COIL STUDIES AT PRINCETON

J. S. CARTWRIGHT

Princeton

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The coil case was one of the first cases initiated at the Center in 1958. After investigating coil manufacture at several works locations, it became apparent that the hand finishing operations required for filled coil manufacture are not readily adaptable to automatic operations. Therefore, the best approach to introduce new methods of coil manufacture appeared to be the development of an automatic winding machine which would produce a finished coil wound on a bobbin. In 1960 two bobbin wound coils, the Touch Tone Transformer coil and the Transistorized Telephone Handset coil were introduced to Western Electric. Since then, bobbin wound coils have been increasing by the millions yearly in such coils as the Miniature Key Relay coil and various pulse transformers. Most new designs from BTL are based on bobbin wound coils and the future promises even more usage in such systems as ESS.

Investigation in the areas of wire tensioning, wire distribution and terminating were conducted in the early stages of the coil case. A report titled "Coil Case History", technical report No. PRN-185 dated 1/31/64 covers this in detail and refers to the specific technical reports concerning each investigation.

The greatest effort at the ERC has been towards the automation of coil winding. Early goals of the automatic coil winder were to prove feasibility and to develop a machine as versatile as possible. To attain this development, work began on two experimental machines employing different winding principles, namely, the flyer type and the rotating bobbin. In flyer winding the bobbin is held stationary while the required turns are wrapped by means of a rotating wire distributor or flyer. This machine was designed, built, and operated on an experimental basis, however, it soon became apparent that flyer type winding results in certain limitations.

The second machine or rotating bobbin type, employed a Meteor 301 coil winder as the nucleus of an experimental single spindle coil winding machine. (See

Figure #1) After considerable modification, including the development of several new mechanisms and an electrical control system, this machine proved the feasibility of automating the manufacture of bobbin coils.

Upon completion of the single spindle feasibility model, the design of an advanced five spindle model was initiated to make the Miniature Key Relay Coil being manufactured at Kearny. (See Figure #2)

The principal functions of this fully automatic machine are: winding to exact turns at speeds up to 10,000 RPM; winding up to five different windings per coil; terminating; taping as required; and loading and unloading bobbins. The integration of mechanical, pneumatic, and electrical components provides maximum machine versatility for different coil codes on a given bobbin design and conversion to different bobbin sizes or shapes. Bobbins may be any size up to approximately a $2\frac{1}{2}$ inch swing by 3 inches long. In addition, major components of the machine and electrical control system are modular in design for versatility and ease of maintenance.

The multiple spindle winding head which winds five coils simultaneously employs hardened and ground precision #2 helical gears. The spindle assemblies, including shafts, bearings, gears and bobbin fixtures, have been dynamically balanced and are oil mist lubricated to attain winding speeds of 10,000 RPM. Two air actuated detents located in the spindle head assembly, position and lock the bobin in the required rotational position, utilizing the precision gear train to minimize rotational error.

A $1\frac{1}{2}$HP D.C., shunt wound, constant torque motor drives the system at any desired speed from 50 to 10,000 RPM and is coupled to the drive system by an electro-magnetic clutch which is de-energized when the spindle detent locks the head. Winding to exact turns is accomplished by the electronic counter which controls motor speed and actuates the proper bobbin flange detent. The motor also drives the fine and rapid traverse and the taper cam, thus, insuring that these functions are timed with coil rotation. (See Figure #3)

Wire is fed through hollow needles which serve as the wire guiding and terminating devices. The fine traverse system is infinitely variable to accommodate any wire size from 24 gage to 46 gage and drives the needles between two adjustable stops to attain exact bobbin winding length. The rapid traverse system increases the winding pitch to insure that the needle is driven to the desired bobbin flange for terminating while the exact number of turns are being wound.

One of the important developments of this machine was automatic termination. Termination is accomplished by positioning the center of rotation of the needle with the center of the terminal to be wrapped and rotating the needle around the terminal. Since the needle is perpendicular to the axis of coil rotation, terminals must be located in a like manner. (See Figure #4) A lead screw driving a vertical slide is used to position the needle at the desired terminal for wrapping. Although minimum spacing between adjacent terminals must be .150 mils, this minimum may be increased by increments of .050 mils. The spindle locking detents are also employed to allow termination at either side of the bobin flange. An additional slide with motion perpendicular to the axis of the coil moves the needle away from the coil and provides a favorable wire angle for high speed winding.

