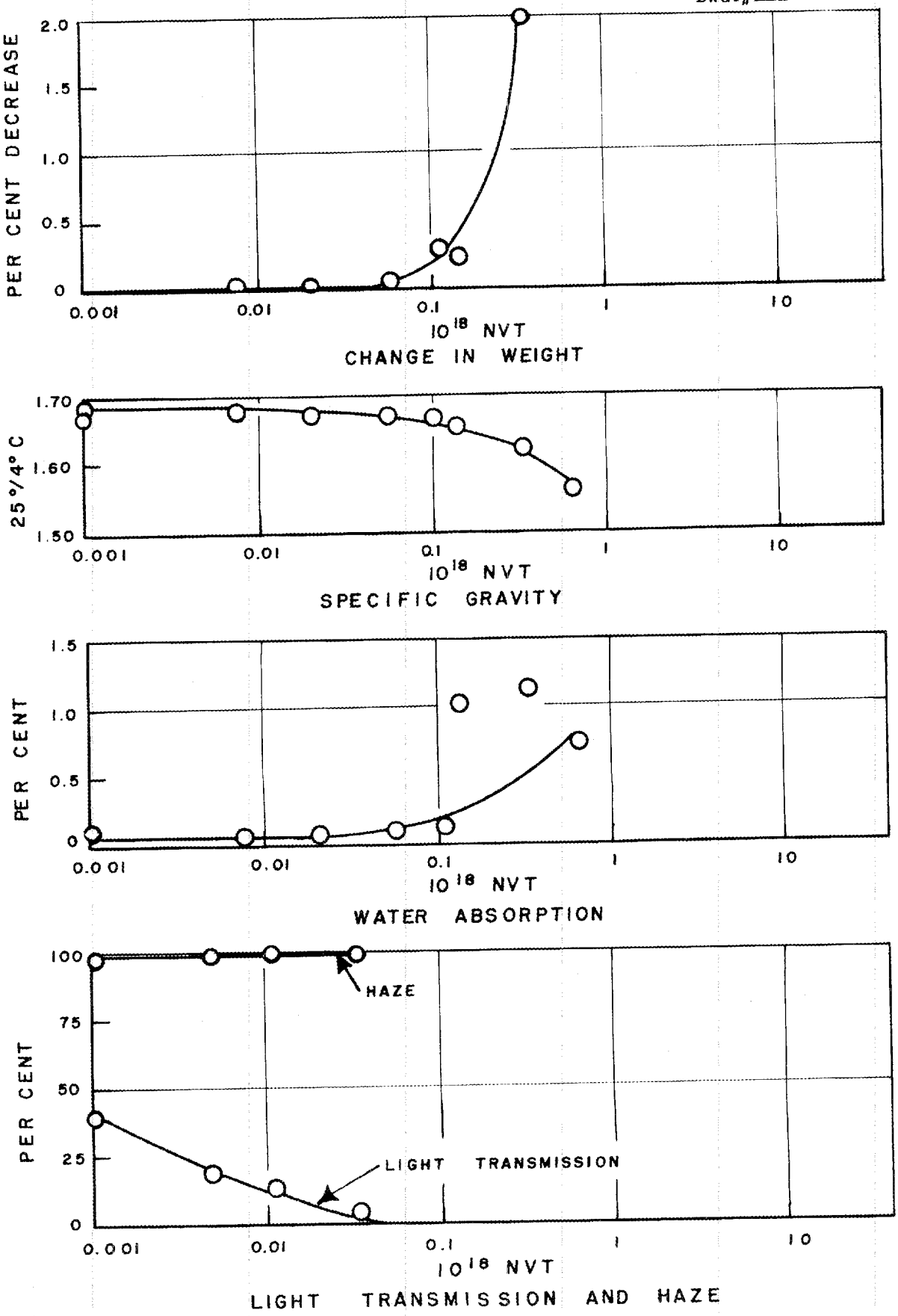


FIGURE 32C SARAN B-115 (POLYVINYLIDENE CHLORIDE)

SARAN B-115

Volume Resistivity of 130 Mil Specimens

10^{18} nvt	ohm cm
0	2×10^{14}
0.067	2×10^{13}
0.096	7×10^{12}
0.15	3×10^{9}
0.34	3×10^{7}

Dielectric Strength of 30 Mil Specimens

10^{18} nvt	volts/mil
0	660
0.53	230

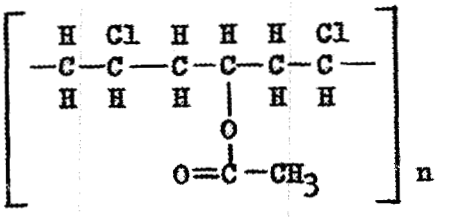
Arc Resistance of 130 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	0	Tracking
0.34	0	"

FIGURE 32 D

VINYLITE VINYL CHLORIDE ACETATE

Classification:	Vinyl polymer
Trade name:	Vinylite
Company:	Bakelite Division, Union Carbide and Carbon Corporation
Resin:	Vinyl chloride acetate polymer
Formula:	



Filler:	None
Description:	Clear - turns black after a very short period of irradiation.
Thickness of Sheets:	0.130 - 0.132 in.
Speed of tensile testing	
Mean rate of straining:	0.7 - 1.5 x 10^{-4} units/sec.
Mean rate of stressing:	30 - 60 lbs/(sq. in.) (sec.)

UNCLASSIFIED
DWG.#11184

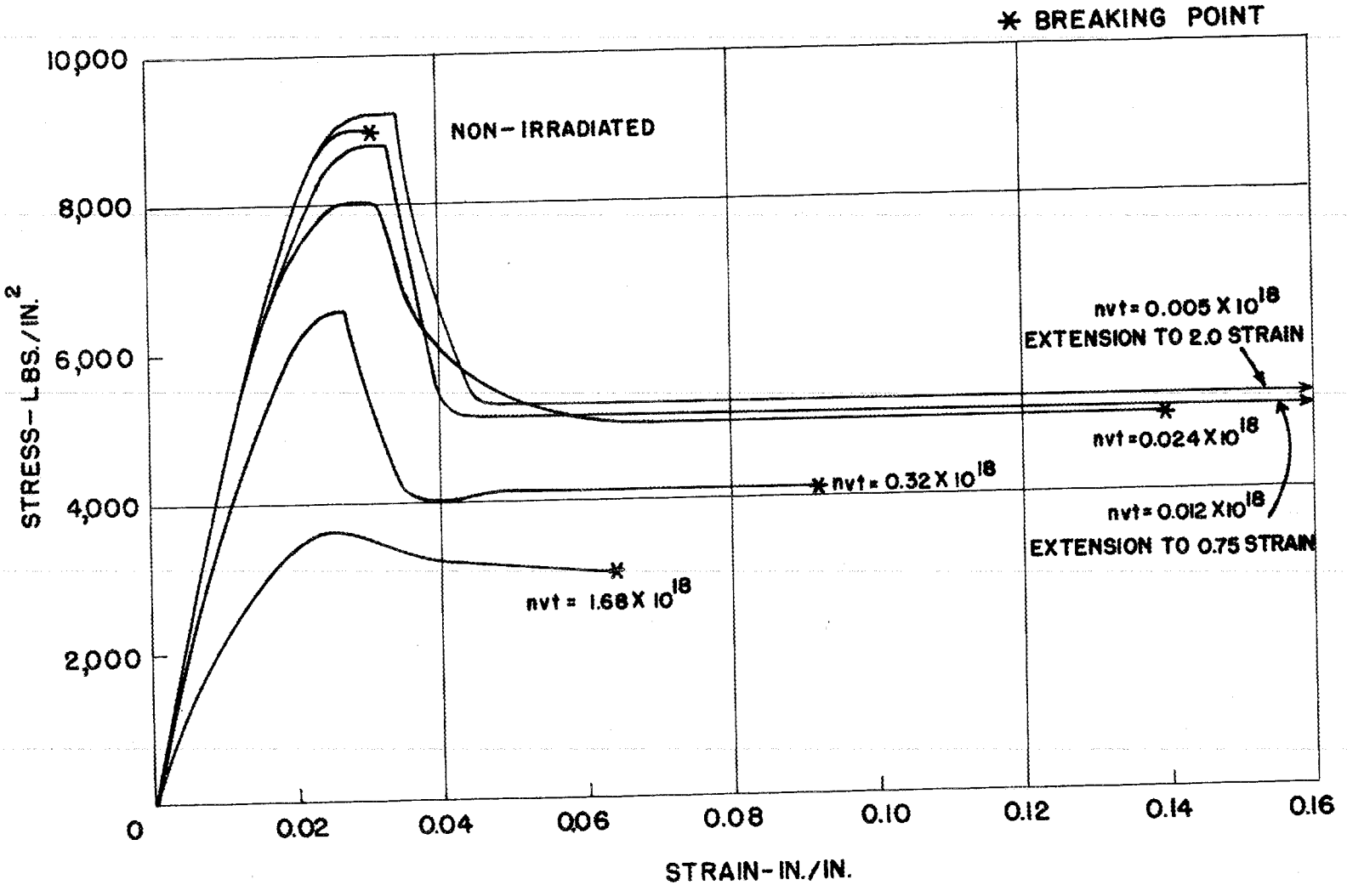
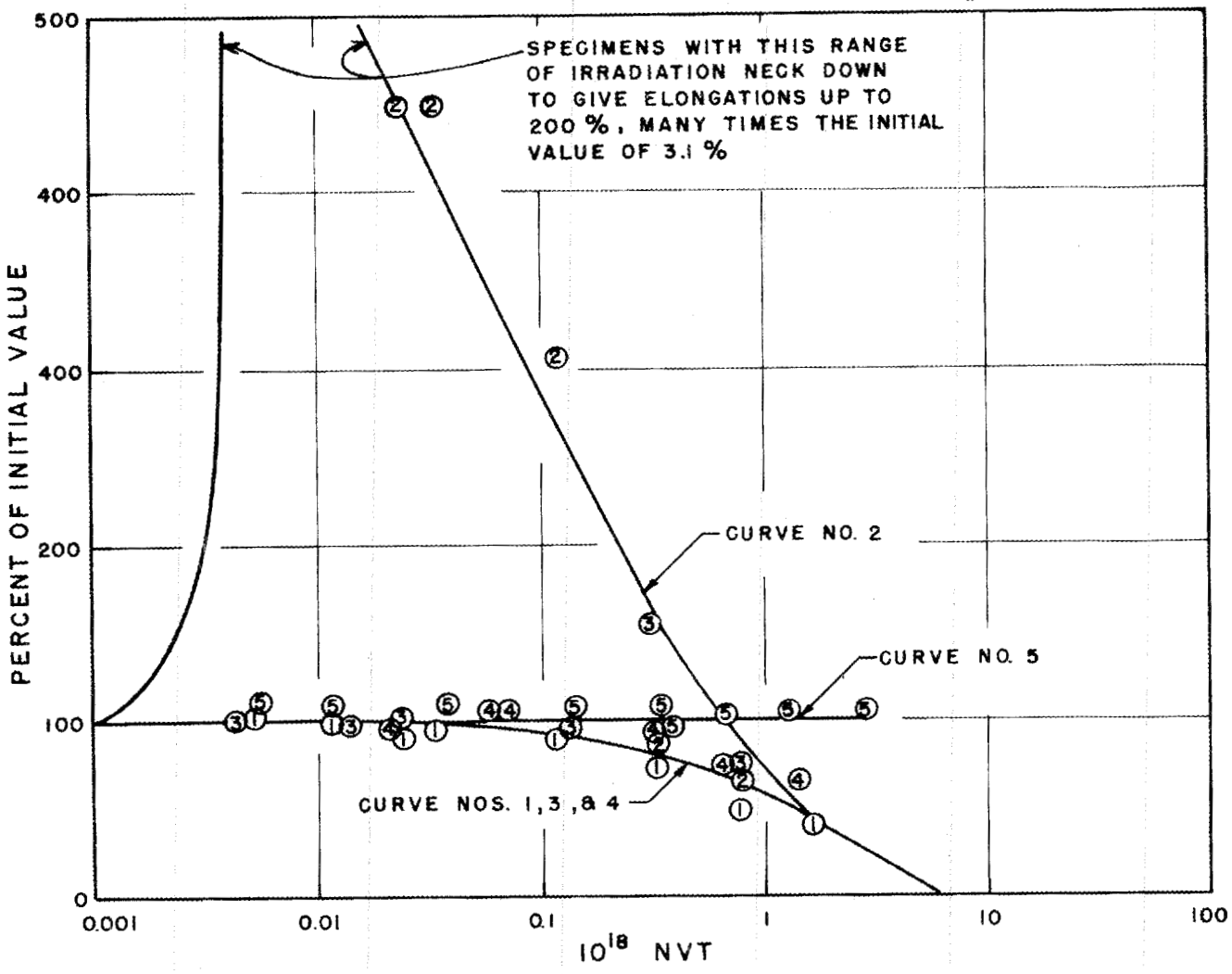
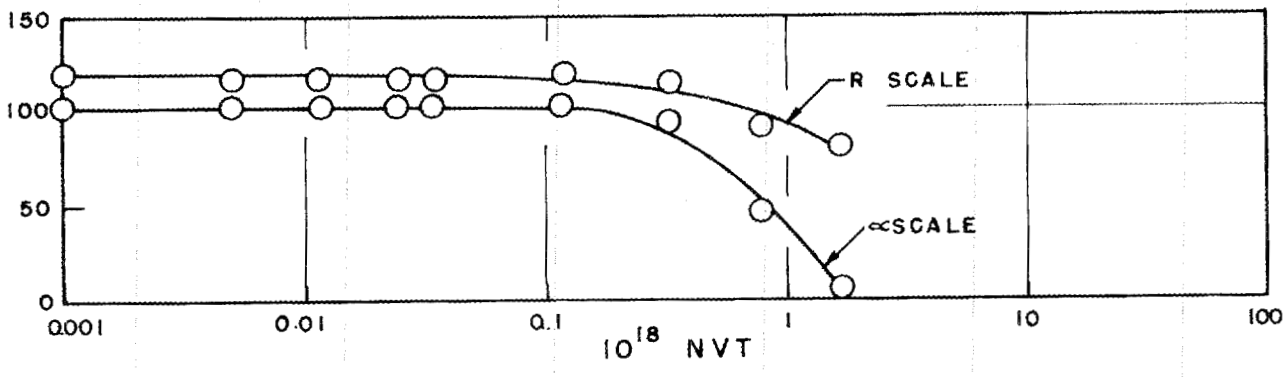


