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DRY ELECTROLYTIC CAPACITORS

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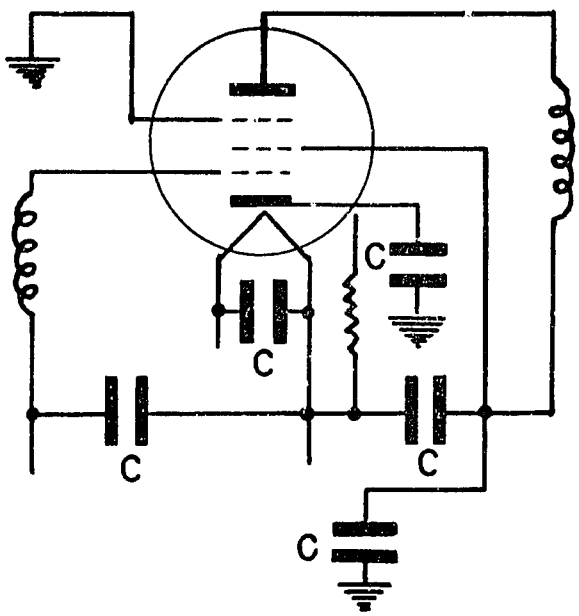

March 1953

PREPARED FOR THE MUTUAL SECURITY AGENCY
Productivity and Technical Assistance Division

BY THE UNITED STATES DEPARTMENT OF LABOR
BUREAU OF LABOR STATISTICS

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Case Study Data on
Productivity and Factory Performance

BLS Report No. 15

DRY ELECTROLYTIC CAPACITORS

(Based on reports submitted by
four selected plants)

Prepared for

Mutual Security Agency
Productivity and Technical Assistance Division

by

The United States Department of Labor
Martin P. Durkin - Secretary

Bureau of Labor Statistics
Ewan Clague - Commissioner

March 1953
Washington, D. C.

Case Study Data on
Productivity and Factory Performance

DRY ELECTROLYTIC CAPACITORS

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FOREWORD

The primary object of this report is to be of use to production managers, superintendents, and methods engineers who are concerned with production problems. It is further hoped that the general discussion of productivity and the presentation of man-hours per unit in the manufacture of dry electrolytic capacitors will be of interest to government, labor, and trade association officials. By examining this report plant officials will be able to compare manufacturing operations in their plants with the operations in one or more of the plants in this study.

Description of Report

This report is divided into four chapters. Chapter I is directed primarily to the reader who is interested in productivity but not in the technical details. Chapter II contains detailed case studies of each plant and will be of value to the plant superintendent or the production engineer. Chapter III is a brief discussion of labor policies and relationships in the industry, together with some case studies of labor adjustments to technological changes. Chapter IV contains supplementary information on the industry and a description of production control methods. The appendix contains information on how the data were collected, a copy of the questionnaire used, and a glossary of trade and technical terms.

The information and data used for the case studies were obtained from plant records and from plant officials by representatives of the Bureau of Labor Statistics who visited each plant. Supplementary information was obtained from other Government agencies and trade associations.

How To Use This Report

In using this report the following procedure is suggested to plant officials:

1. The plant official should refer to tables A and B, pages 4 and 8, to identify the United States plants in this study whose employment, production volume, and integration most nearly approach the situation in his plant. For a breakdown of the manufacturing process into machinery used and man-hours for specific operations, the official should refer to the tables and text in chapter II.

2. Appendix I contains a reproduction of the questionnaire used to obtain the information from the United States plants in this study. If the European production official will use this questionnaire to calculate labor requirements in his plant, he will be able to compare performance in his plant with performance in the plants discussed in this report, and to isolate areas where his plant's performance is relatively good or relatively poor.

3. The European plant official is now ready to compare the machinery and methods described in the report with those existing in his own plant, for those problem areas he has isolated. At this point the report does not give him the precise engineering information he may need but it does tell those familiar with the industry the approximate requirements in terms of volume, methods, machinery, and manpower for approaching the productivity levels illustrated in the individual case studies.

4. For serious problem areas

uncovered in this manner, the expert assistance of engineers, either those within his plant or outside consultants, will be needed. Intensive study must generally be made to correct the conditions found by comparison because these reports do not replace on-the-spot engineers or other specialists, in the analysis of specific situations.

In summary, this report may be likened to a series of gages or meters from which one may measure productivity or factory performance. Unlike most gages, which do not reveal the factors causing their recordings, factory performance studies indicate causes as well as symptoms by giving facts about the technological environment existing at the factories where data were collected. These facts, when studied by a technician familiar with the industry, can be of assistance in efforts to correct the conditions indicated by the gages' reading.

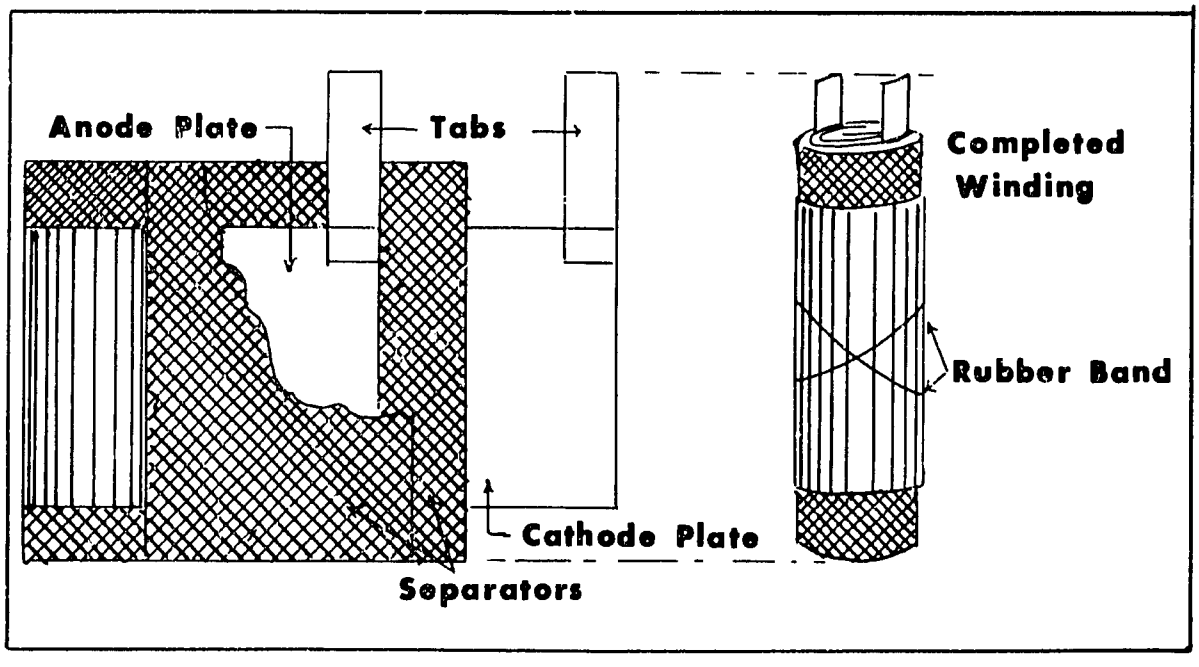

Fig. A Basic construction of a dry electrolytic capacitor.

Case Study Data on
Productivity and Factory Performance

DRY ELECTROLYTIC CAPACITORS 1/

CHAPTER I: GENERAL REPORT

High Lights

Key factors contributing to productivity levels of American plants manufacturing dry electrolytic capacitors are mass production by assembly line techniques, use of specially designed or adapted machinery, close quality control and inspection, and alertness in adapting innovations in production methods to the electrochemical process necessary for capacitor manufacture.

These conditions enable one plant in this study to produce an electrolytic capacitor of a certain specification in slightly more than 1-1/2 man-minutes. Other plants (included in this survey) making capacitors of different specifications require two to three times as many man-minutes. 2/

These labor requirements reflect the results of careful methods analysis on the part of management, and the cooperation of labor in putting method changes into use. Most firms in the industry and all plants in this study have industrial engineering departments which have contributed greatly to present levels of productivity. All plants employ some type of incentive wage or group bonus, thus giving workers an opportunity to earn more pay with increased production. A combination of the above circumstances result in lower unit costs and benefit both the company and its customers. In cases where a method change reduces labor requirements, the displaced employees are absorbed in the plant labor force, whenever possible, in other jobs that have been created as a result of increased production. For this reason both management and labor welcome progress in the reduction of labor requirements. Not only is labor willing to accept method changes introduced by the methods departments, but in some cases it has suggested changes that have been adopted.

Competition and customer demand require close quality control in electrolytic capacitor manufacture. The nature of the product makes it necessary to purchase raw materials of high purity and insure care in handling to prevent contamination during processing. Rigid inspection of raw materials is practiced, and the capacitor is carefully tested at certain intermediate points in the manufacturing process as well as upon completion.

Another characteristic of the industry is the flexibility with which plants may elect to either make or purchase certain component

---

1/ Prepared by William M. Graham and Edward J. Dillon in the Division of Productivity and Technological Developments.

2/ See table A for specifications.

parts of a capacitor. It is possible to buy parts made to specification such as tabs, terminals, covers, cans, and insulating tubes. Some manufacturers prefer on some occasions to buy these parts and at other times to fabricate or finish them in their own plants. It is even possible to purchase etched foil and eliminate this operation, but most manufacturers prefer to do their own etching.

Basic Work Flow

A dry electrolytic capacitor is used in radio and television sets. It is made of two strips of aluminum foil separated by paper and wound into a roll. The name - dry electrolytic capacitor - means that it is nonaqueous or of low-water content. The roll is immersed in an electrolytic solution so that the saturated paper becomes a conductor of electric current. The roll is then assembled into an aluminum can. An additional outer cover may be used. One strip of aluminum foil is specially treated and becomes the anode or positive pole, the other foil is attached to the negative terminal. The primary work flow in an electrolytic capacitor plant can be observed by following the aluminum foil used for the anode from receipt of the foil at the receiving platform to shipment of the capacitor at the shipping platform.

The foil is received in heavy sealed cardboard cartons or wooden boxes, which remain sealed in a storeroom until the foil is needed in the factory. As needed, the cartons are opened for foil inspection. High purity standards for raw materials are always regarded as essential for acceptable quality of finished product. 3/ From the storage room the foil is sent to the foil preparation department. Other parts of the condenser are sent from the storage room to their appropriate place in the production process as needed.

In the foil preparation department the foil is etched, 4/ preformed, rewound, and slit to width. The surface area of the foil is increased by etching, i.e., by passing the foil through a series of tanks filled with acid and cleaning solutions. In preforming, an oxide film is formed on the etched surface by an electrochemical process, again using tanks through which the foil is drawn. These operations are not performed on the cathode foil. The prepared anode foil together with the cathode foil and separating paper are sent for winding to the condenser section preparation department or are returned to inventory to be used as needed.

In the department where condenser sections are prepared, the etched foil is cut to the required length for the anode and a tab or connector is attached. Then, a tab is attached to an appropriate length of cathode foil. The anode foil, separating paper, and cathode foil are assembled in an operation known as winding. The wound or prepared condenser section is then ready for

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3/ Chapter IV of this report contains a section which discusses specifications and purity requirements of essential raw materials of an electrolytic capacitor.

4/ For a definition of this and other terms see glossary, page 67.

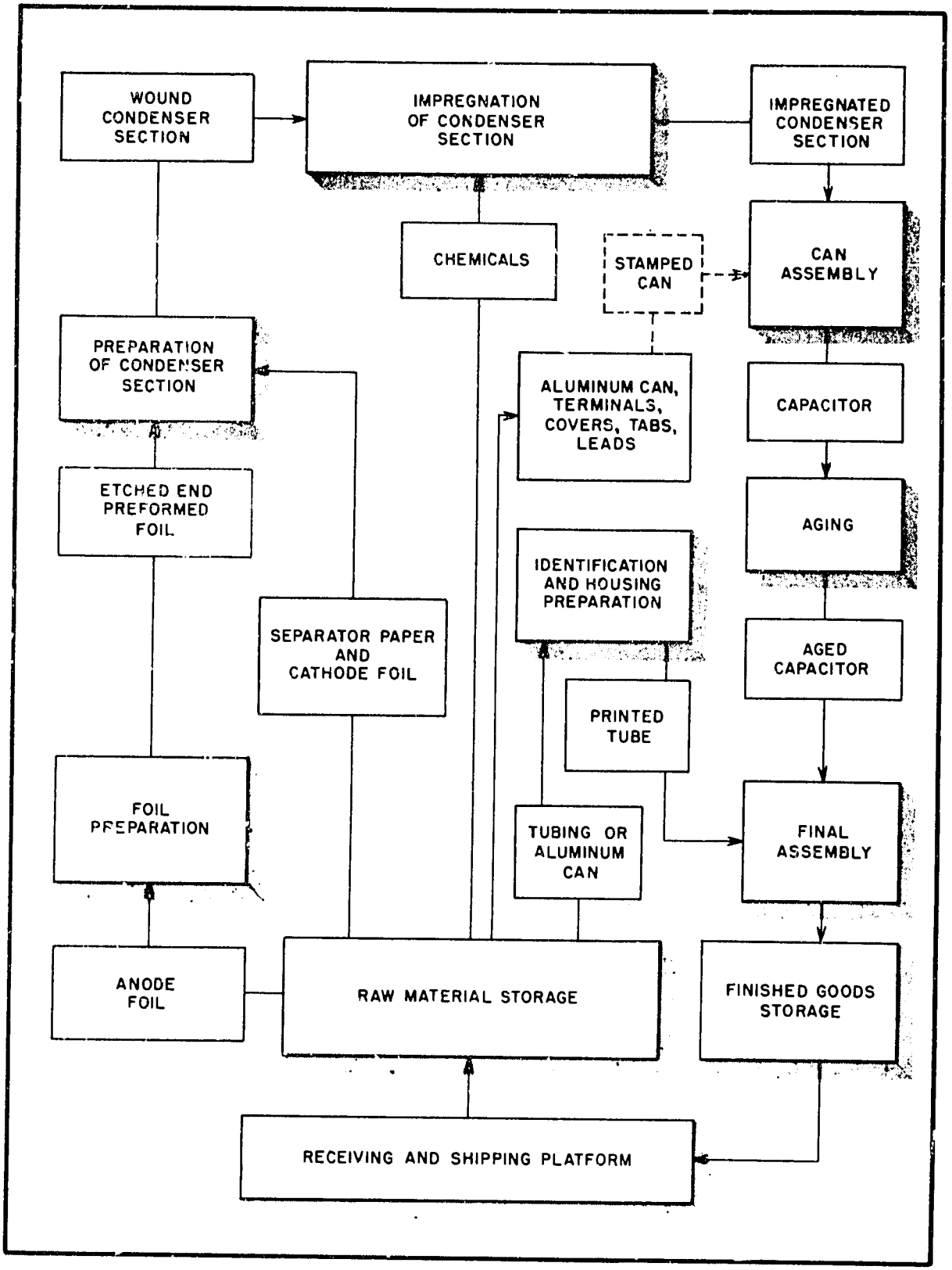

Fig. 3 Typical flow of work in the manufacture of a dry electrolytic capacitor.

Table A. Man-hours per 1,000 units, 1/ and plant and product specifications, in the manufacture of dry electrolytic capacitors, in 4 selected plants, U. S. A., 1951

Man-hours, and plant and product characteristics	Plant			
	A	B	C	D 2/
Man-hours per 1,000 units:				
Total	96.1	65.3	63.2	29.6
Direct	77.8	43.8	45.2	26.0
Indirect	18.3	21.5	18.0	[illegible]
Percent of indirect to direct	23.5	49.0	39.8	13.8
Plant Characteristics:				
Number of employees . .	250-300	over 1,000	over 1,000	700-800
Square feet of floor space	70,000	340,000	180,000	90,000
Product specifications:				
Microfarads	20	20	20	10
Volts (DC)	450	450	450	150
Diameter (inches) . . .	1-1/16	1-1/16	1	11/16
Length (inches)	2-3/16	1-3/4	2	1-1/4
Application: top chassis (T), or under chassis (U) . .	U	U	T	U
Mounting: leads or hardware (L), or twist prong (TP) . .	L	L	TP	L
Terminals: bare tinned copper leads (CL), or solder lugs (S) . . .	CL	CL	S	CL
Insulating tube: wax impregnated paper (P), or none (N)	P	P	N	P

1/ This report uses the convention of many U. S. capacitor manufacturers of computing man-hour requirements in terms of thousands of units.

2/ Throughout this report data for plant characteristics refer only to the capacitor division of this plant except where otherwise specified.