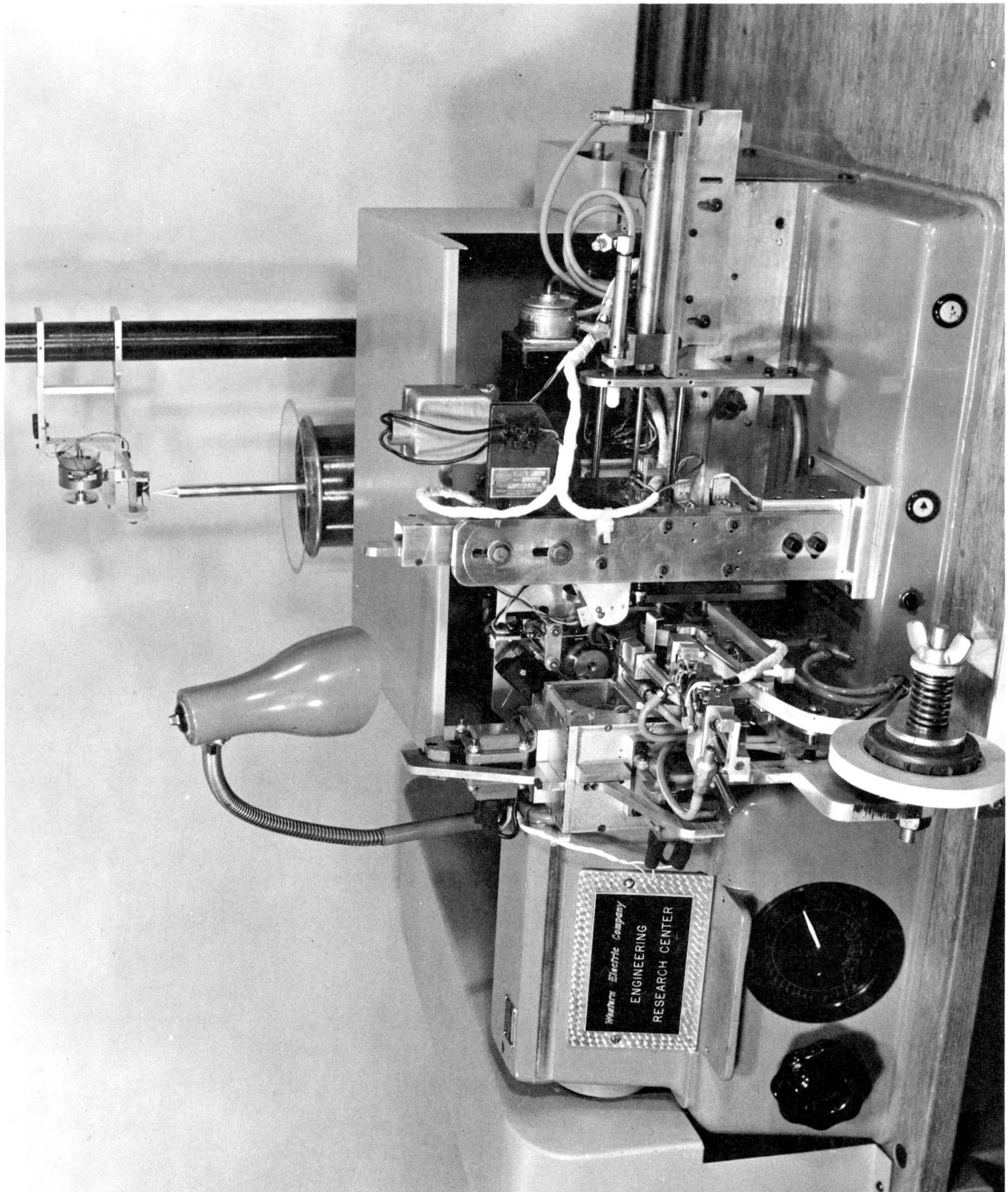

Figure 1

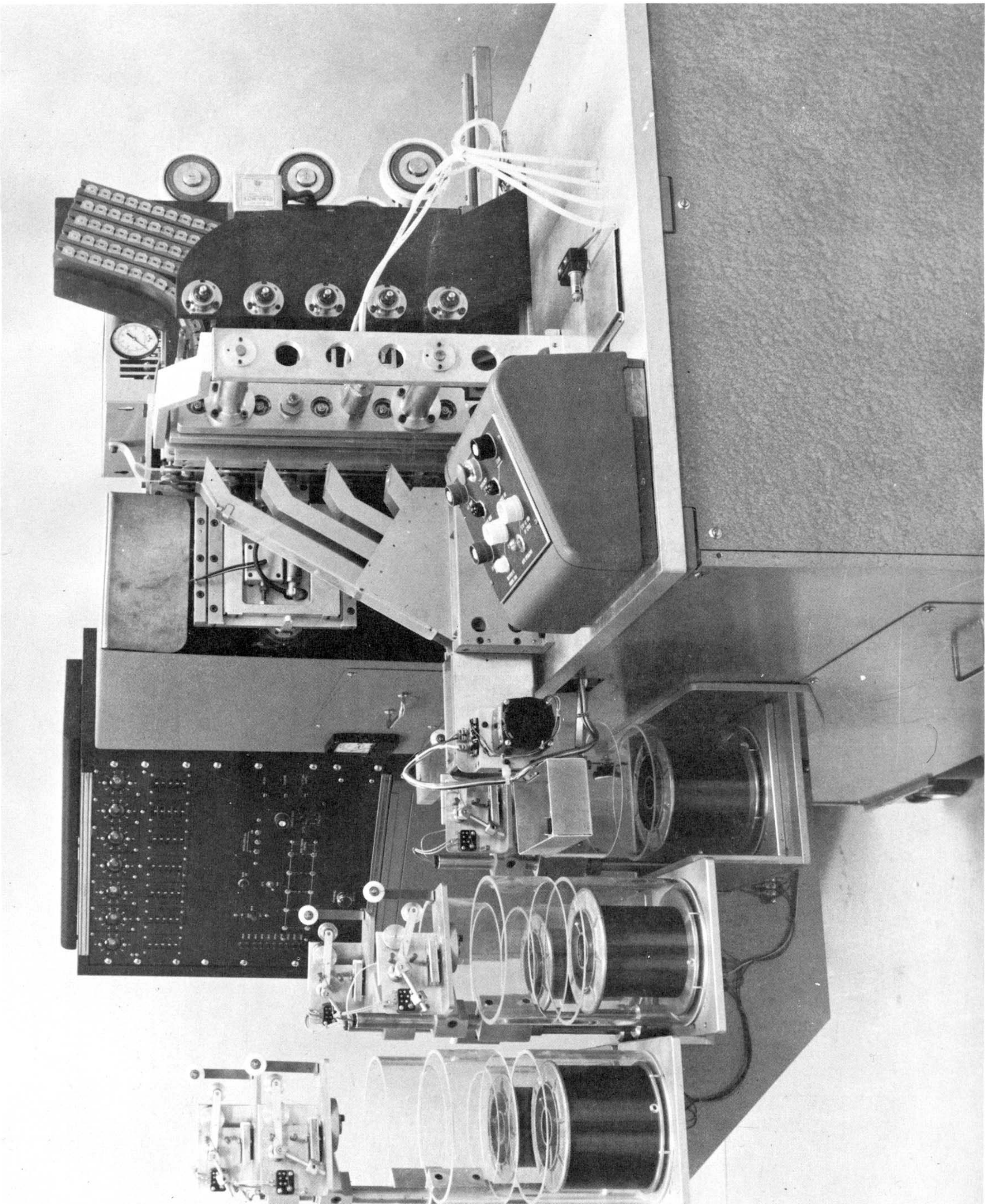

Figure 2

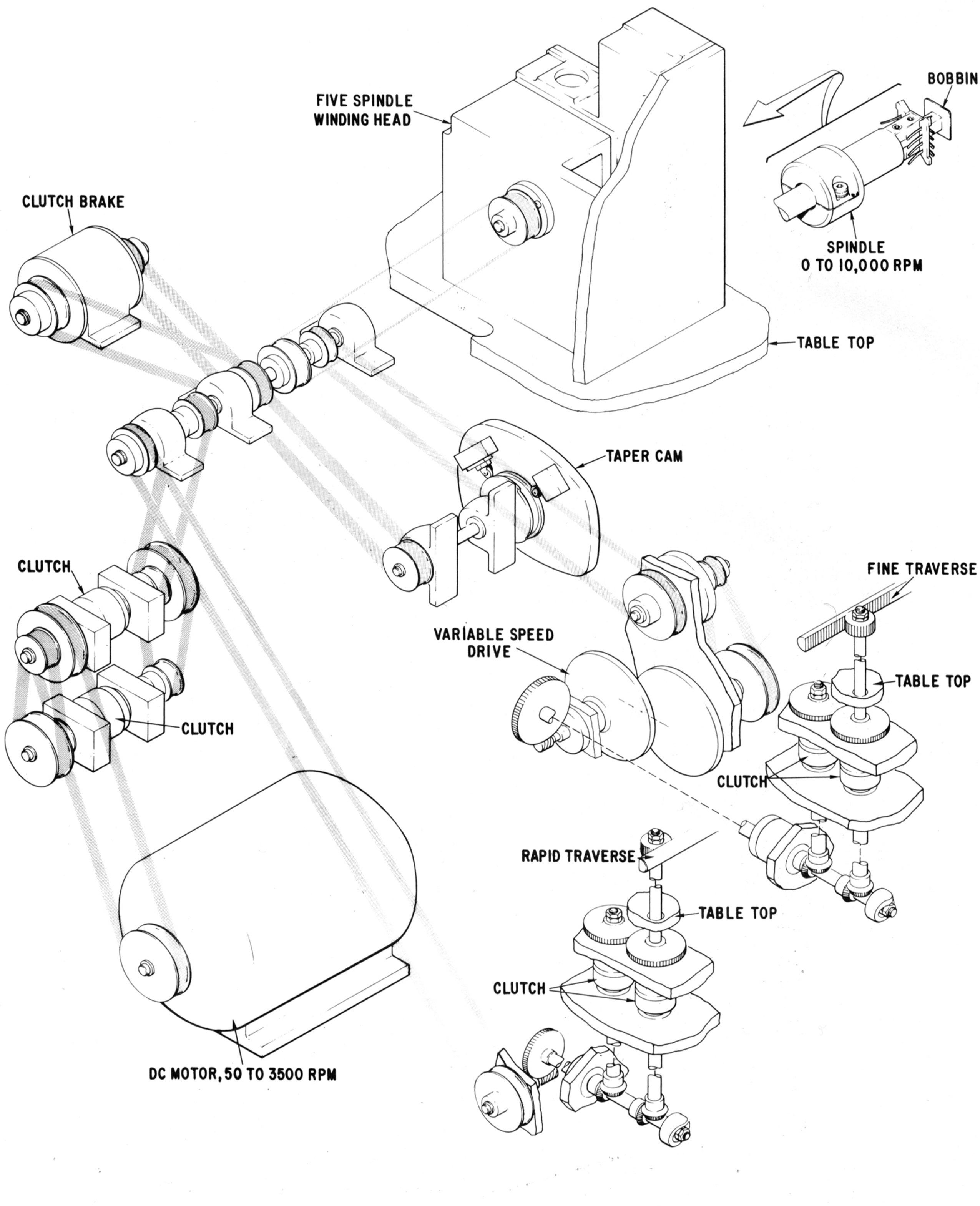
FIVE SPINDLE
WINDING HEAD
BOBBIN
SPINDLE
0 TO 10,000 RPM
CLUTCH BRAKE
TABLE TOP
TAPER CAM
FINE TRAVERSE
CLUTCH
VARIABLE SPEED
DRIVE
TABLE TOP
CLUTCH
CLUTCH
RAPID TRAVERSE
TABLE TOP
CLUTCH
DC MOTOR, 50 TO 3500 RPM

