March 31, 1964 J. RABINOW ETAL 3,127,167

SHEET STACKER OR FEEDER

Filed March 31, 1961 3 Sheets-Sheet 1

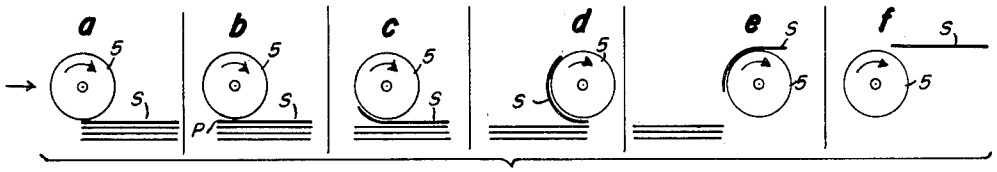


FIG. 1

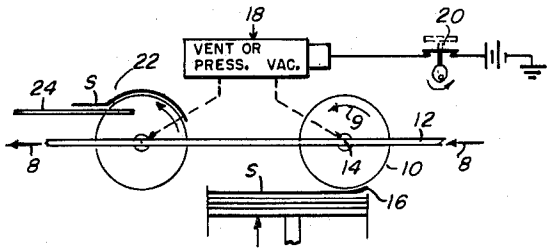


FIG. 2

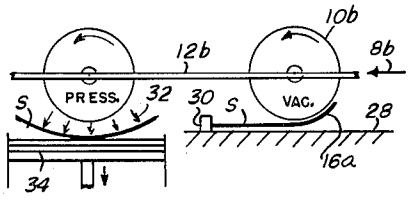


FIG. 2a

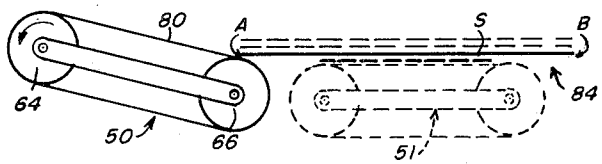


FIG. 6

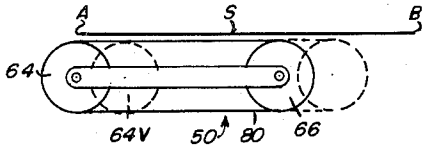


FIG. 6a

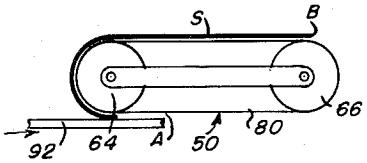


FIG. 6b

