Dec. 1, 1953 A. FOWLER 2,661,208

FEEDING OF MAGNETIC SHEET MATERIAL

Filed May 16, 1951 4 Sheets-Sheet 1

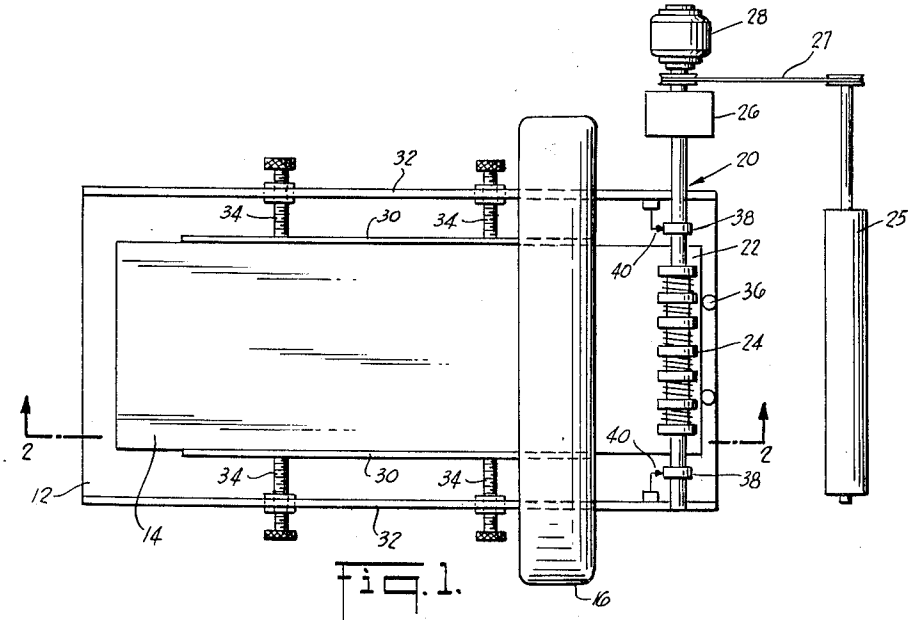


Fig. 1.

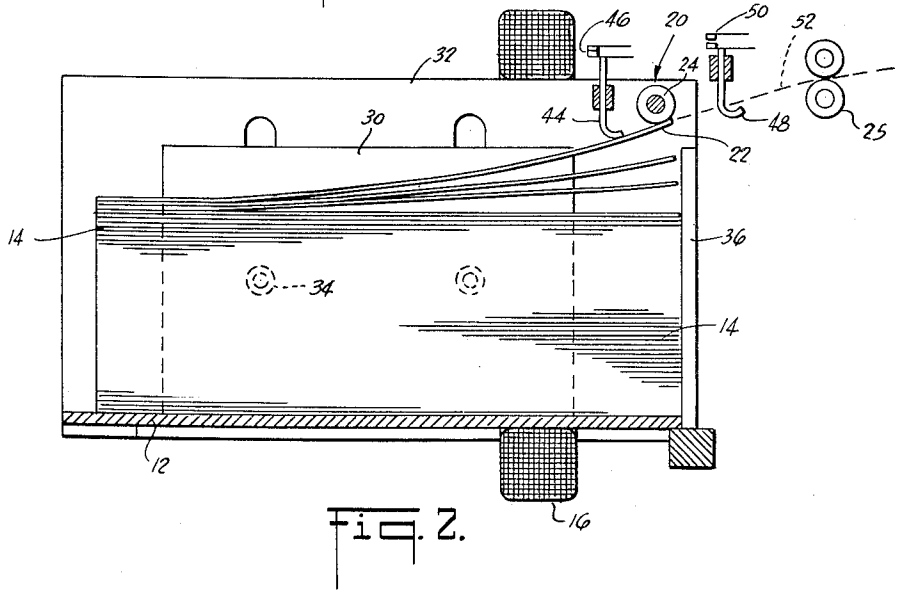


Fig. 2.

INVENTOR.
ALEXANDER FOWLER
BY James and Franklin
ATTORNEYS

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FEEDING OF MAGNETIC SHEET MATERIAL

Filed May 16, 1951 4 Sheets-Sheet 2

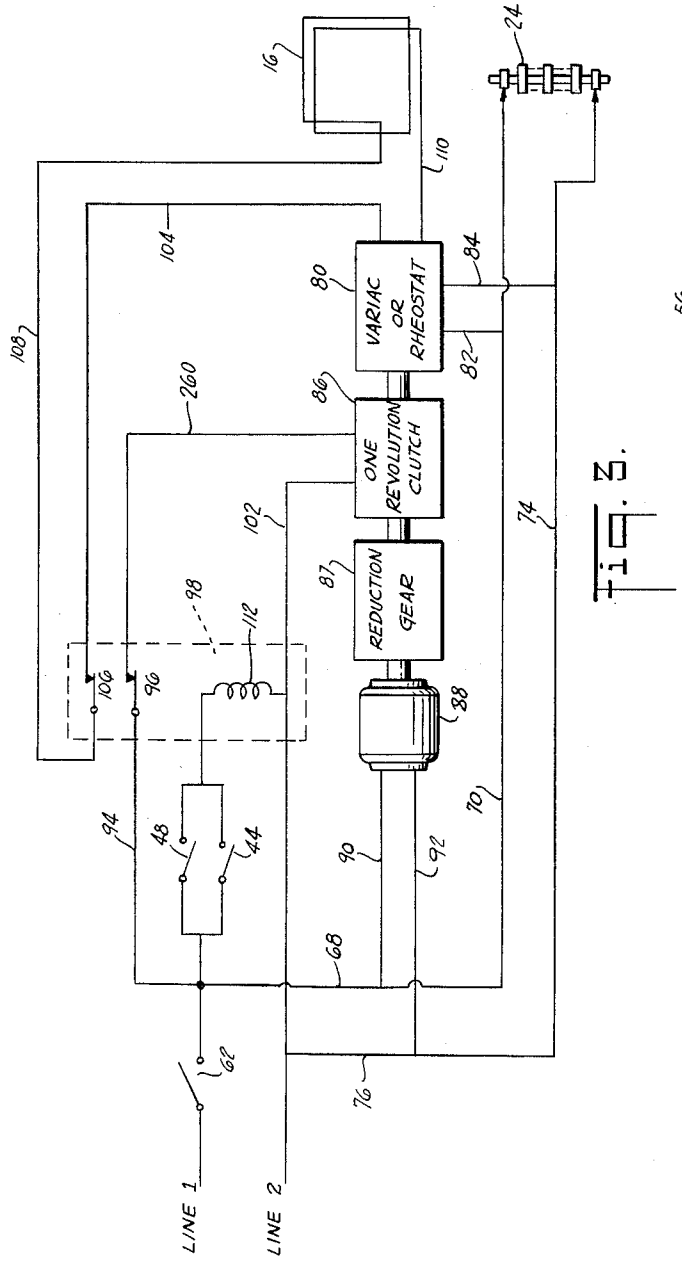


Fig. 2.

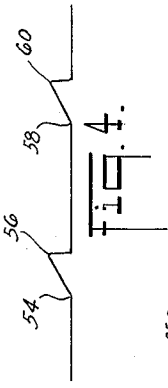


Fig. 4.

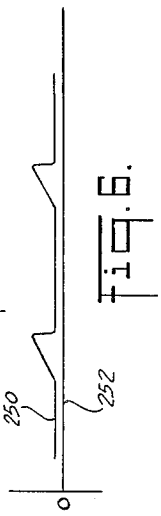


Fig. 6.

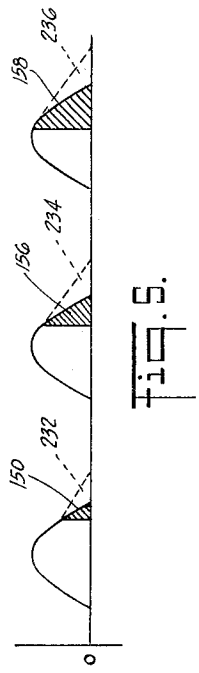


Fig. 5.

INVENTOR.
ALEXANDER FOWLER

BY James and Franklin

ATTORNEYS

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FEEDING OF MAGNETIC SHEET MATERIAL

