TEKTRONIX TRANSFORMERS

...... THEIR DESIGN AND MANUFACTURE

TEKTRONIX TRANSFORMERS . . .

THEIR DESIGN AND MANUFACTURE

SECTION I

PART 1 - GENERAL INFORMATION

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SECTION I

PART 1 - GENERAL INFORMATION

INTRODUCTION

Transformers are considered the simplest and most efficient electrical machines. Essentially, they consist of a magnetic core structure, wire or other forms of electrical conductors, electrical insulation, and suitable mechanical mountings.

An electrical transformer is an electromagnetic device for changing the voltage or pressure of an alternating current source. It may also be used to furnish a number of isolated alternating current voltages of desired magnitude from one power source.

Transformers are used in many electrical devices; a monumental effort has gone into their design refinements and the development of materials to produce maximum efficiencies and service life.

It was this same search for quality and reliability that led to Tektronix manufacture of its own transformers for oscilloscope applications. Much of our knowledge is basic; some of our methods and design criteria are considered unique.

This manual is written to serve as a reference and guide to our special knowledge. We've also included many tables, formulas and other data necessary to the design and manufacture of transformers. We've prepared it in a form that can be revised and added to as we improve our techniques and increase our ability to produce equipment of the highest quality and capabilities.

We've divided the manual into general information sections for the more casual reader; detailed data sections are provided for those who are directly concerned with transformer design and manufacture.

This part of the manual is limited to transformers for use on conventional power frequencies (50 to 60 cycles per second) and 400 cycle per second mobile power sources (whose actual frequency may vary from 320 to 1150 cycles per second).

ILLUSTRATION CREDITS

Page	Source
2	Allegheny Ludlum - "Magnetic Materials"
3	" " " "
4	" " " "
5	" " " "
6	" " " "
7	" " " "

MAGNETICS . . . . . . SOME OF ITS ALPHABET, SYMBOLS AND DEFINITIONS

<u>Magnetizing Force</u> (Necessary to create magnetic field) . . . or H, in Oersteds. One oersted = 2.015 ampere turns (reciprocal = .495). H = 1 Gilbert per cm.

<u>Magnetic Flux Density</u> (Degree of concentration of a magnetic field)

. . or B, in Gausses. One Gauss = 6.45 lines of force per square inch (reciprocal = .155).

<u>Eddy Currents</u> (Result from changing flux; a source of energy loss)

. . . (or Foucault currents)

μ . . . . permeability = B/H.

H_C . . . . coercive force, or demagnetizing force.

B_R . . . . residual magnetism (remanence), when current flow is reversed.

X . . . . current flow stopped.

Permeability in air, CGS system . . . . = 1; H = B; (English system: H = .313 B).

Maxwell . . . . The CGS unit of magnetic flux = 10^{8} webers.

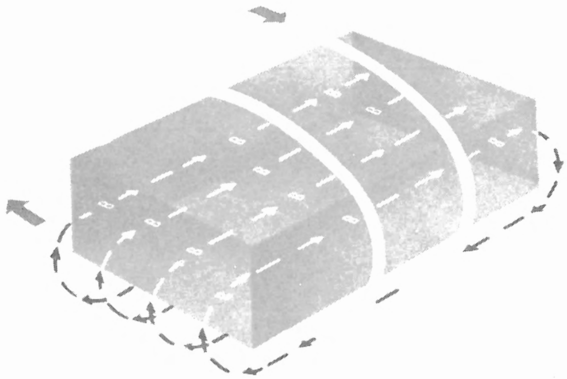
Weber . . . . The practical unit measurement of the amount of magnetic flux which, when linked at a uniform rate with a single turn electric circuit during an interval of one second, will induce in this circuit an EMF of one volt.

Hysteresis . . . . . . The lag in changes of magnetization behind the variations of the magnetizing force.

Circular Mills . . . Wire diameter in thousandths, squared.

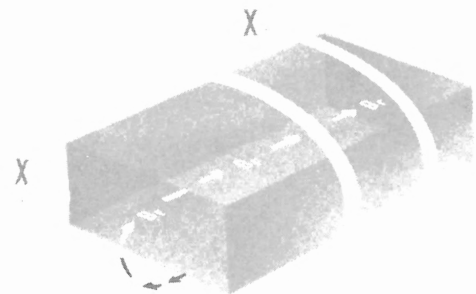
Stacking Factor . . . That portion of core space actually occupied by lamination iron, usually .9 to .94. The remainder is space between laminations and lamination insulation. Stacking factor is based on weight, using 7.65 grams per cubic centimeter as the denominator; the core weight as the numerator.

TO ILLUSTRATE MAGNETICS . . . . . .



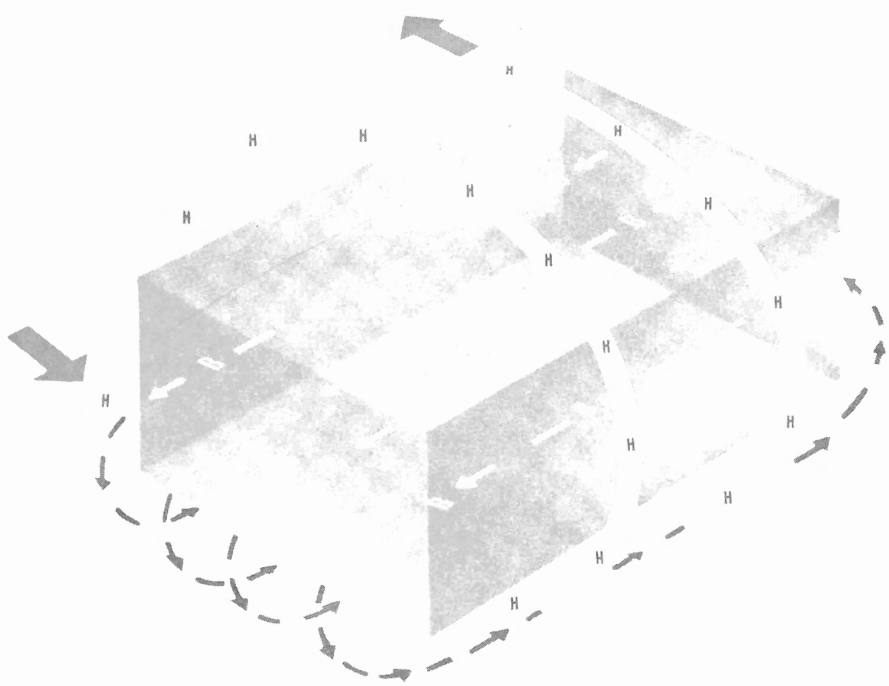
NORMAL FLUX FLOW

CURRENT FLOWS -- INDUCES MAGNETIC FLUX IN PIECE.



CURRENT FLOW STOPS

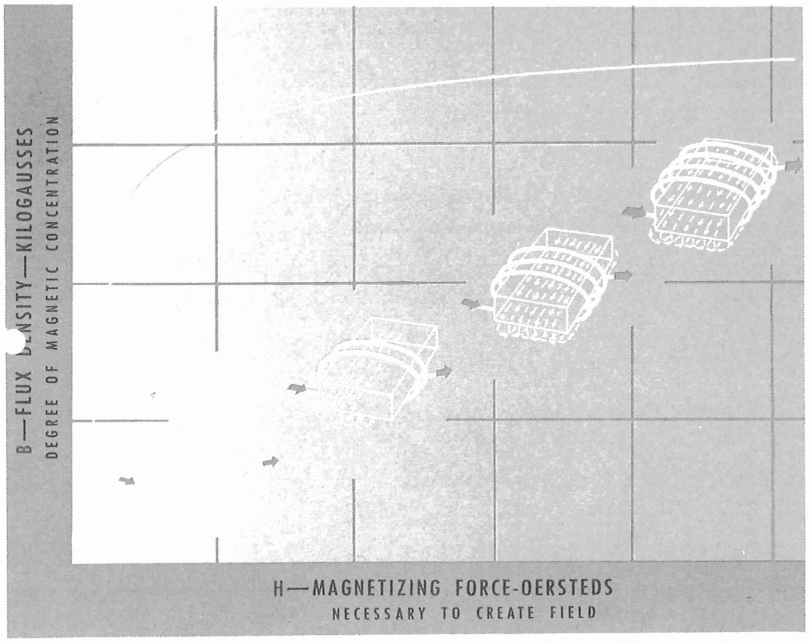
MAGNETIC FIELD COLLAPSES -- VERY SLIGHT RESIDUAL MAGNETISM (B_R) REMAINS.



PERMEABILITY ($\mu = B/H$) EXPRESSES THE EASE BY WHICH H MAGNETIZING FORCE CAN INDUCE B FLUX DENSITY IN A CORE MATERIAL.

MORE ON MAGNETICS . . . . . .

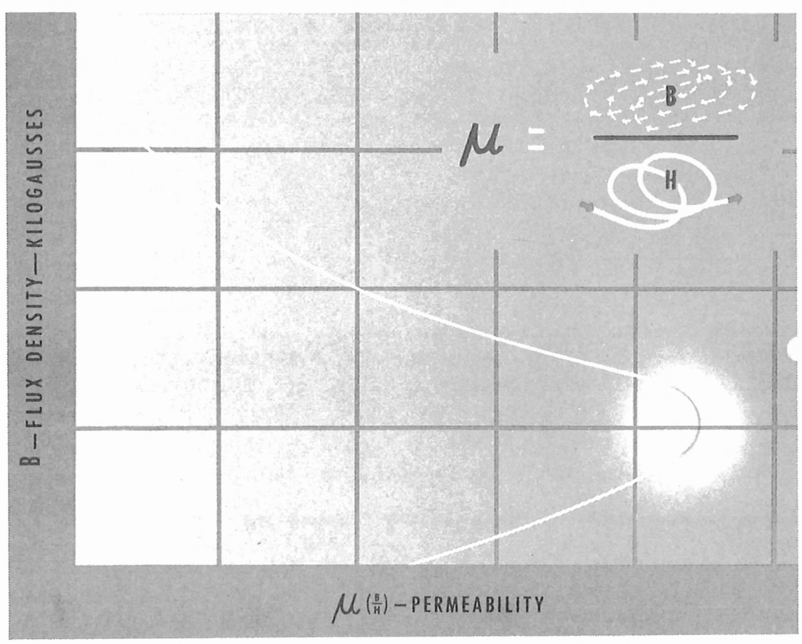
typical magnetization curve



AS MAGNETIZING FORCE "H" IS INCREASED, FLUX DENSITY "B" INCREASES RAPIDLY AT FIRST. A RATHER ABRUPT DECREASE IN MAGNETIZATION RATE THEN OCCURS; THEN THE INCREASE IS SLIGHT.

typical permeability curve

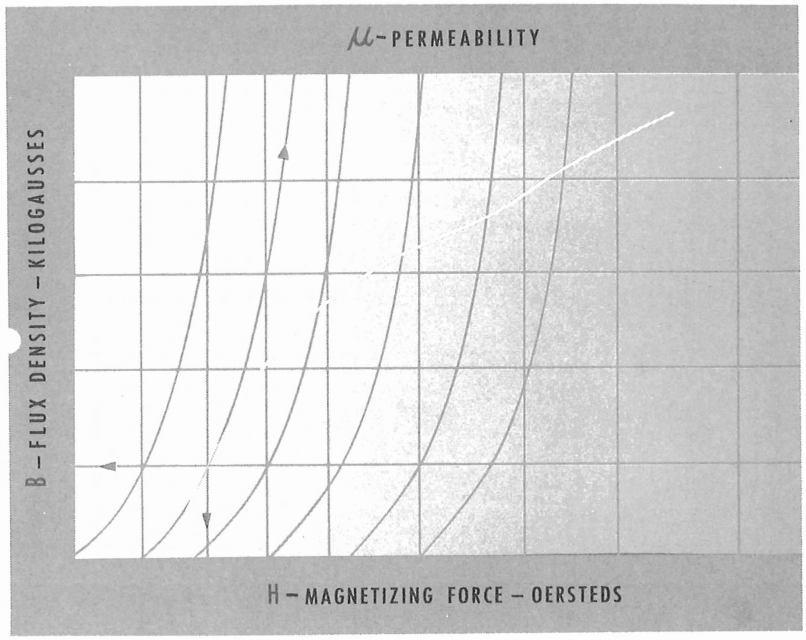
THE RELATIONSHIP BETWEEN B AND H IS NOT LINEAR; THEIR RATIO B/H (PERMEABILITY) ALSO VARIES.



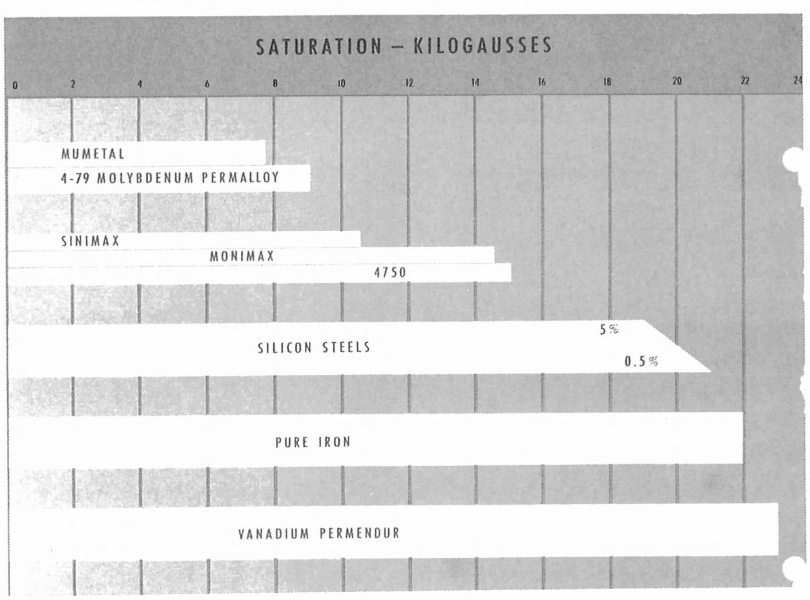
ADDITIONAL ILLUSTRATIONS . . . . . .

A PLOT OF FLUX DENSITY, MAGNETIZING FORCE AND PERMEABILITY FOR A TYPICAL MAGNETIC MATERIAL, READ FROM A SINGLE CURVE.

typical magnetization, permeability and saturation curve

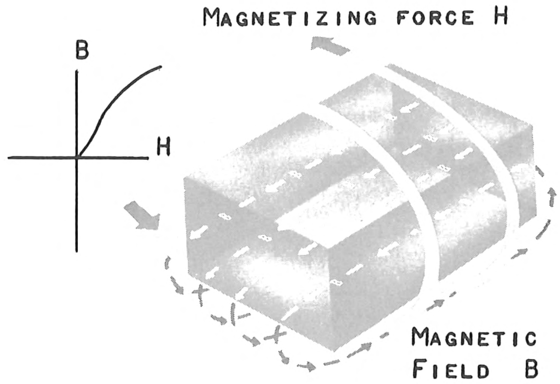


saturation points for magnetic core materials

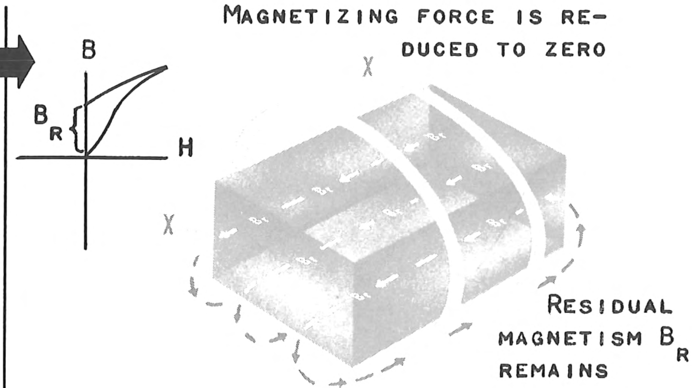


THE SATURATION POINT OF A CORE MATERIAL IS REACHED WHEN ANY FURTHER INCREASE IN MAGNETIZING FORCE "H" CAUSES NO FURTHER USEFUL INCREASE IN FLUX DENSITY "B". SATURATION POINTS VARY WITH DIFFERENT ALLOYS. THE PROPRIETARY MATERIALS SHOWN ARE MANUFACTURED BY ALLEGHENY-LUDLUM STEEL CORPORATION.

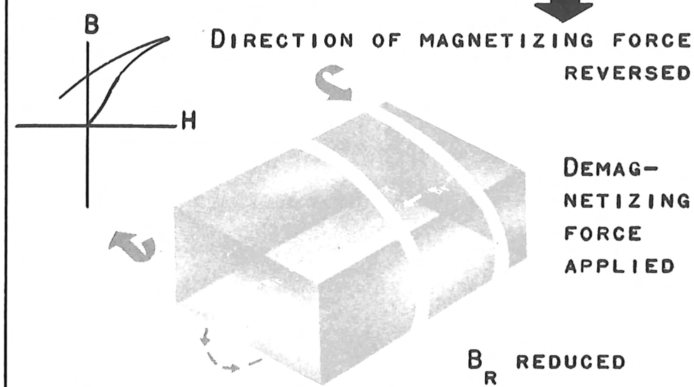
THE HYSTERESIS CYCLE . . . . . .



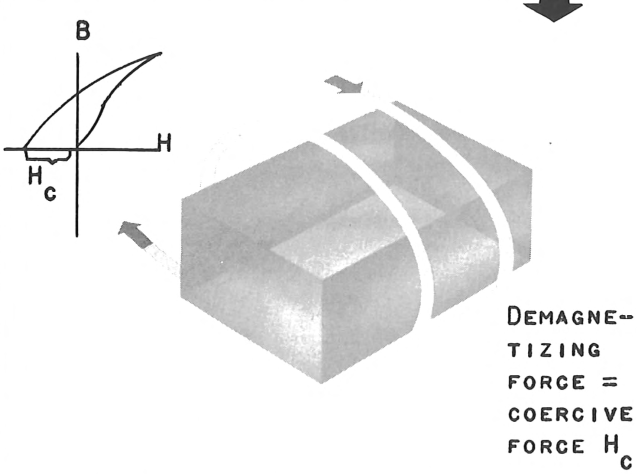
IN AN ALTERNATING CURRENT FIELD, THE CORE IS FIRST MAGNETIZED WHEN THE CURRENT FLOWS IN ONE DIRECTION.



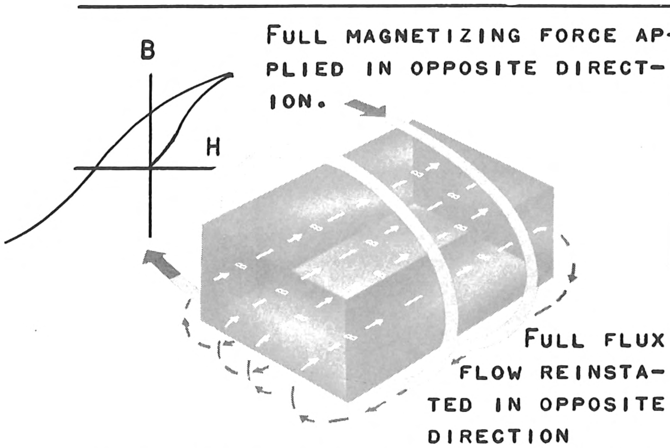
WHEN CURRENT IS REDUCED TO ZERO, FLUX DENSITY IS ONLY PARTIALLY REDUCED. THE RESIDUAL FLUX IS B_R.



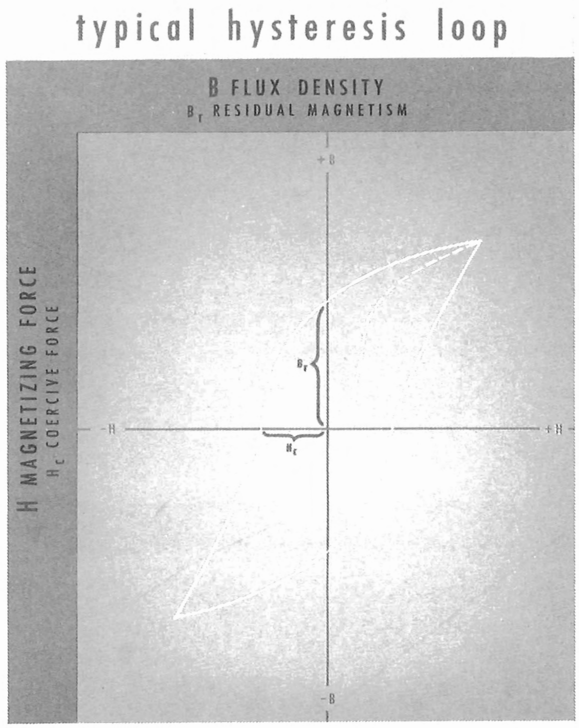
AS MAGNETIZING FORCE IS APPLIED IN OPPOSITE DIRECTION, BY REVERSAL OF THE CURRENT DIRECTION ......



...... A POINT IS REACHED WHERE FLUX IS REDUCED TO ZERO. THIS DEMAGNETIZING FORCE IS THE COERCIVE FORCE H_C.

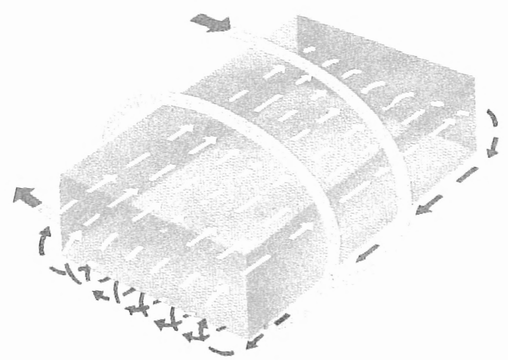


AS MAGNETIZING FORCE IS FURTHER INCREASED TO MAXIMUM VALUE, THE MATERIAL AGAIN ATTAINS ITS MAXIMUM FLUX DENSITY, BUT IN THE OPPOSITE DIRECTION.

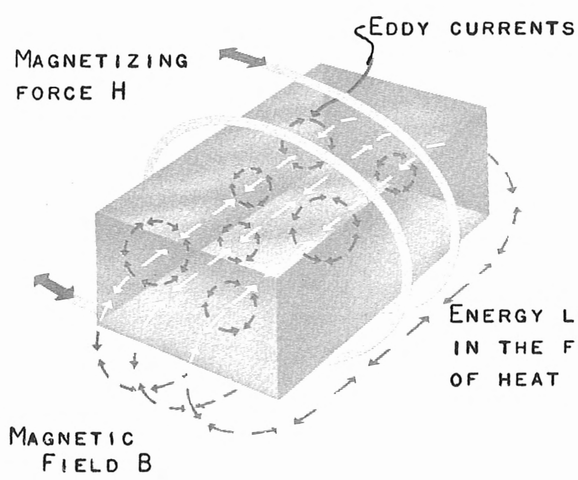


HYSTERESIS IS THE LAG IN CHANGES OF MAGNITUDE BEHIND THE VARIATIONS OF THE MAGNETIC FORCE.

COMPLETING THE HYSTERESIS CYCLE PRODUCES A CLOSED "HYSTERESIS LOOP"; THE ENCLOSED AREA IS A MEASURE OF THE ENERGY LOST IN THE CORE MATERIAL DURING THAT CYCLE. IN ALTERNATING CURRENT APPLICATIONS, THE TOTAL HYSTERESIS POWER LOSS WILL DEPEND ON THE FREQUENCY.



A TYPICAL HYSTERESIS LOOP FOR MAGNETIC CORE MATERIAL -- SMALL COERCIVE FORCE H_C REQUIRED TO ELIMINATE LARGE RESIDUAL MAGNETISM B_R.



EDDY CURRENTS

IN ADDITION TO HYSTERESIS LOSS, ENERGY IS ALSO LOST THROUGH EDDY (FOUCAULT) CURRENTS. THESE SMALL ELECTRICAL CURRENTS ARE INDUCED IN THE CORE MATERIAL BY THE CHANGING FLUX. THEIR MAGNITUDE DEPENDS ON THE FREQUENCY AND FLUX DENSITY IMPOSED BY THE APPLICATION AND ON THE SPECIFIC RESISTANCE AND THICKNESS OF THE CORE MATERIAL.

CONDUCTOR TERMINOLOGY . . . . AND MATERIALS

Magnet wire is specified thus:

The United States .... actual diameter of the bare conductor, in inches; or in B and S (Brown and Sharp), usually called the American Wire Gauge. In this system, each number represents the approximate amount of one draw in the drawing process of copper magnet wire. There is no American Standard for magnet wire sizes.

In England .... British Standard Wire Gauge

Continental Europe .... Actual diameter, in millimeters

Transformer design is concerned with the area of the conductor in circular mills. Some points to remember:

a. Use a factor of 1.26 to determine areas of successive wire sizes.

b. Diameters halve, or double (approximately) every six wire sizes; areas double every three sizes.

c. Areas change by a ratio of 10 in every 10 wire sizes.

d. Compute area of square or rectangular wire in square mills -- convert to circular mills by multiplying area by 1.273 (circular to square mill reciprocal = .7854).

Copper is the time-honored conductor material; aluminum is also used for many applications. Each has its advantages -- and disadvantages. We'll compare them, briefly:

Stretch .... Aluminum stretches to a much greater extent than copper in the winding process ..... but .....
Resistance .... of copper is increased (by work hardening) considerably more than aluminum when it's wound.

Weight .... Copper weighs 3.3. times as much as aluminum ..... but .....
Conductivity ..... of aluminum is only 61.8 per cent that of copper.

Space factor ..... copper has a much better space factor than aluminum ..... but .....
Costs .... of aluminum are only 40 per cent that of copper, per foot for a given wire size.

Aluminum presents a contact problem where leads are brought out; copper is readily solderable or can be brazed.

Aluminum is widely used in thin strips hard anodized for interlayer insulation -- this increases its space factor.

CORE MATERIALS . . . . . .

Radical improvements have been made in core efficiencies in the more than 80 years of design and manufacture of electrical equipment. In the early days, hoop iron -- of uncertain chemistry and haphazard rolling techniques -- was used for core structures. The industry has progressed to steels with carefully controlled analyses; much attention is paid to the improved electrical characteristics which can be obtained by proper rolling procedures.

The silicon steels are the most widely used core materials. Produced by several steel manufacturers under a variety of tradenames, these range from about 0.5 per cent to 5.0 per cent silicon. Other materials -- for special applications at Tektronix -- are high purity irons, iron/nickel alloys, iron/nickel alloys with silicon, molybdenum, copper and chrome, iron/cobalt alloys (with or without vanadium) and "ferrites" or ceramic process alloy cores.

The addition of silicon to steel increases its electrical resistance, thus reducing eddy current losses. It also minimizes the effect of "aging", a phenomenon resulting in increased energy loss after the steel has been in service for some time. But silicon steel must be properly heat-treated to achieve the metallurgical stability necessary to prevent aging. On the debit side, silicon lowers magnetic saturation and, in the higher ranges, it causes embrittlement.

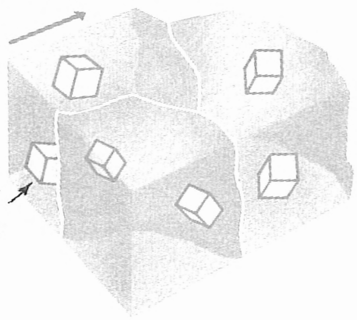
The arrangment of the crystalline structure -- or grain orientation -- is a significant factor affecting the magnetic characteristics of steels. When measured at right angles to the rolling direction, many of these properties are from 10 to 15 per cent poorer compared to the same properties measured in the direction of rolling.

Oriented grain core materials are punched or sheared into required shapes along the direction of rolling so that the longest portion of the magnetic path is in the best magnetic direction.

Refer to AISI Standards for Electrical Steels for more detailed information on production and metallurgical requirements. Test procedures for electrical steels are covered by ASTM A-34-55.

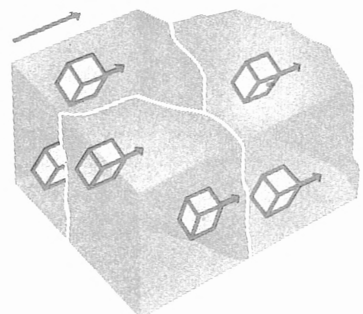
We've illustrated grain orientation and the variations in permeability obtainable in different directions along a single crystal of iron on the following page.

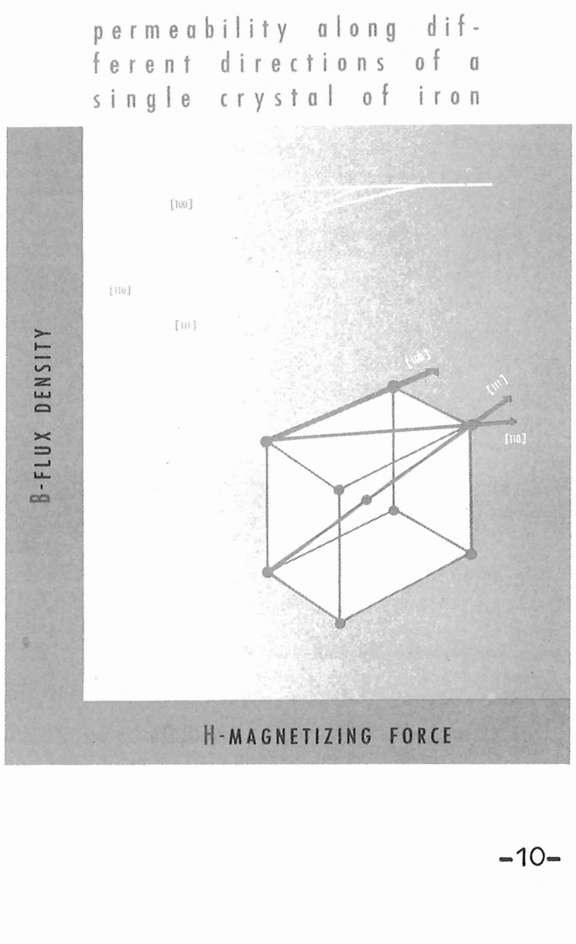
ORIENTATION IN GRAINS OF IRON



RANDOM ORIENTATION

PREFERRED ORIENTATION AFTER COLD ROLLING AND ANNEALING.



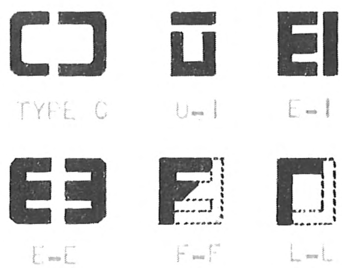


THIS CHART SHOWS THE WIDE DIFFERENCES IN PERMEABILITY OBTAINABLE IN DIFFERENT DIRECTIONS ALONG A SINGLE CRYSTAL (GRAIN) OF IRON.

THE CORE STRUCTURE . . . . . .

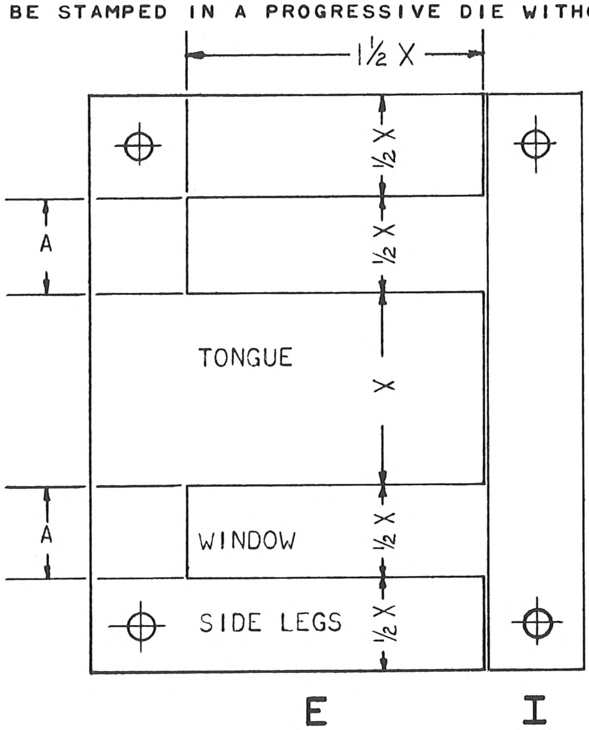
At normal flux densities, core losses in oriented silicon steels are very low. The limitation on the core, therefore, is its flux handling capacity (regular and external field), rather than loss; the overall permeability of the core structure is the important consideration.

Cores are manufactured by stacking laminations of electrical steels. There are several lamination configurations. For example:



But Tektronix uses the E-I lamination almost exclusively; we'll cover this type only.

The "scrapless" E-I lamination is produced by punching two butting E's. These standard laminations are available from several sources. They're usually stamped from a continuous coil of slit-to-size stock; the dimensions are such that they may be stamped in a progressive die without wasting material.



SCRAPLESS

In this lamination, the I's are formed from the windows. Note these proportions:

Assuming that X = tongue width;

- a. Tongue length is 1½ X;
- b. Window width is ½ X;
- c. Side leg width is ½ X;
- d. Magnetic path length = tongue size X 6.

Lamination sizes are referred to by tongue width -- thus, a 1" scrapless lamination has a 1" tongue width.

