AUTOMATION and MANAGEMENT

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Table of Contents

PART I. THE NATURE OF AUTOMATIC MANUFACTURING

PART II. EXPERIENCES WITH AUTOMATION

PART III. CRITICAL AREAS OF AUTOMATION

APPENDICES

List of Exhibits

CHAPTER 3

Evolution of Automation: Electric Lamps vs. Shoes

STUDY of these two high-volume industries emphasizes that mechanization of the production system is a matter of evolution. It will be seen that automaticity then grows out of the spread and refinement of constraint, as theorized in the last chapter. However, for the manufacturing executive, the significant question is: Why does progress in automation vary so greatly between industries?

Perhaps the comparison of manufacturing techniques in these two industries will aid understanding and suggest useful criteria for successful automation. On the surface, the volume appears adequate to justify automation for both electric lamps and shoes and both have had at least half a century of machine refinement. Yet the older industry dealing basically with one apparently simple material is the least mechanized; and the more precise and complex product is manufactured in a highly automatic way. Why? What are some of the factors that facilitate or inhibit the growth of automatic manufacturing?

ELECTRIC LAMP MANUFACTURING

The lamp industry is an especially interesting example of mechanization development because the electric lamp presents a complex manufacturing problem. Widely different kinds of materials—metals, glass, gas—are involved; a number of the components are extremely fragile; several of them must be made to a high degree of precision; the product requires delicate assembly work; the testing of every unit for functional performance is essential; and the fragility of the product requires packaging at the moment the testing is completed. Thus, lamp making employs many manufacturing arts and, as a problem in automation, it is unusually involved.

To encourage demand for electric current the mass production of lamps at low cost has been an objective of the lamp industry for many years. Today, several thousand types of lamps are manufactured on a commercial basis. About 80% of this demand is concentrated in fewer than 100 types of lamps. (This statistic is exclusive of the vacuum tube industry which creates a product looking somewhat like the lamp, but far different.) To illustrate the progress of automation in the lamp industry, the 60-watt incandescent lamp was chosen. It is a typical size and can be isolated as a product of many years' design and manufacturing study.

Phase 1, Prior to 1920

A typical layout of a Westinghouse Electric Corporation manufacturing unit of this period is shown in Exhibit 3-1.[1] It is a functional arrangement (departmental setup) with a stem department, an inserting department, an exhaust department, and a testing department, as shown. Some machinery was used, and in most cases an individual operator manned a single machine. Exhausting, however, was mechanized to the point where one operator manned a series of exhausting stations. There was a great deal of hand work in the assembly of the lamps.

The manufacturing areas in the earliest days were not laid out in sequence as shown in this illustration. Far more often each department was located in any convenient space without particular regard to being

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[1] W. B. Gero, *A Brief Summary of Automation in the Lamp Division* (Westinghouse Electric Corporation, April 1, 1955). The illustrations and manufacturing technique information in this chapter are drawn from this report, which Mr. Donald Burnham, Vice President of Manufacturing, kindly had prepared to answer questions I raised. The balance of the data was supplied by the Lamp Division of Westinghouse. The interpretation, however, is solely my responsibility, as is Exhibit 3-8 and some of the elaborations in Exhibits 3-6 and 3-7.

adjacent to the next operation in the production sequence. As each operator finished a batch of parts, he put them into a container which was hand carried or trucked to the next department. In general, this departmental layout was standard production technique prior to 1920. In some cases, it was carried on long after that, particularly for other than the common sizes of lamps. As of the period covered by Exhibit 3-1, the standard operations (excluding the preparation of the parts) were:

1. Stem making.	Combining of lead wires with glass, fiber, and arbor.
2. Inserting of stems.	Inserting wire with hook on one end in button or arbor.
3. Mounting.	Mounting filament on supports and connecting with leads.
4. Tubulating.	Combining exhaust tube to top of bulb.
5. Sealing.	Combining tubulated bulb with mounted stem.
6. Exhaust.	Exhausting air from bulb through exhaust tube and sealing tube.
7. Flashing.	Initial lighting of lamp on predetermined schedule.
8. Basing and soldering.	Affixing base to end of lamp and soldering connections.
9. Monogramming.	Labeling of lamp.
10. Test.	Final inspection.
11. Packing.	Wrapping individual lamp, placing in outer container.

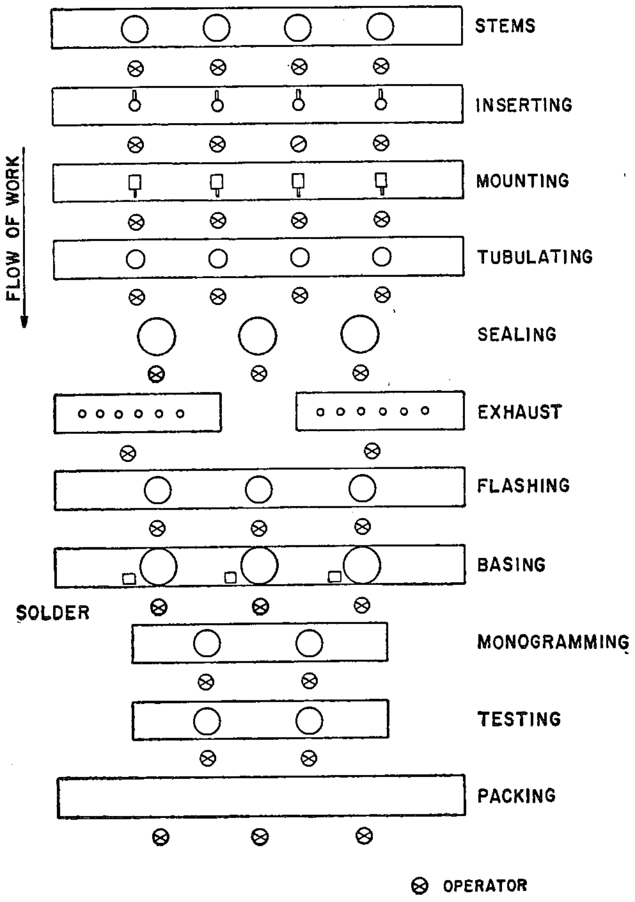
Approximately ten operators produced about 200 lamps per hour. There were two drawbacks to this production system: (a) large stocks of materials always were in process; (b) material-in-process was exposed to the atmosphere for a considerable time. Exposure had a deteriorating effect upon some of the components and thus affected quality.

Phase 2, 1920–1925

About 1920–1925 the manufacturing art advanced through the system illustrated in Exhibit 3-2. This layout reflects the first successful grouping of equipment. In effect, it was a production line—a collection of machinery so arranged spatially and balanced in capacities that the product moved from one operation to the next with little waiting time, and the production rate of each machine grouping was roughly equivalent to that of its neighbors. This layout reduced the amount of material handling. It reflected a significant advance in the level of mechanization of some individual operations. In addition, more of the production operations were mechanized.

Possibly the important innovation from the point of view of manufacturing evolution was the pacing of operations by indexing machines.

Exhibit 3-1. Electric Lamp Manufacturing by Functional Layout, Westinghouse Electric Corporation, 1920–1925



Departmental type layout was used prior to 1920. The only significant mechanization was the use of the multistation exhausting machines. They were simply batteries of exhausting stations manned by one operator.

"Indexing" means that materials are fed into the machine which then moves them from station to station (indexes), pausing momentarily so that successive production steps can be completed. A uniformity of flow—automatic, nonvarying timing—results. Indexing machines have the effect of contributing or forcing uniformity of pace to production operations on each side of themselves, in order to receive or provide parts at the indexing machines' rates.

Another advantage of indexing machinery is reduction of work-in-process. The work does not sit on the worker's bench after he has finished an operation and until he completes the batch. In effect, there is only one piece in process at each work station (and sometimes a few more pieces in the handling system between stations). This saving in work-in-process further contributes to a gain in quality in lamp manufacturing, since the time in process is much shorter and less deterioration of parts is encountered.

A major innovation in this manufacturing system of 1920–1925 was the rotating exhausting machine. The machine was connected to the exhausting system through a rotating valve, thus enabling continuous movement through the exhausting process. No pauses were required to engage and disengage the exhaust line to each bulb, which was, in effect, done automatically. Nor was there any waiting until the operator got around to disconnecting an exhausted bulb. The rotating table carried the lamps through the process and to the common unloading point at an unvarying pace.

The number of manufacturing operations was reduced from eleven to eight. The compounding of operations—that is, the performance of two or more operations at a single machine station—began to appear and is evident in the following list of operations required:

1. Stem making, incorporating exhaust tube.
2. Machine inserting and hook forming (one support at a time.)
3. Hand mounting of filament.
4. Sealing and monogramming.
5. Exhaust.
6. Basing and soldering.
7. Flashing.
8. Packing.