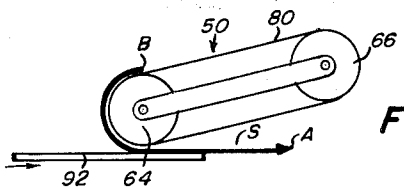


FIG. 6c

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FIG. 3

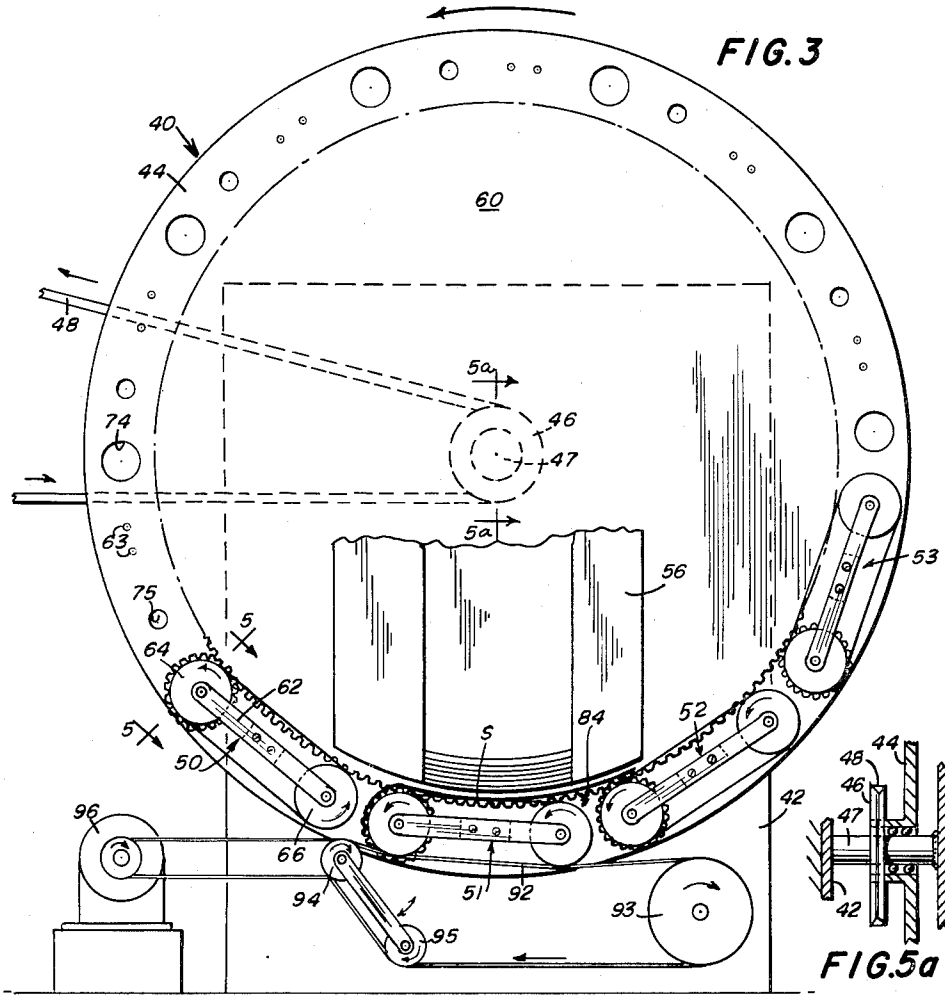


FIG. 5a

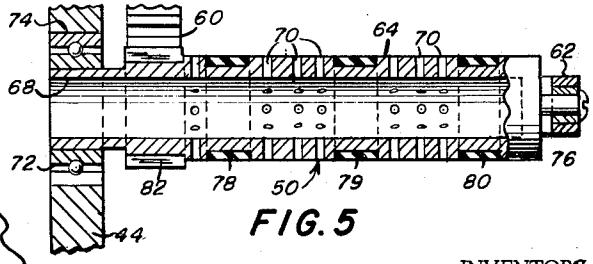


FIG. 5

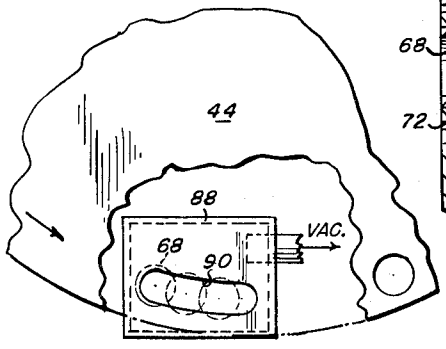


FIG. 4

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SHEET STACKER OR FEEDER

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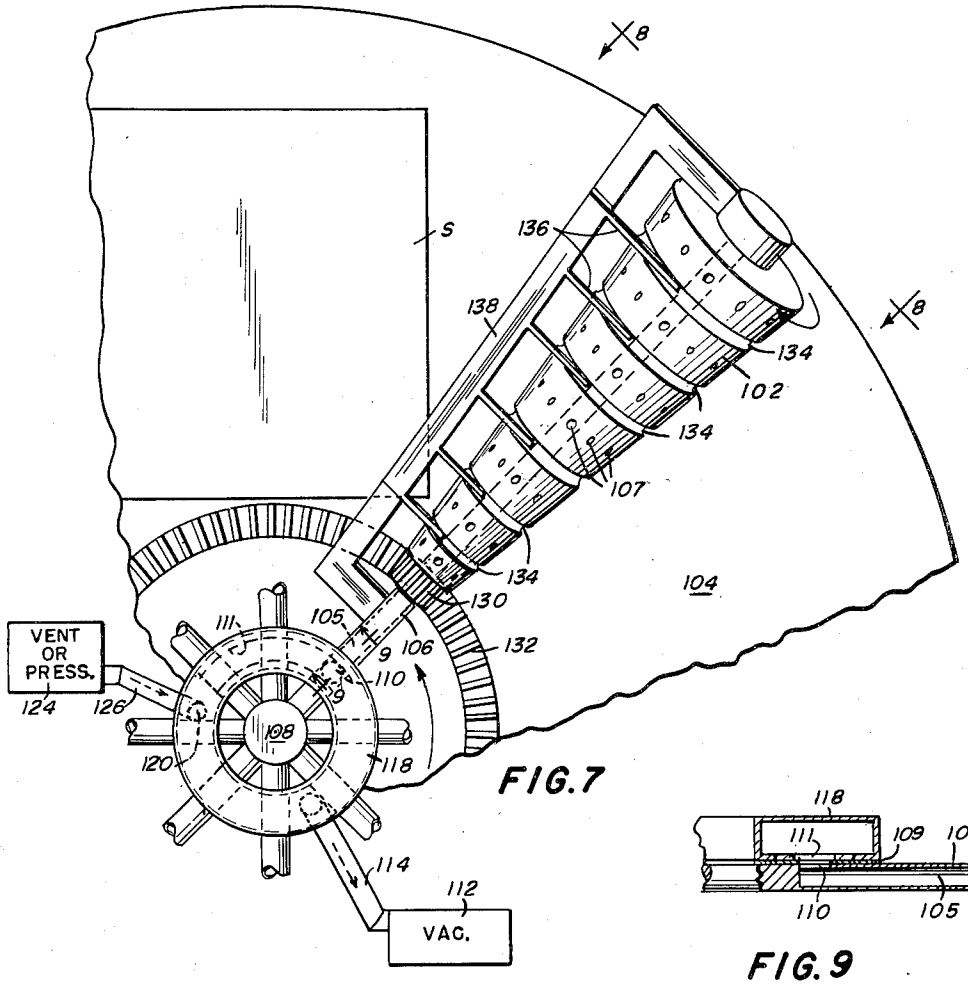


