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Non-Cellulosic Fibers Their Properties and Influence on The Characteristics of Handsheets

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NON-CELLULOSIC FIBERS

THEIR PROPERTIES AND INFLUENCE

ON THE CHARACTERISTICS OF HANDSHEETS

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ABSTRACT

Some non-cellulosic fibers have been discussed as to their paper making characteristics.

In the field of inorganic chemistry only glass fibers have been used in paper making. The methods used in the conversion of the brittle filament into paper have been described in detail.

In the field of thermoplastic fibers, Vinyon, a copolymer of vinyl chloride and vinyl acetate; Saran, a copolymer of vinylidene chloride and vinyl chloride; and Styrene, polymerized styrene units, have been discussed. The limited data found in the literature on the performance of Vinyon have been presented.

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Introduction

A major factor in the constant expansion of the paper industry during the last twenty years is the success paper makers have had in improving existing papers and introducing new speciality papers to the converter. Many of these new papers have been made possible by the use of new resins, waxes, improved paper making techniques or new fibrous raw materials, particularly non-cellulosic fibers.

The speciality paper manufacturers however, have not as yet ventured far into the use of non-cellulose fibers as a paper making material. Those few companies which have done so are now enjoying a handsome return. Failure to enter this field is due mainly to the fact that the new fibers are significantly different in their properties as compared to cellulose fibers, thus requiring new paper making techniques.

This paper will review work that has been done on non-cellulosic fiber content papers and present further research findings.

Glass Fiber Paper - Uses and Potential Uses

Research to adapt glass fibers to paper making was started around 1943. Since that time a number of glass fiber content papers have been produced.

According to an anonymous author (1), the tearing resistance of explosive paper, used for wrapping dynamite, is greatly increased by the addition of ten per cent, by weight, of three-quarter inch milled

glass fibers. The presence of the glass fibers is said to provide a better bond between the paper and the paraffin used to coat it. Because dispersion of the glass fibers in the paper gives it more uniform strength, the page disintegrates after the explosion instead of leaving small pieces to smolder and perhaps cause a fire.

Furthermore, ten per cent, by weight, of the milled glass fibers dispersed in filtering paper gives it more uniform capillarity and speeds the filtering process. The fibers are highly adsorbent (not absorbent) and act as veins which conduct moisture rapidly throughout the paper (1). The chemical inertness of glass gives the filter high resistance to corrosive chemicals. Gas filtration is another job which glass fibers do satisfactorily.

Because of this high adsorption characteristic, ten per cent, by weight, of the glass fibers in laminating paper speeds impregnation by the resin and reduces curing time (1). A ply of glass fiber paper could act as a reinforcing material in plastic laminates.

Some high strength paper manufacturers are experimenting with waterproof paper and carton sealing tapes that have a percentage of glass fibers contained in a Kraft furnish (2).

Glass fibers not only equal asbestos but excel in many respects (4). A comparison of the economics of both fibrous raw materials may be seen from Table I.

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Table I Comparison of Asbestos and Glass Fibers

Asbestos Fibers	Glass Fibers
(1) 300 or 400 lb. of usable fibers from a ton of asbestos as mined.	(1) Yield is very high.
(2) Must be dusted, washed.	(2) Clean and ready for the beater.
(3) Supports mildew growth easily when with cellulose.	(3) Will not support mildew growth as well as asbestos when with cellulose.
(4) Shipped from long distances.	(4) Manufactured in United States.

Because of its excellent insulating qualities and high heat resistance, glass fiber paper should receive extensive use in the electronics and electrical equipment field (5).

Papers made from glass fibers can have such characteristics as high resistance to heat, chemicals, mildew, and attack by vermin; low moisture adsorption; dimensional stability; high permeability to air and water with very high retention of solid particles; electrical characteristics normally associated with glass; appreciable strength; and lack of odor.

One can easily see the potential of papers having the above properties. Some of the properties of commercial glass fibers may be seen from Table II.

Table II Physical Characteristics of Glass Fibers (9)

Tensile Strength (Std. is 70° F. at 65% r.h.)	Std. 6.3 to 6.9
	Wet. 5.4 to 5.8
Elongation	Std. 3 to 4
	Wet. 2.5 to 3.5
Elastic Recovery (%)	100%
Tensile Stress (PSI)	204,000 to 220,000
Average Stiffness (g.p.d.)*	322

*g.p.d. - grams per denier

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Table II (Cont'd.)	
Specific Gravity (d.c.m.)	2.54
Effect of Heat	Will not burn; strength begins to decrease at 600° F. and continues to decline to limiting temperature of about 1,000 to 1,500° F.; softens at 1,500° F.
Effect of Sunlight	None
Water Absorbency	Up to 3% (surface)
Effect of Acids	Attacked by hydrofluoric and phosphoric only
Effect of Alkalis	Attacked by hot solutions of weak alkalis and cold solutions of strong alkalis.
Effect of Organic Soluents	Insoluble
Resistance to Mildew	Not attacked

Paper Manufacturing on Semi Commercial Equipment

According to experiments conducted by the National Bureau of Standards in cooperation with the Naval Research Laboratory, changes in conventional paper making procedure had to be made when glass fibers were used. These changes were necessitated chiefly by the fact that glass fibers are brittle and are easily broken by usual stock preparation techniques; also, because fibers cannot be fibrillated and gelatinized like cellulose fibers (3).

Beating and Delivery to Paper Machine

A fifty pound beater with copper lined tub and manganese bronze bars and plate was used for the following study (3).

Because of non-hydrating properties, little beating is needed to reduce the glass fibers to paper making size. The time required varied from fifteen to ninety minutes at a temperature of $72^{\circ} \pm 2^{\circ}$ F. At

concentrations over one per cent, undesirable breakage of the fibers occurred, and above two per cent the stock became so bulky that it would not circulate properly. Beater roll settings ranged from 0.08 to 0.008 inches off the bed plate. When the roll was lowered to the bed plate, the resultant paper contained pinholes which led to poor filtering efficiency.

Beater stock was dropped into a chest, pumped through the stuff box, and into the fan pump where it was mixed with white water drained from the paper machine.

The Jordan was by-passed because Bouer-McNett pulp classification tests showed that the fan pump shortened the long fibers as much as twenty-five per cent. Extra short fibers would result in weaker paper.

A riffle box was used to remove any heavy particles of glass from the stock since by-passing the screens was required because the glass fibers separated from the water and remained on the screen plates. The stock went directly onto the paper machine wire from the riffle box at a concentration of 0.03 per cent.

Paper Machine Operations with Glass Fibers

For the following work a twenty-nine inch fourdrinier paper making machine with a wire thirty-three feet long, one press, nine fifteen inch driers, and a reel were used (3).

A woolen jacket which acted as a cushion was placed on the first press top roll since it was found that passage of glass-fiber paper

through rolls of which one or both surfaces were metal, a product containing pinholes was obtained. A rubber covered roll or granite roll was also found satisfactory as a substitute for the jacket covered roll. Using these arrangements, the pressure on the paper could be increased without injuring the fibers (3).