Filed May 16, 1951 4 Sheets-Sheet 3

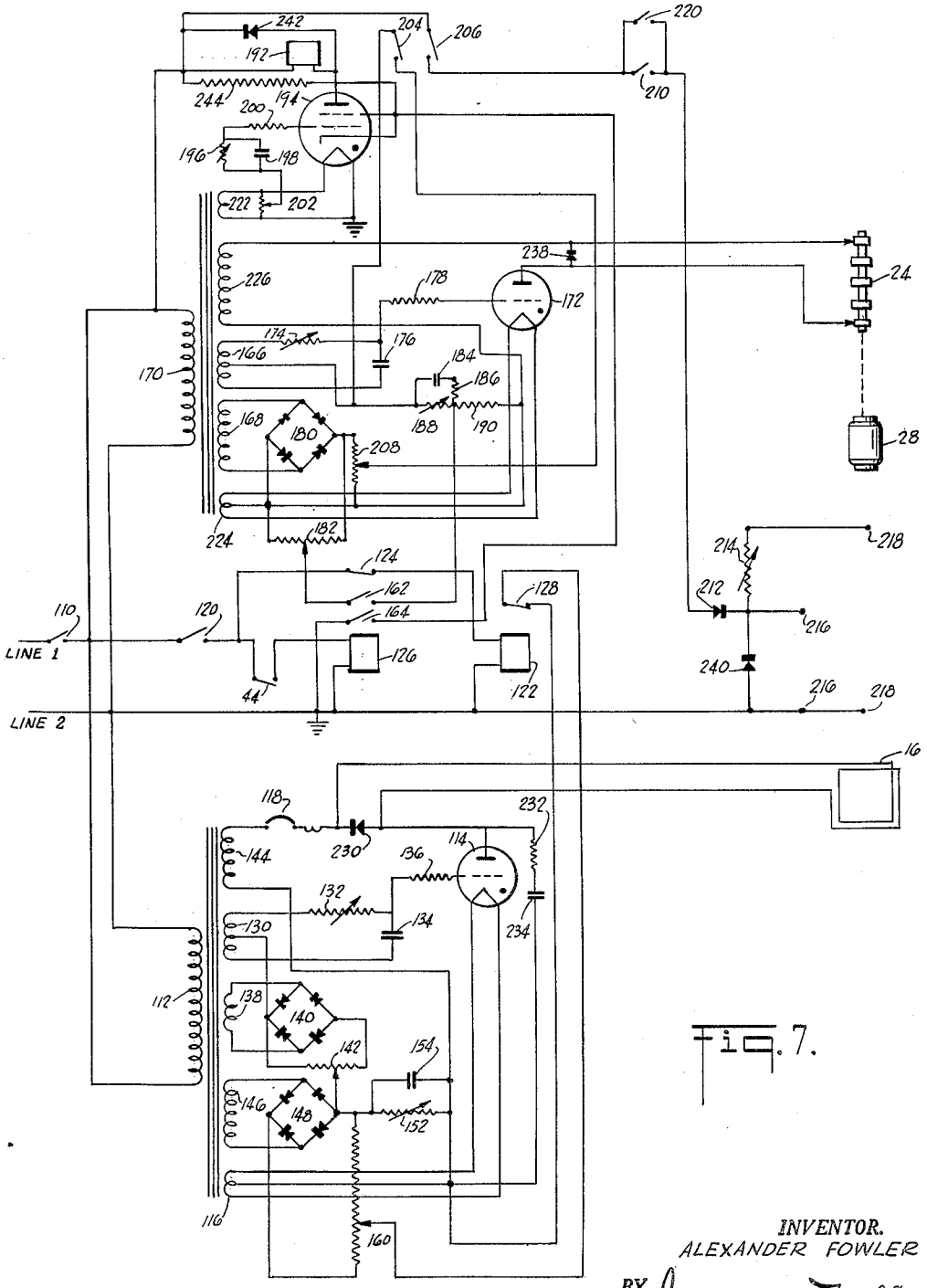


Fig. 7.

INVENTOR.
ALEXANDER FOWLER
BY James and Franklin
ATTORNEYS

Dec. 1, 1953 A. FOWLER 2,661,208

FEEDING OF MAGNETIC SHEET MATERIAL

Filed May 16, 1951 4 Sheets-Sheet 4

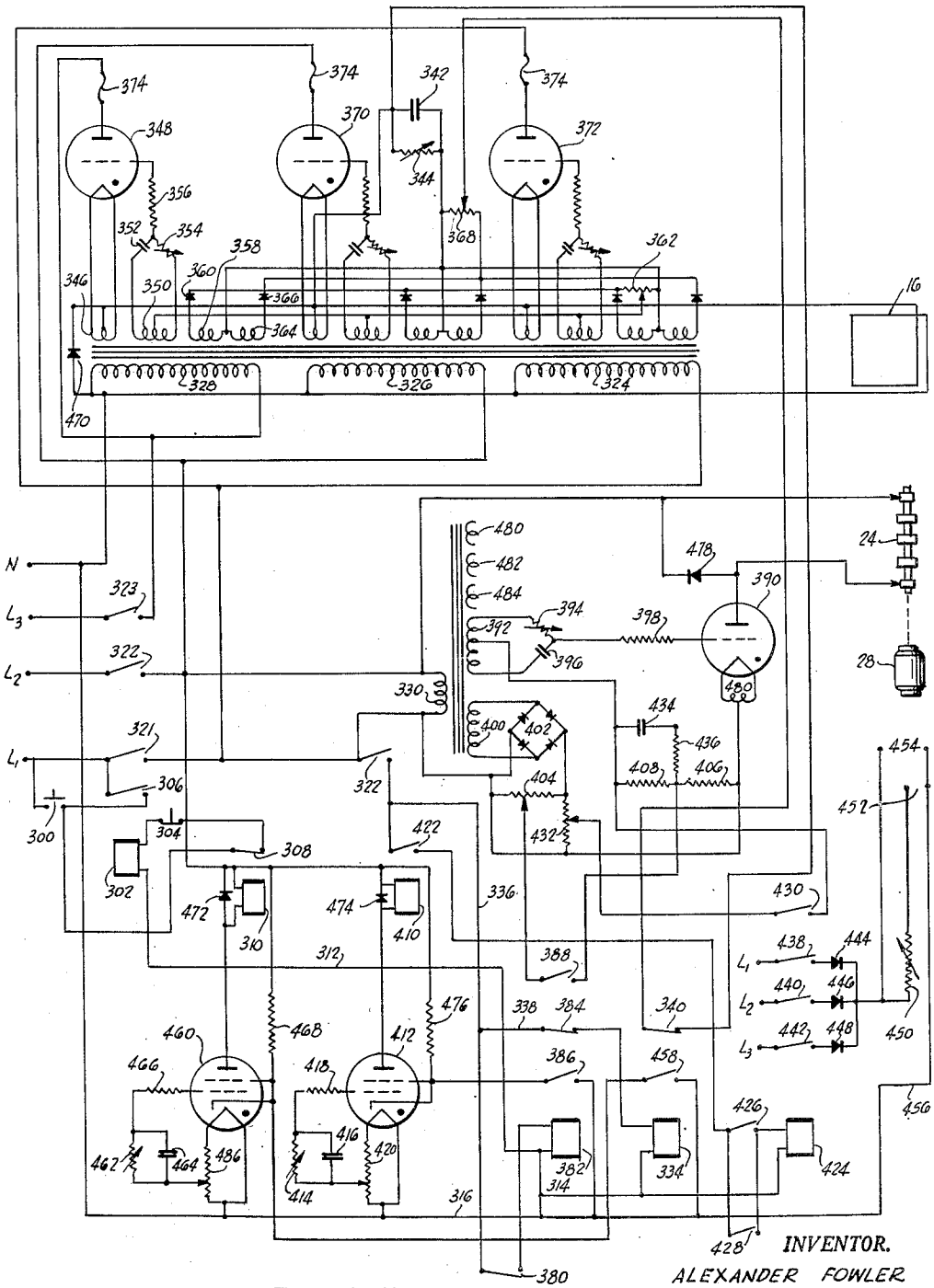


Fig. 8.

INVENTOR.
ALEXANDER FOWLER
BY James and Franklin
ATTORNEYS

Patented Dec. 1, 1953

2,661,208

UNITED STATES PATENT OFFICE

2,661,208

FEEDING OF MAGNETIC SHEET MATERIAL

Alexander Fowler, Brooklyn, N. Y., assignor to Hercules Electric & Mfg. Co., Inc., Brooklyn, N. Y., a corporation of New York

Application May 16, 1951, Serial No. 226,656

28 Claims. (Cl. 271—18)

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This invention relates to the feeding of sheet material, and more particularly to the automatic separation and feeding of single sheets in succession from a stack of ferromagnetic sheets.

The primary object of the present invention is to generally improve magnetic sheet separation and feeding apparatus. A more particular object is to produce a wide separation of the sheets magnetically.

A further object of the invention is to guard against the possibility of more than one sheet adhering to the feed roller. In accordance with my invention this object of insuring the feeding of only a single sheet at a time may be fulfilled by energizing the main induction coil with a slowly growing current (or one tooth of a low speed saw-tooth wave). In such case the topmost sheet begins to separate ahead of the next subjacent sheet, and so on, and there is a relatively wide and individual separation of the sheets as the topmost sheet reaches the feed roller. When the top most sheet reaches the feed roller the energization of the main induction coil is terminated, and the topmost sheet is promptly fed from the stack.

A further object of the present invention is to eliminate the need for an elevator table by affording so substantial a lift of the topmost sheet as to accommodate the reduced height of the stack as it is consumed.

Still another object of the present invention is to provide electronic circuits and apparatus for supplying the desired saw-tooth or growth current for energization of the magnetic field. The term "growth current" is more apt than "saw-tooth current" because for the present purpose the important thing is that the current grow from a relatively low value to a relatively high value, but there is no need for the increase to be a linear one.

Still another object of the present invention is to provide electronic circuits which will operate on a single phase power supply, and on a three phase power supply.

In many cases the sheets of the stack tend to adhere tightly because of an oil film therebetween. This is particularly true in winter, for although the separating means may be located in a building, the sheets are more usually stored outdoors or in an unheated storage shed from which they are brought to the separating means without a long warm-up period in which they might gradually acquire the building temperature. Further objects of the present invention are to provide apparatus which will help overcome adhesion between the sheets, and which will prevent repeated or renewed adhesion of the sheets while in the sheet separating apparatus.

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For certain purposes it may be desired to feed each sheet bit by bit, as for example to a shearing press, until the entire sheet is consumed, before starting the separation and feed of a second sheet, and a further feature and object of the present invention is to provide means for this purpose.

To accomplish the foregoing general objects, and other more particular objects which will hereinafter appear, my invention resides in the sheet separating and feeding elements, and their relation one to another, as are hereinafter more particularly described in the following specification. The specification is accompanied by drawings in which:

Fig. 1 is a plan view of sheet separating and feeding apparatus embodying features of my invention;

Fig. 2 is a section taken in elevation approximately in the plane of the line 2—2 of Fig. 1;

Fig. 3 is a schematic wiring diagram explanatory of one form of my invention;

Fig. 4 is explanatory of a current growth curve or saw-tooth wave used in my invention;

Fig. 5 is explanatory of the operation of a modified electronic apparatus shown in Fig. 7;

Fig. 6 is a current growth curve generally similar to that shown in Fig. 4 but explanatory of a modification;

Fig. 7 is a schematic wiring diagram for an electronic form of my apparatus energized from a single phase power supply; and

Fig. 8 is a schematic wiring diagram of electronic apparatus energized from a three phase power supply.

The present application is a continuation-in-part of my prior application of like title, Serial No. 129,662, filed November 26, 1949, and some of the foregoing objects, as well as the subject matter of Figs. 1 through 4 hereinafter described, have been taken from that application, while the additional subject matter is new in the present application.