FIG. 7

FIG. 9

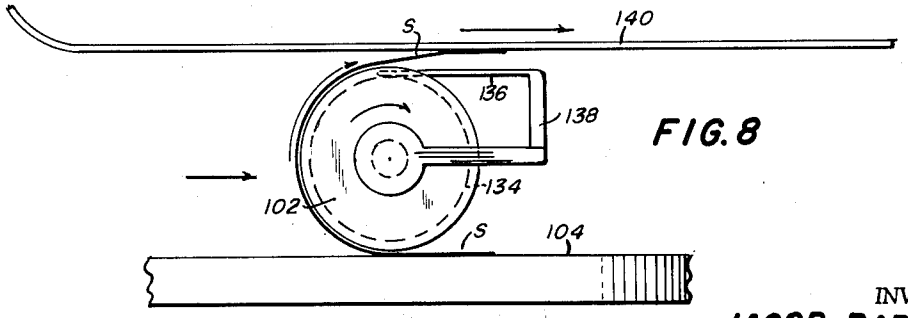


FIG. 8

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3,127,167

SHEET STACKER OR FEEDER

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Filed Mar. 31, 1961, Ser. No. 99,840
7 Claims. (Cl. 271—27)

This invention relates to the art of stacking and/or feeding sheets, especially flexible sheets.

As a result of improvements in high speed paper sheet-using machines, e.g. reading machines, counting devices, collating machines, computers, etc., there is a need for accurate, faster sheet handling equipment. Merely over-speeding currently available paper sheet stackers or feeders is insufficient because of their inherent design. For example, a low speed feeder when operating above design speed may tear the sheets, become jammed or pick up more than one sheet at a time. The problem of "doubles" (picking up more than one sheet) has been in existence for a long time, as evidenced by the J. Abrams Patent No. 907,944 of 1908.

An object of this invention is to provide a system for stacking and/or feeding flexible sheets reliably at very high speed.

The principle of our invention is to engage and move each sheet by a member which has zero velocity with respect to the sheet even though the sheet is at rest when engaged by the sheet moving member. A member which is constrained to cycloidal (epicycloidal, hypocycloidal, etc.) motion meets this requirement. Accordingly, in actual practice we can translate a roller (or the equivalent) over a sheet while rotating the roller about its axis at a rate such that the surface speed of the roller is zero with respect to the sheet. In other words, the roller simply rolls on the surface of the sheet. If suction is applied to the roller while it so rolls, the sheet will adhere to the surface of the roller and be conveyed with the translation of the roller. Some important advantages of this system are that the sheet is not slid, pushed, nor pulled from the stack. This minimizes or eliminates inter-sheet friction, vacuum attraction and static charge problems (where they exist).

The nearest approach to our invention in the prior patents of which we are aware, is exemplified in the two Nelson Patents Nos. 2,752,154 and 2,936,169 and Carlisle Patent No. 2,806,695. These patents show rotary drums which pick-off sheets from a stack. But the sheets are extracted (or fed) from a stack by a drum having a high surface speed with respect to the sheets. In contrast, our invention requires the surface speed of the sheet contacting member to be zero (or negligible) with respect to the sheet. The invention is built around the concept of smoothly rolling a sheet from an adjacent surface, whether or not the surface physically supports the sheet. An example of an "adjacent surface" which does not support the sheet is where the bottom sheet of a stack is removed.