FIGURE 33A STRESS STRAIN CURVES FOR PILE IRRADIATED VINYL CHLORIDE ACETATE

UNCLASSIFIED
DWG.#11185



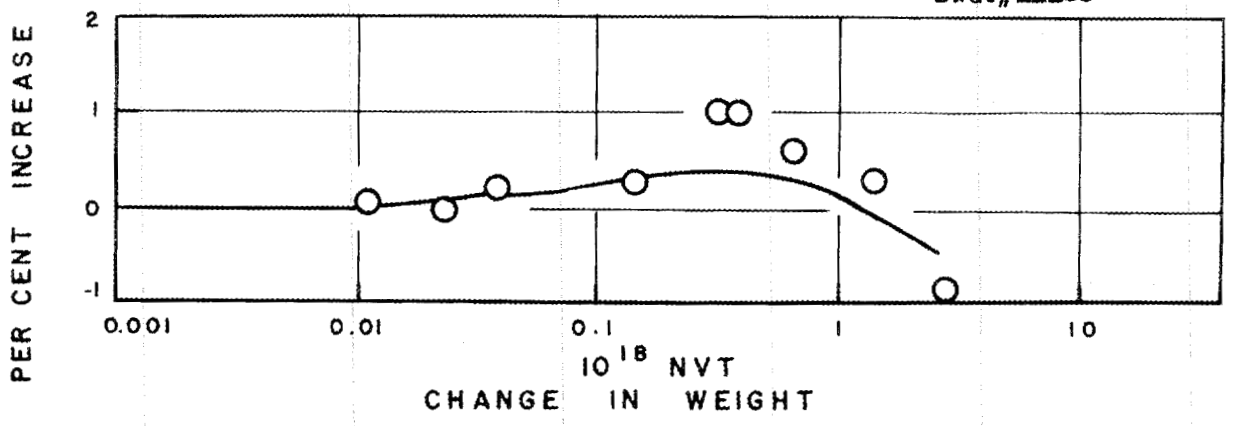
CURVE NO.	PROPERTY	INITIAL VALUE
1	TENSILE STRENGTH	9000 LBS./SQ.IN.
2	ELONGATION	3.1 %
3	ELASTIC MODULUS	4.8 X 10^5 LBS./SQ.IN.
4	SHEAR STRENGTH	6800 LBS./SQ.IN.
5	IMPACT STRENGTH	0.5 FT. LBS./IN. OF NOTCH



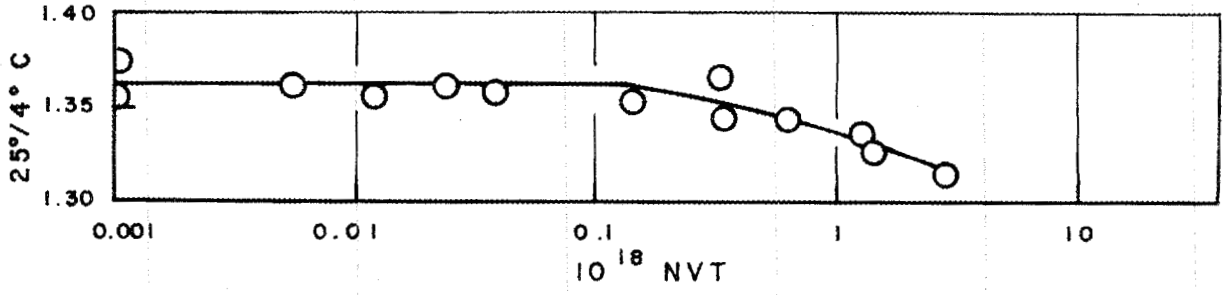
ROCKWELL HARDNESS

FIGURE 33B VINYL CHLORIDE ACETATE

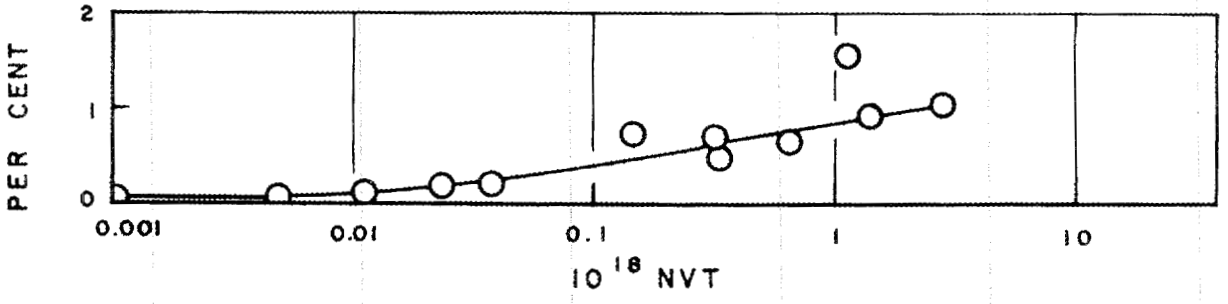
UNCLASSIFIED
DWG.#11186



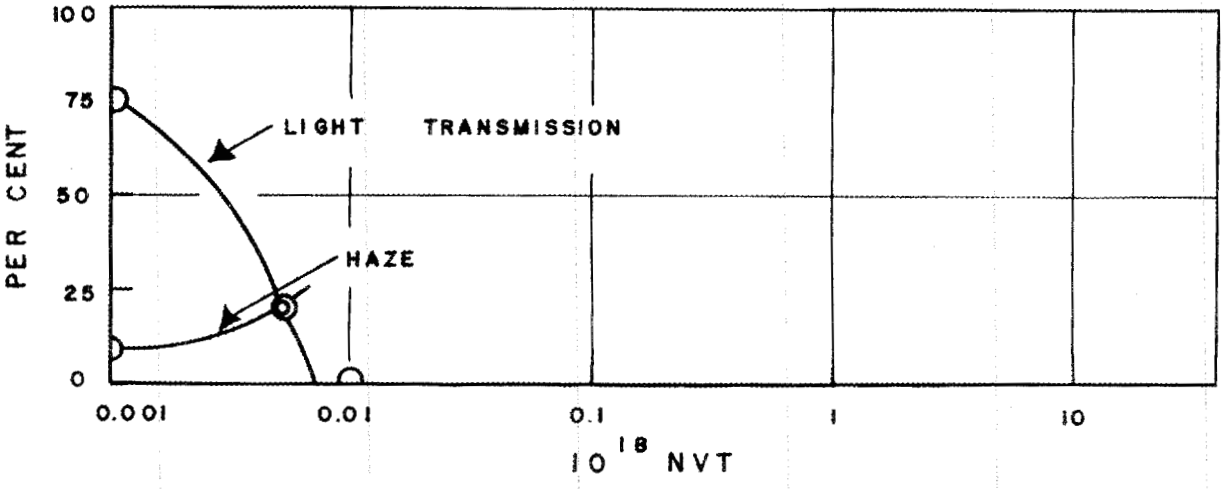
CHANGE IN WEIGHT



SPECIFIC GRAVITY



WATER ABSORPTION



LIGHT TRANSMISSION AND HAZE

FIGURE 33C VINYL CHLORIDE ACETATE

UNCLASSIFIED
DWG.#11187

VINYLITE

Volume Resistivity of 130 Mil Specimens

10^{18} nvt	ohm cm
0	$> 10^{14}$
0.021	$> 10^{14}$
0.33	$< 10^{6}$

Dielectric Strength of 20 Mil Specimens

10^{18} nvt	volts/mil
0	1100
0.53	600

Arc Resistance of 130 Mil Specimens

10^{18} nvt	Arc Resistance, sec	Manner of Failure
0	70	Carbonized
0.02	20	"
0.07	10	"
0.3	0	-

FIGURE 33 D

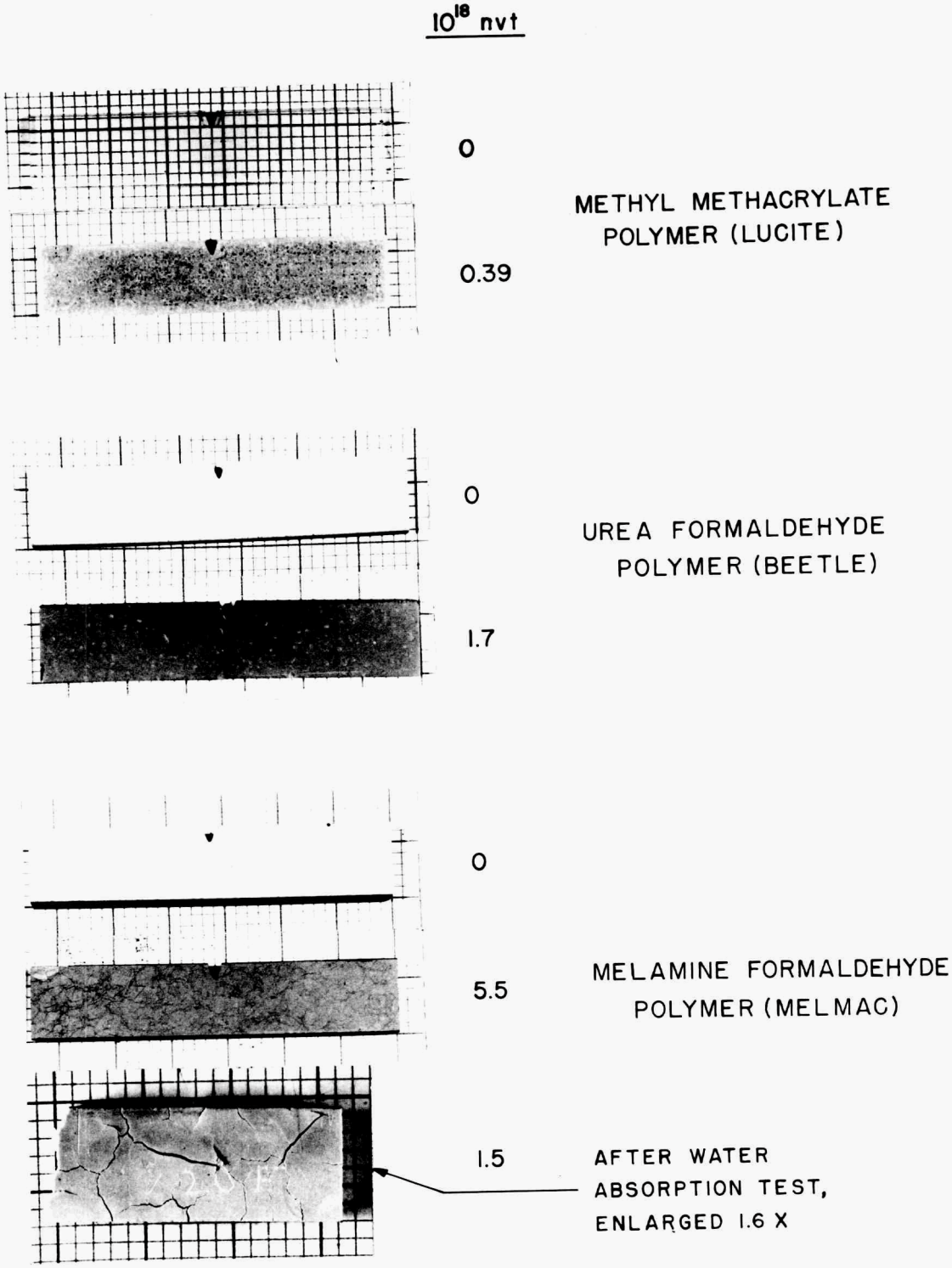

10^{18} nvt
0
METHYL METHACRYLATE POLYMER (LUCITE)
0.39
0
UREA FORMALDEHYDE POLYMER (BEETLE)
1.7
0
5.5
MELAMINE FORMALDEHYDE POLYMER (MELMAC)
1.5
AFTER WATER ABSORPTION TEST, ENLARGED 1.6 X