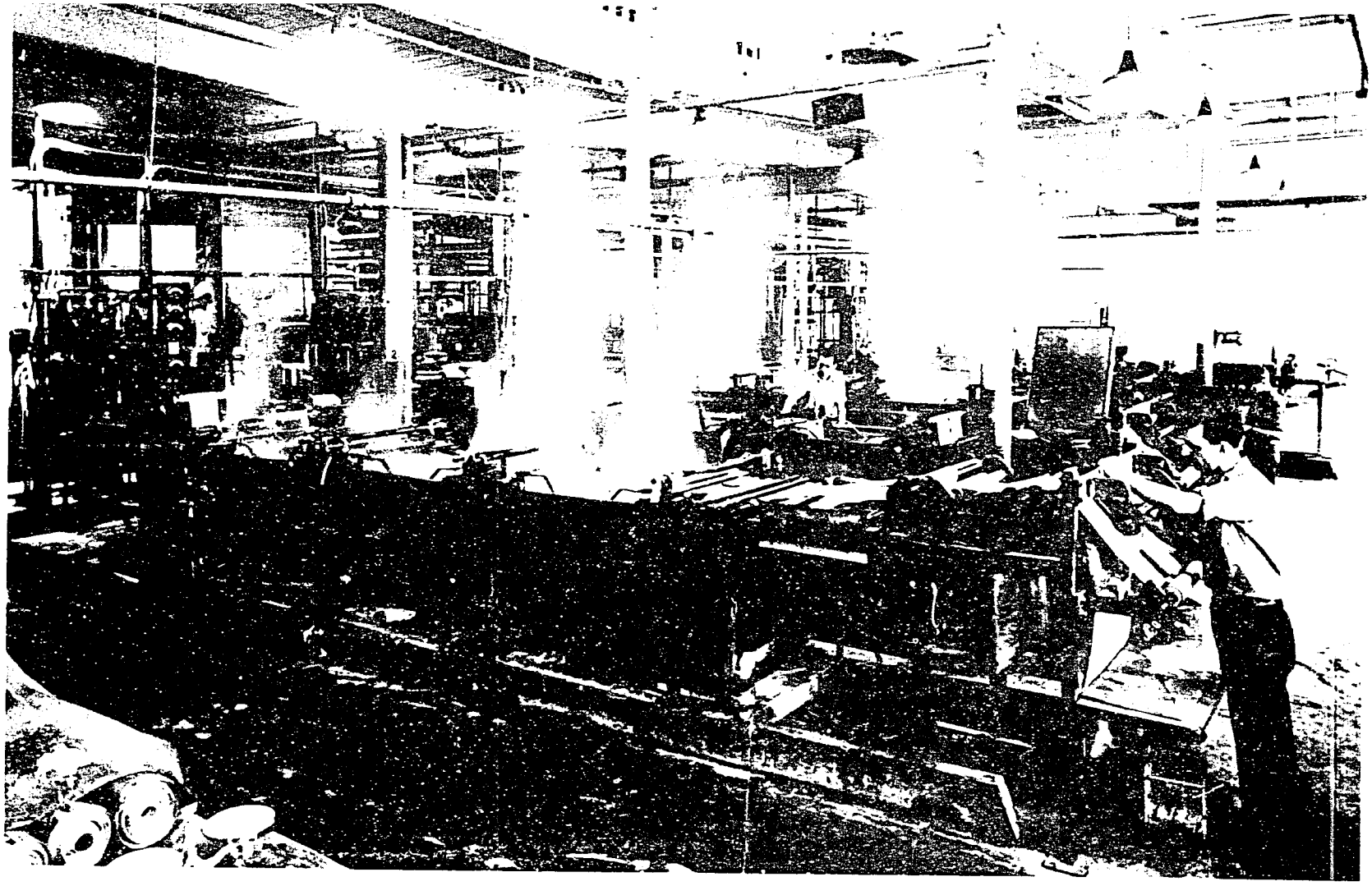

Fig. C Preforming aluminum foil for anode of dry electrolytic capacitor. Rigid chemical control assures a uniform film.

impregnation.

The impregnation department usually consists of a series of specially built centrifuges into which the prepared condenser sections are placed. For ease in handling, these sections are set in baskets. The electrolyte to be used enters the centrifuge and is forced into the separating paper. Some manufacturers impregnate by other systems such as by vacuum, or soaking the condenser section.

After impregnation the section is sent to the can assembly department. Here, the terminals are attached to the tabs, the section is inserted into an aluminum can, and the can is sealed. After assembly into the can the capacitor is ready to be aged. Some manufacturers, however, prefer to age the capacitor before completing the assembly of the condenser section and can.

Aging is carried out on specially designed racks. It strengthens the dielectric coating on the anode and is a continuation of the preforming operation. Some manufacturers test the capacitors at this point. This process is followed by final assembly.

Before the final assembly operation another department prepares the paper tube or aluminum can that will be the outermost covering of the final product. The container is stamped with identifying information, and in the case of insulated paper tube capacitors, the tube is wax-impregnated or varnished for insulating purposes. A nonimpregnated plastic tube is sometimes used instead of the paper tube.

In final assembly the aluminum can is put into the paper tube and the capacitor is prepared for shipment. After a final test, the capacitors are sent to storage until an order is completed for shipment.

Plant and Product Characteristics

The age, size, and design of the buildings and equipment vary widely among the four plants of this study. Plant A is the least modern and Plant D the most modern of the four. Age of buildings and factors such as numbers of buildings and floors, type of construction, and modifications for modern production techniques, are discussed further in chapter II of this report.

Productivity in key operations is often closely tied to the design of the machinery used. Much of this equipment is specially designed and built by the plants themselves. Though detailed information on these machines is generally regarded as confidential, it should be pointed out that importance is attached to the efficiency of minor pieces of equipment as well as to that of large items such as the etching machine. In each plant, special jigs and fixtures are used in every possible operation. These holding devices are of varied and special designs.

All of the cooperating plants produce a full line of electrolytic capacitors as well as a variety of such other types as paper, oil, and usually, ceramic and mica capacitors. Plant A is the only plant which does not make other products also. The capacitor division is a separate entity in Plant D. Chapter II contains further details of the variety of

products manufactured in reporting plants.

All plants produce single-, double-, and triple-section capacitors by mass production techniques. Each plant has what is known as an electrolytic department or "line" which can produce electrolytic capacitors according to customer specification. The reported product is one specification of several that are manufactured in the electrolytic department, and constitutes but a part of the total plant electrolytic capacitor production. The manufacture of the reported product is characteristic of all dry electrolytic capacitors made in the plant.

The products reported by the four cooperating companies are all single-section dry electrolytic capacitors with etched aluminum foil encased in hermetically sealed aluminum cylinders suitable for installation in radio or television receiving sets. Major differences in

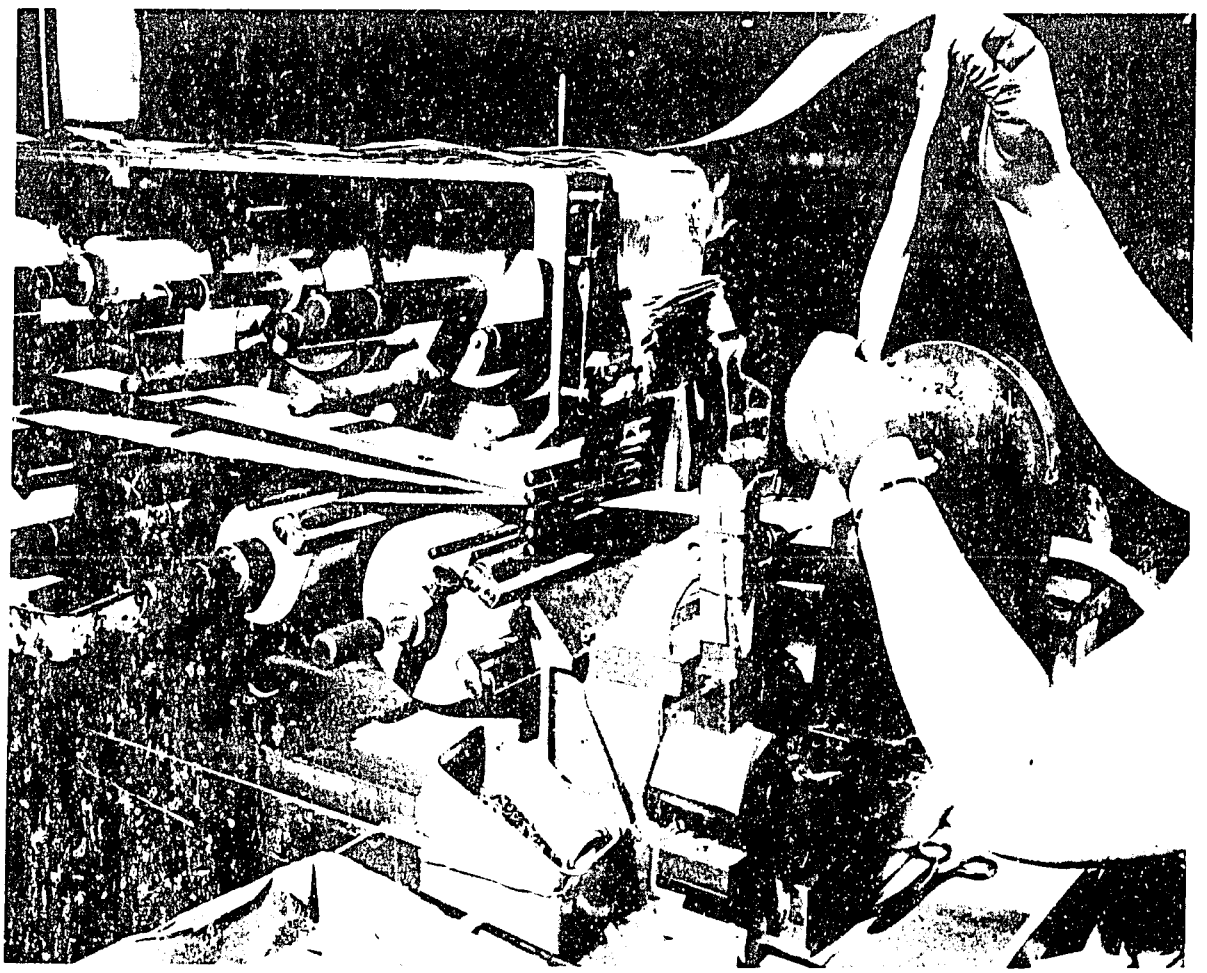

Fig. D A dry electrolytic capacitor winding machine. Note the rubber gloves to keep perspiration from reaching foil. The rubber bands used to hold the rolled condenser sections are tested for purity before being used.

Table B. Direct man-hours in the manufacture of 1,000 dry electrolytic capacitors in 4 selected plants, by groups of related operations, U. S. A., 1951

Department, or group of related operations	Man-hours required in plant			
	A	B	C	D
Direct labor operations, total 1/ . .	77.8	43	45.2	23.6
Foil preparation	3.5	1.8	5.8	.3
Preparation of condenser section .	13.2	17.1	12.8	7.0
Impregnation of condenser section .	4.0	2.0	2.0	.8
Can assembly	25.1	13.0	18.9	10.7
Aging (formation)	22.5	3.1	3.4	1.9
Identification and housing preparation	(2/)	1.1	2.3	(2/)
Final assembly to tube	9.5	4.9	(2/)	2.9

1/ See table 13 and accompanying text in chapter II for source of man-hour totals.

2/ Operations not performed.

specification are listed in table A. Other specification differences are pointed out in chapter II.

To assure the purity of all components, each plant has a system of specification requirements for raw materials as well as of inspection and testing procedures. These are followed by electrical tests of the capacitors after key operations. The nature and arrangement of these checks on product quality vary among plants but in each case a final test is given and every unit is given a test to determine its electrical characteristics.

Case Study Data on
Productivity and Factory Performance

DRY ELECTROLYTIC CAPACITORS

CHAPTER II: DETAILED REPORT

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DRY ELECTROLYTIC CAPACITORS

CHAPTER II: DETAILED REPORT

The Case Study Method

The "case study" method of presentation has been used in this report wherever possible. Unless otherwise noted, figures refer to actual plants, departments, and operations. Averages which may be computed from the data should be handled with caution because production figures have not been reduced to a common unit of output. For example, no two plants report on capacitors of the same dimensions. One plant reported on a product of half the capacity and one-third the voltage of the others, and another plant reported on a capacitor with a can and mountings of distinctly different design.

The reference period and plant letter codes used with the following data refer to the same plants as in chapter I of this report.

Plant and Operating Characteristics

Diversification. All plants in this study are equipped to make a wide assortment of capacitors. Electrolytic, paper, and oil capacitors are made at each plant, and all except Plant A list also ceramic and mica capacitors in their catalogues. Only Plant A manufactures capacitors exclusively. The other plants produce also varying types of other products such as resistors, vibrators, switches, or test instruments.

Plant D makes a number of products other than capacitors. The shipments of its capacitor division were 71 percent electrolytics, but type reported was only 9 percent of these shipments. On the other hand, the majority of Plant A's shipments were capacitors of a type other than electrolytics. Of the four plants, Plant C makes the widest variety of capacitors. Plant B also has a complete line of capacitors but the greater part consist of electrolytics.

Buildings. Plant A rents a brick and concrete building with wooden flooring. The building has not been modified to utilize modern production techniques as applied to electrolytic capacitors. Plant B's buildings are of a standard brick, steel, and wood construction. Special areas for process type operations have been provided recently. Air-conditioning and better ventilation have been added as has a separately housed steam plant. In the buildings of Plant C no structural changes have been made. New layouts have been fitted into available space. Ventilating equipment has been installed where needed. In the buildings of Plant D brick, concrete block, and steel frames are used. These buildings are not only newer than those of the other three plants, but have been enlarged for new production techniques as well.

Training Programs. The training of new employees are basically the same in each plant. Trainees are given on-the-job instructions under close supervision of a foreman or

Table 1. Extent of specialization of 4 selected plants manufacturing electrolytic capacitors, U. S. A., 1951

Plant	Percent of total value of products assignable to dry electrolytic capacitors	Rank by variety of products manufactured other than electrolytic capacitors
A	5	2
B	45	4
C	20	3
D	1/ 71	1

1/ This figure is for capacitor division only and does not include value of other products manufactured.

Table 2. Type of buildings used by 4 selected plants manufacturing capacitors, U. S. A., 1951

Building characteristic	Plant			
	A	B 1/	C	D 1/
Square feet of floor space	70,000	340,000	180,000	90,000
Number of buildings . . .	1	4	2	3
Number of floors	3	1,1,1,3	(2/)	1,1,2
Approximate age (years) .	35-45	25-35	50-60	5-15
Originally designed for production techniques as applied to electrolytic capacitors . . .	No	No	No	Yes
Structural modifications for modern production techniques	No	Yes	No	Yes

1/ Not shown are 2 small buildings (boiler room and office) at Plant B, and a warehouse location a mile and a half from Plant D.

2/ Information not available.

specially selected operator. This may be supplemented by tours of the plant and orientation classes in which groups of new employees are given information on matters such as company policies and products, how their jobs fit into overall operations, and the importance of care in handling materials.

Training for supervisors is similar to that for production workers but more detailed. Informal meetings for newer foremen are held regularly. These conferences may cover a wide variety of topics such as company policy, indoctrination, proper personnel relations, and union functions. Some technical training is conducted by the engineering staff. Printed matter on these subjects is made available to interested personnel.

Production Scheduling. Although the electrolytic line runs continuously, each plant has developed some system by which capacitors of various specifications are sent through the line in lots. Plant D reports an elaborate system of paper controls for production planning and scheduling. On the other hand, Plant A relies primarily on verbal directions from the production engineer to those affected by each new production order.

When a new order comes in, the sales department transmits it to the engineering department for approval and any necessary corrections or development of specifications. After material control has assured the availability of the specified parts, a production schedule is set up using adjusted standard man-hours and the known available productive facilities. A desired production rate, determined by the accumulation of orders and the supplier's and customer's delivery schedules, is a major part of this production schedule.

If the unit to be made is a variation of a standard model, the production foreman re-checks the material requirements and orders any needed parts. Such parts are usually brackets or a specially designed can and are purchased from suppliers whenever possible (table 5). Additional tools and fixtures are set up as required and as a rule no special instructions are needed for the operators, because variations in size and type of material used are the only differences between jobs.

