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INTERNATIONAL COOPERATION ADMINISTRATION
OFFICE OF INDUSTRIAL RESOURCES

TECHNICAL INQUIRY SERVICE

ELECTRIC MOTORS AND TRANSFORMERS

73,236

FOREWORD

The Technical Inquiry Service answers inquiries from overseas on factory or commercial establishment, operation, management, and engineering. This brochure is one of a series based on these technical inquiries.

This report is designed to provide only a general picture of the factors that must be considered in establishing and operating a factory of this type. In most cases, plans for actual installations will require expert engineering and financial advice in order to meet specific local conditions.

Mention of the name of any firm, product, or process in this report is not to be considered a recommendation or endorsement by the International Cooperation Administration, but merely a citation that is typical in its field.

Industrial reports prepared for ICA under special contract are customarily reviewed and edited before publication. This report, however, like other technical inquiry replies, has not been reviewed; it is the sole responsibility of the firm that prepared the report.

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For further information and assistance, readers should contact their local Productivity Center, Industrial Institute, Servicio, or United States Operations Mission.

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Section I

ELECTRIC MOTORS

INTRODUCTION

A small plant to manufacture fractional and small horsepower motors up to 5 hp can be established for approximately $150,000. A general breakdown of this cost is $100,000 for plant and equipment, and $50,000 for working capital.

This capitalization is based on U. S. estimates and will vary with local conditions. It is based on a monthly production of around 2,000 units in fractional horsepower or around 1,000 units of 5 hp motors.

There are a variety of fractional and small horsepower motors that can be manufactured. Although most manufacturers build more than one type of motor, the normal practice is to produce only one type per production run in order to obtain the maximum utilization of machinery and labor.

Most manufacturers of small motors buy a large share of the component parts used to build a motor. In some cases, with small firms, up to 80 percent of the parts that go into motor production are bought. The decision of whether parts are bought or built depends upon their cost and availability compared with in-plant production.

GENERAL ASSUMPTIONS

In order to make realistic estimates in this report, the following assumptions have been made:

1. The costs of building materials necessary to construct a plant are based on average prices prevailing in the United States in areas that are not highly industrialized.

2. Labor and operating costs are based on averages for the skills described in the United States.

3. Employees are paid on a time rate, not piece work.

4. Engineering and other professional services are available.

5. The cost of tools and equipment are based on costs prevailing in the United States.

6. Production processes will follow those used in the United States.

7. No custom work will be undertaken.

8. Skilled labor of the same caliber as that found in the United States for similar production is available.

9. The plant operates on a 40 hour week, one shift labor force.

10. The necessary raw materials, subassemblies and other manufactured parts are available.

11. Adequate transportation facilities are available at the plant site.

12. Adequate light, heat, water and electricity are available at the plant site.

13. A market for the products does exist and will remain constant. No provision has been made for marketing costs.

14. The following costs cannot be estimated realistically and have not been included: freight rates, taxes, interest, state enforced employee benefits, insurance and land values.

PRODUCT SPECIFICATIONS

Motors are classified or identified by their size, application, electrical type, mechanical protection, methods of cooling, variability of speed, etc.

The construction of motors has been standardized so that a wide variety of motors can be built with the least amount of re-tooling. Motor manufacturers, for example, build only a limited number of frame sizes. These are built in accordance with industry-adopted standards and dimensions. Tables of these standard dimensions are easily obtainable.

The advantages of standardization are: simplified design and manufacturing procedures, reduction in die, tool and machine equipment, and a reduced number of parts that must be kept in inventory.

It is recommended, therefore, that a new manufacturer of motors should only build standard type motors at first. Construction of special type motors should not be undertaken until manufacturing experience has been gained. Neither should a new manufacturer engage in motor repair work initially. Seldom do manufacturers find it profitable to combine new production with repair work.

Types of Motors

Motors fall into three general categories: d.c. motors that operate on direct current only; universal motors that operate on either d.c. or a.c. current; and a.c. motors that function on alternating current only.

Basically, electric motors are machines that convert electrical energy into mechanical energy. There are two basic ways of doing this: by energizing both the stationary (stator) and rotating (rotor) part of the motor; or by energizing only one part of the motor. Normally the stator is energized with the rotor receiving energy inductively.

The d.c. motors and some types of a.c. motors are built on the first principle. Most motors today, however, are built on the induction principle.

The induction motor operating on alternating current has become the standard type for most industrial, farm and home uses. These motors are classified, according to the current on which they operate, as either single phase or polyphase motors.

Fractional horsepower motors are normally of the single phase type, although they can be used for higher ratings if three-phase current is not available. Polyphase induction motors are normally used for ratings above one horsepower.

A single-phase induction motor in its simplest form is not self-starting. Some means must be provided to bring the motor to its rated speed, after which it will run as a pure induction motor. This has led to the development of several types of starting methods, the type of motor being called by the name of the starting method. The common types of single-phase induction motors are: split-phase, capacitor (single and double), repulsion-induction, and shaded pole. Each of the motors has particular uses for which it is best suited.

There are a variety of polyphase induction motors manufactured. Generally, they are classified and defined on the basis of mechanical construction and methods of cooling. Examples of standard classifications are: open machine, open drip-proof machine, splashproof machine, etc.

Within these classifications may be found induction motors with either squirrel-cage or wound-rotor construction and different methods of armature windings.

The type of motor purchased is determined by the use that it is to serve under specific conditions. Such things, for example, as the type of current supply available; whether the load is steady, subject to fluctuation or variable with load; a need for constant speed or variable speed; whether continuous or intermittent operation is desired; and special conditions surrounding the use of the motor such as abnormal temperature, inflammable atmosphere, dust and dirt, etc.

A market survey by the prospective manufacturer of small electric motors is necessary before a decision can be made on the type and quantity of motors to be produced.

Once the type of motor production has been determined, specific designs can be drawn. Production standards are available in the U.S. from the American Standards Association, Inc., 70 East 45th Street, New York 17, N. Y. and the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

These are organizations that have established industry-approved standards for the manufacture of equipment. In the electrical industry, the NEMA standards are widely used. These standards define a product as to nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, quality, rating, testing and the service for which it is designed.

A list of the NEMA publications can be obtained free by writing to that organization. Prices for individual standards run from a few cents up to around $4.00.

Table 1. Component parts of electric motors showing items normally produced in-plant and those purchased

Item	Number required	Fabricate	Purchase
Housing or case	1	x	
Bands	1	x	
End covers	2	x	
Terminal box assembly	1	x	
Nameplates	1		x
Handles (lifting)	per design	x	
Base or stand	1	x	
Bearings or bushings	2		x
Shims and thrust washers	per design	x	
Lubricating cups	per design	x	
Attaching hardware	per design		x
Stator assembly	1	x	
Core laminations	per design	x	
Coils	per design	x	
Tape	as required		x
Insulation paper	as required		x
Rotor assembly	1	x	
Rotor shaft	1	x	
End rings	per design	x	
Fan	1	x	
Commutator	1		x
Brush holder assembly	1		x
Carbon brushes	2		x
Automatic switching mechanism	1		x

MANUFACTURING OPERATIONS

The following manufacturing processes and sequences of operations are based on making or buying parts as shown in Table 1.

Housings

The housings for electric motors (including the end covers, base or stand, nameplates and terminal boxes) can be formed from sheet metal, cut from steel or aluminum tube, or made from aluminum or iron castings. The preferred method today uses aluminum because it is easier to work with, lighter, and dissipates heat more readily than other metals and requires no finish. Hardware for attaching or mounting must be drilled and reamed, mating surfaces machined and polished and bearing seating holes drilled and reamed. All parts must be carefully inspected and checked for tolerances before finishing. Finishing may be by painting or plating. The cover plates, nameplates and terminal boxes are fabricated from sheet stock and attached to the housing. Attaching and mounting hardware are generally bought.

Operation	Required equipment
1. Housing	
a. Cast	Subcontract
or	
b. Form	Power forming rolls Welding equipment
c. Cut	Power hack saw
d. Machine facings	Lathe
e. Drill and ream holes	Drill press
f. Inspect	Hand tools, shop jig
g. Paint (if needed)	Spray gun
h. Bake	Oven or infra-red ray banks
2. End Covers	
a. Cast	Subcontract
or	
b. Form	10-75 ton press

c. Machine facings	Lathe
d. Drill and ream holes	Drill press
e. Inspect	Hand tools, shop jig
f. Paint (if required)	Spray gun
g. Bake	Oven or infra-red ray banks
3. Base	
a. Cast or	Subcontract
b. Form	Foot shears, power forming rolls .50-75 ton press, welding equipment
c. Inspect	Hand tools, shop jig
d. Paint (if required)	Spray gun
e. Bake	Oven or infra-red ray banks
4. Covers, bands, nameplates and terminal boxes	
a. Form	Foot shears
b. Weld or rivet (terminal boxes)	Welding equipment, punch or drill press, hand riveting equipment
c. Paint	Spray gun
d. Bake	Oven or infra-red ray banks

Stators

The stator or field is the stationary part of an electric motor. It consists of a stator core, which is made up of a number of thin steel laminations forming the magnetic circuit, and a main and auxiliary winding. The auxiliary winding is used only on induction type motors. The windings, when assembled into the core, carry the electric current which sets up a magnetic circuit. The steel laminations are blanked and punched on a small punch press and assembled by hand to form the core. The core is likewise insulated by hand. Winding the coils may be performed by machine or by hand; for economy, hand winding is not recommended. Assembling the coils, dipping and baking, however, are hand operations.

Operation	Required equipment
a. Blank laminations	Punch press
b. Punch laminations	Punch press
(Note: a and b may be done simultaneously)	
c. Assemble laminations	Hand tools, shop jig
d. Check laminations	Hand tools
e. Press and bolt laminations	20 ton press
f. Insulate core slots	Hand tools
g. Wind stator as per design	Hand or machine winder
h. Connect poles as per design	Hand tools
i. Dip in baking varnish	Vat
j. Bake assembly	Ovens
k. Inspect and test	Testing equipment

Rotors

The rotor is the rotating member of an electric motor. It consists of a core made up of a number of laminations similar to those used in the stator. The principal differences between the rotors used on universal type motors and induction type motors are that a commutator is included as part of the universal rotor assembly and the windings are of wire construction. In the induction type rotor no commutator is used, and aluminum or copper bars are used in place of wire windings.

Operation	Required equipment
Universal brush type rotors	
a. Blank laminations	Punch press
b. Punch laminations	Punch press
(Note: a and b may be done simultaneously)	

Operation	Required equipment
Universal brush type rotors (cont'd)	
c. Assemble laminations	Hand tools, shop jig
d. Insulate core slots	Hand tools
e. Press core on shaft	20 ton press
f. Machine rotor shaft	Lathe
g. Wind armature	Hand or machine winder
h. Press on commutator	20 ton press
i. Set leads to commutator and solder	Hand tools
j. Dip in baking varnish	Vat
k. Bake assembly	Oven
l. Turn commutator and undercut mica	Lathe, mica undercutter
m. Inspect, test and balance	Testing equipment, balancing equipment
Induction type rotors	
a. Blank laminations	Punch press
b. Punch laminations	Punch press
(Note: a and b may be done simultaneously)	
c. Assemble laminations	Hand tools and shop jig
d. Press on shaft	20 ton press
e. Assemble rotor bars as per design	Hand tools
f. Machine rotor	Lathe
g. Balance	Balancing machine
h. Inspect and test	Motor analyzer

Operation	Required equipment
Final assembly	
a. Install stator in housing	Hand tools or press
b. Install rotor and shaft assembly	Hand tools
c. Install automatic devices as per design	Hand tools
d. Attach end covers, nameplates, base and terminal boxes	Hand tools
e. Test	Motor analyzer
f. Pack or crate	Hand tools
g. Store	Hand truck

LABOR REQUIREMENTS

The total labor force required to operate a plant for the manufacture of various types and sizes of electric motors is dependent upon the design of the motor, type and size of motor, and any special features of it. In addition, the in-plant labor force will be directly affected by the amount of component parts purchased.

Assuming that a plant will be equipped with the tools and equipment listed in Table 4 and that component parts will be purchased as shown in Table 1, the following estimates of labor requirements have been made. (Average U.S. hourly wage rates have been used.)