Glass-fiber paper was found to have more strength when wet than when dry and that handling over the drying rolls and onto the reel is facilitated by keeping an appreciable amount of moisture in the paper; fifty per cent was found satisfactory. The rolls of high porosity paper lost moisture quickly so that an equilibrium of about 0.01 per cent was soon reached (3).

<u>Mechanism of Glass Fiber Bonding</u>

It is the opinion of O'Leary, Scribner, Missimer, and Erving (3), members of the Paper Section, National Bureau of Standards, that an all glass fiber paper owes its strength to friction between fibers. The coefficient of friction of the surfaces of the glass fibers, and the pressure between them resulting from their elastic deformation in the structure, are the important factors. These prime factors to consider when beating glass fibers and beating should be conducted so as to produce a uniform suspension with as little breakage as possible.

<u>Fiberfrax - A Ceramic Fiber</u>

The Carborundum Company, Niagara Falls, New York has developed a ceramic fiber made by melting together fifty per cent Silicon dioxide

and fifty per cent Aluminum oxide, and air blasing a stream of the molten mass to produce fibers up to three inches in length and an average diameter of four microns (8). This fiber can withstand temperatures as high as 3,000° F. without melting, has chemical inertness, light weight, sound-deadening ability, electrical insulating characteristics, filtration efficiency, and low heat transmission (6).

Navy scientists see potential uses as insulation in nuclear energy power plants. Ceramic fibers contain neither boron or similar chemical elements which trap neutrons and become radioactive when in the neighborhood of necular reactors of piles (7).

Fineness and random arrangement of the fibers make the material practical as a superior filter for gases and liquids in chemical operations. In tests, particles as fine as 0.3 micron have been strained out (7).

The properties of Fiberfrax fibers may be seen from Table III.

Table III	Physical Characteristics of Fiberfrax (8)
Length of Fibers Blown	Up to 3 inches in length - not crystalline
Diameter of Fibers	Average of 4 microns
Effect of Heat	Can resist temperatures up to 2,300° F. without loss of properties; does not soften at temperatures approaching 3,000° F.
Density	Weighs about 2 pounds per cubic foot.

Paper Making Using Fiberfrax

The National Bureau of Standards in cooperation with the Naval Research Laboratory made test runs of ceramic fiber paper on semi-

commercial equipment. The details of this experiment have not as yet been published in their entirety (7).

Thermoplastic Fibers in Paper Making

The interest in thermoplastic fibers in paper making is due chiefly to their ability to produce a heat sealing paper of high wet strength. Principle polymers available are the vinyl resin type:

Vinyon, Saran, Polystyrene (10).

Of these, Vinyon has been the only one sufficiently available in fine staple form to make it attractive for commercial paper use (10).

One of the producers of thermoplastic fiber content papers is the C. H. Dexter and Sons, Inc., Windsor Locks, Connecticut, who manufacture tea bag paper under the patents of Fay H. Osborne (10).

Vinyon Staple in Paper - Uses and Potential Uses

Uses found for a lightweight speciality paper containing Vinyon are for filtering purposes, heat seal packaging, hair waving tissue, overlays, model aircraft covering. A lightweight Vinyon-Hemp paper has found a ready market in the tea bag field (10).

Heavier papers of Vinyon-kraft blends have been found to possess good stability and moldable features when the Vinyon in the sheet is activated by means of heat and pressure. Such uses as battery plate separators, electrical applications, and molded preforms can be made from these papers (10).

The physical and chemical characteristics of Vinyon can be seen in Table IV.

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Table IV Physical and Chemical Characteristics of Vinyon (10) (11)

Chemical make-up	Copolymer of Vinyl Chloride and Vinyl Acetate
Effect of Heat on Vinyon H H Staple	
Softening Temperature	125 - 140° F.
Shrinkage Temperature	140 - 150° F.
Tacky Temperature	185 - 215° F.
Melting Temperature	275 - 300° F.
Characteristics of Vinyon that have found use in Paper	
Fiber length	0.5" to 4.0" as preferred
Fiber diameter	0.7 mil (5.5 denier)
Tensile strength	1½ gram to 2.75 gram
Specific gram	1.34
Water Absorbency	0.1%
Dielectric strength	650 volts per mil (poor conductor)
Resistance to acids	Good
Resistance to alkalies	Good
Resistance to sunlight	Good
Resistance to organic soluents	Insoluble in gasoline, mineral oils, alcohols, and glycols; soluble in ketones
Effect of heat	Non-combustible
Resistance to mildew	Not attacked

Paper Making from Vinyon

Vinyon H H staple and not multifilament yarn is used as fibrous raw material. The use of fiber cut from multifilament yarn offers obstacles from the processing and economical angle. Vinyon H H staple can be supplied by the American Viscose Corporation in the denier and staple length listed in Table V.

Table V Denier and Staple Length (11)

2 denier	3/4" to 5" length
3 denier	1/2" to 5" length
5.5 denier	1/4" to 5" length

From the physical characteristics table it can be seen that for making paper the Vinyon fibers need reduction in length while thermo-

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plastic properties and low water adsorption will make for trouble in dispersing and beating.

Shearer (10) reports a series of beating experiments in which the following variables were studied:

1. Distilled water vs. tap water.
2. Old stock vs. fresh spun fiber.
3. Washing prior to beating.
4. Variation in rate of addition of stock.
6. Variation in amount of fiber added.

None of these changes were effective in eliminating the air bubbles which were found to form on the surface of the fibers. This condition increased as beating proceeded, and finally the fibers floated. Increased bed plate pressure increased the rate of fiber breakdown and reduced the time of occurrence of fiber floating.

A number of surface active agents were studied as a possible remedy for fiber floating. Among these were lauryl pyridinium chloride, soaking in sodium Hydroxide Tergitol, and Triton K-60. Of these, Triton K-60, a cationic wetting agent of the alkyl quaternary ammonium type, manufactured by Rohm & Haas, appeared most effective. However, the wetting agent led to excessive foaming. A anti-foam agent, Nopco KF, was combined with the Triton K-60 which gave a beautiful dispersion that was air bubble and foam free. Shearer states that the optimum concentration for each of these was established between 0.05 per cent and 0.01 per cent based on the weight of water (10).

Vinyon fibers which go into the manufacture of tea bag paper is

soaked in a one and one-half per cent sodium hydroxide solution for several hours. After the sheet is formed, the alkali may be washed out or neutralized in subsequent operations (12).

Experiments to determine the extent of fiber breakdown in the beater were run where fiber concentration, time of beating, and pressure on the bed plate were variables. Beating was done in a laboratory size beater. The effects of beating concentrations are shown in Table VI.

Table VI	Effects of Beating Concentrations
1%	Breakdown was high (10 Minutes) and considered excessive for paper making
1-1/3%	Breakdown appeared excessive
2-1/2%	Breakdown not excessive (1/16" to 1/8" in four hours) (10).