. . . . . . TO CONTINUE CORE STRUCTURES

To promote optimum operating efficiencies, these factors must be considered:

A. Permeability of the material at operating flux densities. Some material is annealed and processed to obtain high initial permeability or high permeability at -- say 50 gauss -- rather than high permeability in the 12,000 to 15,000 gauss region;

B. Maximum stacking factor. This requires material of uniform thickness, with good surface characteristics. The laminations must be flat and free from burrs;

C. Minimum air gap. Accurate stampings, flat across the ends of the side legs and tongue and with smooth sides on the I's, are required.

Consider the illustration of a typical scrapless lamination on the preceding page. It's apparent that the flux at points "A" is at right angles to the grain, presenting a poor flux path. The mounting holes are also "in the way" of the magnetic flux. Core performance can be improved by changing the shape of the laminations ......

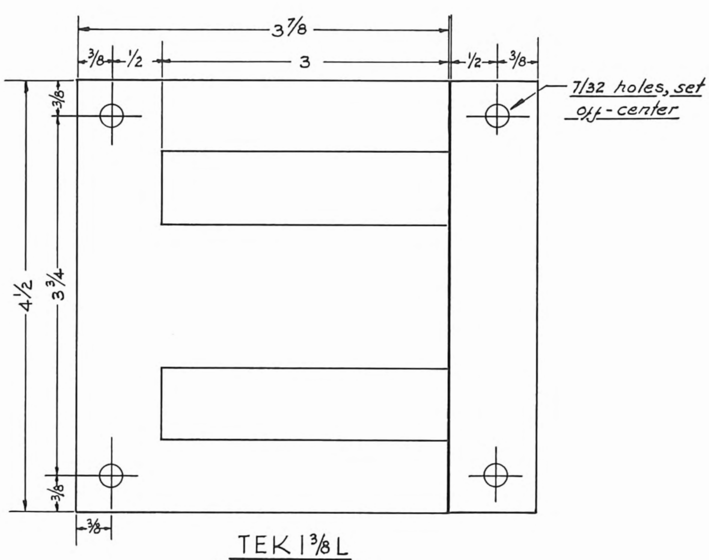
A. Increase the width of the back legs and I's and/or increase the ratio of length "A" to the tongue length;

B. Set the holes to the outside or eliminate them in favor of other mounting methods;

C. Lengthen the tongue and increase the width of the window.

But these improvements are frequently made at the cost of wasted material (thus, increased unit cost), and stamping is often more difficult.

The Tektronix high efficiency 1-3/8" L lamination is a practical solution to many of the problems inherent in a standard lamination. Numerous tests indicate it's 20 per cent more efficient than a standard scrapless. It's more efficient for its cubic size than a standard 12 or 14 mil "C" core, whereas standard laminations are less efficient than C cores.



TEK 1⅜L

DISCUSSING THE TEKTRONIX 1-3/8" L LAMINATION . . . . . .

IN THIS LAMINATION (SQUARE STACK 1-3/8" L);

VOLUME .... 22 CUBIC INCHES

WEIGHT .... 6.05 LBS.; 16.2 LAMINATIONS PER LB.

STACKING FACTOR.. 0.9

$$B_{MAX} = \frac{30.7 \times 10^{-3}}{K_L N}$$

$$\text{HENRIES } L_A = (.556 \times 10^{-8}) K_L N^2 UAC$$

$L = 10.9"$

AREA = 1.89 SQUARE INCHES

WINDOW AREA = 2.63 SQUARE INCHES.

THE BEST CORE MATERIALS WILL NOT ASSURE OPTIMUM PERFORMANCE IN A TRANSFORMER. GOOD DESIGN AND CAREFUL ATTENTION TO MANUFACTURING TECHNIQUES AND QUALITY CONTROL PROCEDURES ARE PARALLEL REQUISITES.

EXTREME CARE MUST BE EXERCISED TO:

A. PREVENT UNEVEN OR EXCESSIVE PRESSURES IN THE MECHANICAL CLAMPING OF LAMINATIONS. UNEQUAL STRAIN WILL SERIOUSLY IMPAIR MAGNETIC CHARACTERISTICS.

B. MINIMIZE BURRS ON THE STAMPINGS. GOOD PRACTICE LIMITS BURRS TO MUCH LESS THAN 0.003" ON 0.014" MATERIAL.

C. PROPERLY ANNEAL THE PARTS AFTER FABRICATION.

AND THE OTHER TRANSFORMER MATERIALS . . . . . .

INSULATION

There are three basic types of electrical insulation:

A. Incrganic .... mica, glass, ceramics, etc.;

B. Organics .... paper, cloths, synthetic materials, varnishes, etc.;

C. Semi-organics ...... silicones (resins, varnishes, etc.).

These materials are classified -- by AIEE Standard No. 1 -- as to maximum temperature ratings for continuous operating conditions. Like this:

The Class	The Material	Maximum "HotSpot"
O	Cotton, Silk, etc. (not impregnated)	90° C
A	Cotton, silk, paper, etc. (impregnated)	105° C
B	Mica, glass fiber, asbestos, etc.	130° C
F	Mica, glass fiber, asbestos, etc., with suitable binders.	155° C
H	Silicones, mica, glass fiber, asbestos, etc., with suitable binders.	180° C
C	Insulation that consists entirely of mica, porcelain, glass, quartz and similar inorganic materials.	220° C

Most of Tek's units are designed for Class A operation, but we use many Class B and F materials.

Core tubes -- the forms on which coils are wound -- are classed as ground insulation. Most commercial tubes are Type A. They're fabricated by spirally wrapping sufficient layers of gummed paper over a mandrel to obtain the required electrical and mechanical strengths. The same procedure is used with paper and phenolic resins. Class B and F units use fiber glass or synthetic mica, with a polyester or similar resin for the binder. The same base materials are used for Class H, with silicone resins as the binder.

Tektronix makes its own core tubes, from fish paper. Despite the fact it's only 0.020" thick (much thinner than commercial types, it saves space in the window), fish paper has excellent mechanical strength and rigidity, to hold its shape and resist cutting by the laminations.

We use Kraft coil paper, 100 per cent rag paper, fish paper, polyester web or mat, and varnished polyester mat for interlayer insulation in winding coils. Each has its own peculiarities and advantages for a specific application. Kraft coil paper, which is inexpensive and tough, is also used for wrappers.

For its wire enamels, Tektronix is standardizing on a heavy film build poly-urethane, with an outer coating of Nylon. Poly-urethane imparts high dielectric strength, has a low loss factor, and provides an excellent base for the nylon. Nylon's slick surface promotes ease of winding; it also has good abrasion resistance and cleanliness. The poly-urethane and nylon coat-

INGS ARE SELF-FLUXING. THIS MAKES SOLDER POT TINNING POSSIBLE, ELIMINATING MECHANICAL STRIPPING METHODS.

TUBING

IT'S BEEN DIFFICULT TO FIND A TUBING THAT WOULD MEET ALL OUR REQUIREMENTS:

A. EASY TO STRIP.

B. ABRASION-RESISTANT.

C. FLEXIBLE.

D. COMPATIBLE WITH OUR IMPREGNATION PROCESSES.

E. MECHANICALLY STRONG.

F. SMOOTH.

WE NOW USE A GRADE BB1 FIBER GLASS SLEEVING, IMPREGNATED WITH A SPECIAL POLYESTER RESIN, AS OUR GENERAL-PURPOSE TUBING.

ELECTRICAL TAPES

ELECTRICAL PRESSURE-SENSITVE TAPES PLAY A VERY IMPORTANT PART IN COIL CONSTRUCTION. THEIR PRIMARY FUNCTIONS ARE TO HOLD WIRES IN PLACE, AT THE SAME TIME INSULATING THEM FROM OTHER PARTS IN THE UNITS. SOME COROLLARY REQUIREMENTS ARE:

A. RESIST ABRASION.

B. PROVIDE A MOISTURE BARRIER.

C. PROVIDE A LEAD IDENTIFICATION (BY USE OF COLORED TAPE).

D. OCCUPY A GIVEN AMOUNT OF SPACE.

SOME OF THE FACTORS INVOLVED IN SELECTING ELECTRICAL TAPES FOR SPECIFIC APPLICATIONS ARE:

A. CLASS OF INSULATION, BASED ON THE AIEE MAXIMUM HOT SPOT CLASSIFICATIONS PREVIOUSLY DESCRIBED. MOST ELECTRICAL TAPES ARE CLASS A; CLASS B AND H TAPES ARE ALSO AVAILABLE.

B. TEAR STRENGTH. THE HEAVIER THE WIRE GAUGE, THE GREATER THE NEED FOR A TAPE WITH A HIGH TEAR STRENGTH.

C. TAPE CORROSIVENESS. SOME OF THE MATERIALS USED IN PROCESSING TAPE BACKINGS MAY CONTRIBUTE TO WIRE CORROSION -- E.G., PAPER TAPES CONTAIN A HIGH CONCENTRATION OF SALTS, WHICH PROMOTES ELECTROLYTIC CORROSION.

D. DIELECTRIC STRENGTH. THE ABILITY TO WITHSTAND DESIGNED VOLTAGES WITHOUT BREAKING DOWN IS IMPORTANT.

E. TEMPERATURES INVOLVED. ELECTRICAL TAPES MUST BE ABLE TO WITHSTAND THE ELEVATED TEMPERATURES INVOLVED IN BAKING THE UNITS TO EXPEL MOISTURE.

WE'RE TALKING ABOUT ELECTRICAL TAPES . . . . . .

F. Surface texture. "Crepe" surfaces conform to irregular configurations better than "flat" textures.

G. Costs.

ASTM D-1000-53T specifies test procedures for electrical tapes. In general, this specification covers these tests:

A. Adhesion.

B. Insulation resistance.

C. Value of indirect electrolytic corrosion current.

Tektronix has standardized on a rayon cloth electrical tape, with a rubber base adhesive which will heat cure and which also has excellent "tack" before it's heated.

THE IMPREGNANTS

After electrical units are baked to expel moisture, they are then impregnated. Tektronix has always used an oil-modified phenolic-alkyd varnish compound for this purpose. This heat cures from the inside out, due to the heat-reactive properties of the resin. But we're now changing over to a resin-modified type varnish (polyester) which is also heat-reactive.

We also use various epoxy resins, as well as a high melting-point wax compound.

TERMINAL BOARDS

Terminal boards must provide adequate mechanical and electrical strength, and must present a good appearance. Fabrication problems as well as cost influence the selection of materials -- we believe the better grade phenolics to be the best choice, economically.

CERTAIN BASIC FORMULAS . . . . . . AND DESIGN/PERFORMANCE CRITERIA

THESE ARE SOME OF THE FORMULAS REGULARLY USED IN TRANSFORMER DESIGN:

(1) $$L = \frac{3.19\ N^2 A\ \mu_{EFF}\ 10^{-8} K}{\ell_C}$$, WHERE:

L = INDUCTANCE IN HENRIES N = NUMBER OF TURNS

A = CORE CROSS SECTION, IN SQUARE INCHES

μ EFF = EFFECTIVE PERMEABILITY OF COMPLETE CORE AND AIR GAP

ℓC = LENGTH OF MAGNETIC PATH, IN INCHES

K = STACKING FACTOR (.9 IS GENERALLY ASSUMED)

* * * * * * * * * * * * * * *

(2) $$B_{MAX} = \frac{A\ 58.7 \times 10^3}{KN}$$ GAUSSES PER VOLT, AT 60 CYCLES, WHERE;

A = CROSS SECTION, IN SQUARE INCHES

N = NUMBER OF TURNS

* * * * * * * * * * * * * * *

TEKTRONIX TRANSFORMERS ARE DESIGNED FOR A MEAN PRIMARY VOLTAGE OF 117. FOR A 1" CROSS SECTION, A STACKING FACTOR OF UNITY WOULD REQUIRE 680 TURNS. ASSUMING A STACKING FACTOR OF .9, THIS BECOME 756 TURNS FOR 117 VOLTS AT A FLUX DENSITY OF 10,000 GAUSS.

FORMULA (2) IS DERIVED FROM THE BASIC FORMULA WHICH ASSUMES A SINE WAVE:

(3) $$B_{MAX} = \frac{E \times 10^8}{4 \times \text{FORM FACTOR} \times N \times A \times F}$$

A = SQUARE CENTIMETERS

THE CORE ACTUALLY"SEES"THE AVERAGE VOLTAGE. THE RMS VOLTAGE OF A SINE WAVE IS 1.1 X THE AVERAGE VOLTAGE -- THIS RELATIONSHIP IS CALLED THE FORM FACTOR.

DURING EVERY CYCLE, THE VOLTAGE CHANGES ABRUPTLY FOUR TIMES. THE RESULTANT FLUX "CUTS" EACH TURN, INTRODUCING A COUNTER EMF IN THE PRIMARY AND INDUCING A VOLTAGE IN THE SECONDARY.

IT CAN THUS BE SEEN THAT WAVE FORM, FREQUENCY, VOLTAGE, CORE MAGNETIC CAPABILITIES AND CORE AREA ARE ALL INTER-RELATED.

THE 10^8 IN THE DENOMINATOR OF THE ABOVE FORMULA IS THE AMOUNT OF MAGNETIC FLUX REQUIRED TO INDUCE ONE VOLT.

DESIGN AND PERFORMANCE CRITERIA

WE CONSIDER THE PRINCIPAL REQUIREMENTS OF A POWER TRANSFORMER TO BE:

A. LONG LIFE.

B. RELIABILITY.

C. REASONABLE OPERATING TEMPERATURE.

D. ABILITY TO MEET THE DESIGN REQUIREMENTS.

E. ECONOMY.

F. GOOD APPEARANCE.

. . . . . . DESIGN AND PERFORMANCE CRITERIA

AND THESE ARE SOME OF THE FACTORS TO BE CONSIDERED (THEY'RE ALL INTER-RELATED) -- AND WHAT'S INVOLVED:

A. KEEP COPPER LOSS (I^2R) LOW	USE OPTIMUM WIRE AND CORE SIZE.
B. MINIMIZE CORE LOSS (THROUGH HYSTERESIS AND EDDY CURRENTS).....	BY PROPER CORE SIZE, GRADE OF MATERIAL, OPTIMUM FLUX DENSITY AND CORRECT ASSEMBLY.
C. KEEP EXTERNAL FIELD LOW	THROUGH PROPER CORE ASSEMBLY, REASONABLE FLUX DENSITY AND CORRECT GRADES OF MATERIAL.
D. PROVIDE HIGH REGULATION	BY ADEQUATE CORE SIZE, CORRECT ASSEMBLY, FLUX DENSITY AND SUFFICIENT COPPER.
E. MINIMIZE CUBIC AREA; KEEP WEIGHTS REASONABLE	BY OVERALL GOOD DESIGN AND ASSEMBLY.
F. KEEP TEMPERATURE RISE LOW	REQUIRES CONSIDERATION OF THERMAL EFFECTS IN CONJUNCTION WITH GOOD DESIGN.
G. ASSURE QUIET OPERATION	BY GOOD CORE DESIGN, REASONABLE FLUX DENSITIES, CAREFUL ASSEMBLY AND GOOD IMPREGNATION.
H. PROVIDE A PRACTICAL SHAPE FOR A PARTICULAR APPLICATION	BY CHOICE OF CORE SIZE AND SHAPE.
I. COSTS	MUST BE KEPT AT LOWEST POSSIBLE LEVELS, WITHOUT JEOPARDIZING THE REQUIREMENTS FOR THE EQUIPMENT. THIS CAN BE ACHIEVED BY BALANCED DESIGN AND BY GIVING ADEQUATE CONSIDERATION TO ALL MATERIALS AVAILABLE, MAKING THE BEST ECONOMIC CHOICES THROUGHOUT.

TEKTRONIX TRANSFORMERS . . .
THEIR DESIGN AND MANUFACTURE

SECTION I

PART 2 - DETAIL DATA ON MATERIALS AND DESIGN

TABLE OF CONTENTS

SECTION I

PART 2 - DETAIL DATA

PREFACE

Thus far, we've dealt mostly in the generalities of transformer materials, basic magnetics and design factors, with a few specific details to clarify particular points.

It's important to record and understand these generalities. But modern transformer design and manufacture -- particularly of the high quality and performance standards demanded of the Tektronix units -- is predicated on highly specialized knowledge.

We depend on our suppliers, whose research and development has facilitated many of the improvements in the field, for much of the data we use in transformer design and specification of materials. We parallel this with our own special knowledge and advancements in the state of the art.

It's difficult to verbalize some of our lore. Much of it results from experiment and experience which is translated into "feel" rather than instruction. This part of the manual will, however, record some of the more tangible aspects of our knowledge and skills.

CREDITS

Page	Source
20-22	American Institute of Electrical Engineers, Publication No. 1.
28	Westinghouse Electric Corporation.
35-38	Irvington Division, Minnesota Mining and Manufacturing Company.
44	Permacel
47-51	The John C. Dolph Company.

TEMPERATURE CLASSIFICATIONS FOR MAGNET WIRES

Temperature ratings for magnet wire are generally based on Publication No. 1 of the American Institute of Electrical Engineers, General Principles Upon Which Temperature Limits are Based in the Rating of Electric Equipment, dated June, 1957.

AIEE No. 1 establishes certain classes of Insulating Materials; these are given below. It is recognized, however, that temperature alone does not determine the suitability of an insulation. Processing of equipment and appliances, supplemental insulations and impregnations, compatability of all components, mechanical support, and environment and service conditions encountered are some of the other factors that influence magnet wire life; these too should be considered in all designs.

Excessively high temperatures impair the useful properties of magnet wire insulations, cause deterioration and, in the ultimate, result in curtailed life. The limiting Insulation Temperature (limiting hottest-spot temperature) is defined in AIEE No. 1 as the temperature selected for a desired length of life of the insulation. Temperature classes for the limiting insulation temperature and definitions of insulating materials for these classes as contained in AIEE No. 1 are indicated below:

Temperature Classification	Definitions of Insulating Materials
90 C (Class O)	Materials or combinations of materials such as cotton, silk, and paper without impregnation. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 90 C.
105 C (Class A)	Materials or combinations of materials such as cotton, silk, and paper when suitably impregnated or coated or when immersed in a dielectric liquid such as oil. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 105 C.
130 C (Class B)	Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials or combinations of materials not necessarily inorganic, may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 130 C.

TEMPERATURE CLASSIFICATIONS FOR MAGNET WIRES

Temperature Classification	Definitions of Insulating Materials
155 (Class F)	Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other Materials or combinations of materials, not necessarily inorganic, may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 155 C.
180 C (Class H)	Materials or combinations of materials such as silicone elastomer, mica, glass fiber, asbestos, etc. with suitable bonding substances such as appropriate silicone resins. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 180 C.
220 C	Materials or combinations of materials which by experience or accepted tests can be shown to be capable of operation at 220 C.
Over 220 C (Class C)	Insulation that consists entirely of mica, porcelain, glass, quartz, and similar inorganic materials. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to be capable of operation at temperatures over 220 C.

Notes:

1. Insulation is considered to be "impregnated" when a suitable substance provides a bond between components of the structure and also a degree of filling and surface coverage sufficient to give adequate performance under the extremes of temperature, surface contamination (moisture, dirt, etc.), and mechanical stress expected in service. The impregnant must not flow or deteriorate enough at operating temperature so as to seriously affect performance in service.

2. The electrical and mechanical properties of the insulation must not be impaired by the prolonged application of the limiting insulation temperature permitted for the specific insulation class. The word "impaired" is here used in the sense of causing any change which could disqualify the insulating material for continuously performing its intended function whether creepage spacing, mechanical support, or dielectric barrier action.

(NOTES, CONTINUED)

3. IN THE ABOVE DEFINITIONS THE WORDS "ACCEPTED TESTS" ARE INTENDED TO REFER TO RECOGNIZED TEST PROCEDURES ESTABLISHED FOR THE THERMAL EVALUATION OF MATERIALS BY THEMSELVES OR IN SIMPLE COMBINATIONS. EXPERIENCE OR TEST DATA, USED IN CLASSIFYING INSULATING MATERIALS, ARE DISTINCT FROM THE EXPERIENCE OR TEST DATA DERIVED FOR THE USE OF MATERIALS IN COMPLETE INSULATING SYSTEMS. THE THERMAL ENDURANCE OF COMPLETE SYSTEMS MAY BE DETERMINED BY TEST PROCEDURES SPECIFIED BY THE RESPONSIBLE TECHNICAL COMMITTEES. A MATERIAL THAT IS CLASSIFIED AS SUITABLE FOR A GIVEN TEMPERATURE IN THE ABOVE MAY BE FOUND SUITABLE FOR A DIFFERENT TEMPERATURE, EITHER HIGHER OR LOWER, BY AN INSULATION SYSTEM TEST PROCEDURE. FOR EXAMPLE, IT HAS BEEN FOUND THAT SOME MATERIALS SUITABLE FOR OPERATION AT ONE TEMPERATURE IN AIR MAY BE SUITABLE FOR A HIGHER TEMPERATURE WHEN USED IN A SYSTEM OPERATED IN AN INERT GAS ATMOSPHERE.

4. IT IS IMPORTANT TO RECOGNIZE THAT OTHER CHARACTERISTICS, IN ADDITION TO THERMAL ENDURANCE, SUCH AS MECHANICAL STRENGTH, MOISTURE RESISTANCE, AND CORONA ENDURANCE, ARE REQUIRED IN VARYING DEGREES IN DIFFERENT APPLICATIONS FOR THE SUCCESSFUL USE OF INSULATING MATERIALS.

DATA ON NYLON/POLY-URETHANE COATED MAGNET WIRE

Tektronix uses a film-insulated solderable magnet wire having a Nylon coat over a Poly-urethane enamel. Nylon and Poly-urethane are both solderable. Nylon promotes ease in winding; Poly-urethane is moisture resistant.

Other features offered by Nylon/Poly-urethane coated magnet wire are:

A. Colored for easy identification.

B. It's available in three grades -- single, heavy (which Tektronix uses), and triple -- and in a range of sizes from 15 AWG to 40 AWG.

C. It's the best choice where these combined properties are necessary:

(1) Excellent solderability.

(2) Outstanding slipperiness and toughness for severe winding conditions.

(3) Superior moisture resistance.

(4) High dielectric strength.

(5) Hot resistance to varnishes and potting compounds.

(6) High thermoplastic flow temperatures.

(7) Excellent flexibility.

D. Fine wire can be used to advantage in devices having limited winding space and requiring highest space factor.

E. Heavy-film wire is used for all heavy-duty equipment demanding tough, wear-resistant insulation with greatly extended "overload" protection.

F. This wire solders readily at 680°F, producing firm, electrically sound connections.

G. It has very good moisture resistance, giving it excellent dielectric properties under all humid conditions. The dielectric strength is high and the dielectric loss is low, even at 100 per cent relative humidity conditions.

H. The Nylon coating permits random wiring with higher tension and faster speeds.

I. It can be potted with insurance against chemical attack from hot compounds and heat cut-through problems.

J. It's rated at Class 105C (AIEE Class A).

Refer to MIL-W-583A for military requirements.

The table on the following pages lists the properties of a typical Nylon/Poly-urethane coated magnet wire.

DATA ON NYLON/POLY-URETHANE COATED MAGNET WIRE

Name of Test	Description	Results
PHYSICAL PROPERTIES		
Adherence	NEMA snap test	OK
Flexibility	As received - 1X Stretched 25% and 1X After 168 hours at 125C wound on 3X mandrel.	OK OK OK
Elongation	Elongation to failure at a rate not greater than 12 inches per minute	Wire Size / Minimum Elongation 15-20 30% OK 21-35 25% OK 26-35 20% OK 36-40 15% OK
Abrasion scrape	NEMA repeated scrape test (0.016 in. needle)	Average strokes 39-91
Solvent crazing	Visual inspection	Does not craze
CHEMICAL PROPERTIES		
Solvent resistance	24 hour immersion in solvent, followed by a cheesecloth wipe.	Solvent / Results V.M.&P Naptha OK Toluol OK Ethanol OK 1% KOH OK 5% H_2SO_4 OK
THERMAL PROPERTIES		
Thermal stability	AIEE Test procedures	Class A Rating
Heat shock	One hour in oven at 125C after 1X mandrel wrap. One hour in oven at 125C after 25% elongation and 1X mandrel wrap.	OK OK
Solderability	Immersed in 50/50 tin-lead solder at 360C	Wire Size / Time Sec. 21 9-15 39 2-4
ELECTRICAL PROPERTIES		
Dielectric strength	NEMA twist as received	Grade / Volts Per Mil Single 3000-4800 Heavy 2500-3200 Triple 2200-2600
Dissipation factor (D) and Dielectric constant (K)	Measurements in mercury at 25 C and 50% relative humidity	Frequency / D / K 100 cps 1.0 3.60 1000 cps 1.7 3.63 10 KC 2.2 3.58 100 KC 2.8 3.41 1 MC 2.2 3.28

GENERAL DATA ON ROUND MAGNET WIRE

BARE CONDUCTORS

Size AWG	Area Circular Mils	Area Square Mils	Nominal Diameter Inches	Nominal Weight, Pounds per 1,000 Feet	Feet per Pound	Resistance, Ohms per 1,000 Feet 20 C (68 F)	Resistance, Ohms per Pound 20 C (68 F)	Heavy Film Dia-meters
4/0	211,600	166,200	.4600	640.5	1.561	.04901		
3/0	167,800	131,800	.4096	507.8	1.969	.06182		
2/0	133,100	104,500	.3648	402.8	2.482	.07793		
1/0	105,600	82,910	.3249	319.5	3.130	.09825		
1	83,690	65,730	.2893	253.3	3.947	.1239		
2	66,360	52,120	.2576	200.9	4.979	.1563		
3	52,620	41,330	.2294	159.3	6.278	.1971		
4	41,740	32,780	.2043	126.3	7.915	.2485		.2114
5	33,090	25,990	.1819	100.2	9.984	.3135		.1886
6	26,240	20,610	.1620	79.44	12.59	.3952		.1682
7	20,820	16,350	.1443	63.03	15.87	.4981		.1501
8	16,510	12,970	.1285	49.98	20.01	.6281		.1342
9	13,090	10,280	.1144	39.61	25.24	.7925		.1198
10	10,380	8,155	.1019	31.43	31.82	.9988	.03178	.1071
11	8,230	6,460	.0907	24.9	40.2	1.26	.0506	.0957
12	6,530	5,130	.0808	19.8	50.6	1.59	.0804	.0855
13	5,180	4,070	.0720	15.7	63.7	2.00	.127	.0765
14	4,110	3,230	.0641	12.4	80.4	2.52	.203	.0684
15	3,260	2,560	.0571	9.87	101	3.18	.322	.0613
16	2,580	2,030	.0508	7.81	128	4.02	.514	.0548
17	2,050	1,610	.0453	6.21	161	5.05	.814	.0492
18	1,620	1,280	.0403	4.92	203	6.39	1.30	.0440
19	1,290	1,010	.0359	3.90	256	8.05	2.06	.0395
20	1,020	804	.0320	3.10	323	10.1	3.27	.0353
21	812	638	.0285	2.46	407	12.8	5.19	.0317
22	640	503	.0253	1.94	516	16.2	8.36	.0284
23	511	401	.0226	1.55	647	20.3	13.1	.0255
24	404	317	.0201	1.22	818	25.7	21.0	.0229
25	320	252	.0179	.970	1,030	32.4	33.4	.0206
26	253	199	.0159	.765	1,310	41.0	53.6	.0185
27	202	158	.0142	.610	1,640	51.4	84.3	.0165
28	159	125	.0126	.481	2,080	65.3	136	.0148
29	128	100	.0113	.387	2,590	81.2	210	.0134
30	100	78.5	.0100	.303	3,300	104	343	.0120
31	79.2	62.2	.0089	.240	4,170	131	546	.0108
32	64.0	50.3	.0080	.194	5,160	162	836	.0098
33	50.4	39.6	.0071	.153	6,560	206	1,350	.0088
34	39.7	31.2	.0063	.120	8,320	261	2,180	.0078
35	31.4	24.6	.0056	.0949	10,500	331	3,480	.0070
36	25.0	19.6	.0050	.0757	13,200	415	5,480	.0063
37	20.2	15.9	.0045	.0613	16,300	512	8,360	.0057
38	16.0	12.6	.0040	.0484	20,600	648	13,400	.0051
39	12.2	9.62	.0035	.0371	27,000	847	22,800	.0045
40	9.61	7.55	.0031	.0291	34,400	1,080	37,100	.0040
41	7.84	6.16	.0028	.0237	42,100	1,320	55,700	.0036
42	6.25	4.91	.0025	.0189	52,900	1,660	87,700	.0032
43	4.84	3.80	.0022	.0147	68,300	2,140	146,000	.0029
44	4.00	3.14	.0020	.0121	82,600	2,590	214,000	.0027

The above data are approximate and subject to normal manufacturing tolerances.

Note 1. Conductor resistances quoted are based upon 100% (IACS) conductivity metal at 20 C (68 F) in accordance with ASTM Specifications B3 and B258, and represent average values for commercial wire.

Note 2. To obtain resistance at any operating temperature:

$R_t = R_{20C}\,[1 + 0.00393\,(t - 20)]$, where

R_{20C} = conductor resistances quoted in the table, and

t = operating temperature (deg. C)

ABOUT WIRE HANDLING . . . . . .

IN WINDING, WIRE SIZES 17 THROUGH 39 REPRESENT AN ALLOWABLE WINDING TENSION OF 20 TO 1. IN HAND WINDING, THIS REQUIRES A HIGHLY DEVELOPED SENSE OF FEEL ....

TOO LITTLE TENSION . . . . MEANS LOOSE, SLOPPY COILS;

TOO MUCH TENSION . . . . RESULTS IN CUPPED CORE TUBES, DAMAGED LAYER INSULATION, INCREASED CONDUCTOR RESISTANCE FROM STRETCHING, INCREASED CONDUCTOR RESISTANCE (IN THE CASE OF COPPER) FROM WORK HARDENING, POOR CONFORMANCE FROM WORK HARDENING CAUSING THE CONDUCTORS TO SPRING BACK AND, IN EXTREME CASES, BREAKAGE OF THE WIRE.

CONSIDERABLE KNOW-HOW IS REQUIRED TO SET UP SEMI-AUTOMATIC LAYER WINDERS -- ESPECIALLY WHEN USING THE FINE WIRE SIZES. ONE OF THE BEST AIDS IS A TENSION METER WHICH CAN BE USED ON ANY CONDUCTOR WHILE THE MACHINE IS OPERATING. THIS PERMITS DUPLICATING SET-UPS WHICH HAVE BEEN PROVED. THE SAXL TENSITRON IS A GOOD DEVICE FOR THIS PURPOSE.

IT SHOULD BE NOTED THAT THE PERIPHERAL SPEED OF THE WINDING IS CONSTANTLY INCREASING WITH THE BUILD OF THE COIL, ASSUMING THAT THE ARBOR SPEED IS CONSTANT. THE ARBOR SPEED (ESPECIALLY WITH RECTANGULAR COILS) HAS QUITE A LOT TO DO WITH THE CONFORMANCE OF THE WINDING -- AND, THUS, ITS ACTUAL PROFILE.

CORES . . . . . . MORE INFORMATION; TYPES AND SIZES USED IN TEKTRONIX INSTRUMENTS

WOUND CORES

"C" TYPE: Our previous discussions on cores have been limited to stamped laminations, with particular emphasis on the "E-I" configuration.

"C" cores are also widely used, especially in 400 CPS aircraft units and military equipment.

Westinghouse Electric Corporation introduced wound cores -- as a practical means of utilizing the unique properties of oriented silicon steel -- during the 1930's. "C" cores are now available from a number of sources, both here and abroad.

Wound cores are made by winding slit-to-width steel strip on a mandrel to a given build. The core is then impregnated with a plastic cement to insure a thorough bond (polyester resin is a suitable adhesive). The core is cut into two pieces and the cut faces are lapped to insure intimate contact between the halves when they are reassembled, for minimum air gap. The cut faces are then etched to remove short circuiting burrs.

Two single-phase cores may be used to form a shell-type transformer. When used as a core type, the winding may be all on one leg, or may be in two identical coils -- one on each leg. A properly designed double-coil type is very efficient.

"C" cores are manufactured in a wide range of sizes. Standard strip thicknesses up to 0.012" are supplied, and may be obtained less than 0.001" thick in special designs.