Although it is possible to have zero relative movement between the sheet and pick-up member by moving the sheet at the same speed as the pick-up member at the instant that the pick up contacts the sheet, this does not solve the problem of relative motion between the sheets as each one is removed, in turn.

Often sheet feeders and stackers rely on an oscillating suction head to move the sheets from one place to another. For instance, see the Abrams patent. Flexible paper sheets are porous, and when the head applies suction to the top (or end) sheet, the pores of the engaged sheet permit the second sheet to become exposed to the vacuum so that it tends to adhere to the engaged sheet. We overcome this problem by having the vacuum initially applied to a small subarea of the sheet near or at an edge

or corner of the sheet and only in an amount sufficient to flex a part of the sheet toward the roller. In other words, we do not try to physically pull the entire sheet from the stack. Instead, we engage an edge or corner, and roll the sheet from the stack requiring only the back surface of a corner or edge to be exposed to atmospheric pressure. It is true that we use vacuum, but only to hold the sheet onto the roller as the rolling action "peels" the sheet from the stack. We can then apply vacuum to the sheet at progressive elemental areas as opposed to a "single shot" application and a direct pulling force on the sheet, as in oscillatory-head feeders.

In a rotary drum feeder, e.g. the Nelson patents, the suction is initially localized on a sheet. But in the absence of our cycloidal motion feature, the problems of inter-sheet friction are formidable.

When our invention is applied to stacking sheets, we may use practically the same physical structure as the feeder. Certain advantages over previous stackers are obtained. The sheet pick-up device, e.g. a roller, will gently lay down the sheet on a stack by rolling the same on the stack. Many stackers have a tendency to bend or crease the sheets. The described cycloidal motion in both obtaining and laying down (stacking) the sheets greatly minimize the possibility of sheet bending, creasing or other forms of mutilation. Furthermore, if a sheet happens to be creased, the rolling action of the roller will press the sheet during stacking, so that the crease will present no problem in stacker operation. Bettter advantage of the pressing feature is obtained if the roller has a comparatively large diameter.

The invention may be embodied in many structural forms, only a few of which are shown. Further, the invention is independent of orientation. Differentt embodiments (or the same ones) may operate vertically, horizontally or any other angle.

Other objects and features of importance will become apparent in following the description of the illustrated forms of the invention which are given by way of example only.

FIGURE 1 is a schematic view showing successive steps *a–f* in practicing the invention as a sheet feeder or stacker.

FIGURE 2 is a schematic view showing the principle of the invention applied to a feeder.

FIGURE 2*a* is a schematic view showing a stacker.

FIGURE 3 is a front view of a machine embodying the invention.

FIGURE 4 is a fragmentary view showing a detail of the machine.

FIGURE 5 is a sectional view taken on the line 5—5 of FIGURE 3.

FIGURE 5*a* is a sectional view taken on line 5*a*—5*a* of FIGURE 3.

FIGURES 6–6*c* inclusive are diagrammatic views showing the method of handling one of the sheets in the machine of FIGURE 3 as the sheet is obtained from a supply and discharged to a utilization device (not shown).

FIGURE 7 is a top view of another form of the invention.

FIGURE 8 is a side view of the form of the invention in FIGURE 7, as viewed along the line 8—8.

FIGURE 9 is a sectional view taken on the line 9—9 of FIGURE 7, showing a valving arrangement.

FIGURE 1 shows a roller 5 in the process of picking up and discharging a sheet *s*. Assume that sheet *s* at position *a* is flat and the roller does not slip on the sheet as it rolls onto the sheet. If that is the case, all points contacting the surface of the roller will describe cycloids with the sheet surface as a ground reference. By definition, then, the relative velocity between the sheet and roller surface is zero.

FIGURE 1, position *a*, shows roller 5 just rolling on the leading edge or corner of sheet *s*. At position *b* the roller has just passed beyond the edge of sheet *s*, and suction is about to be applied to the roller. The application of suction to the roller causes the edge portion of the sheet to adhere to the roller as shown at position *c*. Whether or not a small portion of the sheet is past the line of contact with the roller when the suction is applied, is a matter of choice. The suction could be applied when the roller is at position *a*. We get excellent results, though, when we apply the suction at position *b* when handling highly flexible sheets. With the small "cantilever" portion *p* at the instant of suction, this portion moves easily toward the roller, allowing ambient pressure to get behind a small area of the sheet and free the small portion *p* from the stack.

