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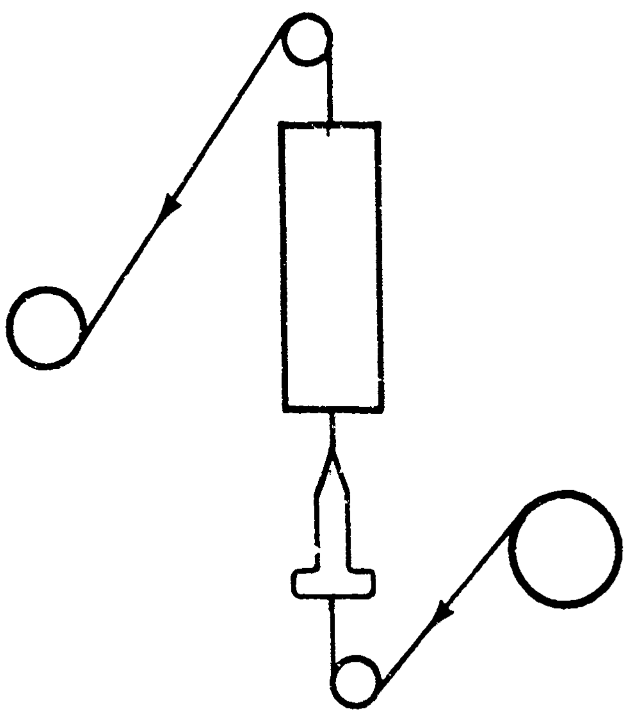

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By D. N. De Young and G. R. Snelling

The importance of "Teflon" tetrafluoroethylene resin as a wire insulating material is due to its unique electrical and physical properties. These properties are discussed in a paper by Doban, Sperati and Sandt (1) and summarized in Table I.

TABLE I

ELECTRICAL AND PHYSICAL PROPERTIES OF "TEFLON"

Property	ASTM Method	Average Value
Continuous Service Temperature		up to 500°F
Dielectric Constant, 23°C (73°F), 60 to 10^9 cps	D150-54T	2.00 - 2.05
Dielectric Strength (short time 0.010")	D149-44	2000 - 3000 volts/mil
(short time 0.080")	D149-44	600 volts/mil
Surface arc resistance	D495-48T	>700 (does not track)
Volume Resistivity, 23°C (73°F), 100% R.H.	D257-52T	$>10^{15}$ ohm-cm
Surface Resistivity, 23°C (73°F), 100% R.H.	D257-52T	3.6 x 10^6 meg ohms
Power Factor, 60 to 10^8 cps	D150-54T	<0.0003
Moisture Absorption	D570-42	<0.01%
Flammability	D635-44	nonflammable
Chemical-resistance		inert to almost all known solvents (1)
Weather Resistance		Excellent (2)
Colorability		Unlimited
Tensile Strength, 23°C (73°F)	D638-52T	1,500 - 3,000 lb/sq in.
Elongation, 23°C (73°F)	D638-52T	100 - 200%

(1) "Teflon" attacked only by alkali metals under certain conditions. Halogens and certain halogenated chemicals and solvents at high temperature and pressures may also affect "Teflon".

(2) No detectable change after 10 years of outdoor exposure in Florida.

* Registered U. S. Patent Office

"Teflon" is used principally for wire insulations which require its excellent electrical properties at high and low service temperatures as discussed by Ely (2) and Ondrejcin (3). Typical end use examples are electronic hook-up wire, aircraft power wire, wire for corrosive areas, coaxial cables, and wire for small electric motors.

There are six processes used in insulating wire with "Teflon". Each of these processes was developed for a specific type of "Teflon" and/or a general application of the insulation as governed by the wall thickness of the jacket. Table II shows the field of use for each of these processes.

TABLE II

WIRE AND CABLE INSULATED WITH "TEFLON"

Method of Processing	Form of "Teflon" Used	Insulation Thickness, mils
Dip Coating	Enamel, made from aqueous dispersion (1)	0.5-1 mil per dip
Extrusion (compounded)	"Teflon" 6 extrusion powder	8 to 50
Calendering	"Teflon" molding powder	15 to 100
Ram or Screw Extrusion	"Teflon" molding powder	40 to 500
Tape Wrapping	Tape made from extrusion powder, molding powder, cast film, or a coated glass fabric	1 and up
Melt Extrusion	"Teflon" 100X	4 and up

(1) "Teflon" enamels are supplied by the Fabrics and Finishes Department of the du Pont Company.

Of these processes calendering and melt extrusion are still in a development stage. Calendering is being studied in an effort to improve on the existing experimental machine design to achieve a unit capable of commercial production. A new resin, "Teflon" 100X perfluorocarbon resin, which is melt extrudable has been developed by the Polychemicals Research Division. The maximum service temperature of this resin is about 100°F lower than the other forms of "Teflon". Should the decision be made to produce this material a commercial plant would not be in operation before 1959.

The extrusion process, often called paste extrusion, is considered to be one of the best processes for applying thin wall insulations of "Teflon" on wire. A number of companies have been in commercial production of wire insulated with "Teflon" via this extrusion process for several years. The basic factors of the extrusion process are being studied within the Polychemicals Department of the du Pont Company. This paper describes the result of the process study to date with emphasis on practical limits of operation and systematic methods of solving fabrication problems.

Rheological Behavior of "Teflon" 6

"Teflon" 6 is an extrusion grade resin having an ultimate particle size of approximately 0.2 microns. Unlike the granular "Teflon" resins used for molding, it is capable of undergoing large plastic deformations when subjected to moderate stresses. When "Teflon" 6 is forced through a conical die the individual particles are elongated into fibers which are considerably stronger than the "Teflon" charged to the die (4). The characteristic work strengthening of "Teflon" 6, due to the elongation of the "Teflon" particles, is the heart of the extrusion process. By virtue of this property a billet or a preform made from the extrusion powder having a low tensile strength of only a few lb/sq in. can be converted into an extrudate having a yield strength of several hundred lb/sq in. A hydrocarbon oil lubricant is mixed with the resin prior to extrusion. The concentration of oil is adjusted to permit the extrusion of a strong extrudate at reasonable pressures.

The Wire Coating Process

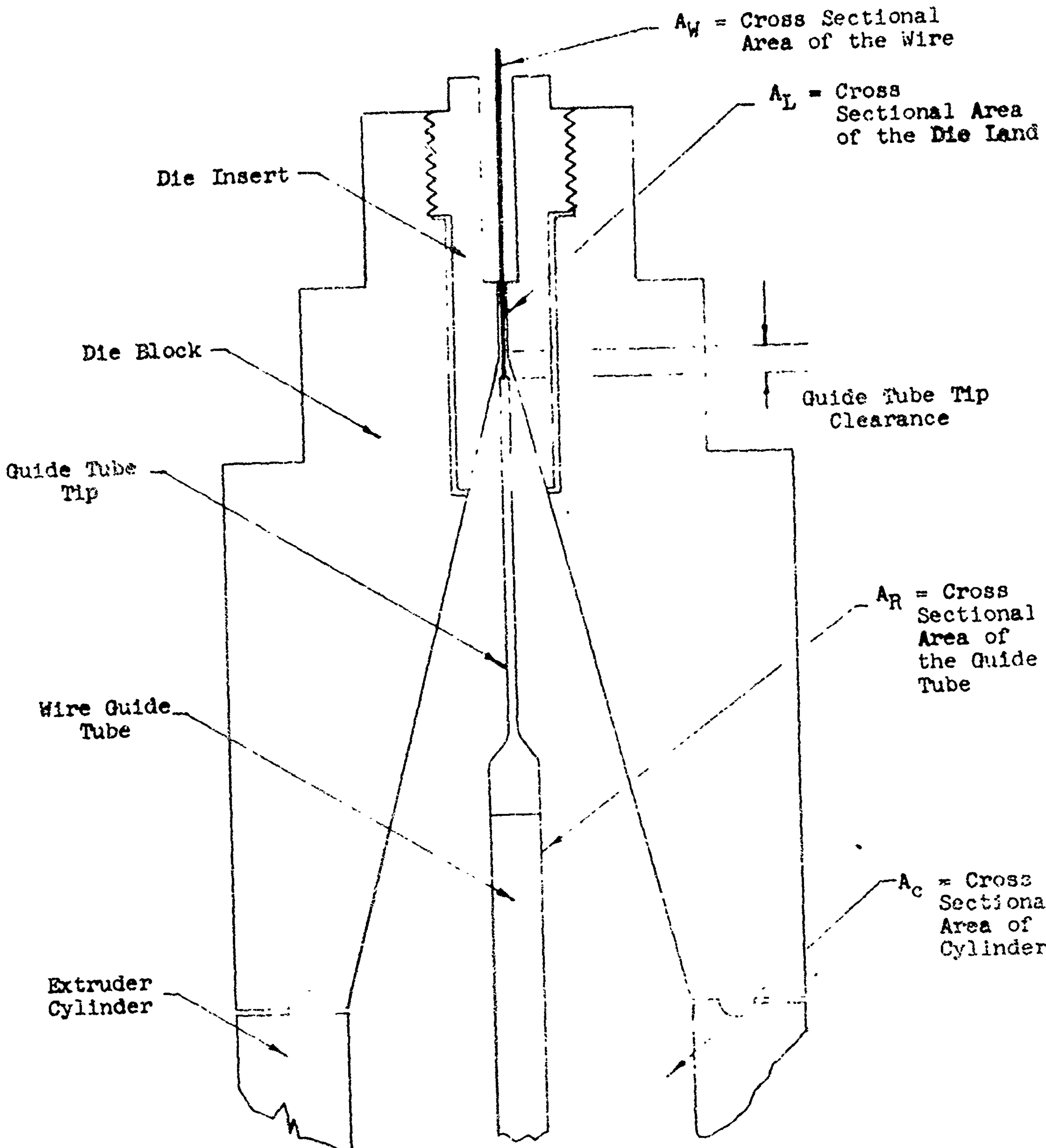
The wire coating process resembles the cold extrusion of metals, except that unlike metal extrusion, extremely large area reductions are possible; in fact, area reductions of over 1000:1 are common. Area reduction, referred to in this paper as reduction ratio, is defined in Figure 1. Die dimensions are used rather than extrudate or product dimensions, as the latter are dependent on process variables.