Inventory Practices. Electrolytic capacitors are usually produced to order. A limited amount of production to stock is practiced. This can be done for only standard items for which a steady demand can be anticipated. However, storage time for an electrolytic capacitor is never extensive because of possible deterioration.

Design and Methods Improvement. Each plant maintains staffs of engineers to design better products and reduce costs. The size of these staffs varies from 4 persons in Plant B to 21 in Plant D. Plant C employs a staff of 94 who do basic engineering research and also design capacitors for specific orders.

During the year each plant made some change in the design of the reported capacitor in order to achieve greater standardization or simplification. As many as 38 alterations were reported in one case. Plant B cites a change to "stud terminal construction" which eliminated a paper disk insulator and two minor operations. Plant A formerly folded anode tabs; now they are staked, a change

Table 3. Number of production workers and percent of female workers producing dry electrolytic capacitors in 4 selected plants, U. S. A., 1951

Plant	Number of "direct" workers used on reported product	Percent female
A	(1/)	71
B	161	64
C	307	49
D	61	89

1/ Information not available.

Table 4. Selected production scheduling practices in 4 plants manufacturing dry electrolytic capacitors, U. S. A., 1951

Scheduling practice	Number of units in plant			
	A	B	C	D
Reported product:				
Average continuous run . .	1,000	1,000	(1/)	200
Smallest continuous run .	25	1	25	75
Largest continuous run . .	10,000	20,000	(1/)	1,000
Average production during reported period:				
All shifts, total	700	37,000	49,000	11,700
Day shift only	700	27,900	49.000	7,000
Number of shifts	1	2	1	2
Variations of reported product made to purchaser's specification, smallest order acceptable:				
Standard models	1	1	25	1
Variations of standard models	1	5	25	1
Special or custom designed models	100	10	25	1

1/ Information not available.

resulting in a 5-percent man-hour saving for this operation in addition to a material-cost saving of 1-1/3 cents per 1,000. Plant D reports that recently a foreman made a suggestion for a change in the method of winding. After testing, the new method was approved. Its installation resulted in a savings of $2 per 1,000 parts. (In this plant an award of 50 percent of the first year's savings is given for each suggestion accepted.)

Each plant has at least one engineer whose primary duty is time-motion study and methods analysis. Plant C uses 20 employees in this type of work. These studies form a basis for developing improved plant layouts manufacturing methods, and production scheduling as well as for solving production problems. Plants B and D were particularly enthusiastic about the effectiveness of engineering studies in reducing unit man-hour requirements. These two plants report regular and continuous analysis of operations to evaluate time standards and the efficiency of methods used.

Inspection Practices. Although the nature and order of performance of inspection operations vary considerably among the plants under study, over-all inspection patterns are similar. Each plant has at least one visual inspection of every unit as well as 100 percent testing for capacity and voltage. All plants except Plant A use statistical quality control methods, and one plant makes agreements with its customers as to what sequential sampling plan shall be used. Checks are performed after critical operations to determine the purity of materials and electrical characteristics of the capacitor. In each case visual inspection and electrical testing are regarded as essential to assure a high quality product.

The Manufacturing Process

A short description of the manufacturing process was given in chapter I. Anode foil processing, the preparation of the condenser section, its impregnation, assembly of condenser section into the can, aging, and final assembly were outlined. Total and departmental labor requirements were shown. The man-hour requirements per 1,000 electrolytic capacitors can be analyzed further by showing requirements for individual operations performed in manufacture.

The number and exact content of operations performed on a capacitor can vary considerably among plants, depending on the complexity of design, the quality of workmanship, and the definition of the term "operation." For the purpose of this analysis, data on production, man-hour requirements, and equipment were obtained on all direct labor operations according to the order, arrangement, and definitions normally used by each of the four plants. In order to show comparative plant performance, certain rearrangements, groupings, and classifications have been made in this presentation. Major departures from actual plant practice are noted as they occur. Man-hour data presented in tables in this part of the report are standard times for these operations. Cooperating companies reported that standard times were a reasonable approximation to actual times. Plant D stated that 10 percent should be added to its standard times to arrive at actual times.

Foil Preparation. The first operation on the anode foil is etching which increases its surface area and thereby its capacitance. An insulating film is then deposited on the foil, which is subsequently slit to the width required for the particular capacitors.

The etching operation consists of placing the rolls of aluminum foil for the anode on mandrels or spindles. Then a series of power-driven rollers pull the foil through a number of tanks filled with solutions that clean the surface, etch the foil, and rid it of impurities that may be deposited in the etching process.

Of the several foil cleaning solutions which maybe used before etching, the one most commonly used is a bath of sodium hydroxide which saponifies any of the oils used in making the foil at the rolling mill. Also used are solutions of carbonate, a mixture of potassium dichromate and sulfuric acid, and other cleansing agents.

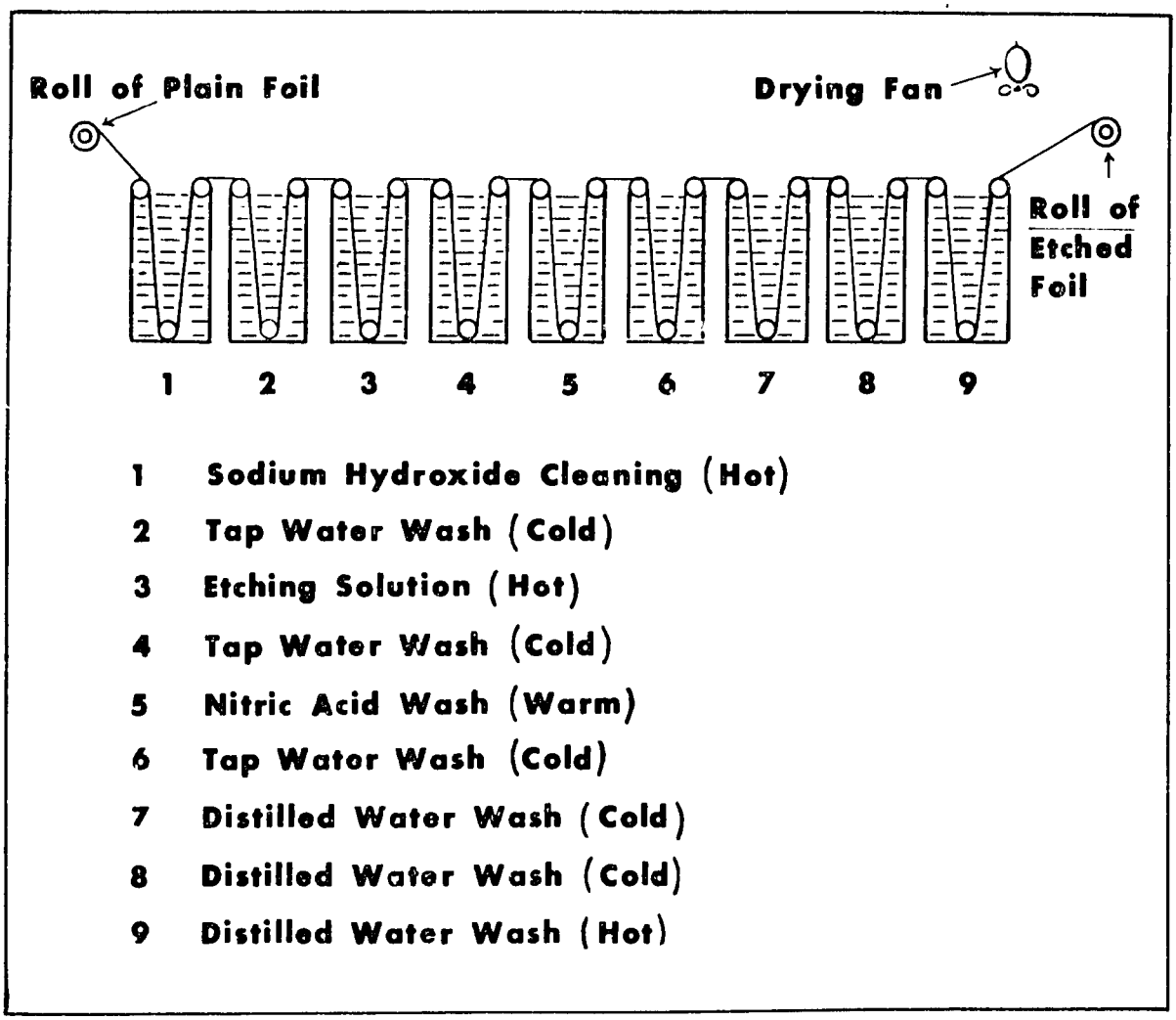

Fig. 1 Typical foil etching system.

Table 5. Source of materials and parts in the manufacture of dry electrolytic capacitors in 4 selected plants, U. S. A., 1951

Material or part	Plant							
	A		B		C		D	
	Fabricate or finish	Purchase	Fabricate or finish	Purchase	Fabricate or finish	Purchase	Fabricate or finish	Purchase
Anode foil in bulk	x		x		x		x	
Cathode foil in bulk		x		x		x		x
Spacer paper		x		x		x		x
Chemicals for electrolyte and washers 1/		x		x		x		x
Aluminum can		x		x		x		x
Bakelite or rubber discs, covers, or tops		x		x	2/ x	2/ x		x
Washers (aluminum)		x		x	(3/)	(3/)		x
Rivets (aluminum)		x		x	(3/)	(3/)		x
Tabs	x		x			x	4/ x	4/ x
Wax or varnish		x		x		x	(3/)	(3/)
Wrapper foil	(3/)	(3/)		x	(3/)	(3/)	(3/)	(3/)
Paper tube		x	x		(3/)	(3/)		x
Terminals or leads		x		x		x		x
Steel mounting ring	(3/)	(3/)	(3/)	(3/)		x	(3/)	(3/)
Scotch tape, rubber bands, ink, etc.		x		x		x		x

1/ Boric acid, borax, manitol (an alcohol), ethylene glycol, ammonia, ammonium borate, ammonium hydroxide, nitric acid or sodium hydroxide. The exact composition of the electrolyte is usually confidential. Man-hours per unit required for its preparation are quite small.

2/ A bottom cover of rubber and bakelite is assembled in the plant. Top cover of bakelite is purchased.

3/ Does not apply.

4/ Positive tab is made in plant whereas negative tab is purchased.

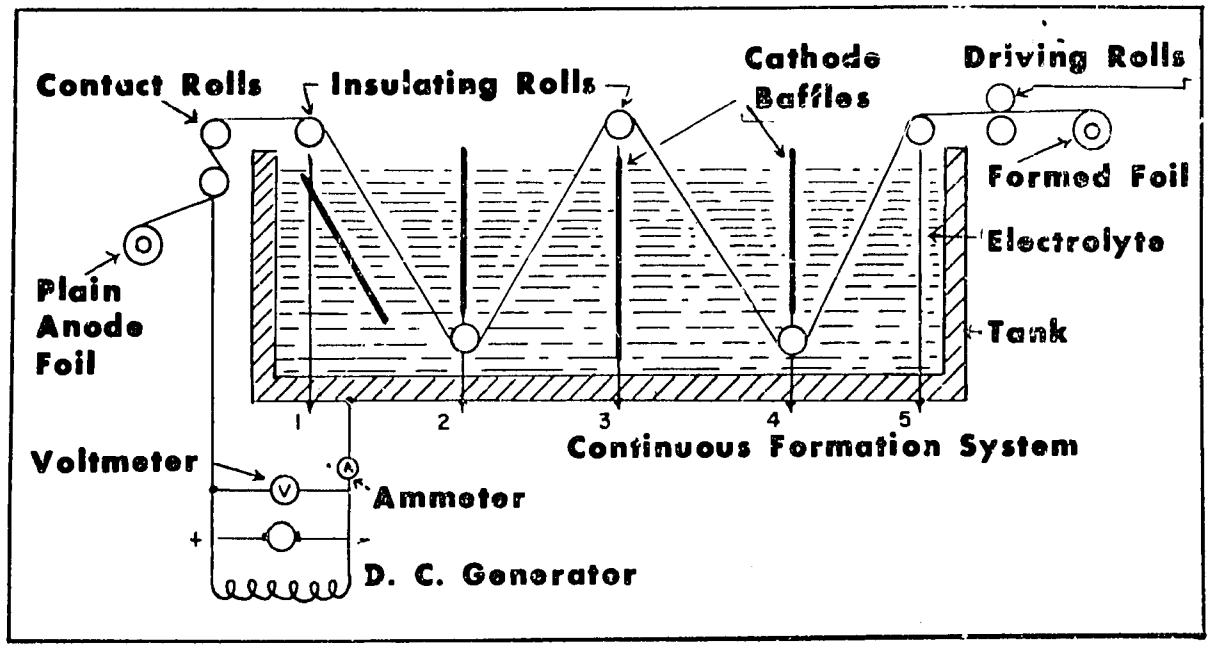

Fig. 2 Typical continuous formation system.

The two general methods of etching are the acid process and the electrochemical process. Hydrochloric acid is used in the first process, and a water solution of sodium chloride in the second. The electrochemical process requires a voltage differential unnecessary in the acid process. Either method gives satisfactory results and individual manufacturers have their own preferences. Heat is generated in the etching process and cooling coils or chambers are used to keep the temperature down.

After etching, the foil is washed in fresh water and then pulled through a tank of nitric acid. The purpose of the nitric acid bath is to convert the chlorides present to soluble nitrates which can be washed off later in tanks or in a combination of water baths and spray rinses. Distilled water is used in the final baths, with the last bath containing a slight amount of boric acid to prevent formation of aluminum hydroxide.

The last steps in the process consist of blowing hot air on the etched foil to dry the surface and winding it into rolls on another mandrel.

The number of rolls that can be etched at once is dependent upon the width of the foil used and the width of the tanks used. The width and design of the etching machinery vary considerably among plants. Most manufacturers etch more than one roll at a time. Plant D reports that its etching machinery has a capacity of 300 feet per hour of foil 17-1/2 inches wide. The speed of the roll through the process can be regulated. The process is geared so that the foil is in the etching solution the correct length of time. Too great a

period will result in etching so deep as to make it difficult or impossible to free the chlorides in subsequent washing operations. This would lead to deterioration and short circuits. Deep etching also weakens the foil. A suggested outline of the etching process is indicated in fig.1 page 16.

After etching, the insulating layer (or dielectric) is formed on the aluminum foil to be used as the anode. This is called preforming or anodizing. The foil is passed through a chemical bath. A predetermined voltage is applied to the solution, the voltage varying with the particular capacitor to be produced.

Aluminum forms at the anode or positive pole of the bath upon electrolysis (the passing of an electric current), and oxygen is evolved which oxidizes the surface of the aluminum foil. The thin film of aluminum oxide formed on the surface of the aluminum foil offers a high resistance to passage of current, an important factor for its use in the capacitor. Continuous application at constant voltage results in a conductance of a minimum value called the leakage current.

The chemistry of the formation process is very complex. It is believed that a thin layer of aluminum oxide and a thicker layer of aluminum hydroxide are formed. This outer layer of aluminum hydroxide is spongy and the presence of some aluminum sulfate and aluminum oxalate is possible. Various solutions are in use --they are composed of a weak acid, a weak salt, and a solvent. Boric acid and borax work well when mixed with manitol.

Table 6. Foil preparation: Direct man-hours per 1,000 electrolytic capacitors in 4 selected plants, by operation, U. S. A., 1951

Operation	Man-hours per 1,000 units in plant -			
	A	B	C	D
Foil preparation, total	3.47	1.75	5.85	1/ 0.33
Etching	(2/)	.35	.85	.07
Preforming	(2/)	1.28	(	.21
Rewinding	(2/)	.05	(5.00	3/ .04
Slitting	(2/)	.07	(	.01

1/ Low man-hours are accomplished in part by processing large rolls. Rolls are 17-1/2 inches wide and weigh 40 to 45 pounds. This plant also takes advantage of high production by using automatic equipment.

2/ Information not available.

3/ Includes rewinding and reslitting. Firm reports inability to slit to 1/2-inch size on first slitting.