Table 2. Direct labor requirements

Skill	Rate per hour		Approximate labor hours for production of the indicated number of units per day of the following size horsepower motors				
	U.S.	Local	1/6 (100)	1/4 (100)	3/4 (100)	1.0 (75)	5.0 (40)
Superintendent	$4.25		8	8	8	8	8
Tool and die maker	2.70		8	8	8	8	8
Machine operators							
a. Skilled	2.37		16	16	24	40	40
b. Semi-skilled	2.10		16	16	16	24	32
Winders							
a. Skilled	1.89		24	24	40	72	96
b. Semi-skilled	1.72		8	16	32	56	80
c. Beginners	1.65		8	8	16	16	24
Finishers							
a. Painters	1.87		8	8	8	8	16
b. Oven operator	1.70		8	8	8	8	16
Final assemblers							
a. Skilled	2.24		16	16	16	24	32
b. Semi-skilled	2.13		8	8	8	16	24
c. Beginners	2.01		8	8	8	8	8
Welders and brazers							
a. Skilled	2.05		8	8	8	24	32
b. Machine operator (spot welder)	1.85		8	8	8	8	8

Table 2. Direct labor requirements (Continued)

Inspectors						
a. Skilled	2.24	8	8	16	16	32
b. Semi-skilled	2.06	8	8	8	16	16
c. Beginners	1.74	8	8	8	8	8
Material handlers						
a. Group leader (expediter)	1.82	8	8	8	8	8
b. Assistants	1.63	8	8	8	24	32
Total direct labor hours		192	208	264	416	552
Direct labor cost per shift		$358.92	$432.08	$519.68	$842.56	$1108.96

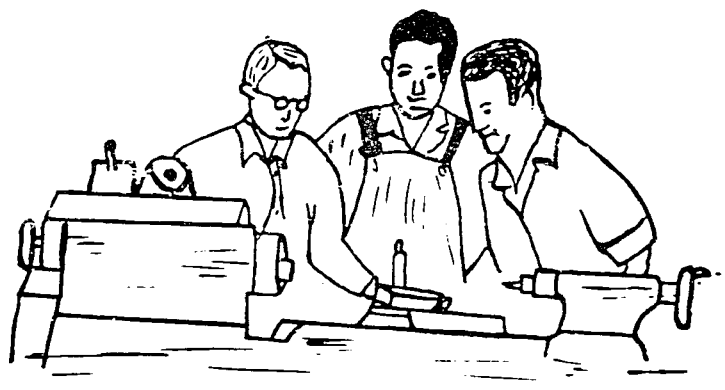


Table 3. Indirect labor and office force requirements

Skill	Rate per hour		Approximate labor hours for production of the indicated number of units per day of the following size horsepower motors				
	U.S.	Local	1/6(100)	1/4(100)	3/4(100)	1.0(75)	5(40)
Shipping and receiving clerk	$1.91		8	8	8	16	16
Packing clerks	1.56		8	8	8	16	24
Truck driver	1.70		8	8	8	8	8
Janitor	1.47		8	8	8	8	8
Plant engineer	1.75		8	8	8	8	8
Total indirect labor hours			40	40	40	56	64
Total indirect labor cost per shift (U.S.)			$67.12	$67.12	$67.12	$94.88	$107.36
OFFICE PERSONNEL REQUIREMENTS							
Bookkeeper	$1.85		8	8	8	8	8
Secretary	1.65		8	8	8	8	8
Typist	1.40		8	8	8	8	8
File clerk	1.25		8	8	8	8	8
Office boy	1.05		8	8	8	8	8
Total office requirement hours			40	40	40	40	40
Total office personnel cost per shift (U.S.)			$57.60	$57.60	$57.60	$57.60	$57.60

TOOLS AND EQUIPMENT

Listed below are the basic tools and equipment required to manufacture small horsepower motors. A plant with this equipment has the flexibility to manufacture a variety of motor sizes and designs. The number of component parts purchased will directly reduce the need for in-plant equipment. (Prices are U.S. averages based on new machinery f.o.b. factory.)

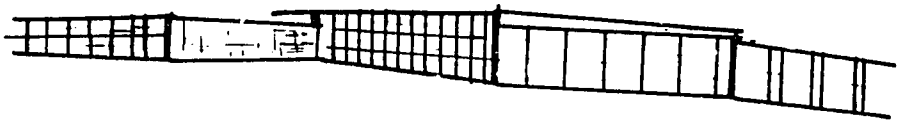
Table 4. Tool and equipment requirements

Item	Average cost (each) U.S.	Average cost (each) Local	Average weight	Number required
75 ton press	$5937.00		2200	1
40 ton press	3385.00		1550	1
20 ton press	2215.00		1295	1
5 ton press	994.00		885	1
Forming rolls	875.00		780	1
Lathe	1700.00		1200	3
Drill press	520.00		700	3
Metal shear	600.00		475	3
Mica undercutting machine	85.00		56	1
Coil taping machine	117.00		36	2
Coil spreader	410.00		300	1
Arbor press	120.00		52	3
Weighing scale	75.00		50	3
Spray gun	60.00		9	1
Vise	32.00		125	4
Insulator former	114.00		14	1
Air compressor	365.00		157	1
Screw machine	900.00		480	1
Rotor coil winder	4750.00		400	1
Stator coil winder	160.00		375	3
Winding head	40.00		30	6
Power hack saw	830.00		395	1
Gas welding kit	75.00		5	1
Electric arc welding machine	550.00		310	1
Spot welding machine	410.00		295	1

Table 4. Tool and equipment requirements (cont'd)

Power buffer	35.00	16	2
Power grinder	55.00	77	2
Hand truck	150.00	55	5
Testing equipment			
a. Dynamometer	300.00	205	2
b. Stator winding tester	50.00	18	1
c. Growler	39.00	13	1
d. Voltage tester	12.00	4	1
Work bench	900.00		(as required custom built)
Spray booth	80.00		1
Baking oven	375.00		1 (custom)
Varnish vat	50.00		2 (custom)
Cleaning vat	100.00		4 (custom)
Dust collector system	1200.00		custom built
Parts bin	500.00		as required
Expendable tools	1000.00		as required
Hand tools	600.00		as required
Motor truck	1800.00	3100	1
Conveyor section	1000.00	1500	300 feet (est.)
Overhead conveyance system	6000.00		custom built
Armature extractor	225.00		1

Total acquisition cost $46,693.00 (U.S.)

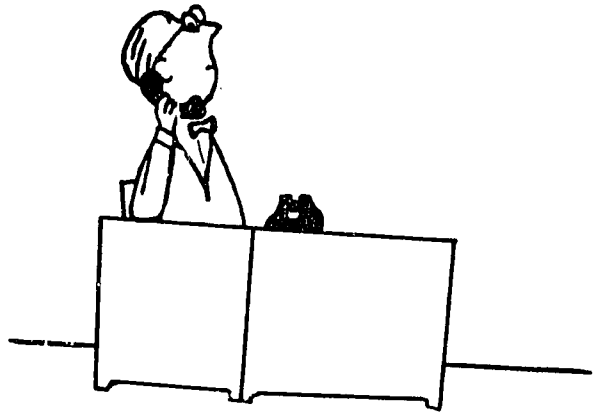


OFFICE EQUIPMENT

An arbitrary amount of $2,000.00 (in U.S.) has been estimated as the average cost for office equipment. This amount would purchase the following items:

Table 5. Office equipment requirements

Item	Number	Cost (each) U.S.	Cost (each) Local
Desk and chair (set)	4	$ 100.00	
Filing cabinet	10	65.00	
Drawing board	2	60.00	
Typewriter	2	150.00	
Adding machine	1	175.00	
General fixtures		355.00	
Total (U.S.)		$2,000.00	



MATERIAL REQUIREMENTS

The basic direct and indirect material requirements, together with the approximate cost, are listed in Tables 6 and 7. This is a 60-day materials estimate, using estimated daily production as given in Table 3.

Table 6. Indirect Material Requirements

Item	Price range U.S.	Price range Local	Unit	60-day stock cost U.S.	60-day stock cost Local
Packing paper	$4.50 - $6.00		hundredweight	$285.00	
Packing box	0.10 - 0.90		each	590.00	
Shipping tags, forms and labels	(custom)			60.00	
Binding steel shipping strap	0.03 - 0.05		foot	220.00	
Preservative	3.75 - 4.25		gallon	60.00	
Lubricant	2.60 - 3.85		gallon	70.00	
Cleaning solvent	0.30 - 0.40		gallon	100.00	
Cleaning cloth	0.40 - 0.60		pound	80.00	
Miscellaneous supplies				100.00	
Total indirect materials (U.S.)				$1,565.00	