FIGURE 34

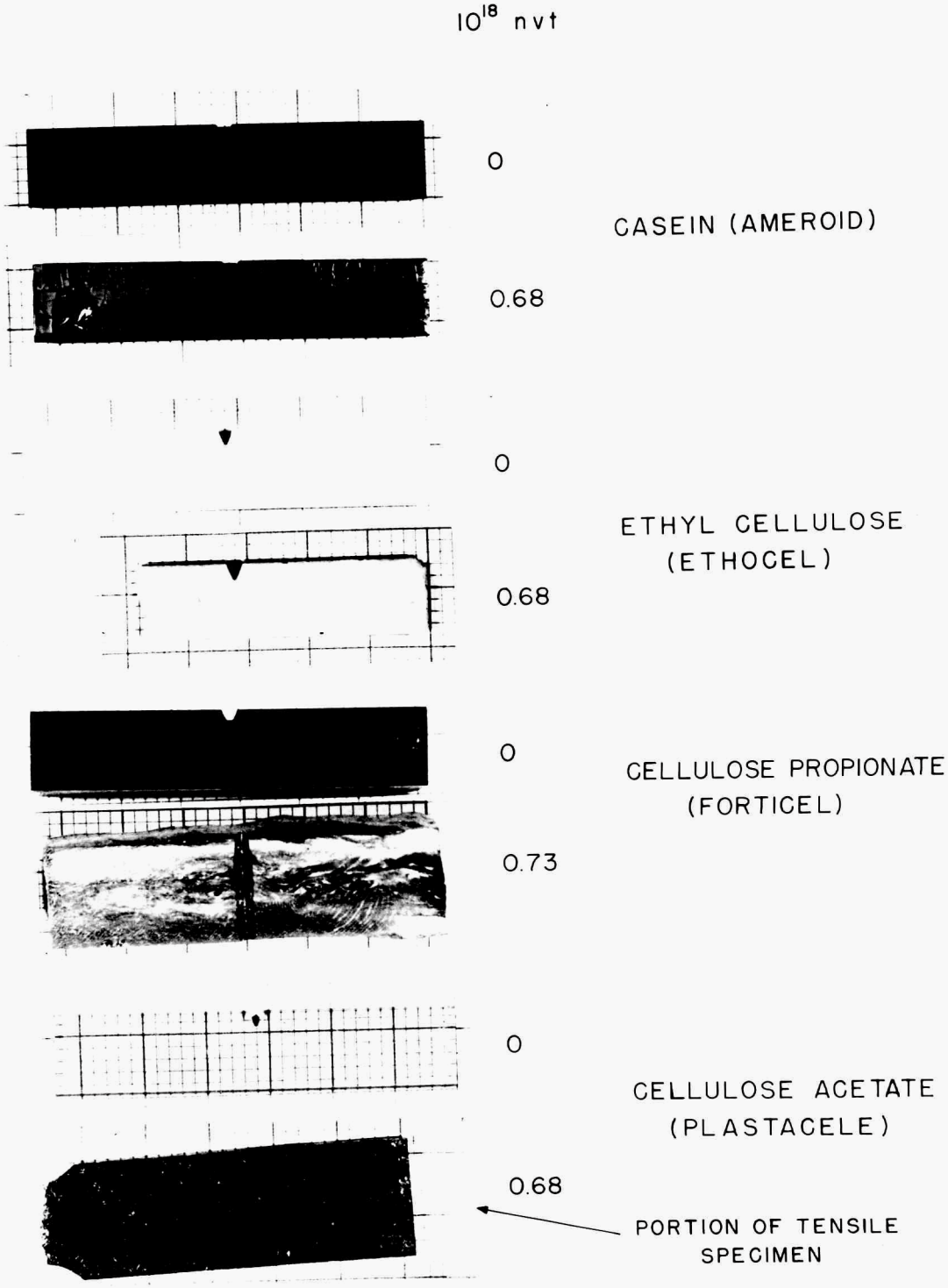
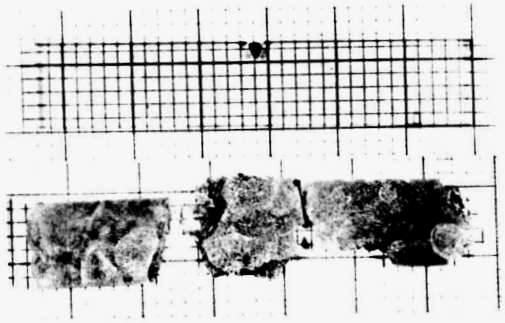

10^{18} nvt
0
CASEIN (AMEROID)
0.68
0
ETHYL CELLULOSE
(ETHOCEL)
0.68
0
CELLULOSE PROPIONATE
(FORTICEL)
0.73
0
CELLULOSE ACETATE
(PLASTACELE)
0.68
PORTION OF TENSILE
SPECIMEN

FIGURE 35

10^{18} nvt



0

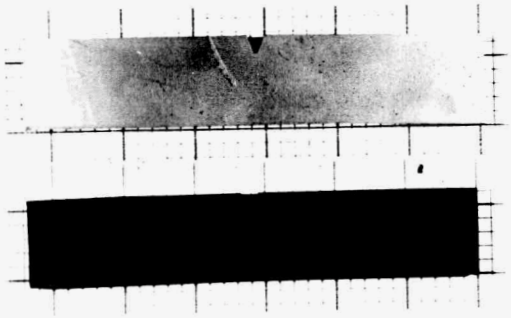
CELLULOSE NITRATE (PYRALIN)

0.68

0

CELLULOSE ACETATE BUTYRATE (TENITE II)