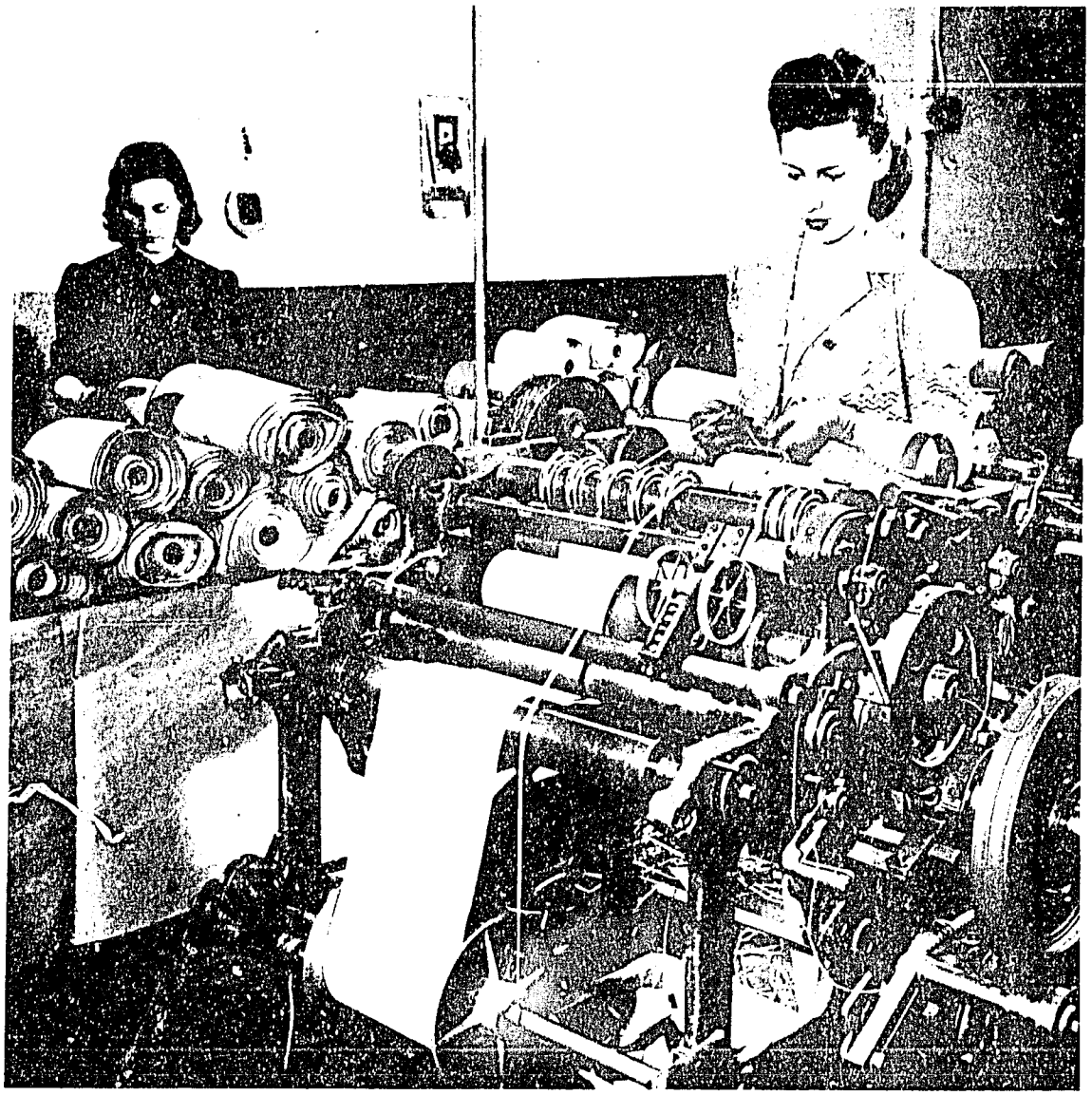

Fig. 3 Cutting bulk rolls of prepared foil to desired width.

A sketch is shown in fig. 2 for a typical preforming process. The machinery in use is peculiar to the individual manufacturer and cannot be identified. It can be said, however, that use is made of wooden tanks containing solutions through which a current is passed. This operation is power-driven and again involves the use of mandrels with idler rolls located in the various tanks. At the end of the process a blast of hot air against the preformed foil dries it. Plant D reports its anodizing equipment has a capacity of 185 feet per hour.

After the preforming operation the foil is rewound for use in anode preparation. The purpose of this

Table 7. Condenser preparation: Direct man-hours per 1,000 electrolytic capacitors in 4 selected plants, by operation, U. S. A., 1951

Operation	Man-hours per 1,000 units in plant -			
	A	B	C	D
Preparation of condenser section: Total	13.2	17.12	12.77	7.00
Cutting anode to length	1.5	.66	.61	.71
Making tabs	(1/)	.32	(1/)	(
Attaching tabs	2.0	9.84	3.66	(1.63
Anode	(2/)	2.19	3/ 2.36	4/ 1.08
Cathode	(2/)	7.65	1.30	.55
Winding	9.7	6.30	8.50	4.66

1/ Tabs are purchased.
2/ Not available.
3/ Figure includes 0.76 man-hours for hand folding the tabs, and 0.46 man-hours for inspecting and smoothing with a hand roller.
4/ Half of this time is allocated to coding and separating tabs.

rewinding is to "true up" the ends of the roll to insure ease of handling and reduce waste. Again, this is a power-driven operation.

Slitting consists of cutting wide rolls of the bulk foil into narrow strips. Rotary knives slice the foil into the desired widths for the specific capacitor to be produced. This width may vary from 1/2 an inch to 5 inches. The operation is power-driven and the foil can be run very fast. Plant D uses a Cameron slitter at a speed of 1,850 feet per hour.

Preparation of Condenser Section. Preparing the condenser section includes cutting the anode foil to length, making and attaching tabs to both anode and cathode foil, and winding the foil and paper separator strips into a roll. The anode foil received on spools from the earlier operations is cut to the required length for the specific capacitor. The machinery used is a modification of an ordinary paper cutter. In some plants it is operated by a foot pedal and more than one roll is cut at once. One plant reports cutting five rolls at the same time.

Some plants purchase tabs for connecting the foil to the terminals, and others manufacture them in their own plants. The tabs are made from rolls of aluminum foil approximately 0.020" thick for the anode tab and 0.010" thick for the cathode. They are cut off by a specially adapted shear -- again, more than one can be cut at once, one plant reporting three at a time.

There are various ways of attaching the anode tabs to the etched and formed aluminum foil. Plant B does

this manually and takes the most time. Another method is used at Plant C where the tab is stitched in an automatic extrusion machine that feeds the tab automatically while the foil is fed manually. This requires 1.14 man-hours per 1,000 units not including the time for folding the tabs by hand. Plant D stakes the tab to the foil and requires the least man-hours per 1,000 (0.55). Plant A also uses the staking process.

Coding the anode tabs is another operation, usually part of attaching the tabs to the foil, and is necessary so that anodes of various capacities can be identified during production. Coding is accomplished by dipping the ends of groups of similar anodes in paint. When the paint dries, the anodes must be separated. After anodes are assembled in the condenser section, the color codes are cut off.

Attaching cathode tabs is similar to attaching the anode tab to the anode foil. Plant D, which per-

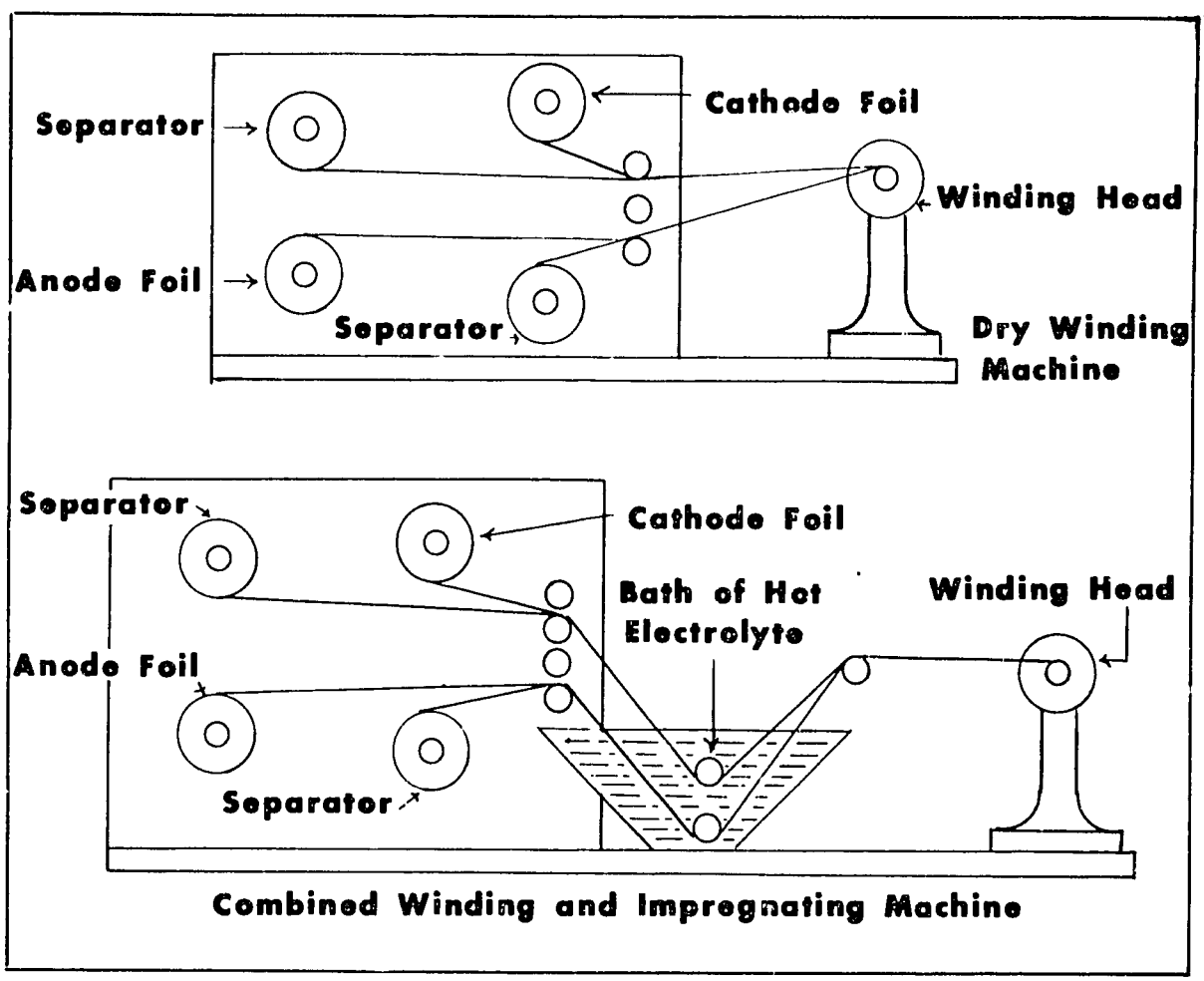

Fig. 4 Two methods of winding or winding and impregnating foil.

Table 8. Impregnation: Direct man-hours per 1,000 electrolytic capacitors in 4 selected plants, by operation, U. S. A., 1951

Operation	Man-hours per 1,000 units in plant -			
	A	B	C	D
Impregnation of condenser sections:				
Total	4	2.33	1.95	0.84
Packing in baskets	(1/)	1.17	.70	(.50
Impregnating	(1/)	.84	.75	(
Other operations 2/	(1/)	.32	.50	.34

1/ Information not available.
2/ Plant B - sorting and counting.
Plant C - cleaning tabs.
Plant D - heat treating.

forms this operation in the fastest time, 0.55 man-hours per 1,000, uses the staking process. Plant C again stitches the foil and the tab - this time by feeding both the foil and the tabs automatically - and requires 1.30 man-hours per 1,000. Plant B attaches the tab by using a power press and again requires the most man-hours per 1,000 (7.65). Plant B does this after the winding operation.

For winding, each manufacturer has developed his own machinery. Essentially, the machine is a power-driven spindle which holds a mandrel on which paper and foil are wound from rolls placed on idler spindles. These spindles are in the rear of the machine, and the foil and paper feed into the same plane as the winding spindle. The cathode foil is purchased in rolls already cut to the appropriate width. The condenser section is wound with the cathode foil on the outside and paper separators divide the layers of cathode and anode foil. As the winding is completed, the separators and the cathode are cut to the same length as the anode foil. An elastic band is placed around the wound condenser section to prevent unwinding. (See fig. A for a diagram of the basic form of construction of a dry electrolytic capacitor.)

Impregnation of Condenser Section. Impregnation creates an electrolytic conductor between the anode and cathode foil by saturating the paper separators with an electrolyte. The name "dry electrolytic capacitor" means that it is nonaqueous or of low-water content. The electrolyte is boric acid and a solvent such as ethylene glycol or manitol (an alcohol). The ethylene glycol permits use of the capacitor in freezing temperatures. The addition of ammonia increases the conductivity. The exact formulas used by a firm are generally regarded as confidential.

Before the actual impregnation operation, the wound condenser sec-

tions are placed in baskets. These baskets facilitate handling and allow any excess solution used in impregnation to drain off through the perforations in the bottom of the basket. Impregnation may be done with or without the aid of a centrifuge. If a centrifuge is used, care must be taken to stack the condenser sections in a prescribed order. Approximately 200 condenser sections may be packed in a single aluminum basket. This is a hand operation.

If a commercial centrifuge is used the baskets (approximately 8) are placed in it and a quantity of electrolyte is admitted. The centrifuge then is turned on and the separating paper is saturated. The solution also penetrates the spongy layer on the dielectric, thus filling up the pores. The time required for impregnation depends on the difference in pressure along the radius of the basket, the penetrability of the separator paper, the tightness

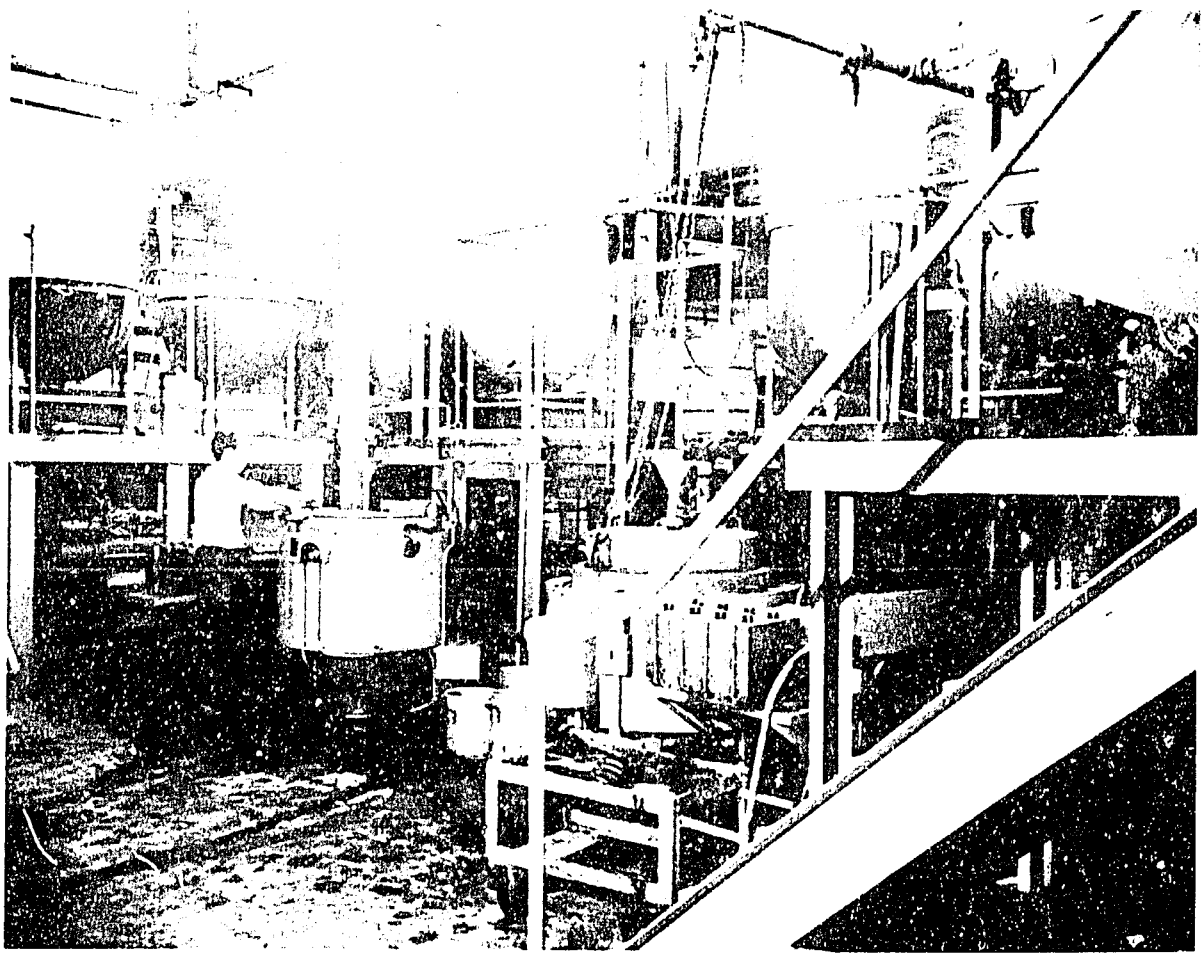

Fig. 5 Upper part of photograph shows vats used for preparing electrolyte. Two centrifuges are shown below them.