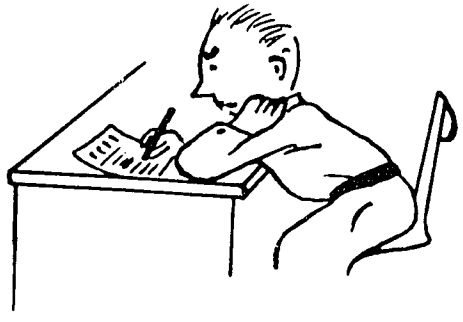
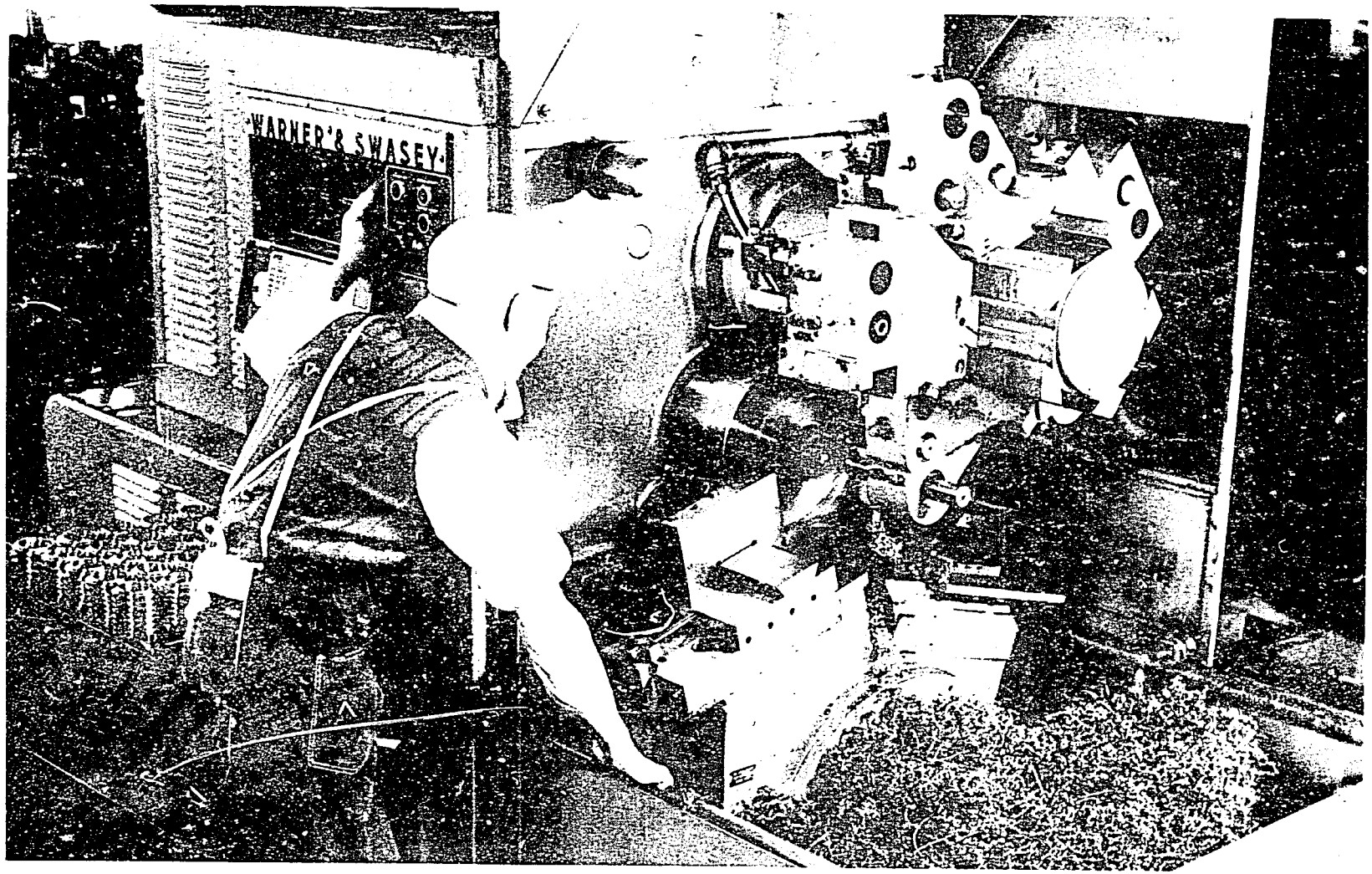
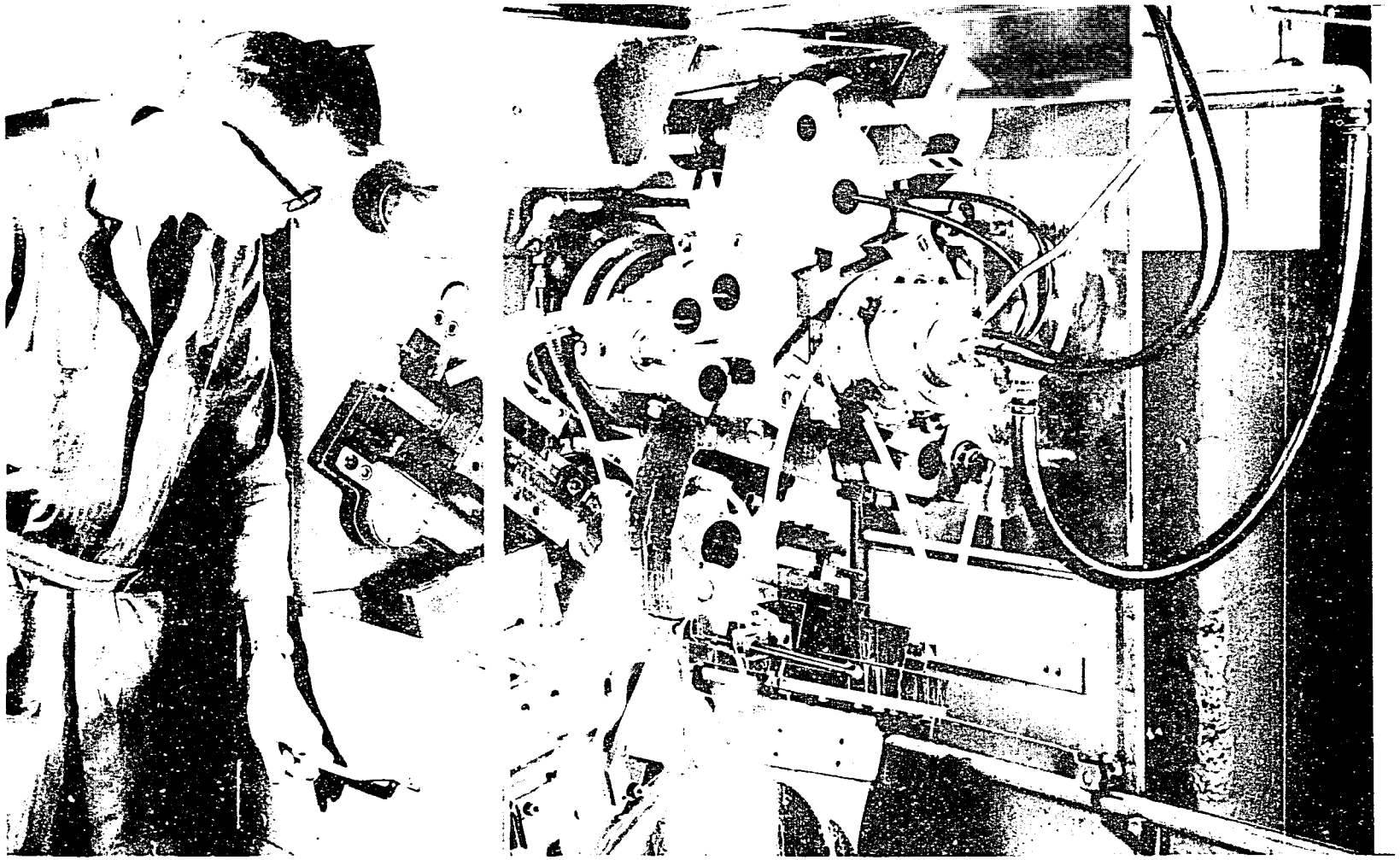


Table 7. Direct material requirements

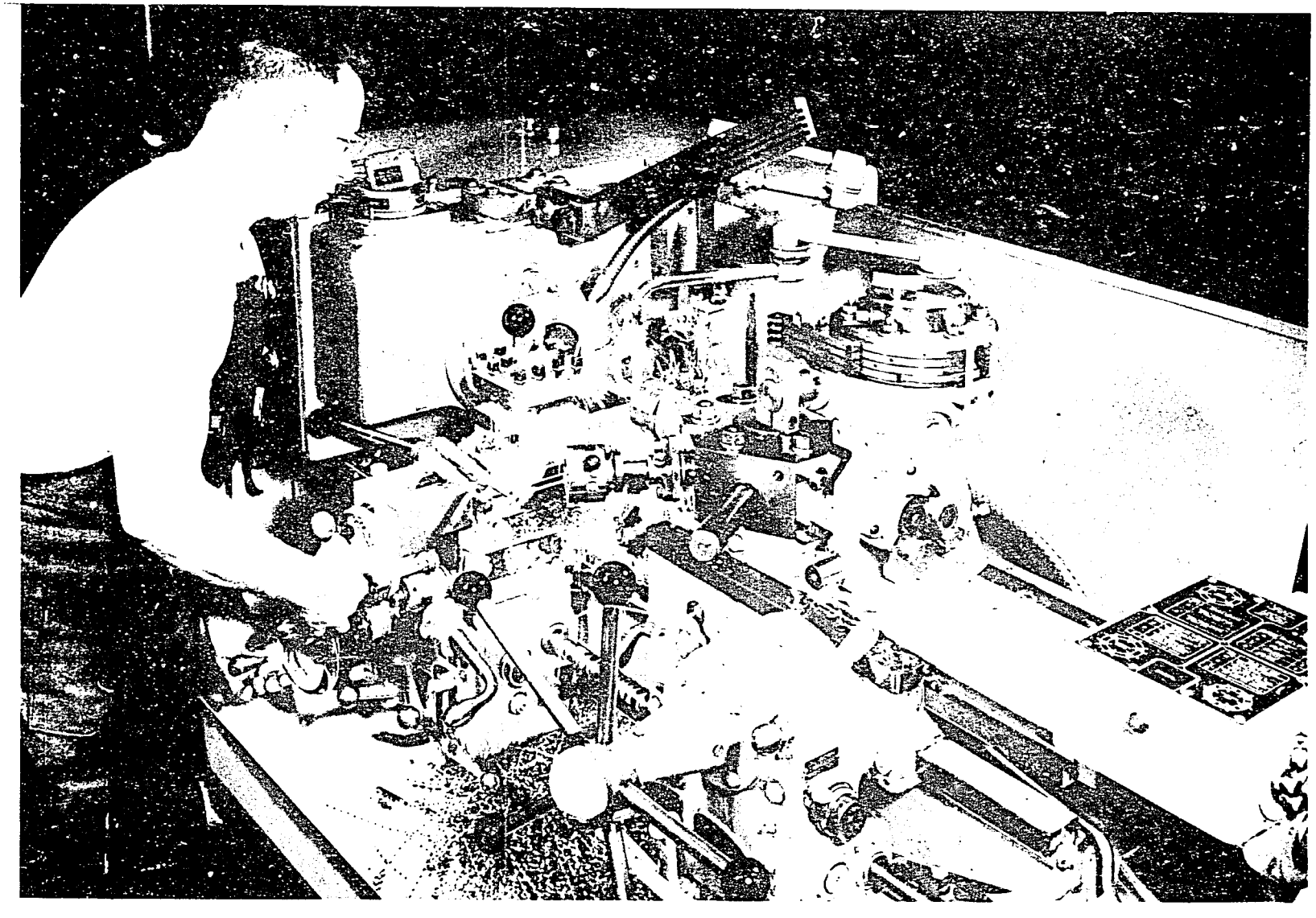
Item	Price range		Unit	60-day stock cost	
	U.S.	Local		U.S.	Local
Sheet metal	$15.00 -$20.00		hundredweight	$ 1050.00	
Sheet aluminum	40.00 - 60.00		hundredweight	2400.00	
Round steel stock	8.00 - 12.00		hundredweight	250.00	
Copper wire	0.54 - 1.65		pound	7600.00	
Copper bar	0.49 - 0.54		pound	4040.00	
Varnish	9.00 - 12.50		gallon	900.00	
Ball bearings	1.43 - 6.05		each	9840.00	
Sleeve bearings	0.44 - 1.77		each	7200.00	
Fibre wedge	0.60 - 0.95		1000	155.00	
Tape	1.90 - 3.50		1500 inch	295.00	
Insulation paper	3.05 - 7.16		1500 inch	300.00	
Capacitor	0.98 - 4.12		each	1100.00	
Carbon brush	0.08 - 0.30		each	300.00	
Commutator	0.85 - 3.60		each	3500.00	
Brush spring	0.06 - 0.17		each	165.00	
Gasket	0.01 - 0.13		each	100.00	
Centrifugal switch	2.10 - 16.00		each	1100.00	
Small motor switch	0.70 - 1.60		each	800.00	
Brush holding rig	1.40 - 3.60		each	1150.00	
Hardware	0.01 - 0.10		each	1200.00	
Total direct materials (U.S.)				$43,445.00	



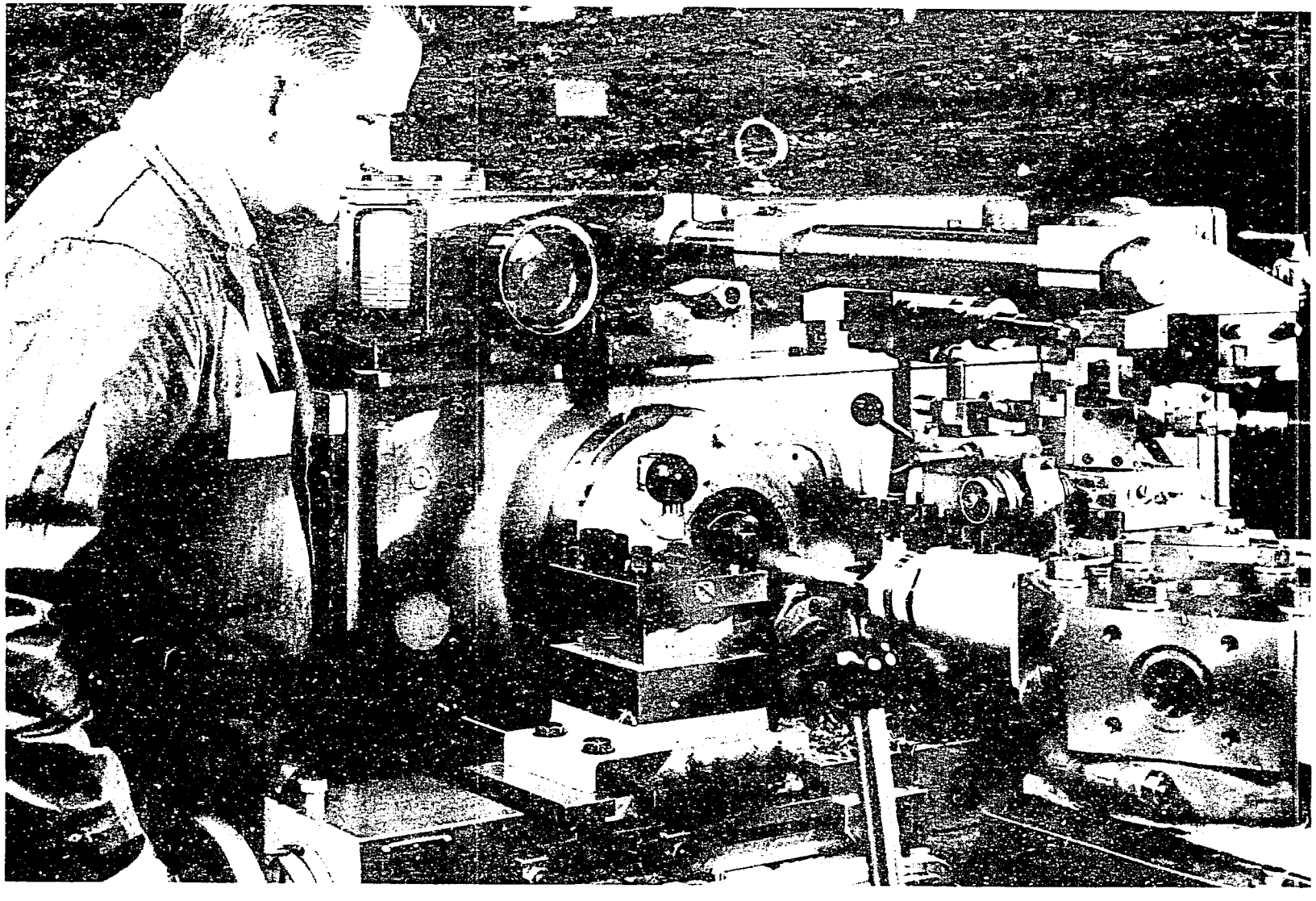
Model 2AC single spindle automatic chucking machine machining end bells (an automatic turret lathe). Courtesy of The Warner & Swasey Co., Cleveland, Ohio.