These refinements were not due to improvement of machinery or mechanization of former hand jobs alone. A significant product design change was evident in this stage. The exhaust tube was incorporated in the stem of the lamp bulb, rather than in its apex. This had great advantages in simplifying the original sequence of production operations since (a) it eliminated one assembly job—No. 4, Tubulating—and (b) it simplified No. 6, Exhaust.

The indexing rate controlled the speed of production. It was such that the line produced approximately 300 lamps per hour using a crew of five operators.

Phase 3, 1925–1936

During the period 1925–1936 the lamp production line took the form schematically suggested in Exhibit 3-3. Spreading of mechanization along the production sequence is evident. A considerable amount of labor was eliminated by mechanizing material movement between machines. Automatic transfer arms, automatic loading for the exhaust machine, and similar work-feeding devices were part of the system.

Several other basic forms of mechanical evolution marked this major step: most important was the combining of sealing and exhausting into one machine. Compounding of several machines on one machine base produced important effects: Though the "Sealex" machine was larger than either of the machines that it replaced, it required less total space. There was also a simplification of power supply, a reduction in space for servicing, space for operators and, of course, the elimination of manual handling between the machines. These factors further reduced the work in process.

A technical process change at this stage forced the addition of another "production process"—cooling. Because heat was applied to the bulb to facilitate exhausting, it became necessary to add a cooling conveyor. Thus, functional operation and movement were combined as the lamps cooled on their way to the basing machine.

Other significant steps were: The flashing test was integrated into the basing machine. Fluxing and soldering were each made automatic. They were placed adjacent to the basing machine and were so closely integrated with it that they could almost be considered as part of it. The same was true of the exhaust tube operation and the flaring—both were made automatic and both were intimately linked with the stem-making machine.

This system produced approximately 700 lamps per hour. Seven persons were required to operate it, the two additional persons being needed for mounting.

Phase 4, 1936–1955

Lamp manufacturing from 1936 through 1955 is approximately described by the layout of Exhibit 3-4. Glass flares, exhaust tubing, lead wires, and coils were automatically formed and delivered to the stem-making machine. The stem machine automatically assembled them and delivered the stems by conveyor to the next operation. The operator for this machine was a combined inspector, material supplier, and, partially, a relief operator for the other positions. The mounting operation was made automatic. The mechanization of this assembly job eliminated three operators.

The compounding of functions in a single machine unit continued. The preparation of stem components, the assembling of these components, and their mounting were combined in one machine.

This machine system produced 1,350 lamps per hour. A crew of four operators was required.

Westinghouse engineers have advised that it is entirely possible to perform, nonmanually, all the remaining operations of loading the sealing-exhaust machine, basing, testing, and packing. However, they say:

> . . . present design of machine does not lend itself readily to much higher speeds, which would have to be attained in order to justify the cost of conversion. With the progress already made there is a good possibility for more complete automation. Radical changes and improvements in equipment are envisioned by equipment designers for the not-too-distant future.[2]

Parallel with 50 years of refinement of the production machinery and the mechanization of all the production operations, there were equally important, although perhaps less spectacular, design changes and

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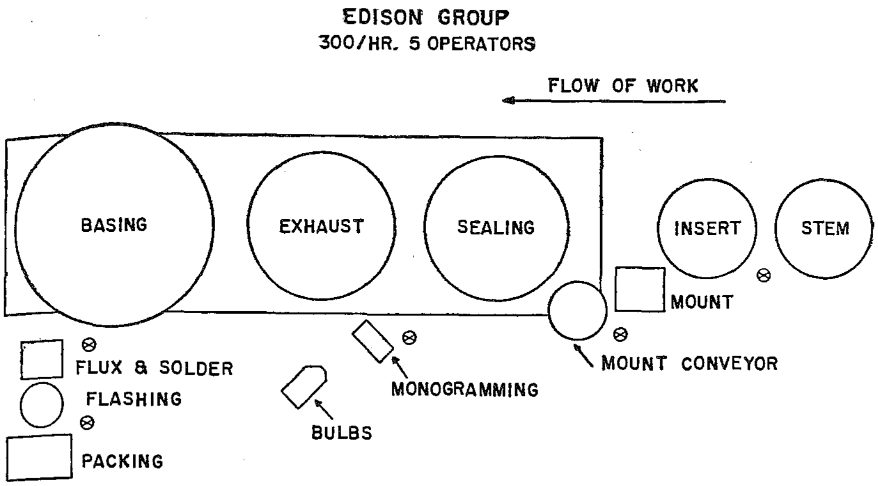
[2] W. B. Gero, *A Brief Summary of Automation in the Lamp Division.*

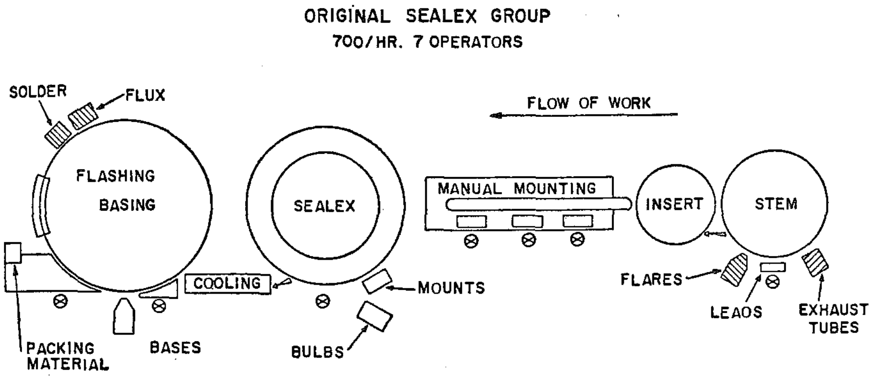
Exhibit 3-2. Evolution of Lamp Production Line, Westinghouse Electric Corporation, 1920–1925



"Edison Group" production line arrangement and the introduction of automaticity through rotary indexing machines is evident in the 1920–1925 period. Integration between mechanized areas and elements is limited.

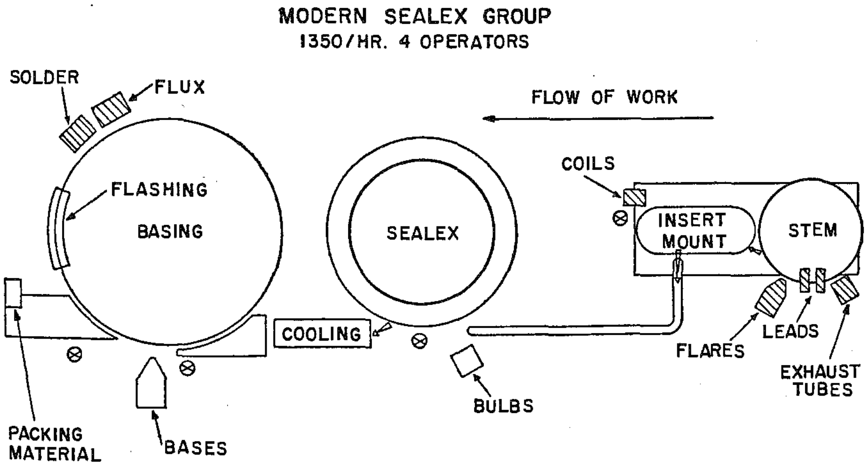
Note: Each circle represents a rotating machine that indexes to successive stations for performance of the required sequence of production actions. The effect is to create a continuous flow of parts for the next machine.

Exhibit 3-3. Beginnings of Integration and Continuous Flow in Lamp Production, Westinghouse Electric Corporation, 1925–1936



Original "Sealex Group" of 1925–1936 shows combinations of machines, automatic production and automatic handling, and feeding of parts. The combining of operations on one machine base, particularly sealing and exhausting, was especially important.

Exhibit 3-4. Spread of Automaticity in Lamp Manufacturing, Westinghouse Electric Corporation, 1936–1955

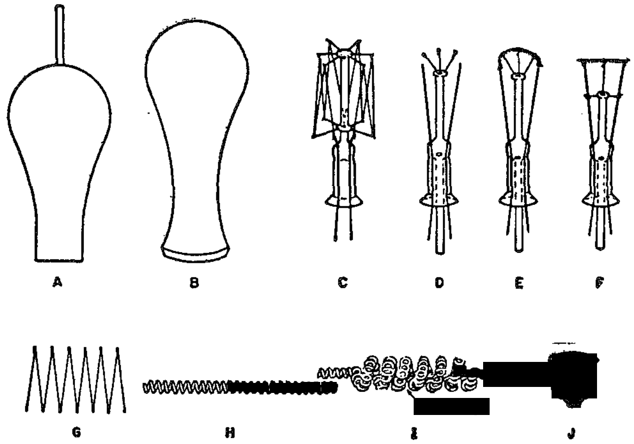


System in use in 1954 shows the spread of automaticity to parts manufacturing, subassembly, and material handling. More combinations of operations on one machine base are evident. The growth of automatic assembly is especially significant.