Figure 3

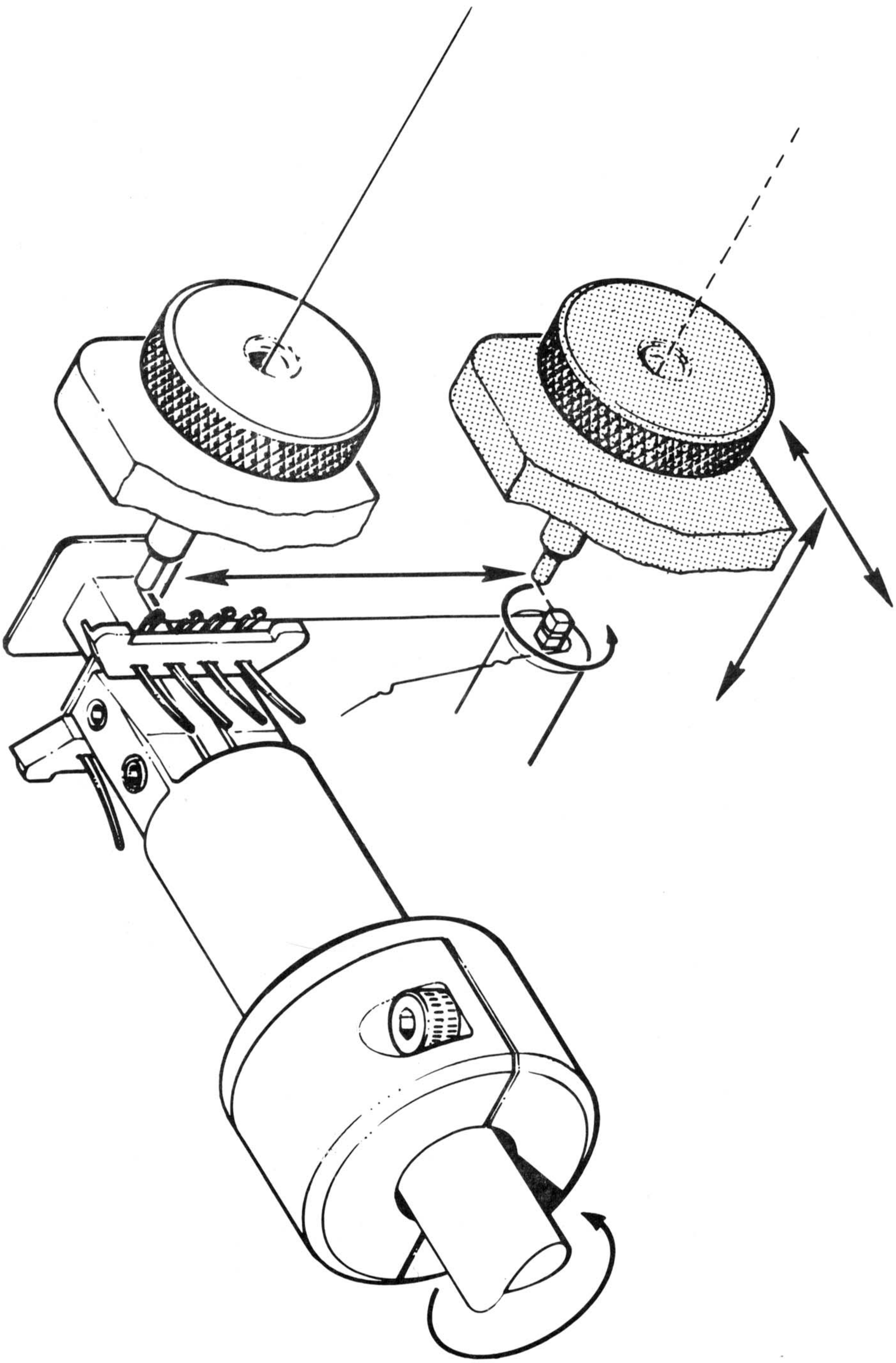

Figure 4

A basic requirement of automatic coil winding is that the wire be held captive at all times. The method employed on the present machine wraps the wire on a self-stripping storage pin between coil windings. In order to eliminate long tail wires at terminations, a new device has been developed which incorporates a wire cutter and clamping device in conjunction with the terminating needle.

The wire is supplied from a spool through a tensioning device that employs a hysteresis brake to provide individual control of the wire tension at each spindle. (See Figure #5) The control system programs the wire tension for two predetermined values; one for wire winding and the other for wire termination. A wire break detector is actuated if a wire breaks or when a spool is depleted. The control system allows the remaining coils to be completed but stops the machine after unloading the coils.

Taping requirements for a coil may be twofold: a coil may require only a cover tape, or may require tape between two or more windings in addition to a cover tape. The taper developed at the ERC is capable of meeting either requirement and may also apply one or two wraps. The taper employs the demand principle for applying tape. (See Figure #6) The tape is brought into contact with the rotating bobbin and is cut to the required length. The taping unit is mounted on a cam-actuated slide in such a manner that it may be easily removed as a unit for replenishing the tape supply or converting to another coil width.

When large quantities of coils using the same bobbin size are required, automatic bobbin loading and unloading may be justified. Bobbin loading is accomplished by feeding five rows of bobbins down magazine tracks using a vibrator. The bobbins are moved by pickup arms to the live tailstock which transfers the bobbins to the winding arbors. The tailstock also supports the bobbins during winding. Detecting micro-switches insure that all five bobbins are loaded. Unloading is performed by stripping the coils from the tailstock arbors into unloading chutes which deliver the finished coils to a box. The entire loading and unloading cycles is cam operated and may be repeated without affecting the timing sequence of the machine.

The control system is designed around a dual, multiple preset counter (See Figure #7) which initiates the sequence of events in the winding cycle through a stepping switch and a series of relays. The stepping switch adds to the flexibility of the winding machine operations. With specific machine functions assigned to each of the various levels, operations such as terminating order, wire cutting sequence, taping points and picking side detents for stopping the spindle may be easily changed or omitted. The circuits are designed so that a new operation cannot be started until the previous one is completed and, if a malfunction should occur, the machine will stop at the point of the malfunction.