Referring to the drawing, and more particularly to Figs. 1 and 2, the apparatus comprises a bed or table 12 for supporting a stack of sheets 14, and an induction coil 16 which extends entirely around the stack 14 and the table 12, and which acts as a sheet separating means. The axis of the coil extends in the direction in which the sheets are to be fed, which in this case is horizontally, from left to right. The ap-

paratus further includes feed means generally designated 20 for feeding the uppermost sheet 22 through the coil 16 and away from the stack 14. The feed means 20 preferably includes an electro-magnetic roller 24 capable of feeding sheet 22 with the latter disposed beneath the roller. The roller is preferably intermittently driven, as by means of a magnetic clutch 26 disposed between the roller and a constantly rotating motor 28. The latter may rotate one or more sets of later feed rollers, indicated schematically at 25, through a drive 27.

The sheets may be stacked between guide plates 30, supported within side plates 32, preferably by means of adjusting screws 34, so that sheets of different width may be accommodated. The sheets are aligned at their forward edge by means of front stops such as the posts 36, which are preferably made of non-magnetic material. The table 12, on the other hand, may be made of ferrous or magnetic material in order to repel and raise even the last sheet of the stack.

Before referring to the wiring diagram, attention is directed to the slip rings 38 (Fig. 1) and brushes 40 which supply magnetizing current to the coils 42 of the feed roller 24. Also the feeler 44 (Fig. 2) controlling switch contacts 46. When the topmost sheet 22 reaches the feed roller 24 the feeler is moved from a lower down-position to the position 44 shown, thus closing the normally open contacts 46. It will be understood that the showing in Fig. 2 is merely schematic, and that in practice a fully enclosed and sensitive microswitch may be used for the intended purpose. Moreover, other means to discriminate between the absence or presence of a sheet may be used.

It is desirable to delay re-energization of the main induction coil until the trailing edge of a preceding sheet has safely left the magnetic feed roller 24. This avoids any possibility of the next top sheet being caused to fly upward prematurely, in which case the forward portion of said sheet may strike the bottom of the trailing portion of the preceding sheet, thus holding it back both physically and magnetically, or, in the alternative, causing the second sheet to be prematurely pulled forward by the first sheet. This result may be accomplished by using a time delay relay, or by using a second feeler, and the latter arrangement is schematically shown in Fig. 2 in which it will be seen that a second feeler 48 is provided outside the stack, said feeler serving to close contacts 50 when engaged by a sheet 52 passing through feed rollers 25. This is described further as an incident to the description of Fig. 3 which follows.

Motor-driven growth curve circuit

Referring now to Fig. 3, the main feature of this arrangement is that the induction coil 16 is energized by a gradually increasing current which starts at zero and rises to a desired value. Thus the current may follow an intermittent saw-tooth wave such as that illustrated in Fig. 4. In Fig. 4 it will be seen that the current rises from the point 54 to a maximum at 56, whereupon it is cut off and remains off until the point 58. The interval between points 56 and 58 corresponds to the time during which the sheet is fed away from the stack by the feed roller. When the main induction coil 16 is re-energized beginning at point 58 the current again increases to a maximum as indicated at 60 and is again cut off.

If the induction coil is energized in this manner the topmost sheet tends to be raised from the next subjacent sheet before the latter is raised at all, whereupon both rise before the third sheet rises, so that the fanning out or divergence or separation of the sheets is maintained as the induction coil is further energized. In any event the topmost sheet alone reaches the feed roller, and the induction coil may then be de-energized without danger of the feed roller holding more than one sheet. Indeed, by promptly de-energizing the induction coil when the topmost sheet reaches the feed roller it is found that the feed roller may be left at full energization, and further that it may be kept under constant rotation. Thus the apparatus of Fig. 3 is more complicated in introducing suitable means to apply a growth current or saw-tooth current to the induction coil, but may be simplified in other respects as by eliminating the electrically operated clutch for the feed roller shown in Fig. 1.

Referring to Fig. 3, a main power switch 62 is closed to supply power from an ordinary source indicated by lines 1 and 2. This supplies power through conductors 68 and 70 to feed roller 24, the return being through conductors 74 and 76 to line 2. The power supply to the induction coil 16 is varied by means of a suitable variable impedance 80. If the power supply is alternating current this may be either a conventional "Variac" or a rheostat. "Variac" is a trade name of the General Radio Company for a variable voltage transformer (disclosed in Patent #2,009,013). It is a device which increases or decreases voltage by mechanical rotation of a contact engaging the windings of a transformer. If the power supply is direct current the variable impedance would, of course, be a rheostat. The power supply to the Variac 80 is from line 1 through conductors 68, 70 and 82, the return being through conductors 84, 74, and 76, and back to line 2.

The Variac 80 is driven through a one-revolution clutch 86 and reduction gearing 87 by means of a motor 88 energized from the power line through conductors 90 and 92. One-revolution clutch 87 is electrically operated, and is initially engaged because of a supply of power from line 1 through conductor 94, normally closed contacts 96 of relay 98, and a conductor 100. The return is through a conductor 102 to line 2. The resulting rotation of the Variac causes a growth in output current from zero until the one-revolution clutch disengages. The power available in this way for the main induction coil 16 could grow to a value greater than needed to raise the first sheet into engagement with the feed roller, but the power supply is interrupted by suitable means as soon as the sheet reaches the feed roller. The mechanical rotation of the Variac is continued under drive of motor 88, and is terminated after one revolution by the operation of the one-revolution clutch, thus preparing the apparatus for the separation and delivery of the next sheet.

In the meantime the growing current is supplied from the Variac through conductor 104, the normally closed contacts 106 of relay 98, and conductor 108 to the induction coil 16, the return being through conductor 110.

In the present apparatus the complete passage of a sheet is determined by the use of two feelers as shown in Fig. 2, instead of a single feeler combined with a time delay relay, although either arrangement might be used. The first and second feelers or microswitches are in-

dicated at 44 and 48. The contacts are normally open. When the topmost sheet flies upward and reaches the feed roller it closes the switch 44, thus energizing relay coil 112 and so opening the contacts 106 and thereby interrupting the energization of the induction coil. This drops all sheets but the uppermost sheet, the latter being held by the fully magnetized feed roller, which may be constantly rotated and which promptly begins feeding the sheet out of the stack. In this case the feed roller may be permanently magnetized, as by making the same of Alnico or other highly magnetic material. However, as here shown it is magnetized electrically, with a constant current supply.

Energization of relay 93 opens the contacts 96 and thus de-energizes the electrically controlled clutch 86 so that when it disengages at the end of a single revolution it will not again engage unless and until the preceding sheet has been fed entirely out of the apparatus.

When the trailing edge of the sheet leaves the feeler 44 the relay coil 112 is not yet de-energized because of the action of the feeler 48, and therefore the main induction coil is not yet re-energized. However, when the trailing edge of the sheet leaves the second feeler 48 the relay coil 112 is de-energized, the contacts 96 and 106 are again closed, and the induction coil is again energized to raise another sheet to the feed roller.

In Fig. 3 the drive motor for feed roller 24 is not shown. It may be any motor connected to the available power supply. It may run continuously, and the feed roller may be energized continuosly, with no disadvantage except a slight waste of electric power. Continuous feed of sheets one after another is contemplated. However, by additions to the circuit one may provide intermittent energization of the motor or/and the roller, and manual or treadle controlled feed. Thus a clutch 26 is shown in Fig. 1, for intermittent operation of the feed roller while permitting continuous run of the motor 28. Some of these features are described later.

It will be seen that the described apparatus provides a gradually increasing current in the main winding 16. The term "gradually" is to be understood in a relative sense, for if the apparatus is operated at high speed to feed a sheet every few seconds the entire growth of the current may occur in a very short time, yet that time is long compared to an instantaneous application of full current. With a growth current the first sheet will be raised from the second, following which the second will be raised from the third, while the first will tend to maintain its distance from the second, and so on, thus causing all the sheets to separate from one another and to fan out over a substantial distance. This eliminates the need for critical adjustment of the circuit elements and current values. It provides a large tolerance in the operation of the apparatus, so that if one sheet varies somewhat from another in thickness or weight, etc., the operation will nevertheless be unhampered.

Even the refinement of an elevator table has been found unnecessary, and in a particular case I have located the feed roller 16'' above the table, making it possible to feed sheets from a stack 14'' high. The stack may be fed down to a thickness of, say 2'', so that in effect, a 12'' stack may be fed, and then another 12'' stack added to the residual sheets.

The residual stack is preferably left on the table because it acts as a priming stack and makes possible the full desired lift. If only two sheets were left on the table the magnetic force might separate them a few inches, but by having nine or ten sheets left on the table there is a multiple separation between the multiple sheets, so that the top sheet may be raised the desired 14'' to the feed roller. Thus when feeding the last few sheets above the priming stack the entire priming stack may be seen to fan up and down during each feed cycle. This incidentally helps insure breakage of the oil seal between successive sheets.

Single phase electronic circuit

The system of Fig. 3 is an electro-mechanical system because of the motor drive employed to produce the growth current. However, a substantially wholly electronic system is shown in Fig. 7, and eliminates the need for the motor, clutch, and Variac shown in Fig. 3. The specific system employs a thyratron, and fires the thyratron by means of a trigger wave. The main induction coil of the apparatus receives the D. C. or rectification increments. The trigger wave is shifted, and this provides a growth current because of the increasing increments of plate current as the firing point of the thyratron changes.

The plate and grid waves of the thyratron may be of like frequency and each of uniform magnitude, but relatively shiftable in phase. With the waves 180° out of phase no current will flow, and with the waves in phase a maximum current will flow. At intermediate values the current supplied by the thyratron may be varied by shifting the phase of the trigger wave supplied to the grid. On the other hand the trigger wave and the plate wave may be given a phase difference which is maintained constant, and the axis of the trigger wave may be raised or lowered by changing the magnitude of a bias superimposed thereon. This also has the effect of varying the plate current, and because either method or a combination or both may be employed I prefer to use the broad term "shift" in respect to the trigger wave, in order to include either a phase shift or a bias shift, or both.

Referring to Fig. 7, the main coil is shown at 16, and the magnetic feed roller at 24, the latter being driven by a motor 28. Single phase power is supplied at lines 1 and 2. The apparatus of Figs. 1 and 2 applies to this circuit, except that the clutch 26 of Fig. 1, and the second trip switch or microswitch 48 of Fig. 2, are omitted. The first trip switch 44 is employed.