KEY TO EXHIBITS

⊗ OPERATOR
▨ AUTOMATIC
⟸ AUTOMATIC HANDLING

Exhibit 3-5. Component Design Changes that Facilitated Automatic Forming and Assembly in Lamp Manufacturing, Westinghouse Electric Corporation, 1908–1955



The exhaust tube on the bulb at A was incorporated in the stem (as seen in D), thus simplifying bulb production through design B. Sketches C, D, E, and F show stages in mount and filament design that facilitated mechanization of forming and assembly operations. Similar improvements in filaments, G, H, and I, aided mechanization. The current base, J, is adaptable to mechanized forming and assembly.

developments that were essential to facilitate automatic production. Some of these are not pictured or charted since they include such things as changes in the gas content, in the hardness of metals, in the crystalline structure of metals, or in electrical and other characteristics of the materials. For example, the concentration of wire into coils that could more easily be mounted or assembled mechanically was not possible without the development of wire that would resist sagging under the high temperatures that occurred when the lamp was lighted. Thus, the development of nonsag crystalline structure of tungsten was fully as important a step toward automation as was the machine for doing the job. This same improvement greatly increased the light output of the lamps.

Some of these changes in component parts, which contributed to progress in mechanization, were as follows:

The early machine-blown bulbs are illustrated in Exhibit 3-5A. The light bulb neck and collet were not well adapted for high-speed sealing. Furthermore the light bulb had to be sealed both at the base and at the exhaust tube. The key design change (Exhibit 3-5B) was to machine-blow the bulb from a ribbon of glass, and to use a heavy neck and collet that were easily adapted to high-speed sealing. The exhaust tube was incorporated in the stem rather than in the bulb. Therefore, only one sealing job needed to be done after the bulb had been exhausted.

Refinements in the design of the stem also are shown in Exhibit 3-5. The early conventional stem had hooks over which the straight wire was draped by hand, Exhibit 3-5C. Anyone who has closely examined one of these light bulbs will appreciate the delicacy required to perform this difficult job manually.

The second step was to develop a conventional stem to mount a coiled filament, Exhibit 3-5D. Clearly, fewer manipulations were required to mount the filament, and it would appear that the structure was stronger as well as simpler. Hooked leads with pigtail supports were provided for manual mounting. Notice the exhaust tube in place in the stem.

The automatically mounted stem for the coiled filament is shown in Exhibit 3-5E. Here the leads were straight rather than hooked. To make the stem assembly, the filament, the glass flare, the leads, the exhaust tube, and the support wires were automatically fed into the stem machine and automatically assembled. The stem itself was automatically mounted.

The final development is shown in Exhibit 3-5F. This stem, too, was automatically assembled and mounted, but it was designed for the coiled coil filament. It can be seen in the sketch that support requirements were reduced, which simplified the design of the stem.

Meanwhile, the coil itself underwent redesign. This light-producing filament is a very delicate piece of tungsten wire. In Exhibit 3-5G we see the preformed wire that had to be draped over the supports of Exhibit 3-5C. To drape such fine wire on flimsy supports by mechanical means was extremely difficult and was a manual operation. This filament, incidentally, had to operate in a vacuum, so creation of a suitable vacuum was essential.

To shorten the long filament and therefore simplify the draping operation, the filament was coiled, Exhibit 3-5H. Since it was now of shorter length and was fairly rigid, it was adapted to automatic mounting. This made possible the stem construction in Exhibit 3-5E. Further evolution of mechanization occurred even within this single part. Originally, the supports for this coil were secured around the filament by hand manipulation. Eventually this job was mechanized so that fixing the coil on the stem could be made completely automatic. This type of coil was used in gas-filled lamps.

To shorten the coil further and concentrate more light-producing element within the light bulb, the recoiled filament was created. Its appearance is shown in Exhibit 3-5I. Because of its comparative rigidity it was well adapted to automatic mounting. It is the standard in the 1955 electric lamps.

The type of base used in 1955 for automatic operations is shown in Exhibit 3-5J. It, too, is adapted to prefilling, conveying through slide feeds, threading over lead wires, and soldering operations. All these operations have been mechanized except for the threading of the lead wire. This job is well on the road

EXHIBIT 3-6. SIGNIFICANT CHANGES IN PRODUCTION METHODS AFFECTING THE MECHANIZATION OF LAMP MANUFACTURING, WESTINGHOUSE ELECTRIC CORPORATION, 1908–1955

Operations	*Phase 1 (Exhibit 3-1)* *Prior to 1920*	*Phase 2 (Exhibit 3-2)* *1920–25*	*Phase 3 (Exhibit 3-3)* *1925–36*	*Phase 4 (Exhibit 3-4)* *1936–55*
Stem production	Simple machines manually controlled.	Machine with 6 to 11 heads or "work stations." Predetermined fire setting.	24-head stem machine equipped for straight-through exhaust tubing. One portion serving as an exhaust tube and one portion as an arbor. All glass parts fed automatically.	Same as Phase 3.
Inserting	Hand inserting with single gas flame and tweezers from supports previously cut to length and hooked on one end.	Revolving head holding stem. Button headed by preset fires. Single inserting gun carried wire forward inserting it in hot glass. Cut wire to length and formed hook.	All wires inserted at one time and cut to length, and loop turned on end to receive coil.	Same except loop end of supports are automatically turned around coil.
Mounting	Hand mounting with aid of a manually operated clamper.	Same as Phase 1.	Same as Phase 1.	Automatic.
Sealing	Simple rotating heads fire controlled manually.	8-head machine with preset fires.	36-head sealing, preset fires, automatic transfer of bulbs from loading turret to sealing. Also automatic transfer of sealed lamp to exhaust (part of same machine) and from sealing exhaust machine to basing machine.	Same as Phase 3.
Exhaust	Several stationary positions in a row each accommodating one lamp. Equipped with oven to heat. Rotary oil vacuum pumps. Lamp loaded manually, exhausted by pumps and removed manually.	Rotary machines, few heads.	36-head machine combined with sealing on same chassis.	Same as Phase 3.
Tipping (sealing exhaust tube after exhaust)	With hand torch.	Same as Phase 1.	Automatic on exhaust machine.	Same as Phase 3.
Cooling	None	None	Vertical bucket conveyor between exhaust and basing.	Same as Phase 3.
Basing	Cavities to accommodate base, which was affixed to lamp with cement. Heated with simple burners to set cement. Hand soldering.	Rotary machine with few heads and predetermined fire setting. Hand soldering.	48-head basing reel to which lamp was automatically transferred from exhaust machines. Automatic fluxing and soldering. Lamps flashed automatically also.	Same as Phase 3.
Flashing	A rotary machine lighted lamp on a predetermined schedule.	Same as Phase 1.	Automatic on basing machine.	Same as Phase 3.
Monogramming	On simple equipment, manually operated.	Plunger type by sealing operator.	Automatic on basing machine.	Same as Phase 3.
Testing	Racks manually operated.	Combined with packing.	Same as Phase 2.	Same as Phase 2.
Packing	Manually packed.	Combined with testing.	Same as Phase 2.	Same as Phase 2.

