MANUFACTURE OF FINE GAGE ENAMELED WIRE AT BUFFALO

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Western is believed to have been the first company to use enameled wire for electrical purposes. This was back around the turn of the century with the new material being received enthusiastically by our coil winders who had been subsisting entirely on a diet of silk and cotton served around a strand of copper. Some old correspondence refers to Western's first commercial production of enameled wire at the new Hawthorne enameled wire shop as being in April, 1904. In 1908 the round type enameling machine appeared. This machine was designed and built by Western and, with occasional modification, served as the standard production machine for fine gage enameled wire until the advent of the inclined machine in 1946. Each machine consisted of two separate units - an oven, electrically heated, and a reeling machine. Both units were circular in shape and stood about eight or nine feet high. Figure 1 is a picture of part of the fine wire enameling shop at the Hawthorne location as it appeared about 25 years ago. Twenty strands of wire were handled per machine and each strand could be given up to eight passes or coats of enamel. The wire carrying sheaves beneath the oven proper ran partly immersed in enamel contained in an open pot encircling the base of the oven.

Over the years and as the requirements on enameled wire became more severe, certain deficiencies in the round machines became evident. Some of these were corrected, but some were inherent and could not be overcome by modification. For example, room air disturbances - especially in winter - lack of automatic temperature control, and chimney effect or stack action of the ovens themselves caused baking variations around the oven. The dip and drain method of enamel application seriously limited the speeds at which the finer sizes of wire could be processed without becoming rough or beady.

During this time, studies had been going on at the Laboratories to learn more of the basic facts governing the application and baking of enamel on wire. Researchers at other companies were also busy on the problems associated with wire enameling and articles on the subject appeared in the literature from time to time.

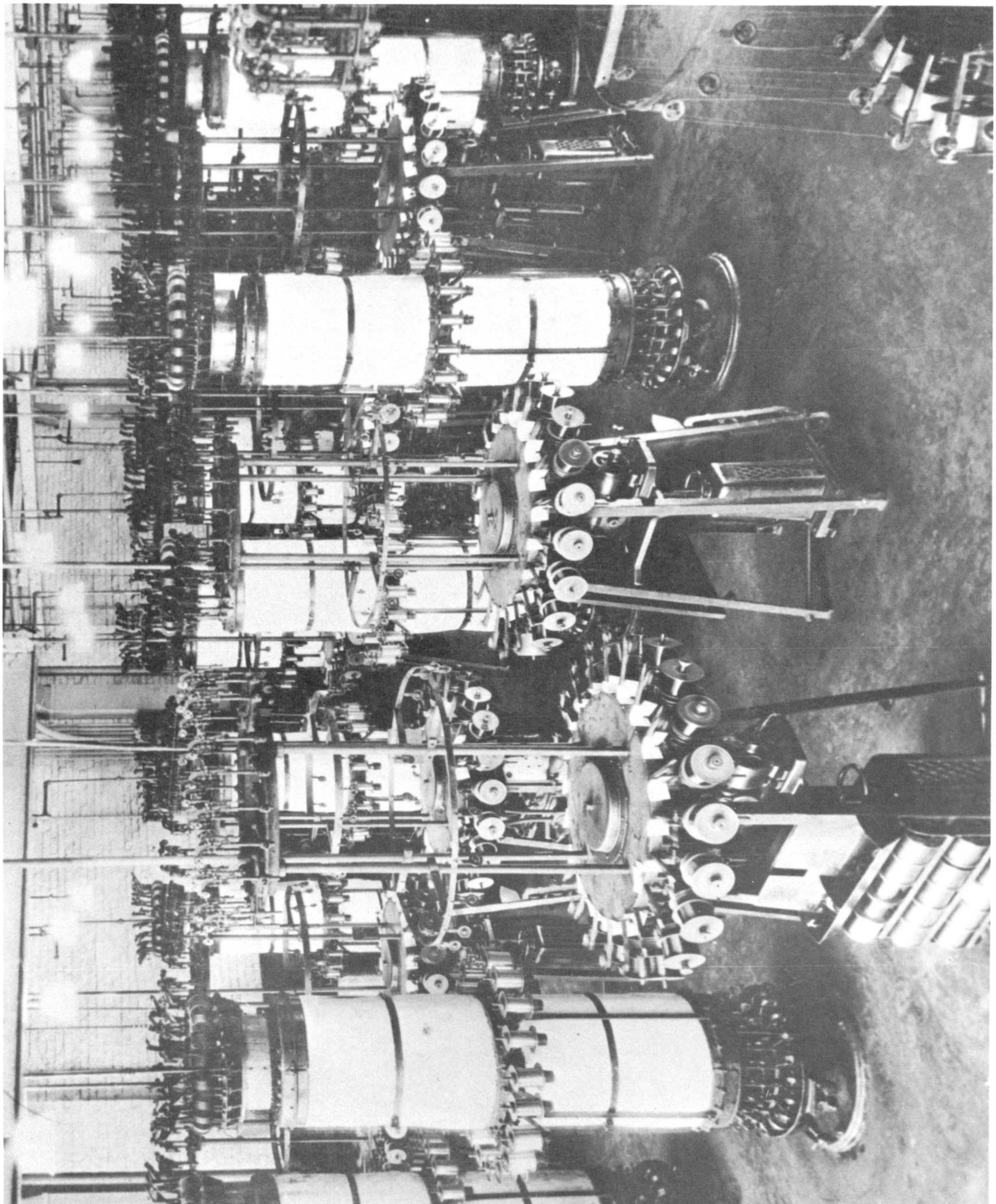

Figure 1

With the idea of utilizing the basic knowledge obtained over the years, development work on a new enameling machine was started at the Hawthorne Plant in the middle thirties. This work led ultimately to the inclined machine which is about to be described. The new machine never got into general use at Hawthorne but when the wire enameling job was shifted to Buffalo in 1946-47 the inclined machine became the standard production unit for fine gage enameled wire (24 - 44 gage). The Buffalo installation consists of 88 machines (1584 heads or production units) with an annual capacity of about 6.8 million pounds of wire on a seven day, three shift basis. Average gage size is 37-1/2 gage. This quantity stretches out to about 20,000,000 miles and requires around 125,000 gallons of wire enamel annually. At present, our product is entirely the oleoresinous type of enameled wire. Figure 2 is a picture of the fine wire enameling shop at Buffalo.