Fig. 6 Capacitors racked for aging. Rack is pushed into an oven where heat and voltage is applied to the capacitor.

Table 9. Assembly of condenser into can: Direct man-hours per 1,000 electrolytic capacitors in 4 selected plants, by operation, U. S. A., 1951

Operation	Man-hours per 1,000 units in plant -			
	A	B	C	D
Assembly of condenser section to can, total	28.6	13.05	19.64	10.68
Bunching terminals and straightening leads	1.7	.56	1.44	(1/)
Assembling covers and terminals (prong-type capacitor)	(2/)	(2/)	6.20	(2/)
Punching and trimming tabs . .	2.2	2.11	4.45	1.76
Attaching tabs to other fittings	17.0	5.70		5.84
Anode tab, washer terminal, etc.	8.5	2.79	1.60	3.08
Cathode tab, etc. to can .	8.5	2.91	3/ 2.85	2.76
Assembling condenser to can .	(4/)	2.15	3/ 3.90	1.11
Positioning mounting ring (prong-type capacitor) . . .	(2/)	(2/)	3/ 2.10	(2/)
Sealing or spinning can . . .	4.2	2.37	3/ .77	1/1.77
Cleaning unit	(2/)	.14	(2/)	.20
Spot testing or inspecting . .	3.5	.02	.78	(5/)

1/ Straightening leads is reported together with can sealing or spinning as a single work step requiring 1.77 man-hours per 1,000 units.

2/ Operation not performed.

3/ Plant C sends the condenser section to the aging process before these operations which are actually performed after aging in the final assembly department.

4/ Time for assembling the condenser section to the can is included under times for attaching tabs.

5/ Information not available.

Table 10. Aging: Direct man-hours per 1,000 electrolytic capacitors in 4 selected plants, by operation, U. S. A., 1951

Operation	Man-hours per 1,000 units in plant -			
	A	B	C	D
Aging (formation) Operations, total	1/ 27.5	2/ 9.40	3.78	1.93
Racking for aging	(	(2.76	1.80	1.09
Aging	(22.5	(	.75	.50
Unracking	(	.33	.90	.34
Electrical characteristics Test or inspection . . .	5	6.31	.33	(3/)

1/ Plant A performs the aging operations after the capacitor is assembled in its paper tube.

2/ Plant B performs the aging operations before the condenser section and can are assembled.

3/ Information not available.

of the winding, the specific gravity of the electrolyte, and the viscosity of the electrolyte at impregnation temperatures.

Plants B and C use specially designed centrifuges for impregnation. Plant D reports that the reported capacitor is impregnated by dipping a basket full of condenser sections into an impregnation paste. This is followed by a heat treatment. The condenser sections are placed in a controlled oven which causes an even and equal distribution of the impregnating paste. Plant A simply places the baskets in the impregnating fluid and allows the condenser sections to soak until impregnation is completed. Management attributes Plant A's comparatively high man-hour requirements (4 man-hours per 1,000) to the use of the older methods of centrifuge or vacuum impregnation.

Immediately after immersing or centrifuging the condenser sections, certain other operations may be performed. (See table 8.) Plant D heat treats as described above. Plant C cleans the tabs by dipping them in a solution and passing them through a gas burner flame. This is done to rid the tabs of possible accumulation of the chemicals used in the impregnation operation that might lead to poor contact at assembly. Plant B manually sorts and counts the condenser sections for internal control purposes.

Can Assembly. The major steps in assembling the condenser section in the can are punching and attaching tabs to foil and terminals, assembling condenser section into can, and sealing the can. Operations are generally similar in all plants except C, which reported on a prong-type capacitor and which must perform the additional operation of assembling covers and terminals. The prong-type

Fig. 7 Printing identifying characteristics on the paper tube used as housing for capacitor.

capacitor requires both an upper and a lower cover which are assembled before can assembly. Covers and terminals are sent from the stockroom and a jig is used for hand assembly in Plant C. The other manufacturers reported on tubular paper capacitors which avoid these operations because they do not use the same type covers.

The leads are straightened as an initial operation in assembling the condenser section to its can. This hand operation is performed to facilitate later operations.

A punch press is used to cut the excess length off the tabs, and a hole is punched in the end of each tab in order to attach the terminal or connector. The tabs are punched and trimmed individually. Plant C does this as part of the operations described in the following paragraphs.

Next, the anode tab is either riveted, clinched, or eyeletted (similar to placing eyelets in shoes) to a specially designed terminal. In Plant C this involved crimping (or bending) the terminal over the top cover. Other plants rivet the tab and terminal. A riveting or eyeletting machine is used unless the terminal is crimped, in which case a small press is used.

Generally, the cathode tab and terminal are attached to the can by a riveting operation in order to have the can act as a ground for the capacitor. Thus, the can is the negative electrode. In Plant C a steel mounting ring is placed over the bottom cover and the cathode tab is welded to this ring by an electric spot welder. This operation cannot take place until after the can is assembled, but is noted here for purposes of comparison.

Assembling the condenser to the can is a hand operation in which the condenser section is inserted in the aluminum can. Plant C shows higher man-hours per 1,000, due probably to the customer's specification that the particular capacitor be held in place in the can by wax. This is customary if the capacitor is to be used in aircraft or in automobiles where vibrations can be anticipated. To accomplish this a wax pot is used and a predetermined volume of wax is dropped into the can before the condenser section is inserted.

Again, Plant C must perform an additional hand operation. A mounting ring is put in place after the cathode tab is attached by welding and before sealing the can.

In the operation of sealing or spinning the can, the edge of the can is crimped over the cover and the can is sealed against leakage. This is accomplished by a power press or a drill press. The machine used may be fed automatically or manually. Plant C uses a dial-fed power press which crimps 8 units at a time. The capacitors are placed by hand in cavities about the circumference of a rotating disc which is then positioned by pressing a pedal.

Table 11. Identification and other "housing" preparations: Direct man-hours per 1,000 electrolytic capacitors in 4 selected plants, 1/ by operation, U. S. A., 1951

Operation	Man-hours per 1,000 units in plant -	
	B	C
Housing preparation, total	1.08	2.34
Identification, printing tube or stamping can . .	.13	.41
Degreasing and cleaning can	(2/)	.51
Painting can bead	(2/)	1.42
Cutting tube	.62	(2/)
Impregnating tube	.33	(2/)

1/ Plants A and D purchase prestamped, waxed, and cut-to-size tubes in the case of the reported product.
2/ Operation not applicable.

Table 12. Final assembly, final test, and packing: Direct man-hours per 1,000 electrolytic capacitors in 4 selected plants, by operation, U. S. A., 1951

Operation	Man-hours per 1,000 units in plant -			
	A	B	C	D
Final assembly, test, and packing, total	13.0	8.67	4.20	2.87
Steam cleaning	(1/)	(1/)	(1/)	.20
Curling tube, first end . .	(	.96	(1/)	(
Inserting can into tube . .	(9.5	1.89	(1/)	(2.67
Curling tube, second end .	(	2.02	(1/)	(
Final testing	3.5	2.60	3.15	(2/)
Packing and counting . . .	(2/)	1.20	1.05	(2/)

1/ Operation not applicable.
2/ Information not available.

Some plants manually clean the can at this point before beginning the aging process. Plant D reports that it uses steam cleaning.

Some manufacturers give an intermediate or spot test at this point, before aging. This is one of two electrical tests to determine bad units before final assembly. Plant A regards this and subsequent testing operations as indirect labor because work is done on a wide variety of products at one time and it is not feasible to allocate this labor to any one product. Plant C only inspects visually at this point before sending the condenser sections to the aging process.

The Aging Process. The purpose of aging is to repair any cracks that may have developed in the dielectric (aluminum oxide) layer on the anode in the manufacturing process. It is a continuation of the preforming operation in the foil preparation department, and assures a better quality capacitor. The capacitors are placed manually on specially designed racks and a predetermined voltage is applied to each unit. The operation is carried out under heat of approximately 85 to 90 degrees centigrade. Steam coils generally supply this heat and the specially designed racks are either hand pushed into the oven or conveyed by overhead trolley. In Plant B, only the condenser sections are put on the racks. Because Plant C does not complete the assembling of the condenser section to its prong-type can until it reaches the final assembly department, only the condenser sections with covers and anode terminal attached are placed on the racks (table 9). It is noteworthy that Plant A requires more than 6 times as many man-hours per 1,000 units (22.5) as Plant B, highest of the other 3 manufacturers on the comparable aging operations.

Plant A takes almost 12 times as long as Plant D. Plant A's management states that efficient aging depends upon the methods used in the earlier operations and attributes slower performance in the aging process to methods used in foil preparation and impregnation as well as to the aging techniques themselves.

Unracking is a manual operation which consists of taking the aged capacitors off the racks.

After the aging process an electrical test is performed to make certain that the capacitors are rated at the correct voltage. In Plant B this is a 100-percent check and in Plant C this is a spot check. Plant A performs only a visual inspection at this point but it is immediately followed by capacity, voltage, and leakage tests as the final operation (table 10, footnote 1, and table 12). The time for this inspection (5 man-hours per 1,000 units) includes some time for reworking faulty units discovered in the final testing. Plant B makes an allowance for rework of 0.9 man-hours per 1,000 units which is not shown in tables 6 through 12.

Identification and Housing Preparation. The paper tube stock which forms the outer housing comes in long lengths of cardboard tubing, which are fed through the hopper of a printing press that prints the capacitor specifications and the manufacturer's name on it at appropriate intervals. If no paper tube insulation is to go on the outside of the can, as is the case with the product reported by Plant C, then the can itself is stamped with the capacitor specifications and the manufacturer's name. A power press with dial feed is used. This is done before can assembly.

The can is dipped in a degreasing solution to clean the surface of packing grease or oils and allowed to drain. A basket containing 200 cans is used to dip them in a tank of the solution.

The can bead is painted to prevent leakage or contamination of the electrolyte. Rubber paint is applied by hand at the point where the negative or ground tab comes through the cover.

Table 13. Summary comparisons of direct man-hours per 1,000 electrolytic capacitors in 4 selected plants, U. S. A., 1951

Type of comparison	Man-hours per 1,000 units in plant -			
	A	B	C	D
Total of tables 6 through 12 .	89.8	53.4	50.5	23.6
Adjusted total of tables 6 through 12	77.8	43.8	45.2	26.0
Adjusted total of tables 6 through 12, excluding operations not performed in every plant	68.3	37.4	34.1	23.2

Table 14. Summary of indirect man-hours per 1,000 electrolytic capacitors in 4 selected plants, by type of labor, U. S. A., 1951

Type of labor	Man-hours per 1,000 units in plant -			
	A	B	C	D
Indirect labor, total	18.3	21.5	18.0	3.6
Line testing and inspecting .	12.0	8.9	4.3	.9
Packing and counting	4.0	1.5	1.0	(1/)
Supervision	(1/)	3.0	1.5	.9
Line service (material handling)	(1/)	(1/)	(1/)	.9
Other indirect	2.3	8.1	11.2	.9

1/ Included by "other indirect" figure.

When a paper insulating tube is used, a bench cutter shears the long printed tube to the required length for the specific capacitor.

The paper tubes are impregnated by either dipping into a wax-like insulating solution and air drying, or spraying with varnish in other instances. Dipping may be done with the aid of a dipping-hoist (hand operated) and baskets containing as many as 500 sections of tubing.

Final Assembly and Final Testing. For final assembly the edge of one end of the paper tube is curled in by a drill press, the can is manually inserted into the tube, and a drill press curls the second end of the tube over the end of the can. Plant B has separated the times for these final assembly operations. Plants A and D show them together as one combined time for final assembly.

Plant C cleans the aluminum can by a steam bath before final assembly to get rid of any deposits that may be present from the aging process.

All plants make a final test for electrical characteristics of the completed capacitor. They use special test meters and other equipment to insure the quality of each unit. This is usually a 100-percent check.

Hand packing is done in all plants and the capacitors are placed in boxes having separators similar to those in egg crates. They are packed in bulk with an average number of 150-200 in a carton.

Comparison of Direct Labor Requirements

Table 13 constitutes a summary of tables 6 through 12, and compares the total direct labor requirements as reported by the 4 cases under study.

Here operations such as testing, inspecting, packing, and counting have been excluded from Plants A, B, and C in order to make the direct labor accounts comparable with those of Plant D where these opera-

tions are performed by indirect employees. As these employees work on a wide variety of products, Plant D cannot allocate this labor to any one product by either time standards or estimates. Plant B's total is greater than the sum of tables 6 through 12 because of a separate account for rework amounting to 0.90 man-hours per 1,000 capacitors. An addition of 10 percent has been made to the time standards of Plant D. This allowance is the plant variance rate.

The bottom line of table 13 shows the adjusted totals of the second line (explained above) after subtraction of those operations which are distinctly not comparable or not performed in each case under study. This gives a direct labor total for only those operations most clearly comparable.

In comparing the direct labor requirements of the four plants, it should be noted that no two plants are reporting on exactly the same product. Table A indicates some of the major differences in specification. The capacitor reported by Plant A has larger dimensions than the others. Plant C's capacitor is housed in a metal container only, the open end of which is fitted with twist-prong mounting tabs. Plant D reported on a product of altogether different size from the others. It has one-half the capacity, and one-third the voltage, and consequently is of smaller dimensions. This firm estimates that 15 percent more time would be required to make a 20-microfarad 450-volt capacitor than the one reported (10 microfarads and 150 volts). To make the latter, more time would be needed in operations such as foil preparation, aging, or materials handling where larger pieces are involved.

Direct labor time for Plant A is high because among other reasons, that plant includes certain material-handling functions not included by the other plants. In this instance, production workers carry materials in small paper boxes, thus adding to the unit man-hours of the operators.

Finally, Plant D emphasized its low direct labor requirements as resulting from high production of all capacitors, which production, in turn, resulted from optimum use of high speed automatic machinery to reduce production time.

Comparison of Indirect Labor Requirements

Because indirect labor figures are computed by using overall ratios of the number of direct to indirect workers, individual figures should be regarded as estimates of indirect requirements. For the purpose of this comparison, the term "indirect labor" includes all man-hours in general factory and departmental overhead costs chargeable to the output of the reported capacitor. Such man-hours are worked by employees engaged in testing, inspecting, material handling, receiving, shipping, storage, plant security, maintenance, repair, janitorial services, record-keeping, supervision, production engineering and other services closely associated with production operations. Man-hours in general administration, office, clerical, account construction, basic research, and sales are excluded.

Plant A's indirect man-hours are minimized by the effect of material handling by production workers. Paper boxes are used to carry materials to the line. This shifts some man-hours to the operations carried

in the direct labor account. Plant C reports that its figures for supervision and other indirect labor are higher than is normally the case.

Inasmuch as the number of indirect workers tend to be fixed, indirect man-hours per 1,000 units are inversely related to volume. The volume of production during the reported period was less than half of what it had been the previous year. For Plant D, of the figure 0.9 man-hours per 1,000 units for other indirect labor (table 14), 0.16 is allocated to engineering. This is 0.6 percent of direct labor. (Plant D's indirect man-hours apply to its capacitor division only.)