Positions *c* and *d* show the sheet *s* being rolled onto the roller without sliding it from the stack. Positions *e* and *f* show the sheet being moved and stripped from the roller and directed toward a utilization device (not shown). The procedure shown in FIGURE 1 applies equally well in a stacker or a feeder. In a stacker the direction of motion, and the sequence of events would, of course, be reversed. FIGURES 2 and 2*a* further illustrate the equivalence.

FIGURE 2 discloses a suction roller or drum **10** which is being displaced, for instance by a pair of conveyor belts or chains **12**, only one of which is shown. The drum-conveyor connection is made at the axis **14** of the drum, and there are means (not shown) to rotate the drum about its axis in the direction of the arrow **9**. The top sheet *s* of a stack is in a plane tangent to the bottom of the drum surface. The sheets are automatically fed upward so that the top sheet of the stack always occupies this position. Means to do this are well known in the art. The rotational speed of drum **10** is synchronized with the linear displacement of the drum, i.e. speed of the conveyor, so that although the drum moves in the direction of the arrow **8** due to the conveyor movement, the surface of the drum rolls on the surface of the top sheet of the stack, i.e. the velocity of the drum surface at the sheet is zero.

When the drum is at the right-hand position in FIGURE 2 a vacuum control, for instance valve **18**, is operated to apply suction to the roller so that the leading edge portion **16** of top sheet *s* adheres to the drum surface. Valve **18** may be operated in any conventional manner, for instance by a circuit, controlled by cam-operated switch **20** synchronized with the movement of conveyor **12**. As the drum is displaced to the left as shown in FIGURE 2, it rolls on the surface of sheet *s*, and meanwhile successive vacuum ports (not shown) in the surface of the drum are closed by the sheet, causing the sheet to adhere to the surface of the drum.

Therefore, drum **10** is conveyed to a discharge station **22** at which the sheet becomes separated from the drum. The removal of the sheet from the drum requires venting the vacuum. To assure sheet removal, pressure may be applied by way of valve **18**. Further, a stripper **24** may be used to help in the removal and guidance of the sheet. The sheet is then carried off to any kind of utilization device (not shown) by means of any conventional conveyor, pusher, etc.

FIGURE 2*a* shows the same principle as in FIGURE 2, except it is applied as a sheet stacker instead of a feeder. Drum **10***b* is moved by conveyor **12***b* in the direction of the arrow **8***b*, and it is rotated at a speed that is predetermined with respect to the linear velocity of the conveyor. The purpose of control over relative speed is to assure that the surface of the drum (at the bottom point) has zero velocity with respect to sheet *s*. Since this is a stacker, we have shown a flat support **28** on which sheets *s* are successively fed by any method. An abutment **30** defines the pick-up station since the sheets moving on support **28** will strike the abutment and stop. The timing is such that a sheet enters the pick-up station before drum **10***b*. Then, as the drum moves forward, the vacuum is applied so that the edge portion **16***a* is adhered to the drum. As the drum rolls on the surface of the sheet *s* (without sliding) the sheet is curled around the drum, conforming to the drum configuration. The vacuum remains applied to the drum until the discharge station **32** is reached, at which valve **18** (shown only in FIGURE 2) vents the vacuum and applies pressure to discharge the sheet onto a stack **34** or any other receiver.

The above description of the principle of our invention deals with a cylindrical drum or roller only for the purpose of facilitating an explanation of this principle. It will later be shown that the surface need not be cylindrical, for instance see FIGURES 6–6*c* and 7. Further, FIGURES 2 and 2*a* disclose elementary devices and procedures for presenting the sheets to the rolling drum and for receiving them. These may be varied quite considerably.

FIGURES 3–5 show an actual machine constructed to operate on the principle schematically shown in FIGURE 1. Machine **40** is shown and described as a feeder, although the same machine, functioning as a stacker, would be similar. The machine consists of a support **42** for disc **44**. The disc is mounted for rotation on a shaft **46** connected to support **42**, and there are means to rotate the disc, diagrammatically shown as a chain or belt drive **48**. A plurality of identical pick-up devices, for instance devices **50**, **51**, **52**, **53**, etc., are attached to the disc for rotation therewith. Although we have illustrated only four pick-up devices, it is understood that the devices will be arranged in a complete circle near the periphery of the disc. Further, any practical number of devices may be used by simply increasing or decreasing the diameter of the disc and/or changing the sizes of the devices **50**, **51**, **52**, etc.