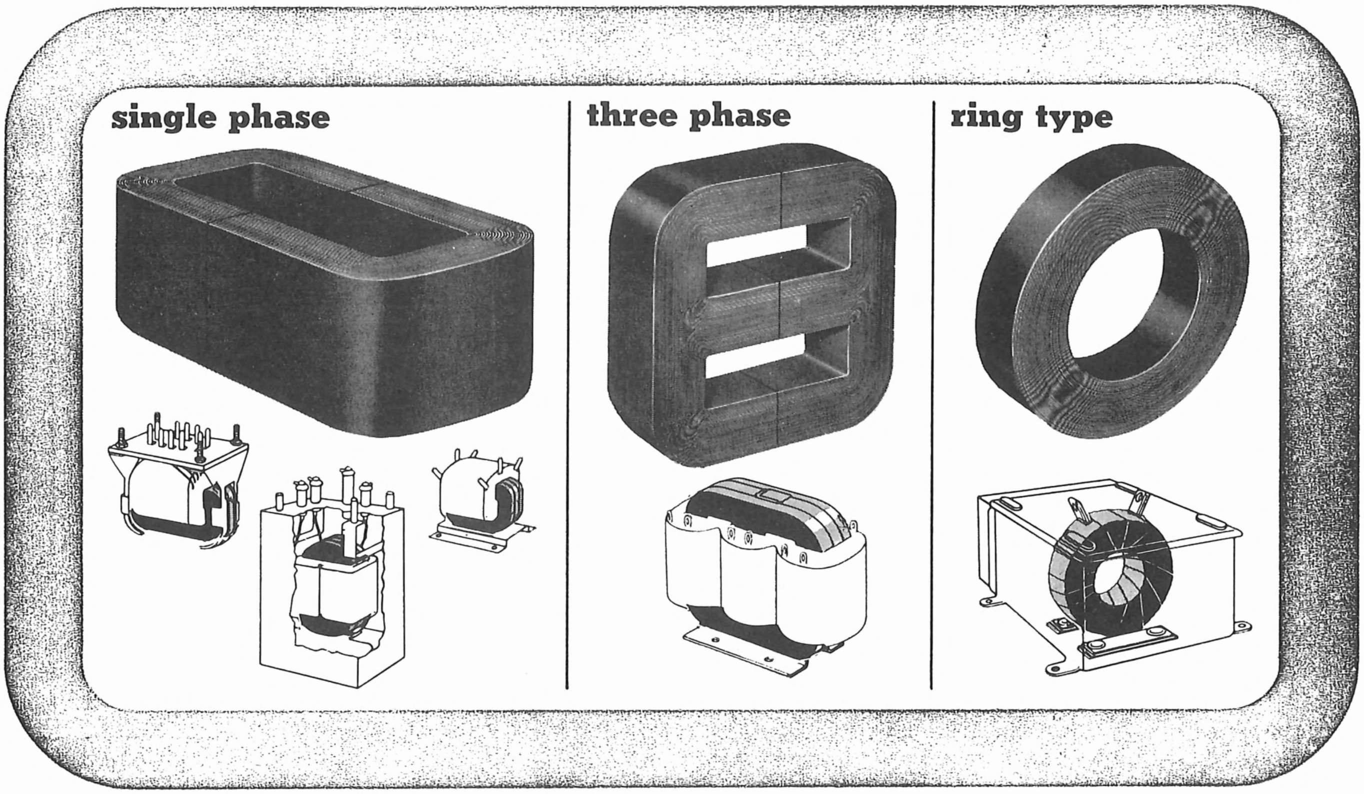
To surmount the mounting problems inherent in this type core, they are generally encased and potted or cast in resin.

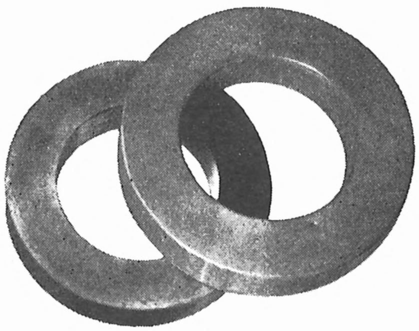
Winding methods are conventional.

"TOROIDAL" CORES: Wound cores are also used in toroidal, or ring-type configurations. Toroidal cores have no air gap, so require a special winding machine (unless wound by hand); toroidal transformers are expensive to build.

These cores are wound with nickel alloy materials -- as well as silicon steels -- in various thicknesses. They're generally supplied in closely conforming boxes or cases of phenolic resin or aluminum filled with an oil or silicone paste. The oil or compound cushions the core from winding stresses and reduces the mechanical hum. Some aluminum-cased types are coated with epoxy resin to provide ground insulation.

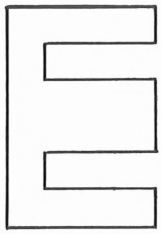
We've illustrated various types of wound cores, as well as our toroid winding operation, in the following photographs.





TYPICAL TOROIDAL CORES

MECHANICAL AND MAGNETIC PARAMETERS OF LAMINATIONS . . . . . .



INDIVIDUAL LAMINATION SPECIFICATION SHEETS LIST BOTH THE WINDOW AREA (W) AND THE CROSS SECTION AREA (A) FOR A SQUARE CROSS SECTION OF LAMINATIONS. USE THIS INFORMATION TO ESTIMATE STACK HEIGHTS OF VARIOUS SIZES AND TYPES OF LAMINATIONS FOR A PARTICULAR APPLICATION.

W ..... IS PROPORTIONAL TO:

AMPERE-TURN CAPACITY OF THE WINDING WHICH CAN BE ACCOMMODATED ON A PARTICULAR CORE.

A..... IS PROPORTIONAL TO:

VOLTS-PER-TURN RATING OF THE CORE, SINCE IT DETERMINES THE TOTAL FLUX CAPACITY OF THE CORE AT A SPECIFIC FLUX DENSITY.

THEREFORE: $W \times A$ IS PROPORTIONAL TO $(\text{AMPERE TURNS})\dfrac{(\text{VOLTS})}{(\text{TURNS})}$ OR VOLT AMPERES.

W x A IS USEFUL TO THE DESIGN ENGINEER IN SELECTING THE CLOSEST AVAILABLE STANDARD SIZE LAMINATION FOR A SPECIFIC APPLICATION.

MAGNETIZATION CURVES FOR VARIOUS SOFT MAGNETIC MATERIALS ARE AVAILABLE FROM THE STEEL PRODUCER, OR SPECIFIC DATA WILL BE SENT BY THE SUPPLIERS UPON REQUEST.

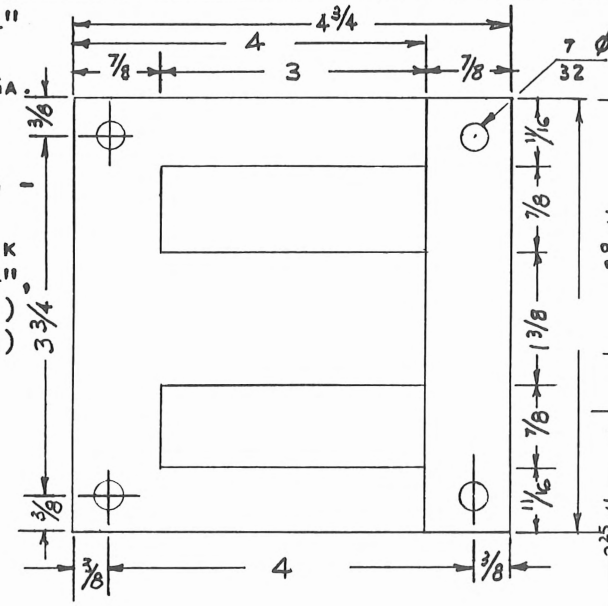
TOLERANCES FOR E-I LAMINATIONS

WIDTH	± 0.008	INCHES	*
LENGTH	± 0.005	"	
WINDOWS	± 0.003	"	
MIDDLE LEG	± 0.003	"	

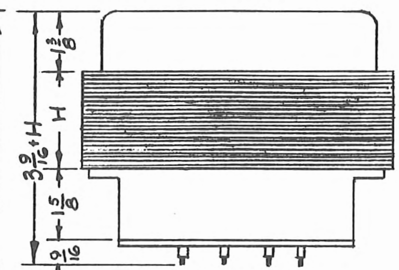
* USUALLY MUCH LESS IN PRACTICE

THESE ARE SOME LAMINATION AND MOUNTING DATA USED BY TEKTRONIX . . . . . .

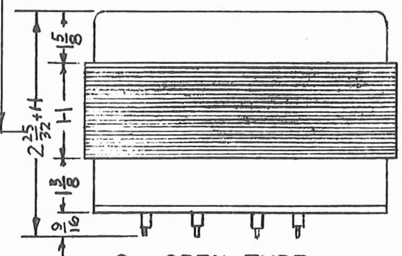
"SPECIAL 1 3/8L"
386-015
MATERIAL - 29 GA.
GRADE M6
ORIENTED
APP. V/A RATING - 200 - 750
H = NORMAL STACK
1.4", 2", 2.4", 2.9" (4.4") (1000VA)



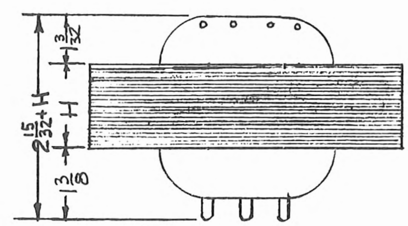
A - DIE CAST



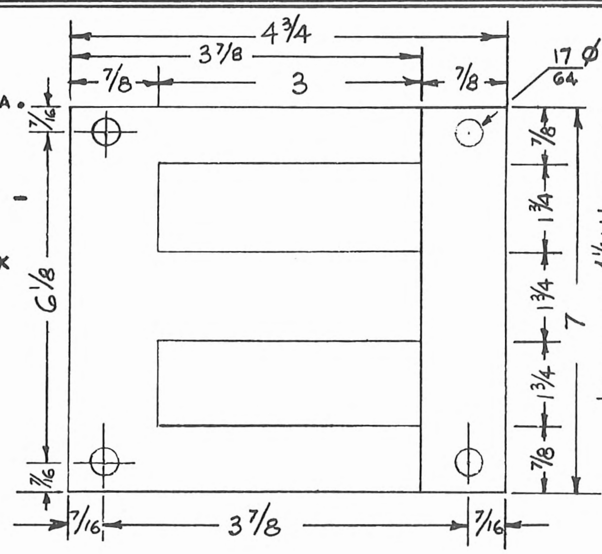
B - DIE CAST



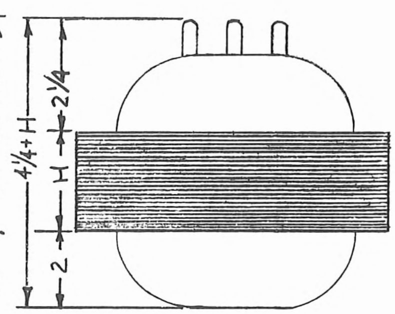
C- OPEN TYPE



"EI 19"
386-023
MATERIAL - 29 GA.
GRADE M6
ORIENTED
APP. V/A RATING - 1.2 KVA
H = NORMAL STACK
2-5"



C



THESE ARE SOME LAMINATION AND MOUNTING DATA USED BY TEKTRONIX . . . . . .

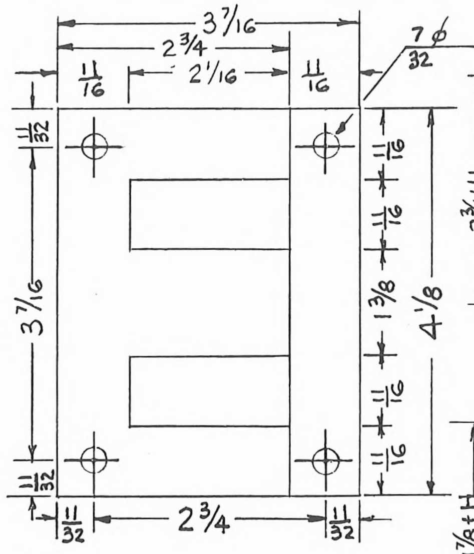
"EI 138"

MATERIAL 29 GA. GRADE M6 (ORIENTED) 386-021

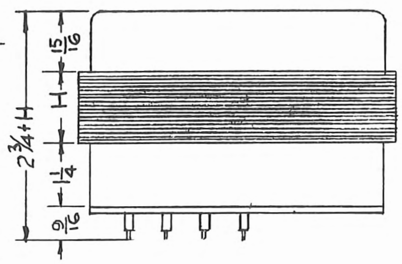
MATERIAL 26 GA. GRADE M15 (ORIENTED) 386-009

APP. V/A RATING - 50 - 200

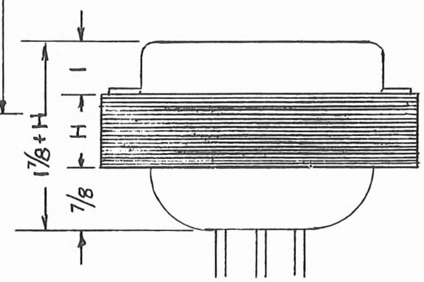
H = NORMAL STACK .7", 1", 1.2", 2" , 2.25"



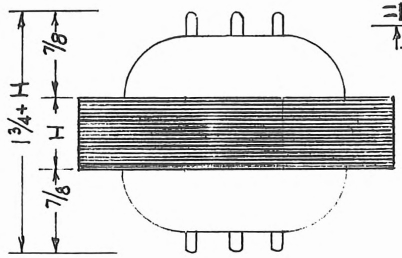
B DIE CAST



D STAMPED COVER



C OPEN TYPE

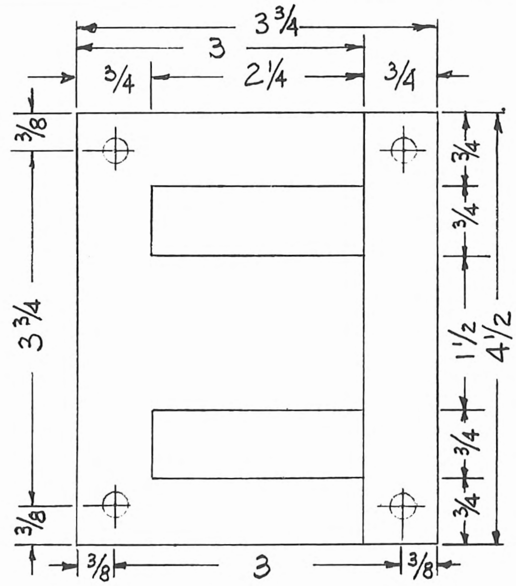


"EI 150"

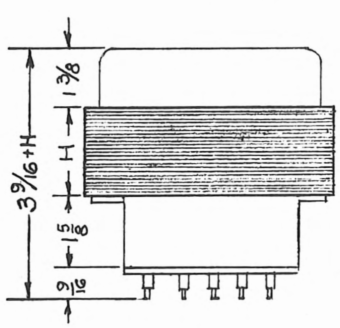
MATERIAL - 29 GA. GRADE M6 ORIENTED

APP. V/A RATING - 150 - 300

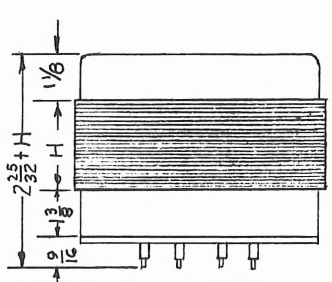
H = NORMAL STACK 1.25", 1.5", 2", 2.5"



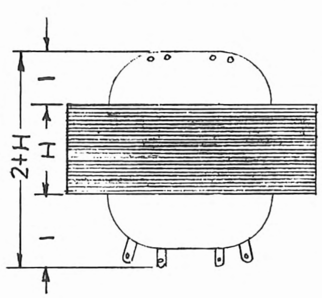
A DIE CAST



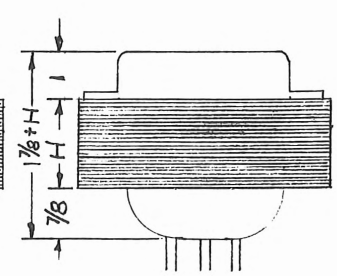
B DIE CAST



C OPEN TYPE

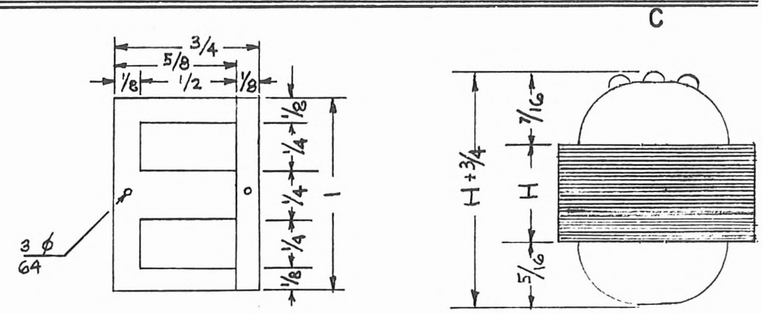


D STAMPED COVER

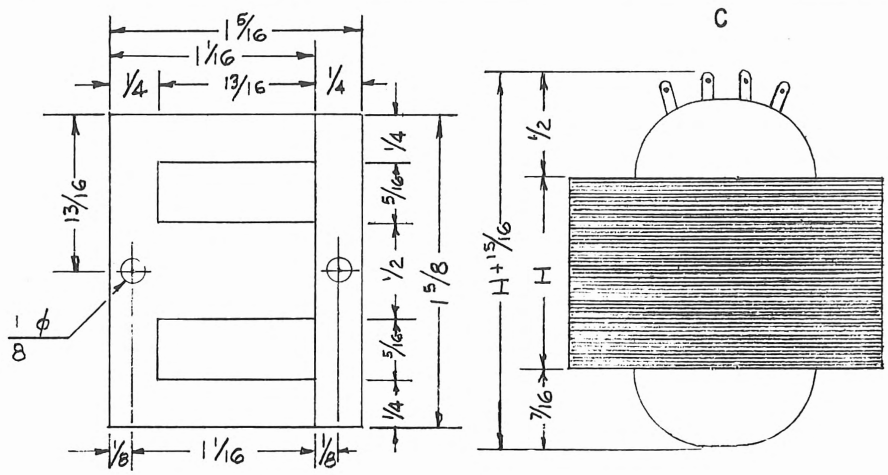


THESE ARE SOME LAMINATION AND MOUNTING DATA USED BY TEKTRONIX . . . . . .

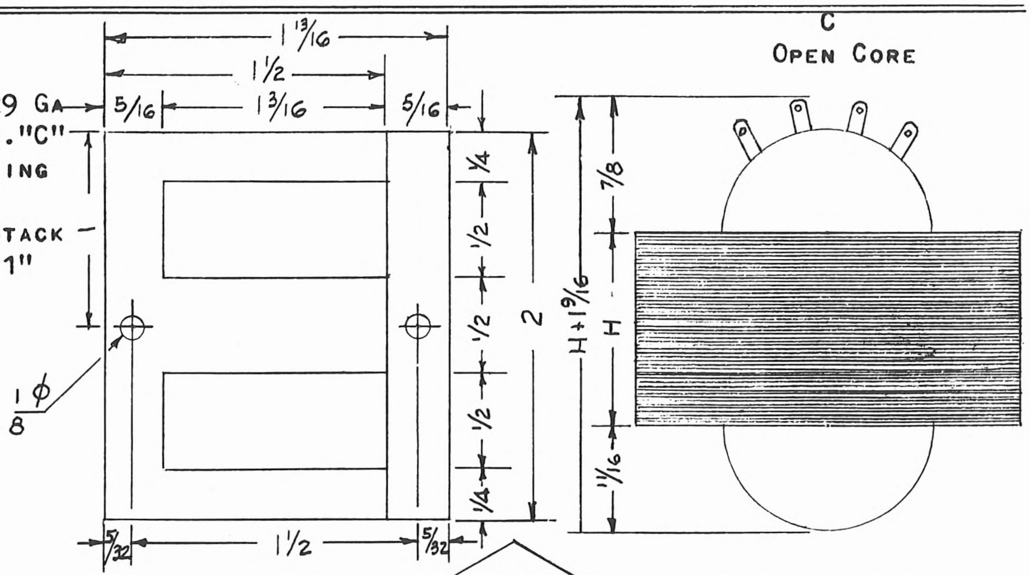
"EI 25"
386-022
MATERIAL - 29 GA. GRADE (ORIENTED)
APP. V/A RATING - UP TO 1
H= NORMAL STACK
1/4" 1/2"

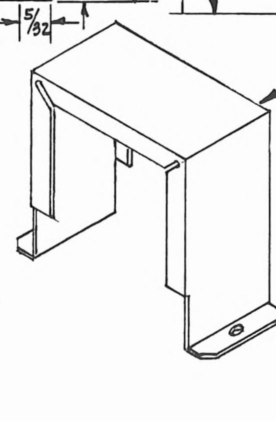


"EI 50"
386-013
MATERIAL - 29 GA. GRADE, TRANS."C"
APP. V/A RATING - UP TO 8
H = NORMAL STACK
1/2" 3/4" 1"



"EI 28"
386-008
MATERIAL - 29 GA. GRADE, TRANS."C"
APP. V/A RATING 5-18
H = NORMAL STACK
1/2" 3/4" 1"

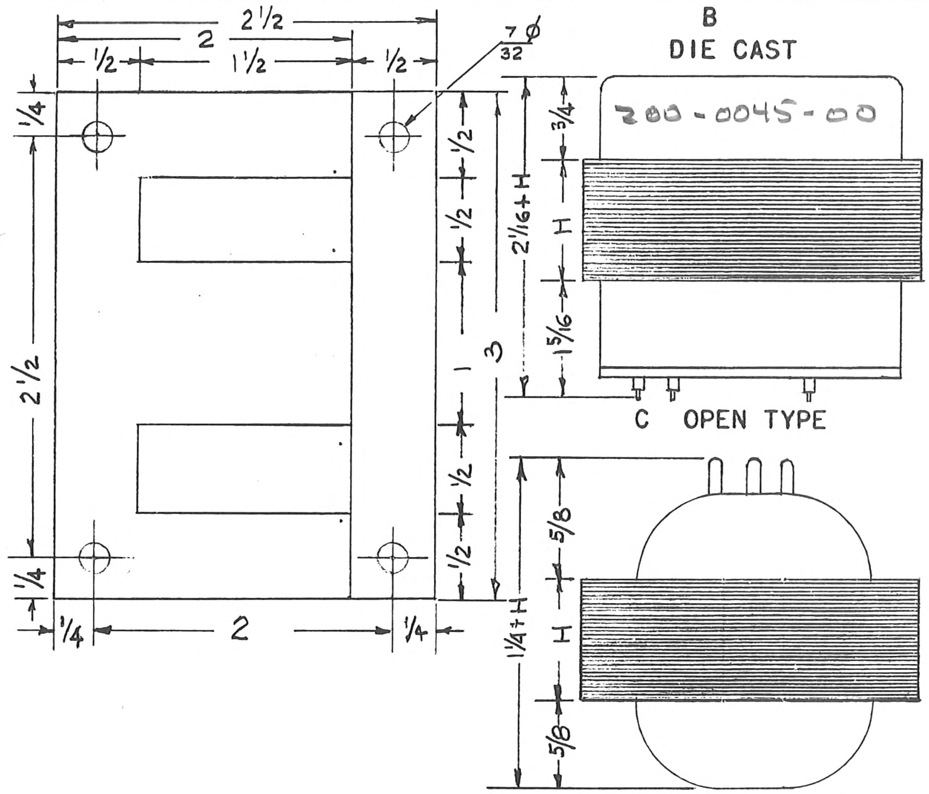




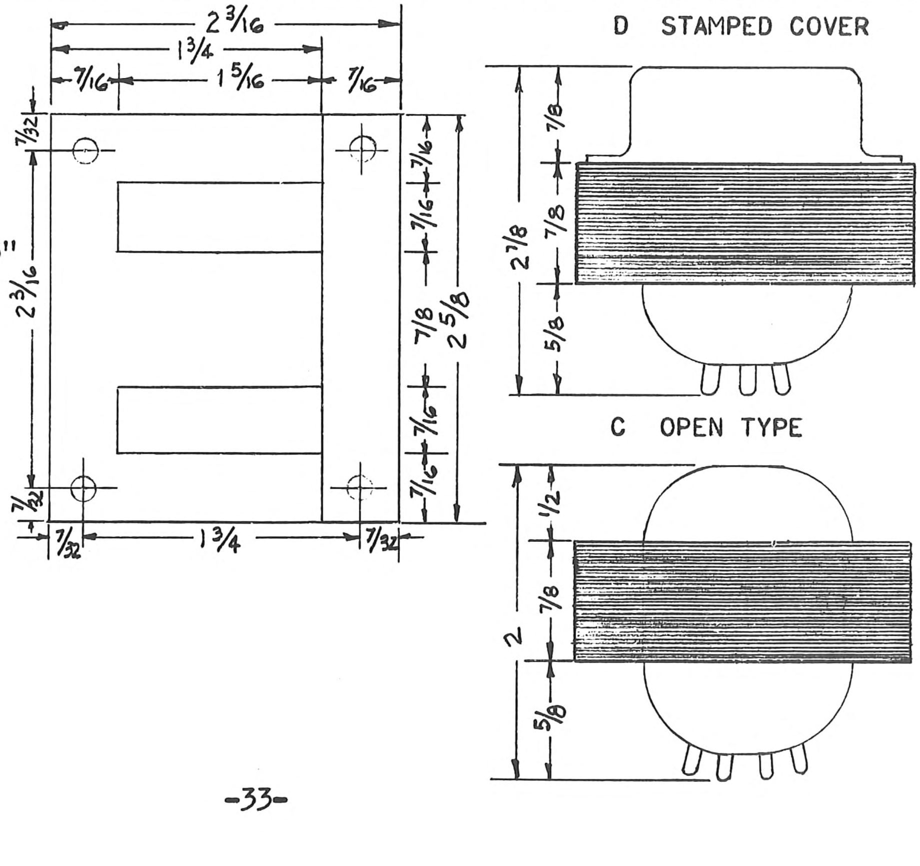
U BRACKETS AVAILABLE FOR 1" STACK

THESE ARE SOME LAMINATION AND MOUNTING DATA USED BY TEKTRONIX . . . . . .

"EI 100"
386-005
MATERIAL - 29 GA.
GRADE M6
ORIENTED
APP. V/A RATING -
30-60
H = NORMAL STACK
1" 1½" 2"



"EI 11"
386-014
MATERIAL - 29 GA.
GRADE M6
ORIENTED
APP. V/A RATING -
30
NORMAL STACK - 7/8"



ABOUT THE INSULATION MATERIALS WHICH TEKTRONIX USES . . . . . .

We use a non-reinforced polyester web almost exclusively for insulating our CRT filament windings. This is a non-impregnated web or felt non-woven fabric. Before its introduction on the market, we tested samples and learned that it absorbs very little moisture, but has an affinity for varnish resins. It makes a good pad around sections of a winding. Its close conformity and varnish pick-up properties reduce space requirements and impart corona resistance; it has good electrical strength.

After impregnation with our varnish, it shows much higher insulation resistance at 90 to 100 degrees centigrade than standard varnished materials.

It's also an excellent material for lap taping high-voltage coils and Pi's.

It follows the contour of coils much better than even bias-cut woven fabrics. Its weak points are low tensile strength and lack of toughness to resist mechanical puncture.

This same material, varnish impregnated and coated, is on the market under the Irvington trade-name "Fibremat". We've listed its properties on Pages 35 to 38.

We've listed typical specifications for the various papers we use on Pages 39 and 40.

Fibremat*

TYPICAL TEST DATA

	.010 Black Fibremat	.010 Yellow Fibremat	.007 Black Fibremat	.007 Yellow Fibremat
Tensile Strength – P.I.W.				
Warp	20	20	15	15
Filler	7	7	5	5
Dielectric Strength – V.P.M.				
1/4" Electrodes				
AS IS	1650	1550	1500	1525
at 80°C	1250	1100	1150	1150
at 105°C	1100	1050	1050	1050
24/25/96	1350	1350	1400	1500
AFTER OIL	1500	1450	1550	1450
6% under tension	1200	1200	1200	1200
Dielectric Constant	2.8–3.2	2.8–3.2	2.8–3.2	2.8–3.2
Electrolytic Corrosion Factor	1.0	1.0	1.0	1.0
Water Absorption – %				
(24 hour immersion)	0.5	0.8	0.3	0.5
Power Factor at 100°C in %				
Conditioned for				
3 hrs. @ 105°C in vacuum	2.5	3.5	2.0	3.5
24 hrs. @ 25°C @ 65% R.H.	4.5	6.5	3.0	7.5
24 hrs. @ 25°C @ 96% R.H.	6.0	12.0	3.5	13.5

GENERAL RESISTANCE TO:

Water	Excellent	Alcohols	Good
Salt Water	Excellent	Hydrocarbons, Aliphatic	Good
Acids	Excellent		
Alkalies	Excellent	Oils	Excellent

*TRADE MARK

DIELECTRIC CONSTANT

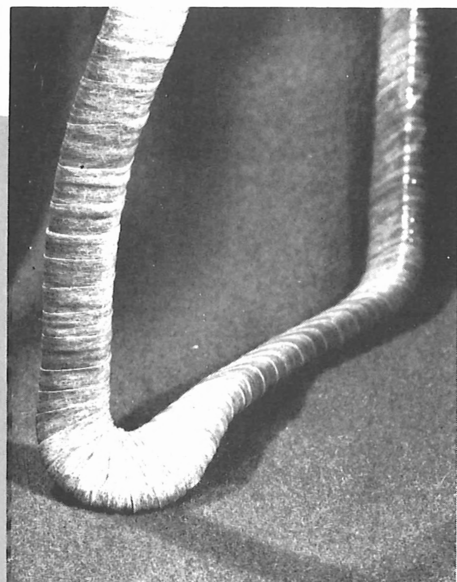
Dielectric Constant – The comparable dielectric constant of **Fibremat** and Varnished Cambric allows its direct substitution in high voltage systems without stress problems. This characteristic permits its application without splice re-design or worker re-education.

FIG. 4

	Fibremat	Bias Cambric
Dielectric Constant	2.8–3.2	3.0–3.2

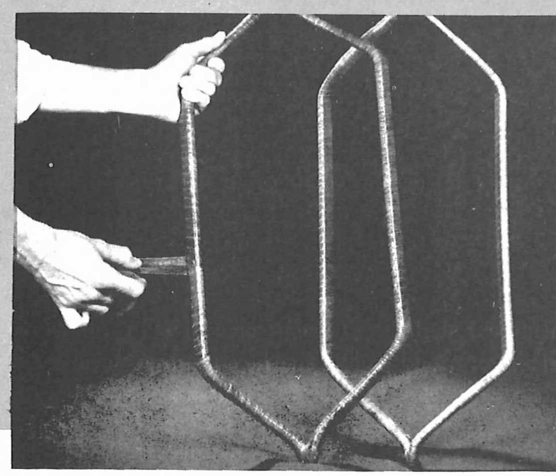
CONFORMABILITY

One of the most important properties of the new material is its extreme conformability in comparison with other forms of coated insulation. **Fibremat** can be pulled down tightly while wrapping knuckles, curved or irregular surfaces to make a neater appearing unit and eliminate air pockets or voids.



FIBREMAT'S exceptional conformability allows for smooth void-free knuckle taping.

Hands of workman wrapping third layer of **Fibremat** displaying how easily it conforms to irregular surfaces. To the right is a coil with a single layer of varnished cambric which already shows the effects of lack of conformability.



Fibremat*

ELECTRICAL IMPROVEMENTS

DIELECTRIC STRENGTH – 1650 VPM – The electrical properties of the polyester web base are such that they materially contribute to the over-all high dielectric strength of **Fibremat.** This contribution is possible since the web was specifically formulated from polyester resins, in themselves an excellent insulating material. The net result is an increase of at least 300 volts per mil over conventional materials.

DIELECTRIC STRENGTH UNDER ELONGATION – As seen in Fig. 1, the structure of **Fibremat** permits extensive elongation without film rupture and resultant loss in dielectric. Its ease of conformability and high dielectric strength allows for higher insulating characteristics in insulation systems requiring varying degrees of elongation.

POWER FACTOR

Power Factor – Low power factor in a high voltage system makes **Fibremat's** advantages outstanding. This characteristic also has great meaning to all electrical manufacturers as the continuity of the low power factor of **Fibremat** under adverse conditions proves its insulation stability. This is illustrated by the comparison below.

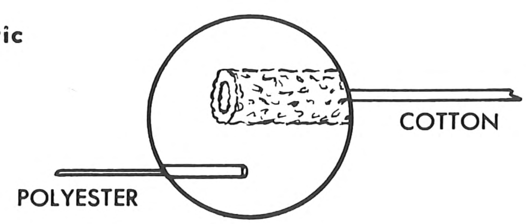
FIG. 3

	Fibremat	Bias Cambric
Power Factor at 100°C – %		
Conditioned at		
3 hrs. @ 105°C in Vacuum	2.5%	4.0%
24 hrs. @ 25°C @ 65% R.H.	4.5%	9.0%
24 hrs. @ 25°C @ 96% R.H.	6.0%	30.0%

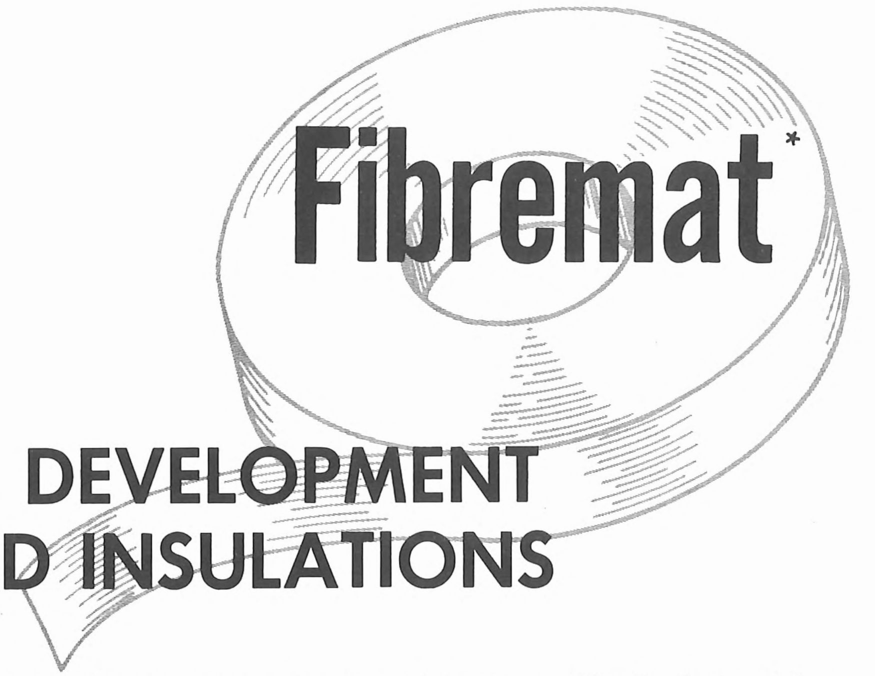
MOISTURE ABSORPTION

Continuous wick-like threads encountered in insulations such as varnished cambrics encourage high moisture absorption. This problem is virtually eliminated with **Fibremat** whose base is made up of a moisture-proof maze of discontinuous polyester fibers.