A second approach beating technique was arrived at by blending the vinyl fibers with cellulose paper making fibers. Cellulose fibers appear to protect the vinyl fiber from the beater blades so that rapid cutting does not occur. Satisfactory beating was obtained in a laboratory beater in three hours on a furnish of twenty per cent cellulose fiber and eighty per cent vinyl fiber at a beater consistency of two per cent (10).

Osborn (12) relates that in the manufacture of tea bag paper, the vinyl fiber and cellulose fiber are beaten separately and combined in a head box with two separate inlets.

Shearer (10) suggests the beating of a small amount of cellulose fiber with the vinyl fiber to prevent it from being cut excessively. Upon the completion of the beating cycle, Shearer states, an addi-

tional amount of cellulose fiber that has been beaten separately should be added to produce a vinyl fiber content paper.

Osborne (12) states in his U. S. patent that the addition of a highly beaten fiber such as caroa, manila hemp, or the like, which will take a hard beating action and hydrate to a point of zero milliliter freeness on the Schopper Freeness tester, will act as a strong bonding agent between long cellulose and thermoplastic fibers. As little as two per cent of the well beaten hard cellulose fibers will bond the furnish so that it will have a high bursting strength tearing resistance and tensile strength. Shearer (12) suggests the addition of five per cent well beaten caroa fiber to promote bonding. The effect of Vinyon HH bonding is shown in Table VII.

Table VII Effect of Vinyon HH Content on Strength of Bonded Rayon, Cotton and Wool Mats

Blend	Direction	Thickness Mils	Density g/cc.	Wt. ozs/sq.yd.	Tensile lbs.
5% Vy - 95% Rayon	M.D.*	14	.40	4.2	7.2
" " Cotton	M.D.	16	.38	4.6	2.4
" " Rayon	C.D.**	16	.40	4.8	7.1
" " Cotton	C.D.	16	.35	4.2	1.6
10% Vy - 90% Rayon	M.D.	14	.44	4.6	18.9
" " Cotton	M.D.	15	.38	4.3	6.3
" " Wool	M.D.	13	.53	5.2	4.0
" " Rayon	C.D.	13	.44	4.3	16.0
" " Cotton	C.D.	15	.38	4.3	3.7
" " Wool	C.D.	13	.50	4.9	2.7
15% Vy - 85% Rayon	M.D.	13	.38	3.7	40.8
" " Cotton	M.D.	15	.38	4.3	10.3
" " Wool	M.D.	11	.63	5.2	11.7
" " Rayon	C.D.	12	.43	4.0	27.0
" " Cotton	C.D.	15	.34	4.4	5.8
" " Wool	C.D.	11	.63	5.2	8.4

*M.D. - Machine Direction **C.D. - Cross Direction

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Table VII (Cont'd.)

Blend		Direction	Thickness Mils	Density g/cc.	Wt. ozs/sq.yd.	Tensile lbs.
25% Vy - 75%	Rayon	M.D.	12	.47	4.0	63.1
" "	Cotton	M.D.	15	.41	4.6	27.7
" "	Wool	M.D.	9	.74	5.1	27.8
" "	Rayon	C.D.	12	.54	4.7	49.0
" "	Cotton	C.D.	15	.42	4.6	19.3
" "	Wool	C.D.	10	.70	5.0	20.3

In the manufacture of tea bag paper a dilute vinyl fiber suspension of about .002 per cent consistency goes to the paper machine wire along with a dilute suspension of cellulosic fibers. The patented head box design used in the manufacture of tea bag paper has two fiber inlet pipes placed in such a way that the thermoplastic fibers are deposited predominantly on the top of the sheet (12).

A paper sheet formed which contains Vinyon may be dried in the regular manner. The heat and pressure of the drier drums and felts are sufficient to give a fair degree of bonding; however, to secure maximum bonding, the sheet should be hot calendered (10).

The effective range for satisfactory bonding is actually very narrow and approaches the melting temperature of the Vinyon staple. Table VIII gives information on the effects of temperature upon fiber bonding.

Table VIII Effect of Temperature on the Bonding of Rayon-Vinyon Mats

25% Vy HH - 75% Rayon

Temp. °F.	Thickness Mils	Density g/cc.	Wt. per square yard - ozs.	Strength lbs.
194	13	0.44	4.3	2
203	13	.43	4.2	5
212	10	.55	4.1	10
230	11	.51	4.2	15

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Table VIII (Cont'd.)

Temp. °F.	Thickness Mils	Density g/cc.	Wt. per square yard - ozs.	Strength lbs.
257	12	.63	5.7	25
275	12	.47	4.2	63
194	13	.47	4.6	14
203	14	.48	5.0	19
212	11	.56	4.6	25
230	10	.69	5.2	35
257	7	.70	3.7	45

If there is a tendency toward the drier drums picking the Vinyon fibers from the sheet, a wrapping of Teflon or glass fabric will prevent this condition (11).

Saran - Potential Papermaking Fiber

As yet, Saran has not been used as a paper making fiber; however, some manufacturers have experimented with Saran monofilaments by placing them between two layers of paper to provide greater strength and stiffness (13). Physical and Chemical Properties Tables IX and X show the characteristics of Saran.

Table IX Physical Properties of Saran (13)

Specific Gravity - - - - - - - - - - - - - - -	$1.70 \pm .05$
Moisture Absorption - - - - - - - - - - - -	Less than 1/10 of 1% after 24 hours immersion.
Color -	Natural color of Saran is a near-white with a faint yellow tint.
Refractive Index - - - - - - - - - - - - - - -	1.60
Melting Point - - - - - - - - - - - - - - - - -	340 - 350° F.
Softening Point - - - - - - - - - - - - - - - -	240 - 280° F.

Table X Chemical Properties of Saran

Effect of acids - - - - - - - - - - - - - -	Outstanding resistance.
Effect of alkalies - - - - - - - - - - -	Outstanding resistance with the exception of ammonium hydroxide.
Effect of organic chemicals - - - - - -	Not affected by alcohols or Aliphatic Hydrocarbons. Aromatic hydrocarbons, Halogenated hydrocarbons, Ketones, esters, and ethers may be detrimental.

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Table X (Cont'd.)

Effect of age	Excellent resistance to degradation.
Effect of sunlight	Slight tendency to darken after prolonged exposure.
Color possibilities	Soft pastels to rich, deep tones.

Saran 's a thermoplastic copolymer of vinylidene chloride and vinyl chloride.

Styrene - Potenti Papermaking Fiber

Styrene is not commercially converted into a staple and used as a paper making fiber. Possibly if a staple was produced and incorporated n paper, a speciality of desirable char cteristics could be produced.

The largest outlet for Styrene today is the molded plast'cs field (14).

Table XI P sical and Chemical Characteristics of Styrene (14)

Specific Gravity	1.05 - 1.0 5
Refractive Index	1.59 - 1.60
Tensile Strength	5,000 - 9,000
Heat Distort on Temperature	160 - 210 °F.
Water absorption, 24 Hrs., 1/8 inch thickness	0,03 - 0.05%
Effect of sunli ht	Yellows slightly
Effect of weak acids	None
Effect of strong acids	Attacked by oxidizing acids
Effect of weak alkalies	None
Effect of strong alkalies	None
Color possibilities	Unlimited

Styrene units (a benzene ring ith a vinyl group side chain) are polymerized to produce polystyrene.