Hopper **56** schematically represents any known means for storing sheets *s* and presenting them to the moving pick-up devices. The hopper is attached to a stationary gear **60** which cooperates with the pick-up devices to introduce a rotational component of movement to portions of each device as they are displaced with disc **44**. Gear **60** is supported by a stationary shaft **47** passing thru the rotating disc **44** (FIGURE 5*a*).

Each pick-up device is made of a frame **62** secured to a face of disc **44**. We have shown pairs of small holes **63** in disc **44** by which to receive fasteners for frame **62**. In production, the frame **62** may be attached to the disc by any conventional means, however, the pairs of small holes provide a location reference in FIGURE 2. Device **50** has two rollers **64** and **66** which rotate in unison. The roller **66** is an idler, whereas roller **64** is driven, and is a controlled suction roller (FIGURES 4 and 5). It has a central passageway **68** with a number of ports **70** registered with it and opening through the surface of the roller. The inner end of the roller is mounted in a bearing **72** which is pressed or otherwise attached in aperture **74** of disc **44**. The outer end of the roller **64** is mounted in a bearing **76** (FIGURE 5) in frame **62**. Roller **66** has its inner end mounted for rotation in an opening **75** (FIGURE 2) in disc **44**, and the outer end of the roller **66** is mounted for rotation in a bearing carried by frame **62**. A plurality of endless belts, e.g. belts **78**, **79** and **80** are mounted in grooves in the pair of rollers.

As disc **44** rotates, the pick-up devices are translated therewith. A rotary motion is produced in the rollers **64** and therefore in the belts **78**, **79** and **80**, and the pinion **82**. The surfaces of the rollers, including the outer surfaces of belts **78**, **79** and **80**, are on the same radius as the pitch circle of the pinion **82**. Gearing **60**, **82** is cycloidal, so that the cycloids defined by points on the pitch circle of the pinion **82** as it rotates with respect to fixed gear **60**, coincide with corresponding cycloids generated by all of the points of the surface of roller **64**. The term "cycloid" is used in a general sense to include epicycloidal, hypocycloidal, and any other arrangement having a cor-

responding function. Actually, since gear 60 is circular, the specie of cycloid for the gearing of machine 40 would be epicycloidal. In our cycloidal system, as in all other cycloidal systems, the moving gear at its pitch circle has zero velocity with respect to the fixed gear. Since the surface of roller 64 that contacts the paper is coincident with the pitch circle, it, too, will have zero velocity with respect to the gear 60. In other words, the gear 62 "rolls" around gear 60. In addition, the surface speed of roller 64, will be zero with regard to any other surface fixed with respect to stationary gear 60 and located at the pitch circle of gear 60. The lowermost sheet *s* in the stack meets this requirement, as will be more fully discussed in connection with FIGURES 6–6*c*.

A single sheet is removed from the hopper each time that a pick-up device passes through the sheet pick-up station 84 at the bottom of the hopper. In this form (vertical "down" feed) of our invention the pick-up devices themselves support the sheets in the stack. As a pick-up device begins to approach station 84, the stack of sheets is partially supported by its front roller 66 and its belts. At a predetermined position of a typical pick-up device 50 just before station 84, suction is applied to passageway 68, for instance by having the passageway register with a vacuum box 88 having an elongate port 90 (FIGURE 4) facing disc 44. At this position a portion of the lowermost sheet in the stack is adhered to the suction roller. As the sheet is removed from the stack in a manner consistent with the generalized cases of FIGURES 1, 2 and 2*a*, it is supported by a conveyor 92 which is also used to eject the sheet. Conveyor 92 is made of one or more belts entrained around an idler drum 93 and around a driven drum 94. Drum 93 may be a valved suction and pressure drum to help eject the sheets, but this is an optional feature. Slack take-up device 95 is gravity operated to keep the conveyor 92 firmly pressed against the lower part of the pick-up device. The speed of the conveyor 92 is synchronized with the speed of the disc 44 in any conventional way, e.g. controlling the speed at which conveyor motor 96 operates to drive conveyor 92, with respect to the speed of disc 44.