This automatic machine had successfully wound 8,000 coils at ERC before being shipped to Kearny in the fall of 1963 on a trial production basis.

The application of this fully automatic coil winder with taping and bobbin loading and unloading capabilities could not be justified economically for a relatively simple coil. Upon re-examination of the ERC design and objectives it became apparent that a semi-automatic machine with approximately twice

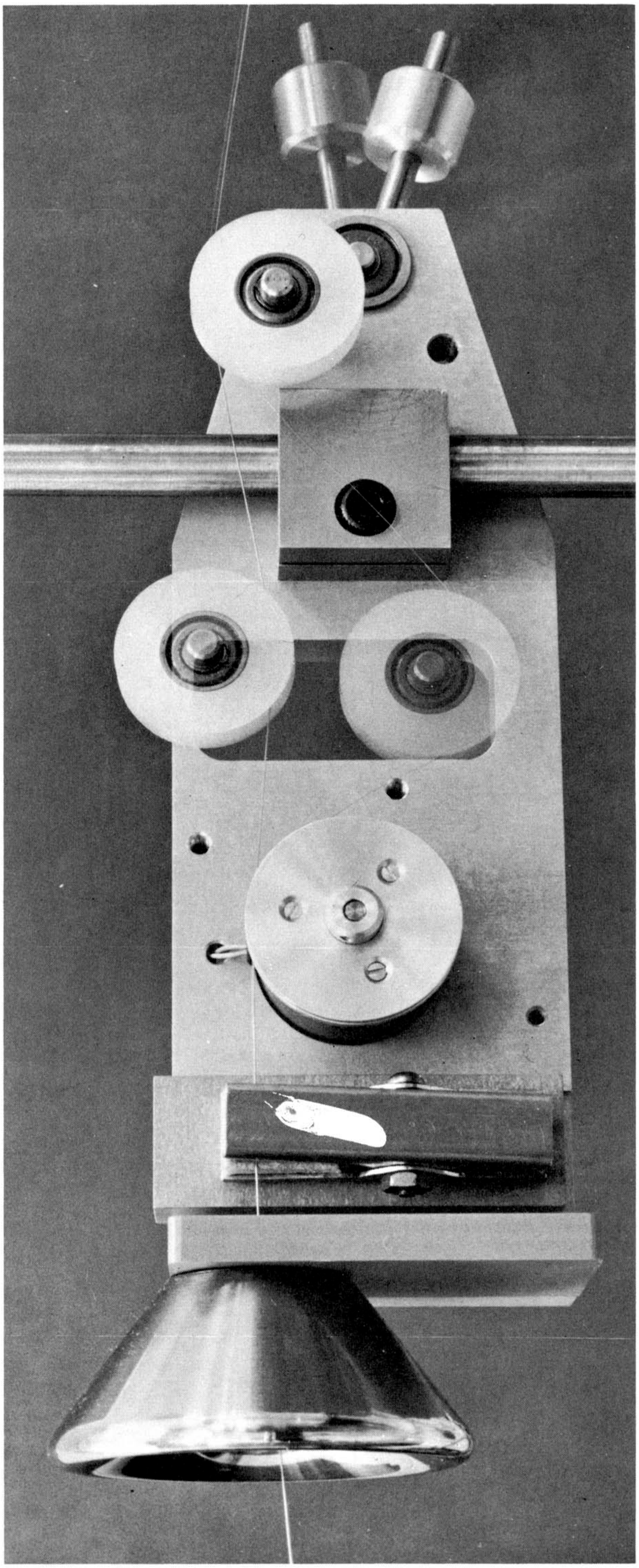

Figure 5

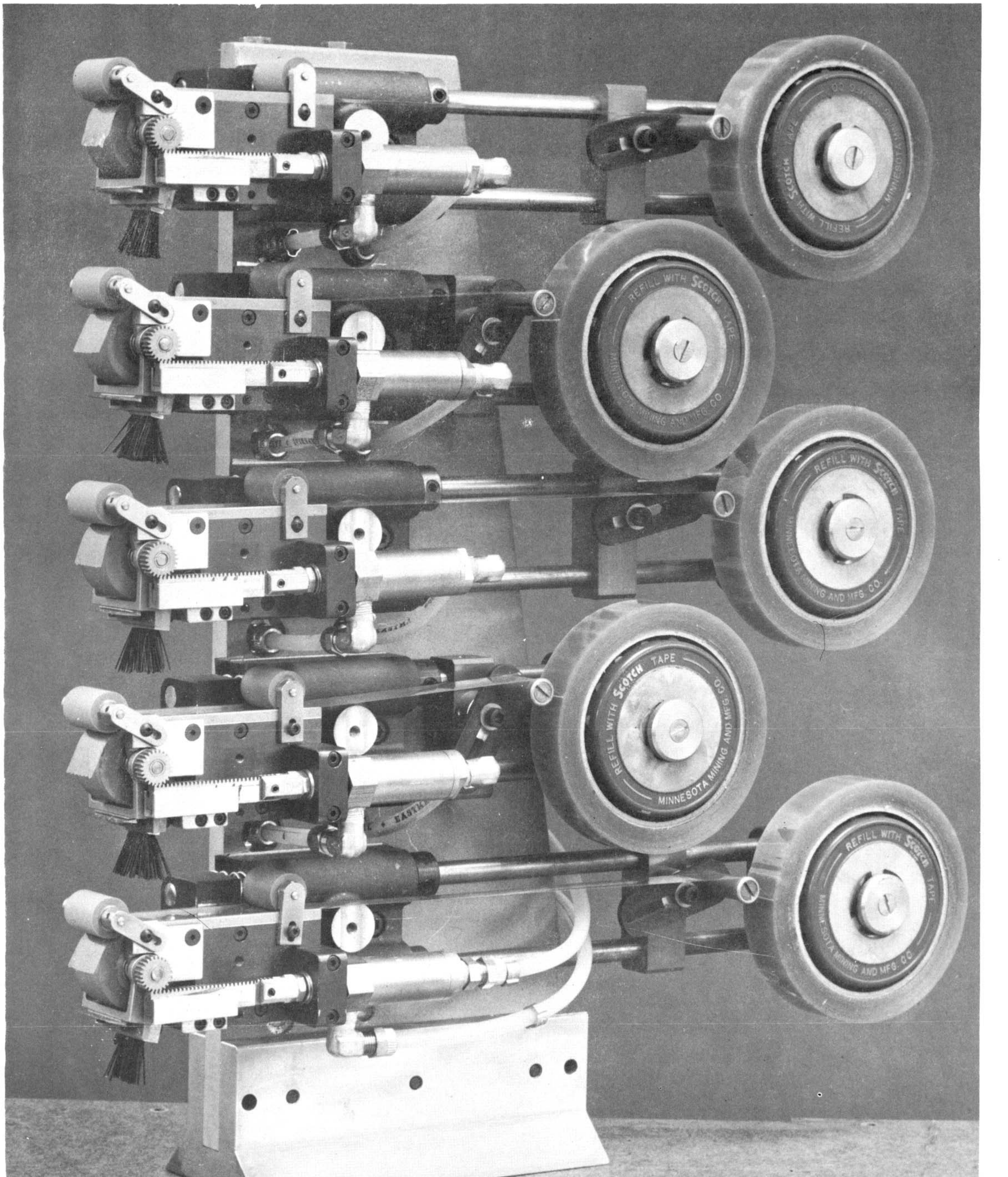

Figure 6

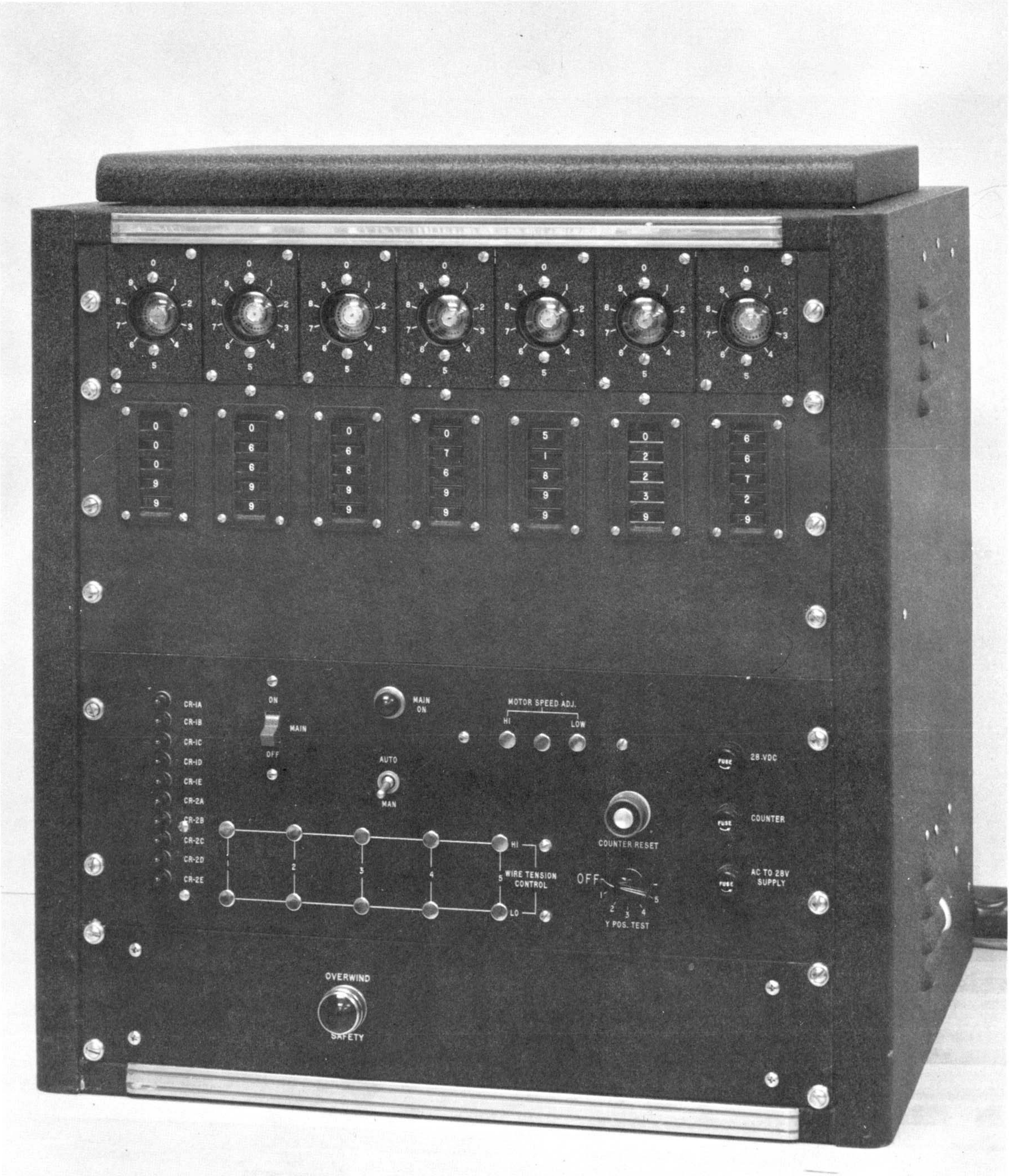
CR-IA
CR-IB
CR-IC
CR-ID
CR-IE
CR-2A
CR-2B
CR-2C
CR-2D
CR-2E
ON
MAIN
OFF
MAIN ON
AUTO
MAN
MOTOR SPEED ADJ.
HI
LOW
28-VDC
COUNTER
AC TO 28V SUPPLY
COUNTER RESET
WIRE TENSION CONTROL
HI
LO
OFF
Y POS. TEST
OVERWIND
SAFETY