THE INCLINED MACHINE

Salient features of the inclined machine are:

1. A roller type of enamel applicator,
2. A rapidly circulating air stream for transferring heat from the heating elements to the baking tubes,
3. A water seal.

With respect to the latter we have found it highly desirable to have one end of the baking tubes sealed in order to eliminate chimney effect and to minimize the effect of room air disturbances. Water was found to make an effective seal but its employment dictated that the oven be inclined. A vertical arrangement is not practical because of the fire hazard (the enamel applicator would be directly above the oven) and operating inconvenience. The machines are highly efficient and operate with a minimum of maintenance and operator attendance. Enameling speeds run from 29 feet a minute for 25 gage to 200 feet a minute on sizes 38 and finer. This compares with a wire speed of from 6 feet per minute for 25 gage to 17 feet per minute for 40 gage on the round type machines for the years 1908 to 1921. The highest wire speed attained by the round machines was during the period of 1940 to 1947 when sizes 38 and finer were run at 71 feet per minute.

Following is a more or less detailed description of our inclined enameling machine. This machine has 18 enameling heads or channels divided into two groups of nine, the groups being spaced laterally because structural members occupy the center of the machine. For convenience the detailed description has been divided into several elements or sections.

Section 1. - Bare Wire Supply

All wire is supplied on spools which rotate as the wire is unwound. The power for spool rotation comes from the main drive capstan and is transmitted through the wire itself. In sizes 34 to 44 AWG, the bare wire is supplied on diecast aluminum spools of about 10 pounds capacity. The spools are held on special arbors affixed to a V-shaped frame mounted directly above the oven. Figure 3 is a general view of the supply arrangement and Figure 4 is a close-up of one of the special spool holders.

For wire sizes 24 through 33 the bare wire is supplied on fabricated steel spools of about 50 pounds capacity. Running of this wire is limited to certain machines (24 in number) which have been equipped with auxiliary arbors.