Typical wire coating equipment is shown schematically in Figure 2. The "Teflon" extrusion powder is mixed with a lubricant, preformed to the shape of the extruder cylinder, and placed in the extruder cylinder. The wire is introduced into the extruder cylinder through a wire guide tube and a guide tube tip. The wire is coated with polymer at a point near the top of the conical die as pressure is applied to the preform by a ram. The extrudate passes through an oven heated to 350 to 575°F, where the lubricant is volatilized. It then passes through a second oven heated to 650 to 750°F, where the coating is sintered or fused. The capstan, wind-up, pay-off, and spark-testing equipment used are standard wire coating equipment. A simple device such as a spring balance for measuring wire tension and equipment for measuring extrusion pressure are useful accessories for process studies.

Handling of the Extrusion Powder

Prior to extrusion, "Teflon" 6 requires careful handling procedures to prevent excessive particle deformation. Scooping of the powder, excessive screening, or any other mechanical deformation of the powder causes sufficient damage to render the particles less suitable for paste extrusion. These deformed particles tend to resist the further deformation required in the extrusion die and cause flaws in the wire coating. Care should be taken during the handling procedures to avoid contamination, which could lead to coating flaws.

During shipping and storage, "Teflon" 6 will at times become compacted. This can be minimized by storing the powder at temperatures below 70°F. Should compaction occur and the lumps fail to break up during a mild screening, the lumps should be impact-screened at 50 to 63°F on a 4-mesh sieve. This procedure results in a powder which will be suitable for use.



$$\text{Reduction Ratio} = \frac{A_c - A_R}{A_L - A_W}$$

Figure 1. Definition of Reduction Ratio

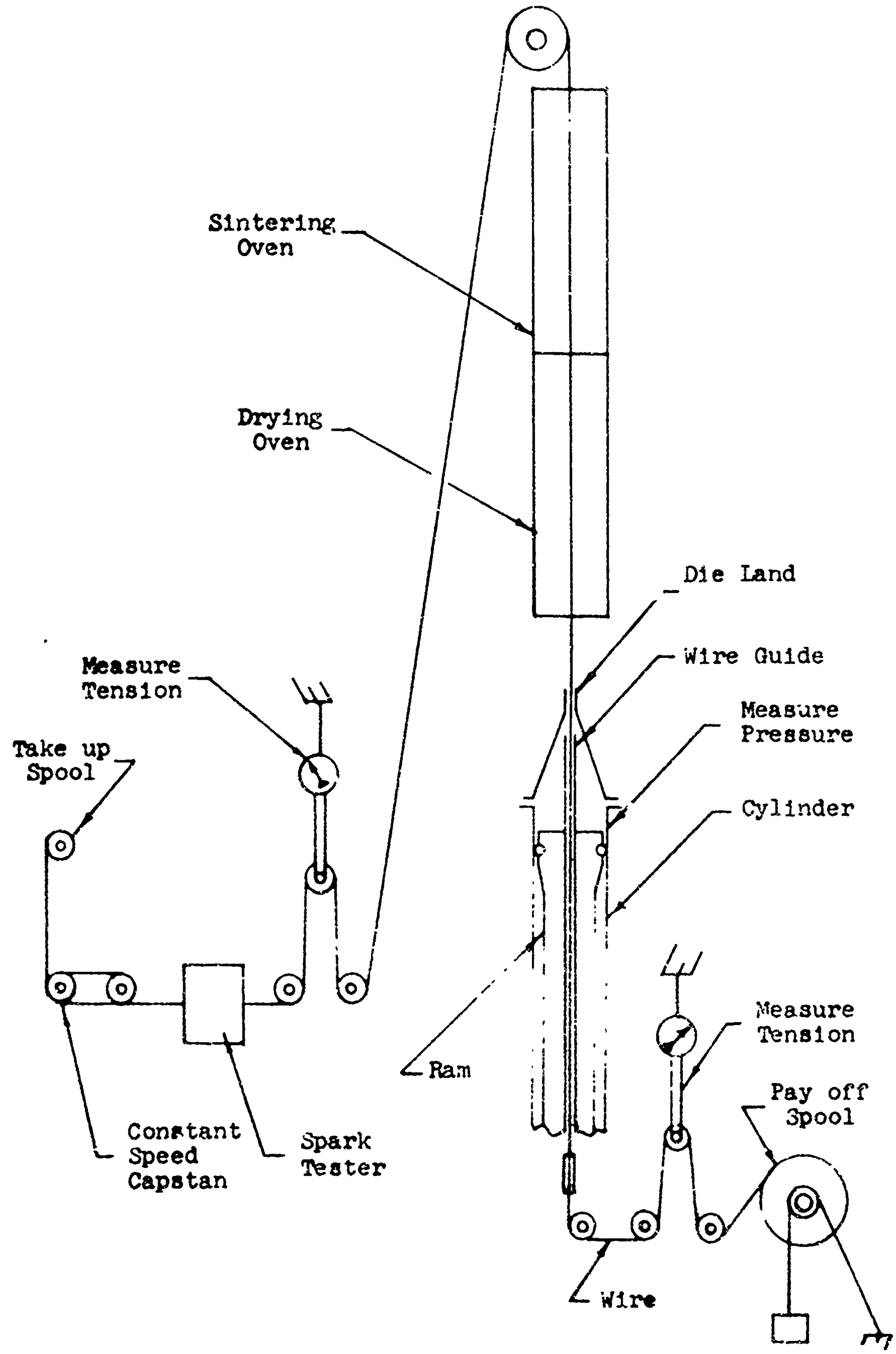


Figure 2 Paste Extrusion Wire Coating Equipment

Preparation of the Lubricated Compound

A very important step in preparing the powder for extrusion is the incorporation of a lubricant. The function of the lubricant in extrusion is to wet the polymer particles, allowing the formation of a paste which can be extruded through a die into various shapes at low pressures. Any organic liquid which will wet "Teflon" can be used as a lubricant provided it meets the requirements implied by the extrusion conditions (4). VM&P grade naphtha[1] is recommended as a lubricant as it is easy to incorporate into the resin, vaporizes completely and rapidly below the sintering temperature (621°F) of the resin, and leaves little or no carbon residue when vaporized. Number 30 white oil[2] is also used as a lubricant by some processors.

The following step-wise procedure is recommended for incorporating the lubricant. The powder should be held at 70 to 80°F during this procedure.