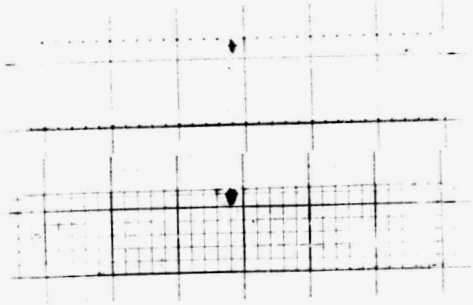
0.73



0

POLYETHYLENE

13



0

FLUOROTHENE

0.32

FIGURE 36

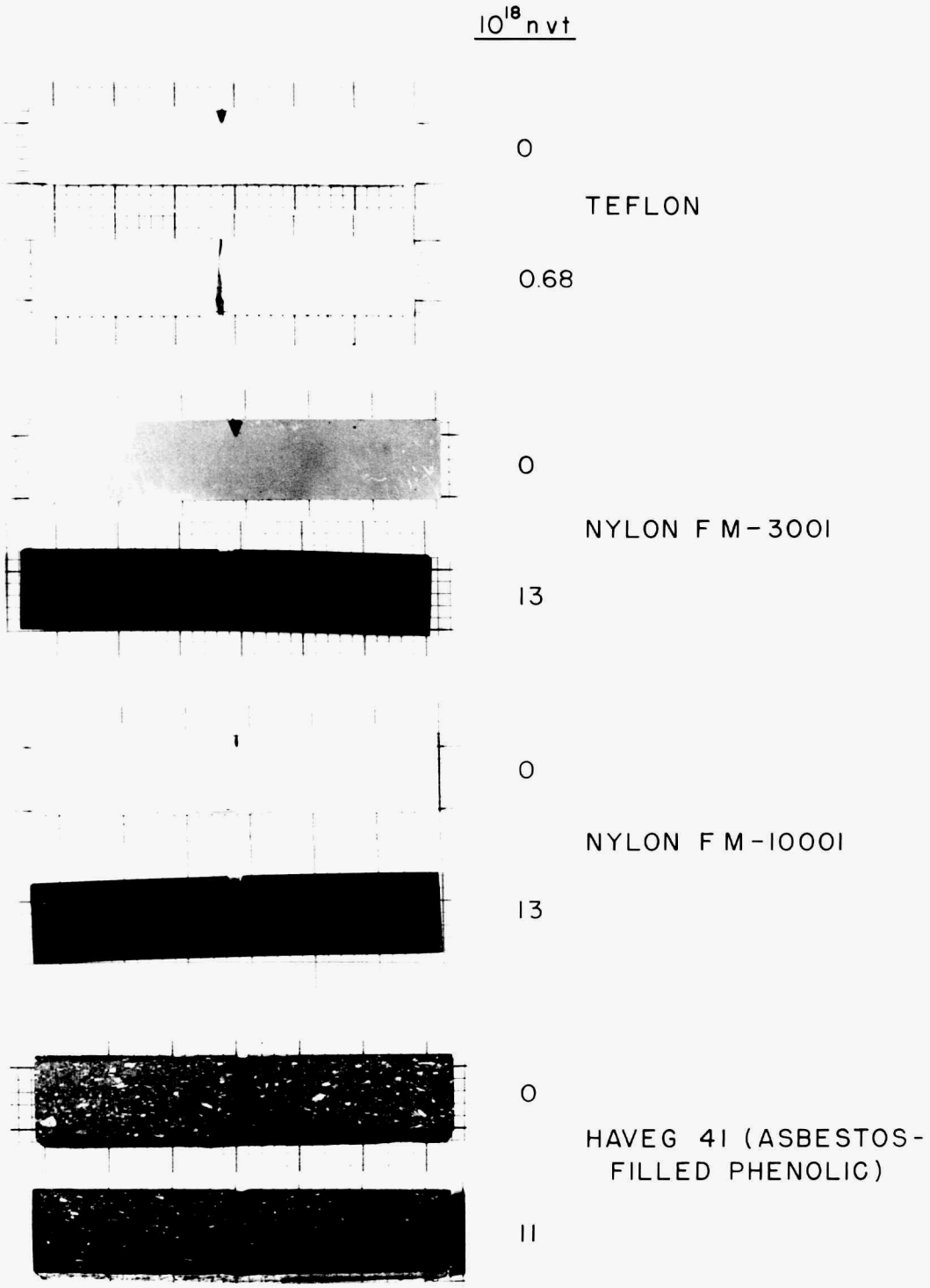

10^{18} n v t
0
TEFLON
0.68
0
NYLON F M-3001
13
0
NYLON F M-10001
13
0
HAVEG 41 (ASBESTOS-FILLED PHENOLIC)
11

FIGURE 37

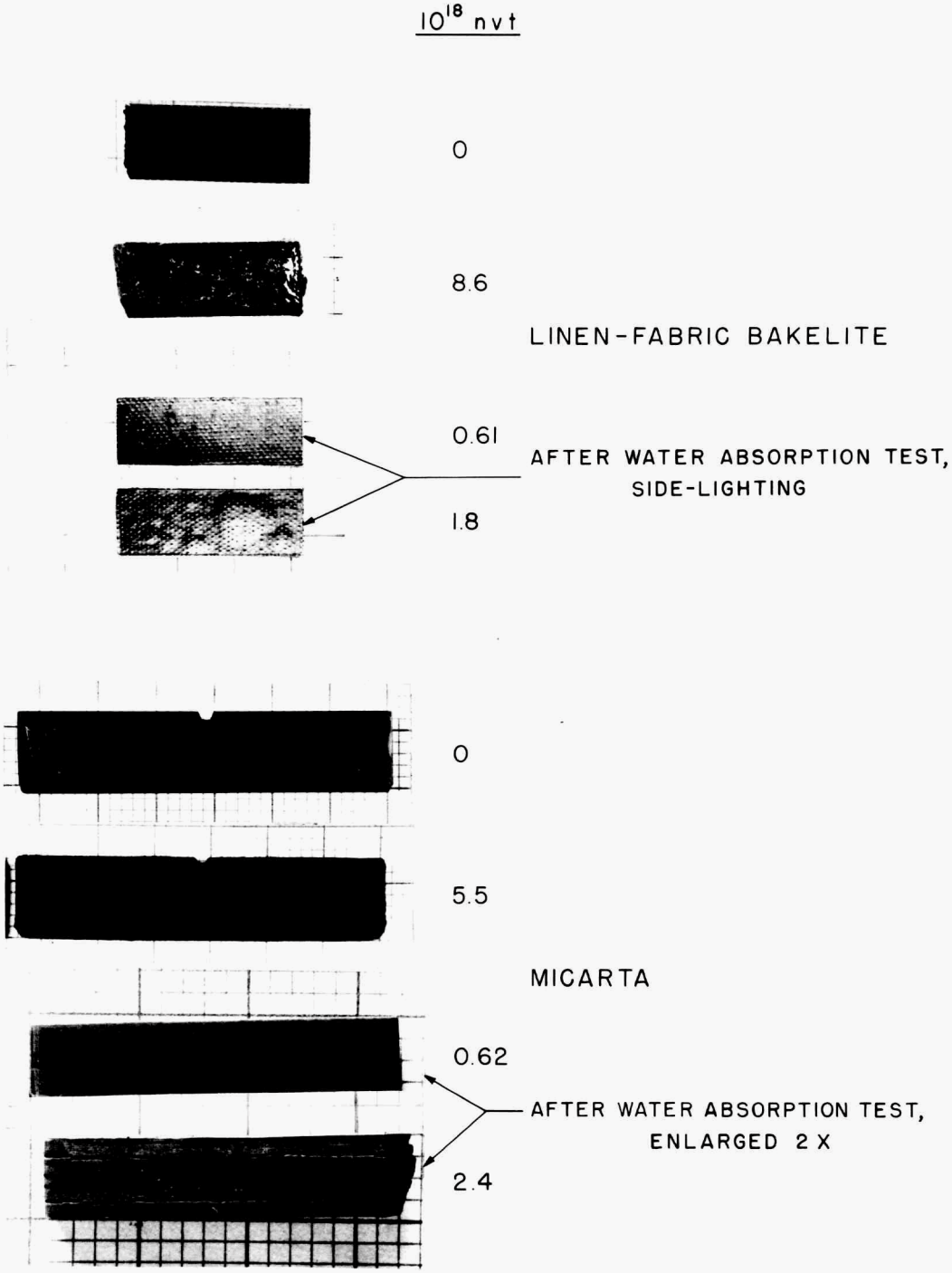
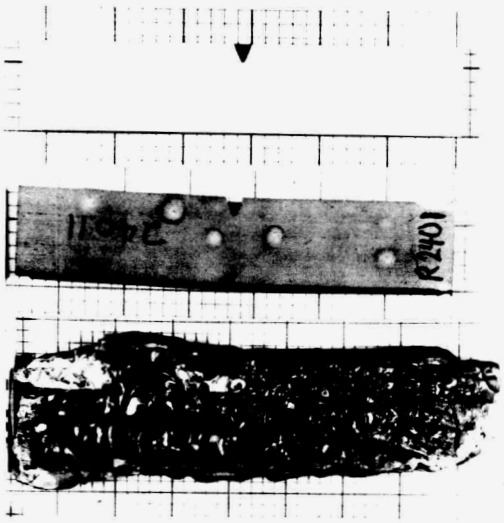

10^{18} nvt
0
8.6
LINEN-FABRIC BAKELITE
0.61
AFTER WATER ABSORPTION TEST,
SIDE-LIGHTING
1.8
0
5.5
MICARTA
0.62
AFTER WATER ABSORPTION TEST,
ENLARGED 2 X
2.4

FIGURE 38

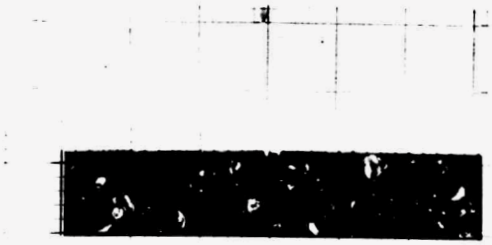
10^{18} nvt



0

2.9 UNFILLED PHENOLIC (CATALIN)

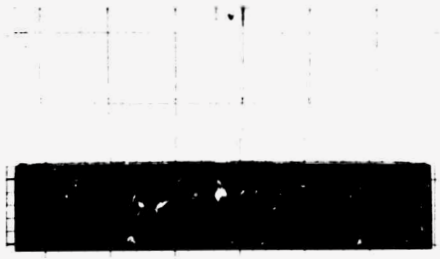
9.2



0

CR-39 POLYESTER (ALLYL DIGLYCOL CARBONATE)

6.0



0

SELECTRON 5038 (POLYESTER)

6.0

FIGURE 39

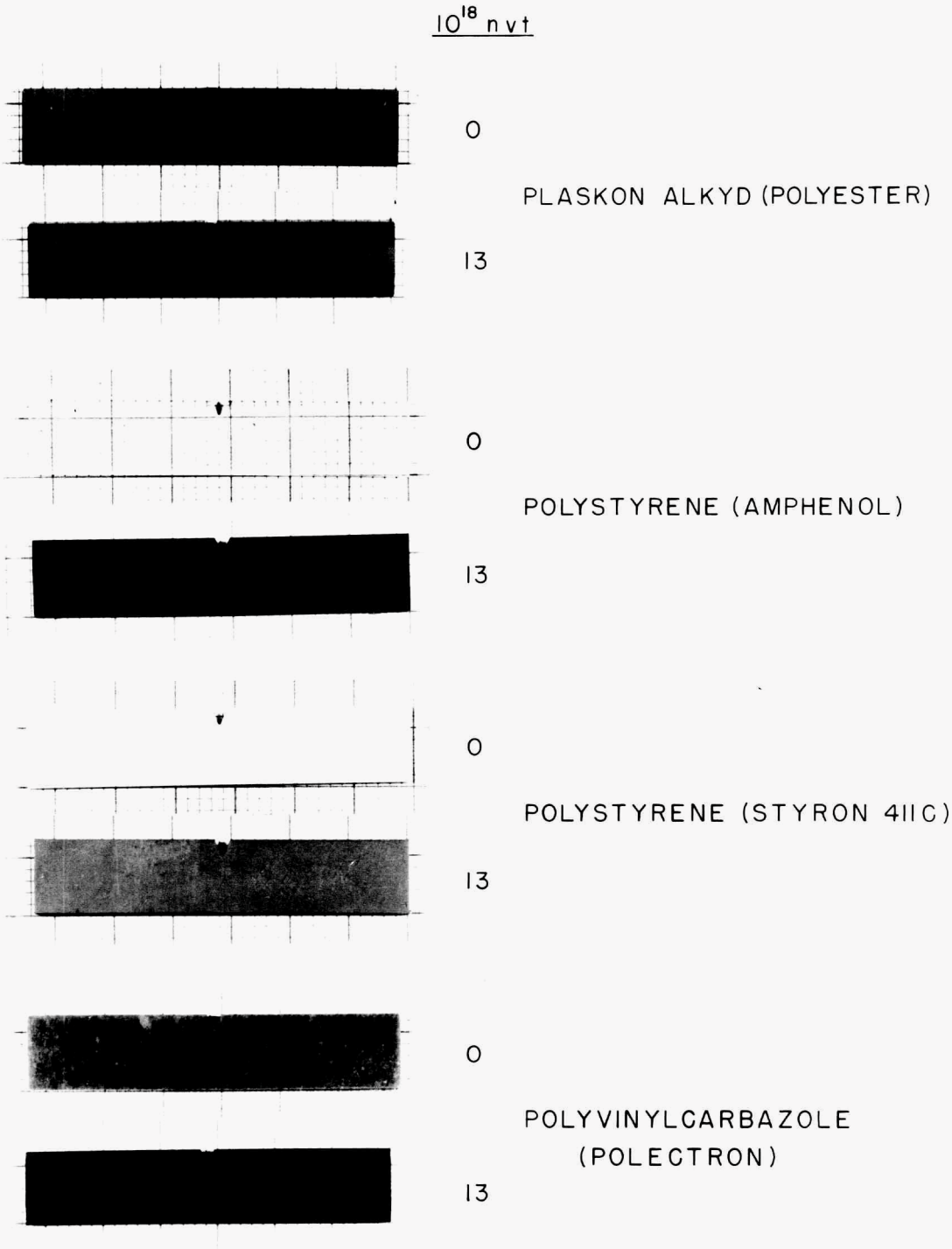

10^{18} n v t
0
PLASKON ALKYD (POLYESTER)
13
0
POLYSTYRENE (AMPHENOL)
13
0
POLYSTYRENE (STYRON 411C)
13
0
POLYVINYLCARBAZOLE
(POLECTRON)
13

FIGURE 40

10^{18} nvt

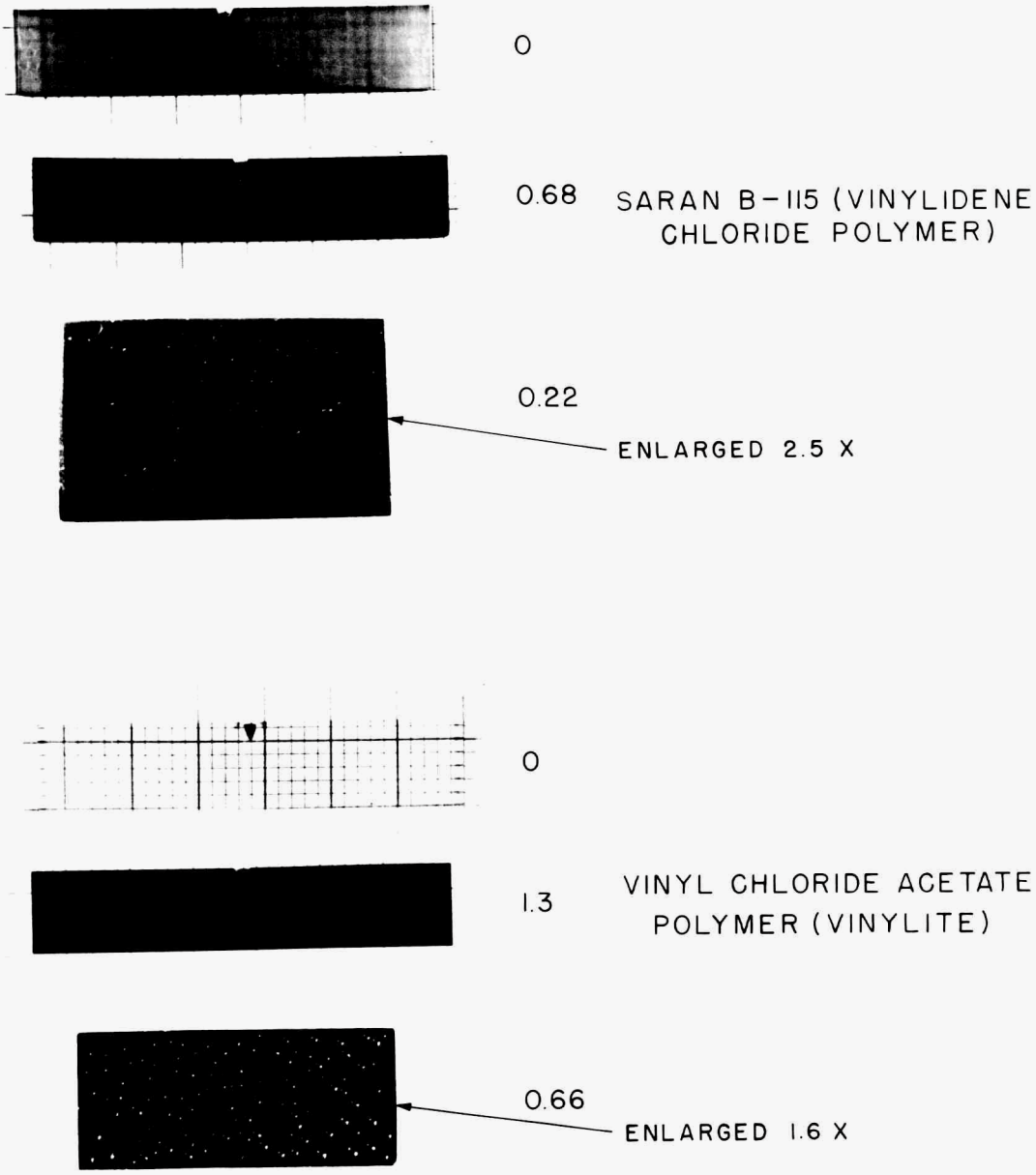


FIGURE 41

ACKNOWLEDGEMENTS

The physical property measurements and irradiation of the materials were done by W. K. Kirkland and R. L. Towns. The cooperation of the plastic companies in supplying the plastic materials and data on these materials is also gratefully acknowledged.