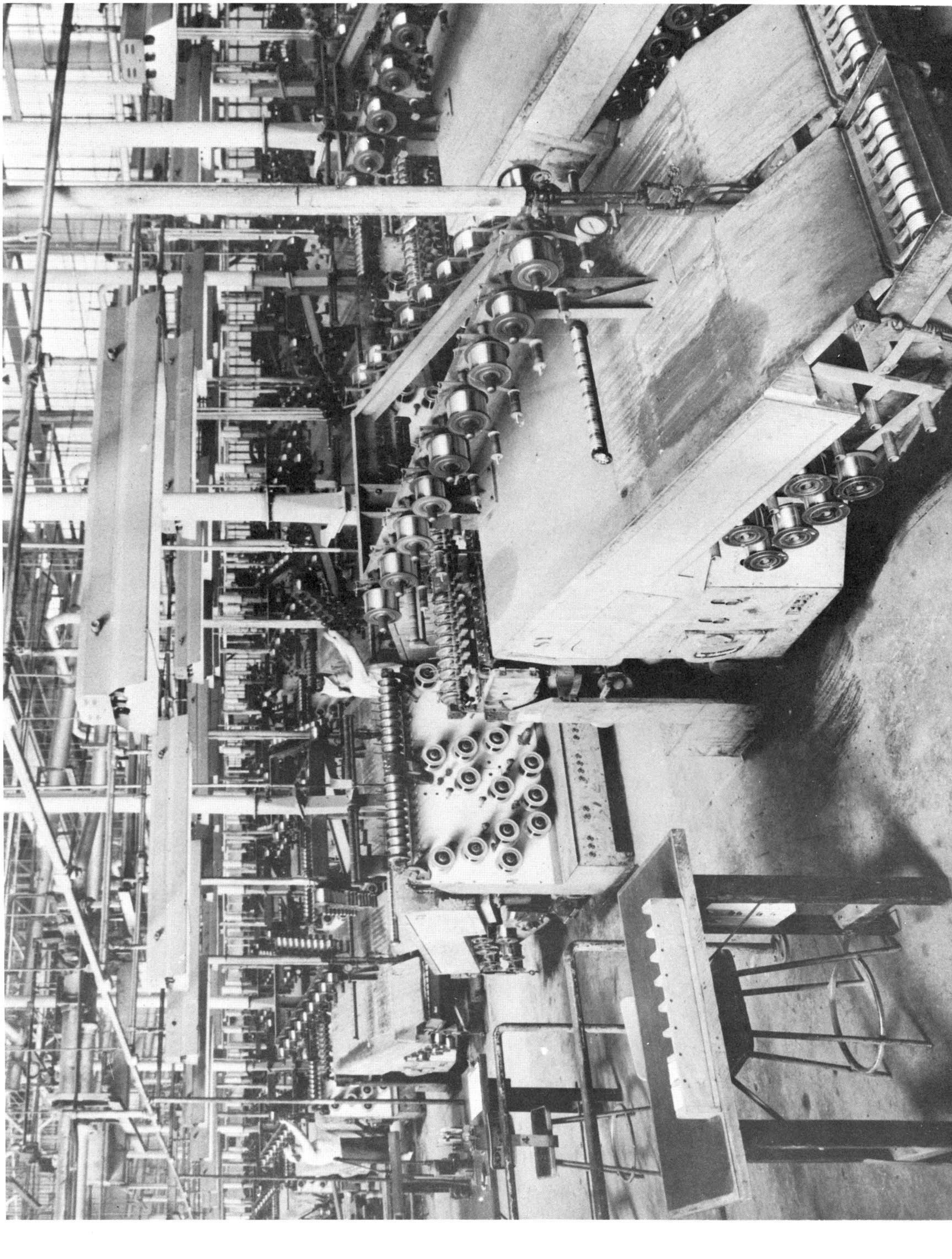

Figure 2

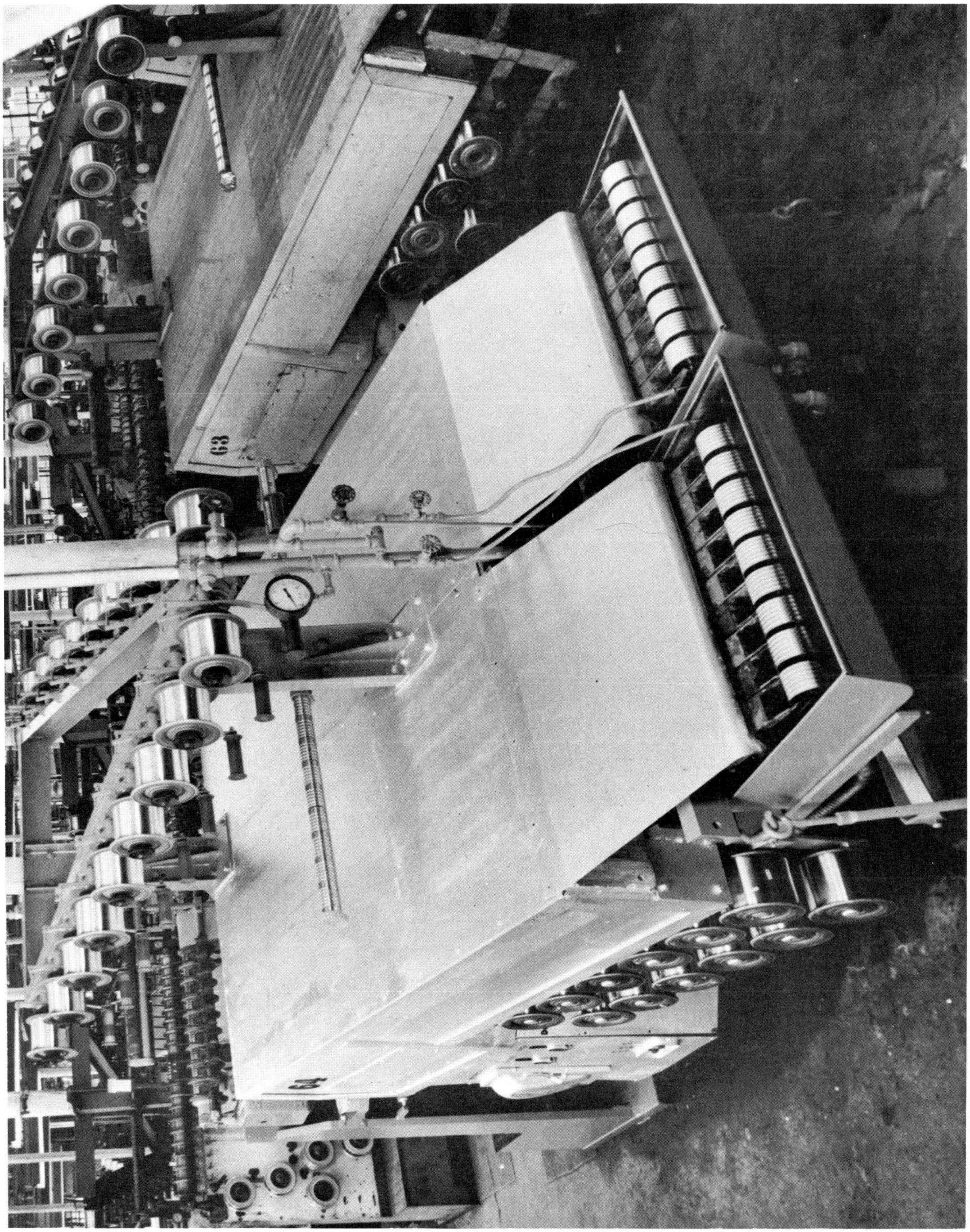

Figure 3

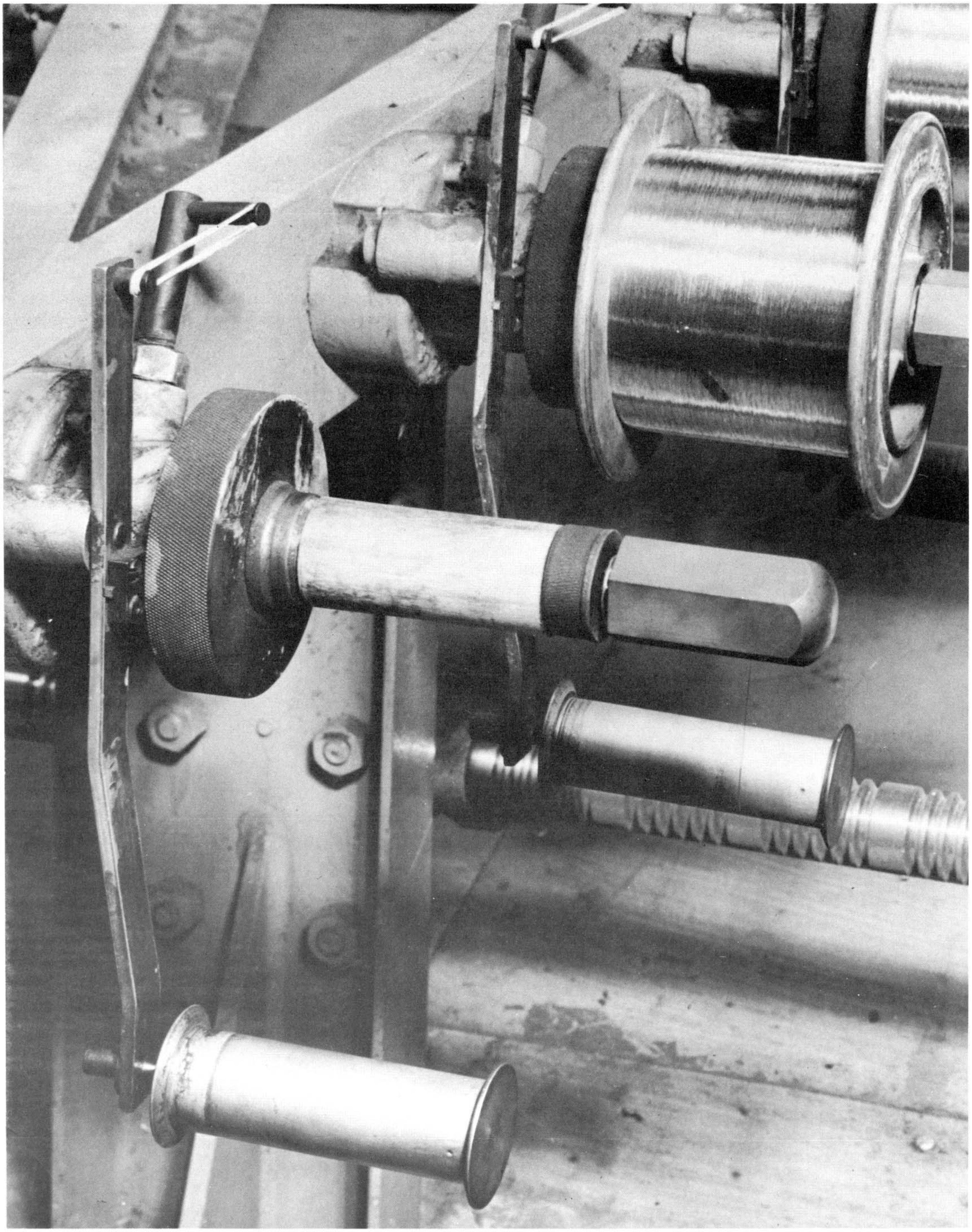

Figure 4

These arbors are in addition to those for the 10 pound spools and are attached to frames resting on the floor directly behind the enameling machine as shown in Figure 5.

Section 2. - Enamel Wire Take-Up

Diecast aluminum spools of 10 pound capacity are used to package the enameled wire. The take-up spools are individually driven by torque motors being directly mounted on the motor shaft which is fitted with an adaptor to match the bore of the spool. The adaptor has a pin drive means which permits take-up spools to be changed on the fly. Tension can be adjusted to match wire size by means of a single powerstat which feeds all the 18 motors on one machine. The torque motor has slip characteristics that permit the spool to slow down in RPM as it becomes filled with wire.

The capstan assembly consists of 18 individual, one piece, stepped groove, clutch controlled, nickel plated capstans mounted on a common drive shaft. Figure 6 shows the capstan assembly and also the take-up spools. Thus, each enameling head can be started or stopped without interfering with the adjacent head. Speed is set for the various wire sizes by means of change gears. A common distributor frame is located back of the take-up panel and can be adjusted for any traverse from 2 to 8 inches. Individual distributor arms extend through the panel for each take-up spool. Each arm has a wire guide pulley and an adjusting screw for properly registering the traverse with the take-up spool.

Section 3. - Enameling Oven