(1) Screen the powder as received in the shipping container through a 4-mesh sieve onto a clean, lint-free, dry sheet of paper.

(2) Transfer a predetermined weight of the screened powder to a clean, dry container having an airtight closure. For example, a one-gallon wide-mouth glass bottle having a metal-foil-lined closure is suitable for a 1000 gram batch of "Teflon".

(3) Add the required amount of lubricant, naphtha, to the "Teflon" in the container. Care should be taken here to prevent the lubricant from wetting the walls of the container, as this hampers the mixing action. The screw-type closure should be taped in place to prevent any loss of lubricant. The ingredients should be weighed with a precision of at least ± 0.2%.

[1] VM&P naphtha of specific gravity 0.735 to 0.749 - boiling range 194 to 300°F.

[2] White oil, "Deobase" No. 30, as supplied by L. Sonneborn Sons & Co.

(4) Shake the container briefly to minimize the wetting of the container wall with liquid.

(5) Place the container on a pair of parallel horizontal rollers which are driven in the same direction at 15 rpm. Allow the container to roll for 15 to 20 minutes. Caution: Do not allow the container to roll for extended periods of time, as this tends to work the "Teflon" particles excessively.

(6) Remove the container from the rolls and age the compounded mixture overnight in the sealed container at room temperature to enable the lubricant to diffuse to the interior of individual particles and surfaces not reached during the rolling process.

The optimum concentration of the lubricant in the compounded mixture is dependent on the extrusion die design, the extruder cylinder diameter, and the wall thickness of the wire insulation applied. Normally the lubricant comprises from 17 to 20% of the total weight of the compounded mixture.

Colored wire coatings can be made by adding various pigments to the compounded mixture. The pigments should be thermally stable at "Teflon" processing temperatures, have a particle size not larger than that of "Teflon" 6, and not tend to agglomerate. Pigment concentrations of 0.1 to 0.3% produce a satisfactory depth of color. The pigment is dry blended with the "Teflon" powder prior to the addition of the lubricant.

Preparation of the Preform

The object of preforming is to press the loose compounded mixture of "Teflon" and the lubricant into a solid cylinder which may be charged into the extruder cylinder. The preform is made by compacting the lubricated "Teflon" mixture in a smooth-finish preform cylinder having a core rod in its center.

The cylinder is about three times as long as the finished preform to allow for the volume reduction of the lubricated "Teflon". The outside diameter of the preform is approximately 50 mils less than the diameter of the extruder cylinder. The core rod diameter is about 10 mils larger than the diameter of the wire guide tube in the extruder cylinder.

When the lubricated "Teflon" is poured into the preform cylinder care should be taken to distribute the powder evenly around the core rod. This insures an even compaction of powder throughout the finished preform.

The effect of preforming pressure on the preform density was determined by measuring the pressure developed on the preforming ram during compaction of the lubricated "Teflon". The rate of travel of the preforming ram was 0.5 in./min to prevent excessive shear stresses in the polymer and to allow the entrapped air to escape. The result of this work is illustrated graphically in Figure 3, from which it is apparent that pressures in excess of 100 lb/sq in. do not affect preform density. In wire-coating operations there was no difference in the extrusion performance of preforms made at 50 to 100 lb/sq in. and those made at 1000 lb/sq in. Thus, preforming pressures of 50 to 100 lb/sq in. are sufficient for preforming. In fact, higher pressures are less desirable as lubricant is squeezed out of the preform.

The quality of the coated wire depends greatly on the preparation and handling of the preform. Care should be taken to avoid any deformation or contamination of the preform when removing it from the preform cylinder and inserting it into the extruder cylinder. Finished preforms should not be allowed to stand exposed to air before using because the lubricant volatilizes, leaving the preforms too dry for extrusion.

<u>The Extruder Cylinder and Ram</u>

Various diameter cylinders are used in the extrusion of "Teflon" for wire insulation. Normally, the diameters range from 3/4" to 2-1/2", the smaller diameter cylinders being required for the smaller wire sizes. The ram is driven by a screw jack mechanism which enables a constant thruput of material regardless of extrusion pressure. This constant thruput

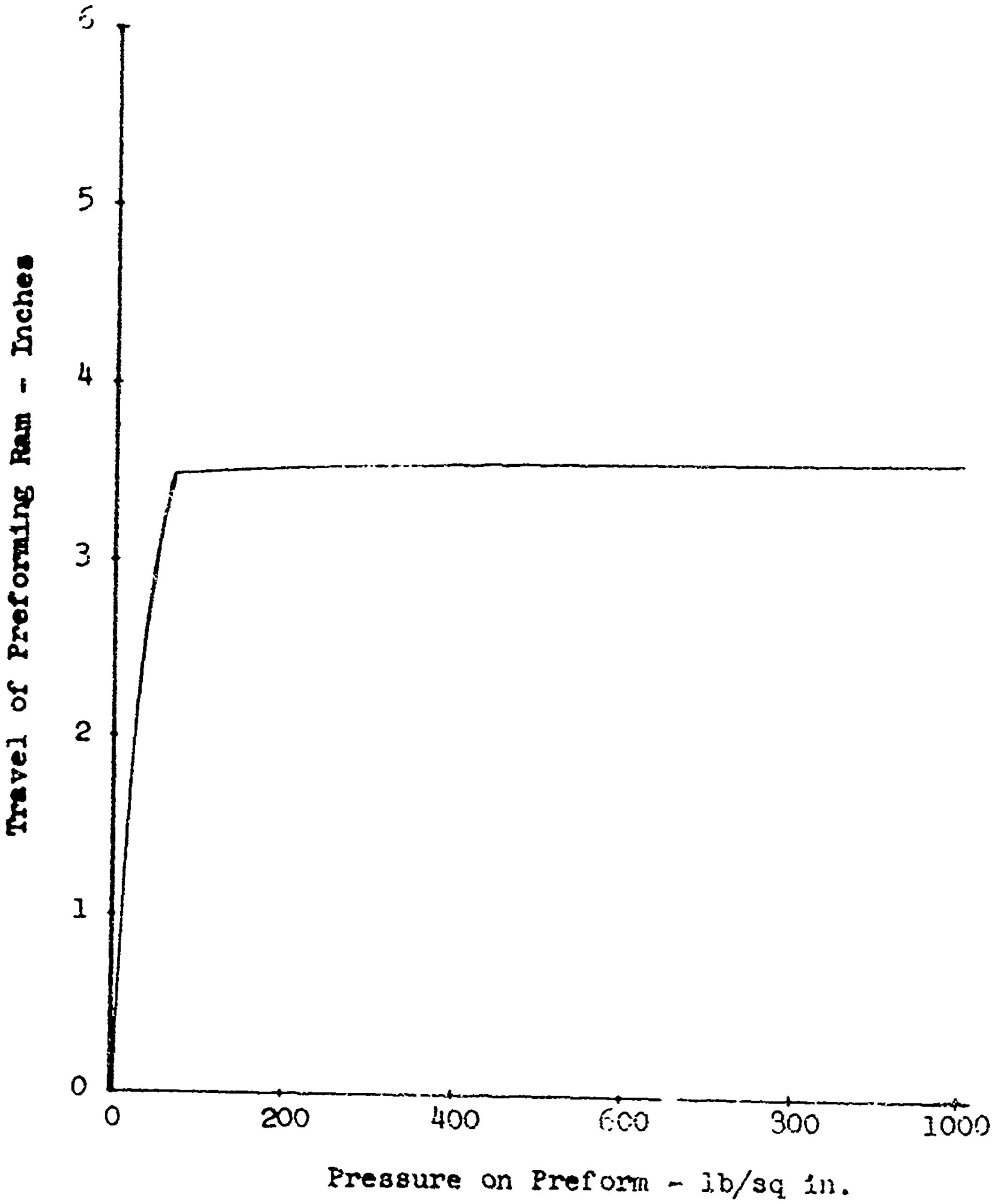


Figure 3 Pressure Developed During Constant Speed Preforming at 0.5 in./min

of material is required to insure good caliper control of the extrudate. A variable speed mechanism drives the ram and allows displacement speeds up to 6 lb/hr of lubricated "Teflon". The extruder cylinder and ram should be able to withstand extrusion pressures of 30,000 lb/sq in.