Exhibit 3-7. Material and Design Changes Affecting the Mechanization of Lamp Manufacturing, Westinghouse Electric Corporation, 1908–1955

Component	*Phase 1 (Exhibit 3-1)* *Prior to 1920*	*Phase 2 (Exhibit 3-2)* *1920–25*	*Phase 3 (Exhibit 3-3)* *1925–36*	*Phase 4 (Exhibit 3-4)* *1936–55*
Filaments	(a) Thorium oxide added to metal to increase resistance to shock. (b) Wire straightened and semimarked to indicate length of filament to be mounted. (c) "Gettered" (chemical agents put on filament by a special process to assist in exhaust).	(a) Nonsag wire developed. (Wire would resist sagging when operated at high temperatures thus reducing need for supports.) (b) Wire concentrated by winding into coils, nonsag structure prevents coil distortion. (c) Getter added on stem machine.	(a) Same as Phase 2. (b) Same as Phase 2 (c) Same as Phase 2.	(a) Same as Phases 2 and 3. (b) Wire further concentrated by recoiling coil on mandrel on a second mandrel. (c) Same as Phases 2 and 3.
Support wire	(a) Tungsten wire similar to filament wire. (b) Wire straightened. Wire then fed into a machine which formed a hook on one end and cut to length desired.	(a) Same or molybdenum wire. (b) Wire straightened, supplied on spools to inserting machine which was arranged to supply wire by groups of supports.	(a) Molybdenum wire. (b) Same as Phase 2.	(a) Same as Phases 2 and 3. (b) Same as Phases 2 and 3.
Lead wire	(a) First a three-piece element of copper outside lamp, platinum through glass, nickel inside lamp. (b) Replaced with same except for dumet through glass (nickel steel core, copper sheath).	Same as (b).	Same as (b).	Same as (b) except inner leads of nickel plated copper for coiled coil and one outer lead to act as a fuse (copper plated iron).
Glass flare	Rotating machine utilized drawn tubing flared and cut to length.	Same—larger, better machine.	Same as Phase 2.	Same as Phases 2 and 3.
Glass arbor	Solid cane glass was cut to length by hand.	Cane glass eliminated. Straight through-the-press exhaust tube. Both cut to length by hand.*	Same, except cut to length by machine.	Same as Phase 3.
Glass exhaust	Short tube cut to length by hand and connected to top of bulb.	Short tube cut to length by hand attached to a stem and connected to inside bulb.	Same as above (arbor).	Same as above (arbor).
Glass bulb	Hand blown. Later rotary machine blown.	Same as Phase 1.	Ribbon machine blown with heavy cullet to facilitate sealing at high speeds. This bulb had more uniform glass distribution which was also favorable for higher speeds.	Same as Phase 3.
Base	Brass medium screw base.	Same as Phase 1.	Same as Phase 1.	Aluminum medium screw base.
Packing	Wrap around tucked ends.	Same as Phase 1.	Open end sleeve.	Same as Phase 3.

* "Cane glass" was a solid glass rod that supported filament assembly in lamp. Bulb was exhausted at the top, thus forming the tip common to bulbs of that period. In the changes described the solid glass rod was eliminated and replaced with a glass tube. This not only supported the filament but was used to exhaust the bulb. It was sealed off at the base end after the bulb had been exhausted.

Exhibit 3-8. Evolution and Productivity of Lamp Manufacturing Technique, Westinghouse Electric Corporation, 1908–1955

Item	*Phase 1 (Exhibit 3-1)* 1908–20	*Phase 2 (Exhibit 3-2)* 1920–25	*Phase 3 (Exhibit 3-3)* 1925–36	*Phase 4 (Exhibit 3-4)* 1936–55
Type of layout and manufacturing system.	Departmental.	Semiproduction line sequence.	Production line.	Semicontinuous production line.
Significant mechanization of operations.	Very little, largely hand tools.	Rotary indexing machines producing steady flow of parts on major operations.	(a) Automatic manufacture of flares and exhaust tubes. (b) Automatic soldering and fluxing. (c) Automatic material handling: stem to insert; sealex to cooling; cooling to basing. (d) Combination of sealing and exhaust; flashing and basing.	(a) Automatic production of leads; coils. (b) Automatic work feeding of exhaust tubes, leads, flares, coils. (c) Automatic mount assembly. (d) Automatic handling; mount to sealex, sealex to cooling.
Number of operators	10	5	7	4
Production/hr/group	200	300	700	1,350
Lamps/operator/day	160	480	800	2,700

toward mechanization, and then the entire basing operation will be automatic.

Thus, the entire mount and its component parts have evolved into a form of manufacturing and assembly that is highly automatic, as a result of progress in a number of areas.

Correlation of these principal changes in materials, processes, and machines that contributed to automation, is shown in Exhibits 3-6, 3-7, and 3-8. These exhibits include some detail not shown on the layouts. They further confirm that automatic manufacture of a complex, multipart product is not a matter of machinery alone. It requires parallel progress in materials and in product design.

In studying this and other automation systems it is evident that certain basic trends are inextricably woven into progress toward automaticity:

1. Mechanization of manually performed operations;
2. Arrangement of machinery into a production operation sequence in which all operations are done at approximately the same rate so that continuous flow can be achieved;
3. Combining of several functions into a single machine base (i.e., a compound machine);
4. Integration of all machines with automatic work feeding, work removal, and material handling devices (between machines) so as to create a work movement system that is nonmanual;
5. Changes in the product design to permit mechanical manipulation, assembly, and other forms of nonmanual working in production operations;
6. Changes in material to permit either the use of a production technique that is more easily made automatic or a design form that is more easily mechanized.

A review of this accomplishment throws facts into contrast against general impressions and common statements about automation:

Lamp manufacturing has been undergoing constant mechanization for almost half a century. Although it is one of the most automatic multipart product manufacturing technologies in existence,[3] it still is not "fully automatic." Automaticity varies in degree and character through the line.

Automaticity has not been a matter of machinery alone. It often has been delayed until material improvements and design changes have been created to make a new step in mechanization possible.

The operators are *not* required to be superskilled. On the contrary, their duties are lighter and are essen-

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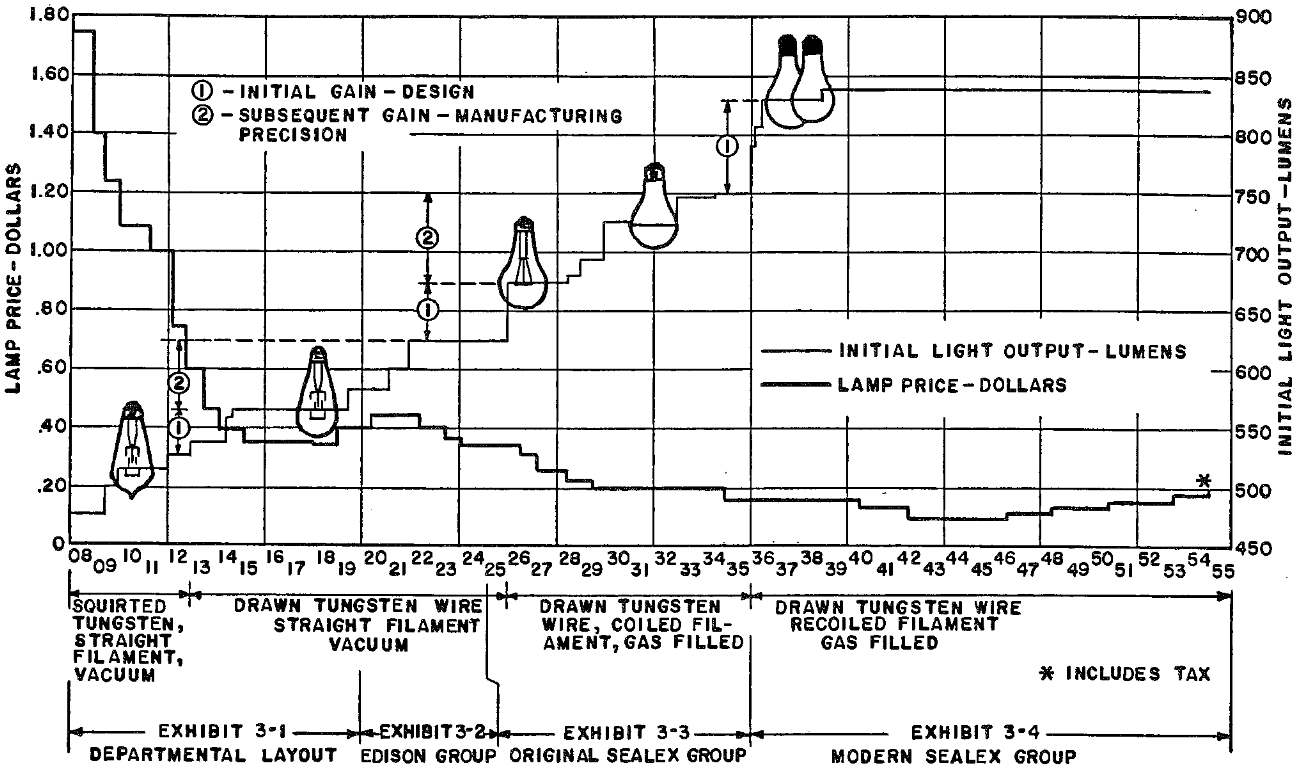
[3] The only other multipart product manufacturing system which (in the author's opinion) is more automatic over-all is the making of small arms ammunition. Although high precision in powder weighing and dimensional accuracy is involved, the product is far less complex and much simpler to assemble.