Figure 3, referred to previously in connection with wire supply, is also a good general view of the oven. The plane of the oven makes an angle of about 15 degrees with the horizontal, hence the name "inclined machine". Each enameling head or channel has its own individual tube where the enamel is baked. The tubes are installed side by side in a well insulated plenum chamber about 70 inches in length and 3-1/2 inches deep. Heat is applied to the outside of the tubes by circulating heated air around them in a closed system at high velocity. Also in the system are the electric heaters and a motor driven blower or fan. One thermocouple, located in the air stream, together with an electronic controller, keep the oven at a pre-set temperature which for the oleoresinous type of enamel we are using varies from about 800°F to 950°F. depending on wire size being run. The electric heaters are on continuously but are switched from high to low heat as required to maintain the desired temperature. The pre-set or indicated temperature is somewhat higher than the actual temperature within the baking tubes.

The lower end of each tube projects from the oven proper about 18 inches and terminates under water thereby sealing the tube against the effect of room air disturbances (drafts). The enamel baking reaction requires oxygen which is supplied by admitting a small flow of air into each tube just above the water seal. The amount of air is of the order of 20 cubic feet per hour and is controlled by a needle valve in the inlet to each tube. Low pressure air (about two pounds) is used and is furnished by a blower driven by a 30 HP motor.