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(6) M. Burton, "Effects of High-energy Radiation on Organic Compounds," Journal of Physical and Colloid Chemistry, 51, 786 (1947)

(7) C. Goodman, The Science and Engineering of Nuclear Power, Volume II, p. 207, "Effects of Radiation on Materials", by A. O. Allen (1949)

(8) J. W. Jones et al, Activation Measurement of the C-Neutron Flux in the Clinton Reactor, MonC-398 (1948)

(9) O. Sisman and C. D. Bopp, Thin Cobalt Foils by Electroplating for Thermal Neutron Monitoring, ORNL-299 (1949)

A P P E N D I X

Test for Tensile Strength

(a modification of ASTM: D638-49T)

Description

A Baldwin Southwark universal testing machine with recording extensiometer (shown in figure 44) was used for this test. The test specimen is shown in figure 42. The speed of testing which is defined as the velocity of separation of the grips when running under no load, was 0.05 inches per minute until a strain of 0.02 was reached at which point the rate of crosshead movement was increased to 0.20 inches per minute and maintained there unitl failure of the specimen.

Procedure

(1) Measure the width and thickness of the specimen with the micrometer (figure 43) before irradiation. Record the minimum value of cross section as determined from several measurements taken along the length of the specimen.

(2) After irradiation, condition the specimen for 7 days at 25 ± 1 °C and 50 ± 2% humidity.

(3) Align the specimen in the grips, attach the extensiometer, start the machine and the recorder, and adjust the speed to 0.05 in./min.

(4) After the strain has passed 0.02, increase the speed to 0.20 in./min. and maintain here until failure.

(5) Record the maximum load carried by the specimen during the test.

(6) Record the extension at the moment of rupture.

Calculations

(1) Tensile Strength is calculated by dividing the maximum load in pounds by the original minimum cross-sectional area of the specimen in square inches.

(2) Percentage Elongation is the extension at the moment of rupture of the specimen divided by the original distance between gage marks and multiplied by one hundred.

(3) Mean Rate of Stressing is the tensile load carried by the specimen when the strain reaches 0.02 or at the moment of rupture, whichever occurs first, divided by the original minimum cross-sectional area of the specimen, and then divided by the time in seconds, measured from the beginning of the test, required to attain the tensile load and strain.

(4) Mean Rate of Straining is the strain at the point described in (3) divided by the time in seconds.

(5) Elastic Modulus is the slope of the initial linear portion of the stress-strain curve.

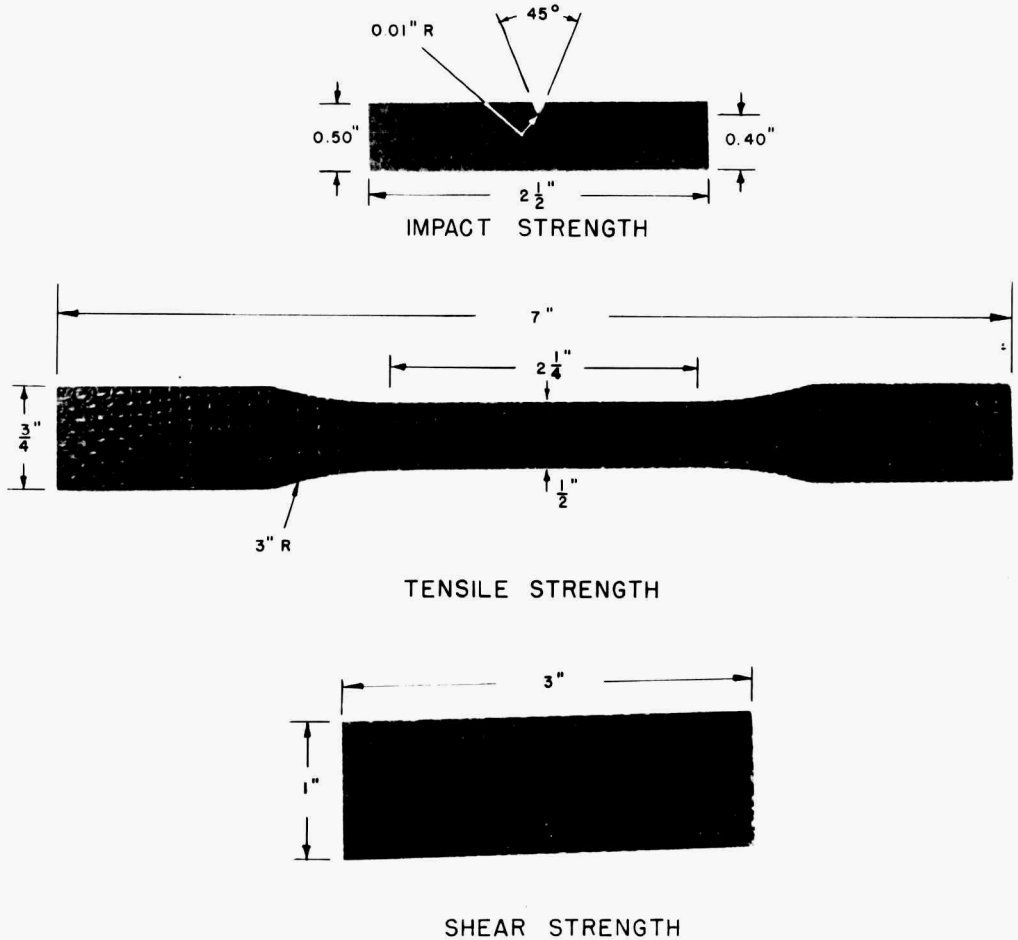

FIGURE 42 TEST SPECIMENS

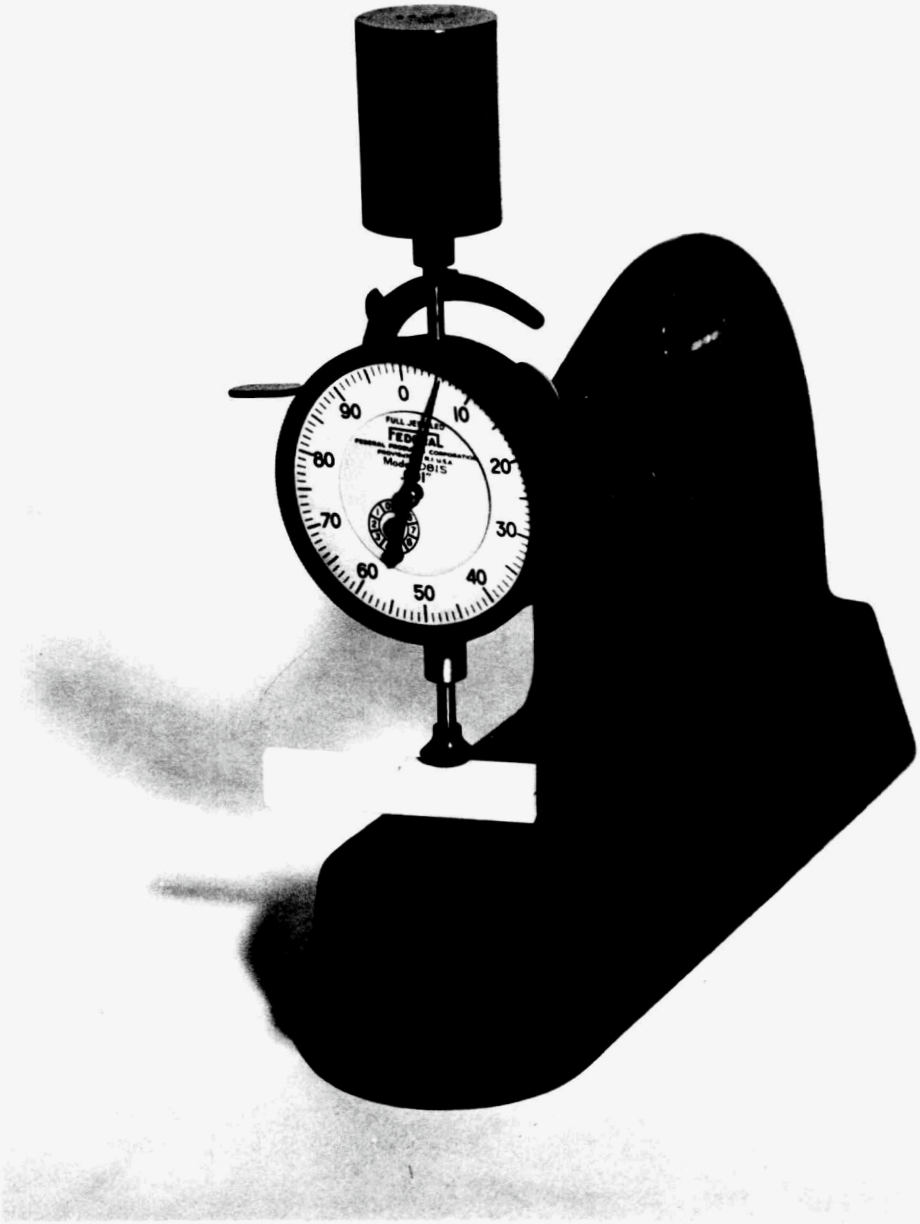

FIGURE 43 DIAL GAGE MICROMETER

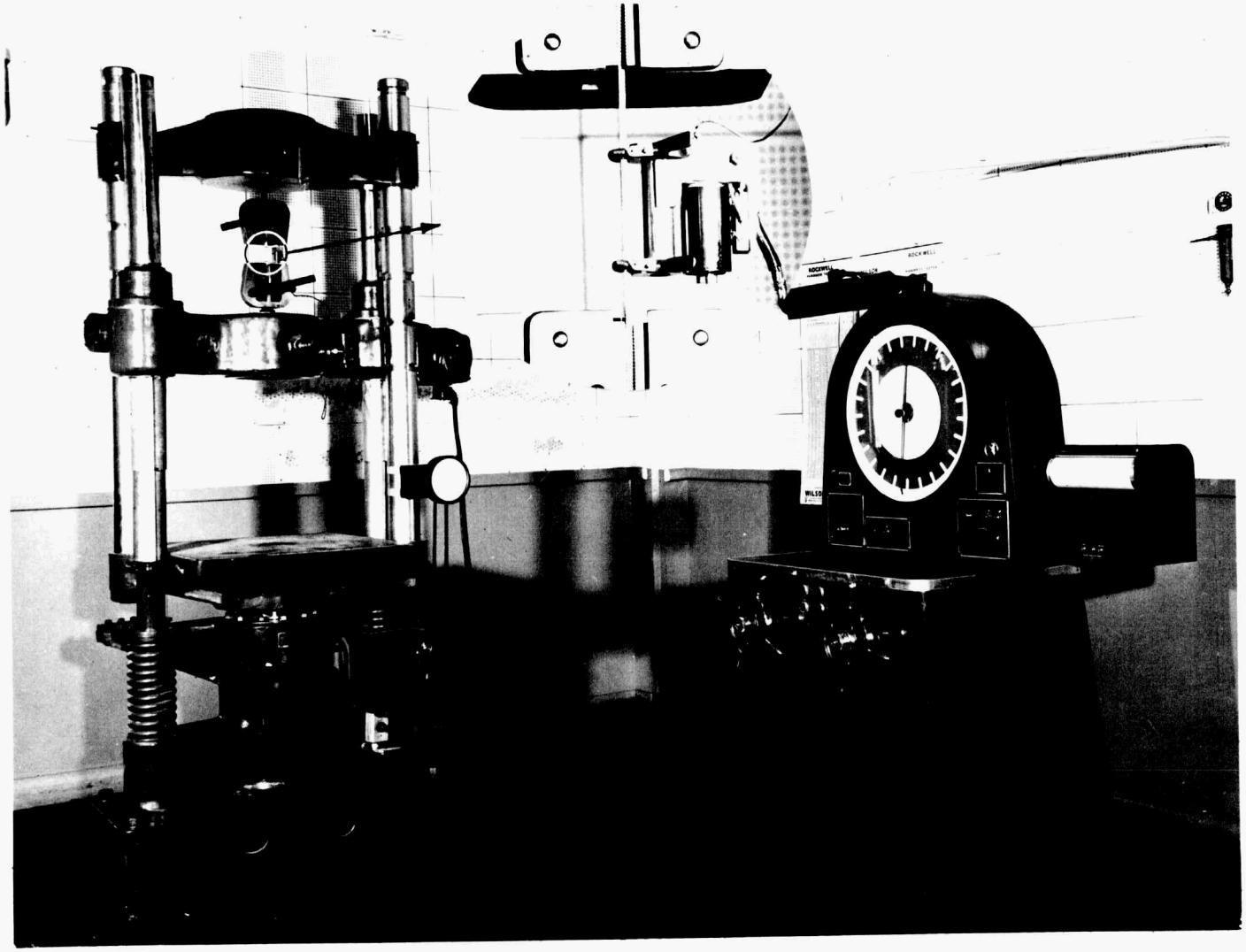

FIGURE 44 TENSILE STRENGTH TEST

Test for Shear Strength (Double Shear)

(a modification of Federal Specification 1041, L-P-406a, p 12)

Description

The Johnson - type shear tool was used with self-aligning compression plates as shown in figure 45. The test specimen was 3 inches in length by 1 inch in width by 1/16 inch to 1/4 inch in thickness. The rate of head travel under load was 0.02 in./min.