Model 2AB single spindle automatic bar machine machining motor shafts (an automatic turret lathe). Courtesy of The Warner & Swasey Co., Cleveland, Ohio.



Model 3EC ram type turret lathe with step turner attachment machining stepped motor shafts (hand operated turret lathe). Courtesy of The Warner & Swasey Co., Cleveland, Ohio.

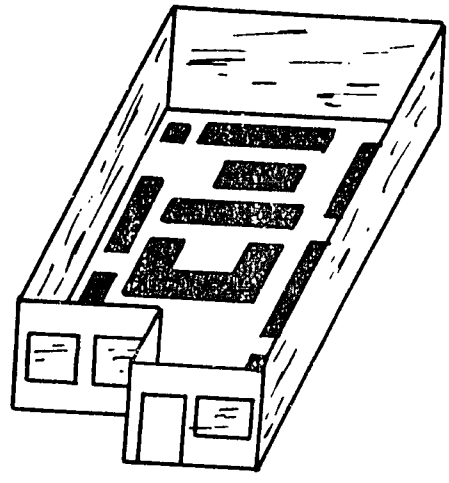


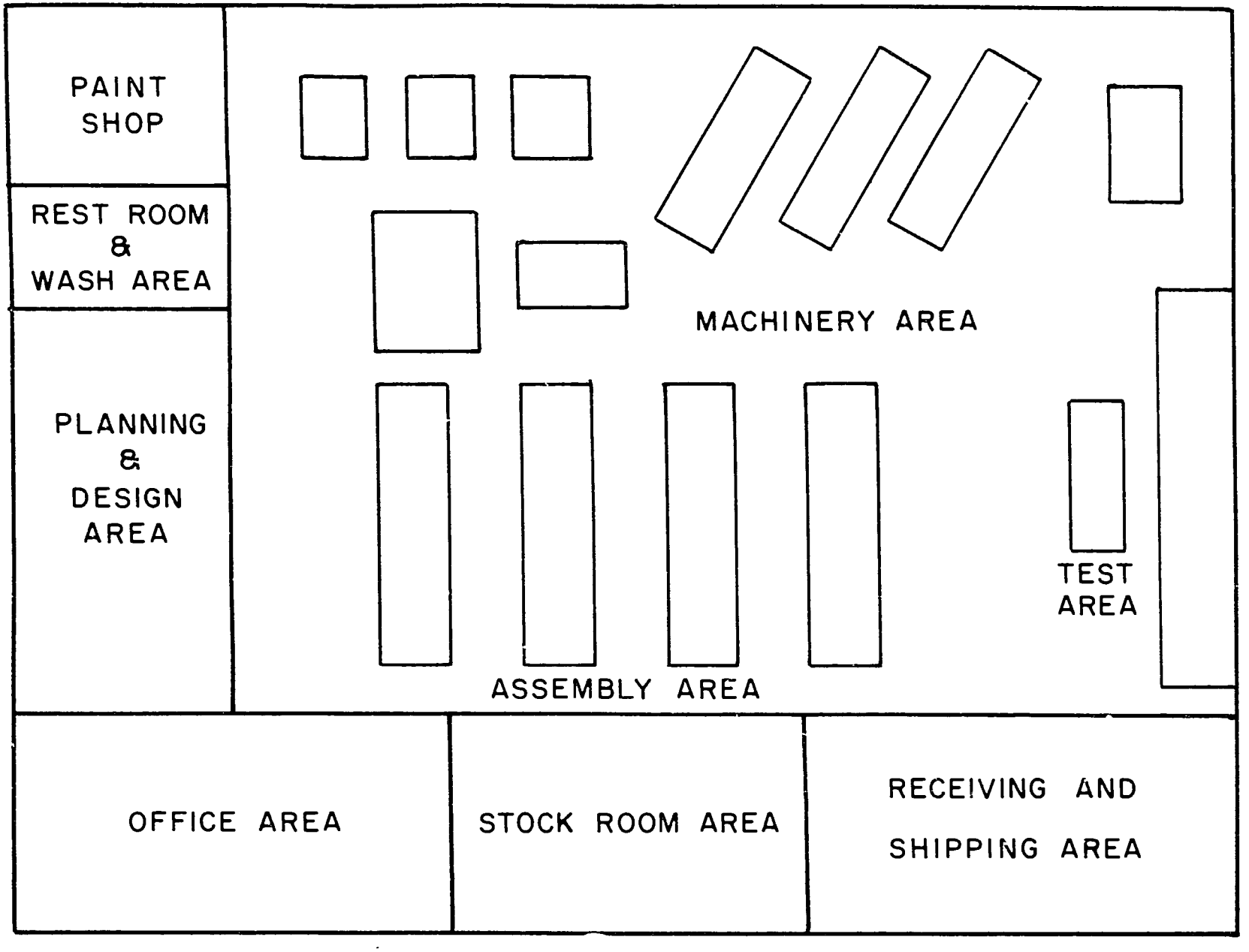
Model 5 ram type turret lathe, equipped with a hydraulic operated cross slide tracer, machining large diameter stepped motor shafts (hand operated turret lathe). Courtesy of The Warner & Swasey Co., Cleveland, Ohio.

PLANT LAYOUT

A sample plant layout is shown on page 24. This will vary according to the production capacity of the plant and the actual shape of the floor space available. Local ordnances as to minimum working space requirements, floor load and health and fire protection must govern the final plant layout.

Ideally, production machinery will be arranged to have a straight production line so that when one step in production is completed the unit is moved to the adjacent area. Although this is not always possible in laying out a plant, it should be a governing rule in order to avoid congestion and lost production time.





PLANT LAYOUT (10,000 SQUARE FEET)

PLANT SITE

The plant should be located where electric power is available and where it is accessible via truck or rail or both and convenient for the working force. Telephone service, water and sewage are required.

It is estimated that a minimum of 15,000 square feet of land will be needed for an adequate plant site. An arbitrary sum of $7,500 has been allowed for the cost of a plant site in this study.

Consideration should be given in the selection of a plant site to future expansion. This factor is important because of its direct effect on the potential production runs that a market survey will reveal.

BUILDING

Floor space for a plant of the capacity discussed in this study runs around 10,000 square feet. Prices in the U.S. for a suitable brick or concrete structure are approximately $4.25 per square foot, including plumbing, wiring and ventilation in areas of low industrialization.

Although the production process is flexible enough to be adapted to existing structures, all floor space used for production purposes should be on one floor.

POWER

A dependable source of electric power is required. Current is needed for lighting, testing equipment and operating production equipment.

WATER

Water is needed for drinking, for sanitary purposes and for fire protection.

FUEL

Plant heating for the comfort of workers may or may not be needed, depending upon the country in which the plant is located.

For a plant of the general size and capacity discussed in this study, a monthly estimate of $400.00 has been made for heat, electric, water, and telephone costs.

TRUCK

The services of a motor truck are required. For the purposes of this study, direct ownership of a vehicle has been assumed. However, this service may be contracted for or obtained through vehicle rental. A sum of $2,000.00 has been allowed for the purchase of a suitable pick-up and delivery truck in this study. This can be reduced, however, through the purchase of a used vehicle if individual circumstances make this advisable.

Table 8. Estimated depreciation

Item	Initial cost		Estimated life (years)	Estimated yearly depreciation	
	U.S.	Local		U.S.	Local
Production equipment	$35,669.00		15	$2,377.93	
Office equipment	2,000.00		10	200.00	
Motor truck	1,800.00		5	360.00	
Conveyor sections	1,000.00		10	100.00	
Overhead conveyor	6,000.00		10	600.00	
Armature extractor	225.00		10	25.00	
Building	50,000.00		25	2,000.00	
Maintenance (3% of building and equipment)				2,900.82	
Total yearly depreciation (U.S.)				$8,563.75	

Table 9. Overhead rate
(30 day)
(based upon average U.S. costs)

Size of motor	1/6 hp	1/4 hp	3/4 hp	1.0 hp	5.0 hp
Heat, light, water and telephone	$ 400.00	$ 400.00	$ 400.00	$ 400.00	$ 400.00
Depreciation	713.62	713.62	713.62	713.62	713.62
Indirect labor	2013.60	2013.60	2013.60	2846.40	3220.80
Indirect materials	782.50	782.50	782.50	782.50	782.50
Office payroll	1728.00	1728.00	1728.00	1728.00	1728.00
Vacation pay (4% annual of direct labor)	287.14	345.65	415.74	674.05	887.20
Office supplies	200.00	200.00	200.00	200.00	200.00
Total overhead rate	6124.86	6183.37	6253.46	7344.57	7932.12
Units of production per month	2200	2200	1650	1650	880
Overhead rates per unit	2.78	2.81	3.78	4.45	9.01

Table 10. Unit cost of manufacturing
(based upon average U.S. costs)

Size of motor	1/6 hp	1/4 hp	3/4 hp	1.0 hp	5.0 hp
Direct materials	$2.67	$ 3.90	$ 7.40	$ 9.60	$23.70
Direct labor	3.59	4.32	8.42	11.23	27.72
Overhead	2.78	2.81	3.78	4.45	9.01
Total cost per unit	9.04	11.03	18.11	25.28	60.43

Table 11. Capital requirements
Working capital (30 days)
(based upon average U.S. costs)

Size of motor	1/6 hp	1/4 hp	3/4 hp	1.0 hp	5.0 hp
Direct materials	$21,722.50	$21,722.50	$21,722.50	$21,722.50	$21,722.50
Direct labor	6,798.00	9,504.00	11,434.50	18,529.50	24,503.60
Operating expenses					
Indirect labor	2,013.60	2,013.60	2,013.60	2,846.40	3,220.80
Utilities	400.00	400.00	400.00	400.00	400.00
Indirect material	782.50	782.50	782.50	782.50	782.50
Office payroll	1,728.00	1,728.00	1,728.00	1,728.00	1,728.00
Office supplies	200.00	200.00	200.00	200.00	200.00
Total working capital	33,644.60	36,358.60	38,281.10	46,208.90	52,557.40
Fixed Assets					
Land and building (land estimated)	$50,000.00	$50,000.00	$50,000.00	$50,000.00	$50,000.00
Equipment	46,694.00	46,694.00	46,694.00	46,694.00	46,694.00
Total capitalization	130,338.60	133,041.60	134,975.10	142,902.90	149,221.40

Table 12. Costs, sales and profits

Item	Estimated Annual Costs (3/4 H.P.)	Actual Annual Costs	Estimated Annual Costs (5 H.P.)	Actual Annual Costs
Direct materials	$146,520.00	—	$250,272.00	—
Direct labor	166,716.00	—	292,723.00	—
Overhead	75,636.00	—	95,679.20	—
*Sales expense	89,100.00	—	77,616.00	—
Total costs	$477,972.00	—	$716,290.20	—
Sales revenue	$891,000.00 (19,800 units @ $45.00 each)	—	$1,108,800.00 (10,560 units @ $105.00 each)	—
Profit before discount allowance	$413,028.00	—	$392,509.80	—
Discount allowance on quantity purchases	267,300.00 (30 percent average used)	—	221,760.00 (20 percent average used)	—
Profit before taxes	$145,728.00	—	$170,749.80	—

* 10 percent of sales price for 3/4 h.p. units has been allowed and 7 percent of sales price for 5 h.p. units.