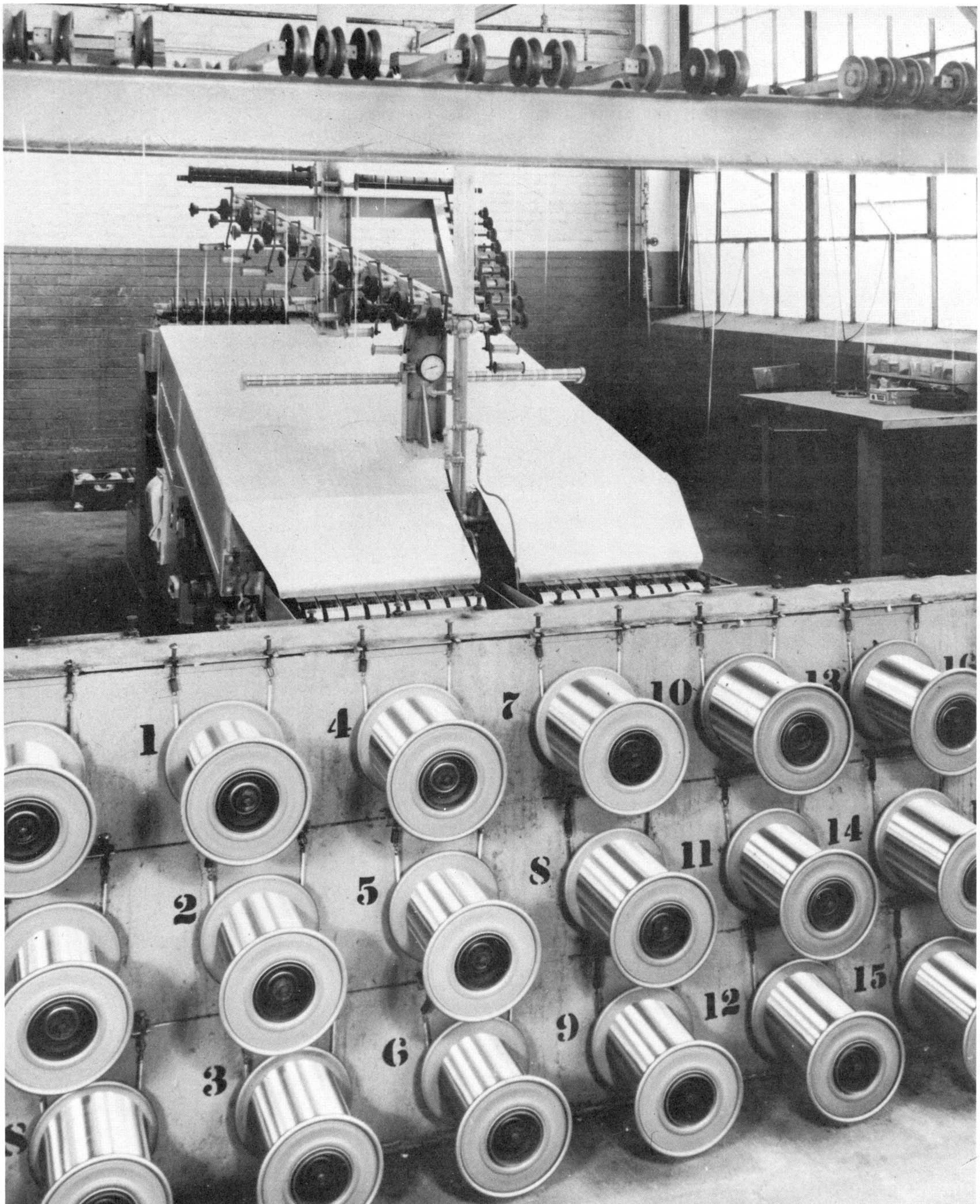

Figure 5

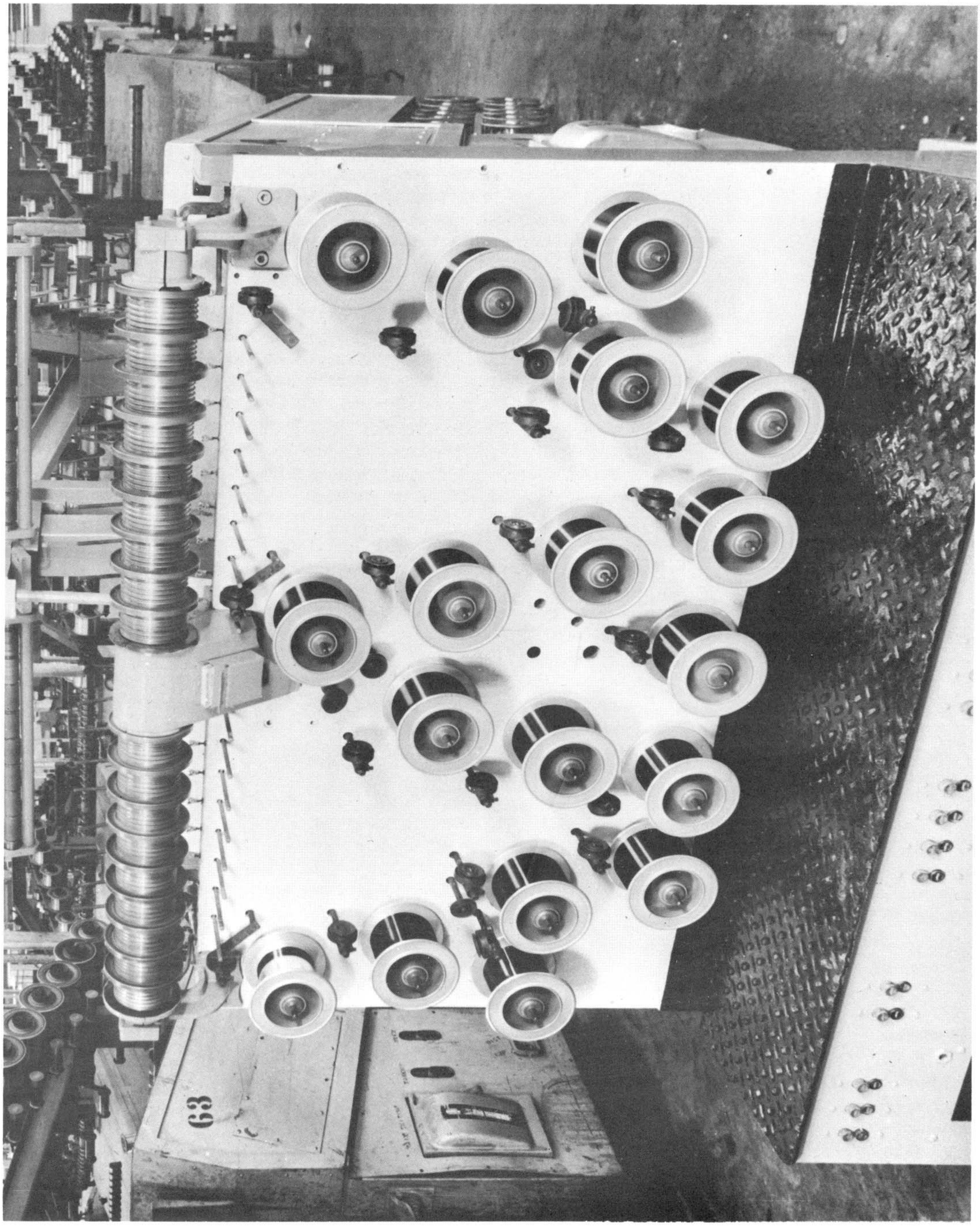

Figure 6

Located at the lower end of each tube and partly submerged in water is a chrome plated, one piece idler or wire return sheave. This sheave is in line with the capstan and like the capstan has its successive grooves machined to slightly increasing diameters. This "stepped groove" feature prevents the wire from sagging in the tube as it expands (increases in length) from the heat of the oven. Actual stretching of the wire is insignificant.

Section 4. Enamel Application

Enamel application is by means of a roller, 3/4 inch in diameter and about four feet long. The roller is articulated, consisting of six grooved sections and a smooth section, the latter being at the center of the machine where there are no baking channels. Associated with the roller is a V-shaped housing or cradle having bearing surfaces for the roller projecting inwardly from the housing walls at each roller joint location. The roller is positioned so that its lower portion is below the top of the housing. The latter is maintained in an overflowing condition with enamel so that the lower portion of the roller is immersed in enamel. A close-up view of the applicator in operation is shown in Figure 7.

The applicator roll is motor driven through a variable speed transmission and turns in the direction of wire travel. Those portions of the roll in line with a baking channel carry a plurality of closely spaced 90° V grooves. It is these grooves that bring enamel from the supply trough to the wire. Groove depth varies from .002" to .030" but on any one roll, all grooves are the same depth. One roll size may be used over a range of three to four wire sizes.

Each enameling machine has a small tank of about six gallons capacity, a pump and a single unit honeycomb filter. The overflow from the applicator returns to the tank and is recirculated through the filter and back to the applicator at a rate of about six gallons per hour.

Section 5. Fume Disposal

Enameling fumes discharge from the baking tubes at the applicator end of the oven. The collecting duct or hood is located directly below the tube openings as is shown in Figure 8. The enamel fumes and a considerable amount of room air are drawn into the hood and then discharged to the outside atmosphere through a large exhaust fan and duct system. One exhaust fan is used for 16 enameling ovens. With the exhaust hood located below the tubes, we avoid condensate dripping on the wire or building up across the tube openings to cause wire breaks. Drip pockets are provided at various points in the duct system for collection of condensate.

Section 6. Operation

Wire speed and roll groove size are specified in the operating instructions. These vary, of course, with the size of wire being insulated. Oven temperature setting, roll speed and powerstat setting for the take-up motors are also specified but only approximately with such deviations as might be required to secure optimum bake and correct film thickness being left up to the "Layout Operator". Some deviations are necessary because of differences between machines. Others are necessary to compensate for the effect of large changes