Procedure

(1) Measure the width and thickness of the specimen with a micrometer before irradiation. Record the average value of cross-section as determined from several measurements taken along the length of the specimen.

(2) After irradiation condition the specimen for 7 days at 25 ± 1 °C and 50 ± 2% humidity.

(3) Align the specimen in the shear tool, start the machine and adjust the speed to 0.02 in./min., continue this speed until failure of the specimen.

(4) Record the maximum load. The shear strength is the load divided by twice the cross-sectional area of the specimen.

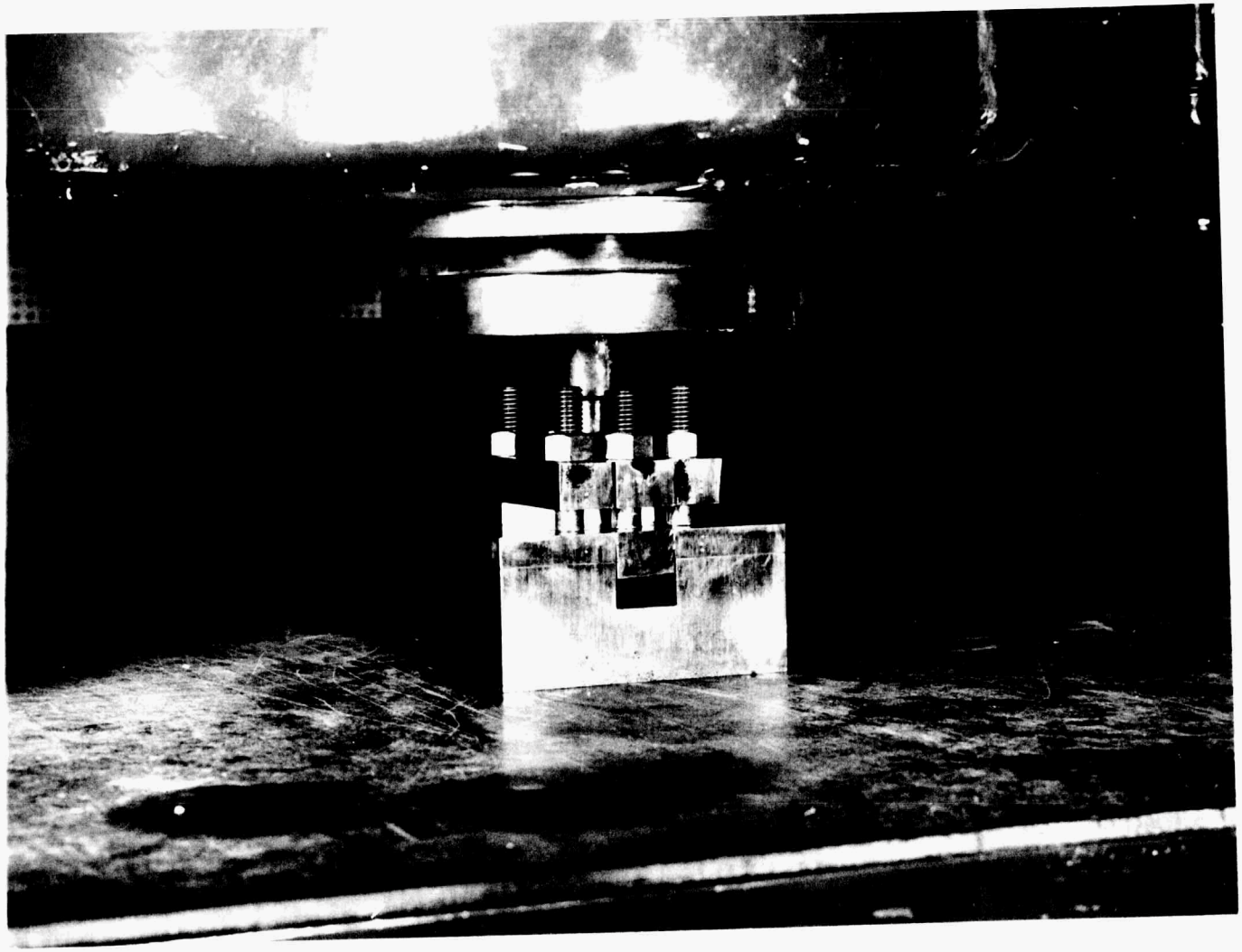

FIGURE 45 SHEAR STRENGTH TEST

Test for Impact Strength

(a modification of ASTM: D 256-47T)

Description

This test is intended to determine the relative susceptibility to fracture by shock as indicated by the energy expended by a Baldwin pendulum cantilever beam impact testing machine of Izod type (shown in figure 46) in breaking a standard specimen (shown in figure 42) in one blow.

Procedure

(1) Measure the thickness of the specimen at the notch with a micrometer before irradiation.

(2) After irradiation condition the specimen for 7 days at 25 ± 1 °C and 50 ± 2% humidity.

(3) Clamp the test specimen rigidly with the center line of the notch on the level of the top of the clamping surface so the blow will be struck on the notched side.

(4) The impact strength is the breaking energy in foot-pounds divided by the thickness of notch in inches.

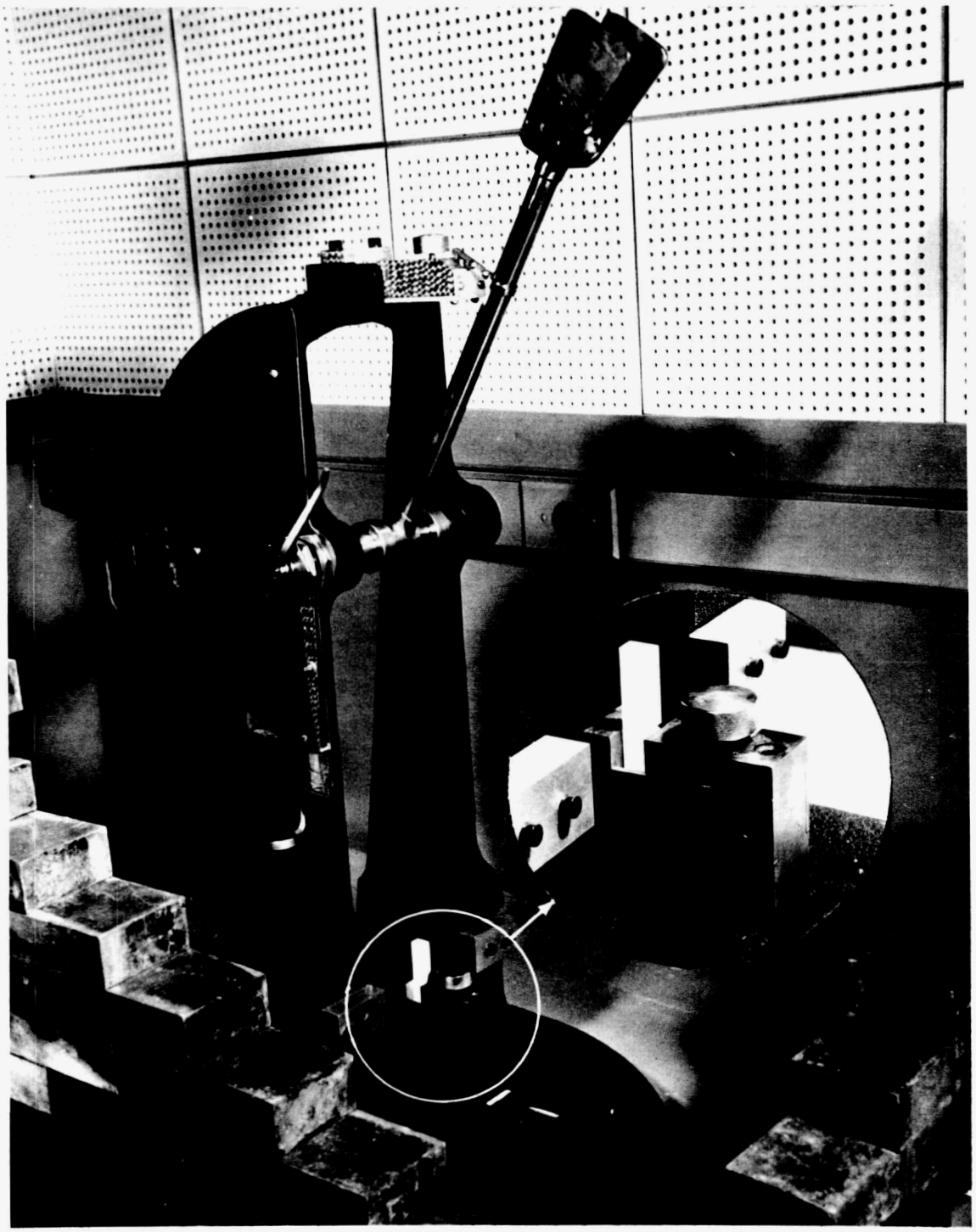

FIGURE 46 IMPACT STRENGTH TEST

Test for Rockwell Hardness

(a modification of ASTM: D 785-48T)

Description

Hardness readings were taken of the Rockwell R and α scales with a Rockwell long stroke (PL) machine (figure 47).

In the Rockwell R scale test a 1/2 inch steel ball indentor and a 60 kilogram major load are employed. The timing of the application of the load is important for many materials. The proportion of the indentation which is recovered on removal of the major load is also significant for many materials, and therefore measurements based on the recovered depth of penetration are not a measure of resistance to indentation under load.

The Rockwell α scale test is a measure of indentation under load. In the Rockwell α scale test a 1/2 inch steel ball indentor and a 60 kilogram major load are again employed, but the reading is taken while the major load is applied. A correction is made for the deflection of the frame of the machine under the major load.

Procedure for the Rockwell R Scale

(1) Condition the test specimen for 7 days at 25 ± 1 °C and 50 ± 2% humidity.

(2) Apply the minor load and set the dial gage at 0 within 10 seconds after applying the minor load.

(3) Apply the major load immediately after the zero setting has been completed.

(4) Remove the major load after exactly 15 seconds.

(5) Take the reading on the red scale exactly 15 seconds after removing the major load. Record the readings as follows:

Count the number of times the needle passed through zero on the red scale on the application of the major load. Subtract from this the number of times the needle passes through zero upon the removal of this load. If the difference is zero, the reading is over 100; if the difference is 1, the reading is between 0 and 100; if the difference is 2, the reading is the scale reading minus 100.

With the long stroke (PL) machine, the range of the R scale is 250 divisions (from plus 130 to minus 120).

Procedure for the Rockwell α Scale

Note: The numbers shown on the standard dial are not used, but the actual number of scale divisions representing indentation are counted.

(1) Determine the deflection of the frame under the 60 kilogram load:

Use a soft copper block as sample and a 1/2 inch indentor. Apply the major load by tripping the lever. (The dial gage now indicates the indentation plus the spring of the frame and any other elastic compressive deformation of the penetrator spindle and penetrator.) Repeat this operation without moving the block until the deflection of the dial gage becomes constant. (No further indentation takes place and only the spring of the instrument remains.) Record this dial gage indication as the correction for the deflection of the frame.

(2) Now apply the minor load to the test specimen and set the dial gage at zero within 10 seconds after applying the minor load.