The table above shows a costs, sales and profits schedule that has been based on 100 percent plant output and sales. This will vary with individual plant efficiency and marketing areas, and reduce profits accordingly. Profits will be increased, however, if the full discount allowance used in this study is not required to market the product.

For estimating purposes, an additional expense allowance of $10,000.00 per year should be allowed to cover insurance and interest on borrowed capital.

SAFETY

Employee safety is a prime and continuing responsibility. Safety guards should be placed around all hazardous machinery; walking areas should be well designated; safety warnings should be well displayed where needed; and continuing efforts should be exerted to keep employees safety conscious.

First aid kits and fire fighting equipment should be placed throughout the plant and employees drilled periodically in their use. Specific personnel should be designated to take charge in health or fire emergencies.

Awards for safety suggestions from employees is one way to encourage safety practices by employees.

TRAINING

Training programs are one of the best ways to insure competent employee performance and a continuing supply of skilled workers. The type of training program needed will vary with the skills of the workers employed. Generally, however, a program should be devised so that each worker has the opportunity of improving his proficiency in his job as well as learning a higher skill within the plant.

Employee suggestions for improvements in production should be encouraged with award incentives.

ACCOUNTING

No attempt is made in this study to outline a system of accounting and cost control. Such a system is dependent upon specific production plans. Once these have been formulated, the accounting system best suited to the company operations can be adopted. The importance of a good accounting and cost control system makes it imperative that expert advice be obtained. Generalizations in this field would be of little or no use and might tend to be misleading.

SUMMARY

For a capitalization of around $150,000 it is possible to establish a small plant to manufacture fractional and small horsepower motors up to 5 hp. Whether a plant of this type as outlined in this study would prove to be a sound financial investment depends upon specific local conditions and marketing possibilities.

The purpose of this study is to provide a general concept of the requirements to establish a plant so that local factors such as materials and supplies, markets, labor force, and financing arrangements can be properly weighed in making a final decision.

LITERATURE REFERENCES

National Electrical Manufacturers Association
155 E. 44th Street, New York 17, New York

American Standards Association, Inc.
70 East 45th Street, New York 17, N. Y.

National Association of Machinery Dealers
1346 Connecticut Avenue, N.W., Washington, D. C.

"Induction Motors, Single-phase & Polyphase"
Charles S. Siskind
McGraw-Hill Book Company, Inc.

"Machine Tools for Engineers"
Charles R. Hine
McGraw-Hill Book Company, Inc.

VISUAL AIDS (16mm)

*"Repulsion Motor Principles" (18 minute) explains construction of repulsion motor, rotor circuits and effect of brush position, short-circuiting and brush-listing mechanism, and application of repulsion motors.

"Split-Phase Motor Principles" (17 minute) explains the construction of the stator and rotor, comparison of winding in two-phase stator and split-phase stator, effects of winding resistances and inductive reactances, and use of capacitor to produce phase displacement.

*"Rotating Magnetic Fields" (13 minute) shows rotating magnetic field pattern; explains a two-pole, three-phase stator; traces three-phase winding in the demonstration stator; shows three factors that cause rotation of the magnetic field, how sine curves indicate flow changes in a three-phase circuit, and construction of polyphase motors.

The following is a list of machine tool manufacturers and consulting engineering firms, selected at random from U.S. companies.

Machine tool manufacturers

The Warner and Swasey Company
Cleveland, Ohio

The Bullard Company
Bridgeport, Connecticut

South Bend Lathe Works
South Bend, Indiana

The Cleveland Twist Drill Co.
Cleveland, Ohio

Rockford Machine Tool Co.
Rockford, Illinois

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*Available from the International Cooperation Administration's film library on a loan basis.

Kearney and Trecker Corporation
Milwaukee, Wisconsin

The Lapointe Machine Tool Company
Hudson, Massachusetts

Consulting engineers

Peter F. Loftus Corporation
Pittsburgh, Pennsylvania

Tippett & Gee
Abilene, Texas

The J. G. White Engineering Corporation
80 Broad Street, New York, N. Y.

Jackson & Moreland, Inc.
Boston, Massachusetts

Section II

TRANSFORMERS

INTRODUCTION

A small plant to manufacture fractional transformers up to 10 kva can be established for approximately $150,000. A general breakdown of this cost is $100,000 for plant and equipment, and $50,000 for working capital.

This capitalization is based on U. S. estimates and will vary with local conditions. It is based on a monthly production of around 2200 units in fractional kva or around 550 units from 1 to 10 kva (kilo-volt-amperes).

GENERAL ASSUMPTIONS

Assumptions applicable to electric motor manufacturing (Section I) also apply here.

PRODUCT SPECIFICATIONS

Transformers are devices that transfer electrical energy from one source of electricity to another. This is done without a change of frequency by the principle of electromagnetic induction. It is accomplished through the use of electric circuits connected by a common magnet circuit.

In their simplest form, transformers consist of a laminated magnetic steel core that has both a primary and secondary coil wound around it. The primary coil takes current from the source and the secondary coil transmits this energy to an application or use.

Transformers are manufactured in two basic types, the core type and the shell type. In the core type, the coils surround most of the magnetic circuit. In the shell type, the magnetic circuit surrounds the windings. These are built in single-phase and three-phase designs.

Small transformers from fractional kva up to around 100 kva are built as single-phase transformers. Three-phase transformers are normally used in the higher kva ratings. They are manufactured, however, for 3 kva ratings.

Most transformers are contained in sheet metal housings or tanks for their operating protection.

Transformer housings are of two general categories that further identify transformers by type. They are the dry-type transformer, where the core and coils are placed dry inside a container, and the liquid-immersed transformer. A liquid-immersed transformer is one in which the core and coils are immersed in a special insulating oil that serves both to insulate the windings and to keep them cool.

Core Type Transformer

Core type transformers are normally built with half of the primary and secondary coils placed around each leg of the transformer core. Insulation is used to keep them apart. They are wound on wooden forms, then dipped in an insulating varnish and baked before being placed on the core.

After the coils have been varnished and baked, the core is inserted. For core-type transformers, the core consists of L-shaped die-cut laminations of good quality magnetic steel containing around 4 per cent silicon. For 60-cycle service individual laminations are usually cut 0.014 inches in thickness and coated with a varnish insulation of about 0.001-inch thickness.

The laminations are inserted through the wound coils so that the butt joints of successive layers are interleaved between the flat surfaces on both sides. Both the primary and secondary coils are placed around the core with the low-voltage coil leads at the top and the high-voltage leads at the bottom.

Shell-type Transformers

In shell-type transformers the primary and secondary coils are wound on forms with alternate layers of insulation. The windings are made in a somewhat oval shape. When completed, the coils are varnished and baked before the core is inserted. Cores for shell-type transformers may be made from die-cut laminations cut as straight pieces. One lamination is placed through the center of the shell with the others forming a rectangular shape around the shell. Successive layers of the laminations are interleaved to keep surfaces flat.

Transformer cores are also made by coiling preformed strip steel around the coils. This is considered to be one of the best ways of building small transformers today. This results in a smaller, more rigid core per kva rating, generally has a lower iron loss at high flux densities and is cheaper to build.

Design

Transformers are designed for the use they are to serve. The first consideration is the output required in volt-amperes or kva. Then, the type of construction best suited for the use of the transformer is determined. This includes such items as whether the transformer is to be of the dry type, liquid-immersed, single-phase, three-phase, etc.

Once this has been decided, the next step is to determine the size of the overall transformer, the size of the core required, and the amount of winding needed for the coil. Mathematical tables are readily available that can be used in working out the core and coil specifications.

Within the general categories of use, manufacturers must from necessity standardize their designs for production. A market survey by the prospective manufacturer will be the guide as to the type of transformers built.

The following mechanical information shows the dimensions of typical dry-type and liquid-immersed transformers.

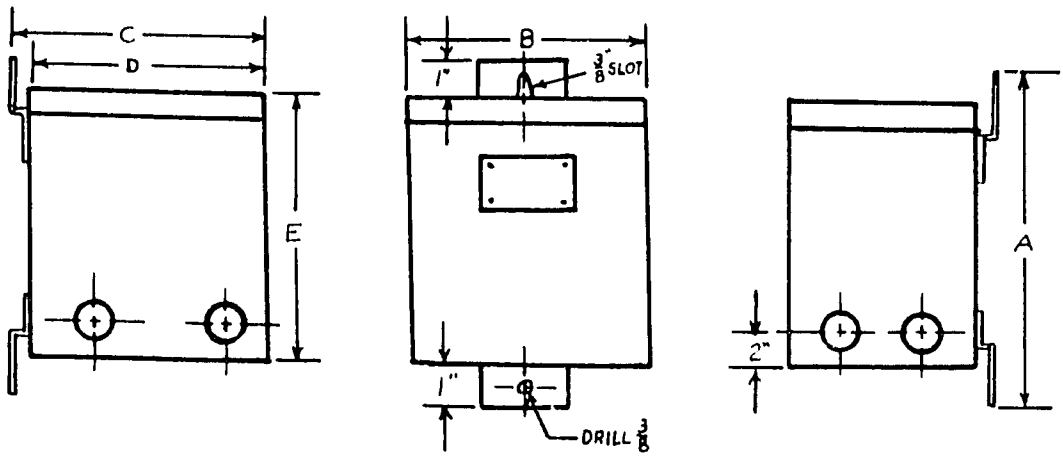


Table 13. Dry-type (totally enclosed)

KVA	Approximate dimensions (in inches) A	B	C	D	E	Weight (pounds)
3	17	10	10	9	15	65
5	19	11	11	10	17	95
10	20	12	13	12	18	150

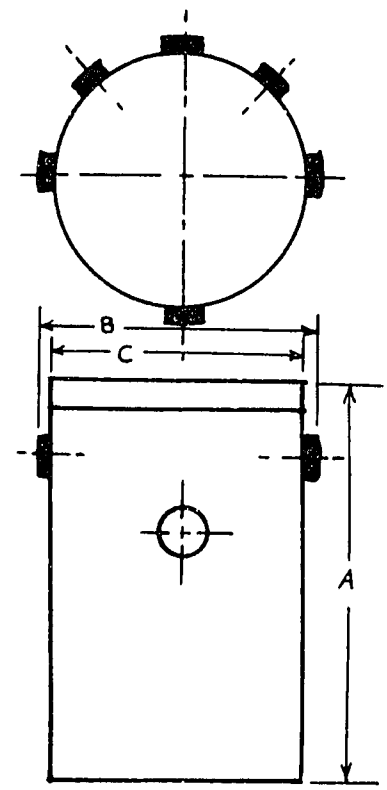


Table 14. Liquid-type

KVA	Approximate dimensions (inches) X	Y	Z	Weight (pounds)	Oil (gallons)
3	22	25	21	150	6
5	22	25	21	180	6
10	25	26	22	260	8

MANUFACTURING OPERATIONS

The small manufacturer should not do custom building unless the quantities involved warrant it. Generally, it is recommended that only one type of transformer be built per production run in order to obtain the optimum from both machinery and labor.

Manufacturing Process

The general manufacturing process for building a dry-type transformer having a shell-type coil is explained below.

(A) The transformer coil is wound on a wooden mold. The number of turns of insulated wire that is wound will be determined by the specifications of the transformer. In winding, the wire is kept at an even tension to insure a perfect wind. Counters attached to the winding lathe are used to insure a correct count on turns. An insulation material -- normally with an asbestos base -- is placed between each layer of wire. Asbestos spacers are inserted at intervals to form air ducts to dissipate heat.

Transformers over 1 kva are individually wound, requiring one man and one machine. It takes from one to three hours to make the windings, depending on the size of the transformer.

Transformers of less than one kva can be wound on automatic multiple winding machines. As many as twelve windings can be made with multiple winding machines in a matter of 15 to 30 minutes.