When the main switch 110 is thrown on, the transformer 112 is energized, heating the filament of thyratron tube 114, through secondary 116. After the tube is warmed up a circuit breaker 118 is closed, and then the operating switch 120 is closed, which starts the cycle as follows:

Relay 122 is energized from line 1 through the normally closed contacts 124 of relay 126, which is still de-energized because the trip switch 44 is open. Actuation of relay 122 opens the contacts 128. When contacts 128 of relay 122 open the growth current starts and the sheets begin to separate. The growth current is obtained from the transformer secondary 144, and is controlled by thyratron 114. A trigger wave is supplied from transformer secondary 130 to the grid.

The resistor 132 and capacitor 134 provide a phase shifting circuit for the trigger wave. The series resistor 136 limits the grid current. Resistor 132 of the phase shifting circuit is variable to permit fine control of the phase relation

of trigger wave or grid voltage to plate voltage.

Secondary 138 of transformer 112, in conjunction with full-wave rectifier 140 and potentiometer 142, provides a positive D. C. grid potential or bias which raises the axis of the trigger wave and so increases the amount of plate current fed through the main sheet separating coil 16. This bias may be set for the maximum desired amount of thyratron plate current. Transformer secondary 146 and rectifier 148 supply a negative bias to lower the axis of the trigger wave. The thyratron plate current is in alternate or positive half waves, as suggested in Fig. 5. The trigger wave from secondary 130 has its phase displaced by the resistor and capacitor 132, 134, and has its horizontal axis raised by the bias supply 138, 140, the amount being adjustably controlled by potentiometer 142. As the circuit goes into operation, however, the effect of the rectifier circuit 146, 148 is to pull the axis of the wave down again. It is initially pulled down to a point where none, or if desired, only a small chip of plate current flows as shown at 158 in Fig. 5. The amount that it is pulled down then decreases by reason of an R. C. decay circuit 152, 154 (Fig. 7). As the axis of the A. C. grid voltage wave rises its point of firing of the thyratron keeps moving effectively to the left, thus causing larger and larger chips of plate current to flow through the thyratron as shown at 156 and 158 in Fig. 5. Potentiometer 160 (Fig. 7) is an additional current control which may or may not be required in a particular application. It controls how far the A. C. wave is brought down.

It will be noted that potentiometers 142 and 160 are inter-dependent controls which overlap in the sense that if there is less rise to begin with, then less drop would be needed to reach a certain plate current value. In a sense therefore the duplicate controls may not be needed, and in a simpler circuit one or the other may be employed alone.

Leaving the lower part of the diagram which produces the growth current, the energization of the main coil 16 causes the sheet to rise until it reaches the magnetic roller 24 and the trip switch 44, closing the latter, and energizing the relay 126, which functions to magnetize the feed roller 24 and to start the feed motor 28. In the particular circuit here shown the magnet coils of the feed roller 24 are energized through a thyratron tube 172 controlled much as previously described, but with a view to providing two widely different stages or uniform amounts of magnetization of the feed roll, as well as a complete cut-off when the feed roll is not in use. A relatively small magnetization is adequate to hold the topmost sheet while the main coil 16 is being de-energized to permit descent of the other sheets. A substantially higher degree of magnetization is employed to actually feed the sheet.

It may be explained that I find it preferable to employ a thyratron as a switch for controlling the energization of the roller because it avoids difficulty with oxidation of contacts of ordinary mechanical relays. The thyratron further serves as an energy controlling means, thus eliminating the need for a power rheostat with its high dissipation of energy to bring the feed roller down to desired energization. Moreover, we can incorporate in the same tube circuit a means to provide a time delay action before decay of the magnetic roller current, which delay is desired in the manual operation explained latter. To summarize, in the special case where time delay de-energization is wanted, in addition to two-stage magnetization, the thyratron serves three purposes in one, and is trouble-free in maintenance.

Energization of relay 126 opens contacts 124, deenergizing relay 122, and permitting contacts 128 to again close. This bucks the trigger wave elevating potential of thyratron 114, and so collapses (either completely or partially) the field in the main coil 16. The field in the main coil is collapsed because the trigger wave axis is lowered by rectifier supply 146, 146, thus pulling the A. C. trigger wave down to the point where the thyratron does not fire (or fires at desired minimum).

At the same time relay 126 also closes its contacts 182 and 184. Contacts 182 initiate the cycle of the upper thyratron tube 172 with the aid of secondaries 186 and 188 of transformer 170. Secondary 186 provides the trigger wave, and resistor 174 and capacitor 176 provide the phase shift of the trigger wave, which controls the firing of the thyratron and so controls the degree of energization of the magnetic roller 24. The resistor 178 limits grid current.

Secondary 188, through rectifier 180 and potentiometer 182, through relay contacts 182 leading to the capacitor 184 and resistors 186, 188, 190 provide positive grid potential to thyratron 172, thereby causing whatever plate current is required to energize the magnetic roller at its lower stage of magnetization.

Contacts 184 initiate the operation of a time delay relay built around tube 194. Tube 194 is used with a decay circuit to act as a timer to delay rotation of the feed roller after the sheet has reached the roller (as indicated by closing of the trip switch 44). The time delay here is accomplished through grid rectification by means of resistor 196 and capacitor 198. The resistor 200 is used to limit grid current.

Because of grid rectification the capacitor applies a negative potential on the grid of the tube, and plate current does not flow. However, when the contacts 184 close the charge stored in capacitor 198 during the grid rectification period then discharges through the grid circuit 200, 196, 190, 202, 222, and when the discharge has reached a certain point the tube will fire. It is this time required for discharge that results in the desired time delay action of the circuit.

When the tube 194 fires a relay 192 is energized, closing contacts 204 and 206. Contacts 204 increase the current through magnetic roller 24 by supplying more positive potential than previously applied through contacts 182 of relay 126 to the grid of thyratron 172. For this purpose the adjustment of potentiometer 208 is made higher than that of potentiometer 182. At the same time the closing of relay contacts 206 energizes the feed motor 28 through switch 210, rectifier 212, and rheostat 214.

As so far described the operation would be wholly automatic, the delivery of one sheet following another, but in many applications a manual or pedal control is wanted, and for this purpose it is merely necessary to add any convenient form of manual or pedal switch 220 in parallel with the switch 210 previously mentioned, the latter then being opened or omitted, and the switch 220 being a normally open switch. Thus the diagram shows two arrangements in one, for with automatic operation switch 210 would be

closed and there would be no manual or foot treadle switch, but with switch 210 open it becomes necessary for an operator to close a manual or foot treadle switch 220 to initiate the operation. The motor is a shunt motor symbolized at 28, but electrically the terminals 216 represent the connections to the field of the motor, while the terminals 218 represent the connections to the armature of the motor. A shunt motor is used in order to give a wide range of speed control, and also because it can be started and stopped more readily than a single phase induction motor.

When the sheet leaves the feed roller 24 the trip switch 44 opens and relay 126 is de-energized. This opens contacts 162 and 164, and permits closing of contacts 124. The opening of contacts 164 cuts off the current flow through tube 194, de-energizing relay 192, and opening contacts 204 and 206. The opening of contacts 206 stops the motor. The opening of contacts 204, in conjunction with the opening of contacts 162 of relay 126, completely de-energizes the roller after elapse of a time interval caused by the delay circuit 184, 186 and 188. The closing of contacts 124 operates relay 122, thereby opening contacts 128, and so again initiating the growth current in the main sheet separating coil 16. This causes the cycle to repeat.

The described circuit is designed for apparatus in which not only the feed of an entire sheet, but also the partial feed of a sheet, say only one foot at a time to a shear press, may be controlled manually. In such case a single sheet lift is followed by a whole series of sheet feed movements to the press. For this purpose the feed roller might be left energized continuously, but that is not altogether desirable because of waste of energy, and possible overheating of the feed roller. Instead the feed roller preferably is energized only during its feed action, and is then reduced in energization to a value sufficient to hold the sheet up against the roller, although not enough to feed the sheet. In accordance with the present circuit, instead of the full energization taking place strictly in time with the operation of the feed motor, the time delay circuit 184, 186 prolongs the full energization for a brief interval, say one-half or one second, to make sure that the sheet does not break away from the feed roller because of its own inertia when the roller stops abruptly.

Thus in a simpler form the circuit of Fig. 7 might provide for continuous fully automatic feed of sheets, one immediately after the other, with continuous energization of the feed motor 28 and the feed roller 24. In slightly more complex form the feed roller may be de-energized between feed operations. In still more complex form the feed motor may be de-energized between feed operations. In still more complex form the feed roller may be energized with two degrees of magnetization, a lesser one for holding but not feeding a sheet, and a stronger one for feeding the sheet. In the present circuit there is the still further refinement of prolonging the full energization or magnetization of the roller beyond the rotation of the motor, a feature particularly useful for partial or incremental sheet feed.

Circuit breaker 118 is used in this circuit to protect the thyratron 114, and the main coil, and to act as a cut-off device if the tube is operated at maximum load for too long a time. The circuit breaker includes a thermal time delay mechanism to take care of the possibility of a sheet not being raised. It will be recalled that the raising of a sheet is what cuts off the energization of the main coil 16, and if no sheet is raised to the trip switch 44 something may be assumed to be wrong, and instead of letting the main coil be subjected to full energization indefinitely, it is cut off after, say four seconds, which is beyond any reasonable time needed to raise a sheet.

Secondary 116 of transformer 112 is the filament heating source for thyratron 114. Transformer secondary 222 of transformer 170 is used to heat the cathode of tube 194. The plate circuit of this tube is supplied directly from the line, rather than from a transformer secondary. Secondary 224 of transformer 170 is used to heat the cathode of thyratron 172. Secondary 226 of transformer 170 is used to supply plate current to thyratron 172, and consequently to magnetize the feed roller 24.

The rectifier 230 across the main coil 16 is used to give increased life to thyratron 114, and incidentally add energy to the main coil 16. The rectifier 230 is faced in direction opposite to the rectifier action of the tube, and functions during the negative plate cycle or rectifier cycle of the tube to discharge some of the magnetic energy of the main coil. It should be kept in mind that we deal here with a heavily inductive circuit. The rectifier 230 may be termed a "back rectifier."

An alternate idea which might be used but is thought less preferable is the use of a shunt circuit 232, 234 across the thyratron 114, this being a series R. C. circuit of very small current value to just effect the proper commutation time of the tube. In either case the idea is to help lessen the problem caused by tearing of electron surface material from the cathode of the tube because of the interrupted or pulse nature of the operation.