	Fibremat	Bias Cambric
Water absorption in %	0.5%	7.0%



*TRADE MARK



Fibremat*

A *Unique* DEVELOPMENT IN COATED INSULATIONS

The unique properties of the non-woven polyester web base, specifically designed for this insulation, combined with a specially formulated coating resin allows **Fibremat** to overcome the inherent disadvantages of woven-base insulating materials, both mechanically and electrically.

Woven base materials under elongation, due to continuous fiber construction, actually cut through and rupture the insulating coating. The change in structural pattern from squares in Fig. 1A to diamonds in Fig. 1B illustrates the cutting action of the woven threads. In contrast, when the polyester web is under elongation, it maintains its position relative to the insulating film, eliminating the disruptive forces found in the woven base materials as shown in Fig. 1C and Fig. 1D.

WOVEN CLOTH NO TENSION | WOVEN CLOTH WITH TENSION | FIBREMAT NO TENSION | FIBREMAT WITH TENSION

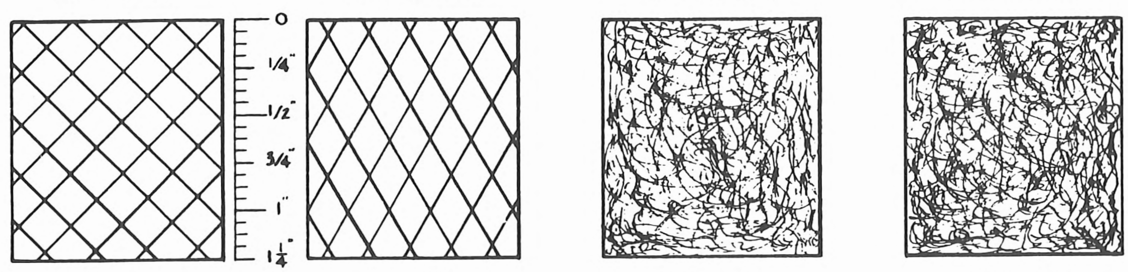


FIG. 1-A | FIG. 1-B | FIG. 1-C | FIG. 1-D

The problem of high moisture absorption in conventional woven-base insulation because of wicking action is effectively solved by the polyester web base. The **Fibremat** base is virtually a moisture-proof maze of discontinuous polyester fibers rather than continuous wick-like threads that encourage high moisture absorption.

*TRADE MARK

THESE ARE STANDARD SPECIFICATIONS FOR VARIOUS TYPES OF PAPERS . . . . .

FISH PAPER

Based on N.E.M.A. STANDARDS & A.S.T.M. SPECIFICATION D-710

Nominal Thickness, Inches	Density, Min. Grams per Cu. Cm.	Dielectric Strength, Min., V. per Mil.	Water Absorption, Max. Per Cent		Tensile Strength, Min. P.S.I.		Bursting Strength, Min., P.S.I.	Tearing Strength, Min., Grams	
			2 Hrs.	24 Hrs.	Crosswise	Lengthwise		Crosswise	Lengthwise
.004	0.90	200	—	—	6000	8000	—	—	—
.005	0.90	200	—	—	6000	8000	75	120	100
.007	0.90	300	—	—	6000	8000	105	220	190
.008	0.90	300	—	—	6000	8000	—	—	—
.010	1.15	300	—	—	6000	8000	150	300	250
.012	1.15	300	—	—	6000	8000	—	—	—
.015	1.15	300	—	—	6000	8000	225	450	375
.020	1.15	250	—	—	6000	8000	325	—	—
over .020 to 1/32	1.15	250	—	—	6000	8000	—	—	—
1/32 to .040 incl.	1.15	250	55	65	6000	8000	—	—	—
over .040 to 3/32 incl.	1.15	175	55	65	6000	8000	—	—	—
over 3/32 to 1/8 incl.	1.20	175	55	65	6000	8000	—	—	—

NOTE: Thickness tolerances are the same as for standard grades of Vulcanized Fibre.

FISH PAPER IS FURNISHED:

IN SHEETS 46" TO 52" WIDE X 84" LONG.
IN ROLLS 46" TO 52" WIDE.
IN STRIPS CUT TO WIDTH AS ORDERED.
IN COILS 1/8" TO 46" AS ORDERED.
COLOR: BLUISH GRAY ONLY.
THICKNESSES: 0.004" TO 1/8" INCLUSIVE.

MORE SPECIFICATIONS FOR PAPERS . . . . . .

PROPERTIES OF A TYPICAL 100 PER CENT RAG PAPER

Thickness, in inches	.007, .010, .015, .020, .025, .030.
Color	Light olive drab
Specific gravity -- gms./cc	1.30 -- 1.40
Finish	Glazed, high density
Tensile MD -- #/sq. in.	12,000 -- 16,000
Tensile CMD -- #/sq. in.	5,500 -- 6,500
Elongation MD -- per cent	7 -- 9
Elongation CMD -- per cent	11 -- 14
Dielectric volts/.001" thickness	400 -- 600
Shrinkage MD -- per cent	.3 -- .5
Shrinkage CMD -- per cent	.8 -- .10
Mullen #/.001" thickness	27
Elmendorf tear MD -- gms./.001"	50 -- 60
Elmendorf tear CMD -- gms./.001"	85 95
pH	6.5 -- 7.0
Ash per cent -- less than	1.
Methanol extractable per cent	.15 -- .35
Naptha extractable per cent	.10 -- .18
Chlorides -- parts per million	8 -- 12
Water abs. -- 15 min. -- approx. per cent ...	100
Water abs. -- 24 hours -- approx. per cent ..	120
Approx. wgt. -- #M/sq. ft., .001" thick	76

Fibre -- 100 per cent rag -- selected cuttings, new cotton. No sizing or chemical treatment.

MD = parallel to grain = machine direction

CMD = across the grain = cross machine direction

OUR GENERAL PURPOSE TUBING . . . . . .

"VARFLEX" BB1 -- WHICH IS MADE ESPECIALLY FOR US -- IS A SYNTHETIC RESIN-IMPREGNATED GLASS SLEEVING COATED WITH A PERMAFIL. IT'S UNUSUALLY FLEXIBLE, TOUGH, ABRASION-RESISTANT AND EASY TO STRIP FROM LEAD ENDS. IT IS SUPERIOR FOR OUR USE TO ANY OTHER TESTED. ITS ELECTRICAL STRENGTH EXCEEDS THE SPECIFICATIONS FOR GRADE BB1.

MOST COMMERCIAL TUBING OF THIS GRADE IS A VINYL COATED GLASS WHICH IS FLEXIBLE, ELECTRICALLY STRONG, ABRASION-RESISTANT, ETC. THESE HAVE THE DRAWBACK FOR US OF BEING HARD TO STRIP, IN ADDITION TO THEIR INTENTIONAL PUSH-BACK QUALITIES.

TUBING SPECIFICATIONS ARE LISTED ON THE FOLLOWING PAGE.

NEMA Designations[2]	DIELECTRIC STRENGTH, VOLTS C-48/25/50[3] Minimum Average	C-48/25/50[3] Minimum Individual	C-96/25/96[4] Minimum Average	C-96/25/96[4] Minimum Individual	Heat Aging[5]	Transformer Oil Immersion (48 Hours at 105°C, —0°C +5°C)	Heat Endurance, 15 Minutes at 225°C ±7°C	Burning Rate, Minimum Seconds to Burn 1 Inch
A-A-1	7000	5000	2100	1500	No failure	No disintegration or swelling	Shall not soften, blister or flow	45
A-B-1	4000	2500	1200	750	No failure	No disintegration or swelling	Shall not soften, blister or flow	45
A-C-1	2500	1500	....	....	......	No disintegration or swelling	Shall not soften, blister or flow	45
A-C-2	1500	800	....	....	......	....	Shall not soften, blister or flow	45
A-C-3	....	....	....	....	......	....	....	..
B-A-1	7000	5000	2800	2000	No failure	No disintegration or swelling	Shall not soften, blister or flow	45
B-B-1	4000	2500	2000	1250	No failure	No disintegration or swelling	Shall not soften, blister or flow	45
B-C-1	2500	1500	....	....	......	No disintegration or swelling	Shall not soften, blister or flow	45
B-C-2	1500	800	....	....	......	....	Shall not soften, blister or flow	45
B-C-3	....	....	....	....	......	....	....	..
H-A-1	7000	5000	2800	2000	No failure*	....	....	45
H-C-1	2500	1500	....	....	......	....	....	45
H-C-2	1500	800	....	....	......	....	....	45
H-C-3	....	....	....	....	......	....	....	..

[1]These are standard NEMA specifications. For details on test procedures and other information refer to NEMA Publication No. VSI-1950. "Standards for Varnish Tubing and Saturated Sleeving."

[2]First letter designates class. Second letter and number designate grade.

[3]After 48 hours at 25°C plus or minus 1°C and at a relative humidity of 50% plus or minus 2%.

[4]After 96 hours at 25°C plus or minus 1°C and at a relative humidity of 96% plus or minus 2%.

[5]Classes A and B, 96 hours at 105°C, minus 0°C plus 5°C. Class H, 96 hours at 200°C plus or minus 5°C.

*If failure occurs after 96 hours at 200°C ± 5°C, the test shall be continued for an additional 96 hours. (Failure after the initial 96 hours may be due to temporary embrittlement which does not constitute failure if flexibility is recovered after an additional 96-hour period.)

TABLE II AVAILABLE COLORS

COLORS	TYPE AND GRADE — Cotton or Rayon Base, Oleoresinous Varnish A-1, B-1	Cotton or Rayon Base, Oleoresinous Varnish C-1, C-2 Heavy Wall	Cotton or Rayon Base, Oleoresinous Varnish C-3	Glass Base, Oleoresinous Varnish A-1, B-1	Glass Base, Oleoresinous Varnish C-1, C-2	Glass Base, Oleoresinous Varnish C-3	Glass Base, Isocyanate Varnish A—Grade B—Grade C—Grade	Glass Base, Vinyl Coating A—Grade B—Grade C—Grade	Glass Base, Silicone Varnish A-1, B-1 C-1, C-2 C-3	Glass Base, Silicone Rubber A-1, B-1 C-1, C-2
Yellow	St.	St.	St.	St.	St.	St.	St.	St.		Sp.
Black	St.	St.	St.	St.	St.	St.		St.	Sp.	
Red	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.		Sp.		Sp.
Green	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.		Sp.		Sp.
Brown	Sp.	Sp.	Sp.	Sp.	Sp.	Sp.		Sp.		Sp.
Blue		Sp.	Sp.		Sp.	Sp.		Sp.		Sp.
Orange			Sp.			Sp.				
White								Sp.		St.
Gray								Sp.		
Tan								Sp.		
Natural Cream									St.	

St.—Standard colors usually carried in stock.

Sp.—Special made-to-order colors not generally carried in stock.

ABOUT ELECTRICAL TAPE . . . . . .

THE GENERAL INFORMATION SECTION OF THIS MANUAL HAS DISCUSSED THE NEED FOR ELECTRICAL TAPES WHICH WILL:

A. RESIST ABRASION.

B. PROVIDE A MOISTURE BARRIER.

C. PROVIDE LEAD IDENTIFICATION (BY USE OF COLORED TAPE).

D. OCCUPY A GIVEN AMOUNT OF SPACE.

WE'VE STATED THAT SOME OF THE FACTORS INVOLVED IN SELECTING ELECTRICAL TAPES FOR SPECIFIC APPLICATIONS ARE:

A. CLASS OF INSULATION.

B. TEAR STRENGTH.

C. TAPE CORROSIVENESS.

D. TEMPERATURES INVOLVED.

E. DIELECTRIC STRENGTH.

F. SURFACE TEXTURE.

G. COSTS.

TEKTRONIX USES "PERMACEL" BRAND ELECTRICAL TAPES. TECHNICAL DATA FOR THIS MATERIAL IS SUMMARIZED ON THE FOLLOWING PAGE.

PERMACEL® PAPER - FILM - CLOTH - LAMINATED ELECTRICAL TAPES

Embodying pressure-sensitive and thermosetting characteristics.
All tests done in accordance with ASTM D-1000-58T.

Permacel No.	Backing	Price List No.	Insulation Class	Curing Cycle (1)	Adhesion (2)	Tensile Strength (lbs./inch)	Elongation %	Thickness Mils	Insulation Resistance in Megohms (Min.) (3)	Electrolytic Corrosion Micro-micromhos (Max.) (3) (4)	Dielectric Strength (Volts)	Chlorides % (Max.)
PAPER												
22	30 lb. Crepe Paper (Black)	86	105C	A	40	20	12	9.5	25	40,000	2,500	.02
23	4 mil Rope Flatback Paper (Black)	86	105C	A	50	60	3	6.5	20	50,000	2,500	.02
27	4 mil Rope Flatback Paper (Tan)	86	105C	A	50	60	3	6.5	20	50,000	3,000	.02
272	3 mil Rope Flatback Paper (Tan)	86	105C	A	50	40	3	5.5	20	50,000	3,000	.02
28	30 lb. Crepe Paper (Tan)	86	105C	A	40	20	12	9.5	25	40,000	3,000	.02
FILM												
25	2 mil Acetate Film (Clear)	86	105C	A	50	25	10	3.5	300,000	4	6,000	.015
251	2 mil Acetate Film (Yellow)	86	105C	A	40	25	10	3.5	300,000	4	6,000	.015
252	1 mil "Mylar"* (Orange-Yellow)	86	105C	A	40	20	100	2.5	2,000,000	0.5	5,500	.015
253	1 mil "Mylar" (Clear)	86	105C	A	50	20	100	2.5	2,000,000	0.5	5,500	.015
254	2 mil "Mylar" (Orange-Yellow)	86	105C	A	45	50	100	3.5	2,000,000	0.5	8,000	.015
255	2 mil "Mylar" (Clear)	86	105C	A	45	50	100	3.5	2,000,000	0.5	8,000	.015
256	1 mil "Mylar" (Yellow)	86	105C	A	50	20	100	2.5	2,000,000	0.5	5,500	—
CLOTH												
20	80 x 80 Cotton Cloth	86	105C	B	30	50	7	11.0	100	10,000	3,000	.02
201	80 x 80 Cotton Cloth (White or Black)	86	105C	A	40	50	7	11.0	100	10,000	3,000	.02
202	68 x 72 Cotton Cloth	86	105C	A	40	45	5	11.0	100	10,000	3,000	.02
21	60 x 52 Glass Cloth	86	130C	A	40	150	5	7.0	1,000	1,000	3,000	.02
24	White Taffeta Acetate Cloth	86	105C	A	35	45	15	8.5	100,000	10	3,000	.005
242	Colored Taffeta Acetate Cloth	86	105C	A	35	45	15	8.5	100,000	10	3,000	.02
LAMINATED												
241	0.88 mil Acetate Film on Acetate Cloth	86	105C	A	40	50	12	9.5	100,000	10	6,500	.015
245	0.88 mil Acetate Film on 3 mil Rope Paper	86	105C	A	35	50	4	8.5	200	5,000	5,000	.02
246	Filament Reinforced Acetate Film	86	105C	A	35	225	12	11.0	100	10,000	6,000	.02
CLASS 180C												
211	Silicone Varnished Glass Cloth	86	180C	C	25	125	5	6.0	2,000	500	4,000	—
212	60 x 52 Glass Cloth	86	180C	C	25	150	6	7.3	2,000	500	3,500	—
421	"Teflon"**	89	180C	C	30	20	250	6.5	500,000	2	12,000	—
422	"Teflon"	89	180C	C	25	19	100	3.5	2,000,000	0.5	8,500	—

*DuPont's Trademark for its Polyester Film
**DuPont's Trademark for its TFE-Fluorocarbon Resin

REFERENCE NOTES

(1) Minimum Curing Cycles
- A — Two hours at 275° F. or one hour at 300° F.
- B — Not thermosetting.
- C — No curing cycle required.

(2) Stripping Speed: 12 inches per minute.

(3) Values obtained at 96% relative humidity.

(4) This test is a measure of electrolytic corrosion and replaces the electrolytic corrosion factor test (ASTM D-1000-48T) which poorly distinguished between corrosive and non-corrosive tapes.

Technical Data figures should not be used in specification writing. Current minimum and maximum values may be obtained upon request.

ABOUT IMPREGNATING MATERIAL . . . . . .

THE VARNISHES USED IN IMPREGNATING TRANSFORMER PARTS ARE CERTAINLY ONE OF THE MOST CRITICAL ASPECTS OF MANUFACTURE. AFTER USING AN OIL-MODIFIED PHENOLIC-ALKYD VARNISH COMPOUND FOR MANY YEARS, WE'RE NOW CHANGING OVER TO A RESIN-MODIFIED TYPE VARNISH. THIS MATERIAL HAS THE FOLLOWING CHARACTERISTICS:

A. CLEAR.

B. SPECIFIC GRAVITY AT 70°F . . . 21.5 TO 23.5 DEGREES VISCOSITY #1 DEMMLER CUP AT 86°F., 18 - 28 SECONDS (THIS IS ABOUT 60 CENTIPOISES).

C. FILM BUILD-UP . . . 2 TO 3 THOUSANDTHS.

D. THINNER . . . MINERAL SPIRITS OR BETTER.

NOTE: VISCOSITY OF OUR VARNISH IS CHECKED AND ADJUSTED DAILY. NO REGULAR CHECK IS MADE ON GRAVITY. TEMPERATURE VARIATIONS AFFECT VISCOSITY MARKEDLY. CURING TIME VARIES FROM THREE HOURS ON SMALL UNITS TO EIGHT HOURS ON LARGE UNITS -- AT 280°F.

SOME OF THE PRECAUTIONS TO BE USED IN HANDLING THIS MATERIAL ARE:

A. AVOID EXCESSIVE TEMPERATURES.

B. MAINTAIN CLEANLINESS.

C. USE EXTREME CARE TO PREVENT CONTAMINATION.

D. USE PROPER THINNER. ADD THINNER <u>SLOWLY</u> WHILE AGITATING VARNISH. VARNISH AND SOLVENT SHOULD BE AT THE SAME TEMPERATURE.

SOME OF THE ELECTRICAL PROPERTIES OF RESIN-MODIFIED VARNISHES ARE:

A. ELECTRIC STRENGTH DRY . . . 4100 V./MIL.

B. ELECTRIC STRENGTH WET . . . 2700 V./MIL.

THE FOLLOWING PAGE LISTS CERTAIN SPECIFICATIONS FOR THERMOSETTING VARNISH.

SPECIFICATIONS FOR (THERMOSETTING) BAKING VARNISH......

Clear baking varnish is formulated as a class F general purpose impregnant and coating for electrical and electronic applications. It's a phenolic-base resin-modified varnish having outstanding flexibility coupled with excellent adhesion, chemical and heat resistance, and high bond strength. Also, its high gloss, tack-free surface and mar resistance make it an excellent coating for a variety of purposes. This varnish cures to a hard, tough, flexible film which will retain these properties at operating temperatures of 155°C.

(Military requirements are specified by MIL-V. 1137A Grade CB, Type M.)

CHARACTERISTICS

1. SPECIFICATIONS
   - Color .... Clear
   - Specific gravity at 70°F ASTM D-287-55 .... 21.5--23.5°
   - Viscosity #1 Demmler Cup at 86°F .... 18-28 sec.
   - Build Up, D.F.T. ASTM D-115-55 .... 2-3 mils
   - Thinner .... Mineral Spirits or better
   - Baking time at 275°F on a strip, ASTM D-115-55 .... 45 min.
   - Corrosive effect on Copper .... None

2. ELECTRICAL PROPERTIES
   - Dielectric strength (Dry) .... 4100 volts/mil
   - Dielectric strength (After 24 Hours water immersion) .... 2800 volts/mil

3. CHEMICAL RESISTANCE
   - Water .... Excellent
   - Acid (10% Sulfuric Acid) .... Excellent
   - Alkali (1% Sodium Hydroxide) .... Excellent
   - Salt Water .... Excellent
   - Oil, ASTM D-115-55 .... Passed

4. CURING TIME IN A 20 GRAM TEST CUP
   - 320°F................ 30 mins.
   - 300°F................ 45 mins.
   - Preferred 275°F................ 60 mins.

5. BAKING CYCLES
   - For a 5 pound unit, 2-4 hours at 275°F.

APPLICATION

Resin-modified varnish may be used in any of the conventional treatment systems. Its versatile physical properties make it a superior varnish suitable for transformers, armatures, stators, random wound and form coils. In preparing form coils, it is suggested they be baked 30 minutes at 275-285°F unit temperature. Then spread coil, insulate and reimpregnate with varnish. Bake for 1½ hours at 275-285°F unit temperature.

MORE ABOUT VARNISH IMPREGNATION . . . . . .

THE FOLLOWING INFORMATION IS BY COURTESY OF THE JOHN C. DOLPH COMPANY:

PREHEATING

"AS A GENERAL PRACTICE, IT IS SUGGESTED THAT ELECTRICAL UNITS REQUIRING VARNISH INSULATION BE PREHEATED. ALL COTTON, SILK AND PAPER COVERINGS AND MANY INORGANIC MATERIALS ABSORB AND RETAIN A CERTAIN AMOUNT OF MOISTURE WHICH, IF ALLOWED TO REMAIN, COULD EVENTUALLY CAUSE ELECTRICAL BREAKDOWN. THE REMOVAL OF MOISTURE FROM INSULATING MATERIALS AND SURFACES OF UNITS BY PREHEATING WILL DEFINITELY RESULT IN HIGHER INSULATION RESISTANCE.

"PREHEATING ALSO AIDS PENETRATION OF VARNISH INTO TIGHTLY WOUND COILS BY LOWERING THE VISCOSITY OF THE VARNISH ADJACENT TO THE UNIT AND BY A 'SUCTION EFFECT'. THE AIR REMAINING INSIDE THE HEATED UNITS HAS EXPANDED CONSIDERABLY AND, WHEN THE WINDINGS ARE IMMERSED IN THE VARNISH, THE AIR COOLS AND CONTRACTS, THUS DRAWING ADDITIONAL VARNISH INTO THE INTERIOR OF THE COIL. UPON REMOVAL FROM THE VARNISH, THE PREHEATED UNITS ARE USUALLY AT A HIGHER TEMPERATURE THAN THE SURROUNDING ATMOSPHERE. THEREFORE, EVAPORATION OF THE SOLVENT IS ACCELERATED. WEIGHING COILS THAT CONTAIN CONSIDERABLE TEXTILE INSULATION BEFORE AND DURING THE PREHEATING CYCLE WILL REVEAL THE EXTENT OF THE MOISTURE DRIVEN OFF AND WILL BE CONCLUSIVE PROOF OF THE IMPORTANCE OF PREHEATING.

"THE PREHEATING TEMPERATURE NEED NOT BE IN EXCESS OF 200°F, BUT IS OFTEN HIGHER TO SPEED THE RATE AT WHICH THE MOISTURE IS DRIVEN OFF. IT IS SUGGESTED THAT THE PREHEATING TEMPERATURES BE BASED ON THE TYPE OF INSULATING MATERIALS EMPLOYED. UNITS HAVING CLASS A INSULATION SHOULD BE PREHEATED AT A TEMPERATURE OF 220°F - 250°F, AND THOSE HAVING CLASS B INSULATION AT 220°F - 300°F.

"THE TIME REQUIRED FOR PREHEAT WILL USUALLY VARY FROM ONE TO SIX HOURS AND WILL DEPEND LARGELY ON THE CONSTRUCTION AND SIZE OF THE UNIT. IT SHOULD BE NOTED THAT PREHEATING WILL NOT REMOVE ALL TRACES OF MOISTURE, ALTHOUGH DRYING THE AIR IN THE OVEN WITH A DRYING AGENT SUCH AS ACTIVATED ALUMINA OR CALCIUM CHLORIDE WILL REMOVE ALL BUT A VERY SLIGHT TRACE OF IT.

"IT IS SUGGESTED THAT PREHEATING BE ACCOMPLISHED BY USING A SEPARATE BAKING OVEN FOR THIS PURPOSE. A TEMPERATURE OF 220°F IS ORDINARILY NOT PRACTICAL FOR A BAKING TEMPERATURE. FOR THIS REASON IT MIGHT BE ADVANTAGEOUS TO HAVE AN OVEN WHICH IS USED SOLELY FOR PREHEATING. OF COURSE, IF A RELIABLE TEMPERATURE CONTROL IS INCORPORATED IN THE BAKING OVEN, IT WILL NOT BE NECESSARY TO CONSIDER THE USE OF SEPARATE OVENS. OCCASIONALLY, MANUFACTURERS PREHEAT THEIR UNITS IN THE VACUUM TANK. THIS IS, OF COURSE, POSSIBLE ONLY WHERE HEATING FACILITIES ARE A PART OF THE VACUUM IMPREGNATING TANK. THERE IS ONE OBJECTIONABLE FEATURE IN REGARD TO THE USE OF THE VACUUM TANK FOR PREHEATING AND THIS IS DUE LARGELY TO THE HEAT STORAGE IN THE VACUUM TANK WALLS. THIS STORED HEAT MAY BE SUFFICIENT TO CHANGE THE CHARACTERISTICS OF MODERN HEAT-REACTIVE VARNISHES AFTER A NUMBER OF TREATMENTS IN THE VARNISH. THE OXIDIZING VARNISHES ARE NOT AFFECTED AS MUCH. AT ANY RATE, IT IS OUR SUGGESTION THAT PREHEATING SHOULD BE CONDUCTED IN A BAKING OVEN.

TO CONTINUE THE ARTICLE ON VARNISHES BY THE JOHN C. DOLPH COMPANY . . . .

VACUUM IMPREGNATION

"EVACUATION: THE COILS SHOULD BE TRANSFERRED FROM THE PREHEATING OVEN TO THE VACUUM TANK AS QUICKLY AS POSSIBLE TO PREVENT ANY EXCESSIVE TEMPERATURE DROP. IT IS DESIRABLE TO HAVE THE VACUUM PUMP STARTED AS SOON AS POSSIBLE AFTER THE LID HAS BEEN TIGHTENED. MOST VACUUM CYCLES CALL FOR A SPECIFIC TIME AND DEGREE OF VACUUM, AND NATURALLY IT WILL TAKE A WHILE BEFORE THE SPECIFIED VACUUM IS OBTAINED. THIS TIME WILL DEPEND UPON THE PUMP SIZE IN RELATION TO THE VACUUM TANK VOLUME. SOME OF THESE UNITS IT WILL TAKE 15 MINUTES BEFORE A 28" HG VACUUM IS REACHED. TIMING OF THE VACUUM CYCLE SHOULD NOT BEGIN UNTIL THE SPECIFIED VACUUM IS OBTAINED. THE DEGREE OF VACUUM SHOULD BE AT LEAST 28" HG OR HIGHER IF POSSIBLE. THE RESIDUAL MOISTURE REMAINING IN THE COILS AFTER PREHEATING THEM WILL, HOWEVER, BE REMOVED VERY RAPIDLY WHEN THE COILS ARE PLACED IN A VACUUM GREATER THAN 28" HG. THIS VACUUM CORRESPONDS APPROXIMATELY TO AN ABSOLUTE PRESSURE LESS THAN 1.8" HG. AT THIS DEGREE OF VACUUM THE BOILING POINT OF WATER IS 97°F, WHICH SHOULD TEND TO REMOVE PRACTICALLY ALL THE MOISTURE FROM THE UNIT. 28" SEEMS TO BE A COMMERCIAL VACUUM AND SHOULD NOT BE TOO DIFFICULT TO OBTAIN.

"EVAPORATION OF RESIDUAL MOISTURE REMAINING IN THE COILS AS POINTED OUT ABOVE IS VERY RAPID UNDER VACUUM AND OFTEN IT HAS BEEN OBSERVED THAT THE SIGHT HOLES ARE FOGGED DUE TO A THIN FILM OF THIS MOISTURE CONDENSING ON THE COLD SURFACE OF THE VACUUM TANK. FOGGING WILL DISAPPEAR IF THE EVACUATION IS CONTINUED BUT IN SOME INSTANCES A 15 MINUTE PERIOD WILL BE REQUIRED. THE MINIMUM TIME OF EVAPORATION ON ANY TYPE OF COIL SHOULD BE 15 MINUTES AND IT DOES NOT SEEM NECESSARY TO EVACUATE FOR A LONGER PERIOD THAN ONE HOUR, PROVIDED THAT THE COILS HAVE A TEMPERATURE OF AT LEAST 150°F WHEN THEY ARE PUT IN THE VACUUM CHAMBER. IT MIGHT BE SAID THAT THE 15 MINUTE PERIOD COULD BE EMPLOYED FOR LOW VOLTAGE COILS AND THE ONE HOUR PERIOD FOR HIGH VOLTAGE COILS.

VARNISH IMPREGNATION

"THE NEXT STEP IS TO DRAW THE VARNISH FROM THE LIQUOR TANK TO THE VACUUM CHAMBER. INVARIABLY TWO SIGHT HOLES ARE PROVIDED ON THE VACUUM TANK COVER IN ORDER THAT THE OPERATOR MAY OBSERVE THE ENTRANCE OF THE VARNISH. ONE OF THESE SIGHT HOLES IS FOR ILLUMINATION OF THE CHAMBER AND THE OTHER IS FOR VISION. IN THE PROCESS OF DRAWING VARNISH INTO THE CHAMBER, IT IS IMPORTANT THAT THE DEGREE OF FOAMING SHOULD BE REDUCED TO A MINIMUM. FOAMING IS DUE TO THE RAPID EVAPORATION OF SOLVENT AND ALSO TO EXPANDING AIR WHICH IS CARRIED OVER WITH THE VARNISH. WHENEVER THIS IS SEEN TO BE EXCESSIVE, A BRIEF OPENING OF THE ATMOSPHERIC VALVE WILL INCREASE THE PRESSURE WITHIN THE CHAMBER TO THE EXTENT THAT MOST OF THE FOAM WILL COLLAPSE. AT ANY RATE, IT IS DESIRABLE TO MAINTAIN A MAXIMUM VACUUM DURING THE ENTRANCE OF THE VARNISH IN ORDER TO GAIN FULL ADVANTAGE OF THIS CYCLE. SPECIFICATIONS SHOULD INDICATE THE MINIMUM VACUUM THAT IS PERMISSIBLE DURING THIS PROCEDURE. VARNISH SHOULD CONTINUE TO ENTER THE CHAMBER UNTIL ALL UNITS ARE COVERED WITH VARNISH, NOT FOAM. THE TIME NECESSARY FOR THIS OPERATION WILL VARY FROM FIVE TO 15 MINUTES, DEPENDING LARGELY ON THE TANK DIMENSIONS. UNDER NO CIRCUMSTANCES SHOULD THE VARNISH COME CLOSER THAN 4" TO THE VACUUM PUMP LINE CONNECTION. A TRAP INSTALLED IN THE PIPE LINE BE-

TWEEN THE VACUUM TANK AND THE CONDENSER VERY OFTEN PREVENTS INSULATING VARNISH FROM ENTERING THE CONDENSER AND PUMP. THIS TRAP ACTS AS A CATCH-ALL FOR SOLID MATERIALS.

SOAKING

"BREAK THE VACUUM BY OPENING THE VALVE TO ATMOSPHERE OR, IF PRESSURE IS NECESSARY, ALLOW THE SPECIFIED PRESSURE OF CO_2 OR OTHER INERT GAS TO DISPLACE THE VACUUM. PRESSURES OF FROM 40 TO 100 LBS. PER SQUARE INCH HAVE BEEN OBSERVED IN PRACTICE. DO NOT USE AIR PRESSURE ABOVE ATMOSPHERIC PARTICULARLY IF LOW FLASH POINT SOLVENTS ARE EMPLOYED. INSULATING VARNISH IS A DIELECTRIC EVEN IN THE WET STATE AND A STATIC CHARGE CAN BE INDUCED THROUGH FRICTIONAL FLOW IN THE PIPE LINE. IF THIS CHARGE IS OF SUFFICIENT MAGNITUDE, SUBSEQUENT DISCHARGE IN A MIXTURE OF AIR AND GAS WOULD BE DANGEROUS. THE GREATER THE AIR PRESSURE, THE MORE THIS MIXTURE APPROACHES THE EXPLOSIVE CONCENTRATION. A FINE MESH METALLIC SCREEN INSERTED IN THE BOTTOM OF THE VACUUM TANK AND PROPERLY GROUNDED TO THE TANK WILL PROBABLY REDUCE THIS DANGER TO A MINIMUM.