CHAPTER III: LABOR IN THE RADIO AND RELATED PRODUCTS INDUSTRY

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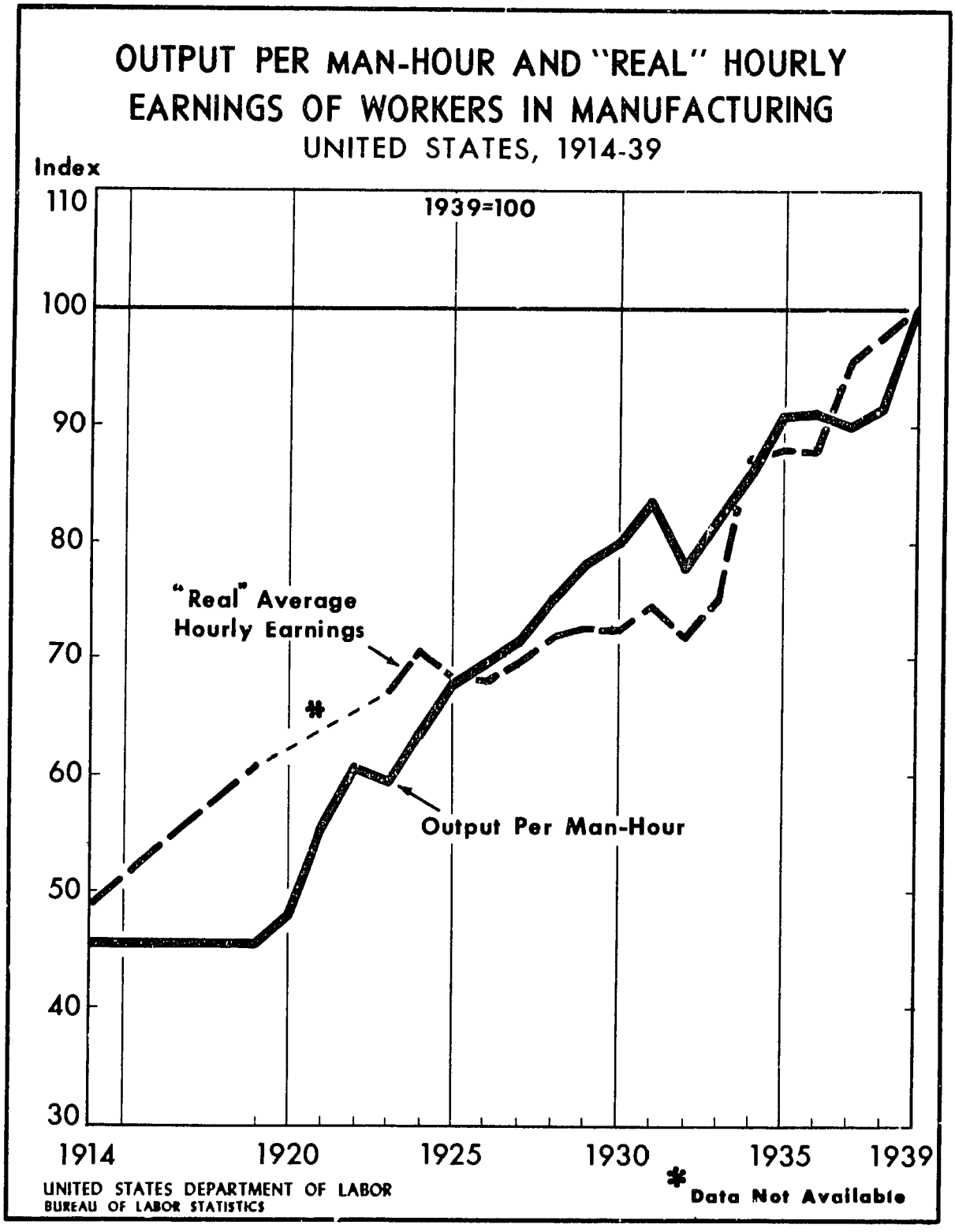

Figure 8 (Real wages and productivity chart).

CHAPTER III: LABOR IN THE RADIO AND RELATED PRODUCTS INDUSTRY

Workers' Earnings

Workers' earnings, along with the earnings of other groups in the United States, have increased in real as well as in monetary terms as a result of improvements in productivity. It is estimated that between 1909 and 1947, the average real weekly earnings of factory workers doubled while the workweek declined one-fifth. These substantial improvements in income could not have been achieved except for increased output per man-hour of work made possible by a constantly improving technology of production. Although all workers have benefited from greater productivity, workers in industries with strong unions have generally been in the forefront in receiving a share of the gain from increased productivity. In addition to higher pay and shorter hours, workers have also chosen to take some of the returns from greater productivity in the form of so-called "fringe benefits" - paid holidays, vacations, pensions, rest periods, improved working conditions, and other nonwage benefits.

Despite the advantages arising from technological change, both organized and unorganized labor have on many occasions in the past resisted the introduction of new methods or machinery because of both the threat of unemployment and the normal resentment of a change in routine common to all individuals. Examples of how management and labor working together have successfully coped with the problem are given toward the end of this chapter.

Table 15. Indexes of productivity, earnings, and prices in United States, 1914-39

Year	Output per man-hour, all manufacturing	Average hourly real earnings
	(1939=100)	
1914	45.5	48.8
1919	45.3	60.5
1920	48.0	(1/)
1921	55.2	(1/)
1922	60.5	(1/)
1923	59.5	67.1
1924	64.4	70.6
1925	67.6	68.4
1926	69.5	68.1
1927	71.3	69.6
1928	75.1	71.8
1929	78.1	72.5
1930	80.0	72.5
1931	83.5	74.4
1932	77.8	71.7
1933	81.9	75.0
1934	85.9	87.3
1935	90.8	88.1
1936	91.0	87.9
1937	90.0	95.4
1938	91.6	97.6
1939	100.0	100.0

1/ Information not available.

Table 16. Amount of worktime required of average American factory worker and of average radio and related products factory workers to buy selected food and clothing items, 1947

Item	Unit of measure	Average factory worker		Average radio and related products factory worker	
		Hours	Minutes	Hours	Minutes
Food:					
Milk	1 liter	--	9	--	10
Eggs	1 dozen	--	34	--	37
Oranges	1 dozen	--	21	--	23
White flour	1 kilo.	--	11	--	12
White wheat bread	1 kilo.	--	13	--	14
Butter	1 kilo.	1	28	1	36
Salt pork	1 kilo.	--	49	--	54
Potatoes	1 kilo.	--	7	--	8
Coffee	1 kilo.	--	51	--	56
Clothing:					
Men:					
Heavy wool suit	1	36	43	40	6
Work shirt	1	1	19	1	26
Socks	1 pair	--	16	--	17
Street shoes	1 pair	6	32	7	8
Work shoes	1 pair	5	56	6	29
Women:					
Wool coat	1	17	53	19	32
Street dress	1	8	20	9	6
House dress	1	2	31	2	45
Rayon and nylon stockings	1 pair	--	53	--	58
Street shoes	1 pair	5	26	5	56

The average income level of workers in American factories and in the radio and related products industry in the period since World War II are shown in tables 16 and 17. In table 16 an attempt is made to eliminate confusion arising from different currencies by showing the cost of common commodities in terms of work minutes required of the average factory worker to buy foods and commodities.

Unions in the Radio and Related Products Industry

Prior to the passage of the National Industrial Recovery Act in 1933, workers in the radio and related products industry were almost entirely unorganized. Section 7a of the N.I.R.A. supported workers in the right to organize and bargain collectively. Some local unions were quickly organized with charters

in the American Federation of Labor; others were unaffiliated. In order to obtain a more unified organization, a council composed of AFL locals and several independent organizations was soon formed.

Later, in March 1936, representatives from 18 local unions, with a membership of approximately 25,000, met in Buffalo, N. Y., where the United Electrical and Radio Workers of America (UE) was formed within the AFL. United Electrical covered workers in all electrical products in addition to radios and related products. In November 1936 United Electrical, now an industrial type union, was granted a charter by the Committee for Industrial Organization. It was expelled from the AFL in 1937 along with other CIO-affiliated unions. At the 1937 convention of the union, jurisdiction was extended to machine-shop workers and the union changed its name to the United Electrical, Radio and Machine Workers of America. By 1948 its membership had risen to more than 400,000 and it had established bargaining rights with most of the larger radio and television manufactors.

In late 1949 the CIO revoked the charter of United Electrical because of policy differences and issued a charter in the name of International Union of Electrical, Radio and Machine Workers known as the IUE. Both the UE, now unaffiliated, and the IUE have large memberships among radio and television plants. A third union, the International Brotherhood of Electrical Workers (AFL) also represents a substantial number of workers in the radio and related products industry. It is estimated that approximately two-thirds of the plants with 51 or more workers are now covered by collective bargaining agreements.

Wage Practices. Workers in factories producing radios, phonographs, television sets, and equipment, including electrolytic capacitors, have also shared in recent gains from

Table 17. Hours and gross earnings of production workers for all manufacturing industries and for radios, television sets, phonographs, and equipment, including electrolytic capacitors, U. S. A., annual average for 1947, 1950, and 1951

Year	Consumers' Price Index 1/	All manufacturing industries			Radios and related products industry		
		Average weekly earnings	Average weekly hours	Average hourly earnings	Average weekly earnings	Average weekly hours	Average hourly earnings
1947	159.6	$49.97	40.4	$1.237	$44.41	39.2	$1.133
1950	171.9	59.33	40.5	1.465	53.85	40.7	1.323
1951	185.6	64.88	40.7	1.594	58.40	40.5	1.442

1/ Consumers' Price Index for moderate income families in large cities as collected by U. S. Bureau of Labor Statistics, Division of Prices and Cost of Living.

Table 18. Average straight-time hourly earnings of workers in selected production occupations in the manufacture of component parts for radio, television sets, and related products, U. S. A., 1951 1/

Occupation	Number of workers	Average hourly earnings
Assemblers	19,551	$1.14
Carpenters, maintenance	157	1.69
Electricians, maintenance	194	1.78
Guards	334	1.28
Inspectors	3,715	1.25
Janitors	695	1.15
Machine-tool operators	1,887	1.44
Machinists	474	1.78
Mechanics, maintenance, and general utility	371	1.66
Punch-press operators	925	1.33
Set-up men, machine tools	222	1.70
Solderers	1,945	1.15
Stock clerks	432	1.30
Stock handlers and truckers, hand testers	4,437	1.23
Tool-and-die makers	802	2.17
Truck drivers	73	1.35
Truckers, power	63	1.30
Welders	149	1.37
Winders, coil	2,011	1.16
Wirers	2,564	1.26

1/ Excludes premium for overtime and night work.

increased productivity. Although prices of the items purchased by middle-income city families rose 16 percent in the recent period (1947-51), average weekly wages in this industry have increased by a greater amount - 31 percent (table 17). The average wage in this industry is about 10 percent below the average for all workers in manufacturing. These lower-than-average wages are probably related to the high proportion of women employees who usually perform many of the semiskilled and unskilled operations such as soldering, wiring, inspecting, and assembly.

Data were available on average weekly hours and average hourly earnings for three of the four plants surveyed for this report. Plants B and C, both located in small cities and in an area with a wage structure lower than the industry average, pay their production workers approximately 30 cents less an hour than does Plant D, which is located in a large city in a higher wage region.

Fringe Benefits. 5/ Since the end of World War II increased welfare benefits have become an important part of collective bargaining negotiations. The November 1951 Bureau of Labor Statistics survey of establishments employing 51 or more workers and primarily engaged in the manufacture of radios, television sets, phonographs, and related products, including electrolytic capacitors, showed that more than 90 percent of all production workers received 1 week's vacation after 1 year of employment. Less than 2 out of every 100 employees were in establishments with no formal vacation plan. After 3 years of service 41 percent of all production workers were receiving 1 week's vacation and 44 percent had 2 weeks. Approximately 3 out of every 10 workers were granted 3 weeks' vacation after 10 years' service.

Table 19. Current hours and earnings in selected plants manufacturing dry electrolytic capacitors, U. S. A., 1951

Plant	Average weekly hours	Average hourly earnings
A	(1/)	(1/)
B	39.5	$1.221
C	44.3	1.224
D	40.6	1.503
Industry average 2/	40.5	1.442

1/ Not available.
2/ Radio, television, phonograph, and component parts industry.

Paid holidays are almost universal in the United States. In November 1951, 96 out of every 100 production employees were receiving pay for holidays. Six or seven paid holidays were provided for three-fourths of the workers.

Approximately a third of the production workers in the radio, television, and related products industry were in establishments with nonproduction bonus plans. Christmas or year-end bonuses (included in more than two-thirds of these plans) and profit-sharing with the workers were the most typical types of bonus plans in operation.

Almost 90 percent of the production workers were covered by insurance or pension plans in which the employer paid at least part of the cost. Approximately three-fourths of the workers received health insurance, life insurance, and hospitalization; 30 out of every 100 workers were under some form of pension plan.

Adjustment to Technological Change

Labor and management in the United States have always been faced with problems arising from changes in processes and the introduction of new machinery. The problems generally include determination of earnings, workload, work schedule, displacement of special skills by new machinery and methods and, in some cases, actual displacement of workers. Over the past 25 years, with the more rapid growth of labor

5/ Nonwage benefits such as paid vacations, holidays, and pensions.

Table 20. Welfare benefits for production and related workers in 4 selected plants manufacturing dry electrolytic capacitors, U. S. A., 1951

Item	Plant			
	A	B	C	D
Years of service required for paid vacations of --				
1 week	1	1	1	1
2 weeks	3	5	1/ 5	3
3 weeks	--	--	--	10
Number of paid holidays a year	(2/)	10	6	6
Number of days sick leave a year	none	none	none	none
Pension and insurance paid by --				
Employer	X	X	--	X
Employer and worker	--	--	X	--
Shift differential 3/				
Evening	10%	10%	10%	$0.15
Night	--	10%	10%	$0.15
Percent of base pay for --				
Saturday	4/ 100	100	150	150
Sunday	200	200	200	200
Holiday	not worked	5/ 250	200	300
Overtime 6/	150	150	150	150

1/ After 3 years' service plant workers receive 7-1/2 days' vacation.

2/ Although at the present time Plant A has 6 nonpaid holidays, negotiations are in process for paying the workers for these holidays.

3/ Shift differential refers to remuneration either in cents per hour or percent of base rate in addition to the regular basic rate of pay for evening hours (3:00 p.m. to 11:00 p.m.) and night hours (11:00 p.m. to 7:00 a.m.).

4/ Plant A pays only straight time for Saturday work. For sixth and seventh consecutive workdays plant workers receive time and a half, and double time, respectively.

5/ Plant workers receive 2-1/2 times their basic salary if they work 6 paid holidays. For 4 other holidays they receive 1-1/2 times their basic salary if they are required to work.

6/ Overtime refers to rate of pay for work after 40 hours a week and after 8 hours a day.

unions, adjustments and solutions to these problems in many instances have been reached on a case by case basis as a result of negotiations between the two parties. The success of the solutions and adjustments has depended almost entirely on the attitudes and procedures with which labor and management approached each case and only incidentally on the technical details of the change itself.

Moreover, negotiations over technological change in many fields of manufacturing indicate that the experience gained from a case in one industry is applicable to problems of change in other industries. Consequently, the methods and ideas developed in negotiations over technological change are used in many industries besides the one in which a problem first appeared. Technical details concerning machines, processes, and conditions of employment still require agreement on a case basis within the framework of ideas and methods handed down from past experience.

The following examples of adjustment to technological change have been selected because of the techniques and procedures they illustrate, without regard to the industry in which they occurred.

Example A. 6/ Technological changes involving displacement of workers have been handled with real care and with genuine concern for employee welfare. In 1945, a division of the company with 76 employees was moved from Cambridge to a new plant in another area in order to be located near the source of supply of raw materials. For 6 to 8 months prior to the move, consideration was given to the placement of the employees affected. Some were transferred to other jobs as normal turnover created openings. A crew of 35 operators was required up to the last moment in order to build up an inventory to supply customers during the transfer of heavy equipment to the new plant. These workers were guaranteed their regular hourly rates regardless of the job to which they might be transferred. The guarantee was based on length of service; 1 month for each year up to 12 months' guarantee. The length of services of these employees ranged from 1 to 10 years. Practically all these employees were placed before their guarantees expired on jobs carrying rates at least as high as their former ones. None of the 76 was laid off, but 2 men and 8 women resigned rather than accept transfers.

Example B. 7/ 1. The company discussed with the union proposed changes in process and the introduction of new machinery. It must keep pace with and, if possible, lead the way in making changes in technology and processes which turn out cheaper and better glass. Accordingly, the company wants freedom to introduce new machines and processes, to shift work from less efficient to more efficient plants, and

---

6/ Abstracted from Causes of Industrial Peace Under Collective Bargaining, Case Study No. 3, National Planning Association, Washington, D. C., 1948.

7/ Abstracted from Causes of Industrial Peace Under Collective Bargaining, Case Study No. 2, National Planning Association, Washington, D. C., 1948.

to make more products with less manpower. If it is unable to achieve these objectives at least in part, its very survival as a business is in jeopardy; the automobile manufacturers, which use a large amount of the glass produced by the company, are "tough customers." The following case is an illustration of the union-management consultation which usually precedes any technological change.