Reduction Ratio[1]

The work of extrusion is mainly expended in a non-recoverable plastic deformation of the particles of "Teflon". Thus for a given reduction ratio the extrusion pressure will be practically independent of the flow rate of the lubricated polymer and directly dependent on the particle deformation imposed. Figure 4 shows the relatively small change in pressure with increased flow rates at various reduction ratios. When other extrusion variables were held constant the extrusion pressure was found to be proportional to the reduction ratio as shown in Figure 5. These measurements were made with both a rheometer[2] and a wire coating machine. Also, as illustrated in Figure 6, the tensile strength of the extrudate is proportional to the extrusion pressure. This is noted by the measurement of the yield stress of "Teflon" 6 beading extruded at various pressures.

In practice, successful fabrication is limited by the upper and lower extremes of reduction ratio. At reduction ratios of 2,000 to 3,000 fracture of the polymer may occur in the die resulting in an extrudate sheared into discontinuous pieces. At reduction ratios around 100, the particles are so lightly compressed that particle boundaries are not eliminated on fusion. These limits also depend on the lubricant concentration and the application in question, and are therefore not clearly definable.

[1] As defined in Figure 1.

[2] The rheometer is a small ram type extruder which is equipped to extrude a solid cylindrical extrudate at either constant pressure or at a constant ram displacement rate. Pressure and ram displacement can be controlled and measured precisely.

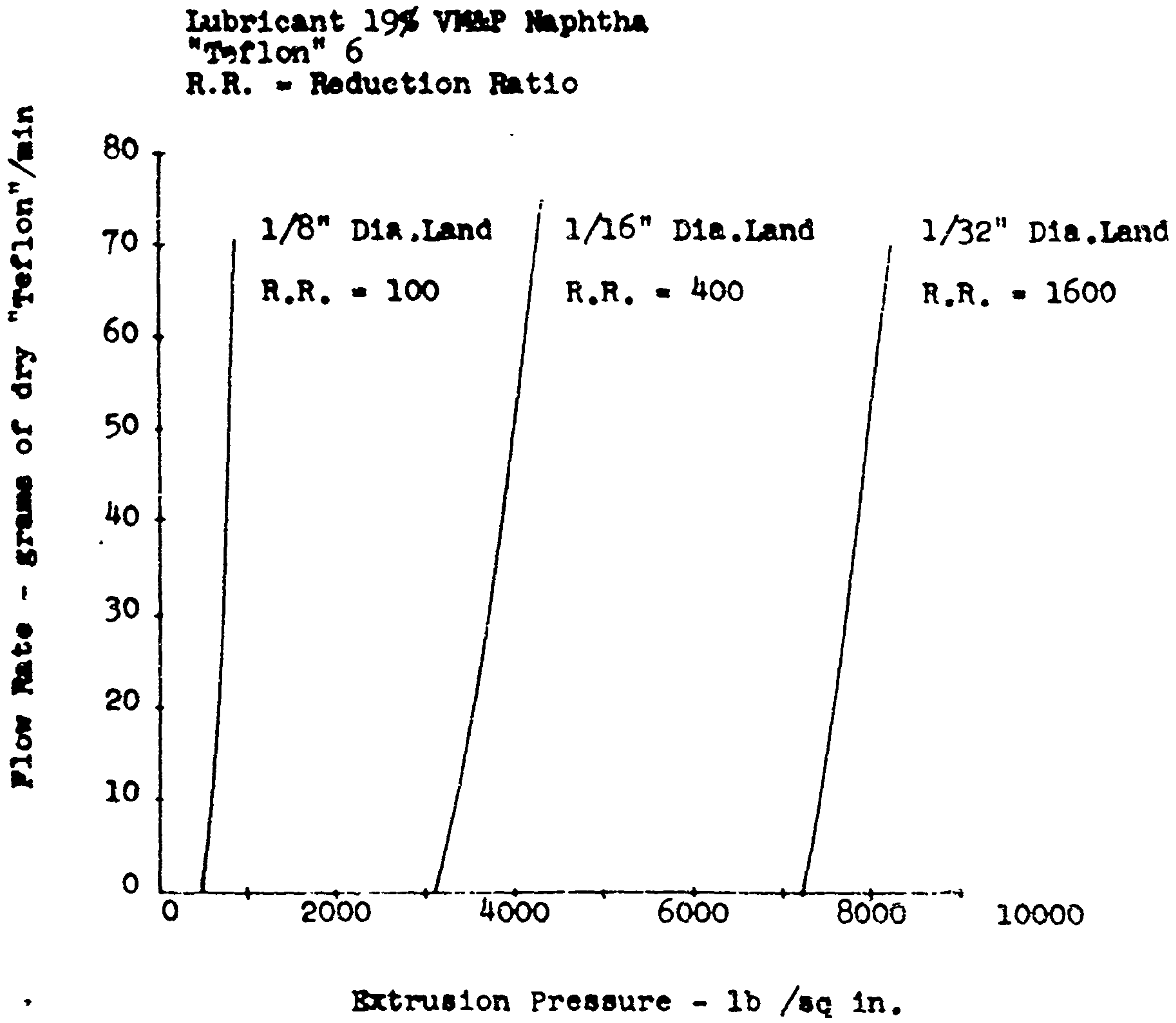


Figure 4. Flow Rate Versus Pressure For Beading Extrusion In A 1-1/4" Diameter Rheometer With 30° Angle Die