EXHIBIT 3-9. LIGHT OUTPUT AND PRICE OF 60-WATT ELECTRIC LAMP RELATED TO DESIGN, MATERIAL, AND MANUFACTURING CHANGES, WESTINGHOUSE ELECTRIC CORPORATION, 1908–1955



The abrupt rises in light output were due initially to the change from a straight filament in a vacuum to a single filament coil in a gas filled bulb and later to the introduction of the coiled coil filament. The increasing automaticity resulted in more uniform lamps and less scrap. Better equipment provided higher precision processing which further increased quality and quantity of output.

tially those of patrolling, inspecting, and workfeeding.

Net employment has not been reduced in the Westinghouse Lamp Division in spite of automation. The number of salaried and hourly paid employees in this division has grown from 2,762 in 1939 to 7,759 in March 1955. This is an increase of over 280% in spite of a major manufacturing phase improvement during these years. (Earlier employment figures were not available, but are known to be lower than the 1939 figure. It should also be appreciated that hundreds of new types of lamps have been introduced, and many of these are produced in a far less mechanized manner than the 60-watt lamp which has been discussed.)

This accomplishment in highly automatic production is not the result of automatic control. Feedback control is not necessarily essential to automatic manufacturing.

The ultimate controlling factor in pacing the growth of automaticity has been machinery cost (or possibly policy) but definitely is not one of technical feasibility. Technically, the operation now could be far more automatic, and automaticity could have been achieved earlier.

What benefits have resulted from this effort?

The accomplishment of this lamp manufacturing program is impressive. Results are charted in Exhibit 3-9. The product is about 170% more efficient in light-producing ability with the same amount of power consumption. The 1955 60-watt lamp sells for roughly one-tenth of the cost of the World War I 60-watt lamp. This price does not take into account the depreciation of the dollar over these years, which makes this cost reduction achievement even more striking. The individual worker of 1955 turns out about seventeen times as many lamps daily as he did at the time of World War I. Employment in the Westinghouse Lamp Division has climbed in spite of this steady progress toward automaticity and increased productivity.

WHY NOT AUTOMATIC SHOE PRODUCTION?

If mechanization can achieve this high degree of automaticity and productivity in the electric lamp industry, should we not expect that automation can do as much for any industry? The claims of many enthusiasts are that it can. All that is needed, they say, is a "fresh and vigorous approach," "progressive management," "imaginative engineering."

Careful examination of the technical and economic problems of a particular industry will show that automation is not necessarily a matter of attitude and effort. Granted that there will be a significant difference in the mechanization accomplishments of the management that is satisfied with the status quo and the management that is not, nevertheless there are certain physical facts, economic forces, and engineering difficulties that make automatic production either impossible, technically impractical, or exorbitantly expensive. For instance, imagine the production and assembly of a jet bomber with the degree of automaticity seen in electric lamp manufacturing.

Confronted with this kind of production problem, the automation enthusiast usually backs off by saying that, of course, one must have a reasonable volume to assure automation: "Given enough volume, anything can be successfully automated." Volume by itself, however, does not necessarily make automation practical. As an example of a high-volume industry that is not automated, consider the shoe industry.

On the surface, the manufacture of shoes has all the potentialities for automation. There is a large annual demand. Efforts have been made to mechanize this industry for roughly 100 years—twice as long as the lamp industry. Yet mechanization (I estimate) stands in the shoe industry at roughly a mixture of the technique in Exhibit 3-1, with a bit of Exhibit 3-2 in form of compound, multifunction machines added. Why hasn't the shoe business gone further toward automaticity?

Background[4]

In 1955 there were about 1,200 shoe factories in the United States turning out close to half a billion pairs of shoes annually. For many years the consumption of shoes has averaged close to three pairs per person each year.

The machinery used to manufacture shoes is of two general classes: "sewing machine" devices that are used to fabricate the uppers of shoes; and the heavier sole-making and joining machinery for making the soles, for mounting heels, and for joining uppers to soles. This latter machinery is a type of equipment manufactured by the United Shoe Machinery Corporation. The former type represents about one-third of the total number of machines in the average shoe factory but less than one-third of the value of the total machinery in the shop. Traditionally this one-third—the "sewing machine" type of equipment—is purchased by the shoe manufacturer. The other two-thirds has been leased from shoe machinery manufacturers.

It is believed that the industry capacity is roughly double the demand. Therefore, the shoe manufacturer is very much at the mercy of the shoe buyer. The shoe buyer—the retailer—buys in small quantities. At the beginning of a season, for instance, he may order several dozen pairs of shoes of a given style. These will have to be distributed across a range of sizes. Should these move well he is likely to reorder a dozen or so pairs of the same style. Again his order will be distributed across many sizes. The shoe manufacturer must supply these shoes quickly and in these small quantities, even though this may involve an uneconomical manufacturing procedure. Competition is too intense for him to let these small orders pass. In fact, competition is so keen that about 30% of the shoe manufacturers lose money annually. A firm realizing a 2% profit on gross sales is considered to be a successful shoe manufacturing business, according to industry spokesmen.

The traditional capitalization practices with regard to machinery have provided an obstacle to mechanical progress. Contrary to the situation in most industries, it is not necessary to buy equipment. One can get into the shoe business at an extremely low cost because the investment in equipment is very low. The would-be manufacturer can lease most of the machinery that he needs. Furthermore (at least prior to the decision forcing United Shoe Machinery to sell as well as to lease its machinery) the shoe machinery manufacturers would make the shop layout for him, assist in the installation of the machinery, instruct his operators, and advise him on methods.

Equipment leasing has a tradition of many years behind it. In 1846 Elias Howe invented the sewing machine. In 1861 McKay introduced the first machine for sewing outsoles on shoes, but because of labor opposition was unable to sell his machine. Not until the manpower shortage of the Civil War created large demands was McKay able to interest many manufacturers. Even then, because of the cost, he introduced this machinery on a system of "pay-as-you-go." Eventually this practice evolved into the present, widespread custom of leasing much shoe machinery.

The shoe manufacturer's major contribution has been skill in selling, in styling, or in the shrewd buying of materials, and not in the development of new manufacturing techniques. Because of this traditional leasing policy and heavy dependency upon the shoe machinery manufacturer for advancements in production technology, the average shoe manufacturer has not been extremely equipment conscious. He is not dedicated to constant refinement of machinery as is, say, the automobile manufacturer. He does not operate in an environment where heavy capital expenditure for improved equipment is considered to be essential for progress. Relatively little machinery has been owned by shoe manufacturers, and only a handful of them have had staffs of machinery development engineers. Many shoe manufacturers do not have an industrial engineering or methods department.

Thus, traditional operating policy has created a dif-

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[4] This material was gathered from several shoe manufacturers and shoe machinery builders, and was then checked by the National Shoe Manufacturers Association against industry figures in its possession.

ferent attitude toward mechanization from that found in the lamp manufacturing business, where each manufacturer must build or buy his own equipment. However, even if equipment procurement was identical to that of the lamp industry, other obstacles make automation difficult.

Since almost a billion individual shoes are made each year, shoes and lamps have one thing very much in common: they are high-volume items. On the surface this would certainly seem to encourage automation. However, this similarity *is* very much on the surface, for there are a series of factors that make the shoe anything but a "standard product." For instance:

Styling. The shoe is an item of costume whose sale is heavily influenced by changes in fashion. There are some exceptions such as work shoes, which are relatively standardized. Yet, on the whole, shoes do not wear out—they are replaced for other reasons. Children may outgrow shoes, it is true, but most replacement of shoes, and particularly women's shoes, arises out of desire to keep up with fashion. Thousands of different styles are created deliberately to encourage business. Thus a standard product of a constant size, shape, proportion, material, and appearance and of the longest life is exactly what is *not* wanted by the retailer or the buyer. Contrast this with factors influencing the sale of lamps. The emphasis on product characteristics desired, especially uniformity, is almost exactly reversed.

Variations in Size. Nonstandardization in shoes is further affected by the human foot. Feet are of so many sizes, shapes, and proportions that approximately 175 combinations appear in army shoes. A brief summation of the statistics shows that today's distribution is about as follows:

MEN'S SHOES: The most popular size is 8½D. About 10% of all men's shoes are sold in this size. Another 15 size width combinations make up about 75% of the shoes sold to men. Each of these combinations represents over 2% of the total volume. The remaining 15% is distributed over perhaps 85 to 100 further size width combinations.