"SOAK COILS FOR A LENGTH OF TIME DEPENDENT ON THE CYCLE USED. WITH 40 LBS. PRESSURE PER SQUARE INCH ON THE SURFACE OF THE VARNISH, THE SOAKING PERIOD NEED NOT BE MORE THAN 15 MINUTES. ON AN ATMOSPHERIC SOAK WE HAVE TO RELY TO SOME EXTENT ON CAPILLARY ACTION AND THIS WILL REQUIRE A SOAKING PERIOD VARYING FROM 15 MINUTES TO ONE HOUR. SOAKING IS A VERY IMPORTANT PART OF THE VACUUM CYCLE AND IT IS NOT UNTIL THIS OPERATION THAT PENETRATION IS OBTAINED.

DRAINING

"AFTER THE SOAKING PERIOD THE UNITS SHOULD BE REMOVED FROM THE VACUUM CHAMBER AND ALLOWED TO DRAIN IN THE OPEN AIR, OVER A CATCH BOARD OR THE VACUUM TANK ITSELF, WHICHEVER IS THE MORE PRACTICAL. UNITS ARE SOMETIMES DRAINED UNDER VACUUM IN ORDER TO REMOVE EXCESS VARNISH AND SPEED THE EVAPORATION OF THE SOLVENT. DO NOT ALLOW THE IMPREGNATED UNITS TO DRAIN IN THE VACUUM CHAMBER AT ATMOSPHERIC PRESSURE AS THE SOLVENT VAPORS WHICH SATURATE THE AIR WITHIN WILL WASH DOWN VARNISH ON THE UNITS, THEREBY LESSENING THE BUILD-UP ON THE OUTSIDE OF THE WINDINGS.

BAKING

"TRANSFER THE COILS TO THE BAKING OVEN AND BAKE FOR THE SPECIFIED PERIOD AND AT THE SPECIFIED TEMPERATURE. SOME VACUUM TANKS ARE PROVIDED WITH HEATING FACILITIES AND SOME SPECIFICATIONS REQUIRE THAT BAKING BE DONE IN THE VACUUM CHAMBER. THIS IS, OF COURSE, ONLY POSSIBLE WITH CERTAIN SYNTHETIC-TYPE VARNISHES INASMUCH AS THESE WILL CURE WITHOUT ACCESS TO AIR.

"IN THE EARLY STAGES OF THE BAKING, THE INTRODUCTION OF FRESH AIR AND THE ESCAPE OF FOUL AIR CONTAINING THE SOLVENT VAPORS MUST BE CONSIDERED, NOT ONLY FROM THE STANDPOINT OF A FIRE HAZARD BUT ALSO BECAUSE OF THE DANGER OF THE HOT SOLVENT VAPORS HAVING A WASHING DOWN ACTION ON THE VARNISHED COILS.

"THE QUESTION IS OFTEN RAISED AS TO WHAT WILL HAPPEN TO COILS WHICH ARE UNDER-BAKED. THE ANSWER TO THIS QUESTION WILL BE GOVERNED BY THE DE-

SIGN OF THE COIL, TYPE OF INSULATION EMPLOYED AND THE APPLICATION. FOR EXAMPLE, COILS WHICH ARE TO BE SUBMERGED IN TRANSFORMER OIL, WHEN INSUFFICIENTLY BAKED, WILL NOT OFFER THE DEGREE OF OIL-PROOFNESS NEEDED FOR THIS APPLICATION AND THE RESULT WOULD BE THE FORMATION OF CONSIDERABLE SLUDGE IN THE OIL.

"IN THE EVENT THAT THE INSULATING VARNISH IS UNDER-BAKED, THERE IS A POSSIBILITY THAT SOME SOLVENT MAY BE RETAINED WITHIN THE COIL AND THIS MAY SOFTEN THE ENAMEL TO SOME EXTENT BECAUSE OF THE LONG PERIOD OF TIME PERMITTING SOLVENT ACTION TO OCCUR. IF THIS CONDITION SHOULD EXIST IN A WINDING, WHEN THE COIL ACQUIRES A TEMPERATURE RISE EQUAL TO ITS RATING, THE ACTION OF THE SOLVENT WOULD BE ACCELERATED, FURTHER AGGRAVATING THE SOFTENING ACTION. ON A COIL USED IN AC CIRCUITS, WINDING FAILURE MAY OCCUR AFTER A LAPSE OF TIME. MORE SUCCESSFUL OPERATION MAY BE POSSIBLE ON DC CIRCUITS.

"THE UNDER-BAKING OF HIGH-VOLTAGE COILS MAY RESULT IN AN INSULATING COATING THAT WILL NOT OFFER THE REQUISITE DIELECTRIC STRENGTH. IT IS TRUE THAT THE DIELECTRIC STRENGTH OF MOST INSULATING VARNISHES IS INCREASED AS THE BAKING TIME INCREASES. NOT ALONE THIS, BUT IN THE EVENT THE DEHYDRATION OF THE COIL DURING THE VACUUM IMPREGNATING CYCLE WAS NOT COMPLETE, IT IS IMPERATIVE THAT THE REMAINING MOISTURE BE DRIVEN OFF DURING THE CURING OF THE VARNISH, AS OTHERWISE, ITS PRESENCE WITH THE VARNISH WOULD RESULT IN AN INSULATION OF EXCEEDINGLY HIGH DIELECTRIC CONSTANT. THE UNLOADING OF THE VARNISH FROM ITS PORTION OF THE DIELECTRIC STRESS CAUSES THE SURROUNDING MEDIUM TO TAKE ON MORE THAN ITS PORTION OF THE STRESS. FOR EXAMPLE, IN THE PROCESS OF TREATING 12,000-VOLT COILS IN OUR LABORATORY, IT WAS NOTICED THAT CONSIDERABLE CORONA SURROUNDED UNDER-BAKED COILS WHEREAS ON COILS THAT HAD BEEN GIVEN AN EXTENSIVE BAKING, CORONA WAS ELIMINATED. IN THIS PARTICULAR CASE, THE VARNISH WHICH WAS USED AS AN IMPREGNANT WAS OF SYNTHETIC NATURE AND IT WAS ALSO KNOWN THAT MOISTURE WAS ONE OF THE PRODUCTS OF POLYMERIZATION. IT IS ABSOLUTELY NECESSARY, THEREFORE, TO BAKE ALL HIGH-VOLTAGE EQUIPMENT SO THAT CURING HAS BEEN CARRIED TO AN ADVANCED STATE, THUS INSURING FREEDOM FROM LATER VOLATILIZATION OF SOME OF THE INGREDIENTS.

"EVERY ONCE IN A WHILE, DESIGNS ARE ENCOUNTERED WHERE THE TEMPERATURE RISE MAY EXCEED 55°C. UNDER-BAKING OF THESE COILS MAY RESULT IN AN INSULATION WHICH IS THERMOPLASTIC. IN OTHER WORDS, WHEN THE OPERATING TEMPERATURE IS REACHED, THE VARNISH MAY SOFTEN TO SUCH AN EXTENT THAT ACTUAL FLOW OF VARNISH MAY OCCUR. IN THE TREATMENT OF THESE UNITS, IT HAS ALWAYS BEEN SUGGESTED THAT THE BAKING TEMPERATURE BE SOMEWHAT IN EXCESS OF THE OPERATING TEMPERATURE. THIS IS TO SAY, IF THE FINAL OPERATING TEMPERATURE OF A COIL IS 250°F, SUCH A COIL SHOULD BE BAKED AT LEAST AT 275°F., PREFERABLY AT 300°F.

"LET US SUMMARIZE THE ADVANTAGES OF PROPER BAKING:

1. RESULTS IN IMPROVED OIL-PROOFNESS.
2. INCREASE IN DIELECTRIC STRENGTH. THE WET DIELECTRIC STRENGTH (IN THE PRESENCE OF MOISTURE) IS GREATLY INCREASED WITH BAKING TIME. INCREASED CORONA RESISTANCE.
3. THE RESISTANCE TO HAZARDOUS OR CORROSIVE ELEMENTS INCREASES.

THE JOHN C. DOLPH COMPANY ARTICLE CONTINUED . . . . . .

4. The rigidity of the winding improves, permitting operation under considerable vibration.

5. Freedom from electrolysis.

6. Elimination of volatizing ingredients."

THESE ARE SPECIFICATIONS FOR A TYPICAL PHENOLIC MATERIAL (GRADE XXXP) WHICH TEKTRONIX USES FOR TERMINAL BOARDS . . . . . .

PROPERTIES (AVERAGE VALUES)

Thickness, in inches	.015 to ¼
Color	Natural/Black
Tensile Strength, psi	7,000
Flexural strength, psi	15,000
Compressive strength, psi.	25,000
Impact strength, ft. lbs. (Izod)	0.4
Moisture absorption per cent, 24 hrs.	1.0
Dielectric strength, volts per mil	650
Power factor at 1,000 KC	.027
Dielectric constant at 1,000 KC.	4.5
Loss factor at 1,000 KC	0.12
Heat resistance (continuous), degrees F	250
Heat resistance (short time), degrees F	275

Some additional design considerations:

Density	1.35
Specific Heat	0.30-0.40 BTU/lb.
Linear expansion coefficient	.000025 per in. per deg. C.
Thermal conductivity.	approx. 2 BTU per sq. ft. per hr. per in. per degree F.

Also see tables published in NEMA Standards for Laminated Products for maximum and minimum values of all grades for various thicknesses.

DESIGN REQUIREMENTS . . . . . . AND SOME SPECIFIC EXAMPLES

At Tektronix, individual instrument requirements influence design decisions in many ways. In one case, particularly high regulation is required perhaps on only one winding. In some cases, external field may have to be kept at what might be considered "unreasonably low" levels. Chassis <u>space</u> may be at a premium in some models -- even though there's adequate <u>height</u>. In other instances, it may be necessary to mount the transformer where it receives little or no air circulation. We're always faced with the problem of keeping costs at the lowest possible levels consistent with our high quality and performance standards.

These are but illustrative of the many variables that have to be considered in transformer design. We'd also like to point out here that our power ratings are for use in a specific instrument and conditions of operation and are not necessarily true if the transformers are used for other purposes.

Obviously, it's impractical to attempt a text-book approach to all the ramifications of transformer design -- most particularly in a quasi-technical publication such as this manual. But we'll offer certain examples that will be helpful to an understanding of some of the design criteria and approaches that are involved.

CONSIDERING CORE DESIGN

The following examples will assume the use of 0.014" (29°) M6 grade oriented silicon steel laminations (scrapless). We'll use the same flux density in each case. These examples should show the inter-relation of some of the factors we've previously mentioned (in the General Information section) in actual design.

<u>THE PROBLEM</u>: To design a transformer to operate from a 117-volt sixty-cycle line to supply a secondary load of 20 volts at five amperes. The unit shall be of the open type (Tektronix type C). We'll consider three design approaches:

Design No. 1 will use a three inch stack of 1" scrapless.

Design No. 2 will use a 7/8" stack of 1-½" scrapless.

Design No. 3 will use a 1.5" stack of 1¼" scrapless.

The flux density, assuming a stacking factor of .9, will be 11,480 gauss. Thus we'll have the same core loss per pound in each example.

Most of the cooling from transformers of this type takes place in direct radiation and conduction from the exposed core surface .....

Design No. 1 will have approximately 27 square inches of surface.

Design No. 2 will have approximately 14 square inches of surface.

Design No. 3 will have approximately 18 square inches of surface.

FURTHER INFORMATION ON CORE DESIGN . . . . . .

IN DESIGN NO. 1, the winding will be:

Primary ..... 200 turns #21
Secondary ... 36 turns 2#17

(Note that this is 600 turns per square inch of cross-section.)

A six per cent allowance is made for leakage reactance and IR drop in the windings, accounting for 36 turns instead of the empirical 34 turns in the secondary.

The primary has 200 turns of 812 circular mill wire (see table, Page 24), or 162,000 circular mill turns. The secondary has 36 turns of 4,100 circular mill wire, or 147,600 circular mill turns.

Primary 162,000
Secondary ... 147,600

Total ..... 310,000 (approx.) circular mill turns. This is considered reasonable for the 3/4 square inches of space in the window. Refer to the illustration on Page 11, where we've stated that lamination sizes are referred to by tongue width (1" in this case) and that tongue lengths and window widths are 1-1/2 and 1/2 times the tongue width, respectively. Therefore, (1.5 x 1) x (.5 x 1) = .75 square inches of window space.

The mean length of the primary turns will be 9". The total primary winding equals 150 feet, or 1.90 ohms. The secondary mean turn is 11" for a total of 396", or .083 ohms.

Calculating the total copper loss -- or I^2R -- we have:

Primary ..... .86 amperes plus the magnetizing current estimated at .14 amperes. This is equal to 1.90 watts loss in the primary.

Secondary ... 5.0 amperes, which gives us 25 x .083 ohms, or 2.08 watts.

Total copper loss is, therefore:

Primary 1.90
Secondary ... 2.08

3.98 watts

Add the estimated core loss .... 2.52 watts

Total Estimated Loss .... 6.50 watts

Since the output is 100 watts, we have an efficiency factor of 94 per cent.

The weight of copper is .79 lbs.

The weight of the core is 4.2 lbs.

IN DESIGN NO. 2, WE CAN TABULATE THE DESIGN CONSIDERATIONS, THUS:

WINDING	NO. OF TURNS	WIRE SIZE	CIRCULAR MILLS	TOTAL LENGTH	OHMS	WATTS LOSS
PRIMARY	458	#21	371,896	238 FT.	3.05	3.05
SECONDARY	83	2#17	340,300	65 FT.	.164	4.1
TOTALS			712,000 (APPROX.) CIRCULAR MILL TURNS			7.15

ADD: ESTIMATED CORE LOSS 1.70

TOTAL LOSS ... 8.85 WATTS

WITH AN OUTPUT OF 100 WATTS, WE HAVE AN EFFICIENCY FACTOR OF 91 PER CENT.

THE WEIGHT OF COPPER IS 1.4 LBS.

THE WEIGHT OF THE CORE IS 2.8 LBS.

IN DESIGN NO. 3, WE'LL TABULATE SIMILAR CONSIDERATIONS, THUS:

WINDING	NO. OF TURNS	WIRE SIZE	CIRCULAR MILLS	TOTAL LENGTH	OHMS	WATTS LOSS
PRIMARY	320	#21	259,840	180 FT.	2.3	2.3
SECONDARY	58	2#17	237,800	45 FT.	.11	2.75
TOTALS			498,000 (APPROX.) CIRCULAR MILL TURNS			5.05

ADD: ESTIMATED CORE LOSS 2.00

TOTAL LOSS ... 7.05 WATTS

WITH AN OUTPUT OF 100 WATTS, WE HAVE AN EFFICIENCY FACTOR OF 93 PER CENT.

THE WEIGHT OF COPPER IS 1.0 LBS.

THE WEIGHT OF THE CORE IS 3.33 LBS.

ANALYZING THE FOREGOING DATA, WE SEE THAT:

DESIGN NO. 1 HAS THE GREATEST SURFACE AREA AND THE LOWEST LOSS, AND IS THE MOST CONSERVATIVELY RATED. IT WILL ALSO HAVE THE BEST VOLTAGE REGULATION. THE COST OF STEEL WILL BE HIGHER, EVEN THOUGH IT'S LIGHTER IN WEIGHT THAN THE OTHER TWO DESIGNS.

DESIGN NO. 2 HAS THE HIGHEST LOSS AND THE LEAST EXPOSED CORE AREA. IT WILL RUN HOTTER THAN EITHER OF THE OTHER TWO DESIGNS. ITS REGULATION WILL BE THE POOREST OF THE THREE EXAMPLES.

CORE DESIGN, CONTINUED . . . . . .

DESIGN NO. 3 HAS ALMOST THE SAME ELECTRICAL EFFICIENCY AS NO. 1, BUT HAS ONLY 76 PER CENT OF THE SURFACE AREA. EXPERIENCE INDICATES IT WOULD SHOW A 10 DEGREE RISE OVER NO. 1.

HAD THE CROSS SECTION AREA BEEN KEPT THE SAME IN ALL THREE EXAMPLES, WE WOULD FIND THAT A SQUARE CROSS SECTION WOULD GIVE THE LOWEST COPPER LOSS AND THE BEST REGULATION. THE LARGER LAMINATIONS, WITH MORE WINDOW SPACE, WOULD PERMIT THE USE OF LARGER WIRE -- THUS, WE'D HAVE LESS COPPER LOSS. SPACE AND WEIGHT WOULD, THEREFORE, BECOME THE LIMITING FACTORS.

NOTE THAT INCREASING THE STACK HEIGHT TO MORE THAN THREE TIMES THE TONGUE WIDTH PRESENTS WINDING PROBLEMS.

WITH ORIENTED SILICON STEEL AT NORMAL FLUX DENSITIES, THE CORE LOSSES ARE VERY LOW. THE LIMITATION ON THE CORE IS ITS FLUX HANDLING CAPACITY (REGULATION AND EXTERNAL FIELD) RATHER THAN LOSS. THUS, THE OVERALL PERMEABILITY OF THE CORE STRUCTURE IS THE IMPORTANT CONSIDERATION.

THE OTHER LOSS FACTOR -- THE COPPER OR CONDUCTOR I^2R IS KEPT LOW BY:

A. USING THE LARGEST CONDUCTOR POSSIBLE;

B. A CAREFUL CHOICE OF INSULATION TO AVOID WASTING WINDOW SPACE;

C. CARE IN WINDING.

THE COPPER UTILIZATION FACTOR (OR, THE PERCENTAGE OF COPPER CROSS SECTION TO THE WINDOW AREA) IS THE FIGURE OF MERIT. THIS GENERALLY INCREASES WITH THE WINDOW SIZE. IN OUR EVERY-DAY WORK, WE CALCULATE THE NUMBER OF CIRCULAR MILL TURNS TO EVALUATE THE PRACTICABILITY OF A CONTEMPLATED WINDING FOR A GIVEN CORE. GENERALLY, THE HIGHER THE SECONDARY VOLTAGE, THE LOWER THE COPPER AREA, SINCE THE RATIO OF INSULATION TO COPPER INCREASES.

WE'VE PREVIOUSLY DISCUSSED INCREASING THE OVERALL EFFICIENCY OF CORES USING STAMPED LAMINATIONS OF ORIENTED GRADE SILICON STEEL OR OTHER HIGH-PERMEABILITY ALLOYS. TO REITERATE:

A. THE FIRST FACTOR TO BE CONSIDERED IS THE PERMEABILITY OF THE MATERIAL ITSELF AT OPERATING FLUX DENSITIES. SOME MATERIAL IS ANNEALED AND PROCESSED TO OBTAIN HIGH INITIAL PERMEABILITY, OR HIGH PERMEABILITY AT SAY 50 GAUSS, RATHER THAN HIGH PERMEABILITY IN THE 12,000 TO 18,000-GAUSS REGION.

B. TO INSURE MAXIMUM STACKING FACTOR, THE MATERIAL MUST BE OF UNIFORM THICKNESS AND HAVE GOOD SURFACE CHARACTERISTICS. THE LAMINATIONS MUST BE FLAT AND BURR-FREE.

C. ACCURATE STAMPINGS, FLAT ACROSS THE ENDS OF THE SIDE LEGS AND TONGUE AND WITH SMOOTH SIDES ON THE I'S, ARE REQUIRED TO KEEP AIR GAP AT A MINIMUM. THE LAMINATIONS MUST BE CAREFULLY AND ACCURATELY STACKED.

WE'VE ALSO DISCUSSED IMPROVING PERFORMANCE BY CHANGING THE SHAPE OF THE LAMINATIONS, AND HAVE ILLUSTRATED THE ADVANTAGES OF THE TEKTRONIX SPECIAL 1-3/8"L LAMINATION OVER A STANDARD SCRAPLESS LAMINATION.

SOME GENERAL CONSIDERATIONS WHICH PERTAIN TO TEKTRONIX STANDARD POWER TRANSFORMERS . . . . . .

CERTAIN WINDINGS MUST BEAR DEFINITE PHASE RELATIONSHIPS TO OTHERS. THESE ARE CALLED OUT ON OUR WINDING SHEETS AND ARE CHECKED ACCORDINGLY WHEN THE UNITS ARE TESTED.

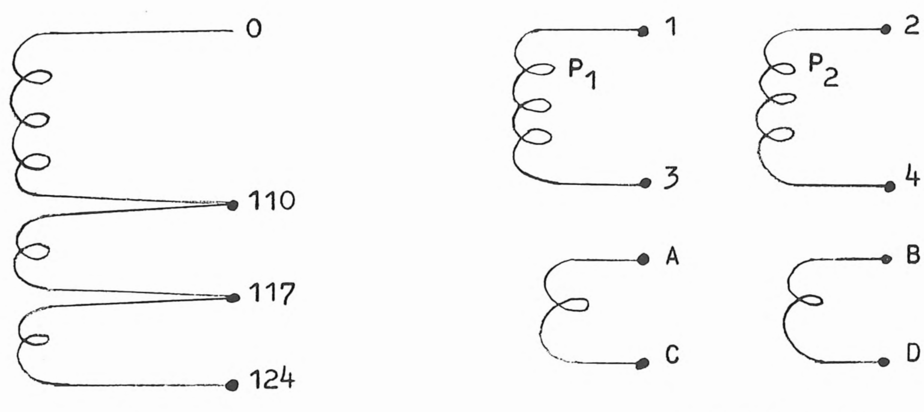
PRACTICALLY ALL OF THE TRANSFORMERS WE NOW PRODUCE HAVE ELECTROSTATIC SHIELDS OF ONE OUNCE PRESSURE-SENSITIVE COPPER BETWEEN THE PRIMARY AND SECONDARY WINDINGS.

IN OUR PREVIOUS DESIGN EXAMPLES, WE INDICATED A RESISTIVE LOAD. IN ACTUAL PRACTICE, OUR COMBINATION PLATE AND FILAMENT (POWER) TRANSFORMERS ARE USED UNDER ABOUT 90 PER CENT POWER FACTOR LOAD CONDITIONS.

IN THE EXAMPLES OF TYPICAL TRANSFORMERS WHICH FOLLOW, WE HAVE NOTED THE DC LEVEL AT WHICH THE WINDING OPERATES, RATHER THAN ITS TERMINAL VOLTAGE. IT'S GOOD DESIGN PRACTICE TO KEEP THE VOLTAGE GRADIENT BETWEEN WINDINGS AS LOW AS PRACTICAL. THUS, THE HIGH VOLTAGE SECONDARIES ARE GENERALLY WOUND WITH THE NEGATIVE SUPPLY FIRST, THEN NEXT THE LOWEST POSITIVE DC SUPPLY, AND SO ON.

WE SHOW EXAMPLES OF OUR #120-064 AND #120-096 TRANSFORMERS AS TYPICAL OF OUR TAPPED PRIMARY TYPE. THEY'RE SOMETIMES REFERRED TO AS EXPORT MODELS. WHEN TERMINAL BOARDS USING OUR STANDARD FORK-TYPE TERMINALS ARE USED, WE USE SEPARATE "BUCK-BOOST" WINDINGS, WHICH CAN BE INSERTED IN SERIES WITH THE PRIMARIES.

CONSIDER THE #120-037 TRANSFORMER. THE TWO "BUCK-BOOST" WINDINGS WOULD CONSIST OF 10 TURNS EACH. THIS, IN ESSENCE, GIVES US THE CHOICE OF A 162T, 172T OR 182T PRIMARY (324, 344, OR 364 IN SERIES). THUS, OUR MEAN PRIMARY VOLTAGES ARE 110, -117, 124-, 220, -234 AND 248 INSTEAD OF THE REGULAR 117-234 VOLT STANDARD.



TAPPED PRI
(TWO IDENTICAL PRI ARE USED)

"BUCK-BOOST"
AC AND BD ARE EQUAL TO SIX PER CENT OF PRI

MORE ON TRANSFORMER DESIGN . . . . . .

The #120-013 transformer was designed as a replacement for the commercial units used in the original 511 oscilloscope. The original units, from five different sources, all had a high failure rate -- perhaps 100 per cent. This was due to corona damaging the insulation associated with the outside of the 1532 turn winding (which is stacked onto one-half of the main high-voltage secondary winding and is used to supply positive and negative 1680 volts through two type 2 x 2 rectifiers) and the elevated filament windings.

Our replacement transformers were layer-wound, using 0.002" Kraft interlayer insulation on the high-voltage secondaries and 0.004" elsewhere. Barriers were one 0.004" Kraft plus one 0.005" varnished cotton cloth. In addition, three layers of 0.007" glass cloth were used to isolate the three elevated filament windings. The glass proved to be an excellent corona-resistant barrier.

During development, the units were given accelerated aging tests by operating them under load at high primary voltage. Induced voltage tests were made by operating primary at 180 volts at 100 CPS. The prototypes met all tests without failure, and this design has proved itself in service.

Let's take a look at some of the features of this unit:

2-1/4" stack of 1-3/8" scrapless laminations

Material -- M15 grade steel

Circular Mill Turns -- 656,000

B Max (117 volts/60 CPS) -- 11,100 gauss

Winding	Volts	Turns	Wire Size	
Primary	117	220	#20	
Secondary	416 - .125A (D.C.)	832 - 0 - 832	#28	
Secondary	765 - .005 ampere (DC)	1532	#35	
Secondary	2.5 - 2 ampere	5	#20	)
Secondary	2.5 - 2 ampere	5	#20	)
Secondary	6.5 - .6 ampere	13	#23	) Elevated
Secondary	5.2 - 4 ampere	10	#17	)

Here are some of the features of our #120-017 Main Power Transformer for the 511A oscilloscope:

2-1/2" stack of 1-1/2" scrapless laminations - originals

Material - M15 steel

Circular Mill Turns -- 784,450

B Max (117 volts/60 CPS) -- 11,000 gauss

THE FEATURES OF THE #120-017 MAIN POWER TRANSFORMER, CONTINUED . . . . . .

Winding	Volts	Turns	Wire Size
Primary	117/234	184	#20
Secondary	260 - .25 amperes (DC)	432 - 0 - 432	#25
Secondary	6.5 - .6 amperes	0-11	#23
Secondary	260 - .035 amperes	432 - 0 - 432	#35
Secondary	6.5 - .6 amperes	0-11	#23
Secondary	6.5 - .6 amperes	0-11	#23
Secondary	6.5 - .3 amperes	0-11	#25
Secondary	6.5 - .45 amperes	0-11	#23
Secondary Calibrator		0-58	#30
Secondary	5.2 - 6 amperes	0-9	3#20
Secondary	6.5 - 10.5 amperes	0-11	3#17

In destruction tests of this unit:

All windings shorted; voltage applied from windings to ground.

BREAKDOWN

A. High voltage secondary to ground at 2800 volts R.M.S.;

B. 10.5A secondary to ground at 4200 volts;

C. CRT filament to ground at 8400 volts. *

*This breakdown occurred between lead and back of adjacent terminal. After clearing, withstood 10,000 volts for one minute.

Normal input watts to this transformer -- 270

Temperature rise -- 50°C (no fan).

In the prototypes, a hot spot was noticed in the main voltage secondary. To correct this, the high voltage secondary was wound next to the core. A shorter mean turn reduced the I^2R and also improved voltage regulation. No excessive heating occurs in the primary. It should be noted that a large input capacitor is used in the filter circuit in this instrument, making for a high peak current. To get good voltage regulation, the resistance of the winding must be kept small. These primaries and main high-voltage secondaries are random wound in two equal Pi's.

NOW, CONSIDER THE #120-012 POWER TRANSFORMER FOR THE 315 'SCOPE . . . . . .

These are the design features:

2" stack of 1-1/2" scrapless

Material - M6

Circular Mill Turns - 721,000

B Max (117 volts/60 CPS) - 12,350

Winding	Volts	Turns	Wire Size
Primary	117/234	0 - 204 - 0 - 204 -	#22
1 Secondary	220 - .125 amperes (DC)	0 - 408	#27
2 Secondary	140 - .310 amperes (DC)	0 - 260	#24
3 Secondary	130 - .290 amperes (DC)	0 - 240	#24
4 Secondary	130 - .150 amperes (DC)	0 - 240	#27
	6.5 - 6 amperes	0 - 12	2#18
	6.5 - 4 amperes	0 - 12	#18
	6.5 - 3.5 amperes	0 - 12	#18
	6.5 - 2.4 amperes	0 - 12	#18 (static shield under/over Teflon barrier) original
	37.5 Fan	0 - 68	#27

Here are some of the details on the #120-037 - 560 VA - power transformer for the 535 oscilloscope:

The primary winding is at 117/234 volts, with 0 - 172 - 0 - 172 turns, using #18 wire.

Shield:

Winding	Volts	Turns	Wire Size
Secondary 1	-150 - .2 amperes (DC)	307	#25
Secondary 2	+100 - .55 amperes (DC)	225	#21
Secondary 3	+225 - .42 amperes (DC)	196	#22

THE FEATURES OF THE #120-037 - 560 VA - POWER TRANSFORMER, CONTINUED . . . . . .

Winding	Volts	Turns	Wire Size
Secondary 4	+350- .24 amperes	182	#24
Secondary 5	+500 - .085 amperes	314	#28
Secondary 6	(-2000 CRT Fil)	10	#23
Secondary 7	6.5 - 4 amperes	10	#17
Secondary 8	6.5 - 4 amperes	10	#17
Secondary 9	6.5 - 4 amperes	10	#17
Secondary 10	6.5 - 7 amperes	10	3#19
Secondary 11	6.5 - 8 amperes	10	2#17
Secondary 12	6.5 - 6 amperes	10	3#20

There is a 2.4" stack of 1-3/8"L laminations, layer wound.

Material - M6

Circular Mill Turns -- 1,280,000

B Max (117 volts/60 CPS) -- 13,200

The insulation in this unit is comprised of 0.010" rag paper (used in barriers in addition to 0.007" Fibremat), and 0.C04" Kraft.

Destruction tests included the following:

A. All windings to ground - 3,000 volts, AC, failures on margin, balance 4,000 volts to ground.

B. 4,000 volts winding to winding.

Originally, this transformer was wound on a 2.9" stack of LE type laminations, using M15 grade 26° material. It had the same number of turns as listed above. Its B Max was 11,000 gauss.

These are some of the details on the #120-064 power transformer for the 316 oscilloscope:

1.5" stack of 1-1/2" scrapless laminations.

Material -- M6

Circular Mill Turns -- 854,000

Since the winding details, etc. are similar to those listed for the #120-096 unit (following), we've omitted them. Details on electrical operation are typical of others using full-wave rectifiers, and supplying heaters.

SOME OF THE DETAILS ON THE #120-064 POWER TRANSFORMER, CONTINUED . . . . . .

VOLTS INPUT	I AMPS	W POWER	V.A.	P.F.
100	2.3	213	230	.926
105	2.36	228	248	.919
117	2.53	267	295	.905
125	2.63	299	329	.908
130	2.71	320	353	.906

AND THESE ARE SOME OF THE DETAILS OF THE #120-096 TRANSFORMER, WHICH ILLUSTRATES THE TAPPED PRIMARY TYPES:

1-1/4" STACK OF 1-1/2" SCRAPLESS LAMINATIONS

MATERIAL -- M6

CIRCULAR MILL TURNS -- 826,500

B MAX -- 13,200 GAUSS

286T-105 VOLTS; 305T-117 VOLTS; 324T-125 VOLTS.

THE PRIMARY WINDING IS AT 117/234 VOLTS, WITH 286-305-324 TURNS AND 19-38-324 TURNS, BOTH USING #22 WIRE.

SHIELD:

SECONDARY	-150 DC	555 TURNS	#27 WIRE
SECONDARY	+150 DC	375 TURNS	#27 WIRE
SECONDARY	+300 DC	565 TURNS	#27 WIRE
SECONDARY	6.5/.6	18 TURNS	#23 CRT FILAMENT
SECONDARY	6.5/.6	18 TURNS	#23 WIRE
SECONDARY	6.5/4.0	18 TURNS	#17 WIRE
SECONDARY	6.5/3.0	18 TURNS	#18 WIRE
SECONDARY	6.5/3.2	18 TURNS	#18 WIRE

SPACE-SAVING POLYESTER WEB IS USED FOR BARRIERS IN THIS UNIT, INCLUDING BARRIERS AROUND OUR CRT FILAMENT WINDINGS.

ABOUT OSCILLATOR TYPE TRANSFORMERS . . . . . .

An oscillator transformer is used to furnish accelerating voltage (s) for the Cathode Ray Tube. Its primary is generally associated with a tube to form a Hartley oscillator circuit. The secondary voltage or voltages are then rectified as desired.