A conveyor system was to be installed in a laminated glass plant in Toledo, Ohio. The local president was called in and told of the company's plans. At first he was quite upset. Later, he enumerated his reasons why the plan would not work. By the time a second meeting was held with full union committee, management had altered its plans to meet several of the objections raised by the local president and had answers read for the others. Again the union representatives expressed their objections to management, and again the company adopted some suggestions and set forth its reasons for insisting that the conveyor system be used. The conveyor system was then installed, but in a way which met many of the union's objections. The union's biggest fear was that earnings would be reduced, and in this respect the company was able to assure the men that they could keep up their bonus earnings on the new jobs. In this case the information-sharing process was used successfully as a means of implementing a management decision.

2. Another time, the company outlined a scheduling problem for the union's consideration. Because the auto manufacturers were short of steel they could not use the glass they had ordered for the next 9-month period. The company had two alternatives. They could cut production drastically at once, lay off a large number of men, and rehire later when the glass could be used at a faster rate; or, they could gamble on the total amount that would be needed for the entire 9 months and schedule the glass at a constant rate, laying off a few workers at once but keeping all the remaining men at work. The company told the union to make the decision, because it felt that the laying off and rehiring of men was the most important consideration involved. The union decided to cut down as much as necessary for the entire period. It is possible this would have been the company's decision, but it recognized the advantage of consulting the union.

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CHAPTER IV: SUPPLEMENTARY INFORMATION

Composition of the Capacitor Industry in the United States

The capacity of the capacitor manufacturing industry in the United States during the 1950-51 period has been estimated at 2 billion units. In the year 1951 the industry operated at about two-thirds capacity. Roughly half of this volume was in fixed capacitors for electronic equipment.

The total volume of the industry is divided among a large number of firms. However, statistics for the third quarter of 1951 from the Controlled Materials Plan of the National Production Authority show that 1 firm produced 22 percent of total dollar volume, 4 firms had 55 percent, the 10 firms with more than 3 percent each had a total of 80 percent, and the 54 largest producers manufactured 95 percent of the total output. Production by type of capacitor is shown in tables 21 and 22.

Technical Notes on Dry Electrolytic Capacitors

A capacitor is a device to retain a measured charge of static electricity until required. In general, the condenser section proper consists of two conducting plates, one positive and one negative, separated by an insulating medium. The less conductive this separating medium, the less leakage the condenser will have. An electrolytic capacitor is dependent on a thin film of aluminum oxide on the surface of the positive plate for capacity. The plates are aluminum foil and the separators are usually paper strips saturated by an electrolyte. In a dry electrolytic capacitor the electrolyte is a nonaqueous or low-water content solution or paste.

Dry electrolytic capacitors can be made by two methods. One is known as the "etched plate" process wherein the high purity aluminum anode foil is etched by a chemical or electrochemical process. The other is a method known as "fabricated plate" wherein high purity aluminum is sprayed onto either paper or gauze. In this report all companies use the etched plate process.

Capacity is directly proportional to the area of one plate multiplied by the dielectric constant, divided by the thickness of the dielectric or insulating medium. Thus, we can double the capacitance by doubling the area of the plate, or by reducing the dielectric or insulating layer by one-half.

In the case of electrolytic capacitors, the area of the plate or foil is increased 400 to 600 percent by etching the foil. After etching, the foil is anodized or preformed, a process by which a very thin film of aluminum oxide and other complex aluminum compounds are deposited on the surface of the foil. This film of aluminum oxide is very thin (approxi-

Table 21. Quantity and value of fixed capacitors for communications and industrial electronic controls manufactured in the U. S. A., 1947 1/

(In thousands)

Product	Total shipments and interplant transfers	
	Quantity	Value f.o.b. plant
Fixed capacitors, total	440,633	2/ $49,392
Electrolytic capacitors . . .	50,437	19,251
Paper capacitors	227,789	20,664
Mica capacitors	72,469	5,410
Ceramic capacitors	89,938	4,067

1/ Excludes capacitors for power factor correction and fluorescent tube ballasts.

2/ All electronic type components for communications and industrial electronic controls valued at $348,916,000.

Source: Census of Manufacturers, 1947, U. S. Department of Commerce, Bureau of the Census.

mately 10^{-5} centimeters) and has a very high resistance to the passage of electric current. Thus, the electrolytic capacitor takes advantage of increased surface area with an extremely thin insulating layer (aluminum oxide). This increases the capacitance tremendously and explains the chief advantages of electrolytic capacitors, which are: (1) large capacitance (8 microfarads or more); (2) space economy -- small size per microfarad for large capacitance; and (3) low cost per microfarad.

The thinness of the insulating oxide film is very important. Electrolytic capacitors are best suited for service where they will be under continuous operation. The dielectric strength and life expectancy of the film depend upon the purity of the raw materials used and the lack of contamination during manufacture.

Instead of using a metallic film for the cathode, an electrolytic capacitor uses a weak electrolyte carried by the paper separator. This reduces the emission of electrons when high voltages are used. The weak electrolyte does not emit electrons as readily as a metal cathode. This is attributable to a close relationship between the electrons and ions of the ionized electrolyte. The leakage current is thereby reduced. It is important to remember that the

Table 22. Number of fixed capacitors for radio and television receivers manufactured in the U. S. A., by type, 1946-51

(In millions)

Year	Type of capacitor			
	Electrolytic	Mica	Ceramic	Tubular
1946	28	57	170	155
1947	35	70	209	196
1948	36	71	214	212
1949	32	61	186	218
1950	58	88	280	351
1951	50	75	236	284

Source: Tele-Tech Jan. 1952 (Caldwell-Clements, Inc.), New York, N. Y.

actual cathode is an electrolyte, and the cathode foil is merely a means of conducting the current to the electrolyte.

The electrolyte serves several functions. As just indicated, one is to conduct the current from the metallic electrode to the active surface of the dielectric film. A solution provides excellent contact between all points of the dielectric and the cathode foil. The electrolyte serves also to continue the forming process by the maintenance and repair of the oxide film. If this film is broken -- that is, if cracks or holes develop in the aluminum oxide -- short circuits might result. It is believed that the electrolyte increases the dielectric constant of the dielectric layer by permeating the surface of it; most electrolytes used have high dielectric constants.

Table 23. Value of production of capacitors for electronic equipment in the U. S. A., by quarter, 1951-52

Year	Quarter			
	First	Second	Third	Fourth
	(In thousands)			
1951	(1/)	(1/)	$34,254	$47,471
1952 . . . . . (estimated)	$52,869	$59,502	63,946	(1/)

1/ Not available.

Source: National Production Authority, Controlled Materials Plan reports from about 70 plants.

SALES
ORDER NO. _____

ORDER SHEET

CREDIT
APPROVAL
By _____

ACCT.

TERRITORY

CHARGE TO

Name _____

Address _____

City _____ State _____

SHIP TO

Name _____

Address _____

City _____ State _____

Cust. No. _____ Date Cust. Order _____ Date Ent. _____

Ship From _____ Ship Via _____ Salesman _____

QUANTITY	CAT. NO.	DESCRIPTION	PRICE	DISC.

Fig. 9 Form issued by sales department for telephone or telegraph orders.

Raw Materials for Dry Electrolytic Capacitors

The anode foil used in electrolytic capacitors is purchased in 40-50-pound rolls. This foil varies in thickness from 0.003 to 0.005 inches, the usual thickness being 0.003 inches. Most of these rolls are from 6 to 8 inches wide and approximately 1,400 feet in length; however, one manufacturer reports using a 17-1/2-inch roll of foil.

The aluminum content of this foil is at least 99.8 percent, the usual degree of purity used. In certain cases, however, it might be necessary to use purer grades of foil, those of 99.85 or 99.9 percent aluminum content.

The surface is very smooth and free from oil or grease and the lubricants used in the rolling mill where the foil was manufactured are cocoanut, palm, or vegetable oils.

This insures easy saponification with a caustic solution before etching.

The cathode foil need not be as pure as the anode foil, and an aluminum content of 99.3 percent is in general use. This foil can also be thinner and usual practice is to use a thickness of 0.001 inches to 0.0025 inches. The surface must be free from oil or grease.

The separator or paper used is made from selected cotton rag stock with the occasional addition of other fibers. The paper is between 0.002 and 0.008 inches thick, the usual thickness being 0.003 inches. Wood pulps are not used extensively in making this paper because the kraft or sulfite pulps would be harmful to the electrolyte. It is necessary to eliminate any chlorides, nitrates, sulfates, or resinous materials.

The raw materials, especially the chemicals, used in the various operations must be free from such impurities as iron or other substances that would affect the electrolytic action. This high degree of purity is necessary for the production of capacitors which meet the high standards demanded by customers.

Constant inspection of the raw materials prevents production difficulties traceable to impurities in the materials used.

Production Planning and Control Forms

These forms, described in this section are the central documents used by a typical firm for its production planning and control system.

Figure 9 shows the order sheet used by the sales department for recording telephone or telegraph orders. The price record shown in figure 10 is used by the sales department to record the price of parts ordered, their description, and part number. These two forms are then sent to the engineering department for approval and correction of drawings if necessary. From there they go to the Ma-

PRICE RECORD

QUANTITY	DESCRIPTION	PRICE

Fig. 10 Form issued by sales department giving price of parts ordered, their description and part number.

ROLL TAG

Date _____ Lot No. _____
Type _____ M. A. _____ Order No. _____
Sub. Asb. _____ Sched. Date _____
Amt. Cond. _____ Anode _____ Cathode _____
Length _____ Remarks _____

ROLLING

Date _____ Lot No. _____
Type _____ M. A. _____ Order No. _____
Sub. Asb. _____ Amt. Sched. _____
Sched. Date _____ Pcs. Rec. _____ Pcs. Rolled _____
Date _____ Staked _____ Pcs. Del. _____
No. Trays _____ Badge No. _____

LOAD

Date _____ Lot No. _____
Type _____ M. A. _____ Order No. _____
Sub. Asb. _____ Amt. Sched. _____
Sched. Date _____ Pcs. Rec. _____ Pcs. Del. _____
Badge No. _____ No. Trays _____

IMPREGNATE

Date _____
Pcs. Del. _____ Badge No. _____ No. Trays _____

AGEING

Date _____ Lot No. _____
Type _____ M. A. _____ Order No. _____
Sub. Asb. _____ Amt. Sched. _____
Sched. Date _____ Pcs. Rec. _____ No. Trays _____
Voltage _____ Racked _____ Removed _____
Pcs. Del. _____ No. Trays _____ Date _____

MECHANICAL ASSEMBLY

Sched. Date _____ Date Rec. _____ Lot No. _____
Type _____ M. A. _____ Order No. _____
Amt. Scheduled _____ Amt. Rec. _____
Rivet or Clean Tabs _____ Punch _____ Rivet _____
Weld or Wrap _____ Pour Tar _____ Tube _____
Pos. Ring or Pour Bi Wax _____ Spin Can _____
Amt. Del. _____ Del. Date _____

ELECTRICAL INSPECTION

Date _____ Lot No. _____
Type _____ M. A. _____ Order No. _____
Sub. Asb. _____ Amt. Sched. _____
Sched. Date _____ Pcs. Rec. _____ No. Trays _____
Hi-Res. _____ N. Aged _____ Open _____ Burn Up _____
High Cap. _____ Hi-P.F. _____ Hi-Leak _____ Low Cap. _____ %
Short _____ Wrong Cond. _____ Hook Up _____
Cold Test _____ Salt Test _____ Misc. _____
Total Rejects _____ Amt. Del. _____ Insp. _____

REPROCESS

Date _____ Lot No. _____
Type _____ M. A. _____ Order No. _____
Amt. _____ Sched. Date _____ Inspector _____

MECHANICAL INSPECTION

Date _____ Lot No. _____
Type _____ M. A. _____ Order No. _____
Sub. Asb. _____ Amt. Sched. _____
Sched. Date _____ Pcs. Rec. _____ No. Trays _____
Stamp _____ Solder _____ Leak _____ Def. Can _____
Def. Term. _____ Def. Spin _____ Def. Rivet _____
Burrs _____ Ex. Tabs _____ Mtg. Ring _____ Misc. _____
Total Rejects _____ Pcs. Del. _____ Date _____
Inspector _____

REPROCESS

Date _____ Lot No. _____
Type _____ M. A. _____ Order No. _____
Amt. _____ Sched. Date _____ Inspector _____

Fig. 11 Batch ticket issued by Material Control Group.

terial Control Group which assigns the sales order number and schedules the production week. A production schedule (fig. 17) is then filled out with the production date and order number.

A batch ticket (fig. 11) is made out by the Material Control Group and is held with the order sheet (fig. 9) and the price record (fig. 10) until production begins. During production the batch ticket accompanies parts in process, and as each operation is completed the proper stub is detached and returned to the Material Control Group for pasting to the production schedule.

A customer's order file jacket (fig. 12) is started by the Material

CUSTOMER'S ORDER FILE

CUSTOMER _____ MA _____ TYPE _____ VOLT. _____

CUST. ORDER _____ DATE _____ SHIP _____ MFR. _____

SALES ORDER _____ STAMPING _____

WORK ORDER _____ DATE _____

BILL OF MATERIALS			SCHEDULE		ROLLING		SHIPPING		DUE
PART NO.	PART NAME	QUANTITY	WEEK OF	QUANTITY	DATE	QUANTITY	DATE	QUANTITY	BAL. DUE

Fig. 12 Customer's file jacket in which all forms for a customer are filed by Material Control Group.

WORK ORDER Nº

_____ PART NO. _____

ROUTING _____ QUANTITY _____

DATE ISSUED _____ ORDER NO. _____

DESCRIPTION _____

MATERIAL REQUIRED _____ CODE NO. _____

_____ QUANTITY _____

_____ SHRINKAGE % _____

DATE REQUIRED _____ CUSTOMER _____

OPERATION NO.									OPERATION NO.									OPERATION NO.								
Date	Pieces Issued	Total	Date	Emp. No.	Pieces Fin.	Total	Scrap	Total	Date	Pieces Issued	Total	Date	Emp. No.	Pieces Fin.	Total	Scrap	Total	Date	Pieces Issued	Total	Date	Emp No.	Pieces Fin.	Total	Scrap	Total

Fig. 13 Work order form held in file jacket until production is started.

PLATE SCHEDULE LOT Nº 13570

Scheduled to be rolled wk. of _____ Shipped wk. of _____ Type _____

Customer _____ M.A. _____

W.O. _____ Amount this schedule _____

ANODE

Part No.	Code & Volts	Description	Tab

CATHODE LOT Nº 13570

W.O. _____ M.A. _____ Amt. _____ Sched. wk. _____ Type _____

Code	Description	Tab

PARTS SCHEDULE LOT Nº 13570

Customer _____ M.A. _____ Sched. wk. _____

W.O. _____ Amt. this schedule _____ Type _____

Part No.	Description	Amount

Fig. 14 Form for foil and part schedule.

MATERIAL CONTROL

DETAIL		REQUIREMENTS		AVAILABLE BALANCE		ON ORDER BALANCE	ACTUAL INVENTORY			
DATE	REFERENCE	QUANTITY	DATE WANTED	PLUS	MINUS		RECEIVED	ISSUED	TOTAL THIS MO. TO DATE	ON HAND BALANCE

Fig. 15 Parts control card.

PART NO. DESCRIPTION UNIT

SPECIFICATIONS

VEN	PURCHASE REQUISITION		
1		4	
2		5	
3		6	

STOCK	REQUISITIONED				ORDERED													
ON HAND	DATE	O.K.	DATE WANTED	QUANTITY	DATE PURCH.	VEN.	P.O. NUMBER	ROUTE TO	PRICE	PER	F.O.B	PRIOR	CONFIRMATION	DIS.	QUANTITY	O.K.	DATE REC'D	DATE PROM.

USAGE														
MONTHS	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL	USED FOR
19														
19														
19														

Fig. 16 Form for recording purchases of each part.

AC WK

LOT NOS.	CUST.	M.A.	W.O.	AMT.	PLATE	ROLL		AGE	ASB	TEST	INSP. REP.	KIND	REMARKS

Fig. 17 Production schedule issued by Material Control Group.

DEPARTMENTAL TRANSFER

FOR TRANSFERRING PARTS, MACHINERY AND OTHER EQUIPMENT FROM ONE DEPT. TO ANOTHER

PARTIAL TRANSFER		FROM DEPT. NO.	For Order No.
FINAL TRANSFER		TO DEPT. NO.	
NO. OF BOXES		ORDER No.	Date

NOTE: MARK "X" IN SQUARE ABOVE TO DENOTE PARTIAL OR FINAL TRANSFER
NOTE: WHEN TRANSFERRING MACHINERY OR EQUIPMENT PRODUCTION COPY TO BE DELIVERED TO ACCOUNTING DEPARTMENT.