The use of a rectifier 230 has an important advantage over the use of a shunt circuit and that is in restoring or making useful some energy which would otherwise be wasted. This is symbolized in Fig. 5 by the parts 232, 234, 236 added to the normal increments 150, 156, 158, the parts 232, 234 and 236 corresponding to the energy fed back from the main coil. This is apart from the improvement in commutation. This same idea has here been employed also in connection with the feed roller circuit and even in connection with one of the relay circuits. Specifically the back rectifier 238 serves the purpose of improving commutation of thyratron 172 and at the same time adding energy to the circuit. The back rectifier 240 is used across the motor circuit to add energy to the circuit. The back rectifier of tube 194 is indicated at 242 and provides additional energy in the non-conducting cycle of tube 194, the additional energy going to relay 192. In all there are four back rectifiers used across inductive loads for the same principle as was explained above, except that in the case of one of them (rectifier 240) there is no question of commutation at a cathode, but in all of them there is some restoration of current from inductive load.

Resistor 244 is used in the circuit to connect the cathode and screen grid to the plate circuit to aid in grid rectification for the timing circuit.

In the description of the circuit of Fig. 7 I mentioned the possibility of only partially instead of wholly collapsing the field of the main induction coil 16. This may be explained with reference to Fig. 6 of the drawing, in which it will be seen that the growth curve or saw-tooth

wave is much like that shown in Fig. 4, except that a minimum current value 250 is provided somewhat above the zero current axis 252. This is a refinement which may be resorted to when dealing with sheets which tend to repeatedly adhere together, as, for example, if coated with a tacky oil film. The partial energization level 250 may be made such as to hold the sheets in slightly fanned or separated condition, so that they will not re-adhere each time they descend. Thus the growth current causes a progressive fanning of the sheets until the uppermost sheet reaches the feed roller, at which time the uppermost sheet is held by the feed roller and the remaining sheets are permitted to descend almost all the way, but not quite far enough to rest firmly on one another with the possibility of re-adhering. To accomplish this result it is merely necessary to so adjust the lowering of the trigger wave of the thyratron 114 (as determined by the inter-related potentiometer adjustments 142 and 160) as to provide small, uniformly maintained increments of plate current instead of complete cut-off.

To summarize the operation of the circuit of Fig. 7, thyratron 114 acts as a valve to control the main sheet lifting coil 16. The transformer secondary 144 supplies plate current and the transformer secondary 130 supplies a trigger wave to the grid. The phase of the trigger wave is shifted by the phase shifting circuit 132, 134. The height of the axis of the trigger wave is determined by adding bias potential supplied from a transformer secondary and bridge rectifier and potentiometer. In the present case there are two such bias circuits, one of which (138, 140, 142) elevates, and the other of which (146, 148, 160) depresses the trigger wave, the latter being effective when the main coil is not functioning, and the former being effective when it is. The growth of the plate current takes place because the trigger wave axis is raised by discharge of potential from the decay circuit 152, 154.

Thyratron 172 acts as a valve to control the magnetization of the feed roller 24. Transformer secondary 220 supplies plate current, and transformer secondary 166 supplies a trigger wave to the grid. The phase of the trigger wave is shifted by phase shifting means 174, 176. The height of the axis of the trigger wave is established by bias potential supplied by transformer secondary 168, rectifier 180 and potentiometer 182. This is adjusted to supply the needed current for the sheet holding stage. The magnetization is increased during the sheet feeding stage by raising the trigger wave axis, this being done by sending current through resistor 208, the current being supplied by relay 192 controlled by a third thyratron 194. The relay 192 also supplies current to operate the motor 28.

If it be desired to delay the start of the sheet feeding operation until after ample time for collapse of the main field and the fanned sheets, such delay is provided by a time delay circuit associated with tube 194 and using R. C. circuit 196, 198. The delay in firing of tube 194 delays both rotation and full magnetization of the feed roller.

If it be desired to briefly continue full energization of the roller after the motor stops, in order to compensate for inertia of the moving sheet, such prolongation is provided by the time delay or decay circuit 184, 186, 188. If semi-automatic sheet feed or fractional sheet feed is desired a suitable normally open manual or treadle switch 220 is employed, the switch 210 being opened or eliminated, but for fully automatic feed of successive sheets the switch 210 is kept closed.

Three phase electronic circuit

Three phase power supply is available in most industrial plants, and is preferred because it makes more efficient use of the power available.

A three phase circuit is shown in Fig. 8. The main power lines are marked L1, L2, and L3, with a neutral return N. The three phases are set up in Y form, but the entire circuit may equally well be set up in delta form, without the neutral return, in those areas of the country where that is the common practice. The circuit also can be adapted for two phase power supply.

Closing pushbutton 300 energizes contactor 302 which remains on through the interlock circuit switch 304. The closing of contacts 321, 322, 323 of the contactor 302 connects the three lines L1, L2 and L3 to the three transformers 324, 326 and 328, respectively, and also energizes the transformer 330. The transformers heat the filaments of the tubes. Contactor 302 sticks by reason of a circuit from L1 through contacts 306 through normally closed contacts 308 of a relay 310, through the coil of contactor 302, and conductors 312, 314, 316, and thence back to the neutral N of the line. After the tubes have been warmed up switch 332 in series with line L1 is closed, thereby energizing relay 334 by way of conductors 336 and 338. This opens the normally closed contacts 340 of relay 334, which initiates operation of the three phase circuit shown in the upper part of the diagram.

This three phase circuit is similar in operation to the previously described single phase circuit, except that there are three circuits, one for each phase, each of the three circuits being the same as that previously described, but with a single R. C. circuit to control the current growth. The R. C. circuit which lets the trigger wave rise is shown at 342 and 344.

Taking phase 3 or the supply from line L3 as typical, the operation is as follows: Secondary 346 of transformer 328 heats the filament of the thyratron 348. The plate is supplied directly from the line L3 rather than from a transformer secondary. Secondary 350 provides the trigger wave, and its phase is shifted by the circuit of condenser 352 and resistor 354. The resistor 356 is used to limit the grid current of the thyratron 348. The resistor 354 is adjustable to determine the phase shift. Secondary 358, together with rectifier 360, supplies the phase number three portion of the current which provides the positive D. C. potential to the grid of the thyratron 348. This positive potential, which is adjustable through potentiometer 362, determines the extent to which the trigger wave axis is raised. This is the maximum rise of the trigger wave, when not pulled down to initial or rest point, which may be either complete shut-off, or a residual value for slight sheet separation as before explained.

The potentiometer 362 which establishes the bias or height to which the trigger wave axis is raised, works in common for all three tubes. For bias purposes D. C. is wanted, and with a three phase circuit the bias producing current is obtained from all three phases with three rectifiers combined. In Fig. 7 a full-wave rectifier circuit 140 was employed, but in a three phase circuit it is enough to use simple half-wave rectifiers,

as shown, because of the overlapping of the three phases.

Secondary 364 of transformer 328 provides the negative bias used to lower the trigger wave to cut off or reduce the current flowing through thyratron 348. Here again there are three secondaries and three rectifiers for the three phases. The potentiometer 368 controls the degree to which the trigger wave is lowered; and here again the currents from all three are combined in a single potentiometer to obtain D. C. applied to all three tubes. The bias potential thus obtained is passed through the combination capacitor 342 and rheostat 344 so that when contacts 340 of relay 334 open the potential will decay through this combination 342, 344, and the time factor of this R. C. circuit determines the rate of growth of the current in the plate circuit of thyratron 348.

Similar description applies to the thyratron 370 of phase 2 and thyratron 372 of phase 1. A fuse 374 is used as a protection in the plate circuit of thyratron 348, and similar fuses are used for the other tubes.

In passing it may be mentioned that while a common control is used to raise the trigger wave, and a common control is used to lower the trigger wave, three independent controls are used for the phase shift of the trigger wave at each tube. This is shown at 352, 354 for thyratron 342 and similar or duplicate controls are shown for thyratrons 370 and 372, respectively. This is desirable because each trigger wave must be shifted in phase relative to the plate wave of its own tube, and also to fire alike, because although the tubes come within manufacturers' specification limits they may nevertheless have slight differences in firing potential, and the independent adjustment here provided makes it possible to bring them into uniform operation.

The combined outputs of the three thyratrons is a D. C. power supply for the main induction coil or sheet separating coil 16, and it is a growth current because of increasing increments, all as previously described in connection with Fig. 5, except that there are increments in three displaced phases which are combined in the common main coil 16. The lower terminal of the coil 16 is connected to the neutral return N, and the upper terminal has all three cathodes connected to it in common.

The ferrous sheet rises until it reaches the feed roller and trips the trip switch 380, shown at the bottom of the diagram. When trip switch 380 is closed it energizes relay 382, thereby opening contacts 364, and so deenergizing relay 334, and thus permitting contacts 340 to again close which provides the negative bias potential necessary to pull the trigger wave down and so collapse the main coil field, because when the full negative potential is applied to the trigger wave it cuts off triggering of the thyratrons (or reduces the output to a small residual).

Besides elimination of the main field, the other things accomplished by the trip switch are to energize the feed roller and to cause its rotation. A thyratron tube may be employed to control the supply of energy to the feed roller, and preferably does so in variable increments determined by shifting a trigger wave, because in that case the thyratron acts both as a switch and as a current controlling means, with no difficulty of dirtying of contacts, etc. Three phase energization of the roller might be employed by using three thyratrons, but in the present circuit the apparatus has been simplified by using only a single phase supply for the feed roller.

The trip switch 380, by actuating relay 382, closes contacts 386 and 388. The latter supplies a trigger wave from transformer secondary 392 to the grid of thyratron 390, through a phase shift circuit comprising a resistor 394 and capacitor 396. Series resistor 398 is used to limit the grid current. The plate of tube 390 is supplied directly from the line L2, instead of from a secondary. The secondary 400 of transformer 392, in conjunction with rectifier 402, provides a positive bias potential to raise the trigger wave. This causes the thyratron to supply current to the magnetic roller 24, for a partial or reduced energization for merely holding but not feeding the sheet. The rise of the trigger wave axis which determines the amount of current flowing through magnetic roller 24 is controlled by adjusting a potentiometer 404. In this apparatus, as in Fig. 7, the feed roller is operated in three stages, the first being zero energization during initial lifting of the sheet. The second is the present partial energization, sufficient to hold the sheet but not feed the sheet. This is applied the instant the sheet operates the trip switch, and before the roller rotates. The current flowing to the magnetic roller is taken from the lines L2 and L1, and is controlled by the thyratron tube 390, while resistors 406 and 408 complete the grid circuit.