(3) Apply the major load immediately after the zero setting has been completed.

(4) Read the dial exactly 15 seconds after the trigger has been tripped to apply the major load.

(5) The value of indentation under load is taken as the reading recorded in (4) minus the correction recorded in (1).

(6) The hardness on the alpha Rockwell scale is 150 minus the indentation under load calculated in (5). (With the long stroke (PL) machine, the range of the α scale is 250 divisions or from plus 150 to minus 100.)

Test for the Change in Weight

Description

The impact strength test specimen shown in figure 42 was weighed before and after irradiation.

Procedure

(1) Condition the specimen for 7 days at 25 ± 1 °C and 50 ± 2% humidity.

(2) Weigh the specimen to the nearest 0.1 milligram.

(3) Irradiate the specimen and again condition it as in (1).

(4) Reweigh the specimen. Calculate the percentage change in weight.

FIGURE 47 HARDNESS TEST

Test for the Specific Gravity

Description

One half of a broken impact specimen was weighed in air and in water or kerosene at 25 ± 1 °C. The kerosene was employed when the specimen floated in water. The specific gravity was taken as the ratio of the weight of the specimen at 25 °C to the weight of an equal volume of water at 4 °C and is expressed thus:

Specific gravity, 25°/4 °C

Since the density of water at 4 °C is 1.000 gm/ml, the specific gravity, 25°/4 °C is equal to the density of the specimen at 25 °C.

Procedure

(1) Condition the specimen for 7 days at 25 ± 1 °C and 50 ± 2% humidity.

(2) Weigh the specimen to the nearest 0.1 milligram in air.

(3) Tare the specimen holder immersed in water (kerosene)

(4) Immerse the specimen in freshly boiled distilled water (kerosene) at 25 ± 1 °C and weigh.

(5) If kerosene was used, determine the specific gravity of the kerosene with a pycnometer.

Calculations

The specific gravity of the plastic is calculated from one of the two following formulas:

(1) Specific gravity, 25°/4 °C = $\frac{a}{a - b}$ x 0.997

where a = weight of the sample in air
b = weight of the sample in water
0.997 = the specific gravity of water, 25°/4 °C.

(2) Specific gravity, 25°/4°C = $\frac{a}{a - c}$ x (specific gravity of kerosene 25°/4°C)

where a = weight of the sample in air
c = weight of the sample in kerosene

Test for Water Absorption

(a modification of ASTM D 570-42)

Description

A 24 hour immersion test was run on one-half of a broken impact specimen.

Procedure

(1) Dry the test specimen in an oven for 24 hours at 50 ± 3 °C.

(2) Cool in a dessicator and immediately weigh.

(3) Immerse the specimen in a container of distilled water at 25 ± 1 °C for 24 hours.

(4) Remove from the water, wipe free from surface water with a dry cloth, and weigh immediately.

(5) Dry in an oven for 24 hours at 50 ± 3 °C.

(6) Cool in a dessicator and immediately reweigh.

Calculations

(1) The percentage in weight during immersion is calculated as based on the dried weight. If weight is lost during immersion, this quantity is taken as zero.

(2) The percentage of soluble matter lost during immersion is calculated from the difference in the initial dried and the redried weight. If the redried weight is greater than the initial dried weight, this quantity is taken as zero.

(3) The percentage of water absorbed is taken as the sum of the quantities calculated in (1) and (2).

Test for Light Transmission and Haze

(a modification of D672-45T)

Description

Haze of transparent plastics was measured on a Haze Meter (Instrument Department No. Q-831-2). The meter (figure 48) consists of a tungsten lamp, a photoelectric cell, and two aperatures: aperature A near the photoelectric cell and aperature B near the lamp. Light transmission is defined as the percentage of the total light registered by the photoelectric cell that is registered when the plastic is placed over aperature A. Haze is defined as the percentage of light that is scattered when the plastic is placed over aperature B.

Procedure

(1) Adjust the current so the meter reading is 100 microamperes, with both aperatures unobstructed.

(2) Place the dust and grease free specimen in position A, and record the meter reading T_A.

(3) Place the specimen in the slot in front of aperature B and record the meter reading T_B.

Calculations

(1) Percentage light transmission is taken as T_A.

(2) Percentage haze is given by

$$\frac{T_A - T_B}{T_A} \times 100$$

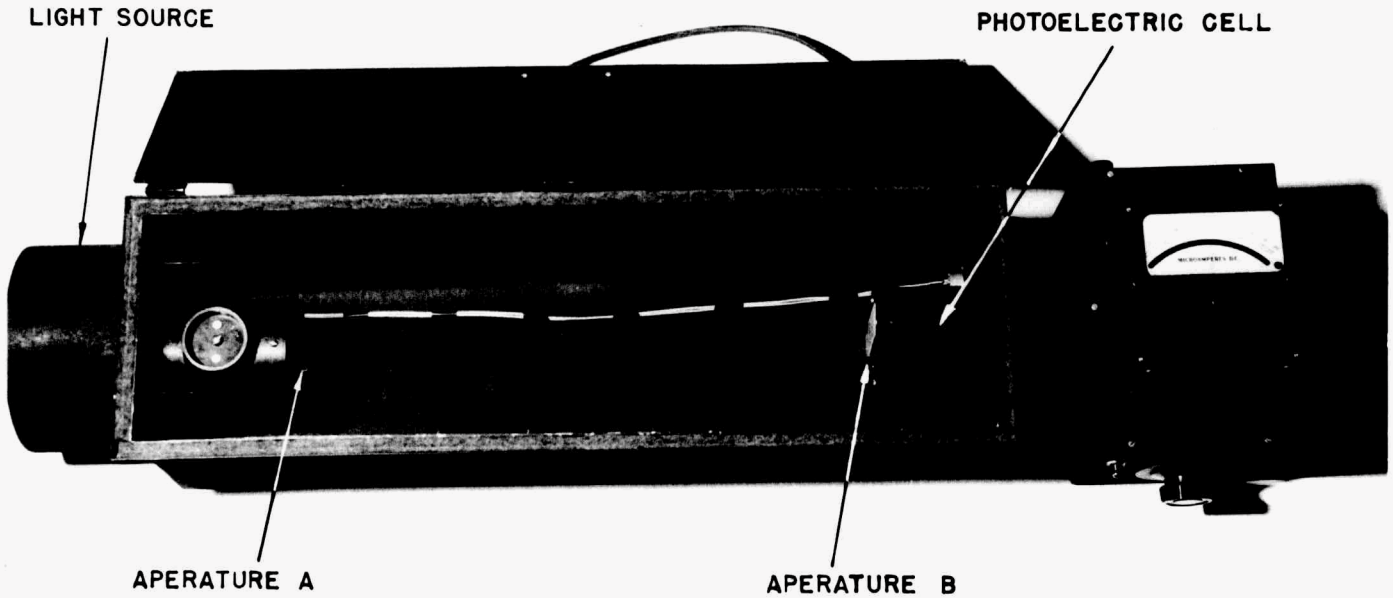

FIGURE 48 LIGHT TRANSMISSION AND HAZE TEST

Test for Volume Resistivity

(a modification of ASTM: D 257-49T)

Description

A sheet of plastic is placed in a mercury electrode assembly and the resistance between the electrodes is measured with the high-megohm bridge (Instrument Department No. Q-782.) The electrode assembly is enclosed in a shield mounted on top of the bridge as shown in figure 49. The upper limit of the bridge is 1.5×10^{13} ohms. Slightly higher insulation resistances may be measured by placing a calibrated resistance in parallel with the electrodes, but the sensitivity is such that the upper limit of measurable resistance is not greatly increased. The area of the mercury contacting each surface of the plastic is 3.08 sq. cm. so that the upper limit measurable for the volume resistivity for an 1/8 inch sheet is

$$1.5 \times 10^{13} \text{ ohms} \times 3.08 \text{ sq. cm.}/(1/8 \times 2.54 \text{ cm.}) = 1.4 \times 10^{14} \text{ ohm cm.}$$

When the high megohm bridge is switched to the "read" position, a potential of about 20 volts is applied across the terminals. The resulting polarization of the plastic test specimen is a function both of the time after the voltage is applied and of the thickness of the specimen. It is necessary to standardize these two variables to obtain comparative readings. Readings were taken one minute after switching to the "read" scale. The thickness was that of the plastic sheet from which test specimens were cut and was consequently nearly the same for test specimens of the same plastic.

Procedure

(1) Measure the thickness of the specimen before exposure to radiation.

(2) After irradiation, condition the specimen for 7 days at 25 ± 1 °C and $50 \pm 2\%$ humidity.

(3) Place the specimen in the electrode assembly, tighten the screws, invert the electrode assembly so the mercury fills the spaces on either side of the specimen, and connect the leads to the high megohm bridge.

(4) Record the resistance reading one minute after switching to the "read" scale.

Calculations

$$\text{Volume Resistivity (ohm cm)} = \frac{\text{Resistance (ohms) x mercury contact area (cm}^2\text{)}}{\text{Thickness of specimen (cm)}}$$

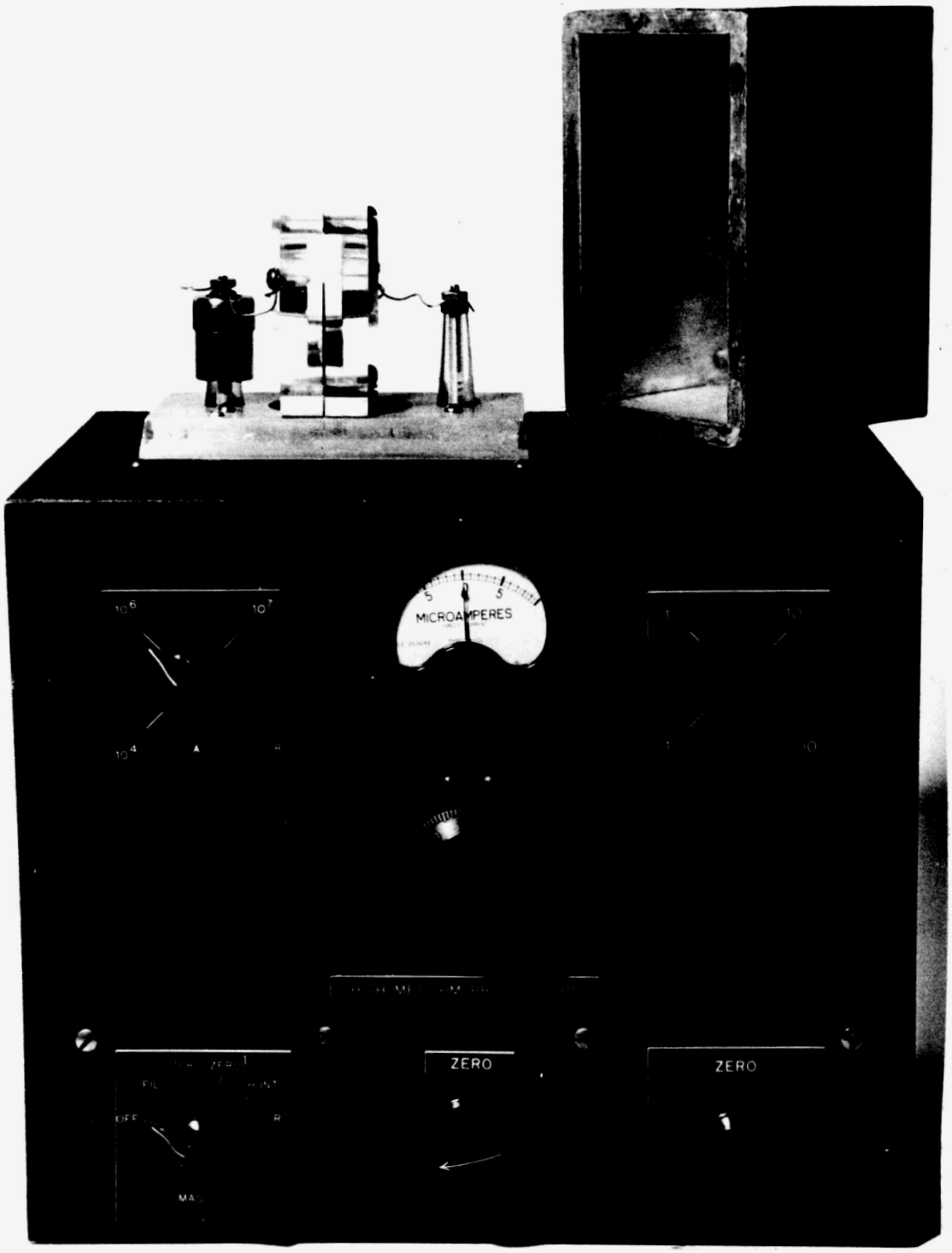

FIGURE 49 VOLUME RESISTIVITY TEST

Test for Dielectric Strength

(a modification of ASTM: D 149-44)

Description

A 30,000 volt, 60 cycle Westinghouse oil testing outfit was used in the test. The oil test cup was modified as shown in figure 50. The standard 1 inch diameter electrodes were replaced by 1/8 inch diameter electrodes; one stationary and one spring mounted. The specimen is held between the electrodes by the pressure of the spring. The test specimens are 1 inch squares and milled down thin enough so that breakdown occurs within the 30,000 volt range. Since the dielectric strength of an insulating material varies with the thickness of the material, only tests made on the same thickness are comparable. The test is made under insulating oil. The maximum value of dielectric strength measurable for a 20 mil specimen is

$$30{,}000 \text{ volts}/20 \text{ mils} = 1500 \text{ volts/mil.}$$

Procedure

(1) Measure the thickness of the specimen with a micrometer before irradiation.