Figure 7

the production rate could be justified economically. (See Figure #8) Bobbins would be manually loaded and unloaded on one of the dual sets of tailstock spindles during the winding cycle. The increased attendance of an operator would be more than offset by the increased production per machine. Further examination in the area of taping resulted in applying the cover tape on a separate taping machine designed and developed at the Center. This further reduced machine cost by approximately 20% with little added labor cost per coil. An important result of eliminating the taper from the winding machine was a substantial increase in machine efficiency, since taping represents the greatest trouble area. A prototype taping machine is presently being evaluated at Kearny (See Figure #9) The five spindle machine was recently returned to the ERC and converted to the semi-automatic design in order to wind ten coils simultaneously, two on each spindle. This machine has been returned to Kearny and is operating on a production basis. (See Figure #10)

Kearny attained quotations based on building three complete machines including the electrical control system and machine wiring. Boesch Manufacturing Co. of Danbury, Connecticut, a manufacturer of toridal coil and bobbin winding machines quoted $26,500 for each machine.

Winston-Salem became interested in the ERC Coil Winder for a multiple wound bobbin transformer coil used in the inband signaling system. This machine would wind and terminate five separate windings with tape between windings as required. Conversion to different coil codes would be programmed by patch board, thus attaining maximum versatility. Bobbins would be loaded and unloaded by an operator, thus reducing machine cost and increasing machine versatility for conversion to different bobbin sizes. A cost reduction case was initiated and approved based on employing two semi-automatic ERC Coil Winders.

Additional applications for these new winding techniques are presently being studied with other Works. These include conversion to bobbin of some filled coils for Wire Spring Relays and also the new Miniature General Purpose Wire Spring Relay being designed.

Traditionally, coil manufacture has been slow to automate. Many excellent coil winding machines are commercially available, but coil finishing operations such as terminating have remained manual operations. The introduction of low cost molded bobbins with inserted terminals and the increasing usage of solder-through wire insulation have made automatic coil winding possible. However, the degree to which a bobbin wound coil may be automated must be based on the resulting savings of automation and the initial machine investment.

Several 16 mm sound and color movies on ERC coil winding developments have been produced and are available for additional information.

J. S. CARTWRIGHT
Princeton

MINIATURE KEY RELAY COIL ANALYSIS

	BACHI COIL WINDER	ERC AUTOMATIC COIL WINDER	ERC SEMI-AUTOMATIC COIL WINDER
Coils/Hour	440 (560)	175 (210)	390 (495)
Machine Cost	$30,000	$40,000	$30,000
No. Machines Required	3	6	3
Total Machine Investment	$90,000	$240,000	$90,000
Basic Labor Hours Per 1000 Coils			
Operators/Machine	(1.0)	(.33)	(.50)
Wind	2.27	1.58	1.10
Terminate	3.79	.12	.18
Rack for Solder	.50	.50	.50
Tape	1.12	.20	1.12
Bend Terminals	----	.50	.50
TOTAL Basic Labor Hours Per 1000 Coils	7.68	2.90	3.40