With the closing of contacts 386 of relay 382 a time delay circuit centering on tube 412 is initiated. This delays action of relay 410 to provide a delay before starting and putting on the full energization of the roller, and among other things, affords time for the sheets, other than the top sheet, to descend. Here again grid rectification takes place through resistor 414 and capacitor 416, while resistor 418 limits the grid current. The potentiometer 420 controls to some degree the time of the delay. The main control is by adjustment of resistor 414 as part of the decay circuit using capacitor 416. The use of a time delay circuit at this point is a refinement, and in many cases will prove neither essential nor even desirable.

It may be mentioned that in this circuit the action of a single relay simultaneously applies full energization to magnetize the feed roller and to start the motor which rotates the feed roller. (In the alternative, it might engage the clutch of a continuously running motor.) The primary reason for the time delay is to delay rotation of the feed roller, but it then is also advantageous to delay full energization because it saves power, and avoids any possibility of tending to feed two sheets forward because of sticking at the back ends of the sheets if the sheets have not been given adequate time to descend fully (or to slightly fanned position). In many installations it will be found that full energization and rotation of the feed roller can be started instantly after the top sheet reaches the feed roller, but this part of the circuit is included in an excess of caution, to make delay available should it be found desirable.

After the time delay of tube 412 runs out it fires and relay 410 is energized, closing contacts 422. This energizes relay 424 through normally closed switch 426, or, if the operation is to be semi-automatic, through a normally open manual or foot switch 428, in which case switch 426 is to be assumed left open or omitted. When relay 424 is energized, contacts 430 close, and provide additional bias potential to the grid of thyratron

390, thereby increasing the plate current through the magnetic roller 24. The bias is controlled by a potentiometer 432, and the additional positive bias shunts or bypasses the R. C. circuit 434, 436, 408.

When relay 424 is energized contacts 438, 440 and 442 also are closed, thereby supplying current to the feed motor (shown symbolically at 28) through rectifiers 444, 446, 448, and rheostat 450. The armature terminals are indicated at 452, and the field terminals are indicated at 454, the motor being an ordinary shunt motor, with advantages previously stated. It receives the combined rectified current from the three phase lines L1, L2 and L3. Rheostat 450 may be used to adjust the speed of the motor. The motor return goes back through conductors 456 and 316 to the neutral return N.

If a foot switch 428 or other manually operated switch should be used for partial sheet feed, a time delay is preferably introduced before collapsing the magnetic field of the magnetic roller 24. This prevents possible dropping of the sheet from the rollers because of the inertia of the sheet when in motion. The desired delay is here obtained by the action of an R. C. circuit which delays the fall of the trigger wave of thyratron 390. The capacitor 434 acting with resistor 408, tends to absorb the new potential applied, thereby slowing up the fall of the trigger wave at the tube as the charge is dissipated through the R. C. circuit.

When the sheet has been wholly fed and leaves the trip switch 336, relay 382 is de-energized, and contacts 386 open, thereby shutting off the timing circuit of tube 412 and relay 416. The relay contacts 422 then open, which in turn opens the circuit of relay 426, thereby opening contacts 438, 440 and 442, which stops the feed motor 28. At the same time contacts 430 of relay 424 reopen, which would partially de-energize the magnetic roller were it not at the same time wholly de-energized because contacts 388 are opened when relay 382 is de-energized, and cut off entirely the flow of current through the thyratron 390 and the magnetic roller.

In addition the de-energization of relay 382 permits contacts 384 to re-close, which in turn energizes relay 334, thereby closing contacts 456 and opening contacts 340. The former initiates a time delay cut-off or non-sheet-lift safety circuit explained later, and the latter re-establish and initiate growth of current in the main coil 16.

Thus the entire cycle begins anew.

Some additional refinements and minor details of the circuit are next described. One is the provision of a non-sheet-lift safety means to cut off energization of the main coil 16 in the event that a sheet is not raised within a reasonable time. In the present case this is done by the provision of a time delay circuit centering about the tube 452. It will be recalled that by closing the operating switch 332 the relay 334 was energized, which in turn opened the contacts 340 to initiate the growth current, and at the same time closed the contacts 456. The latter contacts initiate operation of the time delay circuit, which in turn limits the total time that the growth current circuit may remain in its "on" condition. This may be, say four seconds, for if a sheet is not delivered within some such maximum reasonable time something may be assumed to be wrong, and the power supply to the main coil 16 is cut off.

The time delay circuit operates as follows: Grid rectification takes place through resistor 462 and capacitor 464, and causes a negative potential to be applied to the grid of tube 460 as a result of the charge built up on capacitor 464. Grid resistor 466 is used to limit the grid current. When contacts 458 of relay 334 close, the charge decays through resistors 462 and 466, and when it falls low enough the tube 460 fires, thereby actuating the relay 310 and opening its contacts 308, which shuts off the power to the entire system. This is so because contacts 308 are in the stick circuit of the main contactor 302, and let the contactor open, which opens contacts 321, 322 and 323, and so opens the main lines L1, L2 and L3. Resistor 468 is used to tie the cathode into the plate to aid in grid rectification. During all normal operation a sheet is lifted and reaches the roller long before the tube 460 fires. The tube fires only if for some reason a sheet does not rise to the magnetic roller.

The foregoing description assumed the use of a foot treadle switch 428 affording semi-automatic and even partial sheet feed, as for example to feed a single sheet intermittently through a shearing press or the like. If a foot treadle is not employed for partial sheet feed (switch 426 closed) then the sheets are fed one after another by reason of the fact that when the tail end of the sheet being fed leaves the trip switch 380, the trip switch opens and so initiates the next whole sheet lifting cycle. The growth current or sheet fanning system provides some delay anyway, and there is no need for a special time delay relay to insure a delay between successive sheets. However, if a still longer delay were wanted such a time delay relay could be employed. The time delay circuit here shown for prolonging the energization of the feed roller beyond its rotation, namely, the decay circuit 434, 436, is not needed when the foot switch is omitted, and the parts 434, 436 may simply be eliminated. The identical circuit shown with the parts 434, 436 eliminated would let the full stage energization of the feed roller terminate on termination of rotation.

In this circuit, as in Fig. 7, it is advantageous to employ back rectifiers. The back rectifier 470 helps commutation in the thyratrons 348, 370 and 372, prolongs their life, and provides a more efficient circuit, considering that it is heavily inductive. Back rectifier 472 is used across the relay 310. Rectifier 474 is a back rectifier connected across the relay 416. Rectifier 478 is used as the back rectifier for thyratron 390 and feed roller 24, aiding commutation and increasing the circuit efficiency.

Resistor 476 is used to tie the cathode of tube 412 to the plate, aiding in grid rectification. Transformer secondary 480 is for heating the cathode of thyratron 390, secondary 482 is for heating the cathode of tube 460, and secondary 484 is for heating the cathode of tube 412. In the case of tubes 460 and 412 the secondaries are connected across the filaments and across the potentiometers 488 and 420, that is, the filaments, the secondaries and the potentiometers are all in shunt relation. Potentiometer 486 is used to increase and to adjust the range of the time delay caused by the circuit of tube 460, the primary adjustment being the resistor 462.

To summarize the operation of the circuit of Fig. 8, thyratrons 348, 370 and 372 act as valves for controlling the field of the main sheet lifting coil 16. The lines L1, L2 and L3 supply plate current, and the three transformer secondaries

like secondary 350 supply trigger waves to the grids of the thyratrons. The phase of each trigger wave is shifted relative to its corresponding plate supply by the three phase shifting circuits like the circuit 352, 354, these being independently adjustable to establish a uniform firing point. The maximum height of the axes of all three trigger waves is determined by adding positive bias potential supplied by three transformer secondaries like secondary 358 and associated three rectifiers like rectifier 360, the combined rectified currents being passed through a single potentiometer 362 which affords adjustment of the height. The trigger wave may be depressed by the addition of negative bias potential supplied by three transformer secondaries like the secondary 364 and three rectifiers like its associated rectifier 366. The combined rectified currents are combined in a single potentiometer 368 which also serves to adjust the drop. The desired growth of the current supplied to the main coil 16 is obtained by the use of a decay circuit 342, 344 which reduces the negative bias taken from potentiometer 368.

The thyratron 390 acts as a valve for controlling the magnetization of the feed roller 24. Plate current is supplied directly from the line, and a transformer secondary 392 supplies a trigger wave to the grid. The phase of the trigger wave is shifted by phase shifting means 394, 396. The height of the axis of the trigger wave to supply the needed current for the sheet holding stage is established by bias potential supplied by a transformer secondary 400, rectifier 402, and potentiometer 404. The magnetization is then increased during the sheet feeding stage by raising the trigger wave axis, this being done by sending current through bias potentiometer 432. The current to operate the motor 28 is taken directly from lines L1, L2 and L3 with a neutral return N, the three currents being rectified and combined when using a series motor as here shown. The supply of current to the motor is put on or cut off by a relay 424.

If it be desired to delay the start of the sheet feed operation until after time for collapse of the main field and the fanned sheets, such delay is provided by an adjustable time delay circuit centering about the tube 412. If semi-automatic sheet feed or fractional sheet feed is desired a suitable manual or treadle switch 428 is employed, the switch 426 being opened, but for fully automatic feed of successive sheets the switch 426 is closed. If with fractional sheet feed it be desired to briefly continue full energization of the roller after the motor stops in order to compensate for the inertia of the moving sheet, such prolongation may be provided by the decay circuits 434, 436, 408.