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Experimental Program

In the literature survey preceding this report, it was pointed out that thermoplastic fibers produce paper of unusual characteristics. This experimental program will study the properties of handsheets produced from mixtures of Vinyon and bleached kraft, Saran and bleached Kraft, as well as Vinyon and Fiberglass. A fiber combination of thirty per cent Vinyon and seventy per cent bleached kraft, thirty per cent Saran and seventy per cent bleached kraft, as well as one hundred per cent bleached kraft will be beaten and then combined in various amounts. The combinations of the fiber to be used are shown in Tables I, II, and III as follows:

Table I Combination of Vinyon - Bleached Kraft

Code Number	30% Vinyon 70% Bleached Kraft	100% Bleached Kraft	% Thermoplastic Material in Mixture
A-1	100%	0	30%
B-1	66-2/3%	33-1/3%	20%
C-1	33-1/3%	66-2/3%	10%
D-1	0	100%	0

Table II Combinations of Saran - Bleached Kraft

Code Number	30% Saran 70% Bleached Kraft	100% Bleached Kraft	% Thermoplastic Material in Mixture
A-2	100%	0	30%
B-2	66-2/3%	33-1/3%	20%
C-2	33-1/3%	66-2/3%	10%
D-2	0	100%	0

Table III Combinations of Vinyon - Fiberglass

Code Number	% Vinyon	% Fiberglass
A-3	25%	75%
B-3	50%	50%
C-3	75%	25%
D-3	100%	0
E-3	0	100%

Experimental Procedure

One hundred and eight grams of Vinyon fiber and two hundred and fifty-two grams of moisture free bleached kraft will be beaten at a

consistency of 1.57 per cent to a Canaden freeness of 550 ml.

Stock will be circulated five minutes with no weight on the bedplate leaver arm; then a 5500 gram weight will be applied until beating is completed. The temperature of beating will be 23 $\pm$ 2° C.

Three hundred and sixty grams of bleached kraft will also be beaten to the preceding specifications.

Vinyon staple and Fiberglass will be beaten separately and then combined in various amounts to form handsheets.

Three hundred and sixty grams of Vinyon staple will be beaten at a consistency of 2.5 per cent to a Canaden freeness of 550 ml. The stock will be circulated five minutes with no weight on the bedplate leaver arm; then 5500 grams will be applied until beating is completed. The temperature of beating will be 23 $\pm$ 2° C.

Three hundred and sixty grams of Fiberglass will be beaten at a consistency of 1.0 per cent until a good dispersion of free stock is obtained. To prevent excessive breakage of fibers, the beater roll will be kept 0.08 to 0.008 inches off the bed plate. The temperature of beating is kept at 23 $\pm$ 2° C.

Handsheets with the fiber combinations described earlier will be made and their properties evaluated. The Vinyon-bleached kraft and Saran-bleached kraft combinations will each form nine sets of five handsheets that will be dried in three different ways. Three sets will be air dried, three sets dried at 275 - 300° F. at a pressure of 300 P.S.I., and three sets dried at 325 - 350° F., also at a pressure of 300 P.S.I. The Vinyon-Fiberglass combinations are the same as above, but only two

sets of handsheets instead of three will be dried at the specified temperatures and pressures.

The physical characteristics that will be studied are M. I. T. folding endurance, tearing resistance, tensile strength, elongation, bursting strength, heat sealing, and possibly laminating properties.

Actual Experimental Procedure

One hundred and eight grams of 3.0 denier one-half inch unopened Vinyon HH staple, and two hundred and fifty-two grams of moisture free bleached kraft were beaten at a consistency of 1.57 percent to a Canaden freeness of 555 ml.

Changes had to be made in the proposed experimental procedure in order to beat the Saran staple and bleached kraft mixture. The mixture of thirty percent Saran staple, ten denier one and one-half inch in length, and seventy percent bleached kraft caused plugging of the beater roll at 1.57 percent consistency. To overcome this difficulty a ten liter slurry of the mixture was gradually added to a beater containing ten liters of water which fed the stock under the rotating beater roll. A 5,500 gram weight was on the bed plate leaver arm during this time. Three additional liters of water were added to adjust the temperature to 23 degree C.

Three hundred and sixty grams of bleached kraft were beaten at 1.57 percent consistency to a Canaden freeness of 545 ml. This pulp was combined with the beater Vinyon-bleached kraft and the Saran-bleached kraft to make mixtures containing 30%, 20%, 10%, 0% thermoplastic fiber.

The one-half inch glass fiber staple also had to be beaten by the method described earlier. Beating was stopped at a Canaden freeness of 704 ml so as to prevent excessive shortening of the glass fibers.

Three hundred and sixty grams of one-half inch Vinyon staple were beaten at 1.57 percent consistency to a Canaden freeness of 700 ml.

Hand sheets were formed containing 30%, 20%, 10%, and 0% Vinyon in combination with bleached kraft and Saran in combination with bleached kraft. Eight sets of thirty handsheets were formed. Fifteen sheets from each set were air dried on tappi standard rings at 73 degree F. and 50% relative humidity. The remaining fifteen sheets from each set were pressure dried at elevated temperatures on a Carver laboratory type press. The pressing pressure was 300 PSI and the drying temperature was from 275 to 300 degree F.

Instead of producing handsheets that contained various percentages of glass fibers and Vinyon, two sets were produced containing bleached kraft, glass fiber, and Vinyon. One set contained 50% glass fibers, 25% Vinyon and 25% bleached kraft. The second contained 25% glass fibers, 50% Vinyon and 25% bleached kraft.

The physical characteristics of these handsheets that were studied were M. I. T. folding endurance, tearing resistance, tensite strength, elongation, and bursting strength. Heat sealing and laminating properties were not studied due to the lack of time to design a suitable testing method.

Observations

Non-Cellulosic fibers seem to be shortened very fast by beater action; especially glass fibers. It was observed that the shorter non-cellulosic fibers gave better handsheet formation; and when a handsheet containing short thermoplastic fibers was pressure dried at elevated temperature, superior strength characteristics resulted.

Since the non-cellulosic fibers have no tendency to absorb water and little for the adsorption of water, a very free pulp resulted regardless of the amount of beating. Beating could possibly be carried on until almost no fiber length at all, and still a very free pulp would exist. It was observed that ten liters of glass fiber slurry at 1.57 percent consistency drained free of water almost as fast as it was poured into a tappi sheet mold. When beating a furnish of one hundred percent non-cellulosic fibers, it was observed that the fibers had a tendency to float and resist the wetting action of the water.

A sheet of one hundred percent non-cellulosic fiber could not be couched from the Tappi sheet mold. However, it was found that the addition of twenty-five percent bleached kraft or a small amount of filler clay would produce handsheets that could be couched. Difficulty was encountered in pressure drying the sheets containing glass fibers. The Vinyon had more affinity for the hot platens of the press than for the glass fibers. To overcome this a silicone coating was baked on the surfaces of the platens. Only minor success resulted from this method, since some Vinyon fibers near the surface were still picked from the sheet when the hot platens were opened after pressing.