Attention is now directed to FIGURES 6–6*c* for a detailed description of the operation of the pick-up devices of the machine. Typical pick-up device 50 is shown just entering station 84. The preceding pick-up device 51 is shown in dotted lines merely to indicate that two or more of the devices are in station 84 at the same time so that they also function as a support for the stack of sheets. Sheet *s*, shown as a full line and having its edges indicated at A and B respectively, is the sheet which will be handled by device 50.

When device 50 moves to the position shown in FIGURE 6*a*, sheet *s* is supported by the belts and roller 66. The vacuum timing is such that vacuum is applied to passageway 68 when roller 64 reaches position 64*v* (shown in dotted lines in FIGURE 6*a*). Note that the edge A of sheet *s* projects slightly to the left of the roller 64*v*. As the vacuum is applied, this cantilevered portion is drawn onto the surface of the roller. As device 50 moves to the position in FIGURE 6*b* the sheet is rolled onto the device by engaging successive portions of the sheet and requiring the sheet to curve onto roller 64 and its belts in accordance with the configuration thereof. Notice during these movements of the sheet, edge B stays in the same relative position. Then, as the device continues to move to the position shown in FIGURE 6*c* the edge portion A leaves the field of influence of the vacuum and is guided by conveyor 92 (FIGURES 6*b*, 6*c* and 3) to a utilization device (not shown). As indicated previously, we may use positive pressure to separate the sheet from the pick-up device, although in the machine 40 pressure has been unnecessary. It is preferred to use a mechanical stripper, as shown at 24 in FIGURE 2.

Another form of sheet handling apparatus is shown in FIGURES 7–9. The essential difference between this form and the others is that rollers 102 (only one shown) have no belts and are conical. We have shown a sheet *s* on a flat stationary supporting surface 104. However, the sheet *s* in FIGURE 7 could just as easily be the top sheet of a stack which is automatically elevated through an opening in surface 104 as the sheets are separately removed from the top of the stack.

Roller 102 is mounted for rotation on a suction spindle 106 having a central passage 105 (FIGURE 9). The inner end of the spindle is secured to and driven by a drive shaft 108 (FIGURE 7). Any practical number of spindles and rollers may be radially secured to and driven by shaft 108, depending on the number of sheets desired to be handled for each revolution of the shaft. Roller 102 has an air passage (or is made hollow) registered with the passage 105 in spindle 106, and a plurality of ports 107 arranged in a predetermined pattern to assure pneumatic engagement with sheets at or shortly after initial contact therewith. The application of suction to roller 102 may be accomplished in many ways, one of which is shown in FIGURE 9. Valve plate 109 is secured to spindles 106 and has one port 110 communicating with the passage in each spindle. The ports 110 register with a vacuum chamber 118 and a vent 120 (or pressure source) respectively during each duty cycle of each roller 102. As schematically shown, vacuum source 112 is connected by conduit 114, with vacuum chamber 118 whose lower wall has an elongate port 111 (FIGURES 9 and 7) with which the ports 110 in valve plate 109 communicate. When pressure is used, pressure source 124 is communicated with successive ports 110 for each hollow spindle 106 by way of duct 126 whose open end is connected with 120 and becomes registered with ports 110 when the sheet is removed from the rollers.

As in the other forms of the invention, the surface speed of roller 102 is zero with respect to the top sheet. In other words, the roller rolls on the sheet and does not slide or skid with respect to the sheet. The correct speed of the roller is maintained by any suitable drive mechanism (or it simply rolls on the sheet), for example a pinion 130 and gear 132 respectively. Gear 132 is fixed to a ground reference, and gear 130 is secured to the roller. The pitch circle of gear 132 is at the surface 104 (sheet *s*) so that the gearing itself is cycloidal, with all points on the pitch circle of pinion 130 describing cycloids on the pitch circle of gear 132 and also any surface coplanar therewith.

Roller 102 has circumferential grooves 134 in which stripper fingers 136 are disposed. These are suitably supported, e.g. by frame 138 secured to spindle 106. As shown in FIGURE 8, additional means, as suction conveyor 140 may be used to direct and/or carry the sheets to a utilization device (not shown) as they are removed from roller 102.

In this form of the invention the corner of sheet *s* is first contacted by the inner portion of the roller surface. The arrangement of ports 107 is such that this corner of the sheet covers one or a concentration of ports to assure initial firm gripping of the sheet. The valving (FIGURE 9) is so timed that the ports 107 in the roller become communicated with the vacuum so that the corner of the sheet becomes adhered to the roller. The vacuum may be applied at the apex of the corner of sheet *s* or slightly behind it, similar to FIGURES 1*b* and 1*c*. As the roller continues to rotate on sheet *s*, successive portions of the sheet are engaged by the roller covering other ports 107 and causing sheet *s* to be rolled onto the roller 102, and also causing the sheet to conform to the truncated conical shape of roller 102.