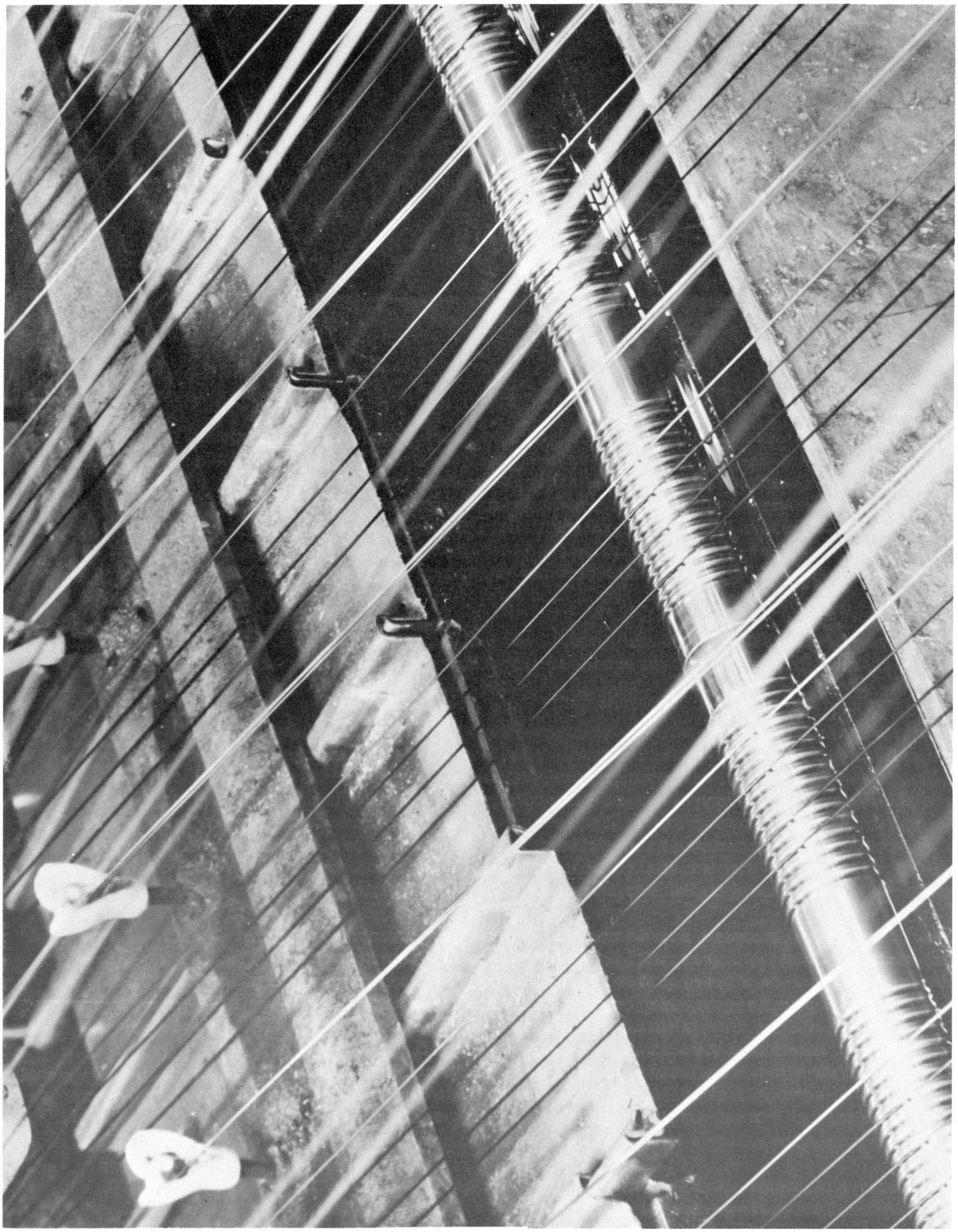

Figure 7

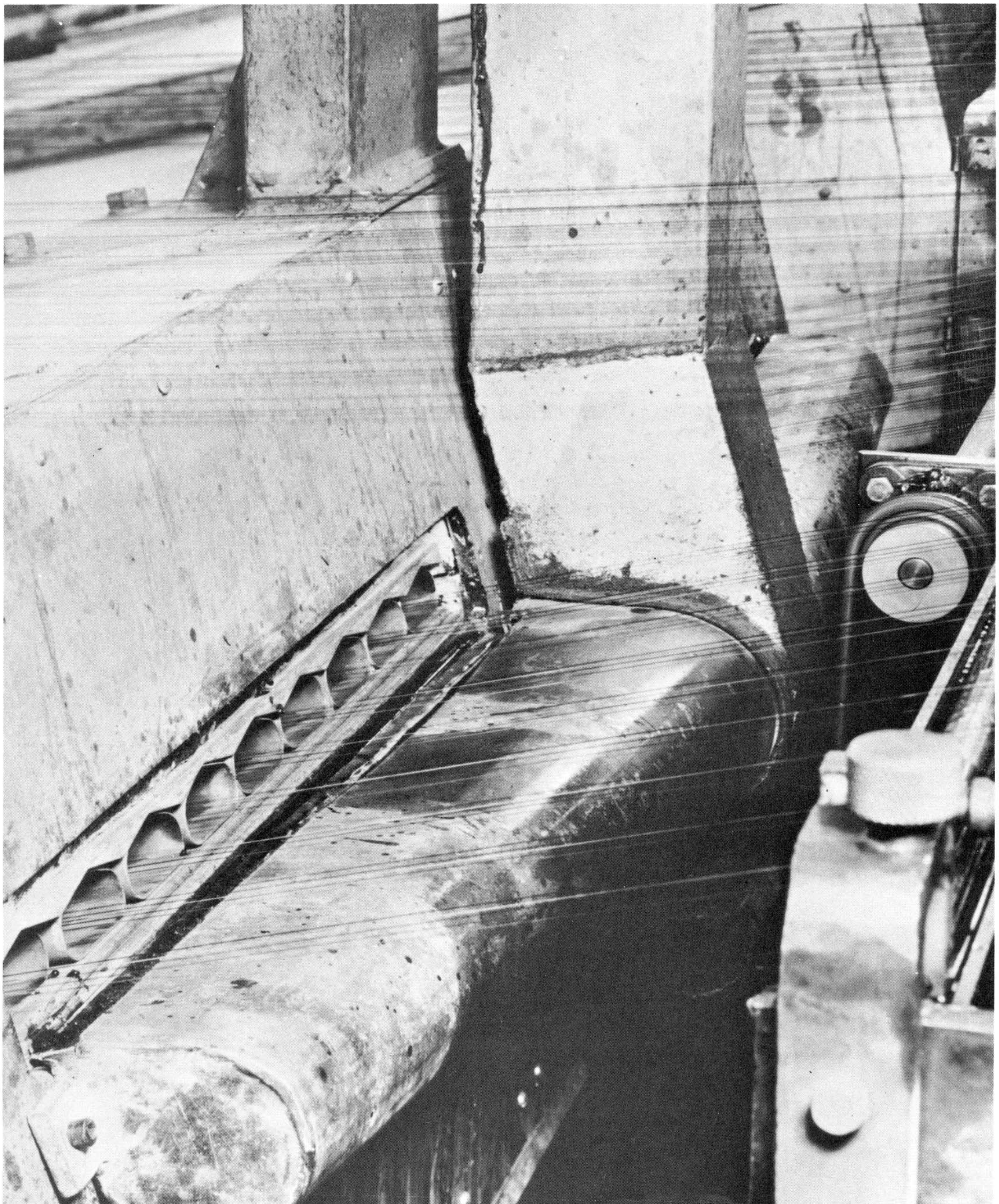

Figure 8

in room temperature which sometimes occur usually from day to night, especially during very hot or very cold weather.

Each operator is assigned 8 machines (144 heads). Operators are concerned only with changing spools, (both take-up and supply) making distributor adjustments to secure level winding, repairing wire breaks, adding fresh enamel to the machines and preparing spool tickets.

There is a "layout" or chief operator for every 30 machines who "sets up" the machines for whatever wire size is to be run, makes oven temperature and roll speed adjustments and cleans out the tubes should they become fouled up with condensate or pieces of wire.

The machines are under continuous operation (7 days, 3 shifts, holidays included) but are shut down for a general cleaning about once every 16 weeks. This is done on a rotation basis so that only one machine at a time is down for this purpose. Down time for cleaning is about eight hours.

Now that you all know how enameled wire is made a word or two is in order about what actually occurs in its making. The oleoresinous wire enameling compound used is really a varnish, consisting of a vegetable oil and a resin to form the insulating film with some volatile solvents added to obtain suitable flow characteristics. Most of you have varnished floors, woodwork, or articles of furniture, and when you finished brushing on the varnish, were content to wait a day or two for the coating to dry. We do a little better than that. Our finer gage wires are run at 200 feet a minute through a six foot oven which gives a drying time of less than 2 seconds. This tremendous acceleration of the drying reaction is accomplished by heat, about 900 to 950 degrees of it.

We have mentioned a 10 pound capacity take-up spool and a wire speed of 200 feet per minute but would like to introduce still another number, namely 33,000, which is the approximate number of feet in a pound of 40 gage wire. With benefit of a little arithmetic we come up with a time interval of about 27 hours required to produce a full spool of 40 gage wire. During this time, of course, some 3 or 4 operators have stood with their fingers crossed hoping that everything was going OK with this and the other 143 spools they are tending. However, when the spools finally do come off, 100% of them are inspected visually with a small portion undergoing further inspection for such physical characteristics as enamel increase, bare and overall diameter, conductor elongation and resistance plus flexibility and inertness of the enamel coating. The inspection is of necessity limited to the outermost visible portion of the spool which represents about the last ten minutes or so of the total running time. In the case of 25 gage wire running time is of the order of 5 to 6 hours.