Experimental Results

The addition of Vinyon HH staple to bleached kraft greatly increased the apparent density, breaking length, folding endurance, elongation, and burst of air dried handsheets as may be seen from table IV and shown graphically in figures I through III. After pressure drying at elevated temperature the breaking length, folding endurance, and burst were further increased while apparent density, elongation, and tear decreased. The comparsion of physical properties of air dried handsheets to the pressure dried at elevated temperature handsheets may be seen graphically in figures I through III.

— Vinyon —

Table IV

Combinations Of Vinyon And Bleached Kraft

Air Dried

Percent Vinyon	Basis Wt. Grams / Meter²	Apparent Density	Breaking Length	Burst Factor	Tear Factor	Folding Endurance	Elongation (Percent)
30	71.5	.256	3324	20.6	139	39	1.56
20	65.0	.262	3396	22.7	172	41	1.40
10	64.5	.236	3250	24.8	198	35	1.52
0	65.0	.240	3024	17.3	227	26	1.42

Pressure – 300 PSI
Temperature – 275-300°

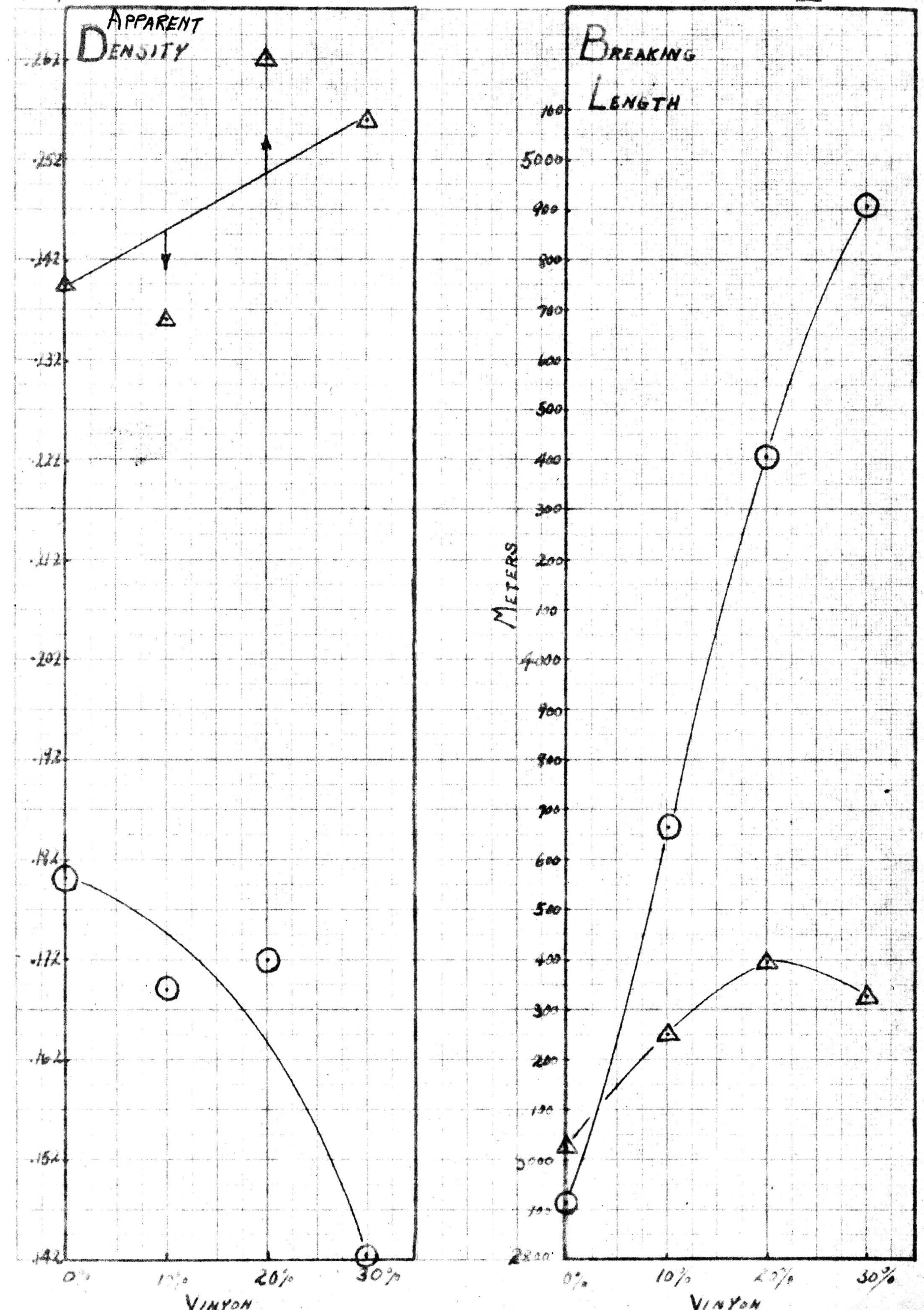
Pressure Dried At Elevated Temperature

Percent Vinyon	Basis Wt. Grams / Meter²	Apparent Density	Breaking Length	Burst Factor	Tear Factor	Folding Endurance	Elongation (Percent)
30	71.5	.142	4906	31.4	67	221	1.20
20	65.0	.172	4606	33.8	92	154	1.16
10	64.5	.169	3662	30.5	119	150	1.36
0	65.0	.180	2913	17.3	197	24	0.92