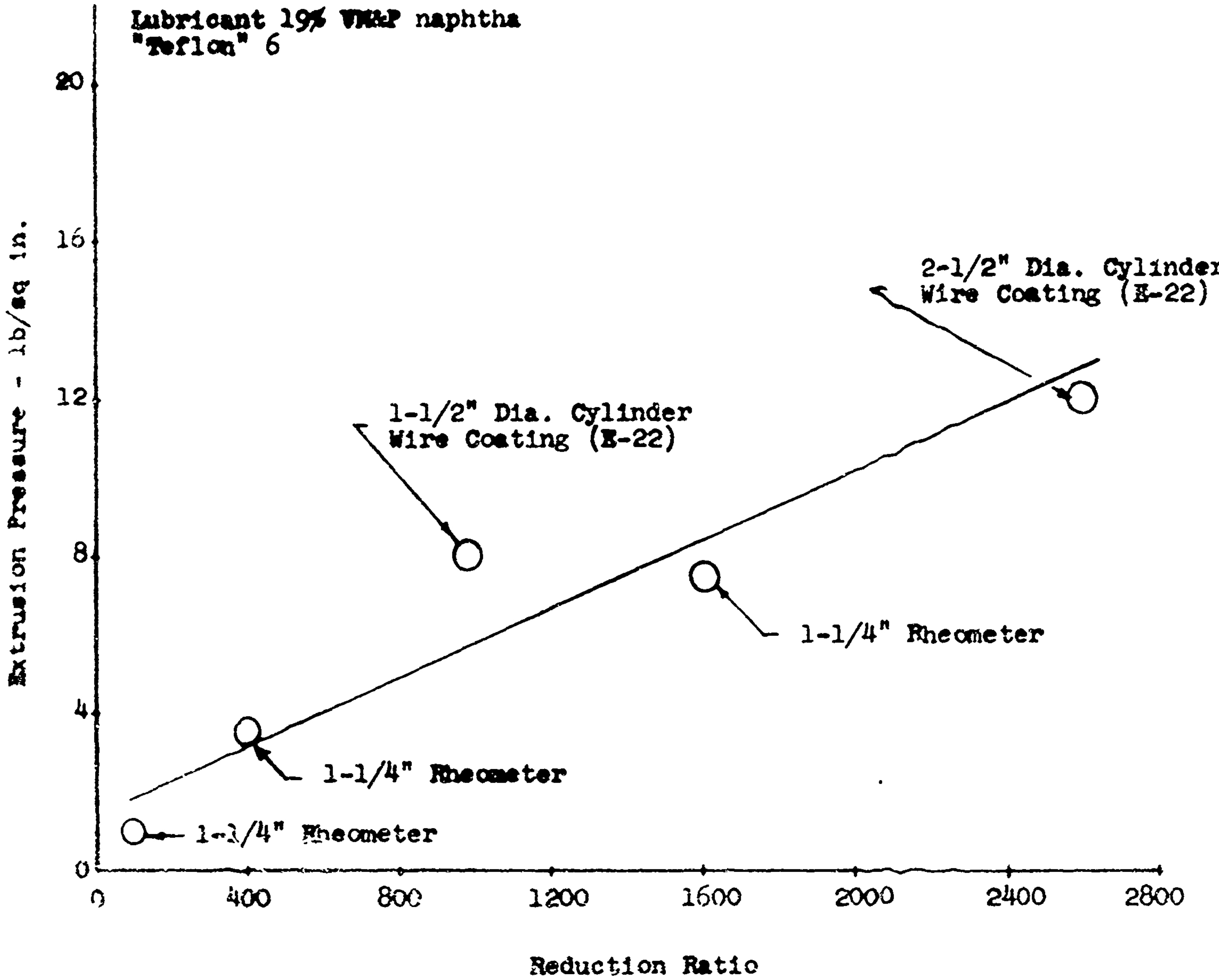


Figure 5. Change in Extrusion Pressure with Reduction Ratio

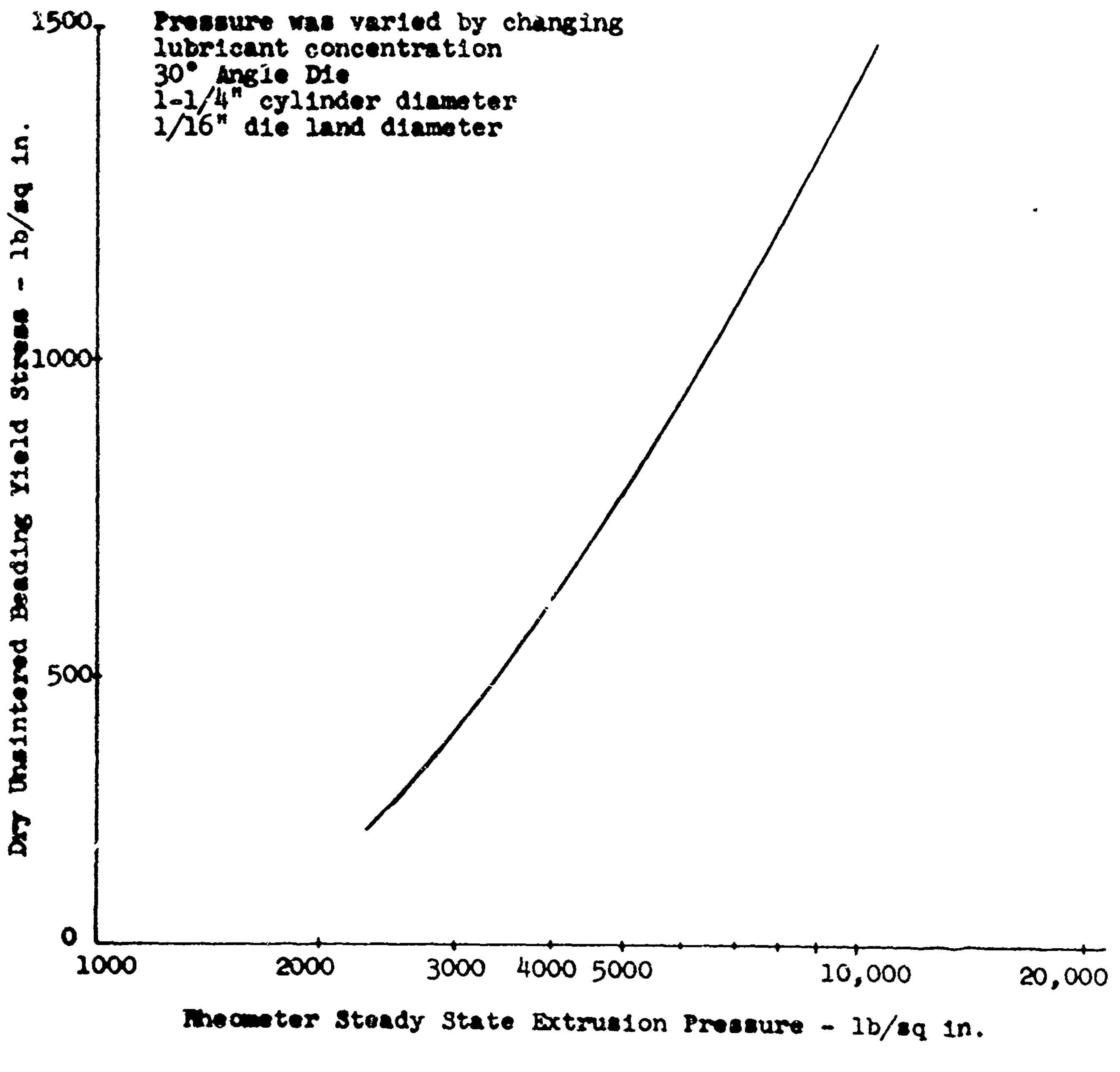


Figure 6 Rheometer Extrusion Pressure
Versus Beading Yield Stress

The Die

The function of the die used in extrusion is to convert the rather weak lubricated preform into a strong fibrous extrudate coating on the wire having the desired wall thickness. The variables affecting the die performance are: the included angle of the die cone, the diameter of the die land, the length of the die land, and the temperature of the die during extrusion.

The included angle of the die cone affects the extrusion pressure and the smoothness of the extrudate. Die angles in excess of 60° appear to be impractical for wire coating owing to the high extrusion pressures developed. Die angles of less than 15° are objectionable because of the large hold-up of material in the die taper and high cost of die fabrication. From experimental extrusion studies we have noted a progressive improvement in the extrudate smoothness with reduction of die angle.

The 20° included angle die is currently the most popular die, particularly for thin-wall hook-up wire fabrication. Dies having an included angle of 30° are also used successfully for thicker wall insulations such as coaxial cable core.

As the extrudate leaves the die land a relaxation of the elastic strains in the extrudate occurs. This causes the outside diameter of the extrudate to be larger than the extrusion die land diameter. The size of the die land diameter serves to control the amount of elastic strain relaxation.

To estimate the die land diameter for a given wire coating application, a knowledge of the desired extrudate diameter is necessary. The extrudate diameter required for a given product diameter is dependent on the lubricant concentration, the crystallinity change in the polymer during sintering and the conductor diameter. The extrudate diameter can be calculated to $\pm$ 1 mil by using equation (1) which was derived for the extrusion of "Teflon" 6 using #30 white oil or VM&P naphtha as a lubricant. The extrudate diameter is related to the volumetric displacement rate of the ram and the wire coating speed by equation (2).

$$\frac{D_E^2 - D_W^2}{D_P^2 - D_W^2} = 0.944 + 2.85 \frac{X}{1-X} \qquad (1)$$

$$V_R = \frac{3\pi}{10^6} (D_E^2 - D_W^2) S_W \qquad (2)$$

where:

D_E = extrudate diameter in mils

D_P = product diameter in mils

D_W = conductor diameter in mils

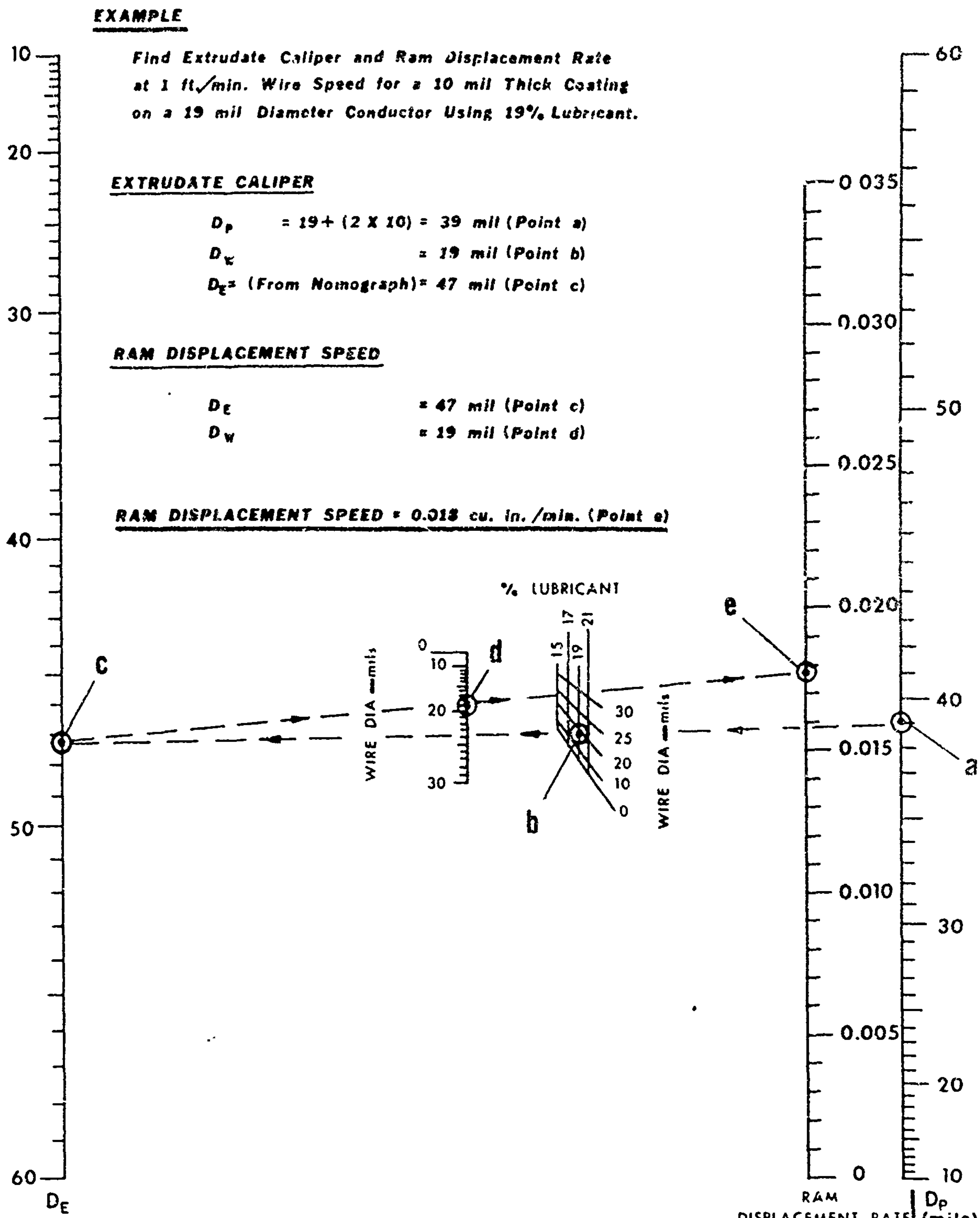
X = lubricant concentration in grams per gram of lubricated "Teflon"

V_R = volumetric displacement rate of ram - cu in./min

S_W = wire coating speed in ft/min

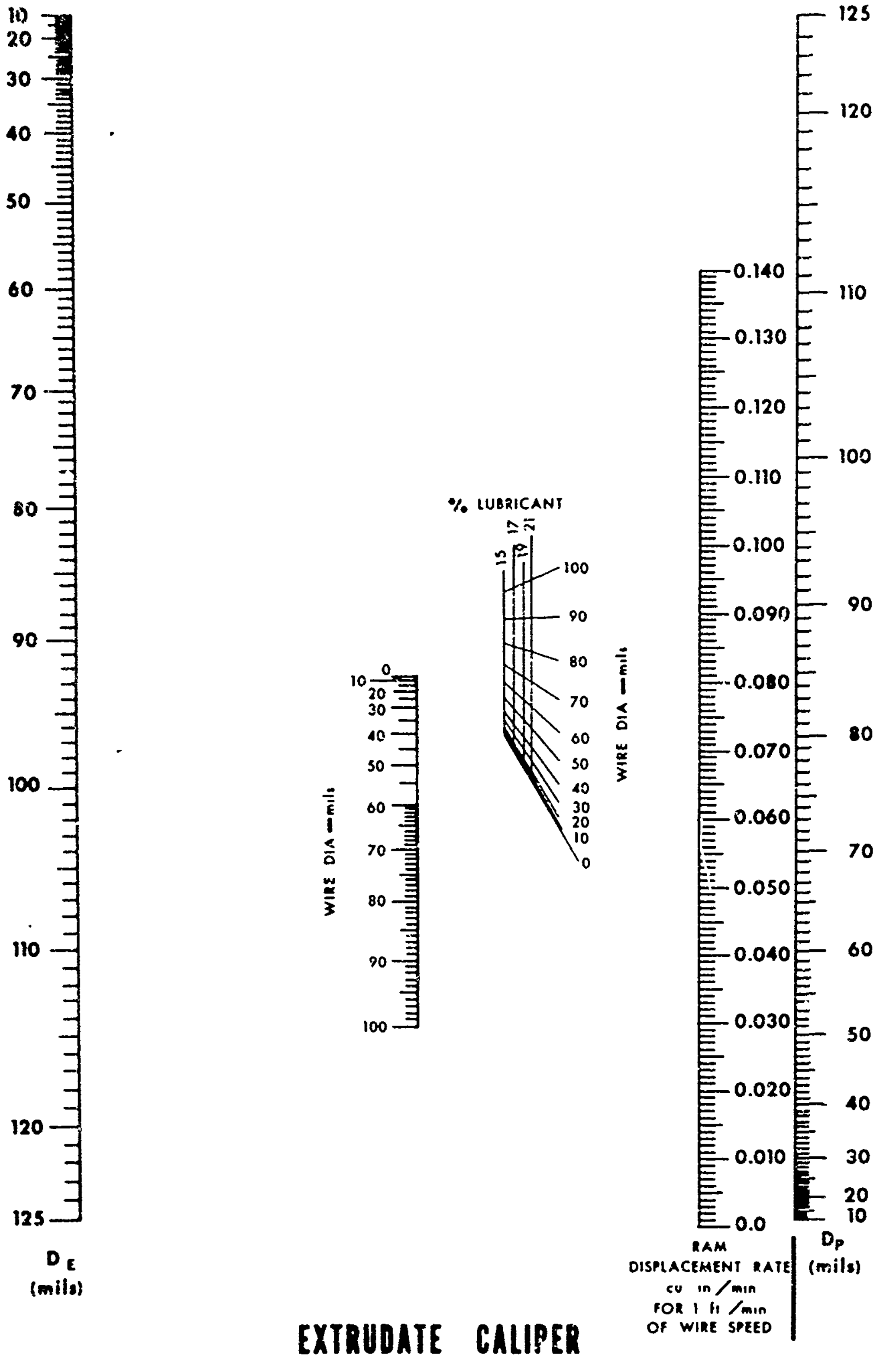
Both equation (1) and (2) are presented as a nomograph in Figures 7 and 8 which can be used for rapid calculations. Having established an extrudate diameter for a given product diameter and a given lubricant concentration determined by experience, one can estimate the die land diameter from Figure 9. Figure 9 was constructed from experimental data taken during the wire coating of various wire constructions. The amount of elastic relaxation or "blow-up" of the paste permitted at the die land exit is reduced as the reduction ratio is increased. If the "blow-up" is not reduced by using as large a die land diameter as possible at high reduction ratios, excessive extrusion pressures will be developed.

During experimental rheometer extrusion studies a marked visual improvement in the surface smoothness of the solid extrudate was observed as the die land length was increased up to one inch. This suggests that a die land length of one inch would produce a smooth surface extrudate in wire coating. This, however, is not true in wire coating because additional shear is present due to the wire which causes the extrudate coating to tear. In practice, die land lengths from 1/4" to