WOMEN'S SHOES: The most popular size is 7B, representing 3% of the total. Another 18 sizes make up 50% of the total sales of all women's shoes. There are about 125 different size width combinations manufactured in most styles.

CHILDREN'S SHOES: There may be up to 80 different sizes of children's shoes in the average manufacturer's line.

The human foot forces this additional variability into the manufacturing operation. To fit men, women, and children, over 300 size/width combinations of shoes must be manufactured. Most of these sizes represent very small percentages of the total volume.

Materials. Progress toward automation in the lamp industry has been highly dependent upon the standardization of materials. How does the shoe business look in this respect? Leather seems to be a simple, easily worked material, but it has been a discouraging obstacle to automaticity.

Leather is skin, and almost all components of shoes are of this organic material, the quality of which varies widely from hide to hide and even from one portion of a given hide to another. Strength and other characteristics even vary with the direction of the grain in the leather. For instance, the stretch and flexibility in leather are greater with the grain than at right angles to it. These variations in physical characteristics between hides and between portions of hides complicate the manufacturing problem. Since shoe materials are nonhomogeneous, nonuniform, and, as one shoe executive said, "non-everything you can think of that is desirable for automatic manufacturing," discretion is required in the selection and application of each piece of material to each part of the shoe. Discretion means that either human skill or extremely complex sensing devices are essential shoe manufacturing operations.

Complexity of Manufacturing. A man's shoe averages approximately 25 pieces. About 150 operations are required to transform these pieces into a finished shoe. Moreover, the operations themselves are quite complex, and in spite of over a century of mechanization only about 80% of these operations are performed on a machine.

Many shoe forming operations require complex motions. There is scarcely a straight line or a reference plane in a shoe. A number of compound curves and many simple curves must be formed. The planes of the various parts of different sizes and styles of shoes do not lie at regular angles, or even at consistent angles to each other. Reproducing the required production motions by machinery with the ability to vary the motions for different sizes is an extremely difficult design problem. Many of the operations require motions with six degrees of freedom: that is, the materials must be manipulated along a straight line in each of the three dimensions and also rotated around each of the three axes. These motions may be required singly; more often they are necessary in various combinations. Any machine designer is aware of the difficulty in producing these complex motions mechanically.

Method of Measurement. A final complication is provided by the traditional method of measuring shoe sizes. The system of measuring shoe lengths originated in 1324 when Edward II decreed that three barleycorns equaled an inch:

> . . . It was found by careful measurement that 39 barley corns placed end to end were equivalent to the length of the longest normal foot. Inasmuch as 3 barley corns equalled one inch and 39 barley corns measured 13 inches, this largest normal foot was called size 13. The other sizes were graded down

> from the longest normal foot 3 sizes or 3 barley corns to the inch. Thus, each variation between half sizes and full sizes represents ⅙ of an inch—the variation between full sizes being ⅓ of an inch. This system of measuring the length of the foot by thirds of an inch still prevails despite the fact that all other measurements on a last are figured in eighths of an inch with the exception of shoe widths which are graded ⅙ of an inch to a width.[5]

This present system therefore is essentially based on an arbitrary arithmetical increase in length, girth, and width as the size of the shoe increases. For instance, men's shoes are built on lasts that increase by one-third of an inch in length in going from any size to the next whole number. The girth, or circumference about the middle of the shoe, increases one-quarter inch between whole sizes. As one goes to a wider shoe in any given size, say, from 8B to 8C, the bottom width increases one-sixteenth of an inch, the length one-twenty-fourth of an inch, and the girth one-fourth of an inch.

In going from one size to the next the increase or decrease in dimension is always the same, which means that the percentage increment is variable. The length increases at one rate and the girth at another rate. This destroys the angular relationship in lasts from size to size. So, because of this arbitrary arithmetic system, there can be no regular relationship or pattern of relationship between the various dimensions of different sizes of shoes.

These arithmetic lasts make it still more difficult to create efficient automatic machinery. It is relatively easy to make a machine to perform, automatically, operations on any given form. If this machine is to handle many sizes of lasts, however, which are in fact *different* forms, the machine design problem is complicated severely. The motions required of a machine now must each be controlled to yield a series of dimensions, curves, and angles unrelated in any systematic way.

On the other hand, if there was a consistent relationship or proportion between the various dimensions as sizes were changed, the machine design problem would become much simpler. What is needed, say United Shoe officials, is a geometric system of sizes. Perhaps this can be appreciated by imagining a photographic enlargement of a last or shoe. If the size of the shoe was increased by a series of "enlargements" of a given last, all the proportions of the shoe would remain constant, the angles would be identical, and other relationships would hold constant throughout the range of sizes. The machinery would trace the same curves and maintain relationships between motions. Then size increases would merely change the scale of movements required.

For some twenty years the research division of United Shoe Machinery Corporation has urged that the shoe industry adopt a system of last sizes based on a 3% increase between each size. With this "geometric last" (which they have developed experimentally and in combination with some new, automated shoe machinery) each linear dimension of the shoe increases 3% for each successive size. Lasts of this design make it much easier to create shoe machinery that perform operations automatically across the entire range of sizes. Furthermore, if adopted, the geometric last would encourage standardization in both the last and in the sizes of many of the pieces that go into the shoe.

The geometric last has been designed to overcome another obstacle to automation. In the present system of "arithmetic" lasts there is literally no single dimension, line, or plane that is constant from size to size. *There is no reference point* from which to work and around which to fix the precise amount of motion required of the automatic machinery. The geometric last incorporates a metal plate in the top of the cone of the last (roughly the horizontal plane through the ankle). This is called an "intelligence plate" or positioning plate. It is made parallel to the plane of the heel seat of the last and is a known distance from it. There are various notches, thimble holes, and slots in this plate to engage mating members in the shoe machinery so as to secure precise alignment and to "tell" the machine what size the shoe is and whether it is a right or a left.

Another improvement is incorporated into the geometric last—separate heel ends. The commonly used system of arithmetic lasts is based on having a complete last for each size and style of shoe (to the extent that the style has a different shape). The shapes of shoes for styling purposes are largely modified in the forepart of the shoe, while the shapes of heels are relatively constant. Thus there are thousands upon thousands of lasts in which the heel portions are relatively or actually identical and only the forepart is different in shape.

In the geometric last system as developed, the last is made of two pieces—a heel and forepart—instead of one. They are hinged on the faces that join each other. Thus any heel end and any forepart of the same size can be joined together. If part of a last is broken, that half can be replaced. If the forepart becomes obsolete as to style, a new forepart of a different style can replace it. This system would lead to standardized heel ends, with standard countermolds, heels, shanks, and all the other parts that go with the heel end of the shoe. In turn, this move would lead to a reduction in inventory in both lasts and shoe materials, as well as a simplification of automatic manufacture.

Will shoes made over such a system of lasts fit the human foot? Shoe machinery officials insist that the geometric last has as good foot fitting ability as lasts made under the present system and that shoes made

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[5] Harold R. Quimby, *The Story of Footwear* (New York, National Shoe Manufacturers Association, 1949), p. 7.

over these lasts are indistinguishable in the shoe store from shoes made over the arithmetic type lasts. The Quartermaster Corps of the U. S. Army has decided to use this geometric system for its next new last for the armed forces.

As of 1957, however, the geometric last was not in widespread use. Progress toward automation has been blocked by the difficulty of creating automatic machinery to perform complex motions around thousands of different arithmetic system lasts now in use. The average shoe manufacturer might require 10,000 to 30,000 lasts on which to make shoes representing over 100 sizes and perhaps several hundred styles in many combinations.

The Evolution of Mechanization in the Shoe Industry

Widespread mechanization in the shoe industry was a relatively late development following the industrial revolution by almost 75 years. A simple chronology of major events affecting American practice from 1750 to 1907 is presented in Appendix VI. From this latter date on, the number of inventions and patents dealing with various elements of the shoe manufacturing process increased so fast that they cannot be listed here. For instance, in 1940 it was computed that more than 8,000 important patents had been recorded in the field of shoe machinery and that these patents had been taken out by more than 3,000 inventors.

How has mechanization proceeded in this field?