Summary Of Testing Data

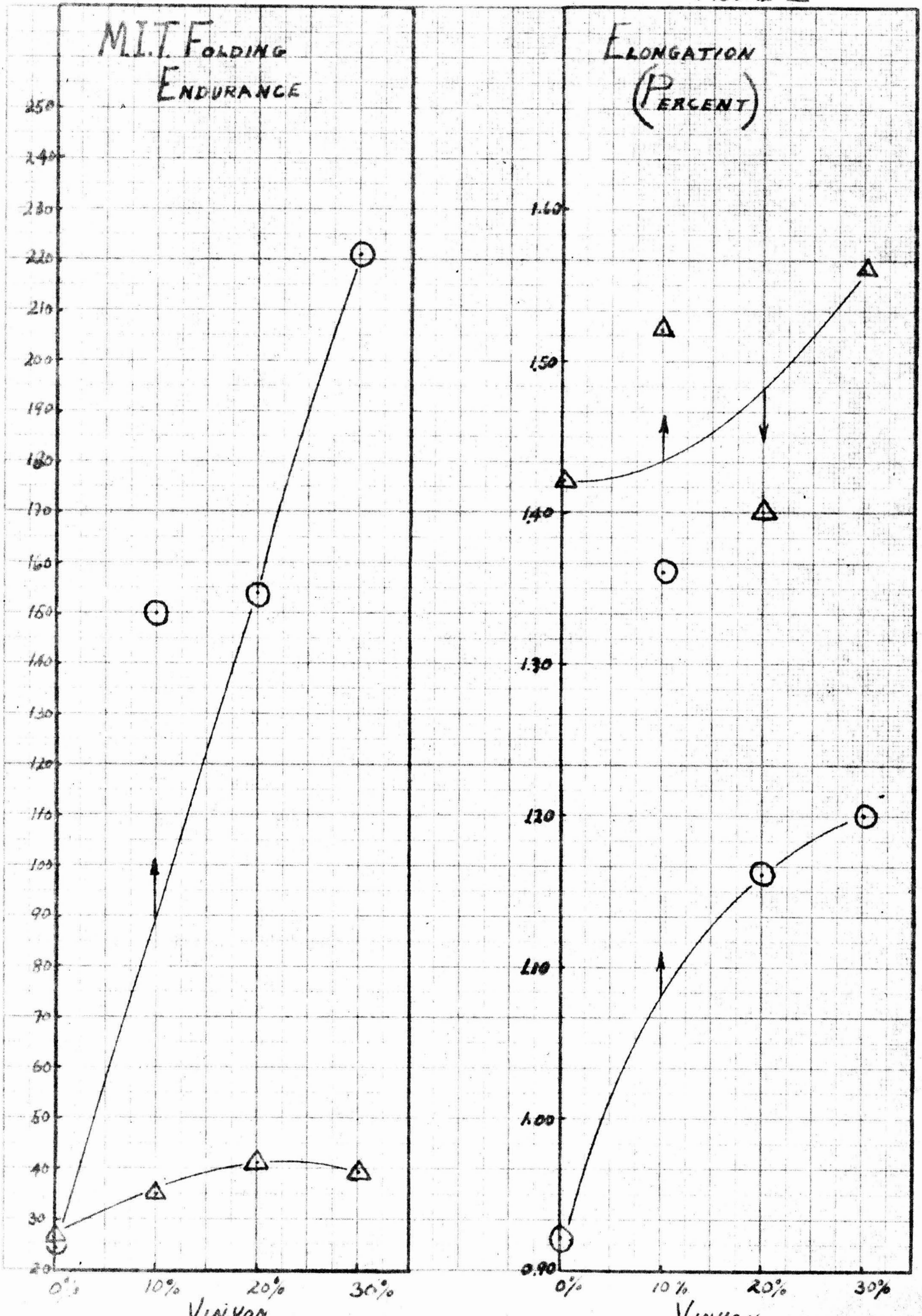
Bleached Kraft — Vinyon — ⊙ Pressure Dried At Elevated Temperature
△ Air Dried

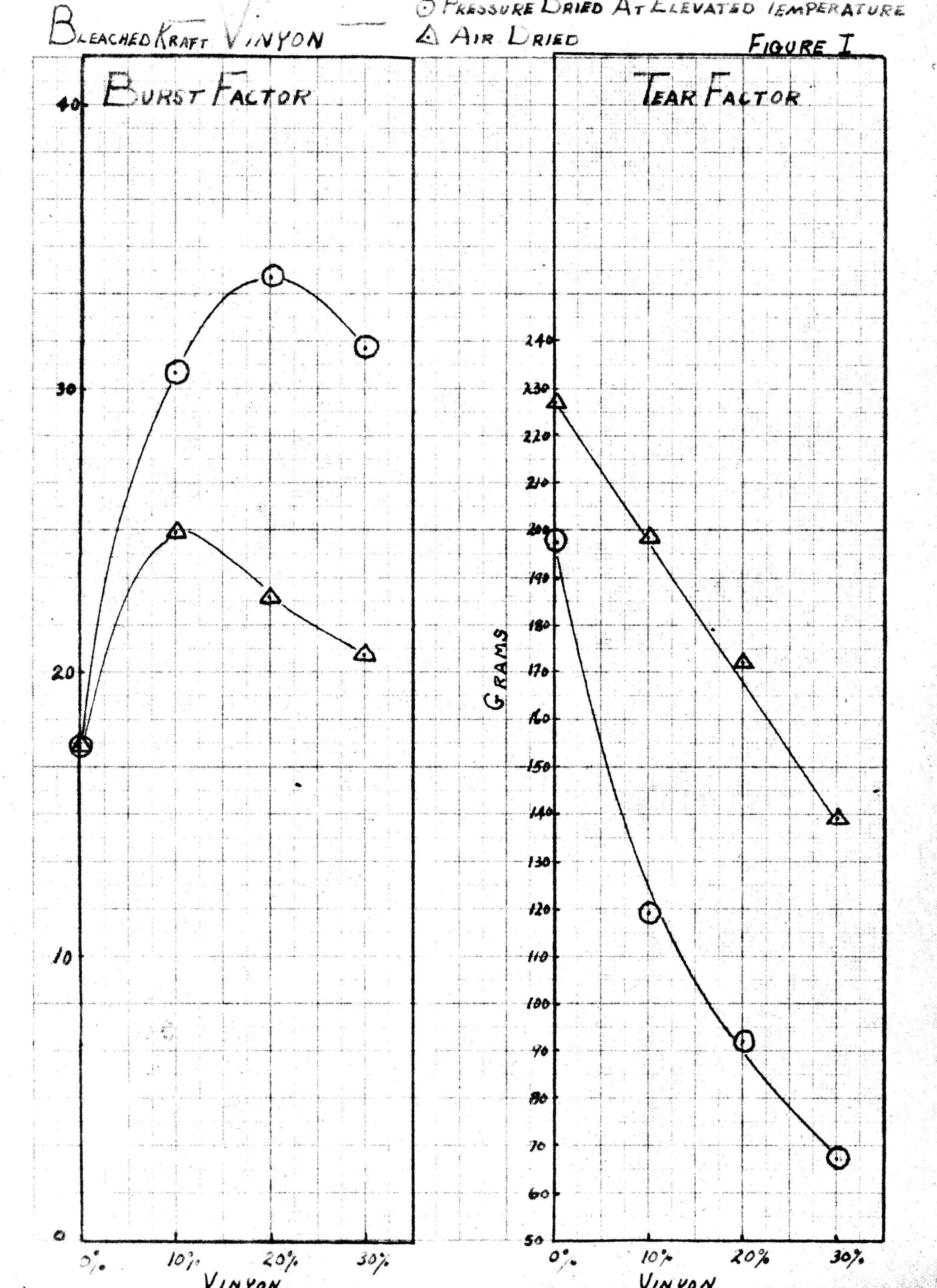
Figure III



Bleached Kraft — Vinyon — ⊙ Pressure Dried At Elevated Temperature
△ Air Dried

Figure II




Bleached Kraft Vinyon
⊙ Pressure Dried At Elevated Temperature
△ Air Dried
Figure I
Burst Factor
40
30
20
10
0
0%
10%
20%
30%
Vinyon
Tear Factor
Grams
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
0%
10%
20%
30%
Vinyon