While our inspection procedure does let some defective wire through, it is a comparatively low cost procedure and is felt to be the most economical overall to the Company. Some finished spools are rewound completely with frequent stops for quality checks. Indications are that about 1 to 1-1/2 percent of the spools contain some defective wire somewhere inside the spool. Of course you people that use the wire find these defective portions and you may or may not complain about it. In some cases an informal complaint is registered; in others the complaint is formal. During the year 1963, Buffalo received 23 formal complaints on enameled wire of which 6 pertained to the Buffalo product and 17 to the product of outside suppliers.

Some of you may be getting a feeling of being discriminated against since we have been talking of full (10 pound) spools while you have been getting some spools that are nearly empty (one pound or even less). We like to think in terms of an average spool weight which is in the neighborhood of 7-1/2 pounds. Some of the reasons for short spools are as follows:

1. Short spools of bare wire from the wire mill. There is no time to elaborate on the reasons for this and some days are worse than others for breaks but the overall average seems to be around 25 pounds of wire drawn per break. (34 gage and finer).

2. Brim full spools of bare wire from the mill. Due to the volume of the enamel coating itself a brim full spool of bare wire would make an over brim full spool of finished wire. Such spools are split into two take-offs.

3. Wire breaks at the enameling machines.

4. Taking a machine out of service temporarily due to periodic cleaning, machine breakdown, operator absence or switching to a different gage of wire. This affects 18 spools at one time.

5. Power failure. This is a very sad event but fortunately occurs only 2 or 3 times a year. Even if the interruption is as short as 2 or 3 seconds, all 1584 heads stop and all 1584 take-up spools must be removed. The sad part for us is that it takes about 8 hours to get everything going again. The sad part for you is about 3,000 short spools.

With this note of sadness our formal talk nears its end. However, let not a few short spools be an indication that we are selling ourselves short from the standpoint of enameled wire quality. Chart No. 1., from our Quality Assurance Organization, illustrates quality of the shipped product for 1963.

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