Early models of Tektronix 'scopes used oscillator supplies, operating at from two to four k.c. These used cores of conventional silicon iron, and were quite efficient.

These have been superseded in later models with supplies operating in the 40 k.c. area, which use Ferrite cores. This permits much smaller and lighter units.

In both types, the transformer primary must act in conjunction with the tank capacitor to form the oscillator "tank" circuit. A large air gap is needed to obtain a satisfactory "Q" and primary inductance (maximum "Q" is obtained when core losses equal the copper loss). Consideration must also be given to keeping the "C" of the secondary windings low. Leakage flux and leakage reactance (high primary to secondary turns ratio) both contribute to poor voltage regulation.

The small size of these units, and the high voltages encountered, create an ever-present corona problem.

For the high frequency types, wax impregnation is the most economical. It provides adequate corona protection, in most cases.

Ferrite core materials are ceramic in nature, containing iron, zinc, nickel, copper and/or other metals. A typical ferrite has these characteristics:

Initial permeability @ 1 m.c./sec. 250

Maximum permeability 1100

Saturation flux density, in gauss 4200

Residual magnetism, in gauss 2700

Coercive force, in Oersteds 2.1

Temperature co-efficient of the initial permeability -- in %/^{o} C .... .40

Curie point in +^{o} C 330

(Curie point "CP" = temperature at which a material becomes non-magnetic -- i.e., the temperature where initial permeability drops to a 10 per cent of its room temperature value. The "CP" of some ferrites is as low as 70 degrees C)

Loss Factor:

$\frac{1}{\mu_o Q}$ . . . . . . @ 1 m.c./sec. 0.00007

@ 5 m.c./sec. 0.0008

(μ_o = initial permeability)

TEKTRONIX TRANSFORMERS . . .

THEIR DESIGN AND MANUFACTURE

SECTION I

PART 3 - DETAIL INFORMATION ON MANUFACTURING PROCESSES

TABLE OF CONTENTS
SECTION I

PART 3 - DETAIL INFORMATION

PREFACE

THIS MANUAL IS NOT A COMPENDIUM OF ALL OUR SKILLS, KNOWLEDGE AND LORE IN THE DESIGN AND MANUFACTURE OF THE TRANSFORMERS USED IN TEKTRONIX OSCILLOSCOPES AND ACCESSORIES.

THIS IS PARTICULARLY TRUE OF PART 3, WHICH DEALS WITH CERTAIN PROCESSES AND DETAILS OF TRANSFORMER MANUFACTURING. ALTHOUGH WE'VE STANDARDIZED MANUFACTURING PROCEDURES AND METHODS TO A HIGH DEGREE, IT'S OBVIOUSLY IMPOSSIBLE TO RECORD ALL THESE IN DETAIL IN A LIMITED DOCUMENT SUCH AS THIS -- OR, IN FACT, ANY DOCUMENT.

SOLUTIONS TO MANY OF OUR DAY-TO-DAY PROBLEMS AS WELL AS MANY OF OUR IMPORTANT MANUFACTURING DECISIONS ARE BASED NOT ONLY ON PREVIOUS EXPERIENCE AND EXPERIMENT -- TOGETHER WITH "TEXTBOOK" KNOWLEDGE -- BUT ALSO ON AN INTUITIVE APPROACH TO PROBLEMS FOR WHICH THERE IS NO SPECIFIC PRECEDENT.

THE FOLLOWING PAGES WILL GENERALLY DESCRIBE THE MAJOR ASPECTS OF TRANSFORMER MANUFACTURING. WE'VE ALSO INCLUDED MANY DETAIL PROCESS SHEETS AND INSTRUCTIONS TO ILLUSTRATE SOME OF OUR PROCEDURES.

THIS IS THE STRUCTURE OF THE TRANSFORMER MANUFACTURING DEPARTMENT . . . . . .

DEPARTMENT MANAGER

Department Secretary

DEPARTMENT ENGINEER

Technician

UNIT MANAGER

COILS GROUP MANAGER	PRE-PRODUCTION GROUP MANAGER	SCHEDULER Q.C. COORDINATOR	XFORM. WINDING GROUP MANAGER	XFORM ASSEMBLY GROUP MANAGER	STACKING & IMPREGNATION GROUP MANAGER
Working Asst. Group Mgr.	Maint. Mech.		Working Ass't. Group Manager	Working Ass't. Group Manager	Working Ass't. Group Manager
Instructor	Draftsman		Instructor	Instructor	Instructor
Coil Winder/ Finishers	Xform Winder/ Assembler		Xformer Winder	Xformer Assembler	Lamination Stacker
			Utility	Utility	Impregnator

ABOUT TRANSFORMER ENGINEERING AND PRE-PRODUCTION . . . . . .

THE TRANSFORMER DEPARTMENT ENGINEERING SECTION DESIGNS ALL TEKTRONIX REGULAR PRODUOTION TRANSFORMERS. THEY CONVERT THE REQUIREMENTS OF THE INSTRUMENT ENGINEER INTO TRANSFORMER DESIGN DATA. THE DEPARTMENT'S PRE-PRODUCTION GROUP USES THIS DATA TO BUILD THE WORKING MODELS NECESSARY TO ACCOMPANY THE INSTRUMENT THROUGH ITS VARIOUS STAGES PRIOR TO REGULAR PRODUCTION.

AT THIS STAGE, THE TRANSFORMER DEPARTMENT GATHERS THE PRODUCTION PROCESS SHEETS, INSPECTION CARDS AND DATA ON LABOR AND MATERIAL REQUIREMENTS. WHEN NEW MATERIALS OR ITEMS ARE TO BE USED, MATERIAL CONTROL ASSIGNS THE NECESSARY NEW TEK PART NUMBERS. THE TRANSFORMER DEPARTMENT ENGINEERS NOTE ALL SPECIFICATIONS PERTINENT TO A PARTICULAR TRANSFORMER ON THE TRACING OF THE TRANSFORMER DRAWING, WHICH IS MAINTAINED IN THE DEPARTMENT'S FILES. MATERIALS TO BE USED ARE EITHER WITHDRAWN FROM STOCK, OR PURCHASED (IF A NEW ITEM), OR ORDERED FROM METALS FABRICATION IF IT'S A SHOP-MADE OR SHOP-PROCESSED ITEM.

ACCEPTANCE OF THE TRANSFORMER BY THE INSTRUMENT ENGINEERS IS THE KEY TO "GO REGULAR". MATERIAL CONTROL ASSIGNS A TEKTRONIX TRANSFORMER NUMBER (120-XXX). THE TRANSFORMER DEPARTMENT ROUTES CHECKED AND APPROVED BILLS OF MATERIALS, LABOR REQUIREMENTS AND DRAWINGS THROUGH THE MATERIALS CONTROL GROUP. MATERIALS CONTROL IS RESPONSIBLE FOR ALERTING THE PURCHASERS, SCHEDULERS AND LABOR REQUIREMENTS GROUPS WHO, IN TURN, COORDINATE THE TRANSFORMER SUB-PARTS TO THE INSTRUMENT SCHEDULE. THE ROUTED AND APPROVED COPY OF THE TRANSFORMER DRAWING IS RETURNED TO THE TRANSFORMER DEPARTMENT FOR PERMANENT FILING.

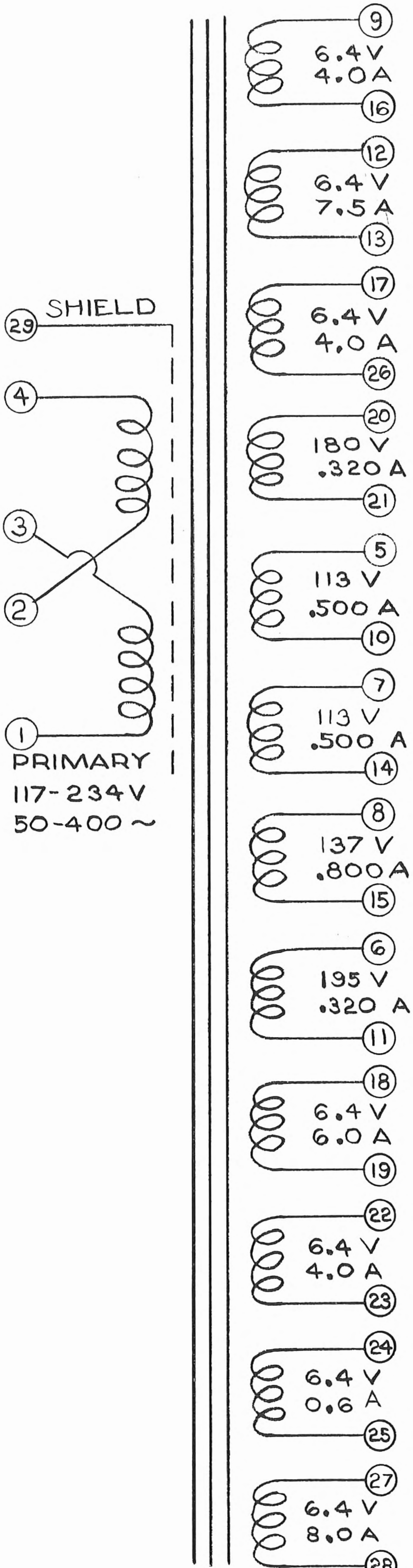
PRIOR TO RECEIPT OF A PILOT-PRODUCTION ORDER FOR THE TRANSFORMER, THE DEPARTMENT PRE-PRODUCTION GROUP FURNISHES THE MANUFACTURING GROUPS ALL NECESSARY PROCESS SHEETS AND TOOLING REQUIREMENTS.

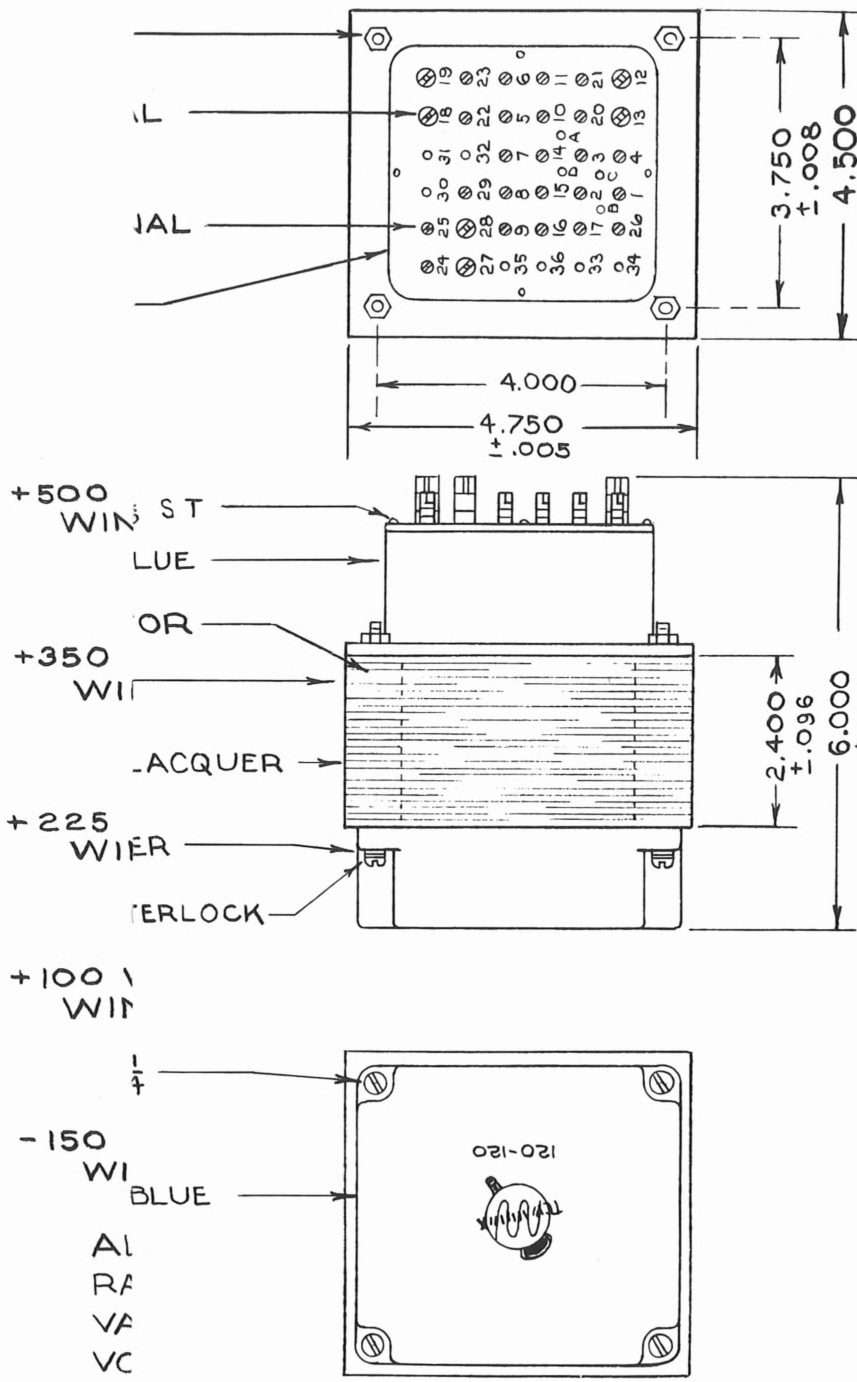
MODIFICATIONS TO EXISTING TRANSFORMERS FOLLOW VIRTUALLY THE SAME PROCEDURE AS A NEW ITEM.

THE TRANSFORMER DEPARTMENT ENGINEERING SECTION NOW CONSISTS OF THE TRANSFORMER ENGINEER AND A TECHNICAL ASSISTANT. THE PRE-PRODUCTION GROUP IS MADE UP OF A GROUP MANAGER AND SKILLED MANUFACTURING WORKERS, INCLUDING A DRAFTSMAN AND A MAINTENANCE MECHANIC.

IN ADDITION TO BEING RESPONSIBLE FOR PREVENTIVE MAINTENANCE, THE MAINTENANCE MECHANIC DESIGNS AND/OR BUILDS THE VARIOUS JIGS AND FIXTURES REQUIRED FOR MANUFACTURING PURPOSES.

THE COMPLEXITIES OF TRANSFORMER ENGINEERING AND PRE-PRODUCTION WORK DICTATE THAT THE PERSONNEL MAKING UP THESE GROUPS HAVE A THOROUGH KNOWLEDGE OF TRANSFORMER DESIGN AND THE MATERIALS AND MANUFACTURING PROCESSES USED IN TEKTRONIX INSTRUMENTS. OTHER ESSENTIALS ARE THE TEMPERAMENT TO PROPERLY REACT TO CHANGE AND THE ABILITY TO OPERATE SELF-SUFFICIENTLY.





INSUL
FOR 4

TEKTRONIX, INC. PORTLAND, OREGON, U.S.A.			
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ICATION NOTICE		SCALE:	ENGR:
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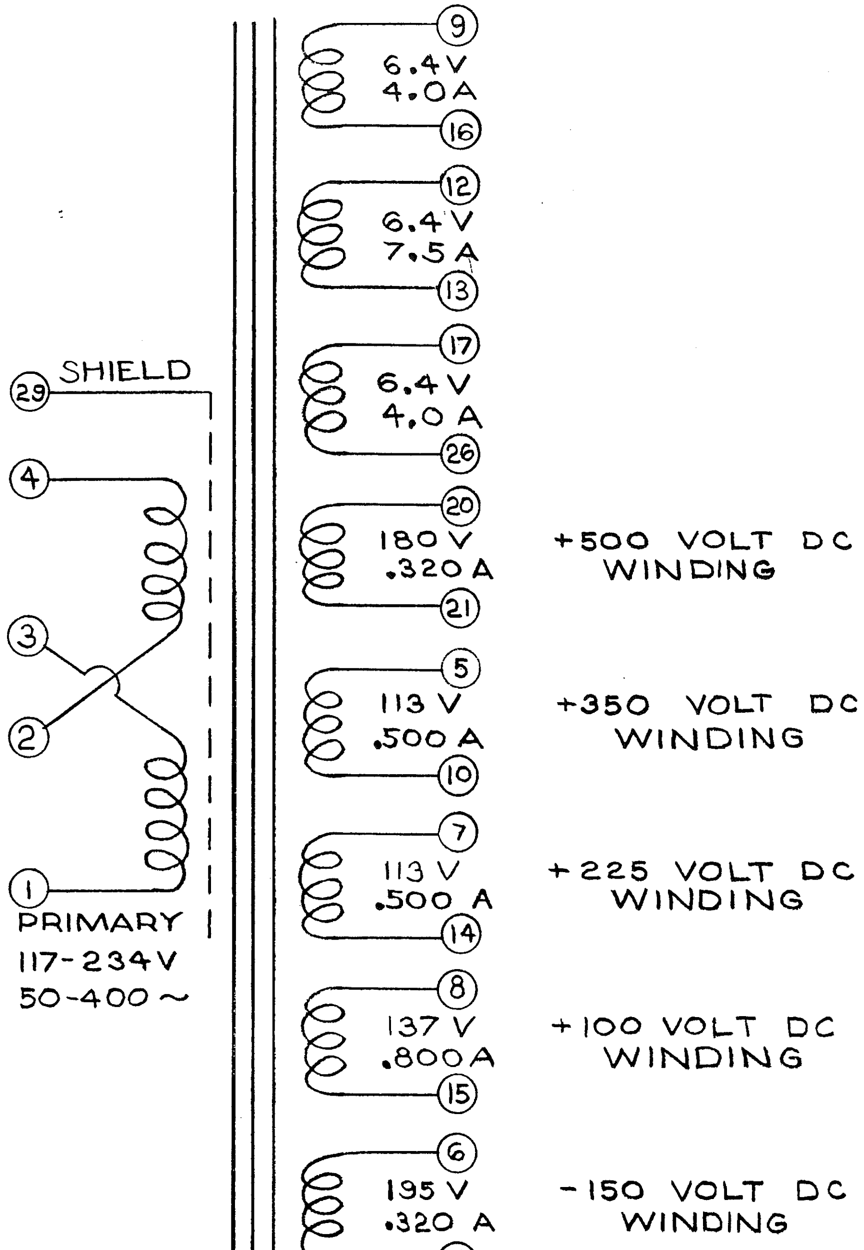
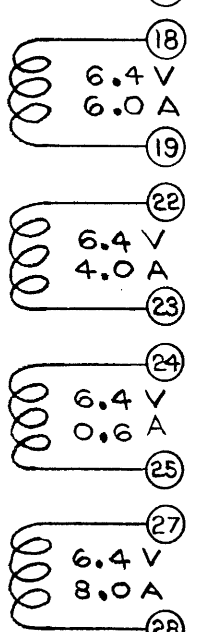
	DATE	PART NO.	DRG. NO.
	BY	120-120	B-1723

DO NOT SCALE DRAWING

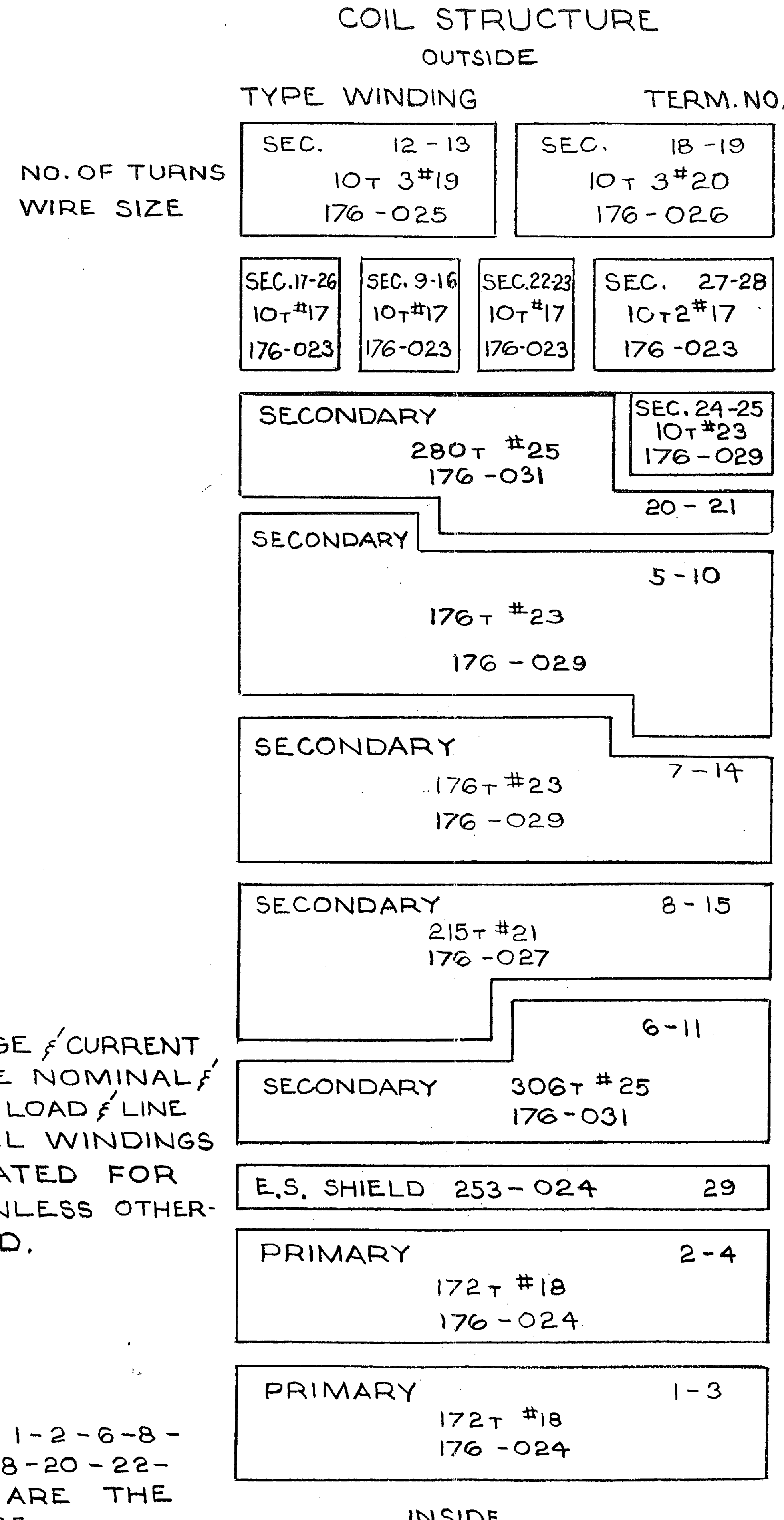


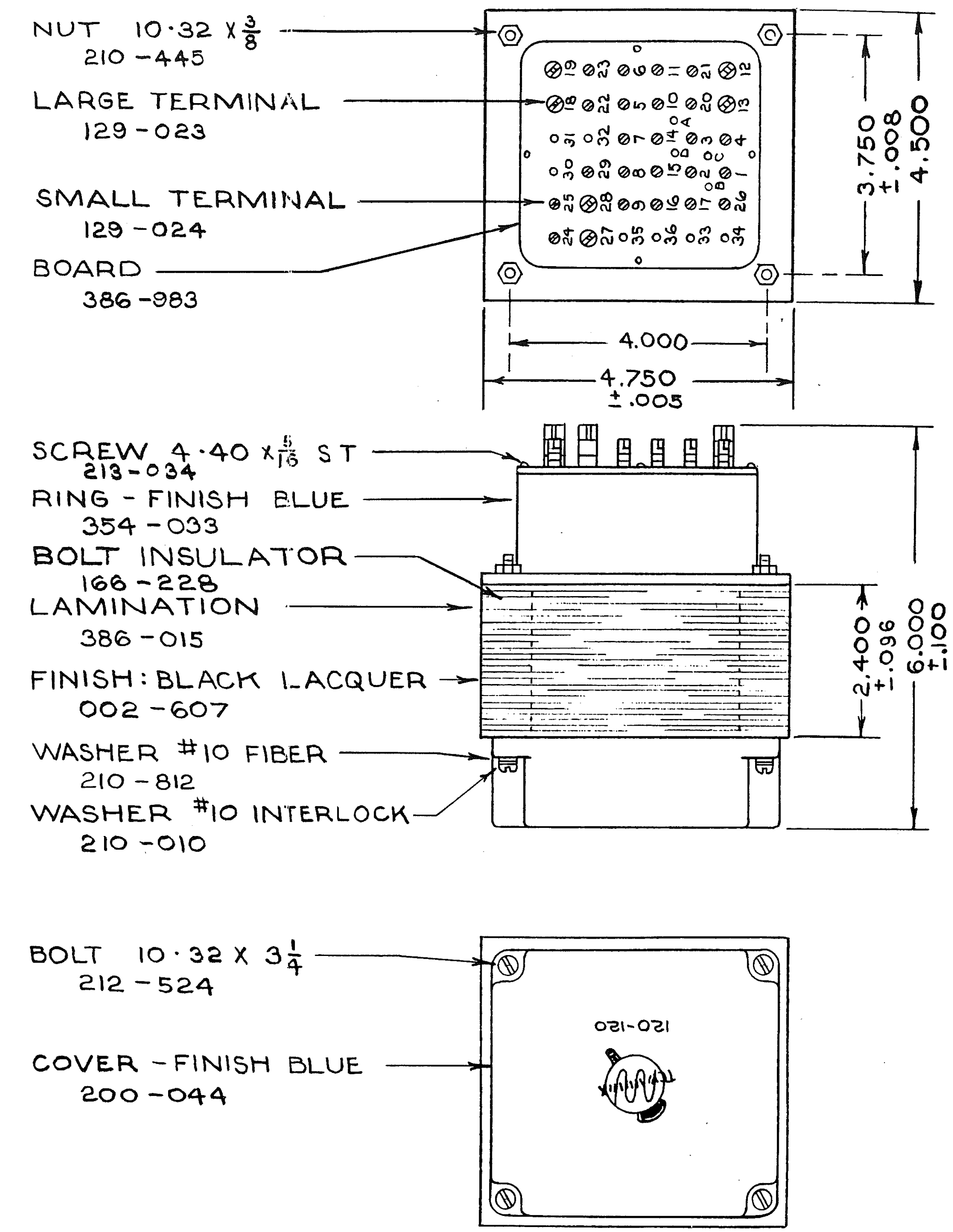
ALL VOLTAGE & CURRENT RATINGS ARE NOMINAL & VARY WITH LOAD & LINE VOLTAGE. ALL WINDINGS ARE INSULATED FOR 600 V DC UNLESS OTHERWISE NOTED.



INSULATED FOR 4 KV DC

TERMINALS 1-2-6-8-9-10-13-14-18-20-22-24-26-27 ARE THE SAME PHASE





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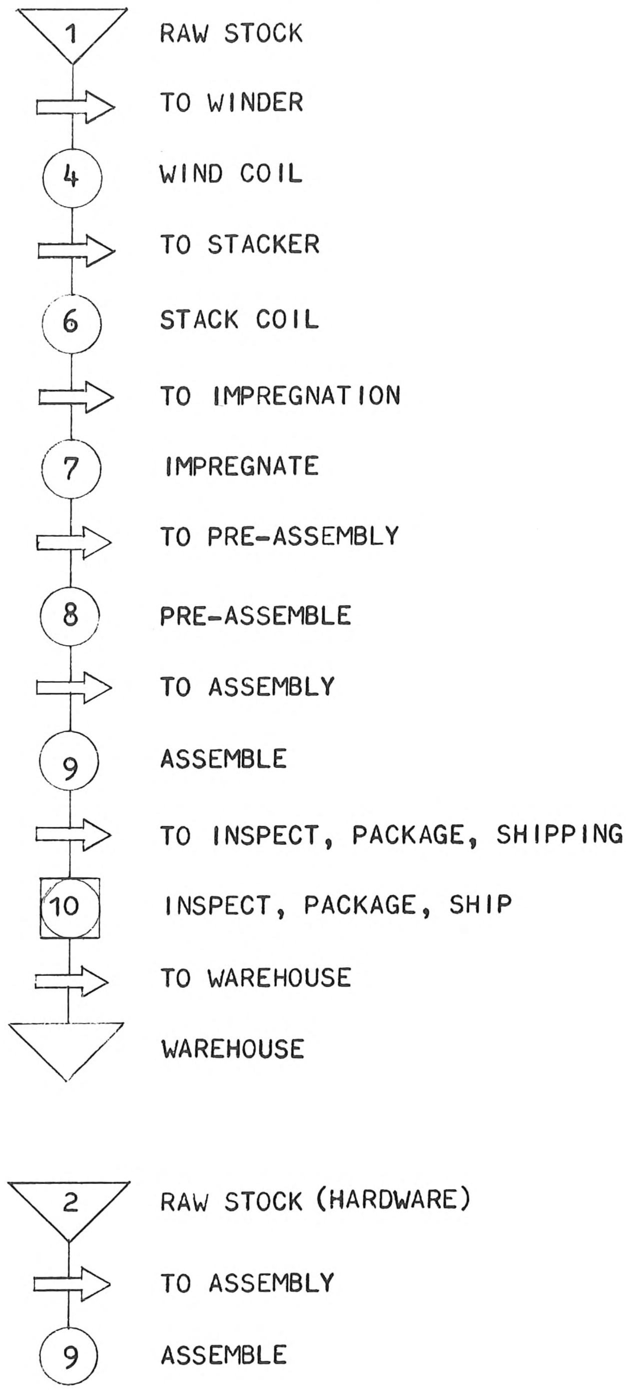
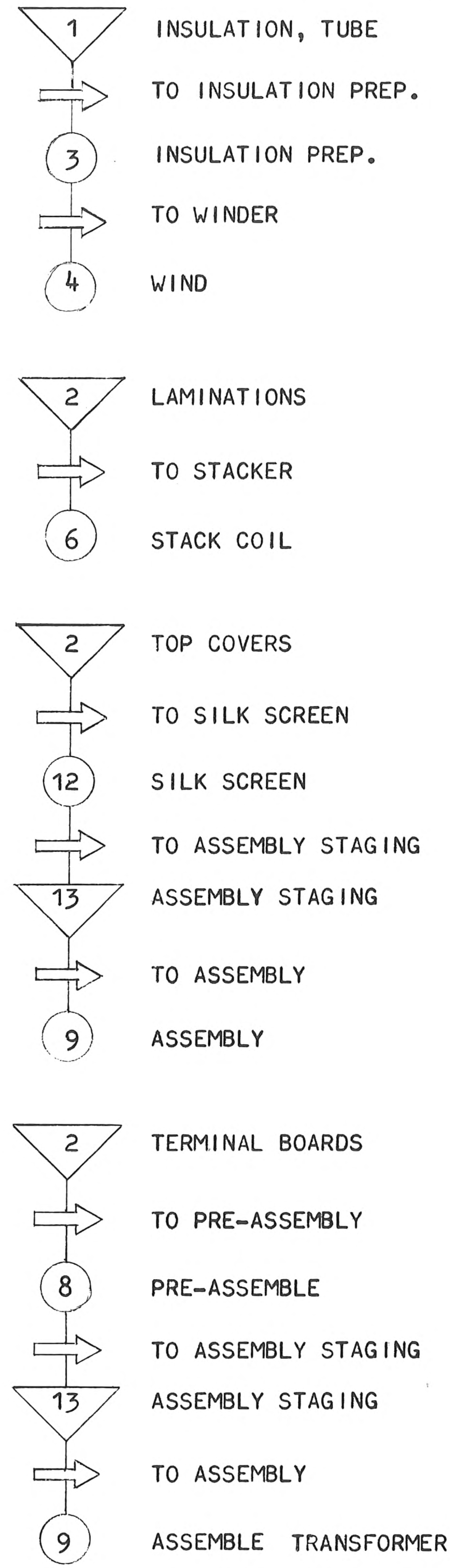
			DATE	PART NO. 120 - 120	DRG. NO. B-1723
			BY		

THIS IS A FLOW CHART FOR MANUFACTURE OF A TRANSFORMER (500A - TYPICAL) . . . .

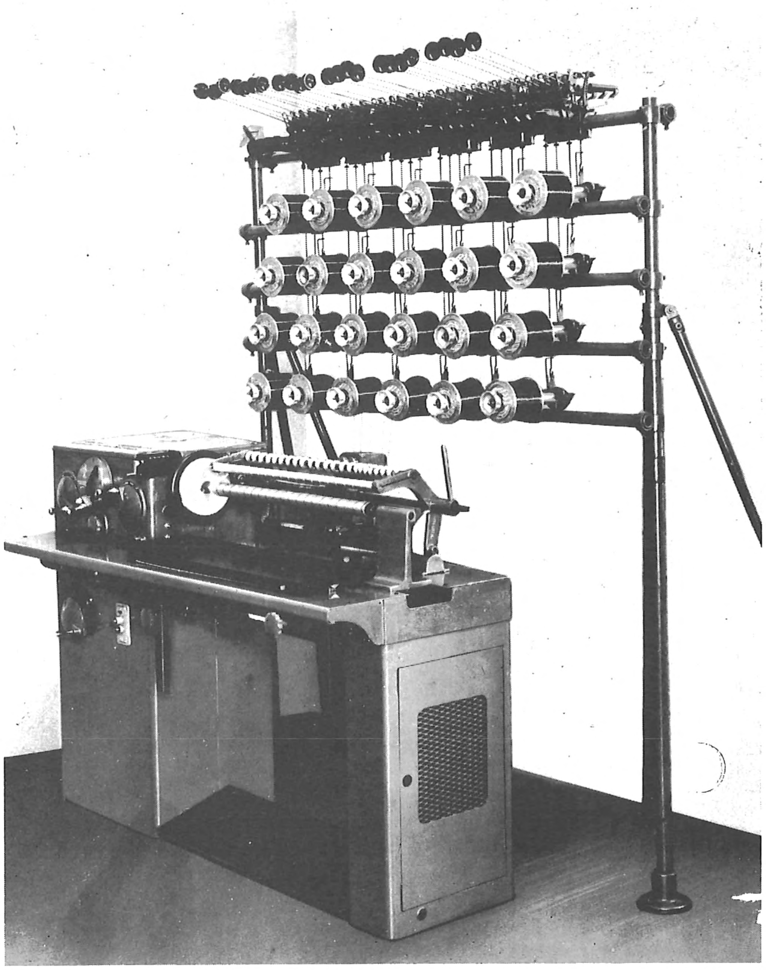




ABOUT TRANSFORMER WINDING . . . . . .