It is understood that various changes, modifications and alterations may be made without departing from the protection of the following claims. For example, we may use mechanical clamps to supplement, or in place of, suction for retention of the sheets on the pick-up devices.

Also, an obvious variation of the machine 40 would be to have hopper 56 located above the machine in place of the illustrated location. This would require minor mechanical variation in construction.

We claim:

1. A sheet handling apparatus for a flexible sheet, said apparatus comprising a rotary structure having an axis of rotation substantially normal to the plane of the surface of the sheet, an outwardly extending roller connected with said rotary structure and having a rolling surface movable approximately in the plane of the flexible sheet, sheet holding and positive control means operative as the roller engages the leading corner portion of the sheet to attach said portion of the sheet to the surface of the roller and to exercise positive control of the sheet by holding the leading portion of the sheet attached until the leading area of the sheet has been curved approximately half way around the roller due to the movement of said rotary structure and the rolling action of said roller, thereby both curving the sheet and orienting the leading portion of the sheet in the same general direction as the remaining portion of the sheet not yet contacted by the roller while under said positive control, and sheet removal means gripping said leading portion of the sheet and pulling it around said roller and away in the same general direction as the motion of said roller as it continues to be moved by said rotary structure.

2. The subject matter of claim 1 and sheet stripping means operative with said roller at a position approximately across from the line of contact of the roller with the sheet to strip the leading area of the sheet from the roller and present said leading area to said sheet removal means.

3. The subject matter of claim 2 wherein said roller surface has a circumferential groove, and said sheet stripping means are partially located in said groove.

4. Sheet handling apparatus operative with a stack of flexible sheets, means vertically supporting the stack at its bottom with the top sheet at a sheet pick up station, said apparatus comprising a rotary structure independent of said stack supporting means and having an axis of rotation normal to the plane of the surface of the top sheet of the stack, an outwardly extending conical roller attached to said rotary structure and movable by said rotary structure and onto the top sheet of the stack in said station, sheet holding and positive control means operative as said roller initially rolls onto the leading portion of the sheet for adhering the leading portion of the sheet to the roller and for exercising positive control of the sheet by securing the sheet to the roller as the roller continues to roll on successive areas of the sheet, said holding and positive control means being effective until said roller has moved sufficiently to wrap the sheet around the roller to form a curve of approximately 180°, to thereby position the leading portion of the sheet above the uncurved portion of the sheet and to orient said leading portion in the same general direction as the motion of the adjacent portion of the rotary structure while continuing to exercise said positive control of the sheet, and means to grip the leading portion of the sheet and take it away from the stack in said general direction by continuing to curve successive areas of the sheet progressively along the length of the sheet following the original curvature formed around said roller.

5. Sheet handling apparatus for a stack of sheets where one sheet of the stack is located in a plane of a sheet pick up station, said apparatus comprising a rotary structure having an axis of rotation perpendicular to the plane of said sheet, said rotary structure including a plurality of outwardly extending conical rollers which are linearly propelled by said structure through said station in a plane parallel to said sheet with the surface of successive rollers engaging successive sheets of said stack, means synchronized with said rotary structure to rotate said rollers as they are moved with said structure, the speed of rotation of said rollers being such that the relative velocity between the rollers and the sheets engaged thereby is zero, sheet retaining and positive control means operative in synchronism with said rotary structure for adhering the said sheet of said stack to a first of said rollers as the first roller initially engages said sheet and for exercising positive control of the sheet by retaining successive elemental areas adhered to the first roller, said retaining means being effective substantially until the roller has moved sufficiently far that the leading edge portion of the sheet has wrapped around the first roller to be directed in approximately the same general direction as linear motion of said first roller as it initially engages the sheet, and means operative in the same direction as said leading edge of the sheet and said roller as it initially engages the sheet for taking away the sheet in the same direction as the linear motion of said first roller.

6. The subject matter of claim 5 and means movable at the same speed as said structure and operable with said first roller approximately across from the line of contact of the first roller with said top sheet of the stack, for stripping the leading edge portion of the sheet from the first roller.

7. The subject matter of claim 5 wherein said means to adhere the sheet to said first roller are pneumatic and include a valve means controlled remotely from said first roller in synchronism with said rotary structure.

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