EXTRUDATE CALIPER
AND RAM DISPLACEMENT RATE
FOR THIN WIRE COATING

FIGURE 7



**EXTRUDATE CALIPER
AND RAM DISPLACEMENT RATE
FOR THIN WIRE COATING**

FIGURE 8

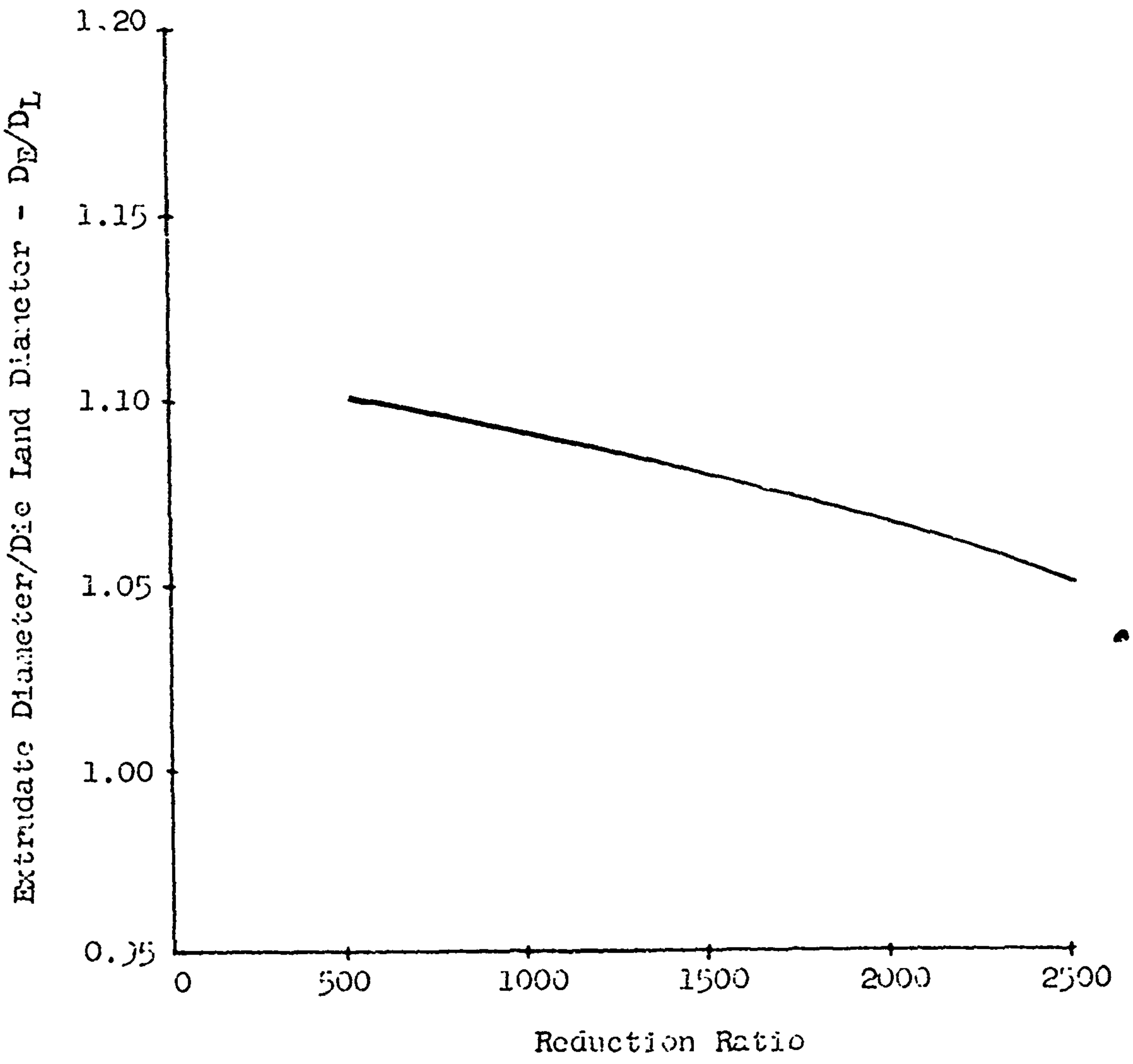


Figure 9. Recommended Ratio of Extrudate Diameter to Land Diameter Versus Reduction Ratio

1/2" have been found to produce an extrudate coating having the smoothest surface possible free from tears.

The temperature of the die during extrusion should be maintained above 75°F. Below 75°F the extrudate coating becomes rough and worthless. This effect is believed to be associated with the room temperature transition of "Teflon" (6). Normally die temperatures of 75 to 140°F are sufficient to produce satisfactory extrudates. Added temperature has little effect on the extrudate quality; however, it does increase the extrusion pressure slightly. Die heating also aids the drying operation by preheating the extrudate, which increases the rate of diffusion of the lubricant to the coating surface where it can be vaporized.

The Guide Tube Tip

The purpose of the guide tube and guide tube tip is to provide a guide for the wire through the extruder cylinder to the entrance of the die land. The clearance between the die land entrance and the guide tube tip can be varied to control the length of wire exposed to the lubricated polymer in the die.

When the clearance between the tip and the die land is properly set the average velocity of the lubricated polymer in this area is the same as the wire speed. If the clearance is too large, the polymer speed is slower than the wire speed which causes excessive shearing of the polymer particles in contact with the wire. This shearing action increases the wire tension enough to cause a wire failure and causes numerous coating flaws. Should the clearance be too small, the guide tube tip tends to plug the die, causing high extrusion pressures. This plugging action causes surging of the lubricated polymer around the wire, resulting in rough, discontinuous coatings.

The guide tube tip clearance also determined how tightly the coating adheres to the wire. In general, the smaller the clearance, the looser the coating on the wire. When extruding heavy wall coatings (thickness greater than 15 mils) the die land diameter is usually greater than the outside diameter of the guide tube tip. If the clearance is too small or the guide tube tip is up in the die land it is possible to extrude a flow free tubing over the wire which has no adherence to the wire.

When applying thin wall insulation, the guide tube tip clearance is very critical. This setting is much less critical as the wall thickness of the insulation increases. Actual setting of the clearance usually involves a trial and error procedure for each type of wire coating application. Typical optimum guide tube tip positions for common coating applications are illustrated in Table III.

TABLE III

DATA FOR GUIDE TIP POSITIONING

Wire Type	Coating Thickness mils	Cylinder Dia. in.	Reduction Ratio	Land Dia. mil	Guide Tip Clearance mil	Limitations
E-22	8-12	2-1/2	2510	58	13	Tension too high if tip lower
EE-22	13-17	2-1/2	1661	68	18	Tension too high if tip lower
Coax Core	40	2-1/2	644	100	130	Loose coating if tip higher Pressure and tension both low and not important this case.
E-22	8-12	1-1/2	978	56	25	Pressure too high if tip higher. Position for min. coating flaws.

Drying and Sintering

The "Teflon" extrudate as it leaves the extrusion die contains about 19% by total weight or 40% by volume of naphtha lubricant. In the drying oven this lubricant diffuses to the surface of the coating and is vaporized. It is important that all the vaporization of the lubricant take place on the coating surface to prevent vapor cracking. The rate of diffusion and vaporization is controlled by the drying oven temperature. Drying oven temperatures generally used are about 300°F at the entrance up to 575°F at the exit.

During drying operations the oven should be exhausted sufficiently to keep the naphtha fume concentration below 0.9%. This is to insure adequate protection from fire.

The coating as it leaves the drying oven is very porous. The forces of coalescence in sintering are strong enough to eliminate these voids at the expense of a reduction in the coating diameter. A transition temperature of 621°F must be attained for a few seconds by the coating to effect this sintering. While the "Teflon" is in the gel state ($>$ 621°F) it should not be submitted to stresses. To enable the coating to be sintered properly the sintering oven is maintained at 700 - 750°F.

The sintering oven should also be supplied with an exhaust system to remove possible trace quantities of toxic fumes given off during sintering or from coated wire left inadvertently in the hot ovens.

When using the recommended oven temperatures, 300 to 575°F for drying and 700 to 750°F for sintering, approximately one-half of the total oven length should be used for drying. The oven capacity is in most cases the factor which limits the wire coating speed. For example, a 20 foot oven limits the coating speed of Type E-22 wire to less than 30 ft/min. The limiting coating speed of any given fabrication for a fixed oven length can be determined by varying the coating speed until the product is properly sintered. When the natural product has an opaque white appearance it is insufficiently sintered and when it is a transparent dark brown, or a dull grey it is over sintered. Properly sintered natural material is slightly opalescent, almost colorless, and flexible.

The actual temperature of the wire as it passes through the ovens can be traced by coating a length of iron wire and a length of constantan wire, butt joined together. This serves as a traveling thermocouple which when connected to a potentiometer indicates the temperature of the wire under the "Teflon" coating at any oven position. The oven temperature profile so obtained is useful in setting oven temperatures to obtain an efficient use of the entire oven capacity. Figure 10 illustrates a typical trace made with a thermocouple having the same dimensions as Type E-22 hook-up wire.

Drying and sintering rates can at times be increased by increasing oven temperatures. Temperatures in excess of those recommended for the drying ovens often cause flaws in "Teflon" coating. Higher temperatures in the sintering ovens can be used provided the coating temperature does not exceed 720°F. Above 720°F degradation of the "Teflon" coating begins to take place.

Typical ovens used commercially consist of long metal pipes 1" or 2" in diameter which are heated by electrical coils, strip or band heaters. The wall temperatures of these ovens should be controlled and measured to ± 10°F at intervals along the oven length.