—SARAN—

TABLE V

COMBINATIONS OF SARAN AND BLEACHED KRAFT

AIR DRIED

PER-CENT SARAN	BASIS WT. GRAMS/METER²	APPARENT DENSITY	BREAKING LENGTH	BURST FACTOR	TEAR FACTOR	FOLDING ENDURANCE	ELONGATION (PERCENT)
30	62.0	.3070	3179	23.8	222	21	1.30
20	62.5	.2600	3150	20.2	236	24	1.14
10	63.0	.2340	3170	20.1	244	21	1.36
0	62.5	.2320	2905	20.2	215	20	1.20

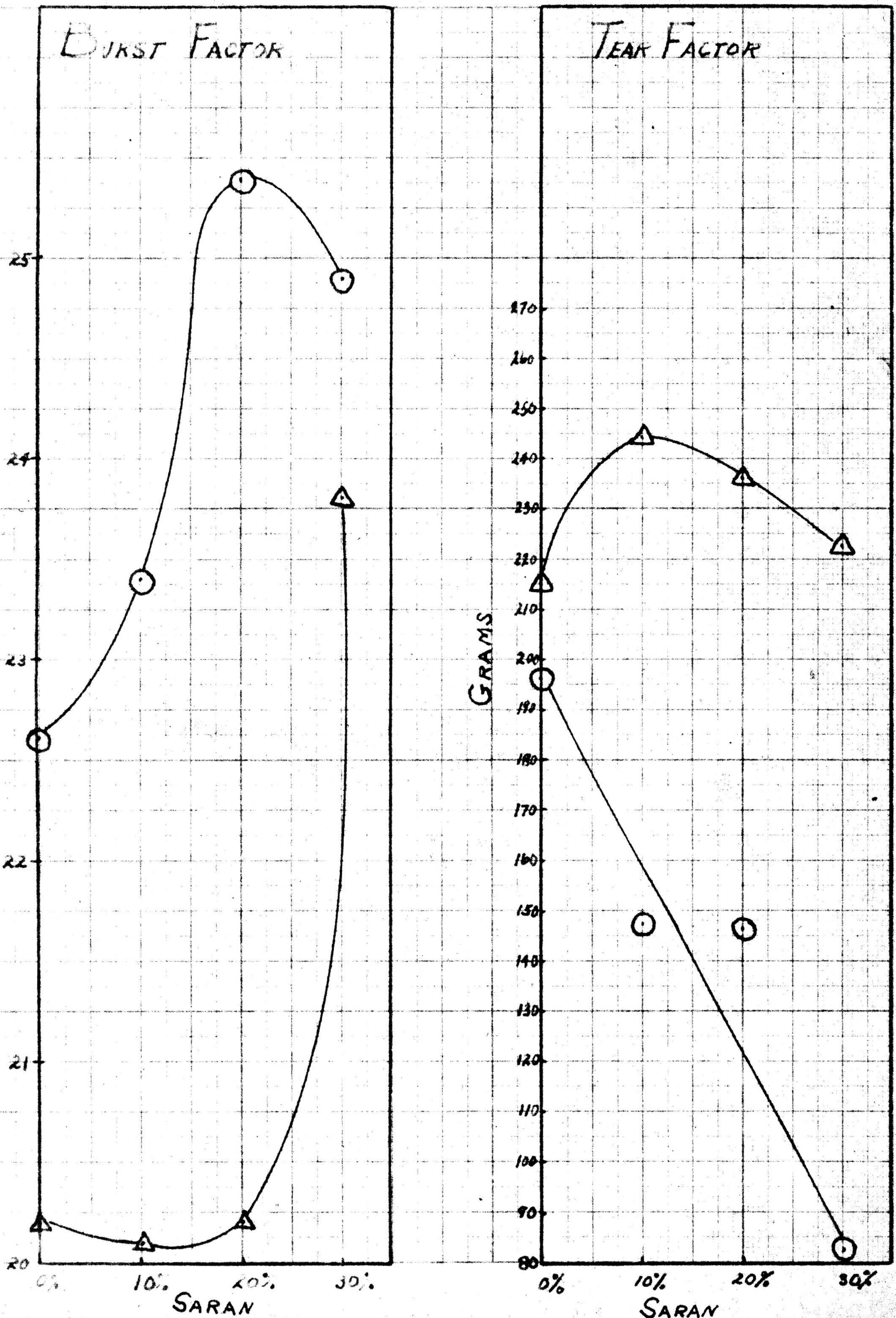
PRESSURE - 300PSI
TEMPERATURE - 275-300°F