QUANTITY	PART NO.	DESCRIPTION	VALUE

AUTHORIZED BY	DELIVERED BY	RECEIVED BY

Fig. 18 Departmental transfer slip issued by shipping clerk.

CLOSED ORDER REPORT

Date _____

Customer _____ Cust. Order No. _____

Sales Order No. _____ Amt. _____

M.A. _____ Type _____

Amt. Shipped _____ Short _____ Over _____

Remarks _____

White – Sales Copy
Pink – Open Order Dept.

Signed _____

Fig. 19 Closed order report issued by shipping clerk.

RAW MATERIAL REQUISITION
STORES - FACTORY - STORES

RAW MATERIAL REQUISITION
STORES - MATERIAL CONTROL

RAW MATERIAL REQUISITION
STORES - COST DEPARTMENT
(CHARGE)

STOREKEEPER:
PLEASE DELIVER THE FOLLOWING MATERIAL TO THE DEPARTMENT DESIGNATED HEREIN:

DATE	CODE NO.	DESCRIPTION	
WORK ORDER NO.	DRAWING NO.	PRODUCT CLASS	CREDIT RAW MATERIAL ACCOUNT
UNIT	QUANTITIES: ACTUAL	STANDARD	
STANDARD UNIT COST	EXTENSIONS: ACTUAL	STANDARD	
DATE	DEPARTMENT TO WHICH ISSUED	DELIVER TO	LOCATION
REQUISITION PREPARED BY	FILLED BY	DATE	

Fig. 20 Raw material requisition form issued by foreman.

MATERIAL REQUISITION

"CHARGE"

FINISHED GOODS	
GENERAL STORES	
PART STOCK	

DATE _____

KINDLY DELIVER THE FOLLOWING MATERIAL, PARTS OR FINISHED ARTICLES TO BEARER FOR _____ DEPT.

AND CHARGE TO ORDER NUMBER

NOTE: MARK "X" IN SQUARE ABOVE TO DENOTE WHICH STOCK ROOM MATERIALS OR PARTS ARE DRAWN FROM. THIS IS IMPORTANT

QUANTITY	Units	STOCK or PART NO.	DESCRIPTION	Unit Price	AMOUNT	
					Purchase	Mfd.

AUTHORIZED BY	FILLED BY	RECEIVED BY

Fig. 21 Material requisition "charge" issued by foreman.

EXCESS MATERIAL AND PARTS REQUISITION — **STORES - FACTORY - STORES**

EXCESS MATERIAL AND PARTS REQUISITION — **STORES - MATERIAL CONTROL**

EXCESS MATERIAL AND PARTS REQUISITION — **STORES - COST DEPARTMENT**

STOREKEEPER:

PLEASE DELIVER THE FOLLOWING MATERIAL OR PARTS TO THE DEPARTMENT DESIGNATED HEREIN:

DATE	CODE OR PART NO.	DESCRIPTION	
TO BE USED ON WORK ORDER NO.	DRAWING NO.	PRODUCT CLASS NO.	DEPARTMENT TO WHICH ISSUED
UNIT	QUANTITY	UNIT COST	EXTENSION

REASON

APPROVED BY

DATE

Fig. 22 Excess material and parts requisition issued by foreman.

Control Group. In this jacket are placed the work order (fig. 13) and the foil and part schedule (fig. 14). The work order is held in this file until the scheduled production week and is then sent to the inspection department. The foil and part schedule is used to start production. This schedule has four colored copies. The white copy goes to the parts section, the pink copy to the anode stock section, the yellow copy goes to the cathode stock section, the green copy is held in the customer's file jacket.

The parts control card (fig. 15) and the form for recording purchases of each part (fig. 16) are issued by the Material Control Group and maintained in files in this section. The parts control card gives a running inventory for each purchased part. Physical inventory is made once a year. The other form is a record of purchases made for each part and is used as an historical record of parts ordered.

The production schedule (fig. 17) is maintained by the Material Control Group and as production progresses the actual number of parts to leave each section is recorded. This information is obtained from the batch ticket (fig. 11) whose stubs are returned to the Material Control Group.

A departmental transfer slip (fig. 18) is issued when the finished product is ready to leave the production line and be sent to the shipping department. This slip has three colored copies. The white copy accompanies the material, one pink copy is sent to the Material Control Group, and the other pink copy is sent to the production superintendent.

The closed order report (fig. 19) is issued when the batch being shipped completes the order. It is filled out by the shipping clerk and sent to the necessary sections to notify them the order is completed. The white copy goes to the sales department. The pink copy goes to the Material Control Group and is placed in the customer's file jacket which is filed for future reference. At this time the work order (fig. 13) is sent from the inspection department to the Material Control Group where it is closed out. It is then sent to the central cost section for their record of the completed order.

When the stock of raw materials in a foreman's section becomes depleted, a raw material requisition (fig. 20) is issued. The yellow copy goes to the central cost department, and the white copy to the storeroom. The pink copy is also sent to the storeroom and accompanies the raw material back to the section that ordered it.

For purchased parts a material requisition (fig. 21) is used. The white copy goes to the central cost department and the yellow copy to the storeroom. The blue copy also goes to the storeroom and accompanies the purchased parts back to the section that ordered them.

When parts or materials have been scrapped during the production process, an excess material and parts requisition (fig. 22) is used to get the additional items needed to complete the order. The pink copy goes to the central cost department, and the yellow copy to the storeroom. The blue copy also goes to the storeroom and accompanies the materials back to the section that ordered them.

APPENDIX

Data for this report were collected by field agents of the Bureau who personally visited selected plants which cooperated voluntarily in supplying answers to the questions asked in the questionnaire. The questionnaire used is reproduced in abbreviated form -- all the questions and instructions are included but the space allowed for answers has been only indicated. In the actual questionnaire ample space is allowed for answering and field agents are instructed to use additional paper to make their answers as complete as possible, particularly for the narrative type questions.

It was not possible to get usable answers for all of the questions from each of the plants. However the major portion of the information requested was obtained.

UNITED STATES DEPARTMENT OF LABOR
Bureau of Labor Statistics
Washington 25, D. C.

CONFIDENTIAL

PRODUCTIVITY AND FACTORY PERFORMANCE

Electrical Equipment Manufacturing

Name of company_____ Address_____
Plant name_____ Address_____

Officials interviewed: Cross out word not applicable:
(Co.)(Plant)_____ Title_____
(Co.)(Plant)_____ Title_____
(Co.)(Plant)_____ Title_____

A. SPECIFICATIONS

List specifications of reported product:_____

B. PRODUCTION: MAN-HOURS

1. Man-hours per reported item:

   a. Select an average full production period on the reported item: Dates, from_____ to_____
   b. Total number of reported items produced during this period_____
   c. Total actual factory man-hours on reported item during this period_____
   d. Total actual direct man-hours on reported item during this period_____
   e. Total actual indirect man-hours on reported item during this period_____
   f. List the labor classifications included in the direct and indirect man-hour figures given in (d) and (e) above:_____
   g. Describe exactly the procedure used to derive direct and indirect man-hours in (d) and (e) above:_____

C. PRODUCTION SCHEDULING AND INSPECTION

1. Production run per reported item:

   a. Average continuous run of reported item, number of items_____
   b. Smallest number in one continuous run_____
   c. Largest number in one continuous run_____
   d. Production method, line_____, job lot_____, other (describe)_____
   e. Average actual production during reported period: Number day shift_____, total number per 24 hours if more than one shift_____, number of shifts_____.

2. Scheduling

a. Describe fully the methods used in production scheduling and control for the reported or similar item, paying particular attention to factors such as planning for change-over to this model, organization of flow of materials or components, relative to product design, etc.

_____

b. Custom production:
(1) Is a variation of the reported item made to purchasers' specification? Yes_____ No_____.
(2) If output of this model was included in B (1) b, give the number of such units produced_____.
(3) What is the smallest order (in units) acceptable: For standard models of the reported item_____; for variations of standard models_____; for special or custom made models_____.

c. Describe the changes made in normal production arrangements upon the introduction of a run of a variation of a standard model, or of a special or custom made model, in terms of actual examples_____

3. Design and methods improvement

a. Does this plant have a design department? (Check) Yes____ No____.
If "no," does it contract for the services usually performed by such a department? (Check) Yes____ No____.
Describe department or services:_____

b. How many are employed in design department?_____

c. Does this plant maintain an engineering (methods analysis, etc.) department to improve plant layout, manufacturing methods, etc., or make provisions for such activity? Yes____ No____ Describe_____

d. How many are employed in this engineering department?_____

e. Describe management's view of the effectiveness of this department in reducing man-hour requirements for the reported model or related models_____

f. How frequently and on what scale are operations analyzed to evaluate standard time, etc?_____

4. Standardization and Simplification

a. During the year prior to the reporting period, how many changes were made in the design of the reported item in the interest of standardization (interchangeability)?_____

b. Describe fully a typical example of such change_____

c. During the year prior to the reporting period, how many changes were made in the design of the reported item in the interest of simplification of operations?_____

d. Describe fully a typical example of such change:_____

5. Inspection

a. Are any statistical quality control methods used in any of the manufacturing operations? Yes___No___. If yes, describe_____

b. Other systems used: (Describe)_____

6. Jigs and Fixtures

Describe the extent to which jigs and fixtures are used in key operations, furnishing descriptions (and drawings) of several examples, if possible.

_____

D. GENERAL PLANT INFORMATION

1. List major categories all items produced within the plant and their total value of shipment during 1950:_____

2. Employment:

a. Number employed in plant during reported period:

Total - all plant employees _____

Total - production and related employees _____

Total - direct production employees _____

Total - indirect production employees _____

Non-production employees _____

b. Average length of workweek (excluding overtime) during reported period_____hours.

3. Plant employment by department, occupations, sex, and payment method during reported period.

DEPARTMENT	List key occupations	Number of workers		Method of payment (Check)	
		Total	Female	Pc. Rate	Hourly
All Departments	XXXXXXXXX			XXXXXXX	XXXXXX
1.					

4. Training programs:

a. Describe training program for production workers (1) on in-plant basis; (2) using outside resources (schools, etc.)_____

b. Describe training program for supervisors_____

5. Plant buildings:

Name and Use	Sq. Ft. by Floor			Age	Type of Construction and Special Features
	1	2	3		

a. Were buildings designed originally for modern production techniques? Yes___ No___.
b. Were buildings modified for use of modern production techniques? Yes___ No___. If yes, describe:_____

6. Secure the following, if available:

a. Sales literature, catalogs, etc.
b. Pictures of products reported.
c. Floor plans and work flow charts of plant if readily available.
d. Forms used in scheduling work, controlling inventory, etc.

The data submitted on this schedule will be seen only by sworn employees of the Bureau of Labor Statistics. The data will not be released in any form which permits identification with any specific company, without your written permission.
Survey submitted by_____

E. ANALYSIS OF PARTS AND ASSEMBLY OPERATIONS

1. List of parts, materials and components for reported product

Part Name	Manufactured (Check) In Plant	Purchased 1/	Used in Operation Sequence No. 2/

1/ Check as purchased, items made in other plants of same company.
2/ Enter operation sequence No. of sheet in which the part, material or component is used in E. 2.

2. Analysis of manufacturing process

On the attached sheets, indicate operations performed in order of their actual sequence in the plant. Indicate man-hours per operation in every case: Actual man-hours wherever possible, and standard or estimated hours otherwise. Attach time standards if available. In the space below describe the method of deriving these actual man-hours and the time standards and the time period to which they relate.

Name of Plant_____
Operation Sequence Number_____
Part or Product Produced_____

Parts, Materials and Components Used 1/_____

1/ If subassembly of previous operation is used, identify by operation number.

Operation Performed (Nature of Work Done in Each Step)	Machinery Used 2/		Material's Moving Device and Destination	Man-Hours 4/ Per Operation or Part
	Name, Make, Model, Type Drive 3/	Capacity Per Unit Time		

2/ If possible, secure blueprint or drawings of specially designed machines, special jigs, and fixtures and attach to operational sheet.

3/ Note "L" if line drive, "U" if unit drive, "G" if group drive.

4/ Actual man-hours preferably, standard time otherwise.

GLOSSARY

Anode	:	The positive terminal of an electric source; the electrode by which the current enters an electrolyte on its way to the other pole. An etched aluminum foil often serves this function in dry electrolytic capacitors.
Anodizing, or preforming	:	A process by which a hard, noncorroding oxide film is deposited on aluminum or light alloys. In one method aluminum foil is made the anode in an electrolytic cell containing chromic or sulphuric acid.
Can bead	:	The point at which the negative or ground tab extends through the cover of an aluminum can prong-type capacitor.
Capacitance	:	The property of a body by virtue of which a quantity of electricity has to be imported to it to raise its potential above that of the surroundings. The capacitance between two bodies is the ratio of the charge to the potential between them. It is usually measured in microfarads. Also defined as the ratio of charge to voltage expressed in microfarads.
Capacitor	:	A piece of electrical apparatus consisting of two conducting plates separated by a layer of insulating material. This causes an appreciable capacitance, each electrode carrying a charge of electricity. In this report, the word "capacitor" is used to mean a completely assembled condenser section, terminals, aluminum can, and housing or fixtures.
Cathode	:	The negative pole or electrode of certain types of electrical equipment such as an electrolytic cell, capacitor, or vacuum tube. Opposed to anode (see above).
Clinching	:	Fastening securely, especially by turning over the point or edge of one part.
Condenser section	:	As used in this report, condenser section refers to that part of a capacitor consisting of the wound cathode foil, separating paper, and prepared anode foil with the tabs.

Conductance	:	The property of a material by virtue of which it allows an electric current to flow through it when a potential difference is applied. It is the reciprocal of resistance.
Crimping	:	The compressing of a metal ring or cap so as to reduce its diameter. Such corrugations are used to hold parts inside the ring or cap.
Dial feed	:	A device which feeds a machine, such as a press, by means of a disc with clamps or cavities holding the unit being worked upon so that an operator can rotate it into position.
Dielectric	:	A substance capable of supporting an electric stress. A material which resists the passage of an electric current.
Dielectric constant	:	The ratio of the capacitance of a condenser section (with the dielectric between the electrodes) to the capacitance when air is between the electrodes.
Dielectric strength	:	The strength required to puncture the dielectric expressed in volts per centimeter or millimeter.
Direct labor	:	All factory labor involved in actual production of the reported product. Direct man-hours are worked by employees engaged in fabricating, processing, and assembling the reported product. Some plants include operations such as packing, inspecting, or testing as direct labor.
Dry electrolytic capacitor	:	A capacitor in which the electrolyte between the plates is nonaqueous or of low-water content. It is dependent for capacity on a film of aluminum oxide on the surface of the anode foil.
Electrolyte	:	An electrolytic conductor, especially a liquid. A substance which on dissolution in a suitable solvent conducts electrolytically.
Electrolytic capacitor	:	A capacitor in which the dielectric between the plates utilizes an electrolyte instead of the more usual solid insulating material. There are wet and dry electrolytic capacitors.
Etching	:	The process of increasing the surface area of the aluminum foil by acid baths or by an electrochemical process.

Factory labor	:	The sum of direct and indirect productive labor excluding such costs as general administration, office clerical, engineering, research, and sales.
Formation and aging	:	Formation is actually the combination of two operations: preforming and aging. However, forming and aging are often referred to synonomously. After the foil is etched, it is anodized or preformed where a layer of aluminum oxide is built up on the foil. After impregnation the condenser section is aged or formed. This is done by applying a voltage to the condenser section under heat. The purpose is to continue the preforming and repair any cracks that may have developed in the aluminum oxide film.
Indirect labor	:	All labor in general factory and departmental overhead cost chargeable to the output of the reported product. Indirect man-hours are worked by employees engaged in testing, inspecting, material handling, receiving, shipping, storage, plant security, maintenance, repair, janitorial services, record-keeping, supervision, production engineering, and other services closely associated with production operations.
Leakage current	:	Current flowing from one pole of an electric system to earth or to another pole through the insulation. Usually confined to currents of small value.
Man-hour requirements	:	The time needed to produce a specified product or operation measured in the number of hours of labor (see unit man-hours).
Standard time	:	The expected time, as established by a time study (any detailed analysis of work time), required by an average worker to perform a specified operation or group of operations without undue fatigue or hardship.
Stitching	:	A means of attaching an aluminum tab to another piece of foil by a punch and die which extrudes a metal point. The operation is similar to a needle piercing a piece of paper.

Tab	:	An aluminum connector attached to the foil and the terminals. It is made by folding and cutting aluminum foil.
Unit man-hours	:	The man-hours required to produce a single unit of a specified product.