General

There may be difficulty in separating the sheets due to oil film adhesion. Even when the apparatus is used indoors it often receives a stack of sheets fresh from outdoors storage, and because of the cold temperature in winter, and the long time which it would take for the sheets to acquire room temperature, the sheets stick very tightly because the oil film is congealed. A first improvement is to not let the growth current come down to zero. Instead the minimum current (as shown in Fig. 6) keeps at least some slight separation of the sheets, and this prevents them from again adhering and avoids the need to completely break the seal each time. Another step found useful in a serious case is to limit the height of the stack to only a few inches so that the separation of the sheets is a maximum during each cycle. Still another step is the retention of a residuary stack beneath the stack being fed.

It is believed that the construction and operation, as well as the advantages of my improved apparatus for separating and feeding sheets, will be apparent from the foregoing detailed description thereof. Although single phase power is used for the feed roller, three phase power may be used. The advantage of the single phase circuit shown is economy in construction and apparatus, with some sacrifice in electrical efficiency. On the other hand, by accepting a greater apparatus cost for a three phase thyratron supply to the feed roller, one may gain slightly better electrical efficiency. This is merely a matter of engineering judgment for any one particular installation. In general the feed roller uses much less power than the main induction coil, which explains why in the present case a three phase supply is used for the main induction coil, while using only a single phase supply for the feed roller. Incidentally, there is arguably some advantage in single phase supply for the feed roller because it may supply a degree of slight pulsation and vibration of the sheet, which may facilitate sheet separation at the lower rear end of the sheet, despite adhesive oil film.

The circuits of Figs. 7 and 8 are almost fully electronic in that even for time delay a tube and circuit are employed. An electronic time delay relay is more trouble-free than an electro-mechanical time delay relay, but the latter may be used. There is no important change, for nowadays one can buy a complete electronic time delay relay assembly, just as one can buy an electro-mechanical time delay relay, to use in a circuit at a desired point.

The sheets may be fed one after another automatically with or without time delay therebetween. The sheets may also be fed semi-automatically, requiring a manual or pedal switch operation, and the sheets may be fed incrementally as when working with a shear press or the like. The feed roll may be energized continuously or may be deenergized when not in use, and if desired, may be energized in two different stages, one for holding and one for feeding. The feed motor may be operated continuously or only when in use. When feeding sheets incrementally the full energization of the feed roller may be prolonged slightly beyond the operation of the motor to overcome inertia of the moving sheet. Safety means may be provided to guard against prolonged energization of the main coil in the event that no sheet is lifted within a reasonably short time. Back rectifiers may be provided to increase the efficiency of the circuit. Re-adhesion of oil film coated sheets may be prevented by maintaining a small holding current through the main coil instead of cutting off the current entirely. Many of these features are, of course, optional.

It will be understood that to obtain the benefit of the growth current idea it is not at all essential to simultaneously employ the large coil surrounding the stack, which invention constitutes the subject matter of my aforesaid copending application Serial No. 129,662, filed November 26, 1949, of which the present application is a continuation-in-part. In other words, while I have shown my invention applied to a

main coil which entirely surrounds the stack of sheets, the growth current idea is equally well applicable to numerous other possible forms of magnet employed to magnetize the sheets and to thereby cause them to mutually repel.

It will also be understood that while I have shown the sheets disposed and fed horizontally, the sheets and the surrounding apparatus may be oriented differently. For example, the sheets may be stacked in nearly upright position and repelled at their upper edges, the sheets then turning away from the group about their lower edges until they engage feed means.

It will therefore be apparent that while I have shown and described the invention in several preferred forms, changes may be made in the structures disclosed without departing from the scope of the invention as sought to be defined in the following claims. In many claims the reference to a top sheet and the raising of a top sheet to a holding means above the stack, etc. is to be understood primarily in a relative sense, because the sheets need not necessarily be initially stacked in horizontal position.

I claim:

1. The method of separating the end ferromagnetic sheet from a group of ferromagnetic sheets by magnetic repulsion between sheets, which includes passing a very feeble magnetic field through the entire group of sheets and relatively gradually increasing the strength of the magnetic field passing through the entire group of sheets as a function of time until the end sheet has been moved away a desired distance.

2. The method of separating the top ferromagnetic sheet from a stack of ferromagnetic sheets by magnetic repulsion between sheets, which includes passing a very feeble magnetic field through the stack of sheets and relatively gradually increasing the strength of the magnetic field as a function of time until the top sheet has been raised to a desired height, holding the top sheet, then cutting off the magnetic field to permit the remaining sheets to fall, and then removing the held top sheet.

3. Apparatus for separating the end ferromagnetic sheet from a group of ferromagnetic sheets by magnetic repulsion between sheets, said apparatus including an electromagnet so positioned as to pass a magnetic field through the entire group of sheets, a source of current to energize the electromagnet, and means for relatively gradually increasing the strength of the current in order to increase the strength of the magnetic field passing through the entire group of sheets as a function of time until the end sheet has been moved away a desired distance.

4. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets by magnetic repulsion between sheets, said apparatus including an electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current for energizing said electromagnet, a sheet holding means disposed above the stack, means to relatively gradually increase the strength of the current and consequently the strength of the magnetic field as a function of time until the top sheet has been raised to the sheet holding means, means to sharply reduce the magnetic field to permit sheets other than the top sheet to descend, and means to cause feeding of the held top sheet away from the stack.

5. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including an electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current to energize the electromagnet, and means for relatively gradually increasing the strength of the current in order to increase the strength of the magnetic field as a function of time until the top sheet has been raised to a desired height, said electromagnet comprising a coil extending entirely around the stack with the axis of the coil extending generally in the direction of the plane of the sheets.

6. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including an electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current for energizing said electromagnet, a sheet holding means disposed above the stack, means to relatively gradually increase the strength of the current and consequently the strength of the magnetic field as a function of time until the top sheet has been raised to the sheet holding means, means to sharply reduce the magnetic field to a small amount which permits sheets other than the top sheet to descend but which is adequate to keep the next sheets slightly separated to prevent re-adhesion, and means to cause feeding of the held top sheet away from the stack.

7. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including an electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current to energize the electromagnet, a thyratron to control the flow of current to the electromagnet, and means to apply a trigger wave to the grid of the thyratron in shifting bias or phase relation so as to supply gradually increasing increments of plate current to the magnet in order to increase the strength of the magnetic field as a function of time until the top sheet has been raised to desired height.

8. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including an electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current to energize the electromagnet, a sheet holding means disposed above the stack, a thyratron to control the flow of current to the electromagnet, means to apply a trigger wave to the grid of the thyratron in shifting bias or phase relation so as to supply gradually increasing increments of plate current to the magnet in order to increase the strength of the magnetic field as a function of time until the top sheet has been raised to the sheet holding means, means to abruptly shift the trigger wave to sharply reduce the magnetic field to permit sheets other than the top sheet to descend, and means to cause feeding of the held top sheet away from the stack.

9. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including an electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current to energize the electromagnet, a sheet holding means disposed above the stack, a thyratron to control the flow of current to the electromagnet, means to apply a trigger wave to the grid of the thyratron in shifting bias or phase relation so as to supply gradually increasing increments of

plate current to the magnet in order to increase the strength of the magnetic field as a function of time until the top sheet has been raised to the sheet holding means, means to abruptly shift the trigger wave to sharply reduce the magnetic field to a small amount which permits sheets other than the top sheet to descend but which is adequate to keep the next sheet slightly separated to prevent re-adhesion, and means to cause feeding of the held top sheet away from the stack.

10. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including a main electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current for energizing said electromagnet, means to relatively gradually increase the strength of the currrent and consequently the strength of the magnetic field as a function of time until the top sheet has been raised to the sheet holding means, an electromagnetic sheet feed roller disposed above the stack, means to sharply reduce the main magnetic field to permit sheets other than the top sheet to descend, a thyratron for controlling the supply of current from the source to the roller, means to supply a trigger wave to fire the thyratron in order to supply increments of current to the roller, and means to shift the trigger wave to different bias or phase positions.

11. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including a main electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current for energizing said electromagnetic, means to relatively gradually increase the strength of the current and consequently the strength of the magnetic field as a function of time until the top sheet has been raised to the sheet holding means, an electromagnetic sheet feed roller disposed above the stack, means to sharply reduce the main magnetic field to permit sheets other than the top sheet to descend, a thyratron for controlling the supply of current from the source to the roller, means to supply a trigger wave to fire the thyratron in order to supply increments of current to the roller, and means to shift the trigger wave to three different bias or phase positions corresponding to complete cut-off, a holding current sufficient to hold the top sheet but inadequate to feed the sheet, and a feed current sufficient to grip the sheet tightly for feeding the same.

12. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including a main electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current to energize the electromagnet, an electromagnetic sheet feed roller disposed above the stack, a first thyratron to control the flow of current to the electromagnet, means to apply a trigger wave to the grid of the thyratron in shifting bias or phase relation so as to supply gradually increasing increments of plate current to the magnet in order to increase the strength of the magnetic field as a function of time until the top sheet has been raised to the roller, means to abruptly shift the trigger wave to sharply reduce the magnetic field to permit sheets other than the top sheet to descend, a second thyratron for controlling the supply of current from the source to the roller, means to supply a trigger wave to fire the thyratron to supply increments of current to the roller, and means to shift the trigger wave to different bias or phase positions in properly timed relation to the operation of the main magnet.

13. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including a main electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current to energize the electromagnet, an electromagnetic sheet feed roller disposed above the stack, a first thyratron to control the flow of current to the electromagnet, means to apply a trigger wave to the grid of the first thyratron in shifting bias or phase relation so as to supply gradually increasing increments of plate current to the magnet in order to increase the strength of the magnetic field as a function of time until the top sheet has been raised to the roller, means to abruptly shift the trigger wave to sharply reduce the magnetic field to permit sheets other than the top sheet to descend, a second thyratron for controlling the supply of current from the source to the roller, means to supply a trigger wave to fire the second thyratron to supply increments of current to the roller, and means to shift the trigger wave to three different bias or phase positions corresponding to complete cut-off, a holding current sufficient to hold the top sheet but inadequate to feed the sheet, and a feed current sufficient to grip the sheet tightly for feeding the same.

14. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including an electromagnet so positioned as to pass a magnetic field through the stack of sheets, a three-phase source of current to energize the electromagnet, three thyratrons to control the flow of current to the electromagnet from the three phases respectively, means to apply trigger waves to the grids of the thyratrons so as to supply increments of plate current to the magnet, and a single means to simultaneously shift the three trigger waves in order to supply gradually increasing increments in order to increase the strength of the magnetic field as a function of time until the top sheet has been raised to desired height.

15. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including an electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current to energize the electromagnet, means for relatively gradually increasing the strength of the current in order to increase the strength of the magnetic field as a function of time until the top sheet has been raised to a desired height, and time delay relay means to cut off the supply of current to the electromagnet if a sheet is not raised in response to energization of the magnet.

16. Apparatus for separating the top ferromagnetic sheet from a stack of ferromagnetic sheets, said apparatus including an electromagnet so positioned as to pass a magnetic field through the stack of sheets, a source of current for energizing said electromagnet, a sheet holding means disposed above the stack, means to relatively gradually increase the strength of the current and consequently the strength of the magnetic field as a function of time until the top sheet has been raised to the sheet holding means, means to sharply reduce the magnetic field to permit sheets

other than the top sheet to descend, means to cause feeding of the held top sheet away from the stack, and a time delay relay to delay feeding of the top sheet until after the other sheets have had time to descend.

17. Apparatus for separating and successively feeding ferromagnetic sheets from a stack of sheets, said apparatus comprising a support for the stack of sheets, an induction coil extending entirely around the stack of sheets, with the axis of the coil extending generally in the direction of the plane of the sheets and generally perpendicular to the desired direction of separation of the sheets, means to energize the coil in order to raise and separate the uppermost sheets of the stack, and feed means to receive and feed the uppermost sheet away from the coil and stack, said means to energize the induction coil including current varying circuit elements arranged and operated to energize the induction coil with a current of relatively gradually increasing magnitude in order to help insure the separation of the topmost sheet from the immediately subjacent sheet.

18. Apparatus for separating and successively feeding ferromagnetic sheets from a stack of sheets, said apparatus comprising a support for the stack of sheets, an induction coil extending entirely around the stack of sheets, a sheet feeding means disposed near the leading end of the stack, drive means for intermittently driving the feed means, means to energize the induction coil in order to raise and separate the uppermost sheet of the stack and to bring it to the feed means, and appropriate switch means for the induction coil interlocked with the drive means whereby the induction coil is energized while the feed means is inoperative and is de-energized while the feed means is operative, said circuit elements energize the induction coil including current varying circuit elements arranged and operated to energize the induction coil with a current of relatively gradually increasing magnitude in order to help insure the separation of the topmost sheet from the immediately subjacent sheet.

19. Apparatus for separating and successively feeding ferromagnetic sheets from a stack of sheets, said apparatus comprising a support for the stack of sheets, a main induction winding extending entirely around the stack of sheets, a magnetic roller having a magnetizing coil, intermittently operable drive means for intermittently rotating the roller, means to energize the main induction winding in order to raise and separate the uppermost sheet of the stack and to bring it to the roller, means for supplying current to said coil, means to energize the roller coil to only a limited extent sufficient to hold the uppermost sheet when the feed roller is not rotating, means to more strongly energize the coil in order to feed the sheet without appreciable slippage when the roller is rotated, and appropriate switch means to energize the main induction winding when the feed roller is stationary, and to de-energize the main induction winding when the feed roller is rotating, said means to energize the main induction winding including current varying circuit elements arranged and operated to energize the main induction winding by a current of relatively gradually increasing magnitude in order to help insure the separation of the topmost sheet from the immediately subjacent sheet.

20. Apparatus for separating and successively feeding ferromagnetic sheets from an upright stack of generally horizontal sheets, said apparatus comprising a support for the stack of sheets, an induction coil disposed in an upright plane and having each of its windings extending entirely around the stack of sheets, with the top of the coil higher than the top of the stack to provide substantial clearance therebetween, and with the axis of the coil extending generally horizontally in the direction in which the sheets are to be fed, means to energize the coil in order to raise and separate the uppermost sheets of the stack, said means including current varying circuit elements arranged to supply the induction coil with a current of relatively gradually increasing intensity in order to help insure the separation of the topmost sheet from the immediately subjacent sheet, and feed means to receive the uppermost sheet when raised and to feed it in a generally horizontal direction away from the coil and stack.

21. Apparatus for separating and successively feeding ferromagnetic sheets from an upright stack of generally horizontal sheets, said apparatus comprising a support for the stack of sheets, an induction coil disposed in an upright plane and having each of its windings extending entirely around the stack of sheets, with the top of the coil higher than the top of the stack to provide substantial clearance therebetween, and with the axis of the coil extending generally horizontally in the direction in which the sheets are to be fed, means to energize the coil in order to raise and separate the uppermost sheets of the stack, said means including current varying circuit elements arranged to supply the induction coil with a current of relatively gradually increasing intensity in order to help insure the separation of the topmost sheet from the immediately subjacent sheet, and a magnetic feed roller having a horizontal axis extending across the direction of feed and disposed at a point higher than the stack but lower than the top of the induction coil, said magnetic feed roller serving to receive the uppermost sheet when raised and to feed it in a generally horizontal direction away from the coil and stack.

22. Apparatus for separating and successively feeding ferromagnetic sheets from a stack of sheets, said apparatus comprising a support for the stack of sheets, an induction coil extending entirely around the stack of sheets, with the axis of the coil extending generally in the direction of the plane of the sheets and generally perpendicular to the desired direction of separation of the sheets, means to energize the coil in order to raise and separate the uppermost sheets of the stack, and feed means to receive and feed the uppermost sheet away from the coil and stack, said means to energize the induction coil including a variable impedance driven by a motor and a one-revolution clutch, whereby the induction coil is energized by a current of gradually increasing intensity in order to help insure the separation of the topmost sheet from the immediately subjacent sheet.

23. Apparatus for separating and successively feeding ferromagnetic sheets from a stack of sheets, said apparatus comprising a support for the stack of sheets, an induction coil extending entirely around the stack of sheets, a sheet feeding means disposed near the leading end of the stack, drive means for intermittently driving the feed means, means to energize the induction coil in order to raise and separate the uppermost sheet of the stack and to bring it to the feed

means, and appropriate switch means for the induction coil interlocked with the drive means whereby the induction coil is energized while the feed means is inoperative and is de-energized while the feed means is operative, said means to energize the induction coil including a variable impedance driven by a motor and a one-revolution clutch, whereby the induction coil is energized by a current of gradually increasing intensity in order to help insure the separation of the topmost sheet from the immediately subjacent sheet.

24. Apparatus for separating and successively feeding ferromagnetic sheets from a stack of sheets, said apparatus comprising a support for the stack of sheets, a main induction winding extending entirely around the stack of sheets, a magnetic roller having a magnetizing coil, intermittently operable drive means for intermittently rotating the roller, means to energize the main induction winding in order to raise and separate the uppermost sheet of the stack and to bring it to the roller, means for supplying current to said coil, means to energize the coil to only a limited extent sufficient to hold the uppermost sheet when the feed roller is not rotating, means to more strongly energize the coil in order to feed the sheet without appreciable slippage when the roller is rotated, and appropriate switch means to energize the main induction winding when the feed roller is stationary, and to de-energize the main induction winding when the feed roller is rotating, said means to energize the main induction winding including a variable impedance driven by a motor and a one-revolution clutch, whereby the main induction winding is energized by a current of gradually increasing intensity in order to help insure the separation of the topmost sheet from the immediately subjacent sheet.

25. Apparatus for separating ferromagnetic sheets from a stack of such sheets, said apparatus comprising a support for the stack of sheets, an induction coil extending entirely around the stack of sheets, with the axis of the coil extending generally in the direction of the plane of the sheets and generally perpendicular to the desired direction of separation of the sheets, a source of power to energize the coil in order to raise and separate the uppermost sheets of the stack, and current varying circuit elements between said source and said coil arranged and operated each time a sheet is to be separated to energize the induction coil with a current of relatively gradually increasing magnitude in order to help insure the separation of the topmost sheet from the immediately subjacent sheet.

26. Apparatus for separating ferromagnetic sheets from a stack of such sheets, said apparatus comprising a support for the stack of sheets, an induction coil disposed with the axis of the coil extending generally in the direction of the plane of the sheets and generally perpendicular to the desired direction of separation of the sheets, said coil being so large in diametral dimension that the sheets may be moved through the induction coil in the direction of the axis of the coil, and said coil being disposed so close to the stack that the field of the coil runs through the stack, with the stack acting as a core for the field and coil, a source of power to energize the coil in order to raise and separate the uppermost sheets of the stack, said current varying circuit elements between said source and said coil arranged and operated each time a sheet is to be separated to energize the induction coil with a current of relatively gradually increasing magnitude in order to help insure the separation of the topmost sheet from the immediately subjacent sheet.

27. Apparatus for separating ferromagnetic sheets for removal from an upright stack of generally horizontal sheets, said apparatus comprising a support for the stack of sheets, an induction coil disposed in an upright plane and having each of its windings extending entirely around the stack of sheets, with the top of the coil higher than the top of the stack to provide substantial clearance therebetween, and with the axis of the coil exending generally horizontally in the direction in which the sheets are to be removed and generally perpendicular to the desired direction of separation of the sheets, a source of power to energize the coil in order to raise and separate the uppermost sheets of the stack, and current varying circuit elements between said source and said coil arranged and operated each time a sheet is to be separated to energize the induction coil with a current of relatively gradually increasing magnitude in order to help insure the separation of the topmost sheet from the immediately subjacent sheet.

28. Apparatus for separating ferromagnetic sheets for removal from an upright stack of generally horizontal sheets, said apparatus comprising a support for the stack of sheets, an induction coil disposed in an upright plane with the top of the coil higher than the top of the stack to provide substantial difference in elevation therebetween, and with the axis of the coil extending generally horizontally in the direction in which the sheets are to be removed, said coil being so large in diametral dimension that the sheets may be moved through the coil in the direction of the axis of the coil, and said coil being disposed so close to the stack that the field of the coil runs through the stack, with the stack acting as a core for the field and the coil, a source of power to energize the coil in order to raise and separate the uppermost sheets of the stack, said current varying circuit elements between said source and said coil arranged and operated each time a sheet is to be separated to energize the induction coil with a current of relatively gradually increasing magnitude in order to help insure the separation of the topmost sheet from the immediately subjacent sheet.

ALEXANDER FOWLER.

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