WE'VE DIVIDED THE WINDING AREA INTO FOUR SECTIONS TO EFFICIENTLY PROCESS THE VARIOUS TYPES AND QUANTITIES OF TEKTRONIX-BUILT TRANSFORMERS.

ONE BANK -- OR LINE--USES LAYER WINDERS. THESE ARE SEMI-AUTOMATIC MACHINES, DESIGNED FOR LONG PRODUCTION RUNS (AT LEAST EIGHT HOURS IS DESIRABLE) AND #20 TO #42 WIRE SIZE RANGE. THE LEESONA 108 IS TYPICAL OF THE MACHINES IN THIS LINE:



THE SCREW TRAVERSE WITH PROPER GEARING ACTION WILL ALLOW THE MACHINE TO AUTOMATICALLY ADVANCE SUBSEQUENT TURNS OF A SPECIFIC SIZE OF WIRE A GIVEN DISTANCE ALONG THE CORE TUBE. THE NUMBER OF COILS THAT CAN BE WOUND AT ONE TIME IS LIMITED BY THE LENGTH OF COIL AND THE OVERALL MANDREL LENGTH. MANDRELS IN PRESENT USE ALLOW PRODUCTION OF FROM FOUR TO 12 COILS AT ONCE. THE TENSION DEVICES, MOUNTED AT THE MACHINE, CONTROL WIRE TENSION. AFTER THE INITIAL MACHINE SET-UP -- BASED ON EXPERIENCE OR INSTRUCTION MANUAL -- THE PRIMARY CONCERN OF THE OPERATOR IS PLACEMENT OF LEAD BREAKOUTS, INSERTION OF INSULATION, AND THE PROPER NUMBER OF TURNS. ALL THESE ARE DIRECTED BY THE APPLICABLE PROCESS SHEET (SEE FOLLOWING PAGE FOR TYPICAL PROCESS SHEET).

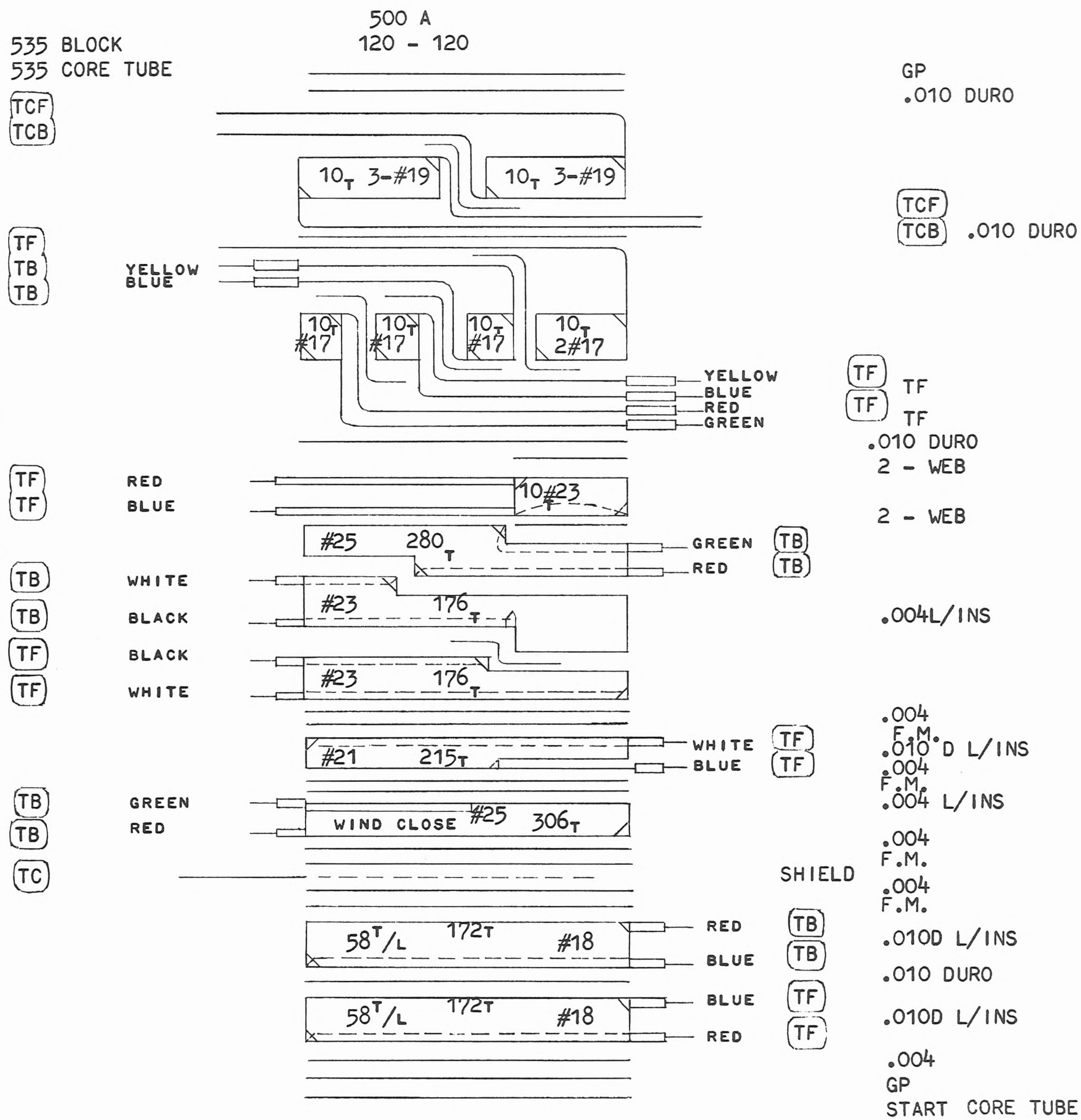
WITH THE TREND TOWARDS MINIATURIZATION IN WIRE AND COIL SIZES, THESE MACHINES LEND THEMSELVES WELL TO OPERATION BY WOMEN EMPLOYEES WITH A HIGH DEGREE OF MANUAL DEXTERITY, ABILITY TO DO PRECISION WORK AND SUFFICIENT MECHANICAL APTITUDE TO SET UP AND BE AWARE OF MACHINE OPERATION.

ANOTHER BANK OF SEMI-AUTOMATIC MACHINES USES CROSS (OR PI) WINDERS. A COMBINED GEAR-CAM SET UP WINDS COILS WITH VARIOUS CROSSOVERS PER TURN, OVER A GIVEN COIL WIDTH. TENSION DEVICES ATTACHED TO THE MACHINE REGULATE THE WIRE TENSION. WE'VE PICTURED THE LEESONA 111 ON THE FOLLOWING PAGE.

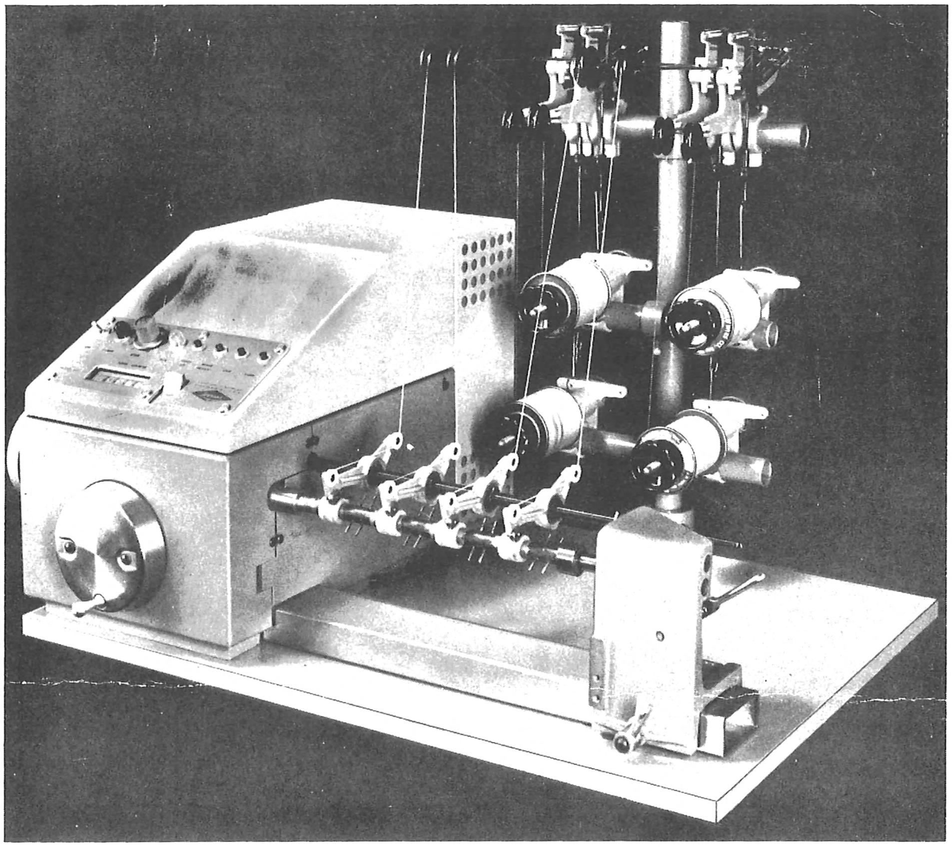
-69-

CODE

TC = TOP OF COIL, ON CENTER
TB = TOP OF COIL, BACK
TF = TOP OF COIL, FRONT
TCF = TOP OF COIL, BETWEEN CENTER AND FRONT
TCB = TOP OF COIL, BETWEEN CENTER AND BACK
START CORE TUBE = .020 FISH PAPER
GP = .005 GUMMED KRAFT
F.M. = FIBREMAT
L/INS. = LAYER INSULATION
.010 = DURO INSULATION
.004 = KRAFT PAPER
WEB = UNSATURATED
(symbol) = TAPE AROUND COIL WITH ACETATE CLOTH TAPE
(symbol) = SLEEVED BREAKOUT
(symbol) = UNSLEEVED BREAKOUT
--- = CROSS OVER
(symbol) = TIE DOWN POINT OR WIND START AND/OR FINISH
----—— = SHIELD AND LEAD



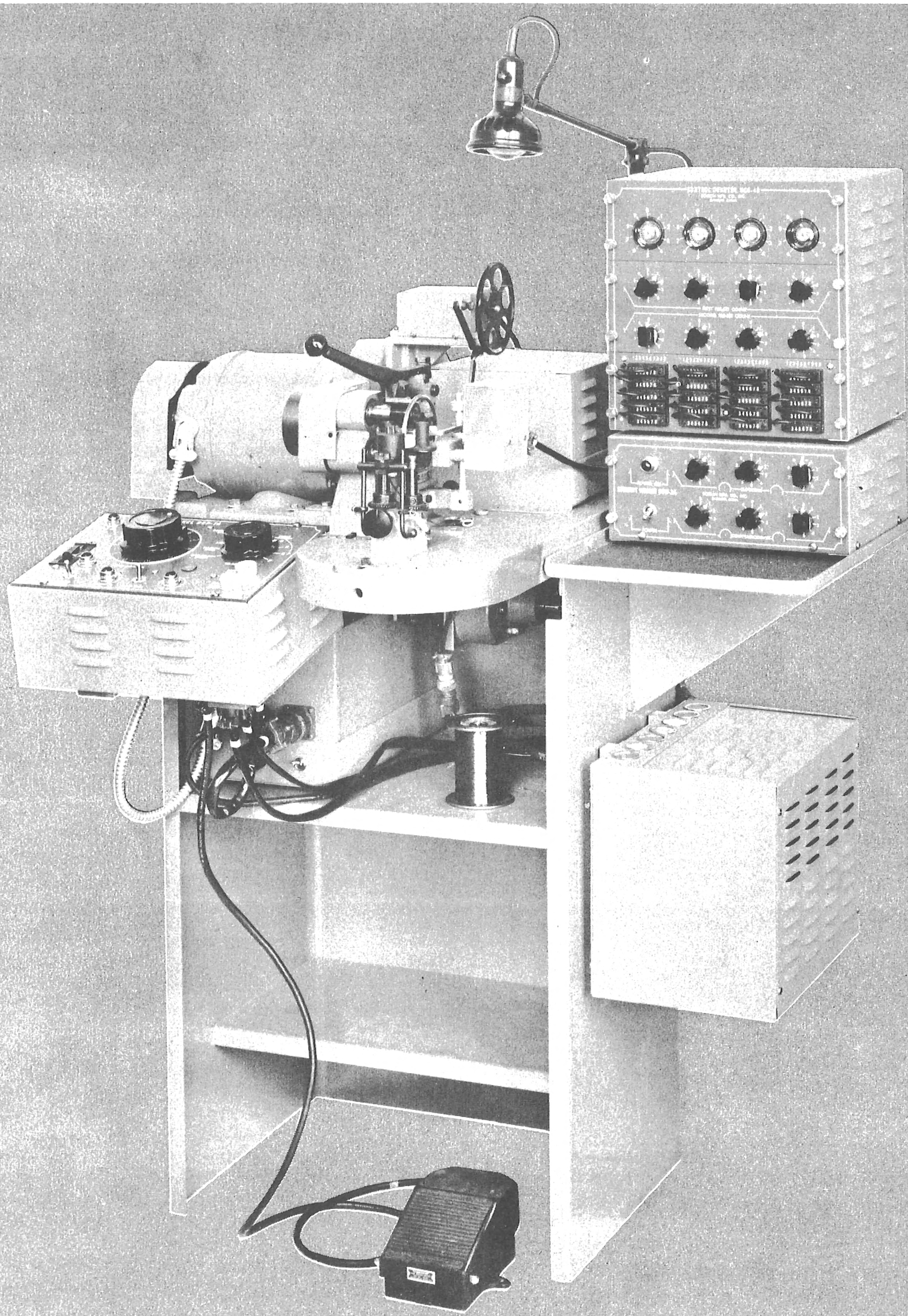
THIS IS A LEESONA 111 CROSS WOUND COIL WINDER . . . . . .



PRESENTLY, THESE MACHINES HANDLE THE HIGH-VOLTAGE TRANSFORMERS AND LATTICE WOUND INDUCTORS. THE MACHINE CAPABILITIES AND LIMITATIONS ARE MUCH THE SAME AS THOSE OF THE LAYER WINDERS. THE PERSONNEL REQUIREMENTS ARE IDENTICAL.

THE THIRD STYLE OF WINDING MACHINE IS THE TOROIDAL WINDER (WE'VE ILLUSTRATED A BOSCH TW300 ON THE FOLLOWING PAGE). THIS MACHINE WINDS THE WIRE AROUND THE DOUGHNUT OR TOROIDAL CORE MATERIAL. WINDING IS A TWO-STAGE OPERATION: (1) A PRESCRIBED WIRE LENGTH IS WOUND ON THE SHUTTLE; (2) THE WIRE IS THEN TRANSFERRED TO THE CORE BY MEANS OF A SLIDER ON THE SHUTTLE. OUR TOROIDAL WINDERS ARE EQUIPPED WITH ELECTRONIC PRE-DETERMINING COUNTERS. THESE ALLOW SPECIFIC WIRE LENGTHS TO BE WOUND ON THE SHUTTLE, WHICH IS RELATED TO A DEFINITE TURNS COUNT ON THE CORE. DIRECTION OF ROTATION, WIRE SPACING AND TENSION ARE HANDLED BY MACHINE SET-UP.

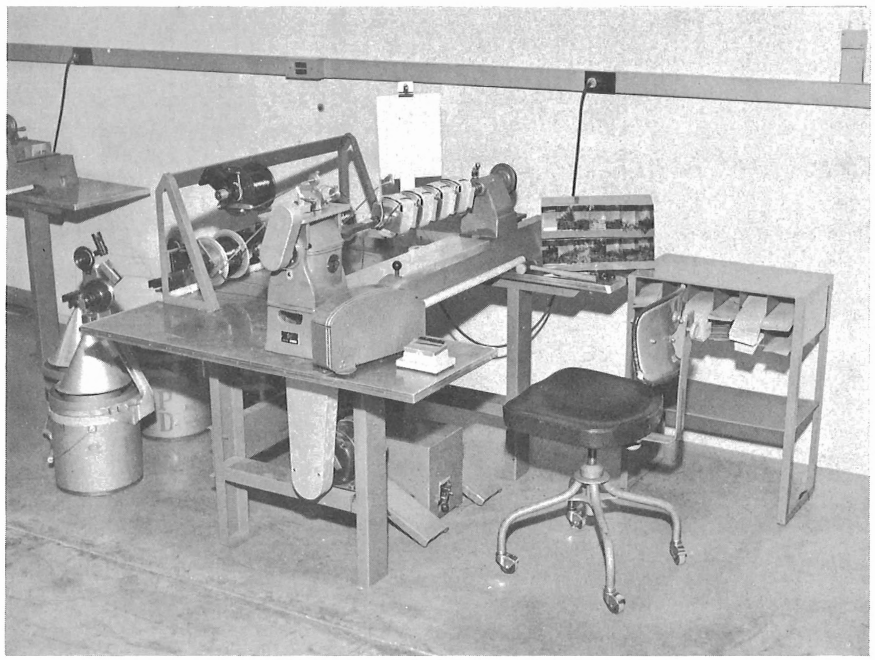
THE PRIMARY CONCERN OF THE OPERATOR IS TO FOLLOW THE PROCESS SHEET (SEE PAGE FOR AN EXAMPLE) REGARDING CORRECT WIRE SIZE, TURNS AND MACHINE SET-UP, AND TO APPLY THE LAYER INSULATION AND BREAK-OUT LEADS. PERSONNEL REQUIREMENTS ARE IDENTICAL TO THE OTHER SEMI-AUTOMATIC MACHINES WE'VE PREVIOUSLY DESCRIBED.



The electronically controlled Model TW-300 Toroidal Winder is the result of a very extensive research and development program aimed at providing faster production at lower cost, more uniform winding and precise turns count. The major item in the electronic system is a control counter utilizing new principles which provide the means for controlling several entirely new production aid features such as slow-start slow-stop of the driving motor, automatic winding of segments, progressive winding and other forward steps toward automation in toroidal production.

MORE ABOUT TRANSFORMER WINDING . . . . . .

THE REMAINING WINDING MACHINES ARE THE HAND WINDERS. THESE TEKTRONIX-BUILT UNITS ARE DESIGNED TO HANDLE THE LAYER-WOUND LOW VOLTAGE TRANSFORMERS IN CURRENT PRODUCTION. THE MACHINE IS A MODIFIED LATHE BED MOUNTED ON A SPECIAL TABLE. IT'S POWERED BY A 1,725 RPM, 1/2 HORSEPOWER COMPOUND WOUND DC MOTOR CONTROLLED BY A SPECIAL DC POWER SUPPLY. THIS COMBINATION PRODUCES VARIABLE SPEED CONTROL, HYSTERESIS BRAKING AND REVERSING ACTION. TURNS ARE NOTED BY A CHAIN-DRIVEN, ONE-TO-ONE TURNS COUNTER.



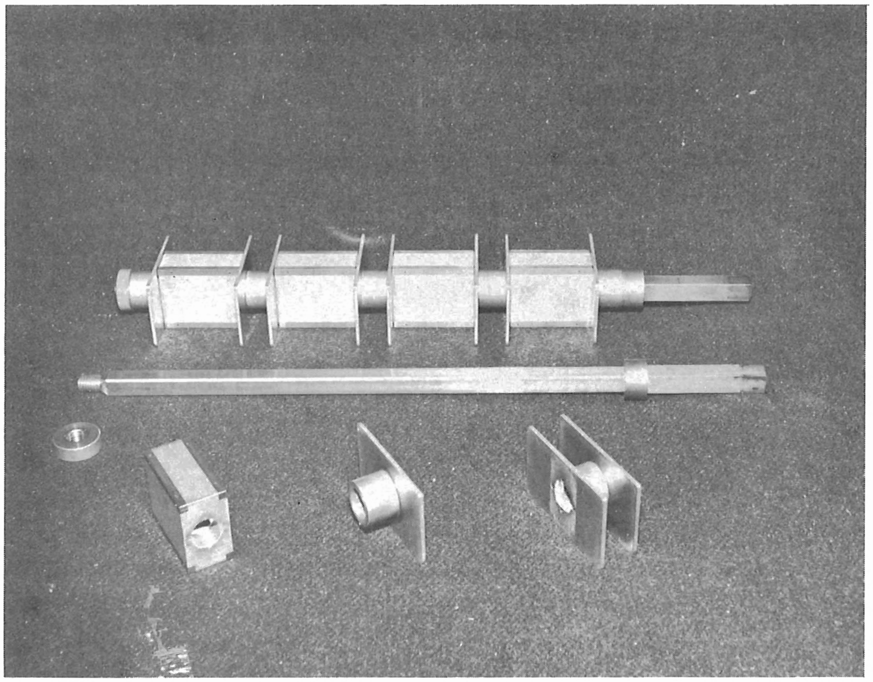
THESE MACHINES DIFFER FROM THE AUTOMATICS, INASMUCH AS WIRE SPACING AND TENSION ARE DEPENDENT ON THE OPERATOR'S SKILL. THEY HANDLE THE LARGER WIRE SIZES AND LARGER TRANSFORMERS, IN ADDITION TO PUTTING FILAMENT WINDINGS ON BEHIND THE AUTOMATICS' OUTPUT, WHEN NECESSARY. TO DATE, WIRE AND TRANSFORMER SIZES HAVE DICTATED OPERATION OF THE HAND WINDERS BY MALE EMPLOYEES EXCLUSIVELY. IN ADDITION TO THE OTHER ATTRIBUTES WE'VE LISTED AS DESIRABLE, PHYSICAL STAMINA IS AN ASSET FOR OPERATING THE HAND WINDERS.

ALL WINDING MACHINES ARE EQUIPPED WITH TAPE DISPENSERS, TUBING AND INSULATION RACKS, AND SUFFICIENT WIRE DE-REELERS TO HANDLE THE NORMAL REQUIREMENTS OF THE PARTICULAR MACHINE.

ANOTHER JOB CLASSIFICATION IN THE WINDING AREA IS THAT OF UTILITY MAN OR WOMAN. THESE PEOPLE SUPPLY EACH WINDER WITH THE INSULATION AND TUBING KIT REQUIRED FOR THE UNIT TO BE WOUND, THUS MINIMIZING DOWN TIME ON THE MACHINES. ALL INSULATION AND TUBING ARE RE-CUT TO SIZE IN ACCORDANCE WITH THE INSULATION LIST. THE UTILITY GROUP ATTACHED LEADS TO SHIELDS AND FORMS CORE TUBES.

ABOUT THE WINDING OPERATION . . . . . .

THE NORMAL OPERATION PATTERN OF THE WINDING AREA BEGINS WHEN AN ORDER IS RECEIVED FROM THE SCHEDULER. ON RECEIPT OF THIS, THE UTILITY GROUP WILL CONSTRUCT THE CORE TUBES AND MAKE UP THE VARIOUS KITS. THESE ARE DELIVERED TO THE WINDER TOGETHER WITH THE PROCESS SHEET, WHICH CALLS OUT THE WINDING BLOCKS AND MANDREL NEEDED (SEE ILLUSTRATION BELOW), THE WIRE SIZE, POSITIONING OF LEAD BREAK-OUTS, CODED TUBING FOR THE LEADS, POINT OF INSERTION, AMOUNT AND TYPE OF INSULATION, AND TURNS PER WINDING. THE COMPLETED COIL IS THEN DELIVERED TO THE STACKING AND IMPREGNATION GROUP.



INSTRUCTIONS FOR QUALITY TRANSFORMER WINDING

1. CONSTANTLY REFER TO PROCESS SHEET.
2. USE THE MINIMUM AMOUNT OF MALLET WORK NECESSARY TO FORM COILS.
3. NEVER POUND ON COIL LEADS OR EDGES.
4. PLACE TAPE AND INSULATION SO THAT OVERLAPS BUILD SQUARE COIL AND AWAY FROM COIL SIDES.
5. INSULATE OVER AND UNDER LEADS THAT CROSS OVER WINDINGS AND WHEN WINDING OVER LEADS.
6. MAINTAIN PRESCRIBED MARGIN BETWEEN WIRE AND COIL EXTREMES.
7. PROPER LEAD PLACEMENT AND CORRECT TUBING AIDS TRANSFORMER ASSEMBLY.
8. PLACE LEAD BREAKOUTS TO BUILD A SQUARE COIL; PLACE THEM WELL ABOVE TOP LAMINATION LINE.
9. A STACKED OR ADDITIVE COUNT HAS HISTORICALLY LED TO A TURNS-OFF QUALITY PROBLEM.
10. REFER QUESTIONS TO GROUP MANAGER.
11. MAINTAIN MINIMUM WIRE TENSION AT ALL TIMES.

500 A
Part 120-120

Insulation Kit				Tubing Kit			
Tek #	Material	Cut Size	Amt.	Tek #	Size & Color	Amt.	Lgth.
252-514	.020 Fish	8 3/4" x 2 31/32"	1	162-501	#10 Black	2	3"
252-517	.004 Kraft	8 1/2" x 2 31/32"	1	162-504	#20 Black	2	7"
252-517	.004 Kraft	11" x 2 31/32"	4	162-508	#16 Red	3	7"
252-517	.004 Kraft	13 1/2" x 2 31/32"	2	162-510	#20 Red	1	7"
252-518	.005 Gum	8 1/4" x 2 31/32"	1	162-511	#24 Red	2	7"
				162-521	#24 Green	2	7"
252-518	.005 Gum	14 1/2" x 2 31/32"	1	162-512	#10 Yellow	2	3"
252-521	.010 Duro	9 1/2" x 3"	3	162-514	#16 Yellow	2	7"
252-521	.010 Duro	10 1/2" x 3"	2	162-518	#16 Green	1	7"
252-521	.010 Duro	11 1/2" x 3"	3	162-521	#24 Yellow	2	7"
252-521	.010 Duro	12 1/2" x 3"	3	162-522	#16 Blue	4	7"
252-521	.010 Duro	13 1/2" x 3"	3	162-524	#20 Blue	2	7"
252-521	.010 Duro	14 1/2" x 3"	3	162-526	#13 White	2	3½"
253-024	.001 Copper	9 3/4" x 2 3/4"	1	162-527	#18 White	1	4"
253-026	Fiber Mat	11 3/4" x 3"	4	162-527	#18 White	1	7"
253-020	P.E. Web	Use as required		162-528	#20 White	2	7"
253-015	1/2" Acetate Cloth Tape	Use as required					

Note:

1. 0.020 Fish is formed with brake, using 500 A bending jigs.
2. Attach #22 tinned copper wire (six inch) as per sample -- to 0.001 copper shield.

TYPE 81 P I
PART 120-168

			Wire Size	Gears	Turns/Layer
Tube Material	3-1/2" x 12"		#31	100-60	80 T/L
Tube Size	1/2" x1"		#29	100-48	64 T/L
Cut Size	1-3/16"				
Throw	7/8"				

3/16" Copper Strips

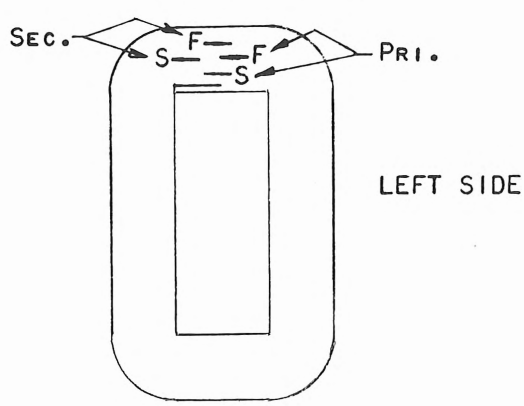
180 AA 1 Insulation

		Terminal No.
Nine Coils per Stick	1-GP on Core Tube START RIGHT	
1200T #31		2-1
	2-004 Kraft	
825T #29		4-3
	2-004 Kraft 1-GP	

INSULATION KIT

Material	Size	Amount
Fish Paper (Core Tube)	3-1/2" x 12"	(1)
Gum Paper	3-1/2" x 12"	(3)
.004 Kraft	9" x 12"	(1)
	12" x 12"	(1)
.002 Kraft	4" x 12"	(8)
	4-1/2" x 12"	(6)
	5" x 12"	(4)
	5-1/2" x 12"	(5)
	6" x 12"	(3)

MARK - HEAT - SAW



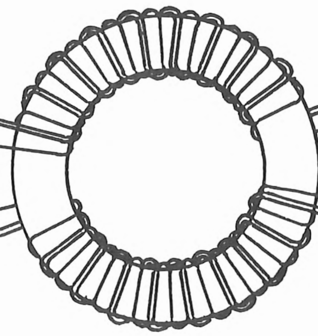
500 A
PART 120-120

535 BLOCK			
535 CORE TUBE		1-GP) ON CORE TUBE 1-.004)	
172	#18	START RED END BLUE 1-DURO	1-3
172	#18	START BLUE END RED 1-FIBREMAT 1-.004	2-4
	SHIELD	2-3/4" x 9-7/8" 1 FIBREMAT 1-.004	29
306T	#25	START RED END GREEN (.004 BETWEEN) 1 FIBREMAT 1-.004 -- WIND CLOSE AND CONT. SAME LAYER	6-11
215T	#21	START BLUE END WHITE 1 FIBREMAT 1-.004	8-15
176T	#23	START WHITE END BLACK (.004 BETWEEN) 1-TAPE CONT. SAME LAYER	14-7
176T	#23	START BLACK END WHITE (.004 BETWEEN) 1-TAPE CONT. SAME LAYER	10-5
280T	#25	START RED END GREEN (.004 BETWEEN) CONT. SAME LAYER	20-21
10T	#23	START BLUE END RED 2-WEB (UNDER) (OVER) 1-DURO	PUT OUTSIDE WHITES → 24-25
10T	#17	START GREEN END RED	26-17
10T	#17	START BLUE END YELLOW	9-16
10T	#17	START BLUE END YELLOW	22-23
10T	2#17	WIRE LEADS 1-DURO	27-28
10T	3#19	WIRE LEADS) WIND IN SAME DIRECTION WIRE LEADS) 1-DURO 1-GP	12-13 18-19

FOR EXPORT ADD

10T	2#21	START YELLOW END GREEN	A-C
10T	2#21	START GREEN END YELLOW 1-DURO 1-GP	B-D

HERE ARE MANUFACTURING DETAILS FOR THE 110 TOROID N UNIT (120-163) . . . . . .



THE MACHINE SET UP

50 TURNS OF #23 WIRE
GRAHAM 6.3 LOAD 15' EACH HALF
WINDING SPEED - 4.0; LOAD SPEED 3.4

FORM: 276-518

TUBING

#18 GREEN FOR TAP	5 IN.
#20 YELLOW	5 IN.
#20 YELLOW	5 IN.

WIRE: 176-029 #23

INSTRUCTIONS FOR WINDING

WIND #1 PRI.(50 TURNS) ON 1/2 OF CORE
WIND #2 PRI.(50 TURNS) ATOP #1 PRI.
WIND BOTH IN SAME DIRECTION

USE YELLOW MYLAR TO TAPE START AND FINISH LEADS ON BOTTOM PRI. 253-019

USE CLEAR MYLAR TO TAPE START AND FINISH LEADS ON TOP PRI. 253-021

WIND #1 A PRI. (50 TURNS) ON 1/2 CORE
WIND #2 A PRI. (50 TURNS) ATOP #1 A PRI.
WIND IN SAME DIRECTION AS 1 AND 2 PRI.