(B) After the winding has been completed, the coil is dried in an electrically heated oven. Generally, the oven is heated to around 250 to 275 degrees Fahrenheit. If cotton tape has been used on the coil it is important not to raise the oven heat over 300 degrees Fahrenheit, as the tape will begin to char at this temperature. The trend in manufacturing today, however, is to use glass insulation that can withstand higher temperatures.

Normally it takes from 2 to 3 hours to dry all of the moisture out of a coil. This will vary, however, with the insulation and oven used. The oven manufacturer's recommendations should be followed for exact baking times.

(C) After the coil has been dried, it is immersed in a tank of varnish. Most manufacturers use a silicon varnish today, although any high-thermal varnish can be used. Any transformer that is to be immersed in oil, however, must have an oil-proof varnish. The coil is left in the varnish tank until it is well impregnated. The time period for this depends upon the size of the transformer. As a rule of thumb, the coil is left in the varnish tank until it stops bubbling. This will take at least 30 minutes, depending upon the depth of the winding.

(D) The next step is to allow the excess varnish to drip off the coil and air dry until the varnish starts to harden. Once the coil has dried, it is put back into the baking oven and left until the varnish is cured. Curing normally takes about 6 hours. Again, the oven manufacturer's recommendations should be followed for specific times.

(E) The coil is then given a preliminary turns-ratio test before adding the core, hardware and steel support frames. Finally, the transformer is placed in an enclosed metal case to protect it from dust and weather.

MATERIALS COSTS

The following table shows the cost range for materials of the component parts of small transformers. Because of the wide variation in transformer types and materials used, the cost figures are for planning purposes only and will vary with specific designs.

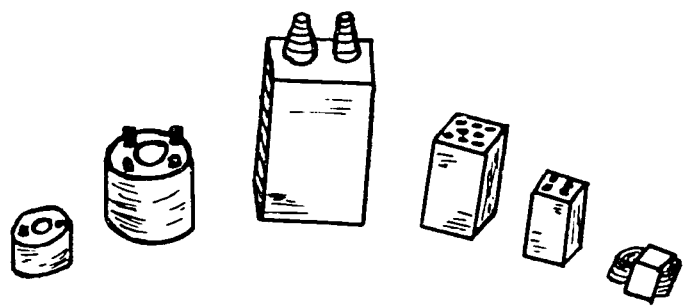
Item	Fractional kva Cost Range	1-10 kva Cost Range
Coils	$1.32 - $5.56	$ 5.56 - $26.23
Insulation	.79 - 3.34	3.34 - 15.76
Core	1.58 - 6.69	6.69 - 31.50
Frame assembly	.26 - 1.11	1.11 - 5.25
Container	.52 - 2.22	2.22 - 10.50
Fittings	.79 - 3.34	3.34 - 15.76
Total	$5.26 -$22.26	$22.26 -$105.00

Table 15. Indirect labor and office force requirements

Skill	Rate per hour U.S.	Rate per hour Local	Approximate labor hours for production of the indicated number of units per day of the size transformers indicated. Fractional kva (100)	1-10 kva (25)
Shipping and receiving clerk	$1.91		8 $(15.28)	8$(15.28)
Packing clerk	1.56		16 (24.96)	8 (12.48)
Truck driver	1.70		8 (13.60)	8 (13.60)
Janitor	1.47		8 (11.76)	8 (11.76)
Plant engineer	1.75		8 (14.00)	8 (14.00)
Design engineer	4.25		8 (36.00)	8 (36.00)
Total indirect labor hours			56	48
Total indirect labor cost per shift			$115.60	$103.12
OFFICE PERSONNEL				
Bookkeeper	$1.85		8	8
Secretary	1.65		8	8
Typist	1.40		8	8
File clerk	1.25		8	8
Office boy	1.05		8	8
Total office requirement hours			40	40
Total office personnel cost per shift			$57.60	$57.60

Table 15. Indirect labor and office force requirements (Continued)

DIRECT LABOR					
Superintendent	$4.25	8	$34.00	8	$34.00
Winders	1.89	8	15.12	40	75.60
Assemblers	2.24	24	53.76	24	53.76
Painter	1.87	8	14.96	8	14.96
Oven operator	1.70	8	13.60	8	13.60
Welder	1.85	8	14.80	8	14.80
Vat operator	1.70	8	13.60	8	13.60
Testers	2.24	16	35.84	8	17.92
Inspector	2.24	16	35.84	8	17.92
Material handlers	1.63	8	13.04	8	13.04
Total direct labor hours		112		128	
Total direct labor cost per shift			$244.56		$269.20



DIRECT MATERIALS

Table 16. Direct material requirements

Items	Price range	Unit	Estimated 30-day stock
Copper wire	$0.45 - $1.00	pound	$11,250.00
Insulation	.15 - 5.50	yard/pound	3,600.00
Varnish	9.00 - 20.00	gallon	1,500.00
Oil (if needed)	.56 - .70	gallon	1,800.00
Cable lead wire	.40 - .50	foot	675.00
Dataplate	.10 - .20	each	15.00
Parts Purchased			
Core	$10.00 - 40.00		9,000.00
Frame assembly	.50 - 3.50		1,200.00
Container	1.00 - 7.50		2,500.00
Tank	3.00 - 12.00		4,000.00
Bushings	1.50 - 12.00		3,000.00
	Total direct materials		$38,540.00

Assuming only coils made and other parts purchased.

Material requirements based on production rate as shown in Table 15. Requirements for oil, tank and bushings not needed if liquid-type transformers are not manufactured.

INDIRECT MATERIALS

Table 17. Indirect material requirements

Item	Price range	Unit	Estimated 30-day stock
Shipping crate	$ .50 - $1.00	each	$250.00
Binding steel shipping strap	.03 - .05	foot	320.00
Shipping tag, forms and labels	Custom		25.00
Miscellaneous supplies			50.00
Total indirect materials			$420.00

TOOLS AND EQUIPMENT

Table 18. Tools and equipment

Item	Cost range	Number required
Multiple winding machine (10-12 windings) fractional	$3-$5,000	1
Winding machines (for 1-10 kva)	4-5,000	5
Bake ovens	4-6,000	2 (custom)
Varnish vat	50	3 (custom)
Overhead conveyance system	4-6,000	1 (custom)
Conveyor section	1-2,000	1 (custom) 300-500 ft.
Spray booth	100	1
Spray gun	60	1
Hand tools	500	as required
Electric arc welding machine	500	1
Vacuum pump	1- 200	1

Table 18. Tools and equipment (Continued)

Hand truck	150	4
Oil pump	100	1
Motor truck	2,000	1
Scales	75	1
Testing equipment		
Turns-ratio test equipment	1-2,000	1
High potential test equipment	5,000 and up	1
High frequency test equipment	8,000 and up	1
Polarity test equipment	400	1

TESTING EQUIPMENT

Turns-ratio test equipment comes in both portable and large desk-cabinet styles. The equipment is designed to make low-voltage and high-voltage tests of coils, and it is sometimes called "coil tester" or "coil-turn counter" equipment.

The purpose of the equipment is to detect the presence of short-circuited turns or defective insulation in coils before they are installed in the final transformer assembly. The normal practice in manufacturing plants is to have both a low-voltage tester and a high-voltage tester.

The low-voltage tester will show the presence and approximate number of short-circuited turns in a coil. This tester requires a power supply: single phase, 105-125 or 220 volts, 60 cycles, 50 watts. The size is approximately 10 to 12 inches square and 10 to 12 inches high. (Weight is about 24 pounds.)

The high-voltage tester is used when an overvoltage test is required for insulation between turns and layers of unmounted coils. Power supply required: 105-125 volts, 60 cycles, 450 watts. (Weight is about 200 pounds.)

High-potential test equipment is available in various capacities to test fractional transformers or the 10 kva transformers. The equipment measures the crest value of voltage on sample regardless of wave shape, internal voltage drop, or variation in line voltage. Defects are indicated by dials or light indicators.

The small equipment is suitable for measuring 0 to 3,500 volts. Power supply: 105-125 volts, 50 or 60 cycles, a.c., 60 watts. Weight is about 25 pounds. Size: approximately 15 x 8 x 10 inches.

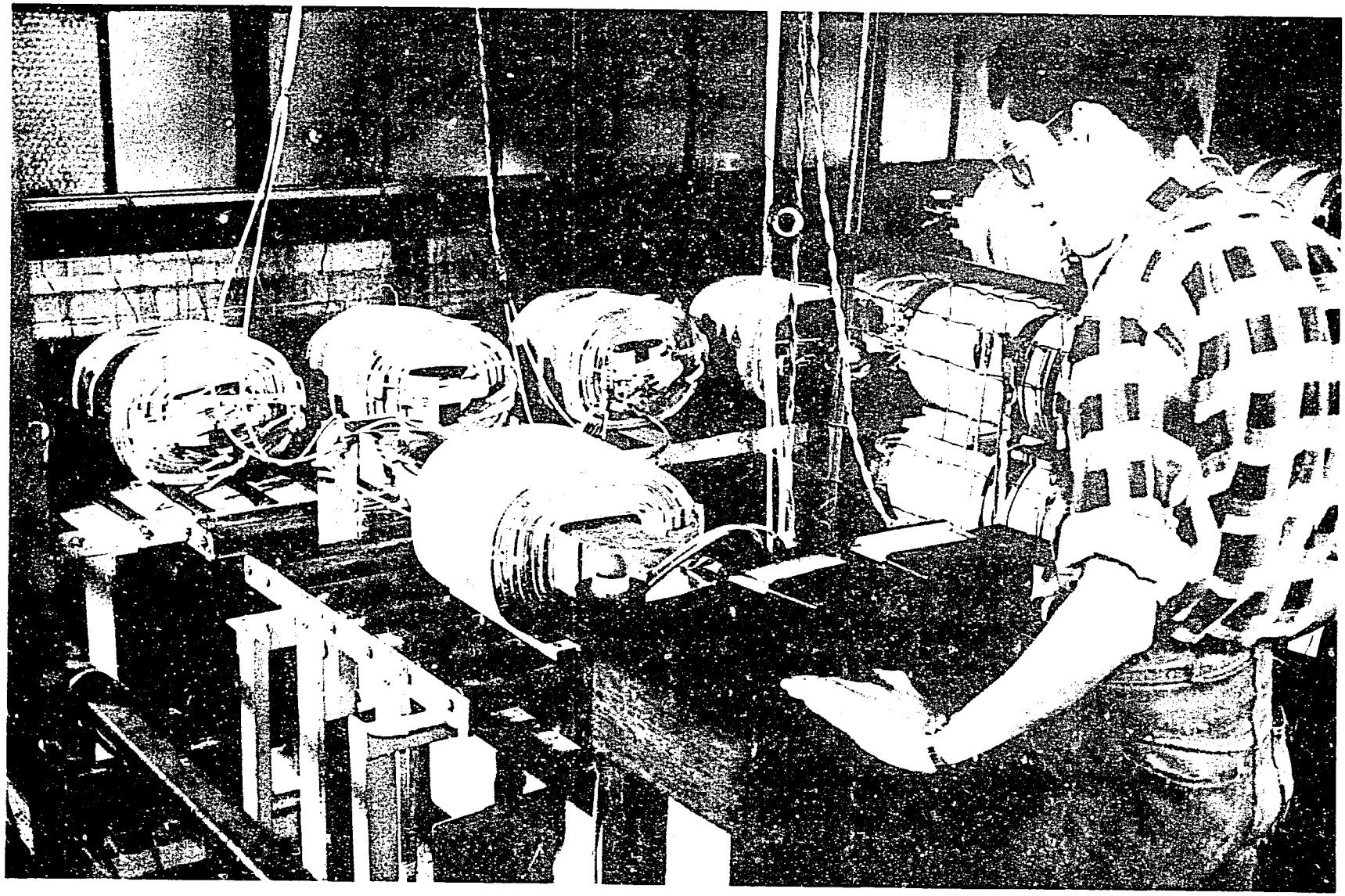
Equipment for measuring higher voltages normally is available on a caster truck that can be moved about the plant. Stationary units are also available. These sets are designed for operation from single-phase 60-cycle, 115-230-volt supply circuits. Weight is approximately 500 pounds. Size: about 24 x 20 x 30 inches.

It is possible to obtain general purpose test sets that can be used for various tests from low to very high voltages. Whether it is best to obtain general purpose test equipment or individual units depends upon production plans. Generally, however, individual test units are recommended.