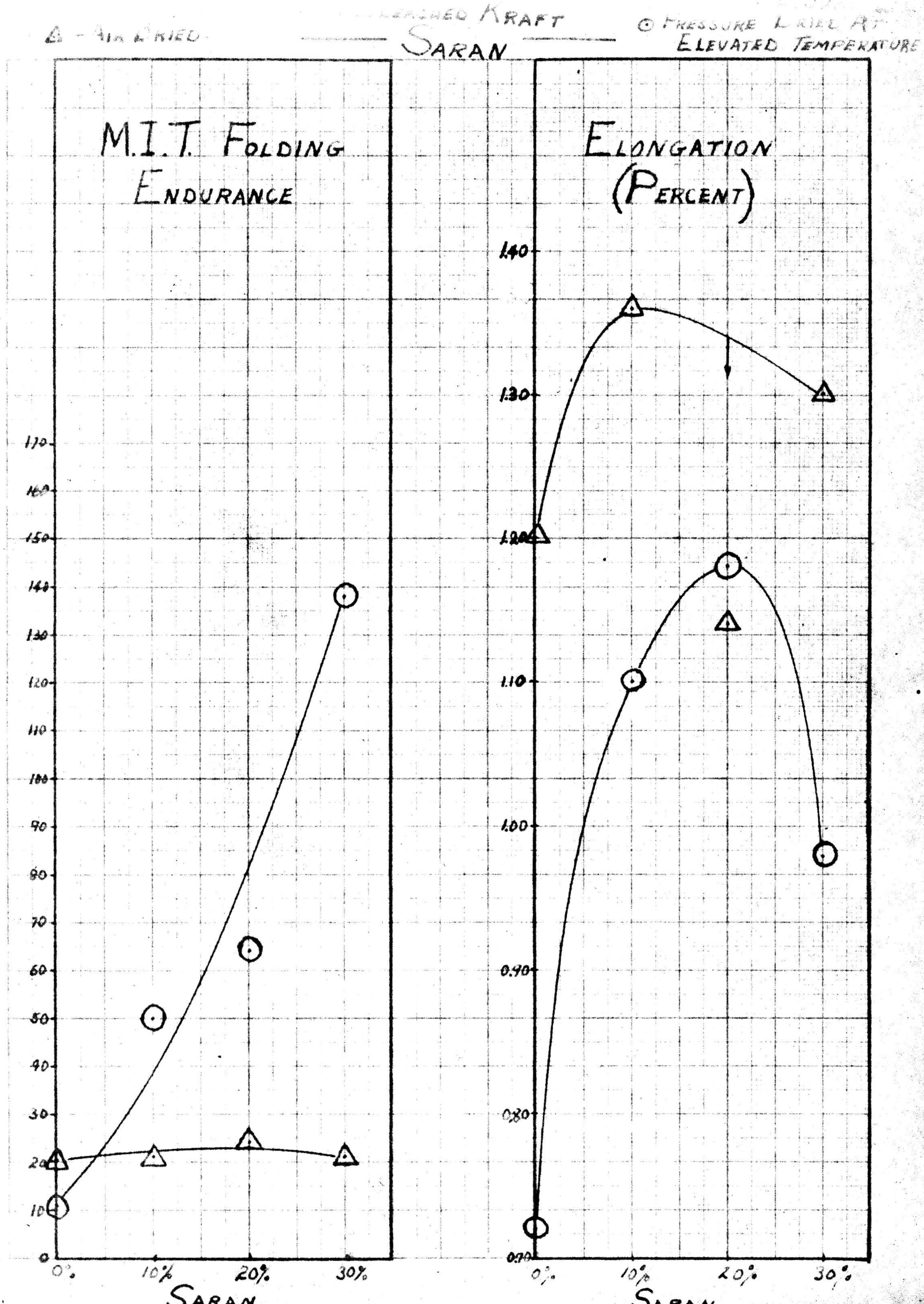
PRESSURE DRIED AT ELEVATED TEMPERATURE

PER-CENT SARAN	BASIS WT. GRAMS/METER²	APPARENT DENSITY	BREAKING LENGTH	BURST FACTOR	TEAR FACTOR	FOLDING ENDURANCE	ELONGATION (PERCENT)
30	62.0	.1640	4380	24.9	82	138	0.98
20	61.0	.1950	3819	25.4	146	64	1.18
10	63.0	.1815	3555	23.4	147	50	1.10
0	62.0	.2170	2730	22.6	196	11	0.72

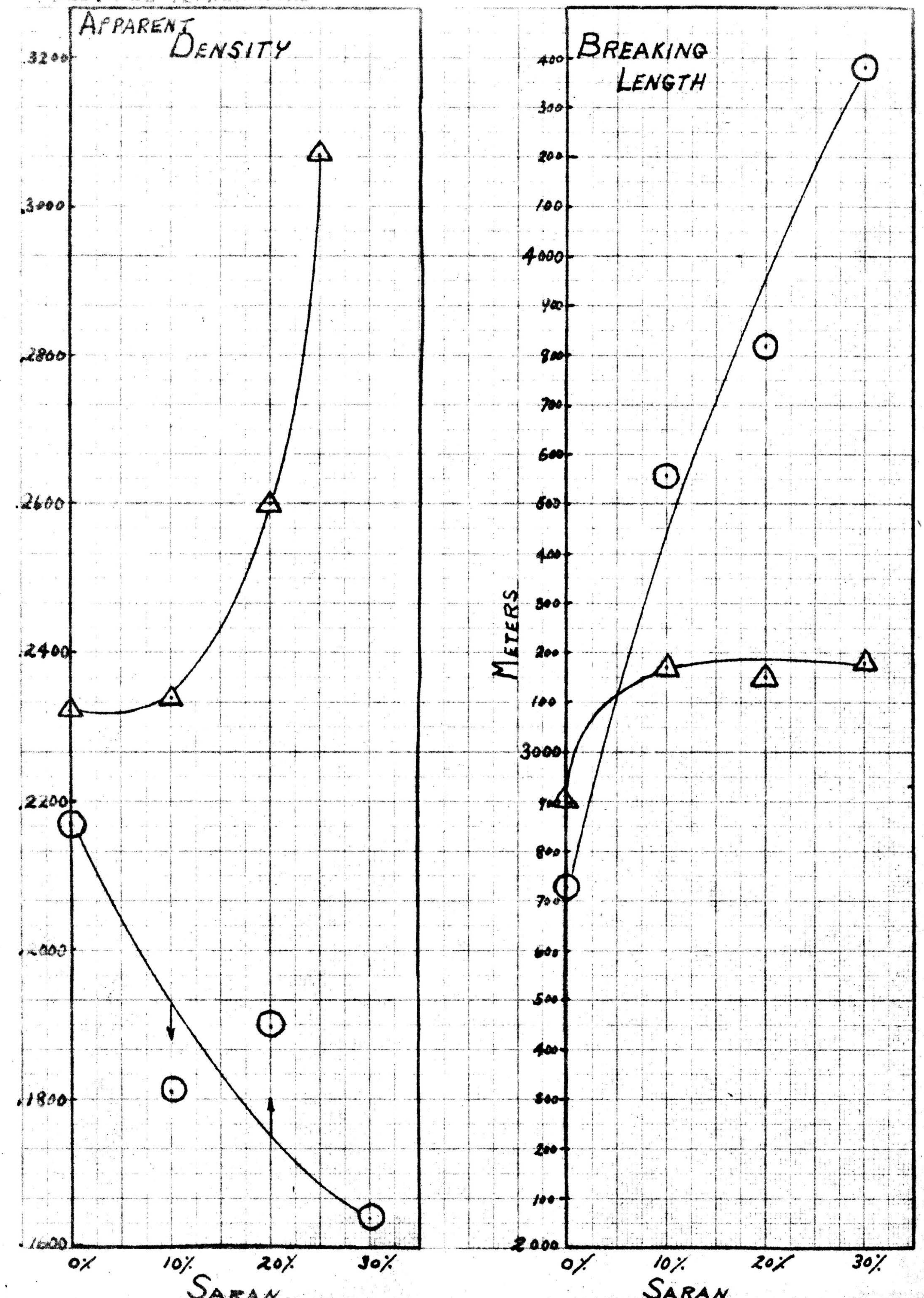
SUMMARY OF TESTING DATA

O - Pressure Drill at Elevated Temperature — Saran — Bleached Kraft




Δ - AIR DRIED
KRAFT
SARAN
⊙ PRESSURE DRIED AT ELEVATED TEMPERATURE
M.I.T. FOLDING ENDURANCE
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0%
10%
20%
30%
SARAN
ELONGATION (PERCENT)
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0%
10%
20%
30%

Elevated Temperature — Saran — Bleached Kraft



The physical properties of Saran and bleached kraft handsheets were similar to those of Vinyon and bleached kraft in that the apparent density, breaking length, folding endurance, elongation, and burst of air dried handsheets increased as the percentage of Saran increased. This may be seen from table V and shown graphically in figures IV through VI. The breaking length, folding endurance, and burst were further increased while apparent density, elongation and tear decreased after pressure drying at elevated temperatures.

Pressure dried handsheets containing Vinyon were much higher in breaking length, burst, and folding endurance than handsheets containing Saran. However, the apparent density and tear of Saran content handsheets was greater than for Vinyon content handsheets.

Conclusion

Vinyon and Saran thermoplastic fibers in combination with bleached kraft increase apparent density, breaking length, folding endurance, elongation, and burst of air dried handsheets. The application of heat and pressure will cause the thermoplastic fiber to soften and adhere to the cellulose fibers producing a superior bond between the fibers. This superior bonding will greatly increase the folding endurance, breaking length, and burst

Tear and apparent density will be increased by the addition of long thermoplastic fibers and the air drying the handsheets. Pressure drying at elevated temperatures decreases the apparent density and the tear.