Development in shoe machinery follows the same traditional pattern of other machinery evolution:

1. Development of machines, hand powered, to do jobs that were difficult to do manually or with hand tools.
2. Application of power to the machines.
3. Development of the duplicate operation type of machine, in which the machinery performs its action on a number of parts at once, or on a series of parts in very rapid sequence.
4. Prior to, or simultaneously with, the third stage, refinement of the machine to do a number of successive operations to the material. In effect, the combining of several production operations into one machine frame. These operations may be done simultaneously or in sequence, but the same effect of compounding the machinery is present.
5. The 1957 stage of development (which begins to parallel phase 3 (1925–1936) of electric lamp manufacturing) can be seen in current machinery to a very limited extent. The classical theory of constraint is especially evident in United Shoe Machinery's experimental machinery intended to achieve at least partial automation (based on the geometric last). (a) Each production machine is constructed so as to minimize or eliminate manual manipulation of the work and/or the tool. Thus, the production action becomes automatic. (b) Transportation into the machine and out of it—work feeding—is made automatic. (c) Nonmanual movement of material between production machines and areas is extended by some mechanical device, usually a form of conveyor, so that the work moves automatically from operation to operation.

The chronology in Appendix VI and further study of shoe manufacturing [6] will reconfirm that progress in machine design alone is not sufficient for automaticity. Mechanization advances, it is seen, depend upon parallel refinement and innovation *in materials* such as the substitution of nails for pegs or rubber for leather heels, *in processes* such as the glued sole, and *in product redesign*, the Goodyear welt, for instance.

As in lamp manufacturing, these advances do not happen at a steady rate, nor do they yield uniform degrees of mechanization throughout the plant. For instance, in the shoe industry the machine for securing uppers to the inner sole is a device that drives nine nails at once. This is a multiple operation machine in which the worker positions the last and the parts of the shoe in the machine, and then actuates the machine to perform the nailing action. Basically, his job is work feeding. Nor far away one finds a sewing machine in which the operator introduces a shoe, actuates the machine, then manipulates the shoe under the sewing head in order to sew around the sole in the desired pattern. Here work feeding plus guidance is required. At still another machine one finds the hopper-fed mechanism into which parts are loaded and automatically fed into the machine for application to the shoe as required. This operation is semiautomatic. Conveyorized movement between work stations and production areas is far from universal.

The present art, then, is far from automatic. To achieve complete automation, all these task elements —processing, work feeding, work removal, and transportation to the next work location—must be accomplished automatically. In the shoe manufacturing industry automaticity is only beginning. How fast will it spread? Let us further consider the current attempt of the United Shoe Machinery Corporation to create an automatic production system described below.

A Current Automation Effort

In United Shoe Machinery's laboratories experimental machinery of a highly automatic nature can be seen operating. Parts of the upper and the sole of the shoe are mounted on geometric lasts, which in turn are fixed to a special carrier. The conveyor takes these carriers through the production line. The conveyor does not run into each machine. Rather, the machines are spotted on appropriate sides of the conveyor for heel and toe operations. This arrangement eliminates the need to reorient the shoes between different operations. Just before reaching a machine the

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[6] *Outline of Shoemaking Procedures*, United Shoe Machinery Corporation, May 27, 1948; and Harold R. Quimby, *Shoemaking in Action* (New York, National Shoe Manufacturers Association, 1947).

carrier is stopped, although the conveyor continues to move. Through holes in the intelligence plate on the cone of the last the size of the shoe is sensed. This information is translated into adjustments in the machine. The shoe is then automatically fed by a transfer mechanism into the work station of the machine. The last and shoe are positioned and secured by sensing and locking on the intelligence plate, and the machine performs its operation. Then the fixture releases the last which is fed rapidly back to the conveyor line. Here the carrier is quickly transported to the next machine in the line.

This "manless manufacture" does not apply to the whole sequence of shoe manufacturing. At present efforts are being concentrated on joining soles to uppers and associated phases of the manufacturing process. The difficulty of automating some of these complex motions is great, yet some remarkable mechanization has been achieved. A series of ingenious devices—"wipers" and "grippers"—has been devised to seize the leather and pull it smoothly and uniformly around compound shapes such as the toe of the last. If the reader will visualize taking a piece of leather and pulling it over the toe of his shoe, holding it tightly yet so uniformly and smoothly that no wrinkles are evident while he nails it or clinches it into the sole, he will appreciate that this is no simple task to mechanize. Now imagine a machine that will do this with a wide range of sizes, styles, and types of leather.

Many design problems still exist. Consider, for instance, the simple matter of work piece orientation. Traditional machinery was designed for manual operation. Thus it was arranged to work with a shoe in a position favorable to the operators' vision—sole up, sole down, toe forward, or heel forward, flat or angled, as the case might require. Now, if the old machinery is to be made automatic, additional mechanisms must be introduced to reverse and orient the shoe from operation to operation, now toe forward—sole down, now heel forward—sole up, and so on. To be constantly reorienting and rotating the work piece from machine to machine adds to the machine design problem.

On the other hand, to do the logical thing—to put the shoe into each machine in the same position—requires almost a completely new start on most shoe machinery. Orientation, alone, requires a major redesign effort aside from the automaticity involved.

A second complication lies in the matter of manufacturing singles or pairs. It would seem that the best approach to automaticity would be to turn out pairs of shoes, rather than singles, so that a later matching problem and the readjustment of machinery from right to left would be avoided. Yet, machines that manufacture in pairs are again a break from tradition. They, too, require a complete new machine design start.

Integrating conveyorized feeding with the automatic machinery is not much of a problem from the technical point of view, once the matter of work orientation is overcome. The big obstacle to automation lies in the current use of the arithmetic last. With the geometric last the problem becomes mechanically solvable, since all the machinery action can be based upon uniform increases in scale between sizes.

In 1956 this automatic shoe machinery (representing only a fraction of the total shoe manufacturing process) had not been completely perfected, although several million dollars had been spent upon its development. There is no doubt that it will be refined, and eventually will be introduced in part in some places. Still, it is clear that the "automatic factory" in the shoe business is remote. And, it is not for lack of mechanical skill or management "daring" that automation in this business will proceed slowly. There are still other obstacles.

Obstacles to Automation

Variation in the Product and Its Parts. Automation of the lamp line has been accomplished because the product is standardized in performance and design and includes many standardized components. Although the parts of the lamp are extremely fragile they are consistent in size, strength, and many other physical characteristics. In short, the product and its parts are uniform. What can be done to eliminate variations in shoes and shoe components?

Styling. In 1947 buying surveys showed that shoe purchases by women were motivated 75% by fashion, 3% by durability, and 22% by both.[7] Of 13 feminine articles surveyed, shoes were highest in fashion motivation. Therefore, the shoe manufacturers must create numerous new styles each season. Often these style changes mean different parts, different sizes and shapes of parts, different materials, and different shapes for the forepart of the shoe.

Dare the manufacturer abandon changes in styling to encourage automation? With the possible exception of work shoes, this does not seem feasible.

Sizes. Can anything be done about the 300 sizes required to fit the human foot? Evidently not. Would it be possible to apply automation to the high-volume sizes, say, the men's 8½ shoe? If roughly 10% of the men's shoe business is in this size, this might offer a fair target for automation. However, styling changes within this size range have the effect of making total automation difficult, since a radical style change yields a completely different product.

Material. Since leather is such an unpredictable and inconsistent material, why not change to something else? Suppose, for instance, that a synthetic material could be turned out by the yard with the desired strength, durability, breathing, performance, and ap-

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[7] Harold R. Quimby, *The Story of Footwear*, p. 32.

pearance characteristics; it would certainly encourage automation. Unfortunately no such material has yet been invented.

There have been thousands of attempts to substitute other materials for leather. In today's shoes are rubber, plastic, nylon, cork, and many other things introduced successfully into shoe construction. Currently, United Shoe Machinery is introducing the first plastic material for insoles which officials believe is at the point where it is equivalent to leather in necessary properties. Nevertheless, shoe manufacturers have not been able to find any material that combines the breathing characteristics, the comfort, the appearance, and the flexibility and durability of leather for outer parts of the shoe. Leather still is the major material in the shoe business. It seems that the industry must either automate around it or forego automation until another material is found.

Shoe Construction. Perhaps the whole concept of making shoes is wrong. Why should a shoe be made of 25 pieces? Why should it be an assembly job? Why not cast liquid material around a model of the human foot? Casting appears to be a quick and simple way to obtain the complex shape of the shoe. It would overcome a host of obstacles and automation would, indeed, be facilitated.

Another possibility might be to mold shoes by pressing a few pieces of sheet material around the shoe form. Certainly that would be much more conducive to mechanization than the patchwork joining of pieces as at present.

In theory, both these ideas are good and there are some 800 patents on such methods of making shoes. Unfortunately, either the appearance of the shoes or the shortcomings of the materials leave such shoes far from salable. Is it possible that a sales campaign could be thrown behind the cast or molded shoe to make it acceptable? Who would care to take this gamble?

For the moment it looks as though automation will have to proceed around present shoe construction.