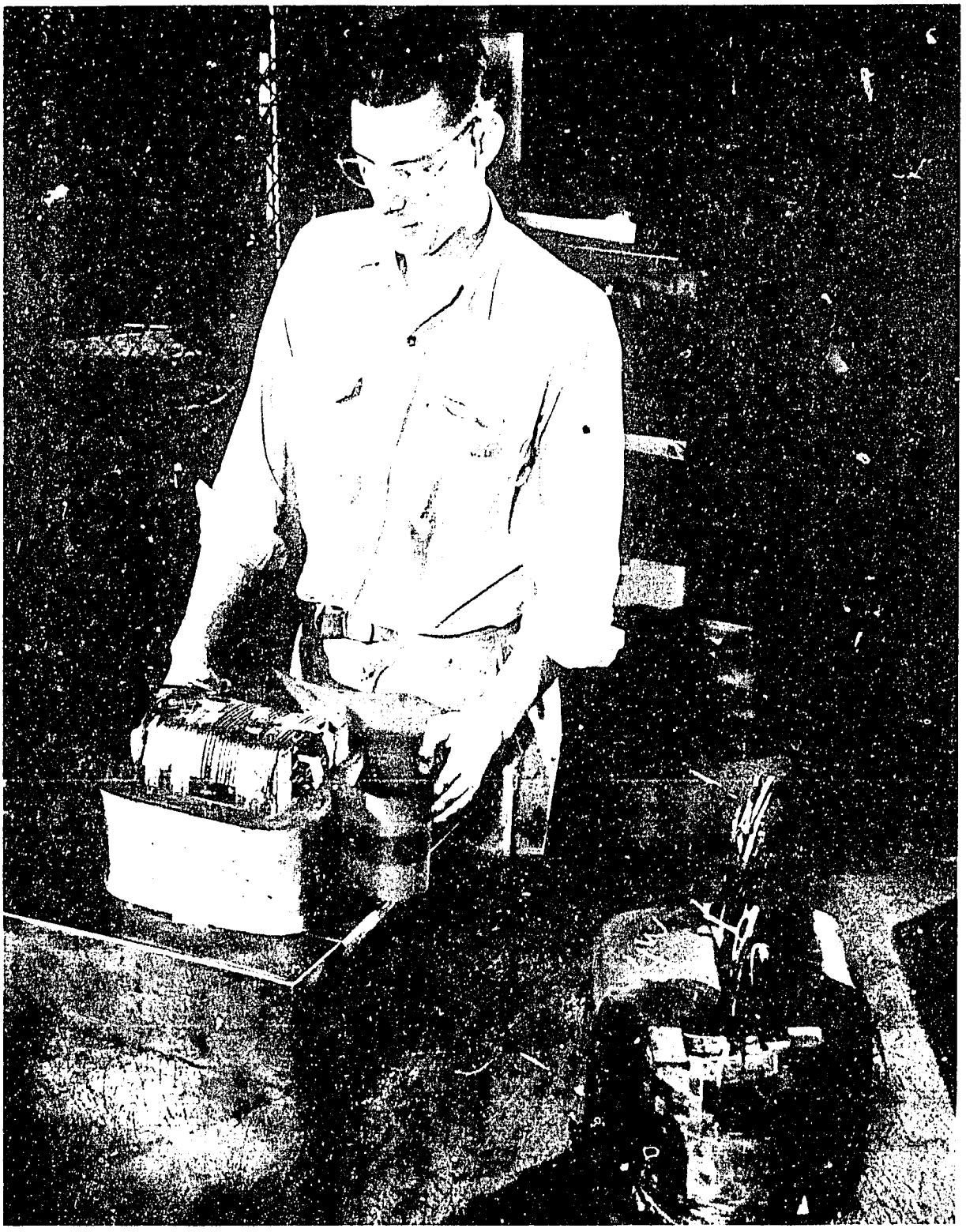
Table 19. Office equipment requirements

Item	Number required	Cost (each)
Desk and chair (set)	4	$ 100.00
Filing cabinet	10	65.00
Drawing board	2	60.00
Typewriter	2	150.00
Adding machine	1	175.00
General fixtures	-	355.00
		$2,000.00

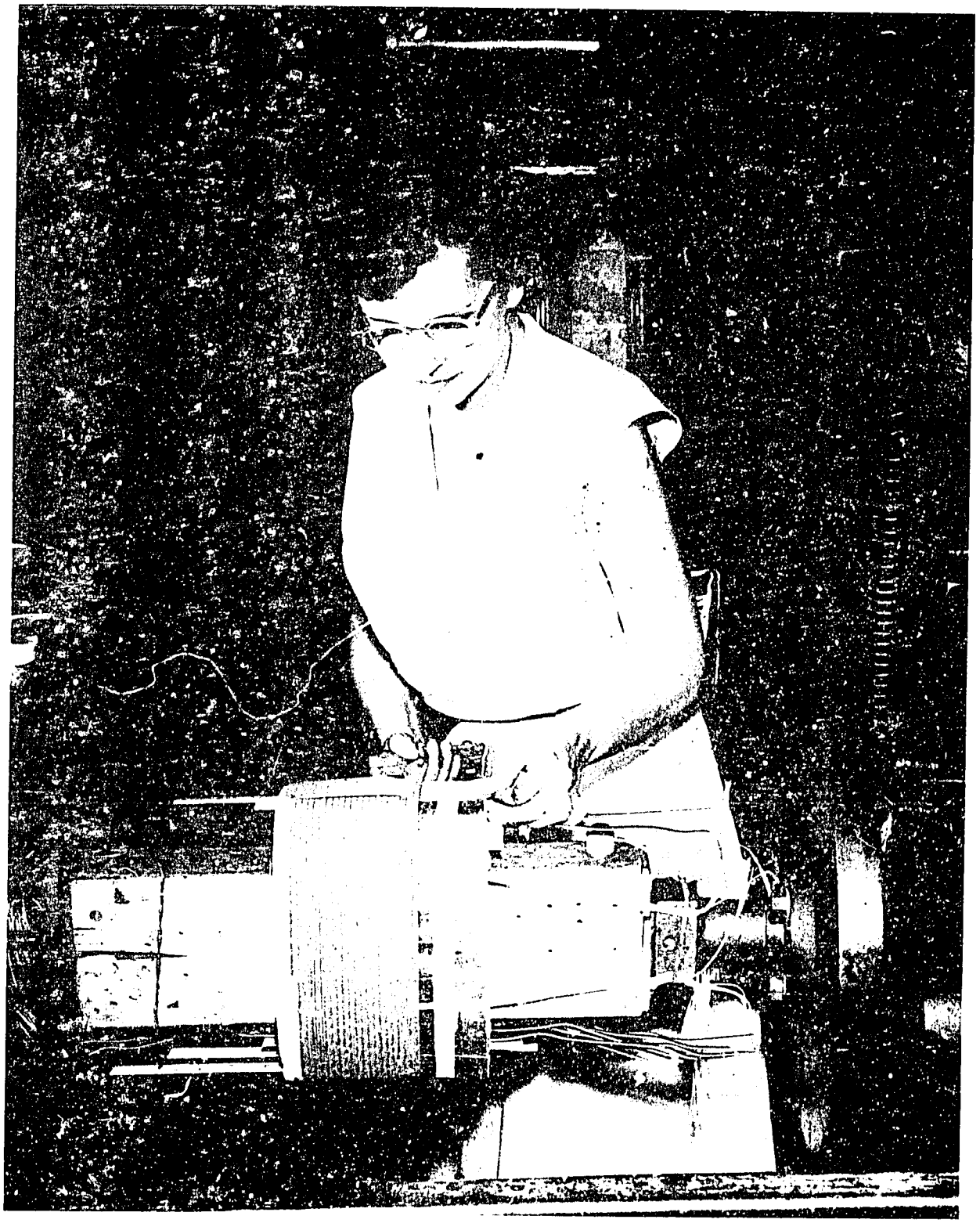
Inserting a liquid type transformer into its tank. Courtesy of Allis-Chalmers Mfg. Co.



Completed coils receive preliminary turns ratio test. Courtesy of Allis-Chalmers Mfg. Co.



Lacing core steel through the windings of a Class "H" dry type distribution transformer. Courtesy of Allis-Chalmers Mfg. Co.