During the experimental wire coating process studies a number of processing difficulties were noted which can be remedied quite easily. Table IV summarizes our experience in "trouble shooting" the wire coating process.

Summary

The purpose of ~~our~~ study of "Teflon" 6 extrusion, sometimes referred to as paste extrusion, for insulating wire with "Teflon" was to determine the effect of each of the operating variables on the quality of the wire insulation. The die design, guide tip clearance, and the oven temperatures were found to be the most critical variables. For optimum machine performance the ram displacement rate and the wire speed should be controlled as accurately as possible.

The extrusion process in its present stage of development is a suitable means for the commercial production of wire insulated with "Teflon" It enables the use of the excellent properties of the "Teflon" insulated wire in many commercial applications.

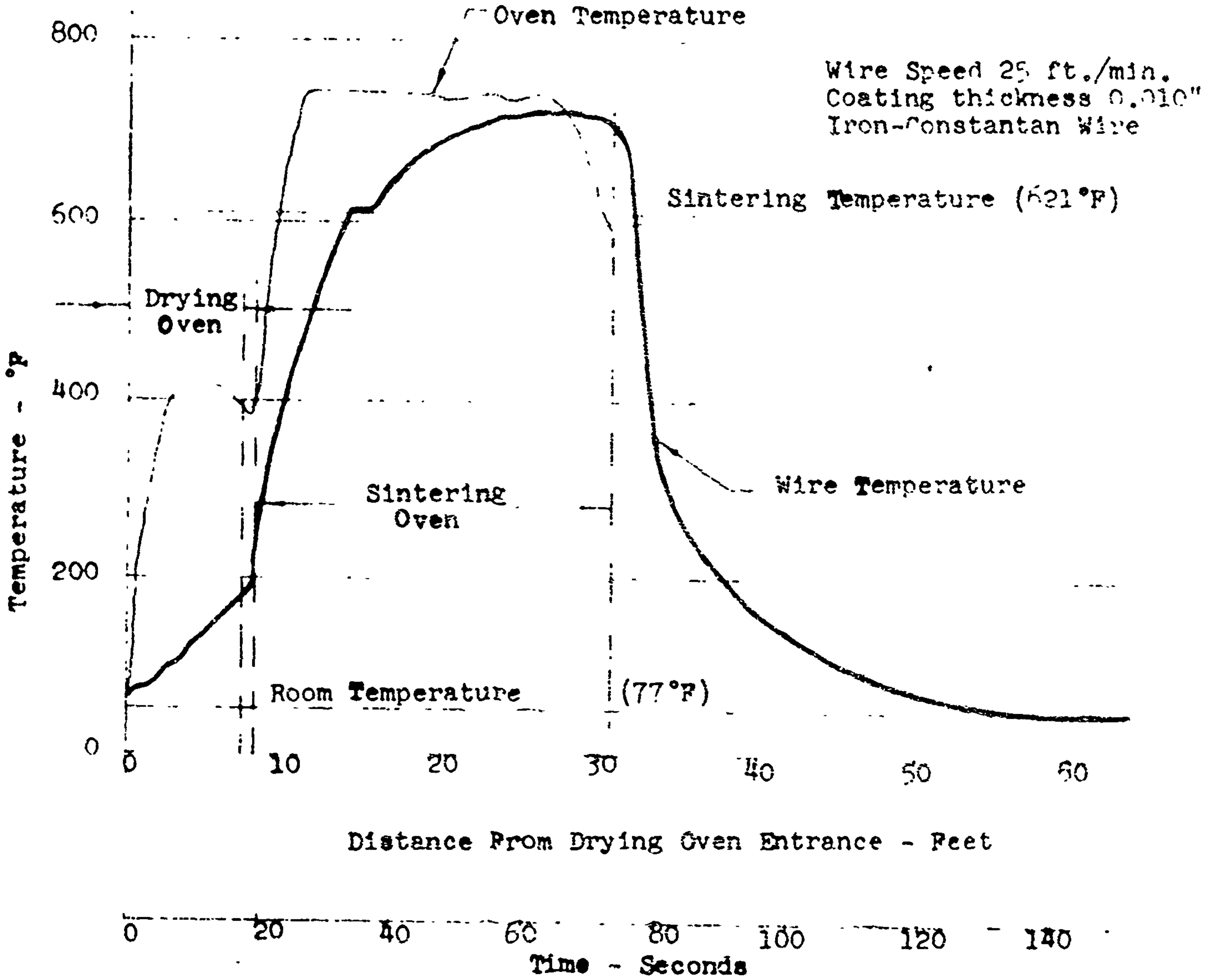


Figure 10 Oven Temperature Trace

TABLE IV

"TEFLON" WIRE COATING PROCESSING DIFFICULTIES AND THEIR REMEDIES

Description	Source	Remedy
High tension in wire, paste extruding back into guide tube tip.	Guide tip clearance too large.	Decrease guide tip clearance until the wire tension is <5 lbs., use Table III as a guide.
Excessive extrusion pressure, polymer released from die in surges, wire sags above the die.	Guide tip clearance too small and tip partially plugs polymer flow to die land.	Increase guide tip clearance until surging vanishes, use Table III as a guide.
Extrudate coating on wire rough, corrugated or buckled.	a) Die land diameter too small. b) Ram speed too fast. c) Wire speed too slow.	a,b,c) Calculate die diameter, wire and ram speed for fabrication. Use Figures 7, 8, and 9. b,c) Adjust ram and wire speed to produce the proper diameter extrudate.
Wire off center in coating, polymer extrudes preferentially on one side of the die.	a) Die land diameter too large. b) Wire guide tube or guide tube tip is bent and off center c) Wire and ram speed not properly adjusted.	a,c) Calculate die diameter, wire and ram speed for fabrication. Use Figures 7, 8, and 9. b) Straighten or replace bent tube or tip.
Extrudate surface rough and irregular in shape.	Die land too short.	Increase die land length, recommended length 1/4" to 1/2".
Extrudate surface smooth, however, occasional tears in coating occur exposing conductor.	Die land too long.	Shorten die land length, recommend length 1/4" to 1/2".
Extrudate very fibrous, extrusion pressure very high, possible machine stalls.	Concentration of lubricant too low.	Increase lubricant concentration in range of 17 to 20%. Check preforming operation to prevent any loss of lubricant prior to charging the preform into the machine.

Description	Source	Remedy
Extrudate rough and weak, lubricant squirts from the die.	Concentration of lubricant too high.	Decrease lubricant concentration in range of 17 to 20%.
Extrusions are always unsatisfactory because of excessive extrusion pressure, high wire tension, or spark failures. No practical setting of conditions do any good.	a) Reduction ratio too high. b) Included angle of the die too large.	a) Reduce the reduction ratio by using a smaller extrusion cylinder. b) Use a die having a smaller included angle.
Excessive spark failures, a) Rough extrudate.	a) Due to any of above sources.	a) The above listed remedy for corresponding source.
b) Smooth extrudate.	b) Drying oven temperatures too high. c) Coating entering the sintering oven still containing lubricant.	b) Keep drying temperatures below 575°F. c) Decrease wire speed if drying ovens at maximum temperature. If not at maximum temperature, increase the drying oven temperature.
Excessive spark failures in coating at higher wire speeds when all conditions are set properly. Acceptable coating at lower speeds	Mechanical stressing of the coating when it is at the sintering temperature (621°F).	Allow coating to cool sufficiently $<$400°F after exit from the sintering ovens before flexing it over sheaves.
Wire persistently snags before entering guide tube tip.	a) Insufficient braking at the wire pay-off. b) Faulty stranding of the wire.	a) Increase braking at the pay-off. b) Use a good grade of concentric stranded conductor having a lay of 1/3 or tighter.
Product coating has an opaque white appearance.	The coating is insufficiently sintered.	Raise the sintering oven temperature or reduce the wire coating speed.

Description	Source	Remedy
Product coating transparent and has a dark brown or is opaque and a dull grey.	The coating is over-sintered.	Reduce the sintering oven temperature or increase the wire coating speed until the coating is slightly opalescent, almcst colorless, and flexible.
Coating shreads at the die.	Die or polymer too cold during extrusion.	Maintain a die temperature of 70°F. to 140°F.
Random coating flaws, mechanical and electrical breaks.	Contamination of the polymer - over-worked particles, dirt, dust, etc.	Keep contamination at a low level during blending and preforming.

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