Fig. #8

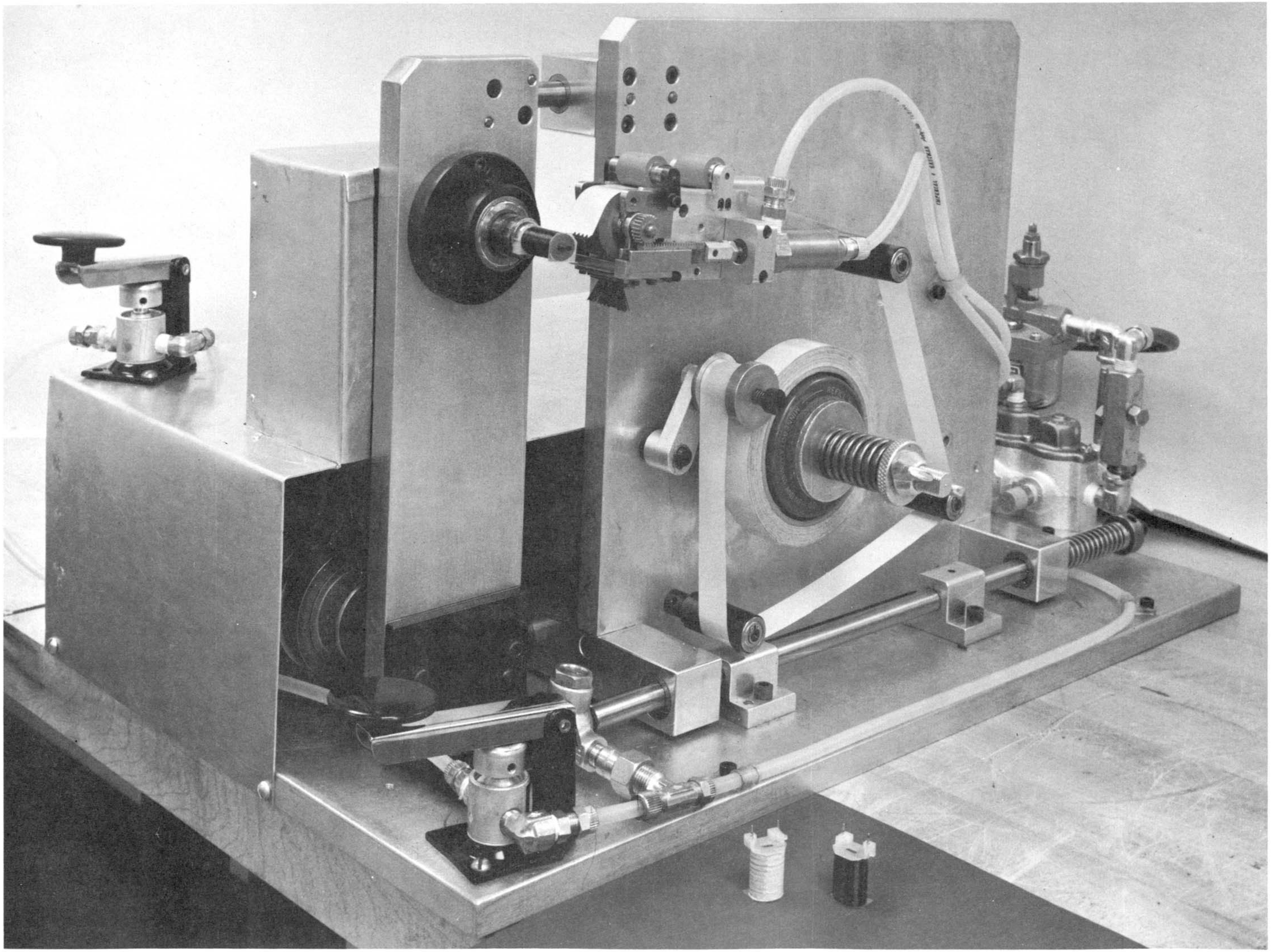

Figure 9

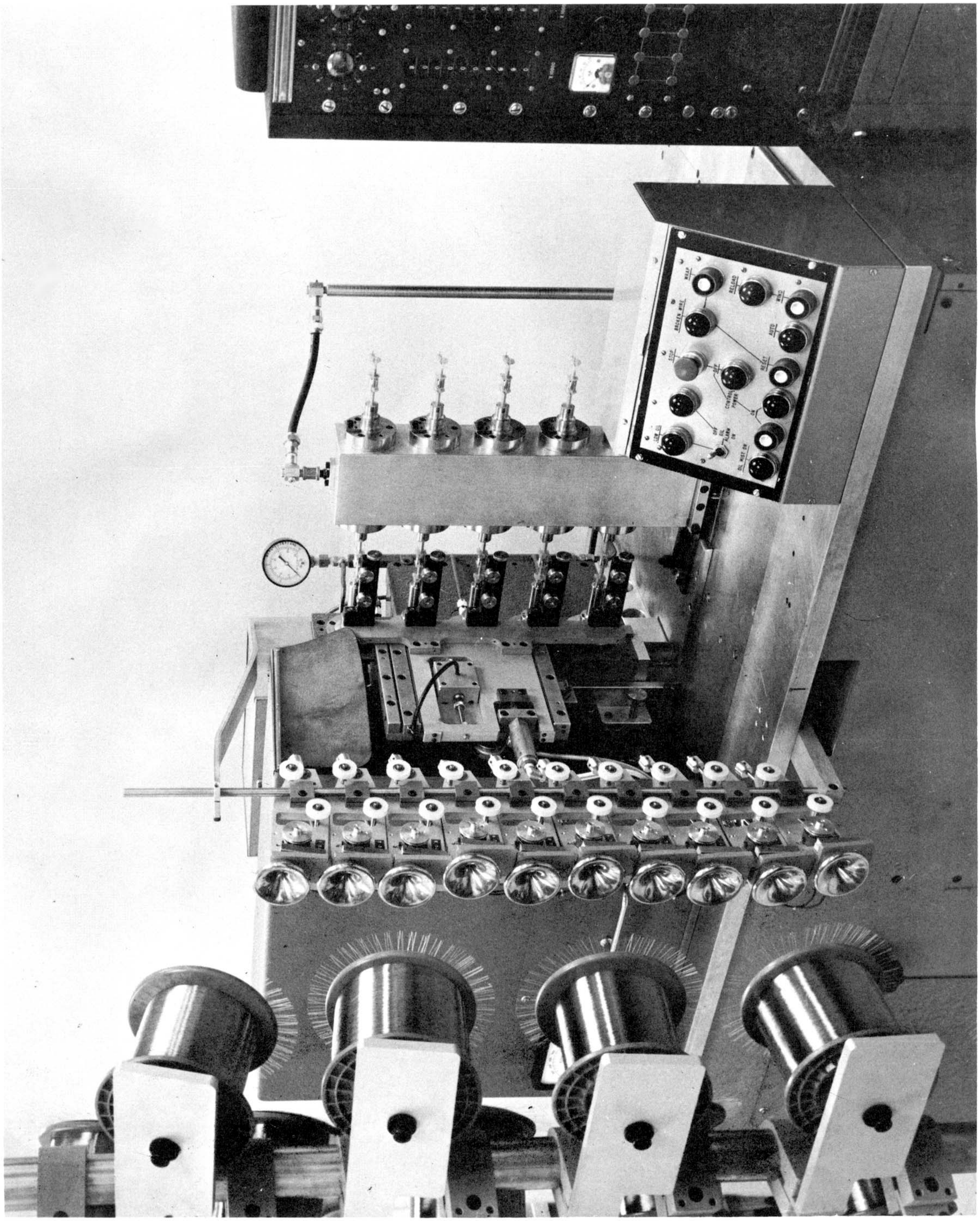

Figure 10