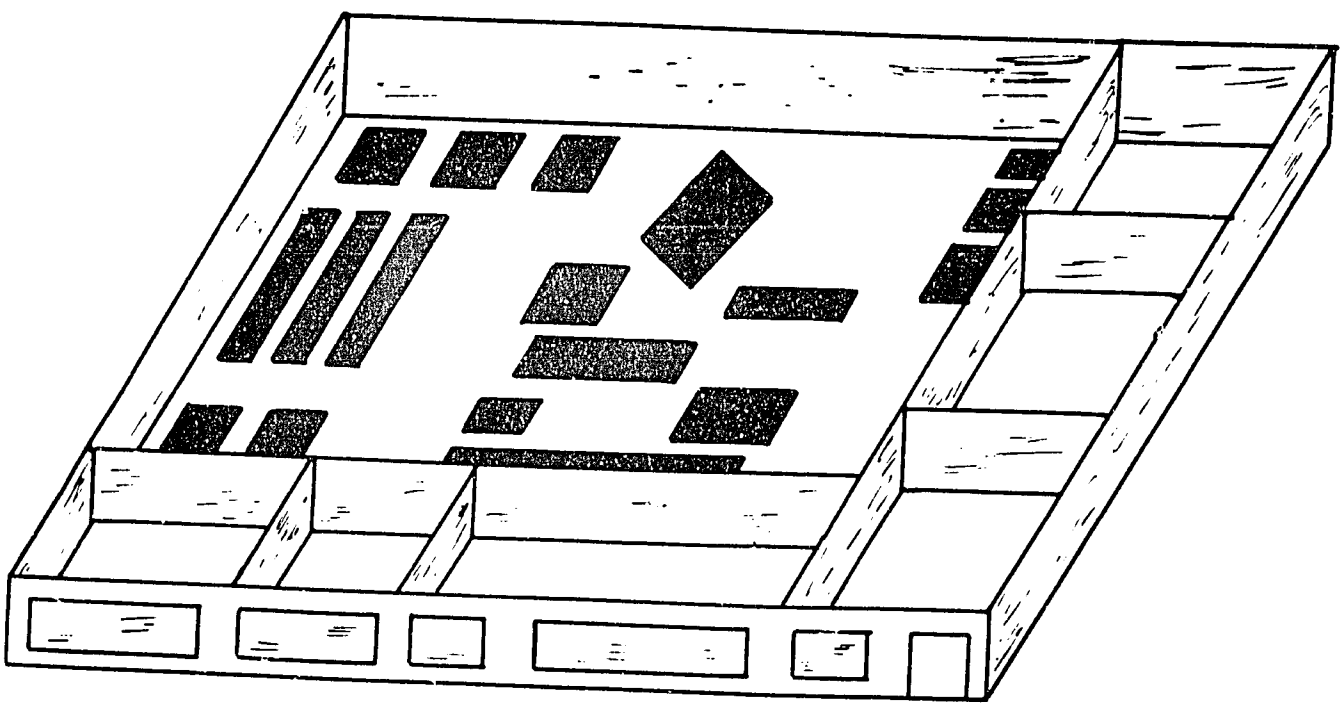


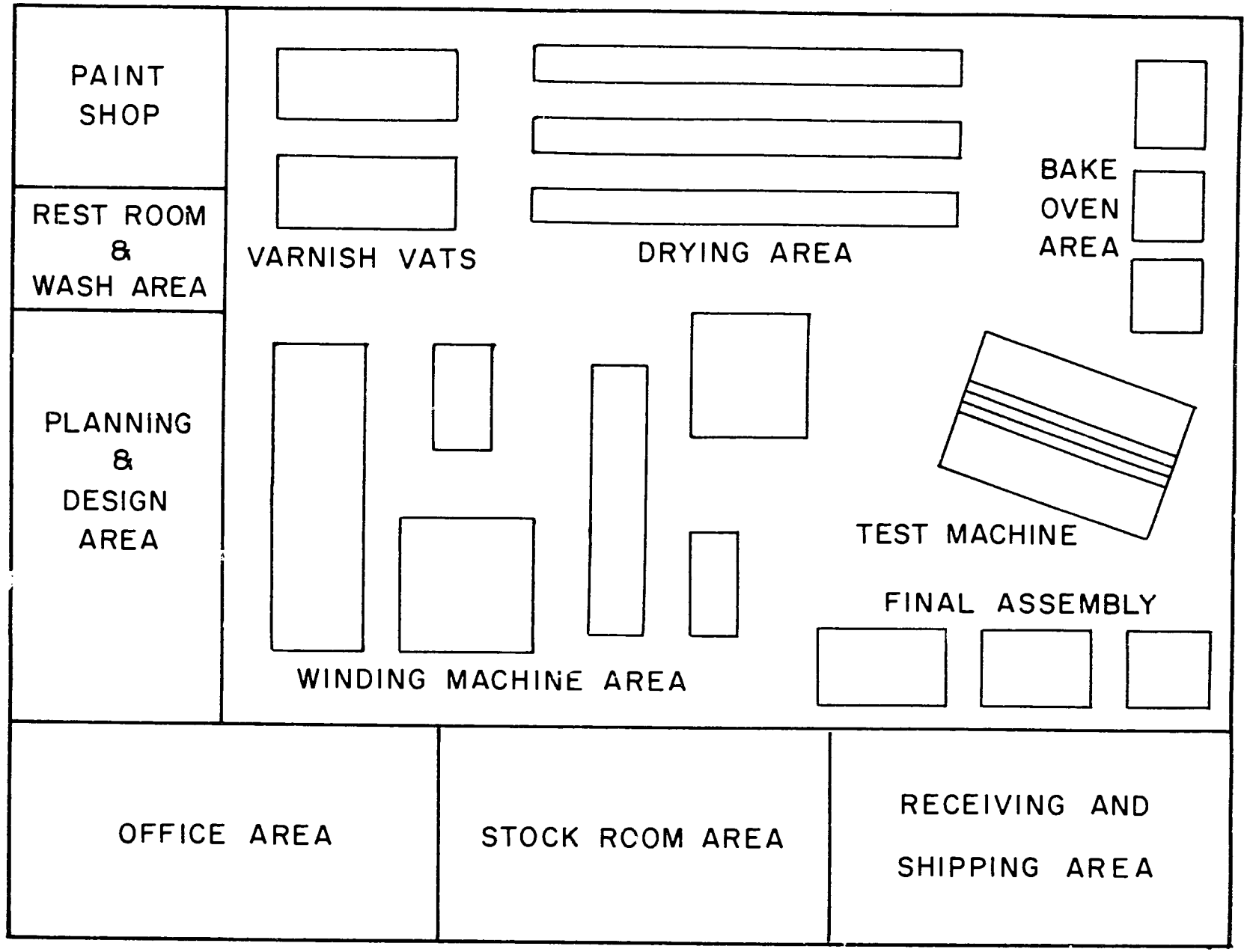
Winding the coil of a Class "H" dry type distribution transformer. Courtesy of Allis-Chalmers Mfg. Co.

PLANT LAYOUT

A sample plant layout is shown. Machinery arrangement will vary according to the production capacity of the plant and the actual shape of the floor space available. Local ordnances as to minimum working space requirements, floor load and health and fire protection will govern the final plant layout, also.

Ideally, production machinery will be arranged to have a straight production line so that when one step in production is completed the unit is moved to the adjacent area. Although this is not always possible in laying out a plant, it should be a governing rule in order to avoid congestion and lost production time.





PLANT LAYOUT (10,000 SQUARE FEET)

PLANT SITE

The plant should be located where electric power is available, where it is accessible via truck or rail or both, and convenient for the working force. Telephone service, water and sewage are required.

It is estimated that a minimum of 15,000 square feet of land will be needed for an adequate plant site. An arbitrary sum of $7,500 has been allowed for the cost of a plant site in this study.

Consideration should be given in the selection of a plant site for future expansion. The importance of this factor is affected directly by the potential production that a market survey will reveal.

BUILDING

The floor space for a plant of the capacity discussed in this study is approximately 10,000 square feet. U. S. prices for a suitable brick or concrete structure are approximately $4.25 per square foot, including plumbing, wiring and ventilation in areas of low industrialization.

Although the production process is flexible enough to be adapted to existing structures, all floor space used for production purposes should be on one floor.

POWER

A dependable source of electric power is required. Current is needed for lighting, testing equipment and operating production equipment.

WATER

Water is needed for drinking, for sanitary purposes and for fire protection.

FUEL

Plant heating for the comfort of workers may or may not be needed, depending upon the country in which the plant is located.

For a plant of the general size and capacity discussed in this study, a monthly estimate of $400.00 has been made for heat, electricity, water, and telephone costs.

TRUCK

The services of a motor truck are required. For the purposes of this study, direct ownership of a vehicle has been assumed. However, this service may be contracted for or obtained through vehicle rental. A sum of $2,000.00 has been allowed for the purchase of a suitable pick-up and delivery truck in this study. This can be reduced, however, through the purchase of a used vehicle if individual circumstances make this advisable.

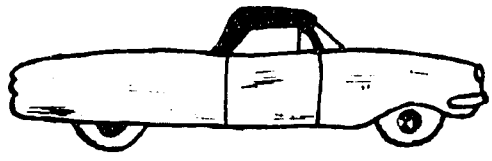


Table 20. Capital requirements

Item	Fractional kva	1-10 kva
Working capital (30 days)		
Direct materials	$38,540.00	$38,540.00
Direct labor	5,380.32	6,022.40
Operating expenses		
Indirect labor	2,543.20	2,268.64
Utilities	400.00	400.00
Indirect material	420.00	420.00
Office payroll	1,728.00	1,728.00
Office supplies	200.00	200.00
Total working capital	$49,211.52	$49,579.04
Fixed Assets		
Land and building (estimated)	$50,000.00	$50,000.00
Equipment	56,685.00	56,685.00
Total capitalization	$155,896.52	$156,264.04

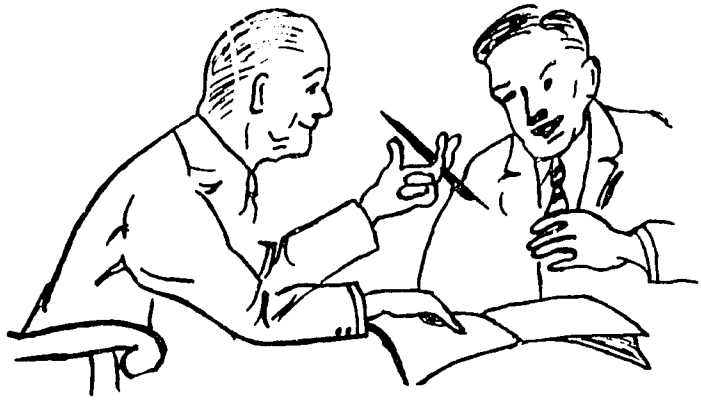


Table 21. Overhead rate
(30 days)

Item	Fractional Kva	1-10 Kva
Heat, light, water telephone	$ 400.00	$ 400.00
Depreciation	732.62	732.62
Indirect labor	2,312.00	2,062.40
Indirect material	420.00	420.00
Office payroll	1,728.00	1,728.00
Vacation pay (4% of annual direct labor)	195.64	216.96
Office supplies	200.00	200.00
Total overhead rate	$5,988.26	$5,759.98
Units of production	2,200	550
Overhead rate per unit	$ 2.72	$ 10.47

UNIT COST OF MANUFACTURING

Item	Fractional Kva cost range	1-10 Kva cost range
Direct materials	$5.26 -$22.26	$22.26 -$105.00
Direct labor	2.44 - 14.84	14.84 - 70.00
Overhead	2.72	10.47

Table 22. Depreciation and maintenance

Item	Initial cost	Estimated life (in years)	Estimated annual depreciation
Production equipment	$52,685.00	15	$3,512.33
Motor truck	2,000.00	5	400.00
Office equipment	2,000.00	10	200.00
Building	42,500.00	25	1,700.00
	Total yearly depreciation		$5,812.33
	Maintenance (building and equipment)		$2,975.55
	Total yearly depreciation and maintenance		$8,787.88
	Monthly rate - $732.62		

Table 23. Costs, sales and profits

Item	Estimated annual costs (1/2 kva)	Actual annual costs	Estimated annual costs (5 kva)	Actual annual costs
Direct materials	$ 363,264.00	—	$346,500.00	—
Direct labor	163,680.00	—	231,000.00	—
Overhead	71,808.00	—	69,102.00	—
*Sales expense	105,600.00	—	66,990.00	—
Total costs	$ 704,352.00	—	$713,592.00	—
Sales revenue	$1,056,000.00 (26,400 units @ $40.00)	—	$957,000.00 (6,600 units @ $145.00)	—
Profit before discount allowance	$ 351,648.00	—	$243,408.00	—
Discount allowance on quantity purchases	316,800.00 (30 percent average used)	—	191,400.00 (20 percent average used)	—
Profit before taxes	$ 34,848.00	—	$ 52,008.00	—

* 10 percent of sales price for 1/2 kva units has been allowed and 7 percent of sales price for 5 kva units.

The above table shows a costs, sales andprofits schedule that has been based on 100 percent plant output and sales. This will vary with individual plant efficiency and marketing areas, and reduce profits accordingly. Profits will be increased, however, if the full discount allowance used in this study is not required to market the product.

For estimating purposes, an additional expense allowance of $10,000.00 per year should be allowed to cover insurance and interest on borrowed capital.

SAFETY

Employee safety is a prime and continuing responsibility. Safety guards should be placed around all hazardous machinery. Walking areas should be well designated. Safety warnings should be well displayed where needed. Continuing efforts should be exerted to keep employees safety conscious.

First aid kits and fire fighting equipment should be placed throughout the plant and employees drilled periodically in their use. Specific personnel should be designated to take charge in health or fire emergencies.

Employees should be given awards for safety suggestions to encourage safe practices.

TRAINING

Training programs help to achieve competent employee performance and provide a continuing supply of skilled workers. The type of training program needed will vary with the skills of the workers employed. Generally, however, a program should be devised that provides all workers with the opportunity to improve their proficiency in their immediate job and acquire higher skills.

Employees should be encouraged to make suggestions for improvements in production. Incentive awards should be offered.

ACCOUNTING

No attempt is made here to outline a system of accounting and cost control. Such a system is always dependent upon specific production plans. Once these plans have been formulated, then an accounting system suited to the company operations can be adopted. The importance of a good accounting and cost control system makes it imperative that expert advice be obtained.

SUMMARY

For a capitalization of approximately $150,000 it is possible to establish a small plant to manufacture transformers as large as 10 kva. Whether a plant of this type, as outlined in this study, would prove to be a sound financial investment depends upon specific local conditions and marketing potentials.

This study has provided a general concept of the factors involved in establishing a transformer plant. Local factors such as materials and supplies, markets, labor force, and financing arrangements can now be properly weighed to make a final decision.

LITERATURE REFERENCES

National Electrical Manufacturers Association
155 East 44th Street, New York 17, New York

American Standards Association, Inc.
70 East 45th Street, New York 17, New York

National Association of Machinery Dealers
1346 Connecticut Ave., N. W., Washington, D. C.

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McGraw-Hill Book Co., Inc.
330 West 42nd Street, New York 36, New York

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330 W. 42nd St., New York, N. Y.

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1250 6th Ave., New York 20, N. Y.

Electrical Design News, Rogers Publishing Co.
Englewood, California

Product Design & Development, Chilton Co.
Chestnut & 56th Sts., Philadelphia 39, Pa.

The following is a list of machine tool manufacturers and consulting engineering firms, selected at random from U. S. companies.

Machine Tool Manufacturers

The Warner and Swasey Company
Cleveland, Ohio

The Bullard Company
Bridgeport, Connecticut

South Bend Lathe Works
South Bend, Indiana

The Cleveland Twist Drill Co.
Cleveland, Ohio

Rockford Machine Tool Co.
Rockford, Illinois

Kearney and Trecker Corporation
Milwaukee, Wisconsin

The Lapointe Machine Tool Company
Hudson, Massachusetts

Consulting Engineers

Peter F. Loftus Corporation
Pittsburgh, Pennsylvania

Tippett & Gee
Abilene, Texas

The J. G. White Engineering Corporation
80 Broad Street, New York, N. Y.

Jackson & Moreland, Inc.
Boston, Massachusetts

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