(2) After irradiation, condition the specimen for 7 days at 25 ± 1 °C and 50 ± 2% humidity.

(3) Clean the specimen with white gasoline, center it between the electrodes, fill the cup with insulating oil, and place the test cup in position in the apparatus.

(4) Increase the voltage from zero to breakdown at the uniform rate of 0.5 kv/sec.

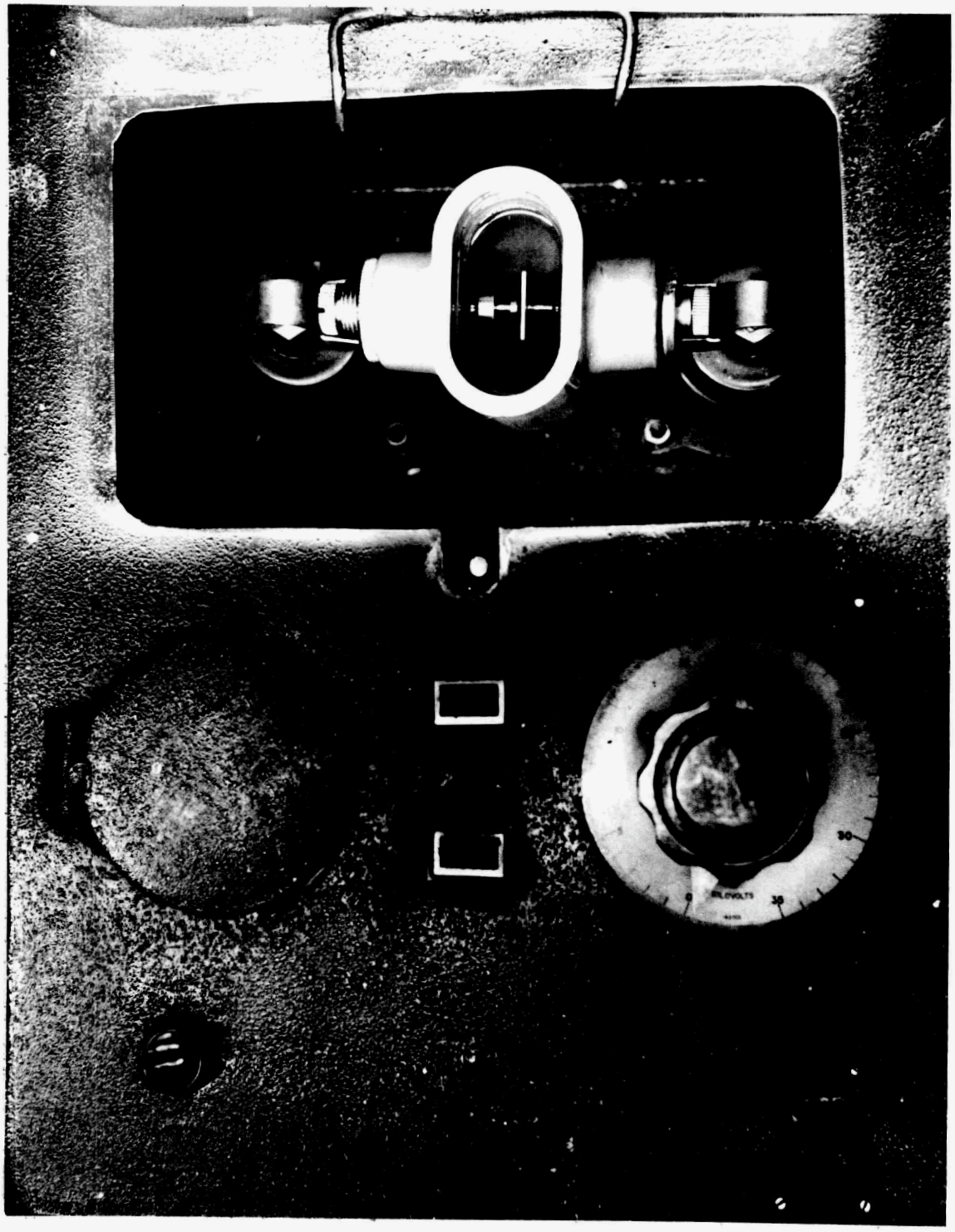

FIGURE 50 DIELECTRIC STRENGTH TEST

Test for Arc Resistance

(a modification of ASTM: D 495-42)

Description

The arc resistance tester (Instrument Department No. Q-919-1) shown in figure 51 was designed for this test. The electrodes are threaded steel rods 0.166 inches in diameter, equipped with tungsten wire tips 0.060 inches in diameter, which have a conical point with a 60° included angle. The electrodes are screwed into a Lucite block at 45° to the vertical and are adjusted to give a gap of 0.32 inches. Both electrodes lie in the same vertical plane. The weight of the block is supported on the two electrode points. (The Lucite block electrode mounting was found to be unsatisfactory for testing materials of arc resistance greater than 300 seconds, since the heat generated in the electrodes at this time was sufficient to soften the Lucite. For values above 300 seconds a wood block may be used.)

The sequence of steps listed below was automatically controlled by a timing and switching circuit.

Current (ma)	Time Cycle	Approximate Rate of Heat Generation (watts)	Total Time (seconds)
10	1/4 second on, 1 3/4 sec. off	3	60
10	1/4 second on, 3/4 sec. off	6	120
10	1/4 second on, 1/4 sec. off	12	180
10	Continuous	24	240
20	Continuous	34	300
30	Continuous	45	360
40	Continuous	56	420
50	Continuous	67	480
60	Continuous	79	540
70	Continuous	91	600
80	Continuous	103	660
90	Continuous	115	720
100	Continuous	128	780

Arc resistance is determined by this method as the total elapsed time in seconds until failure is observed. "Failure" is defined as the time a conducting path is formed across the specimen and the arc disappears into the material. Three kinds of failure have been observed:

(1) The specimen bursts into flame without the formation of a visible conducting path in the substance.

(2) A thin wiry line is formed between the electrodes -- "tracking".

(3) Carbonization occurs on the surface until sufficient carbon is present to carry the current.

Failure is usually quite definite; however, for some materials the definition is more difficult. If the trend toward failure increases over a fairly broad interval of time before all parts of the arc have disappeared, the end point is considered to have been rached only when all parts of the surface between the electrodes are carrying the current. However, if in successive arc intervals, the dielectric conducts the current only in the latter part of the "on" time, the first such interval is designated as failure.

Certain insulators do not lend themselves to classification by an arc resistance test because of melting, gumming, fouling of electrodes, flaming, mechanical disintegration by cracking, etc. The time at which these events occurred is recorded only for comparison among specimens of the same plastic but with different periods of irradiation. This should not be considered as a measurement of arc resistance.

"It has been found that changes in the timing of the intermittent arc, and in the current, as well as other circuit changes affecting the nature of discharge, can not only affect the duration of a test of most samples in a group of dissimilar materials, but can drastically alter their positions in order of rank.

It is therefore obvious that data obtained by this method, and the arbitrary conditions of test that have been assigned, should not be employed to infer that the materials examined occupy an unchanging quality relationship to each other, regardless of conditions of anticipated use."

Procedure

(1) Before irradiation, measure the thickness of the specimen with a micrometer.

(2) After irradiation, condition the test specimen for 7 days at 25 ± 1 °C and 50 ± 2% humidity.

(3) Adjust the electrodes so the gap is 0.32 inches, place the electrodes on the test specimen, and close the door to the Lucite specimen chamber.

(4) Start the timing circuit. Start a stopwatch at the first arc. Record the time in seconds until the arc in air disappears and a bright line appears between the electrodes. Describe the manner of failure.

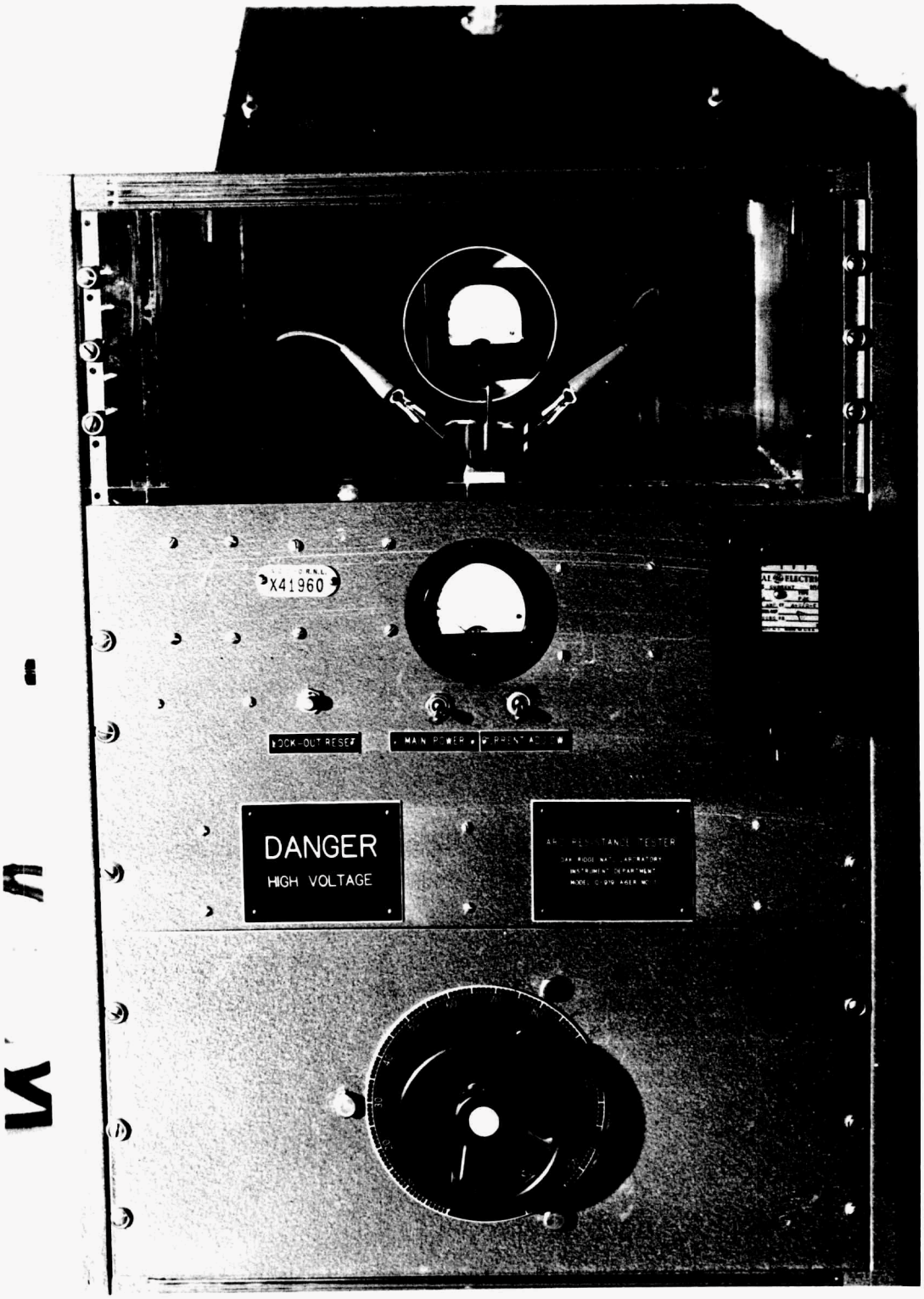

FIGURE 51 ARC RESISTANCE TEST