The Arithmetic Last. As previously pointed out, it is possible to automate the production of any given shoe around a given size of last. With the arithmetic last, however, there is no reference point and no consistent relationship among the proportions of the shoe throughout a range of sizes. Automation seems to require that the manufacturer adopt a geometric last.

At present the average shoe manufacturer has somewhere between 10,000 and 30,000 lasts. They represent a principal proportion of his investment and are worth about $3 a pair. To achieve automation he must discard these lasts and invest in the geometric type. This is another cost that must be recovered out of savings through automated equipment. Consider, too, that the lasts are only the first discard. If the manufacturer is to achieve automation, *he must replace just about all his shoe machinery as well.*

How many shoe manufacturers are prepared to replace their lasts, replace their machinery, and install machinery at least several times more expensive than the former equipment? How much of a gain in productivity, in uniformity, in reduction of scrap, in reduction of inventory, and other advantages will it take to pay for this? It appears that not very many of the shoe factories can afford to modernize on this scale very quickly.

An interesting aspect of automation is suggested here. If a principal objective or accomplishment of this automation is to make labor savings, how much could the manufacturer hope to save? The present average manufacturing cost of shoes is around $4, and 25% of this is labor. Thus, assuming that no one was required in the shop, the savings would be about $1 a pair. However, the machinery now under development will automate only a few of the shoe manufacturing operations. It would be more reasonable to expect that labor requirements might be reduced by, say, 10% to 25%. This savings would not pay for very expensive equipment rapidly.

Assuming that automation was adopted, however, it brings up another difficulty. There must be a period of transition between the present factory and the "semiautomated" one. The geometric last must be introduced, yet it must be compatible with whatever old machinery is retained. This is unusually awkward because of the orientation and work positioning problem explained earlier. So, the shoe industry is caught in a peculiar web of mechanical problems in which a major step toward automation is possible only if the shoe manufacturers abandon most of their existing machinery. The piecemeal approach of the lamp industry is not so feasible.

Traditional Buying Practice. If one could set up machinery to run off, say, a season's supply of size 8½-D in style XXX in one production run, significant gains in automation probably could be produced even with existing types of machinery. Refinements in plant layout, automatic material handling devices between machines, and work-feeding and removal devices probably could be added to existing machinery to achieve further automation. Can the manufacturer produce in larger lots?

Present buying practice is such that it forces the shoe manufacturer to produce in lots of, say, a dozen pairs, or at the best a few gross. How automatic would the automobile engine line be if it had to produce 175 variations of engines in lots of a few dozen at a time? The variability in the sales ordering system is the obstacle in the shoe industry. How can it be changed? Should the manufacturer build for stock and let the wholesaler take up the slack between supply and demand?

If some very accurate form of market research could establish the approximate sales of a given style and size in advance of manufacturing, these items could be run off and stocked for distribution as required. What market research technique is precise enough to do this for an item whose sales appeal is heavily based upon fashion? What happens when an aggressive competitor introduces a more attractive style than was anticipated?

Traditional Machinery Policy. A serious obstacle to automation in the shoe business would appear to be growing out of the low-cost, low-equipment capitalization tradition of shoe manufacturing. One official of a shoe machinery manufacturing firm commented:

> I'm not so sure that we haven't created our own troubles here. This practice of leasing shoe machinery has placed the emphasis for production developments in the machinery manufacturer's hands rather than in the shoe manufacturer's hands. The recent decision against United Shoe, forcing them to sell shoe machinery, as well as lease it, has completely confused the picture. Nobody knows exactly what will happen. However, shoe manufacturers have been getting an enormous amount of help out of the machinery manufacturers. By habit they've turned to them for production assistance. With purchasing of equipment where will the initiative for automation come from? How many shoe manufacturers have machine design engineers who are going to conceive and demand automatic equipment?

One might speculate that the shoe manufacturers are likely to continue to come to the shoe machinery manufacturer for automatic machinery. At present few of them have experienced staffs of manufacturing engineers similar to those who conceive integrated production systems in the automobile and appliance manufacturing fields. How fast can the shoe manufacturer develop this kind of staff skill? He has learned to look to shoe machinery manufacturers for production innovation and it will take time to change this approach.

Against the traditional low-cost, low-investment pattern of operations, which shoe companies are prepared to buy extremely expensive automatic equipment? What managements are inspired and equipped to develop it themselves? Only those with significant financial resources can invest in further automaticity on their own.[8]

Why not, then, lease or buy "automated" machinery? If the pattern of leasing machinery continues, can it be expected that the shoe manufacturers will be able to pay the lease charges required to support the development of extremely advanced forms of automatic machinery? Literally millions of dollars have gone into present mechanization developments. Many millions more will be required to go significantly further in the direction of automaticity. Will the production savings to the lessor support the high income needed by the research force? Who will provide the initiative, since the traditional leasing practice has been disturbed and made the machinery manufacturer more uncertain of the future of his business?

One might argue on the other side—at least in theory. If the steady income on leased machinery begins to dwindle, is there not an incentive for the shoe machinery manufacturer to institute an even more vigorous program of machinery development in order to encourage obsolescence and machinery replacement? One United Shoe official (speaking only for himself) does not agree. He says:

> Leasing spreads income over a period of time and acts to level out income, and therefore guarantees research. That the sale machinery business cannot do.

In view of the intensive research efforts of the machine tool manufacturers, one is tempted to challenge this statement. Still, right or wrong, it seems certain that the traditional leasing practice plus the sudden shift from leasing to buying has disturbed machinery development to the point where efforts toward automation may be delayed until the situation is clarified.

The shoe machinery manufacturers say that their research programs have been vigorously pursued for many years; that they have introduced new machinery developments as fast as the industry could find the labor savings to pay for them on a leased basis. Furthermore, they point out that they have been trying for 20 years to get the shoe manufacturers to adopt the geometric last so that changes and advances in machinery could be made more effectively. The shoe manufacturer's investment in lasts and his unwillingness to destroy them and invest in a new system have been the bar to machinery improvements and have blocked progress toward automation. The machinery user, they say, not the machinery manufacturer, must take the next step.

However, only the largest of the shoe manufacturers will have the capital to develop "automatic" shoe manufacturing production lines. The small manufacturer, who has existed in the world of low equipment cost, will find that both the purchase and the development of completely automatic machinery are going to create financial problems. It is doubtful whether many small manufacturers see the need for a manufacturing engineering organization; and even more doubtful if they will be willing or able to invest in the kind of technical help and machinery development program required in their own plants to lift them to significantly higher levels of mechanization.

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[8] I do not want to imply that automation *always* requires a much greater financial investment. We shall see examples later on in which it does not. However, in view of the state of the art and the unique character of the development problems, a tremendous amount of engineering research is going to have to be carried on to create automatic shoe machinery. It undoubtedly will be an expensive program.

INDUSTRY REQUIREMENTS FOR AUTOMATION

In a comparison of electric lamp and shoe manufacturing, one can identify serious obstacles to automation that exist in many industries.

Like the manufacturer of shoes, manufacturers in many other industries do not have a free choice of materials. They do not have freedom to modify the shape of the product to simplify automatic manufacturing. They do not have the freedom to create or force uniformity. They do not have a sales environment that is predictable or that encourages manufacturing in large lots. They do not have personnel within their organizations who are conditioned to or capable of making an aggressive attack on mechanization.

Lack of uniformity throws difficulties in the way of automaticity. This uniformity may be missing in the design of the product, in the sales pattern, or even in the material itself. Any one of these obstacles can bar automation. The shoe industry faces all of them.

Similar examination of other industries will demonstrate that automatic production cannot be achieved overnight. We have seen that machinery, alone, is not the answer—it takes parallel progress in other production areas as discussed earlier. The shoe industry presents a new requirement: the need for a marketing environment that encourages uniformity and is compatible with inherent limitations in the machinery and process.

This comparative analysis seems to confirm that (a) automation is an evolutionary trend and not an absolute quality; (b) some industries are exceedingly difficult to automate or impractical to automate; (c) widespread "fully automatic manufacturing" is in the far future. There is little doubt, however, that we shall continue to see gains in productivity as the production line is further refined and integrated into a harmonious machine-like whole, even though it is not completely automatic.

For these reasons, the managerial task for achieving automation is not simply that of keeping in touch with equipment developments. It is to pursue productivity improvements on a company-wide front, including design, materials, processes, and marketing practices that will facilitate automaticity rather than in the machinery area alone.

The major problem for management is to perceive the direction and possibilities for constructing an environment that will support automaticity and to press forward at a rate and in a manner that are economically and technically desirable in their own particular firm, with due regard to easing the impact on the work force.