LEAD LENGTHS

#1A START AND #2 FINISH - TWIST TOGETHER - CUT TO 5 INCH

#1 START AND #2A FINISH - TWIST TOGETHER - CUT TO 5 INCH

#1 FINISH 2" - # 1 A START 2-3/4"

#2A START 2" - #2 FINISH 2-3/4"

FINISH

TIN TWISTED ENDS UP CLOSE TO CORE - TIN LEADS BACK 1"

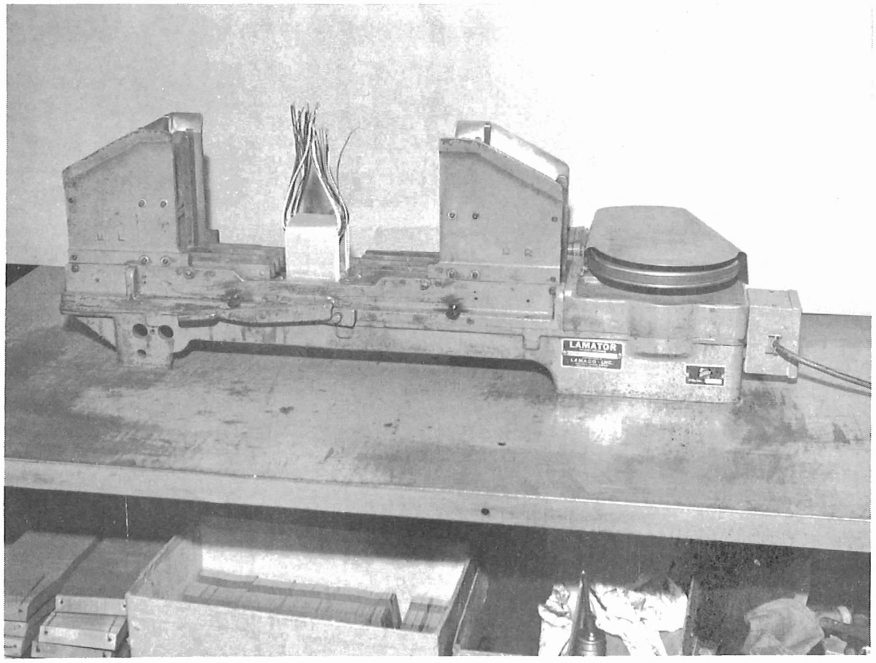
SET SWITCH ON METER TO #3 - TEST FOR BALANCED READING - BETWEEN 25 AND 27

BOTH SIDES MUST READ THE SAME

COVER SPLICES WITH 1/4" CLEAR MYLAR - PUT ON TUBING - SEND TO OVEN FOR POTTING IN 201-010 PLASTIC POTS - STAMP -163 ON FINISHED PRODUCT.

IN THE STACKING AND IMPREGNATION AREAS . . . . . .

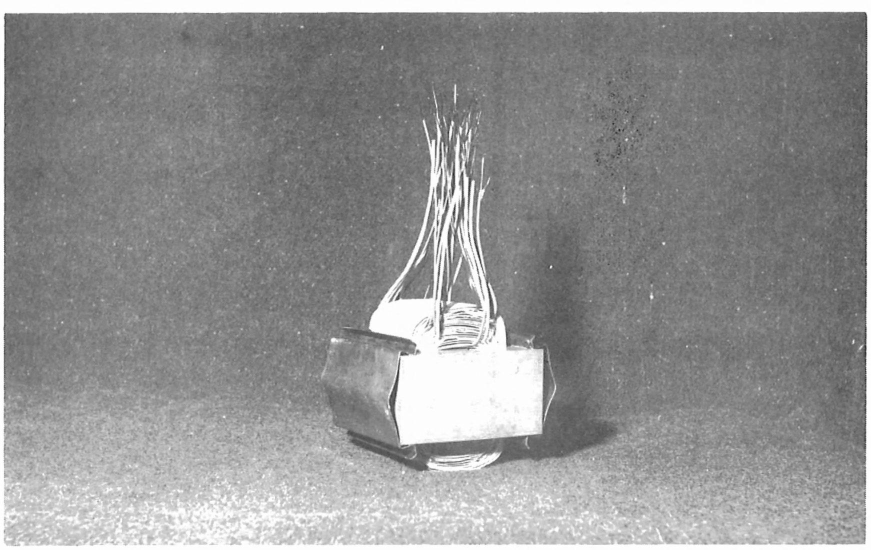
THE WOUND COIL (WHEN NECESSARY) IS FIRST TAPED AT TOP AND BOTTOM; THIS AIDS IN INSULATION AND INSURES ADHERENCE OF CORE TUBE TO WINDINGS. AFTER TAPING, THE LARGER PRODUCTION RUNS AND/OR IDENTICAL CORE SIZE COILS ARE PLACED IN THE "LAMATOR" OR STACKING MACHINE.



AT THE PRESENT TIME, WE HAVE TWO STACKING MACHINES, EACH HANDLING A SPECIFIC LAMINATION SIZE. THEY'RE DESIGNED TO INTERLEAVE E AND I LAMINATIONS INTO THE COIL. AFTER THE MACHINE'S MAGAZINE IS LOADED WITH STRINGS OF STEEL, A FEELER GAUGE -- WORKING WITH THE SLIDE CARRIAGE -- WILL INSERT INTERLACED E AND I LAMINATIONS. A LIMIT SWITCH STOPS THE MACHINE.

THE FULLNESS OF OUR PRESENT COILS MAKES IT POSSIBLE TO MACHINE-STACK TO APPROXIMATELY 95 PER CENT COMPLETION. THE BALANCE OF THE COIL IS HAND-STACKED, WITH KEEPERS (REWORKED E'S) BEING PLACED ON TOP AND BOTTOM OF THE STACK.

THE STACKED COIL IS SQUARED IN THE HYDRAULIC VISE, TO ELIMINATE AIR GAPS BETWEEN THE E AND I LAMINATIONS AND AT THE SAME TIME ALIGN THE MOUNTING HOLES IN THE STEEL. A PHOS-BRONZE CLIP IS PLACED AROUND THE SQUARED STACK TO INSURE ALIGNMENT WHILE THE COIL IS BEING IMPREGNATED.



MORE ABOUT THE STACKING ANDIMPREGNATION AREA . . . . . .

THOSE TRANSFORMERS USING LAMINATIONS NOT COMPATIBLE WITH OUR EXISTING MACHINES ARE ENTIRELY HAND-STACKED.

THE STACK HEIGHT IS ESTABLISHED BY THE BOBBIN SIZE OR CORE OPENING. THE POSSIBILITY OF INSUFFICIENT OR EXCESSIVE STEEL IS MINIMIZED BY HAVING CAPABLE AND CONSCIENTIOUS LAMINATION STACKING PERSONNEL.

THE NORMAL STACKING PROCESS SHEET CALLS OUT SPECIFICS REGARDING TAPING, CLIPPING, SIDE INSULATION WHEN NECESSARY, AND OTHER PERTINENT DATA .....

STACKING PROCESS SHEET

500 A
PART 120-120

LAMINATIONS	386-015
STACK	MACHINE
TAPE	NONE
SIDE BURNS	NONE
KEEPERS	REWORKED .015
CLIPS	#1

..... BUT THE QUALITY STACK COMES FROM EXPERIENCE AND A "FEEL" FOR THE OPERATION.

HIGH VOLTAGE OR LATTICE WOUND TRANSFORMERS USE A FERRITE E CORE CONSTRUCTION, WITH MATCHING E'S BEING PLACED AROUND EACH SIDE OF THE CORE. A PRESCRIBED AIR GAP IS GROUND OUT OF THE CENTER LEGS OF THE CORE; THE OUTSIDE LEGS ARE TAPED TOGETHER AND HELD WITH A CLIP WHILE THE UNIT IS BEING IMPREGNATED.

ON TOROIDAL TRANSFORMERS, THE WIRE IS WOUND DIRECTLY ON THE CORE MATERIAL, ELIMINATING THE NEED FOR STACKING.

QUALIFICATIONS FOR A GOOD LAMINATION STACKER INCLUDE ABOVE-AVERAGE FINGER DEXTERITY, GOOD PERCEPTION AND GENERAL GOOD HEALTH.

TRANSFORMERS RANGE IN SIZE FROM SMALL ONE INCH STACKS OF FINE STEEL UP TO 16 POUNDS.

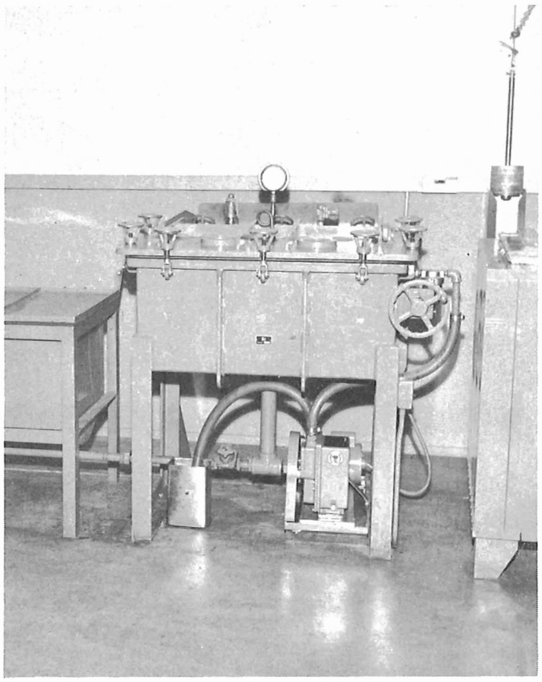
ABOUT IMPREGNATION

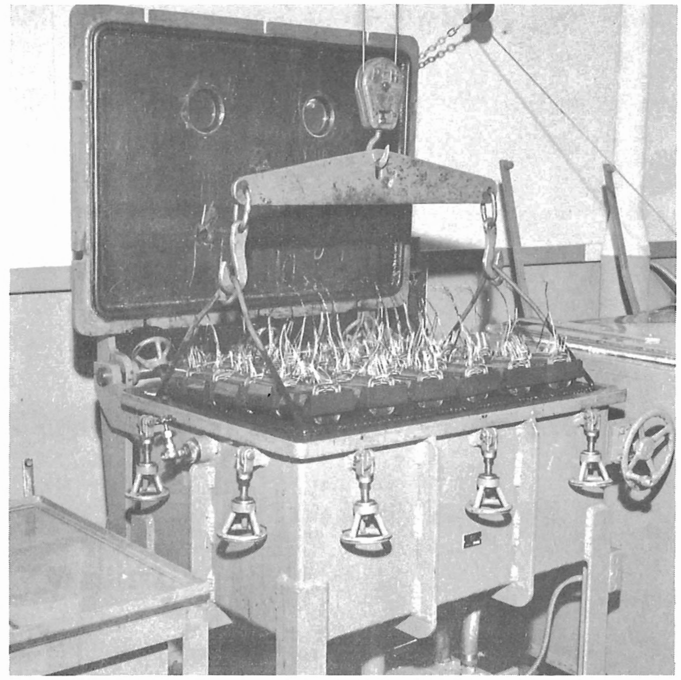
AFTER STACKING, THE TRANSFORMERS ARE ANNEALED FOR APPROXIMATELY TWO HOURS AT 285°F. THIS REMOVES THE MOISTURE, RELIEVES WINDING PRESSURES AND SETS THE THERMO-SETTING ADHESIVES USED ON TAPE AND COPPER SHIELDS. THE TRANSFORMER IS THEN COOLED TO APPROXIMATELY 100°F -- THEN VARNISHED UNDER VACUUM FOR ABOUT AN HOUR (OR UNTIL OBSERVATION DETECTS THE THOROUGHNESS OF PENETRATION). THE VACUUM IS REMOVED AND THE EXCESS VARNISH IS DRAINED FROM THE UNITS. THE TRANSFORMERS ARE THEN RETURNED TO THE OVEN, WHERE THE VARNISH IS CURED FOR APPROXIMATELY SIX HOURS AT 285°F. WE FOLLOW THIS PROCEDURE FOR THE MAJORITY OF TEKTRONIX-BUILT LOW VOLTAGE TRANSFORMERS.

THE VARNISH WE NOW USE IS A CLEAR, THERMO-SETTING, MODIFIED POLYESTER INSULATING TYPE. THE PRESENT IMPREGNATION TANKS ARE RECTANGULAR, OF WELDED STEEL CONSTRUCTION, AND ARE THE TOP-OPENING TYPE. TOPS ARE EQUIPPED WITH

TO CONTINUE THE DISCUSSION OF THE IMPREGNATION AREA . . . . . .

DIAL TYPE VACUUM GAUGES AND SIGHT GLASSES FOR OBSERVATION. STORAGE TANKS ARE ATTACHED TO THE IMPREGNATION TANKS. THE VARNISH IS FORCED INTO THE TRANSFORMER BY VACUUM IN THE IMPREGNATION TANK AND IS THEN GRAVITY-FED BACK INTO THE STORAGE TANK WHEN THE CYCLE IS COMPLETE.

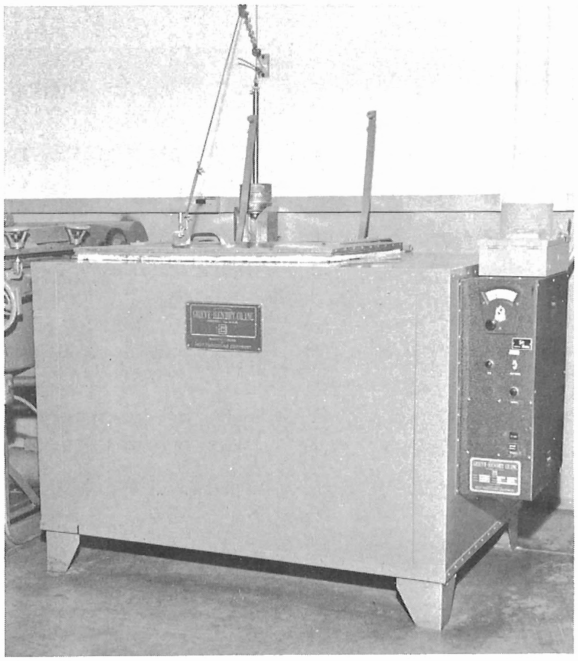


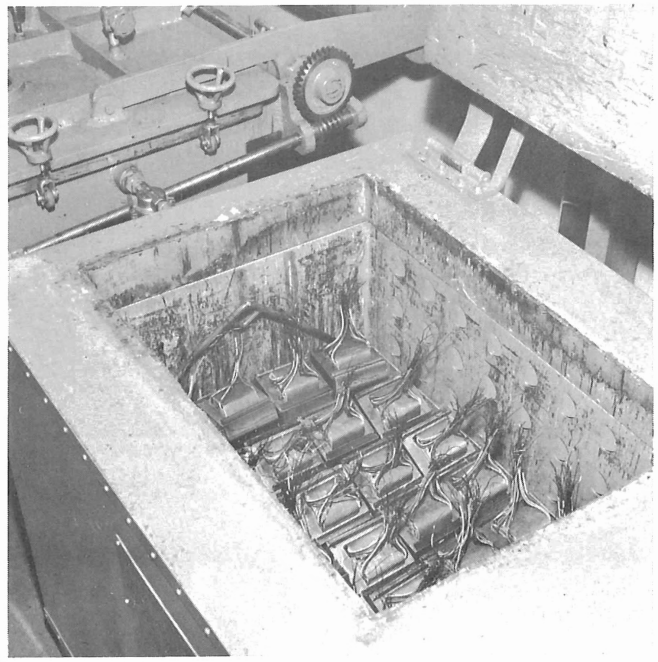


THE ELECTRIC BAKING OVENS WE NOW USE ARE CABINET MODELS, TOP-LOADING, WITH A SEVEN KW HEAT INPUT CAPACITY. BAFFLES SEPARATE THE HEAT CHAMBER FROM THE WORK CHAMBER, ELIMINATING HEAT TRANSFER FROM DIRECT RADIATION. THE OVENS ARE EQUIPPED WITH ADJUSTABLE DAMPERS ON AIR INTAKES, EXHAUST OUTLETS WITH ADJUSTABLE LOUVERS (ARRANGED FOR HORIZONTAL AIRFLOW) OVER THE ENTIRE AREA OF SUPPLY, AND RETURN DUCTWORK WITHIN THE WORK CHAMBER TO INSURE MAXIMUM TEMPERATURE UNIFORMITY. THE RE-CIRCULATION BLOWER, CONSTRUCTED OF HEAVY DUTY HIGH PRESSURE STEEL PLATE, IS RATED AT 2,400 CFM. IT'S DRIVEN BY A ONE-HALF HORSEPOWER MOTOR THROUGH V-BELTS AND VARIABLE PITCH SHEAVE.

SEE THE FOLLOWING PAGE FOR AN ILLUSTRATION OF THE ELECTRIC BAKING OVEN WE NOW USE.

THIS IS THE ELECTRIC BAKING OVEN WE USE . . . . . .



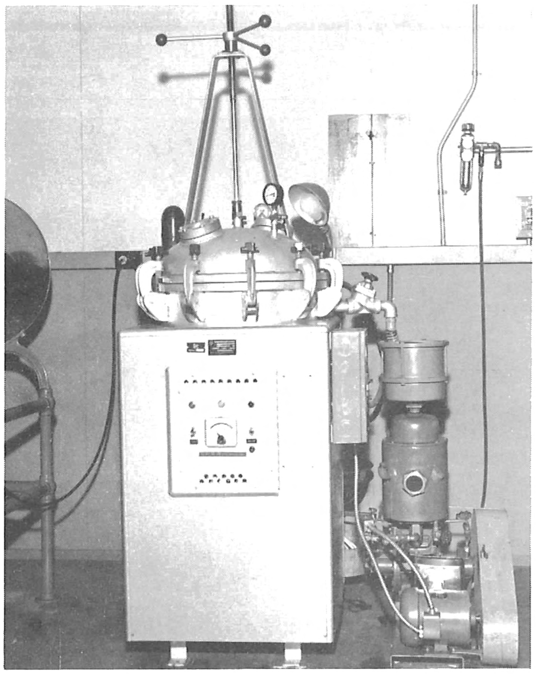


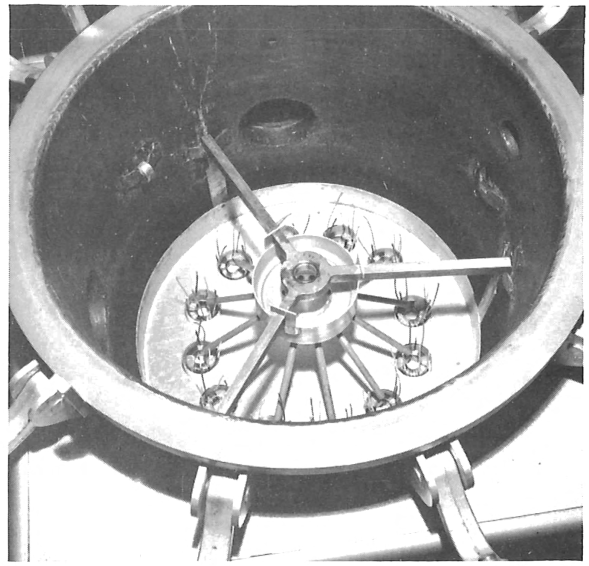
THE CONTROL PANEL INCLUDES A 100° TO 650° RANGE INDICATING TEMPERATURE CONTROLLER, SEPARATE INDICATOR LIGHTS FOR THE BLOWER AND HEATER, AND A TIMED SWITCH. THE FAN MOTOR AND HEATING ELEMENTS ARE SO WIRED AS TO SHUT OFF THE HEATERS IF THE BLOWER IS INOPERATIVE, BUT TO ALLOW BLOWER OPERATION WITHOUT HEAT ELEMENTS. WE CHECK THE OVEN TEMPERATURES PERIODICALLY AND ADJUST THE INDICATORS ACCORDINGLY. BOTH THE OVENS AND THE IMPREGNATION UNITS ARE LOADED BY AN OVERHEAD CRANE.

THE MAJORITY OF HIGH VOLTAGE TRANSFORMERS ARE IMPREGNATED IN A THERMOPLASTIC, HIGH MELTING-POINT WAX. THE TRANSFORMERS ARE PREHEATED AND IMMERSED HOT IN THE MOLTEN WAX. THOROUGHNESS OF PENETRATION IS DETERMINED BY VISUAL INSPECTION. THE UNITS ARE DRAINED AND LET STAND UNTIL THE WAX IS SET, WHICH COMPLETES THE WAX IMPREGNATION.

SPECIFICATIONS ON CERTAIN TRANSFORMERS REQUIRE THAT THEY BE ENCAPSULATED (OR POTTED) IN ONE OF THE VARIOUS EPOXY COMPOUNDS. THESE UNITS ARE PROCESSED IN AN ELECTRICALLY-HEATED AUTOMATIC ENCAPSULATING MACHINE, LIKE WE'VE PICTURED ON THE FOLLOWING PAGE.

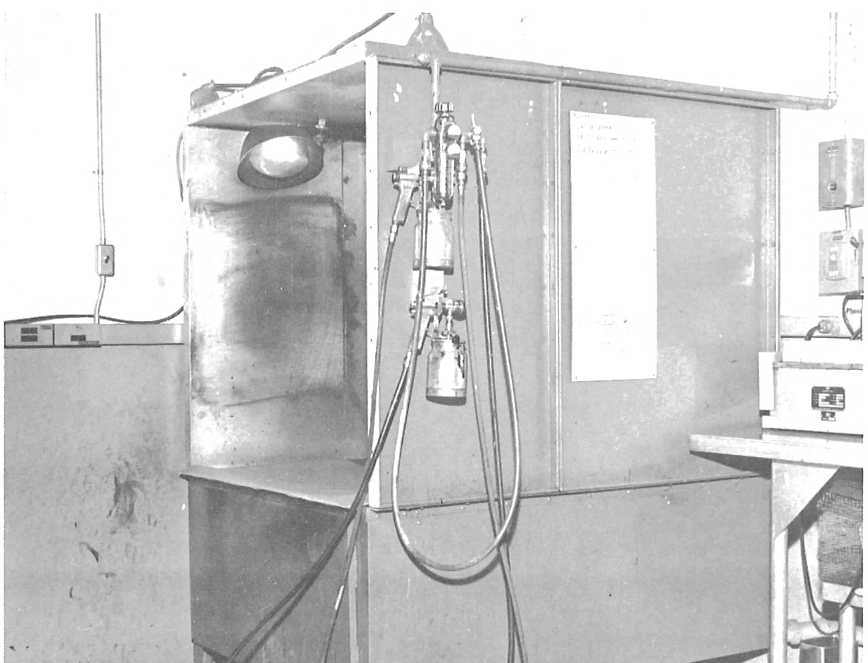
THIS IS A "RED POINT" ENCAPSULATING MACHINE . . . . . .





THE COMPOUNDS ARE MIXED AND INJECTED UNDER VACUUM. AFTER THE AIR HAS BEEN THOROUGHLY REMOVED AND THE UNITS ARE COMPLETELY IMPREGNATED, THEY ARE CURED IN THE OVENS. CURING TIMES, COMPOUND MIXES AND HANDLING PROCESSES ARE ESTABLISHED BY THE COMPOUND BEING USED.

IN ADDITION TO THE IMPREGNATION AND ENCAPSULATION EQUIPMENT, THIS AREA HAS A PAINT SPRAY BOOTH, EQUIPPED WITH AIR EXHAUST.



SPECIAL UNITS, INCLUDING THE OPEN-TYPE ASSEMBLED TRANSFORMERS, HAVE PAINT OR LACQUER APPLIED BY A REGULATED AIR GUN IN THIS AREA.

CONTINUING THE DISCUSSION OF THE IMPREGNATION AREA . . . . . .

WE USE UPRIGHT OVENS (WITH MUCH THE SAME CHARACTERISTICS AS THE FLOOR MODELS, EXCEPT FOR OPENING AND SIZE) TO SET OR BAKE PAINT, PARTS WHICH HAVE BEEN SILK-SCREENED AND ENCAPSULATED TRANSFORMERS.

A TICKET LIKE THIS ACCOMPANIES THE TRANSFORMER(S) THROUGH THE VARIOUS OVEN OPERATIONS.

______ OVEN

ANNEAL	FROM	______	TO	______
COOLER	FROM	______	TO	______
VARNISH	FROM	______	TO	______
DRAIN	FROM	______	TO	______
BAKE	FROM	______	TO	5:00 PM
CLOCK	FROM	______	TO	7:00 AM

FOR STACKED BAKING

SWITCH FROM #____ TO #____ OVEN

ITEMS

TO CONCLUDE THE DISCUSSION OF THE STACKING AND IMPREGNATION AREA . . . . . .

BECAUSE OF THE RANGE OF MATERIALS AND THE OPERATIONS INVOLVED, THOSE PERSONS WORKING IN TRANSFORMER IMPREGNATION SHOULD HAVE A HIGH DEGREE OF VERSATILITY, COUPLED WITH BETTER-THAN-AVERAGE PRECISION AND PERCEPTIVE ABILITIES.

THE VARIOUS SOLVENTS AND COMPOUNDS BEING USED, AND THE HIGH TEMPERATURE OF THE IMPREGNATION ROOM, ARE THE LEAST PLEASANT ASPECTS OF THE WORK.

SOME OF THE DETAILS OF TRANSFORMER ASSEMBLY . . . . . .

IMPREGNATED TRANSFORMERS ARE RECEIVED HOT FROM THE OVENS; THE EXCESS VARNISH THAT ACCUMULATES IS IMMEDIATELY REMOVED. ON THE CLOSED CONSTRUCTION TRANSFORMERS USING COVERS AND TERMINAL BOARDS, THE LEADS ARE CUT TO SPECIFIC LENGTHS (DEPENDENT ON LEAD DRESS AND TERMINAL LOCATION). AFTER CUTTING, THE TUBING IS STRIPPED BACK -- ALLOWING SUFFICIENT EXPOSED WIRE FOR WRAPPING ON THE TERMINALS.

THE INSULATION ON THE WIRE ITSELF IS REMOVED IN A WIRE STRIPPING MACHINE. THE STRIPPING WHEELS USED FOR MOST LOW-VOLTAGE TRANSFORMER WIRES ARE ONE AND ONE-HALF INCH RINGLOCK STEEL WIRE. THE FINER WIRES OF THE HIGH-VOLTAGE TRANSFORMERS ARE STRIPPED WITH ONE INCH FIBRE GLASS WHEELS. IN THE OPEN CONSTRUCTION TRANSFORMER, THE WIRE INSULATION IS REMOVED IN A SOLDER POT AS THE WIRES ARE BEING TINNED.

WE THEN COAT THE EXPOSED SURFACE OF THE CORES WITH BLACK BRUSHING LACQUER. THOSE CORES WITH OPEN STYLE OF CONSTRUCTION ARE RETURNED TO THE PAINT BOOTH FOR SPRAYING WITH BLACK GLYPTAL, A SEMI-GLOSS INSULATING ENAMEL.

THE COIL LEADS ARE DRESSED FROM THEIR BREAK-OUT CORNERS TO THE TERMINAL PLACEMENT POSITION; THE PROPER RING IS PLACED AROUND THE UPPER HALF OF THE TRANSFORMER; THE WIRES ARE THEN INSERTED INTO THE CORRECT TERMINAL AS PER INSTRUCTION SHEET (SEE FOLLOWING PAGES FOR INSTRUCTION SHEET SAMPLES).

THE TRANSFORMER MOVES ALONG THE ASSEMBLY LINE FOR ATTACHMENT OF END BELLS OR CAST COVERS. WRAPPING THE LEADS AROUND THE TERMINALS AND THEN SOLDERING WILL COMPLETE THE ASSEMBLY OPERATION.

HIGH VOLTAGE TRANSFORMERS ARE ASSEMBLED TO TERMINAL BOARDS PRIOR TO IMPREGNATION; THE HOOK-UP LEADS ARE ATTACHED PRIOR TO INSPECTION. MOST ENCAPSULATED TRANSFORMERS ARE COMPLETELY ASSEMBLED PRIOR TO ENCAPSULATION.

WE DO A CONSIDERABLE AMOUNT OF PRE-ASSEMBLY IN THE ASSEMBLY AREA. THE TERMINAL BOARDS (OF PAPER PHENOLIC MATERIAL) AND THE TERMINALS (A MACHINED BRASS PIECE) ARE JOINED. WE USE A STAKING PRESS. THE ITEM BEING BUILT WILL CALL OUT THE SIZE AND PLACEMENT OF TERMINALS IN THE VARIOUS BOARDS, AS INSTRUCTED BY THE TERMINAL BOARD PROCESS SHEET (EXAMPLE FOLLOWS).

THIS WORK IS DONE BY THE UTILITY GROUP WHO WILL ALSO, WHEN NECESSARY, PLACE THE MYLAR TUBING AND WASHERS ON THE CORE BOLTS USED.

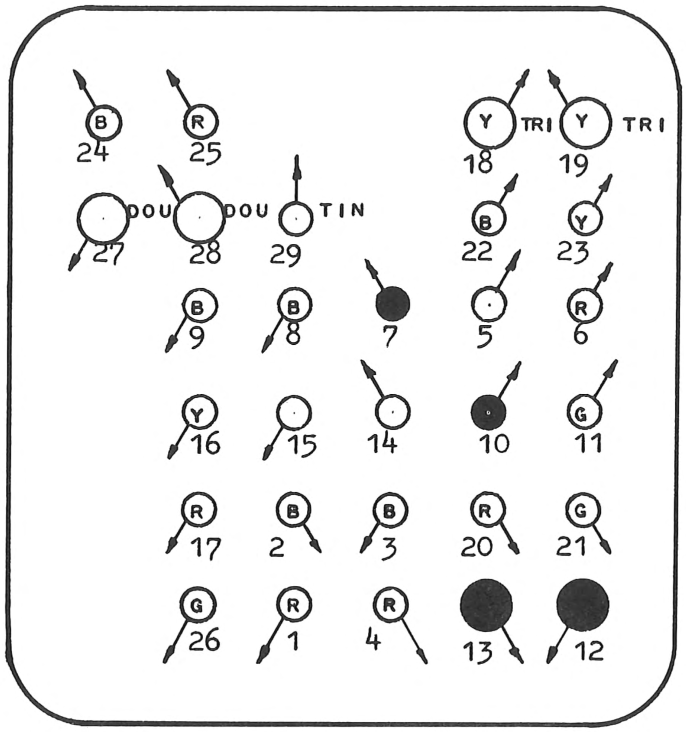
CLOSED TRANSFORMERS ARE IDENTIFIED BY THE SILK-SCREENED TEKTRONIX NUMBER ON THE COVER; THE SCREENING IS DONE BEFORE THE COVER IS PLACED ON THE TRANSFORMER. THE OPEN CONSTRUCTION TYPE MAY HAVE THE TEK NUMBER ON A PRINTED LABEL, WHICH IS ALSO USED TO DESIGNATE THE WINDINGS.

AFTER SOLDERING, THE TRANSFORMERS ARE TESTED FOR PROPER TURNS, PHASING, EXCITATION CURRENT AND BREAKDOWNS BETWEEN WINDINGS, ELECTROSTATIC SHIELDS AND THE CORE MATERIAL. A VISUAL INSPECTION DURING THE PACKAGING OR BOXING PROCESS ROUNDS OUT INSPECTION AND TESTING.

. . . . . . TEKTRONIX TRANSFORMERS ARE GUARANTEED FOR THE LIFE OF THE INSTRUMENTS OF WHICH THEY ARE A PART . . . . . .

500 A
PART 120-120

TUBE 27
#13 WHITE 3½"
TUBE 28
#13 WHITE 3"
TUBE 29
#18 WHITE 2¾"



TUBE
18-19 #10 YELLOW) 2¾"
13-12 #10 BLACK)

NOTE
DOU = DOUBLE WIRE
TRI = TRIPLE WIRE
TIN = TINNED WIRE

B = BLUE
Y = YELLOW
G = GREEN
R = RED

NOTE: ARROW DENOTES COIL CORNER OF LEAD BREAKOUT

BOARD 386-983
RING 354-033
TOP COVER 120-120 200-044
BOLTS 10-32 x 3¼ 212-524
NUTS 10-32 x 3/8 210-445
WASHERS - #10 INTERLOCKING 210-010
SCREWS 4-40 x 5/16" ST 213-034

TOP PLATE - PRI UP TO LEFT - NO. TO YOU

500 A

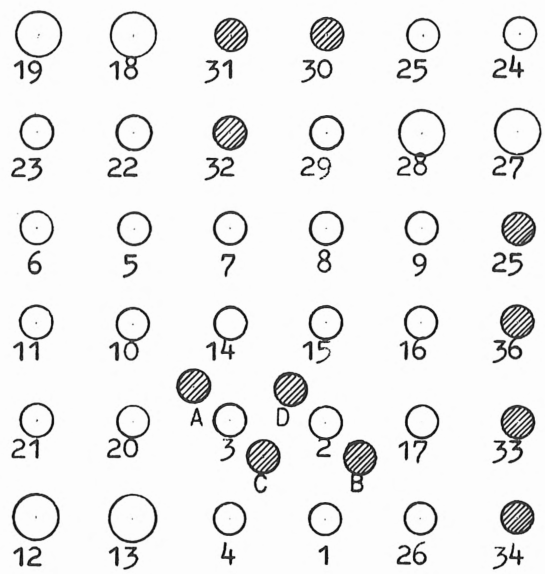
T - (120-120)

TERMINAL BOARD PROCESS SHEET

BASIC BOARD: 386-983

129-023

TERMINAL NOS.
12
13
18
19
27
28



129-024

TERMINAL	NOS.
1	17
2	20
3	21
4	22
5	23
6	24
7	25
8	26
9	29
10	
11	
14	
15	
16	

(hatched circle) .... OMIT TERMINAL